Ministry for Primary Industries
Manatū Ahu Matua

Ngāti Rangi & Atihau–Whanganui Inc – Land Feasibility Study

Contract 16440

Final Report

MPI Technical Paper No: 2013/09

Prepared for the Ministry for Primary Industries

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Summary

A regional land feasibility study was carried out for the Ministry for Primary Industries (MPI) between 1 April and 3 May 2013. The study area is defined below.

Objective

Phase 1: Identify and map the productive potential of the Māori land blocks within the Ngāti Rangi rohe and surrounding and/or neighbouring the Atihau–Whanganui Incorporation blocks (totalling c. 42 000 ha) in the study area.

Phase 2: Identify and map the mānuka/kānuka cover on each of the Māori land blocks surrounding, and or neighbouring the Atihau–Whanganui Incorporation (AWHI) blocks (totalling c. 42 000 ha) in the study area.

Study area

The proposed study area was outlined on a map provided by Ngāti Rangi and AWHI (Che Wilson, 15/3/13) and checked and validated 4 April 2013. [redacted]

Project phases

Five main project phases were carried out between 1 April and 3 May 2013:

- Phase 1: Define case study boundary and Māori land blocks of interest
- Phase 2: Collect and collate base information and infrastructure data
- Phase 3: Resource data collection and collation
- Phase 4: Analyses, evaluation, and documentation
- Phase 5: Outputs/products (e.g. technical report, GIS maps)

Results

See next section

Key findings

Main high level findings to date:

- Total study area = **242 148 ha**
- Large areas of mānuka/kānuka exist on neighbouring blocks. Together with the AWHI area, there is [redacted] ha of mānuka/kānuka in the study area.
- Other uses for mānuka/kānuka should be explored (such as nutraceuticals, pharmaceuticals, carbon credits) to increase revenue streams – on top of /as well as honey production/soil, etc. Wood energy and biofuels could also be options for the future in some areas.
- Exotic forest covers approximately [redacted] ha in the study area. [redacted]
- A large proportion of the land is steep hill country [redacted] but largely productive for sheep and beef farming (e.g. red meat – sustainable branding). Productive land needs to be differentiated at the farm plan scale (e.g. 1:10 000 – 1:25 000)
- [redacted] A large proportion of land in the study area is considered very steep and erosion prone [redacted] – that should be allowed to regenerate (and be fenced off) or planted in forestry. The coarse analysis in this report aligns to a more detailed regional study (Page et al. 2005) that mapped highly erodible lands for Horizons regional council and is also superseded on specific land blocks by farm plans. Part of this steep erodible land is already in trees and scrub, mitigating erosion risk to some extent, and giving adequate protection and soil conservation to hillsides. [redacted]
- All steep gully/landslide prone riparian areas (next to streams and rivers) should be fenced/planted in trees/scrub to reduce erosion, improve soil conservation, and reduce sediment runoff.
- If water quality and/or high sediment loads is perceived to be an issue, a strict sediment or nutrient management system needs to be planned for, particularly in sensitive catchments under a range of land uses.
- Sustainable land management programmes (term to be defined in future discussion with landowners and MPI) should be introduced across all high productive farmland for increased sheep and beef production, to support opportunities for sustainable branding, and for soil conservation.
- Focus on best land (Class 4, 6 and best parts of Class 7) for increasing pastoral production and in future use accurate stock-carrying-capacity information (e.g. stock units/per hectare) to confirm actual and potential production levels.
- Best high producing pastoral land-extensive farming of livestock-sheep and beef [redacted] makes up [redacted] in the study area. Often low hill country. Best land, most versatile land [redacted] makes up [redacted] ha in the study area and can support the largest range of land-uses from cropping, dairying to forestry.
- [redacted] Small areas, some neighbouring Māori land blocks, are suited for cropping and horticulture. [redacted]
- Class 4 land (typical rolling to undulating land), can be used for limited arable use and livestock farming, and makes up [redacted] ha –high producing land for pastoral farming but has extreme limitations (e.g. soils, climate) for cropping

1 Introduction

A regional land feasibility study was carried out for MPI from 1 April – 3 May 2013. The study area is defined below.

1.1 Objective

Phase 1: Identify and map the productive potential of the Māori land blocks within Ngāti Rangi and surrounding rohe, and surrounding and/or neighbouring the AWHI blocks [redacted] in the study area.

Phase 2: Identify and map the mānuka/kānuka cover on each of the Māori land blocks in the study area.

1.2 Study area

The proposed study area was outlined on a map provided by Che Wilson (15/3/13) and checked and validated 4 April 2013. [redacted]

[redacted]

1.3 Project phases

Five main project phases were carried out between 1 April and 3 May 2013:

- Phase 1: Define case study boundary and Māori land blocks of interest
- Phase 2: Collect and collate base information and infrastructure data
- Phase 3: Resource data collection and collation
- Phase 4: Analyses, evaluation, and documentation
- Phase 5: Outputs/products (e.g. technical report, GIS maps)

1.4 Background

Ngāti Rangi and AWHI are interested in developing a collaborative land management approach that will support an increase in production across the land blocks of AWHI and surrounding lands, including the Ngāti Rangi rohe. Previous land management and GIS mapping studies were carried out in 2007 on the AWHI land blocks (Harmsworth *et al*. 2007; Tahi *et al*. 2007).

In late March 2013, AWHI sought MPI's assistance to develop a land feasibility study for AWHI land and adjacent land blocks. There was also interest in ascertaining the extent of mānuka/kānuka coverage on these blocks. MPI contracted Landcare Research to undertake this work.

This study is a first step in assisting Ngati Rangi and AWHI to better understand the profile of their lands. This work aligns with MPI's objective for partnering with Māori Incorporations, Trusts and Iwi to enable increased production of Māori land-based assets. By facilitating the provision of detailed, robust information, MPI aims to assist Ngāti Rangi and AWHI in identifying optimal land use and inform management decisions, both to increase productivity and bring currently under-utilised land into productivity.

1.5 Ngāti Rangi

Ngāti Rangi is an ancient pre-migration iwi affiliated to the Whanganui Confederation of tribes. The tribal rohe is not entirely covered by the study area. Ngāti Rangi tūpuna were involved in the vested lands establishment and have been active with AWHI since incorporation in 1970 (see below).

The Ngāti Rangi Trust was established in 1992 by key kaumātua and Ngāti Rangi claimants with the endorsement of the Whanganui River Māori Trust Board. The Trust was established to co-ordinate and manage iwi affairs and progress the settlement of Treaty grievances, in particular Mount Ruapehu. Over time other organisations were established to progress the maintenance and development of Ngāti Rangi. The Ngāti Rangi Community Health Centre (est. 1996) provides health services to the community; there is also a kura kaupapa, Te Kura Kaupapa o Ngāti Rangi (est. 1997), and four kōhanga reo in the rohe.

[redacted]

1.6 Atihau–Whanganui vested lands

Within the Ruapehu study area the AWHI vested lands make up a total area of approximately [redacted] This includes all 'resumed lands' currently managed by AWHI. This underlying information will provide the basis for a framework that will enable Māori entities to improve the productivity and profitability of their land-based assets.

Key definitions used within AWHI lands:

- *'Vested lands'* is used in this technical report to mean all the AWHI lands that were vested last century and are progressively being returned. *'Leased lands'* means all vested lands that are still currently under lease, and *'freehold'* means other blocks under current freehold title.
- *'Resumed land'* is currently 'Incorporation-managed lands' within the 'total vested lands' that are now being managed by the AWHI, irrespective of the type of land use, e.g. farming, forestry, Nga Whenua Rahui, etc.
- *'Effectively farmed'* is the area within the 'Incorporation-managed lands' being farmed and under productive agricultural use.

1.7 Historical

The AWHI was established in 1970, to receive land originally vested in the Aotea Māori Land Council by Whanganui Māori land owners in 1903 (AWHI web site). The Incorporation was to take back approximately 101 000 acres or c. 42 000 hectares of 'vested' land (similar in size to Lake Taupō). To take back this vested land, the Incorporation, under imposed legislation, has to purchase the improvements of leased land when any leases expire (usually a 21-lease period). By systematically purchasing farm improvements on land and leases over the past 30 years or thereabouts, the Incorporation now farms 17 000 ha (c. 41 652 effective acres), in 8 farm stations most under beef and sheep, with 1 station in Dairy production. Together the 8 stations are wintering effectively about 180 000 stock units (AWHI web site)

[redacted]

The core business activity of AWHI is sheep and beef farming. Present land uses are pastoral farming (sheep, beef, and some dairying Land planted in production forestry now makes up an estimated [redacted] The Incorporation has no subsidiaries but has joint ventures in forestry. [redacted]

[redacted]

Figure 1: Study area defined in this report.

2 Method – Phases of work

GIS analyses and interpretation using a range of land resource datasets (Appendix 2) was completed April 2013. Five main project phases were followed 1 April to 3 May 2013:

- Phase 1: Define case study boundary and Māori land blocks of interest
- Phase 2: Collect and collate base information and infrastructure data
- Phase 3: Resource data collection and collation
- Phase 4: Analyses, evaluation, and documentation
- Phase 5: Outputs/products (e.g. technical report, GIS maps)

Details are given below in Table 1

Table 1: Project phases and outputs

Project Phase	Outputs
1. Define case study boundary and Māori land blocks of interest	Define case study area and Māori land blocks of interest: • Define study area of interest, geographic areas, catchment boundaries, roads, rivers, etc. • Define Māori land block boundaries of interest • Check maps and study area with Atihau Whanganui members and MPI • Digitise and check boundaries against Digital Cadastral (DCDB) data if necessary
2. Collect and collate base information and infrastructure data	Provide base layer information suitable for study area, catchments, and land blocks • Aerial photographs & other imagery (e.g. satellite) • Topographic information • Infrastructure (roads, fences, tracks, etc.) • Property boundaries – cadastral • Hydrology (e.g. rivers, lakes, streams) • Digital Elevation Model (DEM) – contours
3. Resource data collection and collation	Collect and collate GIS data layers at, e.g. map @ c. 1:100 000 for whole study area and c. 1:50 000 scale for selected detailed areas and specific blocks. • New Zealand Land Resource Inventory (NZLRI) • Land use capability (LUC) classification of land • Soils (Fundamental Soil Layers FSL) • Vegetative cover/Land use (LCDBv3) – mānuka/kānuka (as a subset) • Atihau–Whanganui blocks (previous study) • Māori freehold land – Māori Land Court land blocks (MoJ) • Cadastral information – DCDB (LINZ)
4. Analyses, evaluation, and documentation	Analyze and evaluate resource data and document maps, summary statistics, tables and graphics, for the study area and some land blocks • Describe land resource characteristics important for predefined study area and some blocks • Provide land resource statistics/analyses for study area and some blocks • Identify land use potential/options (e.g. c. 3 land suitability maps)
5. Outputs/products	• Selected GIS maps of study area and some land blocks, e.g. ready-to-print (.pdf) versions of maps, jpegs, power-point slides • Package data layers for GIS viewing using suitable software to allow ongoing desktop access • Have input into a short 10-page technical report

Key datasets used in this study are described below:

Maori land block data

Māori land block data were derived under an agreement of use from the Ministry of Justice in 2012 (Harmsworth & McDowall 2011). It represents all Maori freehold land in New Zealand administered by the Maori Land Court.

New Zealand Land Resource Inventory (NZLRI)

The New Zealand Land Resource Inventory (NZLRI) is a national spatial land resource GIS database at a uniform scale of 1:50 000 (NZLRI GIS database 2013; Harmsworth et al. 2007), with over 100 000 land management polygons (map units) for New Zealand delineated primarily on the basis of landform and a physical inventory. The NZLRI has become an integral part of regional and district sustainable land planning and policy in New Zealand. It comprises two core sets of information (Lynn et al. 2009):

- An inventory of classified data describing five physical factors (rock type, soil unit, slope angle, erosion type and degree, and vegetative cover)
- A Land Use Capability (LUC) assessment for each map unit (polygon).

Land Use Capability (LUC)

The LUC system (Fletcher 1987; Lynn et al. 2009) categorises and ranks all land in New Zealand according to its limitations and versatility for agricultural production and sustainable land use. It is a national standardised classification for New Zealand that classifies land into eight main classes, Class I to Class VIII, 1–8 (Table 6). Roman numerals were used originally as unique identifiers but Arabic numbers (i.e. 1, 2, 3) are now used on GIS maps. The classification has three key hierarchical components:

- LUC class (most general level; Table 6),
- LUC subclass (subdivides the LUC class), and
- LUC unit (most detailed level).

Table 2: Land Use Capability (LUC) system of mapping and definitions used in the New Zealand Land Resource Inventory (NZLRI)

Land Use Capability class (NZLRI)	Description of land versatility
1 (I)	Arable. Most versatile multiple-use land, few limitations for arable use
2 (II)	Arable. Good land with slight limitations for arable use
3 (III)	Arable. Moderate limitations for arable use restricting crops able to be grown
4 (IV)	Arable. Severe limitations for arable use or cultivation. Requires care; more suited to permanent pasture and forestry
5 (V)	Non-arable. Unsuitable for cropping. Negligible erosion under pasture and forestry
6 (VI)	Non-arable. Productive pastoral hill country, slight to severe limitations and hazards
7 (VII)	Non-arable. Moderate to very severe limitations
8 (VIII)	Non-arable. Very severe to extreme limitations, requiring permanent vegetative cover and protection

Land Profiling/land suitability maps

For determining the productive potential of land and land use options in the study area, the land was categorised into 3 main groups:

1. Class 1, 2, and 3 land: The most versatile (high value) land in the study area, can be used for a range of land use options with few physical limitations for long term sustainable agricultural use. Can include intensive agriculture, dairying, cropping, horticulture and forestry.
2. Class 4, 5, 6 land: Typically high productivity hill country and rolling land (moderate versatility) suited to a range of landuses including pastoral farming (e.g. sheep and beef), some fodder cropping, but excludes most arable use, cropping and horticulture. Includes floodplains with a moderate risk to flooding.
3. Class 7, and 8 land: Land with the highest physical limitations and has lower productivity. Typically steep hill country and often erosion prone. Needs careful soil conservation management, such as erosion and flooding control. Suited to extensive pastoralism and forestry or options such as, regenerating scrub and permanent vegetative cover. Class 7 land can be highly productive for extensive agriculture, such sheep and beef, with careful management. Class 8 land is high risk land, and should be targeted for erosion control, protection, full and extensive vegetative cover protection.

Soils

Soil types in the study area were mapped using the national soils database and according to the New Zealand Soils Classification (NZSC) codes and descriptions (Hewitt 1998) shown in Appendix 2.

Land Cover Database v3

LCDB v3.0 was released in July 2012. This land cover database (LCDB) is a national thematic classification of vegetative/land cover and land use classes. The current version LCDB v3 contains 33 classes of land cover designed to be compatible with earlier LCDB versions. The polygon features contain a code and boundary representing the land cover type at each of three periods; summer 1996/97, summer 2001/02, and summer 2008/09. The data set was designed to be compatible in scale and accuracy with Land Information New Zealand's 1:50 000 topographic database.

The list of classes used in LCDB v3.0 can be found in the document LCDB2-3 Correlation Table along with the mapping from the class set used in the previous version (LCDB-2). This document is available as an attachment to this dataset (see below), and on the LCDB project site: (www.lcdb.scinfo.org.nz).

3 Results

A large range of GIS maps are presented for the study area showing the location of Māori land blocks. Map themes include:

- The defined study area and Māori land blocks (including AWHI)
- LUC classes
- Soils NZSC classes
- Vegetative land/cover
- Mānuka/Kānuka
- Land suitability maps (LUC categories)

Total Study area = 242 148 ha

Table 3: Land Use Classification assessed within the study area (measured in HA) from the NZLRI

[redacted]

Total area of Mānuka/Kānuka [redacted] ha

For determining the productive potential of land and land-use options in the study area, the land was categorised into 3 main groups:

1. Class 2 and 3 land: [redacted] ha – The most versatile (high value) land in the study area, can be used for a range of land use options with few physical limitations for long term sustainable agricultural use. Can include intensive agriculture, dairying, cropping, horticulture and forestry.
2. Class 4, 5, and 6 land: [redacted] ha – Typically high productivity hill country and rolling land (moderate versatility) suited to a range of landuses including pastoral farming (e.g. sheep and beef), some fodder cropping, but excludes most arable use, cropping and horticulture. Includes floodplains with a moderate risk to flooding.
3. Class 7, and 8 land[redacted] ha – Land with the highest physical limitations and has lower productivity. Typically steep hill country and often erosion prone. Needs careful soil conservation management, such as erosion and flooding control. Suited to extensive pastoralism and forestry or options such as, regenerating scrub and permanent vegetative cover. With careful management, Class 7 land can be highly productive for extensive agriculture, such sheep and beef. Class 8 land is high risk land, and should be targeted for erosion control, protection, full and extensive vegetative cover protection.

Some land (especially steep erodible Class 7 and Class 8 land) is often referred to as 'marginal' or 'unproductive'. The common definitions of 'marginal land' and 'undeveloped land' are useful when considering land use opportunities and sustainable land management, and a definition is given below (Harmsworth et al. 2007):

> *Marginal land: land with severe limitations to agricultural use, often steep >26°, typically highly susceptible to erosion, can have moderate to extreme soil limitations. Generally land with a low productive pastoral capacity and least versatility. Not suited*

to long term pastoral use, suited to a permanent protective vegetative cover, and requiring very good environmental management. Marginal land commonly uses the NZLRI erosion classes with a potential of greater than 3.

Undeveloped land: is usually used to reference land regarded as underutilised, not developed, or not in a productive state. It is usually in unimproved pasture and/or scrublands, and not used to attain its productive potential or productive capacity. Whether land reaches its productive potential depends on its inherent physical characteristics, development opportunities, and sustainable land management.

4 Risks, constraints, physical limitations

4.1 Risks

A general statement is made in this section to highlight issues, risks and constraints that need to be considered and elaborated on in any future land development/management strategy, especially at the farm scale and district level. There will be a need to investigate and explore these issues in greater detail to assess impacts and implications for further land development and to mitigate and manage these risks and constraints accordingly.

4.1.1 Climate

Climate change (Harmsworth et al. 2010) should be planned for in terms of increased frequency of high intensity rainfall events and flooding. There is an increased probability of high frequency intense rainstorms, with the current 50-, 100-, 150-, and 200-year storm events becoming more likely in any year. Also predicted is an increase in mean annual temperature of about 2°C in New Zealand to 2090, which would have a marked effect on pasture growth rates and cropping, and would increase biosecurity risks (e.g. establishment of exotic insect pests) and associated problems. Increasing rainfall can lead to increased erosion rates, land erosion, flooding, and widespread damage. It is therefore pertinent to plan for these climate changes and to ‘future proof landscapes’ to a more resilient, less vulnerable state or condition. Issues such as climate change demand integrated approaches to land use planning at regional and local level.

4.1.2 Volcanic

There is a volcanic eruption and lahar risk, particularly in northern parts of the study area near Ruapehu and Tongariro. Ash cover can be problematic to pastures, forestry, and mānuka honey. Land use options should consider this risk.

4.1.3 Erosion

Because of the erosion prone nature of large tracts of hilly to mountainous terrain (Page et al. 2005), land-use options that support closed vegetative cover, regenerating scrub and forestry on steep erosion prone slopes should be encouraged (Fletcher 1987).

4.1.4 Flooding

Lowland areas susceptible to flood events should be planned for (Fletcher 1987).

4.2 Constraints

4.2.1 Climate

Climate varies considerably across the study area, but is generally cooler towards the north, with lower mean annual temperatures and higher rainfalls. Rainfall ranges from 1000mm at Whanganui to 1250 mm at Ohakune, and rising to above 2000 mm at Ruapehu. Average annual snowfall at the Turoa ski field is 2–3 m. Mean annual temperatures range from 8.0°C in the north near Ohakune, to 13–14°C in the south-western parts of the study area. This climate, with higher rainfalls in the north, and a higher number of days of frost, will inhibit a range of land-use options, such as cropping and horticulture. It will limit the range of crops that can be grown in the study area and will also affect plant growth rates.

Favourable microclimates might occur in areas such as valleys and downlands, and in sheltered areas. The climate fits the C_3 climate region (Fletcher 1987) “warm summers, very heavy rain at times predominantly from the south and southeast. Annual rainfall is between 1500 and 2500 mm at higher elevations”. The Ohakune climatological station (610 m a.s.l.) had an average of 106 ground frosts and 4.3 days of snow per year (1961–1974). Mean air temperature at Ohakune is 10.1°C. Towards Whanganui near the coast, 50.7 days of ground frost are recorded, with annual temperatures of about 13°C. Rainfall at the Whanganui coast lowers to about 1000 mm p.a.

Mean solar radiation is crucial for realising the potential for cropping, horticulture, and intensive agriculture. This will be a major limiting factor for many crops and horticultural varieties. Solar radiation ranged from 14.4 MJ m^{-2} day in the south to less than 14.0 MJ m^{-2} day in the north near Ohakune.

4.2.2 Soils

Highly productive soils for horticulture and arable cropping are limited in the study area. Soils on mudstones are highly fertile. Most soils are suited for pastoral use and extensive grazing regimes. Some shallow volcanic soil terrains in the north may be difficult to manage; however, thicker volcanic ash covered landscapes are highly suited for farming and forestry and vegetable cropping in the central study area, e.g. near Ohakune.

5 Conclusions

Within the defined study area:

- A broad overview is given of land capability and land versatility in the study area, and an initial assessment of land suitability is given, as a basis for future discussion
- A general statement of issues, risks and constraints is given for future discussion and planning
- Large areas of mānuka/kānuka (approximately [redacted] were mapped in the study area, on land surrounding and neighbouring the AWHI blocks. Classes 4, 5, 6 land are highly suited to pastoral farming, such as sheep and beef, and remain highly productive
- Large tracts of land (especially very steep erodible parts of Class 7 and Class 8) are steep and hilly and erosion prone. The land most prone to erosion is more suited to permanent and extensive vegetative cover such as regenerating scrub, mānuka honey production, and/or forestry
- Lowland and rolling areas may be suited to more intensive agriculture such as dairying
- Limited areas of highly versatile land (Classes 1, 2, 3) are mapped as suited for arable land use, cropping, and vegetable growing. The range of suitable crops is limited because of climate and soils
- There are significant opportunities to increase and diversify agricultural production into multifunctional land uses across land blocks
- Many areas are already being productively and sustainably farmed with livestock Large areas of significant native forest ecosystems, with significant biodiversity and ecological value, were identified in the study area on AWHI and neighbouring blocks

[redacted]

6 Recommendations

[redacted]

7 References

Atihau Whanganui Incorporation (AWHI) web site (accessed 3–24 April 2013) http://www.atihau.co.nz/

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Appendix 1 – Data Sources

GIS maps were produced in this project. They are based on a number of key data sources.

Table 4: Data and data sources used in this project

Data	Source
Ruapehu study area boundary digitized in GIS	AWHI and MPI
Base Information New Zealand 1:50 000 Digital Topographical database,2nd edn. Digital Licence Number TD201200/90	Land Information New Zealand (LINZ)
• New Zealand Land Resource Inventory (NZLRI) and LUC classification • New Zealand Soil Classification (NZSC) • Soils data and fundamental soil data layers • Land Cover Database 3 (LCDBV3) • Ecosat digital elevation model (15 m)	Landcare Research
• Mānuka/kānuka layer (LCDB3)	Landcare Research
Māori land block data (overlay) • Māori freehold land in New Zealand administered by the Maori Land Court	An agreement of use from the Ministry of Justice in 2012

Appendix 2 – Soils

A large range of soil types occurs across the study area. They have been mapped according to the New Zealand Soils Classification NZSC (Hewitt 1998) and are described below under their respective soil codes. NZSC is a national hierarchical soils classification divided into Order (highest most general level), Group, Subgroup, and then into soil types. For example:

- Order [e.g. L]
- Group [e.g. LO]
- Subgroup [e.g. LOT]

In this study soils are mapped and coloured to Order level. From the NZSC the most common soils in the Atihau–Whanganui district are the **[L]** Allophanic (e.g. LOT); **[B]** Brown Groups (e.g. BFT, BOP, BLT, BOT); **[R]** Recent (e.g. ROT); and **[G]** Gley soils (e.g. GRA, GOT) (Hewitt 1998). Raw soils (W) will also predominate where there is little topsoil or subsoil remaining on steep hill sides which have been affected by repeated and historic landsliding and slumping. The soils are typically Brown and Recent soils on the steepland hill country on sandstones, siltstones, and mudstones in the south-west and north-west of the study area. Patches of volcanic ash are also mapped on gentler slopes in the steepland hill country. The allophanic soils are mapped on the downlands, undulating and flat land of the volcanic ash terrains in the north-east towards Ohakune. Recent and Gley soils are commonly mapped on the alluvial and floodplain areas. A brief description of the main attributes and properties of each soil order and group from the New Zealand Soil Classification (Hewitt 1998) is given below and can be used with the GIS soils map.

[L] Allophanic

Main allophanic soil sub-group mapped in the AWHI study area from the soil order L are the LOT: Typic Orthic Allophanic Soils.

Allophanic soils are formed predominantly from North Island air-fall tephra, and from the weathering products of volcanic rocks. They can also occur from weathering of greywacke. They cover just 5% of New Zealand. They are common soils in the north-eastern parts of the study area on stable easier hill country, rolling land, and terraces, where the influences of Taupo Pumice are small but other volcanic ashes are high.

They are dominated by the minerals allophane, imogolite and ferrihydrite (often referred to as amorphous or poorly crystalline minerals). These stiff-jelly-like minerals coat the sand and silt grains and maintain a very porous, low density, weak structure. The soils are identified by a distinctly greasy feel when moistened and rubbed firmly between the fingers. They are easy to dig and samples crumble very easily when crushed in the hand.

- Physical Properties: Because the bulk density is very low and there is little resistance to root growth, topsoil and subsoil horizons are very friable. Potential root depth is very deep and the rooting medium is good. There is little resistance to root extension and penetration. Carbon contents are medium to high.
- Drainage: Rapid permeability and high water retention, macro-porosity very high, rapid drainage at low soil moisture tensions. Good topsoil stability – soils resist puddling under impact of machinery or grazing animals in wet weather.
- Erosion rates: Generally low except on steep slopes or exposed sites and under cultivation on rolling slopes. Slight to insignificant erosion under pasture. Topsoils are stable and

resist the impact of machinery or grazing animals in wet weather. Soils can lose strength on disturbance. Exposed topsoil may be susceptible to wind erosion.
- Chemical properties: Natural fertility is low and limited. It requires phosphorus, potassium, and magnesium on dairy farms. P retention and phosphate retention are high in topsoils, so the ability to retain phosphorous is very high. Pasture may respond to lime where pH is less than 5.3. High shrinkage potential (on drying). Minerals include allophane, imogolite, ferrihydrite, and/or aluminium/humus complexes. Clay content typically 10–25%. Bases: Low 1–2 cmol 100 g. No significant trace element deficiencies, although cobalt is marginal, and soils are generally strongly leached. Sulphate reserves are held in B horizons.
- Biological properties: Active soil fauna. Soils contain large populations of soil organisms, particularly in A horizons. Microbial biomass high.
- Climate: Soils are usually moist with more than 1000 mm per year rainfall and soil moisture deficits are either absent or transitory.

Table 5: Allophanic soil definitions

Soil groups of the Allophanic Soils order [L]	Nearest equivalent New Zealand Genetic Soil Classification classes
	NZ genetic: Y-B loams, may include weakly weathered red and brown loams, and upland country Y-B earths.
Perch-gley Allophanic Soils (LP) – periodic wetness caused by a perched watertable	*Perch-gley Allophanic Soils (LP)* – gley soils
Gley Allophanic Soils (LG) – periodic wetness caused by a groundwater table	*Gley Allophanic Soils (LG)* – gley soils
Impeded Allophanic Soils (LI) – have a hard layer that impedes roots and water	*Impeded Allophanic Soils (LI)* – Yellow-brown loams
Orthic Allophanic Soils (LO) – other Allophanic Soils	*Orthic Allophanic Soils (LO)* – yellow-brown loams.
	Taxonomy: Aquands, Cryands, Udands.

[B] Brown

Main Brown soils mapped in the AWHI study area are:

- BFT: Typic Firm Brown Soils.
- BOP: Pallic Orthic Brown Soils.
- BLT: Typic Allophanic Brown Soils.
- BOT: Typic Orthic Brown Soils.
- BOM: Mottled Orthic Brown Soils.

Brown soils occur where summer drought is uncommon (except in some stony and sandy sites) and which are not waterlogged in winter. Soils are mapped as Brown on parent materials such as weakly weathered Tertiary aged sedimentary rocks where older weathered volcanic tephric material is not thick. If the volcanic ash is thick the P retention values are too low for the soils to qualify as Allophanic [L]. They are common soils in the AWHI study area, mainly on hill country on sandstones and mudstones where erosion is not severe, and where there is little or no older weathered tephric material present. Brown soils are the most extensive New Zealand soils, covering 43% of New Zealand. The soils show dark grey-brown topsoils and brown or yellow-brown subsoils. The brown colour is caused by thin coatings of iron oxides weathered from the parent material.

- Physical properties: Soils have a yellowish brown colour to upper part of B horizon. They have relatively stable topsoils with well developed polyhedral or spheroidal topsoil structure and aggregates are not readily dispersed. Root penetration is very good and native plant roots can penetrate deeply. Available water capacity is low.
- Drainage: Good, with macroporosity generally moderate (10–14%).
- Chemical properties: Soils have low to moderate base saturation. Clay minerals are dominantly mica/illile and vermiculite, with allophane in Allophanic Brown Soils. Secondary iron (Fe) and aluminium (Al) oxides are dispersed throughout the soil mass. P retention is moderate to very high. Low to moderate base saturation values in subsoils are usually less than 50% KCL-extractable. Al levels are usually more than 1.5 cmol(+)/kg except where clay contents are relatively low. C/N ratios are moderate to low.
- Biological properties: Soils contain large, active populations of soil organisms, particularly earthworms.
- Climate: Moist; rainfall more than 1000 mm per year. Soils are rarely dry except for some stony and sandy soils.

Table 6: Brown soil definitions

Soil groups of the Brown Soils order [B]	Nearest equivalent New Zealand Genetic Soil Classification classes
	NZ genetic: Y-B earths, Y-B sands, southern B-G loams and clays, Y-B earth/Y-G earth intergrades
Allophanic Brown Soils (BL) – have a horizon with soil properties dominated by allophanic material	*Allophanic Brown Soils (BL)* – yellow-brown earths (upland and high country)
Sandy Brown Soils (BS) – dominated by sand or loamy sand to depth	*Sandy Brown Soils (BS)* – yellow-brown sands
Oxidic Brown Soils (BX) – similar to Oxidic Soils but with significant weatherable minerals	*Oxidic Brown Soils (BX)* – yellow-brown earths (northern)
Mafic Brown Soils (BM) – in materials from dark igneous rocks or sediments	*Mafic Brown Soils (BM)* – brown granular loams and clays
Acid Brown Soils (BA) – strongly or extremely acid	*Acid Brown Soils (BA)* – podzolised yellow-brown shallow and stony soils
Firm Brown Soils (BF) – strong, apedal subsurface horizon	*Firm Brown soils (BF)* – yellow-brown earths, yellow-brown shallow and stony soils
Orthic Brown Soils (BO) – Other Brown Soils	*Orthic Brown Soils (BO)* – yellow-brown earths, yellow-brown shallow and stony soils
	Taxonomy: Dystrochrepts.

[G] Gley

Main Gley soils mapped in the AWHI study area are:

- GRA: Acidic Recent Gley Soils
- GOT: Typic Orthic Gley Soils

Gley Soils occur throughout New Zealand usually in low parts of the landscape (e.g. flood plains), where there are high groundwater tables, and in places where there are seepages. They usually form on alluvial or colluvial material and can contain peat. Flooding and deposition is likely on low lying sites. They cover about 3% of New Zealand. In the Atihau–Whanganui project study area these soils occur in low parts, depressions, and drained areas, such as floodplains and near wetlands. Gley soils could be mapped in more detail and accuracy in the AWHI study area using higher levels of mapping resolution.

Gley soils commonly form after being artificially drained to provide productive agricultural land. They are strongly affected by waterlogging and are chemically reduced soils. They have light grey subsoils, usually with reddish brown or brown mottles. The grey colours usually extend deeper than 90 cm. Waterlogging occurs in winter and spring, and some soils remain wet all year.

- Physical properties: Colours are usually greyish and topsoils have a high level of organic matter (OM). Rooting depth is shallow, limited by poor aeration. Bulk densities are relatively high.
- Drainage: Poorly to very poorly drained, with high groundwater tables, shallow potential rooting depth, and relatively high bulk density. Drainage is necessary for most agricultural development. In undrained conditions, saturation occurs for long periods, oxygen is limited, and reducing conditions occur. Most crops respond well to drainage.
- Erosion: Minimal. Limited trafficability and, when soils are wet, pugging damage by stock is likely.
- Chemical properties: Soils have common segregated iron and manganese oxide mottles, concretions, or nodules. Organic matter content is usually high. A wide range of clay minerals reflects the mineralogy of the gleyed material from which soils are derived. Mineralogy classes include Mixed, Illitic, and Smectitic. Iron and manganese oxides are usually segregated. Nitrogen requirements are higher than for associated well drained soils.
- Biological properties: Many soil organisms are restricted because of anaerobic conditions.
- Climate: Rainfall ranges from less than 1000 mm/yr to over 2000 mm per year. Soils are typically in wet zones.

Table 7: Gley soil definitions

NZSC soil groups of the Gley Soils order [G]	Nearest equivalent New Zealand Genetic Soil Classification classes
	NZ genetic: gley and gleyed recent
Sulphuric Gley Soils (GU) – sulphuric acid or the mineral jarosite in marine estuarine soils	*Sulphuric Gley Soils* (GU) – gley soils
Sandy Gley Soils (GS) – dominated by sand or loamy sand to depth	*Sandy Gley Soils* (GS) – gley soils
Acid Gley Soils (GA) – strongly or extremely acid	*Acid Gley Soils* (GA) – gley soils
Oxidic Gley Soils (GX) – similar to Oxidic Soils but with less iron oxide	*Oxidic Gley Soils* (GX) – gley soils
Recent Gley Soils (GR) – on young land surfaces, mainly alluvial or estuarine	*Recent Gley Soils* (GR) – gleyed recent soils
Orthic Gley Soils (GO) – other Gley Soils	*Orthic Gley Soils* (GO) – gleyed recent soils
	Taxonomy: Aquents, Aquepts, and Aquox (Oxidic Gley soils).

[N] Granular

Granular soils occur throughout New Zealand on landforms such as hills and mountains, downlands, and terraces. Parent materials are strongly weathered tephras, mostly older than 50 000 yrs and they may also be derived from basaltic and andesitic rocks (with possible additions of wind-blown (*aeolian*) material). These soils usually have a brown to yellowish colour. These soils are rare in the AWHI study area.

- Physical properties: Brown to yellowish. Rooting depth is limited: extension of plant roots in the subsoil is limited by high penetration resistance, wetness, or aluminium toxicity. When wet, the soil's workability and trafficability is limited, and is constrained by stickiness and plasticity.
- Drainage: Permeability is slow and saturated hydraulic conductivity is slow or marginally slow in parts of the profile, resulting in periods of perching of water.
- Chemical properties: Strongly weathered soils with low nutrient reserves; reserves of phosphorus, potassium, and magnesium are low, particularly in the Oxidic group. Clays: moderate clay activity. CEC >16 cmol per kg (clay) and ECEC ranges from about 8 to 16 cmol/kg (clay). Mineralogy: kandic. Phosphorus status is low but phosphorus fixation may be high (high P retention levels). Sulphate tends to be strongly adsorbed in B horizons.
- Biological properties: Large range of biological activity, can be restricted by deep clays
- Climate: Occur under a wide range of climate types.

Table 8: Granular soil definitions

NZSC Soil groups of the Granular Soils order [N]	Nearest equivalent New Zealand Genetic Soil Classification classes
Perch-Gley (NP) *Melanic (NE)* *Oxidic (NX)* *Orthic (NO)*	Brown-Granular loams and clays Taxonomy: Ultisols, occ. Alfisols.

[E] Melanic

Melanic soils occur on large range of landforms throughout New Zealand, but are commonly formed on parent materials comprising calcium or calcite rocks or mafic, ultramafic rocks (basalt, peridotite). These soils are rare in the AWHI study area.

- Physical properties: The structural stability of topsoils is high. Soils have high OM associated with clay minerals. There is a high resistance to structural damage under heavy cropping unless the OM content is greatly reduced. Porosity is stabilised by divalent ion/organic matter/clay complexes. Rooting is deep, except on shallow soils on rock or soils with high water tables.
- Chemical properties: Mineralogy: Smectitic, Illitic or Kandic. Clays are typically swelling clays – smectite – or minerals with interstratifications of smectite with high shrink/swell potential. Soil materials are often sticky to plastic. P retention is moderate to high.
- Biological properties: Large range of biological activity. C/N ratios are low except where there is high precipitation.
- Climate: Occur under a wide range of climate types.

Table 9: Melanic soil definitions

NZSC Soil groups of the Melanic Soils order [E]	Nearest equivalent New Zealand Genetic Soil Classification classes
Vertic (EV) *Perch-Gley (EP)* *Rendzic (ER)* *Mafic (EM)* *Orthic (EO)*	Rendzinas, rendzic intergrades, Y-G earths, Y-B earths. Taxonomy: Mollisols, Vertisols, Inceptisols.

[O] Organic

Organic Soils occur in wetlands in most parts of New Zealand or under forest that produces acid litter in areas with high precipitation. Peats, typically very poorly to poorly drained, cover only 1% of New Zealand. They are formed in the partly decomposed remains of wetland plants (peat) or forest litter. Some mineral material may be present but the soil is dominated by organic matter. These soils are rare in the AWHI study area.

- Physical properties: Organic soils have very low bulk densities, low bearing strength, high shrinkage potential when dried, very low thermal conductivity, and high total available water capacity. Bulk density is low and ranges from 0.03 to 0.4 Mg m^3, and the soils have low bearing strength. Thermal conductivity is very low and soils warm and cool slowly – bare soil surfaces have high radiance. Shrinkage potential is high and soils shrink markedly on drying, losing OM because of oxidation. The AWC is high. Plant available water capacity may be moderate, with frequent water deficiency for crops and pasture.

- Drainage: Organic soils formed in peats are very poorly drained, while those from litter may range from well drained to very poorly drained.
- Chemical properties: Soils have high cation exchange capacities, but are usually strongly or extremely acid, and nutrient deficiencies are common. Soils are deficient in major nutrients – nitrogen, phosphorus, potassium, and sulphur, and also in trace elements – copper, selenium, and molybdenum. Organic matter is up to 70%. Organic components have high surface area and a high negative charge that varies markedly with pH. CEC values are very high: from 40 to 170 cmol kg.
- Biological properties: High carbon/nitrogen ratios (range 18–70) with the highest in unfertilised and uncultivated O soils. The high C/N ratio indicates slow decomposition rates. Many soil organisms are restricted because of anaerobic conditions.
- Climate: Occur under a wide range of climate types.

Table 10: Organic soil definitions

Soil groups of the Organic Soils order [O]	Nearest equivalent New Zealand Genetic Soil Classification classes
	NZ genetic: organic
Litter Organic Soils (OL) – thick litter that has accumulated under forest	Litter Organic Soils (OL) – unclassified
Fibric Organic Soils (OF) – in peat with plant fibres that are only weakly decomposed	Fibric Organic Soils (OF) – organic soils
Mesic Organic Soils (OM) – in peat that is moderately decomposed	Mesic Organic Soils (OM) – organic soils
Humic Organic Soils (OH) – in peat that is strongly decomposed.	Humic organic Soils (OH) – organic soils
	Taxonomy: Histosols

[X] Oxidic

Oxidic soils occur throughout New Zealand on a range of landforms including rolling to hilly and mountainous terrain, and terraces. Soils are typically formed on parent materials such as andesites, dolerites, and basalts of Tertiary to Upper Cretaceous age. These soils are rare in the Atihau–Whanganui project study area.

- Physical properties: Topsoils have well developed spheroidal or polyhedral pedal structure and bulk densities are typically low. The rooting depth is typically limited by high dry bulk density and high penetration resistance particularly in well drained soils. Plant root depths are shallow to medium. Infiltration is moderate to rapid. Hydraulic conductivity is moderate in the surface and upper B horizons, giving excellent trafficability and workability after rain. Permeability is slow and hydraulic conductivity decreases to slow or marginally slow with depth. Perching of water occurs after high intensity rainfalls. The duration of wetness varies from 1 to 2 days. Soil-water deficits occur in summer and are exacerbated by low readily available water capacity and shallow rooting depths.

- Chemical properties: Oxidic soils contain low activity phyllosilicate clays and secondary oxides which give rise to variable charge properties. Strongly weathered soils with low nutrient reserves, particularly of potassium, magnesium, calcium, and phosphorus. Mineralogy includes kandic, ferritic, and aluminitic mineral classes. High clay contents, ranging from 50–90% but clays have low activity. CEC is low at field pH. ECEC: less than 12 cmol/kg (clay) and CEC less than 16 cmol/kg (clay) and some subhorizons have a net positive charge. P retention is high, ranging from 60–90%. High sulphate adsorption in B horizons.
- Biological properties: Typically low biological activity.
- Climate: Occur under a wide range of climate types.

Table 11: Oxidic soil definitions

NZSC Soil groups or the Oxidic Soils order [X]	Nearest equivalent New Zealand Genetic Soil Classification classes
Perch-gley (XP)	NZ Genetic soil: Many northern BG clays and loams.
Nodular (XN)	Many northern Brown Granular clays and loams.
Orthic (XO)	Soil Taxonomy: Oxisols

[P] Pallic

Pallic Soils occur predominantly in the seasonally dry eastern parts of the North and South Islands, and the Manawatu–Whanganui region. They are typically confined to lower rainfall inland areas and near the coast. They cover 12% of New Zealand. Pallic soils become dry in summer and wet in winter. These soils are rare in the AWHI study area.

Parent materials are commonly loess, derived from greywacke and hard sandstone rocks. They have pale subsoils because the iron oxides content is low. The soils have a weak structure and high density in subsurface horizons.

- Physical properties: Soils have slow permeability with limited rooting depth, and medium to high bulk density. Subsurface horizons have restricted permeability, particularly soils with fragipans or duripans in which permeability is very slow. Rooting depth is limited and potential rooting depth is limited by a subsurface horizon of high bulk density at shallow depths.
- Erosion: These soils are susceptible to erosion because of their high potential for slaking and dispersion. Soil material, particularly in B horizons, is strongly dispersive and will readily slake. Topsoil structures may break down under prolonged impact by heavy machinery or continuous tillage.
- Drainage: Perched water tables. Soils are poorly to moderately well drained and have water tables perched on slowly permeable layers.

Chemical properties: These soils have medium to high natural nutrient content (except for sulphur), high base saturation, low concentrations of secondary oxides, and low organic matter contents. Base saturation values in subsoils are high, often more than 50%, except in perch-gleyed pallic soils where values may be lower in horizons over fragipans (dense soil layers). Low concentration of secondary oxides. P retention less than 30% in topsoils and subsoils. A high proportion of inorganic P is non-occluded, and a high proportion of total P is in organic form. Extractable iron and Al values are low or moderate, with a significant proportion of secondary iron oxides occurring in redox segregations. Levels of extractable sulphur are low. Clays include Mica/illite. Common mineralogy includes illitic or clay-mineralic classes.

- Biological properties: Soils are strongly worm-mixed at the boundary between the A and B horizons. Topsoil worm activity is greatly reduced during summer periods of soil moisture deficit.
- Climate: Annual rainfall is usually between 500 and 1000 mm, and the climate is typically droughty in summer, and moist and wet in winter. A spring surplus of soil water is common but the annual surplus is <2000 mm per annum. The average annual deficit is approx. 90–200 mm per year.

Table 12: Pallic soil definitions

NZSC soil groups of the Pallic Soils order [P]	Nearest equivalent New Zealand Genetic Soil Classification classes
Perch-gley Pallic Soils (PP) – periodic wetness caused by a perched watertable	NZ genetic: Most YG earths and intergrades. Y-G earths/YB earths.
Duric Pallic Soils (PU) – silica-cemented pan in the subsoil	
Fragic Pallic Soils (PX) – a compact pan in the subsoil	
Laminar Pallic Soils (PL) – clay accumulation as thin bands in the subsoil	
Argillic Pallic Soils (PJ) – clay accumulation as thin coatings on peds or in pores	
Immature Pallic Soils (PI) – weakly expressed pallic soil features	Taxonomy: Aqualfs, Aquepts, Ustalfs, Udalfs, Ochrepts.

[Z] Podzols

Podzol soils occur in areas of high rainfall (~>1800 mm per annum) and are usually associated with forest trees that produce an acid litter. They are most common in Northland, the North Island high country, and the West Coast and high country of the South Island. The soils occur mainly in materials from silica-rich rocks such as granite, greywacke, schist, rhyolite, or rhyolitic ash. They cover 13% of New Zealand. They are found in the highest upland areas (>550 m a.s.l.) of the central North Island in mountain lands especially with some volcanic ash cover, typically on plains, flat to gently rolling terrain, downlands, and terraces at high altitude. Soils occur on a range of rocktypes in upland areas including sandstone, consolidated sandstone, and greywacke. These soils are rare in the AWHI study area.

They are strongly acid soils that usually have a bleached (whitish silica) horizon immediately beneath the topsoil. Sandy Taupo and Waimihia tephric soil materials are prone to processes that result in the formation of Podzols. This bleached horizon is the source of aluminium and iron oxides, which have accumulated, in association with organic matter, in an underlying dark or reddish horizon.

- Physical Properties: Cemented or compacted B horizons are common, with associated slow permeability and limited root depth. E and B horizons are weakly pedal or lack pedality. Soils extremely acid in A and E horizons. The rooting depth is limited by low pH and aluminium toxicity, or by pans which cause wetness problems. Areas with soil water surplus for much of the year.
- Chemical properties: Podzols have low natural fertility, low base saturation, and are strongly acid. Secondary oxides and other clay materials are strongly differentiated with depth. Clays such as mica-smectite or smectite often occur in A and E horizons. Hydroxy-coated or interlayered minerals or allophane often occur in B horizons. Carbon/nitrogen ratios are very high. Wide ranges of mineralogy classes are common. KCl-extractable Al levels are high and aluminium in soil solution may be toxic to some plants. Very low natural fertility.
- Biological properties: Podzols have low biological activity, with low levels of faunal activity and a low rate of mineralisation. The vegetation comprises plants that deposit a mor-forming acid litter with a low nutrient content.
- Climate: Typically wet, the soils are moist throughout the year with annual rainfall more than about 1500 mm.

Table 13: Podzol soil definitions

NZSC Soil groups of the Podzol order [Z]	Nearest equivalent New Zealand Genetic Soil Classification classes
	NZ genetic: podzols, podzolised Y-B earths.
Densipan Podzol Soils (ZD) – high density, pale, pan just beneath the topsoil	Densipan Podzol Soils (ZD) – podzols
Perch-gley Podzol Soils (ZP) – periodic wetness caused by a perched watertable	*Perch-gley Podzol Soils* (ZP) – gley-podzols
Groundwater-gley Podzol Soils (ZG) – periodic wetness caused by a groundwater table	*Groundwater-gley Podzol Soils* (ZG) – gley-podzols
Pan Podzol Soils (ZX) – with a subsoil cemented pan	*Pan Podzol Soils* (ZX) – podzols
Orthic Podzol Soils (ZO) – other Podzols	*Orthic Podzol Soils* (ZO) – podzols
	Taxonomy: Spodosols.

[M] Pumice

Pumice Soils occur mainly close to the central North Island, particularly near the Volcanic Plateau and have formed on volcanic, ash deposits, and flow tephra. They are sandy or gravelly soils dominated by pumice, or pumice sand with a high content of natural glass. They cover about 7% of New Zealand. The AWHI study area being adjacent to and part of the the central North Island volcanic centre (mainly Taupo), has very deep pumice soils in places. Pumice soils only form on sandy pumice about 25cm thick, especially where Taupo and Waimihia ash materials are frequently present in the topsoils. They occur in tephra ranging from 700–3500 years old. Pumice Soils are formed in both Taupo Pumice (1850 ± 10 yr B.P.) and Waimihia Lapilli (3280 ± 20 yr B.P.) in the AWHI study area. These soils occur sporadically in the study area and are especially recorded at higher levels of mapping resolution.

- Physical properties: They have low soil strengths, high macroporosity, and allow deep rooting. Soils are weak when disturbed, but generally resist livestock treading damage. Clay contents are low, generally less than 10%. Glass is predominant in sand fractions. The very high macroporosity enables rapid drainage at low soil-water tensions. Available water content is high. Water contents at field capacity are less than the plastic limit.
- Erosion: Potential for erosion by water is high. Landforms prone to rilling, tunnel gully, and gullying.
- Drainage: Excess water drains rapidly but the soils can store large amounts of water for plants. Soils are non-plastic, weak when disturbed, and resistant to pugging. Pumice soils are susceptible to compaction, such as vehicle loading and livestock treading, with consequent reduced infiltration and potential erosion from water concentration areas.
- Chemical properties: The pumice is fresh or only moderately weathered with low reserves of major nutrient elements. Reserve potassium (Kc) is low and exchangeable magnesium is very low. Trace elements, particularly cobalt, copper, molybdenum, boron, iodine, and selenium, are commonly deficient. Clay minerals are dominated by allophane and imogolite, as coatings around glass or pumice particles. P retention is moderate to high. Mineralogy: Glassy, amorphic classes. Sulphur, potassium, nitrogen, phosphorus, and magnesium are usually required for agricultural or horticultural crops.
- Biological properties: Soil animal populations are low with most species concentrated in the topsoil. Earthworm populations are limited by drought or where soils have a coarse texture and low organic matter.
- Climate: Pumice soils occur under a range of climate types.

Table 14: Pumice soil definitions

NZSC Soil groups [M]	Nearest equivalent NZ Genetic Soil Classification classes
	NZ genetic: Y-B pumice soils, Y-B loams with high glass content.
Perch-gley Pumice Soils (MP) – periodic wetness caused by a perched watertable	*Perch-gley Pumice Soils* (MP) – gley soils
Impeded Pumice Soils (MI) – with a subsoil layer that restricts water movement and roots	*Impeded Pumice Soils* (MI) – yellow-brown pumice soils
Orthic Pumice Soil (MO) – other Pumice Soils	*Orthic Pumice Soil* (MO) – yellow-brown pumice soils
	Taxonomy: Vitrands, Vitricryands, Vitraquands.

[W] Raw

Raw soils are scattered throughout New Zealand, particularly in association with high mountains (e.g. alpine rock areas and active screes), steep erodible hill slopes, braided rivers, beaches, and tidal estuaries. They cover about 3% of New Zealand. Raw soils occur in the steepest ‘unstable’ parts (e.g. actively eroding) of the AWHI study area particularly in the south and south-west. Landforms are typically steep hill to mountainous, steep foothills, eroded areas (e.g. landslide) adjacent to and in gullies, on active slips, slumps, earthflows, or on sites in valleys where there is frequent sediment deposition.

Raw soils occur in environments where the development of topsoils is prevented by rockiness, active erosion, or deposition. They are very young soils on active surfaces and often not in situ, and therefore lack distinct topsoil development or become unstable at shallow depths.

- Physical properties: Raw Soils have no B horizon, and the topsoil is either absent or less than 5 cm thick. They are weakly developed, recent (fresh or weakly weathered) soils. Pedogenetic horizons are lacking apart from rudimentary topsoil. Mineralogy is inherited, and similar to that of the parent material.
- Erosion: Soils are not aggregated and prone to erosion. Environments are actively eroding or depositing. Vegetation: sparse.
- Chemical properties: Fertility is limited by lack of organic matter and nitrogen deficiency.
- Biological properties: Vegetation cover is sparse and often consists of ephemeral herbaceous plants, mosses, or lichens.
- Climate: Often formed under higher rainfalls or areas prone to high intensity rainfalls.

Table 15: Raw soil definitions

NZSC Soil groups of the Raw Soils order [W]	Nearest equivalent New Zealand Genetic Soils Classification classes
Gley Raw soils (WG) – periodically wet	*Gley Raw soils* (WG) – unclassified
Hydrothermal Raw Soils (WH) – soils naturally warmed by geothermal activity	*Hydrothermal Raw Soils* (WH) – hydrothermal soils
Rocky Raw Soils (WX) – rock at shallow depths	*Rocky Raw Soils* (WX) – unclassified
Sandy Raw Soils (WS) – dominated by sand or loamy sand to depth	*Sandy Raw Soils* (WS) – unclassified
Fluvial Raw Soils (WF) – in sediments deposited by flowing water	*Fluvial Raw Soils* (WF) – unclassified
Tephric Raw Soils (WT) – in sediments originating as volcanic ejecta	*Tephric Raw Soils* (WT) – unclassified
Orthic Raw soils (WO) – other Raw Soils	*Orthic Raw soils* (WO) – unclassified
	Taxonomy: Entisols or unclassified

[R] Recent

Main Recent soils mapped in the AWHI study area are:

- ROT: Typic Orthic Recent Soils.

Recent soils occur throughout New Zealand on young land surfaces, including alluvial flood plains, unstable steep slopes, and slopes mantled by very young tephra. Parent materials include gravels, sands, and silts from a range of rocktypes. Their age varies depending upon the environment and soil materials but most are less than 1000–2000 years old. They cover 6% of New Zealand. These soils are very common in much of the eroding and steep hill country and river valleys of the Atihau–Whanganui district.

They are weakly developed (weak soil structure) and show limited signs of soil-forming processes. Development is mainly confined to topsoils, with a distinct topsoil but a B horizon either absent or only weakly expressed as they lack pedality or are only weakly pedal.

- Physical properties: Soil texture varies, with common stratification of contrasting materials, and spatial variability is high. They are generally deep rooting and have high plant-available water capacity. Drainage is good.
- Erosion: Subject to flooding, streambank erosion, and deposition.
- Chemical properties: Natural fertility is usually high with high base saturation. The mineralogy in recent soils strongly reflects that of the parent material, and illite is common except on tephras which have high glass content. Phosphorous retention is generally low or very low unless the soils are formed from mafic materials where the P retention may be higher.
- Biological properties: A continuous cover of vascular plants is normally well established.
- Climate: Recent soils occur under a range of climate types

Table 16: Recent soil defintions

NZSC Soil groups of the Recent Soils order [R]	Nearest equivalent New Zealand Genetic Soil Classification classes
	NZ genetic: Recent
Hydrothermal Recent Soils (RH) – soils naturally warmed by geothermal activity	*Hydrothermal Recent Soils* (RH) – recent soils
Rocky Recent Soils (RX) – Rock at shallow depths	*Rocky Recent Soils* (RX) – lithosols
Sandy Recent Soils (RS) – dominated by sand or loamy sand to depth	*Sandy Recent Soils* (RS) – recent soils
Fluvial Recent Soils (RF) – in sediments deposited by flowing water	*Fluvial Recent Soils* (RF) – recent soils
Tephric Recent Soils (RT) –in sediments originating as volcanic ejecta	*Tephric Recent Soils* (RT) – recent soils
Orthic Recent Soils (RO) – other Recent Soils, most commonly on slopes	*Orthic Recent Soils* (RO) – recent soils
	Taxonomy: Entisols, Inceptisols, Andisols

[U] Ultic

Ultic soils occur on a range of landforms. Parent materials are weathered. These soils are rare in the AWHI study area.

- Physical properties: Highly weathered.
- Drainage: Imperfectly to poorly drained. Permeability slow. Clay dominated profiles inhibit drainage.
- Erosion: Susceptible to livestock treading damage or compaction during wet periods; surface horizons prone to dispersion, especially erodible within clayey or silty surface horizons.
- Chemical properties: Within clayey subsoils CEC values are medium to high. Ultic soils have a range of minerals but Kandic and Smectitic types are most common. P retention: moderate to high in B horizons and low in A and E horizons (low contents of secondary iron oxides). Nutrients: Low reserves. Low levels of extractable P (<3mg 100 g) and total P (<20 mg 100 g). Low solubility and low inorganic P reserves. KCL-extractable Al levels >1cmol (+)/kg are common. Toxic Al in B horizons may inhibit root function. Low concentration of reserve magnesium and potassium (from strong weathering). Toxic Al in B horizons may inhibit root function. Low concentration of reserve magnesium and potassium (from strong weathering).
- Biological properties: Biological activity is generally low.
- Climate: Ultic soils occur under a range of climate types.

Table 17: Ultic soil definitions

NZSC Soil groups or the Ultic Soils order [U]	Nearest equivalent New Zealand Genetic Soil Classification classes
Densipan (UD)	NZ genetic: central Y-B earths, northern Y-B earths, podzols. Northern Y-B earths.
Albic (UE)	Taxonomy: Ultic, Ultisols.
Perch-gley (UP)	
Sandy (US)	
Yellow (UY)	

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