Pattle Delamore Partners Limited

TECHNICAL MEMORANDUM

INVESTIGATION	Irrigation Soil Water Balance Model Summary	**PROJECT**	Takapau Plant Wastewater Irrigation Consenting
CLIENT	**Silver Fern Farms Limited**	**PROJECT NO**	A02164500
		PREPARED BY	James Scouller and Neeraj Pratap
		SIGNATURES	
		DATE	28 June 2019

Introduction

This technical memorandum has been prepared by Pattle Delamore Partners Ltd (PDP) on behalf of Silver Fern Farms Limited to summarise computational modelling of the irrigation to land systems at Takapau. The memorandum should be read in conjunction with the assessment of environmental effects (AEE) prepared by PDP for renewal of consents at the site including the discharge to land consents governing process wastewater irrigation (DP981043Ld & DP981044Ad) and domestic wastewater irrigation (DP981040L).

The Takapau site has two separate wastewater irrigation systems. The first is a process wastewater system that irrigates DAF-treated process wastewater via travelling irrigator to 218 ha of surrounding land owned by Silver Fern Farms. The second is the domestic wastewater system which irrigates treated sewage effluent to 1.6 ha of Silver Fern Farms' land via border-dyke. The process wastewater can be temporarily stored (for a maximum of 1 day) in a holding pond at the site before being irrigated, and up to 65 mm may be applied over each travelling irrigator run. Return times vary depending on the amount applied. The domestic wastewater is stored in an oxidation pond, and up to 750 m^3 is irrigated on half the available land area every 21 days (42-day effective return period). Silver Fern Farms currently monitor daily wastewater irrigation volumes and have some soil moisture telemetry installed in key locations throughout the site (see map A, Appendix A).

PDP maintains a proprietary daily soil water balance model that provides a way to estimate soil water content for irrigation decision making for various projects. This is an alternative to, or can complement, continuous soil moisture telemetry, which is not usually practical to install for all areas of a wastewater irrigation system receiving irrigation. While not required to run the soil water balance model, any soil moisture telemetry data that is available provides a useful way to check the modelled water content for different soils to ensure results predicted by the model elsewhere are reasonable.

The soil water balance model has been run for both the process wastewater and domestic wastewater irrigation systems over the period of available wastewater records in order to better understand how both systems perform (in terms of drainage and exceedances of field capacity) under different climatic conditions. The model was also used to generate an estimate of what could be achieved if the current operation were to be changed to a higher frequency lower application depth spray irrigation system, such as could be achieved with centre pivots.

Model Description

The general principle of the PDP daily soil mass balance model is to track the mass of water (and nutrients for some applications) entering and leaving the soil over a fixed depth profile (i.e. the root-zone) so that the water content of that fixed profile can be determined to inform irrigation decision making. Water from rainfall or irrigation can enter the soil profile via infiltration and either be stored in the soil or lost via plant evapotranspiration and drainage to groundwater. Nutrients (nitrogen and phosphorus), where included in the modelling, can enter the soil from wastewater irrigation or fertiliser applications, can remain in the soil to be taken up by plants (and eventually removed via grazing/harvesting), be lost via leaching to groundwater (primarily nitrogen), or be lost via soil erosion during runoff events (primarily phosphorus). This water/nutrient mass balance tracking approach is illustrated conceptually in Figure 1, and shows how it can include alternate disposal and storage options for some applications. Key components are described in detail below.

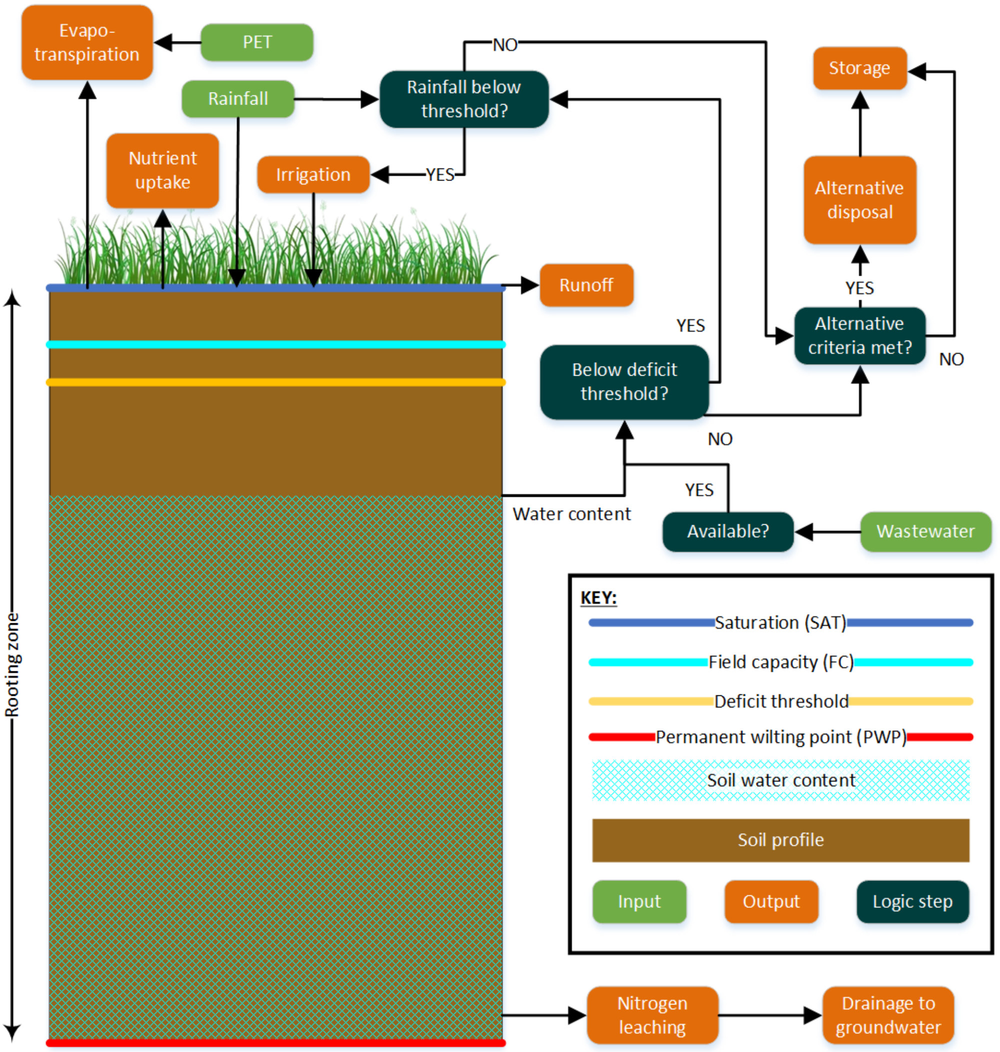

Figure 1: Soil water balance conceptual diagram.

Irrigation

For deficit irrigation, to inform irrigation decision making, the model specifies threshold soil moisture levels for calculating water deficits. If there is a water deficit, irrigation occurs if wastewater is available. The maximum irrigation application can either be set to a fixed application rate, or to the difference between the deficit threshold and current soil moisture content. Irrigation can be prioritised over other treatment alternatives where these exist (surface water discharge) at different times throughout the year. If irrigation is not possible when it has priority (e.g. due to high soil moisture), storage or other alternatives can be considered instead. For the Silver Fern Farms Takapau modelling, the model has been used to simulate what has occurred under current management based on the input data provided.

Alternative disposal

Alternative disposal methods in the PDP model can be prioritised over irrigation at different times. If discharge to the alternative is not possible when it has priority (e.g. a surface water discharge being restricted due to low flows), storage (if available) or irrigation to land can be considered instead. For the Silver Fern Farms Takapau modelling, there are no alternate discharges so this is not relevant to the modelling.

Storage

Storage in the model is flexible. The model makes allowances for both small-scale storage tanks and larger-scale storage ponds that incorporate rainfall, seepage and evaporation losses. Storage of water (or wastewater) is only considered if at least one higher priority option (i.e. irrigation to land or another alternative such as discharge to groundwater via rapid infiltration) is unavailable. For the Silver Fern Farms Takapau modelling, there is limited storage available and even if the pond was larger, increased storage times would result in adverse wastewater effects for the current wastewater stream. There is now a small amount of fresh water available for irrigation, and if storage was made available for this in future, the model could be amended to incorporate this.

Drainage

Drainage to groundwater from the root-zone is assumed to begin once the soil reaches field capacity and continues at an increasing rate (linear or exponential) until the soil is saturated. At saturation, drainage occurs at the maximum drainage rate of the soil. An example of this drainage behaviour is given in Figure 2.

The maximum drainage rate is usually assumed to be the unsaturated hydraulic conductivity of the soil (K_{-40}), which is representative of drainage through soil micropores. This excludes any macropores that may or may not be present depending on soil conditions. Using K_{-40} as the drainage rate relies on two assumptions:

- the surface infiltration rate of irrigation and rainfall is not limiting (i.e. surface infiltration rates exceed the hydraulic conductivity of the soil); and
- the underlying strata has a similar or higher permeability that the soil in the root-zone (true for moderate and well-drained soils).

Where the second assumption is not valid, such as with an underlying clay or silt pan, the maximum drainage rate can be set to the hydraulic conductivity of the sub-surface media instead, as that will be limiting water movement out of the root-zone. This is relevant to Block E for the Silver Fern Farms Takapau modelling.

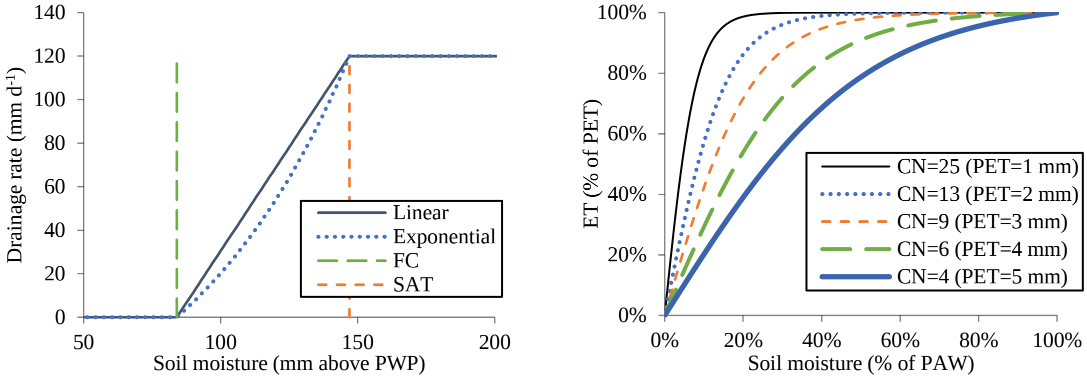

Figure 2: Example exponential and linear drainage rate relationships (left) and evapotranspiration soil moisture content adjustment by curve number (right).

Evapotranspiration

The amount of evapotranspiration (ET) from the soil is a function of the soil moisture content. Water becomes more difficult for plants to draw from the soil as the soil becomes drier. In the PDP model it is assumed that actual evapotranspiration from the soil is given by the relationship with potential evapotranspiration (PET) shown in Figure 2. The illustrated relationship (Heiler, 1981) is a mathematical approximation of experimental data (Denmead & Shaw, 1962) that does not account for variances with soil type. The different curve numbers allow adjustment of the relationship for different climates and soil types as appropriate. This has been provided for in the Silver Fern Farms Takapau model.

Rainfall

Irrigation can be suspended for the remainder of a rainfall event in the model if the daily rainfall exceeds a specified threshold and there is an alternative disposal option available (e.g. discharge elsewhere or storage). Given the Silver Fern Farms modelling objective is to simulate previous irrigation, this is not relevant to the Silver Fern Farms Takapau model.

Runoff

As wastewater irrigation typically occurs on flat or shallow sloped areas, rainfall losses due to overland flow runoff are generally ignored in the PDP model (hydraulically conservative, provided the irrigation application rates are low enough to not cause runoff during irrigation). For hilly areas, such as drip irrigation to tree plantations, the model uses calibrated runoff coefficients to estimate the portion of rainfall that is lost to runoff. In the case of Silver Fern Farms, the site is on flat land, so no run-off has been provided for. This is likely to overestimate drainage due to high rainfall events, so adds conservatism to the estimates of drainage.

Nitrogen leaching

The complex nitrogen transformation processes that occur in soil (e.g. nitrification, denitrification, mobilisation and mineralisation) have been simplified in the PDP model to date. While more complex processes can be incorporated, it has been reasonable to assume all applied nitrogen is readily available for conversion into nitrate that can be lost to leaching when a drainage event occurs, if it is first not taken up by plants. While this is not true in practice, it does provide a conservative assessment of potential nitrogen leaching. For Silver Fern

Farms, OVERSEER modelling has already been carried out, which allows for more complex processes. For this reason, nitrogen leaching has not been modelled.

Nutrient uptake

Uptake by plants in the model is calculated based on dry-matter production rates for various crops and climates throughout New Zealand. Masses of nitrogen and phosphorus are then calculated based on chemical leaf analysis for healthy crops. Some sites have actual crop uptake data available from laboratory analysis for use in the model. As outlined above, OVERSEER modelling has already been carried out so nutrient uptake has not needed to be included in the model.

Input Data

Wastewater

Daily wastewater volumes for the process and domestic systems have been provided by Silver Fern Farms. The domestic wastewater volume dataset is for September 2005 to September 2017; it lists the volume applied to each of the two border-dyke irrigation areas (Dam dyke 1 & 2 shown in Map B, Appendix A). The process wastewater volume dataset is for September 2010 to September 2017; it gives the volume of wastewater applied to each run daily. Note that additional wastewater volume data was recorded from October 2009 to September 2010, but the data provided showed all irrigation being applied to only eight different irrigation runs (AS-R1, B1-R1, B3-R5, B3-R11, C2-R5, D-R18, E5-R8, and E6-R10). It was assumed this was a recording error and that irrigation was actually applied to many different runs over this period. In some cases, duplicate values were encountered in the recorded run information (i.e. two or three volumes recorded for the same run on the same day). In these instances, the duplicate volumes were removed on the basis the appeared to be entered in error.

Soil Moisture

Silver Fern Farms provided PDP with soil moisture data (given as a percentage) collected from September 2014 to September 2018. The location of the soil moisture meters at the site is shown in Map A, Appendix A. Note there are also several soil moisture meters on an unirrigated control block. Soil moisture data is logged for each sensor every 15 minutes. The data showed several instances where the meters appeared to report incorrectly, usually because the decimal point appeared to be in the wrong location (for example, 41.0% would be reported as 410%). In these cases, adjacent values to the errors were used to correct the recording.

Irrigation Areas

For the domestic irrigation system, irrigation occurs on two 0.8 ha blocks (Dam dyke 1 & 2 shown in Map B, Appendix A), while the process wastewater system involves irrigation across various travelling irrigator runs. These runs were digitised based on an old map provided by Silver Fern Farms and are shown in Map B, Appendix A. When runs were digitised, some discrepancies were found between the calculated area of the digitised runs and the area of the runs reported in Silver Fern Farms' irrigation records; however, the total irrigated area remained similar, so the digitised areas for each run were used in the process wastewater model. The total area of all runs in each sub-block from both the Silver Fern Farms' irrigation records and the digitised run map are given in Table 1.

Table 1: Irrigation Run Areas

Sub-Block	Silver Fern Farms Irrigation Area (ha)	PDP Digitised Area (ha)
A North	35.2	35.0
A South	35.7	36.4
B1	8.4	7.0
B2	4.1	4.2
B3	9.8	8.9
C1	4.9	4.9
C2	20.7	21.6
D	25.9	26.7
E1	11.7	11.1
E2	12.0	11.5
E3	5.3	6.1
E4	6.0	6.3
E5	12.4	11.0
E6	15.8	17.2
E7	5.9	5.8
Total	**213.7**	**214.0**

Rainfall

Silver Fern Farms has an onsite rainfall gauge at Takapau with data available from 2011 onwards. However, this rainfall data was incomplete and did not cover the full period over which wastewater irrigation records were available. To overcome this, a long-term rainfall dataset for the modelling was created using data from the following rainfall stations:

- Taniwha (1971-1990, gaps filled with Mt Vernon 2);
- Mt Vernon 2 (1991-2003, gaps filled with VCSN 29457); and
- Station Road (2004-Present, gaps filled with Mt Vernon 2 then VCSN 29457).

Figure 3 shows the annual rainfall from the combined data set compared to the onsite rainfall gauge at Silver Fern Farms Takapau. Average annual rainfall for the area is estimated to be approximately 790 mm/year using these datasets.

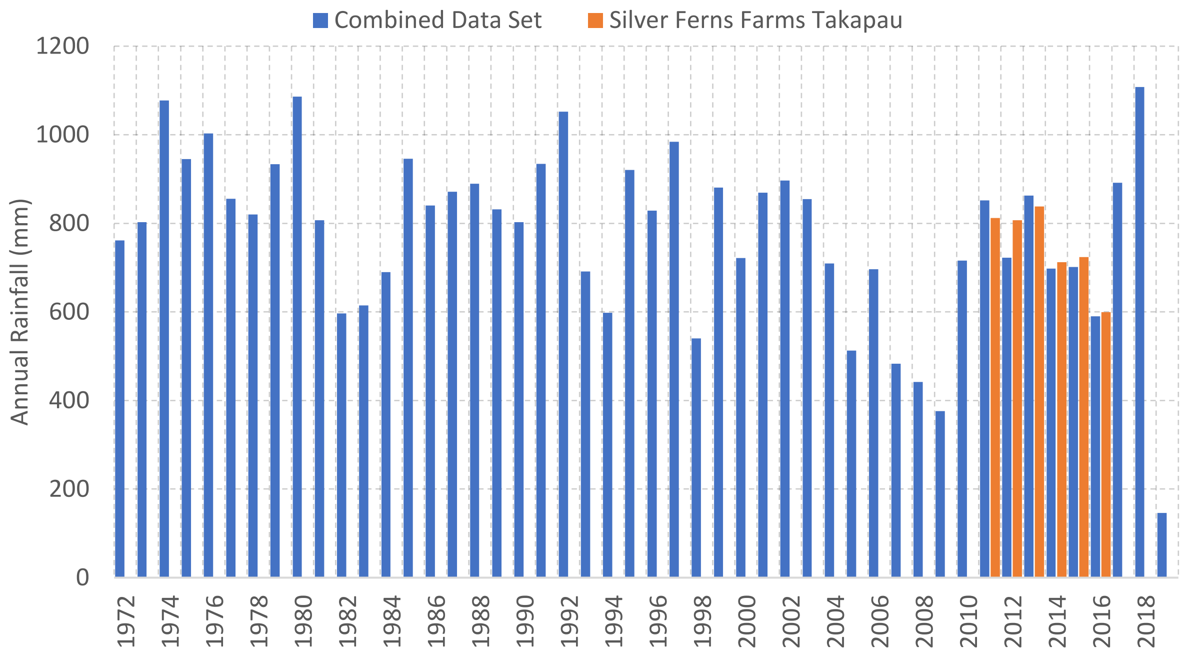

Figure 3: Annual rainfall data

Potential Evapotranspiration (PET)

PET records from the Onga Onga and Waipukurau climate stations (Hawke's Bay Regional Council) were obtained, but this data was not used for the soil moisture model as it relied upon the Priestly-Taylor method for calculating PET. This method tends to produce variable estimates of PET compared to the Penman Method. Instead, Penman PET data was obtained from NIWA's Virtual Climate Network (Station 29457). Shorter Penman PET records were obtained from the Ashcott Road and Waipawa climate stations (NIWA) and used to verify the virtual record. Annual Penman PET data is shown in Figure 4. Average annual PET for the area is approximately 890 mm/year using these datasets.

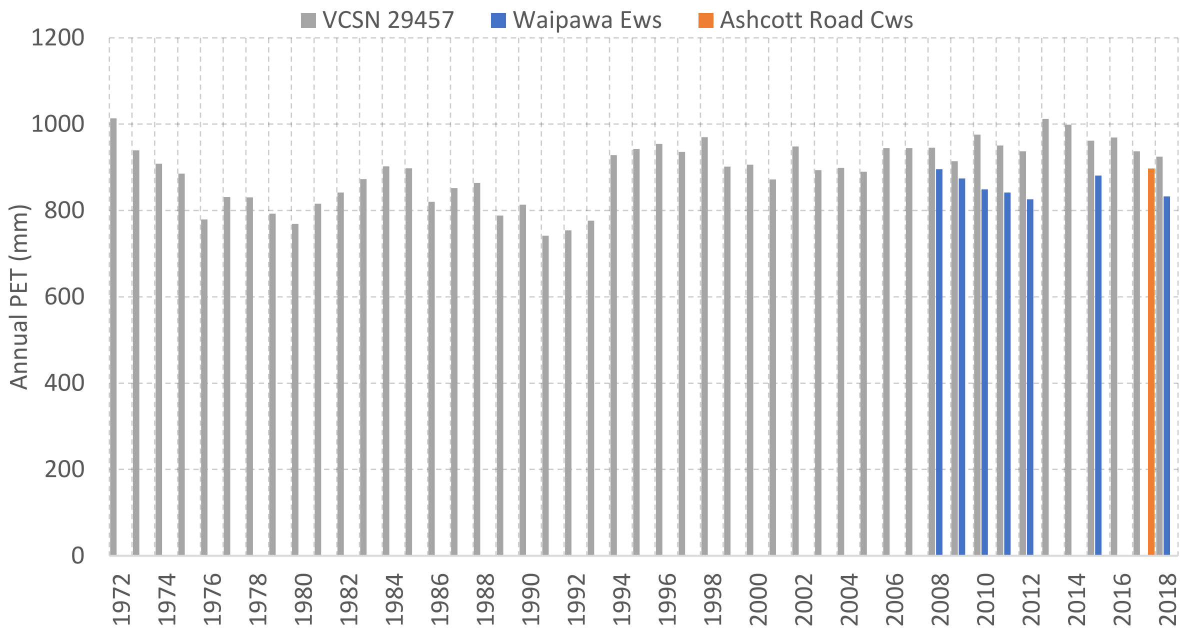

Figure 4: Annual potential evapotranspiration (PET) data

Soils

Soil-type delineations for the site was already available from previous work (see Map A, Appendix A), however soil water holding information had to be obtained from S-Map (Landcare Research). For cases where irrigation run areas intersected multiple soil types, an area-weighted average value was used in the model.

For the modelling, drainage rates were assumed to follow exponential curve relationships similar to those given in Figure 2. The maximum drainage rate in the function was assumed to be the median of unsaturated (micropore drainage only) hydraulic conductivity tests carried out on site (10 mm/hour or 240 mm/day). This assumed that surface infiltration rates and sub-surface infiltration rates are not limiting. For the poorly-draining gley Poporangi soils in block E where a tight clay layer exists approximately 200 mm below the surface, a drainage rate of 1 mm/day (typical of clay) was assumed instead as drainage through this horizon is limiting. Rooting depths for this block were assumed to be limited to 200 mm, regardless of crop type.

Landuse

Crop types alternate on the irrigated process wastewater land between grass pasture and lucerne. For the modelling, 2015/2016 landuse data provided by Silver Fern Farms was assumed to apply. Rooting depths of 1.0 m were assumed for all lucerne areas (Control Block and Block B), while rooting depths of 0.6 m were used for the grass pasture areas (Irrigation New Zealand, 2007).

Nutrient uptake, nitrogen leaching and runoff

The nutrient uptake and nitrogen leaching components of the model were disabled for the purposes of this assessment as the goal was to calculate soil moisture and drainage to groundwater, and OVERSEER modelling has already been completed for the site. Runoff was disabled to make the conservative assumption that all rainfall and irrigation water infiltrated the soil profile, as the irrigation land is relatively flat.

Domestic Wastewater Model

The domestic wastewater irrigation model was run using the input data described above for the period 1 Jan 2005 – 30 Sep 2017.

The modelled drainage for the wastewater discharge is shown in Figure 5. As expected, the model indicates that the irrigation results in a significant increase in the annual drainage compared to the control block. Annual average drainage for the border-dyke areas is approximately 690 mm/year compared to 130 mm/year from the control block.

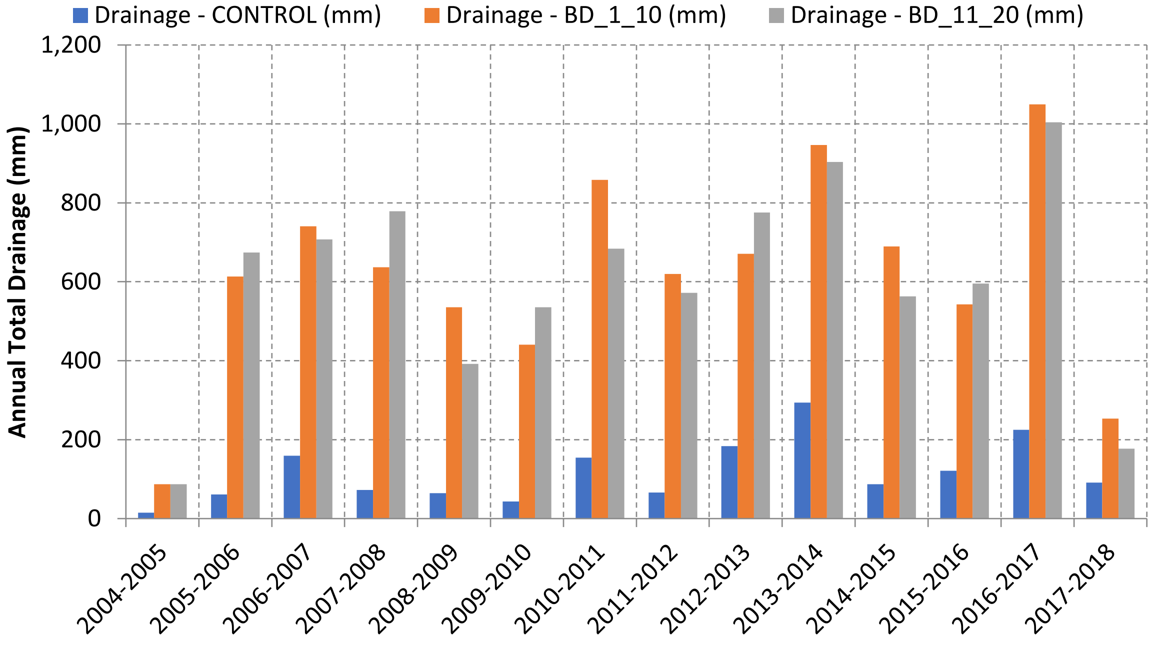

Figure 5: Modelled drainage from domestic drainage system (2005-2018)

The model calculated the irrigation applied across the domestic border-dyke areas averages 680 mm/year over the entire modelling period. Annual average rainfall over this period is approximately 660 mm/year, and actual ET from the border-dyke areas was calculated to be approximately 640 mm/year (compared to PET of 950 mm/year over the model period). These figures indicate that the water lost to drainage (approximately 700 mm) is largely due to the high hydraulic loading and low actual ET by plants from the soil.

The modelled soil moisture results for the 1-10 block (marked as Dam Dyke 1 in Map B, Appendix A) for an example wet and dry season are shown in Figure 6 and Figure 7, respectively.

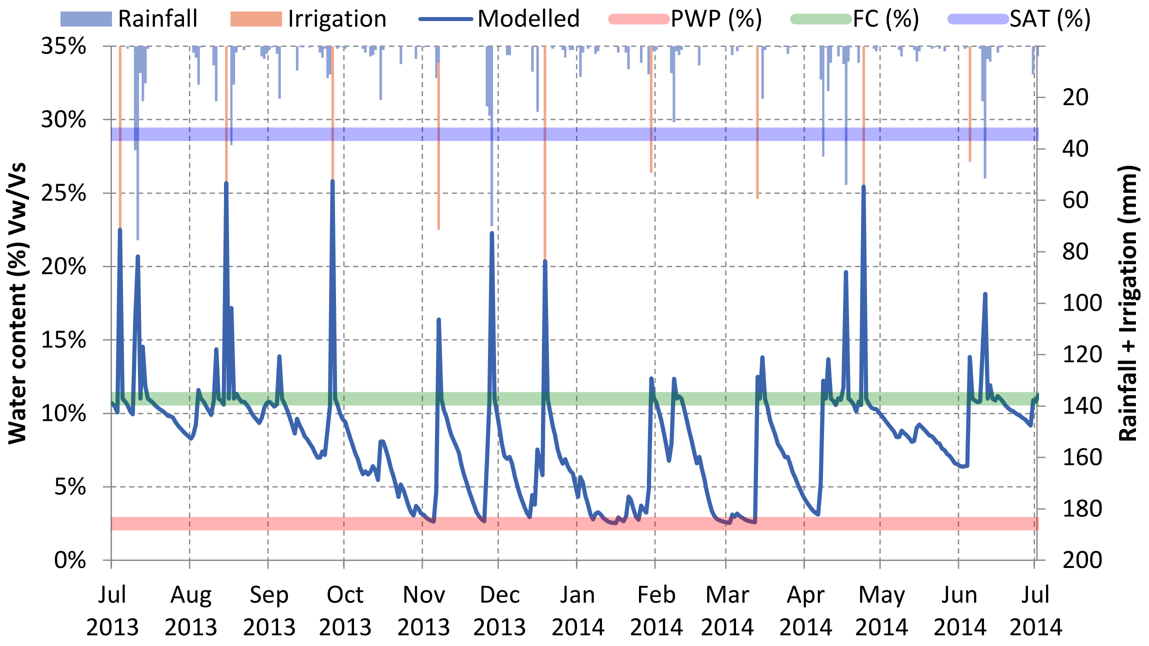

Figure 6: Border Dyke area 1-10, soil moisture content during wet season (2013 – 2014)

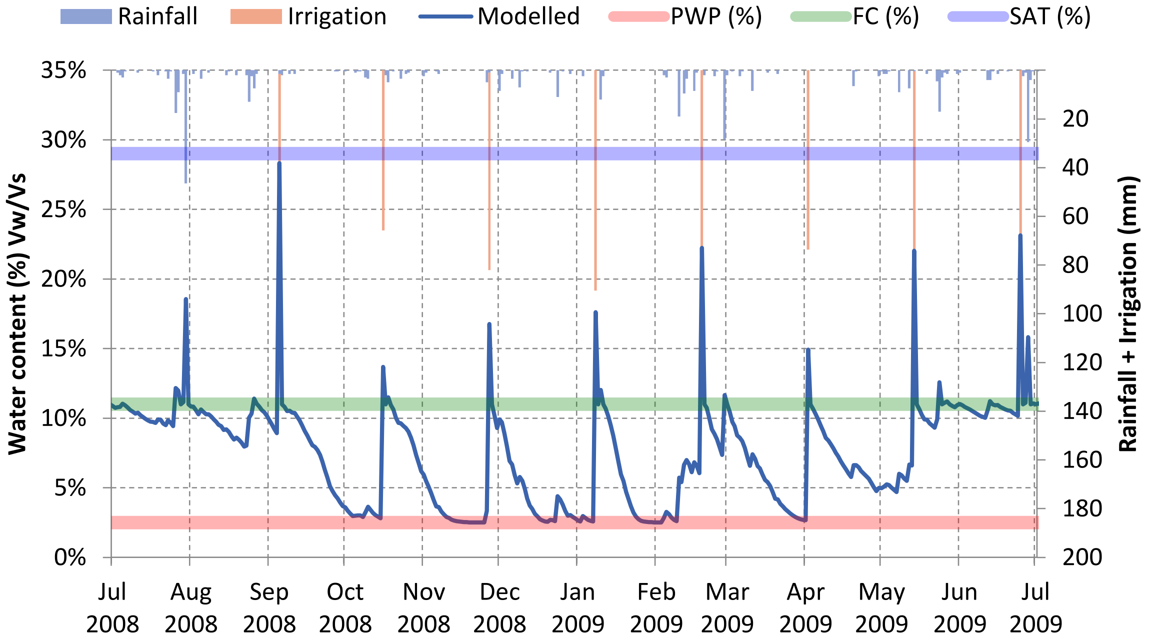

Figure 7: Border Dyke area 1-10, soil moisture content during dry season (2008 – 2009)

The results illustrate how irrigation is applied consistently (in large doses) to an individual area every 42 days. This method of application means the irrigation applications always cause the soil to exceed field capacity, even during a dry year, which results in drainage to groundwater. The large return interval also means that the soil is modelled to dry out to permanent wilting point (PWP) in between irrigation events, which inhibits grass growth and reduces the amount of actual evapotranspiration (ET) from the soil, as water becomes harder for plant roots to extract from the soil.

The domestic wastewater is currently applied to the two 0.8 ha areas such that each area receives approximately 750 m^3 of irrigation every 42 days. An alternative option has been modelled to assess the potential to increase the amount of ET from the soil and reduce drainage. The model was re-run assuming wastewater is applied daily (approximately 36 m³ per application). This equates to an application rate of 2.2 mm/day over the whole 1.6 ha area. The model indicates making this change would reduce the annual average drainage from approximately 690 mm to approximately 550 mm. The reduction in drainage is because the extreme dry periods between applications can be avoided and water is instead lost as ET during summer (actual ET increases from an average of approximately 640 mm/year to 770 mm/year).

Process Wastewater Model

The process wastewater model was run using the input data described above for the period 1 Jan 2010 – 30 Sep 2017.

Figure 8 shows an example of the modelled soil moisture content for Run 15 in Block D (Takapau soil, grass pasture) against the 15-minute soil moisture data collected from the three sensors located in the run area. The modelled soil moisture content follows the trends of the measured soil moisture content closely but does not go as low as the measured data. This offset is expected to be caused by differences in the soil water holding properties and/or rooting depth assumed for the run for this modelling compared to what was used to calibrate the soil moisture meters initially (that information is not now available).

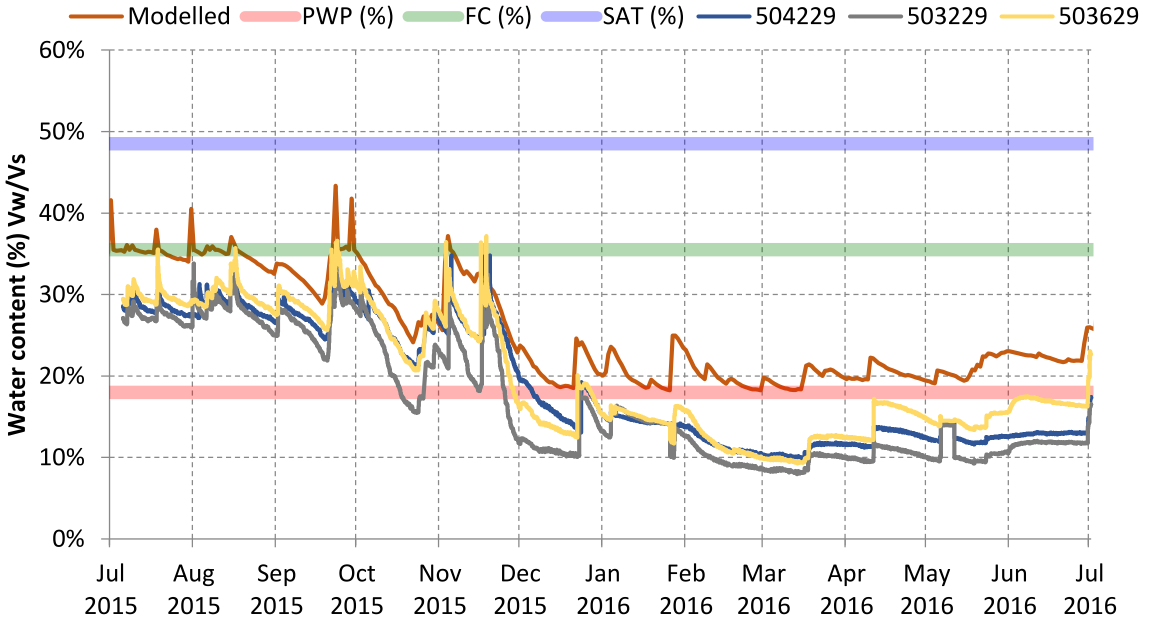

Figure 8: Run 15, Block D soil moisture content (2015-2016)

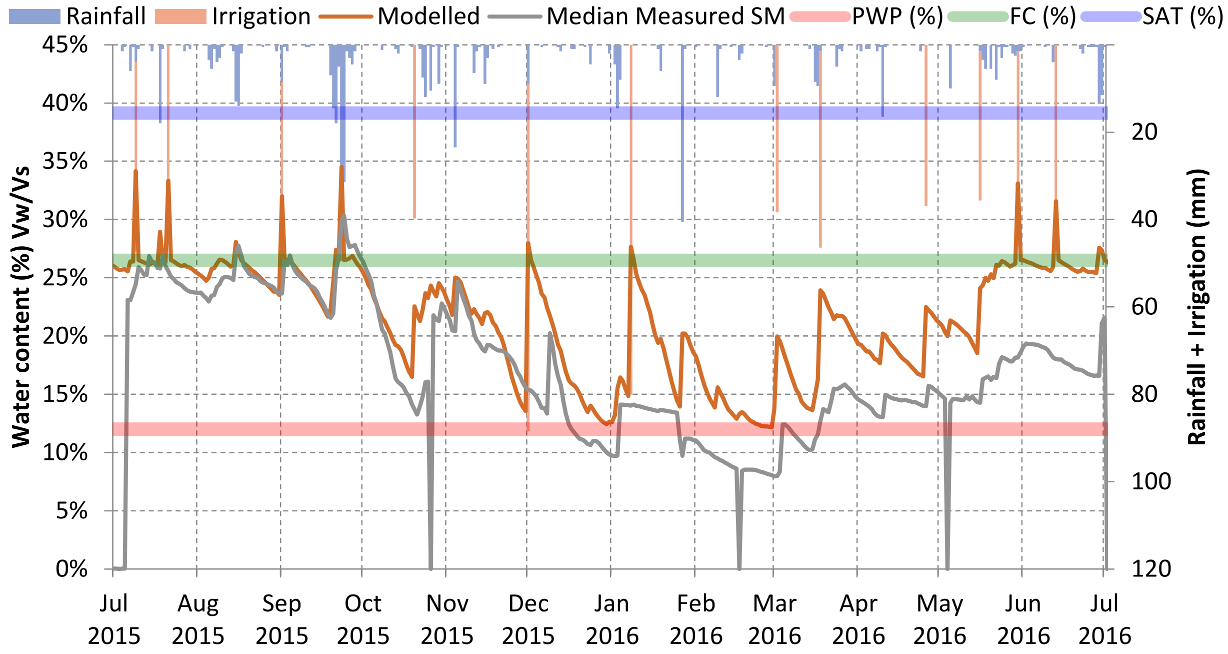

Figure 9: Run 4, Block A South soil moisture content and irrigation events (2015-2016)

Figure 9 shows the modelled soil moisture content for Run 4 in the A South Block (shallow Takapau and Tikokino soils with grass pasture) with rainfall and irrigation events on the secondary axis. The daily median of soil moisture sensors in the run area is also shown.

The measured daily median soil moisture content shows a similar pattern to the modelled moisture content but does not appear as responsive to rainfall and irrigation events as the modelled soil moisture. This behaviour is likely in part due to taking a median of soil moisture content measurements recorded over different depths throughout a day.

The model results in Figure 9 show that irrigation during October to May is generally being applied when the soil has a significant deficit with respect to field capacity. Outside these months, irrigation events tend to occur when the soil is close to field capacity (e.g. July, September and June irrigation events) which results in greater drainage to groundwater, as expected. Irrigation is generally applied in larger doses of 40-50 mm which results in an immediate flux of water through the soil profile. In these times, soil moisture is elevated due to low evapotranspiration rates from cooler temperatures and more frequent rainfall. Irrigation must be applied as there is no alternative option for disposing of wastewater. It is noted that, despite this, irrigation is still likely to be the best method of disposal at these times, in terms of potential environmental effects (less than a direct discharge to groundwater or surface water). Changes to the timing and depth of irrigation events could be helpful to reduce drainage, which is considered further below.

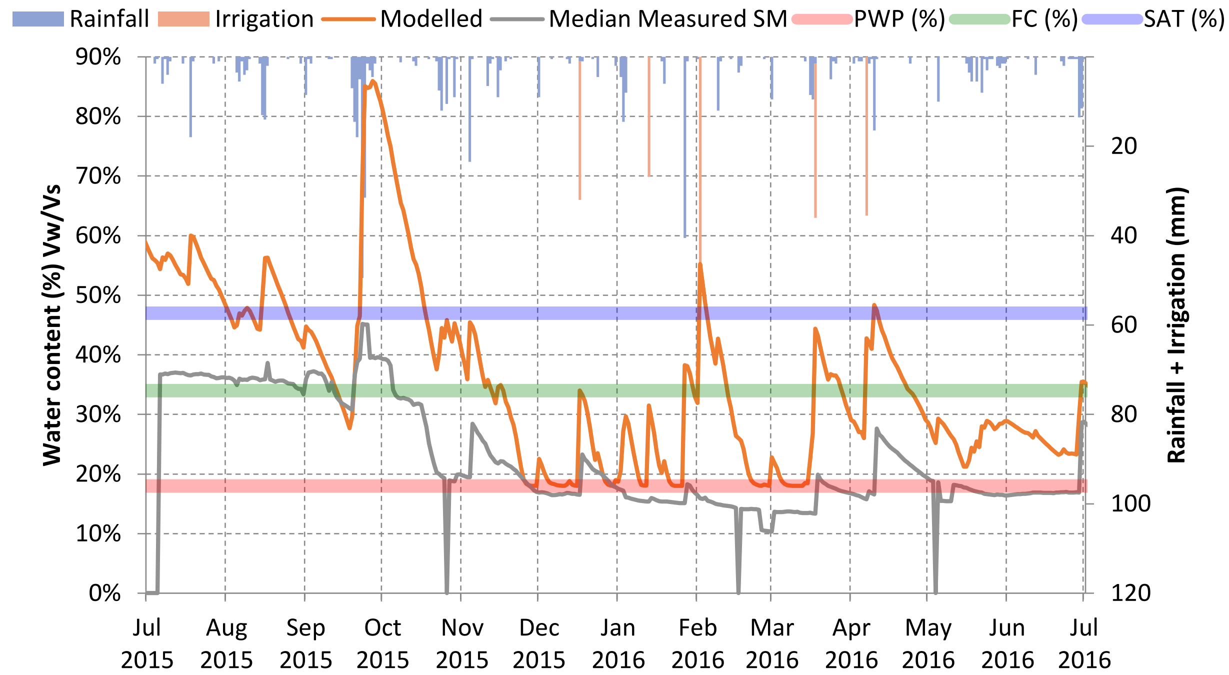

Figure 10: Run 4, Block E6 soil moisture content and irrigation events (2015-2016)

Figure 10 shows the modelled soil moisture content for Run 4 in Block E6 (drainage impeded gley Poporangi soil with grass pasture). In this case the modelled soil moisture content shows much greater spikes in response to rainfall and irrigation events – often exceeding saturation for long periods of time. This is due to the conservative assumption that drainage from the gley soils in the E-block is limited to 1 mm/day due to the tight clay layer 200 mm below ground. The actual soil moisture data indicates that the soil does not retain as much water. This could indicate that a higher drainage rate can be expected from the gley Poporangi soils, or that the soil moisture meters may be recording the averaged water content which includes drier soil below the tight clay horizon at 200 mm below ground. The modelled soil water content indicates that irrigation events on the E-block soils generally only occur when there is a deficit; however, because the available water profile is limited to a 200 mm rooting depth, the soil moisture content increases above field capacity (and sometimes up to saturation) in response to these events. This poses a risk for the soils becoming waterlogged and possible runoff to other areas (when the soil is saturated).

The model predicted average annual drainage from the whole area of approximately 380 mm/year, with values ranging from 260-540 mm/year, depending on rainfall and how much irrigation was applied. In contrast, modelled results from the un-irrigated control block show dryland drainage ranging from 60-290 mm/year, with an average of 160 mm/year. In a wet year (e.g. 2013-2014), drainage on the irrigated areas increased to 510 mm/year while in a dry year (2015-2016) drainage decreased to 260 mm/year. Figure 11 shows the modelled soil moisture content for Run 3 in Block B1 (Tikokino soil, Lucerne) during this example wet year and Figure 12 shows the modelled moisture content during this example dry year. During the dry year, field capacity is not exceeded except during October to May, while during the wet year, more frequent rainfall causes some drainage in response to irrigation events during October and December.

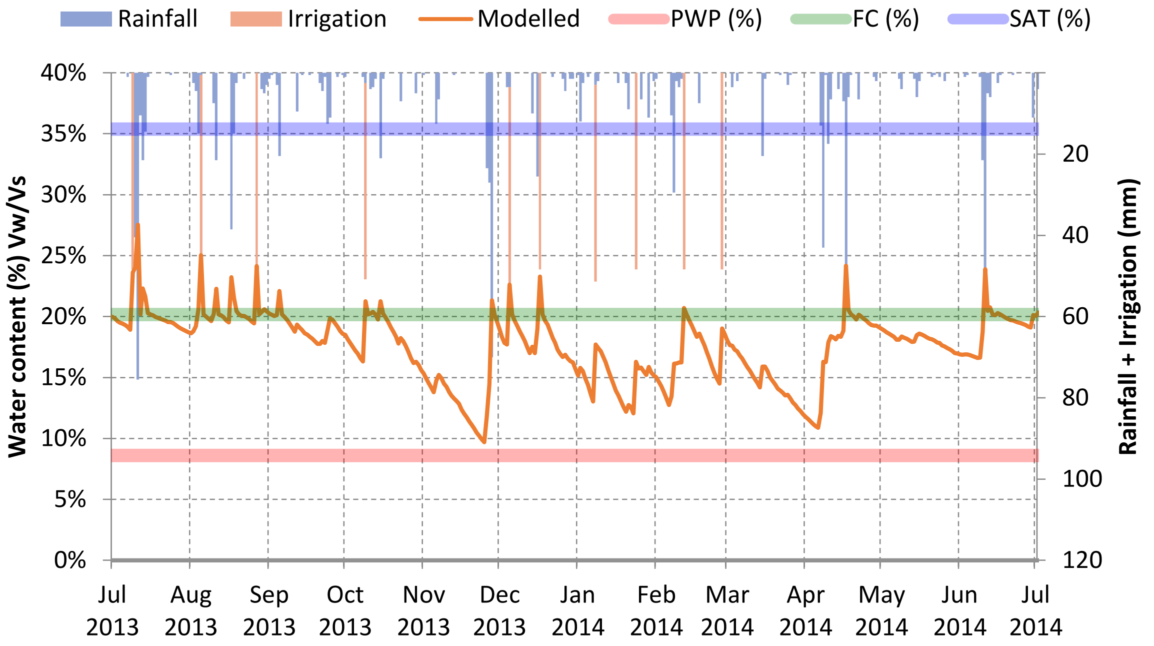

Figure 11: Run 3, Block B1 soil moisture content wet year (2013-2014)

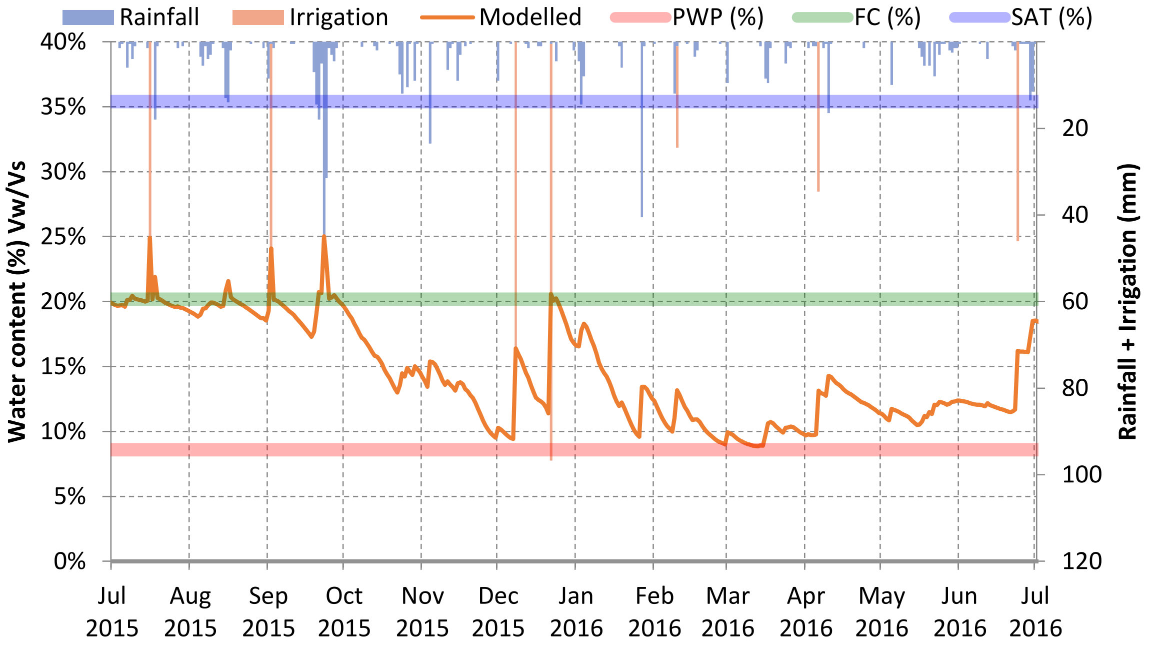

Figure 12: Run 3, Block B1 soil moisture content dry year (2015-2016)

The process wastewater is currently applied via 12 travelling irrigators, rotating between 152 runs with an average daily application of 3,221 m³ (typically resulting in applications of 50-60 mm on individual runs). In order to quantify potential improvements in drainage that could be obtained by switching to a lower-intensity, higher frequency irrigation system, the model was run assuming a larger scale spray irrigation system (e.g. centre pivots) was in place to allow the irrigation to operate over a 3 day return period (13 mm per application). The model indicates this change would slightly reduce drainage, with annual average drainage reducing from 380 mm/year to 365 mm/year. This reduction is not significant, as the overall hydraulic load has not changed significantly; however, as Figure 13 shows, the change results in a significant reduction in the days of irrigation occurring when the soil is above field capacity compared to current operations. Note that even with this change in irrigation methodology, deficit irrigation (i.e. only irrigating when the soil is below field capacity) is still not achievable over the colder months (April – September).

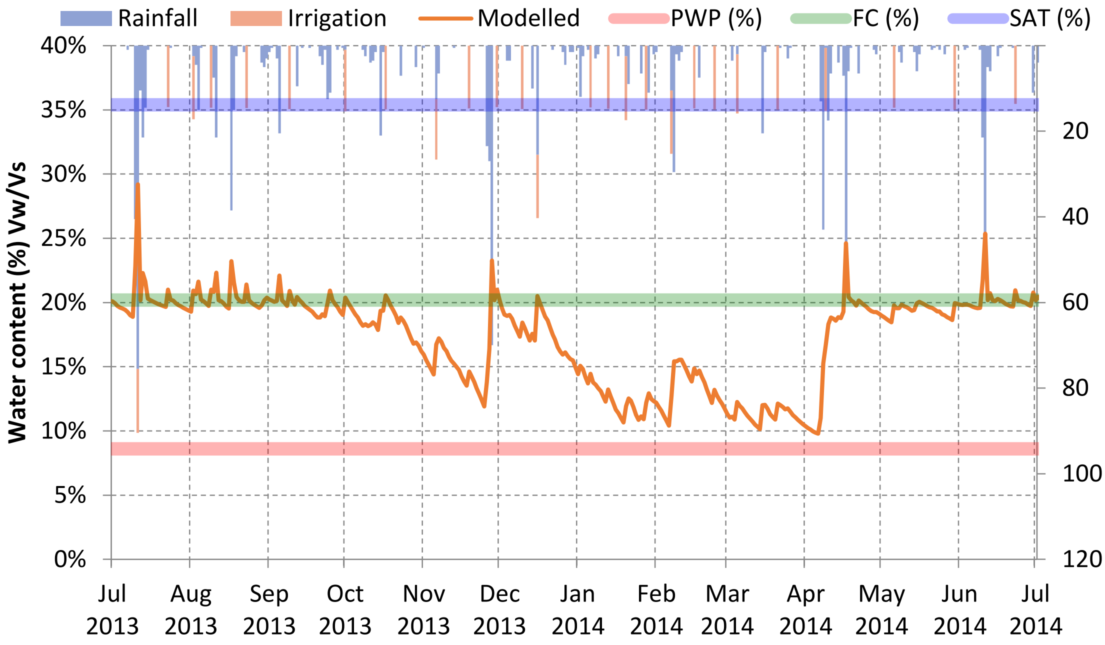

Figure 13: Run 3, Block B1 soil moisture content for centre pivot irrigation during a wet year (2013-2014)

Summary

The process wastewater and domestic wastewater irrigation systems at Silver Fern Farms Takapau were successfully modelled using a daily soil water balance model and irrigation records provided by Silver Fern Farms.

The results of the modelling for the domestic wastewater irrigation system over the 2005-2017 period indicate that the current wastewater applications of approximately 750 m³ every 42 days almost always result in the soil exceeding field capacity and hence excess drainage to groundwater. Furthermore, the soil regularly dries out to permanent wilting point between applications which reduces the actual ET achieved by plant roots during summer months. The model predicts annual average drainage of approximately 690 mm/year over the modelling period under an average hydraulic load of 640 mm/year. This could potentially be reduced to 550 mm/year if wastewater were applied daily (e.g. via a spray system) to the entire border-dyke area.

The process wastewater irrigation model indicated that the model provides good predictions of soil moisture content trends, but some further calibration of the soil water holding properties may be required to better align the results with the existing soil moisture meters. Irrigation applications over the 2010-2017 generally occurred when the soil is below field capacity during the October to May period, with the exception of particularly wet years such as 2013-2014. Outside this period, evapotranspiration rates are too low and irrigation applications must occur when the soil is at or above field capacity as there is no alternative disposal option (and irrigation is still likely to result in lower environmental effects compared to other disposal options). The model also showed that irrigation on the poorly-draining gley soils prevalent in the E-Block is being managed so that irrigation starts when the soil has a deficit; however, the small soil profile depth expected to be available (200 mm maximum rooting depth due to a tight clay layer present below the surface) means that irrigation applications are likely to exceed the capacity of the soil and cause it to exceed field capacity and sometimes, saturation. This presents a risk for the soils becoming waterlogged and potentially causing runoff to other areas.

The process wastewater irrigation model predicts an annual average drainage rate of approximately 380 mm/year, with drainage during wet years increasing up to 510-540 mm/year. A comparative scenario was run assuming the irrigation system was a higher-frequency, lower intensity system operating on a 3 day return period. This resulted in a small average drainage reduction from 380 mm/year to 365 mm/year, but it also demonstrated that irrigation events during the summer months could then be managed so exceedances of field capacity could be avoided even during wet years.

This memorandum has been prepared by Pattle Delamore Partners (PDP) on the specific instructions Silver Fern Farms Limited for the limited purposes described in the memorandum. PDP accepts no liability if the memorandum is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

This memorandum has been prepared by PDP on the basis of information provided by Silver Fern Farms Limited and others (not directly contracted by PDP for the work), including Hawkes Bay Regional Council and NIWA. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the memorandum. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

References

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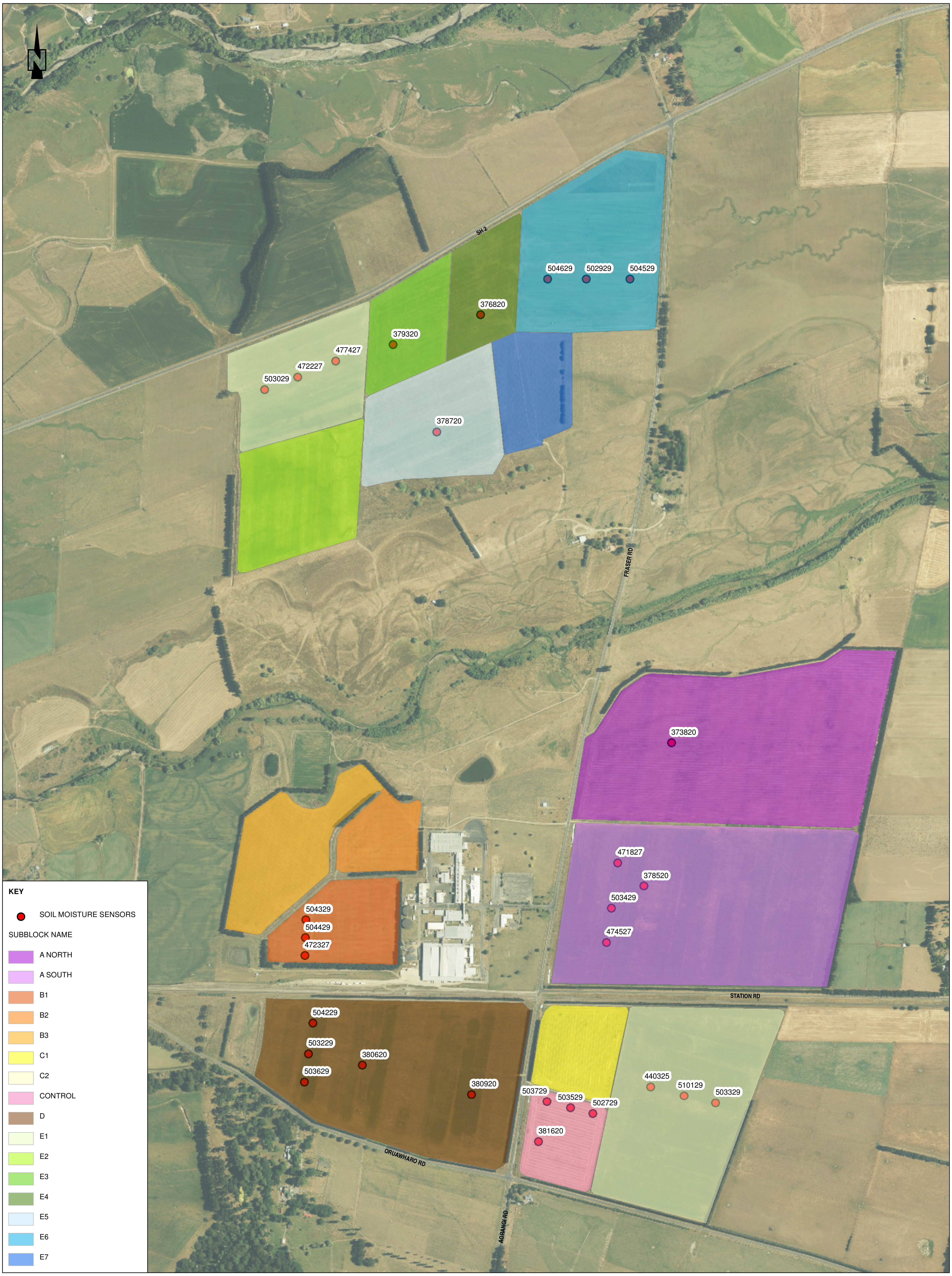
APPENDIX A: MAPS

SILVER FERN FARMS TAKAPAU RECONSENTING



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1. AERIAL IMAGERY SOURCED FROM THE LINZ DATA SERVICE AND LICENCED FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.

MAP A : IRRIGATION SUB-BLOCKS AND SOIL MOISTURE SENSOR LOCATIONS

SCALE : 1:10,000 (A3)

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METRES

PATTLE DELAMORE PARTNERS LTD

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SOURCE:
1. AERIAL IMAGERY SOURCED FROM THE LINZ DATA SERVICE AND LICENCED FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.

MAP B : IRRIGATION RUNS AND SOIL TYPES

SCALE : 1:10,000 (A3)

0 50 100 200 300

METRES