Title: **Land use and water quality**

Purpose: To encourage the Ruamāhanga Whaitua Committee to think about the environmental and social impacts of land use change.

To provide a history of land use change, as well as a current snapshot of land use in the Ruamāhanga Whaitua.

Author: Andrew Stewart

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Contact the Ruamāhanga Whaitua Committee
34 Chapel Street
Masterton
PO Box 41
Ruamāhangawhaitua@gw.govt.nz

T 0800 496 734
F 06 378 2146

Land use and water quality

Contents

1. Key points

- There has been significant land use change since 1850, with removal of native vegetation, and modification of waterbodies.
- Sheep and beef farming is the predominant land use in 2014. Sheep and beef farming is dominant in the eastern part of the whaitua. Native bush is the second largest land use, and is particularly important in the western areas of the whaitua.
- Dairying occupies a much smaller proportion than the two largest land uses. There has been a relatively small change in the extent of dairying in the last 15 years.
- The trend for land use change in the last 15 years has been the intensification of land use rather than a major change in the type of land use.
- Urban areas occupy a very small proportion of the whaitua but have a proportionally larger impact than the area they occupy compared to other land uses.

2. Introduction

Land use affects water quality and quantity. Changing patterns of land use have shaped existing water quality in the catchment and future land use will shape future water quality. Understanding the links between land use and water quality is useful when discussing limit setting in the whaitua.

Factors such as vegetation coverage and agricultural practices affect water quality and quantity. Urban land use affects water quality through stormwater discharges and discharges from sewerage treatment plants operation. Management of rivers and riparian margins is another aspect of land use that has implications for water quality.

This paper will outline links between land use and water quality and quantity, as well as providing a snap shot of current land use and as a history of land use change in the Ruamāhanga whaitua. Key points are summarised in the main body of paper, however this paper should be read in conjunction with the attached Appendices, which provide some historical background to areas covered here.

3. Land use effects on water quality

There are many aspects of water quality. Different land uses will affect different parameters to varying extent. Therefore, as the mix of land use in the whaitua changes, the risk to different aspects of water quality will change. In this discussion the key parameters affected by land use and land use practices are:

- sediment generation
- nutrient loading
- bacterial contamination
- effects on mauri

For more information on these parameters see Appendix 1.

Traditionally the links between land use and water quality are seen as flowing in one direction.
Land use changes → this has an effect on water quality.

What are the potential for effects to flow the other way?
When limits are placed on water quality → how will this affect land use change?

4. Vegetation Coverage

Vegetation cover affects water quality by changing the susceptibility of land to erosion. As erosion susceptibility increases, sedimentation of waterways and consequently phosphorus loadings to waterways will increase.

Vegetation coverage also affects catchment hydrology, and with it water quantity. The main mechanism by which tall vegetation affects the water balance is through evaporation of intercepted rainfall, reducing the amount of water available for runoff and stream flow. Potential reductions in annual water yield of between 30 and 80% have been measured following afforestation of pasture.

Afforestation also affects peak flows, particularly for small flood events. There is debate though about whether these effects are seen at a large catchment scale. The effect of afforestation on low flows is less well studied. Low flows are reduced following afforestation but it appears that in some cases low flows are affected to a lesser extent than annual yield.

4.1 Vegetation coverage 2008

Table 1. Current estimates of vegetation coverage based on satellite data from 2008.

Vegetation class	Hectares	Percentage
Cropland	3705	1.0%
Exotic forest	14148	4.0%
Grassland - With woody biomass	17173	4.8%
Natural Forest	94219	26.5%
Other	390	0.1%
Pasture	212612	59.8%
Settlements	2275	0.6%
Wetland - Open water	10395	2.9%
Wetland - Vegetated non forest	633	0.2%
Grand Total	**355549**	**100%**

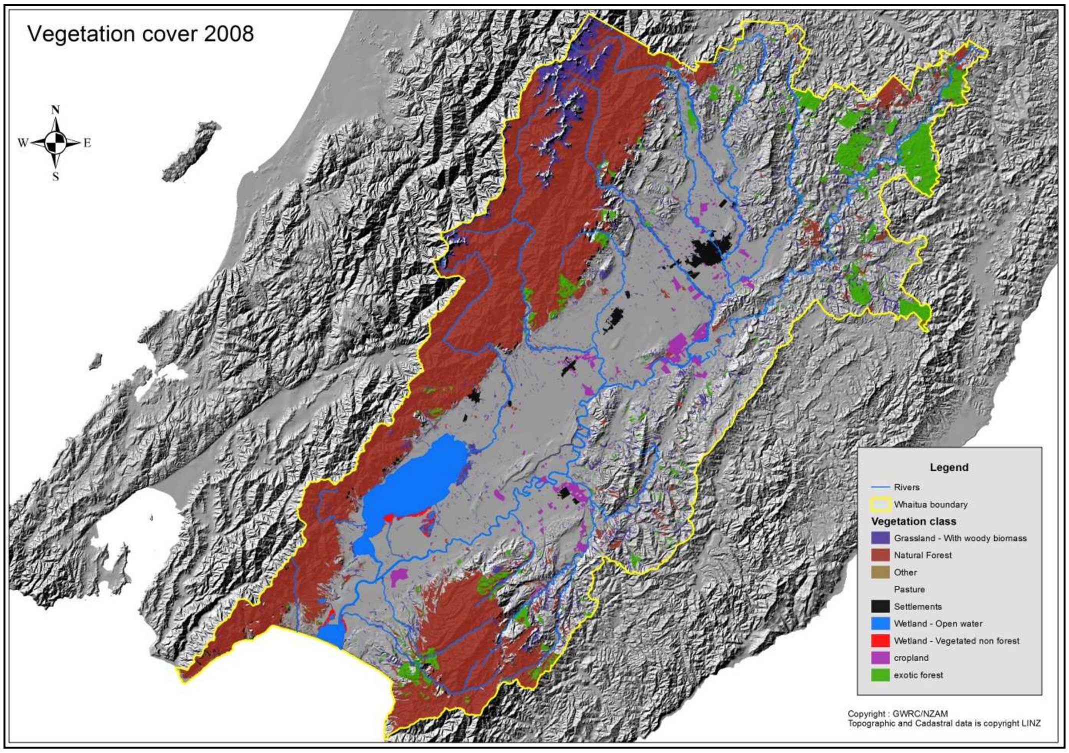


Figure 1: Vegetation cover in the Ruamāhanga whaitua

Comparing this satellite data against more recent aerial photos indicates there are limitations in the accuracy when classifying vegetation classes. In particular, there is some confusion between the classification of native and exotic vegetation. Also, there are areas recorded as pasture which contain either erosion control plantings and/or scattered native vegetation, thereby overestimating the area of pasture and underestimating the area of grassland with woody biomass. Given these limitations, the figures are likely to be accurate +/- 5%.

5. Agricultural land use

Agriculture is the dominant form of land use in the Ruamāhanga whaitua. In this paper, agriculture refers to grazing, cropping, horticulture, viticulture and forestry enterprises.

Different land uses impact on different water quality parameters. For example, the grazing of livestock has a greater impact on microbial contamination of waterways than forestry. The intensity of agricultural practices, combined with the technologies used by the agricultural production system, also determines the impact that the agricultural enterprise has on water quality. For example, the nitrogen lost from dairy farms can vary significantly depending on farming practices used and the intensity of stocking rates.

Early agricultural practices within the whaitua were typically lesser intensity and arguably had a lesser overall impact, given the scale and extent of the land use, at that time. Climate limited the extent of agricultural activities, which in turn affected the establishment of viable communities and settlements. The introduction of new crops such as potato, wheat and a range of fruit and vegetables meant that higher densities of settlements were established in inland Wairarapa, which had not been possible under pre European time, with the less climatically tolerant kumara.

European settlers and squatters introduced new agricultural practices and transformed the landscape. Since then agricultural land use has continued to change, with new enterprises and land uses being adopted and developed. Changes are driven by fluctuating economic fortunes of the different agricultural sectors, land price, as well as the development of new technologies to overcome limitations that restrict the economic viability of agricultural enterprises.

Agricultural practices and technologies affect water quality. Examples include the practice of vegetation clearance, (which in turn led to the development of re vegetation techniques to control soil erosion), drainage, aerial topdressing, and changes to dairy effluent management. Availability of water for irrigation also influences the pattern of land use. Further irrigation resulting from the Wairarapa Water Use Project will lead to changes in land use if the project proceeds. Agricultural technology and land use practice will continue to change. This will include changes to practices that mitigate the impact of a certain land use on water quality.

5.1 Sheep and beef

Sheep and beef farming were some of the earlier European farming systems in the Wairarapa. Wairarapa's hill country was extensively developed in the period following World War 2. Government rehabilitation schemes settled farmers on comparatively small blocks and generous subsidies encouraged the development of pasture on scrub-covered lands. The development of aerial topdressing with lime and superphosphate enabled increased production.

The removal of subsidies in the mid-1980s changed the direction of hill country farming. Farmers were unable to maintain costly marginally economic pastures and stocking rates declined. Some recently converted land reverted to 'scrub', while other land was converted to plantation forestry (Winter, 2010).

5.2 Forestry

Large-scale forestry was first introduced to the Wairarapa in the 1940s when the Government started planting the Ngaumu block (outside the whaitua) to help stabilise erosion prone land and to provide housing timber. Forestry planting doubled in the 1990s but in recent years has curtailed and now planting and harvesting rates are in equilibrium (Winter, 2010).

Commercial pine forests are located in the northeast quadrant of the Masterton District, in the foothills in Carterton District and around the Aorangi Mountains in the South Wairarapa District. Some of the trees in this latter area were originally planted by Greater Wellington Regional Council (GWRC) to reduce erosion, but have since been felled (Chrystall, 2007).

5.3 Dairy

Dairying has a long history in the Wairarapa valley with records of the first dairy factory, established around 1883. Dairy farming predominates on the alluvial plains around Carterton and around the shores of Lake Wairarapa. Dairy farms and dairy runoffs comprise 12 percent of land area in the whaitua.

The following statistics of dairy numbers in the Wairarapa, taken from the Annual New Zealand Dairy Statistics (Dairy New Zealand and Livestock Improvement Corporation, 2013).

Table 2. Dairy Cow numbers in the Wairarapa

	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13
Masterton	7209	7214	7045	7738	7881	7976	8121	7515	6875	7656	7980	8107	7847	8075	8517
Carterton	22262	22757	22531	22186	22515	22050	22250	20879	20760	20013	20616	20701	20524	20801	21453
South Wai	31888	31586	34571	34620	35466	35604	34858	34916	35422	35479	37085	37577	37061	38416	38294
TOTAL	61359	61557	64147	64544	65862	65630	65229	63310	63057	63148	65681	66385	65432	67292	68264

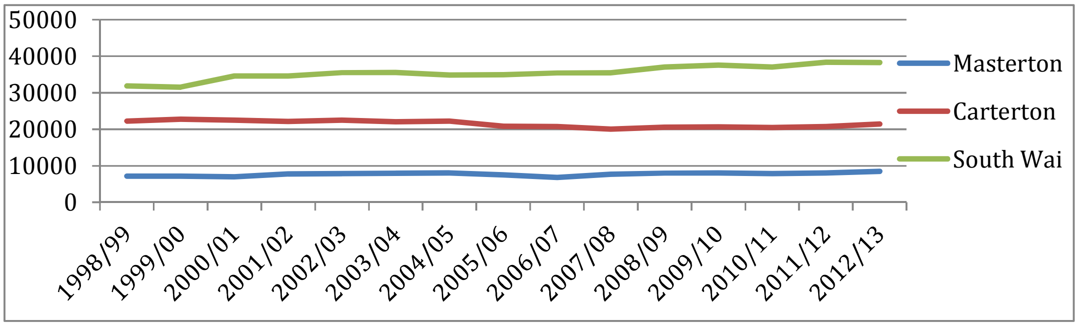
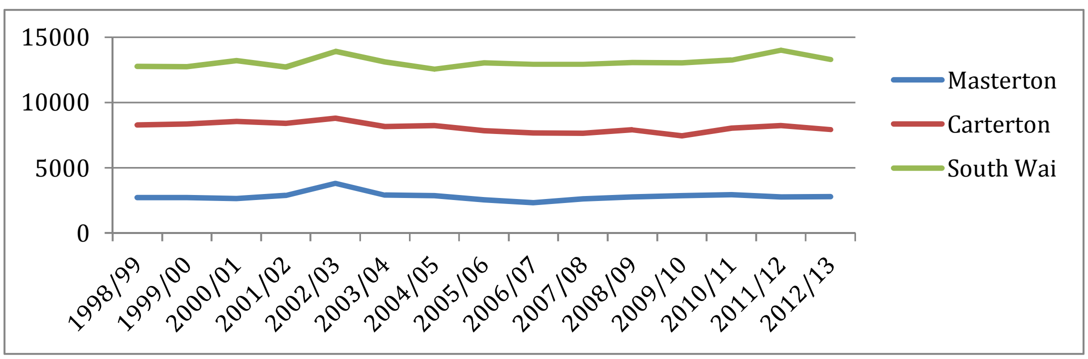


Table 3. Hectares of Dairy Land Use in Wairarapa 1998 -2013

	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13
Total Cows	61359	61557	64147	64544	65862	65630	65229	63310	63057	63148	65681	66385	65432	67292	68264
Total Hectares	23754	23838	24387	23980	26519	24157	23638	23398	22915	23194	23725	23327	24217	24978	24021



Note: Total effective hectares from 1998 -2002 were calculated from the average farm size by the number of herds. This accounts for the difference in hectares of dairy use shown in Table 3 and table 4.

5.4 Horticulture and viticulture

Horticulture was the first agricultural enterprise in the Ruamāhanga whaitua. There are records of cultivated land around the Palliser Coast from earliest stages of human occupation. The later introduction of potatoes, wheat and other fruit and vegetables enabled permanent settlements to be established in the interior.

Horticulture was an important industry in the region, especially on the rich alluvial soils that accommodated extensive market gardens, and a large number of berry and pip fruit orchards. The Greytown fruit industry flourished, but rising costs and poor returns have seen this industry shrink in importance.

Viticulture and fruit growing are the dominant horticultural land uses in the Ruamāhanga whaitua - although they only occupy less than 1% of land area. The Wairarapa region is New Zealand's sixth-largest winemaking region, concentrating on producing premium wines. In 2007 there were 829 hectares in grapes, about 6% of New Zealand's total. The wine industry is concentrated on the gravel soils and dry climate of Martinborough, although there are also plantings in East Taratahi, Gladstone and at Opaki, north of Masterton (Winter, 2010). As at 2001, there were 38 fruit growers in the Wairarapa, with pear and apple orchards scattered around Masterton and Greytown, and a few east of Martinborough. Olive growing began in 1991 with a grove of 60 trees in Martinborough. The industry now reaches as far as Masterton and has 70,000 trees. It comprises boutique enterprises producing high-quality oil, mainly for the domestic market. The growers produce about 15% of New Zealand's olive oil. (The encyclopaedia of New Zealand) Six market gardens were recorded in 2007, the largest of which are located around the Greytown area. A mushroom factory is located at Parkvale, outside Carterton.

Although horticultural and viticultural practices do not generate significant amounts of discharge that directly enters the waterways, some of them abstract large volumes of water for irrigation and frost control (Chrystall, 2007).

5.5 Other agriculture

One of the largest piggeries in the country is located within the Wairarapa, near Carterton. It holds a consent discharge up to 550 cubic metres of effluent to land per day.

5.6 Land Use in 2014

Table 4 and Figure 2 below show the current extent of land use in the Ruamāhanga whaitua using data combined from a number of sources including Agribase and individual farmer surveys.

Table 4: Land use in Ruamāhanga whaitua 2014

Land Use	Hectares	Percent
Sheep Beef Deer	165200	46.5%
Native Bush	83300	23.4%
Dairy and dairy support	42100	11.8%
Arable Mixed	15700	4.4%
Lifestyle	12900	3.6%
Hydro and waterways	12400	3.5%
Forestry	11500	3.2%
Road and Rail	4100	1.2%
Urban	3200	0.9%
Other	2600	0.7%
Viticulture	1600	0.5%
Horticulture	800	0.2%
Total	**355400**	**100%**

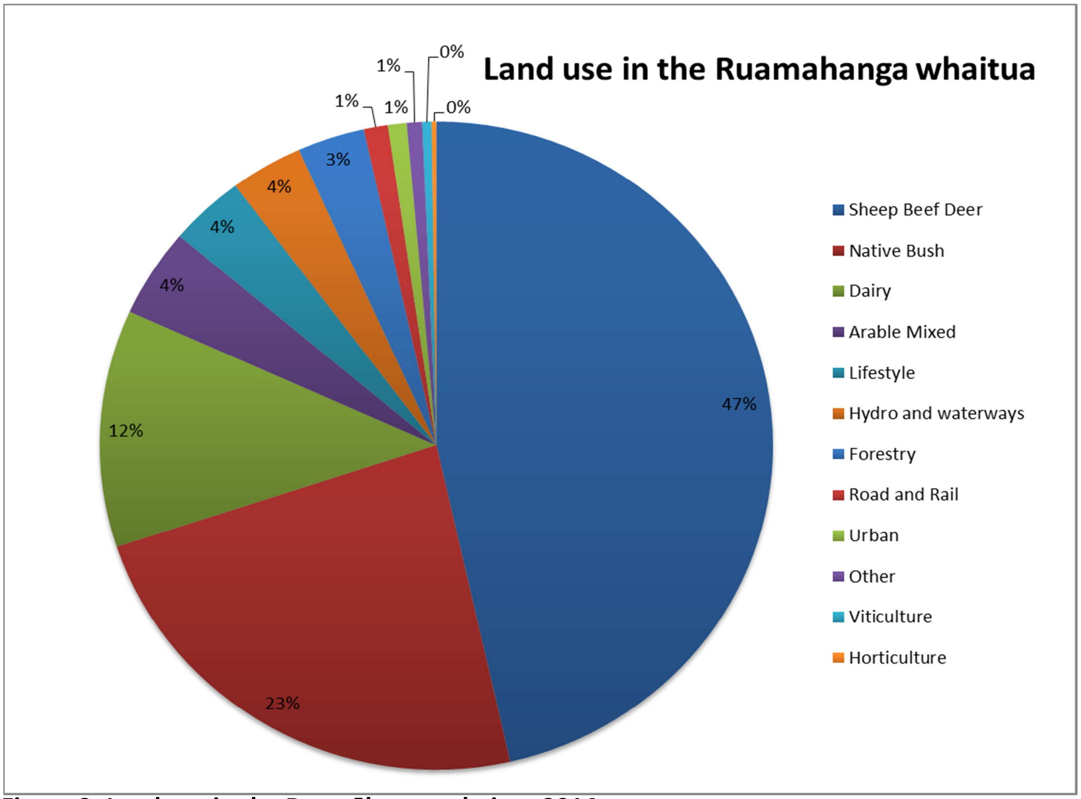


Figure 2: Land use in the Ruamāhanga whaitua 2014

Sheep, beef and deer farming is the predominant land use in the Ruamāhanga whaitua. It occupies approximately double the land area of the second largest land use, native vegetation. Together, almost three quarters of the whaitua is occupied by these two land uses.

Different figures for the area of dairying are reported in Table 4 and Table 3. The differences are due to two reasons. First, Table 4 combines dairying and dairying support as opposed to dairy farms milking platforms. Second, Table 4 is based on the predominant land use of a land parcel, as opposed to the effective hectares of a dairy farm as assessed by LIC.

Note: the data presented in Table 4 and Figure 2 will continue to be updated. This is the first cut at combining different data sources to map land use in the Ruamāhanga whaitua. While it is the best information available, it will continue to be improved.

Figure 3 shows a strong correlation between land use and land use capability (LUC) within the whaitua. Sheep and beef farming is typically located in the eastern hill country which is mainly LUC classes 5, 6 and 7. Dairy and mixed arable are located on LUC classes 1-4, while native forest is strongly linked to LUC classes 7 and 8.

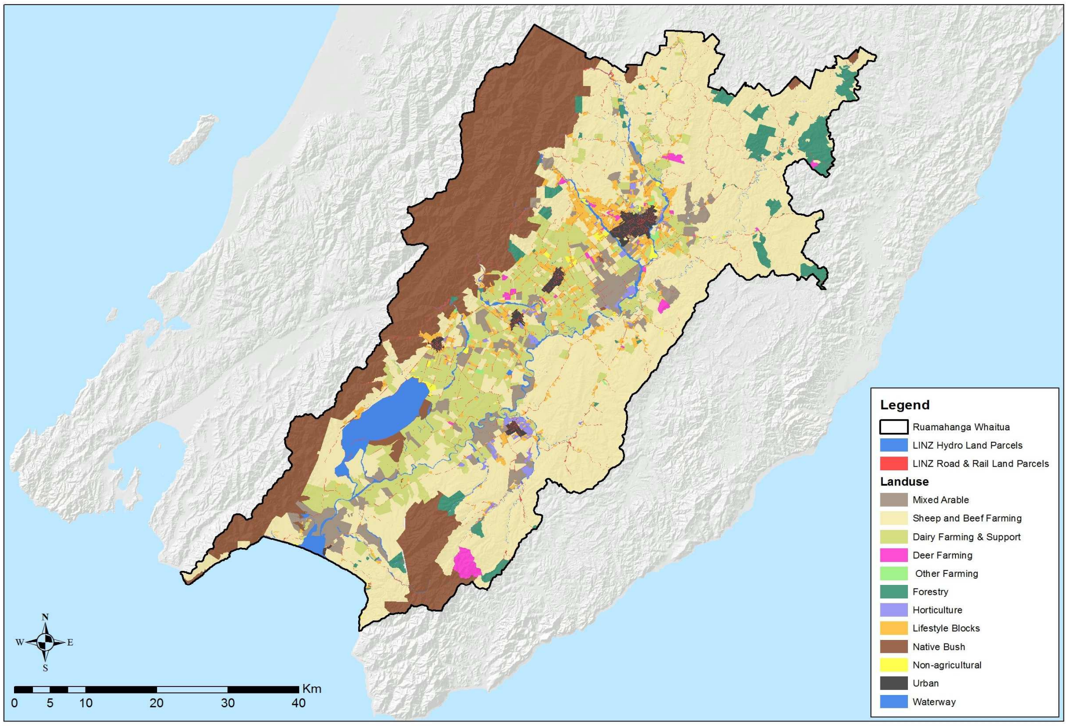


Figure 3. Distribution of land use in Ruamāhanga whaitua

6. Major changes in land use practices and the impacts on water

Agricultural and horticultural practices continually change and develop. Agricultural technologies, alongside economics, topography, geology, soils, and climate, drive land use and the consequential impacts of land use on water quality and quantity. This section outlines some significant developments and changes in land use that have occurred in the Ruamāhanga whaitua.

6.1 Vegetation clearance in hill country

Vegetation cover, particularly on hill country, has significant implications for the effect of land use on water quality and quantity. Vegetation clearance to provide pasture on certain classes of hill country has resulted in increased erosion, and an ongoing susceptibility of these classes of country to erosion risk.

Soil disturbance and resulting bare soil on susceptible land surfaces can be reduced using soil conservation cover, such as woody vegetation, which can provide a stabilising effect, if it is sufficiently dense to exert various root re-enforcements and de-watering effects (Crippen and Hicks, 2011).

The results of regional soil stability surveys undertaken in 2002 and 2010 showed that the majority of the region's soil is intact. There is a slight increase in stable and erosion-prone (inactive) land surfaces across the region over this period; this is mainly due to the re-vegetation of some former erosion scars. However, soil disturbance caused by land use activities increased from 11% to 15% of the Ruamāhanga catchment between 2002 and 2010.

Land use activities that caused the most soil disturbance in 2010 included farm and forest tracking, cultivation, spraying for pasture renewal and grazing pressure. Although only a small total percentage, between 2002 and 2010 the amount of bare soil caused by cropping and horticulture and, to a lesser extent, dairy farming, has increased. In contrast, there was a significant decrease in the amount of bare soil caused by drystock farming – although it continued to be the largest contributing land use of bare soil in 2010 (owing mainly to it representing the dominant land use in hill country areas of the region).

Bare soil on relatively flat and stable land is generally smaller in scale and relates to specific land use activities (such as tracking and grazing pressure) compared to bare soil on hill country caused by erosion which can be much more widespread. The effects of bare soil on flat land are also more localised, but the soil can still be damaged by compaction or lost through erosion, affecting production and nearby waterways (Sorenson, 2012).

6.2 Aerial topdressing

The introduction of aerial topdressing in 1949 changed stocking rates and increased the productivity of Wairarapa hill country. Since the fifties, aerial topdressing has become a standard management technique to apply fertiliser and lime to pasture.

Increased productivity through aerial topdressing changed hill country farming enterprises. The full utilisation of increased soil fertility requires other changes in farm management such as greater paddock subdivision, heavier and more controlled stocking, and, in some cases, larger areas of supplementary crops and hay to feed the greater number of sheep and cattle during periods of feed shortage. Better provision of drinking water, and more access tracks, also tends to accompany higher productivity.

In the early fifties hill country properties carried store stock with high wether numbers in many cases, with cows to clean up roughage and fulfil a role in opening up scrub country. Increased development allowed changes to prime lamb and beef production. Evidence from the Whareama catchment (outside the whaitua, but indicative of hill country in the whaitua) shows significant increases in stock numbers, and an equally significant drop in cattle numbers from the fifties to the eighties (Brown Copeland and Co, , 1985). This indicates that a greater number of sheep were farmed. The reasons were cited, including decreasing cattle numbers by farmers, decreases in cattle prices were lower and that erosion was worse under high cattle numbers.

In all, the consequences of increased top dressing and reductions in cattle densities include a reduction in surface/sheet erosion through improved pasture cover, and increased nutrient cycling through the agricultural system. Increases in Olsen P levels on farms would mean that as sediment was lost from farms, higher P losses would accompany the soil loss. Reducing cattle numbers would have reduced impacts on soil quality, potentially reducing surface water runoff, and reducing susceptibility of certain classes of hill country to erosion.

6.3 Dairy effluent disposal

Collected effluent is generated in the dairy shed, on feedpads and underpasses, and from piggeries, stockyards and stock trucks. On a dairy farm, collected effluent typically represents about 10% of the nutrients released to the environment. The other 90% is released directly onto the paddock as dung and urine.

Since the adoption of the 1999 Discharge to Land Plan, all consents for discharge of collected effluent in our region have been to land, instead of to water. In November 2006, there were 179 consents to discharge dairy effluent to land in the Wairarapa, and only three short term consents to discharge effluent to water. There have been no consents to discharge effluent to water since 1999

Forsyth (2005, p. 15) concluded that the shift in effluent discharges from water to land has meant a decrease of 60 tonnes of nitrogen being discharged directly into rivers annually in the Wellington Region.

7. Contaminated sites

Some types of land use can continue to affect water quality after the land use has ceased. Certain forms of historical land use have left a legacy of soil contamination, which has the potential to affect water quality. One example is old sheep dips sites. It is difficult to quantify the effect that these sites are having on water quality at a catchment level because there is limited information about the extent of contaminated sites within the Ruamāhanga whaitua.

GWRC holds a register of sites where activities involving hazardous substances have or may have taken place. This register, which is formally known as the Selected Land Use Register (SLUR), is held on behalf of the eight Territorial Authorities in the Wellington region. The SLUR records sites that fit the definitions in the Ministry for the Environment's Hazardous Activities and Industries List (Hail).

Sites registered in SLUR are known or suspected to have been involved (historically or currently) in the use, storage or disposal of hazardous substances. Consequently, these sites may contain residues of these substances. In some cases these sites will be "contaminated sites" and in others not; to distinguish between sites, SLUR classifies them under six categories.

SLUR records any information that is available relating to the site, such as:

- The history of the activities that have or are believed to have occurred on the site
- The nature and concentration of hazardous substances
- Any remediation or mitigation measures that have taken place
- Any site management plans

8. Land tenure

Land tenure (land ownership) is an underlying factor influencing land use. Land tenure determines responsibility for deciding what land use practices will occur on a particular piece of land. Changes to land tenure, from tribal use to the introduction of leasing and later land ownership, significantly affected land use practices (more information is in Appendix 3). Understanding past changes to land tenure provides an insight into what has driven land development and hence influenced water quality in the whaitua.

Publicly and privately owned land often result in different emphasis on priority outcomes for land use. Public forms of land tenure may have different objectives and manage land to provide services that provide wider public benefit such as the provision of soil conservation services. Private land ownership typically results in land uses that focus on maximizing productivity of marketable goods. Historically, off farm impacts, such as impacts on water quality, have not played a large part in determining land use and land use practices on private land. Recent changes in societal attitudes and resource management have led to greater emphasis on accounting for off farm impacts of private land use.

Almost 74% of land in the Ruamāhanga whaitua is in private ownership. The Department of Conservation manages public land, which includes the Tararua/Orongorongo and Aorangi State Forest parks and Wairarapa Moana, total nearly 25% of the balance. Currently, Māori , Territorial Local Authorities and Greater Wellington Regional own less than 2% of land. There are some farm block holdings designated as Māori land, a number of which are land locked. Greater Wellington's land holdings are primarily soil conservation forest reserves and the lower end of the Oporua Floodway (Gunn, 2010).

9. Urban land use

Urban areas cover a small proportion of the Ruamāhanga whaitua, though they are an intensive form of land use. Population growth is the main driver affecting the intensity of land use in an urban setting. Urban development is characterised by an increase in impervious surfaces. This increases surface runoff to stormwater systems and carries contaminants such as oil, sediment, chemicals and rubbish.

Urban settlement in the whaitua started when the introduction of new agricultural crops allowed permanent settlements to be established in inland Wairarapa. At first urban development grew slowly, but as farming became more productive urban development increased. In the 1870s Masterton overtook Greytown as Wairarapa's major town.Further urban development occurred as European settlers entered the region in the 1840s. Interestingly, urban development at this time was tightly linked to rural land use changes as settlers were offered urban sections and rural land parcels as part of a planned development strategy.

In the 20th century Masterton kept growing, but never enough to dominate the region. From the 1960s, people and businesses left for opportunities elsewhere. In the 1980s, with government deregulation and protective tariffs lifted, more businesses closed resulting in further changes in the nature of urban areas..

Urban populations requires community sewage systems, which collect waste where it is treated before being discharged to the environment. Urban wastewater treatment has historically discharged treated effluent to waterways; this continues though there is a move to discharge small volumes of effluent to land. Urban areas also has high property values and are high priority areas for flood protection. Flood protection strategies can have significant effects on water quality, discussed latter.

Wairarapa's population is not predicted to significantly increase or decline in the next 20 years. The population of Wairarapa's biggest centre, Masterton, has remained steady with predictions for 2031 is that it will sustain a net loss of 600 people. In 2011 Masterton District was home to 23,500 people; the 2031 projections expects 22,900, across the district. Carterton had 7260 in 2012 which is expected to increase to 8110. South Wairarapa has 9120 people and is expected to have 9300 by 2031 (Fuller, 2012).

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10. Land use and flood protection

Flood protection works are another form of land use that affects water quality. Land use off the rivers, particularly changes in vegetation cover, affects the need for flood protection works. Management of rivers for flood protection has extensively modified the rivers in the Ruamāhanaga whaitua.

River works occur throughout the Wairarapa valley with the aim of controlling river meander and reducing the risk of flood damage to land and property. Such measures include the construction of groynes made of rock or rails, along with gravel bunds and stop bank protection works. Pole and stake planting of willows are also used to strengthen channel banks and provide buffer vegetation.

Vegetation is routinely cleared from active river channels to prevent reduction in flow capacity. However, river works only provide temporary solutions to issues. Channel modification, re-alignment and straightening of a channel creates non-natural form and during a flood event a river will tend to rework its shape back to a natural character form, meaning on-going work is required.

11. Future land use changes and social implications

One of the potential drivers of future land change in the Ruamāhanga whaitua would be an increase in irrigated land through the Wairarapa Water Use Project (WWUP). Land use changes are likely to be significant if the project proceeds.

Changing land use has the potential to affect water quality, as well as create social impacts. As land use changes, people with different skills replace families holding 'traditional' skills. . The leadership role of families who remain is critical during this change period. These local families act both to validate the new land use and maintain some sense of stability. Furthermore, there can be a resulting positive impact on local schools, sports and recreation facilities and other social services, strengthening rural communities, in addition to negative effect of community change. One factor shaping a community resilience to change is the rate at which change occurs.

Land use changes work patterns and roles of the farm family. Similar changes are required to the skills base of farming service providers - contractors, skilled labour, rural service providers and small business people. When rapid land use change occurs, local skills and resources may not align with new production systems and local workers and small businesses may be left outside the new, burgeoning economy. Rural towns, which have not recognised the potential of the land use change, will lose service provision and other commercial activity to towns where these provisions will be sought and satisfied.

12. Summary

Land use associated with agriculture, urban areas and river management affects water quality. The scale of impacts from a particular land use reflects a combination of the intensity of the land use and any mitigation technologies used. It is also important to recognize that different land uses affect different water quality parameters and that the overall impact on water quality within the whaitua will reflect the mix of land use in the area.

As well as affecting water quality, land use choices help shape the social makeup of the Wairarapa community. Land use in the Ruamāhanga whaitua continually changes in response to economic, technological and social factors. While traditionally land use is seen to precede water quality impacts, the process of imposing limits on water quality parameters has the potential to affect the choice of land use in the future.

These interactions between water quality, social impacts and land use illustrate that decisions on water quality limits will have a wide impact on the Wairarapa community because of how integrated these factors are.

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Report prepared by		Report approved by	
Andrew Stewart	Date	Alastair Smaill	Date

Appendix 1: Water quality parameters

There are many aspects of water quality. Different land uses will affect different parameters to varying extent. Therefore, as the mix of land use in the whaitua changes, the risk to different aspects of water quality will change. In this discussion the key parameters affected by land use and land use practices are:

- sediment
- nutrient loading
- bacterial contamination
- effects on mauri.

Sediment

Both natural processes and land use activities can cause soil erosion, resulting in bare soil and reduced land productivity. Eroded soil becomes mobile in rainfall and can adversely impact the environment if the eroded soil enters water bodies such as rivers, lakes and wetlands (Sorenson, 2012). Erosion debris of silts and gravels enters rivers via surface runoff, increases the risk of flooding, and contributes to loss of aquatic habitat and increased sediment loads (Ministry for the Environment 2007).

Soil erosion can also have significant economic and social impacts. Erosion can damage roads, buildings and other infrastructure, and in large landslide events can lead to social upheaval, reduced revenue and added cost of reinstating infrastructure.

Managing vegetation coverage is important in controlling the impacts of erosion and consequently the impacts of sedimentation on water quality. Soil conservation management strategies such as planting of woody vegetation, space-planted trees and forestry, are used throughout New Zealand to reduce the occurrence of mass movement erosion on pastoral hill country.

Nutrients

Most of the nitrogen and phosphorus in freshwater originates from diffuse sources on land (Parliamentary Commissioner for the Environment, 2013) .The nature and scale of these diffuse sources depend largely on how the land is used. When land uses in a catchment change, the nutrient loads on the streams in that catchment are also likely to change. While the impact of nutrients on water quality can vary, it is clear that if nutrient loads increase significantly, so does the pressure on water quality.

The weight of stock on the soil surface can cause waterlogged soils to become ‘pugged’, and so nutrients are more likely to be washed off across the surface directly into waterways. Compacted soil is difficult for plant roots to penetrate, further slowing plant growth and take-up of nitrogen.

There is a fundamental distinction between nitrogen and phosphorus that not only affects how they get into water and how easy they are to control, but how they ‘behave’ in water.

Nitrogen – in the forms in which it generally gets into water – is very soluble. This means that it can flow relatively easily across land, and leach down through soil into groundwater, before making its way into rivers, streams and lakes, and down into aquifers. Most of the nitrogen that enters fresh water is available for plant growth in the water, fertilizing aquatic plants, algae and pest plants.

In contrast, phosphorus tends to stick to soil and is not as easily washed away by water. Much of the phosphorus in waterways originated as naturally occurring phosphorus in soil. As soil is washed into water, it builds up as layers of phosphorus-rich sediment. Some phosphorus is dissolved in water and can be taken up by aquatic plants, but most phosphorus in waterways is trapped and accumulates in the sediment. This trapped phosphorus can later be released again under the right conditions and thus be available for plant growth.

Nitrogen and phosphorus also enter waterways as direct discharges from wastewater treatment plants.

Nitrogen

On a per hectare basis, the highest losses of nitrogen come from land used for market gardening, in part because vegetables do not take up nitrogen efficiently. The lowest nitrogen loss per hectare comes from forested land and scrub. Losses from livestock farming lie in between.

The main source of nitrogen in New Zealand's waterways is urine from farm animals. Urine contains urea, which is rich in nitrogen. Urine acts as a nitrogen fertiliser, but the grass cannot grow fast enough to take up all the nitrogen in urine patches. When paddocks are waterlogged, the nitrogen can wash straight through the soil before plants can use it. This occurs particularly in winter.

Over the last twenty years, sales of nitrogen fertiliser have increased steeply. But while some nitrogen entering waterways will have come from nitrogen fertiliser, this fertiliser is a much smaller source of nitrogen than animal urine. However, the increased use of urea fertiliser has, along with irrigation and supplementary feed, enabled higher stocking rates, and more animals mean more urine.

Phosphorus

Historically, phosphorus has accumulated in waterways where land has been cleared, with the highest rates occurring where rainfall is high, slopes are steep and soils are prone to erosion. Phosphorus occurs naturally in soil, but the use of superphosphate fertiliser on hill country, which began in the 1950s, increased the phosphorus in soil and thus the losses into water (Parliamentary Commissioner for the Environment, 2013).

Sewage and animal effluent are rich in phosphorus. Wastewater from towns, dairy factories, freezing works, and pulp and paper plants can be large point sources of phosphorus. Although these point sources can be significant at specific places and times of year, they are much less significant at a national level than the diffuse sources of phosphorus.

E.coli

The major health risk from swimming (primary contact with water) arises from ingesting disease-causing microorganisms (pathogens) through the mouth, nasal passages and ears. Pathogens might be bacterial or viral, and include such things as campylobacter, cryptosporidium, giardia, hepatitis A viruses, and salmonella. Many enter waterways through contamination from animal or human faecal matter. Escherichia coli (fresh water) and enterococci (marine) are used as cost-effective, surrogate indicators of harmful pathogens.

Bacteria levels are often highest after rainfall when faecal matter is carried from the land into waterways. Examples of common sources of bacteria include effluent run-off from farmland, human wastewater discharges, stormwater outfalls, and domestic and wild animal waste (MfE).

Mauri

Mauri, the life force that exists in all things in the natural world, can be harmed by insensitive resource management practices. For example, the health and vitality of the sea, streams and rivers and the plants and animals they support can be threatened by activities such as discharges of pollutants, storm water, sewage and runoff of contaminants from land; excessive water use; changing the course of water bodies or diverting water between catchments or rivers.

Rivers are considered the life blood of the land and that the well-being of a river is reflected in the well-being of people. Similarly, the mauri of the land and air and the plants and animals they support can be harmed by practices such as clearance of vegetation, soil disturbance and disposal of wastes. To guard against harm to mauri, management practices must respect this life force.

Water bodies are viewed holistically and cannot be distinguished from the surrounding land and catchments. Water provides cultural and spiritual sustenance, is viewed as the source of life with life giving properties and is regarded as a taonga.

Appendix 2: Vegetation Cover

Vegetation cover affects water quality directly and indirectly. Direct impacts affect the susceptibility of land to erosion, while indirectly changes in vegetation affect land use, which in turn affects water quality. As erosion susceptibility increases, sedimentation of waterways and consequently phosphorus loadings to waterways will increase.

Vegetation coverage will also affect catchment hydrology. The main mechanism by which tall vegetation affects the water balance is through evaporation of intercepted rainfall, thereby reducing the amount of water available for runoff and stream flow. In experimental studies around New Zealand, reductions in annual water yield of between 30 and 80% have been measured following afforestation of pasture. These figures are lower where afforestation has replaced scrub (Davie, 2005).

The effect of afforestation on peak flows is considerable, particularly for small flood events, although there is some evidence that storms with long return periods may also be substantially reduced following afforestation. There is considerable debate whether these effects can be seen at a large catchment scale (Davie, 2005). The effect of afforestation on low flows is less well studied. Low flows are reduced following afforestation but it appears that in some cases low flows are affected to a lesser extent than annual yield (Davie, 2005).

Historical vegetation coverage

The Ruamāhanga floodplain falls within the Wairarapa Plains Ecological District. Prior to human settlement, podocarp-dominant forest covered most of the Ecological district. Fires in the 17th century destroyed most of the original podocarp forest (totara in the drier areas and kahikatea, matai, raupo, harakeke and sedges in the wetter areas). Native grasslands, fernland, swamps and scrub then replaced the forest. (Gunn, 2010)

The vegetation of the Wairarapa around the 1840s was characterised by variety. (Hill, 1963) The whole area was a patchwork of grass, swamp, scrub and forest mingled in varying proportions. The land along the Ruamāhanga River was in dense bush and fringing the Ridge was a swamp containing Phormium tenax. 'About a mile to the north were low-lying ridges on which grew manuka (*Leptospermum scoparium*) and a small variety of flax, interspersed with open spaces covered with grass and tall rushes' (Bidwill and Woodhouse, 1927, p. 8), In describing the vegetation of the Wairarapa Valley, one observer noted that grassland covered about 200,000 acres, forest covered about 80,000 acres, while there were nearly 25,000 acres of fern and scrub and about 20,000 acres of swamp.

To the west of Lake Wairarapa, the mixed podocarp/broadleaf forest extended down from the Rimutaka Range to reach the lake margin and bush extended into the valley at several points, notably in a 20,000 acre block between the Waingawa and Waiohine Rivers. At its northern end the valley was closed off by an area of bush-clad hills that extended with little break to a clearing in the vicinity of the Manawatu Gorge.

The swampland was of two types, neither of which were described in detail by then contemporary observers. In the vicinity of the present Morrison Bush was the Kaitara 'swamp forest', vividly described by the missionary-botanist William Colenso who had the misfortune to stumble across it. 'The bush concealed a swamp, a network of deep pools between which 10 or 12 feet high sedges luxuriantly grew, the whole intersected with rotten logs and prostrate trees' (Colenso in Bagnall and Peterson, 1948). Little less forbidding to the traveller was the unforested swamp which occurred mainly adjacent to Lake Wairarapa. Here the vegetation was mainly grasses and sedges including toe-toe (*Arundo conspicua*), raupo (*Typha angustifolia*), *Alxopecurus geniculatus, Hierochloe redolens, Zoysia pungens* (especially near the sea), *Glyceria stricta*, as well as flax (*Phormium tenax*) and sow-thistle (*Sonchus* spp.). Herbs such as*Epilobium nummularifolium, E. confertifolium, E. alsinoides, E. rotundifolium, Myriophyllum elatinoides, M. robustum, M. propinquum, Cardamine sp.* (Colenso's 'excellent cress'), *Rorippa islandica, Ranunculus macropus* and *Cotula coronopifolia* were also reported by Colenso.

In the hill country to the east of the Wairarapa Valley, the four major elements of forest, grassland, fern and scrub and swamp were repeated but with grassland and swamp being found only in small discontinuous patches. The Haurangi and Maungaraki Ranges were largely in mixed podocarp/broadleaf forest with some beech at around 2,500 feet. However, the hills, as distinct from the ranges, were largely fern-clad but with a good deal of Angelica spp. and grass among the fern (Hill, 1963).

Changes to vegetation coverage

As European settlement increased the numbers of associated sheep and cattle grew. Grazing and browsing by sheep and cattle affected the vegetation. The broadleaf forest shrubs and juvenile trees were reported as being 'eagerly devoured' by cattle (Allom, 1849, p. 201). Cattle thus had significant effects upon the species composition of all forest areas to which they had access, and in the absence of fences, these areas must have been quite extensive. The fern and scrub was also opened up by trampling and thus made available for sheep. 'Cattle … speedily destroy the fern and grass takes its place … the fern has, in many parts, disappeared, and thousands of acres of the native rye-grass, and other grass are now to be found' (Allom, 1849, p. 21).

With the arrival of the European settlers much of the remaining forest was removed, smaller wetlands were drained, native fernland and scrub cleared. Indigenous ecosystems have now been largely replaced with exotic pasture, riparian margins and tree shelter belts. In the southern area the extensive wetlands have been drained following the development of the Lower Wairarapa Valley Development Scheme. (Gunn, 2010) Hill (1963) also points out that it was rarely the established pastoralists who were responsible for destroying the forest. Rather it was the small farmer on a 30-100 acre plot hacked and burned out of the bush who sought to replace the forest with pasture.

The impacts of vegetation clearance on erosion and consequentially sedimentation of rivers was recognised after significant vegetation clearance had occured. Programmes re-establishing vegetation as a soil conservation measure were started in the Ruamāhanga whaitua in the early 1950s.

Ongoing monitoring of these programmes provides some indication of the extent of this work. Crippen and Hicks (2011) found the percentage of the Wellington region which has some form of soil conservation cover has increased over recent years. This was predominantly as a result of over 13,800 ha of forest plantations, but also an additional 8,900 ha of farmland (predominantly drystock pasture) being retired so that native vegetation is able to regenerate, or farmland being planted with forestry or soil conservation poles. The bare soil percentages for farmland and forest plantations were not large in 2002 or 2010, reflecting that these land uses are carried out just in part on unstable land and also that fresh erosion either has been minimal or has quickly re-vegetated between the 2002 and 2010 surveys. Given that a large storm affected much of the hill country in February 2004 and July 2006, the latter explanation is more likely (Crippen & Hicks 2011). (Sorenson, 2012).

Appendix 3: Land Tenure

Historical changes in land tenure

Traditional Māori society did not have a concept of absolute ownership of land. Whanau (extended families) and hapū (sub-tribes) could have different rights to the same piece of land. One group may have the right to catch birds in a clump of trees, another to fish in the water nearby, and yet another to grow crops on the surrounding land. Exclusive boundaries were rare, and rights were constantly being renegotiated (The encyclopaedia of New Zealand).

Haami Te Whaiti presents a detailed review of early Māori history and land occupation in a chapter within Wairarapa Moana: The Lake and its people. Direct reference to this material is suggested rather than attempting to summarise the chapter here.

Significant changes to land tenure occurred after European settlers and squatters arrived in the Wairarapa. Winter (2010) provides a summary of changes in land tenure that occurred from the 1840s. Māori were keen for Pakeha settlers and, rather than wait for the New Zealand Company to acquire land in the Wairarapa, four entrepreneurs – Charles Clifford, William Vavasour, Henry Petre, and Frederick Weld negotiated in March 1844 for the lease of the open country to be known as Wharekaka Station for £12 per annum. Other leases soon followed and in April 1845 twelve stations were listed in a Wellington Independent table with between forty and fifty Europeans living in the district (Bagnall, 1976). Once farming became established, wool was quickly the main export item.

According to Ben Schrader (2009) in the article 'Wairarapa region - European settlement': The runholders' relations with their landlords were cordial. Māori sought Pakeha neighbours because it gave them mana (status), trading opportunities and protection from enemies. Pakeha depended on Māori for food, labour and transport. Although the leasing system seemed to suit both leaseholders and their landlords, it became illegal under the Native Land Purchase Ordinance of 1846, designed to facilitate the sale of land to the Government for new settlers.

The main motivation behind the Government's decision in late 1846 to make leasing illegal was to guide Māori towards permanently alienating their land. Leasing was not considered an appropriate solution to the ultimate Government problem of providing enough land for settlers when Māori claimed all the land (Goldsmith, 1996).

From mounting pressure and on recommendations of surveyors S. C. Brees and H. S. Tiffen, the New Zealand Company obtained authority for purchase of 250,000 acres for a Church of England settlement in the Wairarapa. The first attempt at negotiating a purchase in 1847 failed. The leases in place provided Māori with steady income, and they were strongly opposed to sale. A second attempt by Native Secretary Henry T. Kemp followed in 1848 and local Māori agreed to sell but at a price the buyers would not pay and the Church of England settlement was established in Canterbury.

To deal with the cause of the failure of purchase, no new leases were meant to be taken up but in fact the area leased expanded and rental income rose. The majority of the leaseholders in the Wairarapa appealed to Government for some legal authority to be established as there was method of resolving land disputes between Māori and their tenants, and between the tenants. They said the longer purchase was postponed the more averse to sale the Māori were.

The first Government purchase of a quarter million acres in the Wairarapa was negotiated by Donald McLean on the back of Hawkes Bay purchases and was signed on 22 June 1853 by Wiremu Te Potangoroa. The price was £2,500 and the block included the coast between the Waimata Stream and Whareama River, reaching inland to the Wangaehu (sic) and Ihuraua River. Sir George Grey personally travelled to Wairarapa to negotiate further sales and his personal mana meant further sales followed, including 350,000 acres around Lake Wairarapa, (Wairarapa Moana) 40,000 acres of the Tuhitarata Block, 40,000 acres on the western side of the valley, and a number of homestead purchases (Bagnall, 976).

A map of land tenure in the Wairarapa around 1860 is available online from the Alexander Turnbull library. Permission has not been obtained to present the map in this paper .

http://www.teara.govt.nz/en/interactive/19516/land-ownership-in-wairarapa-around-1860

Appendix 4: Agricultural land use

Agricultural land use varies across the Wairarapa and is directly influenced by topography, geology, soils, climate, economics and technological development. (Winter, 2010)

Climate in Wairarapa Moana played a critical part in the ability of Māori to establish viable communities and settlements. Māori gardening practices were heavily reliant on the annual mean temperature and the length of the growing season for the cultivation of root crops forming the basis of their economic system. Kumara for example could not grow in frost prone areas. This had implications for the establishment of permanent self-sufficient communities. (Barnett, 2013)

European crops such as potato and, later, wheat, and a range of fruit and vegetables meant that permanent settlements could be established in the interior, which had not been possible with the less climatically tolerant kumara. (Te Whaiiti, 2013)

Land tenure changed during European settlement which resulted in changing patterns of land use. European settlers and squatters introduced new agricultural practices which transformed the landscape. There were an estimated 40,000 sheep and 3,000 cattle by 1853. (Hill, 1963)

In 1854 the twin small farm settlements of Greytown and Masterton were founded. The two villages, established by members of the Small Farms Association, and the Government-sponsored towns of Carterton and Featherston which followed shortly, were created to allow men of limited capital to purchase enough land to form small farms.

The pattern of agricultural development in the Wairarapa was strongly influenced by soil type and climatic considerations. The eastern hill country was slowly cleared of most remaining native forest and converted to grassland. It generally sustained extensive sheep and beef producing stations, many of which had to shift their produce by sea, the double handling involved adding to the cost of transport. Many of these large holdings were broken up in the early 20th century, by a combination of Government acquisition and family subdivision.

The land in the valley and in the wetter western foothills was traditionally farmed in much smaller blocks, with lamb fattening, dairying and cropping, often in conjunction with each other, being more important.

Cropping was strong on the floor of the plains at times but has never had the importance of more traditional areas such as Canterbury. In the past, wheat and oats were major crops but now mixed cropping (mainly barley and peas) predominates and arable farming accounts for less than 2% of the Wairarapa land use.

Agricultural development has continued since the 1850s, with new enterprises and landuses being adopted. Some have become established and expanded, others have played a smaller and more fleeting part in the patterns of agricultural land use. These changes have often been driven by changing economic fortunes of the different forms of agriculture.

Appendix 5: Urban development

Introduction

Urban areas cover a small proportion of the Ruamāhanga whaitua, though they are areas of intensive land use. Urban development is characterized by an increase in impervious surfaces which increase surface runoff to stormwater systems while carrying contaminants such as oil, sediment, chemicals and rubbish.

A concentrated population requires community sewage systems which collect waste where it can be treated before being discharged to the environment. Urban waste treatment has historically discharged treated effluent to waterways; this is still continuing though there is a move to small volumes of effluent being discharged to land.

Urban areas have high property values and are high priority areas for flood protection.

Historical urban development

Urban land use has had an impact on surrounding waterways. Understanding the development of urban areas and the links to rural land use provides some context to understand water quality in the Ruamāhanga whaitua.

A summary of European settlement in the Wairarapa is provided by Winter (Winter, 2010) The first European explorer to sight Wairarapa was James Cook in 1770 (Bagnall, 1979).

The establishment of the New Zealand Company's Wellington settlement in 1840 led to the inland exploration of the Wairarapa area, the pressure for grazing land leading to a number of expeditions taking place in the early 1840s. The first significant trip was by surveyor Robert Stokes and companion JW Child and two Māori guides in November 1841 followed by a second larger expedition in May 1842 led by assistant surveyor Charles H. Kettle and Cadet Arthur Willis. Other parties followed, and reports to the Company urged the opening of the Wairarapa to settlement.

Around the same time the Small Farms Association was formed (Schrader, 2009), "Out of concern that large runholders were stopping working people from accessing Wairarapa farmland, Joseph Masters lobbied to set up a 100-acre town on the Wairarapa plain where citizens would own a one-acre town section and a 40-acre dairy farm. By the end of the year the government had approved two settlements. The association would buy and sell the town sections; farms would be bought directly from the Crown". Of the first towns, Greytown, was sited on the recently purchased Tauherenikau Block. After negotiations with Ngāti Hamua leader Te Retimana Te Korou, land beside the Waipoua River was bought for Masterton. The first small farmers arrived in 1854. The Association was dissolved in the early 1870s, and surplus town sections were put into land trusts to benefit each community. These settlements were the first planned inland towns in New Zealand.

Featherston and Carterton followed in 1857 and Martinborough was set out by the Hon. John Martin in 1881. Bagnall (1976) states that, "By 1865 settlers in Featherston, Greytown, Carterton and Masterton were managing to survive with less hardship from their established cultivation and a little reciprocal trade. There was at least one main street in each, with the promise of homes, even shops, to fill out the vacant sections."

The Rimutaka Road opened on 10th June 1856 after 10 years of construction (Bagnall, 1976). In 1871, Scandinavian and other immigrant settlers were recruited by the government to build roads and railways in the heavily forested Te Tapere Nui a Whatonga, Seventy Mile Bush. In exchange for work the immigrants would be given 40 acres of farmland (Schrader, 2009).The Scandinavian settlers built the road from Kopuaranga to the north. Work on the improvement of the Featherston - Masterton road started in 1862 and district roads branching east and west from this road followed, the road to Castlepoint being completed in 1879 (Bagnall, 1976).

Urban sewerage systems

Masterton

Masterton District Council presented a summary of the Masterton wastewater system in 2007. (Masterton District Council, 2007) The first sewerage scheme for Masterton was constructed circa 1900 and involved a septic tank sited adjacent to the present landfill site on Nursery Road. In 1914, the sewer was extended to the Homebush area where new septic tanks were constructed close to where the present oxidation pond system is sited. The Lansdowne area, which had previously had its own system, was connected to the Borough sewerage system in 1963 via a siphon over the Waipoua River.

Small stabilisation ponds, designed to reduce the level of solids in the wastewater, were constructed between the septic tanks and open channel discharge to the Ruamāhanga River in the mid to late 1960s.

Due to problems with overloading of the septic tank system, three oxidation ponds (primary and secondary) at Homebush were built in 1970-71, and commissioned in 1971, with the plant discharging into the Makoura Stream, just above its confluence with the Ruamāhanga River.

In 1991, the MWTP was upgraded to include an inlet step screen (6mm aperture) and hydraulic press, two aerators in each of the primary ponds and an operations building. In 2009 Masterton District Council obtained consents to construct new ponds as treatment and storage facilities, and to construct a border-strip irrigation system to dispose of a proportion of the treated effluent to land. The remaining treated effluent will be discharged to the Ruamāhanga river at flows above 12.3 m3 sec in summer and 6.15 m 3 /sec in winter.

Table 5: Summary of the first six months of the irrigation scheme with 70% of the irrigation area operational

Volume M litres	Nov	Dec	Jan	Feb	Mar	Apr	Total	
Discharge total	627.7	539.9	385.9	280.1	362.0	527.5	2723.2	
River Discharge	598.7	468.8	371.8	219.4	323.2	518.5	2500.5	91.8%
Irrigation	29.0	71.1	14.1	60.7	38.8	9.0	222.7	8.2%
Influent	503.6	477.6	390.8	323.0	331.4	450.3	2476.7	
Percentages	Nov	Dec	Jan	Feb	Mar	Apr		
River Discharge	95.4%	86.8%	96.4%	78.3%	89.3%	98.3%		
Irrigation	4.6%	13.2%	3.6%	21.7%	10.7%	1.7%		

Carterton

The Carterton Wastewater Treatment Plant (CWWTP) is owned by the Carterton District Council and has been located on approximately 16 ha of land on Dalefield Road, Carterton since the 1960s. It supports the second largest town in the Wairarapa, with a population of approximately 4,200, and several medium sized 'wet' industries. It sits adjacent to, and discharges into, the Mangatarere Stream.

The most recent upgrades to the treatment plant include:

- implementation of a land discharge system (2005)
- implementation of a heated sludge digester (2009); and
- a microfiltration pilot plant trial (2009/10**)**

The wastewater is primarily gravity fed into the treatment plant with the aid of six small pump stations where there is insufficient natural fall. Then the water treatment process consists of:

- fine screening
- primary sedimentation with sludge digestion
- secondary and tertiary oxidation ponds (4.3 hectares); and
- surface flow wetlands

Once it has passed through the 1.6 hectare) wetland area, the treated wastewater enters a drain alongside wetland system where it flows for 150 metres until it discharges into the Mangatarere Stream. The Mangatarere Steam flows into the Waiohine River, which is a tributary of the Ruamāhanga River.

Irrigation to land occurs during the summer period, generally January to March but often into April. The treated wastewater is pumped from the Mangatarere Stream discharge point after passing through the wetlands to a lined holding pond before being further treated by disc filtration and (in future) Ultra Violet (UV) irradiation. After this further treatment, it is irrigated by surface and sub-surface drip line to 2.5 hectares of Carterton District Council land directly adjacent to the oxidation ponds (Figure 1). Discharge to the Mangatarere Stream also continues during periods of irrigation.

South Wairarapa

South Wairarapa has three municipal wastewater systems as well as a small system at Lake Ferry.

The Greytown Wastewater Treatment Plant (GWWTP) is situated on four hectares of land about three kilometres southeast of Greytown on Pah Road. It is adjacent to the Ruamāhanga River, about one kilometre downstream from the confluence with the Waiohine River. The treatment plant services approximately 2250 people.

The treatment plant consists of two clay lined oxidation ponds; a primary pond and a tertiary pond. The tertiary pond is divided into three cells separated by a rock groyne system designed to further improve treatment.

The transfer pipe between the two ponds draws from 0.5 metres below the surface. This combined with baffles on the transfer pip and final outlet structure prevents the transfer of floating debris between ponds and the receiving water. Effluent is discharged to the Papawai Stream, a tributary of the Ruamāhanga River, via a single pipe.

The Featherston Wastewater Treatment Plant is located about two kilometres from the Featherston township on a 53 hectare site. It services a population of around 2200 .

The treatment plant was constructed in the 1970's and consists of two unlined oxidation ponds in series. Sewage is gravity fed into pond one, flowing through a channel into the second pond. Treated wastewater is then discharged via an open channel to Donald's Creek, a tributary to Abbott's Creek which discharges to Lake Wairarapa. At average flows and normal water levels the ponds have a hydraulic retention period of 45 days; at peak flows this can reduce to less than ten days.

In 2011 an Ultraviolet light disinfection unit was installed, reducing bacteria and pathogens in treated wastewater.

The Martinborough Wastewater Treatment Plant (MWWTP) is located on 3.47 hectares, 1.8km northwest of the Martinborough Township and is accessed via private property. It was built in the 1970's and services approximately 1500 residents and a few industrial and commercial activities.

The treatment process is composed of a gravity fed primary oxidation pond with a capacity of 23,000m3. At normal conditions the hydraulic retention time is 47 days, while at peak flow this can reduce to 10 days. The oxidation pond treats the wastewater by biological activity and enables settling of solids, forming sludge.. In 1998 two surface aerators were installed to enhance biological treatment. The water then passes through rock groynes and an outlet structure with a curtain before flowing into the lined maturation cells. In 2011 a lift pump station and UV disinfection were installed to improve pathogen removal. The treated wastewater then travels via gravity to the Ruamāhanga River via a 50m unlined outfall channel.

Appendix 6: Contaminated sites

Some types of land use can continue to affect water quality after the land use has ceased. Certain forms of historical land use have left a legacy of soil contamination, which has the potential to affect water quality. It is difficult to quantify the effect that these sites are having on water quality at a catchment level because there is limited information about the extent of contaminated sites within the Ruamāhanga whaitua.

Catchment		Ruamāhanga Whaitua	
Total number of properties with a SN entry:		384	
MfE HAIL Classification		# Properties in each HAIL	% OF TOTAL
A Chemical manufacture, application and bulk storage		204	53.1
B Electrical and electronic works, power generation and transmission		8	2.1
C Explosives and ordinances production, storage and use		4	1.0
D Metal extraction, refining and reprocessing, storage and use		29	7.6
E Mineral extraction, refining and reprocessing, storage and use		10	2.6
F Vehicle refuelling, service and repair		112	29.2
G Cemeteries and waste recycling, treatment and disposal		64	16.7
H Land that has been subject to the migration of hazardous substances from adjacent land		1	0.3
GWRC CATEGORY			
1	Verified History of Hazardous Activity or Industry	303	78.9
2	Unverified History of Hazardous Activity or Industry	2	0.5
3	Contamination Confirmed	13	3.4
4	Contamination Acceptable Managed/Remediated for	62	16.1
5	No Identified Contamination	3	0.8
6	Entered on Database in Error	1	0.3

Sheep dips

Dipping sheep to control external parasites was a legal requirement in New Zealand from 1849 to 1993. Controlling external parasites on sheep (including keds, ticks and lice) was important for both animal welfare and the economy.

The sheep dip chemicals used before 1980 are very persistent in the environment. Arsenic was used from 1840 to 1980 and organochlorine pesticides were used from 1945 to 1961. The use and disposal of these chemicals at sheep dip sites has created a legacy of soil and water contamination by persistent chemicals at levels that are hazardous to humans, livestock and the environment (Gaw, 2012).

Arsenic does not break down in soil or water and organochlorine pesticides can take decades to degrade in the environment. Organochlorine pesticides and arsenic can leach slowly down the soil profile and can contaminate groundwater. The extent of leaching will depend on the soil type, with greater leaching occurring in sandy soils. The amount of rainfall or irrigation will also influence leaching of contaminants through the soil. Leaching may mean that the highest concentrations of contaminants are below the soil surface at some sites. Soil contamination has been measured to a depth of five metres below a former sheep dip.

Contaminated soil can be transported to adjacent paddocks and waterways through surface runoff (rainfall and irrigation water) and wind-blown dust. Contaminated groundwater may discharge into nearby waterways (Gaw, 2012).

Appendix 7: River management

River management and river morphology

Greater Wellington provide a summary of changes to river morphology in the Ruamāhanga catchment. (Greater Wellington, 2013) Humans have had an influence on floodplain and channel form characteristics in the Wairarapa since early settlement, and it is suggested that the impact of European settlement came at a time when the indigenous vegetation was already in a state of flux (Holloway, 1950). At the time the land along the Ruamāhanga River was covered with dense bush and detailed surveys of the Waingawa River from 1900 show native scrub coverage of the banks and islands (Williams, 2010).

As European farming expanded, deforestation increased, especially in mid to lower areas of catchments (Blaschke et. al., 2008). Natural rates of erosion are significant in the unstable Tararua environment and deforestation exposed soil and rock to rain, sun and wind, adding to erosion and increasing sedimentation of rivers (Parkyn and Chisnall, 2002). This was coupled with the introduction and spread of exotic animals such as deer, pigs, and possums in the 19th century and the spread of goats in the 1930's (Brougham and McLennan, 1983).

In his 1952 Masters of Science thesis, R.H. Hunter examined causes of accelerated erosion. He found that the grazing of seedlings, destruction of soil holding plants/ground cover, trampling of the ground floor and the forming of tracks by such exotic species directly attributed to the prevention of regeneration, lowering of the timberline, an increase in drainage channels, increased slipping and delayed regrowth of slip scars, thus accelerating erosion.

However, the effect of erosion on sedimentation and flooding is often not observed until decades later when storms, earthquakes or uplift trigger movement of sediment stored in catchments (Blaschke et. al., 2008). Therefore aggradation of river beds may have been prominent for decades after large events such as the 1855 Mw 8.2-8.3 Wairarapa earthquake and the 1942 Mw 7.2 and 7.0 earthquakes, with an increase in sediment loads resulting from large scale slipping in the Tararua Ranges. Major erosion was observed from 1935 onwards as the effects of deforestation and flora destruction in remaining forests began to have a telling impact on erosion rates (Waitangi Tribunal, 2010). Subsequent deposition of material on the Wairarapa plains would have resulted in the aggradation of river beds.

European settlers introduced the use of willows for bank protection (Williams, 2010), and as development increased more detailed flood protection measures were sought to protect farmland and housing areas. In 1935 Mr A.W. Reynolds prepared a report for the Masterton Borough Council that described the disadvantages of constraining a river channel with stopbanks and recommended the establishment of flood relief channels from the Waipoua River to the Ruamāhanga River. However to the contrary the Waipoua River was realigned, diverted and stopbanks constructed in the early 1940's (Heslop et. al., 1996). Introduced species such as gorse, broom, lupins and lucerne also became established throughout the river channels and altered river response to gravel movement (Williams, 2010).

In the 1950's to 1980's extensive reforestation of mid and upper catchments took place throughout New Zealand, mainly by catchment boards and the New Zealand Forest service. A concerted effort was also made to deal with exotic pests and protect the native plants and wildlife (Roche, 2002). High prices for deer skins in the late 1940's saw a major decline in the Tararua population (Hunter, 1952), which to a large degree has been kept at a sub-maximum level since. A decrease in deer numbers prompted rejuvenation in some areas, however damage continued in areas where goats were numerous (Hunter, 1952). Reforestation was complimented further in the 1980's and 1990's where replanting of land unsuitable for farming by private landowners was high (Blaschke et. al., 2008). Due to the nature of New Zealand terrain any damage to the vegetation cover accelerates erosion; therefore such afforestation has been shown to reduce terrestrial erosion and sediment yields (Vaughan, 1984; Maclaren, 1996).

In the case of the Wairarapa and the Tararua Ranges in particular, high rainfall and unstable geological terrain make for naturally high sediment loads (Blaschke et. al., 2008). However afforestation, rejuvenation of undergrowth due to reduced exotic animals and the revegetation of river banks reduces sediment yield to waterways. The effects on sedimentation from major land movements would have also subsided with the majority of slip material from major earthquakes in 1942 likely to have been transported into the river system. This may form part of the reason behind the present day trend of degradation in the Wairarapa Rivers, with less sediment input resulting in down cutting through previously built up material.

Degradation can help improve channel capacity but it can also increase the risk of flood damage by undermining stopbanks (Blaschke et. al., 2008). River works aiming to control river meander and reduce the risk of flood damage to land and property are employed throughout the Wairarapa Rivers. Such measures include the construction of groynes made of rock or rails, along with gravel bunds and stopbank protection works. Pole and stake planting of willows and cabled willows are also utilised to strengthen channel banks and provided buffer vegetation. However the width, density and erosion resistance of riparian buffers often varies along a reach and and branches can be formed from breakouts during flood events (Williams, 2010).

Vegetation is also routinely cleared from active river channels to prevent reduction in flow capacity. However river works only provide temporary solutions to issues. Channel modification, re-alignment and straightening of a channel creates non-natural form and during a flood event a river will tend to rework its shape back to a natural character form, meaning on-going work is required (Williams, 2010).

Flood control riparian planting

Willows dominate the riparian margins with alternative species such as silver beech and alders causing problems along the waterways. In the lower reaches of the Ruamāhanga River (especially the saline zone) native grasses are being planted within the Lower Wairarapa Valley Development Scheme. Outside the river schemes willows have the potential when unmaintained to cause problems in the waterway. Buffer zones created by the river schemes are often fenced off which can result in pest plant issues.

Buffer zones on the eastern and western tributaries in the lower Ruamāhanga valley connect the Aorangi and Remutaka mountains, illustrating how riparian margins can be used to enhance values such as biodiversity, as well contributing to water quality outcomes (Gunn, 2010).

Appendix 8: Future land use and social impacts

Land use will continue to change in the Ruamāhanga whaitua. It is impossible to know what these changes will be, however it is useful to be aware of predictions that others have made.

Future land use change

The Parliamentary Commissioner for the environment released a report looking at land use and nutrient pollution. (Parliamentary Commissioner for the Environment, 2013) This report looked at land use on a regional basis and tracked land use change from 1996 – 2008. The report has also predicted land use change until 2020.

Data are not available specifically for the Ruamāhanga whaitua area as the report looked took a regional approach. However at the regional scale the predictions are:

Land Use	Change in area 1996-2020 (ha)
Sheep and beef	-55000
Dairy	+24600
Forestry	+30000
Scrub	-400

If this land use change occurs it is predicted that the nitrogen load in the region would increase 17% and the phosphorus load would decrease 2%

Wairarapa Water Use Project

One of the potential drivers of future land change in the Ruamāhanga whaitua is irrigation through the Wairarapa Water Use Project (WWUP). Assumptions about future land use changes associated with the project are presented by Nimmo Bell. (Nimmo Bell and Co Ltd,, 2010)

In the scenario presented, it is assumed that approximately 15,500ha hectares could be irrigated 25 years after the project starts. This assumption is based on conclusions reached in Baker & Associates (2009). The rationale behind this rate of adoption is that:

- with two-thirds of the potentially irrigable area currently in sheep and beef, and that using irrigation for sheep and beef production is not economically viable, it will most likely require a change in land ownership for land to be converted to a new irrigated land use;

- even with a desire to change to an irrigated land use, existing landowners are likely to have a limited ability to finance on-farm infrastructure; and

- irrigated farming systems are not currently widely used in region and that it can require a new generation of landowners to fully exploit the opportunities that exist with irrigation.

Using these assumptions, the area in dry-land sheep and beef is expected to roughly halve (from 19,748 ha to 9,574ha) with a major increase in irrigated dairy farming and intensive arable production such as specialist seed crops. A similar shift in land use is also expected for dry-land arable and dairy. There is expected to be a modest increase in viticulture due to the limited availability of suitable soils within the irrigation zone, lower profitability and high development costs.

Table 6: Forecast Land use under the with irrigation development (Year 25)

With Scheme	Land Use	Hectares
Dryland	Arable	635
	Sheep and beef	9874
	Dairy	4122
	Viticulture	
Total Dryland		**14632**
Irrigated	Intensive arable	2871
	Intensive dairy	12121
	Intensive viticulture	376
Total irrigated		**15368**
Total		**30000**

Table 7: Forecast land use without irrigation development (year 25)

With Scheme	Land Use	Hectares
Dryland	Arable	1207
	Sheep and beef	18761
	Dairy	7833
	Viticulture	
Total Dryland		**27800**
Irrigated	Intensive arable	347
	Intensive dairy	1603
	Intensive viticulture	249
Total irrigated		**2199**
Total		**30000**

Social impacts of land use change

The introduction of irrigation into farming systems creates distinct social impacts through changed and new farming systems, and wider demographic and community changes. These are detailed by (McCrostie, 2001), with a summary provided below.

On-farm establishment costs, intensive labour requirements and profit margins for both old and new products will be the three deciding factors if irrigation is to be taken up by a farm family. The relationship between youth, enthusiasm and irrigation results in a demographic change in the community with younger farm families replacing middle-aged families.

When irrigation is introduced, new land uses such as dairying are attracted into the community. Waves of different people with different skills replace families holding ‘traditional’ skills, with the result that the community can initially be destabilised. The leadership role of those families who remain, either changing their own skills base or upgrading their existing production to effectively use irrigation, is critical during this interim period. These local families act both to validate the new land use and maintain some sense of stability. Where established social constructs are under threat, they become 'social anchors' around whom the new emerging community will gather. Furthermore, there can be a resulting positive impact on local schools, sports and recreation facilities and other social services, strengthening rural communities.

Irrigation changes work patterns and roles of the farm family, demanding a wider skills base. irrigation also demands similar changes to the skills base of farming service providers - contractors, skilled labour, rural service providers and small business people. When the production base of the land is changed the service provision must also change if it is to be relevant. Often local skills and resources are not congruent with the new production systems and local workers and small businesses are left outside the new, burgeoning economy. Rural towns, which have not recognised the potential of the new irrigation based production system, will lose service provision and other commercial activity to towns where these provisions will be sought and satisfied.

Irrigation provides an economic climate in which entrepreneurial innovation flourishes, not only on the land but also in the service towns. First, the potential of the new production base must be realised and second there must be a willingness by a range of farming service providers to extend personal skills and acumen. The research and advisory sectors must respond to the changed land use bought about by irrigation if the local and regional economy is to benefit fully. The rural service sector must continue to be relevant to the new farming systems in a new economy driven by irrigation.

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