MOTT MACDONALD

Consideration of Alternative Treatment and Disposal Options

Featherston Wastewater Treatment Plant

28 February 2017

Mott MacDonald
Level 1, 23 Union Street
Auckland Central
Auckland 1010
PO Box 37525, Parnell,
1151
New Zealand

T +64 (0)9 375 2400
mottmac.com

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Mott MacDonald New Zealand Limited
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Contents

Executive summary

The South Wairarapa District Council (SWDC) is currently in the process of seeking resource consents for the Featherston Waste Water Treatment Plant (FWWTP). This report presents the evaluation of alternative options to treat and dispose of the wastewater produced by the Featherston community in accordance with Section 88 and Schedule 4 of the Resource Management Act (1991).

Mott MacDonald has considered 21 combinations of improvements, treatment upgrades and/or discharge alternatives. Where each option was a combination of the following:

- Inflow and infiltration (I/I) rehabilitation and re-reticulation Options
- Treatment Options
  - Pond enhancements (screening, floating treatment wetlands, in-pond coagulant dosing or DAF)
  - Pond replacements options (high rate treatment)
  - Land treatment
- Discharge Options
  - Water discharge
  - Land discharge with storage
  - Land discharge with contingency winter discharges to water or to land through high rate application
  - Combined land and water (direct or indirect) discharges.

In addition to the above options, consideration was also given to the possibility of a combined district-wide wastewater scheme.

A tiered multi-criteria analysis (MCA) was used to select the "best practical option" (BPO) to prevent or minimise the adverse effects on the environment whilst having regards to the financial implications to the community.

Based on the multi-criteria analysis, the BPO recommendation for the FWWTP upgrade is as follows:

- Prioritise inflow/infiltration reduction in the short-term (within the current Long Term Plan period) as this has been shown to offer benefits in terms of flow reduction resulting in significant saving in both capital and operational costs for both treatment and land disposal options.
- Continue with a stand-alone wastewater scheme due to the significant investment in reticulation infrastructure required for a combined district-wide wastewater scheme.
- Land application of the majority of the treated wastewater and storage of flows when land treatment is not appropriate to cater for 90 percent of storage flows and the remainder being discharged to Donald Creek in winter under a high stream flow discharge regime.
- Staging of the scheme to manage both costs to the community and environmental effects with I/I reduction and removal of discharges to Donald Creek during summer prioritised in the short-term.

1 Introduction

1.1 Purpose

The South Wairarapa District Council (SWDC) is currently in the process of seeking resource consents for the Featherston Waste Water Treatment Plant (FWWTP). As part of its application for resource consent to discharge contaminants, in accordance with Section 88 and Schedule 4 of the Resource Management Act (RMA, 1991), SWDC must provide an assessment of any possible alternative methods of discharge, including discharge into any other receiving environment. SWDC engaged Mott MacDonald to evaluate alternative options to treat and dispose of the wastewater produced by the Featherston community. This report documents the assessment undertaken by Mott MacDonald and forms part of the Assessment of Environmental Effects (AEE) to support the FWWTP resource consent applications.

1.2 Site Description

The FWWTP is located 2km south of the Featherston township and comprises of two oxidation ponds (or waste stabilisation ponds (WSP)) constructed in the 1960's, typical of the era and of similar small communities within New Zealand. The outflow from the ponds is further treated by Ultra-violet (UV) disinfection and the treated effluent is discharged to Donald Creek, which joins Abbott Creek, which then discharges into Lake Wairarapa some 4-5 km downstream. A detailed description of the treatment plant and the receiving environments is provided in the Main AEE Report.

1.3 Influent Flows

The typical average daily flow (ADF) of wastewater generated by a community with a population of the size of Featherston is in the order of 560 m^3/day. However, the ADF at the FWWTP is over 400% in excess of the typical, at 2,566 m^3/day, with a measured peak daily flow (PDF) of 5,480 m^3/day (95th percentile flow). The source of the excess flows have been investigated and are principally from the inflow of stormwater and the infiltration of groundwater (I/I) into the Featherston sewerage network, which is estimated to comprise up to 74% of the total inflow received at the Featherston WWTP.

As the influent flow volume entering the FWWTP is the main factor in dictating the size of any treatment and disposal options to be considered, then inflow and infiltration (I/I) reduction should be a priority for the Featherston wastewater scheme. Previous investigations have identified that a significant portion of the I/I flow to the FWWTP is groundwater infiltration (GWI). Decreasing the volume of GWI through the Featherston network and WWTP will not only result in a significant reduction in future capital expenditure, it will have a bearing on ongoing operational costs. Further analysis of the effects of I/I and options for rehabilitation are discussed in Section 2.

1.4 Treatment & Disposal Options Investigations

A high level feasibility study comparing options for a combined district wide wastewater treatment and disposal scheme against individual stand-alone wastewater treatment and disposal schemes for the South Wairarapa townships was undertaken by AWT in 2013[1]. The findings of this study identified that a stand-alone wastewater treatment and disposal schemes for the three townships was the preferred strategic approach. These findings are presented in Section 3.

[1] See reference AWT 2013a

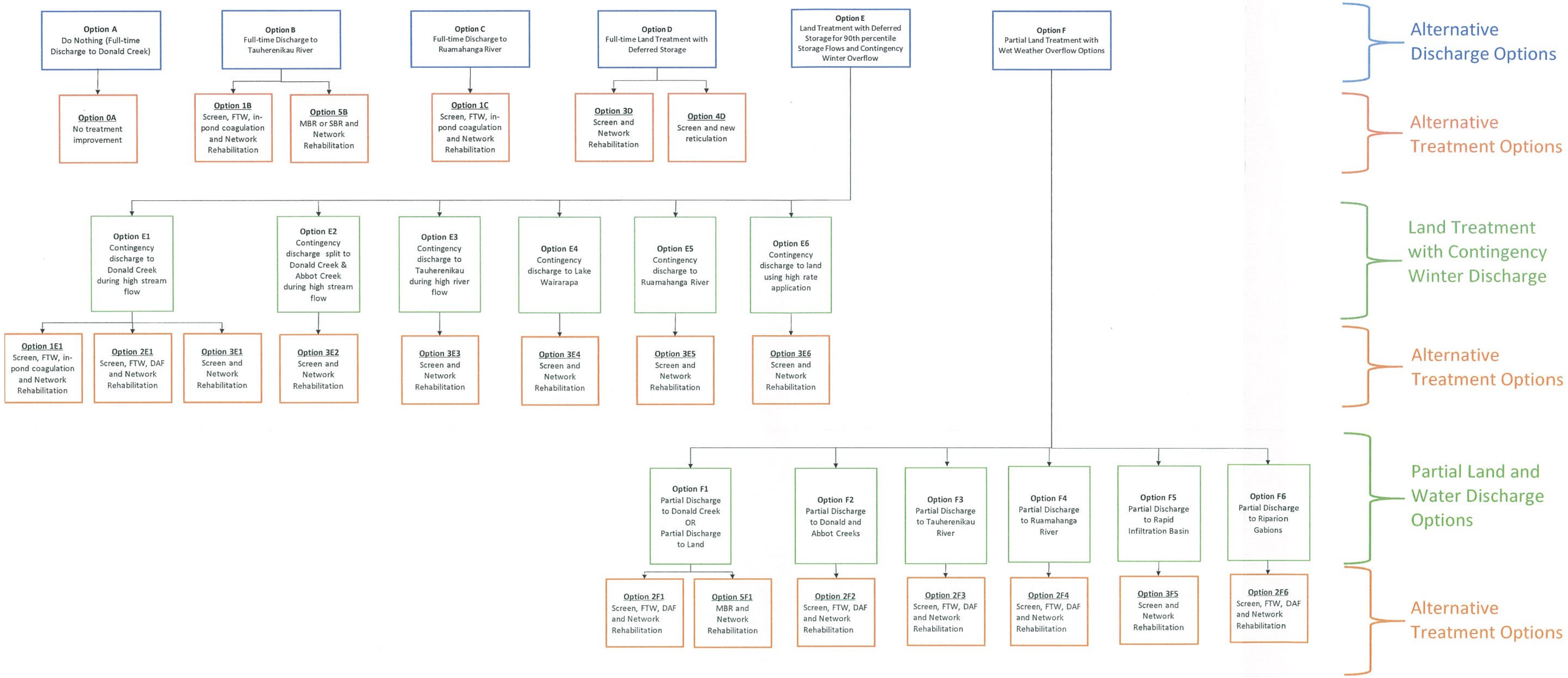
Various stand-alone treatment and disposal options have subsequently been considered for the long-term treatment and disposal of wastewater from FWWTP. These treatment and disposal options can be configured in various combinations, resulting in different levels of performance, environmental outcomes and costs. Figure 1 below summarises the key combinations of options that have been considered and these are discussed in further detail in Sections 4 and 5.

The various combinations have been evaluated qualitatively and quantitatively in Section 6 (based on high level concept design costs where available) though a multi-criteria analysis using criteria consistent with selecting the "best practical option" (BPO) to prevent or minimise any adverse effects caused by the FWWTP discharges either to land, water or to air.

The selected best practical option for SWDC to consider implementing on behalf of the Featherston Community and the basis for its selection is discussed in Section 7.

Final conclusions for the options evaluation are provided in Section 8.

Figure 1: Alternative Disposal and Treatment Options Tree



2 Inflow and Infiltration (I/I) Rehabilitation

2.1 Previous Investigations

AWT (2013a) undertook a review of historical influent data to the existing wastewater treatment ponds at Featherston. The analysis highlighted that the dry weather inflows into the FWWTP are in the order of 2 - 5 times greater than expected from a typical community the size of Featherston. AWT (2013a) noted that indicators, like constant baseline dry weather night wastewater inflows, strongly suggest the majority of additional flow is from groundwater infiltration which appears to be entering the township sewerage system year round and increasing significantly in winter. Direct stormwater inflows were also evident but appear to contribute a minor overall addition to the total wastewater volume entering the system.

2.2 Previous Investigations

AWT (2013a) undertook a review of historical influent data to the existing wastewater treatment ponds at Featherston. The analysis highlighted that the dry weather inflows into the FWWTP are in the order of 2 - 5 times greater than expected from a typical community the size of Featherston. AWT (2013a) noted that indicators, like constant baseline dry weather night wastewater inflows, strongly suggest the majority of additional flow is from groundwater infiltration which appears to be entering the township sewerage system year round and increasing significantly in winter. Direct stormwater inflows were also evident but appear to contribute a minor overall addition to the total wastewater volume entering the system.

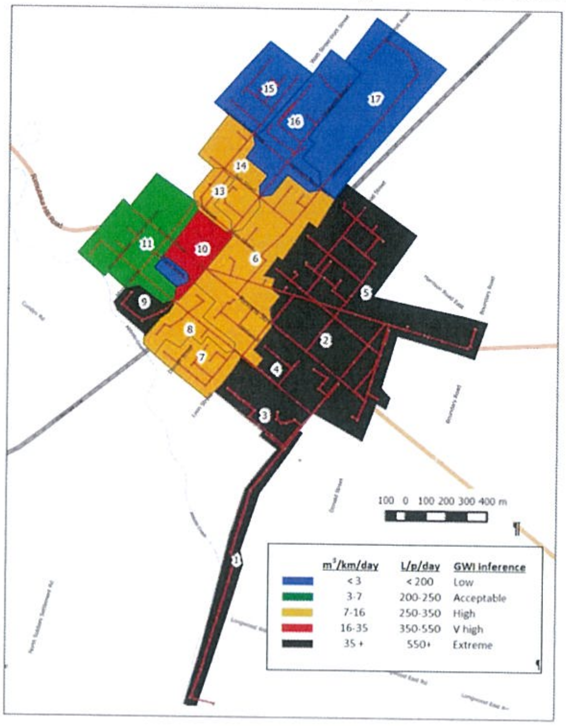
AWT (2013a) recommended that SWDC's immediate focus should be to address GWI source detection followed by prioritised rehabilitation to reduce GWI inputs into the network. As a second priority, it was recommended that sources of stormwater inflow be identified and addressed.

I/I is considered the most significant issue at Featherston and the main factor responsible for the treatment fluctuations observed (g2e, 2013a and AWT 2013a). High level concept analysis of costs for potential treatment and disposal upgrade options at Featherston showed that reducing I/I flows through sewer network improvements will significantly reduce capital as well as ongoing operational costs at the FWWTP (AWT, 2013b).

As the overall cost benefit of I/I reduction largely depends on how much of the network needs to be remediated, night flow isolation investigations were undertaken to quantify the volume of GWI entering the network and isolate the areas of the catchment contributing the greatest GWI flows (AWT 2013b). The results of the night flow isolation investigations found that:

- Study Area 1 (trunk main, Figure 2) contributes the most GWI (9.29 L/s out of the total 18.75L/s of night flow) and comprises only 7% of the total network.
- The top 5 ranked catchments contribute 85% of the GWI flow yet comprise only 23% of the total pipe length.
- Beyond the top 5 catchments, night flow contributions are wide spread with the remaining 17% of night flow coming from 77% of the total pipe length.

Figure 2: Classification of Study Areas based on Night Flowrate (AWT 2013b).



2.3 Cost Implications of Reduced Inflow

2.3.1 Targeted I/I Reduction - Treatment Option 1 - 4

Rehabilitation costs and expected percentage reductions in average daily flow (ADF) for the Top 5 ranked I/I contributing catchments have been used to calculate the estimated net present value (NPV) of possible treatment and disposal schemes versus different levels of I/I rehabilitation and reduction. This exercise was undertaken to identify the optimum level of investment in I/I rehabilitation and reduction versus treatment and disposal investment to identify the combination of the two resulting in the lowest overall capital cost. AWT (2013b) identified for a high rate treatment system with a direct discharge to water that a 31% reduction in ADF through I/I reduction resulted in the lowest overall cost. Comparatively the most economical "Full" land disposal scenario was identified at 35% reduction in ADF through I/I reduction.

I/I rehabilitation has been identified as the primary focus for FWWTP over the short to medium term (the following 5-10 years) for all treatment and disposal options considered as part of this options evaluation, and this priority has been reflected in the SWDC Long Term Plan.

It is important to note that all treatment and disposal options considered in Sections 5 and 6 have assumed that the targeted I/I reduction has been achieved and this is reflected in the sizing of the options and the high level cost estimates produced. The flow criteria applied is as follows:

Table 1: Flow Criteria for all options including Targeted I/I Reduction

	No I/I Reduction	I/I Reduction		
		High Rate Treatment Option sizing	Water Disposal Options	Land Disposal Options
	m³/d			
Inflow Average Daily Flow(1)	2,566	1,765		
90th%ile(1)	4,468	3,083		
Outflow Average Daily Flow(2)	2,235		1,542	1,453
90th%ile(2)	4,136		2,854	2,688

Source: (1) based on SWDC inflow data collected between 18/03/2005 and 7/11/2016 but excludes data between 1/7/2013 and 1/10/2014 prior to new inlet meter being installed. (2) based on SWDC outflow data collected between 18/03/2005 and 7/11/2016.

For the purpose of this evaluation ADF reduction targets are based on the implementation of a network rehabilitation programme targeting rainfall dependent infiltration and groundwater infiltration. Infiltration contributes additional flow volume following rainfall or when groundwater levels submerge the network seasonally and the effect (and effectiveness of rehabilitation) is best observed over a long time period. It is therefore recommended that ADF target reductions are assessed on an annual basis. Wet weather peaking factors and peak wet weather flows are not expected to be reduced to the same extent as infiltration as the rehabilitation programme does not specifically target inflow sources such as direct stormwater connections. Any reductions in wet weather flows are incidental to the main objective of total volume reduction through targeted infiltration rehabilitation.

2.3.2 Re-reticulation - Treatment Option 5

Whilst targeted I/I reduction has the effect of reducing the treatment and disposal costs, in the case of land disposal scenarios and for the reasons discussed in Section 5.4 (i.e. significant storage requirements), it will still be necessary to either discharge to water or load up the land disposal scheme outside of the summer months. Therefore, a further option has been considered in which the entire gravity reticulation network in Featherston is replaced with a new low pressure sewer system, thus removing the vast majority of the I/I. This option involves provision of on-site pumping stations (i.e. grinder pumps) for individual properties or clusters of properties discharging into a low pressure public sewer. The fact that the system operates under pressure excludes the possibility of inflow and infiltration downstream of the on-site pumping stations. As such, this option offers the potential to design a land disposal system without the need for a contingency wet weather overflow to water.

An assumption has been made that only the worst laterals are replaced and that those that are in reasonable condition and above the groundwater level are intercepted; thus a small allowance has been made for rain dependant infiltration. Some investigation to remove any existing cross-connections from roof tops will be required; however, the responsibility and cost for removing these should lie with the home owner. A per capita dry weather flow (DWF) of 220 L/p/day has been allowed in this option, based on the lowest dry weather flow found in AWT (2013b). Allowing for some additional infiltration due to existing laterals a maximum daily flow of 250 L/p/day has been assumed.

This gives a future design DWF of 518 m³/day and a maximum daily flow of 589 m³/d, based on the following assumptions:

- Per capita DWF = 220 L/p/day; maximum daily flow = 250 L/p/day;
- 996 properties x 2.3 occupancy = 2290 people;
- Population in 2031 will increase by 30 people, followed by growth at 0.073%;
- Extrapolating this to 2051 gives 2355 people.

2.4 Implication of Reduced Inflow on FWWTP Performance

Reduced ADF not only has an impact on cost for SWDC, but will also have positive impacts on Featherston's current oxidation ponds and their performance.

The main parameters used for the design of facultative ponds systems are:

- The depth of the pond (in m)
- The pond length/breadth ratio (unitless)
- The surface organic loading rate (in kgBOD_5 /ha.d) and
- The hydraulic retention time (in days).

The depth and breadth of the Featherston ponds will remain unchanged (first two points).

The surface loading is related to the daily influent mass loads. The daily influent mass loads (kg/d) of Biological Oxygen Demand (BOD_5) and nutrients are not expected to change. This is because of two factors: (i) the I/I water entering the system is likely to be largely free of these contaminants; and (ii) as I/I flows are reduced there will be less dilution resulting in a stronger influent (more concentrated BOD_5 and nutrients) than currently.

Therefore the only design factor that will change with I/I reduction is the hydraulic retention time (HRT) of the ponds. The HRT corresponds to the average time the influent water will spend in the ponds prior to being discharged into the environment. An increase in HRT will allow the microorganisms more time to stabilise (treat and remove) the organic matter in the wastewater and allows more time for natural disinfection of the wastewater from sunlight and biological processes occurring in the ponds.

2.4.1 Targeted I/I Reduction Effects on Effluent Quality

Mott MacDonald has assessed the performance improvements of BOD_5, nutrients and pathogens as a result of the reduced I/I predicted using a pond treatment model based on equations and parameters commonly applied for the design of facultative ponds. A key assumption of the assessment was that contaminant mass loads entering the plant were unlikely to reduce as a result of a reduction in I/I (i.e. higher concentrations of pollutants due to flow reduction). The projected effluent concentrations derived from the pond treatment model following I/I reduction have been applied in the Mass Balance Model calculations used in the Assessment of Effects on the Environment (AEE) to support the FWWTP resource consent applications (refer to Appendix 8 of the Main AEE report).

The following provides a summary of findings from the pond treatment model for each of the key pollutants discharged from the FWWTP, based on an annual average 35% reduction in ADF through targeted I/I reduction.

2.4.1.1 Biological Oxygen Demand (BOD_5) and Total Suspended Solids (TSS)

The total BOD_5 entering a WWTP comprises two principal fractions (1) soluble and (2) particulate. The load of soluble BOD_5 removed (in kg/d) by the ponds will be higher with reduced ADF (more time for the pond's biomass to remove soluble BOD_5), thus reducing the load of soluble BOD_5 discharged to the environment. Effluent soluble BOD_5 load reductions of up to a third (of the existing load discharged) may be possible under ideal local environmental conditions.

Although more soluble BOD_5 load will be removed (due to the increased HRT), the influent concentration will be higher resulting in relatively similar effluent soluble BOD_5 concentrations in the final effluent as those currently observed. However the volume of flow will be reduced and hence the soluble BOD_5 mass load on the receiving environment will be reduced by up to a third.

The particulate fraction of the influent BOD_5 (the BOD associated with the influent TSS) will settle within the pond where it will undergo anaerobic decomposition and be hydrolysed to soluble BOD_5. Oxidation of the soluble BOD_5 in the upper layers of the pond will result in growth of new biomass and algae which will then contribute to the final effluent TSS and BOD_5 depending on the level of TSS removal within the pond (1 mg of TSS represents an average of 0.35 mg of particulate BOD_5). It is not possible to confidently model the impact the I/I reduction will have on pond effluent TSS and particulate BOD_5 concentrations, due to the complex effects of a range of environmental conditions on the ponds and the impact this has on algae production (sunlight, temperature and wind induced mixing are environmental factors that influence algae production). Thus the impact of I/I reduction on particulate BOD_5 and TSS is uncertain:

- Increased HRT is likely to be positive in terms of influent solids settling, as velocities through the pond will be reduced, encouraging settling.
- However a significant portion of facultative pond effluent suspended solids and particulate BOD is comprised of algae (60 – 90%), which does not settle well. Algae concentration in the pond (and subsequently in the pond final effluent) may increase following any reduction in I/I due to the longer HRT (more time for the algae to grow).

Typical effluent TSS values used for pond treatment design are between 40 mg/L and 150mg/L (current Featherston TSS average concentration: 31mg/L) and effluent total BOD_5 values (soluble + particulate) between 30 mg/L and 150mg/L (current Featherston total BOD_5 average concentration: 17mg/L). The surface loading rate on the primary pond averages just under 70 kgBOD_5/ha/day which is less than the typical design figure of 100 kgBOD_5/ha/day quoted for facultative ponds and indicates that the ponds are lightly loaded; however, the primary reason for the low treated effluent concentrations is likely to be the very dilute influent wastewater. Based on the average flow rate and the population served, the per capita flow is estimated to be close to 1,000 L/head/day, which is around four times higher (or more dilute) than normal strength domestic sewage, owing to the high I/I in the network. Due to the uncertainties around TSS and particulate BOD removal, it has been assumed that there will be no change in TSS or BOD effluent concentrations to those currently measured from the ponds, assuming that the benefit to settlement is offset by an increase in algal solids. As such, the current effluent concentrations have been applied in the Mass Balance calculations.

It is worth noting that algal BOD is chemically, physically and biologically different in nature to the BOD in raw sewage and can in some cases be seen as beneficial to the receiving environment, as algae produce oxygen via photosynthesis during daylight hours. This fact is recognised in some countries where more relaxed BOD standards may be applied to effluents from pond treatment systems where the effluent BOD is largely derived from algae.

2.4.1.2 Nitrogen

In terms of nitrogen, the main removal mechanisms in facultative ponds are ammonia stripping (due to high pH in ponds caused by algae growth) and nitrogen uptake by the pond's biomass followed by settling. Modelling indicates an increase in effluent concentration post I/I reduction largely owing to the increase in influent concentration; however, there is only a marginal change in effluent total nitrogen load post I/I reduction due to the reduction in flow. The model however does not take into account pH fluctuations as a result of the reduced I/I and thus the increased likelihood of greater ammonia stripping. During summer months when lower flows and greater residence time would occur, algal populations would have greater influence on pond pH which may result in increased ammonia stripping during summer low flow and high sunshine periods.

It is also possible that the treatment plant influent nitrogen load may be influenced by the I/I reduction, as some of the groundwater may be contaminated by other land-use nutrient discharges upstream of the reticulation catchment. However, in the absence of influent and groundwater quality data, it is difficult to assess what reduction in nitrogen concentrations might be observed if any. To confirm this sampling and testing would be required. In the absence of such information a conservative approach has been taken in the mass balance calculations for median Ammoniacal-N effluent concentrations by assuming an increase in summer and winter months post I/I works of approximately 10% and 50% respectively. This may in fact result in an over-estimate of the potential environmental impacts and can only be verified through ongoing monitoring.

Although we have assumed an increase in Ammoniacal-N effluent concentrations, as the volume of flow will be reduced, the increase in Total Nitrogen and Ammoniacal-N mass loads on the receiving environment will be less pronounced, at around 10%.

2.4.1.3 Phosphorus

The primary pathway for phosphorus removal in pond systems is assimilation in algae leaving with the effluent (~10% of algae mass), and by precipitation under high pH conditions. Removal is typically expected to be around 35% in facultative and aerated ponds, and can be as high as 60 – 80% in shallow ponds with low hydraulic loading. Lower hydraulic loading rates are therefore likely to have a positive effect on the settling of particulate matter at the FWWTP due to the shallow nature of the ponds. By reducing I/I flows (lower hydraulic loading), it is expected that some improvement in phosphorus removal can be expected through improved precipitation (particularly during summer months). However these effects are difficult to predict with certainty and therefore for the purpose of the mass balance calculations, a conservative assumption has been made that the phosphorus effluent concentrations increase in proportion to the increase in influent concentration. This assumption results in no change to the estimated effluent mass load discharged from the ponds post I/I reduction.

2.4.1.4 Pathogens

In terms of pathogens (assuming *E.coli* as an indicator), the increased HRT will also have a positive impact on their reduction, since the increased retention time will allow greater solar UV radiation inactivation. The improvement in terms of E.coli level in the pond effluent is likely to be very significant (i.e. 30 – 40% lower than present pond effluent concentrations). However as the plant is equipped with a UV disinfection system to treat the pond effluent prior to discharge, the level of pathogens in the final effluent discharged to the environment may not be significantly different from the level of performance currently achieved. Some increase in algal solids in the effluent is likely to be seen due to the increased HRT (as discussed in section 2.4.1.1), which could potentially lower UV transmissivity and impact on the performance of the UV system. However, this is likely to be offset by the greater pathogen kill in the ponds and the lower peak flows passing through the UV system. Overall it is reasonable to assume that the final effluent *E.coli* concentrations will be similar to current levels.

As a contingency it is possible to install a second UV reactor in series with the existing unit to increase the pathogen kill in future if required.

2.4.1.5 Conclusion

Whilst many of the treated effluent concentrations will remain unchanged following implementation of the I/I reduction, and in fact there may be slight increases in the phosphorus and nitrogen concentrations, there will be some positive impact in terms of the mass loads being discharged to the receiving environment.

The organic and solids loads are expected to reduce by up to a third, while the phosphorus load will remain unchanged and the ammonia/nitrogen load may increase slightly. It should be borne in mind that there are always some uncertainties regarding the predictions of natural treatment processes such as facultative ponds, due to the complex effects of a range of environmental conditions and it is possible that the performance with respect to ammonia and phosphorus removal may be better than predicted if algal activity improves owing to the greater retention time and results in higher pH conditions. The estimated net change in treated effluent concentration and mass load predicted by the pond treatment model is summarised in Table 2.

Table 2: Predicted Change in FWWTP Effluent Following Targeted Network Rehabilitation

	E Coli	$cBOD_5$	TSS	TN	NH_4-N	DIN	TP
Concentration summer	0%	0%	0%	+10%	+10%	+10%	+50%
Concentration winter	0%	0%	0%	+25%	+25%	+25%	+50%
Mass Load	NA	-94%	NC	-79%	-90%	-70%	-92%

Notes – Values presented for final upgrade stage. Change in concentration calculated from difference between pre and post I/I as per Table 3. Changes in mass load calculated from the mass balance model by comparison between modelled existing and modelled final upgrade stage. NC = Not calculated as TSS was not modelled.

The predicted effluent quality pre and post the targeted I/I rehabilitation works is presented in Table 3.

Table 3 Predicted Effluent Quality Pre and Post Targeted I/I Reduction

Stage	Season	Parameter								
		BOD_5 (g O_2/m^3)	TSS (g/m^3)	TN (g/m^3)	NH_4-N (g/m^3)	DIN (g/m^3)	TNO_x-N (g/m^3)	DRP (g/m^3)	TP (g/m^3)	E.coli (cfu/100ml)
Pre I/I Works	Summer median	17.3	46	9.1	4.3	4.5	0.32	1.8	2.5	27
	Summer 95%ile	33.6	131	13.6	11.1	11.2	1.3	4.5	5.3	850
	Winter Median	14.2	25	8.4	4.9	5.9	0.98	1.0	1.3	
	Winter 95%ile	31	95	16.4	11.6	12.1	2.8	2.8	3.9	
Post I/I Works	Summer median	17	46	10.0	4.7	4.9	0.35	2.2	3.1	
	Summer 95%ile	34	131	14.9	12.2	12.4	1.4	5.6	6.6	
	Winter Median	14	25	12.6	7.3	8.8	1.5	1.5	2.0	
	Winter 95%ile	31	95	24.5	17.4	18.2	4.3	4.4	5.9	

2.4.2 Re-reticulation

The above discussion on the effect of I/I reduction on the performance of the FWWTP, applies similarly to the re-reticulation option. In the case of re-reticulation there is an estimated 72% reduction in the annual average flow. The estimated net change in treated effluent concentration and mass load predicted by the pond treatment model is summarised in Table 4.

Table 4: Predicted Change in FWWTP Effluent Following Re-reticulation

	E Coli	$cBOD_5$	TSS	TN	NH_4-N	DIN	TP
Concentration	0%	+28%	0%	+182%	+90%	+81%	+271%
Mass Load	-72%	-80%	-72%	-21%	-47%	-21%	0%

It can be seen, that whilst the reduction in flow will lead to an increase in the concentration of many parameters, in most cases there is a significant reduction in the mass load being discharged to the receiving environment. The predicted effluent quality pre and post the targeted I/I Reduction works is presented in Table 5.

Table 5 Predicted Effluent Concentrations Post Re-reticulation Works

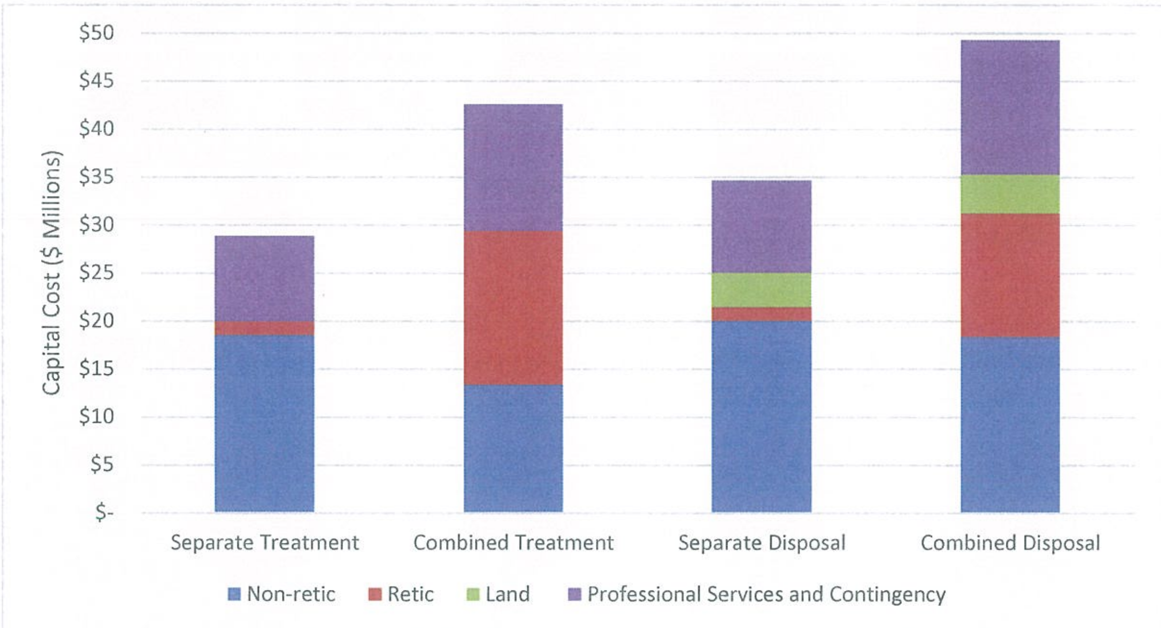
	E.coli (cfu/100ml)	BOD_5 (g O_2/m^3)	TSS (g/m³)	TN (g/m³)	NH_4-N (g/m³)	DIN (g/m³)	TNO_x-N (g/m³)	DRP (g/m³)	TP (g/m³)
Summer Median	27	16.5	35.0	16.5	8.4	9.1	0.5	5.2	6.5
Winter Median	8	13.2	21.5	23.2	14.3	15.0	0.5	5.2	6.5

3 Combined Versus Individual Schemes

SWDC engaged AWT (2013a) to evaluate the economic feasibility of combining the Greytown, Martinborough and Featherston WWTPs into a single site for either a combined land irrigation or combined high rate treatment plant scheme. The addition of Carterton flows was also considered for a combined land irrigation option.

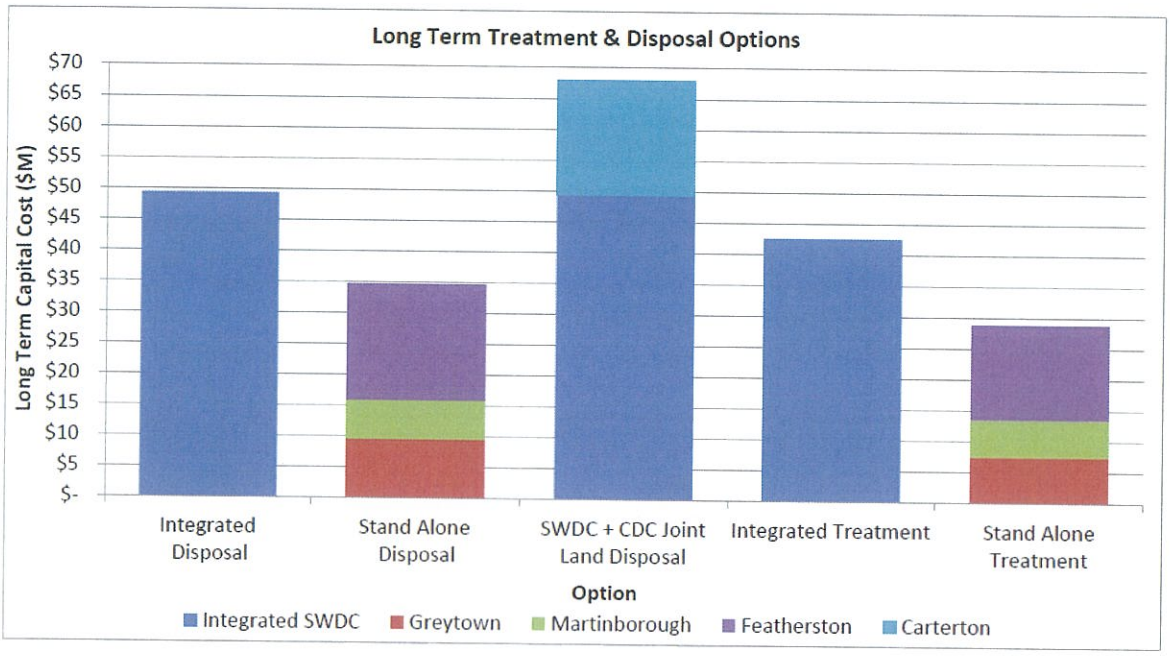
While some economies of scale could be achieved through a combined scheme, it was shown that greater capital investment would be required than retaining and upgrading the separate schemes due to the distances between the townships and the significant investment in reticulation infrastructure required to combine them (Figure 3).

Figure 3: Comparison of capital cost estimates by infrastructure type



Furthermore, the addition of Carterton increased the joint land disposal scheme capital costs by approximately 28%, which is consistent given Carterton would contribute approximately 30% of the flow into a combined scheme (Figure 4).

Figure 4: Summary of long term treatment and disposal options by town



As a result of this high level analysis, SWDC decided to pursue three separate community wastewater schemes. As a consequence, this report is hereinafter limited to consideration of stand-alone treatment and disposal options for the Featherston Community.

Further details of the combined versus individual scheme assessment can be found in the AWT (2013a) report cited in section 9.

4 Alternative Treatment Options

Alongside the disposal options discussed in Section 5, various options for treatment wastewater at the FWWTP have been investigated and are discussed in the following section. The alternative treatment options considered to that of the status quo include:

- Pond enhancement and modification options;
- Pond replacements options (high rate treatment); and
- Land treatment.

The combinations of treatment and disposal options considered are summarised in Figure 1 and presented in Appendix B.

4.1 Status Quo / "Do Nothing" Treatment Option – Treatment Option 0

In a review of the existing FWWTP performance by *g2e* (2013), it was determined that, based on analysis of the remaining water depth, pond volumes and the plant's remaining overall treatment capacity, the quality of treatment which should theoretically be achievable is close to what the plant is currently achieving, especially in respect to final effluent TSS and BOD_5 concentrations, thus the plant is currently performing as would be expected.

Concerns regarding the effects of the existing discharge on Donald Creek have been identified and treatment deficiencies of the current pond based system in terms of limitations in nutrient removal have been recognised.

Specifically the existing discharge has been observed to have the following effects on the environment:

- ***Scum*** has been observed in summer on the water surface within Donald Creek downstream of the FWWTP discharge beyond the reasonable mixing zone (Coffey, 2013). Planktonic algae from the oxidation ponds has been associated with the formation of the scum. Scum on the water surface however has not been observed during spring months (Hamill, 2017). It is a requirement of Section 107(c) of the RMA that such effects (the production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials) shall be absent in water receiving discharges, after reasonable mixing. Based on the above, compliance with s107(c) of the RMA is not being achieved during summer and autumn low flow conditions but is unlikely to be a compliance issue in winter and spring.

- ***Foam*** has been observed, accumulating within the discharge channel and against the banks within Donald Creek downstream of the discharge during summer months (Coffey, 2013). During a spring survey, foam was observed both upstream and downstream of the discharge but not within the discharge channel (Hamill, 2017). Stable foam in WWTPs results from the interaction between gas bubbles (for example from turbulence), surfactant and hydrophobic particles. Surface-active components, such as detergents can stabilise gas bubbles. The gas-water interface is even more robust if small hydrophobic particles (such as grease) are also present with the surfactants. A grab sample taken on 2 August 2016 of the effluent reported a low level of detergent present (0.2mg/L – detection limit 0.1mg/L) and did not indicate a problem with surfactant, however it is acknowledged this finding is limited to a single result. Foam observed in Donald Creek may also be a result of macrophyte decomposition. It is a requirement of Section 107(c) of the RMA that such effects (the production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials) shall be absent in water receiving discharges, after reasonable mixing. Based on the above, compliance with s107(c) of the RMA is not being achieved during summer and autumn low flow conditions and compliance during winter and spring is uncertain.

- ***Discolouration.*** Turbid/discoloured water has been observed within the discharge channel and on occasion in Donald Creek downstream of the FWWTP discharge, particularly during summer months (Coffey 2010; Coffey 2013; Forbes 2013). The discolouration has been described at times as being green, indicating the presence of algae; and turbid-brown at other times. The brown discoloration could potentially indicate brown algae; however, further microscopic investigation would be required to confirm this. There is no evidence of the discolouration occurring during spring months within Donald Creek when stream base flows are higher (Hamill, 2017). It is a requirement of Section 107(d) of the RMA that such effects (any conspicuous change in the colour or visual clarity) shall be absent in water receiving discharges, after reasonable mixing. During summer months the discolouration has been observed to extend beyond what is considered to be the reasonable mixing zone.

- ***Significant adverse effects on aquatic ecosystems***. Summer ecological surveys assessing macroinvertebrate community structure have confirmed the existing discharge is significantly compromising water quality downstream of the discharge and thus having a significant adverse effect on instream community structure (Coffey, 2010 and 2013). Sampling during Spring found that the WWTP discharge was having only a small impact on the periphyton cover and macroinvertebrate communities in Donald Creek. It is a requirement of Section 107(g) of the RMA that such effects (any significant adverse effects on aquatic ecosystems) shall be absent in water receiving discharges, after reasonable mixing. Significant effects on aquatic ecosystems within Donald Creek have been observed during summer months, however these effects are less pronounced in winter/spring. The difference in the effect of the discharge in spring compared to summer is likely to reflect seasonal differences in stream flow, effluent quality and water temperature (Hamill 2017).

- ***Sewage Fungus*** has been observed in summer within Donald Creek, growing on submerged substrate downstream of the FWWTP discharge beyond the reasonable mixing zone (Coffey, 2010 and 2013). The principal component is a filamentous bacterium *Sphaerotilus natans*. This occurs when readily degradable dissolved organic compounds (measured directly as soluble BOD), is present in the stream. Sewage fungus has not been observed during spring months (Hamill, 2017). The absence of sewage fungus in spring suggests its growth may be seasonal, being less in cooler months due to the increasing dilution of soluble BOD afforded at the higher stream flows, coupled with the lower water temperatures and potential flushing effects of the stream high flows.

The status quo treatment and disposal system would be unable to achieve satisfactory treatment to comply with likely long-term effluent quality limits prescribed in any future discharge to water consent and/or meet the requirements of the RMA and in particular s107. Maintaining the existing discharge would also be inconsistent with the policy framework within the relevant Regional Plans to '*maintain and enhance water quality*'.

As such the SWDC "status-quo / do nothing" treatment option in conjunction with any full-time continuous discharge to Donald Creek has been discounted from further assessment (**Option 0A**).

4.2 Pond Enhancement and Modifications

SWDC has sought advice from a number of technical experts and suppliers on a variety of alternatives to improve treatment performance at the FWWTP. Option evaluations were carried out by NZET (2012) and *g2e* (2013a,b,c), and included a mixture of pond enhancement, end of pond treatment and pond replacement solutions. Appendix A provides a summary of the alternative pond enhancement and modifications considered in the earlier technical studies.

Based on the recommendations of the earlier studies and for comparative purposes with high rate treatment options, Mott MacDonald has identified three potential upgrade options to the existing oxidation ponds that may provide the best practical 'enhancement' option for the existing pond based treatment system depending on the chosen disposal option.

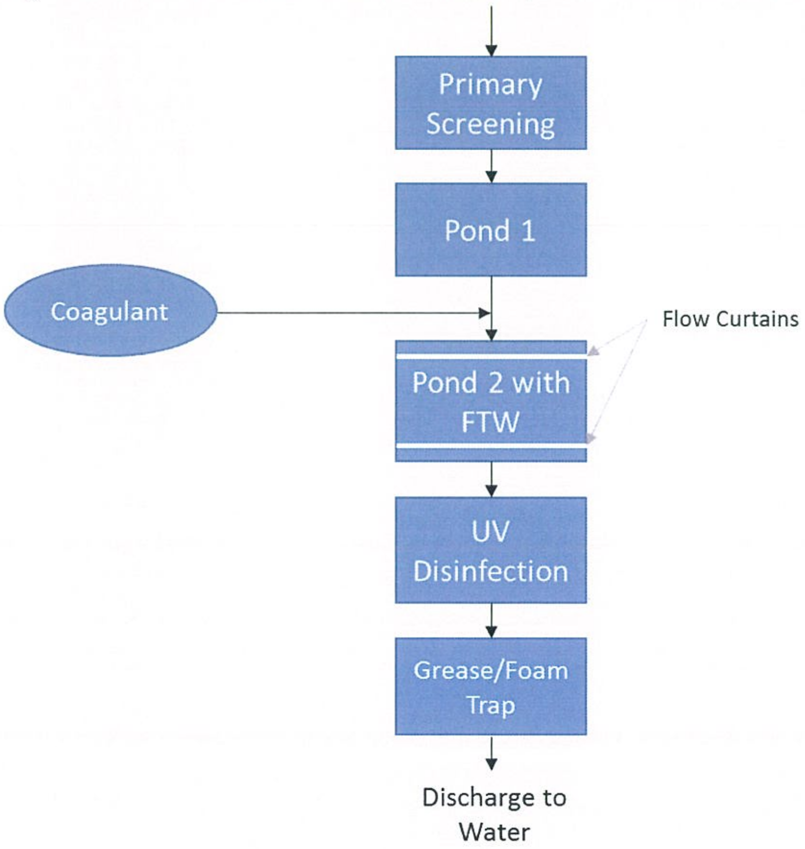
The pond enhancement options considered will enable some level of renovation of the final effluent, however, none will provide sufficient removal of ammonia and other nitrogen constituents reliably to avoid toxicity effects in some of the receiving waterbodies considered in this assessment due to insufficient dilution and mixing in that receiving environment. The justification for the elimination of combinations of treatment and disposal options (on the grounds of environmental outcomes) is presented in Appendix B.

4.2.1 Pond Enhancement - Treatment Option 1

For those disposal options, whereby a continued full time discharge to water has been considered the following enhancements have been proposed:

- Primary Screening – prevent gross solids from entering the ponds.
- Coagulant Dosing – between ponds where there is mixing to enhance coagulation and settling of phosphorus and algae.
- Floating Treatment Wetlands (FTW) and covers (or similar) – within Pond 2 to reduce algae concentrations in the final effluent and improve TSS.
- Flow Directing Curtains – configured to provide a long flow path through a FTW and prevent short circuiting.
- Grease/Foam Trap.

Figure 5: Pond Enhancement Treatment Option 1 Process Flow Schematic



This option would be expected to achieve some further reduction in BOD_5, suspended solids and Phosphorus in the final effluent. Pathogens may increase within the ponds themselves as a result of water fowl being attracted to the ponds and shading by the addition of the FTW, however, this increase should be mitigated by the existing UV disinfection unit in combination with the expected reduction in TSS. Nitrogen removal through the plant would however remain limited as the enhancements proposed for this option would not serve to nitrify and denitrify wastewater. A grease/foam trap has been included to minimise the potential for foam and oil/grease in the discharge to water.

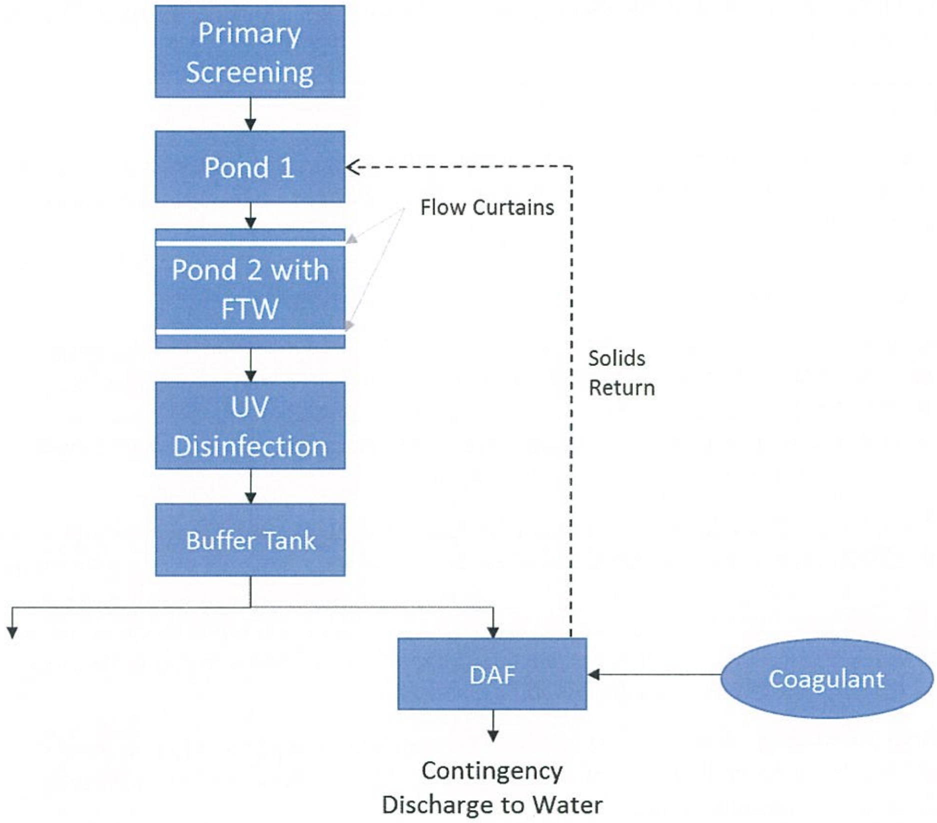
4.2.2 Pond Enhancement - Treatment Option 2

When considering a combined land and water based discharge regime, the additional potential treatment benefit of discharging treated wastewater to land, in terms of plant uptake of nutrients like nitrogen and phosphorus is recognised. As such for those disposal options where combinations of land and water discharge are considered in conjunction with a prolonged staging (i.e final stage not implemented for 30-35 years)[2], it is proposed to retain the oxidation ponds and UV treatment unit prior to land disposal with further treatment as follows:

- Primary Screening – prevent gross solids from entering the ponds.
- Land Treatment / Land Discharge.
- Floating Treatment Wetlands (FTW) and cover (or similar) – within Pond 2 to reduce algae concentrations in the final effluent and improve TSS.
- Flow Directing Curtains – configured to provide a long flow path through a FTW and prevent short circuiting.
- Buffer tank to act as a contingency in the event of a mechanical plant failure or extreme wet weather event.
- DAF unit with coagulant dosing on the outlet of the buffer tank for P removal prior to water discharge.

[2] Staging of the scheme is discussed in Section 7

Figure 6: Pond Enhancement Treatment Option 2 Process Flow Schematic



This option would be expected to achieve some further reduction in suspended solids and phosphorus in the final effluent discharging to water. Pathogens may increase within the ponds themselves as a result of water fowl being attracted to the ponds and shading by the addition of the FTW, however, this increase should be mitigated by the existing UV disinfection unit in combination with the expected reduction in TSS. Nitrogen removal through the plant would however remain limited as the enhancements proposed for this option would not serve to nitrify and denitrify wastewater. The DAF unit would minimise the potential for foam and oil/grease in the discharge to water.

This option differs from Pond Enhancement Treatment – Option 1 in that the intention is to retain phosphorus in the effluent discharged to land (for plant uptake) and remove phosphorus from effluent to be discharged to water.

4.2.3 Pond Enhancement - Treatment Options 3 & 4

Like Treatment Option 2 above, when considering a land based discharge regime, the additional potential treatment benefit of discharging wastewater to land, in terms of plant uptake of nutrients like nitrogen and phosphorus is recognised. As such for those disposal option where full time land application, or combinations of land with contingency discharges to water during the height of winter are considered in conjunction with a shortened staging (i.e. intermediate staging brought forward and implemented almost immediately and final stage within 20 years or two LTP cycles), it is proposed to retain the oxidation ponds and UV treatment unit prior to land disposal with further treatment limited to the following:

- Primary Screening – prevent gross solids from entering the ponds.
- Land Treatment / Land Discharge

This option would be expected to provide very little improvement in effluent quality and would rely on land treatment and acceptable dilution/mixing within the water receiving environment, possibly managed by way of a controlled discharge regime.

4.3 Partial or Complete Replacement of the Oxidation Ponds

A number of options involving the partial or complete replacement of the existing pond system have also been considered for improving effluent quality at FWWTP and comprise of high rate treatment process solutions. These are discussed below.

4.3.1 Membrane Bioreactor – Treatment Option 5

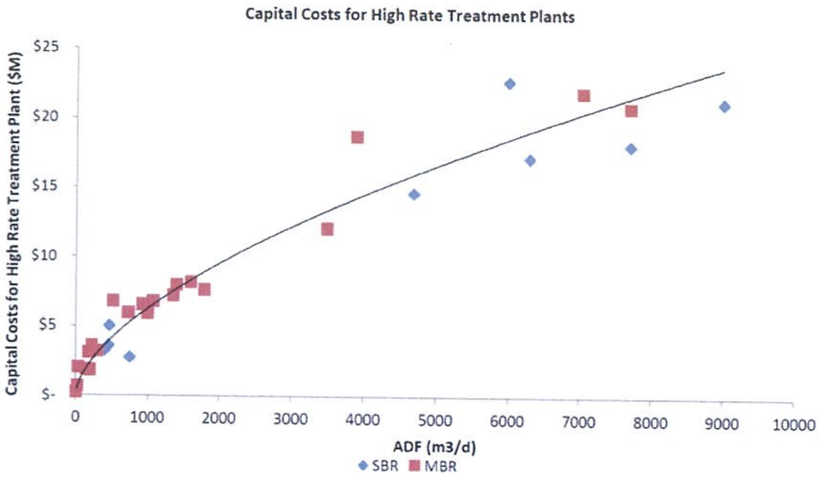
In Membrane Bioreactor (MBR) processes wastewater is treated in a series of anaerobic/anoxic/aerobic treatment zones similar to a conventional activated sludge plant before entering a membrane tank for solids liquid separation. Membrane Bioreactors operate very similar to conventional activated sludge processes except that microfiltration/ultrafiltration membranes are used for solid/liquid separation instead of a clarifier. The pore size of the membranes is sufficiently fine to provide disinfection.

The installation of an MBR at FWWTP would provide a very high level of treatment including nutrient removal and disinfection. MBRs have a small footprint area thus land area requirements would not be an issue for FWWTP. MBR processes are however expensive to install and operate and generally more costly than conventional high rate wastewater treatment. Membrane filters have a definite hydraulic peak flow maximum and hence the sizing is very sensitive to the peak design flow. Hence in a catchment like Featherston with a high I/I component this technology would be expensive.

The technology has become increasingly popular for reliably pre-treated waste streams and has gained wider acceptance where I/I has been controlled. Therefore a focus of mitigating Featherston's I/I issues would be critical if SWDC were to pursue this option.

The preliminary capital cost for a high rate treatment plant such as a membrane bioreactor, has been estimated based on the ADF of 1,765 m^3/day following targeted I/I rehabilitation work and the cost curve derived from Mott MacDonald's project database of over 30 MBR and SBR plants in New Zealand, presented in Figure 7.

Figure 7: Cost curve for high rate treatment plant capex cost



4.3.2 Sequential Batch Reactors – Treatment Option 5

Sequential Batch Reactors (SBRs) treat wastewater in a batch process. The reactor operates in a sequence of timed phases of filling, aeration, anoxic reaction, anaerobic reaction, settling, and decanting in the same tank. An SBR separates the treatment steps in time (sequential time phases in the same tank) in contrast to a conventional activated sludge process which separates the treatment steps in space (simultaneous reaction in separate tanks with a continuous through-flow). SBRs typically have more than one reactor and the batch process in each reactor is offset in time across the reactors such that only one reactor at a time is filling.

The installation of an SBR plant at FWWTP would provide a high level of treatment including nutrient removal, but would require tertiary treatment such as the existing UV disinfection system for pathogen removal. SBRs can deal with higher flow variations than MBRs, however their sizing is still very dependent on the peak flows they will need to process. Therefore as with the MBR option, a focus of mitigating Featherstons I/I issues would be critical prior to SBR design if SWDC were to pursue this option.

The cost and footprint of a MBR and SBR plant are unlikely to be significantly different at this high level assessment stage.

All high rate treatment options would resolve existing issues with scums, discoloration and foaming. In addition, it is expected that there would be a significant reduction in residual soluble biodegradable COD which should address the sewage fungus issues, discussed in section 4.1.

4.4 Land Treatment

Land application or land treatment is where wastewater is applied at a rate that allows the soil and plant system to utilise most of the applied water and nutrients, and pathogen attenuation occurs in the soil or on the surface of the land and plants due to natural processes such as disinfection from sunlight. This alternative is also a means of disposal and thus has been discussed in further detail in Section 5.

5 Alternative Discharge Options

Alongside treatment improvements, various options for discharging treated wastewater have been investigated and are discussed in the following section. The alternative discharge options considered to that of the status quo include:

- Full-time alternative discharge to water options (i.e. Tauherenikau River, Ruamahanga River).
- Full-time land treatment with 100% Deferred storage.
- Land Treatment with Deferred storage for 90%ile storage flows and Contingency Discharges to water (i.e. Donald Creek, dual discharge to Abbot and Donald Creeks, Tauherenikau River, Lake Wairarapa) or to land (i.e. high rate irrigation application).
- Partial Land Treatment with Wet Weather Discharges to water (i.e. Donald Creek, dual discharge to Abbot and Donald Creeks, Tauherenikau River, Ruamahanga River) or land via Rapid Infiltration.
- Beneficial Reuse.

The combinations of treatment and disposal options considered are summarised in Figure 1 and presented in Appendix B.

5.1 Status Quo / 'Do Nothing' Full-time Discharge to Donald Creek – Discharge Option A

The existing FWWTP discharge has been found to have significant effects on the water quality and aquatic ecosystems in Donald Creek as detailed earlier in Section 4.1. Maintaining the existing discharge at the same effluent quality would be inconsistent with the RMA s107 and policy framework within the relevant Regional Plans to 'maintain and enhance water quality'.

Given the concerns regarding the existing continuous discharge and its effects on Donald Creek, significant improvements in treatment would be required through the installation of a high rate treatment plant, to significantly improve the water quality in Donald Creek to comply with ANZECC (2000) and GWRC guidelines for an all year discharge. Even then, a standard high rate treatment process may not suffice and thus expensive and complex enhancements to the treatment process could be required to ensure appropriate water quality guidelines are met consistently during critical summer low flow periods. Further detailed assessment of high rate treatment capabilities and time-step mass balance modelling would be required to confirm such an option and was considered outside the scope of the evaluation.

As such a full-time discharge to Donald Creek has not been considered any further as part of this evaluation assessment.

5.2 Full-time Discharge to Tauherenikau River – Discharge Option B

The Tauherenikau River is located approximately 3.5km east of FWWTP. A possible 4.3 km pipeline route would be required to convey the treated wastewater from the FWWTP to the Tauherenikau River. The Tauherenikau River is a much larger, braided river, compared to Donald Creek, and ultimately flows into the Lake Wairarapa. A river flow recorder on the River, near the Gorge (some distance upstream of the site), suggests the average river flow is approximately 2.0 m³/s. Greg Butcher (*pers comm*, 2016) has advised that during summer low flows, a reduction in flow between the Tauherenikau River Gorge monitoring site and the River south of SH53 is observed. In addition, during low flow conditions the Tauherenikau south of SH53 can become dry (subsurface flow). Based on a limited set of low flow concurrent gauging's along the Tauherenikau, it has been suggested there may be a reasonably consistent 1 m³/s loss in flow between the Gorge and the River closer to the FWWTP. In the absence of any downstream gauging at higher flows, a revised conservative estimate of the River average flows closer to the plant have been made of 1m³/s. This estimate of flow suggests on average a three-fold increase in dilution exists in the Tauherenikau compared with Donald Creek (average flows of 0.35 m^3/s based on synthetic flow data produced by PGWES, 2016).

Advantages of discharging to the Tauherenikau River may include:

- Removing the contaminant load from Donald Creek which would significantly improve downstream water quality in terms of heterotrophic and periphyton growths, ammonia toxicity and significant decline in macro-invertebrate indices. Although upstream the overall stream health would remain in a degraded state as a result of upstream contaminant inputs.
- Greater dilution of the discharge and potentially better mixing available due to the larger river flows in the Tauherenikau for a majority of the year.

However, disadvantages to a continuous discharge to the Tauherenikau River may include:

- Effects on community and cultural values as a result of a continued discharge to water;
- Potential degradation of the present ecological value(s) of the downstream reach of the Tauherenikau River (MCI score currently excellent indicating excellent water quality and/or habitat conditions);
- Inconsistencies with the SWDC Wastewater Strategy and Regional Policies and Objectives to move to land based discharge regimes; and,
- Based on a high level mass balance assessment, the assimilative capacity in the River may:
  - Exceed the NIWA (2016) guidelines for DRP and TP at river flows less than 3x median without treatment. Any increase in DRP downstream of the discharge could result in undesirable periphyton growths in the River during these times, thus potentially effecting recreational values of the River unless a high level of treatment for Phosphorus removal is applied.
  - Exceed the National Policy Statement for Freshwater Management (NPS-FM) Attribute B maximum[3] for Ammonia toxicity and NIWA (2016) DIN guideline during winter months and at times when effluent concentrations are high and river flows are less than 1/2 median, without some form of nitrogen removal. It is noted that this type of event would be considered infrequent and further investigation would be required to ascertain their likely occurrence and thus the need for nitrogen removal.

Specific flow data in the vicinity of the proposed discharge point is unavailable, and certain water quality information (such as BOD) is unavailable for the Tauherenikau River. Therefore, more site specific flow and water quality data would be required to fully assess this option.

As shown in Figure 8, the rising main would run from the WWTP UV outlet, directly through Council-owned land, along the road corridor and then through a discharge structure such as a diffuser into the river. A shorter alignment may be achievable through adjacent farmland by seeking landowner approval and easements; however, as this is a high level concept design and evaluation we have taken a more conservative approach assuming a pipeline route along road berms.

The concept design for a Tauherenikau River discharge includes a; pumping station, rising main and river outlet works. A design flow rate of either 2,854 m^3/d (or 50 L/s) or 3,083 m^3/d (54L/s) has been applied depending on the treatment option selected, and which is the estimated 90th percentile discharge flow in 2025, and accounts for targeted flow reductions following I/I rehabilitation. It is assumed that buffering of high flows would be provided for within the existing ponds and this would need to be confirmed at a more detailed design stage. A pumping station and rising main has been selected as the preferred option due to the flat to upward-sloping grade of the land from the FWWTP to the river, and because a smaller pipe size could be used with a rising main as opposed to a gravity pipeline.

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[3] It is noted that the purpose of the NPS-FM guidelines was to guide regulators and their communities in setting catchment wide targets and was not for the purpose of assessing effects from point source discharges, however in the absence of any other recent guidelines or statutory standards they have been applied here as an indicator of potential effects only.

Figure 8: Possible Pipeline Route for Tauherenikau River Discharge

Table 6: Design Attributes – Full-time Discharge to Tauherenikau River

Description	Units	Value
Maximum Design Flow	L/s	50 - 54
Nominal Pipeline Diameter	mm	280
Pipeline Length	m	4,300

This option would require resource consents for the discharge into the Tauherenikau River and associated works and structures within the river bed, as well as any landuse consents and easements related to the construction of the pipeline.

If this option is to be given further consideration, a more thorough investigation is recommended, particularly into the existing river characteristics (flow and quality) to complete a comprehensive assessment of environmental effects for this river. Ecological values of the river are noted to be high and any summer discharges from the Featherston WWTP would likely be associated with nuisance growths of periphyton as a result of DRP loads to the River unless a high level of treatment for phosphorus removal is implemented. As such treatment options considered in conjunction with this disposal option have included Pond Enhancement Option 1 and High Rate Treatment Options 5 (**Options 1B and 5B**).

5.3 Full-time Discharge to Ruamahanga River – Discharge Option C

The Ruamahanga River, located approximately 14.7km east of FWWTP, has been identified as a potential alternative waterbody to discharge into, replacing the existing discharge to Donald Creek or the alternative Tauherenikau River discharge.

The Ruamahanga River is a larger river system than the Tauherenikau River and ultimately flows into Lake Onoke and Palliser Bay, thus this option would remove the discharge from the Lake Wairarapa catchment. Flow gauging on the Ruamahanga River at the Waihenga Bridge (GWRC, 2014) indicates the 7 day lowest flow (in 2013/14) was in the order of 10.4 m^3/s; compared to the Tauherenikau River at the Gorge site which recorded a 7 day lowest flow of 1.45 m^3/s. As a consequence the Ruamahanga River has a greater hydraulic capacity, in the order of a 10 fold increase from the Tauherenikau River; however as a result of upstream inputs to the Ruamahanga, background DRP concentrations in the River provide a similar constraint to that in the Tauherenikau River.

Advantages of discharging to the Ruamahanga River may include:

- Removal of the contaminant load from Donald Creek which would significantly improve its downstream water quality, although upstream the overall stream health will remain in a degraded state as a result of upstream contaminant inputs;
- Removal of contaminant loads to Lake Wairarapa – although it is noted that the proportion of current contaminant load from the FWWTP to Lake Wairarapa is relatively small compared with other landuse contaminant inputs in the lake catchment (estimated to be approximately 2.0% - see Chapter 6 of the Main AEE report for further detail);
- Greater dilution of the discharge for most contaminants and potentially better mixing due to the larger river flows all year round.

However, disadvantages to a continuous discharge to the Ruamahanga River may include:

- Effects on community and cultural values as a result of a continued discharge to water;
- Inconsistencies with the SWDC Wastewater Strategy, Regional Policies and Objectives, and the approach taken with upstream WWTP's moving to land based discharge regimes;
- Potential degradation of the present ecological value(s) of the downstream reach of the River (MCI score currently good indicating good water quality and/or habitat conditions); and
- Based on a high level mass balance assessment, the assimilative capacity in the River is likely to have:
  - limited capacity for DRP as upstream water quality exceeds the NIWA (2016) guidelines and plant contribution to River DRP without treatment for Phosphorus removal would be high during periods of River low flows. Any increase in DRP downstream of the discharge could result in undesirable periphyton growths in the River during summer low flow conditions, thus potentially effecting recreational values of the River.
  - limited capacity for DIN as upstream water quality exceeds the NIWA (2016) guidelines, although estimated plant contribution without targeted N removal is potentially small.
  - Minimal impact on Ammoniacal nitrogen and total oxidised nitrogen river concentrations even though the mass balance model suggests concentrations may exceed ANZECC default guidelines for lowland streams during summer low flow conditions. Concentrations in NH_4-N and TOX remain extremely low and are not likely to be of concern although further investigation would be recommended to confirm this.

The possible rising main route (14.7 km) is presented in Figure 9. A design flow rate of 50 L/s has been applied and accounts for targeted flow reductions following I/I rehabilitation. The proposed route follows the road corridor where possible; however a shorter alignment may be achievable through more farmland than already indicated by seeking planning and easements. This option would require resource consents for the discharge into the Ruamahanga River and associated structures, earthworks and works within waterbodies, as well as any landuse consents and easements related to the construction of the pipeline.

Figure 9: Possible Pipeline Route for Ruamahanga River Discharge

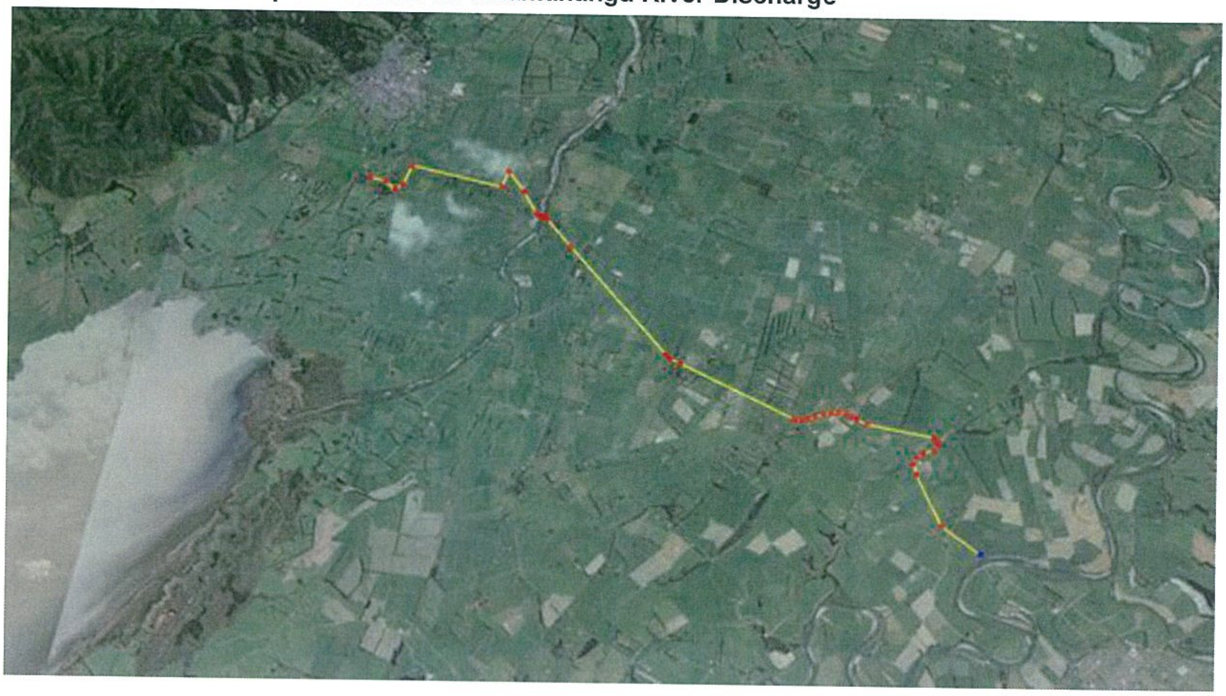


Table 7: Design Attributes – Full-time Discharge to Ruamahanga River

Description	Units	Value
Maximum Design Flow	L/s	50 - 54
Nominal Pipeline Diameter	mm	355
Pipeline Length	km	14.7

In order to pursue this option, any summer discharges from the Featherston WWTP could be associated with nuisance growths of periphyton as a result of DRP loads to the River unless treatment for Phosphorus removal is implemented. As such treatment options considered in conjunction with this disposal option have included Pond Enhancement Option 1 (**Option 1C**). High rate treatment using MBR or SBR was considered to be unnecessary and cost prohibitive.

5.4 Land Treatment

Land application or land treatment is where wastewater is applied at a rate that allows the soil and plant system to utilise most of the applied water and nutrients, and pathogen attenuation occurs in the soil or on the surface of the land and plants due to natural processes such as disinfection from sunlight.

Land located near to the FWWTP is flat to gently undulating and therefore well suited to wastewater application infrastructure. It is also unlikely to be subject to slope stability issues. Disadvantages however are the high groundwater levels in the area and the young, poorly structured, and therefore slowly draining nature of some of the soils.

SWDC commissioned a preliminary assessment of options for effluent disposal to land (LEI, 2012). This desktop investigation identified potential areas for land application as being:

- Adjacent to the right bank of Abbot Creek, beginning within 500 m of the FWWTP, corresponding to the outwash plains of streams and rivers leaving the ranges; and
- The large outwash fan between the Tauherenikau and Waiohine Rivers (approx. 27 km²), bounded by the Rimutaka foothills and extending toward Te Maire Ridge.

Three properties were identified by SWDC as potentially available for land application of wastewater (albeit not all within the land areas identified by LEI in their desktop study discussed above) and included SWDC owned land adjacent to the FWWTP at Donald Street (12.6 ha, <100m), the adjacent golf course (33ha, 650m), and nearby privately owned Geange Farm (155 ha, 300m). A forth property, Hodder Farm (167ha) was identified as potentially available in 2014.

LEI has assessed each of the properties, both through desktop and field investigations (LEI 2013 & 2017), to confirm the suitability and limitations for land treatment. The LEI assessments conclude land treatment is feasible, although limitations in soil drainage and depth to groundwater are evident for the SWDC Adjacent Block, Golf Course, parts of Geange Farm (40%) and Hodder Farm. These limitations could be appropriately managed, but would result in constraints in the number of days per year on which wastewater application could occur when compared with land better suited to land application.

LEI developed an empirical water and nutrient budget model which determined the following capacities of each land block for receiving treated wastewater (prior to I/I reduction works):

- SWDC Adjacent block – 6% of annual average discharge volume.
- Geange Farm – 36% of annual average discharge volume.
- Hodder Farm – 100% of annual average discharge volume in combination with 422,000m^3 storage, to achieve a deficit type scheme and avoid discharges to surface water.

The LEI model also determined the limitation for land treatment of Featherston's wastewater to be hydraulic rather than nutrient limited. This means that improvements to treatment performance through the addition of nutrient removal processes would not result in changes to the land area or storage requirements, reiterating the need for I/I reduction to assist in reducing the size and associated costs of the scheme.

Consideration was also given to the option of pumping effluent to the Rimutaka Forest Park for land treatment. Aside from any administrative issues associated with discharging in the Regional Park, the preliminary assessment proved to be cost prohibitive due to site constraints (i.e. steep land resulting in low application rates and thus large land area requirements), with costs significantly higher than a high rate treatment plant or combining treatment with another plant in another separate location.

Based on the above, land treatment with deferred storage and combined land and water discharge options to reduce pond storage size have been further investigated and are discussed in the following sections.

5.4.1 Full time Discharge to Land – Discharge Option D

5.4.1.1 Full-time Discharge to Land with Network Rehabilitation – Option 3D

In 2014, SWDC had the opportunity to secure land at Hodder Farm, as such this assessment has been based on land treatment at the SWDC Adjacent block and Hodder Farm which is known to have sufficient area to take the full flow from the FWWTP and are both located adjacent to the FWWTP site. This option would see land application occurring mainly during summer months and to a lesser extent during shoulder months with much of the inflow to the plant being stored over winter as a result of high groundwater levels.

The additional potential treatment benefit of discharging treated wastewater to land, in terms of plant uptake of nutrients like nitrogen and phosphorus has been recognised and Pond Enhancement Option 3 (see Section 4.2.3) has been proposed in conjunction with this disposal option (**Option 3D**) for evaluation purposes.

Based on the work undertaken by LEI, it was determined that a deficit irrigation scheme would not be feasible for Featherston based on the volumes to be managed and large storage requirements, thus a non-deficit irrigation regime was considered as part of this options evaluation. However, storage requirements remain excessively large, with estimated volumes of between 280,000m³ and 395,000m³ required based on the LEI water budget model which has accounted for targeted flow reductions following I/I rehabilitation[4] and depending on site restrictions put in place (i.e. stock and vehicle access). Land irrigation area required for this option also range between 90ha and 116ha depending on site restrictions.

A high level concept design of a 280,500m³ deferred storage pond and 90ha land irrigation area has been developed for sizing and costing purposes and is presented in Table 8.

Table 8: Design Attributes – Land Area and Deferred Storage Pond for 100%ile storage flows assuming I/I reduction

Description	Units	Value
Design Working Storage Volume	m³	280,500
Pond Depth	m	4.1
Pond Area	ha	8
Irrigation Area	ha	90
Gross Land Area	ha	117

Storage of this size is considered unfeasible in terms of cost, constructability and ongoing operation and would be substantially underutilised for most years modelled (LEI, 2017). Options to further reduce pond storage requirements have also been considered and these are discussed in greater detail in Section 5.4.2 and 5.4.3.

5.4.1.2 Full-time Discharge to Land with Re-reticulation of Network – Option 4D

The full re-reticulation of the Featherston network with a low pressure sewer network would substantially reduce the incoming flows into Featherston WWTP (by approximately 74%) as presented in Section 2.2.2. These reduced flows would allow for a deficit irrigation scheme, as the deferred storage requirement would significantly reduce to somewhere in the order of 32,000m³. Land irrigation area requirements would also substantially reduce (approximately 48ha). As with Option 3D above, full-time land discharge would reduce the modifications and improvements required to the pond treatment system and thus this option has been coupled with Pond Enhancement Option 4 (see Section 4.2.3) for evaluation purposes (**Option 4D**).

The substantial cost savings recognised by the reduced size of the land treatment system and storage pond are shown to be significantly offset by the substantial re-reticulation costs required. Although this is a favourable long-term solution for the environment and future generations that would see a brand new reticulation system with a long asset life, the elimination of I/I from the network and thus result in a far more manageable volume of effluent to treat and dispose of, the costs appear prohibitive at this time.

5.4.2 Land Treatment with 90%ile Deferred Storage and Contingency Discharge – Discharge Option E

As indicated above, substantial pond storage to achieve a deficit or non-deficit land treatment scheme is required to avoid all discharges to water unless the network is re-reticulated. Therefore, contingency disposal options to manage the winter peak wet weather flows have been included as part of this options evaluation resulting in a reduced storage volume requirement.

The contingency disposal options discussed below all account for targeted flow reductions following I/I rehabilitation and propose storage volumes capable of containing the 90th percentile stored volume as determined by the LEI water budget model. A 90th percentile design containment approach was taken for Greytown and Martinborough schemes, thus the same approach has been considered for Featherston.

[4] A reduction in storage volume and land areas is possible within the existing proposal (i.e. as assessed by LEI, 2017) if SWDC place limitations on the land use activities (stock and vehicle access).

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.

Based on LEI's water balance model, and assuming site restrictions are imposed (i.e. stock and vehicle access) it is understood that a storage volume of approximately 176,000m³ (assuming targeted I/I reduction level is achieved)[5,6] would be necessary to avoid discharges to water for up to the 90th percentile storage flows and a land irrigation area of 90ha.

A high level concept design of the deferred storage pond has been developed for sizing and costing purposes and is presented in Table 9. The exact location of the storage pond would be confirmed at detailed design stage and may be better positioned elsewhere on the site, however for this high level evaluation, it has been positioned down-gradient of the existing plant to minimise pumping costs (see Figure 10). Due to the size of storage pond, this option would require resource consents for the damming of water alongside consents for the land discharge and any associated water discharge.

Figure 10: Potential Location of Deferred Storage Pond

Table 9: Design Attributes – Land Area and Deferred Storage Pond for 100%ile storage flows assuming I/I reduction

Description	Units	Value
Design Working Storage Volume	m³	176,000
Pond Depth	m	4.1

[5] Or 277,000m³ (assuming no I/I reduction)

[6] We acknowledge this volume has been updated to 186,000m³ as documented in the LEI "Assessment of Environmental Effects of Discharge of Featherston Treated Wastewater to Land" February 2017 report. The volume however depends greatly on the depth and thus surface area applied in the water balance. Costings undertaken at this high level contain suitable margin to account for these potential changes in design.

Description	Units	Value
Pond Area	ha	5.3
Land Irrigation Area	ha	90
Gross Land Area	ha	117

Management of the proposed scheme has been based on deferred irrigation, with a total number of discharge days between 114-228 days per year, depending on rotation of application rates.

Most years would see contingency overflows from the deferred storage during wet months (primarily July, August and September of on average 55,000m^3). The maximum contingency flow rate to be discharged under the scenario is 6,000 m^3/d (70 L/s)[7] and has been applied in the concept design sizing discussed for each disposal option considered below.

Disposal options for these contingency overflows are presented in the following sections and include:

- Contingency discharge to Donald Creek.
- Contingency discharge split between Abbot Creek and Donald Creek.
- Contingency discharge to the Tauherenikau River.
- Contingency discharge to Lake Wairarapa.
- Contingency discharge to Ruamahanga River.
- Contingency discharge to Land via High Rate Application.

Consideration of treatment of the contingency flow prior to discharge has been made depending on the receiving environment proposed. It is noted that high rate biological treatment processes (MBR/SBR) are not suitable for the treatment of occasional flows and therefore have not been considered in any of the following option scenarios.

5.4.2.1 Contingency Discharge to Donald Creek – Discharge Option E1

This option proposes the contingency discharge would continue via the existing discharge channel to Donald Creek and therefore no modifications to the disposal system in this regard is proposed.

The frequency and total annual volume of discharged flows would be significantly reduced compared with the current situation (approximately 6% of the total annual average flow following targeted I/I reduction); thereby significantly reducing the overall mass loads of contaminants to the surrounding environment and thus reducing the environmental impacts. However, there remains a lack of assimilative capacity in Donald Creek for nutrients such as DIN and DRP as a result of upstream contamination.

Three methods have been proposed to mitigate potential issues in Donald Creek downstream of the intermittent contingency discharge and have been assessed as part of this options evaluations:

1. Extended staging timeframes, polishing of wastewater with FTW technology and coagulant dosing within the ponds for P removal, followed by a high stream flow discharge regime once contingency discharge stage is in place (**Option 1E1**).
2. Minimised staging timeframes, polishing of wastewater with FTW technology, followed by P removal via DAF and high flow discharge regime once the contingency discharge stage is in place (**Option 2E1**).
3. Minimised staging timeframes, minor pond modifications and implementation of a high flow discharge regime on the contingency discharge (**Option 3E1**).

[7] Derived from the LEI water balance modelling but is based on the flow regime within Donald Creek. An assumption the same maximum discharge rate applies to all alternative receiving environments has been made in the absence of detailed modelling for each receiving environment.

To reduce potential effects on Donald Creek a discharge regime correlating to high stream flow would be adopted on the contingency discharge. Three times median flow is a generally accepted "rule of thumb" of the flow at which stream substrate becomes mobile, and essentially periphyton biomass can be assumed to be removed at such flows. In the case of Donald Creek, it is likely that lower flow events (>2x median flow) will result in some removal of nuisance growths from the stream bed (Hamill, 2017). Therefore, nutrient concentrations during such events would not have an adverse ecological impact. It is considered such a discharge regime could be manageable at Featherston to address these contingency flows.

In the event the land treatment staging is to be prolonged, but to avoid "sunk" costs at the final upgrade stage, polishing of the discharge using FTW technology and coagulant dosing for P removal have been considered to further improve compliance with regional planning policies and to a large extent meet s107 requirements (Pond Enhancement **Option 1E1**). This would see the benefit to plant growth of Phosphorus in the wastewater applied to land being lost.

In the event scheme staging is to be minimised but it is found that ongoing removal of Phosphorus is necessary to protect downstream ecosystems, an alternative treatment process for phosphorus removal using DAF on the contingency discharge has also been considered (Pond Enhancement **Option 2E1**). This option also retains FTW for further polishing of the effluent to assist in meeting s107 requirements in the event the discharge regime was not found to sufficiently mitigate such effects during winter months.

Finally by way of comparison, assuming the scheme staging is advanced within an acceptable timeframe, and the high rate contingency discharge regime alone is shown to result in effects that are considered tolerable, then the third option proposes no additional treatment requirements (Pond Enhancement **Option 3E1**).

It is important to note that none of these options would resolve concerns regarding ammonia toxicity and DIN until such time as the completed land application scheme including deferred storage was in place. High rate biological treatment is the only method whereby nitrogen is removed to acceptable levels with any certainty. However, high rate biological treatment in conjunction with land treatment and large deferred storage as is being considered here would be cost prohibitive.

5.4.2.2 Contingency Discharge to Abbot Creek – Discharge Option E2

Abbot Creek is a small creek that runs along the western edge of FWWTP, eventually joining with Donald Creek approximately 1.5km south of the FWWTP and flowing into Lake Wairarapa. A split discharge of excess flows to Abbot and Donald Creek has been considered with the aim of reducing the contaminant loads directly into Donald Creek, and enabling greater dilution and mixing of the wastewater.

Figure 11 below provides a concept drawing of the pipeline to Abbot Creek. A new flow splitter downstream of the UV outlet would be required such that part of the outlet flow is diverted into a new gravity pipeline, while the remaining flow continues down the existing discharge pipeline to Donald Creek. Variations of this option could be considered such as piping the discharge downstream of the Abbot and Donald Creek confluence to increase potential for dilution. However, for this high level evaluation the scope has been limited to the conceptual design illustrated below.

The winter contingency discharge would be piped to both Creeks during high flow periods to minimise impacts of ammonia toxicity and undesirable growths. There is however limited sampling and flow data for Abbot Creek, therefore the quality and volume of water in the receiving environment is unknown. Random flow gauging undertaken in winter 2016 (Greg Butcher on 29 August 2016 "during a fairly dry winter"[8]) suggests that the flow rate in Abbot Creek directly adjacent to the FWWTP may at times be almost 50% less than flow in Donald Creek at the discharge point. Abbot Creek also appears to loose flow downstream whilst Donald Creek gains flow from groundwater recharge and therefore consistently has greater

[8] Email dated 30 August 2016

baseflow. The concept design details are presented in Table 10. The design flow is based on an assumed equal flow split between the Donald and Abbot Creeks; thus, a daily flow of 3,000 m^3/d into Abbot Creek and 3,000 m^3/d into Donald Creek. The exact discharge split would need to be determined following more detailed effects assessments.

Due to the limited information on water quality in Abbot Creek, the impacts of the proposed regime require further investigation to ascertain whether a greater level of treatment is required. For the purpose of this high level assessment it has been assumed that a high flow discharge regime and split discharge to increase mixing would be sufficient to mitigate any adverse effects at the final stage of development. As such, Pond Enhancement Option 3 has been proposed in conjunction with this disposal option (**Option 3E2**) for evaluation purposes.

Consent for the discharge into Abbot Creek and associated works and structures within the stream bed would be required in addition to the consents required for the land treatment scheme and damming of water.

Figure 11: Split discharge to Abbot and Donald Creeks

Table 10: Design Attributes – Split Contingency Winter Discharge to Abbot Creek

Description	Units	Value
Maximum Design Flow	L/s	34.8

Description	Units	Value
Pipeline Diameter	mm	225
Pipeline Length	m	480

5.4.2.3 Contingency Discharge to Tauherenikau River – Discharge Option E3

This option considers a winter contingency discharge to the Tauherenikau River during flow periods greater than 3 x median flow. The Tauherenikau River has a greater flow rate than Donald Creek, and at these high flows, issues regarding periphyton growth would be sufficiently mitigated. As such simple Pond Enhancement Option 3 has been considered in conjunction with this disposal option (**Option 3E3**).

The pipe alignment is that presented in Figure 8. The concept design includes a pumping station and a rising main designed for a flow rate of 6,000m^3/d, and river outlet works. It is noted that this infrastructure would sit largely unused for a majority of the year with exception to the months of July and August and in some years would not be used at all (average annual discharge days approximately 15 per year).

Table 11: Design Attributes – Contingency Winter Discharge to Tauherenikau River

Description	Units	Value
Maximum Design Flow	L/s	104
Nominal Pipeline Diameter	mm	355
Pipeline Length	m	4,300

Consent for the discharge into the Tauherenikau River and associated works and structures within the River bed as well as any landuse consents and easements related to the construction of the pipeline, consents associated with the land discharge and damming of water would also be required.

5.4.2.4 Contingency Discharge to Lake Wairarapa – Discharge Option E4

The winter contingency flow would be piped and discharged to Lake Wairarapa via the natural wetland system along the northern shores of the Lake.

This option has however been discounted due to the foreseen social and cultural effects of discharging treated wastewater directly to the Lake, particularly due to the Lake's outstanding values and already degraded state. This option would require extensive community and iwi consultation, and ecological assessments undertaken before it could be considered any further from a technical viewpoint.

5.4.2.5 Contingency Discharge to Ruamahanga River – Discharge Option E5

The winter contingency flow would be piped and discharged to the Ruamahanga River. The River has a greater flow rate than Donald Creek and the Tauherenikau River; therefore above 3x median flow there is likely to be sufficient dilution and mixing to mitigate any ecological impacts on the environment in terms of the main contaminant of concern, DRP.

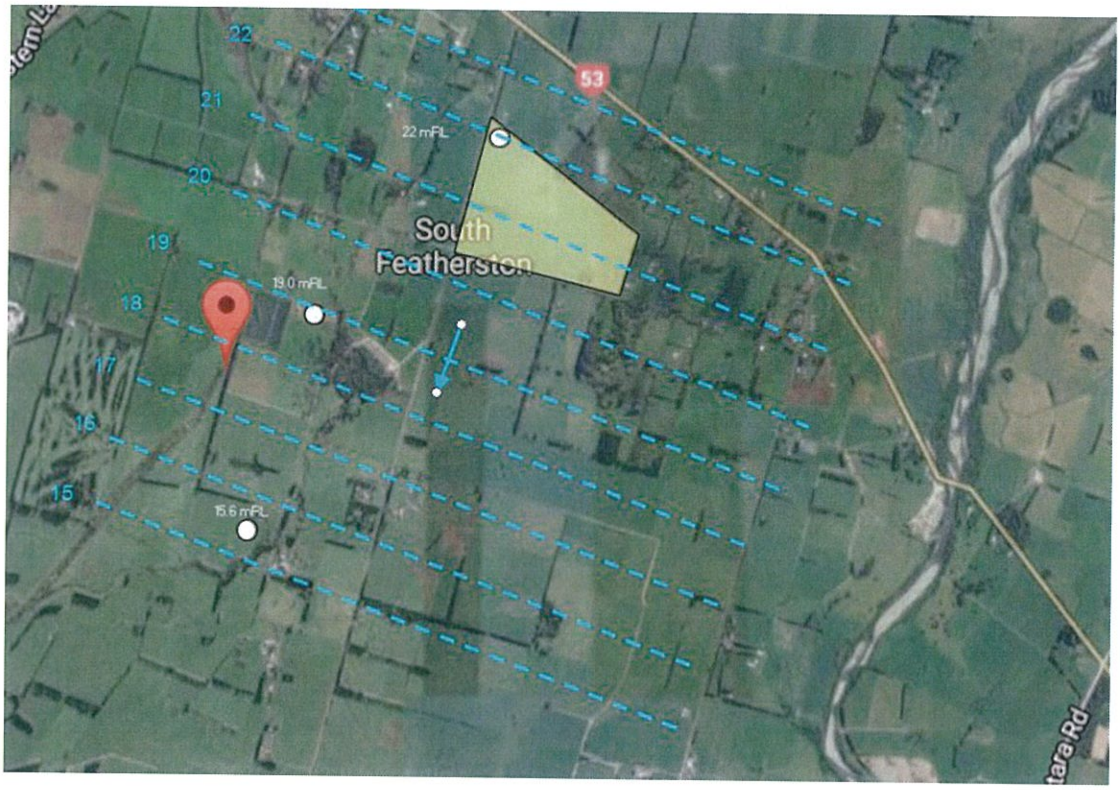
The Ruamahanga River would require a pipeline over 14km long, as such significant reticulation costs would be incurred for a piece of infrastructure that would sit largely unused. This in conjunction with significant costs associated with the proposed land treatment and large storage pond mean this option would be cost prohibitive and therefore has not been considered any further.

5.4.2.6 Contingency Discharge to Land – Discharge Option E6

The contingency flow would be discharged using spray irrigation infrastructure to land in an area in the North-East corner of Hodder Farm, illustrated in Figure 12, during winter months. The application rates have been assumed to be the same as those applied under the deferred irrigation regime of 55mm/d.

The western two thirds of the property is the preferred area for land application and two 8 ha high rate irrigation blocks could be developed in the land available. No additional treatment is proposed and Pond Enhancement Option 3 has been considered in conjunction with this contingency disposal option (**Option 3E6**).

Figure 12: High Rate Irrigation Application Area



GWS (2017) has undertaken a feasibility assessment into the potential effects of this option specifically assessing potential effects on groundwater mounding and groundwater quality (see Appendix C). Model runs simulated the two irrigation blocks with cyclic irrigation on 7 day, 3 day and 1 day return periods. Results indicate a 3 day return period as being the most efficient in reducing mounding effects and mounding is generally at the critical level of 1.5 m after 45 days irrigation. Being able to apply the wastewater at a rate that results in manageable mounding effects and limits the potential for surface breakout is a critical factor in this proposal and initial results have indicated this may be possible. However, GWS have advised that there remains a reasonable amount of uncertainty in the assessment undertaken relating to elevation control, characterisation of the unsaturated zone depth distribution over the site and understanding of the geologic conditions at depth. Due to these uncertainties and the apparent high sensitivity of mounding in relation to aquifer properties, there is residual risk that ponding and surface breakout of wastewater could occur due to topography and soil stratigraphy in localised areas. This could then result in pathogens in run-off entering water ways.

In terms of groundwater quality, modelling confirmed the discharge would not generally result in concentrations of nitrate in the aquifer in excess of Ministry of Health (MoH, 2008) drinking water standards (11.3 mg/L), however in the event wastewater TN might reach 25 mg/L following I/I reduction, bores in areas with already elevated background concentrations could exceed potable limits. This is likely to affect bores in the area to the east. In terms of pathogen contamination, all of the bores down gradient of the high rate land application area would be susceptible to capturing a component of the discharge. Travel times to these bores is in the order of 6 months to the closest takes, indicating the possibility that pathogens (in particular viruses) could enter these bores.

Based on the residual risks described above, GWS recommended these be addressed through detailed investigation and design to confirm whether potential affects could be minimised and/or re-evaluated if this option were to be pursued.

5.4.3 Combined Land and Water Discharge Regime – Disposal Option F

Options to further reduce the pond storage requirements have been considered as part of this evaluation as follows:

- Increasing the irrigable land area available;
- Combined land treatment and direct discharge to water regime (surface water receiving environments considered include Donald Creek, combination of Donald and Abbot Creeks, Tauherenikau River or Ruamahanga River); and
- Combined land treatment and indirect discharge to water via rapid infiltration basin, constructed wetland or infiltration gallery close to the WWTP site.

LEI (2013) determined that including additional irrigation land area decreased the storage volume requirement, however a reduction in the average irrigation depth applied across the area would also result[9]. Table 12 presents a comparison between land area and storage requirements. An increase in deferred irrigation land to 164 % of the original land area (70 to 120 ha), results in a reduction in 90th percentile storage requirements of 8 % (approximately 16,000 m^3 or less) for an additional cost of $1.18M[10]. Thus the overall benefits in reduced storage costs would be contradictory to increased land and additional irrigation equipment costs, and would see the scheme not maximising its full potential.

Table 12: Land Area versus Storage Requirements

90th percentile storage required (m^3)		Non-deficit land area (ha)		
		70	120	200
Deficit land area (ha)	8	189,000	173,000	165,000
	30	188,000	172,500	-
	100	187,000	-	-
	200	187,000	-	-

By optimising the land treatment regime, a balance can be found between discharging as much flow to land as possible (without causing unsustainable nutrient leaching or hydraulic overloading of the soils), storage, and managing part-time discharges through an alternative discharge method. As such land treatment in conjunction with part-time direct and indirect discharge to water have been considered in further detail in the following sections.

9 The reason that extra land does not result in a substantial reduction in the storage volume required is that during those periods when soil conditions are not suitable for discharge to land these conditions occur across all of the land so there is still a need to store wastewater during wet conditions (usually also corresponding to high inflows to the WWTP). However, when irrigation can occur, to a greater land area, the storage is emptied more quickly. This results in an overall lower application depth applied across the site.

10 If storage is approximately $20/$m^3$ that results in a reduction of $320k, for an investment of irrigation equipment at $30 k/ha of $1.5M, thus resulting in an additional cost of $1.18M not including land purchase costs.

In order to determine the sizing and operational parameters for a combined land treatment and water discharge (direct or indirect) regime, the LEI water balance model was used with the following additional assumptions made:

- the soil has a treatment depth of 400m with an available water holding (field) capacity of 15-19mm/100mm;
- land treatment can occur year round assuming rainfall >6mm has not occurred in the preceding 24h
- land treatment can occur unless the field capacity has been exceeded by >1mm when considered over the whole area;
- discharge is to land treatment by preference, and alternative discharge method is considered only if discharge to land cannot occur and there is no remaining storage available;
- no discharge to alternative discharge method between December 1 to March 31;
- discharge to alternative discharge method up to 1,000 m³/day during April, October and November; up to 2,000 m³/day during May, June and September; and up to 3,000 m³/day during July and August.

The combined land treatment and water discharge regime based on the above assumptions results in an average annual volume of approximately 160,000 m³ (~30% of the total average annual volume from the FWWTP) that is required to be disposed of on average 116 days a year (and would not necessarily occur on consecutive days) via an alternative disposal method to the land treatment scheme. The annual volume and frequency of discharge requiring alternative disposal varies from year to year due to climate (i.e. the amount that can be irrigated to land) and inflow variations.

Storage would still be required for land management purposes and under the scenario described above an indicative storage volume of approximately 18,000m³ would be necessary. A land irrigation area of 90ha assuming site restrictions are imposed (i.e. stock and vehicle access) has been proposed.

The maximum excess flow rate to be discharged under the scenario derived from the above assumptions is 3,000 m³/d (34.7L/s) and has been applied in the concept design sizing discussed for each direct and indirect water discharge option below.

Consideration of treatment of the excess flows prior to discharge has been made depending on the receiving environment proposed. It is noted that high rate biological treatment processes are not suitable for the treatment of occasional flows and are therefore only considered for options where the full-flow would be treated to this high level.

5.4.3.1 Partial Discharge to Donald Creek – Discharge Option F1

The optimised land treatment regime prioritises applying flows to land and would only divert excess flow to Donald Creek when land treatment and storage is not possible. It is proposed that no discharges to Donald Creek would occur for up to 4 months each year (e.g. between December – March). The frequency and total annual volume of discharged flows to Donald Creek for this option would be significantly reduced compared with the current situation thereby significantly reducing the overall mass loads of contaminants to the Creek, whilst targeting removal of the discharge from the Creek during summer when effects on aquatic ecosystems are greatest. However, there remains a lack of capacity for Donald Creek to assimilate nutrients due to upstream inputs and under most creek flow conditions, ammonia toxicity may remain an issue to downstream ecosystems. Detailed water quality modelling would be necessary to confirm the level of effect of such a discharge. Thus any continued discharge to Donald Creek of this scale, however intermittent, would likely result in adverse effects on the aquatic ecology that are more than minor and without additional treatment may result in effects that are considered to be significant. For comparative purposes, Pond Enhancement Option 2 has been evaluated in conjunction with this disposal option (**Option 2F1**).

High Rate Biological treatment with partial land discharge has also been considered (**Option 5F1**). This option differs slightly to the assumptions given above due to the fact biological treatment processes require a continuous flow. Due to the high level of treatment proposed, this option would give priority to discharges to water and only discharge to land when stream flows are low. This reduces the land irrigation area requirements and utilises the existing ponds for buffering. An assumption has been made that around half the land area is required for Option 5F1 compared to that predicted for all other partial discharge options (i.e. approximately 45ha).

5.4.3.2 Partial Discharge to Abbot and Donald Creeks – Discharge Option F2

Details of the conceptual design layout for this option have been described in Section 5.4.2.2 and are not repeated here. Pipeline design attributes are presented in Table 13.

Table 13: Design Attributes – Split Discharge to Abbot Creek

Description	Units	Value
Maximum Design Flow	L/s	17.4
Pipeline Diameter	mm	225
Pipeline Length	m	480

The optimised land treatment regime prioritises applying flows to land and would only divert excess flow to Donald and Abbot Creeks when land treatment and storage is not possible. It is proposed that no discharges to the creeks would occur for up to 4 months each year (e.g. between December – March).

Due to very limited flow monitoring and quality sampling data for Abbot Creek, there are significant uncertainties around the existing quality of the waterway, the amount of dilution that could be provided, and the magnitude of environmental effects that may occur as a result of discharging to this creek. Pond Enhancement Option 2 has therefore been proposed in conjunction with this disposal option (**Option 2F2**) as a means of reducing potential environmental risks. Further investigation is required to confirm the likely effects of this option, and in particular the likelihood for issues regarding ammonia toxicity and periphyton growth during shoulder months as a high creek flow discharge regime is not proposed in this case as this would likely increase storage pond volume requirements.

5.4.3.3 Partial Discharge to Tauherenikau River – Discharge Option F3

Similar to a full-time discharge to the Tauherenikau River, the option of a partial discharge to the Tauherenikau River has been considered. The concept design is similar to Option B (see Table 6), with a design flow based on the maximum excess flow rate of 3000 m³/d (52 L/s).

The optimised land treatment regime prioritises applying flows to land and would only divert excess flow to the Tauherenikau River discharge pipeline when land treatment and storage is not possible. It is proposed that no discharges to the river would occur for up to 4 months each year (e.g. between December – March). During this time, the pipeline would be idle. The capital and ongoing operations and maintenance cost of the pipeline must therefore be weighed against the benefit gained from discharging flows to the Tauherenikau River.

Discharging to the Tauherenikau River is expected to provide better environmental outcomes compared with discharging to Abbot or Donald Creeks, particularly due to the higher dilution available in the Tauherenikau River. However the same disadvantages exist as those indicated for a continuous discharge to the Tauherenikau (Option B) such as:

- Effects on community and cultural values as a result of a continued discharge to water;
- Potential degradation of the present excellent ecological value(s) of the downstream reach of the river (MCI score currently excellent indicating excellent water quality and/or habitat conditions); and
- High level mass balance assessment of the assimilative capacity in the Tauherenikau River indicate:
  - (1) DRP and TP at river flows less than 3x median without treatment may be an issue, and

- (2) Ammonia toxicity and exceedance of DIN guideline values may occur during winter months at times when effluent concentrations are high and river flows are less than 1/2 median, without some form of nitrogen removal or avoidance of discharge during winter low flow periods.

As with Option B, in order to pursue this option, a high level of treatment would need to be provided for phosphorus removal. As such, Pond Enhancement Option 2 has been proposed in conjunction with this disposal option (**Option 2F3**) to minimise effects of Phosphorus in the discharge on the receiving environment above median river flow. A risk of DRP concentrations exceeding guideline values would remain at flows below median river flow and further water balance and quality modelling is necessary to confirm this.

Elimination of the discharge from the Tauherenikau River during summer months and avoidance of discharges to the river during winter at below ½ median flows would potentially mitigate any ammonia toxicity issues and exceedences in DIN guidelines values. In the absence of any river flow data and thus daily time step water quality modelling it is difficult to confirm whether such events would be in fact be avoided and thus this risk of ammonia toxicity remains unless high rate biological treatment is implemented[11]. The cost of implementing high rate biological treatment, the conveyance pipeline and the scale of land treatment proposed is considered to be cost prohibitive.

5.4.3.4 Partial Discharge to Ruamahanga River – Discharge Option F4

Similar to the option of discharging excess flow to the Tauherenikau River, this option envisages discharging excess flow to the Ruamahanga River. The concept design details are similar to those presented in the full-time discharge to Ruamahanga River Option (Option C) and is based on a maximum design flow rate of 3000 m^3/d (52 L/s) (see Table 7).

The optimised land treatment regime prioritises applying flows to land and would only divert excess flow to the Ruamahanga River discharge pipeline when land treatment and storage is not possible. It is proposed that no discharges to the Ruamahanga River would occur for up to 4 months each year (e.g. between December – March). During this time, the pipeline would be idle. As with Option F3 the significant capital cost and ongoing operational cost of the pipeline must therefore be weighed against the benefit gained from discharging excess flows to the Ruamahanga River.

Discharging excess flows to the Ruamahanga River is expected to provide improved environmental outcomes compared with discharging to Abbot Creek, Donald Creek or the Tauherenikau River, particularly due to the higher dilution offered by the Ruamahanga and through the removal of the discharge from the Lake Wairarapa catchment. As with Option C, in order to pursue this option, a high level of treatment would need to be provided for phosphorus removal. As such, Pond Enhancement Option 2 has been proposed in conjunction with this disposal option (**Option 2F4**) to minimise effects of Phosphorus in the discharge on the receiving environment above median river flow.

5.4.3.5 Partial Discharge to Land

Discharge to land via rapid infiltration has been considered as an option for discharging excess flows to land and indirectly to water rather than maintaining a continued direct discharge to water. Rapid infiltration can be achieved through a variety of mechanisms, including rapid infiltration basins (RIB), constructed wetlands and infiltration galleries. These options are discussed in the sections below.

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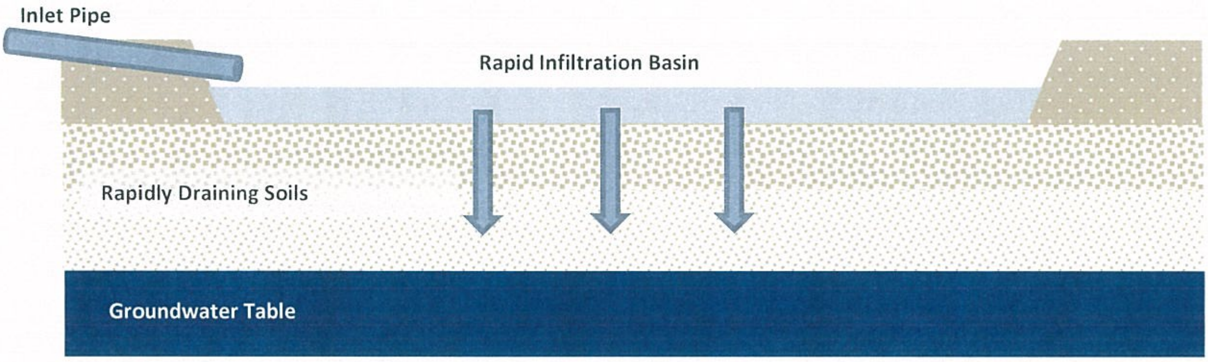
[11] Specific flow data in the vicinity of the proposed discharge is unavailable, and certain water quality information (such as BOD) is unavailable for the Tauherenikau River. Therefore, more site specific flow and water quality data would be required to fully assess this option.

Rapid Infiltration Basin - Discharge Option F5

This option involves discharging treated effluent to a rapid infiltration basin and allowing water to soak through the soils directly to the groundwater table below. A schematic diagram of a RIB is presented in Figure 13 below.

Figure 13: Generic Configuration of Rapid Infiltration Basins



A RIB system is managed by repetitive cycles of hydraulic loading, infiltration and drying. In this option, the RIB system would be loaded only during excess flow events for flows that cannot be applied to the land treatment system. This would typically be during the winter months and to a lesser extent during the shoulder months, when frequent wet weather will impact on both the volume of flow into the WWTP and soil moisture. Because they are designed for rapid infiltration, little to no treatment would be provided by the RIB system.

A concept of a RIB system (Figure 14) has been sized based on discharging a maximum excess flow of (3000 m^3/d). The concept shown in Figure 14 includes two shallow basins in parallel, sited near the FWWTP and proposed land treatment site. The operation of the RIB would involve intermittently flooding the basins (hydraulic loading period) followed by a infiltration period to allow flows to infiltrate through the soils beneath followed by a resting period before the next hydraulic loading period. This disposal option has been proposed in conjunction with Pond Enhancement Option 3 (**Option 3F5**) for evaluation purposes.

Table 14 presents the concept design assumptions and sizing details.

Figure 14: Possible location of Rapid Infiltration Basins

Table 14: Design Attributes – Rapid Infiltration Basin

Description	Units	Value
Basin(s) design volume	m^3	3,000
Number of basins	-	2
Design (minimum) infiltration rate	mm/hr	8.0
Basin design depth	m	0.2
Total land area required	ha	1.58

The proposed RIB is an affordable option for the Featherston Community assuming no further additional treatment is required and goes someway to addressing community and cultural concerns by minimising all but extreme wet weather overflow discharges from surface waters.

Risks however include:

- Unknowns around appropriate loading and resting periods. If drainage is slower than expected and resting periods short, then the generation of odour from potentially stagnant water could arise.
- Groundwater mounding which can lead to effects on local groundwater hydraulic gradients (i.e. changing groundwater direction), springs and ponding, and the mobilisation of contaminants already in the soil or groundwater. Following their review of the hydrogeology of the site, GWS Ltd advised that rapid infiltration via the method proposed in this option would likely result in groundwater mounding issues due to a limited phreatic zone and therefore inadequate assimilative capacity of the aquifer to take the volumes proposed (GWS *pers comm*, Jan 2017).
- Groundwater contamination which can lead to effects on local groundwater users and surface water quality. Contact time of the discharge with soils in the RIB will be minimal and therefore a realistic assumption that no renovation of the effluent will occur through the aquifer has been made. In an investigation recently carried out by Greg Butcher (2016), it is understood that a majority of the discharge plume from the RIB would likely intercept Donald Creek south of the site as a diffuse discharge. The RIB option would mitigate issues regarding discolouration and clarity however contaminant of concern such as nutrients and associated issues with these would likely persist in Donald Creek downstream of RIB. Furthermore, GWS (2017) identified a number of bore users downgradient of the site that would likely intercept a plume generated from the RIB. Contaminants of concern with regard to bore users would be pathogens (in particular viruses) and nitrates. Pond enhancement options 1 and 2 would not mitigate the effects of these contaminants of concern and high rate treatment is considered cost prohibitive in conjunction with this disposal option. Therefore these contaminants of concern would persist under this option as a diffuse discharge to the environment and result in a level of effect that could be considered more challenging to manage than a point source discharge to the Creek.

Based on the above risks, if this option is to be taken forward a thorough site investigation would be required to determine the most suitable location for a RIB system along with a comprehensive assessment of environmental effects, particularly to establish: effects on groundwater mounding, groundwater quality, fate of contaminants, potential effects on downstream users and effects on Donald Creek.

Constructed Wetland

A constructed wetland was considered as an alternative disposal mechanism for excess treated wastewater for flows that cannot be applied to the land treatment system. Treated wastewater would pass through the surface or subsurface wetland prior to discharging into Donald Creek or an alternative waterway. This method of disposal is considered a land contact process that could address cultural values to some extent.

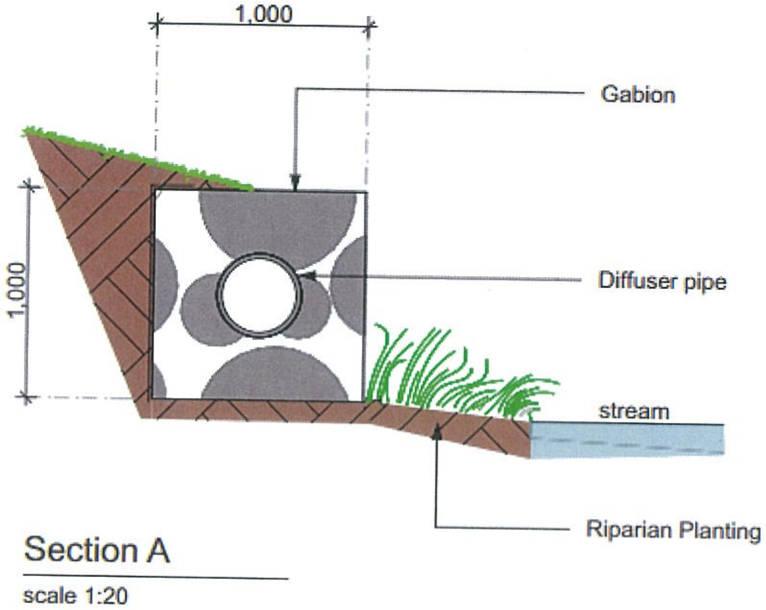
Designing a wetland for the purpose of intermittent disposal (rather than as a 'treatment' process) could potentially shorten the necessary retention time than would typically be required for solids or organic nutrient removal, thus reducing overall wetland size and land/ physical works requirements. However, a constructed wetland would be considerably more expensive, require greater long term maintenance, and potentially lead to increased pathogen levels in the effluent through attracting avian wildlife when compared with the RIB or RIG (see below) options with little added environmental benefit (in terms of improvements in contaminant levels discharged). Thus for these reasons this option has not been considered in any further detail.

Rapid Infiltration Gallery – Discharge Option F6

A Rapid Infiltration Gallery (RIG) disposal system would involve discharging excess flows through a perforated pipe within a rock filled gabion type structure (known as an infiltration gallery) as illustrated in

Figure 15. Discharge flows would be dissipated through the infiltration gallery thus minimising any potential effects of stream erosion and turbulence compared to a direct piped discharge[12].

Figure 15: Schematic of a Rapid Infiltration Gallery



A concept design of a RIG system is shown in Figure 16 and Table 15 sized for discharging the maximum excess flow (3000 m³/d) that cannot be treated and disposed of via the proposed land treatment scheme. The design includes one 20m long gabion structure positioned along the true right bank of Torohonga Creek. The construction of this structure would require works within the watercourse and riparian planting would be necessary to stabilise the area once constructed. The operation of the RIG would involve intermittent discharges to the gallery over approximately 6 hours with the gallery designed to ensure even loading along its length of 6.9l/s. The treated wastewater would dissipate through the diffuser pipe and enter the Creek via a strip of riparian planting. The location of the RIG has been chosen for costing purposes only and to avoid the remnant bush area as minor stream widening works would likely be required. If this option is pursued, site locations further downstream should also be considered as they would likely provide greater dilution and mixing of the discharge.

Table 15: Design Attributes – Rapid Infiltration Gallery

Description	Units	Value
Gallery design volume	m^3	3,000
Number of galleries	-	1
Design infiltration rate	m/s	1.3
Gallery design length	m	20
Total land area required	m^2	20

[12] It is noted that stream erosion and scouring have not been noted as areas of concern in any of the ecological surveys that have been undertaken.

Figure 16: Possible location of Rapid Infiltration Gallery

The proposed RIG would not provide any additional treatment, thus from an environmental effects perspective, this option is very similar to Option F1 – "Partial discharge to Donald Creek". The benefits of this option are its potential to address to some extent cultural values by providing some land contact prior to discharge of treated wastewater to water and enable a more dissipated discharge into the Creek thus reducing potential erosion and scouring effects. Furthermore, groundwater mounding would not be a risk when compared with the RIB option (Option F5).

Without additional treatment, the same concerns regarding the potential ongoing presence of sewage fungus complexes and effects on stream ecological health as a result of limited stream assimilative capacity for nutrients remain. As such, Pond Enhancement Option 2 has been considered in conjunction with this RIG option (**Option 2F6**).

5.5 Beneficial Reuse

In comparison to the beneficial reuse of treated wastewater on the Golf Course and private land owned by SWDC, the beneficial reuse of treated effluent for irrigation to surrounding farmland was considered. Rainfall in the Featherston area is higher than other drier areas of Wairarapa thus water scarcity on farms in this area is less. Safe yield / allocation volume of groundwater within the underlying South Featherston aquifer is not fully allocated therefore the demand for alternative sources of irrigation water is lower than in other parts of the Wairarapa and Wellington Region where some aquifers are fully allocated. The Featherston area is not located within Wairarapa Water Use Project Proposed Scheme which emphasises the lack of need for treated wastewater reuse. Finally, the cost of re-using treated wastewater off-site would be comparatively significant given that reliable and lower cost water sources are currently available for use in close proximity to the demand points. Furthermore it is unlikely that neighbouring farmers would require water during winter months when the largest flows of treated effluent from the plant occur and require management.

In addition, Fonterra have released effluent quality standards[13] that must be met for reuse of effluent on dairy operations to cater for dairy production where the milk produced is supplied to Fonterra (e.g. production of dairy cow fodder) (Fonterra, 2005). Although the level of treatment anticipated from the UV disinfection unit at the FWWTP is high, the stringent Fonterra standards are not guaranteed to be met without additional treatment.

In terms of beneficial reuse as a potable water supply, it is noted the Featherston public drinking water supply is not currently under pressure with regard to water allocation and sustainability. Furthermore, the level of treatment required to provide a potable water supply for use within the Featherston community is cost prohibitive when considered in conjunction with wastewater disposal options as both would be necessary for the surplus of water from the FWWTP.

Given the above, the re-use of treated wastewater for irrigation, drinking water or other uses is not considered feasible at this point of time. SWDC can re-visit the potential for the re-utilisation of treated wastewater in the future if the demand for water increases.

[13] The standard of acceptable treatment is summarised as:

- Sewage or sewage derived material can only be applied to pasture destined for consumption by dairy cattle if it has been secondary treated and disinfected.
- The degree of disinfection required is based on the residual total coliform bacteria in the water. The median concentration of total coliform bacteria must not exceed a most probable number (MPN) of 23 per 100mL (based on a 7 day period) and the maximum number in any one sample over a 30-day period must not exceed an MPN of 240 per 100 mL.

6 Options Evaluation

6.1 Evaluation Process

A two stage evaluation process has been undertaken. First, a long list of options, consisting of 21 combinations of treatment and disposal options were considered. A number of options were initially eliminated based on cost or environmental grounds as has been discussed above in Section 5. A multi-criteria screening assessment then further reduced the number of potential combinations of treatment upgrades from 18 down to a shortlist of 4 combinations to be assessed in more detail in the second stage.

The second stage is a more detailed evaluation of the four shortlisted options for: potential effects on the environment, cultural values, human health and safety, financial implication for SWDC, and consideration of the likelihood that the option would be successful. The objective of the second stage evaluation is to identify the best practical option(s) for SWDC to consider.

6.2 Options Considered

Four (4) alternative options (or improvements) to the current FWWTP treatment process have been identified (as outlined in Section 4), being three pond enhancement options and high rate biological treatment options.

Fifteen (15) alternative options to discharge the treated wastewater from the FWWTP have been identified as outlined in Section 5.

And two (2) network improvement options to reduce the total volume of influent flow to the Featherston WWTP were considered, with the majority of options incorporating targeted network rehabilitation and one option evaluating re-reticulation of the Featherston sewerage network as outlined in Section 2.

Tables 16 – 18 set out each of these options and Figure 1 presents the combinations of treatment and disposal options considered.

Table 16: Alternative (or Improvement) Treatment Options Considered

Category	Option
Pond Enhancement:	
	1) Full-time Water discharge options (primary screening, floating treatment wetland, flow directing curtains, in-pond coagulant dosing, scum/grease trap) (**Option 1**)
	2) Partial and/or contingency water discharge options (primary screening, floating treatment wetland, flow directing curtains, DAF) (**Option 2**)
	3) Land Discharge and contingency water discharge options (primary screening) (**Option 3 and 4**)
Replacement of the Oxidation Ponds with High Rate Treatment (MBR or SBR): (**Option 5**)	
Land Treatment (See Table 17)	

Table 17: Alternative Disposal Options Considered

Category	Option
Full-time River Discharge to:	
	Tauherenikau River (**Option B**)
	Ruamahanga River (**Option C**)
Full Land Treatment with Deferred Storage	
	Land apply all treated wastewater (provision for deferred storage of wastewater (**Option D**)

Category	Option
Land Treatment of 90%ile storage flow volumes and Contingency Discharge (Option E)	
	Contingency winter discharge to Donald Creek (**Option E1**)
	Contingency winter discharge to Donald and Abbot Creeks (**Option E2**)
	Contingency winter discharge to Tauherenikau River (**Option E3**)
	Contingency winter discharge to Lake Wairarapa (**Option E4**)
	Contingency winter discharge to Ruamahanga River (**Option E5**)
	Contingency winter discharge to high rate land irrigation (**Option E6**)
Land Treatment with Partial Discharge to Water (Option F)	
	Partial discharge to Donald Creek (**Option F1**)
	Partial discharge to Donald and Abbot Creek (**Option F2**)
	Partial discharge to Tauherenikau River (**Option F3**)
	Partial discharge to Ruamahanga River (**Option F4**)
	Partial discharge to Rapid Infiltration Basins (**Option F5**)
	Partial discharge to Rapid Infiltration Gallery (**Option F6**)

Table 18: Network Improvement Options Considered

Category	Option
Network Improvements (to reduce total volumes received at Featherston WWTP)	Targeted I/I Reduction
	Re-reticulation

6.3 Multi-Criteria Analysis – Screening Options Evaluation

The criteria listed in Table 19 have been evaluated in a multi-criteria analysis (MCA) to identify the top 4 preferred (or most likely) options to achieve the best environmental outcomes and that may be affordable for the Featherston community.

Table 19: Initial Option Screening – Selection Criteria and Weighting

Criteria	Description	Weighting
Environmental Benefit	Qualitative evaluation of the likely improvement the option will provide the environment (air, land, and water)	4 Excellent 3 Good 2 Fair 1 Poor 0 None
Cost	Measure of the relative cost of the option and ability for the community to afford the option	4 Low cost 3 Moderate cost 2 High cost 1 Very high cost 0 Prohibitively high cost
Technical appropriateness and reliability	Qualitative evaluation of how the option compares with the current state of technical knowledge and option reliability	4 Excellent 3 Good 2 Fair 1 Poor 0 None
	Total	0 (least favoured) to 12 (favoured)

The tabulated MCA results in Appendix B identify the top (favoured) 4 options with a MCA score of 9 or greater. Justification for the elimination of some options and scoring for others is provided in Appendix B. A summary of the top 4 options is reproduced in Table 20.

Table 20: Favoured Alternative Treatment and Disposal Options

Alternative Treatment	Alternative Disposal
Option 5 - High Rate Biological Treatment (to replace Oxidation Ponds)	Option B - Full-time Discharge to Tauherenikau River.
Option 3 - Pond Enhancement (with primary screening)	Option E1 - Land Treatment with Deferred Storage for 90th%ile flow conditions and Contingency winter discharge to Donald Creek.
Option 3 - Pond Enhancement (with primary screening)	Option E6 - Land Treatment with Deferred Storage for 90th%ile flow conditions and Contingency winter discharge to High Rate Irrigation.
Option 5 - High Rate Biological Treatment (to replace Oxidation Ponds)	Option F1 - Combined Land and Water Discharge to Donald Creek

Assumptions made as part of this first stage multi-criteria analysis are summarised below:

- All treatment and disposal options considered have assumed a targeted reduction in ADF of either 31% or 35% (depending on the option being considered) will be achieved through I/I reduction in the network.
- High level capital costs have been used to evaluate the range of option costs and do not take into consideration inflation or whole of life costs.
- A comparison between the proposed treatment options and the status quo has not been undertaken as the 'do nothing' option is considered inappropriate and would not provide an "apples with apples" comparison.
- For Options B and C full-time discharge to either the Tauherenikau or Ruamahanga Rivers it has been assumed that appropriate buffering of flows would be provided within the existing ponds to ensure no overflow to Donald Creek would occur. Further investigation of this would be required if these options are pursued further.
- For all contingency discharge options (Option E) it has been assumed that a high stream flow discharge regime (targeting 3x median stream flow a majority of the time and 2x median flow all of the time) can be achieved. Further investigation would be required to confirm this is achievable if these options are pursued further.
- For Option 5F1 it has been assumed the proposed land treatment scheme would enable all discharges to Donald Creek to be removed at times when creek flows are <1/2 median flow. Further investigation would be required to confirm land area requirements if this option is pursued further.

6.4 Multi-Criteria Analysis – Selection of Best Practical Option

Based on the 4 short-listed options identified in the MCA screening evaluation, a further detailed MCA evaluation has been undertaken to identify which, of the shortlisted options, is the "best practicable option" (BPO) to manage Featherston's wastewater.

It should be noted that the term BPO can be mistaken for "best practice". "Best practice" can be regarded as the best method, technique or technology, based on the current state of technical knowledge that can be applied successfully. However, BPO is regarded as the best method for preventing or minimising the adverse effects on the environment having consideration to:

- The nature of the discharge and the sensitivity of the receiving environment to adverse effects; and
- Financial implications, and the effects on the environment, of that option when compared with other options; and
- The current state of the technical knowledge and the likelihood that the option can be successfully applied.

The criteria and weighting applied in this assessment is summarised in Table 21, where each criteria and option is scored from 1 to 5, where 5 equates to a lower impact, or cost etc.

Table 21: Best Practical Option – Selection Criteria and Weighting

Criteria		Description	Weighting
Environment (total weighting 25)	Aquatic – streams/rivers	Consideration of the discharge (or emission), sensitivity of the receiving environment and potential effects of the discharge (or emission)	5
	Aquatic – lakes		5
	Terrestrial		5
	Groundwater		5
	Air		5
Community / Cultural Values		Consideration of recreational use and cultural values (fishing/gathering), and aesthetics	10
Human health and safety		Risk to human health and safety, contact recreational values, physical hazards associated with poor water clarity (etc)	15
Economic Utility		Consideration for any commercial activities that may be adversely effected by any discharge(s) or emissions	5
Financial Implication to SWDC ratepayers		Relative financial cost, both capital and operational implications	25
Likelihood of success		Evaluation of the risk that the option will not achieve the criteria outlined above	10
Risk		Other risks such as consentability risks.	10
		Total	**100**

Assumptions made:

- The ranking used scores each option between 1 and 5 based on the shortlisted options on the table and has discounted any previous options discarded at Stage 1 (such as the status quo).

The evaluation of the four shortlisted options is presented in Table 22 where a higher weighted value is preferable.

The detailed BPO evaluation has identified Option 3E3 - pond upgrade with screening and land treatment with contingency winter discharge to Donald Creek as the best practical option for SWDC to consider treating and disposing of Featherston's wastewater.

Table 22: Recommended Best Practical Option(s) to Treat and Discharge Featherston's Wastewater

Key		
Key	Value / Impact (1 - 5)	(higher is preferred)
	Weighting	

	Criteria / Option	Environment					Community / Cultural Values
		Aquatic - streams/river	Aquatic - lake	Terrestial	Groundwater	Air	
Option 5B	High Rate Biological Treatment - Full-time discharge to Tauherenikau River	1 Long-term significant improvement to Donald Creek with complete removal of discharge from the Creek. Some degradation of water quality in Tauherenikau but within acceptable guideline values for most of the year. Unknown environmental risk during low flow conditions due to a lack of River water quality and flow data at the proposed point of discharge. 5	2 Lake Wairarapa remains the ultimate receiving environment for this direct discharge, however contaminant load to the Lake would be significantly reduced. 5	4 Minor earthworks during plant and pipeline construction and minor disturbance of the riparian margin of the Tauherenikau 5	5 No direct discharge into groundwater resource 5	5 Low risk of generating odour when operating normally. 5	1 Continued discharge to water and to a new receiving environment that currently has good water quality 10
	BPO Score	5	10	20	25	25	10
Option 3E1	Pond Enhancement (primary screen) - Land Treatment of 90th%ile storage flow volumes with Contingency winter discharge to Donald Creek	3 Long-term significant improvements to Donald Creek with the complete removal of the discharge during summer months and in some years all discharges to water eliminated. Concerns regarding ammonia toxicity minimised to have effects no more than minor. Significnat reduction in loads of N and P to the Creek. Some potential risk around clarity in receiving waters during winter months but upstream clarity is likely to be 5	4 Lake Wairarapa remains the ultimate receiving environment for this indirect and direct discharge, however contaminant load to the Lake would be significant reduced. 5	3 Deferred irrigation scheme operated under a sustainable land management regime, construction effects of large storage pond. Pond may attract water fowl 5	3 Some drainge to occur from land treatment scheme however this would be managed to meet permitted baseline conditions 5	3 Potential risk of generating odour from storage pond during seasonal changes, low health risk from transmission of bacteria/viruses from irrigation droplets 5	4 Almost all discharges to land with exception to extremely wet periods. Meets community and cultural aspirations 10
	BPO Score	15	20	15	15	15	40
Option 3E6	Pond Enhancement (primary screen) - Land Treatment of 90th%ile storage flow volumes with Contingency winter discharge to land via high rate application	4 Significant improvements to Donald Creek, with a minor effect likely to remain as a result of potentially contaminated groundwater (N and P diffuse discharge) inflow to the stream which is difficult to quantify based on current information. 5	5 Lake Wairarapa remains the ultimate receiving environment for this indirect discharge, however contaminant load to the Lake would be significantly reduced. 5	3 Deferred irrigation scheme operated under a sustainable land management regime, construction effects of large storage pond. Pond may attract water fowl 5	2 Groundwater mounding and degradation of groundwater quality a potential risk that requires further investigation. 5	3 Potential risk of generating odour from storage pond during seasonal changes, low health risk from transmission of bacteria/viruses from irrigation droplets 5	5 Only discharges to land. Meets community and cultural aspirations 10
	BPO Score	20	25	15	10	15	50
Option 5F1	High Rate Biological Treatment - Partial Discharge to Land and Water Discharge to Donald Creek	2 Significant improvement to Donald Creek with complete removal of discharge during summer low flow conditions and high level treatment to ensure N and P contributions to the stream are minimised. P and N loads to the stream significant reduced. 5	3 Lake Wairarapa remains the ultimate receiving environment for this direct discharge, however contaminant load to the Lake would be significantly reduced. 5	5 Minor earthworks during plant construction. 5	4 Some minor drainage to groundwater possible but likely to be negligible when land application undertaken during summer months 5	4 Low risk of generating odour when operating normally. 5	3 Continued discharge to water for a majority of the year but provides some land contact during low flow periods when recreational use might be highest (although it is noted that Donald Creek has low overall recreational value and limited access to the public). 10
	BPO Score	10	15	25	20	20	30

	Criteria / Option	Human health and safety	Ecomonic Utility	Financial Implication	Likelihood of Success	Risk	Rank and Total
Option 5B	High Rate Biological Treatment - Full-time discharge to Tauherenikau River	3 Highly treated wastewater to minimise public health risk although discharge would occur when potential for contact recreation is high and receiving environment likely to have high recreational value. 15	1 No income potential from scheme, and perception on water discharge may effect potential other economic uses of the Tauherenikau 5	2 High level costing indicating option captial costs fall within $16 - $21M. 25	5 Highly likely. HRT is proven technology and provides increased process control and a high level of certainty if operated correctly 10	1 Consentability risk around discharge to water body that holds a high level of recreational and cultural value. Risks around compliance with water quality guidelines at low flows. 10	4
	BPO Score	45	5	50	50	10	255
Option 3E1	Pond Enhancement (primary screen) - Land Treatment of 90th%ile storage flow volumes with Contingency winter discharge to Donald Creek	4 UV disinfection applied to wastewater and sunlight (natural UV disinfection) to ponds. Sprinkler technology proposed to minimise spray drift and appropriate buffer distances proposed. Discharge to water to occur in winter months at high stream flows when recreational use of the stream unlikely (it is noted that Donald Creek does not have high recreational value). 15	5 Income potential from cut and carry operation, land application scheme effects on downstream groundwater users no more than minor 5	2 High level costing indicating option captial costs fall within $16 - $21M. 25	4 Likely, land treatment proven in other regions although success will depend on system selection, potential operational issues regarding large storage ponds will require addressing. 10	4 Consentability risk around potential effects in Donald Creek under winter high flow scenario, particularly with regard to clarity. Option provides an acceptable level of protection for fingernail clam. Risk associated with project costs as high level costs may underestimate the costs asssociated with ground improvement requirements for large storage pond. 10	1
	BPO Score	60	25	50	40	40	335
Option 3E6	Pond Enhancement (primary screen) - Land Treatment of 90th%ile storage flow volumes with Contingency winter discharge to land via high rate application	2 UV disinfection applied to wastewater and sunlight (natural UV disinfection) to ponds. Sprinkler technology proposed to minimise spray drift and appropriate buffer distances proposed. No direct discharge to water. Potential for increased nitrates and risk of pathogen contamination to downgradient groundwater users. 15	3 Income potential from land application, effect on downstream groundwater users for economic purposes may result in effects more than minor. 5	2 High level costing indicating option captial costs fall within $16 - $21M. 25	4 Likely, land treatment proven in other regions although success will depend on system selection, potential operational issues regarding large storage ponds will require addressing. 10	3 Consentability risks around potential contamination of groundwater resource and requires further investigation to confirm this level of risk. Risk associated with project costs as high level costs may underestimate the costs asssociated with ground improvement requirements for large storage pond. 10	3
	BPO Score	30	15	50	40	30	300
Option 5F1	High Rate Biological Treatment - Partial Discharge to Land and Water Discharge to Donald Creek	4 UV disinfection applied to wastewater & river discharges avoided during summer low flows when recretaional use of the stream would be highest. Discharge may occur in summer thus discharge not eliminated from creek. Level of treatment is considered appropriate for secondary contact recreation purposes and may meet primary contact recreation guideline requirements. Sprinkler tech proposed to minimise spray drift and appropriate buffer 15	4 Small income potential from cut and carry operation, continued discharge to Donald Creek unlikely to have significnat effect on potential economic uses of this resource 5	2 High level costing indicating option captial costs fall within $16 - $21M. 25	5 Highly likely. HRT is proven technology and provides increased process control and a high level of certainty if operated correctly. Land treatment proven in other regional although success will depend on system selection. 10	2 Consentability risk around continued discharge to water that holds a reasonable level of cultural value. Risks around compliance with water quality guidelines at 1/2 median to median flows and which will depend on the land area requirements which needs further investigation. 10	2
	BPO Score	60	20	50	50	20	320

7 Discussion

In order to obtain the necessary certainty of a long term consent for a discharge from the FWWTP there is a requirement (in accordance with Section 107 of the Resource Management Act) to demonstrate that a future discharge to water and/or land that may enter water, after reasonable mixing will not result in:

- The production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials
- Any conspicuous change in the colour or visual clarity of the receiving waters
- Any emission or objectionable odour
- The rendering of freshwater unsuitable for consumption by farm animals
- Any significant adverse effects on aquatic life.

Furthermore, the Wellington regional planning documents establish a framework of objectives and policies requiring the maintenance or enhancement of water quality, enhancement of amenity and recreational values and opportunities for Maori customary use, and the safeguarding of aquatic ecosystem health by any discharge activity.

It is considered that the best practical option of land treatment with deferred storage will achieve the requirements of Section 107. Further work is necessary to fully understand the potential effects on the environment from contingency overflows over and above the 90th percentile flow conditions and support a long term consent application. It is also important to note that the overall success of a land treatment scheme will depend greatly on the success of the planned network I/I rehabilitation work.

Equally, the importance of removing direct discharges from Donald Creek in a timely manner is recognised while being cognisant of the financial constraints on Council and the associated LTP funding cycles. A benefit of land treatment is its ability to be staged when compared to options such as a switch from pond based treatment to high rate biological treatment. This ability to stage the implementation of infrastructure enables Council to spread expenditure over a number of years. In order to meet affordability requirements, staging options for the scheme have been considered in conjunction with the other planned district wastewater scheme upgrades.

The current SWDC wastewater strategy apportions budgeted expenditure across the three wastewater schemes owned and operated by SWDC. The expenditure has been spread across the three wastewater schemes with the intention that works undertaken at each plant will result in noticeable improvements in terms of reduced flow and/or improved quality from the existing pond schemes within the current LTP period, while planning for and building infrastructure that will contribute to the long-term wastewater strategy over future LTP periods.

The total cost of upgrading the Featherston wastewater scheme will result in significant expenditure to Council. Construction and commissioning of the land treatment scheme (or any of the top four options evaluated) would not be achievable within a single LTP period due to SWDC's limited rating base and the requirement to concurrently undertake improvements to the other two wastewater schemes in the district. To upgrade the Featherston wastewater scheme over one LTP period would require deferment of financial expenditure planned for the Martinborough and/or Greytown wastewater schemes over a 15 year or more period. Thus a strategic, effects-based method of staging upgrade works across the three schemes was considered more appropriate than sequentially staging the individual scheme upgrades. This effects-based staging focuses in the short-term on the removal of direct discharges to water from all three wastewater treatment plants during summer low stream flow conditions and reduction of I/I flows in the Featherston wastewater network within the current LTP period to make the best use of the funding available.

8 Conclusions

Twenty one (21) combinations of treatment and disposal options for the upgrade to the Featherston WWTP have been considered and evaluated. Based on a two stage multi-criteria analysis, it has been determined that a land treatment regime with deferred storage and provision for contingency winter discharges of treated wastewater to Donald Creek is considered the best practicable option.

This option aligns with the objectives of the Regional planning documents and the SWDC long term Wastewater Strategy which promotes the staged implementation of land treatment and the staged reduction of direct discharge of treated wastewater into the District's waterways. The importance of reducing direct discharges into Donald Creek in a timely manner is acknowledged. However, in recognition of the significant expenditure already made by SWDC securing the necessary land, the future significant expenditure necessary to develop the land treatment scheme, and financial constraints on Council with a requirement to invest significant capital expenditure in the other district wastewater schemes, a staging approach for the Featherston wastewater scheme improvements is recommended.

In all options considered in this report, reducing I/I flows into the Featherston sewerage network will offer benefits in terms of reduction of influent wastewater volumes and corresponding reduction in capital costs for future upgrades. The overall long term success of the BPO will be dependent on the success of the I/I rehabilitation work in the short to medium term.

In conclusion, it is considered the Best Practicable Option for FWWTP is a staged land treatment scheme, implemented over a 20 year term supported by a targeted network rehabilitation programme in the short to medium term.

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Appendices

A. Pond Enhancement or Add-on Options

Previous studies have identified a variety of alternatives to improve the treatment performance at the FWWTP (NZET 2012 and *g2e* 2013a,b,c). These included a mixture of pond enhancement and end of pond treatment (add-on) solutions. The following summarises the features and implications of these alternatives.

Mott MacDonald considered that many of these pond solutions would not be acceptable as standalone solutions in the event a continued water discharge were pursued as the necessary level of contaminant removal would unlikely be achievable. This was supported by *g2e* (2013a) who stated, “the existing pond system is currently achieving treatment standards in line with a normal two-pond facultative pond system”... and “is already operating quite close to its theoretical treatment quality. It will therefore be difficult to reach much improved treatment standards solely with the implementation of some basic and simple upgrade options”. For this reason a number of end of pond treatment ‘add-on’ options were also considered.

The following enhancements and add-ons have been considered:

Pond Enhancements

- Desludging
- Flow Curtains
- Overflow / Flow Control Weirs
- Enzyme and Microbial Cultures
- Coagulant Dosing
- Inlet Screen
- Aeration
- Floating Treatment Wetlands
- Floating Covers

Pond Add-On Options

- Soil Beds
- PETRO
- Sand Filtration
- Membrane Filtration
- Additional Disinfection
- BioFiltro
- Constructed Wetlands

Flow Control Options

- Pond Level Control
- Donald’s Creek Flow Control

A.1 Pond Enhancement Options

A.1.1 Desludging

In November 2012 SWDC commissioned Conhur (2012) to undertake a sludge survey of the Featherston WWTP ponds. Opus (2013) evaluated the Conhur's sludge survey observations to assess the requirement for pond desludging. Opus concluded the treatment volume of the ponds is still sufficient to receive the current load and desludging of the ponds would not be required for a number of years. The sludge survey information was also further analysed by *g2e* (2013a) whom identified that the Featherston ponds appear to have been well built with very consistently flat bases. Sludge accumulation is low and indicates desludging has occurred at least once since construction.

Based on the above sludge survey assessment, further desludging within the term of the proposed consent is not considered necessary or likely to provide any significant improvement in performance and/or effluent quality. SWDC intend to continue monitoring sludge accumulation as part of its pond maintenance programme and in the event desludging is required, separate consent will be obtained for this at the time.

A.1.2 Flow Directing Curtains

Flow directional curtains or floating baffles are used as vertical walls which redirect flowing water within a pond through determined paths to increase the HRT and to prevent short-circuiting. There are a variety of curtains or baffles available, and in general consist of a flexible geomembrane that is suspended within the water column at specifically selected locations across a pond.

The installation of floating curtains was considered for FWWTP with the primary aim of embankment protection and the additional benefit of increased pond HRT. It is questionable whether increased HRT as a result of installing flow directional curtains would in fact lead to a quantifiable improvement in effluent quality, considering the reasonable performance currently provided by the ponds to remove BOD_5 and TSS. Furthermore, there is little technical evidence to suggest increased HRT will result in a significant improvement in ammonia or total nitrogen removal within the ponds. However, flow directing curtains might be considered in conjunction with other pond upgrade options such as Floating Treatment Wetlands (see Section A.1.10) as a means of improving the hydraulic flow path though the FTW treatment system.

A.1.3 Overflow and/or Flow Control Weirs

Pond outlet overflow weirs function in two ways: i) to allow the buffering of peak flows in each pond thus increasing HRT and providing hydraulic separation of ponds, and ii) minimising solids carry-over between ponds.

Specifically designed overflow weirs retrofitted to the Featherston ponds were considered, however, the overall benefit of weirs were considered to be negligible in terms of improved treatment performance in comparison to the overall benefit of further I/I reduction works.

This option has not been considered any further as part of the options evaluation.

A.1.4 Enzyme and Microbial Cultures

By dosing appropriate microbes and/or enzymes into a treatment pond, a preferred culture of specific species can develop whose characteristics are more attuned to attacking a specific problem such as managing solids build up through organics reduction, and/or odour management by oxidising sulphide.

Trial doses of microbial cultures have been applied to the Martinborough ponds, however, in the absence of any conclusive performance data for this type of technology (including from other schemes), the benefits of overall treatment improvement for the FWWTP, are considered to be limited. In particular, there is a risk of washout of these microbes/enzymes during periods of high storm flows. Furthermore, due to the large size of the Featherston ponds, the quantity and cost of the cultures being dosed could become a significant ongoing operating cost.

For the above reasons, Enzyme and Microbial Cultures is not considered a feasible option for the FWWTP.

A.1.5 Coagulant Dosing

Addition of a coagulant is used to coagulate contaminants, such as suspended solids or total phosphorous from wastewater. The coagulated solids settle to the bottom of the pond and accumulate as sludge. Depending on the coagulant used, some of the dissolved organics and dissolved reactive phosphorus (DRP) levels can also be reduced via chemical precipitation and settling. Coagulant dosing can occur into the influent stream, followed by flocculation and sedimentation within the normal hydraulic regime of a pond system. Alternatively, coagulant can be added prior to a filter or within a standalone separate settling tank/clarifier to remove the finer floc particles.

The consideration of coagulation treatment by NZET (2012) was driven by the requirement to reduce the phosphorus concentration in Donald's Creek. A reduction in phosphorus entering this waterway was assessed as a practical approach to achieve a reduction in periphyton and phytoplankton growth currently in the creek; based on the assumption that treated wastewater would continue, in the short term at least, to discharge into Donald's Creek.

In addition, preliminary mass balance calculations have been undertaken to determine the consequential increase in Total Nitrogen (TN) and Total Phosphorus (TP) in the Tauherenikau and Ruamahanga Rivers (two possible alternative disposal options) from FWWTP. At mean river flows, the rivers will provide approximately 27 fold and 205 fold dilution respectively of the treated wastewater discharge. The consequence of the likely increase in Total Nitrogen (TN) and Dissolved Reactive Phosphorus (DRP) in the Tauherenikau River would suggest that the ANZECC (2000) nuisance growth trigger limit may be exceeded when the Tauherenikau is at less than median flow condition. This in turn would suggest a monitoring programme would need to be provided to assess the potential for nuisance growths of periphyton forming in the river. It should be noted that exceeding the trigger limit does not automatically result in the formation of nuisance growths, but recognises an increased risk of the potential for growths to occur, which is addressed by recommending monitoring to determine the presence or absence and any potential effects on the aquatic environment.

A similar evaluation of the Ruamahanga River predicts that whilst the river water quality is currently in the 'worst 50%' of all New Zealand lowland rural rivers (LAWA 2016), the additional TN load from the FWWTP is unlikely to result in any material change in TN concentration in the river. However the River is already at assimilative capacity for DRP thus any additional phosphorus load from the FWWTP may trigger a potential increase in nuisance growths in the Ruamahanga River.

Coagulation has therefore been considered for options where a discharge to water may continue.

Coagulation would result in increased volumes of settled solids leading to increased sludge management costs (increased volumes) and has the potential for aluminium residual toxicity issues for the pond and/or receiving water biota depending on the type of coagulant used. If an aluminium based coagulant was used it could also affect sludge disposal costs due to increased aluminium levels in the sludge. These matters can be resolved through design and operational management.

It is important to note that coagulation on its own would not address any nitrogen removal requirements on a discharge.

A.1.6 Inlet Screen

Inlet screening provides the removal of gross solids, rubbish, stringy and fibrous material and debris from entering the ponds. Removal of this material reduces its accumulation on the pond surface and in the pond sludge and therefore reduces the overall sludge volume and prevents this material from causing future pond desludging difficulties (desludging equipment blockage and non-acceptance of sludge as a potential soil conditioner due to litter content).

For this reason it is recommended that an inlet screen be considered for the FWWTP, in conjunction with improving the I/I, which would reduce the magnitude of the peak wet weather flows and result in a reduction in screen size. The optimum configuration for the inlet screens would need to be considered, which might include a number of smaller units to provide flexibility across the range of flows. It is considered that this option would be beneficial for the overall plant operation and future upgrades.

A.1.7 Aeration

To manage any potential future odour issues in Pond 1 during summer periods or high loads, aeration at the pond inlet has been considered. FWWTP has not however had a historical issue with odour and due to its location and surrounds, future odour issues are considered unlikely. Therefore, increasing aeration on the ponds is not considered a priority, and may be unnecessary and/or offer little improvement in treated wastewater quality on its own.

A.1.8 Floating Treatment Wetlands

Floating Treatment Wetlands (FTW) is a variant on traditional constructed treatment wetlands that use either free-floating aquatic plants or sediment-rooted emergent wetland plants with water flowing through the root zone (subsurface flow) or amongst the stems (surface flow). The Floating Treatment Media (FTM) consists of water tolerant plant species grown onto geo-synthetic textiles that provide structural strength, flotation, and a rooting matrix for initial plant development. The key treatment processes occurring within the FTW as promoted by suppliers include: (i) the exposed root systems that uptake nutrients into the plant structure which is later harvested and removed from site, (ii) the root and floating media provide large surface areas for the development of biofilms containing communities of attached-growth micro-organisms responsible for a number of important treatment processes (similar to a fixed film substrate), and (iii) the root structures physically trap particulates within the water column. Biomass that builds up under the FTM sloughs off as heavy particles that are more amenable to settling. Baffles are also used in combination with FTM to provide flow control through the system both horizontally and vertically, minimising short-circuiting, enhancing full mixing and increasing hydraulic retention times by promoting longer flow paths.

Historically the purpose of FTW within wastewater pond systems has been for polishing of suspended solids and to assist with minimising algae growth. However more recently, nutrient removal has become a focus. New installations are relying on aerobic and anoxic zones in combination with the FTM and Fixed Biofilm Attachment Surfaces (FBAS) within the treatment ponds to enable the nitrification and de-nitrification of wastewater to achieve TN removal. The use of synthetic porous textile curtains or BAS for nitrifying bacteria attachment in combination with aeration upfront of the FTM appears to assist in enhancing nitrification processes, whereas beneath the FTM anoxic zones develop promoting the necessary conditions for denitrification. Some form of re-oxygenation of the water leaving the FTW is generally required either through aerators or a passive cascade outlet structure (if required in consent).

Published data on the treatment performance of the various FTW applications is however limited. Niekerken[6] noted that based on international literature, total nitrogen removal within FTW appear to be reasonable with studies showing up to 85% removal, however phosphorus removal has been shown to be less effective (40%)[14]. Much of the scientific research on floating and constructed wetland treatment in New Zealand has focused on stormwater treatment and their use as a wastewater treatment technology is relatively recent. A trial wetland was constructed at the FWWTP in 2010 and was monitored for approximately three years. Unfortunately this pilot system did not perform well, with some reduction in TSS, E.coli and BOD_5 observed but little change in terms of nitrogen or phosphorus removal[15]. A comparison of the performance from other FTW systems installed in New Zealand targeting nutrient removal has been undertaken by AWT (2013c). Results show promising removal performance for BOD, TSS and Ammonia, although the level of improvement does appear to diminish in the warmer summer months. The data available however is very limited[16] and thus the long-term performance reliability of FTW cannot be accurately determined at this time.

FTWs are a passive / low energy process, and are a good retrofit option for pond treatment systems. They are fairly unaffected by fluctuations in water levels within the pond and are relatively easy to maintain. The cover and shelter provided by the FTM promotes conditions conducive to settling by reducing turbulence and light, thus assisting with algae management. The FTW have low capital and operation expenditures compared to other high rate treatment plant options, and they can be configured to address a range of performance objectives (as discussed above). The addition of coagulation dosing can also target Phosphorus removal.

FTW however have a limited track record in New Zealand and overseas with wastewater treatment, particularly with regard to nutrient removal and their long term sustainability and reliability. FTW are difficult to process control if problems arise at the plant or in the event of external influences, and thus specific effluent quality targets are difficult to guarantee. Although there are risks around track record of this system, it is concluded that FTW be considered further for FWWTP in conjunction with coagulant dosing for phosphorus removal, however no reliance on nitrogen removal with this system is recommended.

A.1.9 Floating Covers

Installation of light impermeable cover around the plant outlet to reduce algae and associated TSS prior to UV disinfection has been considered. Covering with floating wetlands or hexagonal floating plastic discs are examples of floating covers used at other plants.

The expected level of improvement is difficult to quantify. Literature states that covering ponds has a very positive impact on the algae growth. However the hydraulic retention time of the referenced ponds vary between 1 month and 4 months. Moreover these examples found in the literature are unfortunately not based on maturation ponds but on irrigation / reclaimed water ponds with high nutrient levels.

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[14] Adrian van Niekerken, Can Waste Stablisation Ponds Challenge Advanced Biological Wastewater Treatment Processes', unknown date.

[15] It is noted the trial was not set-up to target for nutrient removal.

[16] Hunterville WWTP only 1 years' worth of post commissioning data was available at the time of review.

The Featherston ponds total HRT at average daily flow (2,100m^3/d) is around 24 days (considering a total volume of 49,985 m^3). Covering both ponds entirely would provide appropriate hydraulic retention time conditions to prevent algal growth, however, this would also suppress entirely all aerobic biological activity in the ponds and greatly limit the level of treatment of the ponds. Alternatively, partly covering the maturation pond only (which has a hydraulic retention time of only 6-7 days) would probably not impact significantly on algal growth. The literature identifies that various types of algae can be dormant for weeks, or adapt to dark conditions and potentially survive. These types of algae, if present in Featherston ponds, would not be affected by the cover and the high performance of the UV treatment plant to date suggests covering of the ponds is unnecessary.

A.2 Pond Add-On Options

A number of end of pond treatment solutions to enhance the pond effluent (i.e. pond add-on solutions) were considered to improve the overall treatment process. Again, many of these pond add-on solutions would not be acceptable as standalone options in the event a continued water discharge were pursued and would need to be considered in combination with other add-on or in-pond solutions. None of these options would be necessary in a land treatment regime.

A.2.1 Soil Beds

In a soil bed system, effluent is intermittently dosed via a distributed network over the surface of soil beds constructed on a specific slope and is filtered down through the sloping bed under gravity.

A trial of soil beds was undertaken at Carterton WWTP, and initial results (although it is noted the data set is limited to 2 months) showed reasonable removal of TSS, TP and BOD_5, however nitrogen removal was limited. This is not atypical for a soil bed system in New Zealand conditions. Therefore soil beds used at FWWTP are likely to be limited in their ability to ensure the necessary reductions in ammonia and total nitrogen.

Experience from operating soil bed systems shows that, over time the capacity of soil beds would become saturated with phosphorus and solids, resulting in a degradation in effluent quality until replacement of the soil were to be undertaken. The life expectancy of soil beds is uncertain, and therefore could result in significant ongoing opex costs through media sourcing and disposal of potentially contaminated soils. In view of their limited nitrogen removal ability and the uncertainty regarding media disposal/replacement costs, it is not proposed to consider this option further.

A.2.2 PETRO

The PETRO (Pond Enhanced Treatment and Operation) system utilises a multiple pond system in conjunction with a trickling filter or activated sludge process. The system is comprised of a deep primary facultative pond followed by shallow secondary oxidation ponds in combination with either an activated sludge or trickling filter secondary treatment process. The primary pond-based stage of the process is aimed at removing a substantial portion of the organic load. The secondary trickling filter or activated sludge process stage is aimed at nutrient removal followed by a solids/liquids separation system.

The modification of the FWWTP to install a PETRO process would require some pond modifications, and the installation of pump stations and new process units at the plant. The high flows experienced at the plant would also require the design of a large Trickling Filter and Humus Tank to accommodate these high flows.

Whilst this option is likely to reduce reactor sizes and costs when compared with more conventional activated sludge processes, there is a risk of excessive algal growth in the ponds causing process or settleability issues in the trickling filter or activated sludge process. The removal of degradable carbon would also limit the nutrient removal potential in the secondary treatment stage, unless a carbon source were added. This process introduces significant quantities of algae which would make filtration prior to disinfection problematic. Furthermore, recent and relevant trials conducted by SWDC at FWWTP, and in Melbourne have not shown satisfactory treatment results, and the level of Phosphorus removal is also uncertain. Therefore, it is not proposed to consider this option further.

A.2.3 Sand Filtration

Sand filtration beds, remove colloidal and particulate material in accordance with the properties of the filter (e.g. grain size, bed depth and applied surface loading rate). The filter acts through entrapment and adhesion to arrest the solid material and trap them on the surface of or within the body of the media or medium. In some applications it is necessary to pre-treat the effluent flowing into a sand bed to ensure that the particulate solids can be captured. Pre-treatment can comprise of pH adjustment, coagulation and/or flocculation. Sand filters used for treatment of secondary treated municipal wastewater can be located as a final polishing stage where the sand traps residual suspended material and bacteria and can provide a physical matrix for denitrification (conversion of nitrates into nitrogen gas) in conjunction with upstream carbon dosing. Phosphorus can also be precipitated using upstream metals salts coagulants (aluminium, iron).

Sand filters become clogged with flocculent and or entrapped solids after a period in use and they are then backwashed or pressure washed to remove this material. This backwash water is typically run into settling tanks to allow the backwashed solids to settle and the supernatant returned to the ponds with the solids being dewatered and disposed as solid waste. Alternatively, the backwash could be returned to the head of the works for settlement in the ponds.

Trials conducted in Carterton in 2003, using Dynasand filters and a range of coagulants showed a limited improvement in effluent quality with only very high coagulant doses showing a marked improvement. Further trials were to commence in 2012, however the results have not been reviewed.

Sand filters are understood to show variable results in removing algae, as appears to have been found at Carterton; therefore, it is not proposed to consider this option further..

A.2.4 Membrane Filtration

Membrane filtration uses a semi-permeable membrane to separate suspended solid and colloidal solid materials according to their physical properties when a pressure differential is applied across the membrane. Membrane filtration results in effluent virtually free of TSS and with the proper selection of membranes and membrane pore sizes, the process can be effective in the removal of microorganisms (e.g. microfiltration and ultrafiltration membranes target removal of protozoa, bacteria and most viruses) and certain organic species).

Membranes will remove the solids fractions of the pond effluent, supported by trials undertaken at Carterton in 2007, there is however no capacity for nutrient removal in terms of nitrogen or phosphorus. Improvement of nitrogen removal would require addition of aerobic nitrification and denitrification steps. Phosphorus removal could be achieved by metal salt dosing (alum or ferric) prior to membrane filtration.

At the FWWTP a Membrane Filter would be installed on the discharge of the pond and solids filtered out by the membrane would be recycled to the ponds and accumulate there. The ponds would therefore require more frequent desludging. The membrane unit would also need to be very large to treat the plant peak flows, and power consumption would be high due to the permeate being pumped through the membrane. Membranes can be an economical method of solids removal when disinfection is required. However in the case of FWWTP there is an existing UV disinfection system and therefore whilst membranes would incur significant capital and operating costs, the level of treatment provided would not be warranted.

A.2.5 Additional Disinfection

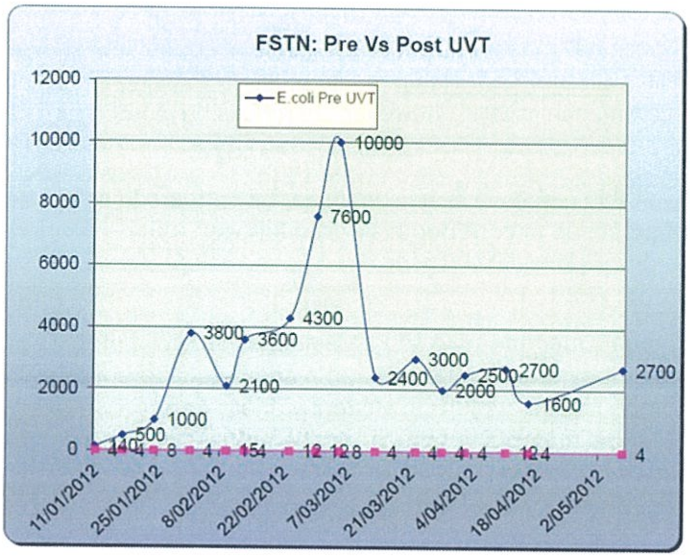
Ultraviolet (UV) disinfection, like membranes, target the reduction of pathogens in the effluent. Effluent is passed through a channel or pipe fitted with an array of bulbs emitting UV light at a frequency that causes damage to the genetic structure of bacteria, viruses, and other pathogens in the effluent as they flow past the bulbs, making them incapable of reproduction. This process can be affected by shielding (shading) from solids, thus in some systems such as pond systems, pre-filtration may be necessary in order to meet high levels of pathogen reduction. The key disadvantages of UV disinfection are (1) frequent lamp maintenance and replacement and (2) additional operations costs – specifically electrical power.

UV disinfection was installed at FWWTP in December 2011, and thus is already in use at the FWWTP. The system is performing well in terms of disinfection, designed with a target effluent quality of less than 100 *E.coli* cfu/100mLs[17]. Therefore other forms of tertiary treatment such a chlorination or ozone have not be considered any further.

The unit has been operating in excess of the target specification with treated *E.coli* values frequently less than 4 cfu/100ml (refer to Figure A1).

Figure A-9-1: FWWTP UV Disinfection Plant Performance

Source: NZET 2012. E.coli (cfu/100mL). Pre disinfection – blue, post disinfection - pink



[17] Procurement spec based on a worst case 140l/sec, ss120mg/l, E Coli influent quality of 20,000 cfu/100ml and transmittivity 60% *pers comm* Bill Sloan (2014)

Other methods of disinfection such as chlorination or ozone have not been considered for the current consent as they would unnecessarily duplicate the existing UV functionality, and have the potential to generate unwanted disinfection by-products.

A.2.6 BioFiltro

Biofiltro is a type of packed bed reactor which utilises timber shavings as a medium and worms to assist in wastewater treatment. Wastewater is sprayed on top of the raised bed which comprises layers of rock and wood shavings. The shavings layer is populated with worms and a micro flora biomass. The liquid trickles through the media and its soluble components are consumed by the bed biomass. This growing biomass becomes the worms' food source. As the worms consume the micro flora, nutrients are assimilated into the mass of each worm as well as being defecated by the worms on the top layer of the bed and over time forms a layer of worm humus. The worms keep the bed in good condition by moving waste to the top layer and also contribute to the aeration of the bed as they create tunnels through it due to their activity.

The difference between this type of system and a conventional trickling filter are the type of media utilised, and the significant part played by the worms. Biofiltro filters TSS as the water percolates through the bed and can treat the organic contaminants and part of the nitrogen pollutants.

A small number of Biofiltro are used in Southland New Zealand, to provide additional treatment to small community pond effluents. Results from one installation at Kaka Point indicate a good level of treatment (unknown data set), however the level of quality would be insufficient to reliably remain within the stringent ammonia and phosphorus discharge limits expected for FWWTP.

The modification of the FWWTP to install a BioFiltro process would require the construction of several large structures and the installation of pumping stations. Again due to high flows experienced at the FWWTP the units would need to be sized to accommodate peak flows which would significantly increase costs. In view of the above shortcomings, it is not proposed to consider this option further.

A.2.7 Constructed Wetlands

A conventional constructed wetland is a surface-flow wetland, where plants are rooted in soil and water flows at a shallow depth through the array of plants and is open to the atmosphere. A sub-surface wetland involves plants growing in a bed of soil and porous media (typically gravel), with water flowing through the bed and the array of plant roots.

With specific design, some reduction in BOD_5 and TSS can be expected. In addition, wetlands have been shown to remove phosphorus, however, typically during early stages of establishment through uptake by the growing plants and/or through adsorption to sediments in sub-surface wetlands. Phosphorus removal, however seldom exceeds 1-3 mg/L and at certain times of the year wetlands can release phosphorus that has been accumulated over the growing season. Extensive nitrogen removal typically requires long hydraulic residence times in wetlands (greater than 14 days), thus resulting in large land area requirements and significant upfront construction costs. Regular harvesting is also required to remove the nitrogen and phosphorus from the system that has accumulated in the wetland via plant uptake.

Construction of a specially designed treatment wetland on the outlet of the FWWTP ponds was considered. The wetland would require significant land and physical works, while providing similar treatment performance as a FTW. Although this is a land contact process, thus to some extent addresses cultural values, it is not expected that the effluent quality would consistently and reliably meet effluent quality requirements for a discharge to surface waterways, particularly for nitrogen removal, and ongoing maintenance and harvesting of the wetlands can be difficult and expensive. Additionally, there is a recognised risk from experience that if the wetland were to follow the existing UV disinfection plant that pathogen levels could potentially increase through external wildlife influences (i.e. wetlands have a tendency to attract waterfowl). In view of the above shortcomings, it is not proposed to consider this option further.

A.3 Flow Control Options

A.3.1 Pond level control

An investigation of potential storage volume availability from reducing I/I to the plant has been undertaken to determine whether such storage could be sufficient for use via pond level controls to hold the pond discharge when the receiving environment (Donald's Creek) is at low flow (below half median). This was considered as a potential immediate short-term option in order to mitigate effects on the environment at critical periods.

Due to limited flow data within Donald's Creek (total of 19 data points at the time), the accuracy of half median flow values used in the analysis is questionable. Furthermore the frequency and likely duration of low flow conditions are also uncertain and an assumption that up to 13 days between accrual periods was made based on information from the Ruamahanga River.

The outcomes of the investigation showed the following:

- Such a system would be difficult operate. It would require the installation of additional instrumentation at the plant and in stream gauging (level sensors, control valves - along with associated maintenance costs and time). The system would need to be well-designed and controlled.
- In terms of soluble BOD_5 and in part pathogen removal, operating the ponds at a lower level (to always keep a volume available for 13 days of summer ADWF storage in case flow in Donald's creek fell below half median flow) would reduce the HRT through the ponds and impact detrimentally on the soluble BOD_5 and pathogens removal (up to 60% for soluble BOD_5 pre I/I works and approximately 30% post I/I works).
- Increasing the waveband height of the ponds by 0.5m to allow for additional storage would be expensive: around $500,000 for both ponds based on high level cost estimates. The modification of the ponds' depth (typically between 1.5 and 2m – currently 1.4m) would also impact their level of treatment, as the intensity of light penetration in the water reduces exponentially with depth.
- Following a holding period when discharge to Donald's Creek would commence again, the plant operators would need to release larger volumes of water than currently discharged into Donald's Creek to free storage volume again for the next dry period (when Donald's Creek flows fall under half median). This discharge regime could result in large volume discharges over short periods of time, which consequently could cause downstream erosion and scouring issues within the Creek.

The overall benefit to Donald's Creek of a pond level control options is considered to be negligible as the impact of the discharge appears reasonable under all flow conditions, not just low flow conditions, due to its lack of upstream assimilative capacity for nitrogen and phosphorus. Therefore, in view of the above challenges and lack of environmental benefits, it has been not recommended to pursue in-pond flow balancing via level control.

A.3.2 Donald Creek Flow Control

An option to use the water stored in the Boar Bush Reservoir to control flows in Donald's Creek has been investigated. This option is aimed at increasing flows in Donald's Creek by drawing from the 40,000m^3 reservoir at Boar Bush Reservoir at critical periods in order to increase dilution of the treatment effluent at the point of discharge into the receiving environment and therefore potentially improve compliance with ANZECC (2000) and Greater Wellington Regional Council (GWRC) guidelines. As per the pond level control option this was considered a potential immediate short-term option to mitigate effects on the environment at critical periods

In the absence of any reservoir water quality information, it has been assumed, the reservoir water has the same contaminant characteristics as the water monitored at the Donald's Creek upstream sampling site. No assessment of the consequences of the higher flows on Donald's Creek stream hydraulics and thus erosion and scouring potential has been undertaken at this stage.

The results show that the additional flow added from the reservoir would allow a slight level of improvement in water quality concentrations for Ammoniacal Nitrogen and BOD_5 downstream of the discharge with the greatest improvements achieved when releasing quite significant flows from the reservoir (up to 0.2m^3/s). At these high release flows, the reservoir would however be drained within 2 to 3 days and does not account for the time needed to refill the reservoir. Minimal improvement pre and post-I/I reduction works is noted in the receiving environment in terms of DRP or Total Nitrogen.

Limited improvement of the receiving environment is expected with this alternative. Also when considering the primary purpose of the Boar Bush Reservoir is to provide an emergency water supply for the residents of Featherston, this option has significant risks and therefore has not been considered any further.

B. MCA Screening

MULTI-CRITERIA ANALYSIS - SCREENING OPTION ANALYSIS

Key

Not considered or discounted for the stated reason	Environmental benefit	Cost	Technical appropriateness and Reliability
	4 Excellent	4 Low Cost	4 Excellent (appropriate and reliable)
	3 Good	3 Moderate Cost	3 Good
	2 Fair	2 High Cost	2 Fair
	1 Poor	1 Very High Cost	1 Poor
	0 None	0 Prohibitively High Cost	0 Very poor (inappropriate and unreliable)

Glossary

FTW - Floating Treatment Wetland
DAF - Dissolved Aeration Flotation
HRT - High Rate Treatment
MBR - Membrane Bioreactor
SBR - Sequencing Batch Reactor

	Treatment / Discharge	Alternative treatment process options – Pond Enhancement: Option 1	Pond Enhancement: Option 2	Pond Enhancement: Option 3	Pond Enhancement: Option 4	High Rate Treatment (HRT): Option 5
		Pond Upgrade (Screen, FTW, in-pond coagulation) - Network Rehabilitation	Pond Upgrade (Screen, FTW, DAF) - Network Rehabilitation	Pond Upgrade (Screen) - Network Rehabilitation	Pond Upgrade (Screen) - Re-reticulation	Membrane Bioreactor or SBR - Network Rehabilitation
Option A	Do Nothing (continued discharge to Donald's Creek)	Pond upgrades unable to address sewage fungus, eutrophication and ammonia toxicity issues in Donald Creek - thus option not considered any further.	Pond upgrades unable to address sewage fungus, eutrophication and ammonia toxicity issues in Donald Creek - thus option not considered any further.	Pond upgrades targeted at land treatment thus options to continue discharge to water have not been considered any further.	Pond upgrades targeted at land treatment thus options to continue discharge to water have not been considered any further.	Potentially an insufficient level of treatment achievable to meet water quality standards for the protection of aquatic ecosystems during summer low flow periods.
	MCA Score					
Option B	Discharge to Tauherenikau River	1 4 3 Likelihood of periphyton growths at <median flow (based on high level mass balance calcs), uncertainty around ammonia toxicity effects. Potential degradation of excellent ecological values. Social and cultural concerns regarding water discharge likely. Low costs. Good level of reliability with in pond coagulant dosing but performance uncertainty with FTW.	HRT was considered as an alternative to DAF as it would target both N and P removal	Pond upgrades targeted at land treatment thus options to continue discharge to water have not been considered any further.	Pond upgrades targeted at land treatment thus options to continue discharge to water have not been considered any further.	4 2 4 HRT would provide the necessary level of treatment to mitigate effects to acceptable levels for most of the year although further investigation required to confirm level of effects during summer low flow periods. Social and cultural concerns regarding water discharge would remain. Moderate costs and high ongoing opex costs. Reliable technology.
	MCA Score	8				10
Option C	Discharge to Ruamahanga River	3 1 2 Would reduce DRP contribution loads to River to around 1% although potential degradation of good ecological values remains a risk. Social and cultural concerns regarding water discharges would remain. Some level of operability risks due to long pipeline and performance uncertainty with FTW.	The level of P removal achieveable with DAF was not warranted with this option and in-pond coagulant dosing was considered appropriate.	Pond upgrades targeted at land treatment thus options to continue discharge to water have not been considered any further.	Pond upgrades targeted at land treatment thus options to continue discharge to water have not been considered any further.	High rate treatment unnecessary and likely to be cost prohibitive
	MCA Score	6				
Option D	Full Land Treatment with Deferred Storage	The assessment of environmental effects by LEI (2017) does not suggest BOD, TSS or P are contaminants of concern for land treatment, therefore further treatment for these contaminants is considered unnecessary.	The assessment of environmental effects by LEI (2017) does not suggest BOD, TSS or P are contaminants of concern for land treatment, therefore further treatment for these contaminants is considered unnecessary.	4 1 2 Achieves complete removal of all discharges to water and applies to land at a sustainable rate and which LEI (2017) has assessed to result in effects that would be no more than minor. Very high cost. Risks with managing an extremely large storage lagoon.	4 0 4 Sound long-term option that would hugely benefit the environment and future generations, however costs at this time considered prohibitive. Latest network technology although risk of stormwater inflow reliant on third party responsibilities. Managaeable storage pond and land treatment areas.	Nutrient removal achieved by HRT processes is not considered necessary when considering full land treatment. N and P are beneficial for optimising plant growth.
	MCA Score			7	8	

MULTI-CRITERIA ANALYSIS - SCREENING OPTION ANALYSIS

Key

Not considered or discounted for the stated reason	Environmental benefit	Cost	Technical appropriateness and Reliability
	4 Excellent	4 Low Cost	4 Excellent (appropriate and reliable)
	3 Good	3 Moderate Cost	3 Good
	2 Fair	2 High Cost	2 Fair
	1 Poor	1 Very High Cost	1 Poor
	0 None	0 Prohibitively High Cost	0 Very poor (inappropriate and unreliable)

Glossary
FTW - Floating Treatment Wetland
DAF - Dissolved Aeration Flotation
HRT - High Rate Treatment
MBR - Membrane Bioreactor
SBR - Sequencing Batch Reactor

	Treatment / Discharge	Alternative treatment process options				
		Pond Enhancement				High Rate Treatment (HRT)
		Option 1	Option 2	Option 3	Option 4	Option 5
		Pond Upgrade (Screen, FTW, in-pond coagulation) - Network Rehabilitation	Pond Upgrade (Screen, FTW, DAF) - Network Rehabilitation	Pond Upgrade (Screen) - Network Rehabilitation	Pond Upgrade (Screen) - Re-reticulation	Membrane Bioreactor or SBR - Network Rehabilitation
Option E	Land Treatment with Deferred Storage for 90th%ile storage flows and Contigency Winter Discharge					
Option E1	Contingency Winter discharge to Donald Creek under high stream flow discharge regime	4 / 1 / 2 Prolonged staging means effects regarding N will persist for longer. Very high cost. Risk of reduced consistency with P removal rates from in-pond cogulant dosing. FTW meet community aspirations however performance reliability uncertain. Pond storage large with risk of operational complexities.	4 / 0 / 3 Reduced staging timeframes lead to imrpovements to surface waters quicker by reducgin discharges to water and applying to land. Cost prohibitive. DAF will consistenty meet P removal targets but won't be implemented until final stage. FTW meets community aspriations however performance reliability uncertain. Pond storage large with risk of operational complexities.	3 / 2 / 4 Reduced staging timeframes lead to improvements to surface waters quicker by reducing discharges to water and applying to land. At final stage, clarity may remain an issue within receiving waters during winter and P removal may be considered necessary to mitigate effects downstream even though high stream flow discharges will be targeted. Pond storage large with risk of operational complexities.	Re-reticulation would result in a significant reduction in inflow volumes to the plant sufficient to enable full time land treatment, therefore this option has not been considered.	High rate biological treatment processes are not suitable for the treatment of occasional flows and therefore have not been considered further for this option.
	MCA Score	7	7	9		
Option E2	Contingency Winter Discharge to Donald Creek & Abbot Creek under high stream flow discharge regime	There is limited water quality information for Abbot Creek. The impacts of a contingency discharge to the Creek requires further investigation to ascertain whether a greater level of treatment is required. For the purpose of this assessment it has been assumed a high flow discharge regime and split discharge would be sufficient to mitigate any adverse effects at the final stage of development.	There is limited water quality information for Abbot Creek. The impacts of a contingency discharge to the Creek requires further investigation to ascertain whether a greater level of treatment is required. For the purpose of this assessment it has been assumed a high flow discharge regime and split discharge would be sufficient to mitigate any adverse effects at the final stage of development.	3 / 2 / 3 Reduced staging timeframes lead to improvements to surface waters quicker by reducing discharge to water and applying to land. At final stage, clarity may remain an issue within receiving waters during winter & P removal may be considered necessary to mitigate effects downstream even though high stream flow discharges to be targeted. Potential degradation of ecological values that may be better than in Donald Creek. High cost. Pond storage large with risk of operation complexities and added complexity with split discharge regime.	Re-reticulation would result in a significant reduction in inflow volumes to the plant sufficient to enable full time land treatment, therefore this option has not been considered.	High rate biological treatment processes are not suitable for the treatment of occasional flows and therefore have not been considered further for this option.
	MCA Score			8		
Option E3	Contingency Winter Discharge to Tauherenikau under high river flow discharge regime	P not considered an issue above 3x median flow therefore no treatment proposed	P not considered an issue above 3x median flow therefore no treatment proposed	4 / 1 / 3 Reduced staging timeframes lead to improvements to surface waters quicker by reducing discharge to water and applying to land. P not considered an issue above 3x median flow in River, discharge likely to be infrequent in nature and limited to winter months. Very high cost. Pond storage large with risk of operation complexities. Pipeline sitting largely unused.	Re-reticulation would result in a significant reduction in inflow volumes to the plant sufficient to enable full time land treatment, therefore this option has not been considered.	High rate biological treatment processes are not suitable for the treatment of occasional flows and therefore have not been considered further for this option.
	MCA Score			8		
Option E4	Contingency Winter Discharge to Lake Wairarapa	This option has however been discounted due to the foreseen social and cultural effects of discharging treated wastewater directly to the Lake	This option has however been discounted due to the foreseen social and cultural effects of discharging treated wastewater directly to the Lake	This option has however been discounted due to the foreseen social and cultural effects of discharging treated wastewater directly to the Lake	Re-reticulation would result in a significant reduction in inflow volumes to the plant sufficient to enable full time land treatment, therefore this option has not been considered.	High rate biological treatment processes are not suitable for the treatment of occasional flows and therefore have not been considered further for this option.
	MCA Score					
Option E5	Contingency Winter Discharge to Ruamahanga River	The combined cost of land treatment and pond enhancements, 90th %ile storage volume and piping 14.5km to the Ruamahanga means this option would be cost prohibitive and has not been considered further.	The combined cost of land treatment and pond enhancements, 90th %ile storage volume and pipeing 14.5km to the Ruamahanga means this option would be cost prohibitive and has not been considered further.	The combined cost of land treatment, 90th %ile storage volume and pipeing 14.5km to the Ruamahanga means this option would be cost prohibitive and has not been considered further.	Re-reticulation would result in a significant reduction in inflow volumes to the plant sufficient to enable full time land treatment, therefore this option has not been considered.	High rate biological treatment processes are not suitable for the treatment of occasional flows and therefore have not been considered further for this option.
	MCA Score					
Option E6	Contingency Winter Discharge to Land via High Rate Irrigation	Further groundwater investigations warranted to prove or otherwise whether additional pond treatment is warranted.	Further groundwater investigations warranted to prove or otherwise whether additional pond treatment is warranted.	3 / 2 / 4 Reduced staging timeframes lead to improvements to surface waters quicker by reducing discharge to water and applying to land. Eliminates all direct discharges to water, but may have effect on groundwater mounding and quality which requires further investigation to quantify. High cost. Pond storage large with risk of operation complexities.	Re-reticulation would result in a significant reduction in inflow volumes to the plant sufficient to enable full time land treatment, therefore this option has not been considered.	High rate biological treatment processes are not suitable for the treatment of occasional flows and therefore have not been considered further for this option.
	MCA Score			9		

Key

Not considered or discounted for the stated reason	Environmental benefit	Cost	Technical appropriateness and Reliability
	4 Excellent	4 Low Cost	4 Excellent (appropriate and reliable)
	3 Good	3 Moderate Cost	3 Good
	2 Fair	2 High Cost	2 Fair
	1 Poor	1 Very High Cost	1 Poor
	0 None	0 Prohibitively High Cost	0 Very poor (inappropriate and unreliable)

Glossary

- FTW - Floating Treatment Wetland
- DAF - Dissolved Aeration Flotation
- HRT - High Rate Treatment
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	Treatment / Discharge	Alternative treatment process options				
		Pond Enhancement				High Rate Treatment (HRT)
		Option 1	Option 2	Option 3	Option 4	Option 5
		Pond Upgrade (Screen, FTW, in-pond coagulation) - Network Rehabilitation	Pond Upgrade (Screen, FTW, DAF) - Network Rehabilitation	Pond Upgrade (Screen) - Network Rehabilitation	Pond Upgrade (Screen) - Re-reticulation	Membrane Bioreactor or SBR - Network Rehabilitation
Option F	Combined Land Treatment and Direct or Indirect Discharge to Water					
Option F1	Partial Discharge to Donald Creek	Higher level of P removal achievable by using high rate treatment such as DAF is required to ensure effects are suitably mitigated downstream, therefore this options has not been considered	[2 / 2 / 3] Potential risk of ammonia toxicity having moderate to significant effects on downstream ecosystems and reasonable contributions of nutrients to the receiving environment remains. Social and cultural concerns likely to remain. High scheme costs. DAF provides reliable level of treatment and would resolve issues regarding discolouration, clarity and foams. Performance of FTW uncertain. Storage pond small and manageable.	P removal is considered necessary to ensure effects are suitably mitigated downstream, therefore this option has not been considered	Re-reticulation would result in a significant reduction in inflow volumes to the plant sufficient to enable full time land treatment, therefore this option has not been considered.	[4 / 2 / 4] This options assumes HRT for entire discharge with land discharge only occurring at low stream flows. HRT to provide necessary level of treatment to mitigate effects when stream flows provide suitable dilution and land treatment would mitigate effects during low flows. Social and cultural concerns regarding water discharge would remain. Moderate costs but high ongoing opex costs. Reliable technology.
	MCA Score		7			10
Option F2	Partial Discharge to Donald & Abbot Creeks	Higher level of P removal achievable by using high rate treatment such as DAF is required to ensure effects are suitably mitigated downstream, therefore this options has not been considered	[2 / 2 / 3] Potential risk of ammonia toxicity on downstream ecosystems at <median flows and reasonable contributions of nutrients to the receiving environment remains. Potential degradation of another receiving environment that ultimately combines with Donald Creek and discharges to the same receiving environment. Social & cultural concerns likely to remain. High scheme costs. DAF provides reliable level of treatment and would resolve issues regarding discolouration, clarity and foams. Performance of FTW uncertain. Storage pond volumes small & manageable.	P removal is considered necessary to ensure effects are suitably mitigated downstream, therefore this option has not been considered	Re-reticulation would result in a significant reduction in inflow volumes to the plant sufficient to enable full time land treatment, therefore this option has not been considered.	HRT in conjunction with land treatment of this scale would be cost prohibitive.
	MCA Score		7			
Option F3	Partial Discharge to Tauherenikau River	Higher level of P removal achievable by using high rate treatment such as DAF is required to ensure effects are suitably mitigated downstream, therefore this options has not been considered	[3 / 1 / 3] DAF will assist in mitigating potential effects of P in the discharge at >median river flows however a risk remains of periphyton growths occuring during shoulder months in low flow conditions. Social and cultural concerns likely to remain. High scheme costs. DAF provides reliable level of treatment andwould resolve issues regarding discolouration, clarity and foams. Performance of FTW uncertain. Sotrage pond volumes small and manageable.	P removal is considered necessary to ensure effects are suitably mitigated downstream, therefore this option has not been considered	Re-reticulation would result in a significant reduction in inflow volumes to the plant sufficient to enable full time land treatment, therefore this option has not been considered.	HRT in conjunction with land treatment of this scale would be cost prohibitive.
	MCA Score		7			
Option F4	Partial Discharge to Ruamahanga River	Higher level of P removal achievable by using high rate treatment such as DAF is required to ensure effects are suitably mitigated downstream, therefore this options has not been considered	[4 / 0 / 1] DAF would provide suitable treatment to resolve downstream issues with P. ocial and cultural concerns likely to remain. Cost prohibitive. Major pipeline infrastructure sits redundant for 4 months of the year. S	P removal is considered necessary to ensure effects are suitably mitigated downstream, therefore this option has not been considered	Re-reticulation would result in a significant reduction in inflow volumes to the plant sufficient to enable full time land treatment, therefore this option has not been considered.	HRT in conjunction with land treatment of this scale would be cost prohibitive.
	MCA Score		5			
Option F5	Partial Discharge to Land and Groundwater via Rapid Infiltration Basin	Not considered	Not considered	[2 / 3 / 1] Risks regarding groundwater mounding, groundwater quality, and odour emissions are likely and require further investigation. May resolve social and cultural concerns. Moderate scheme costs - Reasonably cost effective solution. Operability uncertain potential issues around soakage and anaerobic conditions forming.	Re-reticulation would result in a significant reduction in inflow volumes to the plant sufficient to enable full time land treatment, therefore this option has not been considered.	HRT in conjunction with land treatment of this scale would be cost prohibitive.
	MCA Score			6		
Option F6	Partial Discharge to Donald Creek via Riparian Gabions	Higher level of P removal achievable by using high rate treatment such as DAF is required to ensure effects are suitably mitigated downstream, therefore this options has not been considered	[2 / 2 / 2] This option would provide limited added benefit to Option 2F1 other than providing land contact prior to discharge. This may go someway to addressing cultural concerns but further consultation would be required to confirm this. High scheme costs. DAF provides reliable level of treatment and would resolve issues regarding discolouration, clarity and foams. Performance of FTW uncertain. Storage pond small and manageable.	P removal is considered necessary to ensure effects are suitably mitigated downstream, therefore this option has not been considered	Re-reticulation would result in a significant reduction in inflow volumes to the plant sufficient to enable full time land treatment, therefore this option has not been considered.	HRT in conjunction with land treatment of this scale would be cost prohibitive.
	MCA Score		6			

C. High Rate Irrigation Feasibility Assessment

GWS LTD

7th February 2017

South Wairarapa District Council
PO Box 6
Martinborough 5741

Attention: Bill Sloan

Subject: Assessment of Effects to Groundwater Related to Proposed Contingency land Discharge Area for the South Featherston WWTP

Dear Bill,

1. Background

The following letter provides a summary of the key results related to the effects likely to occur in groundwater from the proposed discharge of wastewater to land in the identified contingency area which is part of the Hodders Farm (referred to as Site B) in South Featherstone. The site location is shown in Figure 1 of the Attachments. This area has previously been described by LEI (June, 2016) and has been the subject of an effects assessment based on deferred irrigation during dry months of the year. This assessment builds on this previous work by assuming high rate irrigation (50 mm/d) will be undertaken during the winter months of July and August each year.

2. Description of Environment

The general environmental setting is described by LEI (June, 2016). The following provides a summary of the key assumptions adopted from this work and, where available, presents additional or new information related to the hydrogeologic setting.

2.1 Site Topography

A detailed site elevation model was not available at the time of preparing this report. However, some elevation information is available in the GWRC GIS database, allowing profiling of the site to be undertaken. Figures 2-3 of the attachments show the general elevations in the area. The site has reasonable relief with elevation ranging from a low of 19 mRL in the south to a peak height of 27.5 m RL in the north. The eastern third of the site appears to be a widespread topographic depression and is the lowest portion of the site. To the west and north the elevation rises. Across all areas of the site depressions exist resulting in up to 3 m change in relief across the area. In the east depressions and table drains are noted that drain south into the Longwood Water Race system.

The site relief is of importance in this assessment as it ultimately determines the depth of unsaturated zone present above the water table, and therefore the degree of mounding that can be allowed before surface breakout occurs.

4 Katote Close, The Gardens
Manurewa
Auckland 2105

Phone: 09 268 8312
Email: chris@gws.co.nz
Web: www.gwsconsulting.co.nz

2.2 Hydrology

Donalds Creek is assumed to be the main surface water receptor with gaining reaches down gradient of the WWTP, meaning discharge of groundwater is assumed to be occurring into the creek here year-round where it will mix with variable stream flows. Upstream of the WWTP, the Torohanga tributary provides the primary source of baseflow during summer months as it is spring feed. Upstream of this confluence Donald Creek can run dry during summer months.

2.2 Hydrogeology

The hydrogeology of the general area is described by LEI. There is limited data available in relation to the groundwater system in the site area and much has been assumed from previous work. An interpretation of the existing piezometric surface has been drawn based on limited information and is provided in Figure 5. Based on this interpreted groundwater level elevation and the surface profile depth of unsaturated zone is <3m on the ridges and as little as 0.5 m in the depressions in the western part of the site. In the eastern part of the site, the expected depth is <1m across most of the area. Aerial photographs support this being a low lying area that may discharge groundwater locally at times of the year as evident by the table drain network that exists.

For the purposes of this assessment the western two thirds of the site have been preferentially adopted for irrigation due to the general higher relief and greater depth of unsaturated zone.

The aquifer parameters used in this assessment have been taken from previous work. The key inputs are as follows:

Vertical Hydraulic Conductivity (Kv) = 4 m/d
Horizontal Hydraulic Conductivity (Kh) = 12 m/d
Conductivity Ratio (Kv/Kh) = 0.3
Specific Yield (Sy) = 0.3
Hydraulic Gradient (i) = 0.003 - 0.005

The South Featherston area has previously been studied to assess the impact of nitrogen on the aquifer (GWRC, 2008). This study has indicated background concentrations of nitrogen of 3 g/m^3 and up to 5.74 g/m^3 near an existing land discharge from a Piggery to the south west of the Hodders Farm. Dissolved Reactive Phosphorous (DRP) is <1 mg/L in all bore locally.

2.3 Scheme Properties

This assessment has determined that the western two thirds of the property is the preferred area for land application and two 8 ha irrigation block could be developed in the land available. Figure 6 shows the conceptual irrigation block layout. Note that the blocks have been oriented with greatest length parallel to the groundwater flow direction to minimise mounding effects. The following assumptions have been used as inputs to this assessment:

Irrigation Rate (IR) = 0.055 m/d
Disposal Field Area (A) = 80,000 m^2

Maximum Daily Land Disposal Rate (Q max) = 4,400 m^3/d
Maximum Duration of Land Disposal (T max) = 45 days

The treated wastewater quality has been assumed to be as follows, depending on project stage:

Total Nitrogen (TN) = 10.5, 15, 25 g/m^3
Ammoniacal Nitrogen (NH4) = 7.4, 12, 18 g/m^3
Dissolved Reactive Phosphorous (DRP) = 2.3, 4, 6 g/m^3

These values have been used as source concentrations in the assessment and represent the 95 percentile values to consider worst case conditions. Buffer distances were adopted as per LEI report of 25 m from the site boundary and 20 m from watercourses.

3. Assessment of Effects

3.1 Methodology

Assessing the effects to groundwater has involved the use of a number of analytical methods. Initial high level calculations were undertaken to assess feasibility and results at conservative levels. This was then followed by the development of numerical groundwater models in both SEEP/W and MODFLOW software packages. Steady state flow conditions were calibrated to the interpreted piezometric surface. This provided the initial conditions for the transient model runs that simulated daily irrigation in the blocks. The MODFLOW modules ModPath and RT3D were used to assess flow paths, contaminant and pathogen transport. Further details on analytical and numerical model inputs are provided in the technical addendum to this report. The results of this assessment are summarised as follows.

3.2 Mounding Effects

Initial assessment considered irrigation at a rate of 55 mm/d in one 8 ha block for 45 days continuously. An additional recharge of 5 mm/d was applied to represent average winter drainage due to rainfall. For the purpose of this assessment a critical mounding limit of 1.5 m has been used to assess whether ponding or surface breakout would occur due to excess mounding. Figures 7 and 8 present the results of the groundwater mounding assessment. Both the analytical and model results have indicated that mounding would reach 1.9 m after 45 day indicating that more than one irrigation field would be required to allow rest and reduce mounding effects. Based on the critical mounding limit, the results indicate one field could operate for 30 days continuously before mounding to reached 1.5 m.

Further model runs simulated two fields with cyclic irrigation on 7 day, 3 day and 1 day return periods. Results indicate a 3 day return period as being the most efficient in reducing mounding effects and mounding is generally at the critical level of 1.5 m after 45 days irrigation. A further model was run to assess the operation of two fields that are separated. Separation of the fields assists in mound decay, however this would include having to utilise the eastern part of the site which is less favourable and likely has a lower critical mounding limit. The results of this scenario indicate mounding up to 1.2 m if some separation between the irrigation fields could be achieved.

Being able to apply the wastewater at a rate that results in manageable mounding effects and limits the potential for surface breakout is a critical factor in this proposal. Initial results have indicated this may be possible. It must be stated however, that there remains a reasonable amount of uncertainty in this assessment. This uncertainty relates to elevation control, characterisation of the unsaturated zone depth distribution over the site and understanding of the geologic conditions at depth. Due to these uncertainties and the apparent high sensitivity of mounding in relation to aquifer properties, we consider there is residual risk that ponding and surface breakout of wastewater could occur due to topography and soil stratigraphy in localised areas. This could then result in pathogens in run-off entering water ways. It is recommended that this residual risk be addressed through detailed investigation and design, and conditions put forward that help manage potential effects occurring.

3.3 Groundwater Quality

Nutrients

The quality of groundwater in the aquifer surrounding the land discharge area will be affected by the discharge. The average aquifer concentration after mixing is dependant on the initial concentration assumed and the background concentrations. Figure 9 shows the typical groundwater plume distribution. The predicted concentrations for various scenarios are shown in Table 1 and 2.

Table 1 Nitrate Nitrogen in Groundwater

	Effluent Concentration		
	10.5 mg/L	15 mg/L	25 mg/L
Background 3.0 mg/L	5.67	7.28	10.84
Background 5.75 mg/L	7.44	9.05	12.61

Table 2 DRP in Groundwater

	Effluent Concentration		
	2.3 mg/L	4 mg/L	6 mg/L
Background 0.1 mg/L	0.88	1.49	2.2

These results indicate that the discharge would not generally result in concentrations of nitrate in the aquifer in excess of Ministry of Health (MoH, 2008) drinking water standards (11.3 mg/L). Where the wastewater TN is 25 mg/L, bores in areas with already elevated background concentrations could exceed potable limits. This is likely to affect bores in the area to the east. Further assessment of this scenario should be considered to assess whether this affect can be minimised and/or re-evaluated.

Pathogens

Pathogens entering the aquifer will be transported within the aquifer. The length of time it takes for pathogen to travel is a function of the hydraulic regime and the texture and distribution of the materials within the aquifer. Under average aquifer conditions the path lines shown in Figure 10 show the zone within which pathogens will travel. Results indicate maximum travel velocities of 500 m/y. Under these conditions it is unlikely that pathogens would still be viable by the time groundwater reached the nearest receiver as it would take

4 Katote Close, The Gardens
Manurewa
Auckland 2105

Phone: 09 268 8312
Email: chris@gws.co.nz
Web: www.gwsconsulting.co.nz

in excess of a year to travel there. It is generally accepted that pathogen die off will occur in groundwater within 12 months (USEPA, 1982).

There are a number of water bores in the area that are used for domestic, stock and irrigation purposes. The domestic and stock supplies are assumed to be small in volume and < 5 m^3/d, while consented take ranges for irrigation range from 1,200 to 3,300 m^3/d. Assessment of the effect of these pumping bores on the flow paths and travel times has been undertaken and the results presented in Figure 10. This analysis shows that the small domestic takes outside of the flow paths are not of high enough yield to alter flow lines. The large groundwater takes peripheral to the land disposal will alter flow lines and capture a component of water from the discharge. All of the bores down gradient of the land disposal will be susceptible to capturing a component of the discharge. Travel times to these bores is in the order of 6 months to the closest takes, indicating the possibility that pathogens (in particular viruses) could enter these bores. Further assessment of this risk should be undertaken to evaluate whether the actual effect is considered real.

3.5 Surface Water Quality

Nutrients

The pathways for nutrient to enter surface water is via the drainage network that may intercept shallow groundwater and from the discharge of deeper groundwater into streams and creeks.

Concentration in groundwater discharging to the drains could be high, however flow in drains is low so the N mass contribution to the creek is low. Calculations indicate <50 m^3/d would enter the drain and the TN mass load would be between 0.1 and 0.6 Kg/d. This water from the drains would ultimately reach Donald Creek.

Groundwater discharge from the land application would likely enter Donald Creek in down gradient gaining reaches at a flow rate in the order of 720 m^3/d with a mass load in the order of 4.1 Kg/d TN an 0.16 mg/L DRP. Donald Creek median low flows have been gauged at 137 l/s (11,836 m^3/d) with a median TN of 2.25 mg/L and DRP of 0.3 mg/L. Based on mixing of these two waters a final stream quality of 2.45 mg/L TN and 0.43 DRP mg/L would result. The discharge would result in a small increase in nitrogen concentration in the Creek, however the background limit is already in excess of the aquatic eco limit of 1.7 mg/L (ANZECC, 2000).

Pathogens

Based on the travel times, it is unlikely that any viable pathogen could discharge directly to surface waters. It is, however, noted that preferential pathways can exist that will reduce the travel times to surface waters. As stated previously, there is the potential for pathogens to discharge into drains, which then discharge to Donalds Creek. In order to minimise this potential a buffer distance of 50 m from main drains is recommended to allow sufficient time for die off.

4. Recommendations

The following recommendations are considered relevant at this stage of evaluating this proposal to further refine the assessment of risk in regards to aspects of this effects assessment. Further assessment of the following is:

- Obtain high resolution site elevation model
- Characterise depth to groundwater across the site and seasonal variation
- Soil profile characterisation across the site (soil physical properties)
- Characterise aquifer stratification
- Site specific aquifer permeability testing
- Assess groundwater use and risk at neighbouring bore with significant takes

Further discussion should be entered into before advancing the proposal for land disposal to ensure the identified risks can either be resolved or managed.

5. References

Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

MOH, 2005 (Revised 2008); Drinking Water Standards for New Zealand 2005. Compiled by National Drinking Water Standards Review Expert Working Group, Ministry of Health. 2005.

Lowe Environmental Impact. June 2016. Assessment of Environmental Effects of Discharge of Featherston Treated Wastewater to Land. Report prepared for the South Featherston District Council.

USEPA-600/1-82-007. 1982. Health Effects of Land Treatment. May 1982.

6. Closure

Should you have any further questions please contact the undersigned.

Chris Simpson
Hydrogeologist

For and on behalf of GWS Limited

Figure 1 Site Location

Figure 2 Topographic Elevation in Site Area

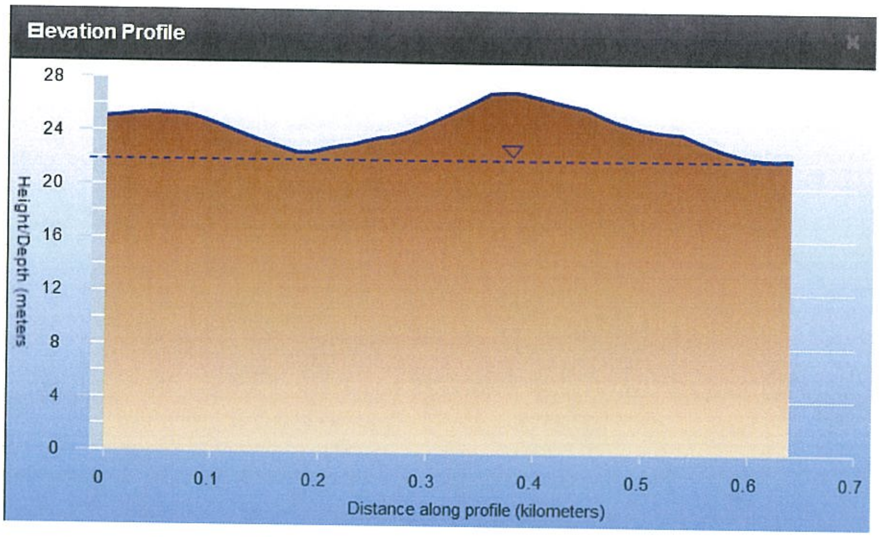

Figure 3 Topographic Profile on Northern Site Boundary

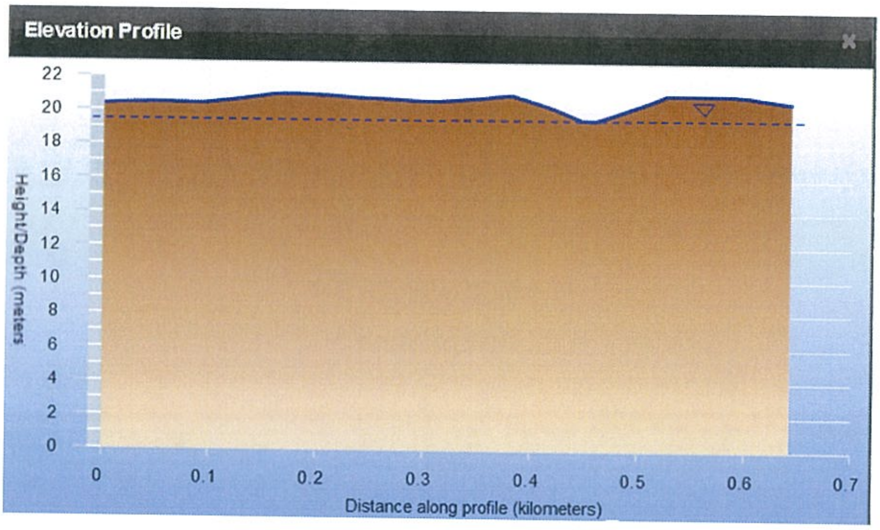

Figure 4 Topographic Profile on Southern Site Boundary

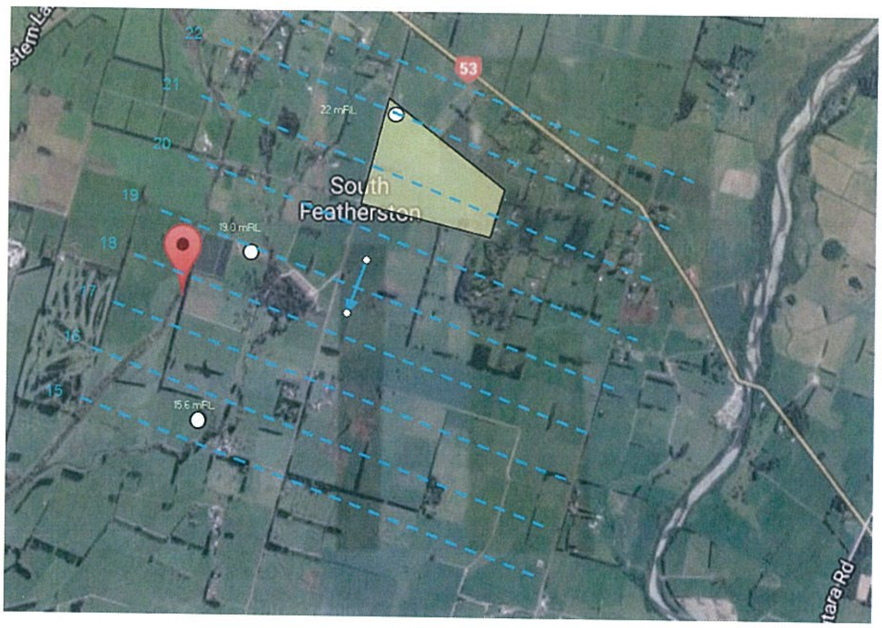

Figure 5 Interpreted Piezometric Surface Map

Figure 6 Conceptual Irrigation Block Layout

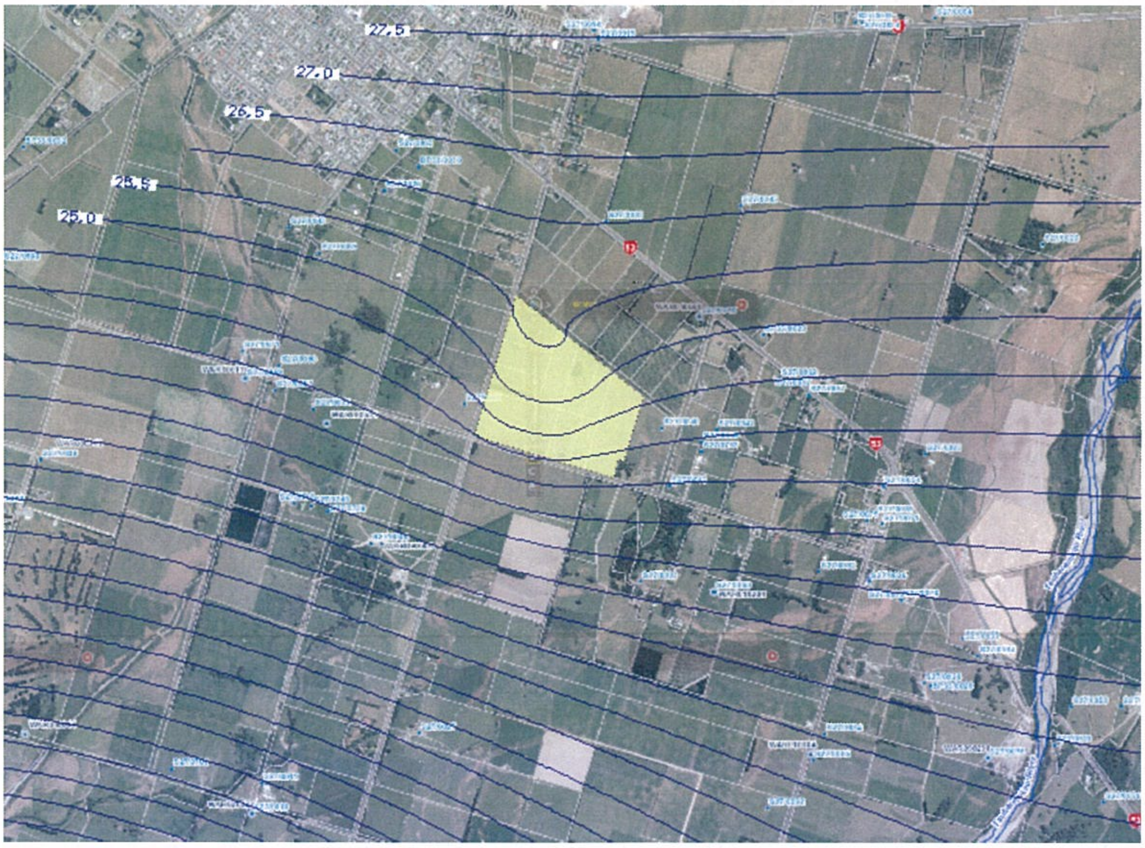

Figure 7 Groundwater Mound Surface

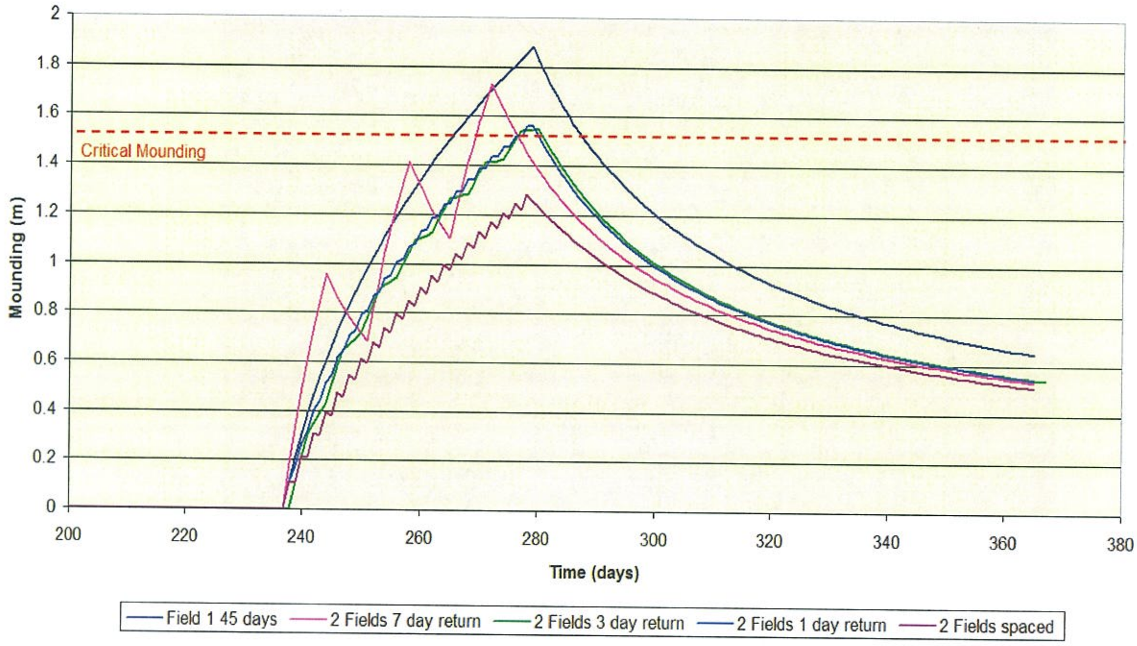

Figure 8 Groundwater Mounding beneath Field

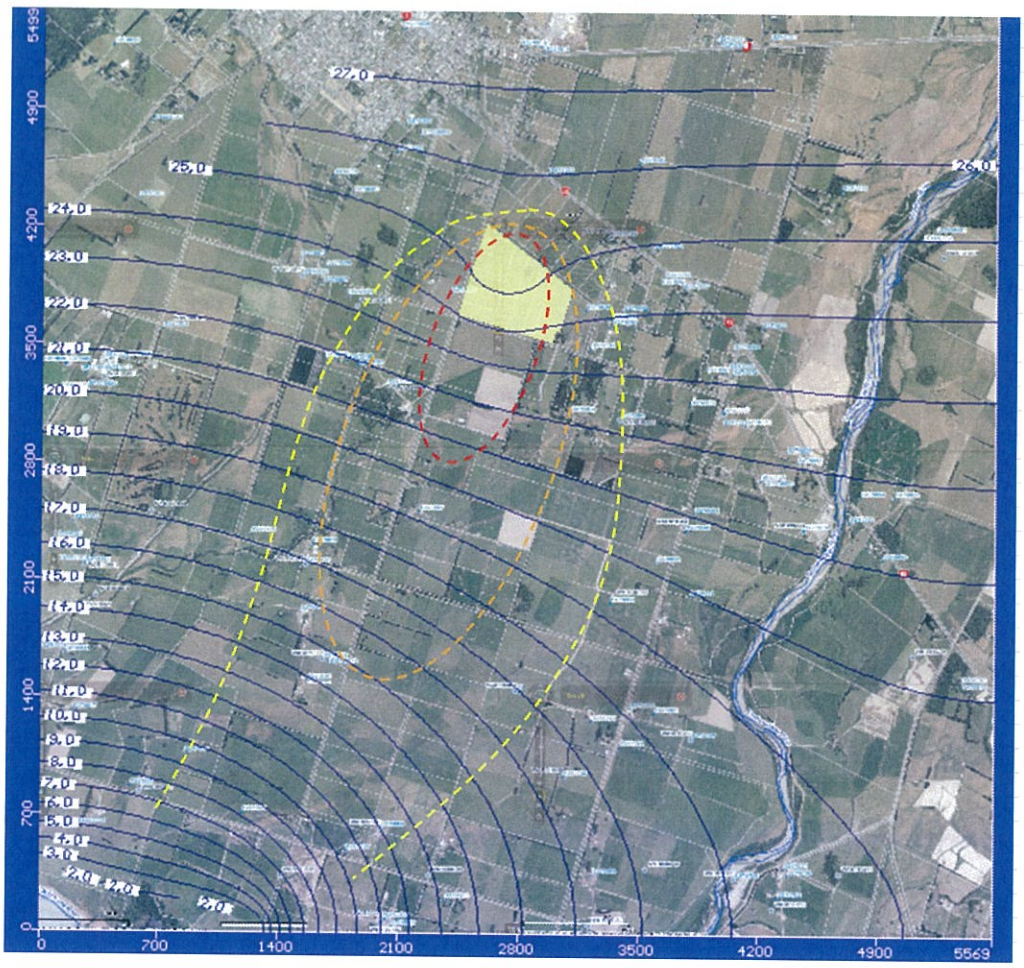

Figure 9 Typical Nutrient Plume Distribution

Figure 10 Flow Path Lines with no Pumping

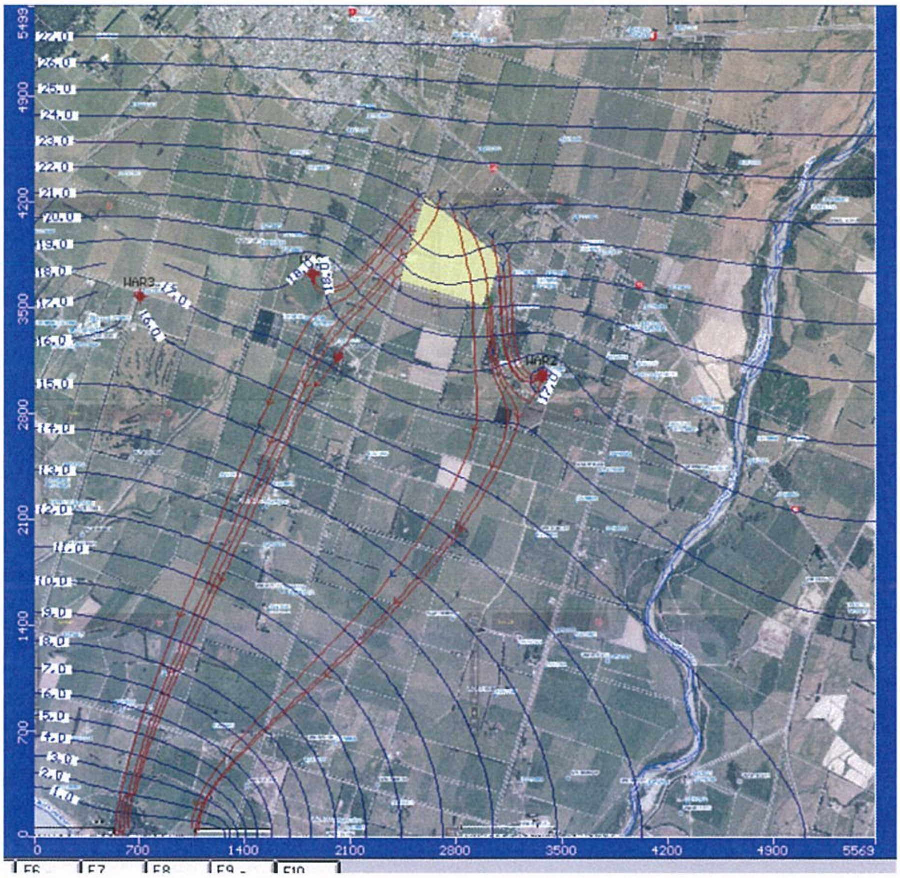

Figure 11 Flow Path Lines with Pumping

Technical Addendum

Groundwater Effects Assessment

Groundwater Mounding Calculations

An initial assessment was undertaken to assess the extent of groundwater mounding effects in relation to the shape of the irrigation field under the proposed loading regime. An iterative approach was uses to vary field length and width resulting in an optimum layout relative to the property area available for irrigation. The best hydraulic efficiency with least mounding effect is obtained by adopting the maximum length and minimum width possible. Example workings using the Hantush (1967) method for the optimum shape field is provided for 45 days and 5 days respectively.

GROUNDWATER MOUND UNDER A RECTANGULAR RECHARGE AREA

Using the Hantush (1967) Derivation

Inputs

w (Percolation Rate): 0.055 [L/T]
K (Hydraulic Conductivity): 12 [L/T]
S (Specific Yield): 0.2 [-]
t (Time): 45 [T]
h_i (Initial Saturated Thickness): 25 [L]
a (Length of Recharge Area): 550 [L]
b (Width of Recharge Area): 145 [L]

****KEEP UNITS CONSISTENT****

Calculate

Results

****Note that because of estimations of an integral function, this is an estimate****

Maximum hydraulic head: 27.19943737 [L]
Increase in hydraulic head: 2.19943737 [L]

GROUNDWATER MOUND UNDER A RECTANGULAR RECHARGE AREA

Using the Hantush (1967) Derivation

Inputs

w (Percolation Rate): 0.055 [L/T]
K (Hydraulic Conductivity): 12 [L/T]
S (Specific Yield): 0.2 [-]
t (Time): 5 [T]
h_i (Initial Saturated Thickness): 25 [L]
a (Length of Recharge Area): 550 [L]
b (Width of Recharge Area): 145 [L]

****KEEP UNITS CONSISTENT****

Calculate

Results

****Note that because of estimations of an integral function, this is an estimate****

Maximum hydraulic head: 26.42641217 [L]
Increase in hydraulic head: 1.42641217 [L]

Hantush, M.S.(1967). ***Growth and Decay of Groundwater-Mounds in Response to Uniform Percolation,*** **Water Resources Research vol. 3, no.1, pp 227-234.**

A more detailed assessment of hydraulic mounding was then undertaken using numerical models to test effects related to operating two disposal fields and varying return irrigation periods.

Numerical Modelling

Model Description

An assessment of groundwater effects has been undertaken using two separate numerical modelling packages; SEEP/W and MODFLOW. The conceptual model is highly simplified and assumes a single layer, monolithic geological conditions representing the upper aquifer system only. The models have been developed as being transient with hydraulic properties and steady state piezometric surface calibrated to the available observational data. The calibrated models have been used to determine the extent of effects presented.

Model Setup

The model grid is shown on Figure 1 and has the following dimensions:

Model Extent (X-Y plane): 5.5 x 5.5 km
Model Thickness (Z Plane): 30 m
Model Elevation: 30 mRL to 3 mRL
Central grid size: 30 x 30 m
Outer grid size: 60 x 60 m

The model grid has been set to assume no-flow to the east and west at the catchment perimeter, with groundwater moving in a predominant north to south direction.

Material Properties

The calibrated model material properties are as presented in the Table 1 below..

Table 1 Model Material Properties

Parameter	Zone 1 (white)	Units
b	300	*m*
Kh	12	*m/d*
Kv	4	*m/d*
Kh/Kv	0.3	
T	350	*m2/d*
S	0.2	

The material properties adopted are simplified based on the aquifer Transmissivity (T) and Storativity parameter defined by LEI (2016). These values for Hydraulic Conductivity (K) and Storativity (S) represent the adopted parameters for the final modelling scenarios.

Boundary Conditions

The models have two static boundary conditions; a constant head boundary at the northern model extent set at 28 m RL (set through calibration) and constant head boundary at the southern model set at 0 m RL representing Lake Wairarapa.

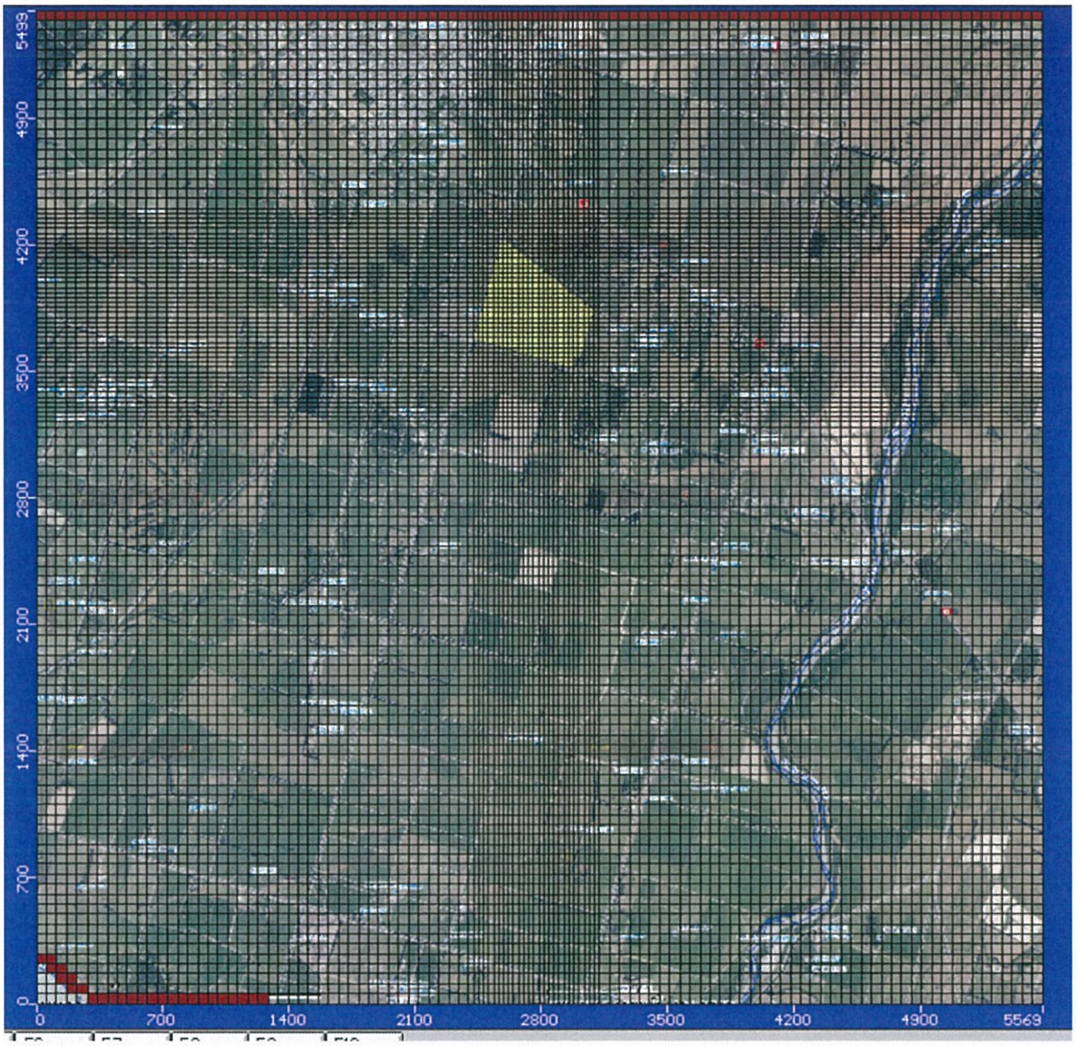

Figure 1 Model Domain Showing Grid Set-up and Constant Head Boundaries

Model Boundary Functions

Irrigation to the disposal fields was simulated in the model by boundary functions that apply water at the proposed rate of 0.055 m/d over time. The model was set-up with daily time steps over 365 days and irrigation was applied at return frequencies determined through model iteration to result in the least mounding of groundwater (1, 3, 5 and 7 day return periods). An additional 0.005 m/d was also applied to the irrigation fields to simulate average winter drainage.

In the Modflow model RT3D was used to simulate nutrient transport. A Recharge Concentration boundary function was used at the source area with a variety of initial nutrient concentrations that represent stages of the WWTP project development.

Pumping and Observation Wells

The model has incorporated the presence of pumping wells in the model domain. Where these bore are known to be for the purpose of domestic and stock watering, a pumping rate of 5 m^3/d was assigned. Those bores with consent to take groundwater for irrigation and other industrial purposes were assigned abstractions rates known from GWRC consent database. These values range from 1,500 to 3,000 m^3/d. Logs for a selection of bores immediately surrounding the irrigation fields were also obtained from GWRC. These indicate bores in the area are typically of shallow depth (<10 m).

B.6 Model Calibration

An initial model calibration was fitted by replicating the general head distribution and gradients from the interpreted piezometric surface map was produced from known groundwater level information at a few locations. Overall a good model calibration was fitted to the observation. It is noted that the groundwater conditions simulate winter high groundwater levels as seasonal groundwater level information was not available at the time of undertaking this assessment. The model was not, therefore, calibrated under transient conditions. Figure 2 provides the calibrated steady state model output.

Figure 2 Steady State Head File

Model Sensitivity

A limited sensitivity analysis has been undertaken by taking the calibrated base model and altering various input parameters. This process has shown that the effects of mounding are most sensitive to the Kh/Kv ratio ie. The extent of anisotropy caused by layering in the upper aquifer. The model is also sensitive to drainable porosity or specific yield.

Model Results

The results from the numerical models have been used to assess mounding risk, nutrient concentrations in the aquifer and in surface water discharges, and travel times along pathlines to assess pathogen risk. Figure 3 provides an example model output for groundwater heads. Figure 4 shows mounding height relative to ground surface level.

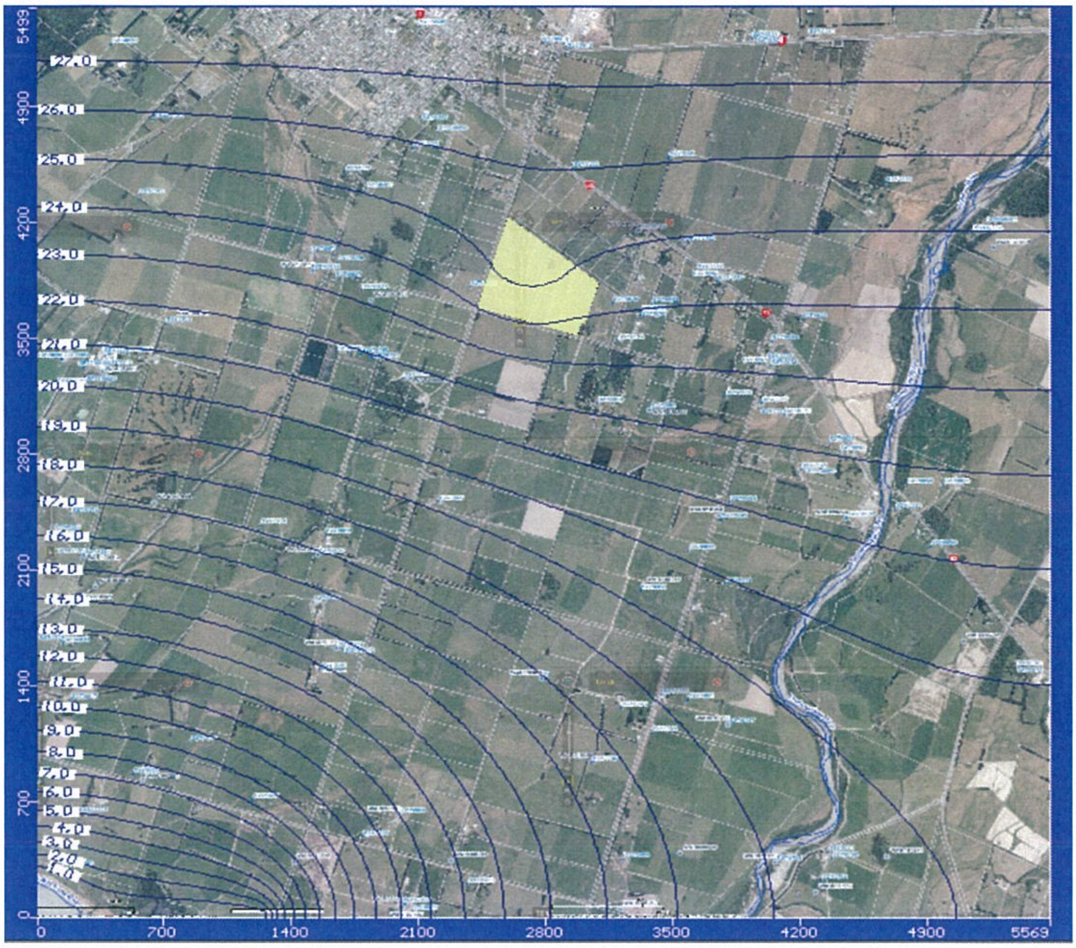

Figure 3 Example Transient Head Distribution During Irrigation

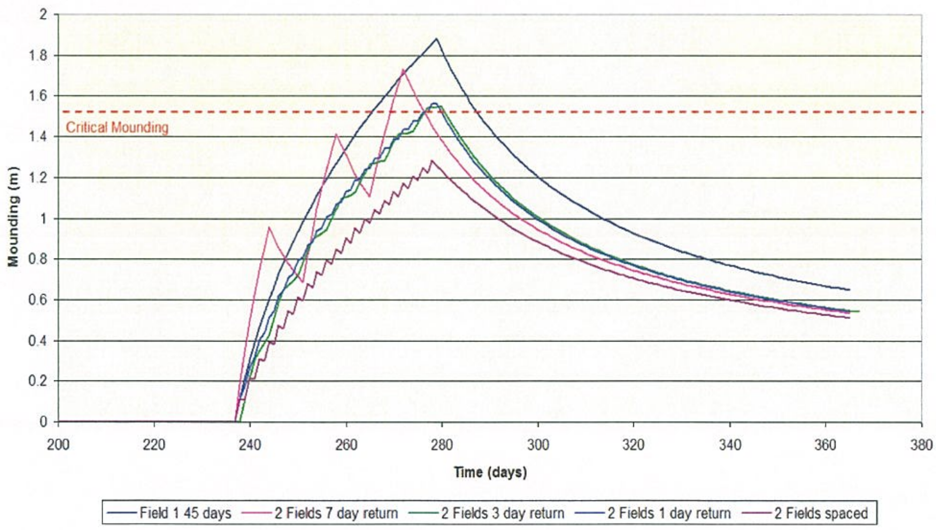

Figure 4 Groundwater Mounding Beneath Field

Figure 4 shows the nutrients concentrations and pathlines resulting from the irrigation with the bores in operation.

Figure 4 **Example Pathline and Nutrient Concentrations During Irrigation**

Mixing Model Calculations

In addition to the numerical model being used to assess nutrient concentrations in groundwater, a series of analytical calculations were undertaken to assess the concentrations after mixing in the aquifer and after discharge and mixing with surface waters. The mixing model is of the following expression:

$$\frac{C_1Q_1 + C_2Q_2}{Q_1+Q_2}$$

Darcys law was used to determine values of flow (Q) where required. Surface water flows were derived from stream gauging. The results after mixing included the initial source concentration of the wastewater, and background concentrations within groundwater or surface waters. The predicted concentrations for various scenarios are shown in Table 2 and 3.

Table 2 Nitrate Nitrogen in Groundwater

	Effluent Concentration		
	10.5 mg/L	15 mg/L	25 mg/L
Background 3.0 mg/L	5.67	7.28	10.84
Background 5.75 mg/L	7.44	9.05	12.61

Table 3 DRP in Groundwater

	Effluent Concentration		
	2.3 mg/L	4 mg/L	6 mg/L
Background 0.1 mg/L	0.88	1.49	2.2

Overall the mixing model calculations are consistent with the concentrations derived from the numerical modelling.