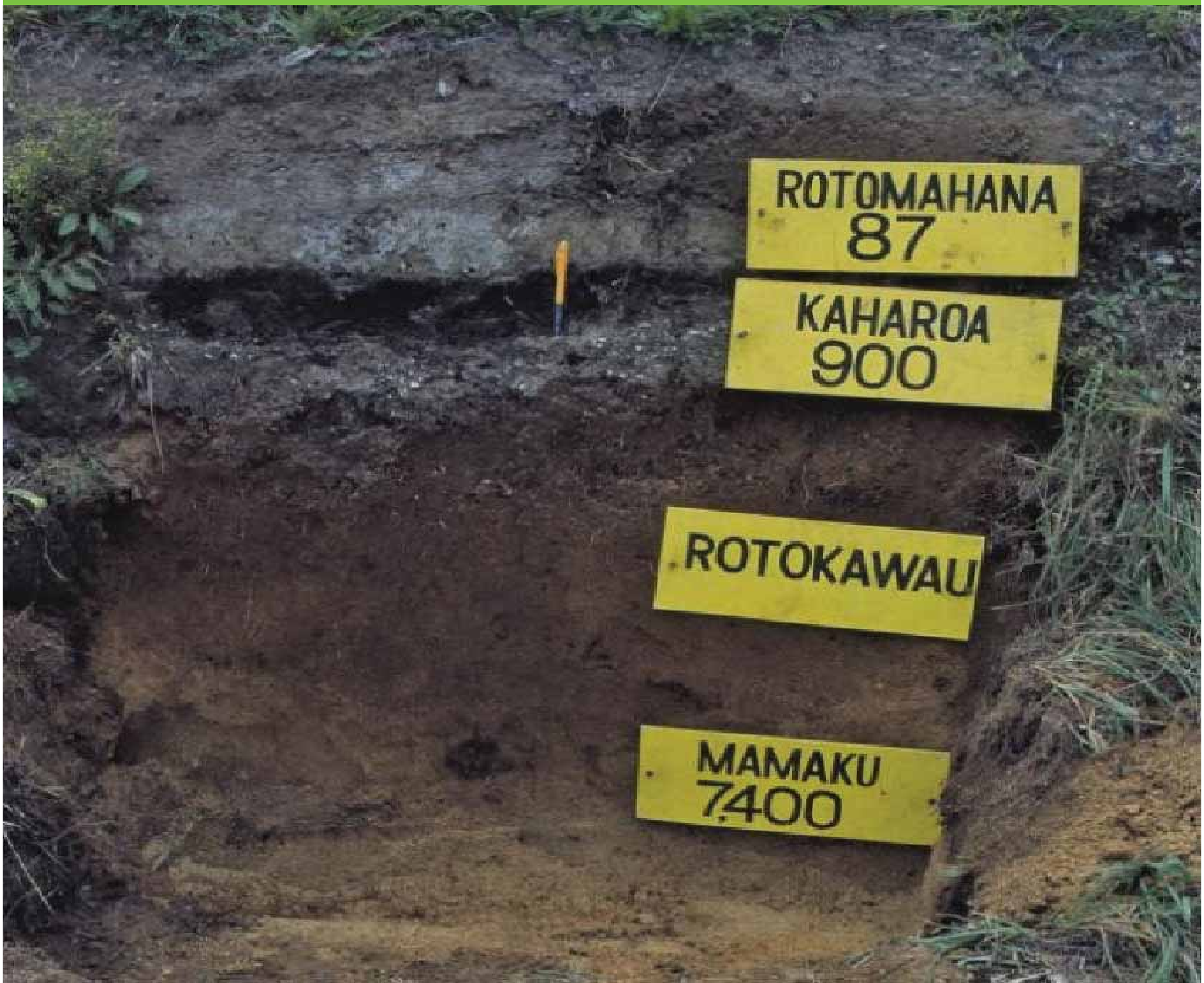
Soils of the Bay of Plenty Volume 2

Central Bay of Plenty



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Preface

Soil is a resource, a living, breathing entity that, if treated properly, will maintain itself.

It's our lifeline for survival. When it has finally been depleted, the human population will disappear.

Project your imagination into the soil below you next time you go into the garden. Think with compassion of the life that exists there. Think, the drama, the harvesting, and the work that carries on ceaselessly. Think about the meaning of being a steward for the earth.

Marjorie Harris, In the Garden (1995)

For as long as I can remember I have been intrigued and fascinated by landscapes and soils of New Zealand, in particular of the Bay of Plenty where I spent a good deal of my career mapping soils. A landscape to me is a puzzle, a closed book, and to be able to open that book, to solve the puzzle by finding out what soils are in the landscape and what are the possibilities for good land use, is a joy we scientists call pedology – the science of soils. It is well developed in New Zealand, as befits a nation which traditionally earned so much of its wealth from the export of produce from the land. We are lucky in that respect that soils of the whole of the Bay of Plenty have now been mapped at a common scale of 1:50,000.

The general public can be excused for thinking that scientists are too pre-occupied with fine details of analysing soils for chemical and physical properties. We classify the soils, map their distribution and indicate their suitability for land use. Much of this knowledge was published by the Soil Bureau of the Department of Scientific and Industrial Research (DSIR) or, later, Landcare Research in reports, many of which are not available to the land user. This three-volume publication aims to make a major part of what we know about the soils of the Bay of Plenty available to farmers, foresters, horticulturists, farm consultants, and the general public.

We are lucky that Environment Bay of Plenty has the insight to finance the project of producing these soil books, and thus communicate soil knowledge to land users. I have enjoyed writing these books and call myself fortunate working with my colleague Dani Guinto who did more than his share producing these books. I hope that many of you will use this soil information to your advantage and getting the best from your land whilst realising your stewardship of the earth.

Wim Rijkse

Acknowledgements

Many of the soil property data were derived from Landcare Research's S-map system, and we are grateful for that. Several photographs were taken from the soil survey of the Te Puke District, Bay of Plenty, New Zealand (unpublished) by W. E. Cotching. Acknowledgement goes to Simon Stokes of Environment Bay of Plenty for initiating this soil guide. The authors thank the many farmers and landowners in the Bay of Plenty for permission to enter their properties and to examine and photograph their soils.

Contents

Part 1: Introduction

The Bay of Plenty region covers approximately 21,836 km^2 (comprising 12,253 km^2 of land and 9,583 km^2 of coastal marine area) extending roughly from Katikati in the west to Cape Runaway in the east, and Rotorua District and parts of the Taupo District in the south.

Major landforms include:

- The low-lying Rangitaiki Plains, the plains near Cape Runaway on which river sediments have been laid down. Other flat coastal areas are located near Te Puke and Opotiki. Land use on the versatile soils on these landforms includes dairying, dry stock and horticulture.

- Much of the coastal land is on terrace-like flattish country on which thick layers of tephra occur. Land use includes dairying, dry stock and horticulture (kiwifruit, citrus, etc).

- The Rotorua Caldera was formed by large ignimbrite eruptions in the past. Land use on the tephric soils includes dry stock, dairying and horticulture, but much of the land is either residential or subdivided into small blocks.

- The Rotorua Caldera is flanked by the Mamaku Plateau where tephra overlies the ignimbrite which erupted out of the caldera. Land use consists of dry stock, some dairying and forestry.

- The Kaingaroa Plateau where tephra overlies ignimbrite. Land use is forestry.

- The Galatea Basin through which the Rangitaiki River flows consists chiefly of terrace-like surfaces covered by tephra. Land use consists of dairying and dry stock.

- Hill country forms much of the background of much of the above landforms.

- Steeplands (lands on slopes greater than 25 degrees) occur throughout the area covered with tephra, and dry stock and dairying are the main land uses. Large areas occur in the Urewera National Park and surrounding area. Much of this land is in indigenous forest or cut-over bush. Elsewhere, the steeplands are used for dry stock farming.

Most previous soil mapping work in the Bay of Plenty was carried out by staff of the former Soil Bureau, a division of the Department of Scientific and Industrial Research. In later years some less published work was carried out by staff of Landcare Research. Publications of detailed soil survey work are listed in the References section.

Environment Bay of Plenty has combined all the major soil surveys and came up with a soil map of the whole region at a scale of 1:50,000 through Landcare Research's S-map system. This resource is available on the Internet and consists of a soil map and soil fact sheets (or soil reports) describing the physical and chemical properties of the soils. Access is through Environment Bay of Plenty's website (http://www.envbop.govt.nz/Environment/Soil-Information.aspx).

This publication is a companion resource to complement the soil information available online. In this publication, the soil information for the Bay of Plenty is provided in three volumes which describe the soils of Western, Central and Eastern Bay of Plenty. Figure 1.1 shows the three soil "sub-region" boundaries.

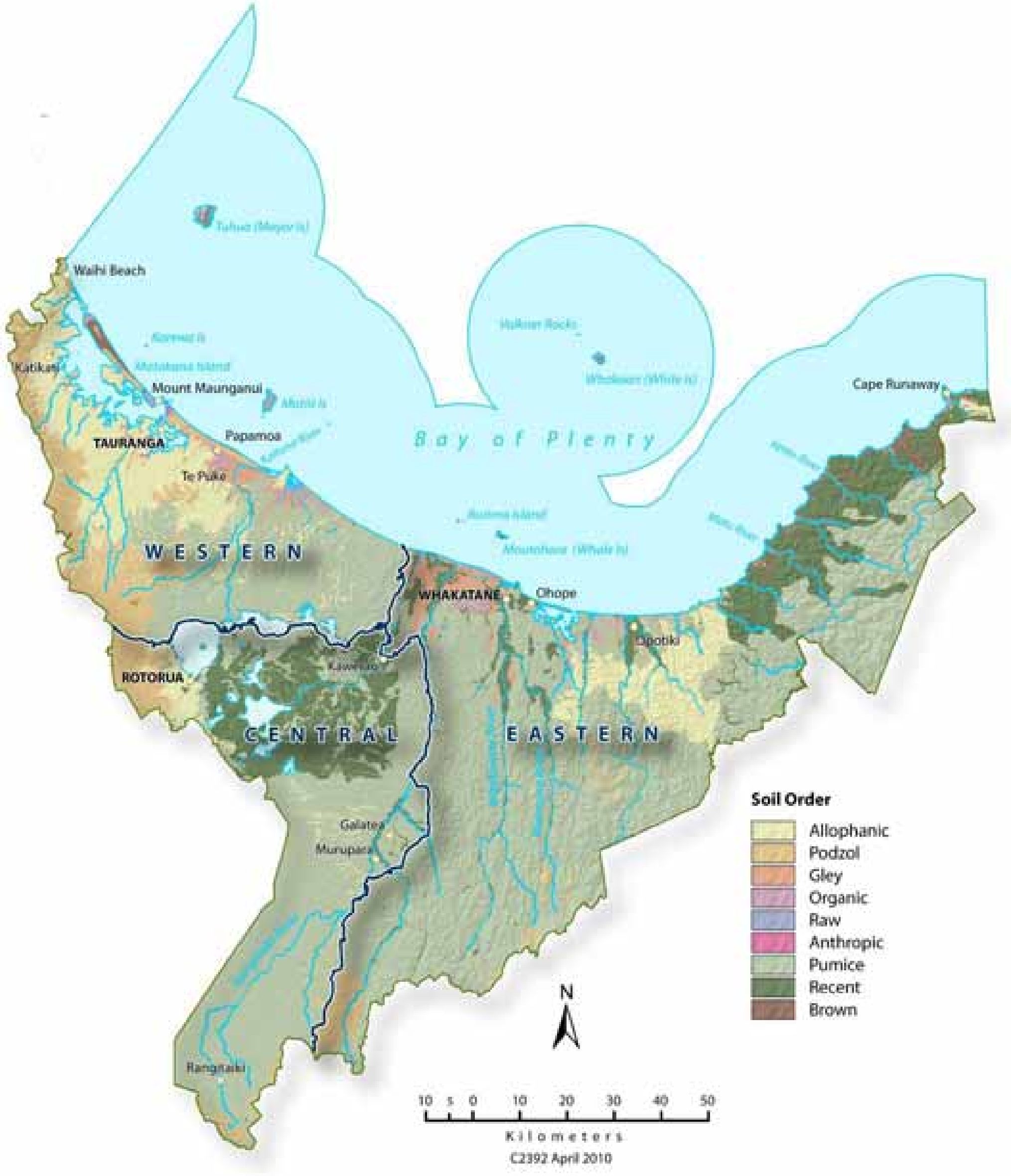

Figure 1.1 General soil map of the Bay of Plenty showing the soil orders and the sub-regional soil boundaries

These boundaries were drawn to minimise the occurrence of soil series common to two or three sub-regions (i.e. they are not based on district council boundaries). Where such overlaps occur (e.g. Matahina soil series occur in all three sub-regions), each soil series entry is repeated in each volume so that if readers are interested in one sub-region only, but their lands or properties of interest are at or close to the boundaries, they need not refer to the remaining volumes. When in doubt, however, it is advisable to consult all three volumes.

Part 2: The soil-forming environment

The interactions among the principal factors of soil formation (parent material, climate, topography, vegetation and time) and soil-forming processes have given the soils of the Bay of Plenty their distinctive characters.

Parent materials range from thick layers of volcanic ash mantling the surface, to alluvium derived from greywacke, sandstone, mudstone and volcanic ash, to peat and wind-blown sand.

The climate of the Bay of Plenty varies from warm and moist in coastal areas to cool and moist in the uplands of Urewera National Park, the Mamaku Plateau and the Kaimai Range. It is probably the most important factor influencing present-day land use.

The influence of topography is somewhat subdued in a landscape mantled by tephra; however, strong dissection of hill country and steepland country influences the layers of tephra remaining on the slopes, and induces erosion and deposition of material on valley floors.

Vegetation has also played an important role in soil development. Changes in vegetation since the commencement of farming and commercial forestry have had considerable effects on properties such as soil stability.

Some of the principal environmental factors and their relationship to the soil pattern are discussed in greater detail below.

2.1 Climate

The Bay of Plenty is somewhat sheltered from the prevailing winds by the high country of the North Island. Consequently, the Bay of Plenty has a sunny climate with dry spells, but may have prolonged heavy rainfall periods.

Annual rainfall ranges from about 1,200 mm at the coast to over 2,000 mm inland at higher elevations, but decreases again in inland basins such as near Murupara.

Rainfall plays an important part in the development of soils. Broadly speaking, the higher the rainfall the stronger the leaching that takes place in the soil and, at annual rainfall over 1,800 mm, podzolisation processes are evident in the subsoil (redder subsoil).

Over 45% of the annual rainfall is recorded in the months from May to August. The driest period is from November to February. Seasonally, winter is generally the wettest and summer the driest part of the year (NZ Meteorological Service, 1973). Days with more than 1.0 mm rainfall range from around 110 a year at the coast to around 130 inland at Minginui Forest.

2.2 Parent materials

Basement rocks in southern parts of the Bay of Plenty consist chiefly of Urewera greywacke, argillite and basal massive, green volcanic sandstone of Jurassic and lower Cretaceous age with Pleistocene sandstone and siltstones south of Awakeri to Taneatua and west of Ruatoki, as well as south of Ohope as far as Waimana and east as far as the Raukokore River south of Cape Runaway. Past and present erosion resulted in generally shallow soils over angular, shattered greywacke, although tephra persists on stable ridges, crests and spurs. Little or no tephra remains on the steep slopes.

In western parts, ignimbrite and rhyolite form the main basement rocks, changing to andesite in the larger Katikati area.

Tertiary mudstones, siltstones, sandstones and gravels occur east of Waihau Bay. The northern part, east of Cape Runaway, is occupied by a large area of basalt.

Generally, these rocks are mantled by volcanic ash, and they are therefore not soil parent materials. However, especially on steep and very steep slopes, the kind of basement rock often determines the pattern and severity of erosion, and base rocks form an important component of the parent material of alluvium in areas such as the Rangitaiki Plains, the Opotiki flood plains and the flood plains near Cape Runaway.

The parent materials of the soils of the Bay of Plenty can be further divided into:

Airfall tephra and flow tephra
Alluvium and colluvium
Peat
Wind-blown sand

2.2.1 Airfall tephra and flow tephra

Volcanic eruptions occurred at different times from sources in Rotorua and Taupo Districts, and these eruptions were commonly violent, depositing coarse volcanic material called lapilli and blocks over the Bay of Plenty. Finer material or ash was usually deposited during the final stages of an eruption at greater distances away from the volcano. The general term used for all unconsolidated clastic volcanic material is tephra, and ash and lapilli refer to the grade or size only, as shown below:

fine ash	less than 0.25 mm
coarse ash	0.25 – 2.0 mm
lapilli	2 – 64 mm
blocks	more than 64 mm

Table 2.1 Volcanic ash showers in the Bay of Plenty.

Ash shower	^{14}C age in years before 1950 and volcanic centre	Occurrence and distribution	Characteristics
Tarawera Ash and Lapilli	64 Mt Tarawera	Western parts of Eastern Bay of Plenty and north of Kopuriki, thickness varies from 70 cm (Tarawera Forest) to 3 cm (near Whakatane).	Very dark greyish brown to dark grey sand and lapilli, lapilli varies in size from about 1 cm in Tarawera Forest to 1 mm near Whakatane.
Rotomahana Mud	64 Lake Rotomahana	Chiefly west and south of Mount Tarawera as far as Lake Rotorua and North towards the coast.	Greyish sandy loam to loamy sand layer at the surface.
Kaharoa Tephra	770 ± 20 Mt Tarawera	10 – 50 cm thick deposits in the northern part of southern and to the west of eastern Bay of Plenty.	Black sandy topsoils overlying pale yellow to white hard lapilli.
Taupo Tephra Taupo Ignimbrite	– Taupō	10 – 60 cm thick in the northern part of southern and to the west of eastern Bay of Plenty; the lower part of the horizon is rich in rhyolite.	Yellowish brown to pale yellow compact sand with few to many soft highly vesicular and fibrous lapilli and some dark grey rhyolite towards the base.
Taupō Lapilli	1850 ± 10 Taupō	Throughout the Bay of Plenty except towards Cape Runaway, varying in thickness from 60 – 70 cm in the southern parts to traces of lapilli in the north-east.	Pale yellow to strong brown uneven sized soft highly vesicular and fibrous lapilli.
Rotongaio Ash	– Taupō	Thin band in southern Bay of Plenty.	Dark grey to grey thin band which serves as a marker bed to indicate lower limit of Taupo lapilli. Not soil-forming.
Hatepe Lapilli	1,900 ± 60 Taupo	2 – 20 cm thick deposits in southern Bay of Plenty.	Light grey evenly sorted loose sand, not soil-forming but useful marker bed.
Waimihia Tephra Waimihia Ash	3,280 ± 20 Taupō	20 – 50 cm around Murupara and increasing in thickness south of Murupara.	Dark brown to dark yellowish brown, greasy gravelly sand to loamy sand.

Ash shower	^{14}C age in years before 1950 and volcanic centre	Occurrence and distribution	Characteristics
Waimihia Lapilli	Taupō		Yellowish brown to dark yellowish brown, greasy gravelly sand, fine pumice gravel or sand, many fine lapilli. Strong brown colours at high altitudes.
Whakatane Tephra	4,830 ± 20 Ōkataina	50 – 60 cm thick through southern Bay of Plenty and western part of eastern Bay of Plenty, soil-forming in north-east and eastern parts of eastern Bay of Plenty.	Strong brown to yellowish brown slightly greasy loamy sand to sand with few to many pale yellow to yellowish brown medium lapilli.
Tuhua Tephra	6,130 ± 30 Mayor Island	30 – 40 cm below the topsoil, mostly north of Tauranga.	Yellowish brown sandy loam to silt loam.
Rotomā Tephra	8,530 ± 10 Ōkataina	Widespread in Bay of Plenty. About 200 cm at Matahina thinning out to 20 – 30 cm in Minginui Forest.	Yellowish brown greasy loamy sand, mostly in the lower subsoil.
Waiohau Tephra	11,850 ± 60 Ōkataina	Similar to Rotoma Tephra.	Yellowish brown greasy sandy loam to loamy sand in the subsoil.
Kawakawa Tephra	22,590 ± 230 Taupō	Various thickness but widespread in Northern Whakatane District.	Yellowish brown greasy sandy loam to loamy sand in the lower subsoil some andesitic ash (Tongariro) included in Southern Whakatane District.
Omataroa Tephra Mangaone Tephra Hauparu Tephra	28 220 ± 630 Ōkataina	Various thicknesses mainly south of the Rangitaiki Plains.	Thick layers of vesicular angular pale grey to pale yellow lapilli layers at several metres depth.
Rotoehu Tephra	ca. 50,000 Ōkataina	Various thicknesses throughout Bay of Plenty.	Distinctive white sand or lapilli at several metres depth.

Various descriptions of tephra occurring in the Bay of Plenty exist (Vucetich and Pullar 1969; Howorth 1975; Froggatt and Lowe 1990). The main ones are summarised in Table 2.1. Many of the listed tephra occur at depth, and only influence the soils where they are susceptible to erosion. For example, south of Ruatoki Valley, Rotoehu Ash overlies weathered greywacke and, where forest roads cut through the tephra layers, water accumulating in Rotoehu lapilli acts as a slide and, in saturated conditions, the whole tephra column slides off the greywacke. The most frequently occurring soil-forming tephra are Tarawera Tephra, Rotomahana Mud, Kaharoa Tephra, Taupo Tephra, Waimihia Tephra, Whakatane Tephra and Tuhua Tephra (See Figures 2.1 and 2.2).

Tarawera Tephra erupted from Mount Tarawera in 1886, and it occurs in topsoils from Galatea Basin towards the coast. It is thickest in the Tarawera Forest (70 cm) and it consists of black to dark greyish-brown angular basaltic ash and lapilli. It is considered to be significant where more than 7 cm thick.

Thickness and size of scoria can be critical on hilly slopes sown in pasture where coarse lapilli erode downslope and pastures fail to establish. The separation between the coarse textured Matahina series and the finer textured Manawahe series is based on such land use differences.

Rotomahana Mud erupted from the sides of Lake Rotomahana during the Tarawera eruption in 1886. The hydrothermally altered ("precooked" by thermal activity) material is quite fertile and supports excellent pastures.

Kaharoa Ash also erupted from Mount Tarawera (about 800 years ago) and it is widespread in central Bay of Plenty, except in southern parts. It consists of ash and white almost non-vesicular lapilli.

The Taupo Pumice Formation, hereafter called Taupo Pumice, represents the products of a series of violent eruptions which occurred shortly after each other in the Taupo area.

Taupo lapilli is the most widespread member of the Formation, and it occurs throughout the Bay of Plenty varying from at least one metre in the south to a few centimetres in the Rangitaiki Plains.

In central and southern areas it overlies Rotongaio Ash, a fine sandy hydrothermally altered mud, varying in thickness from 0.5 to 5 cm. This rests on Hatepe lapilli, a uniformly-graded lapilli (sago-like).

Taupo ignimbrite, formerly called Upper Taupo Pumice, overlies Taupo lapilli in central and southern Bay of Plenty. This material, called flow tephra, was deposited at the latter stages of the Taupo eruptions as a *nuée ardente*, or "glowing avalanche", consisting of an incandescent mixture of ash and pumice moving rapidly like a gas cloud over the landscape. It left thick deposits of pumiceous sand, lapilli and blocks recognisable by poor sorting, compactness and the presence of many charred logs and pieces of charcoal. The lower part of the flow tephra contains much rhyolite, and it was formerly regarded as a separate layer called Rhyolite Block Member. Flow tephra is widespread and thick in large areas of Kāingaroa Forest south of its headquarters, and generally very thinly overlies rolling and hill country in southern Bay of Plenty.

The Waimihia Formation occurs in the subsoil of most soils in central and southern Bay of Plenty. Ash forms the upper part, and lapilli form the lower part. It is about 20 cm thick near Murupara, thickening to 100 to 200 cm in the south of the Bay of Plenty. It is a dark brown to dark yellowish brown greasy gravelly sand to loamy sand overlying yellowish brown to strong brown lapilli.

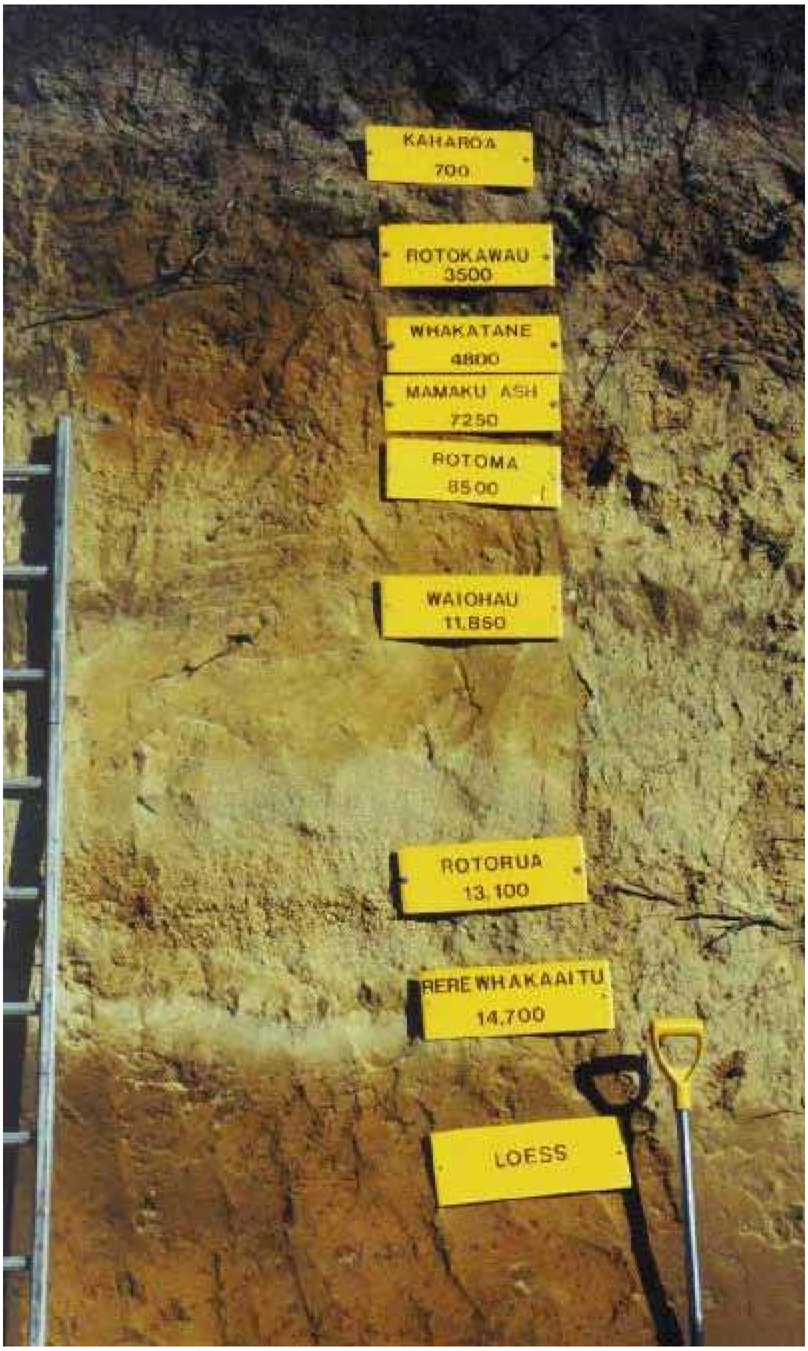

Figure 2.1 Tephra section north of Lake Rotoiti (Note: Numbers are years before present (1950)).

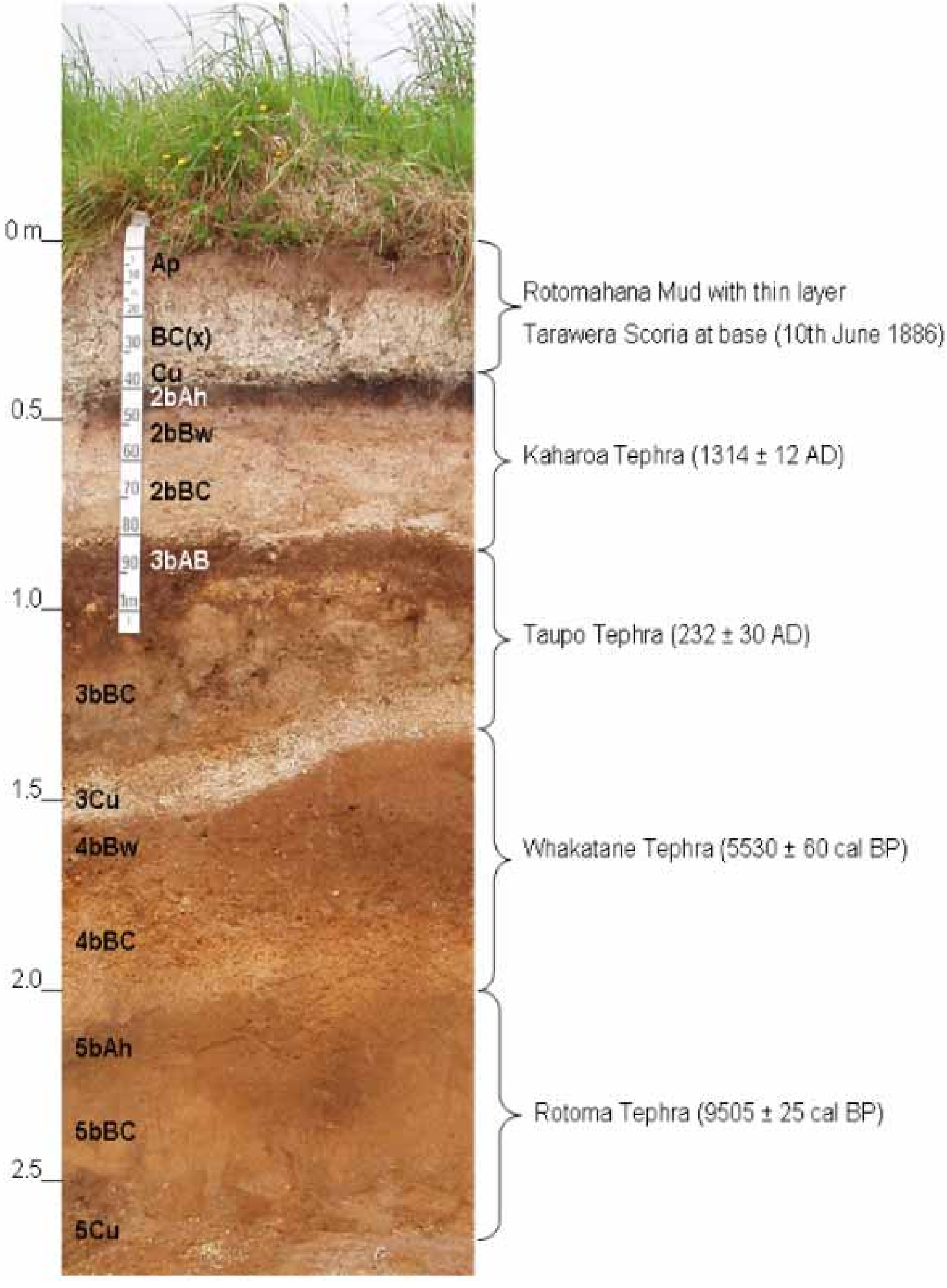

Figure 2.2 Present-day soil (Rotomahana silt loam), buried soil horizons and tephra layers at Brett Road, Rotorua (Source: Lowe 2006)

Whakatane Tephra is 50 to 60 cm thick in most areas and soil-forming in northern and north-eastern parts of Whakatane District where the younger tephra are thinning out. It consists of yellowish-brown to strong brown slightly greasy loamy sand to sand with few pale yellow to yellowish-brown medium lapilli.

Below Whakatane Tephra, various older tephra (and tephric loess) occur consisting of layers of yellowish-brown to pale yellow greasy loamy sand and sand, and layers of pumice lapilli occur with varying thickness. These tephra layers are generally not soil-forming on flat to rolling land, but on hilly and steep land, where the upper tephra have eroded off, they may occur closer to the surface. The tephra are listed in Table 1 with a general description of their occurrence and appearance in the field.

2.2.2 Alluvium and colluvium

Alluvium is widespread in areas such as the Rangitaiki Plains, the Opotiki area and generally on wide flood plains of the main rivers.

Much of the alluvium consists of rounded or sub-rounded pumice re-deposited from erosion products off hills. River alluvium frequently contains large amounts of material derived from sedimentary rocks. On the Rangitaiki Plains, much of the alluvium has been derived from Kaharoa Tephra and it often appears as a fine sandy or silty material (buff layer). It forms a compact layer of about 20 cm restricting root development and natural drainage. It overlies very thin to thin airfall Kaharoa Tephra. Alluvium in the Opotiki area is derived from tephra and greywacke, and near Cape Runaway, the alluvium is derived from greywacke and tephra with some mudstone and siltstone.

Colluvium is the product of erosion from hills accumulated on fans and valley floors. It is extensive in the eastern part of the Galatea Basin and on small fans throughout the Bay of Plenty. In the field it consists of much rounded and semi-rounded lapilli, and it looks often very similar to alluvium except that it tends to be coarser, e.g. contains more lapilli.

2.2.3 Organic materials

Peat occurs in many areas of the Rangitaiki Plains, on the Te Puke flats, and in the Opotiki area where it may occur in thick or thin layers alternating with pumice alluvium and/or airfall tephra. In some small areas, thin to very thin layers of diatomaceous earth occur in the subsoil.

2.2.4 Wind-blown sand

Wind-blown sand occurs in a belt along the coast and in local areas further inland. The dunes along the Rangitaiki Plains coast are covered or mixed with Tarawera Ash and Kaharoa Tephra. The tephra cover on the dunes further inland also includes Taupo Pumice and Whakatane Tephra.

2.3 Topography

Topography influences soil formation by modifying the climatic factor. By controlling the amount of runoff, topography influences the effectiveness of rainfall and the degree to which erosion removes the soil being formed. Similarly, the effectiveness of solar radiation varies with topography since the direction and steepness of slope determine the angle of incidence of the sun's rays. For example, in hill country, north-facing slopes generally receive more seasonal sunlight than south-facing slopes.

Low-lying areas that receive runoff retain most of the water from rainfall and are usually significantly wetter than neighbouring slopes. Variation in soil moisture regimes induced by differences in topographic positions is often the main reason for variation in soil properties over a landscape receiving a similar amount of rainfall per year. The effect of topography on the soil pattern at sub-regional level is discussed in the section on soil landscapes.

2.4 Vegetation

Evidence of pre-historic and pre-European vegetation is inferred from remnant forest pockets and buried wood and stumps. Vegetation patterns are closely related to the other soil-forming factors and soil type.

Dune lands are thought to have supported a forest of podocarp and kauri on the inland dunes and a mixture of pohutukawa and manuka on more coastal dunes. Well-drained terrace-like surfaces near the coast supported a mixed forest (rimu, tawa, kohekohe, kamahi and an occasional red beech or totara). Low-lying swampy areas supported kahikatea and pukatea swamp forest. Further inland, extensive podocarp forest (rata/tawa-rewarewa-mangeao-kamahi) changed to rimu-rata/tawa-kamahi forest where elevation and rainfall increased, such as on the Mamaku Plateau.

Today, much of the Bay of Plenty is sown into pasture or planted into subtropical fruit orchards along the coast, and pine forests further inland. Much of the indigenous forests remain, or are partly cut-over and allowed to re-grow, in the steep country of Eastern Bay of Plenty, and in the Urewera and Kaimai forests.

2.5 Time

Soil-forming factors and processes need time to produce soils. Relatively recently eroded steep slopes, and recent soils derived from alluvium or wind-blown sand, display a limited development of the subsoils. The soils tend to have low clay content, and sand particles dominate the soil matrix because of the limited time of weathering. Soil structures tend to be weakly developed and low levels of organic matter occur. On the other hand, soils derived from older parent materials such as tephra are more weathered, have greater clay content and deeper subsoil development compared with younger soils. Deposition of fresh sediments still continues today from erosion-deposition cycles on hilly slopes and along the main rivers and streams.

Although estimates of the rate of soil formation vary globally from 0.01 to 7.7 mm per year with an average of 0.1 mm per year, it is generally agreed that soil formation is a slow process (Morgan 1995). For example, most allophanic soils have taken between 10,000 and 20,000 years to form, and are clearly irreplaceable (Lowe and Palmer 2005). Thus, the importance of conserving topsoils cannot be overemphasised.

Part 3: Soil landscapes

A soil landscape is a simplified representation of a sequence or pattern of soils in a landscape with respect to landforms or topographic positions. The soil landscapes are portrayed in two-dimensional (by distance and elevation) idealised cross sections of parts of the Bay of Plenty. They are more appropriately called schematic cross sections because in reality one or two soils may be missing in a given area and other soils may be more extensive. This publication uses the concept of soil series which may or may not contain two or more soil types. The schematic cross sections show selected soil types as they occur in soil landscapes. In the examples that follow, soils occurring within a soil landscape will vary from place to place with respect to slope, depth, texture, drainage, and other characteristics (e.g. depth of tephra layers). These differences in characteristics are important because they affect land use and soil management.

Figure 3.1 shows a west-east section across Lake Rotorua. The western part is the Mamaku Plateau on which Podzols (Mamaku, Ngongotaha and Arahiwi series) have developed. The landscape is marked by distinctive tors, which are erosional remnants of the ignimbrite sheet that forms the plateau. Oturoa series occur at lower elevations. These are Well-drained, deep soils used for pasture and horticulture. Small areas of lake deposits occur around Lake Rotorua (Waiowhiro series). East of Lake Rotorua, soils are influenced by deposits of Rotomahana Mud which thickens towards the east. Te Ngae series and Rotoiti series are used for pasture, forestry and cropping. Rotomahana series are primarily used for dairying.

Figure 3.2 is a west-east section near Kawerau. It shows the correlation of soils with Tarawera Tephra in the upper layers. Soils with more than 20 cm Tarawera Tephra are Tarawera series, those with less than 20 cm coarse Tarawera Tephra are Matahina series and those with less than 20 cm fine Tarawera Tephra are Manawahe series. If soils have less than 7 cm Tarawera Tephra, which is difficult to see especially if ploughed, then they are mapped as Whakatane series.

Figure 3.3 shows a sequence of soils derived from Kaharoa Tephra. More than 30 cm of Kaharoa Tephra occurs in Pekepeke, Te Rere and Galatea series. At higher elevations, Ruakituri and Matawai series have less than 30 cm Kaharoa Tephra and are podzolised.

Figure 3.4 shows the soil landscape across the Upper Rangitaiki plains near the Taupo-Napier State Highway. Rangitaiki series derived from Taupo Ignimbrite (formerly called Upper Taupo Pumice) are coarse pumiceous soils with a compact subsoil that forms a root barrier unless ripped. Around the Rangitaiki River, soils are formed from fine (Poronui series) or coarse (Otamatea series) water-sorted pumice. Droughts are common on these soils. Podzols derived from Taupo Pumice occur on higher elevations under high rainfall towards the south (Tihoi series).

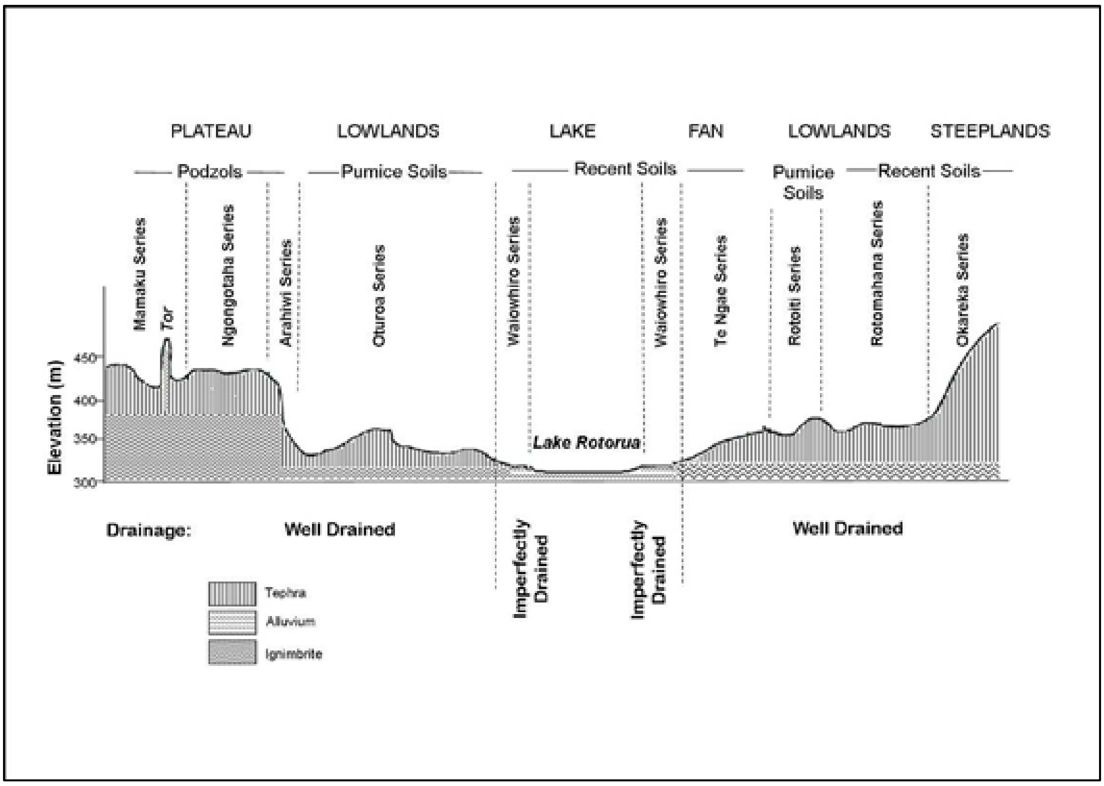

Figure 3.1 Schematic cross section of the soils of the Rotorua Lakes area (Note: Diagram not drawn to scale)

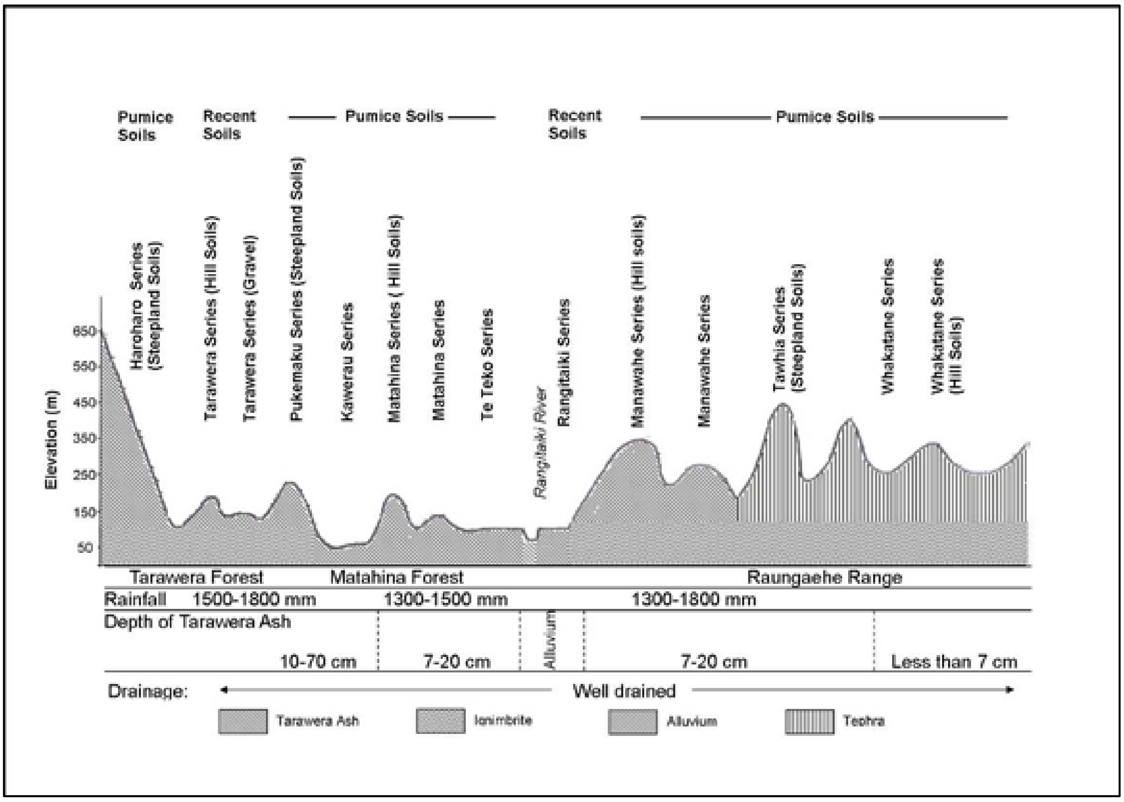

Figure 3.2 Schematic cross section of the soils of Whakatane District (Note: Diagram not drawn to scale)

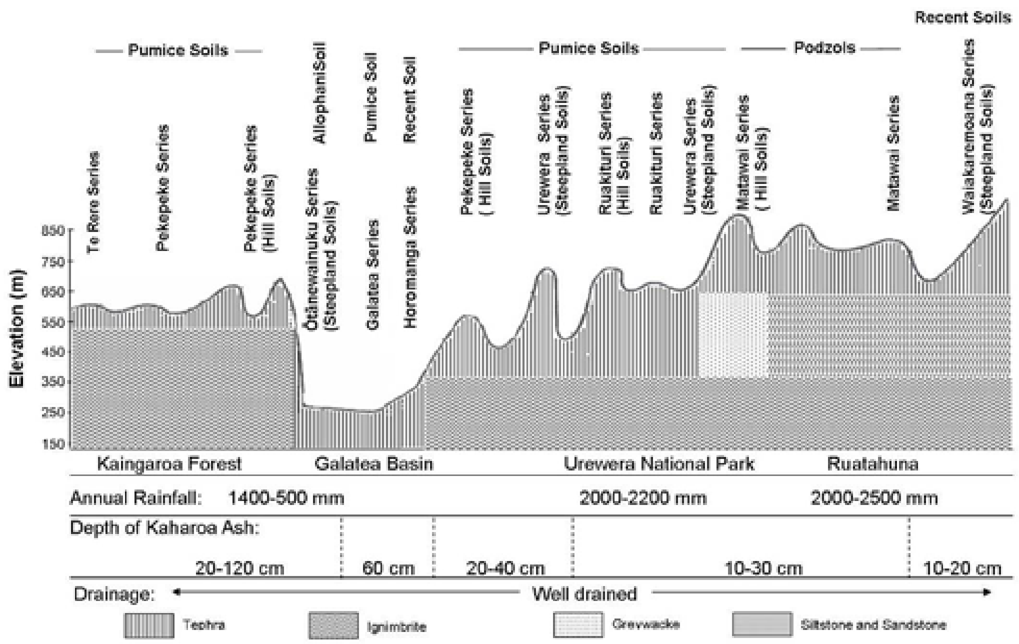

Figure 3.3 *Schematic cross section of the soils of southern Whakatane (Note: Diagram not drawn to scale)*

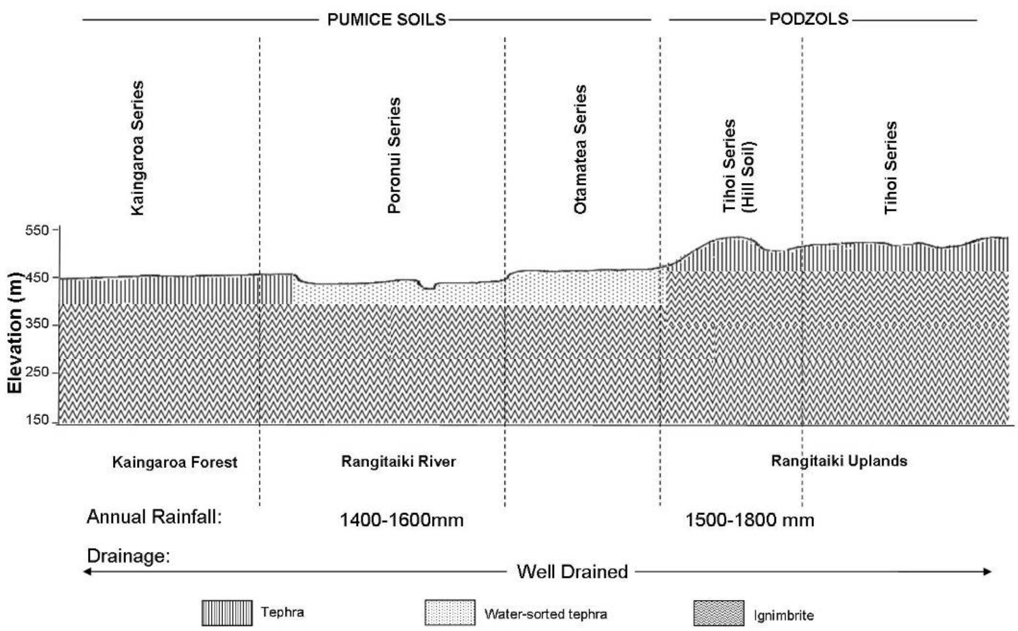

Figure 3.4 *Schematic cross section of the soils of southern Bay of Plenty (Note: Diagram not drawn to scale).*

Part 4: Soil classification

The soils of the Bay of Plenty are discussed according to the New Zealand Soil Classification (Hewitt 1998a; 1998b). The classification has three categories of descending order: Order – Group – Subgroup. The series name can be regarded as a fourth level category in this classification. For example, Waitekauri series are Typic (subgroup) Orthic (group) Allophanic Soils (Order). In this publication, a classification to subgroup level is included in the overview. There are 15 soil orders in the New Zealand Soil Classification System. In the Bay of Plenty, nine soil orders are present (See Figure 1.1). These include: Allophanic Soils, Anthropic (or Man-made) Soils, Brown Soils, Gley Soils, Organic Soils, Podzols, Pumice Soils, Raw Soils and Recent Soils.

4.1 Soil orders in the Bay of Plenty

4.1.1 Allophanic soils

Allophanic soils have properties that are strongly influenced by clay minerals that are poorly crystallised or amorphous (allophane, imogolite, ferrihydrite). They have weak soil strength and are sensitive with low bulk density. The soils are formed from layers of volcanic ash that are visible near the source (Rotorua area) and telescope together further away (East Coast area). They were called yellow-brown loams in previous soil classifications.

The soils typically have dark yellowish-brown grading to yellowish-brown sandy loam to silt loam subsoils with high levels of phosphate-fixing allophane in the clay fraction. Topsoils tend to be 18 cm or more deep with weakly developed structure and black to dark brown colours. The soils have a typically greasy feel when moistened and rubbed firmly between the fingers.

Allophanic soils are generally moderately to strongly leached with low levels of exchangeable calcium, potassium, magnesium and sodium. Reserves of magnesium and potassium are low to very low. Available phosphorus is naturally low with high phosphate retention.

Allophanic soils are friable to a great depth and do not have root-restricting layers. Along coastal Bay of Plenty, these are ideal soils for deep-rooting subtropical plants such as kiwifruit, provided they are sheltered from salt-laden winds. Other uses are pasture (dairying, dry stock), or forestry on steeper slopes. Cropping, such as maize, needs careful management to preserve topsoil structure.

4.1.2 Anthropic soils

Anthropic soils or man-made soils are soils that have been altered by humans, including truncation of natural soils by earth-moving equipment, drastic mixing of natural soils so that their original character is lost, or by deposition of thick layers of organic or inorganic material.

Variation of areas thus affected is great and, in the Bay of Plenty, the worst cases are indicated on the soil maps but are not further described. Many soils were truncated in the 1980s in the kiwifruit growing areas, but such soils have not been mapped separately.

4.1.3 Brown soils

Brown soils have secondary iron oxides evenly dispersed through the soil and give a yellowish-brown colour to the upper part of the subsoil. Base saturation values are usually moderate to very low. Poorly-drained soils are excluded from the order. Summer dryness and winter logging are uncommon.

Most of the brown soils occur in Eastern Bay of Plenty, where they support pasture (dry stock, dairying), forestry and cropping (maize). There are small areas in Western Bay of Plenty on steep slopes largely in indigenous forest.

4.1.4 Gley soils

Gley soils are poorly or very poorly-drained in their natural state. Saturation occurs during prolonged periods, oxygen becomes limited, and reducing conditions occur. They were called gley soils or gleyed soils in previous soil classifications. Gley soils are essentially older wet mineral soils derived from a variety of parent materials including alluvium, colluvium and wind-blown coastal sands. They occur in valley floors, on the upper part of coastal terraces and coastal and river back swamps or former back swamps.

The soils have greyish-looking horizons, which have a lower boundary 90 cm or more from the mineral soil surface. It has low chroma (greyish) colours that occupy 50% or more of the matrix. Yellowish-brown or more reddish mottles are common. Dairying and dry stock are the main uses of gley soils. Maize is grown successfully on many gley soils.

4.1.5 Organic soils

Organic soils have horizons that consist of organic material that, within 60 cm of the soil surface, has 30 cm or more peat accumulated in wet conditions. The soils were also called organic soils in previous soil classifications.

The soils occur in low-lying depressions or former back swamps and valley floors. They are poorly-drained with fluctuating water tables. High water tables reduce the rooting depth to about 20 cm in some areas. Many areas are drained with deep open drains resulting in some shrinkage of the peat. Land use includes dairying and dry stock, but pugging can be a problem during wet winters.

4.1.6 Podzols

Podzols are strongly leached acid soils. They have a horizon of accumulation of aluminium occurring as complexes with organic matter and/or as short range minerals (typically as allophane/imogolite). The soils occur under high rainfall (generally exceeding 1,800 to 2,000 mm annually), mostly at higher elevations (exceeding 600 m), and they are usually associated with forest species which produce an acid litter, such as rimu and beech. Podzols are strongly leached and have low natural nutrient levels. The soils were called podzols or podzolised in previous soil classifications.

In the Bay of Plenty they are used for dry stock grazing and some dairying, forestry, and some cropping on the Mamaku Plateau. Large areas, such as the Urewera Range, are in indigenous forest.

4.1.7 Pumice soils

Pumice soils are soils that are dominated by pumice or pumice sand high in volcanic glass. They have low clay contents and the clay fraction typically contains allophane. They were called yellow-brown pumice soils in previous soil classifications. Pumice soils occur in sandy or pumiceous tephra ranging from 700 to 3,500 years in age.

Clay contents are generally less than 10% and soil strength is weak or very weak. The soils are resistant to pugging and, like the Allophanic soils, have low to very low nutrient levels. The potential for erosion by water is high, especially when the surface vegetation and thin topsoil are removed. Summer droughts occur.

Pumice soils occur throughout Central Bay of Plenty in areas such as Rotorua, Kawerau and parts of the Rangitaiki Plains. Land use includes dry stock farming, dairying, forestry and fodder cropping.

4.1.8 Raw soils

Raw soils lack distinctive topsoil development. They occur in environments where the development of topsoils is prevented by rockiness, active erosion, thermal activity, or deposition. They include beach sands or gravels.

The soils are mostly of medium fertility. They are well-drained with low water-holding capacity, and dry bulk densities above 1.4 tonnes per cubic metre. Main restrictions are frequent flooding, excessive drainage and extreme salinity. The soils are used for dry stock grazing or recreation.

4.1.9 Recent soils

Recent soils show only incipient marks of soil-forming processes because of youthfulness, truncation of an older solum (the combined surface and subsurface horizons) or, less commonly, because the soil material is resistant to alteration. Soil formation has been sufficient to develop distinct topsoils. The concept of the order relates to weak soil development rather than the length of time of soil formation.

The main properties include weak soil development, generally high base saturation, gravel or rock not strongly altered, high potential rooting depth, good drainage, low phosphate retention, high fertility, and susceptibility to erosion and/or sedimentation.

Fluvial recent soils occur on slightly elevated river terraces. These are among the most versatile soils in the Bay of Plenty and land use includes dairying, dry stock and cropping (maize, fodder crops).

Recent soils also occur on hilly or steep slopes where surfaces are renewed after erosion. Land use on such slopes is mostly dry stock or forestry, the latter restricted because of shallow profiles overlying parent rock. Many areas are in indigenous forest.

4.2 Soil horizons

Soil horizon designations are used to indicate certain properties associated with a horizon. For example a topsoil is an A horizon. If that horizon has been ploughed or worked in any way, it becomes an Ap (p=plough) horizon. The following symbols have been used in the text:

A horizon	topsoil
Ap horizon	ploughed topsoil
Ah horizon	non-ploughed horizon
E horizon	bleached horizon immediately below the topsoil, occurs in podzols
Bw horizon	weathered horizon below the A horizon
Bh horizon	subsoil horizon with accumulation of organic matter and often iron and aluminium; occurs in podzols
Bg	gleyed or mottled (wet) horizon below the topsoil
C horizon	unconsolidated or weakly-consolidated mineral horizon that is little affected by soil-forming processes

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Part 5: Key soil management considerations

In this section, important management considerations for Bay of Plenty soils are discussed and generic soil management recommendations provided. Greater emphasis is given to managing the physical properties of soils for crop/animal production and environmental protection since they are more difficult to manipulate or change compared with chemical properties (e.g. nitrogen deficiency, high phosphate retention, acidity) which can be easily corrected by the application of fertilisers, lime, and other soil amendments. For plant growth an ideal soil has, as a rule of thumb, 50% solids, 25% water and 25% air by volume. From a physical standpoint soil management is about knowing one's soil and employing practices that optimise the relative proportions of air and water in the soil's pore spaces. The reader should consult more detailed soil management recommendations available in several excellent publications (e.g. Cornforth 1998; Shepherd 2009; Fertresearch nutrient management booklets: http://www.fertresearch.org.nz/resource-centre/booklets).

5.1 Soil water retention and availability

The retention and availability of water in the soil for plant use is largely determined by soil texture through its influence on the amount and size distribution of soil pores that retain water. Two useful measures of available water-holding capacity are **profile total available water** and **profile readily available water**. **Profile total available water** is the volume of water retained in the soil between field capacity and wilting point expressed as a depth (mm water per 100 cm soil depth). Field capacity may be defined as the water content that a soil reaches after it is saturated and allowed to drain until the drainage rate is negligible compared to evapotranspiration. It is considered the upper limit of the available water range (Figure 5.1). **Profile readily available water** is the volume of water expressed as a depth (mm water per 100 cm soil depth) considered extractable by plants with little effort and, consequently, little limitation to growth. It is the difference between soil field capacity and its water content when plant growth is inhibited by lack of soil water.

Available water-holding capacity is important for two reasons. First, it is a measure of the ability of the soil to sustain good growth and high yields of crops and pastures. Second, it is a measure of the capacity of the soil to store water via rainfall and irrigation (including effluent irrigation). The higher the available water-holding capacity, the more suitable the soil for any type of irrigation.

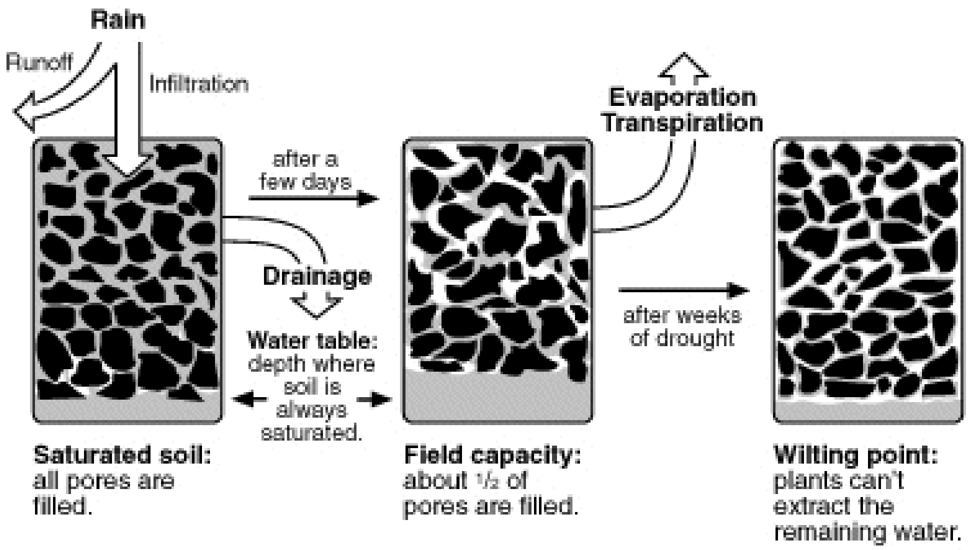


Figure 5.1 Soil water retention and depletion process illustrating the concepts of saturation, field capacity and wilting point. Available water-holding capacity is the amount of water retained between field capacity and wilting point (Source: University of Minnesota 2000).

Organic matter indirectly affects the water-holding capacity of soils by influencing soil structure and pore spaces. Organic matter stabilises soil structure and increases the volume and size of soil pores resulting in increase in water infiltration and water retention. Given the sandy nature of many soils of the Bay of Plenty, the importance of adding and/or retaining organic matter should be part of a sound soil management programme.

5.2 Soil aeration and drainage

Soil aeration reflects the ability of soil to allow exchange of air (particularly oxygen and carbon dioxide gases) between the atmosphere and plant roots. It represents the coarser pores in a soil, which provide the space into which plant roots grow and drain water from saturation to field capacity under the force of gravity. A soil is saturated when the total pore space is filled with water and the level of oxygen in the soil falls. Roots of most dryland plant species obtain oxygen used in aerobic respiration from surrounding pore space. This enables them to selectively absorb nutrients from the soil solution. When soil oxygen concentrations become limiting at saturation, the uptake by plants of major nutrients is inhibited, but manganese, iron and sodium may accumulate to toxic concentrations (Trought 1981). In waterlogged soil in winter time, plant growth may not be a great deal affected because oxygen requirements at that time of the year are small. Poor aeration and high moisture content also directly affect the occurrence and severity of some plant diseases, particularly in horticultural crops, e.g. phytopthora root rot (Cotching 1998).

Soil drainage refers to how much, and how quickly, water is removed from the soil. It also refers to the frequency and duration of periods when the soil is not wet. Drainage depends on three major factors: (1) input into the soil from rainfall, irrigation, seepage and runoff; (2) the flow of water through the soil (permeability); and (3) outlet from the soil or field drains to the collector drains, and from there to the sea (Griffiths 2004). Drainage is important because it affects both the oxygen supply and the temperature of the environment where plant roots and microorganisms thrive. Thus, wet soils will require some form of drainage if they are to be used productively for agriculture, since roots of non-aquatic plants do not normally survive and grow in saturated or waterlogged soils due to the lack of oxygen. Plant growth on partially drained soils will be slow because wetter soils take longer to warm up so that growth does not start until later in the spring. Kiwifruit plants, for example, do not tolerate poor soil drainage. Animals grazing on wet land can compact the soil as they leave deep hoof marks that collect rainfall. Farm machinery may become bogged in wet paddocks and also compact the soil.

Most soil series of the Bay of Plenty have no or few problems with soil drainage as the soils are naturally well-drained. Exceptions include naturally poorly-drained gley and organic soils, which are generally located in coastal areas (Figure 5.2). The soil series descriptions, which form the main part of this publication, indicate whether drainage is a problem by listing the natural drainage class. In most areas in the Bay of Plenty open drains are used, because sandy or loamy subsoils are not suitable for mole drainage.

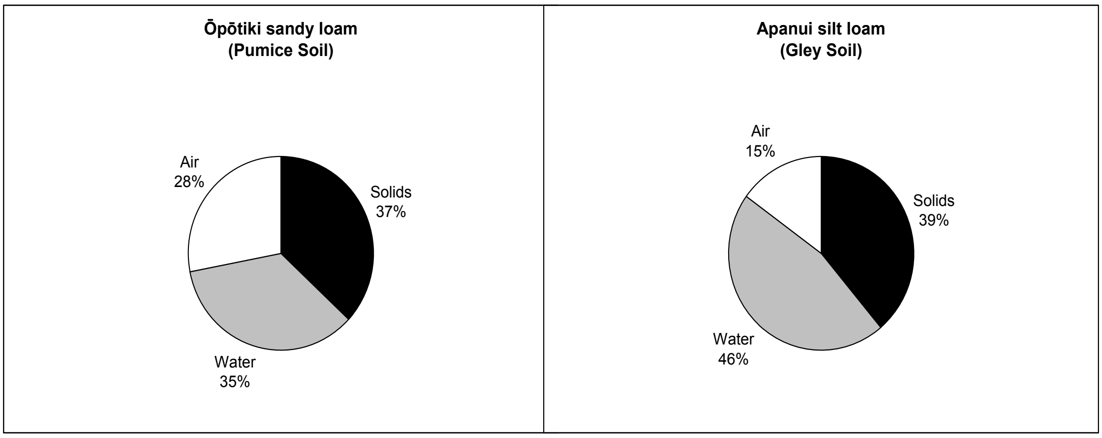


Figure 5.2 Volume composition of a well-drained soil (Ōpōtiki sandy loam) and a poorly-drained soil (Apanui silt loam). Both soil types have almost equal pore space, but the volume occupied by air is much less in the poorly-drained soil because its pore space is largely occupied by water.

5.3 Irrigation

Despite the Bay of Plenty's favourable annual rainfall for pasture and crop production, farmers are increasingly relying on irrigation to boost their productivity or avoid drought risks during the summer months. In particular, irrigation in kiwifruit has become increasingly common as more drought-prone soils are being used for this crop. Irrigation of effluent to soils is also becoming a common practice in dairy farms as a preferred method for treating effluent and for supplying water and nutrients to pasture.

Combined with climate information, knowledge of the water-holding capacity of soils is important (Section 5.1) to determine the correct amount and frequency of water application. Over-irrigation wastes water and energy and increases labour cost. It can also hasten the leaching of applied nutrients below the root zone (leading to contamination of water bodies), impede drainage, and reduce crop/pasture yields. On the other hand, under-irrigation stresses the plant and causes yield reductions. To avoid water stress, irrigation will need to be added to a level close to field capacity when half of the available water has been used by the plant. This is commonly known as the "refill point" or "trigger point".

To avoid under- and over-irrigation, it is important to properly monitor soil moisture in the farm. Tensiometers, gypsum blocks, neutron probes, time domain reflectometry (TDR) and frequency domain reflectometry (FDR) sensors are the main instruments that can be used for monitoring soil moisture.

As water is becoming an expensive commodity nationwide, farmers should also investigate the use of precision irrigation technology (e.g. variable rate irrigation) which uses global positioning system (GPS) satellite guidance technology to take into account differences in soil and/or crop types that can be designated as separate management zones. Water (or fertiliser) application is tailored for each soil type (i.e. wetter soils receive less water than drier ones; fertile areas receive less fertiliser than infertile ones). Benefits include: savings in water, lower fuel consumption, application rates that are tailored for different soil and/or crop types, more efficient water/nutrient application, reduced nutrient runoff and leaching, less track maintenance, and evening out of inaccuracies in water distribution created where sprinkler nozzles are unable to apply the correct amount of water.

5.4 Leaching

Leaching is the process of removal of soluble materials (nutrients, metals and pesticides) in solution by water draining through the soil. The leaching potential of a soil depends on its texture, infiltration capacity, permeability, water-holding capacity, existing soil moisture content (representing a balance between rainfall or irrigation and the amount used by plants through evapotranspiration), concentration of soluble materials, and cation and anion exchange capacity. In addition, the movement of water down the soil profile can be non-uniform due to water flowing preferentially and more rapidly in cracks and other channels like worm holes, root holes, etc. (Figure 5.3). Such enhanced downward flow can carry a range of contaminants including nutrients, pesticides, trace metals, and pathogens in animal manure. Excessive leaching is detrimental since it leads to the loss of applied plant nutrients (e.g. nitrate-nitrogen and sulphate) resulting in greater fertiliser requirements/costs; water contamination when the leached nutrients and other unwanted substances reach the groundwater and eventually streams, rivers and lakes; and long-term acidification of soils due to the removal of basic cations like potassium, calcium and magnesium (Cornforth 1998). Strongly leached soils may occur anywhere, but are most common under high annual rainfall at higher elevations, as in the case of podzols.

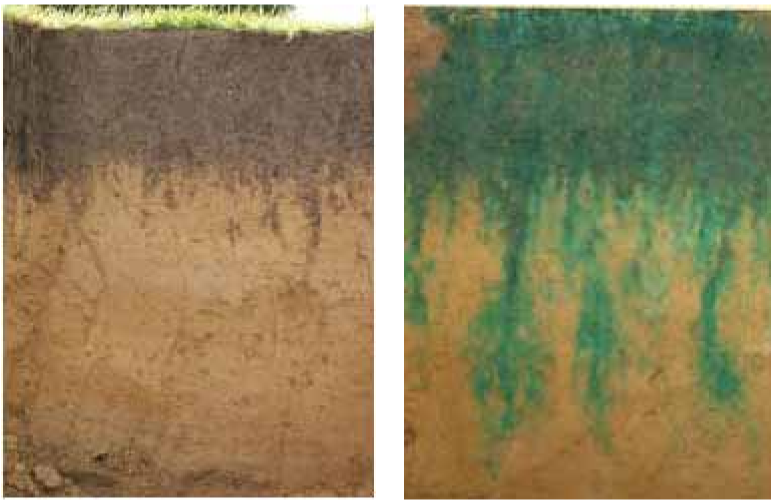


Figure 5.3 Applying water containing a blue dye stain to soil reveals uneven wetting of the soil profile due to water preferentially flowing in cracks and other channels. Nutrients carried by water, like nitrate, can potentially leach below the plant root zone and contaminate groundwater. (Photos from Carrick 2007)

Nutrient leaching is very relevant to the Bay of Plenty because many of the soils have sandy textures. Nutrients in sandy soils with low organic matter content are easily leached because the soils are freely draining and have low nutrient retention capacities. On the other hand, soils containing appreciable clay and organic matter do not leach as much because a greater proportion of inorganic nutrients is adsorbed on the (mostly) negatively-charged exchange complex. Since texture is a basic soil property that is not easily changed, the addition of organic matter to sandy topsoils to increase their nutrient-holding capacity is very important. This applies largely to the nutrient cations potassium, calcium and magnesium which are held on the negative charges of organic matter. Nitrate anions are not held by the negative charges of organic matter, and can therefore still leach.

Leaching losses of nitrate can be reduced by judicious use of nitrogen fertilisers. The proper amount, method and timing of nitrogen fertiliser application are very important. Fertiliser applications should be scheduled to coincide with rapid plant growth to maximise nitrogen uptake. Where possible, applications should be split using smaller doses more often. It is essential to postpone fertiliser application if heavy rain is forecast or if the ground is too wet (near or above field capacity). Fertilisers should not be applied close to wetlands and streams. This will reduce potential for nutrients to be transported off-site during heavy rains. Fertiliser application should be reduced in areas where grazing animals congregate. The soils in these areas often contain sufficient nutrients for plant growth, so fertiliser application is often unnecessary.

5.5 **Erosion**

Accelerated soil erosion significantly affects the productivity and profitability of a farming enterprise both in the short and long term. It is therefore important to understand the processes, erosion types and soil conservation options available to the land manager. In New Zealand three broad categories of soil erosion are recognised, namely: surface erosion, fluvial erosion, and mass movement erosion. The categories are further subdivided into various erosion types (Lynn et al. 2009). Surface erosion involves the movement of a thin layer of soil particles or aggregates on the ground by the action of water, wind or gravity. Fluvial erosion involves the removal of soil material by running water flowing in channels. Mass movement erosion involves movement of soil and/or rock material downslope as a more or less coherent mass under the influence of gravity. Saturation of slope materials by water triggers mass movements.

Deposition, or sedimentation, may be regarded as a fourth erosion category as it is the endpoint of the soil erosion process, and can do as much damage as the removal of soil. Following is a discussion of the different types of erosion that commonly occur in the Bay of Plenty (Figure 5.4).

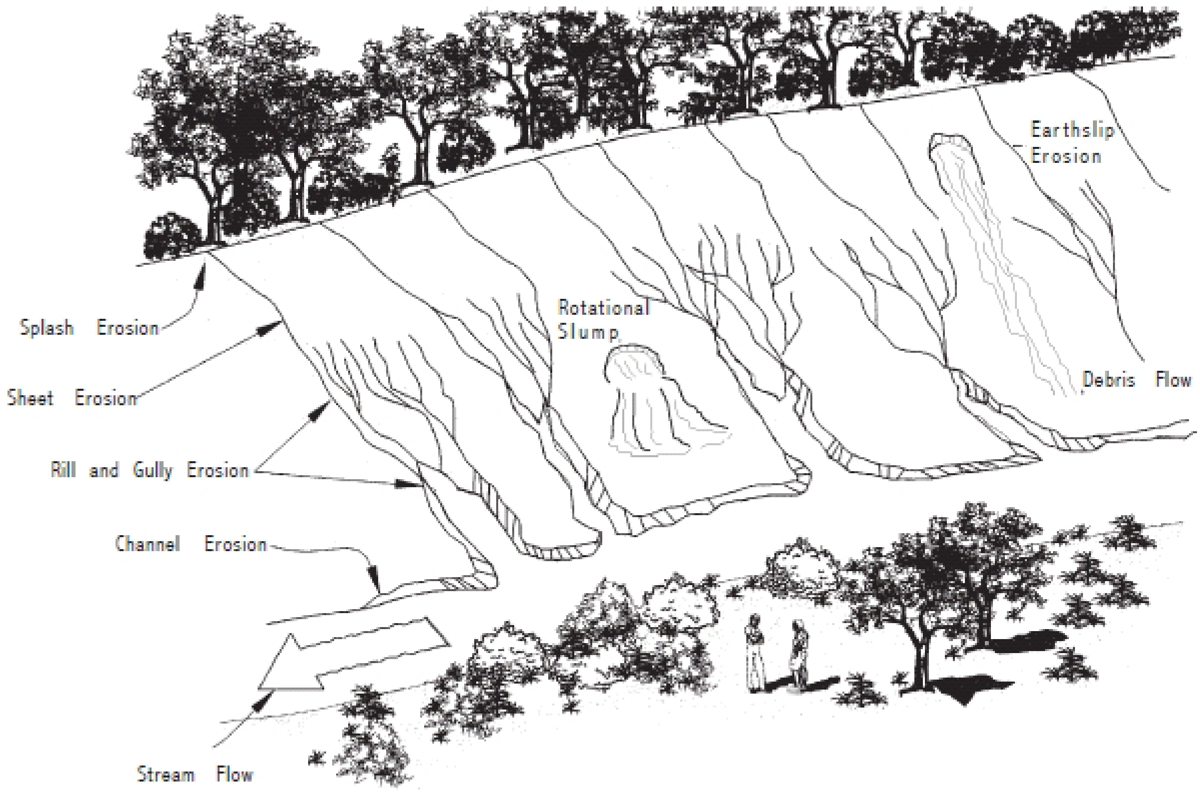


Figure 5.4 Common types of rainfall-induced soil erosion (Source: Auckland Regional Council 1999)

5.5.1 Surface erosion

Sheet (or sheetwash): Erosion in which thin layers of surface material are gradually removed more or less evenly from an extensive area of sloping land. It is caused by a combination of raindrop impact, detachment, and transport of soil particles by surface runoff. It is an insidious form of erosion as it removes topsoil and applied fertiliser.

Scree (or scree creep): The most common erosion type in the Bay of Plenty, whereby slow, gradual, more or less continuous, non-reversible deformation occurs, sustained by soil and rock materials under gravitational stresses. It occurs on many hill slopes and is recognisable by the presence of **terracettes** on slopes. The steeper the slope, the more pronounced the terracettes (see photos of Potikirua and Tawhia steepland soil landscapes in Volume 3).

Wind: Detachment, transport and deposition of loose materials by wind action. It occurs in coastal dune landscapes or along dry riverbeds, and may produce loess; however, loess is rare in the Bay of Plenty. Dry, volcanic ash soils are also very susceptible to this type of erosion. A good practice is avoiding cultivation during dry spells, which results in loss of organic matter.

5.5.2 Fluvial erosion

Rill: The formation of rills by water action. Rills are narrow (less than 30 cm wide) and shallow (less than 60 cm deep) channels that can be removed by tillage operations. However, when neglected, they can slowly develop into gullies.

Gully: The formation of gullies by water action. Gullies are channels which are wide (more than 30 cm) and deep (greater than 60 cm) enough to interfere with, and not be removed by, normal tillage operations. U-shaped gullies are common in the Bay of Plenty because of the relatively soft nature of tephra and alluvial deposits.

Streambank (also called bank or channel erosion): Erosion of soil material from the bank of a stream or watercourse caused by water flowing in stream and river channels, usually during periods of peak flow. Streambank erosion on recent alluvial soils can be very difficult to control as it is a natural process.

Tunnel gully (also known as pipe/shaft erosion, under-runners or tomos): Erosion by percolating water in a layer of subsoil resulting in tunnels or pipes which may collapse, producing gullies. Tunnel gullies may occur in thick subsoil pumice lapilli layers.

5.5.3 Mass movement erosion

Slip: This is a shallow, rapid sliding or flowing movement of soil material downslope, leaving a slip face and debris. The shearing takes place on a well-defined curved surface. It occurs during heavy rainfalls. Most slopes with a steepness of 15˚ can slip.

Slump: This tends to be deeper than a slip and involves downslope movement of large blocks of soil and rock materials. It involves rotational slide movements along curved planes of failure.

Recognising the different soil erosion types is important in planning and implementing appropriate soil conservation and management practices for sustaining agricultural productivity and protecting the environment. Depending on the location and soil type, different erosion types may be present in any given farm, and may require a combination of different soil conservation strategies. In general, preference is always given to biological or vegetative measures over mechanical measures, since they are less expensive and deal directly with reducing raindrop impact, increasing infiltration, reducing runoff volume, and decreasing water and wind velocities (Morgan 1995). Mechanical structures can be costly to install and maintain, and should be viewed as supplementing biological measures to control runoff flows. Surface soils of the Bay of Plenty are generally sandy and are regarded as erodible materials. The importance of maintaining adequate vegetative cover and the addition of organic matter to soils to reduce their susceptibility to erosion cannot be overemphasised.

Table 5.1 provides some general guidelines in combating the different types of erosion. Details of recommended soil conservation practices can be found in the Soil Conservation Technical Handbook published by the Ministry for the Environment (http://www.mfe.govt.nz/publications/land/soil-conservation-handbook-jun01/soil-conserv-handbook-jun01.pdf) and Environment Bay of Plenty's Land Management fact sheets (http://www.envbop.govt.nz/Knowledge-Centre/Land-Management-factsheets.aspx), or by contacting your local land management officer.

5.6 Compaction

An increase in the soil's bulk density or reduction in porosity is referred to as compaction. It is a process of packing the soil particles closer together causing a reduction in the volume of air. Compaction usually eliminates the largest air-filled pores first. Compaction can be caused by cultivation when the soil is wet, animal treading, and farm vehicular traffic. Driving on wet soils breaks down soil aggregates and compacts the soil. Excessive soil compaction restricts soil aeration, reduces plant growth and productivity, impedes drainage, reduces infiltration, and increases runoff generated during intense rains, leading to greater soil erosion losses.

Compaction can be minimised by waiting for the surface soil to dry out before driving on the soil, maintaining good soil structure and drainage, restricting the number of cultivation passes across the paddock, fitting dual wheels to reduce contact pressure and the risk of wheel slip, decreasing tyre pressures to reduce contact pressure, restricting heavy vehicles to the edge of the paddock (Cornforth 1998), practicing zero or minimum tillage, and the use of precision agriculture techniques.

There are few problems with compaction in the Bay of Plenty due to the sandy nature of many of the topsoils. However, compaction may occur in alluvial soils with clay loam topsoils that are used intensively, ploughed often, or when using heavy machinery with rubber tyres. The compaction is broken up by ripping. Compaction by animal treading under very wet soil conditions ("pugging") may also occur in soil types derived from Rotomahana Mud. Careful grazing management such as allowing the soil to dry below field capacity before grazing, limiting the number of hours animals graze on wet paddocks, the use of feed pads, animal shelters, etc. should be considered on such soil types.

Table 5.1 Recommended soil conservation measures for various erosion types. (Adapted from Ngapo 2010)

Erosion type	**Recommended soil conservation measures**
Sheet erosion	• Maintain a good ground cover (vegetation or mulch) to protect soil surface from rain splash erosion. • Add organic matter to soils in the form of crop residues, composts, manures, cover crops, green manure crops, etc. • Practise zero or minimum tillage. • Avoid over-grazing; practice controlled grazing. • Site gates, fences, drinking troughs and other farm infrastructure carefully to avoid heavy concentration of stock on susceptible areas such as steep slopes. • Fence steep areas from flat areas. • Fence to slope aspect to allow for controlled grazing while avoiding over-grazing. • Use appropriate pasture species to suit the soil type. • Consider alternative land uses to grazing (e.g. protection forestry) of very steep slopes.
Wind erosion	• Avoid cultivation during dry spells. • Add organic matter to soils in the form of crop residues, composts, manures, cover crops, green manure crops, etc. • Practice zero or minimum tillage.
Rill erosion	• Stabilise the soil surface by maintaining a good ground cover of vegetation, mulch, and other materials. • Install runoff controls (e.g. graded banks, contour furrows and cut-offs) to reduce the velocity of overland flow. Ensure that runoff controls have a stable outlet. • Employ grass strips when cultivating.
Gully erosion	• Divert runoff away from the gully head. • Control runoff over the gully head using flumes, pipes and drop structures. • Reduce peak runoff rates. • Use a combination of the above methods (the most common method is to use a small detention bund, with adequate storm water detention, and low flow pipes to convey water over or around the gully head). • Employ planting of the gully head (for small gullies only). • Employ planting of stable points at critical locations. • Practise retirement of gullies from grazing in association with runoff control. • Contour ground to "smooth out" small gullies on low terraces (in combination with runoff control and surface vegetation).

Erosion type	Recommended soil conservation measures
Streambank erosion	• Avoid grazing of livestock on streambanks. • Fence and plant streams with careful thought on the type and location of fences and what planting should be done (grass buffers and native species are preferred).
Tunnel gully erosion	• Plant a willow pole in the tunnel hole. • Collapse in with a shovel or digger to remove the risk of lamb or sheep losses. • Bulldoze in or fill the hole with coarse material to filter out any fines. • Fence the tunnel gully to ensure stock do not fall in.
Slips and slumps	• Plant soil-conserving trees (e.g. poplars; willows; native trees like manuka, kanuka).

Part 6: Guide to the soil series descriptions

The soils are listed alphabetically according to soil series. The following is a guide to understanding the soil information contained in the soil series descriptions. Soil-related terms are also described in the Glossary.

6.1 Soil series name

This is the name of the soil series and its corresponding soil map symbol or code. A soil series is a group of soils that have similar profile characteristics except for differences in texture of the surface layer. Traditionally, a soil series is named after the place where the soil was first observed and described (e.g. Matahina series).

6.2 Overview

The overview provides general information on the occurrence and distribution of the soil series, parent materials, physiographic position and slope, colour, profile texture, soil classification (up to subgroup level), vegetation, and/or land use. Where relevant, occurrence of soils under varying rainfall amount is also mentioned (e.g. in the case of Podzols).

It should be noted that soils are rarely homogenous. This is particularly the case with steepland soils which have highly variable characteristics. Thus, if a steepland soil is classified as an allophanic soil, this is a generalisation. In reality, the soil is predominantly allophanic but, when it occurs on steep, eroded slopes, it can also be classified as a recent soil.

6.3 Physical properties

Texture: Texture is the relative proportions of the primary particles in the soil, namely sand (2.00-0.06 mm), silt (0.06-0.002 mm) and clay (<0.002 mm). Particles with diameters less than 2 mm are referred to as the fine earth fraction, while those with diameters greater than 2 mm are called coarse fragments. Sand particles feel gritty, and are large enough to be seen by the naked eye. Silt particles are smaller, and feel smooth, like flour. Clays are much smaller, feel sticky, and can be formed into ribbons and wires when wet. Clay particles are flat, and can be seen only when viewed under a high-powered microscope. Because sand and silt are relatively large, they possess only a small surface area and contribute little to the chemical behaviour of the soil. In contrast, clays are very small, possess a large surface area, carry electrical charges, and are much more chemically active than sand and silt.

Every soil contains a mixture of sand, silt and clay, and this is expressed as a textural class name such as sandy loam, silt loam, clay, etc. A soil that contains a balanced mixture of sand, silt and clay is called a loam. If rock or stone fragments are present in significant quantity, then a coarse fragment modifier, such as gravelly sandy loam, is used. The soil textural triangle (Figure 6.1) shows all the textural class names that result in various combinations of sand, silt and clay. A more generalised, or simplified, textural triangle is used to group the textural classes into sandy, silty, loamy and clayey.

The texture given here actually refers to the simplified textural groupings. Skeletal soils (those with horizons containing 35% or more gravel by volume) and peats are also included as textural groups. A soil can have two or more contrasting textures with depth and is described as layered (e.g. loam over sand, loam over clay, sand over skeletal). In the Bay of Plenty many soils are formed from volcanic deposits, and the 'gravel' consists of pieces of pumice called lapilli.

Texture is a basic property of the soil that is not easily changed. It affects other soil properties, such as water availability, permeability, drainage, and aeration. It also influences nutrient retention, the development of soil structure, and the ease of soil cultivation. Texture influences the balance between water-filled pores and air-filled pores, creating different soil environments for root growth and the activity of microorganisms. Medium-textured soils, such as loam and silt loam, have a range of pore sizes that allows water to flow through the smaller pores and exchange air in the larger pores. Thus, they provide favourable environments for root growth, store large amounts of water for plant use, and have good nutrient-supplying power. Sandy soils have more large pores and fewer small pores. They have good aeration, but store much less water for plant use, and are considered droughty soils. In heavily-fertilised sandy soils rapid water movement increases the risk of groundwater pollution through leaching of excess nutrients such as nitrate.

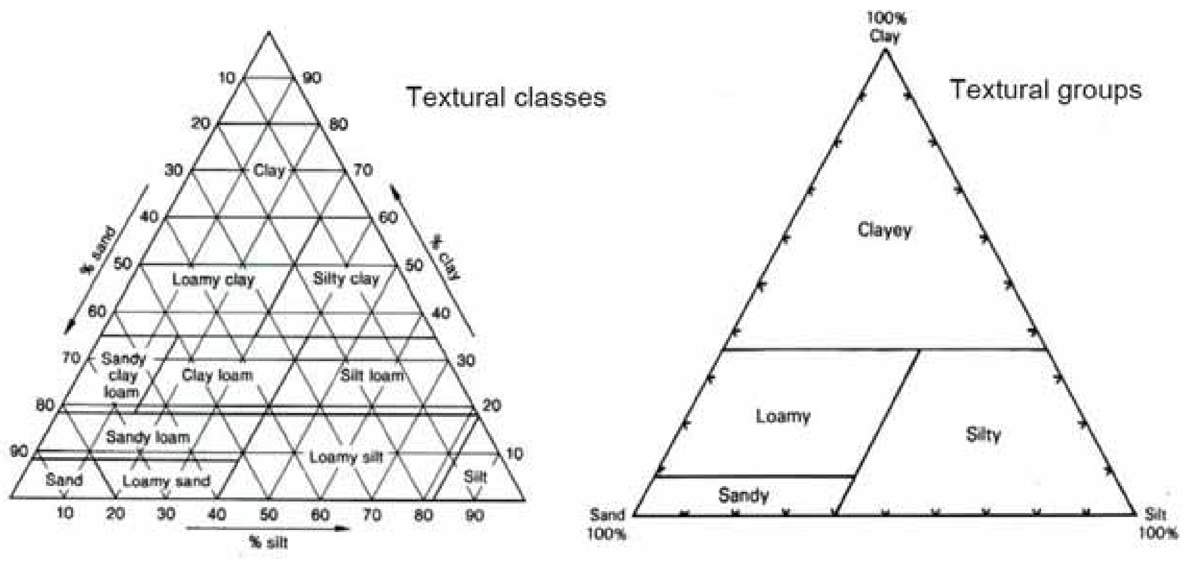


Figure 6.1 Soil textural triangles showing the textural classes (left) and simplified textural groups (right)

Topsoil clay content: This refers to the range of clay content of the topsoil expressed as a percentage. In general, soils of the Bay of Plenty do not contain appreciable amounts of clay. Clay particles are very small with a high surface area per unit weight, giving them a high capacity to adsorb water and other substances. They also carry electrical charges (mostly negative), and so they are the most chemically active part of the soil. Clay is responsible for the swelling and shrinkage of the soil, and makes moist soil sticky. Positively-charged plant nutrient elements (cations), like ammonium, calcium, magnesium and potassium, are adsorbed on the negatively charged surfaces of clays, which helps retain these nutrients in the soil for plant use.

In addition to the amount of clay present in the soil, the type of minerals present also influences soil behaviour. Common clay minerals in Bay of Plenty soils include halloysite or kaolinite, montmorillonite, and allophane. A soil will generally have varying proportions of minerals in the clay fraction. However, the clay fraction of some soils derived from volcanic ash is dominated by allophane – a non-crystalline mineral which imparts good soil structure and high water-holding capacity, but is capable of fixing large amounts of phosphorus (P) rendering it unavailable for plant use.

Potential rooting depth: This refers to the soil depth (in cm) to the top of a barrier (within 1 m of the soil surface) that limits root extension.

Rooting barrier: This is the type of barrier that limits root extension. Root penetration into soil may stop due to a physical barrier (e.g. when it encounters a compacted layer, poor aeration, low moisture content), a chemical barrier (e.g. aluminium toxicity in the subsoil), or a combination of these.

Drainage class: The drainage class indicates how long a soil or part of a soil is saturated with water, and how quickly it can drain excess water. Some soils have mottles, which are spots of grey or brown colour different from the main colour of the soil. Mottles indicate the height of fluctuating water tables. Grey mottles are indicative of waterlogging and reduction of iron compounds in the soil. Drainage of the soil is important so that the pore spaces are able to be filled with oxygen for plant roots to access. Simplified descriptions of soil drainage classes are shown in Table 6.1. A more detailed definition of drainage classes is given in Milne et al. (1995).

Table 6.1 Simplified soil drainage classes

Class	Description
Very poorly-drained	Organic-enriched topsoil (peaty) with grey subsoil
Poorly-drained	Grey layer begins just below the topsoil
Imperfectly drained	Grey layer at 40 – 90 cm depth or mottling within 30 cm of the surface
Moderately well-drained	Grey layer at 60 – 90 cm depth or mottling between 30 and 90 cm
Well-drained	No grey layer or mottling within 80-90 cm depth

Permeability: This is a measure of the rate at which water can flow through the soil. Permeability is dependent on the amount, size, shape and interconnectedness of soil pores which are influenced by soil texture, soil structure, and soil organic matter. Sandy soils have larger pores and more rapid permeability than clayey soils. Good soil structure promotes high permeability by providing stable aggregates consisting of small pores within the aggregates and large pores between them. Organic matter increases permeability through its binding action on soil aggregates. A soil's overall permeability is usually based on the horizon with the slowest permeability class and the depth at which this layer occurs. Permeability is important for ease of drainage, risk of waterlogging, effluent absorption potential, leaching, and water loss. Permeability classes include: slow (less than 4 mm/hr), moderate (4 – 72 mm/hr) and fast (greater than 72 mm/hr).

Profile total available water (0-100 cm): This is the amount of water (in mm) that can be extracted between field capacity (-10 kPa suction) and permanent wilting point (-1500 kPa suction) to a depth of 1 m. Profile total available water is important for droughtiness and overall water availability. Classes are shown in Table 6.2.

Table 6.2 Profile total available water classes

Class	Range (mm)
Low	30 – 60
Low to moderate	60 – 90
Moderate	90 – 120
Moderate to high	120 – 150
High	150 – 250
Very high	250 – 350

Profile readily available water (0-100 cm): This refers to the amount of water (in mm) held in a soil that can be easily extracted by plant roots within the potential rooting depth (i.e. between field capacity (-10 kPa suction) and -100 kPa suction). Classes are shown in Table 6.3.

Topsoil and subsoil bulk density: This is the dry mass of the fine earth fraction (<2 mm) divided by the total soil volume and is expressed in grams per cubic centimetre (g/cm^3), or tonnes per cubic metre (t/m^3). The total or bulk volume consists of the volume of soil solids and the volume of soil pores. Thus, bulk density is a measure of the degree of soil compaction since it includes the volume of pores. Compacting a soil results in a lower volume occupied by pore spaces resulting in higher bulk density. Therefore the higher the bulk density, the lower the porosity, and the slower the drainage.

Table 6.3 Profile readily available water classes

Class	Range (mm)
Very low	<25
Low	25 – 50
Moderate	50 – 75
Moderate to high	75 – 100
High	100 – 150
Very high	150 – 250

Bulk density affects available water content and air capacity of soils and is an indicator of the ease of root penetration. Dry bulk density tends to be higher in soils with higher clay content. Dry bulk densities greater than 1.6 g/cm^3 are likely to be associated with high strength, and may represent an impediment to root penetration. Those lower than 0.4 g/cm^3 are probably associated with material of recent volcanic origin, and are likely to cause engineering problems. Dry bulk densities of less than 0.2 g/cm^3 indicate that considerable shrinkage will occur when these materials are drained, as in the case of peat.

6.4 Chemical properties

Topsoil organic matter: This is the amount of organic matter in the topsoil expressed as a percentage. The typical dark colour of many surface soils is due to organic matter. Organic matter can hold up to 20 times its weight in water, and so improves the water-holding capacity of soils, particularly drought-prone sandy soils. Organic matter cements soil particles into structural units called aggregates, which stabilise soil structure, improve aeration, and increase permeability. Like clay particles, organic matter possesses a high surface area and lots of negative charges. These negative charges attract positively-charged ions (cations), such as calcium, magnesium, potassium, etc., which would otherwise leach in the soil profile. Organic matter is also an important source of plant nutrients. When it decomposes it releases the major plant nutrient elements nitrogen, phosphorus and sulphur. Organic matter exhibits chemical buffering, which helps the soil resist rapid changes in pH. Finally, organic matter plays a crucial role in sequestering carbon from the atmosphere. Because of its many production and environmental benefits, the maintenance of a high level of soil organic matter is essential in any sustainable soil management programme.

Topsoil pretention: Expressed as a percentage, it is a measure of the ability of the soil to remove phosphorus (phosphate) from the soil solution, rendering it unavailable to plants. In acidic soils phosphate is retained by reactive aluminium and iron minerals. In alkaline or calcareous soils phosphate is precipitated as calcium phosphate compounds. In allophanic soils, phosphate is retained by allophanic minerals. High P retention indicates that plants will give a lower response to the same amount of phosphate fertiliser than on a soil with low P retention. This is often the case with allophanic and some pumice soils. Phosphate retention values influence phosphate fertiliser requirements and soil structural stability. P retention classes are shown in Table 6.4.

Table 6.4 Topsoil P retention classes

Class	Range (%)
Very low	<10
Low	10 – 30
Medium	30 – 60
High	60 – 90
Very high	>90

Available P, Ca, Mg and K: This provides a general indication of the levels of available phosphorus, calcium, magnesium and potassium in the soil.

6.5 Soil types/variations

This lists the soil type(s)/variations present within the soil series. The soil type is a subdivision within a soil series to distinguish soils differing in surface texture only (e.g. Taupo sand, Taupo sandy loam, etc.). Phases of soil series which are based on features that affect the use and management of the soil, such as slope, depth, stoniness, etc., are also included. For example, slope steepness is an important factor determining land use, so hill soils (16 – 25 degrees) and/or steepland soils (greater than 25 degrees) are distinguished in some soil series.

6.5.1 Associated and similar soils

This indicates the soils that are geographically associated with the soil series (e.g. soils occurring on similar topographic positions).

6.5.2 General land use suitability ratings

General land use suitability ratings are provided for arable, horticulture, intensive pasture, and forestry land uses. Ratings for each land use include: not suitable, low, moderate, and high. The *management considerations* portion addresses the limitations posed by a particular soil series (e.g. steep slopes, low fertility, etc.).

6.5.3 Management practices to improve suitability

This provides a generic guide to soil management practices to overcome soil limitations and improve suitability of the soil for the various land uses considered.

6.5.4 Soil photos

Soil profile photos of most soil series are included. For other soil series on steep or waterlogged areas, photos of soil landscapes are shown instead.

Part 7: Soils of Central Bay of Plenty

Soil Series Name: Arahiwi (AS)

Overview

Arahiwi soil series occur on steep and very steep uplands, gullies and cliffs of the Mamaku Plateau. The soils are formed from shallow Taupo Tephra on weathered rhyolitic tephra on ignimbrite. Rock outcrops and shallow soils occur. They are mostly covered with rimu-beech forest, cut-over bush or planted in *Pinus radiata*. They are classified as **Typic Orthic Podzols**. Present land use is forestry with few areas in pasture for dry stock grazing.

Physical properties

Texture: Sand over silt loam and sandy loam over ignimbrite

Topsoil clay content: 3 – 7%

Potential rooting depth: Unlimited, except in shallow profiles

Rooting barrier: None, except where ignimbrite occurs within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): High (151 mm), but lower in shallow profiles)

Profile readily available water (0 – 100 cm): Moderate to high (80 mm), but less in shallow soil profiles

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.42 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 15.5%

Topsoil P retention: Medium (42%)

Available P, Ca, Mg and K: Low

Soil types/variations

Arahiwi steepland soils have shallow profiles overlying ignimbrite. Ignimbrite outcrops also occur in highly eroded sites.

Associated and similar soils

Mamaku and Ngongotaha series occur on adjacent rolling and hilly land with thicker tephra overlying ignimbrite.

General land use suitability ratings

Arahiwi steepland soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Steep and very steep slopes, low fertility
Horticulture	Not suitable	Steep and very steep slopes, low fertility, cold climate
Intensive pasture	Low to moderate	Steep and very steep slopes, cool climate, erosion potential, low fertility
Forestry	Moderate	Steep and very steep slopes, cool climate, low fertility

Management practices to improve suitability

- Employ protection forestry on very steep slopes.

Arahiwi steepland soil

Name: Atiamuri (Ai)

Overview

Atiamuri series occur in southern Bay of Plenty on flat to undulating surfaces under relatively low annual rainfall (1200 – 1400 mm).They are derived from Taupo Ignimbrite and developed under shrub-type vegetation and typically have thin (10 to 15 cm) A and Bw horizons. Subsoils are mostly compact below 40 to 60 cm depth with much angular lapilli and blocks. Fragments of carbon occur frequently. The sandy soils have low water-holding capacity and summer droughts are common. Natural soil fertility is low. They are classified as **Welded Immature Pumice Soils**. The soils are used for forestry and grazing dry stock with occasionally fodder cropping. Some areas have been converted from forestry to dairying in recent years.

Physical properties

Texture: Sand

Topsoil clay content: 3 – 8%

Potential rooting depth: 30 – 60 cm

Rooting barrier: Compact pumice

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Low (34 mm)

Profile readily available water (0 – 100 cm): Low (28 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12%

Topsoil P retention: High (62%)

Available P, Ca, Mg and K: Low

Soil types/variations

Atiamuri sandy loam and **Atiamuri loamy sand** soil types occur. Locally, water-sorted pumice overlies the Taupo Ignimbrite. Where these are thicker than 50 cm, **Waipahihi series** have been mapped.

Associated and similar soils

Waipahihi series are derived from water-sorted Taupo Pumice and occur on valley floors (often lapilli-rich, droughty soils). **Whenuaroa series** are derived from water-sorted (lacustrine) pumice (Broadlands area). **Taupo series and Oruanui series** on adjacent rolling and hill country derived from Taupo Pumice. **Kaingaroa series** are also derived from Taupo Ignimbrite but occurring at higher altitude and elevation (Kaingaroa Plateau).

General land use suitability ratings

Atiamuri sand and loamy sand

Land use	Suitability rating	Management considerations
Arable	Low	Droughty soil, weak topsoil structure, low fertility, wind erosion if cultivated during dry spells.
Horticulture	Low to not suitable	Cool climate, droughty soil, weak topsoil structure, compact subsoil, low fertility, wind erosion if cultivated during dry spells.
Intensive pasture	Low to moderate	Summer droughts, low fertility, and low water-holding capacity.
Forestry	Moderate	Droughts affecting young trees, root barrier at 30 to 60 cm, low fertility.

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Plant green crops to increase organic matter and thicken topsoils.
- Forestry: practise ripping, avoid windrowing and damage to topsoils.

Atiamuri sand

Soil Series Name: Awakeri (Aw)

Overview

Awakeri soil series occur on the Rangitaiki Plains around Western Drain Road on flat basins and former stream ridges. They are derived from very thin Tarawera Tephra and Kaharoa Tephra, on very thin peat and alluvium derived from Taupo Tephra. Profiles have black friable sand on very dark brown gravelly sand and pale yellow loose sand. This rests on some 10 cm dark reddish brown peat overlying brown coarse sand. The soils are classified as **Typic Perch-gley Pumice Soils**. Present land use consists of dairying, dry stock and some horticulture (strawberries).

Physical properties

Texture: Sand

Topsoil clay content: 5 – 10%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Imperfectly drained

Permeability: Rapid

Profile total available water (0 – 100 cm): High (151 mm)

Profile readily available water (0 – 100 cm): Moderate to high (78 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 13.8%

Topsoil P retention: Moderate (40%)

Available P, Ca, Mg and K: Low

Soil types/variations

Awakeri sand is the dominant soil type. Some variation in thickness of tephra layers, alluvium and peat occurs.

Associated and similar soils

Te Teko series have coarser textured subsoils while **Pongakawa series** occur on adjacent peaty basins.

General land use suitability ratings

Awakeri sand

Land use	Suitability rating	Management considerations
Arable	Medium	Weakly developed topsoil structure, low fertility, imperfect drainage.
Horticulture	Medium	Weakly developed topsoil structure, low fertility, imperfect drainage.
Intensive pasture	High	Low fertility, imperfect drainage.
Forestry	Not suitable	Imperfect drainage.

Management practices to improve suitability

- Use zero or minimum tillage methods for cropping or market gardening.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Employ artificial drainage (open drains).

Awakeri sand (Note Kaharoa Tephra at 40 to 50 cm depth)

Soil Series Name: Galatea (G)

Overview

Galatea soil series occur in the Galatea Basin on flat to undulating surfaces. Parent materials consist of 60 cm Kaharoa Tephra, on 80 cm Taupo Tephra on Whakatane Tephra. Typically the soils have friable black sandy topsoils overlying brown coarse sand and pale yellow coarse sand. The Taupo buried topsoil is dark yellowish-brown sandy loam which rests on pale yellow fine pumice gravel (Taupo lapilli). The soils are classified as **Immature Orthic Pumice Soil**s. The soils are used for dairying, dry stock and some fodder cropping.

Physical properties

Texture: Sand over loam

Topsoil clay content: 3 – 8%

Potential rooting depth: Unlimited

Rooting barrier: None

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate (102 mm)

Profile readily available water (0 – 100 cm): Moderate (64 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low

Soil types/variations

Galatea sand is the main soil type with very little variation. Small areas have subsoil mottling in shallow depressions.

Associated and similar soils

The soils grade into **Kopuriki series** towards the north of the Galatea Basin where thin Tarawera Tephra overlies the Galatea soil profile. **Horomanga series** occur on gently sloping fans in eastern parts of Galatea Basin. **Rangitaiki series** are alluvial soils along the Rangitaiki River that flows through the Basin.

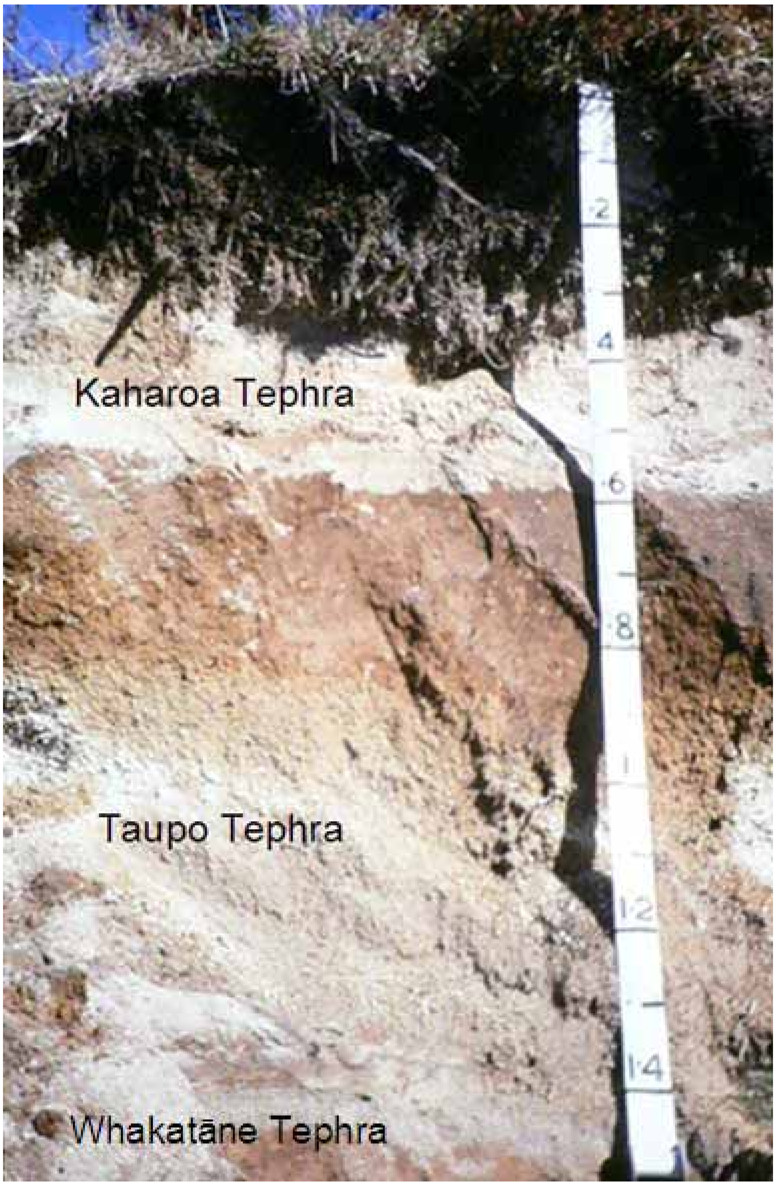
General land use suitability ratings

Galatea sand

Land use	Suitability rating	Management considerations
Arable	Low	Droughty soil, weak topsoil structure; low fertility, wind erosion if cultivated during dry spells.
Horticulture	Low	Cool climate, droughty soil, weak topsoil structure low fertility, wind erosion if cultivated during dry spells.
Intensive pasture	Low to moderate	Summer droughts, low fertility.
Forestry	Moderate to high	Droughts affecting young trees.

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Plant green crops to increase organic matter and thicken topsoils.
- Irrigation is used extensively on Galatea soils.
- Forestry: avoid windrowing and damage to topsoils.



Galatea sand (scale in m)

Soil Series Name: Haparangi (H)

Overview

Haparangi soil series occur south of Rotorua on rolling and hilly land. The soils are derived from shallow Taupo Pumice (less than 50 cm) overlying weathered rhyolitic tephra. Soil profiles show black friable sandy loam topsoils overlying dark yellowish brown sandy loam and loamy sand. They are classified as **Vitric Orthic Allophanic Soils**. Land use consists of dry stock, forestry, dairying and limited fodder cropping.

Physical properties

Texture: Loam

Topsoil clay content: 10 – 18%

Potential rooting depth: Unlimited

Rooting barrier: None

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to high (121 mm)

Profile readily available water (0 – 100 cm): Moderate to high (78 mm)

Topsoil bulk density: 0.78 g/cm^3

Subsoil bulk density: 0.86 g/cm^3

Chemical properties

Topsoil organic matter: 12.9 – 22.4%

Topsoil P retention: High (More than 85%)

Available P, Ca, Mg and K: Low

Soil types/variations

Haparangi sandy loam occurs on flat to rolling land while **Haparangi hill soils** are on hilly slopes. Some areas have thinner Taupo Pumice.

Associated and similar soils

Pohaturoa steepland soils are on steep and vary steep slopes with shallower tephra overlying ignimbrite.

General land use suitability ratings

Haparangi sandy loam

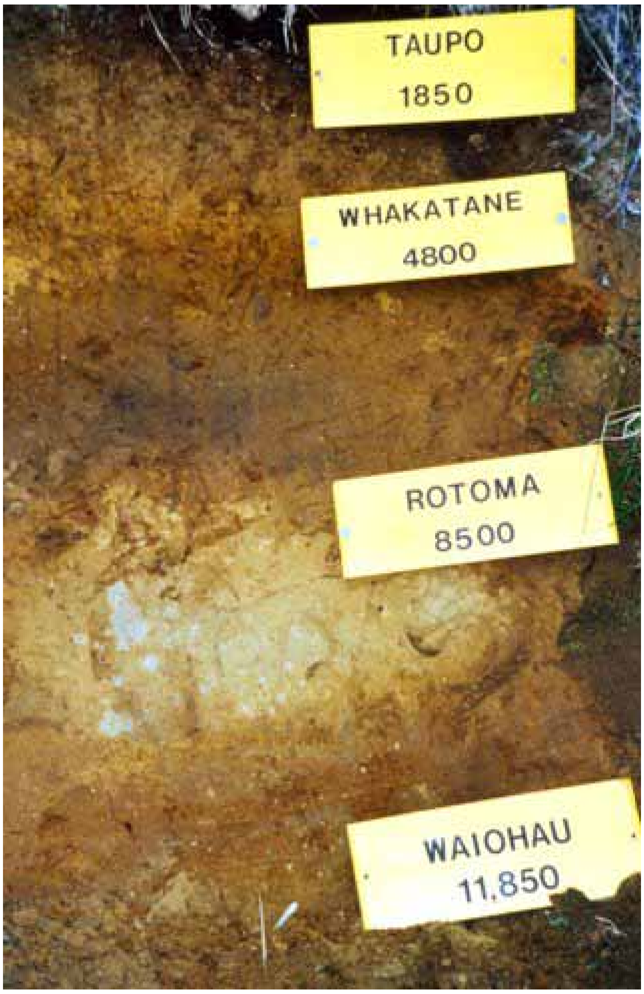
Land use	Suitability rating	Management considerations
Arable	Low	Weak topsoil structure, low fertility, wind erosion if cultivated during dry spells.
Horticulture	Not suitable to low	Cool climate, weak topsoil structure; low fertility, wind erosion if cultivated during dry spells.
Intensive pasture	Moderate	Low fertility.
Forestry	Moderate to high	Low fertility.

Haparangi hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Hilly slopes, weak topsoil structure, low fertility, erosion.
Horticulture	Not suitable	Hilly slopes, weak topsoil structure, low fertility, erosion.
Intensive pasture	Moderate to low	Hilly slopes, low fertility.
Forestry	Moderate to high	Low fertility, hilly slopes.

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Plant green crops to increase organic matter and thicken topsoils.
- Forestry: avoid windrowing and damage to topsoils.



Haparangi sandy loam (Note: Plaques 50 cm long)

Soil Series Name: Haroharo (HS)

Overview

Haroharo steepland soils occur chiefly in and around Tarawera Forest, north of Mount Tarawera. The soils are formed from 10 to 20 cm coarse Tarawera Tephra on Kaharoa Tephra and mixed rhyolitic tephra overlying rhyolite. Soil profiles consist of dark greyish-brown loose gravel overlying dark yellowish-brown sand and yellowish brown sand. The steepland soils are classified as **Immature Orthic Pumice Soils**. They are used for forestry or left in indigenous forest.

Physical properties

Texture: Skeletal

Topsoil clay content: 1 – 4%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within a meter depth

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Low (33 mm)

Profile readily available water (0 – 100 cm): Very low (24 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium to low (30%)

Available P, Ca, Mg and K: Low

Soil types/variations

Haroharo steepland soil is the main soil type.

Associated and similar soils

Tarawera series (with more than 20 cm coarse Tarawera Tephra) and **Matahina series** (with less than 20 cm coarse Tarawera Tephra) occur on small areas of rolling or hilly land.

General land use suitability ratings

Haroharo steepland soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Steep and very steep slopes, severe erosion potential, low fertility.
Horticulture	Not suitable	Steep and very steep slopes, severe erosion potential.
Intensive pasture	Low to unsuitable	Steep and very steep slopes, severe erosion potential.
Forestry	Low	Steep and very steep slopes, severe erosion potential.

Management practices to improve suitability

- These soils are best left in protection forestry because of severe erosion potential.
- Forestry: avoid windrowing and damage to topsoils.

Haroharo steepland soils (Note bare areas of upper slopes where much of the upper tephra have eroded and accumulated on the footslopes)

Soil Series Name: Haumi (HaH)

Overview

Haumi soil series occur near Rainbow Mountain south of Rotorua. The soils are formed from 30 to 50 cm gravelly sand derived from basalt overlying Tarawera lapilli. They occur on hilly slopes and are classified as **Typic Tephric Recent Soils**. The soils are either left in shrub vegetation or in pasture used for dry stock.

Physical Properties

Texture: Skeletal

Topsoil clay content: 2 – 6%

Potential rooting depth: Unlimited

Rooting barrier: None within 1 m depth

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate (108 mm)

Profile readily available water (0 – 100 cm): Moderate (51 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.38 g/cm^3

Chemical Properties

Topsoil organic matter: Less than 8.6%

Topsoil P retention: Low to medium (30%)

Available P, Ca, Mg and K: Low

Soil types/variations

In **Haumi hill soils**, there is slight variation of thickness of tephra layer because of local erosion.

Associated and similar soils

Tarawera series do not have the latest deposits.

General land use suitability ratings

Haumi hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Severe erosion potential, hilly slopes, very low fertility.
Horticulture	Not suitable	Cool climate, severe erosion potential, hilly slopes, very low fertility.
Intensive pasture	Very low	Severe erosion potential, hilly slopes, low fertility.
Forestry	Moderate to low	Severe erosion potential, low fertility.

Management practices to improve suitability

- Soils are best left in shrub as erosion of the loose lapilli at the surface is unavoidable.

Haumi hill soil landscape

Soil Series Name: Horomanga (Hm)

Overview

Horomanga soil series occur on flat to slightly sloping fans on the eastern side of the Galatea Basin. The soils are derived from alluvium and colluvium from tephra and greywacke. Soil profiles are variable but generally consist of very dark brown sand overlying pale yellow coarse sand. The soils are classified as **Typic Tephric Recent Soils**. Land use is mostly dairying or dry stock.

Physical properties

Texture: Sand

Topsoil clay content: 2 – 6%

Potential rooting depth: Unlimited

Rooting barrier: None within 1 m depth

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate (97 mm)

Profile readily available water (0 – 100 cm): Moderate to high (75 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.38g/cm^3

Chemical properties

Topsoil organic matter: Less than 8.6 to 12%

Topsoil P retention: Medium (32%)

Available P, Ca, Mg and K: Low

Soil types/variations

Horomanga sand is the main soil type. **Horomanga mottled silt loam** (poorly drained) occurs at the base of the fans.

Associated and similar soils

Galatea series are on flat terrace-like surfaces derived from airfall Kaharoa and Taupo Tephra. **Kopuriki series** are like Galatea series but with a thin (more than 7 cm) layer of Tarawera Tephra on top. **Rangitaiki series** are alluvial soils along the Rangitaiki River.

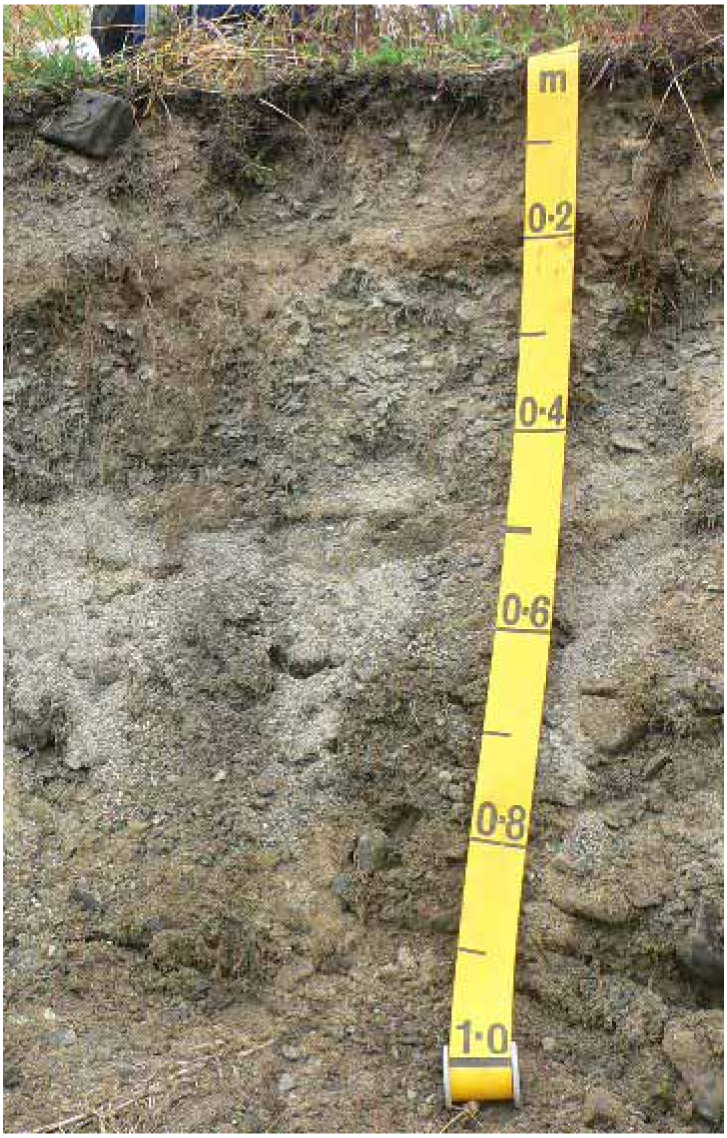
General land use suitability ratings

Horomanga sand

Land use	Suitability rating	Management considerations
Arable	Low	Fragile soil structure, low fertility, summer droughts.
Horticulture	Low	Cool climate, fragile soil structure, low fertility, summer droughts.
Intensive pasture	Low to moderate	Summer droughts, low fertility.
Forestry	Low to moderate	Summer droughts, low fertility.

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Plant green crops to increase organic matter and thicken topsoils.
- Forestry: avoid windrowing and damage to topsoils.



Horomanga sand

Soil Series Name: Kaharoa (Kh)

Overview

Kaharoa soil series occur on the Mamaku Plateau on flat to rolling surfaces and hilly slopes under high annual rainfall (2000 – 2400 mm) at elevations 300 to 400 m above sea level (a.s.l.). The soils are derived from 20 to 40 cm Kaharoa Tephra overlying weathered rhyolitic tephra. Soil profiles consist of very dark brown coarse sand with many white Kaharoa lapilli, overlying very dark greyish-brown coarse sand. At 20 to 30 cm depth, this rests on dark reddish brown sandy loam and yellowish brown loamy sand. The soils are classified as **Typic Orthic Podzols**. Present land use includes dry stock (improved and unimproved pastures) and forestry.

Physical properties

Texture: Sand over loam

Topsoil clay content: 5 – 10%

Potential rooting depth: Unlimited

Rooting barrier: None within 1 m depth

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate (100 mm)

Profile readily available water (0 – 100 cm): Moderate (59 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.42 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 15%

Topsoil P retention: Medium (52%)

Available P, Ca, Mg and K: Low

Soil types/variations

Kaharoa sand occurs on flat to rolling slopes while **Kaharoa hill soils** are found on hilly slopes.

Associated and similar soils

Kaharoa soil series grade into **Mamaku series** where Kaharoa Tephra is restricted to the topsoil and into **Oropi series** which lack the reddish subsoil generally at lower annual rainfall.

General land use suitability ratings

Kaharoa sand

Land use	Suitability rating	Management considerations
Arable	Low	Low fertility, cool climate, fragile topsoil structure, wind erosion if cultivated during dry spells.
Horticulture	Not suitable to low	Cool climate, low fertility.
Intensive pasture	Low to moderate	Low fertility, cool climate.
Forestry	Moderate	Cool climate, low fertility.

Kaharoa hill soils

Land use	Suitability rating	Management considerations
Arable	Low to not suitable	Hilly slopes, cool climate, weak topsoil structure, wind erosion if cultivated during dry spells, low fertility.
Horticulture	Not suitable	Hilly slopes, cool climate, weak topsoil structure, wind erosion if cultivated during dry spells, low fertility.
Intensive pasture	Low to moderate	Hilly slopes, erosion potential under intensive use, cool climate, low fertility.
Forestry	Moderate	Hilly slopes, cool climate, low fertility.

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Plant green crops to increase organic matter and thicken topsoils.
- Forestry: avoid windrowing and damage to topsoils.

Kaharoa sand (scale in 10 cm)

Series Name: Kāingaroa (Kg)

Overview

Kaingaroa soil series occur chiefly on the Kaingaroa Plateau, under 1400 to 1800 mm annual rainfall. The soils are formed from flow tephra, the last deposit of the Taupo eruption which is also called Taupo Ignimbrite. The deposit is compact, especially in southern and central parts of Kaingaroa Plateau. Typically low depressions in the landscape are called frost flats with possible very low winter temperatures. Soil profiles consist of black sand often with many angular lapilli, overlying brownish-yellow sand and light brownish-grey sand with many angular pumice lapilli and block, and fragments of charcoal. The soils are classified as **Welded Impeded Pumice Soils**. Land use is forestry with *Pinus radiata* as the most successful species. Small areas are in pasture (dry stock).

Physical properties

Texture: Sand

Topsoil clay content: 1 – 3%

Potential rooting depth: 40 to 60 cm

Rooting barrier: Compactness at 40 to 60 cm

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Low (50 mm)

Profile readily available water (0 – 100 cm): Low (50 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.18 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 15%

Topsoil P retention: High (62%)

Available P, Ca, Mg and K: Low

Soil types/variations

Kaingaroa gravelly sand occurs in southern Kaingaroa and has a compact subsoil at 30 to 40 cm. **Kaingaroa sand, rolling phase** occurs in central parts of Kaingaroa Plateau with somewhat less coarse lapilli and blocks and the compact layer tends to be at 40 to 60 cm. **Kaingaroa loamy sand, rolling phase** occurs further north and the Taupo Ignimbrite layer is thinner compared with gravelly sand and sand. Compaction starts at 50 to 60 cm.

Associated and similar soils

Taupo series, Oruanui series and Pukerimu series occur on adjacent rolling and hilly land where Taupo Ignimbrite is thinner and there is, therefore, no root barrier.

General land use suitability ratings

Kaingaroa sand and Kaingaroa gravelly sand

Land use	Suitability rating	Management considerations
Arable	Low	Compact subsoil, low fertility, cool climate, fragile topsoil structure susceptible to wind erosion if cultivated during dry spells.
Horticulture	Not suitable	Cold climate, compact subsoil.
Intensive pasture	Low	Low fertility, cool climate.
Forestry	Moderate	Compact subsoil, cool climate, low fertility.

Kaingaroa sand, rolling phase

Land use	Suitability rating	Management considerations
Arable	Low	Compact subsoil, low fertility, cool climate, fragile topsoil structure susceptible to wind erosion if cultivated during dry spells.
Horticulture	Not suitable	Cold climate, compact subsoil.
Intensive pasture	Low to moderate	Low fertility, cool climate.
Forestry	Moderate	Compact subsoil, cool climate low fertility.

Kaingaroa loamy sand, rolling phase

Land use	Suitability rating	Management considerations
Arable	Low	Compact subsoil, low fertility, cool climate, fragile topsoil structure susceptible to wind erosion if cultivated during dry spells.
Horticulture	Not suitable to low	Cold climate, compact subsoil, low fertility, fragile topsoil structure susceptible to wind erosion if cultivated during dry spells.
Intensive pasture	Moderate to low	Low fertility, cool climate, summer droughts.
Forestry	Moderate	Cool climate, low fertility, compact subsoil.

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Plant green crops to increase organic matter and thicken topsoils.
- Practice ripping before planting especially on Kaingaroa gravelly sand and Kaingaroa sand.
- Forestry: avoid windrowing and damage to topsoils.

Kaingaroa gravelly sand (Note very shallow topsoil and B horizon, and the coarse poorly sorted angular pumice throughout the soil profile, scale in m)

Soil Series Name: Kawerau (Kr)

Overview

Kawerau soil series occur on the southern part of the Rangitaiki Plains on flat to undulating terraces. They are derived from thin Tarawera Tephra on pumice alluvium derived from Kaharoa and Taupo Tephra. Profiles show very dark greyish brown coarse sand on dark brown sandy gravel. This rests on dark grey and brown loose sand. The soils are classified as **Immature Orthic Pumice Soils**. These are the first soils to dry out on the Rangitaiki Plains. Present land use includes dry stock, some dairying and some pip fruit orchards.

Physical properties

Texture: Skeletal

Topsoil clay content: 1 – 5%

Potential rooting depth: Unlimited

Rooting barrier: No significant root barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Low (37 mm)

Profile readily available water (0 – 100 cm): Low (28 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low

Soil types/variations

Kawerau sand is generally Well-drained while **Kawerau mottled gravelly sand** has mottling in the subsoil in local shallow depressions and is regarded as imperfectly drained.

Associated and similar soils

Tarawera series have thicker and coarser Tarawera Tephra (more than 20 cm). **Te Teko series** have finer textures.

General land use suitability ratings

Kawerau sand

Land use	Suitability rating	Management considerations
Arable	Low	Low fertility, summer droughts, fragile soil structure.
Horticulture	Low	Low fertility, summer droughts, fragile soil structure.
Intensive pasture	Moderate to low	Summer droughts, low fertility, good winter grazing.
Forestry	Moderate	Summer droughts, flattish areas better used for pasture.

Kawerau mottled gravelly sand

Land use	Suitability rating	Management considerations
Arable	Low	Low fertility, summer droughts, fragile soil structure.
Horticulture	Low to moderate	Fluctuating ground water levels, summer droughts.
Intensive pasture	Moderate to low	Summer droughts, low fertility, good winter grazing.
Forestry	Moderate to low	Fluctuating ground water levels, summer droughts, flattish areas better used for pasture.

Management practices to improve suitability

- Use zero or minimum tillage methods with cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Plant green crops to increase organic matter and thicken topsoils.

Kawerau sand

Soil Series Name: Kawhatiwhati (K)

Overview

Kawhatiwhati soil series have been mapped in northern Kaingaroa Forest in depressions and on valley floors where Kaharoa Tephra was washed in shortly after the eruption. Profiles show 20 to 25 cm black sand overlying pale grey sand and brown coarse and gravelly sand. The soils are classified as **Immature Orthic Pumice Soils**. They are used exclusively for forestry.

Physical properties

Texture: Sand over skeletal

Topsoil clay content: 0 – 3%

Potential rooting depth: Unlimited

Rooting barrier: None within 1 m depth

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Low (57 mm)

Profile readily available water (0 – 100 cm): low (44 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low

Soil types/variations

Kawhatiwhati sand is the most common soil type. Kawhatiwhati **gravelly sand** occurs with profuse lapilli in the topsoil and **Kawhatiwhati shallow sand** has a shallower topsoil.

Associated and similar soils

Waipahihi series are similar but with shallower topsoils and derived from water-sorted Taupo Tephra. **Te Rere and Pekepeke soils** are on adjacent flat, rolling and hilly land.

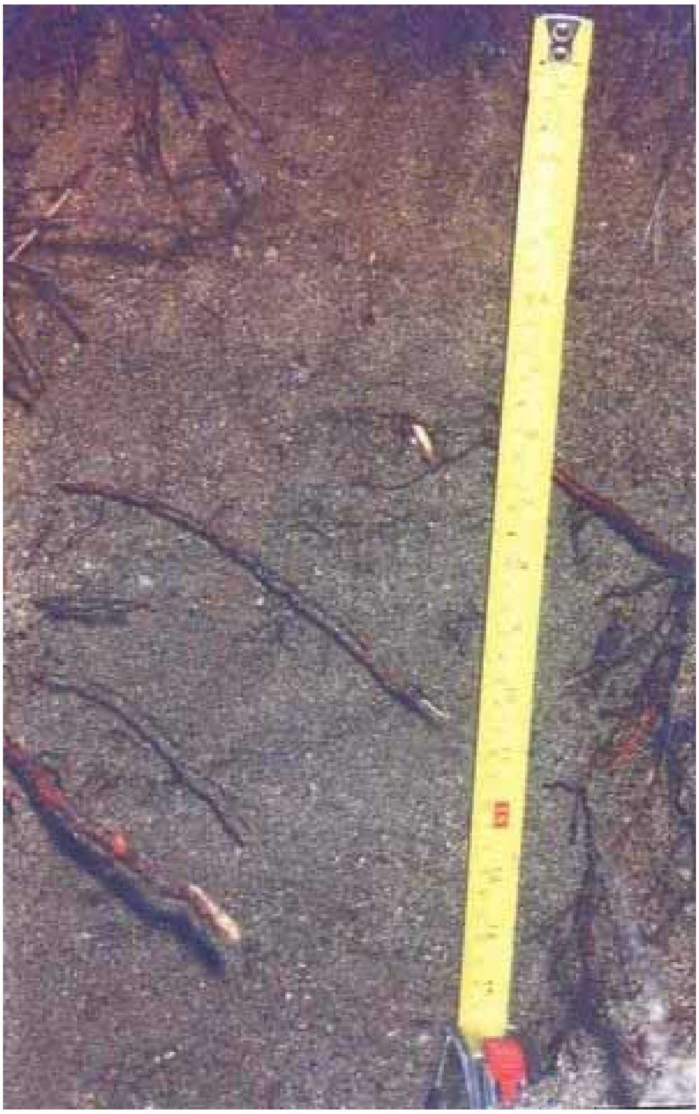
General land use suitability ratings

Kawhatiwhati sand

Land use	Suitability rating	Management considerations
Arable	Low to not suitable	Low fertility, cool climate, fragile topsoil structure susceptible to wind erosion if cultivated during dry spells.
Horticulture	Not suitable	Cool to cold climate, low fertility.
Intensive pasture	Low	Low fertility, cool climate.
Forestry	Moderate	Cool climate, low fertility.

Management practices to improve suitability

- Use zero or minimum tillage methods when working the soil.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Restrict topsoil damage during harvesting.



Kawhatiwhati sand

Soil Series Name: Kopuriki (Kpu)

Overview

Kopuriki soil series have been mapped in the northern Galatea Basin on flat to undulating surfaces. Soils are formed from more than 7 cm Tarawera Tephra, on Kaharoa, Taupo and Whakatane Tephra layers. Soil profiles show very dark greyish brown sandy gravel (Tarawera) on black firm sand (Kaharoa). This overlies pumice gravel layers (Kaharoa and Taupo lapilli) and yellowish-brown sandy loam (Whakatane Tephra). The soils are classified as **Immature Orthic Pumice Soils**. Current land use includes dry stock and dairying.

Physical properties

Texture: Sand

Topsoil clay content: 4 – 6%

Potential rooting depth: Unlimited

Rooting barrier: None within 1 m depth

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to low (82 mm)

Profile readily available water (0 – 100 cm): Moderate (54 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low

Soil types/variations

Kopuriki gravelly sand is the main soil type.

Associated and similar soils

Galatea series where Tarawera Tephra is less than 7 cm thick; **Matahina series** on rolling and hilly surfaces with less than 20 cm coarse Tarawera lapilli at the surface.

General land use suitability ratings

Kopuriki gravelly sand

Land use	Suitability rating	Management considerations
Arable	Low	Low fertility, summer droughts, fragile topsoil structure susceptible to wind erosion if cultivated during dry spells.
Horticulture	Low to not suitable	Cool climate, low fertility, summer droughts, fragile topsoil structure susceptible to wind erosion if cultivated during dry spells.
Intensive pasture	Moderate to low	Low fertility, summer droughts.
Forestry	Moderate	Flattish land better used for pastoral uses, low fertility, fragile topsoil.

Management practices to improve suitability

- Use zero or minimum tillage methods when working the soil.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Restrict topsoil damage during harvesting.

Kopuriki gravelly sand

Soil Series Name: Mamaku (M)

Overview

Mamaku soil series occur on the Mamaku plateau under 2000 mm annual rainfall. The soils are formed from very thin Kaharoa and Taupo Tephras, overlying weathered rhyolitic tephra of which Rotorua lapilli is prominent in the lower subsoil. The tephra overlies ignimbrite. Soil profiles show black loamy sand topsoils overlying greyish-brown sand. This rests on dark reddish-brown greasy loamy sand and sand and the lower subsoil has brown greasy silt loam and strong brown weathered pumice gravel (Rotorua lapilli). The soils are classified as **Humic Orthic Podzols**. Current land use is dairying, dry stock, some fodder cropping, and forestry (indigenous forest and *Pinus radiata*).

Physical properties

Texture: Sand over loam

Topsoil clay content: 5 – 8%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid (rapid over moderate on hill soils)

Profile total available water (0 – 100 cm): Moderate to high (93 mm)

Profile readily available water (0 – 100 cm): Moderate (60 mm)

Topsoil bulk density: 1.08 g/cm^3

Subsoil bulk density: 1.42 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 - 15%

Topsoil P retention: Medium (42%)

Available P, Ca, Mg and K: Low

Soil types/variations

Mamaku loamy sand occurs on flat to rolling land and **Mamaku hill soils** are on hilly slopes. Small areas of shallow peat overlying a more gleyed Mamaku soil also occur.

Associated and similar soils

Arahiwi series on steep and very steep slopes with shallower profiles overlying ignimbrite; **Mangorewa series** with thin Rotokawau Tephra underlying Taupo Tephra; and **Kaharoa series** with thicker Kaharoa Tephra.

General land use suitability ratings

Mamaku loamy sand

Land use	Suitability rating	Management considerations
Arable	Low to moderate	Cool climate, low fertility, fragile topsoil, strongly leached soil.
Horticulture	Not suitable	Cool to cold climate, low fertility.
Intensive pasture	Moderate	Cool climate (short growing season), low fertility, strongly leached soil.
Forestry	Moderate	Cool climate, low fertility.

Management practices to improve suitability

- Use zero or minimum tillage methods when working the soil.
- Avoid cultivating the soil during dry spells.

Mamaku loamy sand

Soil Series Name: Manawahe (Mj)

Overview

Manawahe soil series occur west of the Rangitaiki Plains and east of the Rangitaiki River on rolling to hilly terrain. The soils are formed from 7 to 20 cm sandy Tarawera Tephra on Kaharoa and Taupo Tephra overlying Whakatane Tephra and older weathered rhyolitic tephra. Soil profiles show dark brown gritty sand on brown and light olive brown sand overlying pale yellow fine pumice gravel and yellowish-brown loamy sand. The soils are classified as **Immature Orthic Pumice Soils**. Current land use includes dairying, dry stock, some fodder cropping, and forestry (Pinus radiata).

Physical properties

Texture: Sand and sand over skeletal

Topsoil clay content: 2 – 3%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to low (83 mm)

Profile readily available water (0 – 100 cm): Moderate (62 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low

Soil types/variations

Manawahe loamy sand occurs on flat to rolling land and **Manawahe hill soils** are on hilly slopes. Thickness of Tarawera Tephra varies from 7 to 20 cm. Locally, slightly reddish subsoil occurs.

Associated and similar soils

Matahina series occur on rolling to hilly land with less than 20 cm gravelly Tarawera Tephra on Kaharoa Tephra. They have less water-holding capacity than Manawahe series because of coarser texture. **Pukemaku series** are on steep and very steep slopes where shallower tephra overlies ignimbrite. **Tarawera series** are on easy rolling to hilly land. More than 20 cm gravelly Tarawera Tephra overlies Kaharoa Tephra. They have less water-holding capacity than Manawahe series because of coarser texture. **Whakatane series** are on easy rolling to hilly land with very thin sandy Tarawera Tephra and Kaharoa Tephra overly weathered rhyolitic tephra.

General land use suitability ratings

Manawahe loamy sand

Land use	Suitability rating	Management considerations
Arable	Low to moderate (hill soils not suitable)	Low fertility, fragile topsoil.
Horticulture	Low to moderate (Hill soils not suitable)	Low fertility, fragile topsoil.
Intensive pasture	Moderate	Low fertility, fragile topsoil especially on hilly slopes.
Forestry	High	Low fertility.

Management practices to improve suitability

- Use zero or minimum tillage methods when working the soil.
- Avoid cultivating the soil during dry spells.

Manawahe loamy sand (Note deep topsoil formed from fine Tarawera Tephra and the buried topsoil of Kaharoa Tephra, scale in ft)

Soil Series Name: Mangorewa (Mg)

Overview

Mangorewa soil series occur on undulating to rolling country on the eastern part of the Mamaku Plateau under 2000 to 2500 mm annual rainfall. Soils are formed from a trace of Kaharoa Tephra and thin Taupo Tephra on Rotokawau Tephra, overlying weathered rhyolitic tephra on ignimbrite. Soil profiles have very dark greyish-brown sandy loam topsoils overlying greyish-brown loamy sand on dark reddish-brown loamy sand, resting on dark greyish-brown greasy sandy loam. The soils are classified as **Humic Orthic Podzols**. Current land use is dry stock and some fodder cropping.

Physical properties

Texture: Loam over sand.

Topsoil clay content: 10 – 15%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to high (141 mm)

Profile readily available water (0 – 100 cm): Moderate to high (82 mm)

Topsoil bulk density: 1.09 g/cm^3

Subsoil bulk density: 1.42 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 15.5%

Topsoil P retention: Medium (42%)

Available P, Ca, Mg and K: Probably low levels

Soil types/variations

Mangorewa sandy loam is the main soil type but small areas of peaty loam also occur.

Associated and similar soils

Mamaku hill soils occur on hilly slopes without Rotokawau Tephra. **Pohaturoa steepland soils** occur on steep and very steep slopes with a thinner layer of tephra overlying ignimbrite.

General land use suitability ratings

Mangorewa sandy loam

Land use	Suitability rating	Management considerations
Arable	Low	Cool climate, low fertility, strong leaching, fragile topsoil structure.
Horticulture	Low	Cool climate, low fertility, strong leaching, fragile topsoil structure.
Intensive pasture	Low	Cool climate (short growing season), low fertility, strong leaching, fragile topsoil structure.
Forestry	Moderate	Hilly slopes, slight erosion potential, low fertility.

Management practices to improve suitability

- Use zero or minimum tillage methods when working the soil.
- Avoid cultivating the soil during dry spells.

Mangorewa sandy loam (Note grey lumps of weathered basalt at 0.4 m depth (Rotokawau Tephra))

Soil Series Name: Man-made (MM)

Overview

Man-made soils are soils that have been altered by humans. These soils are extremely variable and no detailed morphological description has been given here. Generally, parent materials are tephra. Large areas are shown on soil maps, but many smaller areas are not. The soils are classified as **Mixed Anthropic Soils** in the New Zealand Soil Classification. Recontoured land supports kiwifruit in coastal areas.

Physical properties

Texture: Loam

Topsoil clay content: 20 - 30%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Moderate

Profile total available water (0 – 100 cm): High (170 mm)

Profile readily available water (0 – 100 cm): Moderate to high (88 mm)

Topsoil bulk density: 1.41 g/cm^3

Subsoil bulk density: 1.42 g/cm^3

Chemical properties

Topsoil organic matter: Not tested

Topsoil P retention: Not known

Available P, Ca, Mg and K: Probably low levels

Soil types/variations

Man-made soils vary from large earthworks to recontoured land.

General land use suitability ratings

Man-made soils

Land use	Suitability rating	Management considerations
Arable	Low	Not considered.
Horticulture	Low to moderate	Recontoured land planted in kiwifruit.
Intensive pasture	Low to moderate	Depending on adequate restoration.
Forestry	Moderate	Depending on adequate restoration.

Management practices to improve suitability

- Replacement of adequate topsoil.
- Ripping and restoring subsoils and thus removing root barriers.

Man-made soil

Soil Series Name: Matahina (Mb)

Overview

Matahina soil series occur in central Whakatane District in the Matahina Forest locality. The soils are formed from less than 20 cm gravelly Tarawera Tephra, on Kaharoa Tephra, on Taupo Tephra and weathered rhyolitic tephra. Topsoils are black gravelly and sand overlying pale yellow coarse sand (Kaharoa lapilli) which rest on very dark brown greasy sandy loam and pale yellow pumice lapilli layer (Taupo lapilli). The soils are classified as **Immature Orthic Pumice Soils**. Current land use is forestry (*Pinus radiata*) and orchards near the Rangitaiki Plains where the climate is milder.

Physical properties

Texture: Sand (skeletal on hilly slopes)

Topsoil clay content: 0 – 4%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to low (74 mm)

Profile readily available water (0 – 100 cm): Low (43 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low

Soil types/variations

Matahina gravelly sand occurs on flat to rolling land and **Matahina hill soils** on hilly slopes. Thickness of Tarawera Tephra varies from 7 to 20 cm, Kaharoa Tephra from 50 to 100 cm, and Taupo Tephra from 40 to 60 cm. Many shallow slips and creep erosion occur on hilly slopes (movement of Tarawera lapilli downslope especially in pasture).

Associated and similar soils

Manawahe series occur on rolling to hilly land with less than 20 cm sandy Tarawera Tephra on Kaharoa Tephra. These soils have somewhat higher water-holding capacity than Matahina series because of finer textures.

Pukemaku series occur on steep and very steep slopes where shallower tephra overlies ignimbrite.

Tarawera series on easy rolling to hilly land where more than 20 cm gravelly Tarawera Tephra overlies Kaharoa Tephra. The soils have lower water-holding capacity than Manawahe series because of coarser textures.

Whakatane series occur on easy rolling to hilly land where very thin sandy Tarawera Tephra and Kaharoa Tephra overly weathered rhyolitic tephra.

General land use suitability ratings

Matahina gravelly sand

Land use	Suitability rating	Management considerations
Arable	Low to not suitable	Low fertility, fragile topsoil, low water-holding capacity, creep erosion.
Horticulture	Not suitable	Cool climate, creep erosion, rolling topography, infertile soils.
Intensive pasture	Moderate to low	Low fertility, fragile topsoil, creep erosion on rolling slopes, low water-holding capacity.
Forestry	Moderate	Low fertility, creep erosion on rolling slopes.

Matahina hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Hilly slopes, severe erosion potential, low water-holding capacity, low fertility, fragile topsoil, creep erosion.
Horticulture	Not suitable	Hilly slopes, cool climate.
Intensive pasture	Low	Hilly slopes, severe erosion potential, low water-holding capacity, low fertility, fragile topsoil, creep erosion.
Forestry	Moderate	Low fertility, severe erosion potential.

Management practices to improve suitability

- Use zero or minimum tillage methods when working the soil.
- Avoid cultivating the soil during dry spells.
- Avoid extensive damage to topsoils during harvesting.

Matahina gravelly sand

Soil Series Name: Maungakakaramea (MkS)

Overview

Maungakakaramea soil series occur on steep and very steep slopes of Maungakaramea (Rainbow Mountain). Parent materials are diverse with some Rotomahana Mud on Taupo Pumice, some hydrothermally altered material, and mixtures of rhyolitic tephra. The soils are classified as **Typic Tephric Recent Soils**. The soils are covered in shrub-type vegetation.

Physical properties

Texture: Loam over skeletal

Topsoil clay content: 25 – 28%

Potential rooting depth: 30 – 60 cm

Rooting barrier: Rock or hot soil temperatures

Drainage class: Well-drained

Permeability: Moderate

Profile total available water (0 – 100 cm): Moderate to low (66 mm)

Profile readily available water (0 – 100 cm): Low (34 mm)

Topsoil bulk density: 1.09 g/cm^3

Subsoil bulk density: 1.38 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (32%)

Available P, Ca, Mg and K: Not known

Soil types/variations

Maungakakaramea steepland soils vary in soil depth and parent materials from Rotomahana Mud to Ngahewa deposits and hydrothermally altered rhyolitic tephra.

Associated and similar soils

Nagahewa series and Rotomahana series occur on adjacent rolling and hilly land.

General land use suitability ratings

Maungakakaramea steepland soil

Land use	Suitability rating	Management considerations
Arable	Not suitable	Steep and very steep slopes.
Horticulture	Not suitable	Steep and very steep slopes, cool climate.
Intensive pasture	Not suitable	Steep and very steep slopes, thermal activity.
Forestry	Not suitable	Steep and very steep slopes, thermal activity.

Management practices to improve suitability

- Prevent erosion by keeping vegetation on the slopes as much as possible.

Maungakakaramea steepland soil landscape

Soil Series Name: Mokai (Mok)

Overview

Mokai soil series occur in shallow depressions in the pumice country of south Western Bay of Plenty. The soils are formed from peat overlying water-sorted Taupo Tephra. Soil profiles consist of dark reddish brown soft peaty loam, on black peaty loam overlying greyish-brown firm fine sandy loam. The soils are classified as **Mellow Humic Organic Soils**. Vegetation includes rushes, flax and raupo with pasture at the edges of swamps where the peat is shallow.

Physical properties

Texture: Peat over sand

Topsoil clay content: 1 – 4%

Potential rooting depth: 40 - 60 cm

Rooting barrier: High ground water levels

Drainage class: Poorly-drained

Permeability: Moderate over slow

Profile total available water (0 – 100 cm): High (150 mm)

Profile readily available water (0 – 100 cm): High (115 mm)

Topsoil bulk density: 0.18 g/cm^3

Subsoil bulk density: 0.18 g/cm^3

Chemical properties

Topsoil organic matter: 34.5 - 69.1%

Topsoil P retention: Not known

Available P, Ca, Mg and K: High to medium in organic material; low in the underlying water-sorted pumice

Soil types/variations

Mokai peaty loam is the main soil type.

Associated and similar soils

Wapahihi series are derived from water-sorted pumice and often occurring adjacent to Mokai series.

General land use suitability ratings

Mokai peaty loam

Land use	Suitability rating	Management considerations
Arable	Not suitable	Poor natural drainage.
Horticulture	Not suitable	Poor natural drainage, cool climate.
Intensive pasture	Not suitable	Poor drainage, pugging under heavy stocking.
Forestry	Not suitable	Poor natural drainage.

Management practices to improve suitability

- Employ surface drainage but note that some areas are difficult or uneconomical to drain and peat could shrink after drainage.
- Establish wetlands.

Mokai peaty loam soil landscape

Soil Series Name: Motumoa (MotS)

Overview

Motumoa soil series occur on steep and very steep slopes of valley sides, volcanic domes and strongly dissected hill country in the south-western part of the Bay of Plenty. Parent material is derived from thin patchy Taupo Tephra overlying weathered rhyolitic tephra on ignimbrite or rhyolite. The soils occur under 1100 to 1800 mm annual rainfall. Soil profiles are variable as past erosion has caused mixing of the tephra layers. Generally, they show black gritty sandy loam on yellowish-brown gritty fine sandy loam resting on strong brown and yellowish brown sandy loam. The soils are classified as **Buried-allophanic Orthic Pumice Soils**. Land use is dry stock with some areas in forestry (*Pinus radiata* or protection forestry).

Physical properties

Texture: Loam

Topsoil clay content: 10 – 15%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): High (164 mm)

Profile readily available water (0 – 100 cm): Moderate to high (88 mm)

Topsoil bulk density: 0.91 g/cm^3

Subsoil bulk density: 0.84 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low

Soil types/variations

Motumoa steepland soils have variable soil profiles which occur because of the mixing of tephra layers through erosion.

Associated and similar soils

Tauhara series where Taupo Pumice layer is complete on steep slopes; **Taupo series and Oruanui series** on easy rolling to hilly slopes with thicker cover of Taupo Pumice; **Waipahihi series** on valley floors derived from water-sorted Taupo Pumice; and **Ngakuru series** on rolling to hilly land without or with very thin and patchy Taupo Tephra.

General land use suitability ratings

Motumoa steepland soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Steep slopes, severe erosion potential.
Horticulture	Not suitable	Steep slopes, severe erosion potential, cool climate.
Intensive pasture	Low	Steep slopes, low fertility, moderate erosion potential.
Forestry	Low to moderate	Steep and very steep slopes, erosion potential, expensive harvesting.

Management practices to improve suitability

- Prevent erosion by keeping vegetation on the slopes as much as possible.
- Avoid over stocking on these steep slopes to minimise accelerated erosion.

Motumoa steepland soil landscape

Soil Series Name: Ngahewa (Ng)

Overview

Ngahewa soil series occur on undulating, rolling and hilly land near Lake Ngahewa close to Rainbow Mountain. The soils are formed from rhyolitic Ngahewa Breccia which is hydrothermally altered pumice which erupted about 100 years ago from nearby vents. The soils have shallow very dark brown stony silt loam, on pale brown clay loam and pale grey stony clay loam. The soils are classified as **Typic Tephric Recent Soils**. Current land use is dry stock and parts are in shrub vegetation.

Physical properties

Texture: Loam over skeletal

Topsoil clay content: 25 – 28%

Potential rooting depth: 25 – 60 cm

Rooting barrier: Acid stony subsoil

Drainage class: Well-drained

Permeability: Moderate

Profile total available water (0 – 100 cm): Low (40 mm)

Profile readily available water (0 – 100 cm): Very low (23 mm)

Topsoil bulk density: 1.09 g/cm^3

Subsoil bulk density: 1.30 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (32%)

Available P, Ca, Mg and K: Low; generally very acid soils

Soil types/variations

Ngahewa stony silt loam is on undulating to rolling lands while Ngahewa hill soils are on moderately steep slopes.

Associated and similar soils

Maungakakaramea series occur on the steep slopes of Rainbow Mountain.

General land use suitability ratings

Ngahewa stony silt loam

Land use	Suitability rating	Management considerations
Arable	Not suitable to low	Acid stony soils of low fertility.
Horticulture	Not suitable	Acid stony soils of low fertility, cool climate.
Intensive pasture	Low to not suitable	Acid stony soils of low fertility.
Forestry	Not suitable	Acid stony soils of low fertility.

Ngahewa hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Hilly slopes, acid stony soils of low fertility.
Horticulture	Not suitable	Hilly slopes, acid stony soils of low fertility, cool climate.
Intensive pasture	Low to not suitable	Hilly slopes, acid stony soils of low fertility.
Forestry	Low	Acid stony soils of low fertility, hilly slopes.

Management practices to improve suitability

- Fertilise with dolomite as well as superphosphate.
- Plant green crops to improve levels of organic matter.

Ngahewa stony silt loam

Soil Series Name: Ngakuru (Na)

Overview

Ngakuru soil series occur on easy rolling, rolling and hill country, chiefly south of Rotorua. The soils are formed from shallow patchy Taupo Tephra overlying weathered rhyolitic tephra on ignimbrite. Soil profiles have black sandy loam overlying brown and yellowish-brown sandy loam on yellowish-brown sand. The soils are classified as **Typic Orthic Allophanic Soils** and occur under 1400 to 1700 mm annual rainfall. Land use on pasture is dry stock (including deer) and dairying.

Physical properties

Texture: Loam over sand

Topsoil clay content: 10 – 18%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate (117 mm)

Profile readily available water (0 – 100 cm): Moderate (74 mm)

Topsoil bulk density: 0.78 g/cm^3

Subsoil bulk density: 0.86 g/cm^3

Chemical properties

Topsoil organic matter: 12.9 -22.4%

Topsoil P retention: High (83%)

Available P, Ca, Mg and K: Low

Soil types/variations

Ngakuru sandy loam occurs on undulating to rolling country while **Ngakuru hill soils** are on moderately steep slopes. The latter has less tephra overlying ignimbrite.

Associated and similar soils

Taupo series and Oruanui series with more than 50 cm Taupo Tephra forming the upper soil horizons; **Haparangi series** on rolling to moderately steep slopes with less than 50 cm Taupo Tephra; and **Pohaturoa series** on steep-sided valleys with thin tephra overlying ignimbrite.

General land use suitability ratings

Ngakuru sandy loam

Land use	Suitability rating	Management considerations
Arable	Medium	Low fertility, rolling slopes, fragile topsoil structure.
Horticulture	Low	Cool climate, rolling slopes, low fertility, fragile topsoil structure.
Intensive pasture	Medium to high	Low fertility.
Forestry	High	Low fertility.

Ngakuru hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Hilly slopes, low fertility, fragile soil structure.
Horticulture	Not suitable	Hilly slopes, low fertility, fragile soil structure.
Intensive pasture	Medium to high	Hilly slopes, low fertility.
Forestry	High	Hilly slopes, low fertility.

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Plant green crops to increase organic matter and thicken topsoils.
- Forestry: avoid windrowing and damage to topsoils.

Ngakuru sandy loam (scale in m)

Soil Series Name: Ngongotahā (No)

Overview

Ngongotaha soil series occur on easy rolling, rolling and hill country, chiefly north-west of Rotorua. The soils are formed from very thin patchy Taupo Tephra overlying weathered rhyolitic tephra on ignimbrite. Soil profiles have black loamy sand overlying dark reddish-brown loamy sand on dark yellowish-brown loamy sand and sandy loam. The lower subsoil has many coarse lapilli (Rotorua lapilli). The soils are classified as **Humose Orthic Podzols** and occur under 1700 to 2000 mm annual rainfall. Land use on pasture is dry stock (including deer) and some in rimu-tawa forest on hilly slopes.

Physical properties

Texture: Sand (loam on hilly slopes)

Topsoil clay content: 5 – 10% (if loamy sand); 15 – 20% (if hill soil)

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate (109 mm)

Profile readily available water (0 – 100 cm): Moderate (70 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.42 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 15.5%

Topsoil P retention: Medium (42%)

Available P, Ca, Mg and K: Low

Soil types/variations

Ngongotaha loamy sand occurs on easy rolling to rolling land. **Ngongotaha hill soils** are on hilly slopes with thinner tephra overlying ignimbrite, with locally thin Rotokawau Tephra below the topsoil.

Associated and similar soils

Arahiwi series on steep and very steep slopes with thinner tephra overlying ignimbrite; **Mamaku series** under higher annual rainfall (more than 2000 mm per year); and **Oturoa series** under lower annual rainfall (not podzolised).

General land use suitability ratings

Ngongotaha loamy sand

Land use	Suitability rating	Management considerations
Arable	Medium	Low fertility, rolling slopes, fragile topsoil structure, cool climate.
Horticulture	Low	Cool climate, low fertility, rolling slopes.
Intensive pasture	Medium to high	Low fertility, cool climate.
Forestry	High	Low fertility.

Ngongotaha hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Hilly slopes, low fertility, fragile soil structure.
Horticulture	Not suitable	Hilly slopes, cool climate, low fertility.
Intensive pasture	Medium	Hilly slopes, low fertility, cool climate.
Forestry	High	Hilly slopes, low fertility.

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Plant green crops to increase organic matter and thicken topsoils.
- Forestry: avoid windrowing and damage to topsoils.

Ngongotaha loamy sand

Soil Series Name: Ōkāreka (OkS)

Overview

Okareka soil series occur east and south-east of Lake Rotorua and around Lake Tarawera on steep and very steep slopes. Parent materials are shallow Rotomahana Mud and Tarawera lapilli on Kaharoa and Taupo Tephra on older weathered rhyolitic tephra on ignimbrite. Soil profiles are variable but generally have thin very dark grey and grey gravelly silt loam (Rotomahana Mud with some Tarawera lapilli) overlying very dark greyish-brown fine sandy loam and dark brown silt loam. These overly dark yellowish-brown greasy sandy loam on pale olive gravelly sand. The soils are classified as **Buried-pumice Tephric Recent Soils**. Current land use is forestry (*Pinus radiata* and totara forests) and some pasture (dry stock).

Physical properties

Texture: Loam

Topsoil clay content: 20 – 30%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to high (141 mm)

Profile readily available water (0 – 100 cm): Moderate (70 mm)

Topsoil bulk density: 1.09 g/cm^3

Subsoil bulk density: 1.30 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (32%)

Available P, Ca, Mg and K: Probably medium

Soil types/variations

Okareka steepland soils vary in amounts of tephra. Ignimbrite outcrops and thick Kaharoa Tephra occurs in places.

Associated and similar soils

Rotomahana series on easy rolling to hilly areas.

General land use suitability ratings

Okareka steepland soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Steep and very steep slopes.
Horticulture	Not suitable	Steep and very steep slopes.
Intensive pasture	Not suitable	Steep and very steep slopes, accelerated erosion potential.
Forestry	Not suitable to low	Steep and very steep slopes, accelerated erosion potential.

Management practices to improve suitability

- Employ protection planting to combat erosion.

Okareka steepland soil landscape near Green Lake

Soil Series Name: Ōkaro (Oka)

Overview

Okaro soil series occur on strongly rolling to hilly land near Lake Okaro. They are derived from Okaro Breccia. The soils were mapped in a complex with Rotomahana series. Profiles show black silt loam with few gravels (weathered rock), on yellowish-brown heavy silt loam, on pinkish-grey stony silty clay loam, overlying Taupo Tephra. The soils are classified as **Allophanic Orthic Pumice Soils**. Land use includes dry stock farming, dairying and some forestry.

Physical properties

Texture: Loam over sand

Topsoil clay content: 20 – 25%

Potential rooting depth: Slight restriction

Rooting barrier: Stony silty clay loam at 30 to 60 cm

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate (100 mm)

Profile readily available water (0 – 100 cm): Moderate (72 mm)

Topsoil bulk density: 0.91 g/cm^3

Subsoil bulk density: 1.30 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Not known but low pH

Soil types/variations

Okaro silt loam is the main soil type.

Associated and similar soils

Okaro series occur as a soil complex with **Rotomahana series** which include **Rotomahana shallow silt loam** and **Rotomahana mottled silt loam**.

General land use suitability ratings

Okaro silt loam

Land use	Suitability rating	Management considerations
Arable	Not suitable to low	Stony soils, strongly rolling and hilly slopes.
Horticulture	Not suitable	Stony soils, strongly rolling and hilly slopes.
Intensive pasture	Moderate to high	Stony soils, hilly slopes.
Forestry	Moderate	Stony soils, hilly slopes.

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Plant green crops to increase organic matter and thicken topsoils.
- Forestry: avoid windrowing and damage to topsoils.

Okaro silt loam

Soil Series Name: Oropi (Or)

Overview

Oropi soil series occur on flat, rolling and hilly uplands south of Te Puke and Tauranga and North of the Rotorua Caldera. The soils are derived from Kaharoa Tephra on thin Taupo Tephra on weathered rhyolitic tephra. They occur under an annual rainfall of 1900 to 2400 mm. Soil profiles show dark brown gritty loamy sand often overlying white coarse sand (Kaharoa lapilli), resting on dark brown and dark yellowish-brown sandy loam, resting on yellowish-brown silt loam. The soils are classified as **Typic Orthic Pumice Soils**. Land use is dry stock, fodder cropping, exotic forestry and pip fruit (apples and pears).

Physical properties

Texture: Sand

Topsoil clay content: 5 – 10%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to high (139 mm)

Profile readily available water (0 – 100 cm): High (87 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 0.84 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low (strongly leached soil)

Soil types/variations

Oropi gritty sand occurs on flat to rolling land while **Oropi hill soils** are on hilly slopes.

Associated and similar soils

Kaharoa series have reddish colours in the subsoil (podzolised). They have thicker layers of Kaharoa Tephra. **Katikati series** occur under lower rainfall and milder climate. They have only a dusting of Kaharoa Tephra.

General land use suitability ratings

Oropi gritty sand

Land use	Suitability rating	Management considerations
Arable	Low	Fragile topsoil, low fertility, cool climate.
Horticulture	Not suitable	Fragile topsoil, low fertility, cool climate.
Intensive pasture	Moderate	Low fertility, cool climate.
Forestry	High	Cool climate.

Oropi hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Hilly slopes, fragile topsoil, low fertility, cool climate.
Horticulture	Not suitable	Hilly slopes, fragile topsoil, low fertility, cool climate.
Intensive pasture	Moderate	Hilly slopes, low fertility, cool climate.
Forestry	High	Cool climate.

Management practices to improve suitability

- Use zero or minimum tillage methods for cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Plant green crops to increase organic matter and thicken topsoils.

Oropi gritty sand

Soil Series Name: Oruanui (Oi)

Overview

Oruanui soil series occur on flat, rolling and hilly land in southern parts of the Bay of Plenty. The soils are formed from more than 50 cm Taupo Pumice on older weathered rhyolitic tephra. The original vegetation was podocarp forest under 1500 to 1800 mm annual rainfall. This resulted in reddish-looking subsoil. Profiles show black to very dark grey sandy topsoils overlying dark brown and dark reddish-brown sand, which rest on strong brown to yellowish-brown loamy sand. The underlying weathered tephra is brown greasy silt loam. The soils are classified as **Podzolic Orthic Pumice Soils**. Land use is dry stock, fodder cropping, dairying and exotic forestry.

Physical properties

Texture: Loam over sand

Topsoil clay content: 5 – 15%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to high (128 mm)

Profile readily available water (0 – 100 cm): Moderate to high (80 mm)

Topsoil bulk density: 0.91 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low (strongly leached soil)

Soil types/variations

Oruanui sand occurs towards Taupo with deeper Taupo Pumice and including a thick lapilli layer. **Oruanui sandy loam** generally has a thinner layer of Taupo Pumice (but more than 50 cm) overlying weathered rhyolitic tephra. **Oruanui hill soils** are on hilly slopes with 50 to 210 cm Taupo Pumice overlying weathered rhyolitic tephra.

Associated and similar soils

Taupo series occur under lower annual rainfall and shrub vegetation, resulting in thinner topsoils and B horizons (about 10 cm). **Tihoi series** occur under 1800 mm or more annual rainfall and a rimu vegetation resulting in Podzols.

General land use suitability ratings

Oruanui sand and sandy loam

Land use	Suitability rating	Management considerations
Arable	Low	Fragile topsoil, low fertility, cool climate.
Horticulture	Low to not suitable	Fragile topsoil, low fertility, cool climate.
Intensive pasture	Moderate to low	Low fertility, cool climate.
Forestry	High	No limitations.

Oruanui hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Hilly slopes, fragile topsoil, low fertility, cool climate.
Horticulture	Not suitable	Hilly slopes, fragile topsoil, low fertility, cool climate.
Intensive pasture	Low to moderate	Hilly slopes, low fertility, cool climate.
Forestry	High	Cool climate, hilly slopes.

Management practices to improve suitability

- Use zero or minimum tillage methods for cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Plant green crops to increase organic matter and thicken topsoils.

Oruanui sand (Note the deep black topsoil, red B horizons, and grey Rotongaio Ash at 90 cm, scale in m)

Soil Series Name: Otamatea (Omg)

Overview

Otamatea soil series occur on flat upland of former water courses in southern parts of the Bay of Plenty near the Taupo - Napier Highway. The soils are formed from water-sorted Taupo Pumice. Common soil profiles have shallow black gravelly sand with many coarse rounded pumice lapilli, overlying yellowish-brown rounded pumice gravels (1 to 20 cm diameter), and resting on light grey pumice gravels and sand. The soils are classified as **Immature Orthic Pumice Soils**. Land use is dry stock, fodder cropping, dairying and exotic forestry.

Physical properties

Texture: Sand

Topsoil clay content: 1 – 7%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Low (49mm)

Profile readily available water (0 – 100 cm): Low (36mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low (strongly leached soil)

Soil types/variations

Otamatea topsoil texture varies from **sand** to **loamy sand**. Small areas of an unmapped rolling phase underlain by compact flow tephra at about 2 to 3 m depth occur.

Associated and similar soils

Poronui series have deeper topsoils and strong brown hues in the subsoil. They occur closer to the river stream bed. **Kaingaroa series** are derived from flow tephra with compact subsoils and formed from angular lapilli and blocks.

General land use suitability ratings

Otamatea gravelly sand

Land use	Suitability rating	Management considerations
Arable	Low	Cold climate, fragile topsoil, low fertility, severe wind erosion risk.
Horticulture	Not suitable	Cold climate, fragile topsoil, low fertility, severe wind erosion risk.
Intensive pasture	Low	Low fertility, cool climate.
Forestry	Moderate	Cool climate, low fertility.

Management practices to improve suitability

- Use zero or minimum tillage methods for cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Plant green crops to increase organic matter and thicken topsoils.

Otamatea gravelly sand (on ignimbrite boulders)

Soil Series Name: Ōtānewainuku (OS)

Overview

Otanewainuku soil series occur in Northern parts of Kaingaroa Forest and North of Te Puke on the Kaimai Ranges. The soils occur on steep and very steep valley sides and hills. They are derived from thin mixed rhyolitic tephra (Kaharoa, Taupo, Mamaku, Rotoma and Rotorua Tephra) overlying ignimbrite. Profiles have black very friable sandy loam on strong brown sandy loam, overlying yellowish-brown clay loam on ignimbrite. The soils are classified as **Immature Orthic Pumice Soils**. Land use is forestry and some dry stock. Many areas are in indigenous forest.

Physical properties

Texture: Loam

Topsoil clay content: 8 – 15%

Potential rooting depth: 50 – 90 cm

Rooting barrier: Low penetration soil material or rock (ignimbrite)

Drainage class: Well-drained

Permeability: Rapid over moderate

Profile total available water (0 – 100 cm): Moderate (115 mm)

Profile readily available water (0 – 100 cm): Moderate (71 mm)

Topsoil bulk density: 0.78 g/cm^3

Subsoil bulk density: 0.86 g/cm^3

Chemical properties

Topsoil organic matter: 12.9 - 22.4%

Topsoil P retention: High (83%)

Available P, Ca, Mg and K: Low (strongly leached soil)

Soil types/variations

Otanewainuku steepland soils are variable. Ignimbrite cliffs, shallow profiles overlying rock, unnamed narrow gully floors where soils are derived from mixed alluvium and colluvium exist.

Associated and similar soils

Pekepeke series and **Te Rere series** in northern Kaingaroa Forest on flat to hilly land; **Ohinepanea series** and **Paengaroa series** north of Te Puke on easy rolling to hilly slopes; **Kawhatiwhati series** in Northern Kaingaroa Forest; **Te Matai series** on wide valley floors derived from alluvium and colluvium.

General land use suitability ratings

Otanewainuku steepland soil

Land use	Suitability rating	Management considerations
Arable	Not suitable	Steep and very steep slopes, cool climate, low fertility.
Horticulture	Not suitable	Steep and very steep slopes, cool climate, low fertility.
Intensive pasture	Low	Steep slopes, low fertility, cool climate.
Forestry	Low	Steep slopes, low fertility.

Management practices to improve suitability

- Employ conservation planting to avoid intensive erosion.
- Use aerial harvesting for forestry to reduce soil damage.

Otanewainuku steepland soil landscape near Maketu

Soil Series Name: Oturoa (Ot)

Overview

Oturoa soil series are mapped west of Lake Rotorua on easy rolling to hilly land. Parent materials are Kaharoa and Taupo Tephra overlying Rotokawau Tephra, Mamaku Tephra, Waiohau Tephra and Rotorua Tephra. Soil profiles consist of very dark greyish brown sand (Kaharoa Tephra) overlying dark brown loamy sand with few Taupo lapilli. They rest on yellowish brown loamy sand and strong brown loamy sand with pockets of greyish brown weathered soft basalt which overly brown greasy sand. The soils are classified as **Typic Orthic Pumice Soils**. Land use is dry stock; fodder cropping, dairying and horticulture (tomatoes, berry fruit, pip fruit (apples and pears)).

Physical properties

Texture: Sand

Topsoil clay content: 2 – 6%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate (95 mm)

Profile readily available water (0 – 100 cm): Moderate (70 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: High (87%)

Available P, Ca, Mg and K: Low (strongly leached soil)

Soil types/variations

Oturoa sand occurs on easy rolling and rolling land while **Oturoa hill soils** are on hilly slopes. Kaharoa Tephra and Rotokawau Tephra become thinner towards the Mamaku Plateau.

Associated and similar soils

Mamaku series and Mangorewa series occur at higher elevations and higher annual rainfall.

General land use suitability ratings

Oturoa sand

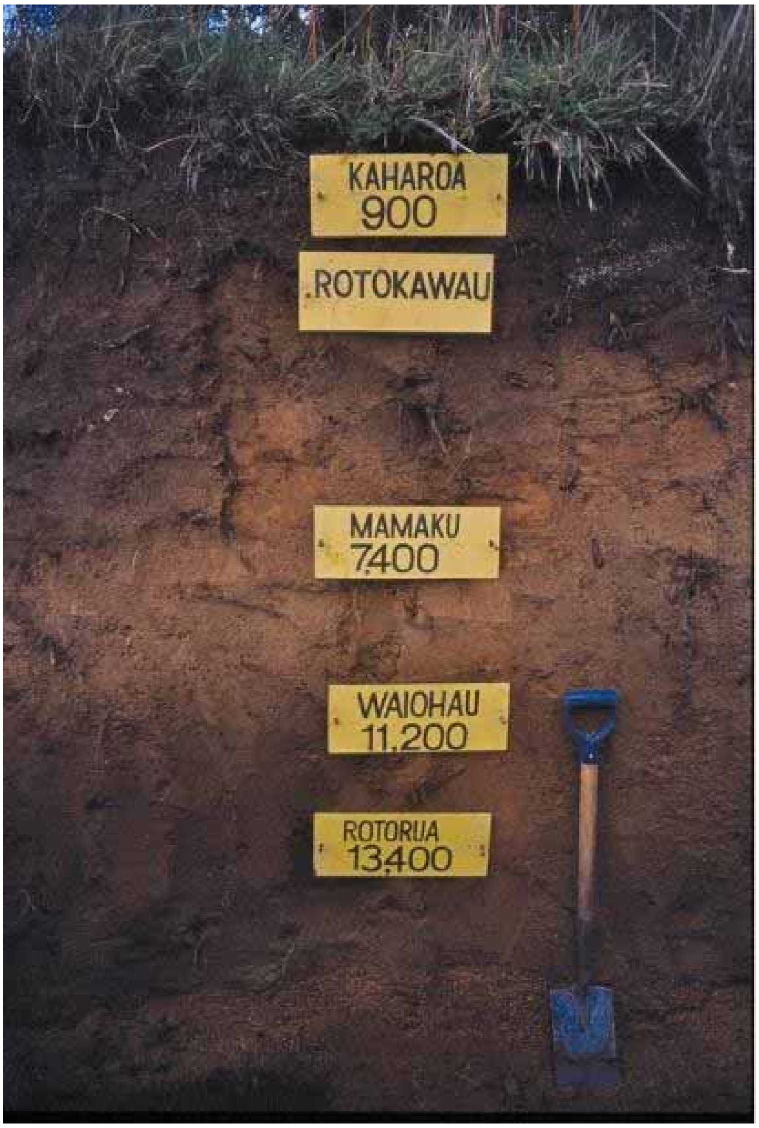
Land use	Suitability rating	Management considerations
Arable	Moderate	Low fertility, fragile topsoil.
Horticulture	Moderate	Low fertility, fragile topsoil.
Intensive pasture	Low	Low fertility.
Forestry	Moderate	Low fertility.

Oturoa hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Hilly slopes; low fertility, fragile topsoil.
Horticulture	Not suitable to low	Hilly slopes, low fertility, fragile topsoil.
Intensive pasture	Moderate to high	Hilly slopes, low fertility.
Forestry	High	Hilly slopes, low fertility.

Management practices to improve suitability

- Use zero or minimum tillage methods for cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Plant green crops to increase organic matter and thicken topsoils.



Oturoa sand

Soil Series Name: Paengaroa (Pg)

Overview

Paengaroa soil series occur north of Lake Rotorua and Lake Rotoiti. Parent materials are thin Kaharoa and Taupo Tephra, overlying weathered rhyolitic tephra. Soil profiles have black loamy sand on yellowish-brown loamy sand which rest on dark yellowish-brown sandy loam. The soils are classified as **Buried-allophanic Orthic Pumice Soils**. Land use is forestry on higher and cooler elevations. Dairying, dry stock maize cropping, kiwifruit and some lucerne on lower elevations towards the Bay of Plenty coast exist.

Physical properties

Texture: Sand

Topsoil clay content: 6 – 9%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): High (162 mm**) Hill soils:** Moderate (107 mm)

Profile readily available water (0 – 100 cm): High (101 mm). **Hill soils:** Moderate (70 mm)

Topsoil bulk density: 0.91 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Medium to low (moderately leached soil)

Soil types/variations

Paengaroa sandy loam and **Paengaroa loamy sand** occur on flat to rolling land while **Paengaroa hill soils** occur on hilly slopes.

Associated and similar soils

Te Puke series do not have the Kaharoa Tephra in the B horizon. Katikati series also do not have Kaharoa Tephra and generally have finer (silt loam, sandy loam) textures. Oropi series are strongly leached and occur under higher annual rainfall and profiles have redder subsoils.

General land use suitability ratings

Paengaroa sandy loam

Land use	Suitability rating	Management considerations
Arable	Moderate at lower altitudes	Moderate fertility, fragile topsoil structure, summer droughts.
Horticulture	Moderate at lower altitudes	Moderate fertility, fragile topsoil structure, summer droughts.
Intensive pasture	Moderate to high at lower altitudes	Moderate fertility, summer droughts.
Forestry	High	No limitations.

Paengaroa hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Hilly slopes, moderate fertility, risk of accelerated erosion.
Horticulture	Not suitable	Hilly slopes.
Intensive pasture	Moderate to high at lower altitudes	Hilly slopes, moderate fertility, risk of erosion under intensive usage, summer droughts.
Forestry	High	Hilly slopes.

Management practices to improve suitability

- Avoid over stocking to reduce erosion risk.

Paengaroa sandy loam

Soil Series Name: Paretotara (PS)

Overview

Paretotara soil series occur on steep and very steep slopes fringing the shores of Lake Rotomahana and Lake Tarawera. They are derived from 20 to 200 cm Rotomahana Mud, on Taupo Tephra, on weathered rhyolitic tephra overlying ignimbrite. Profiles on relatively stable ridges and spurs have very thin dark brown litter and fine sandy loam on brown and greyish-brown fine sandy loam. These overly very dark greyish-brown loamy sand. The soils are classified as **Buried-pumice Tephric Recent Soils**. Land use is restricted to dry stock on stable ridges and spurs. Most of the area remains in shrub-type vegetation.

Physical properties

Texture: Loam over sand

Topsoil clay content: 15 – 20%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid over moderate

Profile total available water (0 – 100 cm): Very low (16 mm)

Profile readily available water (0 – 100 cm): Very low (13 mm)

Topsoil bulk density: 1.09 g/cm^3

Subsoil bulk density: 1.30 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (32%)

Available P, Ca, Mg and K: Medium

Soil types/variations

Paretotara steepland soils are variable. Outcrops of ignimbrite and bare cliffs occur around the lakes.

Associated and similar soils

Rotomahana series occur on flat, rolling and hilly slopes.

General land use suitability ratings

Paretotara steepland soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Steep and very steep slopes.
Horticulture	Not suitable	Steep and very steep slopes, cool climate.
Intensive pasture	Not suitable to low	Steep and very steep slopes, severe erosion potential.
Forestry	Not suitable to low	Steep and very steep slopes, severe erosion potential.

Management practices to improve suitability

- Employ protection forestry to avoid accelerated erosion.

Paretotara steepland soil landscape

Soil Series Name: Pekepeke (Py)

Overview

Pekepeke soil series occur in Northern Kaingaroa Forest on easy rolling, rolling and hilly uplands. The soils are derived from Kaharoa Tephra, on Taupo Tephra on Whakatane Tephra. Profiles have shallow black sand on dark brown and pale yellow coarse sand (Kaharoa Tephra) resting on brown loamy sand and olive brown loamy sand, on pale yellow pumice gravel (Taupo lapilli). Below this layer, dark yellowish-brown loamy sand represents Whakatane Tephra. A feature of these soils is the brown iron and humus-stained subsoil developed under a previous broadleaved-podocarp forest. The soils are classified as **Immature Orthic Pumice Soils**. Land use is predominantly forestry with small areas in dairying or dry stock.

Physical properties

Texture: Sand and sand over skeletal

Topsoil clay content: 0 – 4%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to low (63 mm)

Profile readily available water (0 – 100 cm): Moderate to low (45 to 55 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 - 12%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low

Soil types/variations

The soil types differ in thickness of the tephra layers particularly the Kaharoa Tephra as follows: **Pekepeke sand:** 30 – 130 cm; **Pekepeke hill soils:** 30 – 50 cm; **Pekepeke shallow sand:** 8 – 30 cm; and **Pekepeke hill soils**, shallow sand**:** 8 – 20 cm.

Associated and similar soils

Te Rere series are like Pekepeke series but do not have iron and humus staining in the B horizon. **Otanewainuku** series are on steep and very steep slopes with thinner and more variable tephra layers.

General land use suitability ratings

Pekepeke sand and Pekepeke shallow sand

Land use	Suitability rating	Management considerations
Arable	Low	Fragile topsoil structure, severe wind erosion when cultivated, cool climate, low fertility.
Horticulture	Low to not suitable	Fragile topsoil structure, severe wind erosion when cultivated, cool climate, low fertility.
Intensive pasture	Low to moderate	Summer droughts, low fertility, cool climate.
Forestry	Moderate to high	Low fertility, fragile topsoil.

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Plant green crops to increase organic matter and thicken topsoils.
- Forestry: avoid windrowing and damage to topsoils.

Pekepeke sand (Upper gravelly layer is Kaharoa Tephra, below the dark layer (buried topsoil) Taupo lapilli and below the Taupo lapilli Whakatane Tephra)

Soil Series Name: Pohaturoa (PoS)

Overview

Pohaturoa soil series occur northeast of Lake Rotorua on steep and very steep valley sides. The soils are derived from mixed tephra overlying ignimbrite. Soil profiles have black gritty sand overlying dark yellowish-brown gritty loamy sand (grits are Kaharoa and Taupo lapilli), resting on yellowish-brown loamy sand and sandy loam. The soils are classified as **Immature Orthic Pumice Soils**. Land use is dry stock and forestry. Some areas are in shrub vegetation.

Physical properties

Texture: Loam

Topsoil clay content: 10 – 15%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to high (91 mm)

Profile readily available water (0 – 100 cm): Moderate (51 mm)

Topsoil bulk density: 0.91 g/cm^3

Subsoil bulk density: 0.84 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (55%)

Available P, Ca, Mg and K: Low

Soil types/variations

Pohaturoa steepland soil is the main soil type which varies in total thickness of tephra overlying ignimbrite.

Associated and similar soils

Oropi series are on rolling to hilly land with generally with thicker tephra layers.

General land use suitability ratings

Pohaturoa steepland soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Steep and very slopes.
Horticulture	Not suitable	Steep and very steep slopes.
Intensive pasture	Low	Steep and very steep slopes, moderate erosion potential, low fertility.
Forestry	Moderate to low	Steep and very steep slopes, moderate erosion potential.

Management practices to improve suitability

- Avoid over stocking.
- Use aerial methods of forest harvesting.

Pohaturoa steepland soil

Soil Series Name: Poronui (Poi)

Overview

Poronui soil series occur along streams and rivers on river terraces no longer subject to flooding in the southern and eastern parts of the Whakatane District. The soils are derived from water-sorted Taupo Tephra. Profiles have very dark brown sand overlying dark yellowish brown sand on yellowish-brown, pale yellow and dark grey coarse sand. The soils are classified as **Podzolic Orthic Pumice Soils**. Land use is forestry and some extensive dry stock or dairying with many areas in manuka shrub.

Physical properties

Texture: Sand

Topsoil clay content: 0 – 5%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to low (89 mm)

Profile readily available water (0 – 100 cm): Moderate (68 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low

Soil types/variations

Poronui sand is the main soil type. Some soils have Kaharoa Tephra in the topsoil near Te Waiti.

Associated and similar soils

Rangitaiki series occur on lower terraces subject to frequent flooding.

General land use suitability ratings

Poronui sand

Land use	Suitability rating	Management considerations
Arable	Low to unsuitable	Cold climate, fragile topsoil structure, low natural fertility
Horticulture	Not suitable	Cold climate, fragile topsoil structure, low natural fertility
Intensive pasture	Low	Cold climate with short growing season, low fertility
Forestry	Moderate	Cold climate, low fertility

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Plant green crops to increase organic matter and thicken topsoils.
- Forestry: avoid windrowing and damage to topsoils.

Poronui sand (Layering from flooding is accentuated by iron deposits)

Soil Series Name: Pukemaku (PkS)

Overview

Pukemaku soil series occur in the western parts of Whakatane District, east and northeast of Mount Tarawera on steep and very steep valley and gully sides. The soils are formed from thin (up to 20 cm) Tarawera Tephra on Kaharoa and Taupo Tephra, on weathered rhyolitic tephra on ignimbrite. Profiles have very dark brown gritty sand on dark brown sand and fine gravel resting on brown greasy loamy sand and yellowish-brown to strong brown coarse sand. The soils are classified as **Typic Orthic Pumice Soils**. Land use is sheep farming and protection forestry (rimu–tawa).

Physical properties

Texture: Sand

Topsoil clay content: 0 – 5%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to low (85 mm)

Profile readily available water (0 – 100 cm): Moderate (63 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low

Soil types/variations

Pukemaku steepland soils vary in total thickness of tephra overlying ignimbrite.

Associated and similar soils

Manawahe series on rolling to hilly land, where less than 20 cm fine Tarawera Tephra overlies Kaharoa Tephra on weathered rhyolitic tephra; **Matahina series** on easy rolling to hilly slopes where less than 20 cm coarse Tarawera lapilli overlies Kaharoa Tephra and weathered rhyolitic tephra; **Whakatane series** on easy rolling to hilly slopes where very thin Tarawera Tephra and Kaharoa Tephra overlie weathered rhyolitic tephra; **Haroharo series** on steep and very steep slopes where thicker and coarser Tarawera and Kaharoa Tephra occur.

General land use suitability ratings

Pukemaku steepland soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Steep and very slopes.
Horticulture	Not suitable	Steep and very steep slopes.
Intensive pasture	Low	Steep and very steep slopes, severe erosion potential, low fertility.
Forestry	Low	Steep and very steep slopes, severe erosion potential.

Management practices to improve suitability

- Avoid over stocking.
- Use aerial methods of forest harvesting.

Pukemaku steepland soil landscape

Soil Series Name: Pukerimu (Px)

Overview

Pukerimu soil series occur on easy rolling, rolling and hilly uplands in southern parts of the Whakatane District. The soils are formed from Taupo Tephra on Waimihia Tephra on older weathered rhyolitic tephra. They typically have pumice gravel (Taupo lapilli) at the surface (hill soils) or immediately below the topsoil. Soil profiles have dark brown loamy sand topsoils resting on dark reddish-brown loamy sand with many Taupo lapilli. These sit on top of strong brown pumice gravel on brownish-yellow pumice gravel. The soils are classified as **Podzolic Orthic Pumice Soils**. Land use is forestry, both indigenous (beech, rimu) and plantation (*Pinus radiata*) types.

Physical properties

Texture: Sand and sand over skeletal (hill soils)

Topsoil clay content: 0 – 8%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Low (45 mm)

Profile readily available water (0 – 100 cm): Low (37 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 0.84 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low (strongly leached soils)

Soil types/variations

Pukerimu loamy sand and **sandy loam** soil types occur. Bs horizons vary in colour from reddish brown to strong brown. **Pukerimu hill soils** occur on hilly landscapes.

Associated and similar soils

Tihoi series have pumice lapilli further down the soil profile. **Oruanui series** occur at lower elevations with lower annual rainfall**.**

General land use suitability ratings

Pukerimu loamy sand

Land use	Suitability rating	Management considerations
Arable	Low to unsuitable	Cold climate, fragile topsoil structure, low natural fertility.
Horticulture	Not suitable	Cold climate, fragile topsoil structure, low natural fertility.
Intensive pasture	Low	Cold climate with short growing season, low fertility.
Forestry	Moderate	Cold climate, low fertility.

Pukerimu hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Hilly slopes, cold climate, fragile topsoil structure, strong leaching.
Horticulture	Not suitable	Hilly slopes, cold climate, fragile topsoil structure, low natural fertility.
Intensive pasture	Low	Cold climate with short growing season, low fertility, hilly slopes.
Forestry	Moderate	Cold climate, low fertility, erosion prone.

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Forestry: avoid windrowing and damage to topsoils.

Pukerimu loamy sand

Soil Series Name: Rangitāiki (Ran)

Overview

Rangitaiki soil series occur on flat terraces along streams and rivers throughout the Bay of Plenty. They flood frequently without stop bank protection. Parent material is alluvium derived from greywacke and tephra. Profiles show dark greyish brown sand on dark brown and olive sandy loam, resting on light olive brown sand. The soils are classified as **Typic Fluvial Recent Soils**. Land use (which depends a little on soil texture) consists of dry stock or rough pasture and maize cropping.

Physical properties

Texture: Sand

Topsoil clay content: 2 – 6%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate (103 mm)

Profile readily available water (0 – 100 cm): Moderate (67 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.30 g/cm^3

Chemical properties

Topsoil organic matter: 4.3 – 8.6%

Topsoil P retention: Low (19%)

Available P, Ca, Mg and K: Medium to low

Soil types/variations

Soil types include **gravel, gravelly sand, sand, sandy loam** and **loamy sand**. The finer textures (sandy loam and loamy sand) are more suited to maize cropping.

Associated and similar soils

Ruatoki series (in Opotiki) occur on slightly higher river terraces and have generally finer textures. **Opouriao series** (Opotiki area, East Coast, Rangitaiki plains) occur on levees and naturally flood infrequently. They have deep topsoils and are well developed soils. **Awakaponga series** (Rangitaiki Plains) are poorly drained former back swamps on the same terrace level. **Oweka series** (East Coast) occur on slightly elevated terraces with deeper topsoils.

General land use suitability ratings

Rangitaiki sand

Land use	Suitability rating	Management considerations
Arable	Low to unsuitable	Coarse soil textures, stony in places, flooding without stop banks.
Horticulture	Not suitable	Coarse soil textures, stony in places, flooding without stop banks.
Intensive pasture	Low	Coarse soil textures, stony in places, flooding without stop banks.
Forestry	Not suitable	Coarse soil textures, stony in places, flooding without stop banks.

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.

Rangitaiki sand

Soil Series Name: Rotoiti (Rt)

Overview

Rotoiti soil series occur on easy rolling, rolling and hilly land around the western part of Lake Rotoiti. Parent materials are thin Rotomahana Mud, on more than 20 cm Kaharoa Tephra, on thin Taupo Tephra, on Rotokawau Tephra and older weathered rhyolitic tephra. Soil profiles have very dark grey loamy sand with lumps of greyish-brown sandy loam (Rotomahana Mud) overlying brown gritty sand. They rest on brown sandy loam and brown slightly greasy fine sandy loam with hard fragments of greyish basalt (Rotokawau Tephra) overlying yellowish-brown greasy loamy sand. The soils are classified as **Typic Orthic Pumice Soils**. Land use consists of dry stock, farm forestry (at Tikitere), some fodder cropping, and some horticulture on small land holdings.

Physical properties

Texture: Sand over loam (sand for hill soils)

Topsoil clay content: 3 – 8%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate (119 mm)

Profile readily available water (0 – 100 cm): Moderate (75 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low

Soil types/variations

Rotoiti loamy sand occurs on flat to rolling land while **Rotoiti hill soils** occur on hilly slopes.

Associated and similar soils

Oropi series occur on patches where Kaharoa Tephra is thicker and Rotomahana Mud is less than 7 cm. **Okareka series** are on steep and very steep slopes.

General land use suitability ratings

Rotoiti loamy sand

Land use	Suitability rating	Management considerations
Arable	Low to moderate	Fragile topsoil structure, low natural fertility.
Horticulture	Low to moderate	Fragile topsoil structure, low natural fertility, cool climate for some crops.
Intensive pasture	Moderate	Low fertility.
Forestry	Moderate to high	Low fertility.

Rotoiti hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Hilly slopes, low fertility.
Horticulture	Not suitable	Hilly slopes, low natural fertility.
Intensive pasture	Moderate	Hilly slopes, low to medium fertility.
Forestry	Moderate to high	No limitations.

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Forestry: avoid windrowing and damage to topsoils.

Rotoiti loamy sand

Soil Series Name: Rotomahana (R)

Overview

Rotomahana soil series occur on easy rolling, rolling and hilly land chiefly west of Lake Rotomahana as far as the eastern side of Lake Rotorua and to Rainbow Mountain. Parent materials are Rotomahana Mud, on Kaharoa Tephra, on thin Taupo Tephra, and older weathered rhyolitic tephra. Soil profiles have dark greyish brown fine sandy loam often with some Tarawera lapilli overlying greyish-brown silt loam. At 30 to 120 cm, these overlie black fine sandy loam (buried Taupo topsoil), on dark brown sandy loam which in turn overlie brown and brownish-yellow greasy sandy loam. The soils are classified as **Typic Tephric Recent Soils**. Land use consists of dairying, fodder cropping and some dry stock.

Physical properties

Texture: Loam and loam over sand

Topsoil clay content: 10 – 20% (sandy loam); 20 – 25% (silt loam)

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to high (93 – 132 mm)

Profile readily available water (0 – 100 cm): Moderate to high (74 – 93 mm)

Topsoil bulk density: 1.09 g/cm^3

Subsoil bulk density: 1.30 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (32%)

Available P, Ca, Mg and K: Medium

Soil types/variations

Rotomahana sandy loam occurs on flat to rolling land and has few to many Tarawera lapilli in the upper layers. **Rotomahana silt loam** occurs on flat to rolling land and has few Tarawera lapilli in the topsoil. **Rotomahana hill soils** occur on hilly slopes and have a varying thickness of Rotomahana Mud. **Rotomahana shallow sandy loam** occurs on flat to rolling land and has less than 20 cm Rotomahana Mud on Kaharoa Tephra, Taupo Tephra, and older weathered rhyolitic tephra. R**otomahana hill soils, shallow sandy loam** occur on hill slopes and has less than 20 cm Rotomahana Mud overlying Kaharoa Tephra and a mixture of rhyolitic tephra.

Associated and similar soils

Okareka series are on steep and very steep slopes with varying amounts of Rotomahana Mud. **Rotoiti series** have very thin, often patchy Rotomahana Mud.

General land use suitability ratings

Rotomahana sandy loam and silt loam

Land use	Suitability rating	Management considerations
Arable	Low to moderate	Difficult to work in wet conditions and it tends to crack when dry, summer droughts.
Horticulture	Low to moderate	Difficult to work in wet conditions and it tends to crack when dry, summer droughts, cool climate.
Intensive pasture	High	Summer droughts, pugging in wet conditions.
Forestry	Moderate	Difficult to work when wet.

Rotomahana shallow sandy loam

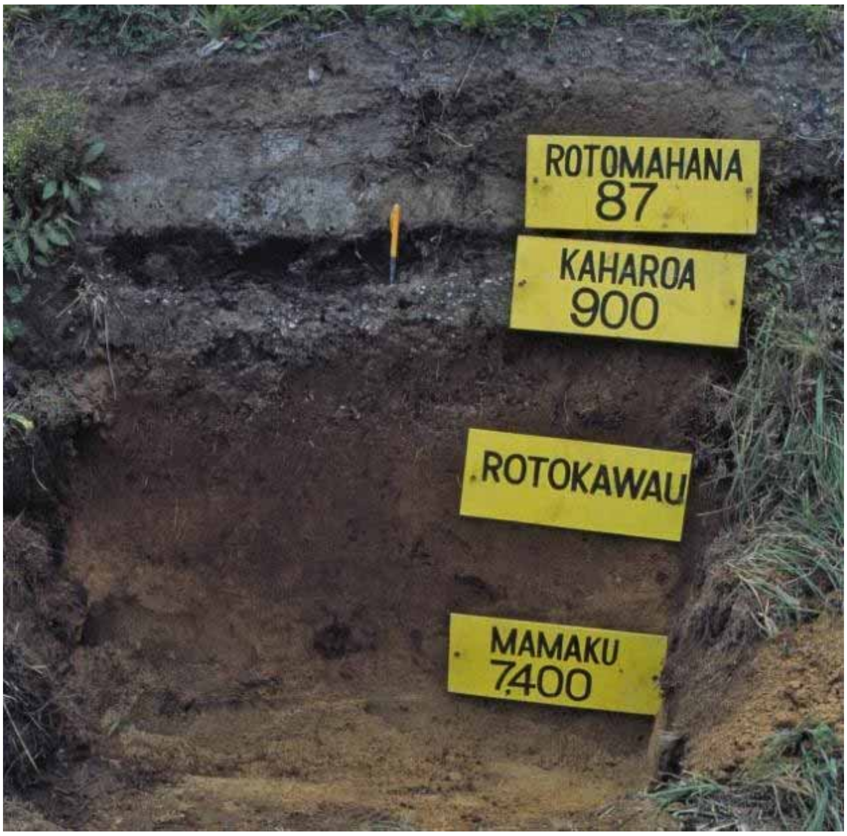
Land use	Suitability rating	Management considerations
Arable	Moderate	Summer droughts.
Horticulture	Moderate	Summer droughts, cool climate.
Intensive pasture	Moderate to high	Pugging during wet conditions.
Forestry	Moderate to high	No limitations.

Rotomahana hill soils and Rotomahana hill soils, shallow sandy loam

Land use	Suitability rating	Management considerations
Arable	Not suitable	Hilly slopes.
Horticulture	Not suitable	Hilly slopes.
Intensive pasture	Moderate	Hilly slopes, pugging during wet conditions.
Forestry	Moderate to high	No limitations.

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Avoid over stocking pastures to reduce soil pugging during the rainy months.
- Forestry: avoid windrowing and damage to topsoils.



Rotomahana silt loam

Soil Series Name: Tarawera (Tr)

Overview

Tarawera soil series occur on easy rolling, rolling and hilly country chiefly in Tarawera Forest in central Whakatane District. The soils are derived from more than 20 cm coarse Tarawera Tephra overlying Kaharoa Tephra. Soil profiles have black to dark greyish-brown coarse Tarawera lapilli overlying black sand and yellowish brown sand. These rest on yellowish brown and pale yellow pumice gravel (Kaharoa Tephra). The soils are classified as **Buried-pumice Tephric Recent Soils**. Land use is forestry and dry stock.

Physical properties

Texture: Sand

Topsoil clay content: 0 – 4%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Low (39 mm)

Profile readily available water (0 – 100 cm): Low (27 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.38 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (32%)

Available P, Ca, Mg and K: Low

Soil types/variations

Tarawera gravel occurs on flat to rolling land. Tarawera Tephra varies in thickness from 23 to 90 cm. Tarawera hill soils are on hill slopes and Tarawera Tephra varies from 23 to 50 cm in thickness with accumulation of eroded material on foot slopes.

Associated and similar soils

Haroharo series are on steep and very steep slopes with thinner layers of tephra overlying ignimbrite

General land use suitability ratings

Tarawera gravel

Land use	Suitability rating	Management considerations
Arable	Low	Cool climate, low fertility, severe erosion potential.
Horticulture	Not suitable	Cool climate, low fertility, severe erosion potential.
Intensive pasture	Low	Low fertility, erosion potential on slopes over 10 degrees.
Forestry	Moderate	Low fertility.

Tarawera hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Hilly slopes, cool climate, low fertility.
Horticulture	Not suitable	Hilly slopes, cool climate, low fertility, severe erosion potential.
Intensive pasture	Low	Hilly slopes, cold climate, low fertility, severe erosion potential.
Forestry	Low	Low fertility, severe erosion potential.

Management practices to improve suitability

- Limit cultivation to slopes below 10 degrees.
- Use low stocking rates with farming.
- Build up organic matter by ploughing in annual crops.
- Maintain a good pasture sward.
- Avoid stock tracking on steep slopes.
- Forestry: avoid windrowing and damage to topsoils.
- Employ protection forestry.

Tarawera gravel (Note thick coarse Tarawera Tephra and buried topsoil of Kaharoa Tephra)

Soil Series Name: Tauhara (TaS)

Overview

Tauhara soil series occur on steep and very steep slopes in the south-western part of Kaingaroa Forest. Parent materials are shallow to moderately thick Taupo Tephra overlying older weathered rhyolitic tephra. Soil profiles have thin very dark greyish brown loose gritty sand on dark yellowish-brown loose gritty sand. These rest on light yellowish-brown loose gravelly sand and pumice gravel. The soils are classified as **Immature Orthic Pumice Soils**. Land use consists of forestry or dry stock farming.

Physical properties

Texture: Sand over skeletal

Topsoil clay content: 0 – 5%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Low (54 mm)

Profile readily available water (0 – 100 cm): Low (39 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low

Soil types/variations

Tauhara steepland soils have a full cover of Taupo Tephra of varying thickness.

Associated and similar soils

Motumoa steepland soils have thinner, patchy and finer Taupo Tephra that overlie older weathered rhyolitic tephra. **Taupo** and **Oruanui series** are on rolling and hilly slopes with thicker Taupo Tephra. **Waipahihi series** are derived from water-sorted Taupo Tephra and occur in valley the floors.

General land use suitability ratings

Tauhara steepland soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Steep slopes, erosion potential.
Horticulture	Not suitable	Steep slopes, erosion potential.
Intensive pasture	Low	Steep slopes, erosion potential, low fertility.
Forestry	Low to moderate	Steep slopes, erosion potential.

Management practices to improve suitability

- Employ aerial harvesting in forestry to prevent severe erosion.
- Use low dry stock stocking rates to prevent further erosion.

Tauhara steepland soil landscape

Soil Series Name: Taupō (Tp)

Overview

Taupo soil series occur in the southern Bay of Plenty on flat to rolling surfaces and hilly slopes under relatively low annual rainfall (1000 - 1400 mm).They are derived from Taupo Pumice, developed under shrub-type vegetation and typically have thin (10 - 15 cm) A and Bw horizons. The sandy soils have low water-holding capacity and summer droughts are common. Natural soil fertility is low. The soils are classified as **Immature Orthic Pumice Soils**. The soils are currently used for forestry and grazing dry stock with occasional fodder cropping. Conversion from forestry to dairying is occurring in places.

Physical properties

Texture: Sand

Topsoil clay content: 2 – 7% (sand and loamy sand); 10 – 15% (sandy loam)

Potential rooting depth: Unlimited

Rooting barrier: None

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to low (63 mm)

Profile readily available water (0 – 100 cm): Low (46 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6-12.0%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low

Soil types/variations

Taupo loamy sand and **Taupo sandy loam** have finer textures and generally slightly better water-holding capacity than **Taupo sand**. **Taupo hill soils** occur on hilly slopes with thinner Taupo Pumice overlying older tephra.

Associated and similar soils

Oruanui series which developed under podocarp forest, under higher annual rainfall (1400 - -1600 mm), have thicker A and B horizons. They are less droughty compared to Taupo series. **Tauhara series and Motumoa series** are on steep slopes with thinner Taupo Pumice overlying older tephra. **Waipahihi series** are derived from water-sorted Taupo Pumice and occur on valley floors. These are lapilli-rich, droughty soils. **Ngakuru series** are derived from thin Taupo Pumice overlying weathered tephra.

General land use suitability ratings

Taupo sand and Taupo loamy sand

Land use	Suitability rating	Management considerations
Arable	Low	Droughty soil, weak topsoil structure; low fertility, wind erosion if cultivated during dry spells, low fertility.
Horticulture	Not suitable to low	Droughty soil, weak topsoil structure; low fertility, wind erosion if cultivated during dry spells, low fertility.
Intensive pasture	Low to moderate	Summer droughts, low fertility.
Forestry	Moderate	Droughts affecting young trees, low fertility.

Taupo sandy loam

Land use	Suitability rating	Management considerations
Arable	Moderate	Weak topsoil structure; low fertility, wind erosion if cultivated during dry spells, low fertility.
Horticulture	Not suitable to low	Droughty soil, weak topsoil structure; low fertility, wind erosion if cultivated during dry spells, low fertility.
Intensive pasture	Moderate	Summer droughts, low fertility.
Forestry	Moderate to high	Low fertility.

Taupo hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Slopes too steep to cultivate.
Horticulture	Not suitable	Hilly slopes, cool climate.
Intensive pasture	Low	Hilly slopes, summer droughts, low fertility.
Forestry	Moderate	Hilly slopes, low fertility.

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.
- Green crops to increase organic matter and thicken topsoils.
- Forestry: avoid windrowing and damage to topsoils.

Taupo sandy loam

Soil Series Name: Te Ngae (Ten)

Overview

Te Ngae soil series occur east of Lake Rotorua on Well-drained low-angle fans. The soils are formed from pumiceous colluvium overlying Rotomahana Mud on pumiceous colluvium and alluvium. Profiles have thin (9 cm) dark brown loamy sand on brown loamy sand. These overlie greyish-brown sandy loam (Rotomahana Mud) on black gravelly loamy sand and dark brown pumice gravel (Kaharoa Tephra) on dark yellowish brown slightly greasy sandy loam. The soils are classified as **Typic Tephric Recent Soils**. Land use consists of dairying, dry stock and cropping (fodder).

Physical properties

Texture: Sand over loam

Topsoil clay content: 5 – 8%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to high (127 mm)

Profile readily available water (0 – 100 cm): Moderate to high (78 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.30 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (32%)

Available P, Mg, K and Ca: Medium

Soil types/variations

Te Ngae loamy sand is the principal soil type.

Associated and similar soils

Waiowhiro series and **Utuhina peaty loam** occur near Lake Rotorua.

General land use suitability ratings

Te Ngae loamy sand

Land use	Suitability rating	Management considerations
Arable	Moderate	Fragile topsoil structure, late soil for cropping.
Horticulture	Moderate to low	Fragile topsoil structure, late soil for cropping, cool climate.
Intensive pasture	Moderate to high	Fragile topsoil structure, late soil for cropping, summer droughts.
Forestry	Moderate to high	Fragile topsoil structure, competition with other land uses.

Management practices to improve suitability

- Use zero or minimum tillage methods for fodder cropping.
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.

Te Ngae loamy sand

Soil Series Name: Te Rere (Te)

Overview

Te Rere soil series occur in Northern Kaingaroa Forest on flat to rolling and hilly slopes. Parent materials are 30 to 60 cm Kaharoa Tephra on Taupo Tephra overlying Whakatane Tephra. Soil profiles consist of black friable sand on light grey weakly compact sand. These rest on white loose pumice gravel on brown loamy sand merging to pale yellow sand. The soils are classified as **Immature Orthic Pumice Soils**. Land use consists of forestry, some dry stock and dairying.

Physical properties

Texture: Sand

Topsoil clay content: 0 – 6%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to low (78 mm), sand, Moderate (94 mm), shallow sand, Moderate to high (129 mm), very shallow sand

Profile readily available water (0 – 100 cm): Moderate (58 mm), sand, Moderate (65 mm), shallow sand, Moderate (71 mm), very shallow sand

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1 %

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low (Strongly leached soil)

Soil types/variations

Soil types vary according to the thickness of tephra layers as follows**: Te Rere sand** with 30 - 60 cm Kaharoa Tephra on Taupo Tephra; **Te Rere shallow sand** with 15 - 30 cm Kaharoa Tephra on Taupo Tephra; **Te Rere very shallow sand** with 7 - 15 cm Kaharoa Tephra on Taupo Tephra. **Te Rere hill soils** are on hilly slopes with a variable layer of Kaharoa Tephra on Taupo Pumice and older rhyolitic tephra.

Associated and similar soils

Pekepeke series have humus staining in the Bw horizon as a result of previous indigenous forest vegetation. **Otanewainuku series** occur on steep and very steep slopes with thinner tephra on ignimbrite.

General land use suitability ratings

Te Rere sand, Te Rere shallow sand and Te Rere very shallow sand

Land use	Suitability rating	Management considerations
Arable	Low	Weakly developed topsoil structure, low natural fertility, cool climate, droughts.
Horticulture	Low to unsuitable	Weakly developed topsoil structure, low natural fertility, cool climate.
Intensive pasture	Low	Cool climate, low natural fertility, summer droughts.
Forestry	Moderate to high	Moisture deficiency at seedling growth stage.

Te Rere hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Hilly slopes, weakly developed topsoil structure, low natural fertility, cool climate, droughts.
Horticulture	Not suitable	Hilly slopes, weakly developed topsoil structure, low natural fertility, cool climate.
Intensive pasture	Low	Hilly slopes, cool climate, low natural fertility, summer droughts.
Forestry	Moderate to high	Hilly slopes, moisture deficiency at seedling growth stage.

Management practices to improve suitability

- Use zero or minimum tillage methods for forestry.
- Avoid working the soil during dry spells to prevent loss of organic matter.

Te Rere sand (Note thick band of white Kaharoa lapilli at the surface)

Soil Series Name: Te Teki (TtS)

Overview

Te Teki soil series occur on steep and very steep slopes, chiefly in central and southern Kaingaroa Forest. The soils are formed from thin Taupo Tephra and Waimihia Tephra on older rhyolitic tephra overlying ignimbrite. Soil profiles have dark reddish-brown shallow topsoils overlying olive grey sand on dark brown sand. These rest on yellowish-brown sand and dark reddish-brown hard sandy loam overlying dark yellowish-brown and yellowish-brown loamy sand. The soils are classified as **Humose Orthic Podzols**. Land use consists of forestry and/or recreation and conservation.

Physical properties

Texture: Sand

Topsoil clay content: 1 – 7%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate (93 mm)

Profile readily available water (0 – 100 cm): Moderate (67 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.42 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 15.5 %

Topsoil P retention: Medium (42%)

Available P, Ca, Mg and K: Low

Soil types/variations

Te Teki steepland soils as described above. Shallow profiles overlying ignimbrite occur where the tephra has eroded off the slope.

Associated and similar soils

Tihoi series and **Pukerimu series** are on easy rolling and hilly slopes with thicker tephra layers. **Urewera series** occur on steep and very steep slopes where tephra overlies greywacke.

General land use suitability ratings

Te Teki steepland soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Steep and very steep slopes, cool climate, low natural fertility.
Horticulture	Not suitable	Steep and very steep slopes, cool climate, low natural fertility.
Intensive pasture	Low	Steep and very steep slopes, cool climate, low natural fertility.
Forestry	Moderate	Steep and very steep slopes, cool climate, low natural fertility.

Management practices to improve suitability

- Use aerial harvesting methods for forestry.

Te Teki steepland soil landscape

Soil Series Name: Tihoi (Toi)

Overview

Tihoi soil series occur in southern parts of Whakatane District on easy rolling to rolling and hilly uplands. Soil profiles consist of dark reddish brown very friable sandy loam on greyish-brown friable loamy sand resting on dark brown sandy loam on light olive firm sand. Lower subsoils are pale yellow pumice gravel (Taupo lapilli). The soils are classified as **Humose Orthic Podzols.** Land use consists of forestry and dry stock.

Physical properties

Texture: Loam over sand (sandy loam); sand over skeletal (hill soils)

Topsoil clay content: 10 – 15% (sandy loam); 2-8% (hill soils)

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to low (90 mm), Low (56 mm), hill soils

Profile readily available water (0 – 100 cm): Moderate (63 mm), Low (27 mm), hill soils

Topsoil bulk density: 1.09 g/cm^3

Subsoil bulk density: 1.42 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 15.5 %

Topsoil P retention: Medium (42%)

Available P, Ca, Mg and K: Low (Strongly leached soil)

Soil types/ variations

Tihoi sandy loam occurs on flat to rolling slopes. **Tihoi hill soils** occur on hilly slopes generally with thinner tephra layers.

Associated and similar soils

Oruanui series occur at lower elevations and lower annual rainfall. **Pukerimu series** are soils where Taupo lapilli layers are at the surface. **Te Teki series** occur on steep and very steep slopes where shallower tephra overlies ignimbrite. **Ruakituri series** are soils where shallow or very shallow Kaharoa Tephra overlies Taupo Pumice.

General land use suitability ratings

Tihoi sandy loam

Land use	Suitability rating	Management considerations
Arable	Low	Weakly developed topsoil structure, low natural fertility, cool climate.
Horticulture	Not suitable	Cool climate, weakly developed topsoil structure, low natural fertility.
Intensive pasture	Low	Cool climate, low natural fertility, summer droughts.
Forestry	Moderate	Cool climate.

Tihoi hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Hilly slopes, weakly developed topsoil structure, low natural fertility, cool climate.
Horticulture	Not suitable	Hilly slopes, cool climate, weakly developed topsoil structure, low natural fertility.
Intensive pasture	Low	Cool climate, low natural fertility, hilly slopes, summer droughts.
Forestry	Moderate	Cool climate, hilly slopes.

Management practices to improve suitability

- Use zero or minimum tillage methods.
- Avoid working the soil during dry spells to prevent loss of organic matter.

Tihoi sandy loam (Note pale horizon below black topsoil and red iron staining in subsoil, scale in m)

Soil Series Name: Tikitere (T)

Overview

Tikitere soil series occur in the Rotorua District in areas with hydrothermal activity. Parent materials are mixed and altered hydrothermal deposits. Soil profiles consist of dark reddish-brown coarse sand on hard olive brown sandy loam overlying brown loamy sand, resting on white and pale yellow firm fine sand with pumice gravel. The soils are classified as **Inactive Hydrothermal Recent Soils.** Land use is recreational.

Physical properties

Texture: Sand

Topsoil clay content: 1 – 5%

Potential rooting depth: 10 – 15 cm

Rooting barrier: Low penetration soil material, acid subsoil

Drainage class: Well-drained

Permeability: Rapid over moderate

Profile total available water (0 – 100 cm): Very low (15 mm)

Profile readily available water (0 – 100 cm): Very low (15 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.30 g/cm^3

Chemical properties

Topsoil organic matter: not known, but presumably low

Topsoil P retention: Low (20%)

Available P, Ca, Mg and K: Low (Very acid soil)

Soil types/variations

Tikitere sand occurs on flat to rolling slopes. **Tikitere hill soils** occur on hilly slopes.

General land use suitability ratings

Tikitere sand and Tikitere hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Shifting hydrothermal activity, very acid soils.
Horticulture	Not suitable	Shifting hydrothermal activity, very acid soils.
Intensive pasture	Not suitable	Shifting hydrothermal activity, very acid soils.
Forestry	Not suitable	Shifting hydrothermal activity, very acid soils.

Management practices to improve suitability

- None recommended.

Tikitere sand (Note the stunted manuka vegetation in the background)

Soil Series Name: Utuhina (Ut)

Overview

Utuhina soil series occur in low-lying areas in the Rotorua area. Parent materials are peat and peaty loam overlying pumiceous lake deposits. Soil profiles consist of black friable peaty loam on black loamy peat resting on pale brown soft silt loam and olive soft sand. The soils are classified as **Mellow Humic Organic Soils**. Land use consists of dry stock

Physical properties

Texture: Peat over sand

Topsoil clay content: 5 – 10%

Potential rooting depth: 40 – 60 cm

Rooting barrier: Anoxic conditions

Drainage class: Poorly drained

Permeability: Moderate

Profile total available water (0 – 100 cm): High (181 mm)

Profile readily available water (0 – 100 cm): High (150 mm)

Topsoil bulk density: 0.18 g/cm^3

Subsoil bulk density: 0.18 g/cm^3

Chemical properties

Topsoil organic matter: 34.5 – 69.0 %

Topsoil P retention: High (62%)

Available P, Ca, Mg and K: Low levels

Soil types/variations

Utuhina peaty loam with peaty materials overlying pumiceous sand is the main soil type.

Associated and similar soils

Waiowhiro series near the edges of depressions are derived from pumiceous lake deposits.

General land use suitability ratings

Utuhina peaty loam

Land use	Suitability rating	Management considerations
Arable	Not suitable	Poorly drained small depressions.
Horticulture	Not suitable	Poorly drained small depressions.
Intensive pasture	Low	Poorly drained small depressions.
Forestry	Not suitable	Poorly drained small depressions.

Management practices to improve suitability

- Employ artificial drainage with open drains.
- Suitable for wetland areas and reserves.

Utuhina peaty loam landscape

Soil Series Name: Waikokomuka (Wo)

Overview

Waikokomuka soil series occur chiefly on easy rolling land bordering the Waiotapu thermal area. Parent materials consist of are Taupo Tephra modified by warm subsoil temperatures. Soil profiles are black friable sand on very dark greyish brown loamy sand overlying dark brown loamy sand. The soils are classified as **Inactive Hydrothermal Recent Soils**. When close to thermal activity, they are classified as **Active Hydrothermal Raw Soils.** Land use consists of limited forestry and dry stock.

Physical properties

Texture: Sand

Topsoil clay content: 4 – 6%

Potential rooting depth: 50 – 70 cm

Rooting barrier: Low penetration soil material, and locally warm or hot subsoils

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to low (72 mm)

Profile readily available water (0 – 100 cm): Moderate (72 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.42 g/cm^3

Chemical properties

Topsoil organic matter: Not known, possibly variable.

Topsoil P retention: Not known

Available P, Ca, Mg and K: Low (acid soils)

Soil types/variations

Wakokomuka loamy sand generally occurs on former hydrothermally active areas. A warm subsoil member occurs but has not been mapped separately.

Associated and similar soils

Ngahewa stony silt loam and **Ngahewa hill soils** on adjacent land. **Taupo sandy loam** occurs on adjacent easy rolling and hilly land.

General land use suitability ratings

Waikokomuka loamy sand

Land use	Suitability rating	Management considerations
Arable	Not suitable	Very acid soils, locally warm subsoil temperatures.
Horticulture	Not suitable	Very acid soils, locally warm subsoil temperatures, cool climate.
Intensive pasture	Low	Very acid soils, locally warm subsoil temperatures.
Forestry	Low	Very acid soils, locally warm subsoil temperatures.

Management practices to improve suitability

- These soils are best left in their natural state.
- Employ low stocking rates for dry stock.

Waikokomuka loamy sand

Soil Series Name: Waimangu (WgH)

Overview

Waimangu soil series occur chiefly on hilly and easy rolling land of the Waimangu thermal area in Rotorua. Parent materials consist of deposits of the Frying Pan eruption of 1917. Soil profiles are very dark greyish brown friable sandy loam, on greyish-brown friable silt loam which rest on pale brown silt loam and fine gravel. The soils are classified as **Allophanic Orthic Pumice Soils.** The land is used as a scenic reserve.

Physical properties

Texture: Loam

Topsoil clay content: 20 – 23%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to high (123 mm)

Profile readily available water (0 – 100 cm): Moderate (66 mm)

Topsoil bulk density: 0.91 g/cm^3

Subsoil bulk density: 0.84 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%.

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low

Soil types/variations

Waimangu sandy loam and **Waimangu hill soils** are included in the series (small areas only).

Associated and similar soils

Taupo sandy loam is on adjacent easy rolling and hilly land.

General land use suitability ratings

Waimangu sandy loam and Waimangu hill soils

Land use	Suitability rating	Management considerations
Arable	Not suitable	Small area totally in reserve, hilly slopes.
Horticulture	Not suitable	Small area totally in reserve, cool climate, hilly slopes.
Intensive pasture	Low	Small area totally in reserve.
Forestry	Low	Small area totally in reserve.

Management practices to improve suitability

- None. These soils are best left in their natural state.

Waimangu hill soil landscape

Soil Series Name: Waiowhiro (Wa)

Overview

Waiowhiro soil series occur around the Rotorua Lakes. Parent materials are pumice from lake deposits. Soil profiles have thin black to very dark brown friable coarse sand overlying dark reddish brown and dark brown loose coarse sand, which rest on dark brown and dark reddish brown loose coarse sand. The soils are classified as **Mottled Tephric Recent Soils**. Agricultural land use consists of dry stock. Much of the land is residential.

Physical properties

Texture: Sand

Topsoil clay content: 2 – 5%

Potential rooting depth: 40 – 80 cm

Rooting barrier: Anoxic conditions

Drainage class: Imperfectly drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Low (39 mm)

Profile readily available water (0 – 100 cm): Low (28 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.38 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (32%)

Available P, Ca, Mg and K: Low

Soil types/variations

Waiowhiro sand is the main soil type. Small areas of peaty loam occur in depressions.

Associated and similar soils

Utuhina peaty loam occurs in low-lying depressions.

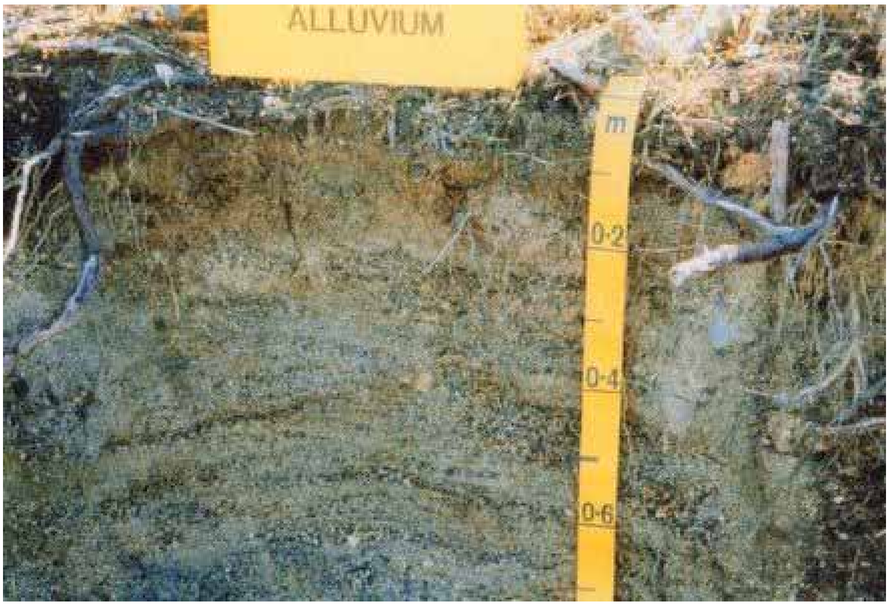
General land use suitability ratings

Waiowhiro sand

Land use	Suitability rating	Management considerations
Arable	Not suitable	Imperfect drainage, very coarse soil textures.
Horticulture	Not suitable	Imperfect drainage, very coarse soil textures.
Intensive pasture	Low	Imperfect drainage, very coarse soil textures.
Forestry	Not suitable	Imperfect drainage, very coarse soil textures.

Management practices to improve suitability

- Drainage (open drains).
- Avoid cultivating the soil during dry spells to prevent loss of organic matter.



Waiowhiro sand

Soil Series Name: Waipahihi (Yp)

Overview

Waipahihi soil series occur in the pumice country on valley floors. Parent material is colluvium or alluvium derived from Taupo Tephra that eroded off adjacent hill slopes. Soil profiles have thin dark brown friable loamy sand topsoils with few rounded lapilli, on dark reddish brown to yellowish-brown firm loamy sand with many rounded pumice lapilli. They overlie light yellowish-brown firm loamy sand and pale brown sand. The soils are classified as **Immature Orthic Pumice Soils.** Land use is dry stock and some dairying.

Physical properties

Texture: Sand

Topsoil clay content: 5 – 8%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to low (85 mm)

Profile readily available water (0 – 100 cm): Moderate (59 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.00 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%.

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low

Soil types/variations

Waipahihi loamy sand as described above. **Waipahihi sand** has coarser textures towards the Taupo area.

Associated and similar soils

Taupo series, **Oruanui series** and **Tauhara series** occur on adjacent rolling and hill country. **Mokai series** occur in low-lying swamps.

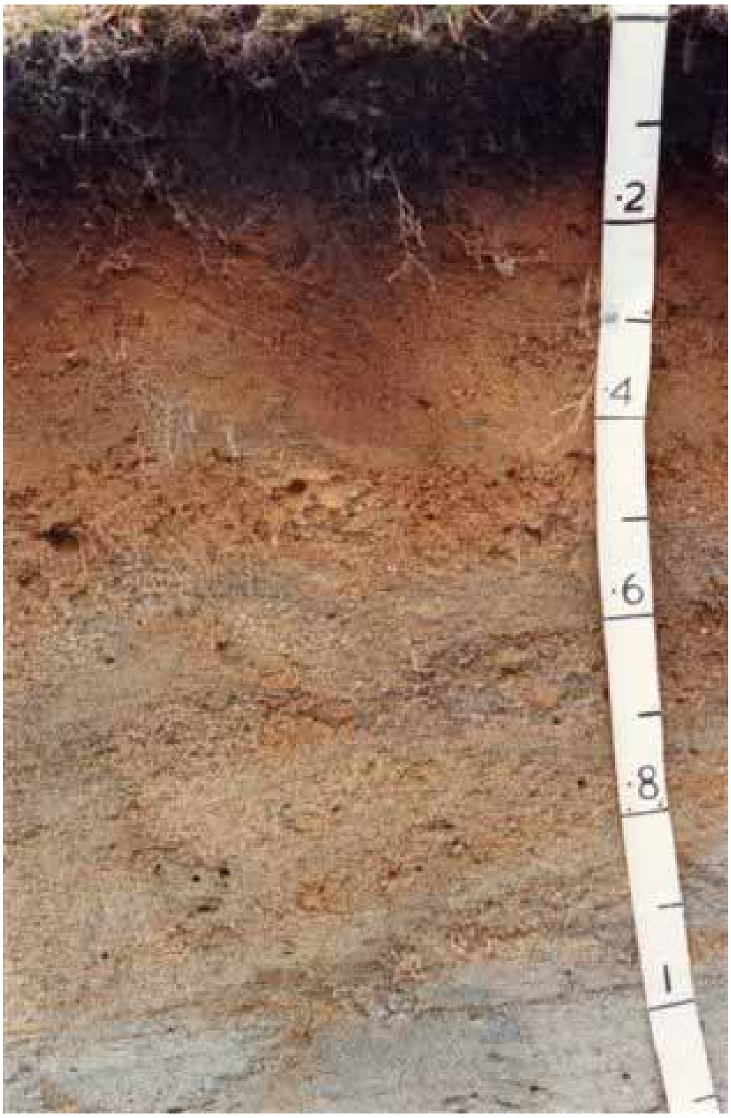
General land use suitability ratings

Waipahihi loamy sand and Waipahihi sand

Land use	Suitability rating	Management considerations
Arable	Low	Coarse textures, cool climate, weakly developed topsoil structure, fodder cropping.
Horticulture	Low to unsuitable	Coarse textures, cool climate, weakly developed topsoil structure.
Intensive pasture	Medium to low	Coarse textures, cool climate, low fertility.
Forestry	Medium to low	Small areas.

Management practices to improve suitability

- Increase organic matter.
- Avoid soil tillage under dry, windy conditions.



Waipahihi sand (Note shallow topsoil and water-sorted layering in the subsoil, scale in m)

Soil Series Name: Waiteti (W)

Overview

Waiteti soil series occur on flat, rolling and hilly uplands of the Mamaku Plateau west of the Rotorua area. Parent materials are thin Kaharoa and Taupo Tephra on weathered rhyolitic tephra on ignimbrite. Soil profiles have dark reddish brown friable loamy sand on dark brown loamy sand which rest on yellowish-brown loamy sand on sand. Below 70 cm, yellowish-brown greasy loamy sand occurs. The soils are classified as **Typic Orthic Podzols.** Land use is dairying, dry stock, or forestry.

Physical properties

Texture: Sand (loamy sand); sand over loam (hill soils)

Topsoil clay content: 5 – 10% (loamy sand); 10 – 15% (hill soils)

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate (95 mm)

Profile readily available water (0 – 100 cm): Moderate (70 mm)

Topsoil bulk density: 1.18 g/cm^3

Subsoil bulk density: 1.42 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 15.5%

Topsoil P retention: Medium (42%)

Available P, Ca, Mg and K: Low (Strongly leached soil)

Soil types/variations

Waiteti loamy sand occurs on easy rolling to rolling land. **Waiteti hill soils** are on hilly land. Small pockets of Kaharoa Tephra occur locally.

Associated and similar soils

Mamaku series are podzols without the Rotokawau Tephra below Taupo Tephra.

General land use suitability ratings

Waiteti loamy sand

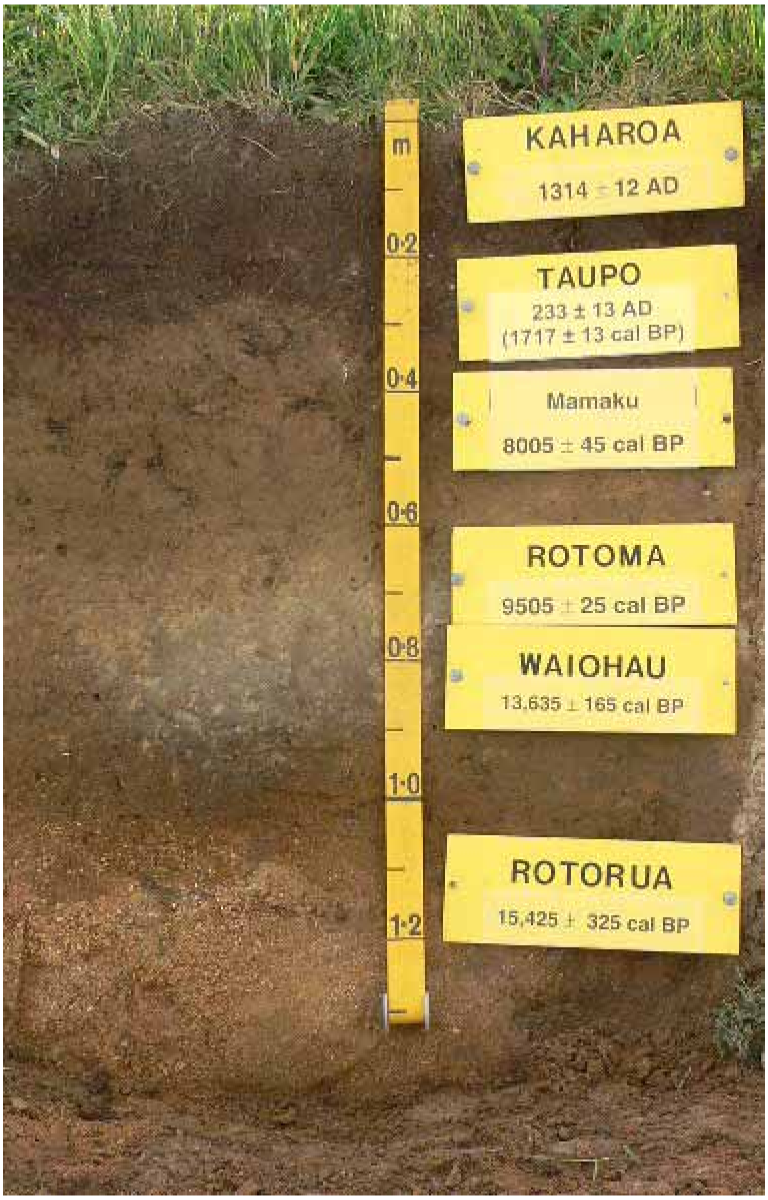
Land use	Suitability rating	Management considerations
Arable	Medium to low	Cool climate, rolling slopes, low fertility.
Horticulture	Low to unsuitable	Cool climate, low nutrient levels, rolling slopes.
Intensive pasture	Medium	Cool climate, low fertility.
Forestry	Medium to high	No limitations.

Waiteti hill soils

Land use	Suitability rating	Management considerations
Arable	Unsuitable	Cool climate, hilly slopes.
Horticulture	Unsuitable	Cool climate, low nutrient levels, hilly slopes.
Intensive pasture	Medium	Hilly slopes, cool climate.
Forestry	Medium to high	Hilly slopes.

Management practices to improve suitability

- Avoid soil tillage under dry, windy conditions.



Waitetī loamy sand

Soil Series Name: Whakarewarewa (Wh)

Overview

Whakarewarewa soil series occur on flat, rolling and hilly slopes in and near Whakarewarewa Forest south of the Rotorua area. Parent materials are shallow patchy Rotomahana Mud on 10 to 30 cm Taupo Tephra, on weathered rhyolitic tephra, Whakatane Tephra, Rotoma Tephra and Rotorua Tephra on ignimbrite. Soil profiles have very dark greyish-brown friable sandy loam, on yellowish brown sandy loam, resting on brownish yellow sand on olive yellow sand. The soils are classified as **Immature Orthic Pumice Soils.** Land use consists of forestry, dairying and dry stock.

Physical properties

Texture: Loam over sand

Topsoil clay content: 10 – 15%

Potential rooting depth: Unlimited

Rooting barrier: No significant barrier within 1 m

Drainage class: Well-drained

Permeability: Rapid

Profile total available water (0 – 100 cm): Moderate to high (121 mm), Moderate (98 mm), hill soils

Profile readily available water (0 – 100 cm): Moderate to high (88 mm), Moderate (68 mm), hill soils

Topsoil bulk density: 0.91 g/cm^3

Subsoil bulk density: 1.18 g/cm^3

Chemical properties

Topsoil organic matter: 8.6 – 12.1%

Topsoil P retention: Medium (51%)

Available P, Ca, Mg and K: Low

Soil types/variations

Whakarewarewa sandy loams are on flat to rolling land. **Whakarewarewa hill soils** occur on hilly slopes.

Associated and similar soils

Okareka steepland soils are on steep and very steep slopes with thinner tephra on ignimbrite. **Ngakuru series** are soils without Taupo Tephra. **Haparangi series** are soils with no Rotomahana Mud and the Whakatane Tephra is thin.

General land use suitability ratings

Whakarewarewa sandy loam

Land use	Suitability rating	Management considerations
Arable	Low	Rolling slopes, unstable soil structure, erosion potential.
Horticulture	Unsuitable	Low nutrient levels, unstable soil structure, rolling slopes.
Intensive pasture	Medium	Erosion potential.
Forestry	High	No limitations.

Whakarewarewa hill soils

Land use	Suitability rating	Management considerations
Arable	Unsuitable	Hilly slopes, unstable soil structure, erosion potential.
Horticulture	Unsuitable	Hilly slopes, unstable soil structure.
Intensive pasture	Medium	Hilly slopes, erosion potential.
Forestry	High	Hilly slopes, erosion potential.

Management practices to improve suitability

- Avoid soil tillage under dry, windy conditions.

Whakarewarewa sandy loam (Note Taupo pumice at spade handle. Spade 90 cm long)

Part 8: Glossary

ABC soil A soil that has an A, a B, and a C horizon.

Absorption Filling up of soil pores with water like a sponge soaks up water.

AC soil A soil that only has an A and a C horizon. Commonly, such soil formed in recent alluvium or on steep, rocky slopes.

Adsorption The attraction of ions or compounds to the surface of a solid. Soil colloids (clay and humus) adsorb large amounts of ions and water.

Aeolian Refers to wind-blown soil materials such as loess and sand.

Aeration The movement of air back and forth between the atmosphere and the pores of a soil.

Allophane A non-crystalline hydrous aluminium silicate clay mineral found in volcanic ash soils.

Allophanic Soils that are dominated by the clay mineral allophane (and also imogolite, ferrihydrite, and/or aluminium-humus complexes). They have a characteristically greasy feel, and high to very high phosphate retention.

Alluvium General term for unconsolidated materials such as gravel, sand, silt, clay or mixtures of these deposited on land by streams.

Andesite Volcanic rock composed essentially of andesine and one or more mafic constituents (such as pyroxene, hornblende, or biotite).

Anoxic Lacking oxygen, as in waterlogged soils.

Available water capacity (or available water-holding capacity) The maximum amount of water a soil can store for plant use in the upper 1 m. It is the difference between the amount of soil water held at **field capacity** (-10 kPa) and the amount at **wilting point** (-1,500 kPa). It is commonly expressed as mm of water. A good soil can provide around 230 – 305 mm of available water, a poor soil about 50 – 75 mm only.

Base saturation The extent to which the adsorption complex of a soil is saturated with exchangeable cations other than hydrogen and aluminium. It is expressed as a percentage of the soil's **cation exchange capacity**.

Breccia A coarse grained, clastic rock composed of angular, broken rock fragments held together by a mineral cement or a fine-grained matrix.

Boulders Rock fragments larger than 200 mm in diameter.

Buff layer Compact layer of alluvium derived from Kaharoa Tephra present in some soils such as Awaiti, Omeheu and Paroa series.

Bulk density Mass of dry soil per unit of bulk volume where **bulk volume** includes the volume of solids as well as the volume of pore spaces (total volume). It is expressed in g/cm^3 or t/m^3.

Caldera A large basin-shaped volcanic depression, more or less circular in form.

Cation exchange capacity The sum total of exchangeable cations that a soil can adsorb. It is expressed as centimoles of charge per kilogram of soil (cmol/kg).

Clastic Consisting of fragments of rocks.

Clay (1) Mineral soil particle with a diameter of less than 0.002 mm; (2) A soil textural class which is very plastic, very sticky and contains 60% or more clay.

Colour Colour gives some clues about the soil. Dark topsoils usually indicate high organic matter levels. Grey colours are indicative of poorly-drained soils. Yellowish-brown and reddish-brown colours generally indicate favourable air – water relations.

Colluvium Rock fragments or soil materials that have accumulated at the base of steep slopes due to gravity.

Compaction Reduction in the porosity of a soil due to cultivation and other mechanical forces.

Consistence The degree of cohesion and adhesion of peds, and the ease with which they are dislodged from the soil profile.

Creep (also called scree creep) Slow mass movement of soil down relatively steep slopes, mainly under the influence of gravity, but enhanced by saturation with water and by alternate freezing and thawing. Commonly seen as terracettes on hill slopes.

Dacite Extrusive rock with principal minerals plagioclase (andesine and oligoclase), quartz, pyroxene or hornblende or both, with minor biotite and sanidine.

Diatomaceous earth Fine, greyish siliceous material composed primarily of the remains of diatoms that have accumulated mainly in water. It may occur as a powder or as a porous, rigid material.

Drainage class The degree of wetness of a soil, as determined by the depth to a water table and the length of time the soil remains saturated. Common drainage classes include well-drained, moderately well-drained, imperfectly drained and poorly-drained.

Droughty A soil incapable of storing much water for plant use. Coarse sandy, stony, gravelly, sandy, shallow and steeply sloping soils are likely to be droughty unless they are supplied with rainfall or irrigation water frequently.

Dune A low hill or bank of drifted sand. Also mounds or ridges of wind-blown or aeolian sand are dunes.

Evapotranspiration. Between periods of rain, water held in the soil is gradually given up by direct evaporation from the soil surface and by plant transpiration. The combined water loss by these two means is called evapotranspiration.

Fan (alluvial) A low, outspread mass of loose materials and/or rock material, commonly with gentle slopes, shaped like an open fan or a segment of a cone, deposited by a stream.

Field capacity The moisture content of a soil when free drainage (one to two days after a heavy rain or irrigation) has virtually stopped. It is the maximum amount of water a soil can retain against the force of gravity. It is also called the upper limit of available water.

Fine earth All soil materials less than 2 mm in diameter.

Flats A flat or surface of low relief. Generally used to indicate flat river terraces.

Floodplain The nearly level surface next to a river that is covered with water when the river floods.

Gleyed Soil that is very wet for long periods of time and is characterized by grey colours, with or without mottles.

Gley soil Soil that formed under poor drainage, resulting in the reduction of iron, manganese and other elements in the profile and in grey colours.

Gravel Small, rounded coarse fragments in soils with a diameter ranging from 2 mm – 200 mm.

Greywacke A type of sandstone characterised by its dark colour, hardness and angular rock particles in a clayey matrix.

Groundwater The water below ground which saturates the subsoil. The upper surface of the zone of saturation is the water table.

Hummocky Regular or irregular small elevations or hillocks.

Humus The relatively resistant fraction of soil organic matter that forms during biological decomposition of organic residues. Humus usually constitutes the major fraction of soil organic matter.

Ignimbrite An igneous rock formed by the lithification of ash flow or pyroclastic flow deposits.

Inclusion An area of soil that is too small to show separately at the scale of the soil map. Inclusions can only be mapped out separately by making very detailed maps at very large scales.

Infiltration The rate at which water enters the soil. It is dependent on the size of pores and the stability of soil aggregates on the soil surface. If water cannot infiltrate, it either ponds on the surface or runs off over the surface.

Landform Any recognisable physical form or feature of the earth's surface having a characteristic shape and resulting from natural causes.

Landscape A portion of the land that the eye can comprehend in a single view, including all its natural characteristics.

Lapilli See **tephra**.

Leaching Removal of soluble materials such as minerals, nutrients, organic chemicals and pesticides from the soil by water passing through it either as rainfall or irrigation.

Levee A long, broad low ridge or embankment of sand and coarse silt, built by a stream on its flood plain and along both sides of its channel, especially in time of flood when water overflowing the normal banks is forced to deposit the coarsest part of its load.

Limiting layer Gravel, pan or stagnant water that limits plant root growth.

Loess Silt and fine sand particles deposited by the wind.

Mottles or Mottling Spots or blotches of grey or brown colour different from the dominant soil colour that indicate the height of fluctuating water tables and hence the degree of soil aeration.

Muck See **peat**.

Mudstone Silt- and clay-containing sedimentary rock that is non-plastic and has a massive appearance.

Organic matter Plant and animal residues in the soil in various stages of decomposition.

Organic soil Soil 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.

Oxbow A crescent-shaped lake formed in an abandoned river bend which has become separated from the stream by a change in the course of the river

Paleosol A soil that formed on a landscape in the past and that has distinctive morphological characteristics resulting from a soil-forming environment that no longer exists at the site. The former soil-forming process was either altered due to environmental change (e.g. climatic change) or interrupted by burial (e.g. occurrence of a **buried soil** during a volcanic eruption or past flooding).

Pan A compact, dense layer in a soil that restricts the movement of water and penetration by plant roots.

Parent material Unconsolidated organic and mineral material from which the soil develops.

Parent rock The rock from which the parent material is derived.

Peat Organic soil material in which the plant residues are still recognisable. This contrasts with **muck** in which the original plant residues cannot be recognised any more.

Ped A naturally-occurring soil aggregate, as opposed to a **clod,** which is formed artificially (e.g. through cultivation).

Permeability The rate at which water moves through the soil. It depends on the amount, size and interconnectedness of the pores, which in turn depend on soil texture, structure and bulk density.

pH The degree of acidity or alkalinity of a soil. A pH of 7 indicates a neutral soil. Lower values indicate acidic soils; higher numbers indicate alkaline soils.

Phosphate, or P, retention Expressed as a percentage, this is a measure of the degree of phosphate retention or immobilisation by soil minerals. For the same amount of phosphate fertiliser applied, soils with high P-retention values will give lower crop yields than soils with low P-retention values.

Podzol A strongly acidic soil that usually has a bleached soil horizon immediately below the topsoil. It occurs in high rainfall areas and is associated with forest trees with an acidic litter.

Pore space Soil space not occupied by solid particles (i.e. occupied by air and water).

Porosity The total volume of pore space in the soil expressed as a percentage of the bulk or total soil volume.

Potential rooting depth Total depth of soil suitable for plant root growth, measured from the surface to the top of a barrier (within 1 m of the soil surface) that limits root extension. Actual rooting depth depends on the depth plant roots actually penetrate.

Pumice Light vesicular form of volcanic glass with a high silica content. It is usually light in colour and some can float on water.

Pumice soil A soil with properties dominated by pumice and glass with a low clay content (which contains allophane). It occurs in sandy or pumiceous tephra with an age range of 700 – 3,500 years.

Readily available water The amount of water easily extractable by plant roots. It is the amount of water held between -10 kPa and -100 kPa suction. It is expressed as an equivalent depth of water in mm.

Ridge A relatively narrow elevation which is prominent on account of the steep angle at which it rises.

Rooting barrier The type of barrier that limits root penetration (e.g. compact soil horizons, pans, rocks, densely packed gravels, anaerobic conditions and high water tables).

Rhyolite A light, fined-grained igneous rock formed by the rapid cooling of lava rich in silica.

Runoff Water that flows over the surface of soil toward a stream or lake without sinking into the soil.

Sand (1) Mineral soil particle with a diameter range of 2.0 – 0.06 mm. Further subdivided into coarse sand (2.0 – 0.6 mm), medium sand (0.6 – 0.2 mm) and fine sand (0.2 – 0.06 mm); (2) A soil textural class containing 80% or more sand.

Sandstone Sedimentary rock consisting predominantly of sand-sized particles.

Scree A heap of rock waste at the base of a cliff or a sheet of coarse debris mantling a mountain slope.

Seepage Water that seeps toward stream channels after infiltration into the ground.

Shale Sedimentary rock formed by the hardening of a clay deposit.

Silt (1) Mineral soil particle with a diameter range of 0.06 – 0.002 mm; (2) A soil textural class (82% or more silt) which feels extremely smooth and silky.

Siltstone Sedimentary rock made up of predominantly silt-sized particles.

Skeletal Soils with horizons containing 35% or more gravel by volume.

Slope The inclination of the land suface expressed in degree angle from the horizontal.

Soil A natural body on the earth's surface that develops in response to climate and organisms acting on a parent material in a specific landscape position over a long period of time. Soil supplies plants with air, water, nutrients and provides mechanical support.

Soil association A group of soils geographically associated in a characteristic repeating pattern, and defined and delineated as a single map unit.

Soil complex (1) A map unit of two or more kinds of soil so intimately intermixed geographically that it is not practical to map them separately at the selected scale of mapping; (2) A more intimate mixing of smaller areas of individual soil mapping units than that in a soil association.

Soil horizon A layer of soil, approximately parallel to the surface, having distinct characteristics produced by soil-forming processes. From top to bottom, soil horizons are named as A, B, and C.

Soil morphology The physical makeup of the soil, which includes thickness and arrangement of soil horizons, colour, texture, structure, consistence, roots, horizon boundaries, etc.

Soil phase A subdivision of a soil series based on features that affect its use and management such as slope, stoniness, flooding, etc.

Soil profile A vertical section of the soil showing all its horizons and extending into the parent material.

Soil series A group of soils that have similar profile characteristics except for differences in texture of the surface layer. Traditionally, a soil series is named after the place where the soil was first observed and described (e.g. Taupo soil series).

Soil survey The process of producing a soil map. A soil surveyor walks over the land, and observes and records soil and landscape features, classifies the soils, and locates soil boundaries in the field. The surveyor uses aerial photos as base maps to delineate soil boundaries and label each area, or polygon, with a map unit symbol.

Soil survey report A publication containing the results of a soil survey of an area. It consists of the soil map, text describing the properties and behaviour of soils, and tables containing interpretations for soil use and management.

Soil type A subdivision within a soil series to distinguish soils differing in surface texture only (e.g. Taupo sand, Taupo sandy loam, etc.).

Soil variant A soil whose properties are believed to be different enough from other known soils to justify creation of a new series name but, because of its limited geographic extent, the creation is not justified.

Stones Rock fragments ranging from boulders to gravels.

Stony Soil that contains 5 – 35% stones in the upper 20 cm. Stones limit the volume of soil that is available for roots to explore for water and nutrients. They can also significantly interfere with or prevent tillage operations. Where stones consist of lapilli, these do not adversely affect land use since these are light materials and do not present an impediment to cultivation.

Spur A subordinate ridge which extends itself from the crest of a hill or mountain like ribs from the vertebral column.

Structure The arrangement of the primary particles sand, silt and clay into larger units called aggregates or peds. Plant roots, clay and organic matter help bind aggregates together.

Subsidence Lowering of the soil surface due to settling or shrinkage. Drainage of organic soils results in subsidence through increased aeration, and the loss of organic matter through decomposition.

Swale A slight depression in an area of generally flat land.

Tephra A name for all unconsolidated **clastic** volcanic material that, during an eruption, is transported through the air from the source. This term should not be confused with grain size classes: fine ash (less than 0.25 mm); coarse ash (0.25 – 2.0 mm); lapilli (2.0 – 64 mm).

Texture The relative proportion of sand, silt and clay particles in a soil. Specific combinations of sand, silt and clay are known as **textural classes**. Examples include sandy loam, silt loam, clay, etc.

Vesicular Containing many small cavities or air holes (as in Taupo Pumice).

Volcanic ash Fine, ash-like rock particles ejected from a volcano during an eruption that may be transported long distances by the wind.

Water table The upper level of water stored under the ground.

Wilting point The moisture content of a soil at which plants can no longer extract water. Clayey soils contain relatively large amounts of water at the wilting point, but it is held so tightly inside the very small pores of the clay that plants are unable to extract it.

Years before present Carbon-14 dating system for tephras using 1950 as the base year.

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Part 10: Index to Central Bay of Plenty soil series

No.	Soil Series Name	Map Symbol	Soil Order	Page
35	Pohaturoa	PoS	Pumice	128
36	Poronui	Poi	Pumice	130
37	Pukemaku	PkS	Pumice	132
38	Pukerimu	Py	Pumice	134
39	Rangitaiki	Ran	Recent	137
40	Rotoiti	Rt	Pumice	140
41	Rotomahana	R	Recent	143
42	Tarawera	Tr	Recent	146
43	Tauhara	TaS	Pumice	149
44	Taupo	Tp	Pumice	151
45	Te Ngae	Ten	Recent	154
46	Te Rere	Te	Pumice	157
47	Te Teki	TtS	Podzol	160
48	Tihoi	Toi	Podzol	162
49	Tikitere	T	Recent	165
50	Utuhina	Ut	Organic	167
51	Waikokomuka	Wo	Recent/Raw	169
52	Waimangu	WgH	Pumice	172
53	Waiowhiro	Wa	Recent	174
54	Waipahihi	Yp	Pumice	176
55	Waiteti	W	Podzol	179
56	Whakarewarewa	Wh	Pumice	182