
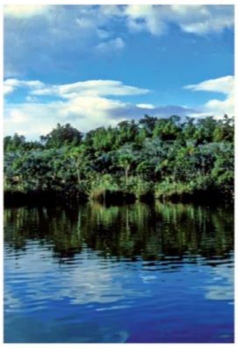

Crop Production, Profit and Nutrient Losses in relation to Irrigation Water Allocation and Reliability – Waimea Plains, Tasman District

Final Report





Landcare Research
Manaaki Whenua

Crop Production, Profit and Nutrient Losses in relation to Irrigation Water Allocation and Reliability – Waimea Plains, Tasman District

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Executive Summary

This project compiles and interprets modelled data to understand how different irrigation water allocations and reliabilities of supply affect production, profit, and nutrient leaching responses for major irrigated land uses of the Waimea Plains near Nelson.

Crop production and nutrient leaching projections were simulated using Plant and Food's SPASMO model for apples, grapes, outdoor vegetables (market gardening) and dairy land uses on four soil types using daily climate data for the forty year period 1972 to 2011. Annual production outputs were then converted into Earnings before Interest Tax and Depreciation (EBITD) using an economic model developed by Fruition Horticulture.

Two broad water management scenarios were modelled to evaluate the effect of varying levels of irrigation water allocation on production, EBITD and nitrate-nitrogen leaching losses. The 'with dam' or 'no water rationing' scenario evaluates the effects of varied weekly irrigation allocation limits but with full reliability of supply up to those weekly limits (0, 7, 14, 21, 28, 35 mm/week and unlimited). The 'no dam' or 'with water rationing' scenario evaluates the same crop-soil-climate combinations but with additional restrictions in irrigation of up to 100% cuts in water take modelled from Tasman District Council's proposed water allocation rules in the event the Waimea Community Dam water augmentation scheme is not built.

Results of this detailed modelling approach – provided in 88 spreadsheets and only summarised in this report - are being applied by MPI to assess whole catchment consequences of setting different water allocation limits, enabling water permit transfers and of establishing the dam.

Broad conclusions from the model results are that:

- Averaged over 40 years of climate, and with full reliability of irrigation supply, yields and EBITD are barely affected when weekly water allocations are reduced from those in the Tasman District Council's Resource Management Plan. Weekly water allocations at which effects on EBITD are noticed are 28mm/week for apples, 14mm/week for grapes, 14mm/week for dairy (as feed can be bought in when irrigation is insufficient) and 28mm/week for an outdoor vegetable market garden.
- Averaged over 40 years of climate, and with regular rationing of irrigation supply under proposed 'no dam/ with rationing' rules, yields and EBITD are affected for higher weekly water allocations than in the 'no rationing' scenario. Weekly water allocations at which effects on EBITD are noticed are 35mm/week for apples, 21mm/week for grapes, 21mm/week on Richmond soils for dairy but 35mm/week on Waimea soils, and 28mm/week for an outdoor vegetable market garden
- Nitrate-nitrogen leaching is more sensitive to soil type than to whether a crop is irrigated or not. Therefore, there is little difference in leaching rates for the 'no rationing' vs 'with rationing' scenarios. For some irrigated crops, leaching is lower than for the dryland equivalent because of the efficiency of plant uptake of nutrients in a fully watered situation. Leaching rates from highest to lowest for the farm systems modelled are dairy, outdoor vegetables, grapes then apples.

- Crops on Ranzau gravelly soils are more sensitive than crops grown on heavier soils for all the above results. Management of irrigation water allocation and nitrate losses on Ranzau soils needs to be a focus when setting catchment limits.

The report concludes with a literature review of the effectiveness of potential mitigation methods for reducing nutrient losses from the types of land uses prevalent on the Waimea Plains. This is a matter being considered by Tasman District Council's Waimea Freshwater and Land Advisory Group.

1 Rationale for this project

This project aims to understand how different irrigation water allocations and reliabilities of supply affect production, profit, and nutrient leaching responses for major irrigated land uses of the Waimea Plains near Nelson.

The project provides time series datasets for these responses that can be used by MPI for modelling economic and land use consequences of different levels of limits for water allocation and therefore of irrigation water reliability.

2 Background

Along with the Ministry for the Environment, MPI is leading national freshwater reforms, which to date have included the establishment of the National Policy Statement for Freshwater Management (NPS-FM) and the Irrigation Acceleration Fund. The purpose of this project, in that context, is to feed into a case study of the Waimea catchment, which in turn seeks to inform development of national policy to maximise the value of fresh water within limits set under the NPS-FM.

Furthermore, MPI is supporting regional councils, including Tasman District Council as a unitary authority, to better understand the economic consequences of alternative approaches and settings for water takes and water quality limits which are required to be set under the National Policy Statement for Freshwater Management (NPS-FM)

Tasman District Council has made policy decisions on water allocation limits for the Waimea catchment in the event the proposed Waimea Community Dam either is or is not built. If not, all water users will suffer water rationing restrictions most summers, and will potentially have irrigation supplies cut off for weeks during drier summers. That scenario may lead some land uses to change, with consequential regional economic impacts.

During 2015 Tasman District Council is in the process of developing water quality limits for water bodies of the Waimea catchment through its Waimea Freshwater and Land Advisory Group (Waimea FLAG) process. Such limits could require improved mitigation practices to reduce nutrient leaching, or even lead to land use change if mitigation practices are insufficient to achieve receiving water limits, especially for nitrate-nitrogen.

Little detailed research has been done on the financial consequences of imposing catchment limits. However some recent regional economic studies have been completed evaluating different allocation regimes among users, especially with nutrient limits, including Hurunui, Manawatu, Rotorua (Daigneault, MacDonald et al 2012). in a report for MPI[1] and in various regional council processes[2].including Selwyn, Hinds, Waikato and Southland for the NPS-FM: This project is a partner project – in a largely horticultural catchment – for a recently

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[1] http://www.motu.org.nz/publications/detail/evaluation_of_the_impact_of_different_policy_options_for_managing_to_water_

[2] http://www.mfe.govt.nz/fresh-water/national-policy-statement/supporting-impact-papers-nps

completed project by Aqualinc Research in the Canterbury's Waimakariri Zone, a largely pastoral dairy and arable land use catchment.

3 Methodology

The project builds on work recently completed by members of this team on (1) modelling nutrient leaching risks from intensified land uses in the Waimea Basin for the Waimea Water Augmentation Committee (WWAC), and (2) water resource assessments supporting the recent Tasman District Council (TDC) plan change relating to water allocation and nutrient management in the Waimea Basin:

> Fenemor AD, Lilburne L, Young RA, Green S, Webb T 2013. Assessing water quality risks and responses with increased irrigation in the Waimea Basin. Landcare Research Contract Report LC1246 for the Waimea Water Augmentation Committee, Tasman District. 42 p.
>
> Fenemor AD 2013. Summary of hydrology and water management bases for decisions on Waimea water management, with and without water augmentation. Landcare Research Report LC1647 to inform Tasman District Council plan change C47. 25 p.

The analysis has been carried out in three stages.

Stage 1: Base Data

A current land use map of the Waimea Plains as at 2013 was developed as a GIS layer, to spatially aggregate production, profit and nitrogen losses from subsequent modelling. An update to a previously developed 2010 land use map was needed to improve its accuracy, and because there appears to be rapid land use change towards market gardening across the plains. Mapping of soil hydraulic properties combined with selection of an appropriate climate site to represent the Waimea Plains allows simulation of irrigation water demand and nutrient leaching. Therefore these datasets have guided selection of the main farm systems for modelling purposes. As the project is focussed on responses to irrigation, those farm systems have been limited to irrigated options only.

This first stage of the project generated maps and datasets of the crop-soil-climate combinations to be used in the SPASMO water demand and nutrient loss modelling and associated financial analyses. 'Crop' includes horticultural and pastoral farm systems.

Stage 2: SPASMO crop modelling, and financial modelling

For the combinations of crop-soil-climate agreed with MPI, we have modified and run Plant & Food Research's SPASMO (Soil-Plant-Atmosphere) model to simulate water demand and production for each of those systems, as well as nitrogen and phosphorus losses.

The model has been used in two ways:

(1) set varied levels of irrigation water allocation available weekly for each crop (e.g. 0, 7, 14, 21, 28, 35 mm/week), from which 40 years of calculated daily water deficits

based on historic climate data can be produced for economic and production analysis, aggregated to any selected time interval (e.g. monthly, annually). These are described in results spreadsheets as the Core Allocation scenarios. They assume 100% security of supply up to the specified weekly allocation and in this report are labelled the 'With Dam' scenarios.

(2) for some chosen fixed irrigation water allocations (e.g. 35 mm/week) the model can be re-run with simulated levels of rationing of water availability triggered by river flows at Wairoa Gorge. This option corresponds to the Tasman Council's 'No Dam' rules which would apply if the proposed Waimea Community Dam is not built, but a higher minimum flow is to be maintained in the Waimea River. These results are described in spreadsheets as 'No Dam' or 'With Rationing' scenarios.

Levels of water allocation to be modelled under (1) and (2) were agreed with MPI.

Crop water deficit datasets from the modelling provide the raw data for analysis of production from Plant & Food Research, and Earnings before Interest, Tax and Depreciation (EBITD) from Fruition Horticulture. Specialised production and financial models were developed drawing on previous research, farm systems data from local growers, and experience with financial modelling within the relevant farming sectors. This analysis has provided the time series of crop production and profit response, to provide particular insight into those responses when water demand exceeds supply.

Commentary includes the effects of different irrigation efficiencies on those outcomes, based on the types of irrigation systems actually used in the Waimea Basin. Those systems comprise primarily solid set spray, mini- and micro-sprinklers and drippers.

The SPASMO modelling has also produced time series of N and P losses from each crop-soil-climate combination. Only nitrate-nitrogen losses have been reported here, because nitrate is already known to be the primary nutrient requiring management and for which catchment limits may be set by the council. The simulations provide a base from which further work on nutrient limits may be undertaken. Nutrient loss mitigation from horticulture and market gardening is highly complex and under review with Horticulture NZ and in the TDC's current Waimea FLAG (Freshwater and Land Advisory Group) process.

Stage 3: Advice and Reporting

This project has been delivered in two stages. First, the base GIS data including the updated land use map, plus spreadsheets for four farm systems for the SPASMO and EBITD modelling were supplied to MPI to provide inputs data for their regional economic land use modelling. Second, and following considerable discussion and further analyses of results, this report summarises the primary observations from the work.

4 2013 Land Use Mapping

In order to identify the most dominant Waimea farm systems for modelling of production, profit, and nutrient leaching responses, a current land use map for the irrigable areas of the Waimea catchment was developed. Initially this was focussed on the ~4500 hectares within the service area for the proposed Waimea Community Dam.

Criteria for selecting dominant land uses were the area in that land use, their relative sensitivity to irrigation water availability, and their likely relative nutrient losses.

A map of land uses current in 2013 (Figure 1) was developed from the following data sources:

- An initial 2010 land use map within the service area completed for a precursor project on nutrient leaching for the Waimea Water Augmentation Committee (in Fenemor et al. 2013), which is developing the Waimea community dam proposal
- Partial Agribase coverage
- Land Cover Database LCDB4 to complete coverage of upper catchment areas draining into irrigable lands
- Waimea East Irrigation Company validation
- Google Earth imagery from March 2013
- Visual ground truthing by driving along the roads of the plains to confirm tentative land uses, e.g. distinguish apple orchard from stonefruit or kiwifruit, vegetable growing land from pasture
- A TDC summer student project to validate land uses in the irrigated parts of the Waimea Plains.

The level of detail is highest in irrigable areas, and lower in hilly non-irrigable areas. The boundaries of the map in Figure 1 correspond in the west to the topographical boundaries of the catchment and the boundary of TDC's Waimea water management zones, including the Wai-iti tributary. The south-eastern boundary follows the hill crests both north-east and southwest of Wairoa Gorge, excluding the Upper Catchments water management zone because there is negligible irrigable land there and the nutrient water quality for the Wairoa River at the gorge is largely unaffected by land use.

Table 1 summarises the land use classes and the area of each shown on the map in Figure 1.

Observations of land use change over past decades suggest increases have occurred in the area of grapes, pipfruit, and lifestyle blocks at the expense of pastoral and kiwifruit land uses. While completing the land use mapping, it was observed by Alistair Paton, manager of the Waimea East Irrigation Company, that water demand for that 1100 ha irrigation scheme had been based on kiwifruit, yet the last kiwifruit orchard has just been removed within the scheme area.

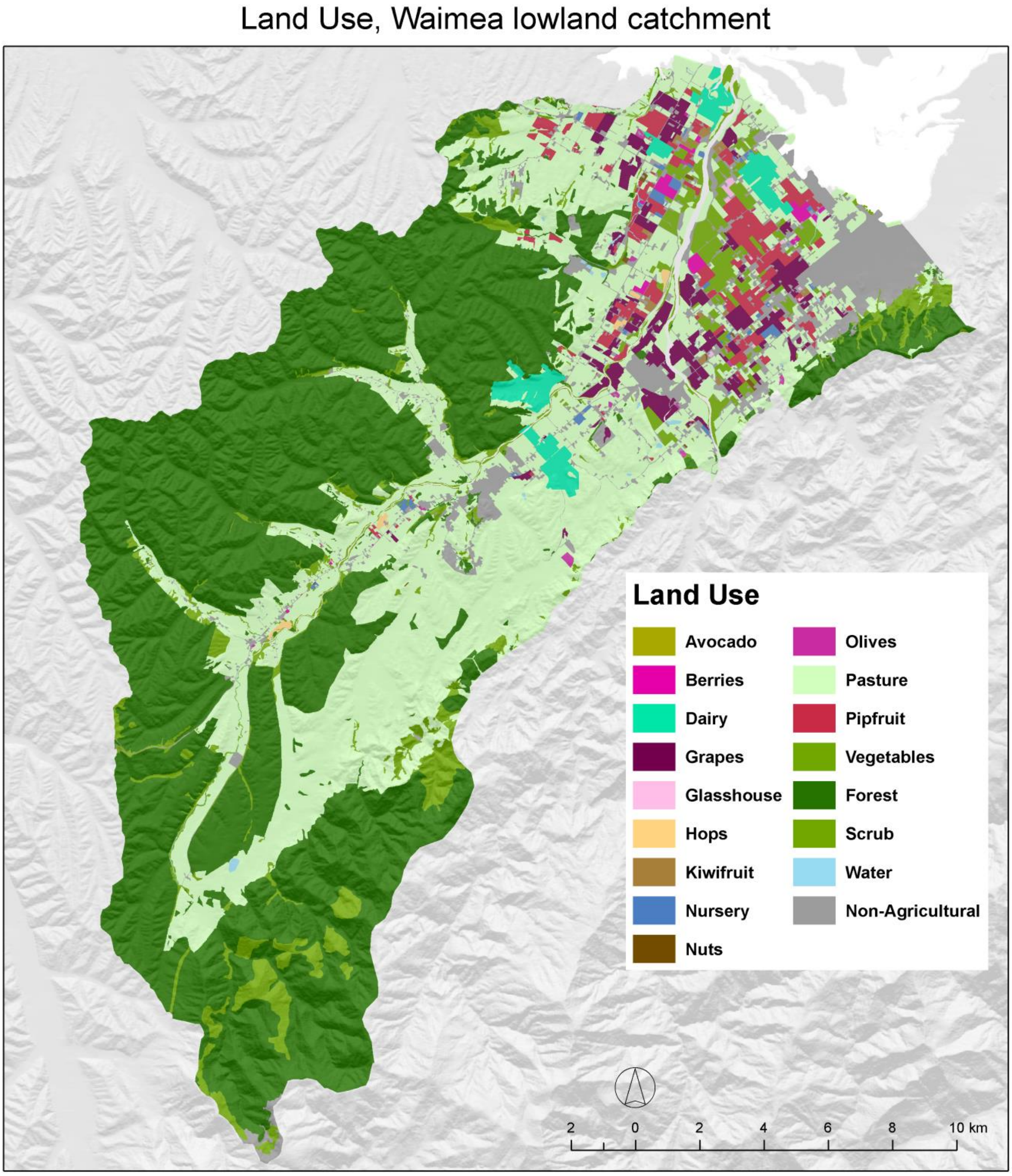

Figure 1: Land use map, Waimea Plains 2013.

Table 1: Land Use classes for the Waimea catchment 2013

Land use class	**Area within Waimea Plains catchment (below Wairoa Gorge)**	**Comments on this class**
Berries	114	Raspberries, boysenberries
Grapes, Olives	1003	Predominantly grapes. Both have low irrigation water demands
Hops	48	
Kiwifruit	65	
Pipfruit, other tree crops	893	Predominantly apples. Other tree crops include stonefruit, hazelnuts, avocado
Outdoor vegetables	705	Includes land in vegetable production even if temporarily in pasture
Nursery	114	Comprises horticultural nurseries on leased land as well as permanent nursery production
Glasshouses	30	Includes vegetables, floriculture, plastic houses
Dairy	615	Commercial scale dairy farms
Pasture	12350	Includes sheep & beef, grassed surfaces of lifestyle blocks
Scrub	2159	Includes riparian shrublands including willows
Forest	19797	Predominantly exotic pine plantings
Non-Agricultural	2691	Includes buildings, roads, urban, industrial areas, curtilage
Water	61	Rivers, significant streams, ponds, reservoirs
TOTAL AREA	**40645ha**	

5 Soils Categorisation

The analysis requires a manageable number of soil groups selected on the basis of their predominance in the areas where major irrigable land use types occur, and representing the range of soil hydraulic properties across the plains that determine variations in irrigation water demand and nutrient leaching.

Soil data were summarised from the National Soils Database (NSD) and additional data were obtained from records held by a local farm consultant, John Bealing of Agfirst Ltd. Detailed mapping carried out by Dr Iain Campbell for Tasman District Council of soils across the Waimea Plains would provide further validation, when available (Andrew Burton, TDC, pers. comm.).

There was considerable debate about the representativeness of the data for field capacity (FC), wilting point (WP), and therefore Total Available Water (TAW=FC–WP) for the Ranzau soils within the Waimea catchment. Assessment of TAW from soil samples collected to assist design of water demand for the Waimea East Irrigation Scheme in the early 1980s suggested the Ranzau soils are much more gravelly and hence permeable than NSD data indicated. Fenemor (1988), in modelling land surface recharge for developing a river-aquifer model for the Waimea catchment, assigned what he labelled a water-holding capacity (same as TAW) for Ranzau soils of 38 mm for a rooting depth of 600 mm. Other samples suggest a higher TAW. A TAW of 110 mm has been adopted for a 1.0-m rooting depth on Ranzau soils in the interim.

Figure 2 (a) and (b) show the soils mapped across the Waimea catchment below the Wairoa Gorge and within the lowland potentially irrigable parts of the catchment. Table 2 lists areas of each soil.

Table 2: Areas of soils within Waimea catchment and lowland areas

Soil series	Area within Waimea Plains catchment (below Wairoa Gorge) (ha)	Area of lowland soils (ha)
Braeburn	143	143
Dovedale	2049	2049
Heslington	1982	62
Lee	616	
Mapua	2261	876
Motukarara	111	
Motupiko	3146	3146
Patriarch	1073	
Pelorus	3681	
Ranzau	2272	2272
Richmond	714	714
Rosedale	8809	1854
Spenser	234	
Spooner	9196	218
Stanley	1	
Waimea	2617	2617
Wakatu	368	368
Wantwood	1129	989
rivers	230	
towns	137	
TOTAL AREA	**40770**	**15309**

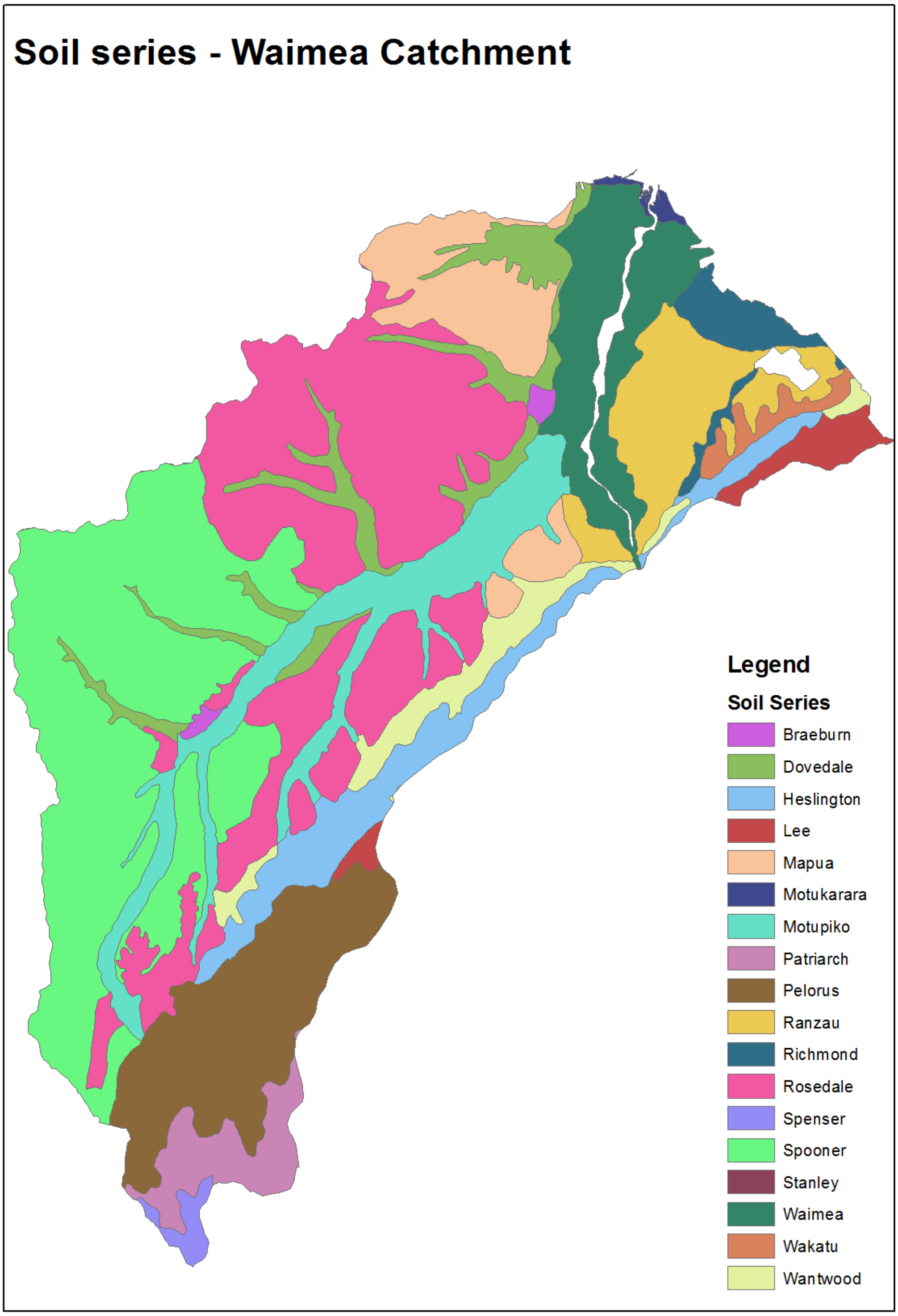

Figure 2(a): Soil series of the Waimea catchment project area.

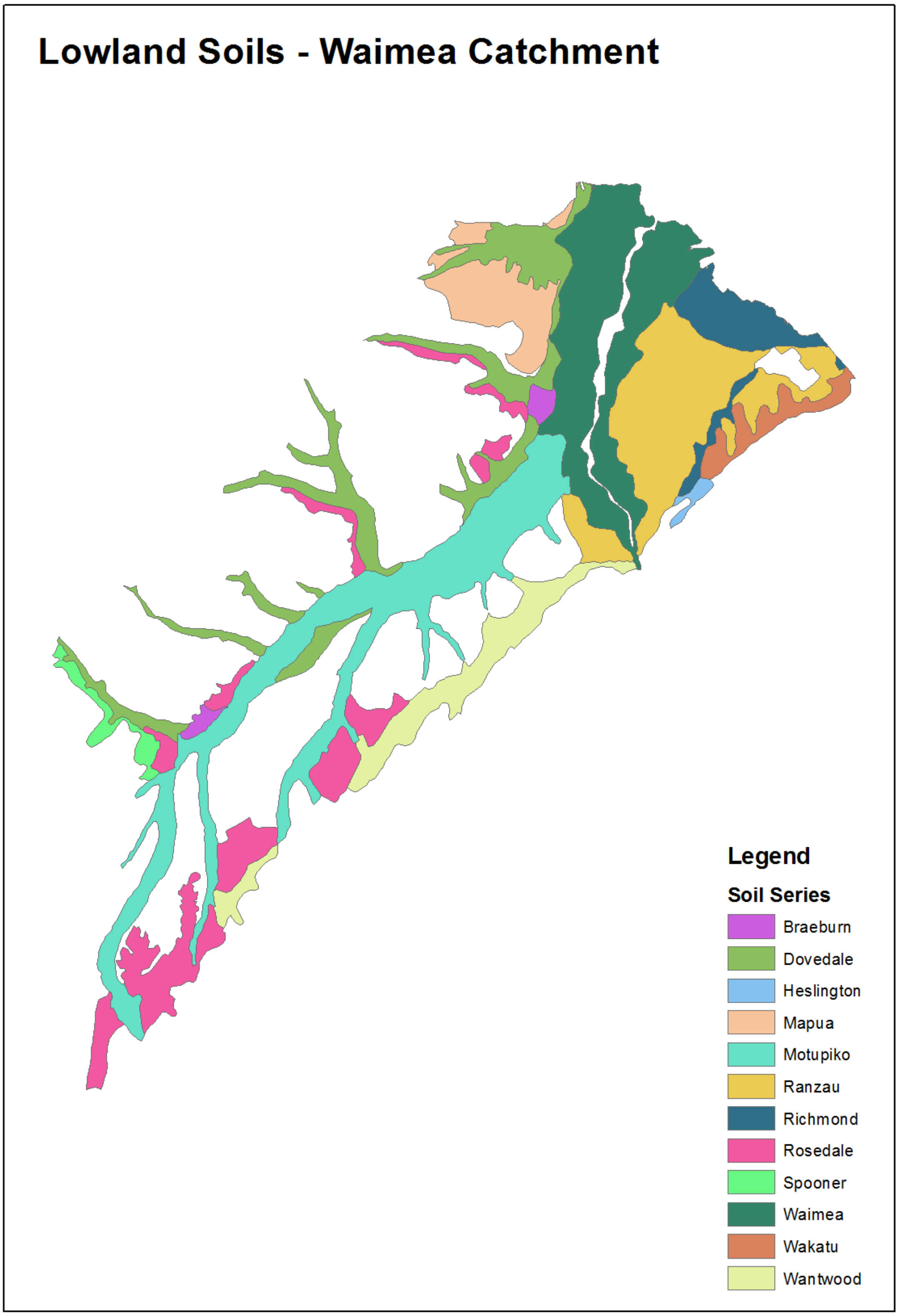

Figure 2(b): Soil series of the valleys and lowlands, Waimea catchment project area.

Table 3 summarises the soils parameters for the four soil groups adopted for this modelling analysis.

Table 3: Soil Groups and Hydraulic Parameters for 1-m soil depth

Soil#	Soil Group	Saturated soil water content (mm)	Field Capacity FC (mm)	Stress Point (mm)	Wilting Point WP (mm)	Total Available Water TAW = FC-WP (mm)	Comments
1	Dovedale silt loam (& Wakatu)	338	208	136	84	124	Sample from Patons Road (Appendix 1)
2	Ranzau stony silt loam	408	149	78	39	110	Composite of 7 samples (Appendix 1); TAW seems high for such a gravelly soil
3	Richmond silt loam (& Heslington)	430	344	239	146	198	Sample from Ranzau Road (Appendix 1)
5	Waimea silt loam & sandy loam; (& Motupiko)	399	287	188	112	175	Waimea was compared with Waimakariri silt loam as an earlier proxy; also similar to Manawatu soils

In summary, the heavier Richmond and Waimea soils will hold more water. The stony gravelly Ranzau soil has lower water holding capacity so would be expected to require irrigating more often and leach more nitrogen. The Dovedale has mid-range TAW intermediate between the other soils modelled.

6 Climate Variability

As the irrigable area of the Waimea Plains totals only around 7500 ha, the climate variability across the area is relatively low. Annual rainfalls range from 990 mm at Nelson airport to about 1200 mm in the southern plains. Variability in rainfall is likely to have a larger effect on irrigation demand and nutrient leaching losses than variability in other parameters such as solar radiation and evapotranspiration.

For this study, to make the number of model simulations manageable, a single climate series has been adopted centred just south of Hope at Virtual Climate Station Network site 20302 (Figure 3). This represents average climate conditions across the plains (Table 4), although we note that annual rainfall at this site is about 60mm higher than at the northern end of the plains at the airport.

We found from comparison of VCSN data with Blenheim data that the global radiation data (MJ/m^2) for the 2000/01 summer for the Waimea sites is grossly underestimated. The dataset was corrected for this critical drought summer only, using a correlation between the two sites. These errors in the VCSN data have been confirmed by NIWA (J Schmidt, pers comm).

Table 4: Average climate parameters for VCSN site 20302, 1972-2011 inclusive

	Annual rainfall (mm)	**Penman Potential Evapotranspiration (mm)**
Mean climate values, site 20302 (Hope) (Waimea West)	1053	956

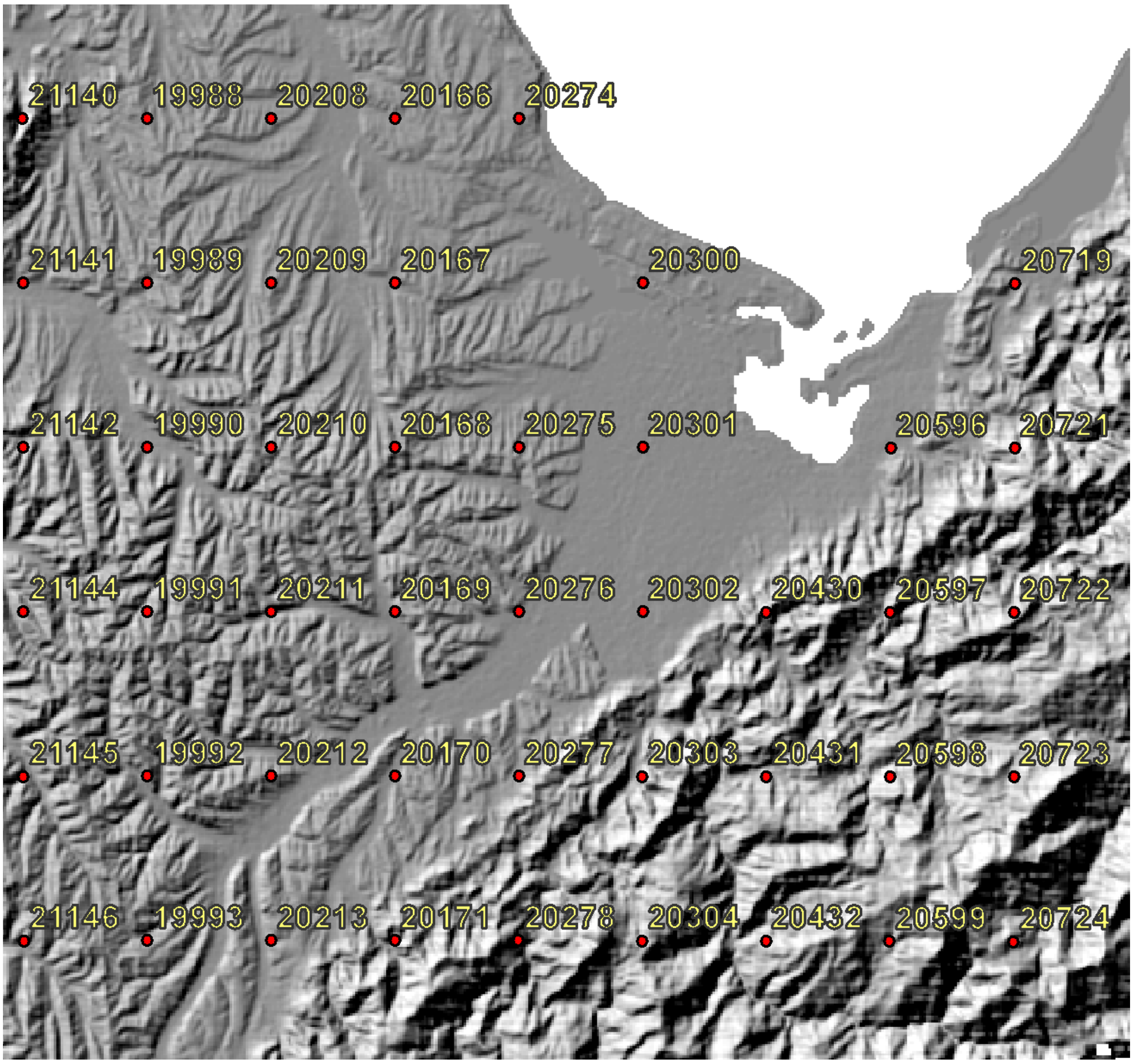

Figure 3: NIWA virtual climate station network sites including 20302 used in simulations.

7 Water Resources and Allocation

The primary water bodies supplying irrigation water across the Waimea Plains are the Wairoa, Waimea and Wai-iti rivers, plus the three aquifers: Appleby Gravel Unconfined Aquifer, Upper Confiner Aquifer and Lower Confined Aquifer (Dicker et al. 1992). Apart from the Waimea East Irrigation Company, which pumps water at the Wairoa Gorge to irrigate up to 1100 ha, most irrigation supplies are from groundwater bores or wells.

Water allocation is managed by the Tasman District Council under policy and rules contained in Part V of the Tasman Resource Management Plan (TRMP) for each water management zone. No new allocations to take water – other than takes from water storage – have been possible since allocation limits were fully subscribed between 1983 and 2000. The reliability of supply for existing water permit holders does not meet the Council's standard of achieving 65% of allocations during a 10-year drought, nor does current water rationing maintain flows during dry summers in the Waimea River. Waimea water resources are therefore considered over-allocated.

A community-driven group, the Waimea Water Augmentation Committee (WWAC), has identified a potential dam site in the upper Lee catchment where 13 Mm^3 of water storage could be provided. The size of the proposed Waimea Community Dam has been based on an assessment of likely future water demand over the next 100 years. Taking account of these water demands, the scheme storage has been sized to maintain a minimum flow in the Waimea River of 1100 L sec^{-1}, and 100% reliability of supply in a drought with a return period of up to 1 in 50 years. Based on projections of future development in the Waimea basin and adjacent areas, additional water will be needed for

- present and future irrigation development
- reticulated water needs from urban residential, commercial and industrial growth
- environmental river flows needed to make up a shortfall between current water usage and possible future restricted usage under recently approved (but under appeal) TRMP plan changes C45–48 if a water augmentation scheme does not proceed (the 'without dam' scenario).

Even if the water augmentation scheme does not proceed, water will ultimately still be needed for the first two purposes listed above. However, the water augmentation scheme offers the opportunity to redress the balance between out-of-stream water use and in-stream values including fisheries, aquatic life, and recreational uses such as swimming. Flows released from the proposed Waimea Community dam would add to low flows depleted by river and groundwater pumping, as well as periodically flushing algae and fine sediments.

Implementing the Waimea Community Dam proposal will provide for up to 5850 ha of irrigation in the Waimea Basin, of which 3800 ha are currently irrigated but with insufficient supply reliability. The current reliability of water supply for the existing 3800ha of irrigated land uses depends on:

(a) whether their water permit has sufficient allocation to cover the entire land parcel
(b) whether the land use is a high water use crop (like pasture, apples, market gardening) or a low water use crop (like grapes)

(c) the physical reliability of their source of supply and

(d) the water rationing regime applying to their water management zone.

Regarding (a), some current water permit holders can maintain supply reliability by irrigating a smaller area, either routinely because their water allocation is insufficient, or during periods of water rationing. Those options would not normally be applied to permanent crops because of the loss of production that ensues.

Regarding (b), because water allocations for irrigation are currently 35 mm/week regardless of land use, holders of water permits for low water use crops are less affected by water rationing because the rationing is calculated as a percentage cut in allocation, not a percentage cut in actual water use. Under plan change C47 it is proposed that this be changed so that water rationing affects all users equally; this is the 'without dam' scenario discussed shortly.

The physical reliability of supply (c) is generally only limited for users with wells on the margins of an aquifer, however reliability of supply is also higher if a user is part of a larger scheme (e.g. the Waimea East Irrigation Company) or has a range of land uses where some require water at different times to others.

Figure 4 shows the boundary of the proposed Waimea Community Dam service zone within which full irrigation is provided for in scheme planning. It also shows the water management zones currently used for water allocation in the Tasman Resource Management Plan.

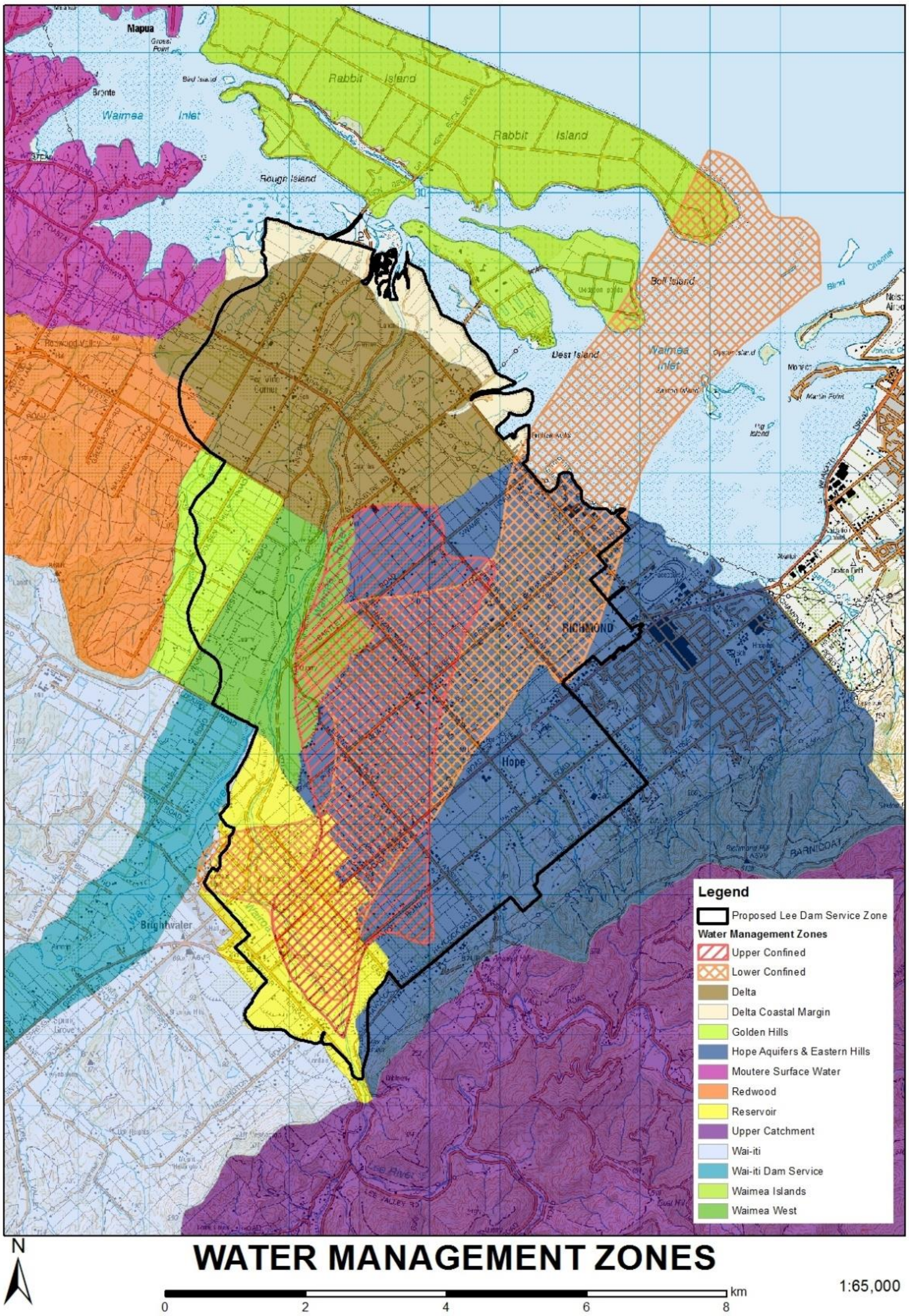

Figure 4: Waimea Plains water management zones and the proposed Waimea Community Dam service zone (from Fenemor et al 2013).

Table 5 summarises the projected consumptive water demand. This comprises 5850 ha of irrigation plus projected non-irrigation demand calculated as hectare equivalents, both based on a peak weekly water usage of 300 m^3 /ha/week (30 mm/week). It is important to note that in aggregate terms, the proposed Waimea Community Dam provides significantly increased reliability of supply for existing water users, surety of minimum flows in the river, plus water for long-term residential and industrial growth, and new irrigation.

The 1105 ha in Table 5 requiring water distribution infrastructure covers various areas outside the service zone for which approximate costings were developed, as described in Landcare Research report LC0910/019. Those areas were 300 ha in the lower Wai-iti, 555 ha in Redwood Valley, and 250 ha near the coast or elsewhere. It is by no means certain that those areas will be serviced, as WWAC expects supply beyond the service zone to be on the basis of first in, first served.

Table 5: Projected water demand (Fenemor 2014)

Water Demand	Hectare equivalents	l/sec equivalent in any week
Existing irrigated area (***lacks full reliability of supply***)	3800	1885
New irrigation	945	469
New irrigation (water distribution infrastructure required)	1105	548
TDC current reticulated water (urban & industry)	620	307
TDC future reticulated water demand (urban and industry)	780	387
Future regional demand (e.g. NCC reticulated water)	515	255
TOTALS	**7765**	**3852**

TRMP plan changes C45-48 recently granted by commissioners, but under appeal, provide for further water allocations to be made if the proposed dam is built (the ‘with dam’ scenario) but for significantly more severe water rationing to be imposed during low river flow conditions under the ‘without dam’ scenario.

The modelling carried out in this project considers the effect of the consequent reduced irrigation water reliability under the ‘without dam’ scenario on production, profit and nutrient leaching. In order to simulate the effects of the new TRMP rules for a ‘without dam’ scenario, we have generated a modelled time series of water rationing cuts that would have occurred had the ‘without dam’ rules applied to existing irrigation water permits during the years 1970–2014. Note that appeals currently being mediated on the rationing rules are discussing the circumstances under which Step4 would be a cease take, for example if seawater intrusion occurs. For the purposes of this modelling it has been assumed that Step 4 would be a cease take, aimed at maintaining a minimum flow in the Waimea River of 800 l/sec. Step 4 restrictions currently specified in the TRMP require a 70% reduction in allocated rate.

Under the ‘without dam’ scenario, renewals of existing irrigation water permits will now need to comply with the lowest of water allocation limits relating both to the soil type that they irrigate, and the type of crop that they irrigate. Irrigation allocations have previously been based solely on soil type. Interestingly, under the ‘with dam’ scenario, the commissioners have decided that the same allocation restrictions should apply, despite providing for site-to-site transfers of water allocations, which could allow higher allocations to be acquired.

These rules are relevant to the modelling undertaken for this project as the modelling allows comparison of the effects of soil properties and crop type on water demand, production, profit and leaching. Table 6 and 7 below reproduce the relevant water allocations from the Tasman Resource Management Plan.

Table 6: Maximum weekly irrigation water allocations by soil type (Fig 31.1D Tasman Resource Management Plan as at 2 August 2014)

SOIL TYPES	RATE (cubic metres/ha/week)	RATE (millimetres/week)
Braeburn	250	25
Dovedale	300	30
Mapua and Rosedale	190	19
Waimea	300	30
Richmond and Wakatu	270	27
Riwaka, Sherry	300	30
Ranzau, Motupiko, Hau and Wantwood	350	35

Table 7: Maximum weekly water allocations by crop type (Fig 31.1DA Tasman Resource Management Plan as at 2 August 2014)

CROP TYPES	RATE (cubic metres/ha/week)	RATE (millimetres/week)
Apples, Pears, Nashi, Hazelnuts	350	35
Grapes, Olives	140	14
Kiwifruit, Feijoa, Chestnut, Plant Nurseries	350	35
Berryfruit, Tobacco, Hemp, Hops, Peonies, Essential oil crops	290	29
Stonefruit, Almonds, Walnuts	290	29
Gardening, cool and warm season vegetable growing, protected floriculture	350	35
Pasture	350	35
Any other irrigated land use	300	30

The weekly allocation limits in Table 6 and Table 7 are the quantities pumped rather than the quantities reaching the soil surface. Compliance is checked by the Council through weekly water meter readings. They are the quantities which have been used in the SPASMO modelling, as the simulations assume the quantity of water specified is the amount applied at the soil surface. This obviously ignores losses prior to the water reaching the soil, which depend on the type of irrigation system used. They also do not compensate for the heterogeneity of water application across the block.

McIndoe (2002) estimated typical losses from New Zealand pressurised irrigation systems as 0-1% losses from leaking pipes, < 3% losses from evaporation in the air, < 5% losses from wind blowing water off the target area, < 2% losses from surface run-off, and < 5% interception losses from the canopy. The major loss (5-30%) is attributed to uneven/excessive application depths and rates.

In the Waimea Plains, crops such as pipfruit, grapes and pumpkins are irrigated using efficient drip or microsprinkler systems with application efficiencies of >90%. Other outdoor market gardening, dairy and other pastoral irrigation use a variety of less efficient sprinkler methods from rotary boom (80-85% efficient), K-line mobile mini-sprinklers (80-90%), larger centre pivots (85-95%) to big guns (65-75%).

The SPASMO water depths should therefore be divided by the application efficiency when setting allocation limits. Based on this literature, Table 8 shows our recommended irrigation efficiencies.

Table 8: Irrigation application efficiencies for Waimea Plains land uses

	Permanent tree crops incl. pipfruit and grapes	**Broad acre crops incl. outdoor market gardening, dairy, arable and pastoral**
Irrigation application efficiency (%)	90%	75%

For the purposes of modelling in SPASMO the ‘without dam’ rationing regime, the following modelled rationing steps have been used from Figure 31.1C of the Tasman Resource Management Plan, except that Step 4 has been assumed to be a complete ‘cease take’:

Step 1 – 20% cut in weekly water allocation

Step 2 – 35% cut

Step 3 – 50% cut

Step 4 – 100% cut, i.e. no water take allowed.

A rationing model has been developed for this work, using the rules shown in Table 9 to consider which rationing step is in place on any day in the 40+ year period simulated. It should be noted that this rationing model is based on an averaged relationship between river flows at Wairoa Gorge (at Irvines) and at Appleby for the current pattern of water takes across the Waimea Plains. River flows at Appleby vary markedly depending on water use by the Waimea East Irrigation Scheme (a pumped river take below the Irvines recorder site) plus the induced losses of flow caused by groundwater pumping across the plains. Therefore the rationing may be slightly less at Step 4 than modelled.

Table 9: Rules applied to Wairoa Gorge daily flow records (Q_{Irvines}) to model Waimea Plains water rationing 1970–2014

When $Q_{\mathrm{Irvines}} < 2{,}750$ l/sec then $R_{\mathrm{step}} = 1$

$2{,}300 < Q_{\mathrm{Irvines}} < 2{,}750$ then $R_{\mathrm{step}} = 1$ or 2 depending on rate of decline of flow recession

When $Q_{\mathrm{Irvines}} < 2{,}300$ then $R_{\mathrm{step}} = 3$

When $Q_{\mathrm{Appleby}} < 800$ then $R_{\mathrm{step}} = 4$ … Based on a regression of Irvines (Wairoa Gorge) and Appleby river flows, and ignoring effects of pumping river flows at Appleby, this can also be approximated as:
When $Q_{\mathrm{Irvines}} < 1{,}800$ then $R_{\mathrm{step}} = 4$ (cease take)

Rationing is imposed starting on a Monday and is reviewed weekly by Council's Dry Weather Task Force (DWTF)

Lifting of rationing depends on river flow (quantity and size of rise), and/or rainfall on the plains, and has been assessed based on what the DWTF would decide, given time of year, degree of crop and rivers stress, and weather outlook.

Rules apply only during irrigation season October-April inclusive.

Results of the modelling have been summarised in Table 10, identifying the contiguous blocks of time each of the stepped cuts in water permit allocations would have applied, had those rationing rules applied during the past 44 years of river flow conditions. Table 10 shows that in only 9 summers out of 44 would no rationing cuts have been imposed on irrigators.

Table 10 also shows that in the worst dry years – as represented by their drought frequency (return period) – a complete cessation of irrigation (Step 4) could have persisted for 2–11 weeks. Return periods of 10 years or more are shown in grey. A return period has been calculated from the lowest 7-day averaged river flow occurring at Wairoa Gorge in each year, using a Gumbel distribution to fit the curve. Mean annual 7-day low flow (MALF) is 2200 l/sec for 1958–2013. The data in Table 10 confirm that the timing of drought and the pattern of river freshes greatly affect the severity of water rationing, more than simply the lowest river flow from which the return period is calculated.

Fenemor (2013) assesses the implications of climate change on these return periods. In summary, expected slightly higher catchment rainfalls by 2090 (+4%) may offset higher summer water demand brought about by higher temperatures (+2°C) and more drought. What is currently a 20-year drought (analysed in terms of increased evapotranspiration) is expected to occur more frequently, every 10–15 years. For a year like that of the 2000/01 summer, the climate change projections would have translated into reductions in Waimea River low flows of about 100 L sec^{-1} within the driest 2 months. Projected small increases in annual rainfall would add more water to the proposed Lee Valley storage reservoir but probably have little direct beneficial effect on the plains during summer.

Table 10: Modelled water rationing annually and related to low flow return periods

Year starting July	7-day low flow return period (years)	Step1 water rationing (blocks of days) 20% cut in allocation	Step2 water rationing (blocks of days) 35% cut in allocation	Step3 water rationing (blocks of days) 50% cut in allocation	Step4 water rationing (blocks of days) Cease water taking	Total water rationing days
1969 (starts 1/1/70)	15	14		7	10	31+
1970	6.5	14+7+20		21+9	7	78
1971	4.6		10+7	13	5	35
1972	88	7	7	13+21	27+26	101
1973	2.6	7+7		8+8		30
1974	2.0	7		22		29
1975	1.3	7+13				20
1976	1.2					0
1977	3.3		14+7	42+11		74
1978	1.3	7	18			25
1979	1.0					0
1980	20		7	23+7	27	64
1981	2.2	7	5	10		22
1982	26		7+7	58+7	52	131
1983	1.3					0
1984	1.6	7	17			24
1985	1.0					0
1986	1.1					0
1987	1.3					0
1988	1.2	3				3
1989	5.8		7+24	7+21	11	70
1990	2.0		23+7+8	7		45
1991	16	6+7	6	7	16	42
1992	1.6	7		4		11
1993	2.3		10			10
1994	1.8	7	5	5		17
1995	1.0					0
1996	2.2		7	7+4		18
1997	2.2	7	21+7	25+8+7		75
1998	1.4	9	7	4		20
1999	1.1					0
2000	25	7		14+6	56+21	104
2001	2.1	14	7	9		30
2002	6.1	7		21+9+8	6+20	71
2003	1.3			38		38
2004	2.0	8+4				12
2005	3.5	7+7	14+13	43+14+12		110
2006	3.7	5+7+7		7+5		31
2007	2.6	7		13		20
2008	1.4		7+14	11+5		37
2009	13		12+7	7+7+7	7+14+6	67
2010	2.1	7	18	14		39
2011	1.2					0
2012	3.1	18+7		20		45
2013	N/A	7+11		18		36
2014 (to 16/12/14 only)	N/A	21				21+

The daily time series of rationing cuts has been used in the SPASMO and financial modelling to assess the added impacts of water rationing on top of various core weekly irrigation allocations assessed in the first simulations.

8 Representative Farm Systems

Rather than selecting a particular land use at paddock scale, the modelling of production, profit, irrigation water use, and nutrient leaching need to take account of the variability of operations at the whole farm scale. This is because of changes in crop mixes over time, movement of animals to and from a property, allowance for areas of a property used for support rather than production activities, and the fact that the basis for financial assessment is the farm unit.

Based on the criteria of predominance of land use by area (Table 1), the major revenue-generating types of farm systems, and likely relative responses to irrigation water availability and nutrient leaching, we have selected the following farm systems:

- Pipfruit – a typical apple orchard
- Dairy – a typical dairy farm
- Grapes – a typical vineyard
- Outdoor vegetable production – a typical large-scale market gardening operation, excluding glasshouse production

Characteristics of each of these farm systems are summarised below.

8.1 Pipfruit

This is an intensive 40-ha apple orchard planted at 3.4 × 1.2 m spacing, corresponding to the MPI model orchard. The variety mix is 20% Royal Gala, 20% Braeburn, 20% Jazz, 20% Pink Lady, and 20% other premium varieties.

Due to a greater volume of intensive orchards and higher level of management on the Waimea Plains, average yield is 67.9 T/ha, which is slightly higher than the 58 T/ha from the 2013 MPI model orchard. Packout is set at 78% (cf. 75% from MPI model) and average fruit size at 106 (170g). Unharvested fruit are assumed at 10% and apple dry matter content as 0.16.

Market returns for apples are averaged from the past five years as this includes good years and poor, which should reflect future volatility. Average price was $23.93 per carton based on 2010–12 data from Pipfruit NZ and 2013–14 data from ENZA.

Fertilizer regime is assumed to involve application of 40 kg N per year, applied as 20 kg/ha post-harvest foliar spray and 20 kg/ha solid fertilizer applied in spring.

Approximately 10% of the planted area is non-producing at any time.

8.2 Dairy

Dairy has been included to provide some comparison with results from similar work already completed for MPI by Aqualinc Research in the Waimakariri.

There are approximately 1000 dairy cows farmed in the central Waimea Plains on five farms. The dairy farm system has been based on data from Dairy NZ (2012) and information kindly provided by Murray King of Kingsway Farms, Appleby.

The model farm is 80 ha with 3.4 cows/ha and a herd of 272 cows, with a targeted annual milk solids production of 1500 kgMS/ha/yr and average annual dry matter production of 16 000 kgDM/ha/yr.

The dairy commodity price is assumed to be $6/kgMS.

When drought occurs, the farm first uses its own supplements, none of which are assumed to have been sold off the property. If own supplements are insufficient, off-farm supplements are purchased up to $0.35/kgDM up to a maximum of 750 kgDM/ha. After Christmas if feed reserves are low, poorer performing cows would start being dried off. In the modelling this is assumed to happen in blocks of 20% of the stock.

The modelled farm assumes 25% of paddocks are excluded from grazing October-December for silage or hay production, unless there is inadequate DM for the herd. Wintering on averages 1 cow/ha with the remainder wintered outside the plains. Younger stock are preferentially wintered off. There is no longer any winter milking on the Waimea Plains.

The fertilizer regime assumes 180 kgN/ha applied as six 30kg/ha applications.

8.3 Grapes

The design vineyard is 9 ha, corresponding to the average size among Nelson winegrowers.

Following analysis of New Zealand Winegrowers statistics and discussion with Phillip Woollaston of Woollaston Estates, the assumed varietal mix for the Waimea Plains is 55% Sauvignon Blanc, 15% Pinot Noir, 15% Pinot Gris, 5% Chardonnay, and 10% other varieties.

Average yield is 9.0 T/ha comprising 11 T/ha for Sauvignon Blanc, 6 T/ha for Pinot Noir, 9 T/ha for Pinot Gris, 8 T/ha for Chardonnay and other varieties.

The commodity prices for grapes averaged from NZ Winegrowers data over the last 5 years were $1216/T for Sauvignon Blanc, $2168/T for Pinot Noir, $1405/T for Pinot Gris, $1516/T for Chardonnay and $1386/T for other varieties.

Fertilizer regime was assumed to involve application of an average of 5kg N per year, although in some vineyards this is applied as an ‘organic’ form and would range from 0 to 20 kgN/ha/yr.

8.4 Outdoor vegetables

The wide range of vegetable crops and rotations used on the Waimea Plains has made it difficult to devise a representative outdoor market gardening operation able to be modelled either in SPASMO or financially.

There are three large grower operations each with some 200ha cropped, plus smaller operators. The use of leased land is common. Growers express a preference for market gardening on a band of land extending from Wairoa Gorge across towards Rabbit Island because of the breeze, lower risk of frosts and more suitable soils (Pierre Gargiulo, Ewers Ltd, pers. comm.).

The design market garden has 45 ha available for planting. In a 12-month cycle this 45 ha has 45 ha of winter lettuces; in Spring/Summer 15 ha are rested (grazed pasture) or a further lettuce crop planted, and there are 15 ha of cabbages and 15 ha of pumpkins. For modelling purposes this comprises a two crop annual cycle, either lettuce/lettuce, lettuces/cabbages, or lettuce/pumpkins.

The fertilizer regime, as suggested following the Waimea FLAG meeting is shown in Table 11(a) and projected yields in Table 11(b).

Table 11(a): Outdoor vegetables fertilizer regime

Crop		N	P	K
Lettuces	Planting	47	34	90
	6 wks later	61	25	73
	2 wks from harvest	117	8	21
	Total	225	67	184
Cabbages	Planting	61	41	132
	6 wks later	57	23	65
	2 wks from harvest	57	23	65
	Total	175	87	262
Pumpkins	Planting	32	22	58
	4 wks later	25	13	34
	Total	57	35	92

We note that the N and P applied to lettuces seems high compared with fertilizer company recommendations[3].

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[3] http://www.yara.co.nz/crop-nutrition/crops/other-crops/lettuce-crop-programme/ This recommendation totals 167 kgN/ha

Table 10(b): Outdoor vegetables projected yields for model calibration

Product	gross production T/hectare	Harvested	TOTAL harvested (t/ha)	TOTAL harvested (crates/ha)	RETURN
Winter Lettuce	20	70%	14	3,574	$8.50/crate (6 heads)
Summer Lettuce	27	90%	24	6,204	$5.85/crate
Pumpkin	31	90%	28	1,393	$0.60/kg
Cabbage	96	60%	57	7,981	$4.00/crate (6 heads)
Fallow/ Green Crop	0	0%	0.0	0	Not modelled

The difference between gross production and harvested allows for losses, either unharvested parts of a crop or whole unharvested paddocks, and uses actual data from a Waimea grower for brassicas (cabbage) and pumpkins, and an estimate for lettuce.

Note that EBITD excludes land costs (i.e. leasing, which is $1,500–$2,000/ha) so that it is directly comparable with the other crops.

9 SPASMO and EBITD Financial Modelling

All water and nutrient calculations have been carried out using Plant & Food Research's SPASMO model (Green et al. 2008, 2012). This model considers the movement of water, solute (e.g. N and P), pesticide, and dissolved organic matter (i.e. dissolved organic carbon (DOC) and dissolved organic nitrogen (DON)) through a one-dimensional soil profile, plus overland flow of sediment and nutrients.

The soil-water balance is calculated by considering the inputs (rainfall and irrigation) and losses (plant uptake, evaporation, runoff and drainage) of water from the soil profile. SPASMO includes components to predict the carbon and nitrogen budgets of the soil. These components allow for a calculation of plant growth and uptake of N, various exchange and transformation processes that occur in the soil and aerial environment, recycling of nutrients and organic material to the soil biomass, and the addition of surface-applied fertilizer and/or effluent to the land, and the returns of dung and urine from grazing animals (Rosen et al. 2004). Model results for the water balance are expressed in terms of mm (= one litre of water per square metre of ground area). The concentration and leaching losses of nutrients are expressed in terms of mg/l and kg/ha, respectively. All calculations are run on a daily basis and the results are presented on a per hectare basis. For all farm systems the production year is simulated October to September and for dairy July to June.

For the climate component, SPASMO uses daily values of global radiation, air temperature (maximum and minimum), relative humidity (maximum and minimum), wind speed, and rainfall. These climate variables are used to calculate a daily water balance, and to grow each of the crops according to a well-defined set of allocation rules that determine dry matter production according to light interception (a function of the green-leaf area) and the availability of soil water and nutrients. Crop growth is curtailed if water and N are in short supply. Irrigation is supplied on the basis of need (Green et al. 1999). In the case of pastoral systems, the grazing management is dictated by animal feed requirements, production targets and pasture supply.

For modelling the soil water balance, SPASMO requires a comprehensive set of soil physical and hydraulic properties. It also computes the various N transformation processes that occur naturally (e.g. decomposition of plant organic nitrogen, Urea → NH_4^+ → NO_3^- → N_2O → N_2 gas), as well as those occurring following the surface addition of water, fertilizer and/or effluent to the land. These processes are described using first-order rate constants that are moderated by the soil conditions (i.e. temperature, moisture content, C:N ratio, etc.). Three forms of mineral N (i.e. urea, ammonium and nitrate), two forms of organic N (i.e. dissolved and resident organic nitrogen), and two forms of P (dissolved reactive P and dissolved organic P) are modelled in the soil domain using a simultaneous set of equations to describe convection, diffusion and sorption of each nutrient species.

For modelling each farm or crop system, each farm type is specified by a production target (e.g. dairy is represented by kg of milk solids per ha, horticulture is represented by kg of product per hectare). For each model run, the input parameters for SPASMO were adjusted to achieve the expected yields and production volumes identified by growers, Fruition Horticulture and Plant and Food Research based on local experience and research results. Further detail on the complexity of the model and the way in which crop phenology is modelled can be found in Green at al. (2012), where SPASMO modelling is described for the Ruataniwha Plains. However, it should be noted that the SPASMO model was substantially further refined and calibrated for this project to simulate multiple market gardening rotations and to simulate more realistically the drying off and feed import scenarios for dairy farms on the Waimea Plains.

Data provided from the SPASMO modelling for each farm-soil-climate scenario comprise:

- Annual median values for soil water balance parameters, nitrogen inputs uptake and losses, dry matter changes and animal impacts on N and P for each of the four soil types for 1972–2013 inclusive (Note 1972-73 data have been excluded from analyses due to start-up modelling inaccuracies)
- Monthly soil water balance values, nitrogen and phosphorus inputs uptake and losses for each of the four soil types for 1972–2013 inclusive
- Annual crop harvest as dry matter and crop nitrogen exported for each of the four soil types for 1972–2013 inclusive
- Summaries of annual irrigation applied, nutrient losses and production.

The production data are used in a financial model to produce for each farm-soil-climate scenario:

- Annual EBITD (earnings before interest, tax and depreciation) for each of the four soil types for 1972–2013 inclusive.

EBITD and EBITD/ha are calculated as Income less Working Expenses which comprise direct and fixed costs. Income is calculated as Yield * Price. Direct costs are those that vary according to production such as wages (including an owner's wages allowance), packaging, chemicals, fertiliser, electricity (irrigation), vehicles, repairs, and maintenance. Fixed costs are those that are similar regardless of production yet linked to property size such as rates, insurance, communication, accountancy, legal/consultancy, fixed electricity supply costs and administration costs.

Each spreadsheet includes a 'Template' sheet that shows exactly what 'average' costs are used for each farm system.

10 Farm-Soil-Climate Scenarios for Modelling

Accounting for the variability in climate and soil hydraulic parameters and the relative predominance, profitability, and nutrient leaching risk from farm systems on the Waimea Plains, as described earlier in this report, we have modelled the irrigation response for the scenarios summarised in Tables 12 and 13 (an additional 7 mm/week scenario is included in the spreadsheets because the modelling approach allowed its inclusion).

There are 72 simulations in Table 12 covering the predominant farm-soil combinations and with irrigation water availability simulated from dryland to the likely maximum water allocation of 35 mm/week. 'Unlimited' refers to a simulation in which the maximum weekly allocation is not capped. For any farm-soil combination, production and EBITD response can be plotted against irrigation water availability.

There are an additional 36 simulations in Table 13. These simulations investigate the potential production and EBITD consequences of applying the TDC water rationing rules for the 'no dam' scenario. The simulations essentially add to selected core allocation scenarios the reductions in water allocation that would have occurred had those rules applied during the past 40 years of river flows. Results of both sets of scenarios can be expressed in terms of reliability of supply by cross-referencing with the drought return periods shown in Table 10.

Spreadsheets supplied with this report are summarised in Appendix 2.

Table 12: Modelled scenarios with varied core weekly irrigation allocations

LAND USE/ FARM SYSTEM	Ranzau soil		Waimea & Motupiko soils		Wakatu & Dovedale soils		Richmond & Heslington soils	
	Climate site VCSN 20302							
Dairy pasture			Dryland	0			Dryland	0
			Max irrigation	14 mm/week			Max irrigation	14 mm/week
				21 mm/week				21 mm/week
				28 mm/week				28 mm/week
				35 mm/week				35 mm/week
				Unlimited				Unlimited
Apples	Dryland	0	Dryland	0	Dryland	0	Dryland	0
	Max irrigation	14 mm/week	Max irrigation	14 mm/week	Max irrigation	14 mm/week	Max irrigation	14mm/week
		21 mm/week		21 mm/week		21 mm/week		21 mm/week
		28 mm/week		28 mm/week		28 mm/week		28 mm/week
		35 mm/week		35 mm/week		35 mm/week		35 mm/week
		Unlimited		Unlimited		Unlimited		Unlimited
Grapes	Dryland	0	Dryland	0	Dryland	0		
	Max irrigation	14mm/week	Max irrigation	14 mm/week	Max irrigation	14 mm/week		
		21 mm/week		21 mm/week		21 mm/week		
		28 mm/week		28 mm/week		28 mm/week		
		35 mm/week		35 mm/week		35 mm/wee		
		Unlimited		Unlimited		Unlimitedk		
Outdoor vegetables	Dryland	0	Dryland	0	Dryland	0		
	Max irrigation	14mm/week	Max irrigation	14 mm/week	Max irrigation	14 mm/week		
		21 mm/week		21 mm/week		21 mm/week		
		28 mm/week		28 mm/week		28 mm/week		
		35 mm/week		35 mm/week		35 mm/week		
		Unlimited		Unlimited		Unlimited		

Table 13: Modelled scenarios with varied core weekly irrigation allocations plus TDC water rationing for the 'no dam' scenario

LAND USE	**Ranzau soil** *Climate station VCSN 20302*		**Waimea & Motupiko soils**		**Wakatu & Dovedale soils**		**Richmond & Heslington soils**	
Dairy pasture			Max irrigation	21 mm/week 28 mm/week 35 mm/week			Max irrigation	21 mm/week 28 mm/week 35 mm/week
Apples	Max irrigation	21 mm/week 28 mm/week 35 mm/week	Max irrigation	21 mm/week 28 mm/week 35 mm/week	Max irrigation	21 mm/week 28 mm/week 35 mm/week	Max irrigation	21 mm/week 28 mm/week 35 mm/week
Grapes	Max irrigation	7 mm/week 14 mm/week 21 mm/week	Max irrigation	7 mm/week 14 mm/week 21 mm/week	Max irrigation	7 mm/week 14 mm/week 21 mm/week		
Outdoor vegetables	Max irrigation	21 mm/week 28 mm/week 35 mm/week	Max irrigation	21 mm/week 28 mm/week 35 mm/week	Max irrigation	21 mm/week 28 mm/week 35 mm/week		

11 Effect of Varied Weekly Irrigation Allocations on Production and Profit

Crop yield (tonnes/ha) results of modelled scenarios from Table 11 are presented in Figure 6. These figures show the production and profit responses averaged over the 40 years 1974–2013 inclusive for apples, grapes, outdoor vegetables and dairy, for four soils, and for weekly irrigation water allocation limits of 0 (dryland), 14, 21, 28 and 35 mm/week. ‘Unlimited’ is a scenario where the full daily irrigation rate calculated from the irrigation scheduling model is applied, even if it exceeds 35 mm/week. The plots are labelled ‘No Rationing’ to distinguish them from those that follow in section 12 in which the Council’s water rationing rules have been added.

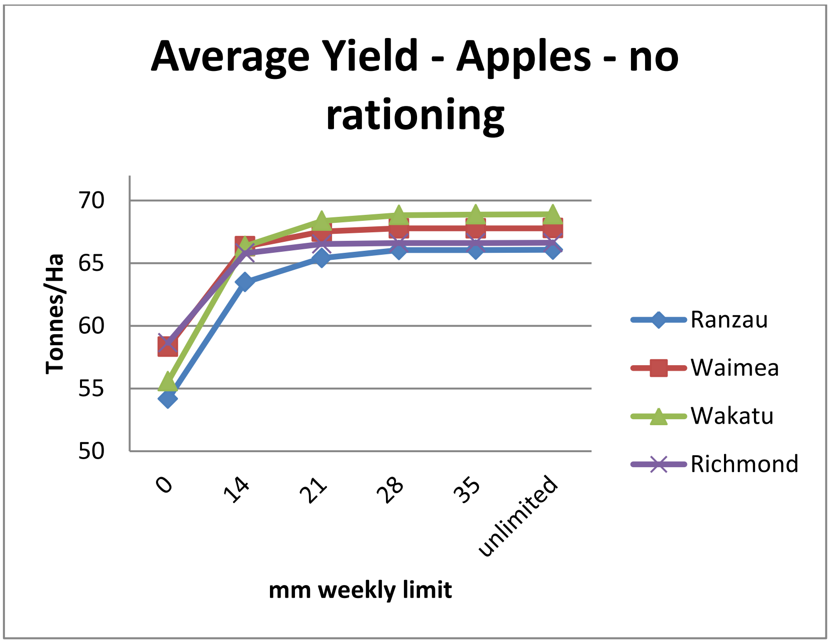

Figure 5: Apple production in response to varied irrigation water allocations.

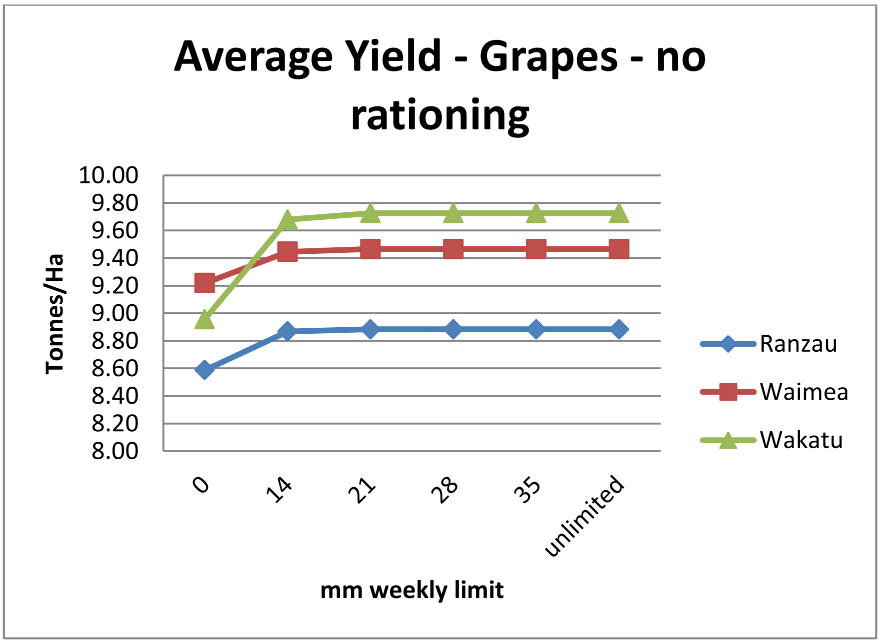

Figure 6: Vineyard production in response to varied irrigation water allocations.

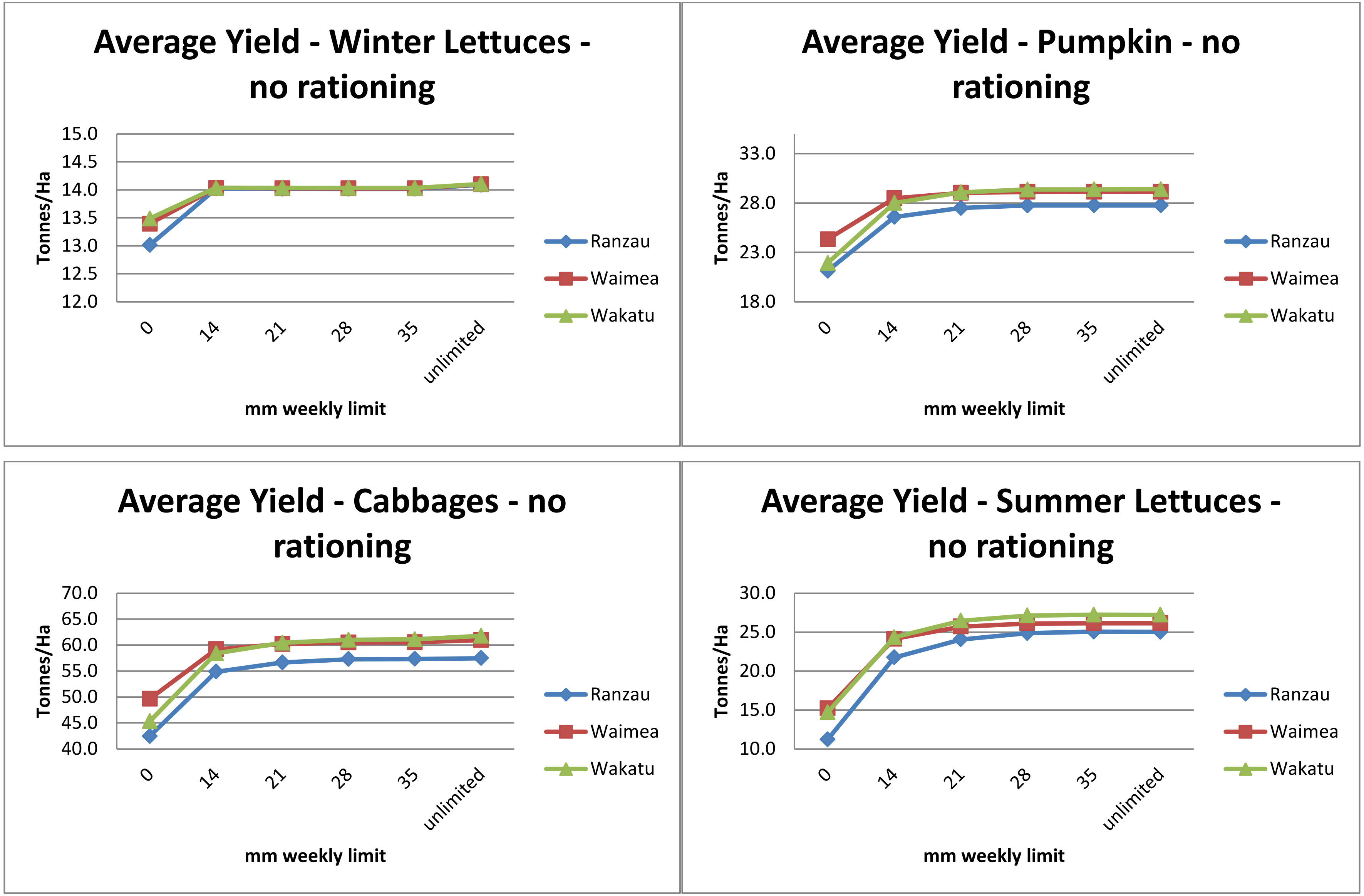

Figure 7: Outdoor vegetable production responses to varied irrigation water allocations.

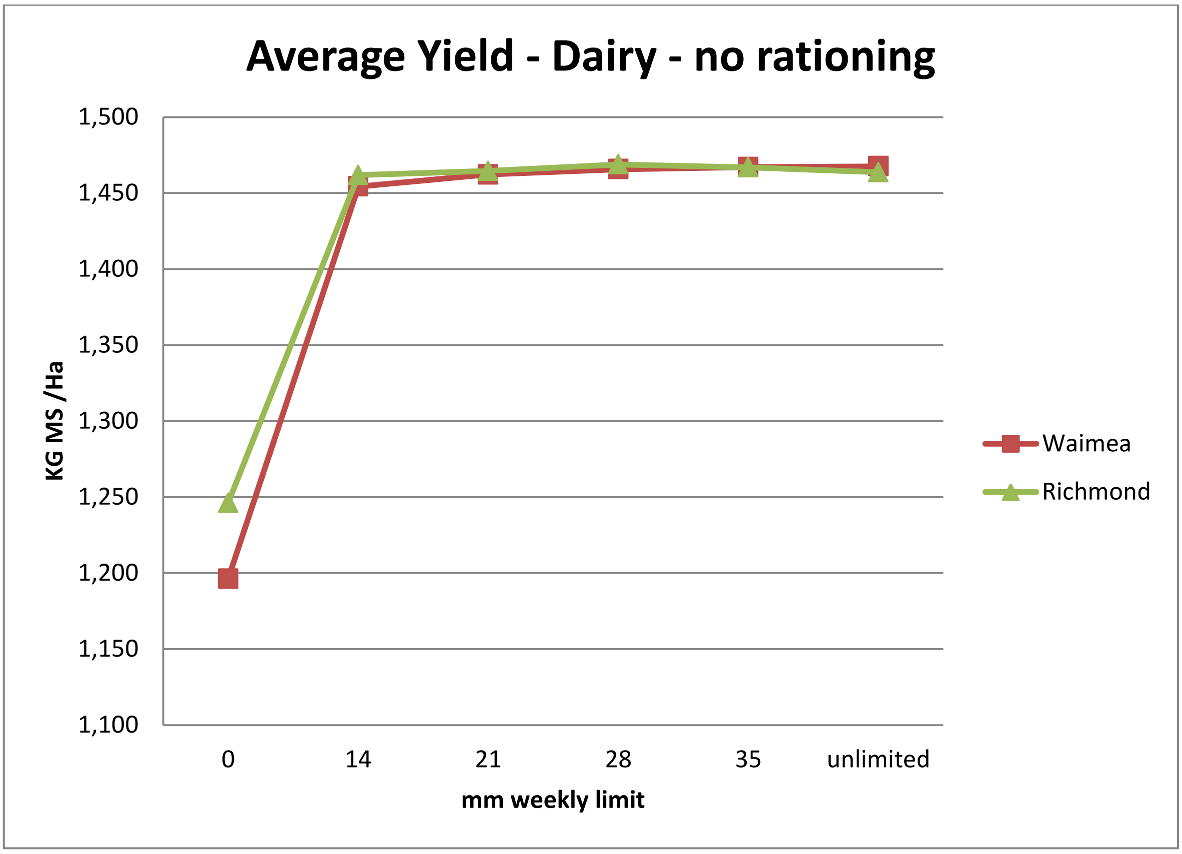

Figure 8: Dairy production in response to varied irrigation water allocations.

Farm profit (Earnings before Interest and Depreciation) results of modelled scenarios from Table 11 are presented in Figures 9–12. In the same manner, these figures show the profit responses averaged over the 40 years 1974–2013 inclusive for apples, grapes, outdoor vegetables and dairy, for the chosen weekly irrigation water allocation limits. Costs of electricity for irrigation comprise a fixed cost component plus a variable rate component accounting for increased electricity costs with increased irrigation applied; the fixed cost component is assumed to apply for the dryland option because the simulation is intended to represent an irrigated property becoming a dryland one.

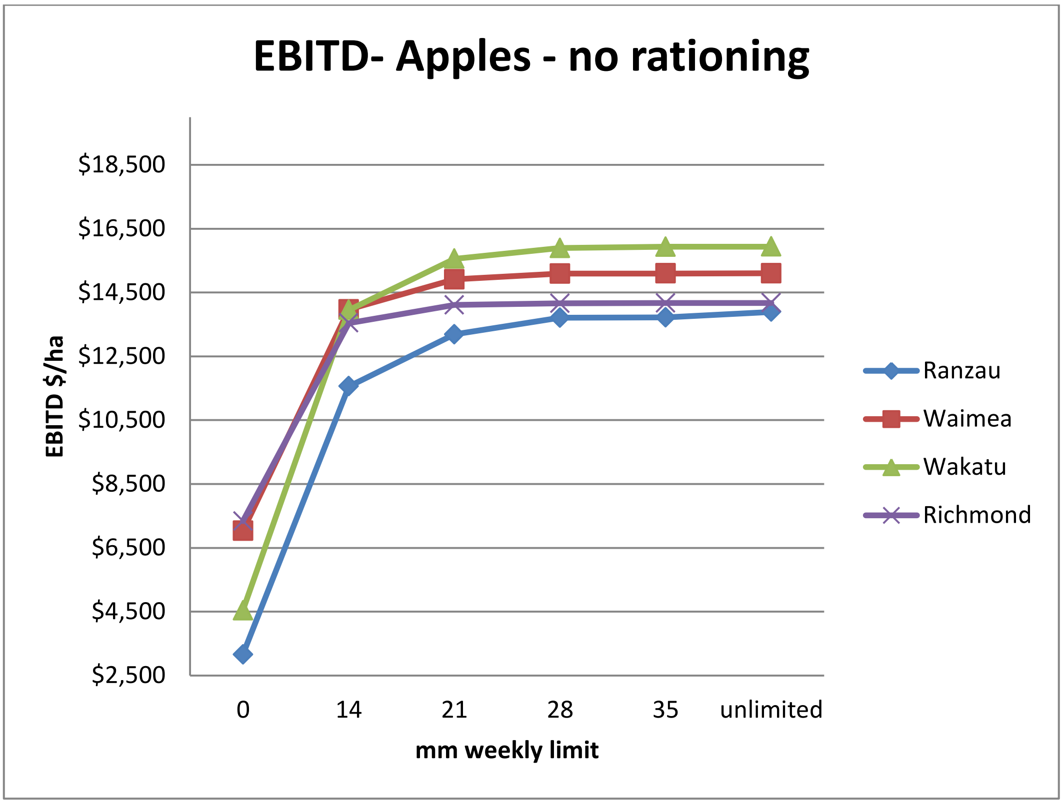

Figure 9: Apple EBITD in response to varied irrigation water allocations.

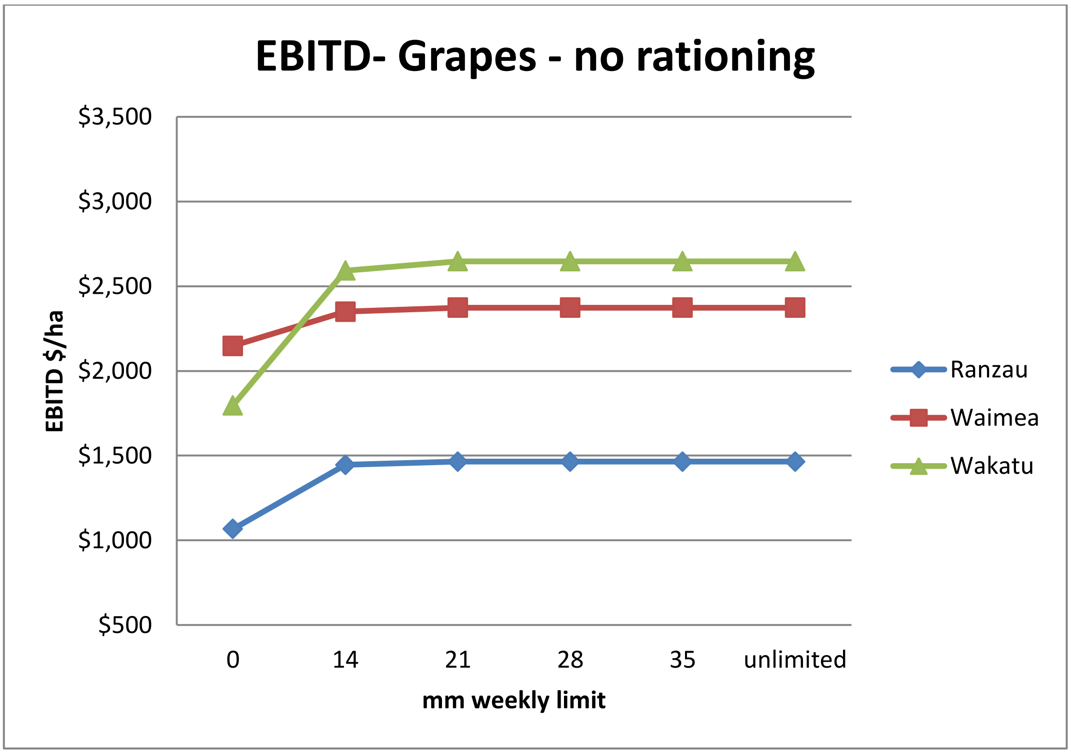

Figure 10: Vineyard EBITD in response to varied irrigation water allocations.

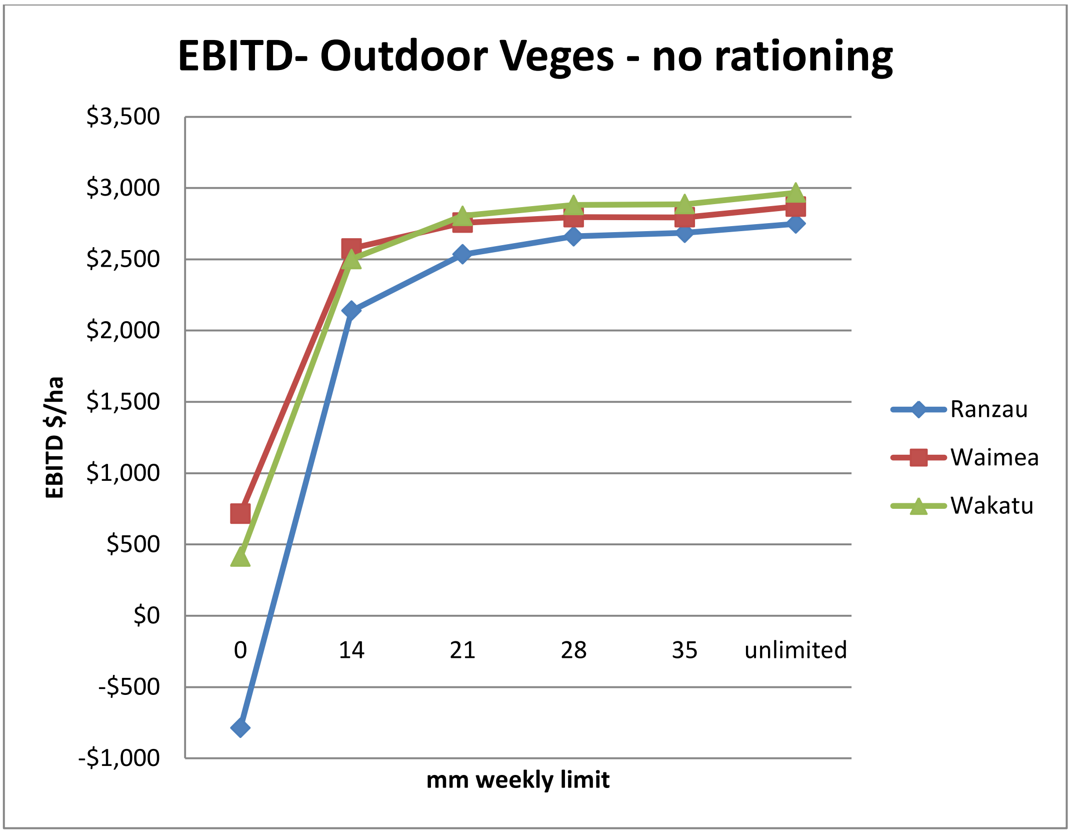

Figure 11: Combined outdoor vege growing EBITD for varied irrigation water allocations.

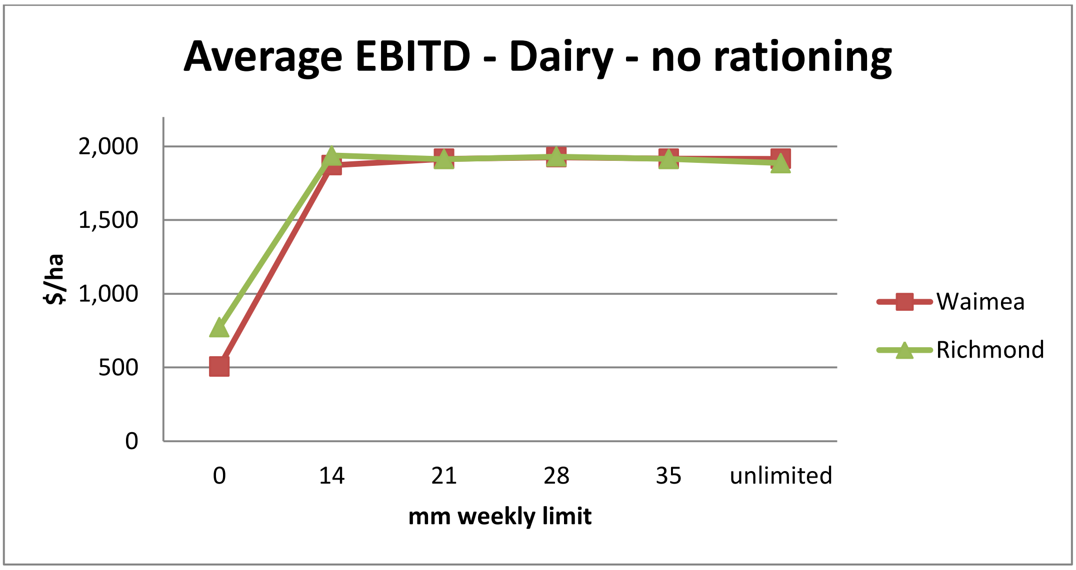

Figure 12: Dairy farm EBITD for varied irrigation water allocations.

To illustrate the effects of dry summers when irrigation has the greatest benefits for production and profit, Figure 13–16 provide examples of EBITD for predominant crop-soil combinations.

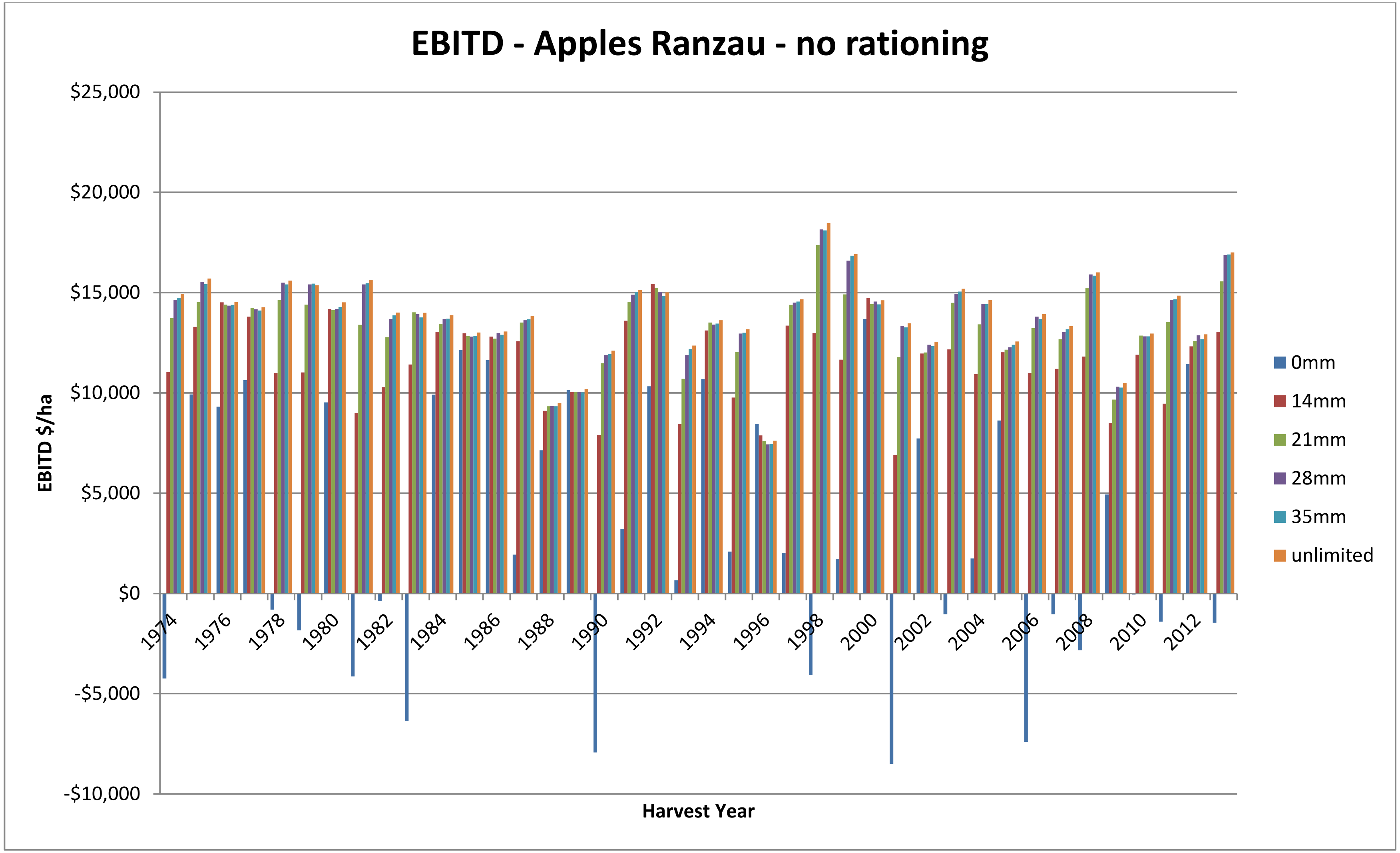

Figure 13: Year to year variability of apple orchard profit (EBITD) on Ranzau stony silt loam for varied irrigation water allocations.

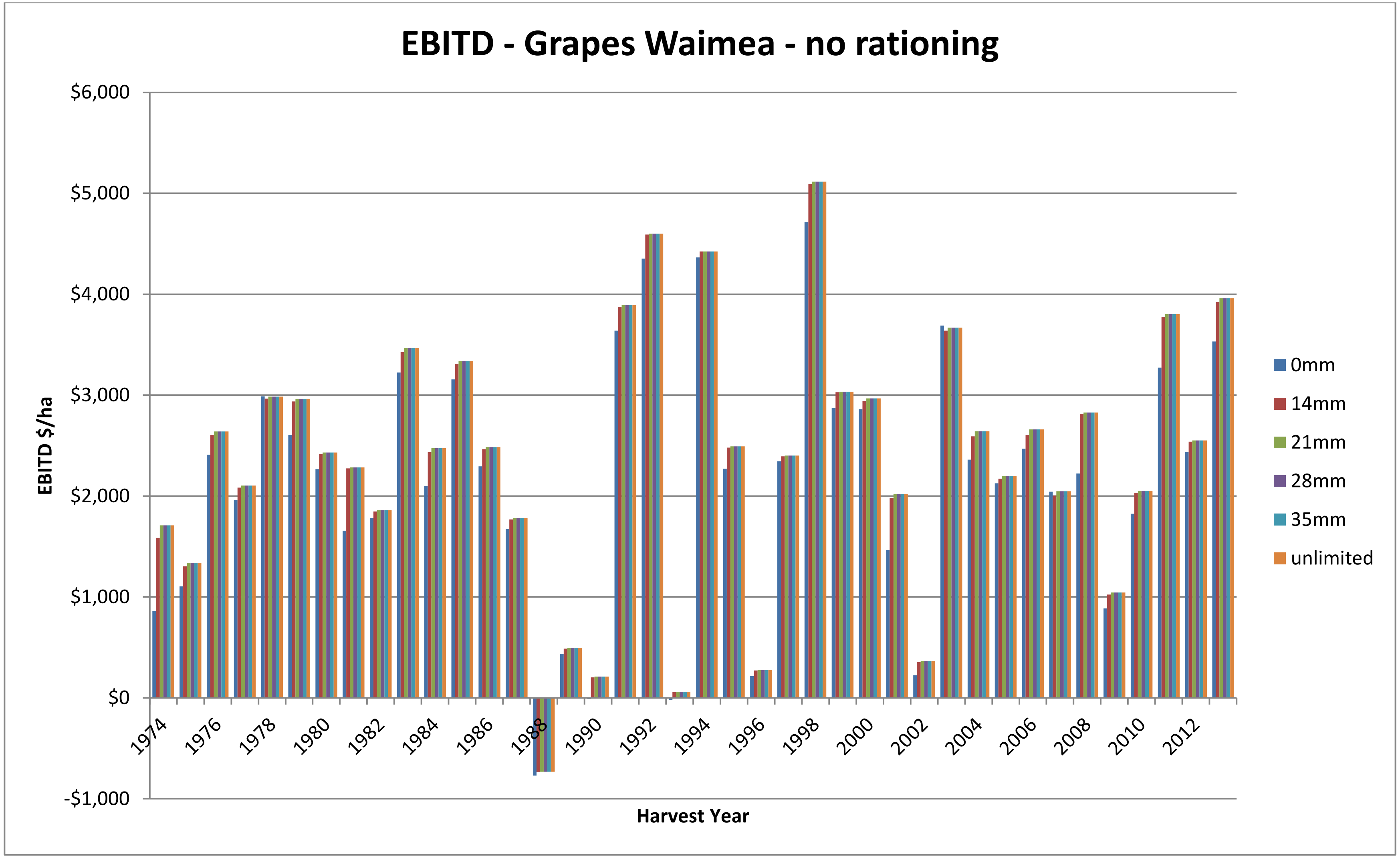

Figure 14: Year to year variability of vineyard profit (EBITD) on Waimea silt loam for varied irrigation water allocations.

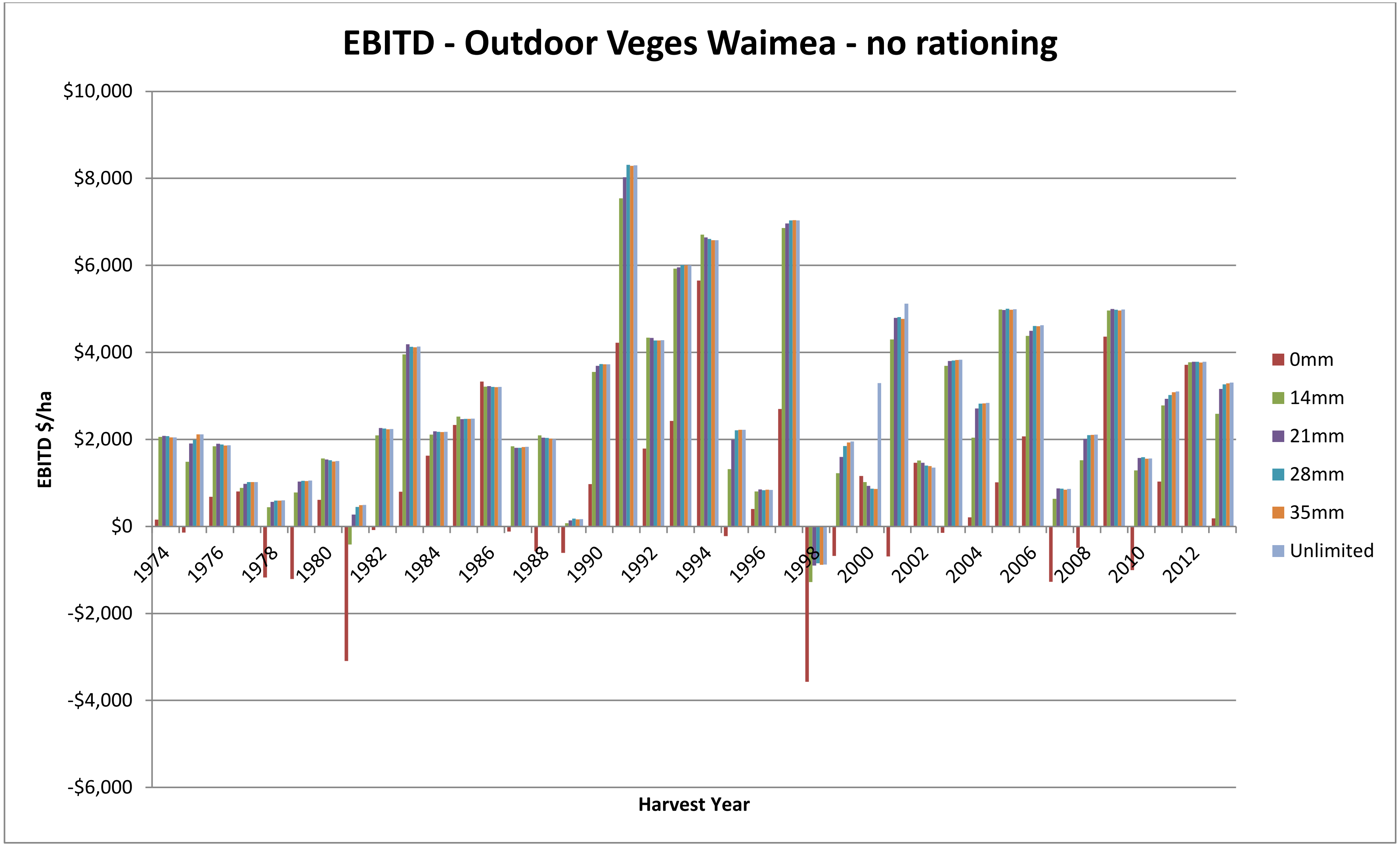

Figure 15: Year to year variability of market gardening profit (EBITD) on Waimea silt loam for varied irrigation water allocations.

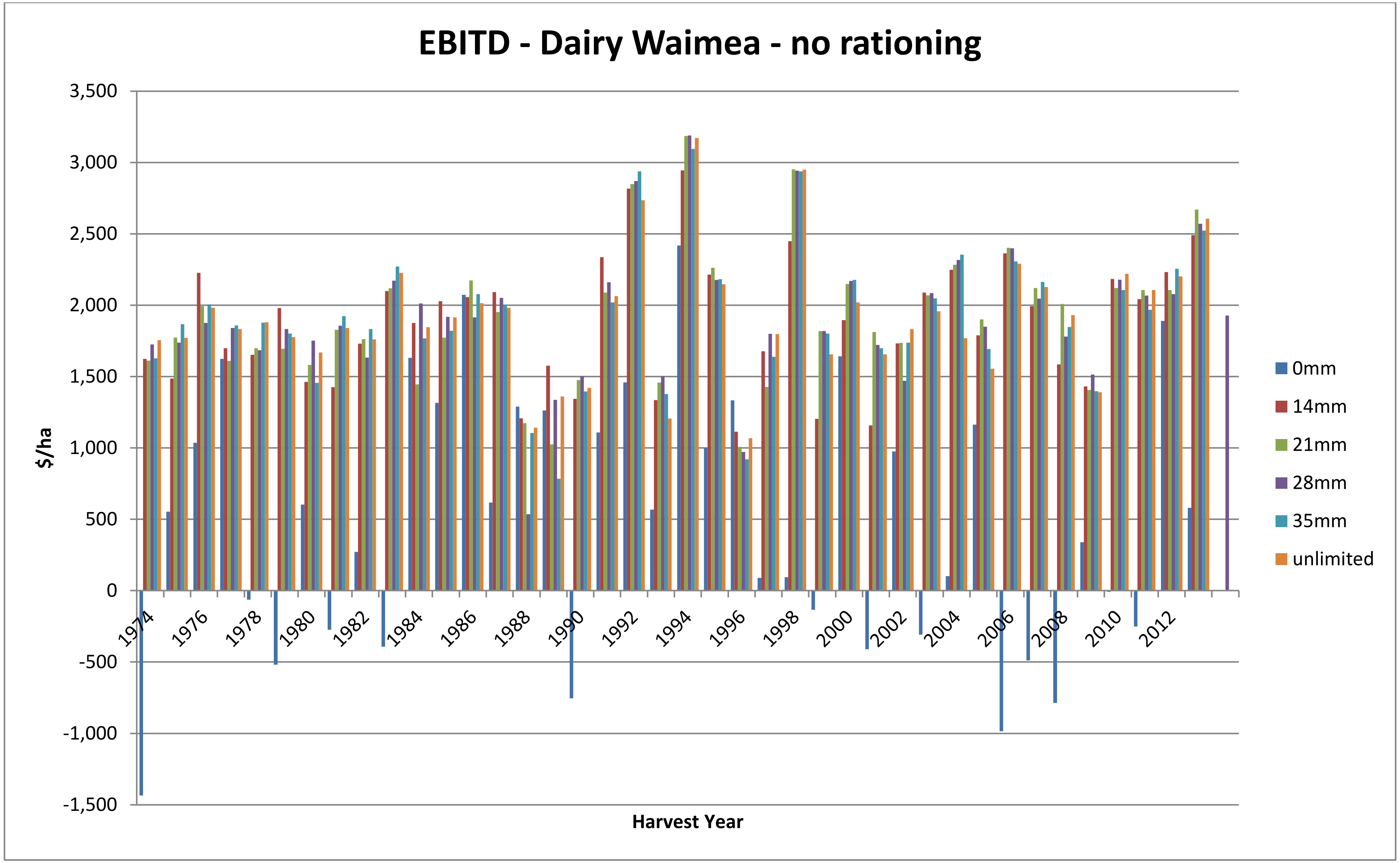

Figure 16: Year to year variability of dairy farm profit (EBITD) on Waimea silt loam for varied irrigation water allocations.

The data from which these plots are drawn is summarised in the spreadsheets provided with this report.

Reviewing these figures, it is apparent that on average over the 40 years modelled, and assuming no within-season water rationing, production of apples would not begin to be affected until weekly allocations were set at less than 28 mm/week. For grapes and dairy, the equivalent weekly water allocation is 14 mm/week. For outdoor vegetables, summer lettuce production would be affected for an allocation of less than 28 mm/week but for pumpkins and cabbage the equivalent allocation is 21 mm/week. Winter lettuces are barely affected because their growing period is mainly outside the irrigation season.

The average EBITD results show the financial response to rainfall with varying amounts of irrigation. They show a similar pattern to the production curves but fall more steeply as irrigation is reduced, because fixed costs of production must still be paid – some annual EBITDs in dry years are negative for this reason. It is noticeable in the figures that production and profit on Ranzau gravelly soils are more sensitive than on heavier soils, as those soils require more frequent watering to maintain soil moisture.

The average production and EBITD results mask the effect of lack of adequate water during dry summers. Figure 13–16 show that dry summers have a major effect on production and EBITD for apples and outdoor vegetables, somewhat for dairy, and only a little for grapes. Natural climate variability has a major effect on yields and profit; however, the results suggest that in order to maintain a consistent profit, apples and outdoor vegetable growing would require a weekly irrigation allocation of 28 mm/week and for grapes and dairy the figure would be 14 mm/week. The growing of outdoor vegetables on Ranzau soils is more susceptible to lack of irrigation than on the heavier soils because of the stony soils and shallow rooting plants. In the case dry summers and dairy farming, it should be noted that the farmer has the option of buying in feed to delay reductions in production, if irrigation cannot maintain pasture production; the results shown here are obviously dependent on assumptions made about feed costs and returns.

12 Effect of Water Rationing on Production and Profit

To compare with results in section 11, in this section the additional effects of water rationing modelled under Council's 'no dam' rules are presented. Crop yield (tonnes/ha) results of modelled scenarios from Table 13 are presented in Figure 17–20. Again, these figures show the production and profit responses averaged over the 40 years 1974–2013 inclusive for apples, grapes, outdoor vegetables, and dairy, for four soils, but for potential weekly irrigation water allocation limits of 21, 28 and 35 mm/week and with water rationing modelled in accordance with Table 9.

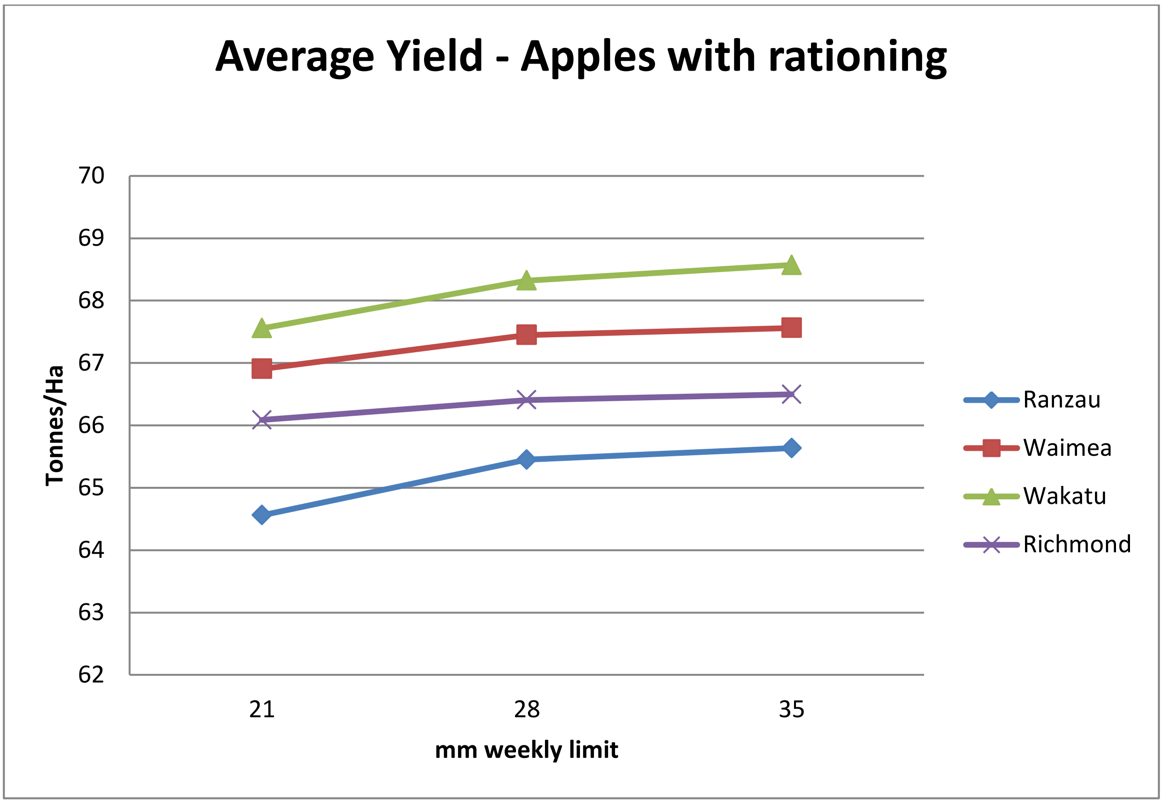

Figure 17: Apple production in response to irrigation allocations with water rationing.

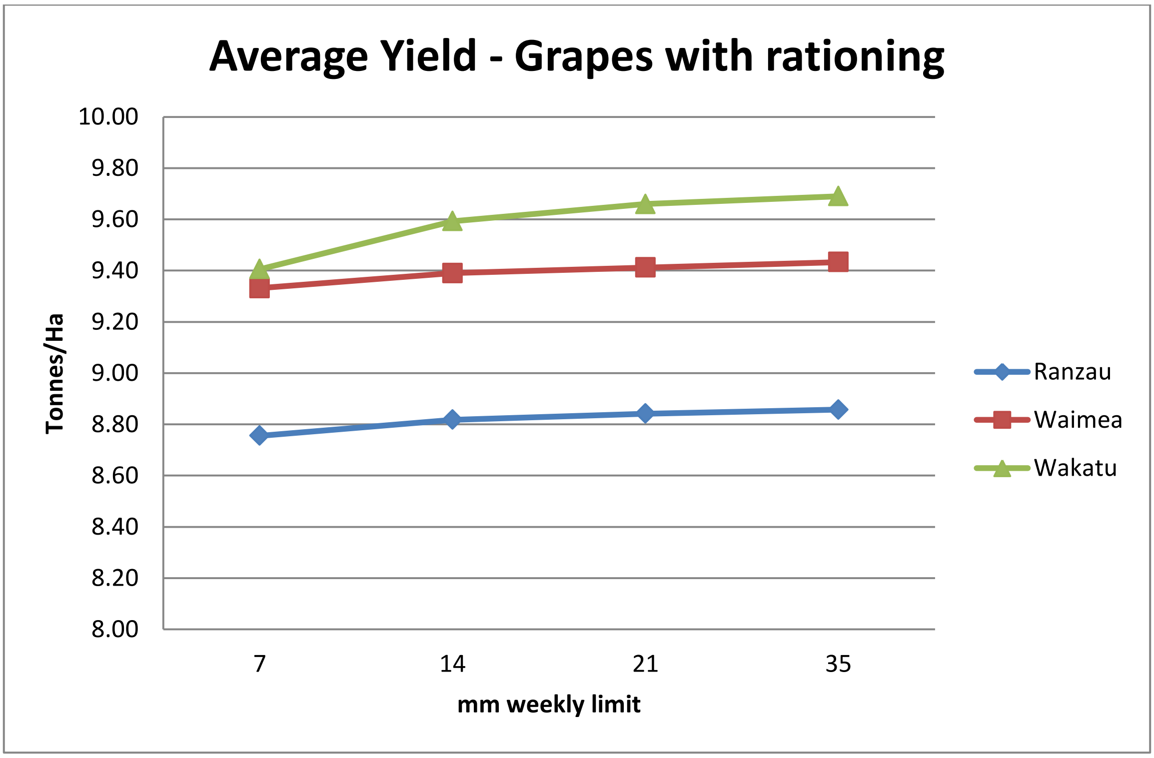

Figure 18: Grape production in response to irrigation allocations with water rationing.

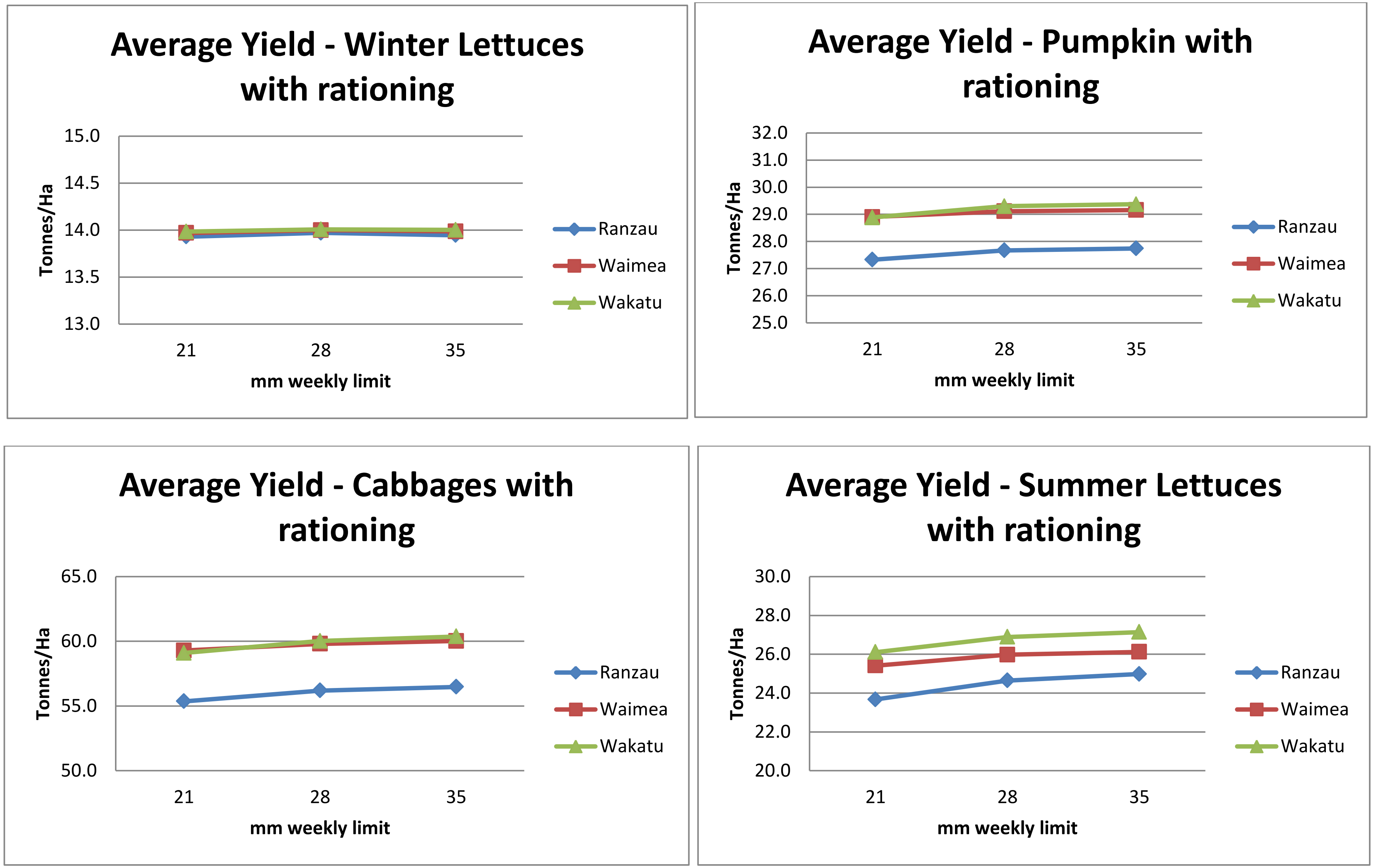

Figure 19: Outdoor vegetable production in response to irrigation allocations with water rationing.

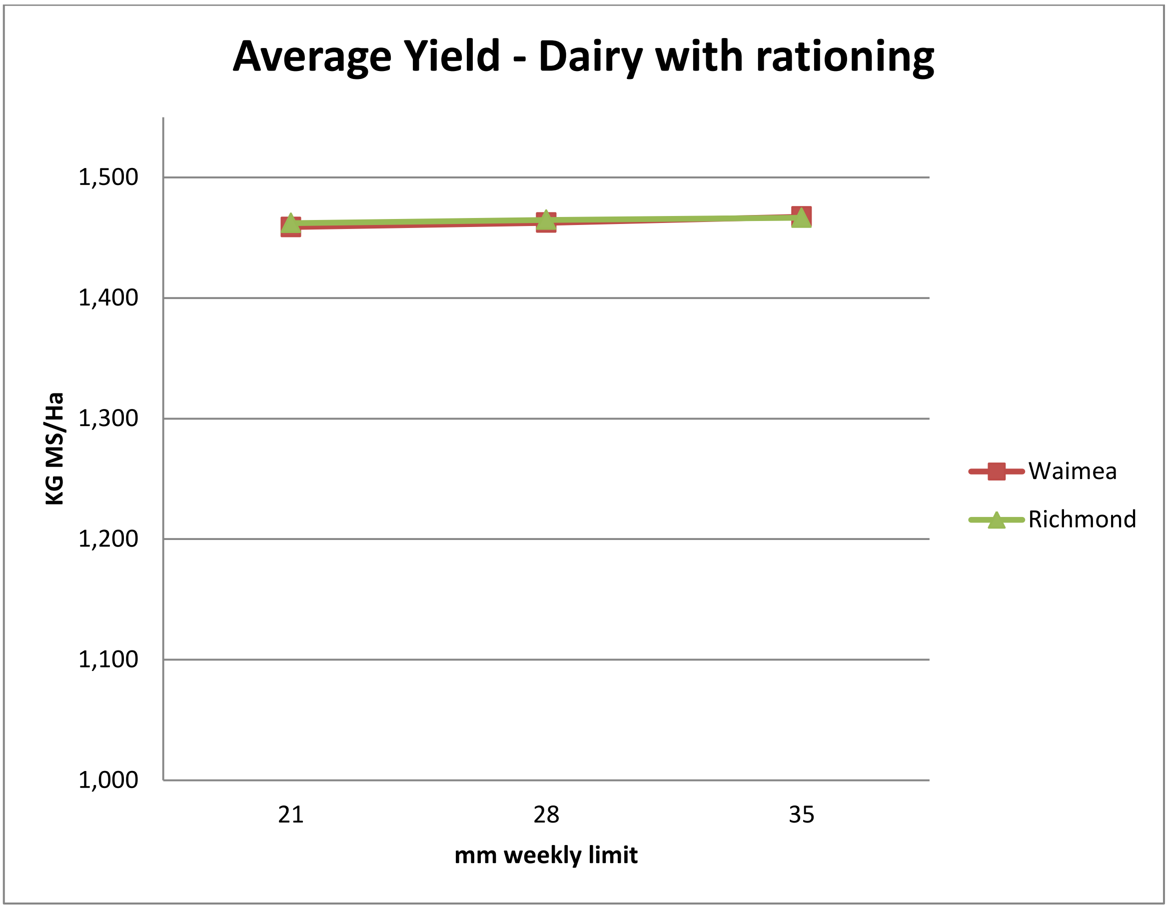

Figure 20: Dairy production in response to irrigation allocations with water rationing.

Farm profit (Earnings before Interest and Depreciation) results of modelled scenarios from Table 13 are presented in Figures 21–24. Again, these figures show the profit responses averaged over the 40 years 1974–2013 inclusive for apples, grapes, outdoor vegetables and dairy, for the chosen weekly irrigation water allocation limits and with water rationing imposed according to the rules summarised in Table 9.

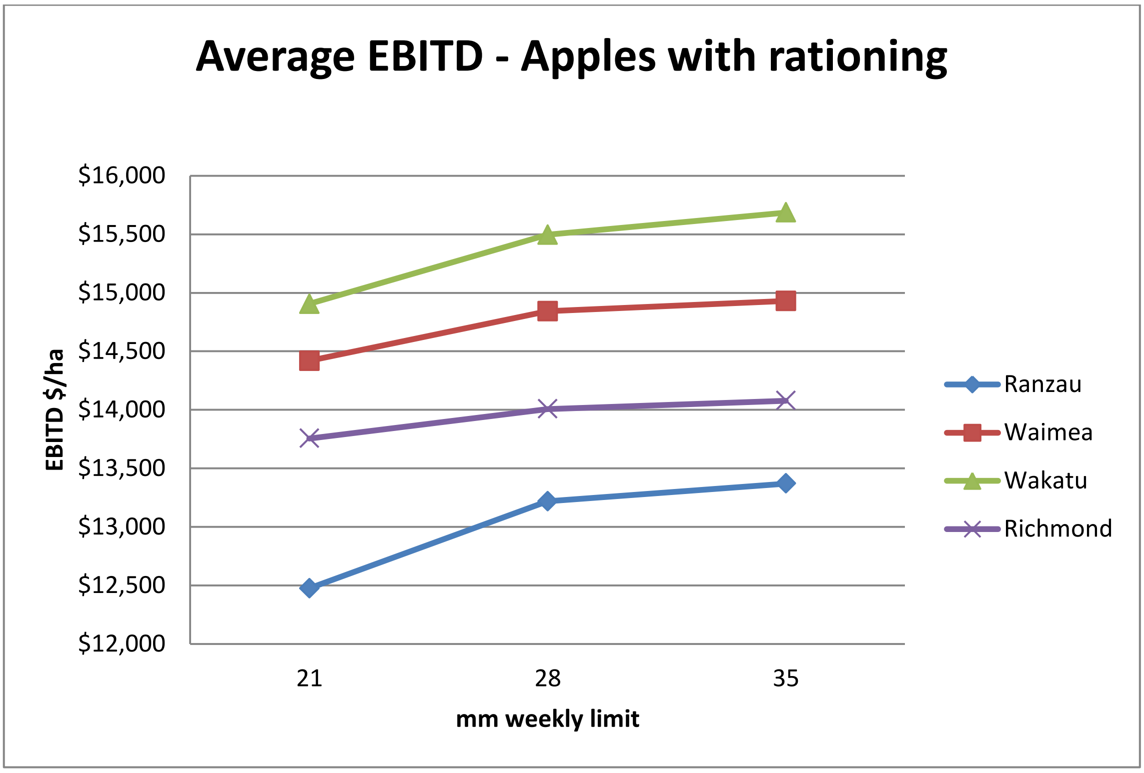

Figure 21: Apple orchard profit in response to irrigation allocations with water rationing.

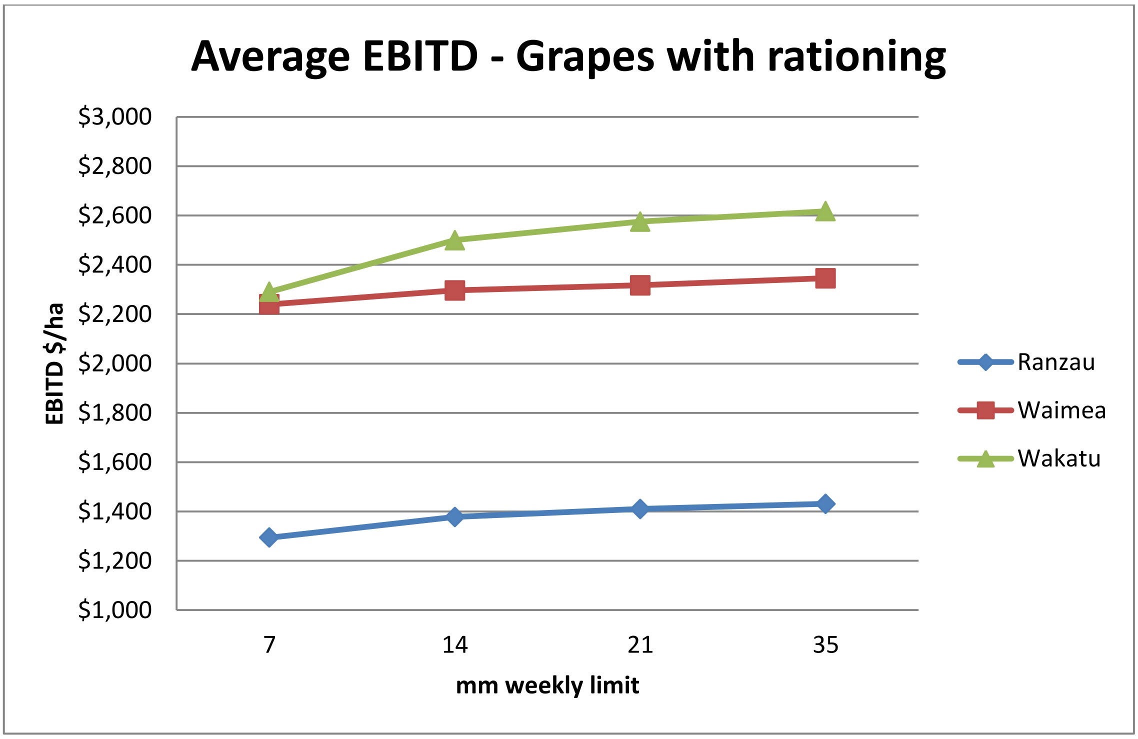

Figure 22: Vineyard profit in response to irrigation allocations with water rationing.

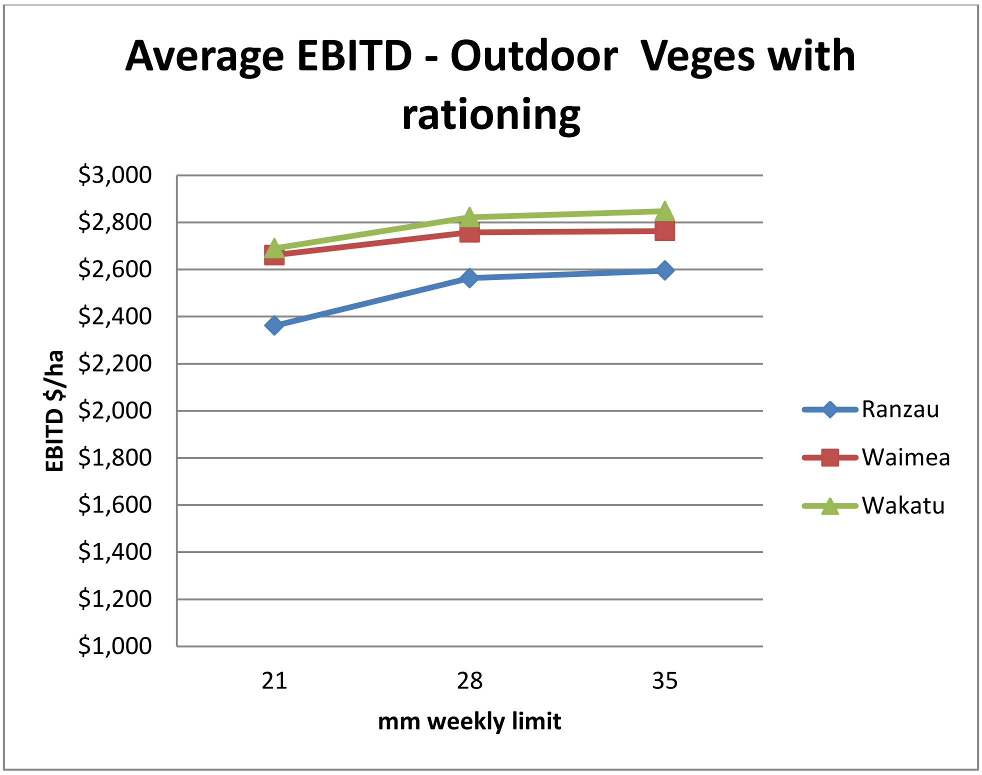

Figure 23: Market gardening profit in response to irrigation allocations with water rationing.

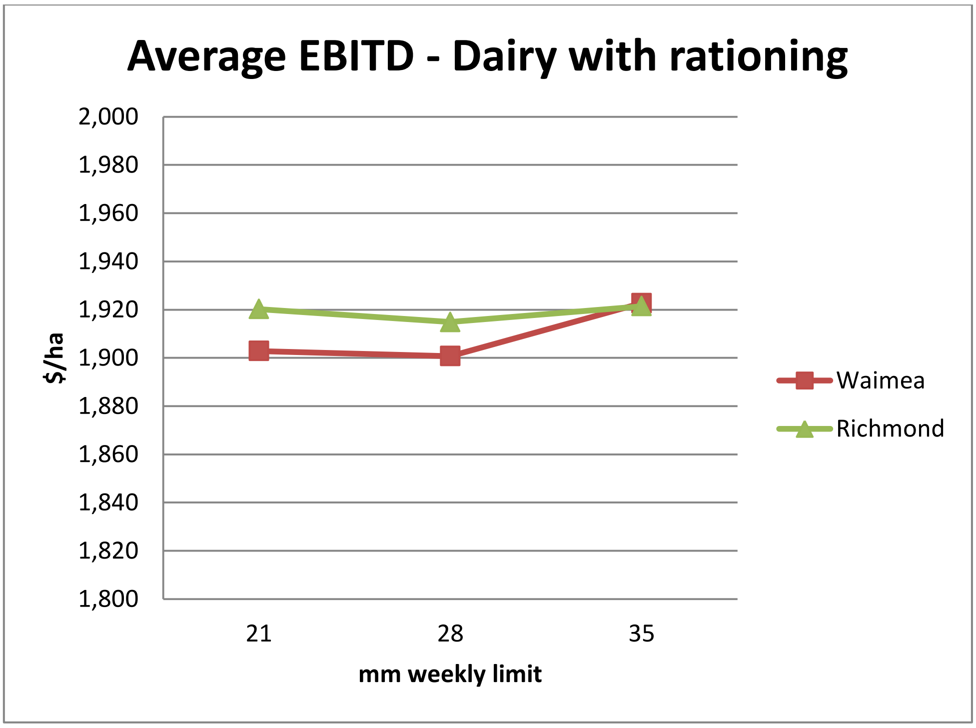

Figure 24: Dairy profit in response to irrigation allocations with water rationing.

Perhaps as expected, the production and EBITD results are more sensitive to weekly water allocation when the ‘no dam’ water rationing is imposed, especially as in some drier years, a ‘cease take’ for irrigation has been assumed at Step 4 rationing. Of the farm systems modelled, dairy and market gardening appear more resilient than grapes and apples.

13 Nitrate-Nitrogen Leaching Responses

The SPASMO model also calculates nutrient losses via leaching and runoff, including calculating nitrogen transformations within each soil layer. Losses due to runoff on the flat lands of the Waimea Plains are negligible. This section of the report summarises nitrate-nitrogen leaching losses averaged over the 40 years 1974–2013 inclusive for apples, grapes, outdoor vegetables, and dairy, for four soils, and for weekly irrigation water allocation limits of 0 (dryland), 7, 14, 21, 28 and 35 mm/week. The between-year variability in nitrate-nitrogen leaching is also presented.

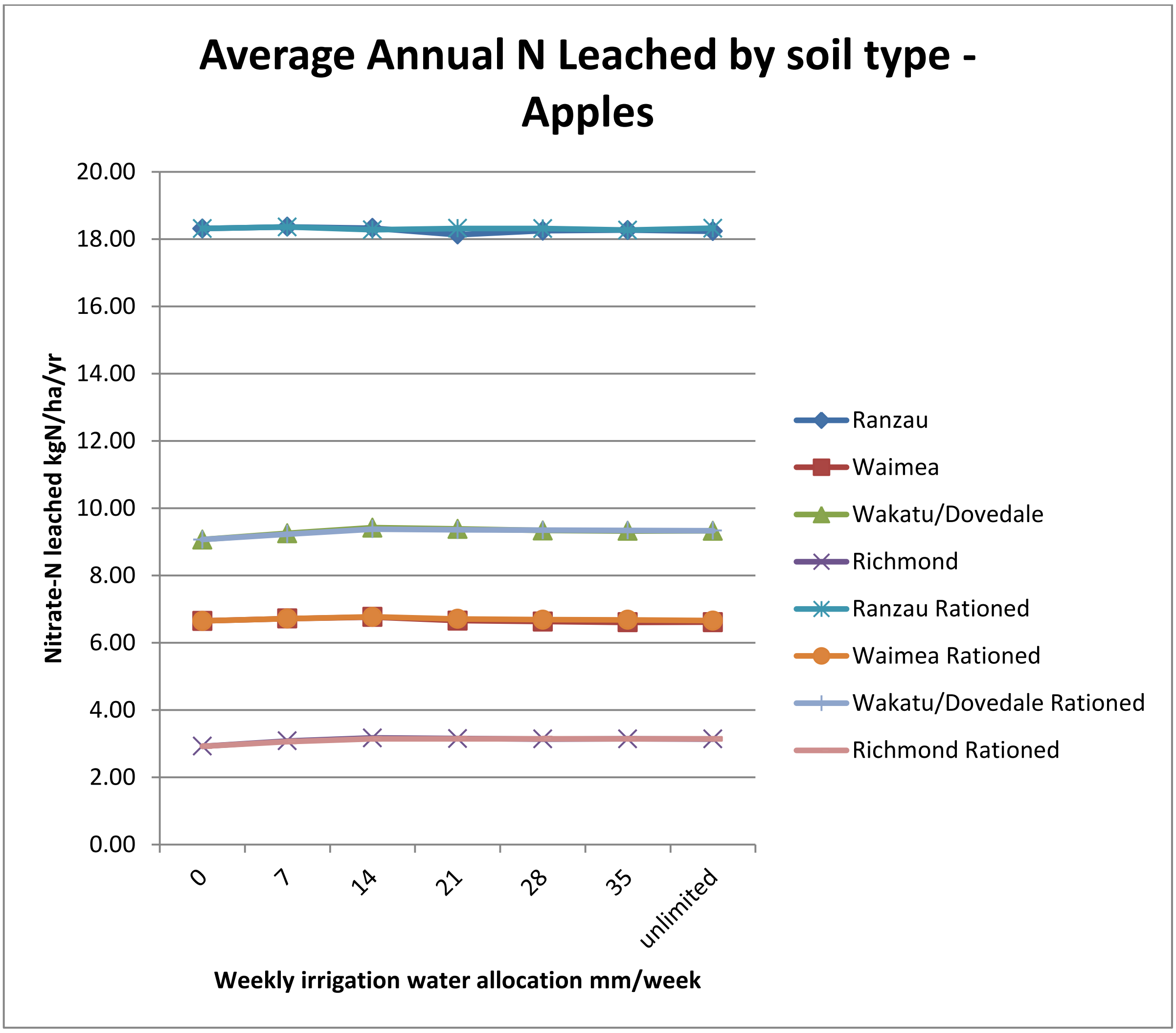

Figure 25: Nitrate leaching from apples kgN/ha/yr by soil type and core water allocation.

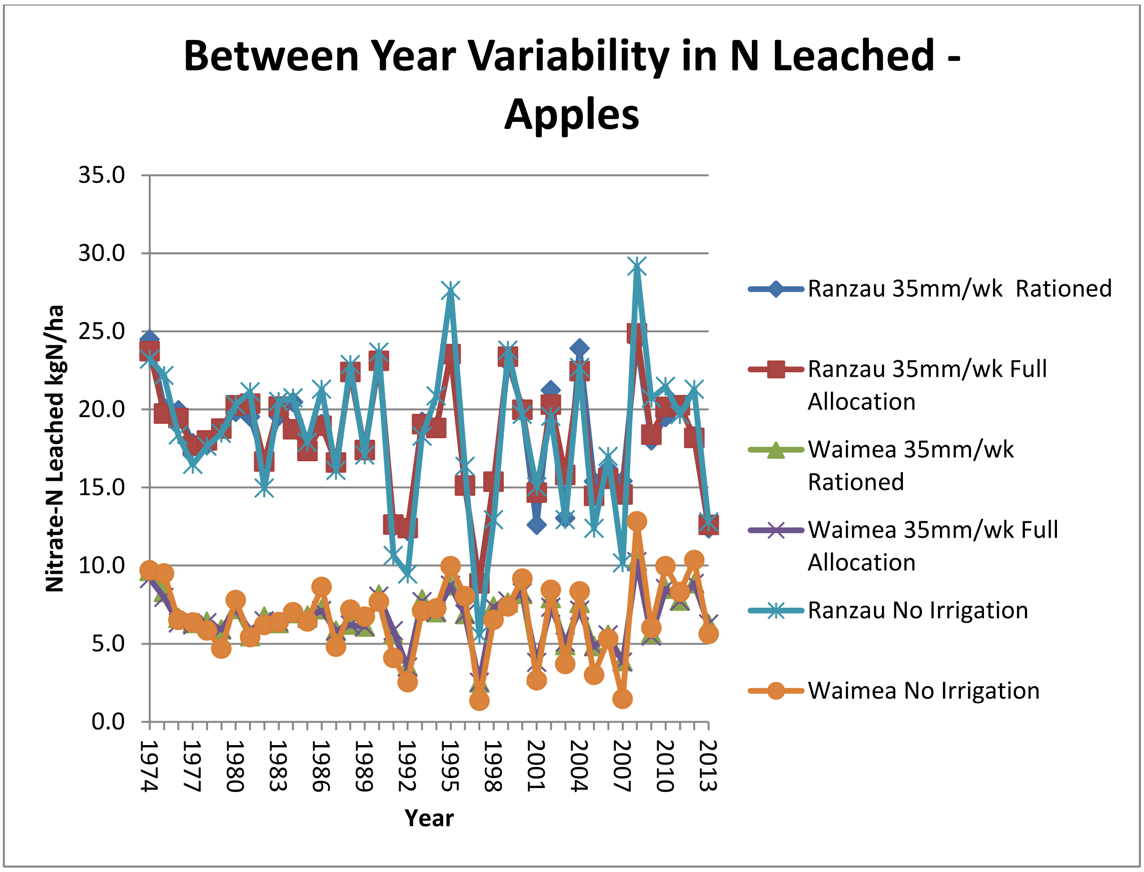

Figure 26: Year to year variation in N leaching from apples for Ranzau and Waimea soils.

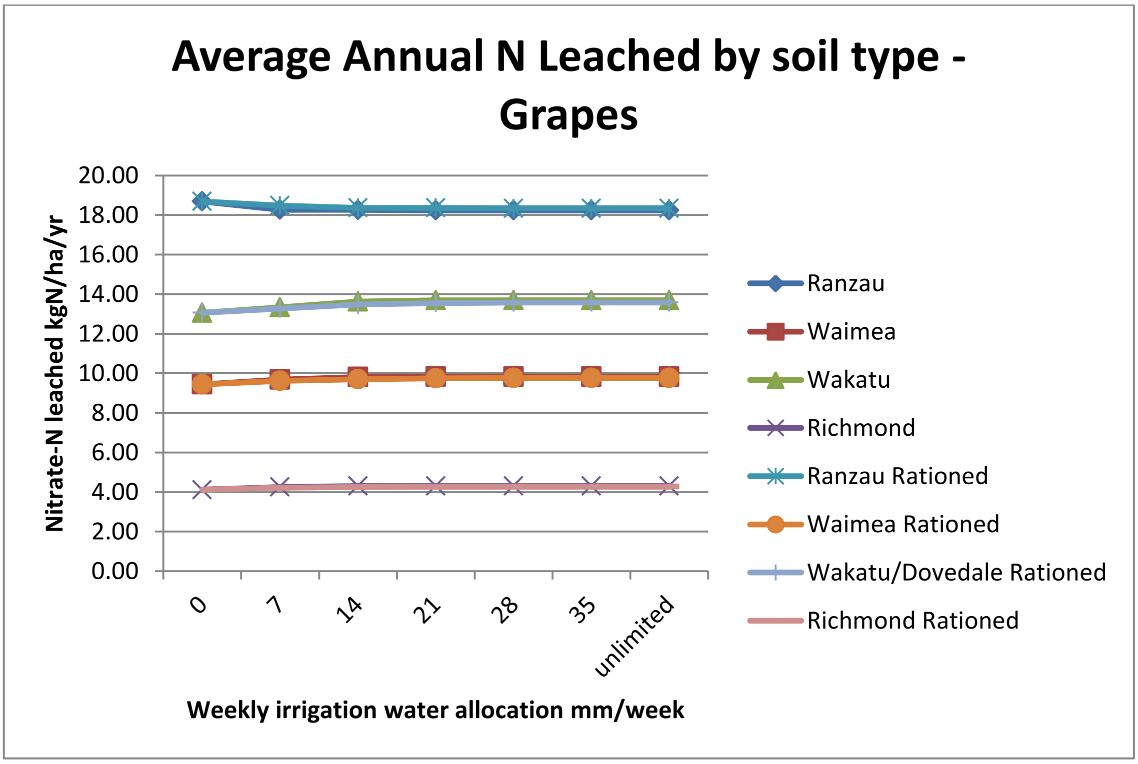

Figure 27: Nitrate leaching from grapes kgN/ha/yr by soil type and core water allocation.

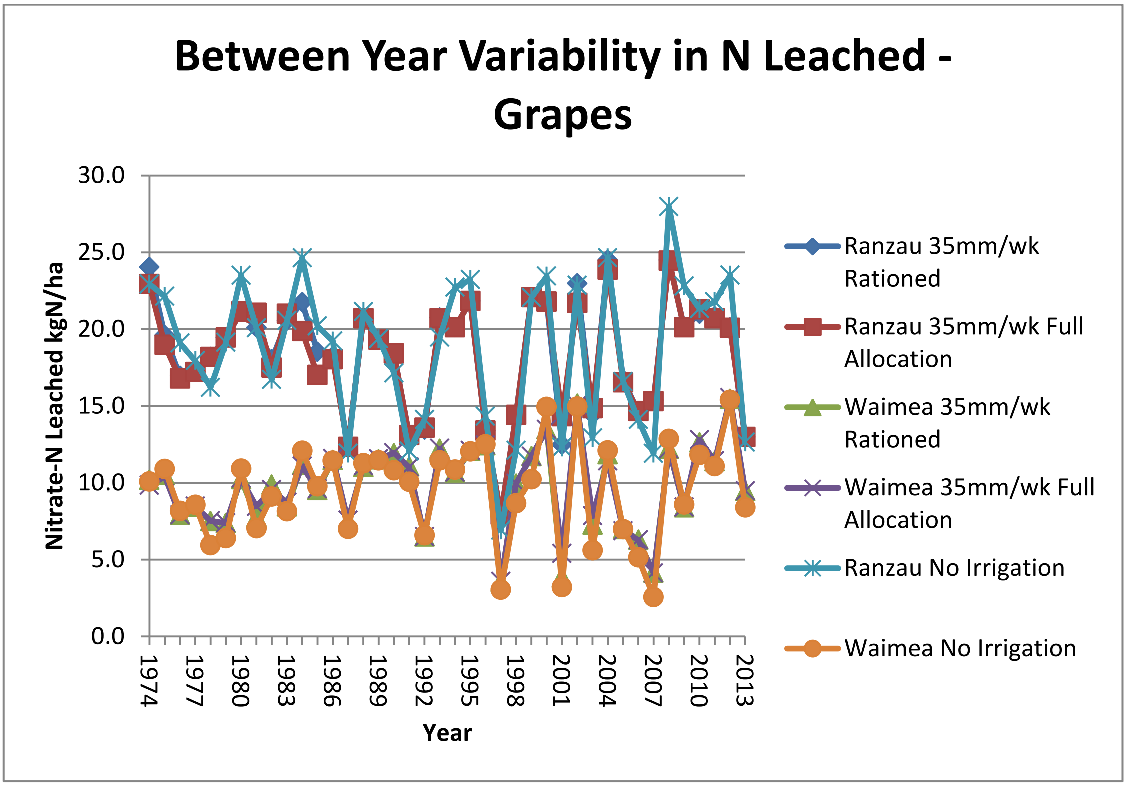

Figure 28: Year to year variation in N leaching from grapes for Ranzau and Waimea soils.

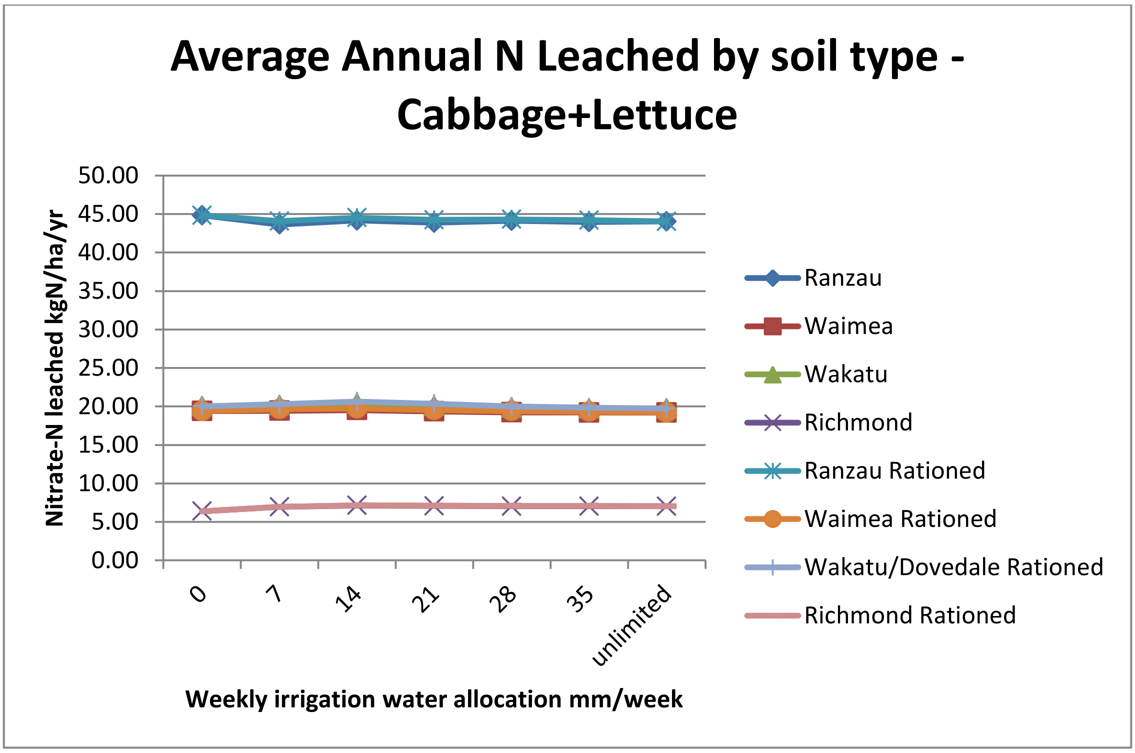

Figure 29: Nitrate leaching from cabbage followed by a lettuce crop in kgN/ha/yr by soil type and core water allocation.

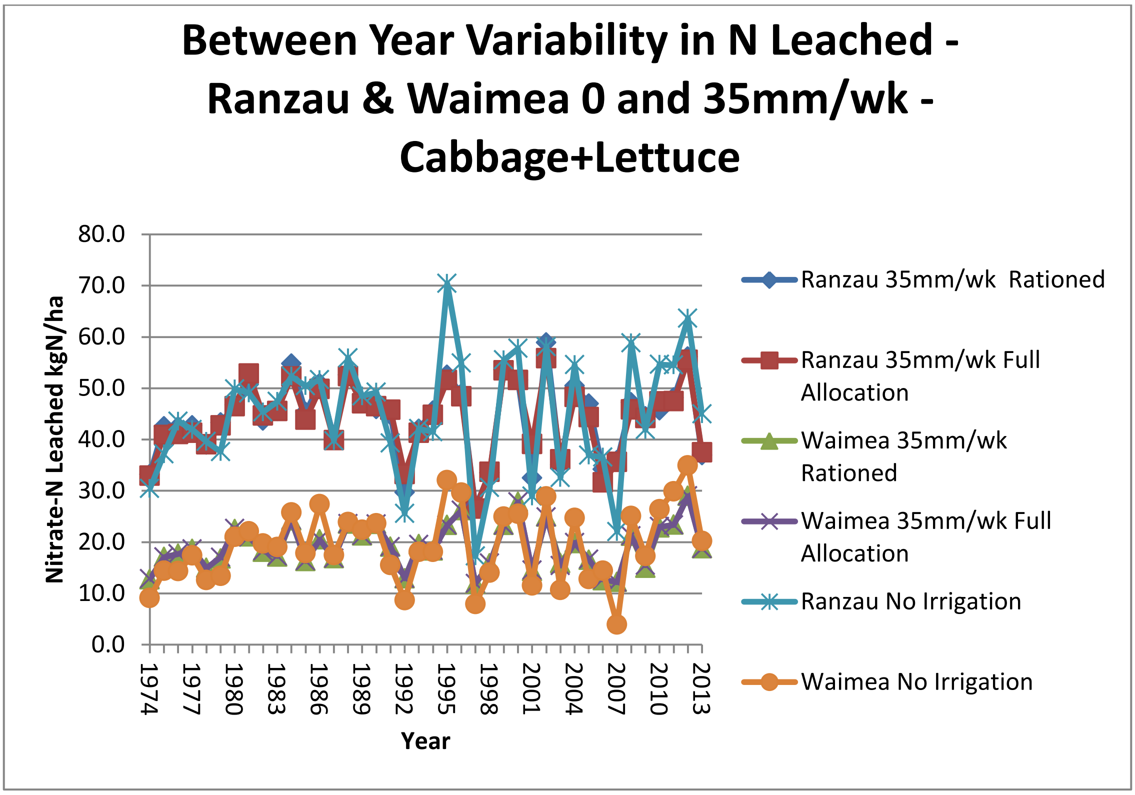

Figure 30: Year to year variation in N leaching from a cabbage/lettuce sequence for Ranzau and Waimea soils.

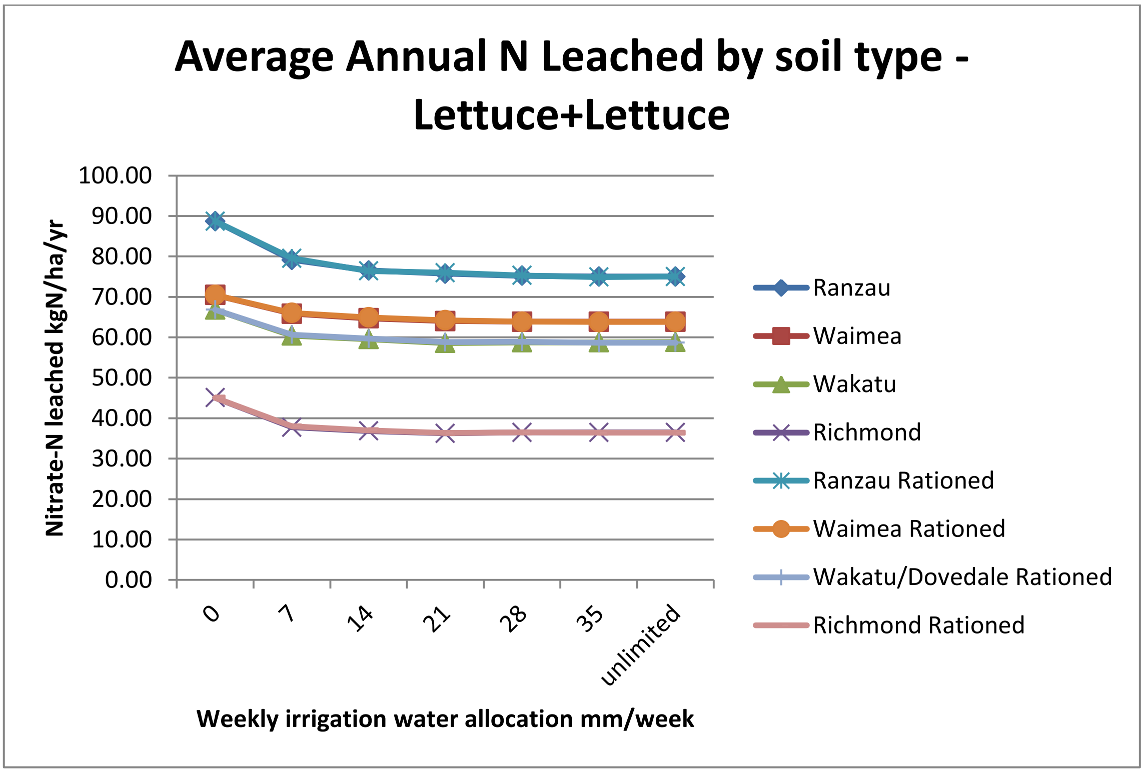

Figure 31: Nitrate leaching from lettuce followed by a lettuce crop in kgN/ha/yr by soil type and core water allocation.

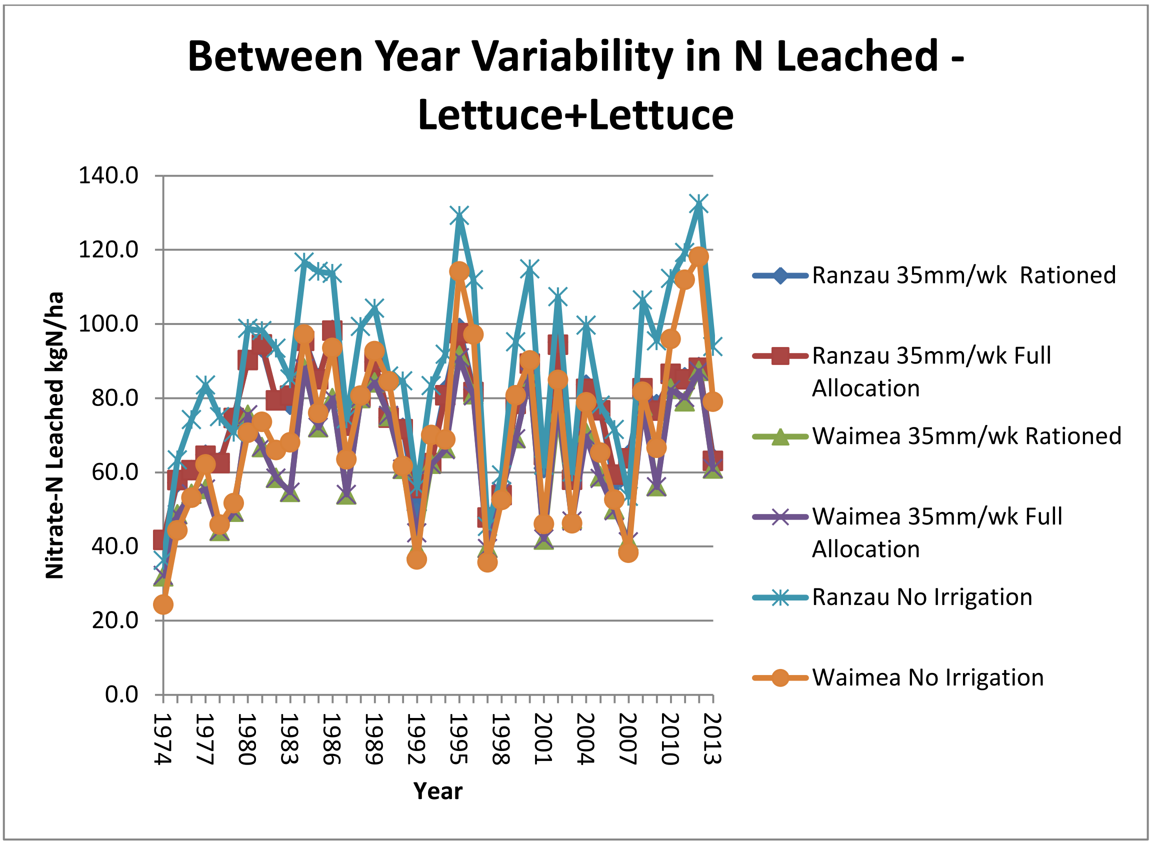

Figure 32: Year to year variation in N leaching from a lettuce/lettuce sequence for Ranzau and Waimea soils.

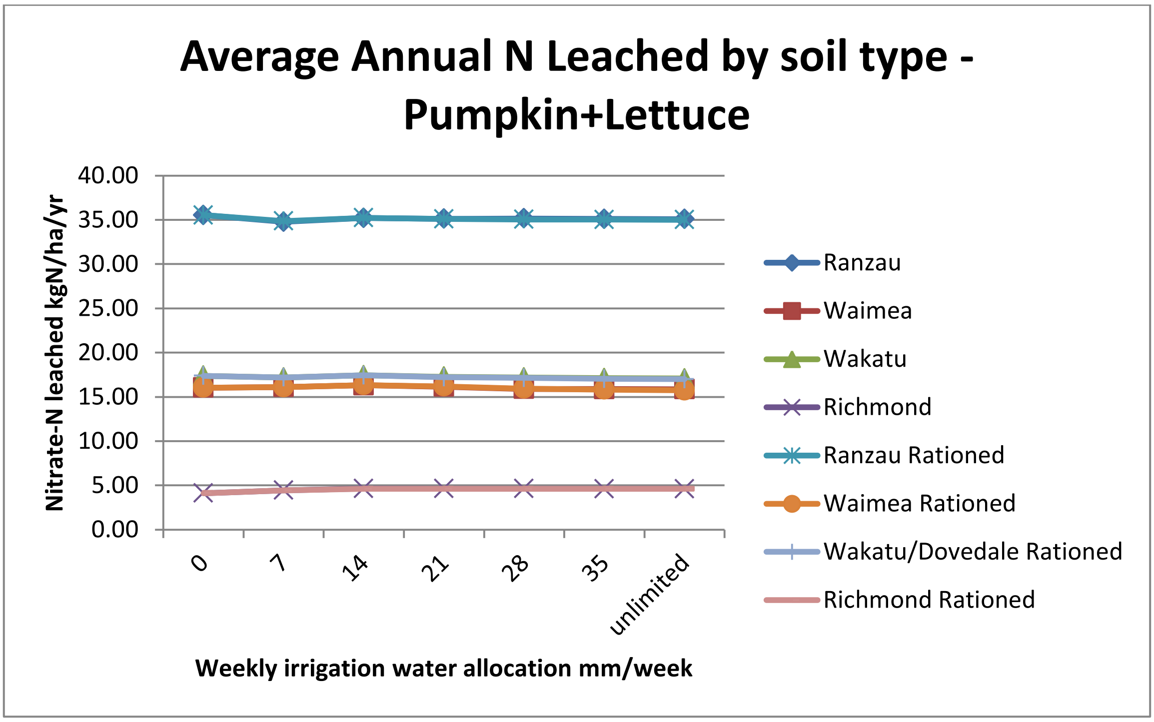

Figure 33: Nitrate leaching from pumpkins followed by a lettuce crop in kgN/ha/yr by soil type and core water allocation.

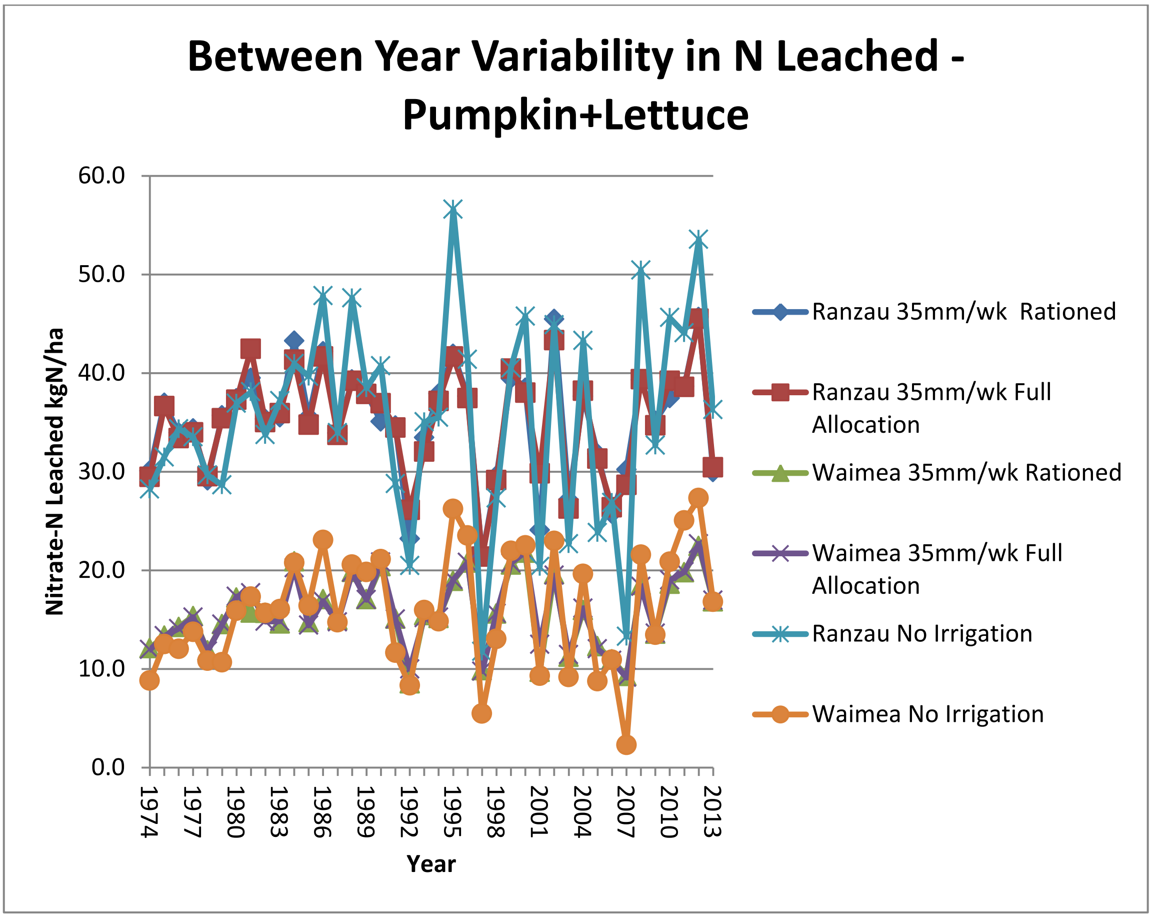

Figure 34: Year to year variation in N leaching from a pumpkin/lettuce sequence for Ranzau and Waimea soils.

Figure 35 compares the leaching rates across the three outdoor vegetable crop combinations modelled, showing that the Lettuce/Lettuce combination has particularly high nitrate losses compared with the Cabbage/Lettuce then the Pumpkin/Lettuce combination.

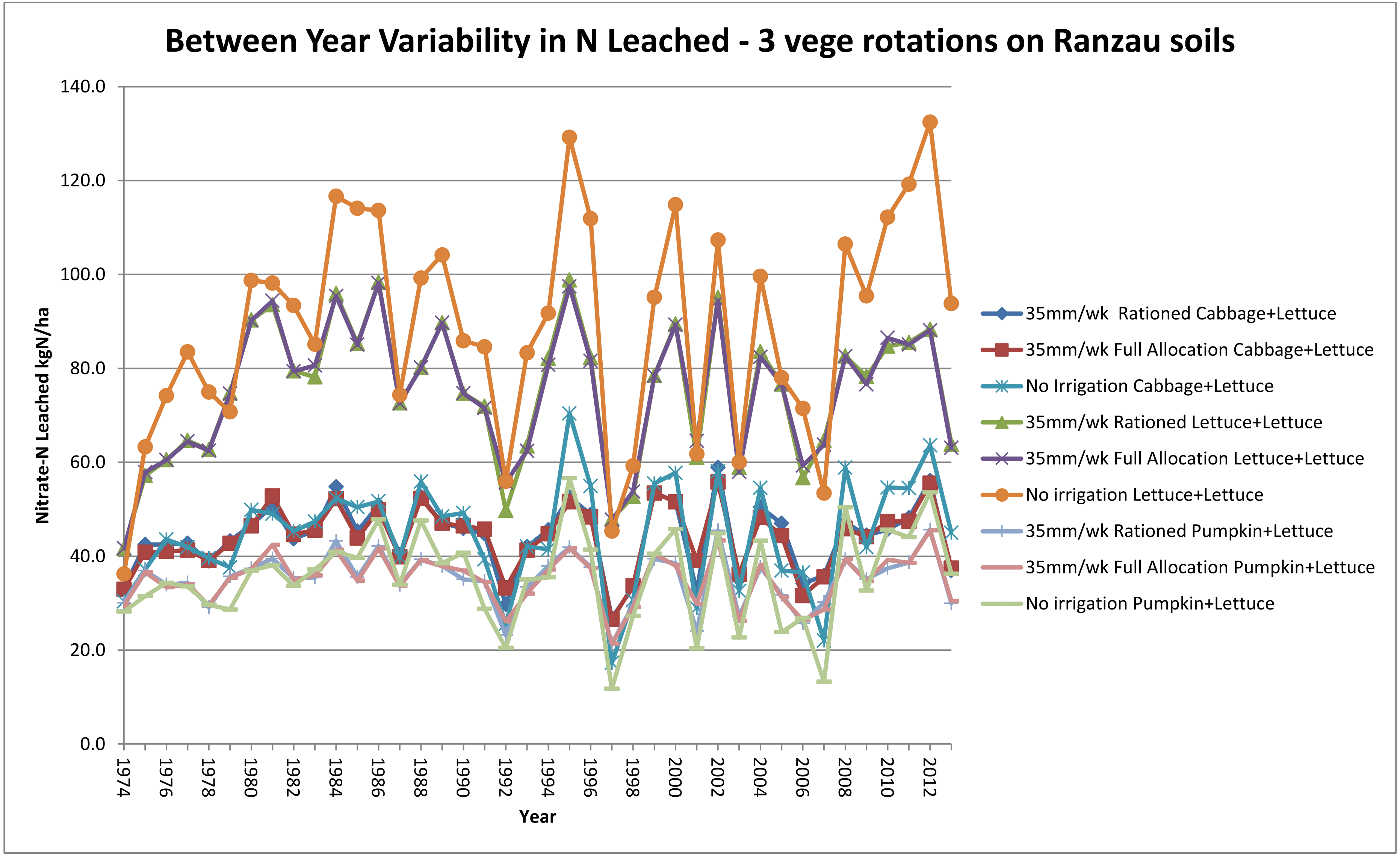

Figure 35: Year on year variability of nitrate losses from market gardening on Ranzau soils under various irrigation scenarios.

Figures 36 and 37 show the simulated nitrate losses for the dairy platform, suggesting that the Richmond soils are more able to contain nitrogen leaching than the others simulated. They also show that optimally irrigated pasture on these soils is likely to leach slightly less than pasture with low irrigation application rates, probably because the pasture is consuming nutrients more efficiently under optimal soil moisture than when it is stressed.

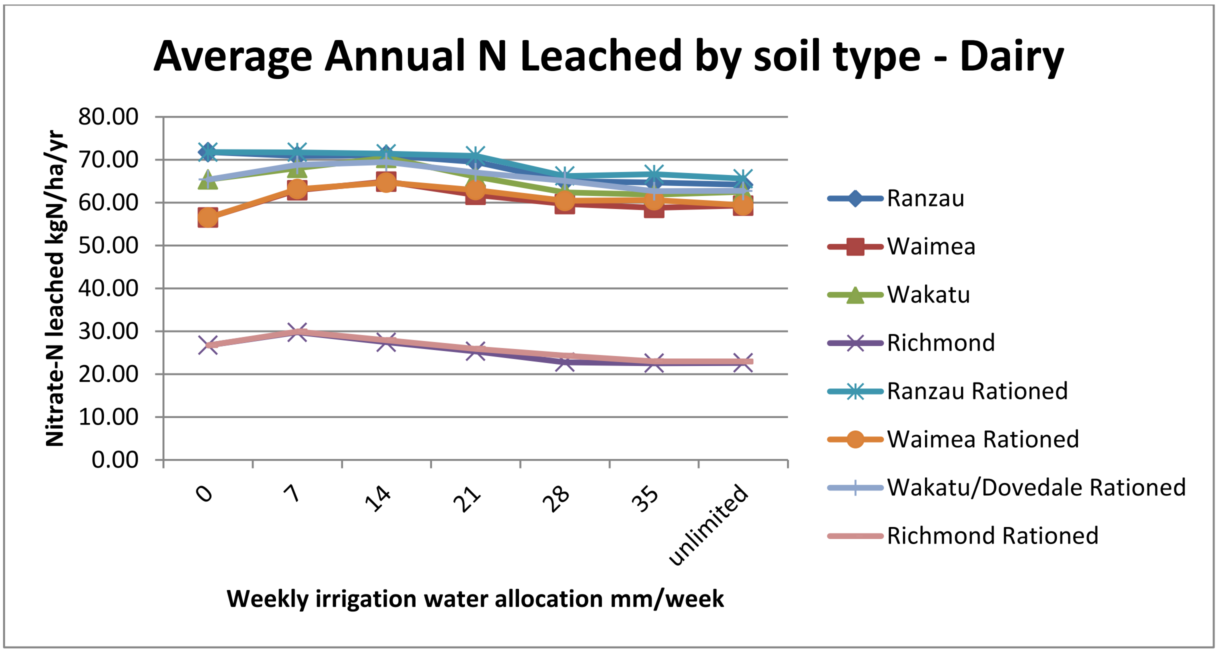

Figure 36: Nitrate leaching from dairy in kgN/ha/yr by soil type and core water allocation.

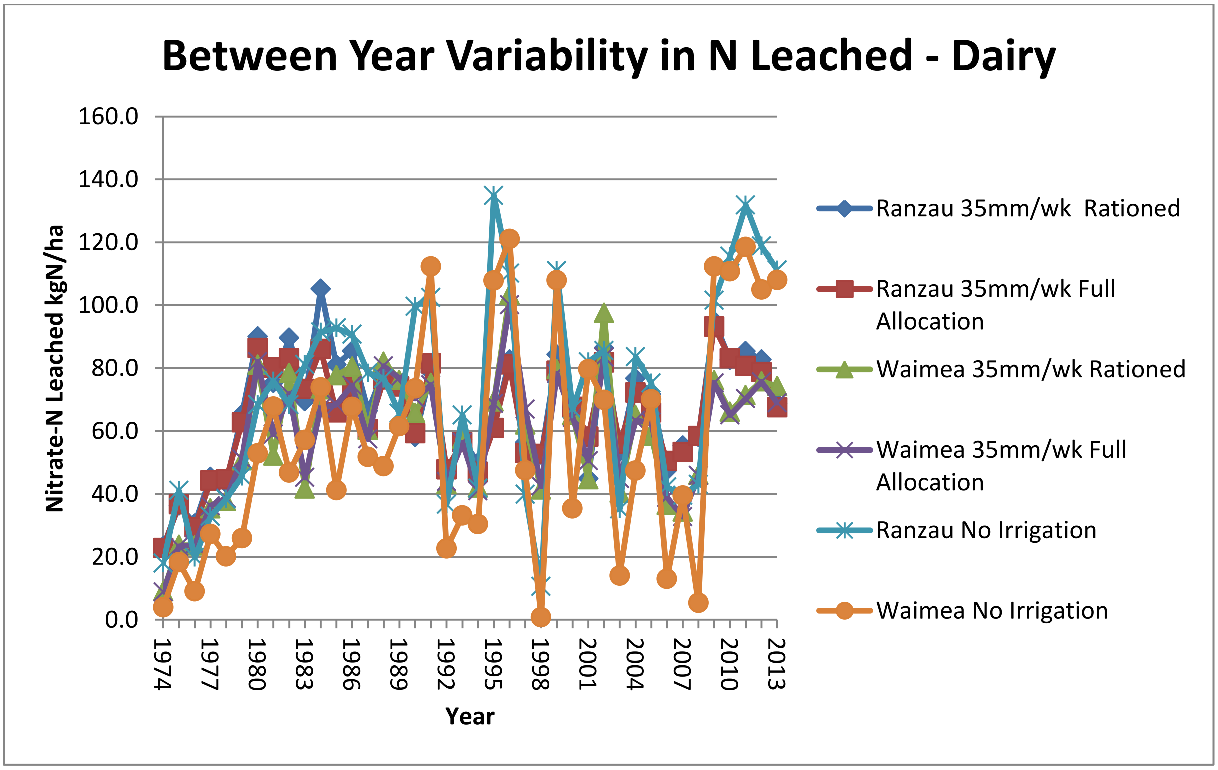

Figure 37: Year to year variation in N leaching from dairy for Ranzau and Waimea soils.

14 Nutrient Loss Mitigation options and their effectiveness

Nutrient losses from livestock farms and horticultural and arable farms can be mitigated through the adoption of farm management options. These nutrient mitigation options could range from management changes to large capital investments and significant system changes.

This section of the report reviews ways in which landowners or Council could reduce the nitrogen losses simulated in section 13. This may be necessary to meet water quality standards or limits set for receiving waters including aquifers, springs, rivers and/or the Waimea Inlet. Some potential limits were recommended in Fenemor et al (2013) which indicated that mitigation may be needed for groundwaters and spring-fed streams, at least under a future land use intensification scenario. This section is at this stage simply a literature review as further work is under way with TDC’s Waimea FLAG to decide water quality limits and management options.

14.1 Pastoral Farming

As Monaghan et al. (2007) state, nutrients excreted by animal dung and urine are the main factor determining nutrient loss from pastoral farms while the effect of fertiliser use is found to be indirect. Management changes that lead to reduction of nutrient losses in pastoral farms include managing the timing and rate of fertiliser application and managing efficiency of stock and feed.

Mitigation of nutrient losses to waterways by eliminating contact of livestock with waterways through fencing, or forcing runoff to flow through riparian buffer zones or constructed wetlands before entering waterways often has high capital costs.

Other mitigation options that involve large capital investments include constructing off-paddock facilities (feed pads, stand-off pads, and winter barns) that can intercept the deposition of dung and urine on paddocks, and upgrading effluent and irrigation systems. Restricting stocking rates and production are significant system change options that can mitigate nutrient losses in pastoral farms.

The effectiveness of the mitigation practices varies with the pastoral farming system and how the mitigation practices are used. Thus it is important to consider the underlying conditions when looking at the efficiency of nutrient mitigation practices from previous studies. These mitigation practices are in some cases considered in ‘bundles’ rather than individually (Journeaux & Wilson 2014; Daigneault et al. 2013).

Monaghan (2009) estimated nutrient reduction for mitigation practices on a dairy farm in the Bog Burn catchment while Brown et al. (2011) looked at nutrient management options in the Hurunui catchment. Journeaux and Wilson (2014) presented estimates of individual practices and bundles of practices from the Apirama catchment as well as reviewing other studies in New Zealand.

Table 14 presents the effectiveness estimates of individual nutrient mitigation practices and Table 15 presents the estimates of bundled practices from Journeaux and Wilson (2014). The effectiveness of nutrient mitigation bundles from the Hinds catchment is estimated in Daigneault et al. (2013) (Table 16).

Table 14: Effectiveness of nutrient mitigation practices from previous New Zealand studies

Mitigation	Effectiveness N (%)	Effectiveness P (%)
NZ (Journeaux & Wilson 2014 – based on a range of research and modelling work)		
Optimum soil P test	Not applicable	5–20
Low solubility P fertiliser	Not applicable	0–20
Stock exclusion from waterways	2–5	3–30
Optimal dairy effluent management	2–6	10–30
Facilitated wetlands	Data not available	<10
No winter N fertiliser	0–15	Not applicable
Nitrification inhibitors	0–35	Not applicable
Wintering cows in herd shelters	18–40	3–15
Constructed wetlands	24–50	–426 (gain)–77
Grass buffer strips	4–14	0–62
Bog Burn Catchment (Monaghan 2009)		
Nitrification inhibitors	25-–5	
Stream fencing	3–13	
Optimal effluent management	2–6	
Wintering shelters	25–35	
Restricted autumn grazing	30–50	
Low N feed	10–15	
Nil N fertiliser	20–30	
Dry stock farming	55–65	
Apirama Catchment (Journeaux & Wilson 2014)		
Stock exclusion – fencing off streams	5	17
Farm dairy effluent storage (90 day) & low volume	5	8
Constructed wetlands	8	8
No winter N fertiliser	15	0
Nitrification inhibitor	13	0
Riparian margins	n/a	n/a
Winter facilities [vs Grazing off-farm over winter]	5	0
Hurunui Catchment (Brown et al. 2011)		
Improved management of farm dairy effluence		20
Increased irrigation efficiency	10	
Stock exclusion from streams and wetlands		High
Nutrient management plans	High	High
Use of nitrification inhibitors	10–15	
Wintering cows in Herd Shelters	32	
Wintering in Herd Shelter+ Restricted grazing of pastures in autumn	49	
Limiting N fertiliser use	40	
Changing from border dyke to spray irrigation		20
Tracks and lanes sited away from streams & lane runoff diverted to land	Medium	
Substituting N-fertilised pasture with low N feeds	Modest	
Grass buffer strips	Modest – Low	
Facilitating the development of natural wetlands	Medium	
Constructed wetlands	High	

Table 15: Effectiveness of bundles of practices – Apirama catchment (Journeaux * Wilson 2014)

Mitigation Practice	N reduction (%)	P reduction (%)
Dairy		
Stock exclusion i.e. fencing off streams (FW)	5	17
FW + Farm dairy effluent storage (ES)	8	25
FW + ES + No winter N (NWN)	23	25
FW + ES + NWN + Nitrogen inhibitor (NI)	35	25
FW + ES + NWN + NI + Riparian Strips (RS)	35	25
FW + ES + NWN + NI + RS + Wintering facilities (WF)	38	33
FW + ES + NWN + NI + RS + WF + Constructed wetlands	40	33
Sheep and Beef		
Stock exclusion i.e. fencing off streams (FW)	0	0
FW + Facilitated wetlands (Wet)	0	0
FW + Wet + Riparian Strips (RS)	0	50

Table 16: Effectiveness of bundles of practices – Hinds catchment (Daigneault et al. 2013)[4]

Management Bundle	Management bundle description	Effectiveness N (%)		
		Dairy	Dairy Support	Sheep and Beef
Good Management Practices (GMP)	Reduction in fertiliser in crops following large winter depositions of nitrogen Dairy to install effluent storage for 30+ days and greater reduction in N use on effluent applied land	0–8	3–5	0
Advanced Mitigation Level 1 Practices (Management changes) (AM1)	Installation of soil moisture monitoring gear and VRI on existing centre pivots No urea applications in May Adjust cropping fertiliser rates and types to best suit plant requirements and timings Use of yield maps to define an assumed 10% of the paddock which only yields half of the paddock average Use variable rate fertiliser technology Limit each urea application to <140 kg/ha Variable Rate Fertiliser Gibberellic Acid to substitute some Spring and Autumn Nitrogen on pastures DCD (Dicyandiamide) Use combined with nitrogen based fertiliser reductions to match Mixed Pasture Sward Short Rotation Ryegrass and White Clover Pasture Modify existing centre pivot irrigators to Variable Rate Irrigation technology on 90% of area Optimise stocking rates	20–60	45–54	30–33
Advanced Mitigation Level 2 Practices (Capital investment) (AM2)	Modify 90% of irrigated area to include centre pivots/laterals fitted with Variable Rate Irrigation technology Employ Normalised Difference in Vegetative Index (NDVI) sensing technology and consequent Variable Rate application of liquid urea Dairy farms to install covered feed pads and required effluent systems	54–63	60–69	30–50
Advanced Mitigation Level 3 Practices (System change) (AM3)	Reduce nitrogen fertiliser applications by 15% and model appropriate reductions in production Reduce stocking rates by 10% (without increasing production to compensate) All cows wintered in barns and dairy farms grow sufficient winter feed (fodder beet to lift) No winter feed crop yields over 14t/ha	78–85	78–85	30–56

Note: In the Hinds Catchment, 2 dairy systems (System4 and System 5), 2 dairy support systems (Fully irrigated system and part irrigated/high rainfall system), and 2 sheep and beef systems (dry land system and part irrigated system) were modelled.

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[4] Mitigations based on Everest (2013),available at http://ecan.govt.nz/publications/Plans/report-hinds-catchment-nutrient-farm-economic-modelling.PDF

14.2 Horticulture and Arable

According to the AgriBusiness Group (2014a), nutrient losses occur mainly due to the relative inefficiency of N use caused by fertiliser and crop residue in horticultural production. This study lists the following issues as causes of N leaching in vegetable growing operations:

- High use of applied N as a result of sparse root systems for the crops (particularly when they are immature)
- Poor N use efficiency
- Short growth periods and therefore (in some cases) multiple crops in one year
- Grown over winter when leaching rates are high due to high rainfall and saturated soils
- Large amounts of crop residue left in the paddock after harvest, which is worked into the soil.

Hence the mitigation options are mainly focused around fertiliser management and crop rotation. The AgriBusiness Group (2014a, b) estimated the effectiveness of nutrient mitigation practices on horticultural farms in the lower Waikato (Table 17) and Horizons regions (Table 18). Daigneault et al. (2013) also presented the effectiveness of nutrient mitigation bundles in arable farms in the Hinds catchment (Table 19).

Table 17: Effectiveness of nutrient mitigation practices for Horticulture Lower Waikato (AgriBusiness Group 2014a)

Scenario	**Average change in N leach (%)**		
	Rotation 1	**Rotation 2**	**Rotation 3**
Limiting N in each application to 80 KgN/ha	3	–6	–5
10% reduction in N	–7	–12	–11
20% reduction in N	–10	–17	–19
30% reduction in N	–16	–22	–30
40% reduction in N	–21	–28	–40
Altering irrigation	–7	–3	–11

Note: Rotation 1: Potato (summer) > Onions > Carrots > Squash > Oats and Rye > Barley (grain) > Oats and Rye

Rotation 2: Squash > Broccoli > Oats and Rye > Lettuce (summer) > Mustard > Onions > Oats and Rye> Potato (Winter)

Rotation 3: Broccoli > Mustard > Lettuce > Cabbage > Mustard > Spinach > Cauliflower > Cabbage >Mustard

Table 18: Effectiveness of nutrient mitigation practices for Horticulture - Horizons (AgriBusiness Group 2014a)

Scenario	**Average change in N leach (%)**			
	Rotation 1	**Rotation 2**	**Rotation 3**	**Rotation 4**
Limiting N in each application to 80 KgN/ha	–7	–8	0	–6
10% reduction in N	0	–4	–5	0
20% reduction in N	–7	–8	–10	–6
30% reduction in N	-7	–15	–21	–6
Altering irrigation	–7	0	–8	–6
Altering tillage practice	0	–4	–10	–6

Note: Rotation1: Pasture (8 years) > Potatoes > Barley > Pasture

Rotation2: Pasture (2 years) > Cabbage > Lettuce > Spinach > Squash > Onions > Pasture

Rotation 3: Broccoli > Spinach > Lettuce > Cabbage > Cauliflower > Cabbage

Rotation 4: Pasture (8 years) > Potato > Carrots > Brussel Sprouts

Table 19: Effectiveness of bundles of practices for Arable land uses – Hinds catchment (Daigneault et al. 2013)[5]

Management Bundle	**Management bundle description**	**Effectiveness N (%)**			
		Arable 1	**Arable 2**	**Arable 3**	**Arable 4**
Good Management Practices (GMP)	Reduction in fertiliser in crops following large winter depositions of nitrogen Dairy to install effluent storage for 30+ days and greater reduction in N use on effluent applied land	0	0	0	0
Advanced Mitigation Level 1 Practices (Management changes) (AM1)	Installation of soil moisture monitoring gear and VRI on existing centre pivots No urea applications in May Adjust cropping fertiliser rates and types to best suit plant requirements and timings Use of yield maps to define an assumed 10% of the paddock which only yields half of the paddock average Use variable rate fertiliser technology Limit each urea application to <140 kg/ha Variable Rate Fertiliser Gibberellic Acid to substitute some Spring and Autumn Nitrogen on pastures DCD (Dicyandiamide) Use combined with nitrogen based fertiliser reductions to match Mixed Pasture Sward Short Rotation Ryegrass and White Clover	55	38	44	0

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[5] Ibid, footnote 3

	Pasture Modify existing centre pivot irrigators to Variable Rate Irrigation technology on 90% of area Optimise stocking rates				
Advanced Mitigation Level 2 Practices (Capital investment) (AM2)	Modify 90% of irrigated area to include centre pivots/laterals fitted with Variable Rate Irrigation technology Employ Normalised Difference in Vegetative Index (NDVI) sensing technology and consequent Variable Rate application of liquid urea Dairy farms to install covered feed pads and required effluent systems	65	52	56	25
Advanced Mitigation Level 3 Practices (System change) (AM3)	Reduce nitrogen fertiliser applications by 15% and model appropriate reductions in production Reduce stocking rates by 10% (without increasing production to compensate) All cows wintered in barns and dairy farms grow sufficient winter feed (fodder beet to lift. No winter feed crop yields over 14 t/ha.	65	55	67	25

Note: Arable 1: Process crops, Arable 2: Small seeds, Arable 3: Livestock and cereal - part irrigated, Arable 4: Livestock and cereal – dry land

Horticulture New Zealand (2014) has developed a Code of Practice for horticultural operations. The Code highlights the difficulty of providing recommendations that fit all operations, given the wide range in scale and intensity of operations and multiple variables of crops, rotations, rainfall, topography and soil types.

The Code is based on a risk assessment approach with five steps:

1. Understanding how nutrient loss occurs and the potential risks: knowledge of movement of nutrients through soil and water and, factors contributing to nutrient loss

2. Having appropriate information on which to base decisions to address the risk: soil tests, paddock history, crop history, rotation and crop selection, and rainfall

3. Assessing the risks within a specific situation: use of the risk template to identify the risk for each contributing factor, and determine the level of risk for the operation

4. Identifying and implementing appropriate management practices to address the identified risks based on the stages of crop cycle (pre-planting, planting and ground preparation, post planting, harvest and post-harvest)

5. Maintaining records to verify how the management practices have been implemented.

The Code lists a range of management practices that can help reduce nutrient losses. They are either Good Management Practices (GMPs) or Best Management Practices (BMPs) and based on the stages of crop cycle, while some can be applied across all crop cycles. These management practices are grouped according to nutrient management and irrigation management.

Horticulture New Zealand does not provide information on the effectiveness of the recommended management practices as they can vary based on the operations. However, the code of practice comes with a checklist that a grower can use to identify the GMPs and BMPs that will be most appropriate for the operation.

Table 20 lists the recommended management options.

Table 20: Management practices to reduce nutrient losses in horticultural operations (Horticulture NZ 2014)

Management Practice			
Pre-planting	**Planting**	**Post-planting**	**Harvest and post- harvest**
Undertake a paddock assessment and plan to ensure that appropriate GMP's and BMP'S are selected	Cultivate soil when conditions appropriate. Minimise soil tillage as much as practicable	Side dressings used to reduce risk.	Use of Cover crops (green feed, oats, mustard, other biological activates) can reduce losses and nutrient use. "Grassing down" increases organic matter
Estimate the residue from the previous crop and any carry over nitrogen such as through the crop not yielding full potential	Plant a row of grain or a cover crop at appropriate intervals as a shelter belt to prevent wind erosion of soil	Proof of operator following management instructions for application, including avoiding spreading into water bodies	Remove as much harvestable crop as possible
Soil testing is conducted on each paddock every 3–5 years	Use contour cropping, including contour rows as a headland near creeks and drains	Nutrient levels are managed according to rainfall, informed by deep N testing and will match likely yield and quality goals	Remove or incorporate crop residues where possible
Soil testing uses a uniform or representative collection pattern	Use riparian margins or buffer strips beside streams and drains	Leaf tests are conducted	
Soil testing is conducted on each paddock every year when a crop is going to be planted	Methods are used to minimise sediment runoff	Plant growth stage dictates volume applied.	
Soil testing is conducted every year based on GPS mapping	Manually assess soil for compaction relative to crop rooting depth and take appropriate action	Water is applied to maintain soil moisture between the wilting point and field capacity	
Nutrient levels are managed according to rainfall, informed by deep N testing and will match likely yield and quality goals	Assess soil for compaction using a penetrometers	Irrigation applied allows achievement of the yield target for fertiliser applied	
Choosing appropriate crops	Adoption of new technology. e.g. use of sub-soil aerator will allow roots deeper into soil	Irrigation efficiency is measurable at greater than 80%	

Plan fertiliser inputs for the crop – both base and side dressings – based on scientific evidence that is available or informed by fertiliser recommendations	Nutrient applications are informed by available information or fertiliser recommendations	Water is metered
Applications of N are managed to taking into account rainfall, field capacity and soil saturation levels	Fertiliser applications are applied relative to the predicted uptake levels of the plant from planting to maturity	On site soil moisture monitoring is conducted
Take into account any organic manures used Ensure that timing of application does not present risk of leaching	Fertiliser spreading equipment is calibrated and can accurately deliver the recommended treatment	Irrigation is variably applied within the paddock to maximise efficiency
Take into account any animals in the rotation	Crop calculators may be used if available and practical for local conditions	Highly automated irrigation systems that allow more frequent applications of less water
Calibrate fertiliser spreading equipment – simple method or complex method	Use improved fertiliser technology where appropriate (e.g. prills/coatings)	Irrigation scheduling is undertaken using a crop model or tied into a soil moisture monitoring system
Obtain advise from a nutrient Fertiliser Advisor or agronomist	Controlled traffic farming technology to increase application efficiency and soil management. Advanced farming systems that make use of GPS mapping and aerial photography	
Plan irrigation requirements	Proof of operator following management instructions for application, including avoiding spreading into water bodies	
	Irrigators are calibrated to ensure that the volume and spread of the water is evenly applied	

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16 References

AgriBusiness Group 2014a. Nutrient performance and financial analysis of Lower Waikato Horticulture Growers. Available online at http://hortnz.co.nz/assets/Uploads/nutrient-performance-and-financial-analysis-of-lower-waikato-horticulture.pdf

AgriBusiness Group 2014b. Nutrient performance and financial analysis of Horticultural Systems in the Horizons Region. Available online at http://hortnz.co.nz/assets/Uploads/Nutrient-Performance-and-Financial-Analysis-of-Horticultural-Systems-in-Horizons-Region-02.pdf

Brown I, Norton N, Wedderburn L, Monaghan R, Harris S, Hayward S, Ford R. 2011. Nutrient management in Hurunui: a case study in identifying options and opportunities. Environment Canterbury Report R11/114. 57 p.

Daigneault A, Samarasinghe O, Lilburne L 2013. Modelling economic impacts of nutrient allocation policies in Canterbury: Hinds Catchment. Landcare Research Report LC1490. 143 p. Available online at http://www.mfe.govt.nz/publications/fresh-water/modelling-economic-impacts-nutrient-allocation-policies-canterbury-hinds

Dairy NZ 2012. Facts and figures for New Zealand dairy farmers. Version 2. Dairy NZ. 92 p.

Dicker MJI, Fenemor AD, Johnston MR 1992. Geology and groundwater resources of the Waimea Plains, Nelson. Geological Bulletin. Lower Hutt, DSIR Geology and Geophysics. 59 p.

Fenemor AD 2013. Summary of hydrology and water management bases for decisions on Waimea water management, with and without water augmentation. Landcare Research contract Report LC1647 to inform Tasman District Council plan change C47. 25 p.

Fenemor AD 1988. A three-dimensional model for management of the Waimea Plains Aquifers, Nelson. Hydrology Centre Publication No. 18. Lower Hutt, DSIR. 133 p.

Fenemor AD, Lilburne L, Young RA, Green S, Webb T 2013. Assessing water quality risks and responses with increased irrigation in the Waimea Basin. Landcare Research Report LC1246 for the Waimea Water Augmentation Committee, Tasman District. 42 p.

Green S, Manderson A, Clothier B, Mackay A 2012. SPASMO modelling of water and nutrients using a GIS framework to estimate catchment loads. Appendix 1 in Rutherford (2012) Modelling the effects of land use on nutrients entering the Tukituki River, Hawke's Bay, NIWA report HAM2012-077 for Hawke's Bay Regional Council.

Green SR, Clothier BE, van den Dijssel C, Deurer M, Davidson P 2008. Measurement and modelling the stress response of grapevines to soil-water deficits in their rootzones. In: Ahuja L. eds. Modeling the response of crops to limited water: Recent advances in understanding and modeling water stress effects on plant growth processes. Soil Science Society America Monograph.

Green SR, van den Dijssel C, Sivakumaran S, Dowling W, Stiefel H 2006. Better wine quality without environmental compromise: a summary of trial results from the Gimblett Gravels project (Year 3). HortResearch client report 16568 to NZ Winegrowers Association. 40 p.

Green S, Manderson A, Clothier B, Mackay A 2012. SPASMO modelling of water and nutrients using a GIS framework to estimate catchment loads. Client report prepared for Hawke's Bay Regional Council, Report number PFR SPTS No. 6846, Plant and Food Research. Included as Appendix 1 in Rutherford K 2012. Modelling the effects of land use on nutrients entering the Tukituki River, Hawke's Bay. Report prepared for Hawke's Bay Regional Council, NIWA Client Report number HAM2012-077. Auckland, National Institute of Water & Atmospheric Research.

Horticulture New Zealand 2014. Code of practice for nutrient management. Available online at http://www.hortnz.co.nz/users/Image/Downloads/PDFs/Code%20of%20Practice%20for%20Nutrient%20Management%20v%201-0%2029%20Aug%202014.pdf

Journeaux P, Wilson K 2014.Economic analysis of the impact on farming of limiting the loss of nitrogen and phosphorus – A catchment case study: Aparima (Southland). MPI Technical Paper No: 2014/20. Available online at http://www.mpi.govt.nz/document-vault/4149

McIndoe I 2002. Efficient and Reasonable Use of Water for Irrigation, Report U01/69, Environment Canterbury.

Monaghan RM, Hedley MJ, Di HJ, McDowell RW, Cameron KC, Ledgard SF 2007. Nutrient management in New Zealand pastures— recent developments and future issues. New Zealand Journal of Agricultural Research 50(2):181–201.

Monaghan RM 2009. The BMP Toolbox – selecting the right best management practice for mitigating farming impacts on water quality. In: Currie LD, Yates LJ eds Nutrient management in a rapidly changing world. Fertilizer and Lime Research Centre Occasional Report No. 22. Pp. 328–334.

Rosen MR, Reeves RR, Green SR, Clothier BE, Ironside N 2004 Prediction of groundwater nitrate contamination after closure of an unlined sheep feedlot in New Zealand. Vadose Zone Journal 3: 990–1006.

Appendix 1 – Soils Base Data (Trevor Webb, Landcare Research, pers. comm.)

top	bot	Texture	rhob	stones	PG	thetas	thetan	alpha	n	m	tot C	tot N	Pret	Ksat	VF clay	VF sand	FC (%v/v)	WP (%v/v)
Ranzau NZ soils databse SB09694																		
0	22	stony silt loam		15							3.4	0.29	32		29	36		
22	31	stony silt loam		25							2.1	0.17	35		29	36		
31	51	v. stony silt loam		40							1.2	0.11	38		25	46		
51	75	v. stony silt loam		35							0.9	0.08	37		27	39		
Ranzau SB09355											SB09355							
0	28										4.4							
28	44										1.6							
44	65										1							
65	85										0.7							
85	105										0.5							
105	125										0.5							
Ranzau SB09356											SB09356							
0	18										5.1							
18	36										2							
36	60										1.6							
60	95										1.6							
95	115										0.6							
Ranzau SB09356											SB09389							
0	25										4.6							
25	40										2.9							
40	52										1.1							
52	80										0.8							
80	110										0.5							
Ranzau (file data - Waimea Plains irrigation, Whites Rd, Hope)																		
0	22	stony silt loam	1.15	10	*2.65*	*56.6*								200			25.9	13.3
22	45	v. stony silt loam	1.01	38	*2.65*	*61.89*								70			24.8	10.1
45	60	v. stony silt loam		55										70				
60	100+	silty clay												*5*				
Ranzau (file data - Waimea Plains irrigation, Hoddy's House block, Hope)																		
0	22	v. stony silt loam	0.79	35	*2.65*	*70.19*								70			24.5	13.0
22	55	v. stony silt loam	0.81	54	*2.65*	*69.43*								70			29.6	10.0
55	100+	v. stony silt loam		65										*100*				
Ranzau (file data - Waimea Plains irrigation, Hoddy's House block, Hope)																		
0	26	stony silt loam	1.03	23	*2.65*	*61.13*								200			28.0	12.8
26	52	v. stony silt loam	0.68	43	*2.65*	*74.34*								80			17.3	7.8
52	72	v. stony silt loam		55										80				
72	100+	v stony coarse sand		65										*500*				
Ranzau composite																		
0	22	stony silt loam	*1.15*	*15*	2.65	56.6					*3.4*	*0.29*	*32*	200	*30*	*36*	*28.0*	*13.0*
22	31	v. stony silt loam	*1.01*	*25*	2.65	61.89					*2.1*	*0.17*	*35*	70	*30*	*36*	*25.0*	*11.0*
31	80	v. stony silt loam	*0.8*	*40*	2.65	69.81					*1.2*	*0.11*	*38*	70	*25*	*46*	*20.0*	*8.0*
80	100+	v stony loamy sand	*0.8*	*60*	2.65	69.81					*0.5*	*0.06*	*37*	*300*	*8*	*80*	*15.0*	*6.0*
Wakatu/Dovedale (file data - Waimea Plains irrigation, Patons Rd)											C and N based on Princhester soil							
0	15	silt loam	1.23	0	*2.65*	*53.58*					*6*	*0.5*	*40*	*100*	*25*	*10*	35.9	11.7
15	38	silt loam	1.43	0	*2.65*	*46.04*					*3.5*	*0.3*	*60*	*50*	*30*	*10*	33.7	17.2
38	48	stony silty clay loan	1.5	15	*2.65*	*43.4*					*0.8*	*0.06*	*50*	*2*	*40*	*20*	34.8	19.2
48	100+	v. stony sandy silt l	1.3	60	*2.65*	*50.94*					*0.6*	*0.04*	*30*	*20*	*15*	*75*	*18.0*	*7.0*
Richmond (file data - Waimea Plains irrigation, Ranzau Rd)											C and N and Pret based on Temuka soil							
0	27	slt loam	1.12	0	*2.65*	*57.74*					*4.3*	*0.43*	*14*	*100*	*35*	*10*	47.9	21.3
27	50	clay loam	1.13	0	*2.65*	*57.36*					*0.6*	*0.06*	*14*	*10*	*43*	*5*	46.4	21.5
50	70	clay	1.3	5	*2.65*	*50.94*					*0.4*	*0.04*	*11*	*1*	*50*	*5*	*47*	*35*
70	100+	very stony loam	1.3	70	*2.65*	*50.94*					*0.2*	*0.02*	*11*	*100*	*10*	*70*	*18.0*	*7.0*
Waimea/Motupiko soils																		
These are young alluvial soils equivalent to Waimakariri and Manawatu soils.																		
Expected to vary from deep silty soils (20-35% clay) to silty over sand soils to areas with shallow and stony profiles. Motupiko may on average be shallower but the difference is																		
In the absence of specific data, suggest creating a dataset based on Manawatu silt loam soils with gravels at 80 cm																		
Dovedale																		
Similar to Wakatu soils as they both have similar texture and underlying gravels with slow permeability.																		

Appendix 2 – Production yields, EBITD and Nitrogen Loss Data Sources

Accompanying this report are 88 spreadsheets containing the raw data from the SPASMO model and from the EBITD financial analyses. For each crop or farm system, and weekly irrigation allocation, and either ‘no rationing’ or ‘with rationing’ scenario, a spreadsheet of production yields, irrigation water use and nutrient losses is provided. In addition, a summary spreadsheet is provided for each crop or farm system containing the annual EBITD outcomes.

In the spreadsheet tables, ‘core’ refers to base weekly irrigation water allocation from Table 12 used in that model run. ‘No dam’ refers to the weekly irrigation water allocations from Table 13 in combination with the water rationing modelled under the Council’s water allocation rules in the absence of the Waimea Community Dam water augmentation scheme.