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Future Water Demand from Pasture Irrigation in the Waikato Region

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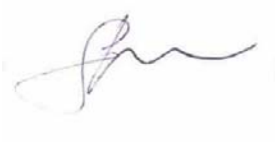
Reviewed by: Sarah Mackay	Signature		Date	07/09/04
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Summary

An irrigation model was developed to identify catchments where future irrigation of dairy pasture may occur in the Waikato Region and to estimate if there is enough surface water and groundwater to meet anticipated demand. The irrigation model takes into account long-term climate data, the available water capacity of the soils, grass production in response to irrigation and economic factors such as capital and operating costs of an irrigation system. The model does not account for all the on-farm variables that may effect the modelled benefits of pasture irrigation, and many of the parameters have been simplified. Thus as also recommended by Morgan & Evans (2003), the model and the results presented should not be used by farmers or farm consultants as an irrigation decision-making tool.

There are few areas in the Waikato where rainfall is not plentiful enough to enable farming. However, farmers are striving to increase profit and this can be achieved through increased grass production and converting it to milk as efficiently as possible. Irrigation in the Waikato provides the ability to have increased and consistent grass growth, which provides more consistent income.

The model identified that most areas of the Region currently utilised for dairying would produce an increased marginal benefit if they irrigated pasture. This is based on the average milksolids payout since 1990 of $4.20.

Many surface water bodies in the Waikato Region are already highly allocated. In the near future a greater portion of the irrigation demand will need to come from groundwater. The combined use of groundwater and surface water will only meet projected demand until approximately 2020, when demand will exceed the availability based on current allocation limits.

Based on the likely spatially widespread use of irrigation, prioritising areas where future irrigation may occur is quite difficult as it is just as likely that future irrigation will occur in the Reporoa Basin as in the Hauraki Plains.

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1 Introduction

Over the next 50 years the need for water for dairy pasture irrigation is likely to become the biggest demand outside hydroelectric generation in the Waikato Region (Hegarty et al. 2001). Predictions by the Ministry of Agriculture and Forestry (MAF) show irrigation levels in the Waikato Region will be 202 percent of the current level in 2010 (Hegarty et al. 2001).

The purpose of this report is to identify catchments where future water pressure due to pasture irrigation may occur in the Waikato Region and how sensitive these catchments are to the predicted water demand. A GIS model was developed to calculate which land in the Region is suitable for pasture irrigation. Future pasture irrigation water demand scenarios have been based on concepts used by Environment Southland which have built on work by Canterbury Regional Council (Morgan & Evans 2003).

These predictions are intended to identify potential issues due to future water demand. They are not intended for use by farmers or farm consultants as an irrigation decision-making tool, as many of the on-farm assumptions do not adequately address the complexities that make up farmers' decision to irrigate (Morgan & Evans 2003).

This study only addresses dairy pasture irrigation, however, other irrigation does occur, particularly for horticulture. From a water demand perspective the volume of water used for pasture irrigation will be greater than that for horticulture (Morgan & Evans 2003; Watt et al. 1997). The modelling results provide a worst case water demand scenario if the land use changed to horticulture. Water quality implications as a result of irrigation are not addressed in this report.

2 Irrigation Model

Farms most likely to convert to pasture irrigation are those where rainfall and soil characteristics limit the amount of grass growth and the installation and operation of an irrigation system are economically viable. This GIS model uses existing information for the Waikato Region relating to the economic worth of irrigation and the associated increase in stock numbers and milksolids (MS)[1] return, as well as irrigation rates based on soil available water capacities and long-term climatic conditions.

The components of the irrigation model are discussed below. The model is divided into three sections;

- Physical limitations such as land slope, soils' response to irrigation, and irrigation rates.
- Economic limitations such as the cost of installing and operating an irrigation system and the financial return from increased stock and milksolids production.
- Financial analysis, for a range of milksolids payouts, catchments are identified where pasture irrigation is physically and economically viable.

The irrigation model's GIS code is detailed in Appendices A, B and C.

2.1 Physical Limitations to Irrigation Potential

2.1.1 Land Slope and Use

Currently the majority of irrigation occurs on land less than 7º slope, however, with improvements in technology there is a move toward irrigating slopes up to 15º (Morgan

[1] Typically presented in units of kilograms of milksolids (kgMS).

& Evans 2003). The Land Resource Inventory[2] was used to identify all land with slopes up to 15º, these are shown in Figure 1. The LandCover Database[3] was used to identify areas of 'Primarily horticulture', 'Primarily pastoral' and 'Planted forest' for land with slopes up to 15º (Figure 2). Of the areas isolated in Figure 2 (7200 km^2), approximately 80 percent have slopes less than 7º and these are mainly distributed in the Hauraki plains, Hamilton Basin and South Waikato. Horticulture accounts for less than one percent of the land area, planted forest for 15 percent and pasture for 84 percent.

It is assumed that the conversion of forestry to pasture occurs on a small scale. Some of the water availability implications of converting forestry to irrigated pasture are discussed in Section 3.2. Figure 2 shows the distribution of planted forest on soils with slopes less than 15º in the Waikato Region. This forms the total potentially irrigable land in the region.

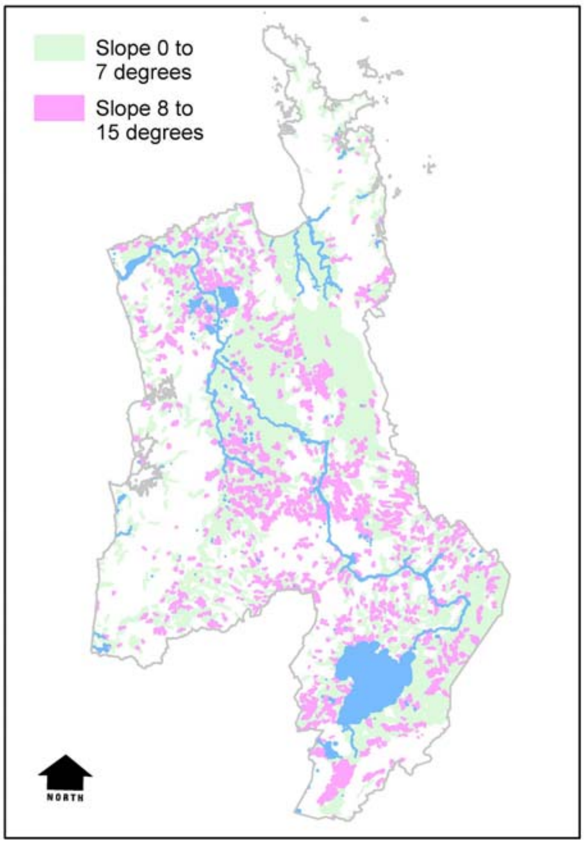

Figure 1: Soils in the Waikato with slopes between 0º and 7º and between 8º and 15º.

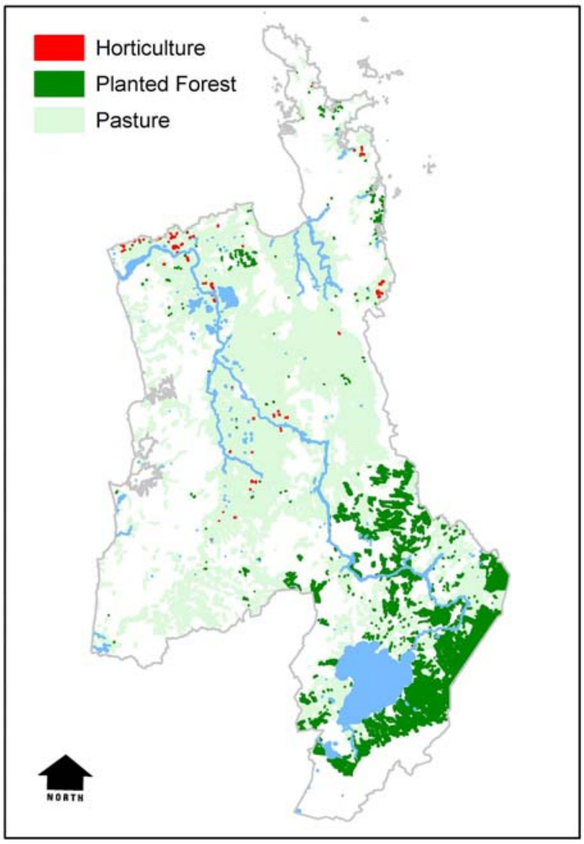

Figure 2: Distribution of horticulture, planted forests and pasture on soils with less than 15º slope in the Waikato Region.

2.1.2 Soil Available Water Capacity

The soils' available water capacity (AWC) are utilised in the model to calculate how much water is required for pasture irrigation.

The soils' AWC is the capacity of a soil to hold water available for use by most plants. It is defined in this report as the difference between the amount of soil water at field

[2] Land resource information derived from the New Zealand Land Resource Inventory (NZLRI) database maintained by Landcare Research NZ Limited. COPYRIGHT RESERVED. Approved for internal reproduction by Environment Waikato (Regional Council), Digital License No. 9532 (applies to all figures and maps in this document).

[3] Landcover data supplied by Terralink NZ Limited. COPYRIGHT RESERVED (applies to all figures and maps in this document).

moisture capacity and the amount at wilting point. The AWCs are used in the irrigation model to determine the mean annual irrigation water requirement.

Work by Watt et al. (1997) for the development of the crop water requirements for irrigation in the Waikato Region found that AWC of the root zones was more important than differences in climate, especially rainfall. The critical factors identified by Watt et al. (1997) for the Waikato Region are the plant rooting depth and tolerance of short-term water deficit. It is the AWC of the root zone which acts as a buffer against short-term water deficits. Watt et al. (1997) gives the AWC for nine representative soils of the Waikato Region. These soils are the Patumahoe, Netherton, Otorohanga, Horotiu, Hamilton, Te Kowhai, Motomaho Peat, Taupo pumice and Kaiangaroa pumice. The data set of AWCs for the rest of the region with slopes less than 15º was calculated by Landcare Research Limited during 2004 for this study. In total, the AWCs of 236 soils were calculated and their spatial distribution is shown in Figure 3.

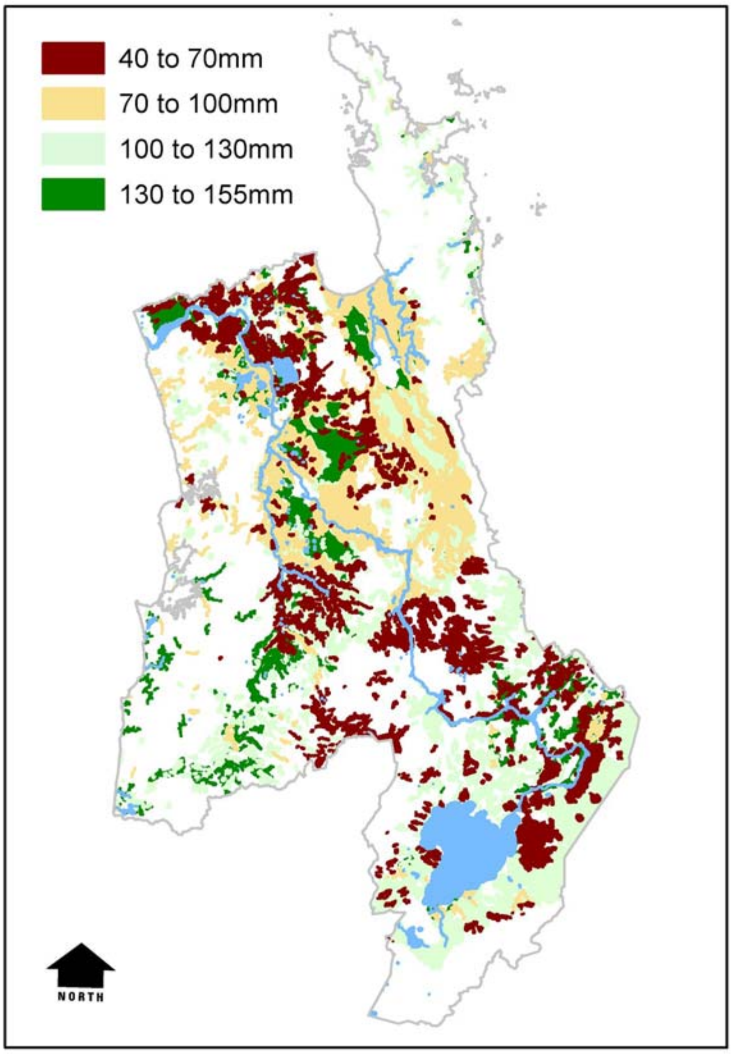

Figure 3: AWC for Soils in the Waikato Region with slopes between 0º and 15º.

2.1.3 Irrigation Regime

The study by Watt et al. (1997) determined crop irrigation guidelines based on the amount of water required for horticulture and pasture irrigation in the Waikato Region. Environment Waikato supports the use of the guidelines to promote water use efficiency in the Proposed Waikato Regional Plan (PWRP). These guidelines are also used in this report.

Watt et al. (1997) used a simple water balance model utilising the soil and climate data for the Waikato Region to estimate the soil moisture levels over a 25-year period

(1972-1996). The water requirements for pasture irrigation in the Waikato were determined to meet the irrigation objectives of never letting the soil moisture level fall below 25 percent of the AWC and keeping the soil moisture above 50 percent of the AWC for 90 percent of the time. From Watt's et al. (1997) study the irrigation model utilises the relationship where the soils' AWC can be used to predict the mean annual water requirement (mm) for pasture irrigation (Figure 4).

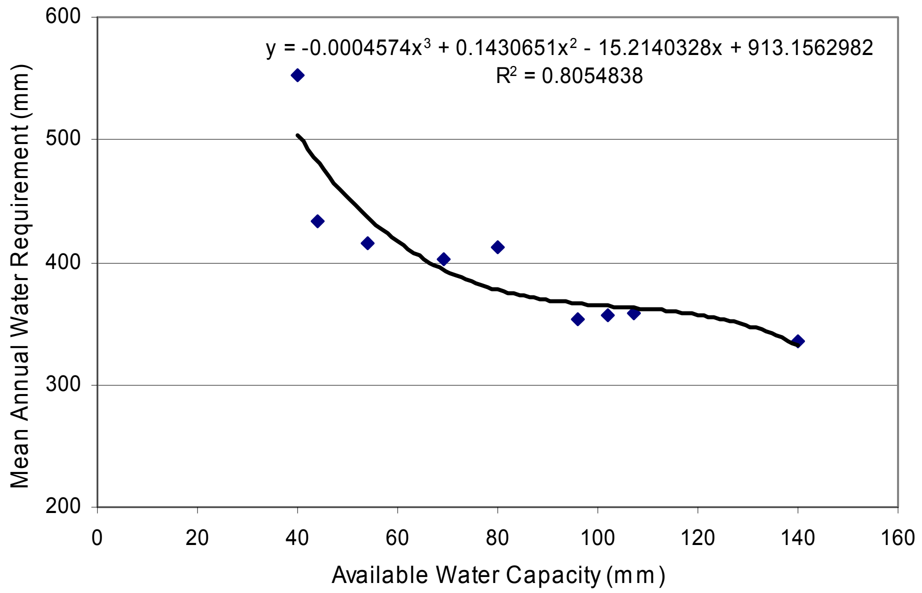

Figure 4: Relationship between AWC and mean annual water requirement for dairy pasture irrigation in the Waikato Region using data from Watt et al. (1997).

2.1.4 Pasture Production in Response to Irrigation

The irrigation model converts each millimetre depth of irrigation into a pasture response of 9.3 kilograms of dry matter per hectare (kgDM/ha). The increase in pasture production or kgDM in response to irrigation is based on the assessment of four previous studies in the Waikato Region, summarised in Table 1. As stated in Thomson (1996), work in the Waikato by Hopewell (1960) showed over a 10-year period an average pasture response of an extra 4,200 kgDM/ha/year for 290 mm/year of irrigation. This equates to 14.5 kgDM/ha/mm. This response is substantially greater than a farmlet study by Hutton (1975) at Ruakura from 1972 to 1975 where the average increase was only 1,100 kgDM/ha/year. The rate of irrigation is unknown but most likely ranged between 235 to 290 mm, which equates to between 4.7 and 3.8 kgDM/ha/mm. Thomson (1996) reported that the difference between the response reported by Hopewell and Hutton was possibly due to the grass composition. The grasses studied by Hopewell had a higher proportion of summer or C4 grasses which are more suited to irrigation and high summer temperatures compared to ryegrass.

Thomson's (1996) own investigations in 1995 and 1996 had 1500 kgDM/ha for an irrigation rate of 235 mm, equating to 6.38 kgDM/ha/mm. The grass composition contained 65 percent ryegrass.

In Reporoa the average annual increase in pasture production was 4200 kgDM/ha with an irrigation demand of 360 mm (Rout 2003). This equates to a pasture response of 11.7 kgDM/mm. There was no comment on the grass composition. Similar pasture responses have also been found for the Waihou area, *pers com* Rout (2004).

The average response of 9.3 kgDM/ha/mm used in the irrigation model takes into account that not all farmers may have optimum grasses suited to irrigation and high summer temperatures. The financial analysis output of the irrigation model is sensitive to the pasture response parameter. Thus using an average value provides a relatively conservative response compared to the studies by Hopewell and Rout.

Table 1: Summary of Waikato studies of pasture response to irrigation.

Study	KgDM/ha/mm of irrigation	Comments
Hutton	3.8 to 4.7	Unsuitable grasses
Hopewell	14.5	
Thompson	6.4	Unsuitable grasses
Rout	12.0	

2.2 Economic Limitations of Irrigation

The previous section lists the information used in the irrigation model to identify which soils are most suitable for receiving water for pasture irrigation, at what rate and what the resulting increase in pasture production will be. However, the economic viability of irrigating requires the economic benefits from increased stocking rates and milksolids return to outweigh the expenses, such as irrigation equipment capital and operation costs. The economic benefits and costs are discussed below and are detailed in Appendix D.

All economic outcomes in the irrigation model assume that the farms are operating to produce a high Economic Farm Surplus (EFS). According to McGrath (1997) the four key features of a high EFS are:

- High milksolids production both per cow and per hectare.
- Focus of farm management is on growing grass and converting it to milk as efficiently as possible.
- Planning farm management decisions.
- Financial management that ensures farm working expenses are contained to below 50 percent of gross farm income and all inputs into the system generate a financial return.

2.2.1 Pasture Production Benefits

According to Howse & Leslie (1997) "Increased pasture utilisation, through increased stocking rates and improved pasture management, is the greatest profit opportunity available to New Zealand farmers today." Since 1986 the greatest increases in spending have been on purchased feed and fertiliser (Howse & Leslie 1997).

The pasture production benefits used in the irrigation model are based on those identified by Rout (2003) from his work in the Reporoa area:

- Forty five percent of the increase in pasture is conserved as supplementary feed for winter, this contributes to the total farm feed budget by reducing the need for off-farm grazing and the purchasing of supplementary feed. The marginal benefit[4] of the supplementary feed is cost at a rate of $0.10 per kgDM. This marginal benefit is similar to work by Penno et al. (1996).
- Thirty three percent of the increase in pasture is converted to an increase in stocking rates at a conversion rate of 3,900 kgDM/cow (DM consumption during the milking season).
- Twenty two percent of the increase in pasture is converted to an increase in per cow milksolids production at the rate of 15 kgDM per kgMS. For Rout's work this equates to an increase of approximately 60 kgMS per cow or 0.10 kgMS/kgDM[5]. This is similar to pasture conversion rates near Hamilton where an increase of approximately 55 kgMS per cow or 0.09 kgMS/kgDM was observed [6](Penno et al. 1996).

[4] Extra benefits resulting, for instance, from the increased consumption of a commodity
[5] Increase of 1890 kgDM/ha (4200 kgDM/ha * 0.45) and 190 kgMS/ha (4200 kgDM/ha * 0.22 / 15 * 3.15) from irrigation.
[6] Increase of 1940 kgDM/ha and 177 kgMS/ha from irrigation.

It is likely that the percentage values above will vary from farm to farm and across the Region. The profits produced by these three components are restricted from being too inflated by using the average pasture response value of 9.3 kgDM/ha/mm of irrigation. The irrigation model calculation of marginal benefit is more sensitive to the pasture response value than to variation in the above three parameters.

2.2.2 Irrigation System Capital and Operating Costs

The capital costs of the irrigation system are highly dependent of the type of system and the distance from water source. The study by Rout (2003) investigated twelve irrigation systems in the Reporoa area, their capital costs ranged from about $80,000 to $1,000,000[7]. The types of irrigation systems were K-lines, long-lateral, centre pivot and travelling gun irrigators. The average annual capital cost of all the installed systems was $279 per ha, including depreciation (Rout 2003).

The average annual operating cost for the twelve systems was $327[8] per ha, taking into account power charges and labour (Rout 2003).

2.2.3 Farm Working Expenses

Farm working expenses in the irrigation model are based on Waikato examples given by MacDonald (1999); McGrath (1997); Penno et al. (1996); Howse & Leslie (1997); Rout (2003). The model includes expenses such as: wages, breeding and herd testing, electricity, pasture and supplements, fertiliser, weed and pest control, vehicle expenses and administration. On an annual basis these expenses are $2243 per ha for a non-irrigated farm with 2.8 cows/ha and $2,338 per ha for an irrigated farm with an increase in stock numbers from 2.8 to 3.16 cows/ha. The small increase in expenditure for the irrigated farm is largely due to the benefits of not having to buy as much supplementary feed as the non-irrigated farm. These expenses are listed in Appendix D.

2.2.4 Income

Typically between 85 to 90 percent of gross farm income is from milk sales (Attrill & Miller 1996). Milk sales are highly dependent on the volume of milksolids produced and the dollar return per kilogram of milksolids. Both these parameters are variable in the pasture irrigation model. As a result of irrigation, stocking numbers and the milksolids produced will increase in response to improved pasture growth. The stock numbers and milksolids production prior to irrigation are based on dairy statistics for the Waikato (LIC 2003). The dollar return is user defined and can be varied to simulate the economic return in different economic climates. The remaining ten to fifteen percent of the income is from net stock sales, rebates and other farm income (Attrill & Miller 1996; Rout 2003). Typically this remaining income is in the order of $290 to $330 per hectare depending on stocking rates (MacDonald 1999; Rout 2003).

2.3 Financial Analysis

In the financial analysis it is deemed that irrigation of dairy pasture is economically viable if an annual marginal benefit of $200 per hectare or more is achieved. This typically relates to the farm working expenses being contained to approximately 60 percent of gross farm income.

Varying the milksolids payout enables the identification of areas in the Region where it is physically and economically viable to irrigate dairy pasture. The average milksolids

[7] Furthest system from water source, about 1 kilometre.
[8] Operating information is patchy, due in part to difficulties for farmers in separating specific irrigation system costs, and in part to the complexity of power pricing schemes Rout, R. 2003: Investigating Dairy Farm Irrigation Efficiency in the Reporoa Basin. Lincoln Environmental, 4963/1. 65 p.

payout between 1990 and 2004 was $4.17/kgMS and ranged between $3.04 and $5.50/kgMS[9].

Even though the irrigation model is largely based on data from Reporoa, the results of the financial analysis produced similar marginal benefits to a recent study in the Waihou Catchment by Rout (2004).

3 Areas Considered Economically Viable for Pasture Irrigation

For a payout of $5.00 per kgMS all of the isolated land currently utilised for pasture and horticulture with slopes less than 15º can be irrigated with a marginal benefit greater than $200 per ha (Figure 5). Ninety five percent of the isolated land can be irrigated for the average payout of 4.20 per kgMS (Figure 5).

The spatial distribution of the profitable irrigation areas are shown in Figure 6. The Hamilton Basin and Hauraki Plains are obvious areas where irrigation is profitable at a payout of between $3 and $4 per kgMS. These areas coincide with the AWCs of less than 100 mm (Figure 3). The Coromandel Peninsula and Waitomo District standout as areas where an above average payout is required to make irrigation profitable. These areas coincide with soils with high AWCs and areas with high annual rainfall, thus requiring fewer days per year of irrigation.

These results are rather optimistic and there are a number of factors that are not accounted for in this analysis. It is assumed that all farmers have capital readily available to purchased irrigation equipment, and that water is in close proximity and readily available. In some areas irrigation may be limited by water quality, excessive iron concentrations in the northern Hauraki Plains are known to limit groundwater use (Hadfield 1993).

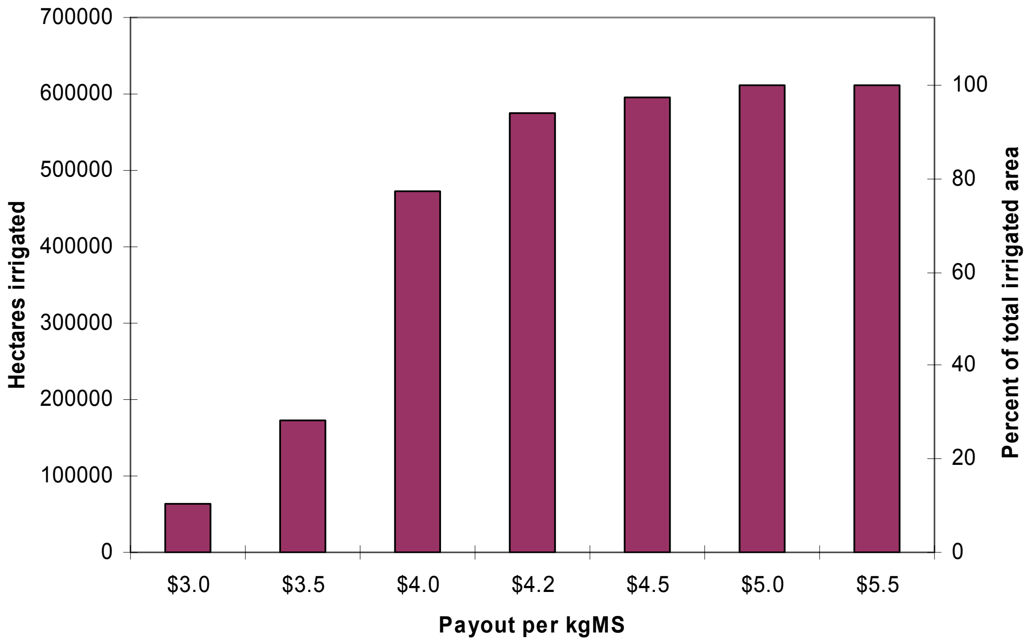

Figure 5: Area of dairy farm land that produces an annual marginal benefit greater than $200 per hectare for the seven milksolid payouts as a result of pasture irrigation.

[9] Payouts are weighted to give real dollar values using the Consumers Price Index for the end of the June quarter. Sourced from Statistics New Zealand LIC 2003: Dairy Statistics 2002-2003. Livestock Improvement Corporation Ltd, Hamilton.

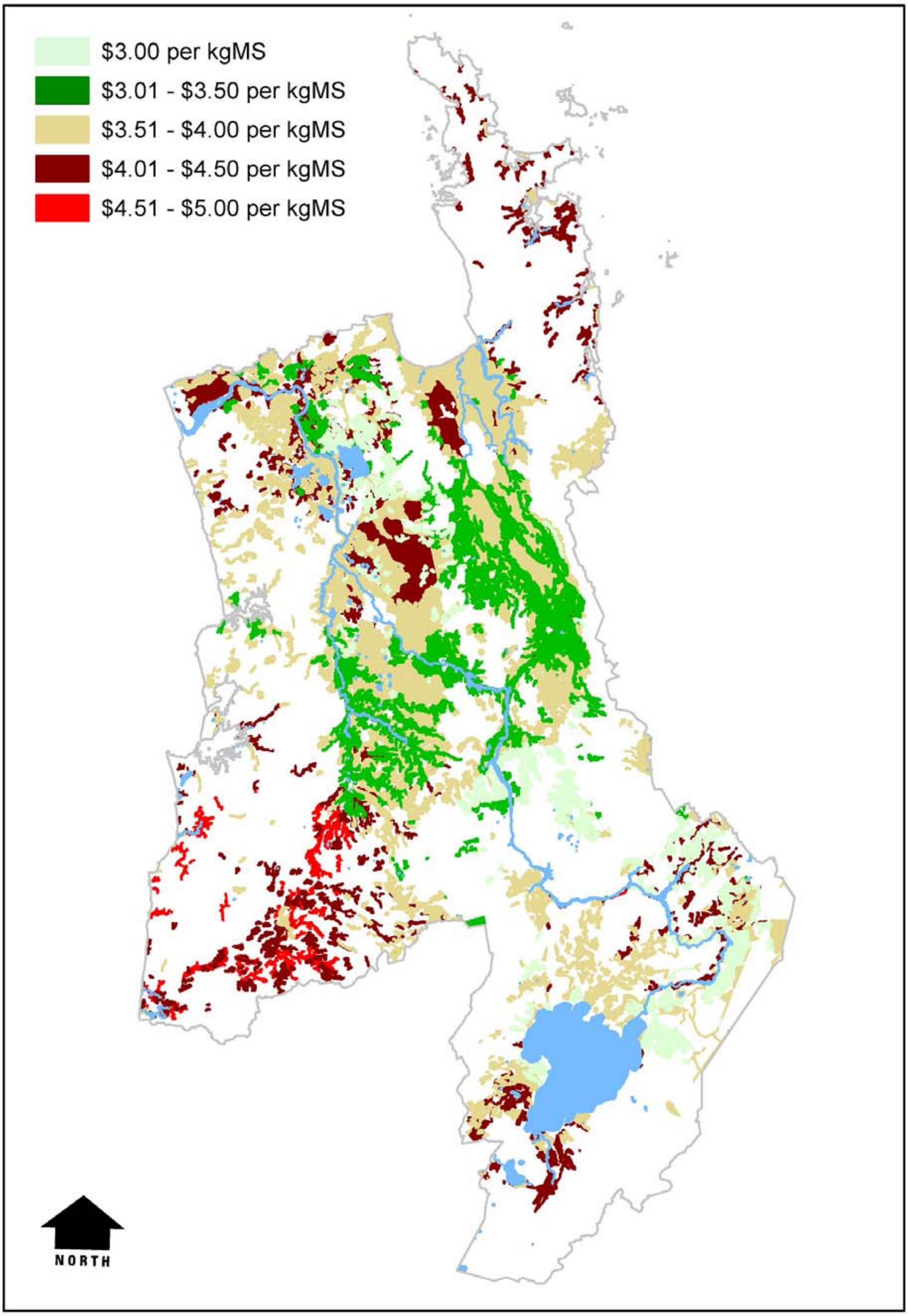

Figure 6: Areas of Pasture and Horticulture that produce an annual marginal benefit of greater than $200 per hectare when irrigated for the five milksolid payout values.

3.1 Pasture Irrigation Demand in 2020 and 2050

Two growth curves have been utilised to provide insight into the amount of land that may be irrigated over the next 50 years. It is assumed in this report that the areas of potential irrigation are distributed evenly across the Region based on their spatial distribution for the average payout of $4.20 per kgMS.

The Ministry of Agriculture and Forestry (MAF) predicted a doubling in pasture irrigation from the year 2000 to 2010 (Hegarty et al. 2001). This is an increase from 4,500[10] hectares to 9,000 hectares of land. Currently in the Waikato pasture irrigation is not the major use of water in terms of the hectares being irrigated. Eighty seven percent of the irrigated land in 2000 was used for horticulture (Lincoln Environmental 2000). However, it is predicted that future use will mainly be from dairy pasture irrigation (Hegarty et al. 2001).

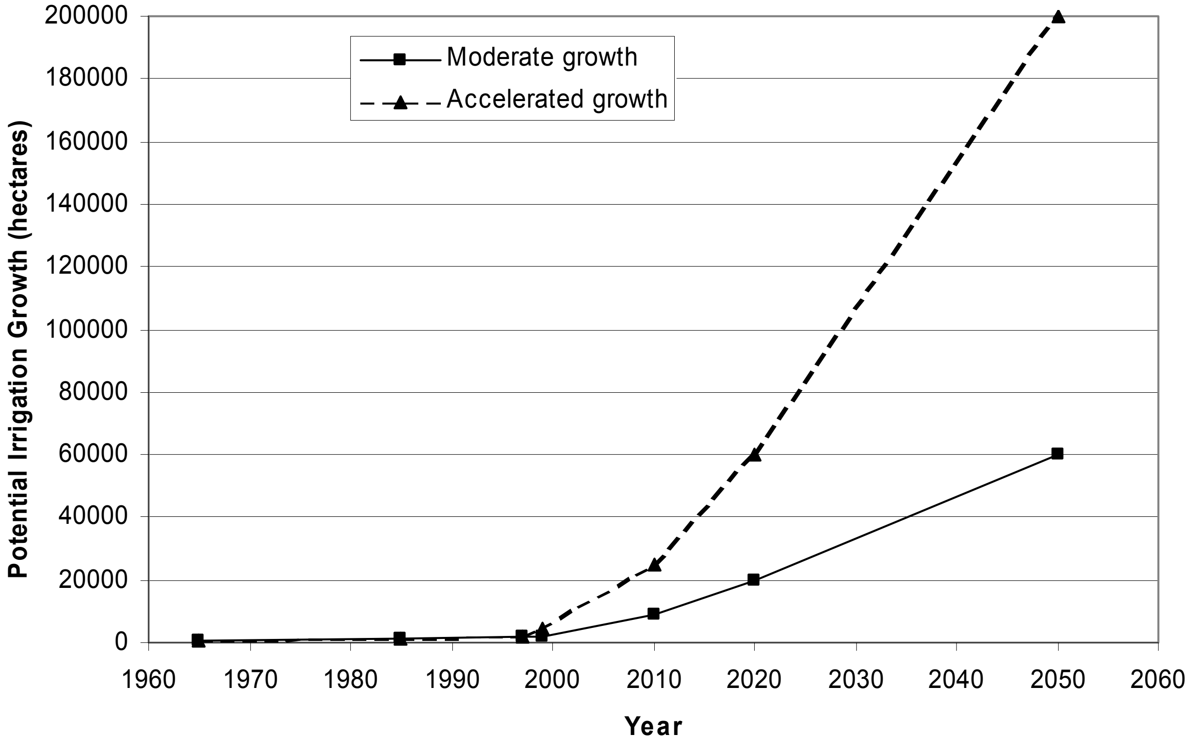

Figure 7: Trend in conversion of land to irrigation between 1965 and 1999 (Lincoln Environmental 2000), as well as moderate and accelerated growth curves through to 2050.

Data from 1965 to 1999 are from farm surveys (Lincoln Environmental 2000). The moderate growth trend in 2010 is based on MAF estimates[11] (Hegarty et al. 2001). The moderate growth trend in 2050 is equivalent to ten percent of the total area shown in Figure 8 for the average payout of $4.20 per kgMS. The accelerated trend prediction in 2050 is equivalent to 35 percent of the total area shown in Figure 8.

The availability of water to enable the predicted conversion to irrigation has been assessed for ten catchments using the moderate and accelerated irrigation growth trends. The results are given in Figure 9.

[10] Environment Waikato's consent database only identified irrigation on 2000 hectares in 2002 (Lincoln Environmental 2000: Information on Water Allocation in New Zealand prepared for Ministry for the Environment. Lincoln Environmental A division of Lincoln Ventures Ltd, Christchurch. 4375/1. 119 p.).

[11] Demand for irrigation was calculated by assuming 50 percent growth in current irrigation plus 25 percent of low water holding capacity soils being irrigated. A second estimate was based on a Nimmo-Bell Ltd estimated market demand projection where market returns impact on land use demand (Hegarty, S.; Thomas, A.; Phillips, F. 2001: Future Water Allocation Issues. Ministry of Agriculture and Forestry, Wellington. 78 p.).

The irrigation model's estimate of the irrigation abstraction rate assumes that the pumping occurs for 24 hours and is distributed over 120 days of each year. It is quite likely that many users may take water for less than 24 hours of each day of operation, thus increasing the percentage of water allocated as shown in Figure 9. The available surface water flow is taken as the allocable portion of the 7-day 5-year return period low flow discharge. The volume of groundwater available for allocation is based the aquifers receiving 360 mm per year of recharge and 50 percent of this recharge is available for abstraction. The only exception is for the Torepatutahi and Waiotapu Catchments where only 20 percent is available for recharge[12]. Approximately 80 percent of the groundwater recharge maintains the baseflow discharge of the surface waters in these two catchments.

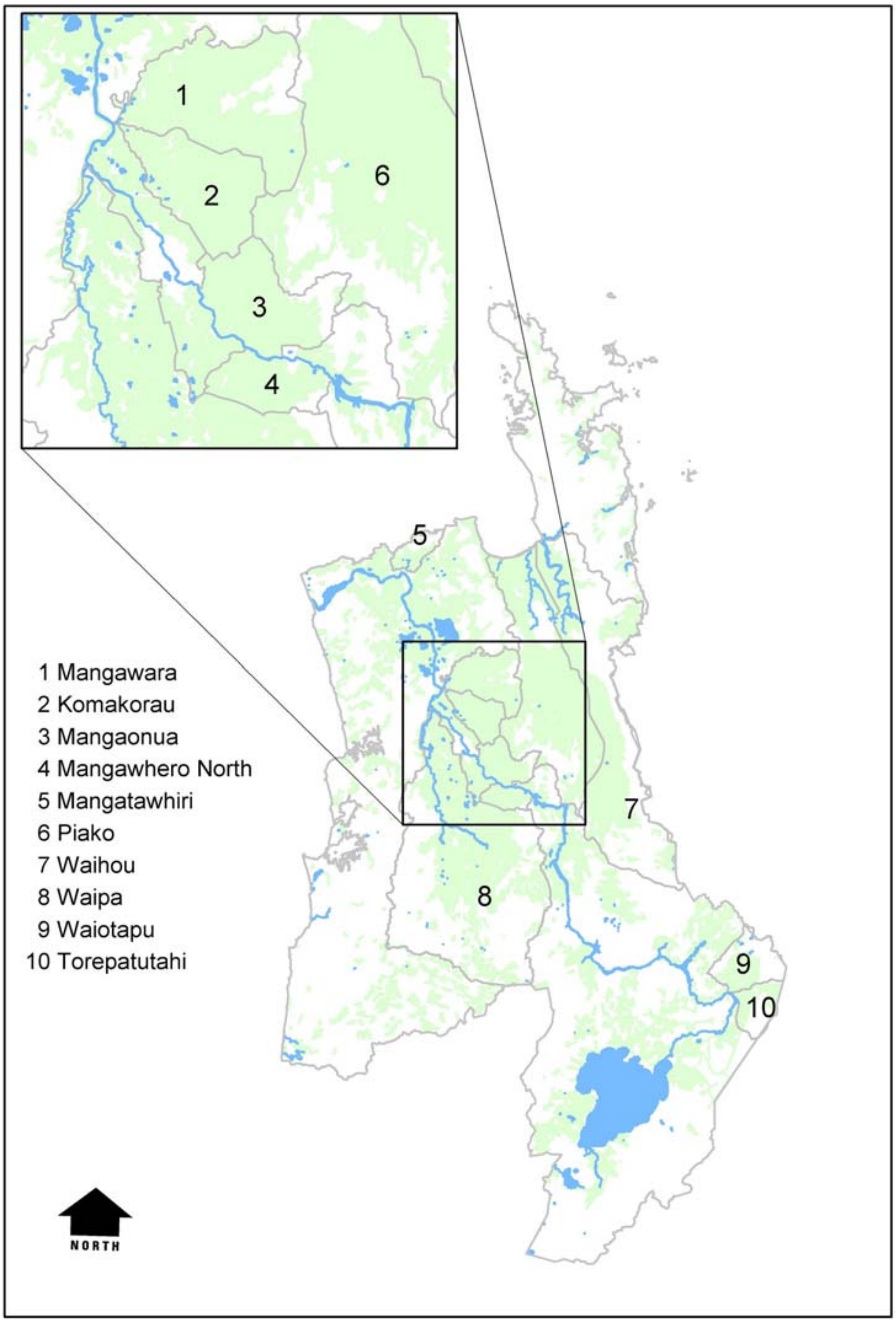

Figure 8: Ten catchments assessed for the availability of water to meet the potential future irrigation demand for the 15-year average milksolids payout of $4.20.

[12] The estimation of the available groundwater is described in two unpublished Environment Waikato documents, Water Resources of the Reporoa Basin – Draft (DOCS #931203) and Adaptive Management Plan for the Initial Estimation of the Waikato Region's Groundwater Allocation (DOCS #787899).

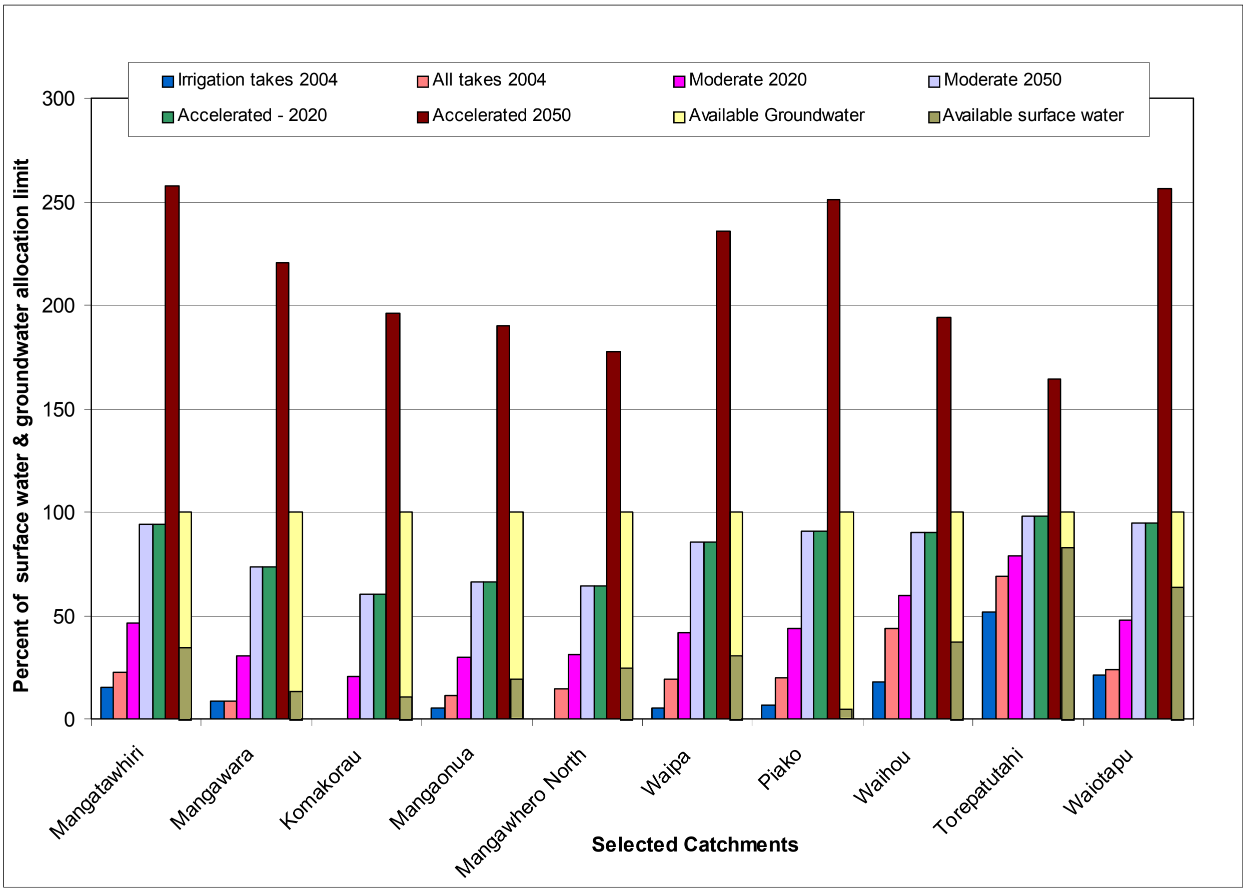

Figure 9: Availability of surface water and groundwater compared to the current water use in 2004 and the moderate and accelerated growth trends for future water use.

All ten catchments are able to meet the predicted irrigation water demand in 2020 and the moderate water demand in 2050. However, in this analysis no account has been made of the increase in water demand from other uses such as industry, stock water, frost protection and municipal supply. The accelerated demand in 2050 far exceeds the available surface water and groundwater availability.

In the Waikato Region two thirds of all consented consumptive water use is from surface water (Hadfield 2001). In the near future, groundwater will need to be utilised to a much greater level as many surface water resources are nearing their allocation limit.

3.2 Converted Forestry Areas Considered Economically Viable for Pasture Irrigation

It is assumed that the conversion from planted forests to pasture occurs on a small scale. Forests in New Zealand are not irrigated but certainly reduce the amount of runoff and groundwater recharge compared to similar catchments in pasture.

The most suitable locations identified by the model for irrigation of pasture that has been converted from planted forests is in the South Waikato and Rotorua Districts (Figure 10 and Figure 11). It is important to note that the financial analysis does not take into account conversion costs from forest to pasture. It assumes that the conversion has already occurred prior to the installation of the irrigation equipment.

The assessment of water availability is more complex for catchments where conversions from forestry to pasture irrigation have occurred compared to conversions from pasture to pasture-irrigation. Changes in the catchment water cycle need to be accounted for when forests are planted or removed.

In South Waikato the typical pasture irrigation requirement is 350 mm/year and is abstracted from both surface water and groundwater. For land that has been converted to pasture from forest, the requirement is also 350 mm/year, however, the conversion will also result in the reduction of approximately 180 mm/year of evapotranspiration due to the removal of trees (Morgan & Evans 2003). Thus, the abstraction of 350 mm/year for irrigation is partially counter balanced by the reduction in evapotranspiration and the associated increase in either or both river flow and aquifer recharge.

It should be noted that the inverse may occur when part of a catchment is converted to forest. The conversion of scrub or pasture to forest will result in a loss of water to aquifers and surface water. The amount of loss is dependent on a number of factors which may include: the area of land converted in relation to the size of the catchment, the type of new species planted and the variation in the new species water demand during its life cycle. The planted forests are essentially water takes from the catchment. Assessing where future conversion to forests may occur will help to identify which catchments are most sensitive to a loss of water from this land use change.

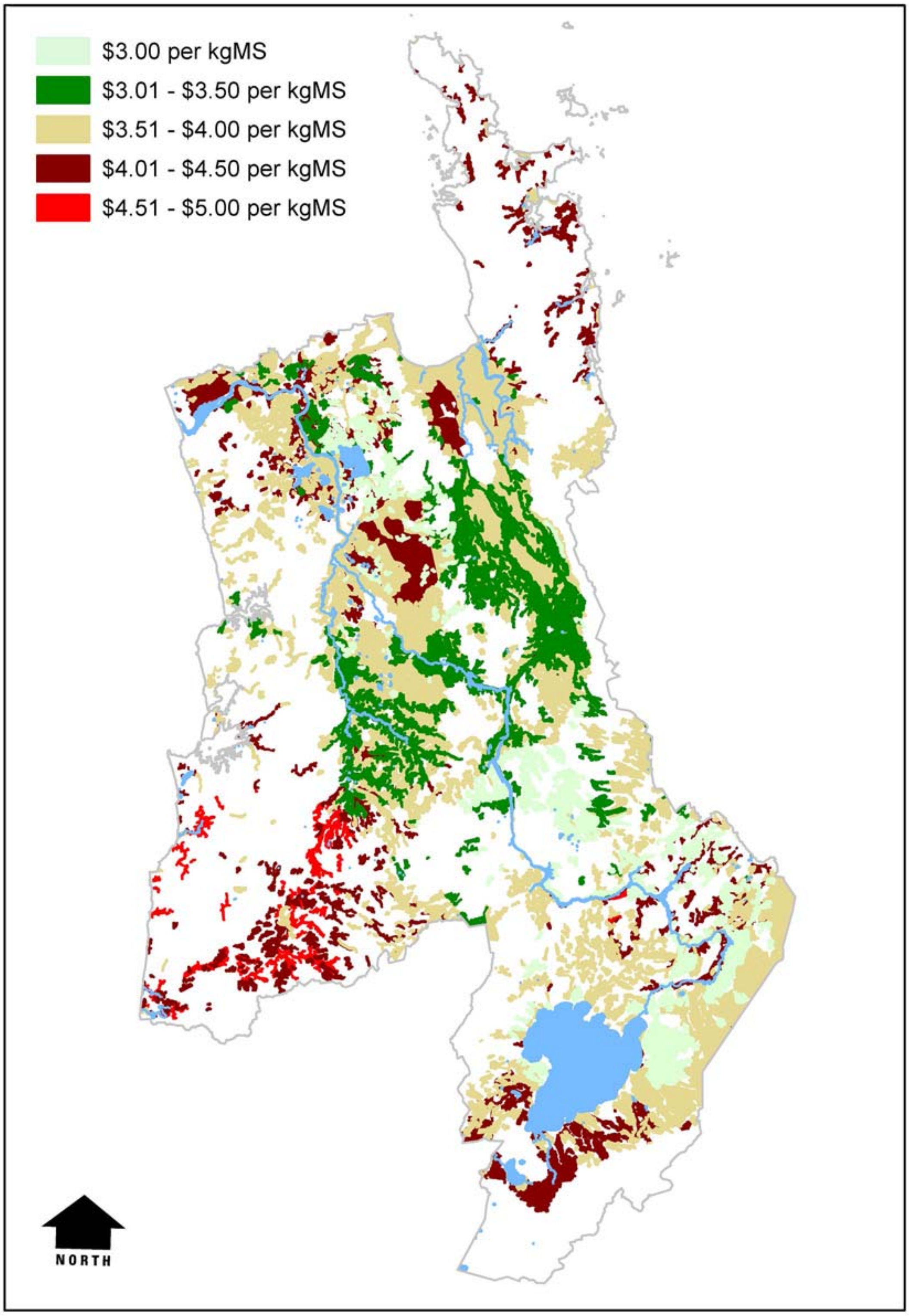

Figure 10: Areas of pasture, horticulture and planted forest that produces an annual marginal benefit of greater than $200 per hectare when irrigated for the five milksolid payout values shown.

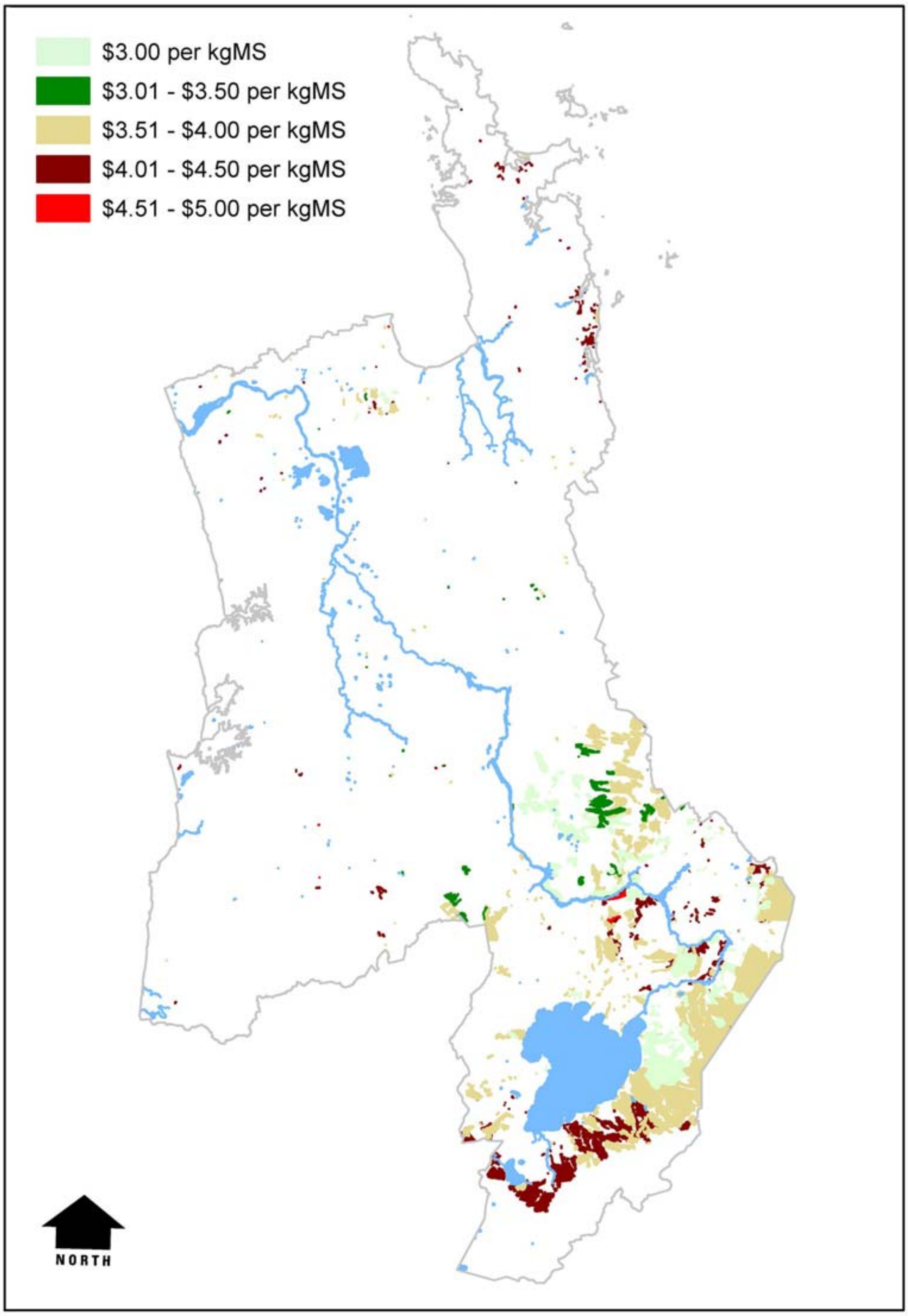

Figure 11: Areas of planted forest that produces an annual marginal benefit of greater than $200 per hectare when irrigated for the five milksolid payout values shown.

3.3 Policy and Consenting Implications

- Potential future irrigation demand based on the model with its inherent assumptions will exceed the availability of groundwater and surface water resources. Some surface waters have allocation limits based on in-stream requirements, however, many have the default limit of 10 percent of the 7-day 5-year return period low flow. As the default limit is reached there will be increased pressure to reassess this default allocation level. Groundwater allocation levels will also need to be set as demand increases. In the PWRP only the Pukekohe shallow basalts have any form of allocation limit.

- As more water bodies become fully allocated an increasing number of water takes will be assessed under the discretionary rule in the PWRP. Improved guidance for staff will be required so they have confidence in implementing this rule correctly and consistently.

- Under the "first-in-first-served" allocation system, water resources may be fully allocated while not accounting for other future needs, such as community supplies.

- Allocation tools are required to give warning before allocation limits are reached. Accurate knowledge of allocation levels could ensure that the correct allocation rules from the PWRP are utilised and water availability and alternatives are investigated. During 2004/05 the GIS software GEOMEDIA is being assessed for its capability to calculate surface water and groundwater allocation levels.

- Irrigation water demand is seasonal. Future irrigation water demand could be met from stored winter flows. This may see pressure for increased winter abstraction rates to fill large storage systems.

- Given that the forestation of pasture land decreases the amount of recharge to rivers and aquifers, policy around the need for consenting of new forest plantings could be examined.

4 Conclusions

The irrigation model has identified the following water allocation implications from irrigating dairy pasture in the Waikato Region.

- The model does not account for all the on-farm variables that may effect the modelled benefits of pasture irrigation, and many of the parameters have been simplified. Thus the model and the results presented should not be used by farmers or farm consultants as an irrigation decision-making tool.

- Irrigation is not required in the Waikato Region for the financial viability of dairy farming. However, farmers are striving to increase profit and this is best achieved through higher milksolid production both per cow and per hectare and focusing on growing grass and converting it to milk as efficiently as possible. Irrigation provides the farmers improved consistency in grass growth and as a result consistent higher incomes. The irrigation model has shown that if most of the land currently utilised for dairying was irrigated for the average payout of $4.20 per kgMS, it would produce a marginal net benefit.

- The irrigation model shows that even soils with reasonably high AWCs (~130 mm) can be irrigated for economic return. As necessity of irrigation for financial viability is not the driver for where irrigation may occur, it is unlikely that the AWC of the soils will drive the distribution of irrigation. Thus there will be as much chance of irrigation occurring in the Hauraki Plains as in the Reporoa Basin. This is not to say that the actual marginal benefit in each location will be the same.

- Many surface water bodies are already highly allocated, in the near future a greater proportion of the irrigation demand will need to come from groundwater. The combined use of groundwater and surface water will only meet demand until approximately 2020 when demand will exceed the availability based on current allocation limits and assuming the projections of demand are also met.

- Pasture irrigation typically occurs during the summer. As allocation limits are reached, the balancing of water demand and supply could be achieved by storing winter rivers flows through to the irrigation season.

- Removal of planted forests could increase the availability of water. This may partially offset the abstraction of water in catchments where forests have been converted to irrigated dairy pasture. Conversely, an increase in planted forests reduces the availability of water for allocation. This will be important when assessing the future availability of water in highly allocated catchments.

- The “first-in-first-served” policy for allocation may result in most of the water being used for irrigation without leaving reserves for other needs, such as community supplies and industries.

- As more catchments become fully allocated, the discretionary rule for surface water takes in the PWRP will be implemented in the majority of assessments. Guidelines are currently being produced to aid Resource Use Officers in the consenting of water takes.

- Water-take consent data management tools will need to be developed so that allocation levels can be assessed accurately and quickly.

- Only two water demand scenarios have been tested. The methodology outlined can be further verified and/or reapplied in the future as more data becomes available from field studies comparing pasture response to irrigation and the associated economic benefits.

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Appendices

A Slope Queries

<u>In GeoMedia Professional (GMP):</u>

Using the LAND_RESOURCE_INVENTORY feature in Oracle Spatial – performed a functional attribute query on the SLOPE column. This had the effect of removing the ‘ characters from SLOPE like “A'   +B'” etc. The functional attribute query used was:

LEFT(Input.SLOPE, 1)+'_'+MID(Input.SLOPE, 7, 1)

This gave us a smaller selection of SLOPE values to select on (in a column called SLOPE_CONCAT). In GMP we then performed the attribute query below to find LRI polygons with slope 0-7% (A% and B%) and 8-15% (C%) (this excludes riverbeds and urban areas):

Then query run GMP is then:

SLOPE_CONCAT LIKE 'A%'
OR SLOPE_CONCAT LIKE 'B%'
OR SLOPE_CONCAT IN ('C_','C_A','C_B')
AND SLOPE <> 'C /D';

This gets us all LRI polygons with appropriate slope values (i.e all A, all B and all predominantly C and secondary A and B).

The results of this query are saved as feature LRI_SLOPE_ABC in the Access database \\PANORAMIX\LAYERS\current\Water_Holding_Capacity\WHC_working.mdb. Redundant LRI columns were removed.

B Available Water Capacity

Using the data supplied for Water Holding Capacity (WHC) of soils within the slope range calculated above (in \\PANORAMIX\LAYERS\current\Water_Holding_Capacity\WHC_raw.xls), the spreadsheet \\PANORAMIX\LAYERS\current\Water_Holding_Capacity\WHC_FOR_GM.xls was generated. This spreadsheet contains a column CONCAT_KEY, which is the SERIES column concatenated with the first character of the NZSC column (derived from the LRI).

Note a record duplicate for Topehaehae_G was added as Topehahae_G to account for spelling mistake in the LRI. The same was done for Patamahoe_N, mis-spelt as Patumahoe_N.

A column CONCAT_KEY was generated for the feature LRI_SLOPE_ABC using functional attributes:

Input.SERIES+'_'+LEFT(Input.NZSC,1)

The XLS \\PANORAMIX\LAYERS\current\Water_Holding_Capacity\WHC_FOR_GM.xls was attached to from GMP and a join made between the two respective CONCAT_KEY columns.

The result of this join was output as a feature called LRI_SLOPE_WHC in \\PANORAMIX\LAYERS\current\Water_Holding_Capacity\WHC_working.mdb.

This resultant feature then contains LRI polygons of less than 15 degrees slope with WHC capacity values. This has a total area of 8,731.48 km^2.

The LANDCOVER_DATABASE (as stored in Environment Waikato's Oracle Spatial GIS database) was used to remove areas of land that were not required for analysis (i.e. areas of Coastal dune vegetation, Coastal sand, Coastal wetland, Indigenous forest, Inland water, Inland wetland, Mangrove, Mine, pit, or quarry site, Urban open space or Urban settlement).

In GMP, a query was done to isolate areas of the LANDCOVER_DATABASE that are Planted Forest, Primarily horticultural, Primarily pastoral, Shrubland or Tussock Grassland.

A spatial intersection of the above query and LRI_SLOPE_WHC was made. The resulting feature was exported as LRI_SLOPE_WHC_LCDB. This feature has a total area of 7,587.17 km^2.

A spatial intersection of LRI_SLOPE_WHC_LCDB was then made with TERRITORIAL_AUTHORITIES[13] from Oracle Spatial in order to split the polygons by District Council. This was output as feature LRI_SLOPE_WHC_LCDB_TA.

Exported through Shapefile to force Compound geometry to Area.

Imported new feature back into \\PANORAMIX\LAYERS\current\Water_Holding_Capacity\WHC_working.mdb as WATER_HOLDING_CAPACITY1.

[13] Territorial Authority boundaries derived from Statistics New Zealand's Digital Meshblock Database (DMDB). Crown Copyright Reserved, DOSLI and Statistics 1994. License Number DDL08.

Removed any areas that were outside TA areas.

Removed all polygons from WATER_HOLDING_CAPACITY1 with SERIES in (‘MSoil’, ‘BRock’).

Calculated Geometry in HA for WATER_HOLDING_CAPACITY1 and output feature **WATER_HOLDING_CAPACITY2** with column AREA_HA.

The resulting feature has an area of 755,3.77km^2.

Taupo soil series was changed from 122 mm to 40 mm. The 122 mm did not match field measurements as given by Watt et al. (1997) due to the physical nature of the Taupo pumice.

Areas which have TAW[14] of 400 mm (which are typical for non-drained peat) that have not been removed from the data via the LCDB wetlands removal were changed to 140 mm to match data given for Motumaho peat by Watt et al. (1997).

An XLS was created for regional dairy stats (\\PANORAMIX\LAYERS\current\Water_Holding_Capacity\REGIONAL_DAIRY_STATS.xls), with average cows per ha, average kg milksolids per effective ha and average kg miksolids per cow.

Attached XLS to GWS and performed a join by TA_NAME in WATER_HOLDING_CAPACITY2 and DISTRICT in XLS.

Output result as **WATER_HOLDING_CAPACITY3**.

Backed up the data as **WATER_HOLDING_CAPACITY4**.

Updated values of >160 TAW to be 95. These soils had higher water capacities than observed during field measurements. Soils of this nature were mainly distributed in the Hauraki Plains

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Using Geomedia Professional, set up a number Functional Attributes using the formulas in the XLS #920994v1.

Resulting Query is **Functional Attributes of WATER_HOLDING_CAPACITY41** (i.e. the ‘raw’ data for the next step).

[14] Total available water capacities (TAW) are the same as available water capacities (AWC).

C Geomedia Working for Map Creation

The following outlines the working undertaken to create maps and statistics used in the above report. These notes are intended only as a record in order to repeat the analysis process.

All working in
\\PANORAMIX\LAYERS\current\Water_Holding_Capacity\water_holding_capacity_100604.gws

a) Creating slope map
b) Performed 3 queries on the feature **WATER_HOLDING_CAPACITY4** on the SLOPE column: SLOPE like 'A*'; SLOPE like 'B*'; SLOPE like 'C*'; named SLOPE_A, SLOPE_B and SLOPE_C. Coloured SLOPE_A and SLOPE_B the same for the 0 – 7 degree range;

c) Creating the LCDB map
d) Performed a query on **WATER_HOLDING_CAPACITY4**, LCDB_CLASS in ('Planted forest','Primarily horticultural','Primarily pastoral'), saved as **LCDB_areas_of_interest**. Displayed the result thematically by LCDB_CLASS;

e) Creating the WHC map
f) Using the **LCDB_areas_of_interest** query created above, displayed the result thematically by TOP_50CM_TAW, using the ranges 40-70, 70-100, 100-130 and 130-155;

g) Creating the Potential Irrigation based on Marginal Return maps
- Performed a series of update, query and feature creation steps to create features based on PAYOUT and MARGINAL_BEN_HA:
  - set PAYOUT = 3 in **WATER_HOLDING_CAPACITY4**
  - queried **Functional Attributes of WATER_HOLDING_CAPACITY41** for LCDB_CLASS in ('Planted forest','Primarily horticultural','Primarily pastoral'), named query as **LCDB_interest_from_FUNC**;
  - wrote new feature class called **PAYOUT_3** from this query;
  - Repeated above steps for payout of 3.5, 4, 4.2 4.5 and 5 (features PAYOUT_3_5, PAYOUT_4, PAYOUT_4_2, PAYOUT_4_5 and PAYOUT_5).
  - Performed a series of queries on the above features to display for MARGINAL_BEN_HA >200 and for LCDB_CLASS in ('Primarily horticultural','Primarily pastoral'). Named PAYOUT_3_BEN>200_LCDB_PH etc.
  - Displayed the 3 queries as overlays.

h) Working out Irrigation m^3 by catchment
- A number of catchment areas were identified from the **ALLOCABLE_FLOW** (as stored in Oracle Spatial as ALLOCABLE_FLOW_RULE_3_3_4_10) feature and from heads up digitising. These were saved as CATCHMENTS feature.
- The features PAYOUT_3, PAYOUT_3_5 PAYOUT_4, PAYOUT_4_2, PAYOUT_4_5 and PAYOUT_5 had a column created POT_IRR_M3, and populated with formula (POT_IRR_MM/1000)*(AREA_HA*10000).
- The 6 queries PAYOUT_3_BEN>200_LCDB_PH etc were intersected with the CATCHMENTS feature.
- The payout features were spatially intersected with the catchments and new areas (in m3) worked out.
- Irrigation by catchment was then worked out using a formula POT_IRR_M3*AREA_M3.

D Summary of Financial Model

The following assumptions of the financial model are from Rout (2003):

a) Pasture and Supplements, includes hay, silage, meal, cropping, pasture renovation, grazing and contractor costs.
The base case is:
Supplementary costs/ha = $484 at stocking rate of 2.8 cows which is equal to $173/cow. This assumed to be a fixed cost per cow.

The irrigation case is:
Supplementary feed for winter feed is 45% of 4200kgDM/ha[15] = 1890 kg/ha
The marginal benefit of increase in feed conservation is at $0.1/kg = $189/ha.

The marginal cost savings are:
$173/cow at 3.155 cows per ha = $545/ha less the marginal benefit of increased feed conservation ($189/ha) i.e. $545 - $189 = $356.

b) Annualised fixed costs are based on depreciation of above and below sections of the systems. The cost of above and below ground costs are system specific as are the depreciation rates, generally a higher proportion of K-lines and long-laterals are above ground than for centre pivot and travelling guns.

c) Operating costs are based on:
- Energy costs comprising of both fixed and consumption charges as listed below:
- Fixed charges (based on typical motor duty) based on information from Trustpower a unit rate of $30/ha was applied. This is typical of the fixed rate applying in the Reporoa area.
- Consumption charges (kWh) are based on energy rate per system type (based on typical operating duty (m)) and average annual volume. A variety of charging schemes apply in the area, therefore an average unit rate charge of $0.12/kWh was adopted for the study.
- Operation and maintenance costs are based on percentage (2-5%) of above system components.
- Labour costs are based on average daily labour requirements (system specific) at an hour charge rate of $25.

d) Farm expenses (non irrigation) are based on typical rates for dairy farms on the following criteria:
- Farm working expenses are based on a pro-rata rate per stock unit from the base case, less cost savings for supplementary feed benefits of irrigation.
- Non cash adjustments are based on pro-rata per stock units from the base case farm.

e) Non cash adjustments:
- Change in stock numbers from Dexcel Farm Fact No.7-3.
- Run-off adjustment is $140/cow, with a minimum of $30,800, for the first farmer and family labour unit plus the percentage of any additional farmer and family labour units multiplied by $25,000.
- If the farm owner works full time on the farm then no adjustment to the EFS wages expense is needed, for example: all the wages paid by the farm in the farm accounts are included in the wages expense. If the farm owner employs a manager to run the farm, the farm manager's wage is excluded from the wages expense for calculating EFS.

[15] The amount of dry matter will vary in the model depending on the amount of irrigation per year and the pasture response which is set at 9.3 kgDM per ha per mm of irrigation. Rout (2003) had a response of 12 KgDM.

Table 2: Summary of financial analysis adapted from Rout (2003).

Financial Analysis	Units	Base Case	Irrigation Case[16]
Stocking Rate	cows/ha	2.8	3.16
MS Production	kgMS/cow	300	362
	kgMS/ha	840	1141
MS Return	$/kgMS	3.7	3.7
Income:			
Milk sales	$/ha	3108	4222
Net Stock Sales, Rebates and Other	$/ha	294	331
Total Income	$/ha	3402	4553
Farm Working Expenses:			
Wages (excl. managers wage)	$/ha	213	240
Animal Health	$/ha	151	170
Breeding and Herd testing	$/ha	81	92
Farm Dairy Expenses	$/ha	56	63
Electricity	$/ha	59	66
Pasture & Supplements	$/ha	484	357
Fertiliser (Incl. Nitrogen)	$/ha	409	461
Freight	$/ha	22	25
Weed and Pest	$/ha	28	32
Repairs & Maintenance	$/ha	260	293
Vehicle Expenses	$/ha	143	161
Standing Charges	$/ha	230	259
Administration	$/ha	90	101
Other	$/ha	17	19
Total Farm Working Expenses:	*$/ha*	*2243*	*2338*
Irrigation Expenses:			
Irrigation Capital costs	$/ha		3250
Above %	$/yr		70
Above Depn %	$/yr		9
Below %	$/yr		30
Below Depn %	$/yr		5
Total annual fixed costs	$/yr		257
Irrigation Operating Costs			
Power costs	$/yr		166
O & M costs	$/yr		91
Labour cost	$/yr		70
Total annual operating costs	$/yr		327
Irrigation Expenses	*$/yr*	*0*	*584*
Total Expenses	$/yr	2243	2922
Non cash Adjustments:			
Change in Stock Numbers	63	176	199
Less Run-off Adjustment	17	48	54
Less Labour Adjustment	164	459	517
Less Depreciation	92	258	290
Total Adjustments:	-210	-588	-663
Economic Farm Surplus:	204	571	968.25
Marginal Benefits ($/ha)			***397***
Return on investment (%)			12.22

[16] Values are based on the weighted average of 12 irrigation systems (4 types) in Reporoa.