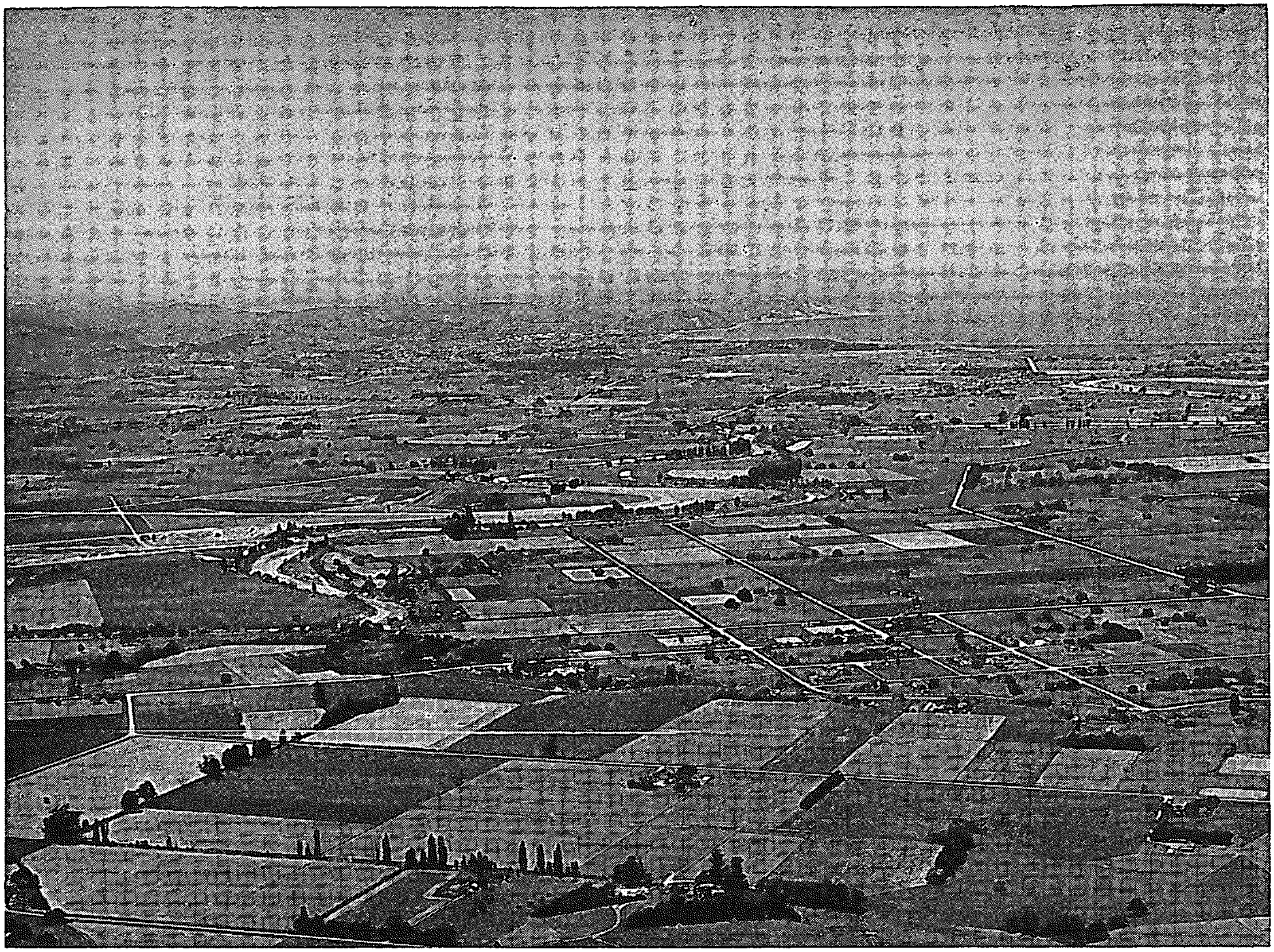
SOILS AND AGRICULTURE OF GISBORNE PLAINS



Photo, Whites Aviation, Ltd.

Fig. 1. Aerial panorama of Gisborne Plains looking east towards Gisborne from Patutahi

NEW ZEALAND DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

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SOILS AND AGRICULTURE OF GISBORNE PLAINS

By

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PREFACE

The Gisborne Plains lie on the east coast of the North Island between East Cape and Hawke's Bay. The area has an equable climate and highly productive soils, but it is rather isolated from large centres of population and markets like Wellington and Auckland. As well, there are periodic, large-scale floodings, which have discouraged intensive settlement and farming. These disadvantages are being gradually overcome by better communications and by the implementation of the Waipaoa River Flood Control Scheme.

The main purposes of this bulletin are:

1. To present a detailed account of the soils and related agriculture of the Gisborne Plains,
2. To indicate how the land may be used to best advantage, and
3. To evaluate the effect of recent floodings on the soils.

These purposes extend beyond the activities of the Soil Bureau and separate contributions were supplied by the following specialists:

Mr H. de O. Chamberlain, Department of Agriculture;
Mr H. Conway, Department of Maori Affairs;
Dr J. F. de Lisle, N.Z. Meteorological Service;
Mr T. L. Grant-Taylor, N.Z. Geological Survey, D.S.I.R.;
Mr J. G. McKee, formerly of Grasslands Division, D.S.I.R.;
Mr A. M. C. Moore, N.Z. Forest Service;
Mr L. R. Renouf, J. Wattie Canneries Ltd;
Mr D. P. Sinclair, Department of Agriculture;
Mr A. D. Todd, Povery Bay Catchment Board;
Mr R. S. Viney, Department of Agriculture.

Specific acknowledgment of these contributions is made in the appropriate sections in the text.

The soil information was compiled by the author from his surveys and from data supplied by other members of Soil Bureau. Valuable assistance in the interpretation of the data and in the preparation of the report was received from members of the Soil Bureau and is gratefully acknowledged. Thanks are also due to the many farmers who volunteered information during the survey; to Miss R. Mason, Mr A. P. Druce, Mr N. Potts, and Mr R. D. Creswell for notes on the vegetation; to the Chief Draughtsman, Department of Lands and Survey, for assistance in draughting preliminary maps, and to the Engineer, Poverty Bay Catchment Board, for use of maps, plans, and sections.

Accompanying the text are soil maps on a scale of 20 chains to an inch. Boundaries of holdings and the names of the occupiers are mainly those at the end of 1952; but details of the Waipaoa Flood Control Scheme are as at the end of 1954. Appendices have been included for those readers who desire further information on climatic elements, soil profiles, and ground water.

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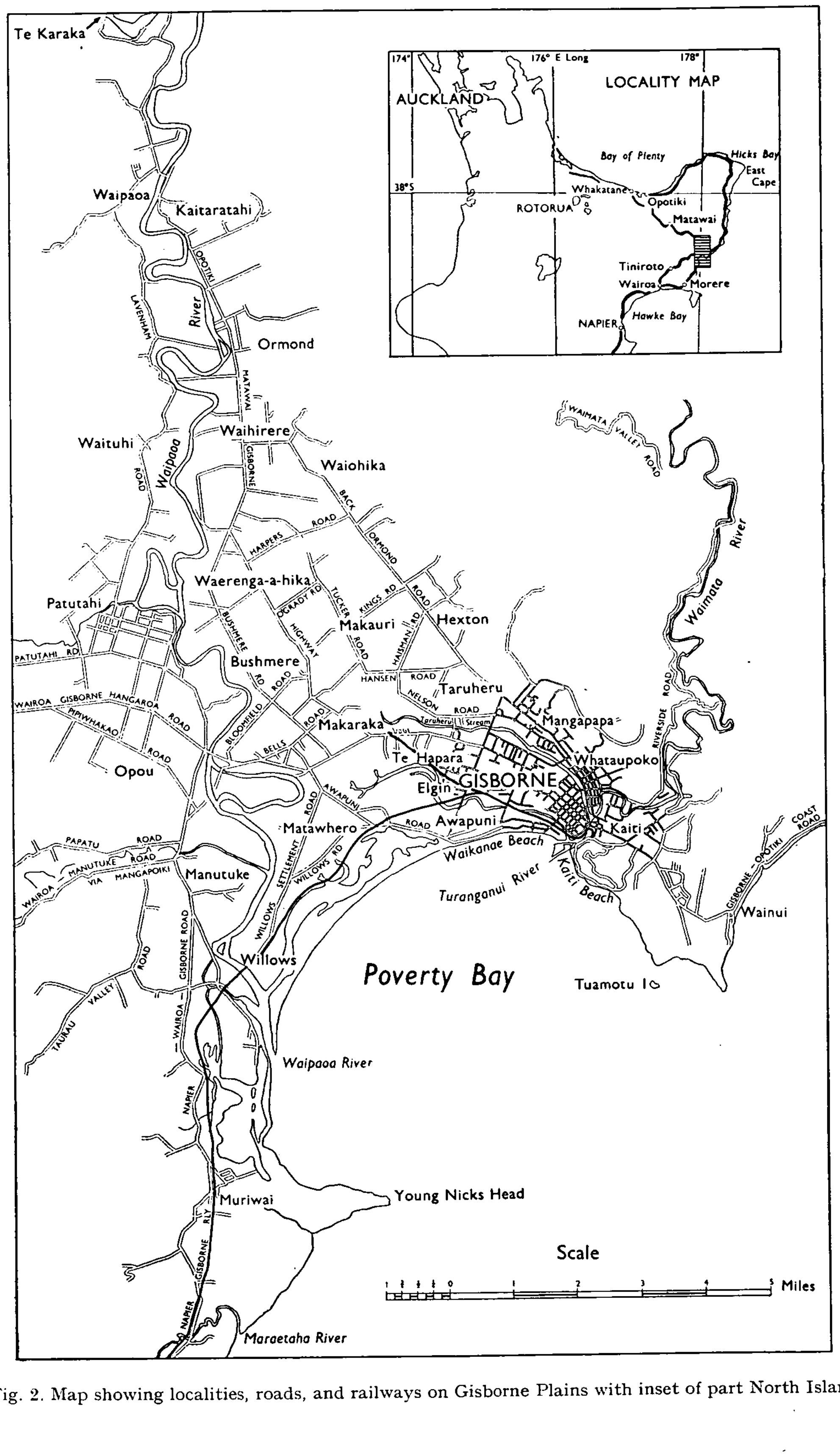


Fig. 2. Map showing localities, roads, and railways on Gisborne Plains with inset of part North Island

Soils and Agriculture of Gisborne Plains

GENERAL DESCRIPTION OF AREA

The Gisborne Plains are a large lowland situated at the lower end of the Waipaoa Valley on the east coast of the North Island of New Zealand (fig. 2). Their shape is roughly that of an isosceles triangle with the apex to the north-west near Te Karaka, 13 miles from the coast, and with the base along Poverty Bay from Young Nick's Head to the mouth of the Turanganui River, a distance of 8 miles. The area is about 50,000 acres and includes most of the flat land shown on sheet N98 and part of that on sheet N107 of the One-mile Provisional series (N.Z. M.S. 1) published by the Department of Lands and Survey, 1946. The area surveyed does not include the high-level terrace on the eastern side of the plains, the small isolated hills near Patutahi, nor areas in tributary valleys much beyond the western margin of sheet N98.

The plains are set amidst steep, strongly sculptured hills. The main river is the Waipaoa, a narrow, entrenched, meandering river with its course slightly west of the middle of the plains. Another large river, the Waimata, enters the plains at Gisborne and there joins with the Taruheru River to form the Turanganui River.

Gisborne, at the junction of the Taruheru and Waimata Rivers, is the principal town and port for a large region of which the plains form a small part. Its chief function is to service the farming industry in Cook, Waikohu, Uawa, and Waiapu Counties and part of Matakaoa county.

HISTORICAL*

During Maori occupation, the area was called Turanga; in 1769 Captain Cook named it Poverty Bay. During European occupation it has been variously called Poverty Bay Flats or Gisborne Flats, but since the Second World War the name Gisborne Plains has come into general use.

*Material for this section is drawn freely from *Historic Poverty Bay*, by J. A. Mackay, 1949.

The Maoris settled more closely the south-west corner of the plains than inland areas; there is evidence from the soils that there were settlements from time to time along the high banks of Waipaoa River from Te Karaka to the sea. Along Poverty Bay one settlement stretched for a mile or more.

The flax trade was started in the late 1820s, and in the early 1830s the Maoris also reared pigs and grew potatoes and maize; as the demand for flax dwindled, maize was grown more extensively. Products of the land were bartered chiefly for firearms. Wheat was grown in 1840, and by 1850 the harvest had risen to 10,000 bushels, most of which was exported to Auckland. By the early 1860s the Maoris' interest in agriculture had waned; Europeans were then looking for land on which to pasture their sheep, and, as the Maori was not familiar with sheep farming, he supplied his labour to the sheep stations.

Bushfelling began in the Bushmere locality in the early 1830s and by 1880 was on an extensive scale. The forest at Opou was destroyed by fire in 1865 and that at Makauri in 1878.

Grassland farming began in 1835 with the purchase, by John William Harris, of land at Opou for the raising of sheep and cattle. In 1851, according to Donald McLean, "the flats were covered in rich grasses", and by 1858 there was a large trade in ryegrass seed with Sydney.

Settlement of the plains was temporarily checked by the East Coast wars in 1865 and by Te Kooti's revolt in 1868; but between 1871 and 1875 there was a rapid advance in settlement. At this time, too, the hills surrounding the plains were being brought into production; large tracts were taken for sheep stations, which were stocked with sheep brought overland from Hawke's Bay. By 1880 most of the land on the plains was settled and fenced.

The plains are now highly developed; settlement has tended towards smaller holdings and has been accelerated by two world wars. After the Second World War, land on well drained soils at Manutuke and Matawhero was selected for subdivision into 10-acre holdings for orchards.

Gisborne began as a trading centre, which was very active about 1840 and later on became a supply base for hill-country stations in the Gisborne - East Coast region. The township site was not surveyed and formally named until 1869. It was proclaimed a borough in 1877 and became a city in 1955. For a long time the chief industry was associated with meat export; but since the Second World War other secondary industries have been established on a small scale. The city is sited almost wholly on flat land which does not rise more than 50 ft above mean sea level. Soils are for the most part sandy and there is sufficient room for expansion to meet the present needs of the city without encroaching too much on highly productive land.

The population in 1874 was 554 and in 50 years grew to more than 12,000. During the next 20 years (to 1945) the increase was only 3,000, but in the decade 1945–55 growth has been more rapid. In 1955 the population of Gisborne city was 20,000, and that on the plains about 5,500. The increased growth after the Second World War may be attributed more to the development of the plains themselves than to that of the hill country round about.

The Port of Gisborne is small but can handle vessels up to 3,000 tons displacement. Larger vessels are loaded in Poverty Bay. The toal tonnage of imports and exports, and cargo lightered in 1902, was about 45,000 tons, and in 1957 was 84,000 tons. Among coastal vessels there is no scheduled service between Gisborne and other ports. Vessels make the round of New Zealand ports in which Gisborne is usually included.

The considerable relief and the soft, unstable rocks of the hill country surrounding the plains are obstacles to good and permanent communications. The Gisborne-Napier railway was opened in 1942 and there is a branch line to Moutohora, 50 miles north-west of Gisborne*. There are two roads south to Napier, one near the coast via Morere and one inland via Tiniroto, and there are two routes to Auckland via Opotiki, one west through Waioeka Gorge, and a much longer one around the coast through Te Araroa and Hicks Bay (fig. 2). There is a daily air service to the South Island and twice-daily flights to both Auckland and Wellington.

*Branch line closed 1959.

Air transport of goods of all sorts, including pedigree livestock, is increasing.

The plains are well served by good, metalled roads which offer quick and easy access to Gisborne (fig. 2). Electricity, supplied by the Poverty Bay Electric Power Board, is everywhere available.

FARMING LAND

The area of flat land on Gisborne plains is approximately 50,000 acres, but only 42,600 acres is available for farming. The proportion of freehold land is 73%, of Maori land 14%, and of Crown land 10%; land vested in the Poverty Bay Catchment Board for purposes of flood control is 3%. The distribution of holdings is given in table 1.

The table shows that more than 50% of the holdings are less than 20 ac and cover slightly more than 10% of the plains. Holdings larger than 100 ac cover nearly 50% of the plains and have 10% of the occupiers. Most occupiers with flat land holdings have little interest in hill-country holdings and therefore most of the production from the plains is considered to be independent of the hill country surrounding them.

PHYSIOGRAPHY

Landscape Units

The plains are a lowland formed by infilling of inlets of the sea (Henderson and Ongley, 1920). They are for the most part flat (fig. 1) and comprise the following distinct physiographic units: flood plains, raised beach, new beach, tidal flats, alluvial fans, high-level terrace, and "plain surrounded islands".

Flood plains are the predominant unit. They are bounded on the south by the tidal flats and on the south-east by the raised beach, which is flanked coastwise by the new beach. They are separated from the hills on the east by remnants of a high-level terrace and by small alluvial fans, and at Patutahi, Muriwai, and Kaiti they surround a number of small hills. In the south, at their widest part, they have a broadly convex surface, but in the north, where they are narrow, the surface is broken by a trench, up to 40 chains wide, extending from Te Karaka to Waerenga-a-Hika. This trench has been carved in the old flood plain and is 7 to 15 ft below it. The floor of the depression is part of the modern flood plain and in it the Waipaoa River is entrenched 25 to 30 ft.

Waipaoa River has a meandering habit and many of its previous courses are marked by cut-off meanders or ox-bow loops, which in the modern

TABLE 1: Size Classes of Holdings on Gisborne Plains and Number of Occupiers of Each Class

Size of holding (ac)	2–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80	81–90	91–100	101–150	151–200	201–250	251–300	301–400	>400	Total
No. occupiers ..	345	147	93	60	51	57	39	23	13	15	36	20	9	6	9	9	932
Aggregate area (ac)..	2,130	2,290	2,310	2,310	2,320	3,160	2,550	1,730	1,100	1,430	4,200	3,490	2,040	1,650	3,170	5,900	41,600*
Percentage occupiers	37·0	15·7	10·0	6·4	5·5	6·1	4·2	2·5	1·4	1·6	3·9	2·1	1·0	0·6	1·0	1·0	100·0
Percentage aggregated area	5·1	5·5	5·6	5·2	5·6	7·6	6·1	4·2	2·6	3·4	10·0	8·4	4·9	4·0	7·6	14·2	100·0

*Holdings of less than 2 ac aggregate 1,000 ac and make up the balance of area available for farming (42,600 ac).

flood plain have been almost filled in but in the old flood plain are still well defined; one good example lies near the Matawhero bridge. Over a long period the river has built up its banks by flooding, layer upon layer, to form natural banks or levees, and on the old flood plain these rise very gradually to a height of 5 to 10 ft above the surrounding terrain. Within the convex bends of meander loops at Matawhero and at Te Wairau the relief is ridgy, but in bends on the modern flood plain at Waerenga-a-Hika and Kaitaratahi the ridges have been obliterated by thick sediments deposited during the last 20 years.

The tributaries of Waipaoa River, the Whakaahu Stream, and Te Arai River, and most other streams, are deep and narrow; the natural levees of tributary streams range in height from 10 to 20 ft.

On the old flood plain at Opou, Makauri, and Ormond are large, shallow, saucer-shaped depressions bounded by levees of rivers and streams on one side and by hills on the other. These were naturally swampy and were drained by very sluggish streams.

The flood plains are really a large fan through the apex of which the Waipaoa River has cut down in two stages to give the old flood plain and the trench. In the trench flooding is frequent, but, south of it, overflows occur only during major floods. The old flood plain has for a long time been above flood level, but in the 1948 flood parts were inundated at Waihirere and Matawhero Railway Station. There is thus a variety of flood plains, including (a) modern flood plain with frequent flooding, (b) modern flood plain with periodic flooding, and (c) old flood plain with no flooding at present (see p. 15).

The *raised beach* (Henderson and Ongley, 1920) occurs about Gisborne city and at Wainui. It is characterised by a series of parallel, closely spaced, continuous sand ridges that start in the Makaraka locality and sweep eastwards in a broad arc to Waimata and Turanganui Rivers. The ridges rise progressively but unevenly from about 15 ft above mean sea level at Childers Road to about 40 ft above mean sea level along Hansen Road, 3 miles inland from the coast. They are 1 to 2 ch wide, are separated by sandy swales 1 to 3 ch wide, and are commonly 3 to 5 ft high with some at 10 ft. From Makaraka, westwards, they dip under the flood plain. The ridges mark the successive shore lines of Poverty Bay over a long period: the older ridges inland preserve the westerly direction of the ancient coast and the newer ones follow the present coastline in a south-westerly direction.

The sand ridges were built up by the sea and they are mantled with 12 in. of volcanic ash, considered to be one of the Taupo showers of 1,800 years ago. The thickness of the sand on either side of Taruheru River varies from 10 to 20 ft, but seawards it is greater.

The *new beach* abuts the raised beach, and its ridges continue, unbroken, to the coast. Its junction with the raised beach is indicated chiefly by the absence of volcanic ash on the new beach and by the occurrence of pumice boulders 3 to 10 in. long and 2 to 6 in. wide in the soil at the junction. This line is considered to be the shore line at the time of the Taupo eruption. Other shore lines are marked by Waikanae Creek and Awapuni Lagoon. There is a short foredune about 20 ft high near Gisborne abattoirs, and the ridges inland fall away to as low as 7 ft above mean sea level about Waikanae Creek but rise again to 17 ft along Childers Road.

Along the coast, from Young Nick's Head to Gisborne abattoirs, is a narrow strip of *tidal flats*, separated from the open sea by foredune and storm beach. The largest individual flat is commonly known as the Awapuni Lagoon.

At the point where streams pass from hills to the plains, a gently sloping *alluvial fan* is sometimes built up. Such fans are restricted to a narrow strip at the foot of the high-level terrace at Hexton and Waiohika and to an irregularly shaped strip at the foot of hills in Kaiti, Tamarau, and Wainui localities. There is also a large fan adjoining the western hills at Patutahi. Commonly, the fans coalesce and have very gentle slopes (2°). At Hexton the fans are built up of loose, porous material through which water moves freely, and consequently lower lying land nearby is wet for long periods.

The name *plain surrounded islands* (Henderson and Ongley, 1920) refers to a number of isolated hills, which, at Patutahi, seem to be connected by buried ridges, and which, at Kaiti Hill, Young Nick's Head, and Tuaheni Point, appear to have been once surrounded by the sea. Shallowly buried ridges also occur at Kaiti and at Mangapapa.

Natural Drainage

The Waipaoa is the principal river and in the 34 miles from Te Karaka to the sea it falls 95 ft. The three main tributaries, the Pouarua, Whakaahu*, and Te Arai, enter the plain from the western hills (fig. 4). In the south-west are four small independent streams, Karaua Creek, Foxley's Creek, Pakowai Stream, and Wairekaia Stream, all of which collect drainage waters from the western hills; the first three discharge into the tidal flats at Muriwai and the fourth into the Maraetaha River near its mouth.

On the eastern side of the plains are several streams that have no connection with Waipaoa River. The Waihirere Stream arises in the eastern hills and, at their foot, flows into the Taruheru River. Waikanae Creek and some tributaries of the Taruheru River rise in small swamps that are continually fed with ground water and periodically replenished with storm water from large artificial drains. On this side of the plains, particularly at Waihirere and Makauri, is a fine network of small natural courses all leading into the main streams. These small channels are commonly dry in summer; they sometimes start abruptly and, in a wet year, small springs may be observed at their sources. This system of small channels actually drains the land on the plains, much more so than does Waipaoa River and its tributaries on the western side. The Kaiti-Tamarau basin is drained by Wainui Stream and Kopuawhakapata Creek.

The volcanic ash that mantles the raised beach occurs in the alluvium of the flood plains as a thin bed of pumice 6 in. thick. On the margins of the plains it may act as an underground drain (see p. 31 and p. 89).

At the time of European settlement the depressions in the flood plains were semi-swamps which acted as temporary reservoirs to collect rainwater that fell into them. Water drained away slowly by sluggish streams and by soaking through the soil. A large area of soils was naturally poorly drained, and, to make the land usable for agriculture, artificial drainage on a large scale was necessary (p. 55).

*Also known as Waikakariki.

CLIMATE

The climate of the plains is mild, equable, and pleasant. July is the coldest month with a mean daily minimum temperature of 39·8°F, and February is the warmest with a mean daily maximum temperature of 76·8°F. The approximate mean annual temperature is 57°F. The relative humidity ranges from 62% in December to 82% in July. Both snow and hail rarely fall, and frosts are infrequent, though they have occurred in all months except January and February. The prevailing wind is north-westerly, which is usually warm and dry; southerly winds are cold and wet but of short duration. Sunshine hours per year average 2,242, which is less than Nelson (2,490), Napier (2,406), and Tauranga (2,376).

The annual rainfall is about 41 in. and is distributed over 120 to 150 rain days, with more rain in late autumn and mid winter. The plains do not have a very high rainfall because they are situated on the east coast in a latitude of prevailing westerly winds; such winds are forced to drop their moisture on high hills well to the west of the plains. Nevertheless, Gisborne receives more rain than Napier (31 in. per annum) because high hills at the coast collect moisture from easterly and south-easterly air streams. This also explains why there is less sunshine than at Napier.

The rainfall is markedly variable and individual heavy falls are as likely to occur on the plains as on the hills. Such heavy falls in the summer and autumn cannot be predicted because the rain is derived from tropical cyclones and extra-tropical depressions, which occur erratically and which move over the northern part of New Zealand.

Climatic elements are further discussed in Appendix 1, where detailed records are set out for reference purposes. The subject of climate, soils, and crop plants is discussed in the section Climate and Agriculture (p. 56) and that of climate and pasture growth is mentioned in the section, Pasture Growth on Gisborne Plains (p. 69). Seasonal rainfall characteristics are illustrated in Appendix 1 (p. 76).

VEGETATION

The probable distribution of the trees and other plants growing at the time of European settlement is plotted in fig. 3. The most common tree was kahikatea (white pine), which grew with pukatea, puriri, and tawa on poorly drained soils, and with tawa, titoki, rimu, and, in a few places, with miro, totara, and matai, on better drained soils about Waipaoa and Te Arai Rivers. There were few puriri trees, however, west of Waipaoa River. On

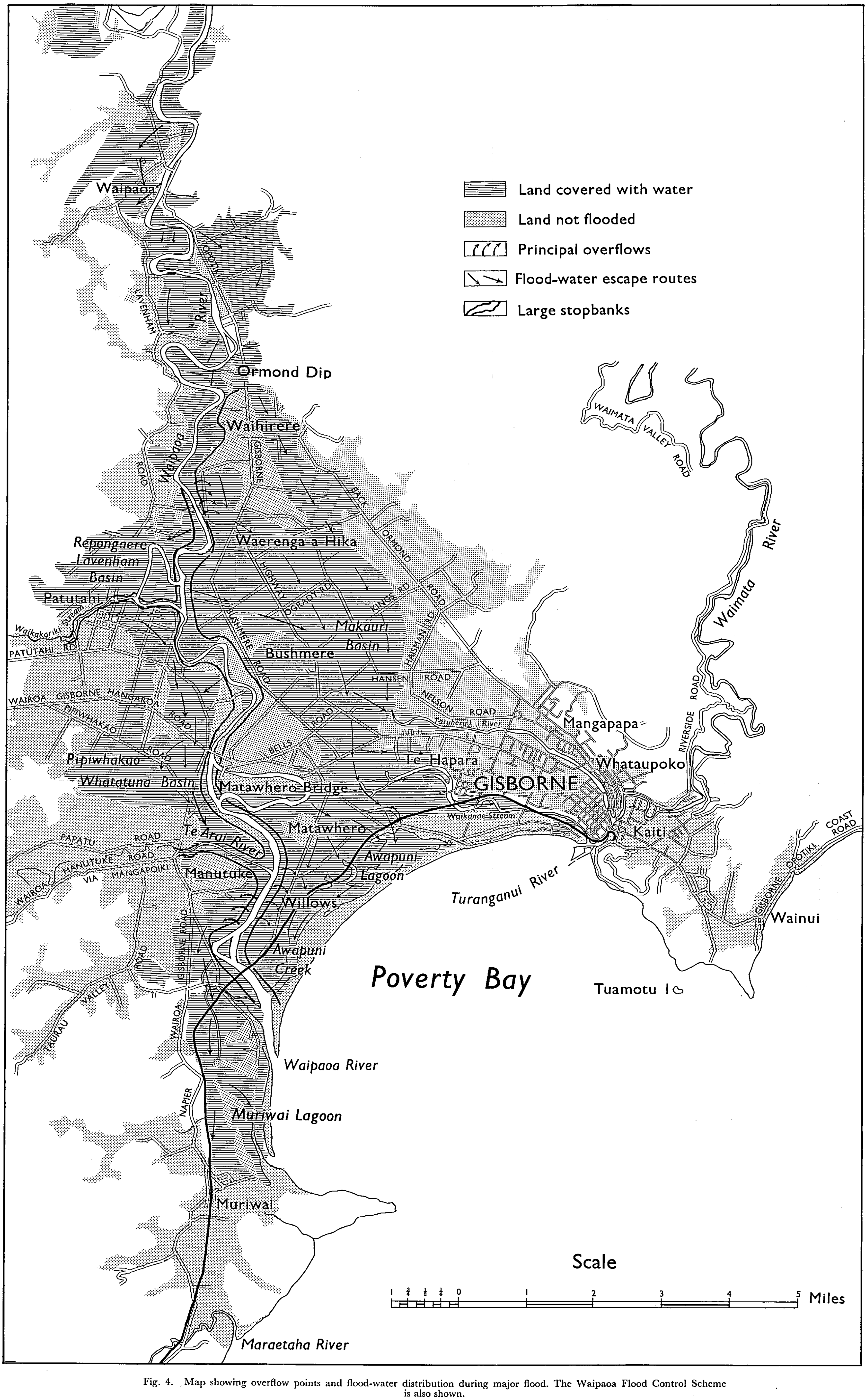


Fig. 4. Map showing overflow points and flood-water distribution during major flood. The Waipaoa Flood Control Scheme is also shown.

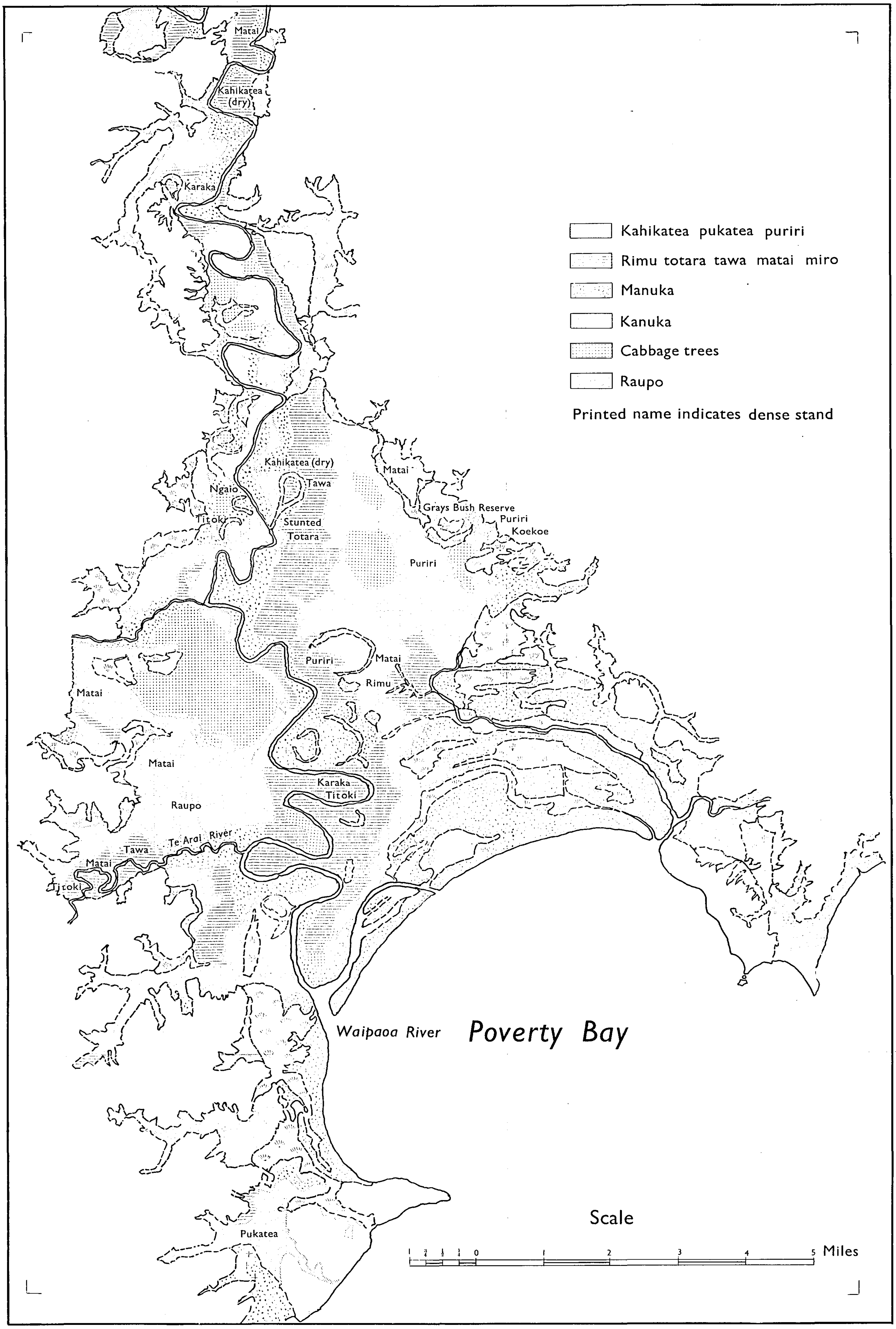


Fig. 3. Map of probable vegetation at the time of European settlement

the beachlands, which extend nearly 3 miles inland, there were mainly manuka and bracken fern with some kanuka. In the swamps, which were small but numerous, raupo, sedges, and toetoe flourished.

Along the high banks of both the Waipaoa and Te Arai Rivers manuka and kanuka grew around small patches of land cleared by the Maoris. Ngaio and karaka trees were also present near Waipaoa River. Later on in the period of European settlement, when much of the white pine forest was felled, cabbage trees began to appear; small groves occur in many localities, the largest single area being in the Patutahi locality.

A probable remnant of the pre-settlement plant cover is preserved at Gray's Bush Reserve, 6 miles north of Gisborne (see sheet 3 of soil map). A description of this remnant by Mr A. M. C. Moore, N.Z. Forest Service, is as follows:

The dominant tree is kahikatea (*Podocarpus dacrydioides*) with pukatea (*Laurelia novae-zelandiae*) as co-dominant and puriri (*Vitex lucens*) and tawa (*Beilschmiedia tawa*) as sub-dominants. The undergrowth is open and includes the following sapling and thicket species in order of preponderance; kawakawa (*Macropiper excelsum*), hangehange (*Geniostoma ligustrifolium*), pigeonwood (*Hedycarya arborea*), mahoe (*Melicytus ramiflorus*), karaka (*Corynocarpus laevigata*), nikau (*Rhopalostylis sapida*), white maire (*Gymnelaea lanceolata*) and three coprosma species. On the outskirts there are ngaio (*Myoporum laetum*), mapou (*Myrsine australis*), tarata (*Pittosporum eugenioides*), lace bark (*Hoheria populnea*), flax (*Phormium tenax*) and wineberry (*Aristotelia serrata*), and on the periphery there is the cabbage tree (*Cordyline australis*). The floor is clean, with only three small species of fern and a few mosses and liverworts. The epiphyte, kiekie, also adopts a prostrate habit on the forest floor.

The forest is young and healthy but there are few seedling trees to replace those that die. Puriri has grown well but tawa is misshapen, and pukatea has developed poorly as a result of attacks by fungus. Dominant trees are surface rooting, which indicates a wet soil in winter. The soil (Makauri clay loam) is naturally poorly drained and, as well, collects more water than usual because of seepage from fans nearby.

The age of some of the kahikatea trees was determined by counting the growth rings; the average of four trees is 429 years and that of one tree 193 years. The average rate of growth is 1 in. in 13 years, which is considered to be slow.

Although the natural vegetation is now largely destroyed sufficient trees remain to give the plains a pleasant wooded appearance. A glossary of plant names is given in Appendix 2.

FLOODING

By A. D. Todd, Poverty Bay Catchment Board

The Gisborne Plains have always been subject to inundation from Waipaoa River. Floods that covered considerable areas of the flats occurred in 1853, 1876, 1879, 1894, 1906, 1910, 1914, 1916, 1932, 1944, 1948, and 1950. Peak discharge of the 1948 flood was gauged at Kanakanaia bridge at Te Karaka, where practically all the flow is contained in the river channel, the discharge being 140,000 cusecs. On the evidence of water levels observed at "Homebush", Waipaoa, peak discharge of the 1876 flood was approximately the same as that of the 1948 flood, these two floods being greater than all others since the commencement of European settlement of the district. All the other floods listed had peak flows at Te Karaka in excess of 80,000 cusecs.

Settlement of the plains has proceeded in spite of the flood threat because of the very high intrinsic value of the land. Capital investment involved in settlement had accumulated to a large sum without any real concerted effort being made to invest in protection of the land from flooding when the 1948 flood (fig. 5) occurred and caused damage assessed at £336,000. This flood and the smaller one of 1950 led to the establishment of the Waipaoa River Flood Control Scheme.

The scheme is designed to contain a flow of 167,000 cusecs at Waerenga-a-Hika and 180,000 below the confluence with the Te Arai River. It consists of three river diversions involving a channel shortening of 5 miles, together with a continuous system of parallel stopbanks, varying in height from 10 to 16 ft and set apart a distance varying from 1,000 to 1,500 ft so as to embrace the river channel and permit a greater depth of flow therein.

Overflow Pattern

Before April 1953, when construction of the flood-control scheme commenced, large floods overflowed from the left bank at Waerenga-a-Hika and Bushmere and from the right bank at Repongaere and at Patutahi (fig. 4). These overflows occurred near the apex of the alluvial fan and flowed away from the river, travelling considerable distances before reaching the sea coast by independent outfall or returning to Waipaoa River near the coast. Overflows from the left bank at Waerenga-a-Hika and Bushmere, after filling the Makauri basin, flowed to the Taruheru Stream and Waikanae Stream and into Awapuni Lagoon, the outfall of which is into the Waipaoa River some 40 ch from its present mouth (fig. 4). The Taruheru and Waikanae Streams both discharge into the

Turanganui River, which has its outfall to the sea at the northern extremity of Poverty Bay.

The overflow from the right bank at Repongaere filled the Lavenham basin before rejoining Waipaoa River near the Waikakariki confluence at Patutahi. Similarly, overflow from the right bank of the river downstream of the Waikakariki confluence and from the right bank of the Waikakariki itself travelled overland to fill the Pipiwhakao-Whatatuna basin before returning to the Te Arai River about 1 mile upstream of its confluence with Waipaoa River. Overflow from the right bank of Te Arai River and of Waipaoa River downstream of the Te Arai confluence flooded the flats between Manutuke and Muriwai before finding an outfall to the sea through the Muriwai Lagoon.

Overflows also occurred from the left bank at several places between the Matawhero Bridge and Awapuni Creek outfall, all of these flowing over the Willows area to the Awapuni Lagoon and thence back to the river (fig. 4). In extremely large floods, water flooding the Ormond Dip area rose high enough to spill over towards Waihirere and thence into the Taruheru Stream (fig. 4).

This overflow pattern had not been materially affected by the numerous small stopbanking schemes carried out by farmers. These stopbanks were in general too low to protect against any but minor floods; a major flood such as that of 1948 easily overtopped all stopbanks.

For how long before European settlement the existing overflow pattern obtained is a matter of conjecture. Departure from an earlier pattern would follow a major natural river cut-off, which by deepening the channel upstream and by shallowing downstream would affect the tendency of the river to overflow its banks in the reaches concerned. Slow but certain changes in the pattern would occur as the banks along reaches from which overflow occurred were raised in level by deposition of silt and sand from the escaping flood water, while banks not subject to overflow for the time being

Photo, Soil Conservation and Rivers Control Council

Fig. 5. View of 1948 flood in the Willows locality

would not be raised by this means and hence tend to become more subject to overflow in later floods.

Changes Since European Settlement

There have been five principal changes in the river catchment since European settlement:

1. Clearing of the bush on the plains has allowed flood water to flow more freely after its escape from the river. Previously, the presence of bush caused the river to deposit much of its silt and sand on land immediately adjoining the river banks and brought about a quicker reduction both in particle size and in total depth of deposit with distance of travel of flood water. Now, with a large proportion of the land under grass, ponding areas remote from the river are filling at a greater rate and with coarser sediments than hitherto.

2. Clearing of the forest in the catchment has altered run-off conditions so as to lessen the interval between floods large enough to overflow the river banks. The plains are, therefore, now subject to more frequent depositions of sediment.

3. Deliberate planting and subsequent natural establishment of willow trees in the channel had (prior to recent clearing) raised the water level at which a flood of a certain size would flow in the channel. The effect of this was to reduce the volume of flood water capable of overflow and so increase the number of floods in a given period. There are no native species of trees or shrubs as resistant to erosive forces as willows; thus channels deeply entrenched in alluvium would in their natural state be comparatively clear of dense vegetation.

4. Because of gully erosion in the crushed argillite area in the Mangatu and upper Waipaoa River catchments, bed levels in the lower 18 miles of channel through the plains have, in places, been raised nearly 3 ft. For comparison, rises of bed levels in the upper reaches are of the order of 20 ft over the same period. Aggradation of the lower river bed has resulted in a loss of channel capacity and so reduced the interval between floods.

5. When the river channel and its catchment were in their natural state, bank erosion in the lower and middle reaches of the main and tributary rivers provided the largest proportion of sediment carried in time of flood, and this sediment was derived from previously deposited alluvium. The quantity of sediment derived from deepening of channels in the upper reaches was small. It is considered that the total quantity of sediment derived from all sources was likewise much less than that carried by floods today.

   Because deep gully erosion in crushed argillites is proceeding at a rapid rate, large quantities of unweathered gravel are being transported at flood times. Gully erosion is also serious in bentonitic mudstones, so that fine sediments from this source are also carried in greatly increased quantity. On the other hand, almost continuous protection by willows throughout the middle and lower reaches has reduced bank erosion considerably and, in consequence, the supply of previously deposited alluvium is much less than before settlement.

Pattern of Flood-plain Deposits

During a major flood the sediments deposited on the modern flood plain are principally clays and silts.

Prior to the Waipaoa River Flood Control Scheme the pattern of deposition was as follows:

1. Frequent flooding with sediment up to 3 in. thick at each flood.
2. Periodic flooding with sediment up to 1 in. thick at each flood.
3. Periodic flooding with muddy waters which may leave a very thin deposit of $\frac{1}{4}$ to $\frac{1}{2}$ in.

The flood deposit pattern is important to the soils. Where deposits are thick as in (1) above, they form the parent material of soils, and where they are thin as in (2) and (3) above, they modify existing soils. The relationship between flood deposits and soil types is noted in table 2 (p. 17).

SOILS

There are many ways of describing soil, but a common approach is to say that soils are composed of mineral matter derived primarily from rocks and of organic matter supplied by plants and organisms. The mineral component comprises particles of various sizes that are grouped into the fractions called sand, silt, and clay in order of increasing fineness. Sand and silt fractions consist mainly of particles of primary minerals such as quartz, feldspars, micas, apatites, and ferromagnesians, which together contain appreciable amounts of elements important in plant nutrition, including calcium, magnesium, potassium, and phosphorus, as well as various trace elements. The clay fraction consists principally of particles of secondary minerals, which are formed by chemical alteration or decomposition of the primary minerals and are often referred to as the clay minerals. These are extremely small, ranging from 1/5,000th, to 1/25 millionth of an inch in diameter. Because of their very small size, clay minerals have an enormous surface area per unit weight and this makes them extremely active, both chemically and physically. The kind and amount of clay present, therefore, is very largely responsible for the way in which a soil "behaves" in the field.

The organic matter of soils comprises the whole of the non-mineral part; it is built up from plant materials that have been digested by soil organisms. It contains plant nutrients but these are in a form unavailable to plants without further decomposition. Like the clay minerals, organic matter is also very reactive and it is generally considered that there is a good deal of interaction or combination between them. Organic matter performs several important functions in the soil; it acts as a reservoir of plant nutrients, which are released on its decomposition or "mineralisation", it holds moisture, it absorbs the sun's heat because of its dark colour, it plays a major role in promoting and preserving good soil structure, and it provides a source of energy and a favourable environment for the teeming micro-organisms that inhabit the upper layers of the soil.

SOIL CLASSIFICATION

On Gisborne Plains, four classes of soils are recognised*:

	ac	%
Recent soils from alluvium occupying	43,640	87·7
Saline gley soils ..	1,170	2·3
Yellow-brown sands ..	2,250	4·5
Yellow-brown pumice soils	2,720	5·5
	49,780	

Recent soils from alluvium occur on flood plains where river sediments are added to the soils from time to time. Where accumulation of inorganic materials is fairly rapid there is scarcely any differentiated topsoil, but where it is slow the topsoil is deep, dark, and granular. The class includes soils that are now beyond flood reach but are as yet little modified by other soil processes like soil leaching and the organic cycle whereby plants return much or little nutrient to the surface. In general they are highly fertile. The alluvium is derived from soft calcareous sedimentary rocks of Cretaceous and Tertiary age.

The soils of this class that are slow draining may be considered as gleyed recent soils. Saturation with water means poor aeration and a check to plant growth. Where the waterlogging is only temporary its effects are indicated by mottled colours in the subsoil.

Saline gley soils occur on tidal flats that are frequently flooded with sea water. The salts in these soils limit plant growth and their elimination presents some difficult agricultural problems.

Yellow-brown sands are formed from accumulations of sandy materials and shell fragments along the coast, and *yellow-brown pumice soils* are derived

*The classification of these soils in relation to published classifications of New Zealand soils is given in Appendix 3.

from rhyolitic pumice, which was deposited as a volcanic ash shower on top of beach lands. Owing to the weak weathering only small amounts of clay occur in yellow-brown sands and yellow-brown pumice soils and they are not chemically as fertile as the recent soils. In both of these classes the level of fertility is related chiefly to the amount of humus in the topsoil.

The soil classes comprise a number of soil types which are the natural units of soil and the basic units of soil classification. For ease of reference by those who work with soils, a soil type is designated by a geographical name coupled with a name that indicates the texture of the topsoil, e.g. *Waihirere silt loam.* On Gisborne Plains the geographic name has been specially chosen so that the name alone indicates the nature of the soil; for instance, Te Hapara is a locality known for its sandy soils, and Waihirere is known for its mellow, well drained soils.

In the soil types there are variations that may be important enough to alter the requirements of land use; these are separated as phases and include *gravelly topsoil phase, mottled subsoil phase,* and *friable topsoil phase.* Soil types that are closely related bear the same geographic name and so belong to the same series, e.g., Waihirere silt loam and Waihirere heavy silt loam.

A list of the soil types and phases of the Gisborne Plains is given in table 2.

TABLE 2. Legend

Soil Map No.		*Notes*
	SOILS OF THE FLOOD PLAINS	
	Recent Soils from Alluvium	
1	Waipaoa silt loam	Frequently flooded; rapidly accumulating; 3 in. fresh alluvium added at each flood; poorly developed structures and low content of organic matter.
1a	Waipaoa heavy silt loam	
1b	Waipaoa clay loam	
1c	Waipaoa mottled clay loam	
2	Matawhero silt loam	Periodically flooded; slowly accumulating; 1 in. fresh alluvium added at each major flood; deep and friable.
2a	Matawhero silt loam, friable topsoil phase	
2b	Matawhero heavy silt loam	
2c	Matawhero heavy silt loam, friable topsoil phase	
2d	Matawhero heavy silt loam, mottled subsoil phase	
2e	Matawhero clay loam	
2f	Matawhero clay loam, friable topsoil phase	
3	Waihirere silt loam	Flood-free for a long time; uneven surfaces; friable and with well developed structures.
3a	Waihirere silt loam, gravelly topsoil phase	
3b	Waihirere silt loam, mottled subsoil phase	
3c	Waihirere heavy silt loam	
3d	Waihirere heavy silt loam, gravelly topsoil phase	
3e	Waihirere heavy silt loam, mottled subsoil phase	
3f	Waihirere clay loam	
	Gleyed Recent Soils from Alluvium	
4	Makaraka heavy silt loam	Periodically flooded; slowly accumulating; 1 in. fresh alluvium added at each major flood; high water table in winter.
4a	Makaraka clay loam	
4b	Makaraka clay loam, saline phase	
5	Makauri clay loam	Periodically flooded with muddy waters only; very slowly accumulating; uneven surfaces; many fissures, especially in summer; high water table in winter.
5a	Makauri clay loam, friable subsoil phase	
6	Kaiti silt loam	Flood-free for a long time; soils consolidated; drainage impeded; well developed blocky structures and firm aggregates; high water table in winter.
6a	Kaiti silt loam, firm topsoil phase	
6b	Kaiti heavy silt loam	
6c	Kaiti clay loam	
6d	Kaiti clay loam, shallow topsoil phase	
	SOILS OF THE TIDAL FLATS	
	Saline Gley Soils	
7	Muriwai clay loam	Salts limit plant growth; agricultural problem; poorly developed structures; high water table in winter.
7a	Muriwai clay	
	SOILS OF THE BEACH LANDS	
	Yellow-brown Sands	
8	Opoutama sand	Firm surface in winter; droughty in summer; fertility depends on content of organic matter in the topsoil.
8a	Opoutama loamy sand	
	Yellow-brown Pumice Soils	
9	Te Hapara sandy loam	
9a	Te Hapara mottled sandy loam	

SOIL DESCRIPTIONS

In a present-day soil survey the soil is examined both in the field and in the laboratory. In the field, observations are made of the site and the soil profile, and in the laboratory the chemical and physical properties are examined and measured. Laboratory work during this survey comprised measurements of the proportions of sand, silt, and clay, acidity, and content of available phosphorus and exchangeable calcium, potassium, and magnesium in the soil. It also included special investigations on soil copper, clay minerals, and soil structure, the results of which are reported on pp. 42–9. In soil descriptions the levels of nutrient elements are given as low, medium, and high; actual measurements are recorded in table 3, pp. 42–3.

The soil descriptions involve some technical terms for which a brief explanation is given:

Texture concerns the relative proportions of sand, silt, and clay in the soil and is described in such terms as sandy loam, silt loam, clay loam, and clay, to mention a few. These assessments are made in the field by feeling the soil with the fingers and are checked from time to time by laboratory analysis of soil samples (see table 6, p. 45).

Structure describes the state of granulation of the soil. Structures in which aggregates fit into one another are called nutty or blocky, depending on their general shape, and those which touch only in places are termed granular.

Consistence is the tendency of the soil to crumble or stick together and is described in such terms as friable, firm, soft, hard, or sticky. It gives an indication of the ease or difficulty in keeping the soil open or porous under cultivation.

pH is an expression of the degree of acidity or alkalinity; a soil is acid when pH values are less than 7 and is alkaline when values are greater than 7.

Cation exchange capacity (*CEC*) is a measure of the power of a soil to hold and supply various elements; it is a more or less stable characteristic of a particular soil.

Base saturation is the ratio of nutrient elements present in a soil to the total that could be held in the same soil; it is usually expressed as a percentage and is a rough and ready index of chemical fertility.

Phosphorus or "available phosphorus" is the amount soluble in 1% citric acid.

The last four terms are more fully explained on p. 40 *et seq.*

Other terms used include *cracking*, which refers to cracks in the top 3 in. of the soil, and *fissuring*, which refers to wide and deep crevices into the subsoil. *Turf* is the surface earth held together with matted roots of grass.

The soil profile is a vertical section through the soil from the surface downwards; it consists of successive layers parallel to the surface. On Gisborne Plains the total depth ranges from 3 ft to 5 ft. Each layer is described separately according to its thickness, colour, consistence, texture, structure, and any other noticeable feature (for detailed descriptions, see Appendix 4, p. 83). Much can be learnt about the soil from close examination of profiles.

One important product of a soil survey is the soil map, which shows the areal extent of soil types and their pattern of occurrence. The soil type is established in the field by the profile and, where this changes, a soil boundary is marked on the map. On Gisborne Plains the land was walked over paddock by paddock and hundreds of bores and pits were sunk and many road cuttings and drains examined to observe the profiles.

The farmer, agricultural adviser, and the soil scientist meet on common ground when discussing the soil type, which is regarded by the scientist as the basic unit of soil classification. Recognition of the separate existence of soils as soil types has distinct practical advantages; knowledge and experience gained on a type in one locality can be applied to the same type in another locality. Soil descriptions, therefore, comprise both observations and measurements as well as experience in land use by farmers and others. The area of each type is given with the alphabetical index to the soil types at the back of the bulletin.

Soils of the Flood Plains

Waipaoa Soils

Waipaoa soils are the "new" soils of the plains and were formed after 1932, when accelerated erosion became serious in parts of Waipaoa River catchment. They differ from Matawhero soils in that flood deposits have accumulated much more rapidly.

Waipaoa soils lie close to Waipaoa River and large tracts occur at Waituhi, Waerenga-a-Hika, and at Willows. At the completion of Waipaoa River Flood Control Scheme, about 3,700 ac of Waipaoa soils will still be subject to flooding and

2,400 ac will be flood-free. In the floodway, land use will be limited to grassland farming.

The soil pattern is similar to the sedimentation pattern: near the banks soils are silt loams, while further away, in low-lying cut-off meander loops, they are clay loams. They are also more sandy in the north where Waipaoa River enters the plains. There is thus a wide range of types, including Waipaoa silt loam, Waipaoa heavy silt loam, Waipaoa clay loam, and Waipaoa mottled clay loam. Farm holdings bordering Waipaoa River have their fence lines nearly at right angles to the channel; a paddock, therefore, may include two or more types that have to be farmed together. Much of the land is given over to maize cropping and is sometimes referred to as the "corn belt" of Gisborne Plains.

During a major flood (such as occurred in 1948) large quantities of lime-bearing sediments are deposited on these soils. The amount of lime (calcium carbonate, $CaCO_3$) deposited in a 3 in. flood layer, for example, is of the order of 10 tons to the acre. In consequence the soils are moderately alkaline, with pH values of about 8. Current flood detritus is derived from raw rock and is therefore very low in organic matter; furthermore, the interval between floodings is too short for an appreciable build-up of organic matter (fig. 6). Consequently, levels of carbon and nitrogen in Waipaoa soils are low (table 3 p. 42).

Although recent soils are usually well supplied with available phosphorus, the levels in Waipaoa soils are only moderate; this perhaps reflects the extreme rawness of the soils – that is, the absence of weathering *in situ* and of the build-up of organic matter. The exchangeable potassium level appears to be generally adequate – barely so in some cases – but reserves in the clay minerals are probably high. Exchangeable magnesium is also adequate at present, but may easily be exhausted. Because of the high calcium (lime) level there is a possibility that a magnesium deficiency may be induced on soils protected from flooding. This is the more likely if much potash is added.

The texture of the various types within the series is reflected in their cation exchange capacities. In the near absence of organic matter this property closely parallels the clay content: the cation exchange capacity of Waipaoa silt loam ranges from 9–17 me.%, and Waipaoa clay loam from 25–29 me.%. Base saturation values are all over 100% owing to the presence of free lime.

Physical properties of Waipaoa soils, particularly those of heavier texture, are influenced by the montmorillonitic clay. This is responsible for the very slow settling of the finer particles from flood waters. Even though they are saturated with calcium, which usually promotes flocculation, these montmorillonitic clays tend to remain finely dispersed, causing a very poor structure. Their propensity for swelling when wet and shrinking on drying results in poaching and sealing in winter and cracking in summer.

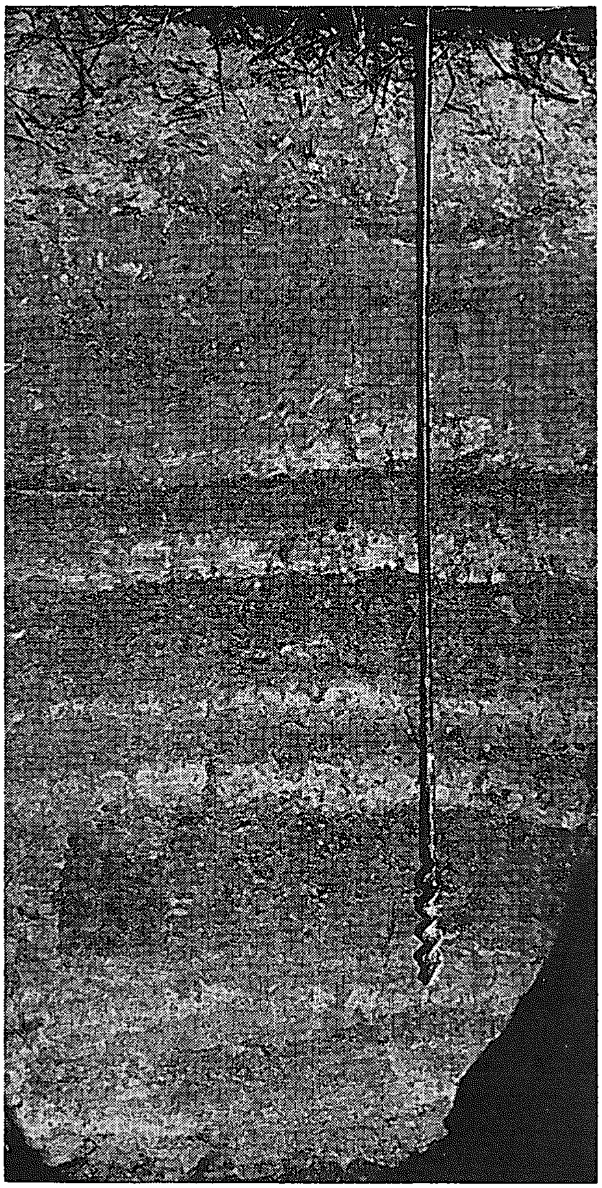
Waipaoa silt loam occupies 2,510 ac on and near the banks of flooding rivers and streams. Because of considerable variation in the texture of flood deposits over a short distance, this unit includes areas with sand, silty sand, and sandy silt textures at the surface. The surface of the sandy parts tends to be ridgy, whereas that of the silt-loam parts is flat and smooth. The sandy parts are of little value to arable farming; but their ridgy surface and excessive drainage makes some of them highly suitable for carrying stock when other lands are too wet. Eventually, many of them will be included in the floodway of the Waipaoa River Flood Control Scheme.

There are many layers in the profile; for example, at Kaitaratahi the top 6 in. is a grey firm silt loam with a soft nutty structure and below it there are successively 6 in. of grey loose sand, 6 in. of finely laminated silty sands, and a 3 in. layer of silty sand and coarse pumice sand in fine bands of ¼ in. Below 21 in. is the pre-1932 soil of brown crumbly silt loam containing many well decayed grass roots and leaves; it is lightly compacted, and has faint, brownish yellow and grey mottles. Because of weakly developed structures, the top 6 in. of silt loams does not drain well, and there are also few crevices for grass roots to penetrate; two years after the 1950 flood such roots were never deeper than 1 in. Sands and silty sands dry out badly in summer.

The land is used for fat-lamb and beef production, maize cropping, and, in large paddocks, for rough grazing. The soil is subject to serious infestation by Indian doab, rhizomes of which are carried in flood sediments; ryegrass-clover pastures are soon invaded and yields of arable crops are reduced if the rhizomes are not destroyed. Buried soils are usually well drained yet retain moisture for long periods. Where they are now protected from further flooding they should be exploited by deep-rooting crops such as lucerne, and, where they lie close to the surface, by maize, which does well in such places.

In **Waipaoa heavy silt loam** (1,370 ac) depositional layers are nearly all of the same texture. The soil is distributed mainly on both sides of Waipaoa River in small strips of 20, 30, and 50 ac, with a larger piece of about 350 ac at Bushmere. Heavy periodic floodings have smoothed out irregularities in the surface, which is now flat and level.

The landscape is marked by lines of stopbanks erected by farmers over the years as a protection against minor floods; but in major floodings these banks serve more as sorting baffles to entrap a medium grade of sediment at each flood. Thus, during the last 20 years, such floodings have raised up a uniformly-textured accretion 15 to 36 in. thick, but commonly about 18 in., with individual flood layers separated by decayed remains of smothered pasture.



Photo, A. P. Underhill

Fig. 6. Soil profile of Waipaoa heavy silt loam at Bushmere

In most places the top 2 in. (1950 flood) is a grey, firm, heavy silt loam with a weakly developed nutty structure. The next 5 in. (1948 flood) is a grey, crumbly, heavy silt loam with faint yellowish brown mottles in lines along old root channels; in the upper part are dead roots of grass smothered by the 1950 flood. This is underlain by a 3 in. layer (1944 flood) of brownish grey, crumbly, heavy silt loam that contains decayed leaves of grass killed by the 1948 flood, and by three more similar layers each 2 in. thick. Underneath are the buried soils (pre-1932), which are more friable, are browner, and have better developed structures. At 45 in. is a dark grey friable clay loam (fig. 6). A detailed profile of this type is given on p. 83.

The 1950, 1948, and 1944 flood layers do not drain freely because there are few aggregates and few spaces between aggregates. Nevertheless, this disadvantage may be offset by numerous fine tubes left by decaying roots, leaves, and stems. Aggregates in the 1950 flood layer are also laminated (fig. 16) and this retards penetration by grass roots to the extent that it takes about two years to establish pasture after a major flood. The surface tends to poach, pack, and seal in winter.

Land use includes maize, sweet corn, and pea cropping, and fat-lamb and beef production. The soil type is best suited to deep-rooting plants like lucerne, which are able to tap nutrients from and draw water out of the highly fertile, permanently moist buried soils and at the same time improve the structure in the top 18 in. At the completion of Waipaoa River Flood Control Scheme, about 750 ac will continue to be flooded.

Waipaoa clay loam (1,800 ac) is a heavy soil, which puddles in winter and cracks very badly in summer. It is distributed in curved, crescent-shaped pieces of about 100 ac on both sides of Waipaoa River, mainly in the Waipaoa, Waituhi, Waerenga-a-Hika, Manutuke, and Willows localities; there is a larger piece of 250 ac at Waituhi. The surface is sufficiently flat and smooth for rainwater to lie in winter. The landscape is marked by lines of low stopbanks.

This type commonly lies farther from Waipaoa River than the other Waipaoa types. It occurs principally in shallow abandoned channels of Waipaoa River where periodically flood waters pond, carrying with them in suspension only the finest of sediment. Flood waters may be up to 3 ft deep, but as they subside a thick slurry, 6 to 8 in. deep, remains. After a few weeks, as water evaporates, sediment precipitates as a thin clay concentrate 2 to 3 in. thick; in some lower lying parts concentration may take much longer if weather is unfavourable for evaporation. The concentrate then consolidates and shrinkage is quite appreciable for a few years; for instance, in 1951 at Patutahi the material accumulated since 1932 was 12 to 18 in. thick; by 1953 the thickness had been reduced to 9 to 12 in., and by 1954 it was 8 to 11 in.

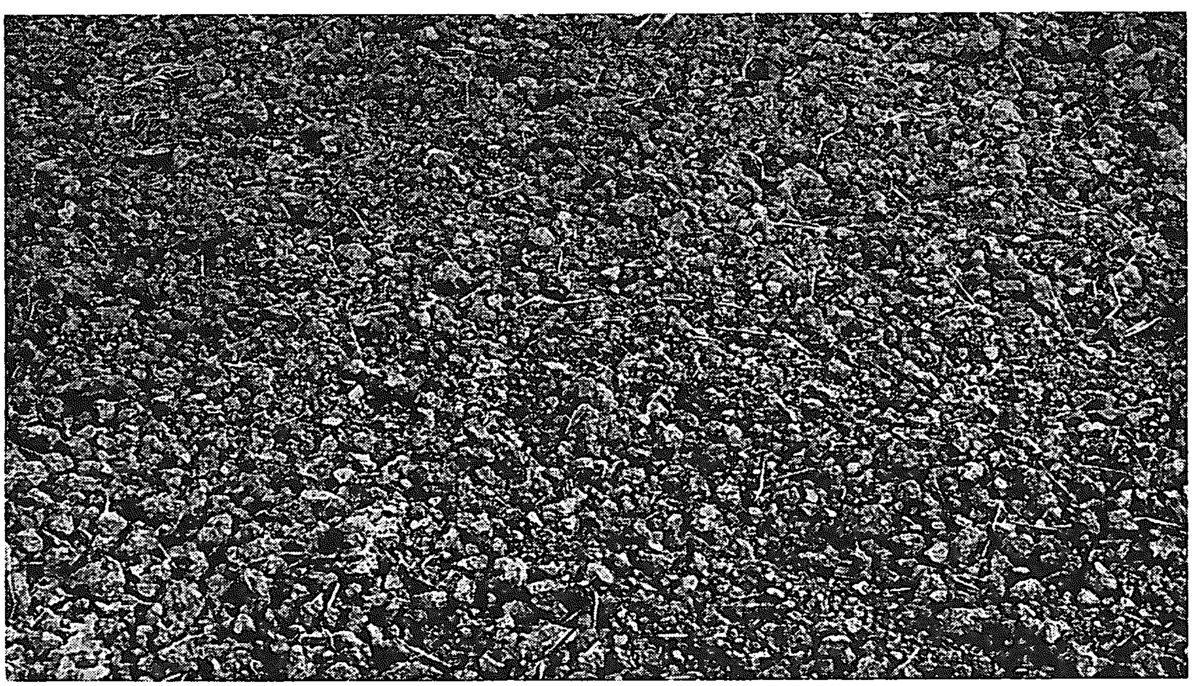
Concentration by ponding ensures that textures of flood layers are almost uniform and there is an absence of bedding in profiles. There are, however, small variations ranging from silty clay loams to clays but as the soils are all heavy no separation was made on the soil map.

At the mouth of Waipaoa River, where the land is under grass with maize as a rotation, the top 4 in. (1950 flood) is a brownish grey, dense clay loam, which becomes sticky and plastic when wet. After 3 years, roots of new grasses have ramified freely to a depth of 1 in. and occasionally to 4 in., but generally the layer is low in organic matter. This passes into a 12 in. layer of grey, very firm clay loam with a moderately developed coarse blocky structure. Aggregates are markedly laminated and are highly coloured, with some reddish brown mottles and streaks along old root channels. Below about 18 in. the soil profile changes to friable buried soils with a well developed structure.

Where there is frequent minor flooding the surface soil is pale grey and almost structureless (p. 48), and buried soils lie at depths of about 36 in. At Waituhi, where surface water lies longest, the soil is studded with small iron concretions, particularly about the 12 in. level.

This soil is very difficult to manage because the top 4 in. tends to become sticky and plastic when wet, thus encouraging severe puddling in winter. Cultivation is troublesome because there is insufficient organic matter to combat the drying out and cracking due to the natural shrinkage and expansion of the clay. The soil must be tilled at the correct moisture content, neither too wet nor too dry, and should be disced and rolled within a few hours of ploughing, particularly during dry, westerly winds. If tilled too wet or too dry it is impossible to lay down other than a rough, cloddy seedbed (fig. 7); indeed, one from a soil allowed to dry out is the more difficult to prepare. In grasslands, a serious weed is Indian doab, and in low-lying parts sedges grow profusely.

The land is used mainly for fat-lamb and beef production and maize cropping. Because of frequent flooding, small pieces of 20 to 100 ac, and aggregating about 800 ac, are often out of production. The patches of sunken, low-lying land are difficult to drain effectively, and the cost is high. At the completion of the Waipaoa River Flood Control Scheme about 1,100 ac will be protected from flooding.



Photo, A. P. Underhill

Fig. 7. Tilth on Waipaoa clay loam at Patutahi. Aggregates about ⅛ natural size.

Waipaoa mottled clay loam occurs in one piece of 460 ac in low-lying parts of the Repongaere locality, where successive floodings since 1932 have buried old, poorly drained soils to a depth of 9 to 18 in. The surface is now level but cut by many open drains.

In a profile along Knight Road, the top 1 in. is a yellow, firm, laminated clay loam (1950 flood) peppered with pale grey fine mottles; the uppermost ¼ in. is much browner than the remainder of the layer; under grass, the soil between the plants is sometimes covered with algae. After three years, roots of new grasses had not spread freely, but a few had penetrated about an inch; roots of clover, however, had penetrated as much as 3 in. The next layer of 8 in. (1948 and 1944 floods) is a grey firm clay with a prismatic structure, which breaks across lamination planes to give very coarse blocky aggregates. Then follows a distinct 3 in. layer of greyish brown firm clay with a blocky structure, and this is joined sharply to a black friable clay. Underneath is a grey clay, which becomes more compact at 30 in.

In winter Waipaoa mottled clay loam becomes massive and slow draining and its surface tends to puddle and poach; in summer it cracks deeply into hexagonal blocks, which break away easily into large dry clods. The black clay underneath is waterlogged in winter but is moist in summer. A fine seedbed is difficult to prepare, as the soil has a particularly weak structure and tends to cloddiness if cultivated too wet or too dry (fig. 7).

The land is used mainly for maize cropping and for fat-lamb and beef production. The soil is unsuitable for deeper rooting plants such as fruit trees or lucerne.

Matawhero Soils

Matawhero soils are deep, friable, and well drained. They are distributed mainly in large, continuous strips about the centre line of the plains from Patutahi township to Te Arai River on the western side of Waipaoa River, and from Waerenga-a-hika to near the mouth on the eastern side. Soil types usually lie together in pieces sufficiently large to carry many whole farms. The total area is 9,910 ac, of which 4,650 ac is not now flooded.

The soils occur on higher lying parts of the modern flood plain and comprise areas near the limits of present-day flooding. On the highest parts no sediment has been added for at least 100 years, and on other parts shallow floodings over a long time have built up a deep, humus-enriched accumulation 18 to 42 in. thick (fig. 8). This accumulation rests on an old black soil. Worm casts and decayed roots impart friability to the soil and there is not as much compaction as in the older Waihirere soils. Flood layers are thicker than on Makaraka soils, which are further away from Waipaoa River.

The principal difference between Matawhero soils that are flooded and those that are not is in the physical properties of the top horizon. On flooded areas the upper 6 to 16 in. is grey and firm and has only a weakly developed structure; on unflooded areas the upper 10 in. is brown and friable and has a moderately developed structure of fine granules. The friable surface horizon offers better aeration and drainage and, as it is not as sensitive to changes in the weather in spring, allows cultivation over a wide range of topsoil moisture. On flooded soils where the horizon is less than 6 in., however, the difference may be minimised by deep ploughing, which turns up more friable soil for the seed bed; nevertheless, the character of the top horizon is important to agriculture and the difference is shown on the soil maps and in the text by adding the term "friable topsoil" to flood-free soils of this series.

Soils still subject to flooding receive free lime in the calcareous sediments left by flood waters – an inch of sediment, for instance, can contain more than 1 ton of free lime per acre. As a result, some of the Matawhero topsoils still subject to flooding are slightly alkaline (pH 7·0 to 7·4); others are slightly acid in the topsoil (pH 6·0) but contain a little free lime in the deeper soil layers.

Chemically, Matawhero soils are differentiated from the Waipaoa soils largely by their higher organic-matter content. The analyses show a distinct organic topsoil, with carbon values from 3 to 7% (equivalent to 5 to 10% organic matter). This organic matter is responsible for higher cation exchange capacity values than are found in Waipaoa soils of similar texture, while the higher citric-soluble phosphorus figures and higher exchangeable potassium figures may be partly due to the return of nutrients to the surface through plants. Exchangeable magnesium is high. Thus these soils are well supplied with plant nutrients with no obvious deficiencies; but applications of nitrogen and phosphate will probably give responses in some soils, particularly with cropping. Base saturations are high, about 80% for soils free from $CaCO_3$ to 100% for the calcareous members.

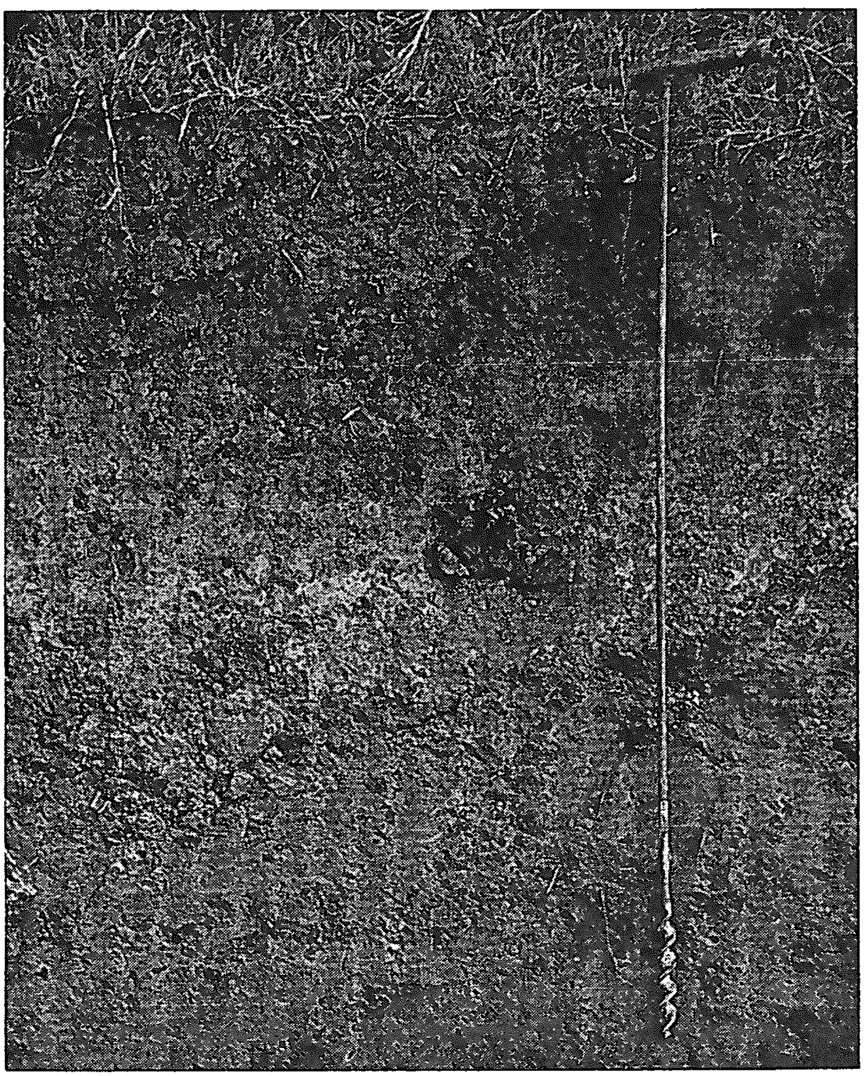
In farming Matawhero soils it is important to preserve or improve the soil structure and also to maintain the supply of organic matter for optimum aeration and drainage in the cultivation layer. As the soils are "new", the structural aggregates tend to be soft.

Three main types are mapped – Matawhero silt loam, Matawhero heavy silt loam, and Matawhero clay loam – and each of these has a friable topsoil phase. A mottled phase of Matawhero silt loam also occurs.

Matawhero silt loam (500 ac) is limited to banks of Waipaoa River at Kaitaratahi and Patutahi, where it occurs in pieces of 100 ac, and at Matawhero, where there is a larger piece of about 200 ac. The surface is smooth with a slight fall away from the river.

Where the soil is undisturbed, the 1950 and 1948 flood layers are clearly seen. Under pasture at Matawhero, the top 2 in. (1950 flood) is a grey firm silt loam with a weakly developed coarse blocky structure, and the next 3 in. (1948 flood) is the same except that the colour is slightly brown and the structure better developed. Underneath is 36 in. of brown friable silt loam with a moderately developed nutty structure, over a black friable silt loam. When cultivated, the 1950 and 1948 flood layers are mixed with the underlying brown silt loam and the resulting seedbed is friable.

It is most important to preserve the structure of this type, for the soil aggregates are weak and tend to slake under beating by heavy rains. The soil should not be overtilled, nor should it have to carry excessive weight. The brown colour below 15 in. indicates free drainage and adequate aeration, and the structure offers easy root penetration through narrow crevices. The subsoil is generally moist.



Photo, A. P. Underhill

Fig. 8. Soil profile of Matawhero silt loam at Matawhero

Land use is mainly maize cropping, market gardening, and sheep and cattle fattening.

Matawhero silt loam, friable topsoil phase (2,530 ac) occurs on the banks of Waipaoa, Te Arai, and Maraetaha Rivers and on small fans near Waihirere Maori settlement. The largest continuous piece, 350 ac, is at Manutuke, and there are smaller pieces of 150 ac at Matawhero and at the mouth of Maraetaha River.

The soil is the most mellow of the plains; it drains freely, yet retains moisture for long periods and the topsoil seldom cracks in a dry summer. It can also absorb much water, largely because the water table is low and because the subsoil is deep and friable. At Matawhero there are silt loam layers, each 1 to 9 in. thick, to a depth of nearly 16 ft. Under grass the top 5 in. is a brown friable silt loam; the next 5 in. is a yellowish brown friable silt loam, this passing down into a crumbly silt loam about 31 in. thick. The granules are small and are pierced by many decayed rootlets. Underneath this friable layer is a 2 in. seam of loose fine sand, and at a depth of 43 in. is a dark brown friable silt loam. At Waihirere Maori settlement there is a small piece of about 40 ac where the topsoil is a loamy sand derived from impure limestone, and, in the convex bends of Waipaoa River at Matawhero and Manutuke are 10 ac strips with gravelly topsoils. In the fans near Waihirere Maori settlement seasonal fluctuations in seepage-water level induce faint grey mottlings at 8 in. from the surface. On the banks of Maraetaha River the soil is more sandy than usual because of alluvium from sandstone hills.

Present land use includes orcharding, market gardening, maize and pea cropping, and lamb and cattle fattening. Matawhero silt loam, friable topsoil phase, is best suited to orcharding. If irrigation is required water can be obtained by pumping from the Waipaoa and Te Arai Rivers or from wells sunk into gravel beds at a depth of 20 to 30 ft.

Matawhero heavy silt loam (2,210 ac) is an extensive soil type occurring in large pieces of 600 ac in the Bushmere locality and in smaller pieces of 100 to 200 ac in the Matawhero and Makaraka localities. The surface is slightly undulating, except at Makaraka, where it is deeply etched by swampy channels which need to be bridged.

Because of surface undulations and capricious flooding by Waipaoa River, the latest flood accretions are variable in thickness and so there is a considerable range of profiles. Flood layers deposited since 1932 are more easily discerned because they are not well assimilated and give the top 3 to 16 in. a banded appearance. A profile from Patutahi is described in detail on pp. 83–4.

The surface 2 in. is a grey, firm, heavy silt loam with a weakly developed coarse nutty structure (1950 flood); live grass roots and organic matter are confined to the uppermost inch. The next $2\frac{1}{2}$ in. (1948 flood) is a brownish grey, firm, silty clay loam with decayed roots and leaves imparting a darker colour to the upper $\frac{1}{2}$ in. In the next 12 in. are bands of brown and pale brown heavy silt loam 2 to 4 in. thick. Brown bands have strongly developed blocky structures and are friable, owing to intimate mixing of decayed leaves, rootlets, and twigs; pale brown bands are less friable, and organic matter is concentrated in pockets. Below 16 in. is a layer of dark brown very friable clay loam, which, beyond 22 in., becomes fairly compacted and, when disturbed, crumbles easily.

When pasture is smothered by flooding it is a common practice to resow on the sediment whilst it is still wet and sticky; but as new flood layers have a poor structure, root penetration is very shallow and there is not a good cover of grass for at least two years. In winter the 1950 and 1948 flood layers seal the surface and the soil is then likely to poach. Faint mottling indicates slow drainage and poor aeration. In arable farming it is desirable to bury these layers and turn up more friable soil. The best soil for a seedbed comes from the friable strongly structured layers below the top horizon; but as this is so variable in depth, the farmer must decide whether it is worth while to deep-plough or not.

The top 16 in. may become droughty in a dry summer, but the buried dark brown soil is always moist. In winter, however, this buried soil is no advantage as its close-fitting aggregates swell and so cause drainage waters to perch on it. Thus the top horizon tends to become waterlogged and to puddle, especially during the harvesting of maize in the months of May and June.

Along the eastern edge of Darton Field are small patches of 10 to 40 ac, which are underlain by a sand stratum at 18 to 24 in. from the surface; they were not shown separately on the soil map.

The land is used mainly for maize and pea cropping, sheep and cattle fattening, and for ryegrass seed production; the soil is suited to deeper rooting plants, such as lucerne.

Matawhero heavy silt loam, friable topsoil phase (1,880 ac) is a friable, strongly structured soil that becomes rather loose on drying out. It occurs near the banks of Waipaoa and Te Arai Rivers at Matawhero and Manutuke, where there are small, individual pieces of 20 to 50 ac and a few larger pieces of 150 ac. The surface, in parts, is dimpled with holes left after stumping, but in other parts has been smoothed over by frequent cultivations.

Under grass at Manutuke the top 7 in. is a brown, friable, heavy silt loam with a strongly developed fine nutty structure and with deep fibrous roots; it contains many dead rootlets. This passes into a brown silty clay loam, which has the same structure as above but is very friable. Below 18 in. the profile is similar to that of Matawhero silt loam. Faint mottling may occur at 24 in., but this is not common. The top 7 to 9 in. becomes loose and droughty in a dry summer, but the buried soil at 36 in. maintains moisture at a steady level, and advantage may be taken of this by growing deeper rooting plants.

There are variations in profiles in the two main localities. In the Te Arai Valley the subsoil is a friable yellow clay loam with a strongly developed structure. The surface seals readily in winter and plant cover reverts quickly to rushes. At Matawhero a firm dark brown clay loam may be as close as 12 in. to the surface.

The land can be ploughed to a fine tilth in spring and, as the topsoil is well aggregated, infiltration is high. Land use includes dairying, fat-lamb and cattle production, and maize and pea cropping.

Matawhero heavy silt loam, mottled subsoil phase (1,120 ac) occurs in pieces of about 300 ac in the Patutahi, Waerenga-a-hika, and Muriwai localities. The profile is much the same as the type (described pp. 83–4), except that the aggregates of the buried soil at 18 in. are tinged blue and stained brown from temporary waterlogging. Below 24 in. the soil is mottled yellowish brown and grey, indicating a fluctuating water table. As the water table drops from about 24 in. in a wet winter to deeper than 5 ft in a dry summer, there is a risk in growing fruit trees in this soil. Land use is the same as for the type.

Matawhero clay loam (1,440 ac) is a heavy soil with firm aggregates; new flood layers in the top horizon are thinner than in the heavy silt loam and the total accumulation above the buried soil is also less. The soil occurs mainly in the Makaraka and Willows localities, where there are individual pieces of about 200 and 400 ac respectively. At Makaraka the terrain is noticeably hummocky and the land is cut by tributary streams of Taruheru River. In Willows locality the surface is flat and smooth, except near the mouth of Waipaoa River where there are narrow low ridges.

Along Pilmer Road, Makaraka, the top 2 in. (1948 flood) is a pale yellow heavy silt loam with a weakly developed nutty structure. Below 2 in. the profile changes abruptly to 10 in. of greyish brown firm clay loam, which has a strongly developed structure and contains many partly decayed grass rootlets. This passes almost imperceptibly into an 8 in. layer of the same colour and texture but with a smaller blocky structure; the layer is bonded rather irregularly to a black, friable, silty clay loam having a fine granular structure, and this is joined at 29 in. to a yellowish brown firm clay loam with a blocky structure.

On this soil it is worth while ploughing deep, because the clay loam aggregates do not break down readily and thus keep the cultivation layer open while the crop is in the ground. In summer the buried soil is always moist. In parts there is some faint orange mottling at 15 to 18 in. because of periodic slow drainage through the compacted subsoil below 29 in. At Makaraka Racecourse and along the eastern edge of Darton Field, and also near Matawhero Railway Station, are small pieces of 12 to 40 ac underlain by a sand stratum at 15 to 30 in.; the soil here dries out badly in summer. These areas were not plotted separately on the soil map.

The land is used for maize cropping, market gardening, and sheep and cattle fattening.

Matawhero clay loam, friable topsoil phase (230 ac) occurs in small pieces of 100 ac at Matawhero and Kaitaratahi. The surface is flat with little run-off.

This soil is heavy, but is friable with a strongly developed structure of mixed blocks and worm casts; it offers a firm surface in winter but cracks badly in a dry summer. In tilling, the draught is heavy, and in order to get a fine tilth the soil must not be too wet or too dry. There is some faint, diffuse, yellowish brown and grey mottling at 9 in. indicating slow subsoil drainage in winter.

The land is used together with other soil types for maize cropping and for sheep and cattle fattening.

Waihirere Soils

Waihirere soils are highly fertile for most crops and, along with Matawhero soils, are the best all-purpose soils of the plains. Their fertility is in large measure due to a combination of good aeration and drainage and an ample supply of plant nutrients. They are distinguished from other recent soils by their black topsoils and yellow subsoils. The areas on which they occur have not been flooded for perhaps hundreds of years. They are widely distributed over the old flood plain and occur mainly in large units in the Waihirere, Matawhero, and Manutuke localities. The total area is 8,740 ac.

Chemically, Waihirere soils are very similar to the Matawhero soils. Base saturation and pH values, however, tend to be rather lower for the Waihirere soils, and free lime is usually absent. Exchangeable potassium levels are exceptionally high in some profiles and not in others, but all contain abundant reserves. Phosphorus levels, however, are not conspicuously high and responses to nitrogen and phosphate would be expected. As with Matawhero soils, cation exchange capacities reflect the texture of the soil as well as the organic-matter content.

The principal types are Waihirere silt loam, Waihirere heavy silt loam, and Waihirere clay loam, and associated with each of the first two is a gravelly phase and a mottled phase.

Waihirere silt loam (1,430 ac) is a mellow soil. It occurs in small scattered pieces of 10 to 50 ac and in two large pieces of 100 ac and 300 ac. The small pieces, 5 to 10 ch wide, lie on the banks of abandoned courses of Waipaoa River; one of the larger pieces lies along the high bank of Waipaoa River at Ormond township and the other straddles the abandoned course of Te Arai River at Manutuke Maori settlement. The surface is broadly convex with a gentle slope away from the old river course, and the fall is sufficient for run-off during heavy rains.

The soil profile contains layers both of silt loam and clay loam, the arrangement of layers varying from locality to locality. At Manutuke the topsoil is a black friable silt loam 9 in. thick with a strongly developed cast granular structure and passes downward into a 24 in. layer of yellowish brown friable silt loam with a moderately developed nutty structure; aggregates are soft and porous (see pp. 48–9). Below 36 in. is a friable silty clay loam with a strongly developed nutty structure. Down to a depth of nearly 20 ft the layers are all aggregated, often with many worm casts. When the soil is dry the subsurface colours are yellow.

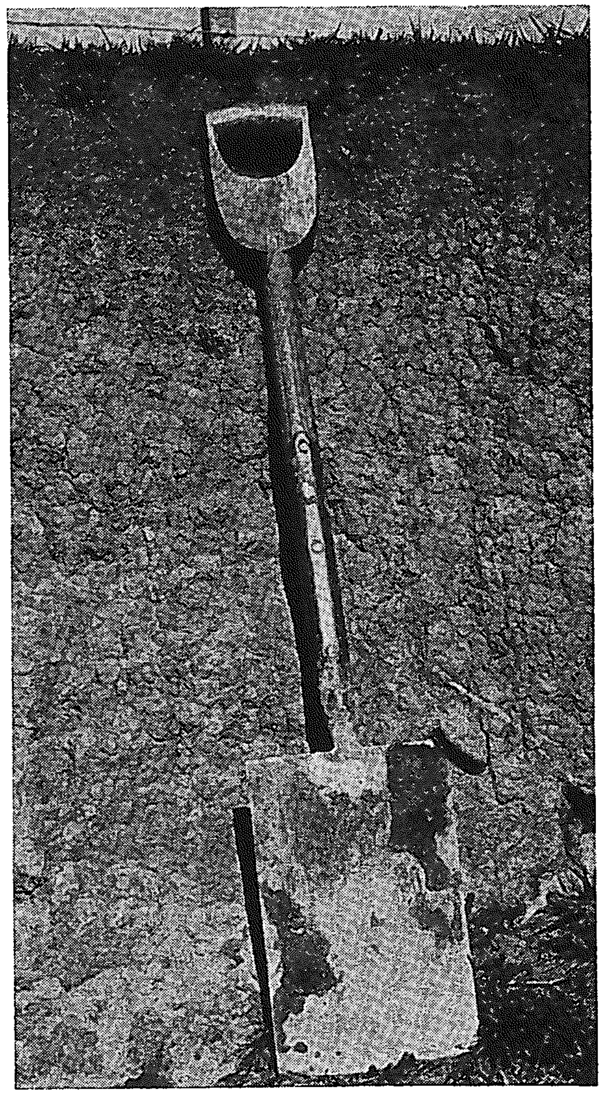
The **gravelly topsoil phase** of **Waihirere silt loam** (490 ac) has a profile similar to that of the type, except that in the lower 4 in. of the topsoil there is a concentration of fine gravel about $\frac{1}{8}$ in. diameter (fig. 9). It occurs mainly in the Waerenga-a-Hika and Matawhero localities.

Waihirere silt loam is free draining and the excellent structure encourages a high moisture retention; with the water table usually at about 10 ft it has a large capacity for storing water. The surface is firm in winter and does not crack in summer, but the topsoil may be droughty in a dry summer. The gravelly phase is an early soil because it has a friable free-working topsoil in spring (pp. 48–9).

These soils are eminently suitable for small orchards, market gardens, and for row cropping, such as peas, beans, and tomatoes. The area on individual farms, however, is often less than 10 ac. The land is used for fattening, dairying, market gardening, and cropping of maize, sweetcorn, and peas.

Waihirere silt loam, mottled subsoil phase (580 ac) occurs in a few pieces of 30 and 100 ac in the Manutuke, Patutahi, and Hexton localities. It is found mainly on old flood plains of smaller streams that have not been built up as high as those of the Waipaoa River.

The profile resembles the main type in texture to a depth of about 36 in., below which there is an



Photo, A. J. Metson

Fig. 9. Soil profile of Waihirere silt loam, gravelly topsoil phase, at Matawhero

8 in. layer of coarse pumice sand (1/16 in. to ⅛ in.). Mottling occurs at 18 in. from the surface, the reddish brown and grey mottles becoming larger and more clearly defined towards the sand layer. Under the sand layer the soil is a heavy silt loam with a weakly developed nutty structure. In winter the sand layer carries water freely and tends to form a perched water table.

Land use includes orcharding, dairying, cropping, and fat-lamb production.

Waihirere heavy silt loam (2,450 ac) is more compact than the silt loam type and is not as free draining. It is distributed widely throughout the plains in 10 ch strips of 10 to 50 ac and in larger pieces of 120 to 200 ac. The larger ones occur in the Waihirere, Waituhi, Patutahi, Manutuke, and Muriwai localities, where they are either irregularly shaped or in strips 10 to 20 ch wide.

The surface is flat with a slight fall away from old river courses. At Waihirere small intermittent streams interfere with the easy movement of agricultural implements and also collect water after heavy rain.

Although there are many layers in the soil, textures of each are mainly heavy silt loams and silty clay loams. The top 9 in. is a black friable heavy silt loam with a strongly developed fine blocky and cast granular structure. This passes gradually into a lightly compacted layer of pale brown heavy silt loam having a moderately developed nutty structure. Below 30 in. there is a friable silt loam, pale brown in colour and having a weakly developed nutty structure. Well preserved worm casts in the subsoil suggest that the topsoil dries out in summer, but the layers below 22 in. are always moist. A profile is described in detail on p. 84.

The **gravelly topsoil phase** of **Waihirere heavy silt loam** (510 ac) has much the same profile, except that in the lower 6 in. of the topsoil there are fine gravels about ⅛ in. diameter. Along the edge of the terrace at Waihirere, between Bruce Road and the main highway from Gisborne to Opotiki, is a concentration of gravels (1 in. diam.) that may have been put there by Maoris in early times. The gravels provide a free-working topsoil and also help to warm up the soil quickly in the spring. This phase is restricted to Kaitaratahi and Waihirere localities, where it occurs principally in 10 to 20 ch wide strips of 120 ac and 360 ac respectively.

Waihirere heavy silt loam and its gravelly phase are eminently suitable for orchards, particularly in the Waihirere locality, where heavy frosts are rare. Present land use includes citrus growing, vineyards, market gardening, cropping of maize and sweet corn, dairying and fat-lamb production, and dairy-stud breeding.

In the Makaraka locality a sand stratum occurs between 18 and 36 in. from the surface; soil above the sand dries out badly in a dry summer. The total area is only 100 ac and was not mapped separately.

Waihirere heavy silt loam, mottled subsoil phase (1,950 ac) is on land with a water table that fluctuates widely from 2 ft in winter to 7 ft in summer. However, it is moderately well drained because of the nutty structure in the subsoil. It is distributed in 10 ch strips of 20 to 50 ac and 20 ch strips of 80 ac; in the Waihirere - Waerenga-a-Hika localities there is a continuous piece of over 600 ac and 10 to 40 ch wide. The areas are drained by small intermittent stream courses that are very wet in winter and spring.

Through worm mixing, the topsoil is a little deeper than usual - 11 to 14 in. At Waerenga-a-Hika the subsoil is a deep crumbly yellowish brown silt loam with brown and grey mottles, resting on a grey silty clay loam with a moderately developed structure. When moist the fine blocky aggregates fit closely together and tend to slow up the drainage so that it is not as early a soil as the main type; the deep silt loam subsoil, however, holds moisture longer. With artificial drainage the subsoil becomes more friable.

In the Makaraka locality there is also a sand stratum between 18 and 36 in., but the total area with this feature is only 50 ac. Soil above this stratum dries out badly in a dry summer.

Land use is mainly dairying and fattening.

Waihirere clay loam (1,330 ac) is a heavy soil and only moderately well drained. Under arable farming it requires careful moisture control and under grassland farming it poaches easily. It occurs principally at Waihirere, Muriwai, and Tamarau, where there are pieces of 100 ac. The surface is flat.

The topsoil is a black firm clay loam 7 in. thick with a strongly developed cast granular structure. This passes into 12 in. of pale brown friable clay loam with a moderately developed structure. Blocks and granules are closely interlocked and there are yellowish brown and grey mottles on their faces. Underneath is a pale brown firm clay with a weakly developed structure and yellowish brown and grey mottles.

The large number of closely packed worm casts in the topsoil permits water to infiltrate slowly, and interlocking worm casts in the second layer make the soil slow draining in winter. When wet, poaching is severe; the cast granules run together under the weight of heavy animals, and poach holes hold surface water sufficiently long to waterlog the grass-root zone to a depth of 3 in. In consequence, pastures tend to become yellow and unthrifty. Continuous heavy stocking tends to over-compact the top 4 in.

The soil becomes hard and droughty in a dry summer and cracks badly with long fissures up to ½ in. wide and 6 in. deep. It has a very narrow moisture range for correct tillage; if cultivated too wet it is very sticky, and if cultivated too dry it is very cloddy. Compacted topsoils cultivated out of grass also produce coarse tilths; under light rain or fine irrigation sprays, however, the clods disintegrate to give a fine tilth. Although cultivations loosen the soil for a time, it tends to pack down and eventually becomes compact again.

In the Makaraka locality there is a sand stratum at between 18 and 36 in., but the total area with this feature is only 100 ac and it was not mapped separately. Soil above the sand dries out in a dry summer.

Land use includes sheep and cattle fattening, dairying, maize cropping, and market gardening. The soil is suitable for market gardening if soil moisture can be controlled.

Makaraka Soils

Makaraka soils occur on the lower lying parts of the modern flood plain, where thin layers of fresh alluvium are added to the surface at each major flood. These soils are distributed mainly in irregular but continuous strips on both sides of Waipaoa River from Patutahi to Te Arai River in the west and from Waerenga-a-Hika to Awapuni Lagoon in the east. The lower lying parts of the flood plain were once swampy, but with periodic flooding these are now partly filled in and the land levelled. Varying thicknesses of filling give very diverse soil profiles. An old soil similar to Kaiti clay loam occurs at depths between 12 and 36 in. and, on this, drainage waters tend to perch in winter and spring.

There are marked changes in the physical properties of these soils according to the season. In winter they are wet, the ground water rising as close as 12 in. to the surface; in a dry summer the top 12 in. becomes loose and friable through shrinking of aggregates and there are many cracks and fissures. At this time the clay loam is especially droughty. In spring strong westerly winds dry out the top 2 in.; the soil appears to be dry, but, in fact, the lower part of the topsoil remains wet. The wetness of the soils has inherent advantages in that it delays the decomposition of dead grass roots, which help to reinforce the aggregates and also act as pores for the free passage of air and water.

Periodic additions of fresh calcareous alluvium keep Makaraka soils well supplied with plant nutrients; they are near neutral (pH 6·9) and are medium in phosphorus and high in calcium and potassium. There is a build-up of organic matter in the topsoil and, because of buried soils, carbon and nitrogen values decrease only slowly down the profile. Traces of free lime commonly occur to a depth of over 3 ft.

As the soils are wet and poorly aerated in spring, they are regarded as late soils best suited to grass or other shallow-rooting crops. Under cropping, nitrogen and perhaps phosphate are probably the main fertiliser requirements.

There are two types, Makaraka heavy silt loam and Makaraka clay loam, and included with the latter is a saline phase.

Makaraka heavy silt loam (2,510 ac) occurs in both large and small units. In the Makauri locality there is one large piece of about 1,000 ac and in the Muriwai locality there is a smaller one of about 400 ac; other individual pieces are of 100 ac. The land is flat and smooth, except at Makauri, where the surface is cut by many intermittent streams.

The 1950 and 1948 floods left little sediment and pastures were able to survive. In the flood layers, which vary in thickness from a mere skin to almost 1 in. new grass roots penetrate freely and worms churn up the raw sediment. After about two years individual flood layers become blended with the soil and are not as well marked as in the profiles of Matawhero soils.

In a typical profile the top 8 in. is a brown friable heavy silt loam with a nutty and cast granular structure; on aggregate faces there are faint grey and yellowish brown mottles. The next 7 in. is similar except that the colour is darker and the structure weakly prismatic; the succeeding 8 in. is a dark brown friable heavy silt loam with a strongly developed nutty structure. At 23 in. there is a grey silty clay loam with yellow mottles and a moderately developed structure. The subsoil is friable when dry but sticky when wet. Mottling throughout the soil indicates slow drainage in winter; drainage waters perch on the buried dark brown soil because the aggregates swell and fit closely together when wet. In a wet winter this type is very poorly drained, particularly in localities where there are intermittent streams, and water may lie on the surface for a time.

Although the structure is moderately well developed, the aggregates themselves are not strong when wet and care is required during cultivation. The surface is not firm enough in winter for cattle, and wheeled vehicles are easily bogged down.

The land is used for lamb and cattle fattening and for cropping of maize and peas. It is best used for grassland farming with cropping as a rotation.

Makaraka clay loam (2,640 ac) is a wet soil with a strongly developed structure of firm aggregates (fig. 16); under permanent grass these are bound together closely by vigorous live roots to produce a strong turf with a springy surface. It is widely distributed in pieces of 50 to 100 ac; but in the Makaraka, Willows, and Pipiwhakao localities it occurs in larger units of 300 ac. The surface is flat and smooth but is cut by many large drains, which have to be bridged.

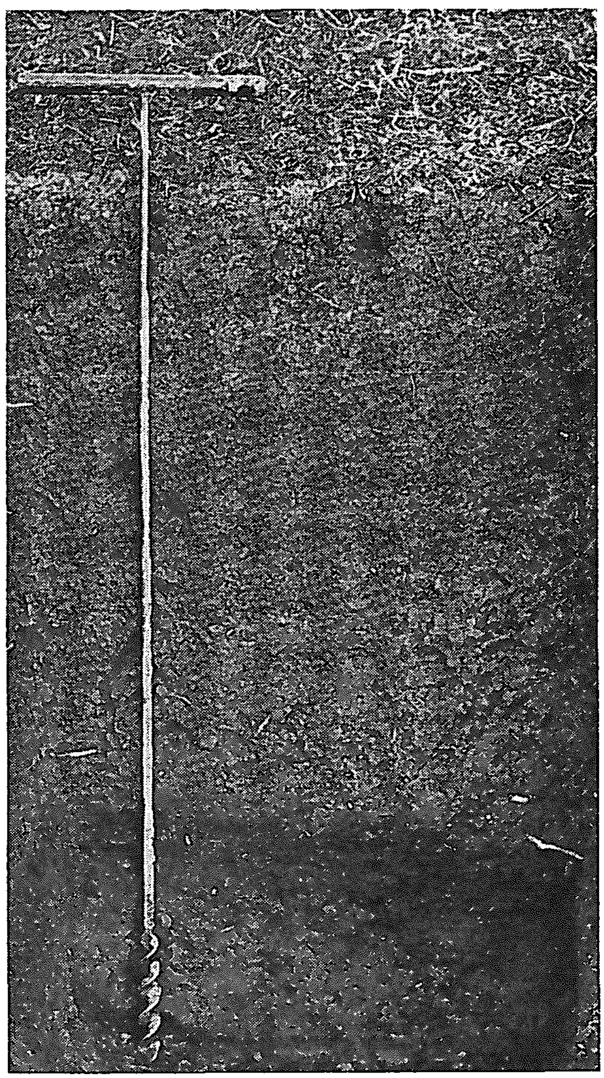
This soil type occurs on the margins of the modern flood plain where flood deposits are very fine in texture. Though flood waters are 4 to 5 ft deep and tend to pond in the Willows and Pipiwhakao localities, all that remains after a major flood is a slurry about 3 in. thick. This eventually is reduced to a firm clay loam layer less than 1 in. thick, and in this layer new roots from surviving pasture plants spread freely.

In profiles (fig. 10) the top 2 in. is a grey firm clay loam with a weakly developed structure (1950 and 1948 floods) and it rests on 11 in. of dark brown friable clay loam with a strongly developed cast granular structure; many dead grass roots are present. Underneath is 6 in. of grey and yellowish brown mottled firm clay with moderately developed structure. This rests on grey, sticky porous clay with tree-root channels filled with old topsoil. Between 24 and 36 in. is a coarse pumice sand layer 5 in. thick that carries water freely in winter; it is underlaid by sticky clay on which drainage waters perch. About Willows Road a sand stratum occurs at 5 ft. A profile from near Willows Road is described in detail on p. 84.

The mottled colours in the subsoil indicate that the soil is wet for periods, the length of which may be judged from the colour of the buried soil (13–19 in.); where it is black and tinged with blue waterlogging is brief, but where it is grey or grey with orange mottles it is waterlogged for long periods. Grey colours are common in the lower lying parts of the Willows and Pipiwhakao localities. The large amount of organic matter in the surface soil is also a pointer to wetness in winter and spring.

In the Pipiwhakao locality the surface soil is high in clay, and the aggregates shrink greatly and become very hard in a dry summer. At such times the soil becomes loose, with aggregates all of the same size and very much like cubes about an inch square. It is difficult to maintain pasture on such a soil. In the Willows locality land ploughed too wet in spring gives a cloddy tilth 3 to 6 in. deep, with clods from $\frac{1}{2}$ to 3 in.; clods may be moist on the surface but are wet inside. During westerly winds clods at the surface dry out within 3 days.

The land is used for lamb and cattle fattening, dairying, and for cropping of maize and peas. Market gardening has been practised under difficulties of flooding and waterlogging. Wheeled vehicles become bogged down very easily in winter.



Photo, A. P. Underhill

Fig. 10. Soil profile of Makaraka clay loam in the Willows locality

Makaraka clay loam, saline phase (420 ac) is restricted to lower lying parts bordering the tidal flats where the ground water is saline. It occurs in pieces of 20 to 100 ac in Awapuni Lagoon and at Muriwai.

Soil profiles are diverse: at Muriwai they are similar to the clay loam type, but in Awapuni Lagoon, where the soil is undisturbed, the 1950 and 1948 flood layers are more prominent. They are each of 2 in. of grey clay loam and are thoroughly impregnated by roots of old-man twitch and sea rush, both of which provide a very strong turf. The next layer of 6 in. is very dark greyish brown and contains an abundance of organic matter ranging from weakly decayed roots and stems of sea rush to strongly decayed plant remains that impart a peatiness to the soil. Aggregates are bound together firmly by live and dead roots. There is a sand stratum at 36 in. near Karaua Creek and at 25 in. in Awapuni Lagoon; at the rear of the fore-ridge the sand starts at 9 in. Very few earthworms were observed in Awapuni Lagoon.

As the land is less than 10 ft above mean sea level, the ground-water level is high; it is 9 in. from surface in winter and nearly 36 in. in summer. Although the ground water is saline the salt does not come to the surface. In Awapuni Lagoon, however, the content of soluble salts is close to the toxic limit and there is a risk of pasture drying up in a dry summer. At Muriwai the ground water is likely to be saline permanently, as tidal streams are continually charging the sand stratum with sea water.

On this phase, only 50 ac has been sown to grass and farmed; the remainder is idle land. The flatness of the land encourages storm-water flooding, but this water can be dispersed by digging sink holes to the sand stratum.

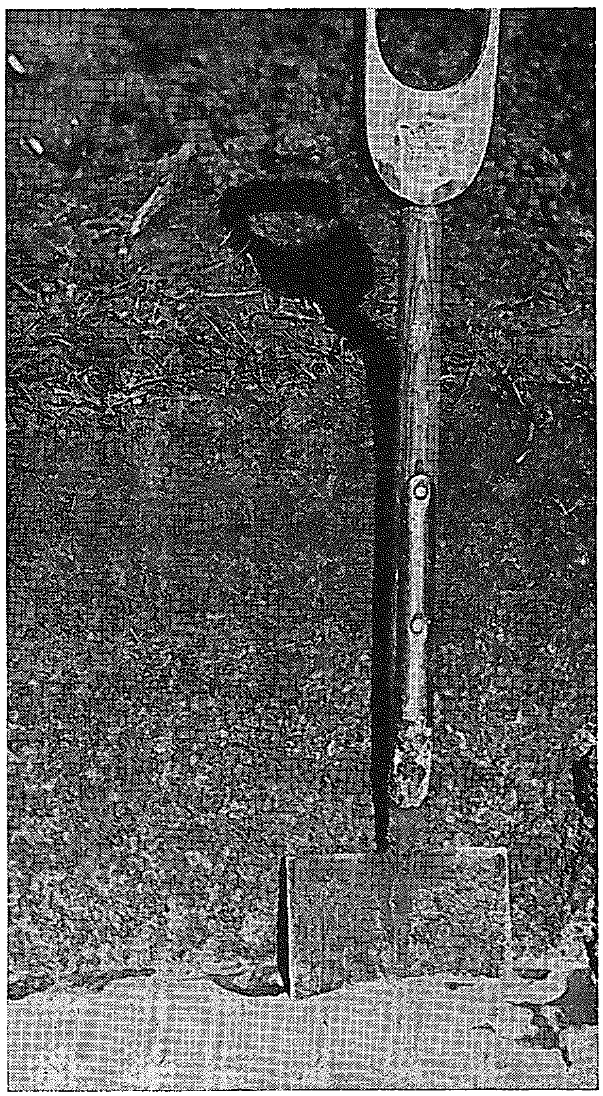
Makauri Soils

In this series the units mapped are Makauri clay loam and a friable subsoil phase of this type.

Makauri clay loam (3,530 ac) is a heavy soil and difficult to manage. It is waterlogged in winter, is wet in spring, and fissures badly in summer. Even with artificial drainage, ground water remains close to the surface in winter (see fig. 11).

This type occurs in large, continuous, regular pieces of about 500 to 1,000 ac in shallow, saucer-shaped depressions at Ormond, Makauri, and Opou, and in smaller units of about 200 ac at Kaitaratahi and Te Karaka; small pieces of 60 ac border the hills at Manutuke. At the time of European settlement the depressions were semi-swamps in which grew dense stands of kahikatea forest.

The surface is flat (fig. 12) but is etched by small, shallow courses of intermittent streams; these flow slowly in winter, and at other times fill up temporarily after heavy rain and remain excessively moist for long periods. In a dry summer the courses crack badly, drainage is excessive, and the soil in them does not easily become moist. The land is cut deeply by large drains that have to be fenced off and bridged, and at Makauri there are deep gullies where intermittent streams join Taruheru River. All of these surface irregularities are a serious hindrance to the use of implements.



Photo, A. J. Metson

Fig. 11. Soil profile of Makauri clay loam at Opou showing high water table during winter of 1950

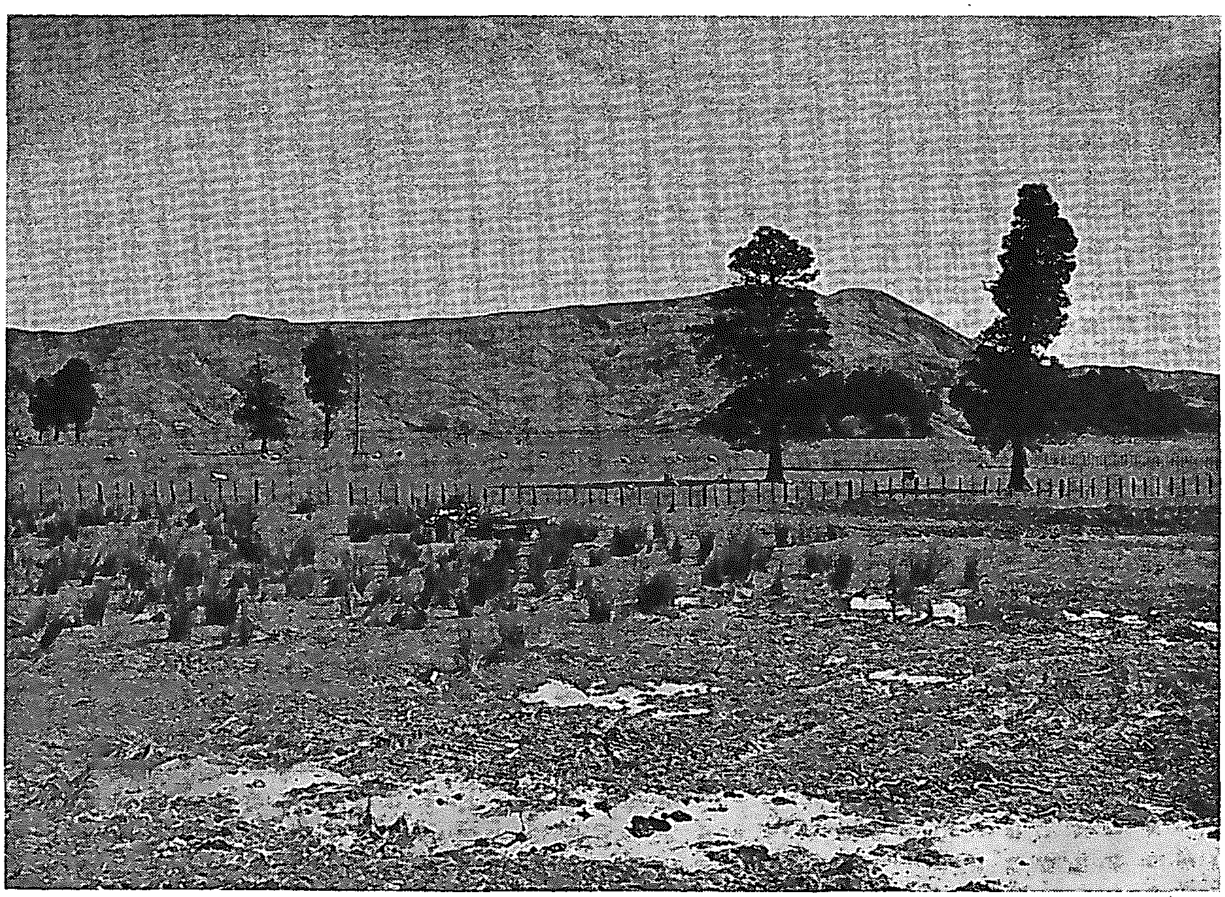
Because it lies in depressions where the natural drainage is slow, the soil retains much of its own storm water. As well, it is flooded periodically by extra storm water from nearby hills. In consequence, land development was not successful until wide and deep drains were dug; apart from removing surface water these are able to cope with large volumes of ground water drawn out of the subsoil through many fissures and old tree-root channels. The large drains also tap water from a pumice layer, 6 in. thick and 3 to 10 ft from the surface. At Opou the pumice layer is underlain by strata of grey and blue plastic clays, which are slowly permeable and form perched water tables.

Ground-water level fluctuates widely. In winter it is within 24 in. of the surface, and in a wet winter is near 12 in.; in summer it falls below 3 ft – in a dry summer below 5 ft. As the ground water contains magnesium salts, a special cement is required for concrete structures in the soil.

Although the soil is covered with water at major floods, sediments deposited are patchy and no more than $\frac{1}{4}$ in. thick. Flood waters, however, are sufficiently calcareous to add small dressings of lime. They tend to pond, but after the flood peak has passed the main drains draw off surface water fairly quickly. The Gisborne-Moutohora railway embankment, between Kings Road and Makauri Stations, serves as a dam and often prevents sediment from being carried over into the basin at Makauri.

Makauri clay loam is moderately acid (pH 5·6 to 5·8) and organic matter is fairly abundant. The plant-nutrient level will remain high for a long time as the soil has a high cation exchange capacity due principally to the expanding clay minerals, mainly montmorillonite. These clay minerals are also responsible for the swelling and shrinkage properties that help to make this soil difficult to farm.

The topsoil of 10 in. is a very dark grey firm clay loam with a strongly developed structure of



Photo, A. J. Metson

Fig. 12. Landscape on Makauri clay loam at Opou

fine blocks and cast granules that in the upper 4 in. are entangled in a mat of fine and coarse dead roots of grasses and sedges (fig. 11). Faces of clods compacted by poaching assume a bluish tinge. The subsoil down to 25 in. is a grey friable clay stippled with red fine mottles. When moist, it has a coarse prismatic structure, which breaks down readily into strongly developed medium-sized blocks; when dry, the blocks shrink so much that the prismatic structure is exaggerated, wide fissures being left between the prisms. Below 25 in. is a pale grey tough clay with a strongly developed structure of fine blocks that are tightly packed together in place but fall apart easily when disturbed. Soil structure is further discussed on pp. 48–9 and a detailed profile description is given on p. 84.

In a dry summer the shrinkage of this soil can disturb ordinary building foundations, and piles require to be sunk into the permanently moist zone below the pumice layer. Fissuring can be lessened by placing concrete pavements around the building or be prevented by raising a foundation ramp from spoil of another soil type, preferably with a silt loam texture.

Topsoil aggregates are very hard in summer; they swell and lock together in winter, particularly below the root mat, and this induces slow drainage, encourages poaching, and promotes waterlogging in the grass-root zone.

Land use includes lamb and cattle fattening, dairying, maize and pea cropping, and grass-seed production.

A **friable subsoil phase** of **Makauri clay loam** (880 ac) occurs in one large piece of 350 ac at Opou and in a few small pieces of 20 to 80 ac at Te Karaka, Kaitaratahi, and Muriwai. It differs from the type in that the topsoil is more sandy and the subsoil more friable to a depth of 36 in.

The top 7 in. is a dark brown firm heavy silt loam with a moderately developed fine blocky and cast granular structure. This passes gradually into a 7 in. layer of grey friable clay loam similar in structure to the topsoil but with more worm casts; the grey colour is relieved by many sharply defined orange small mottles. Old tree roots, encasing black-coloured worm casts, are common. The basal layer is a friable silty clay loam with a moderately developed structure of very fine blocks, many of which are stained brown with iron oxide.

Land use includes lamb and cattle fattening with a small amount of dairying, pig farming, and maize cropping. Rushes are constantly invading the pastures, which need to be harrowed frequently.

Kaiti Soils

Kaiti soils are very wet in winter and dry out and crack badly in summer. In the field they are recognised by their black topsoils and near-white subsoils. The soils occur in shallow depressions along the margins of the plains and have not been flooded for a long time. They cover a relatively large area of 8,850 ac, nearly half of which is distributed in units of about 1,000 ac in the Patutahi, Hexton, and Tamarau localities. Most of the land is farmed. Gisborne city, however, now includes parts of Tamarau–Wainui localities, and it is likely that much of the land there will be lost to farming within the next decade.

There are three types, Kaiti silt loam, Kaiti heavy silt loam, and Kaiti clay loam; associated with the silt loam type is a firm topsoil phase and associated with the clay loam type is a shallow topsoil phase.

Kaiti soils are generally well supplied with plant nutrients, except Kaiti silt loam, firm topsoil phase, which is low in phosphorus and potassium. Owing to differences in clay content, there is a range of cation exchange capacities, the heavier soils having the higher capacities. Topsoils tend to be acid, ranging from moderately acid (pH 5·4) to slightly acid (pH 6·2) (table 3, p. 43).

Kaiti silt loam differs from other Kaiti soils in that the topsoil incorporates pumice. It occurs principally in the Hexton, Whataupoko, Kaiti, and Wainui localities, where it is distributed mainly in pieces of about 100 ac; at Kaiti there is a larger piece of 250 ac. There are also isolated patches of nearly 100 ac in the Patutahi and Muriwai localities; the total area is 2,150 ac, of which about 600 ac is included in Gisborne city.

The soil is commonly found on old natural levees and in clay-floored narrow troughs between old beach ridges, particularly at Whataupoko and Wainui; these parts of the land were lightly mantled with volcanic ash and were consequently flooded by streams on infrequent occasions, mixing alluvium with the ash. Through unevenness of flooding, topsoils are more sandy in some places than in others.

At Kaiti the topsoil is 9 in. thick and consists of a black very friable silt loam with a soft granular structure. Under grass there is a strong fibrous root mat to 3 in. The topsoil passes gradually into a 6 in. layer of yellowish brown friable loamy sand, which rests on a range of materials; at Kaiti the subsoil is a yellow dense clay loam, at Hexton (fig. 13) a soft and friable heavy silt loam, and at Wainui a pale yellow tough clay. All subsoils have weakly developed structures of coarse nuts and blocks. In the troughs at Whataupoko and Wainui the subsoil is a white sticky clay or a clayey sand, 9 to 24 in. thick, this passing downward gradually into fine beach sand.

The topsoil drains freely, but the subsoil is slow draining because of few passages between the large aggregates. Drainage waters tend to perch on the subsoil, and in a wet winter the topsoil is saturated for long periods; waterlogging is marked after heavy rain. In summer the topsoil dries out badly, but the clay loam and clay subsoils remain moist at about 18 in. At Hexton brown mottles in the heavy silt loam subsoil indicate a seasonal drying out to a depth of about 21 in. In July 1951, in a wet winter, ground-water level was at 18 in. from the surface, but in October it fell to below 30 in.

Photo, A. J. Metson

Fig. 13. Soil profile of Kaiti silt loam at Hexton

The soft aggregates in the topsoil and the periodic waterlogging and drying out bring problems to agriculture. When not too wet or too dry, the topsoil works up to a fine tilth, but constant hoeing is required to keep the soil open (fig. 16). Aggregates cannot withstand beating by rains, and waterlogging decreases the bearing strength of the topsoil considerably. On drying out the topsoil becomes powdery and fluffy and in this condition is difficult to wet. In view of these problems it is desirable to encourage grasses that produce a strong turf; in any event, cattle should not be wintered on this soil.

In a vineyard along Glenelg Road, Hexton, hard lumps of black manganese oxide and nodules of iron oxide are concentrated in a narrow horizon 18 in. from the surface; such a concentration of manganese oxide is not known elsewhere on Gisborne Plains.

The uptake of minerals by sweet vernal (*Anthoxanthum odoratum*) has been measured (Wells and Fieldes, 1956); calcium and manganese are high, potassium moderately high, phosphorus and copper low, and molybdenum very low. There is likely to be a pasture response from molybdate topdressing. Because of admixtures of rhyolitic pumice, the trace-element chemistry of Kaiti silt loam is more like that of yellow-brown pumice soils than of recent soils from alluvium.

Present land use includes sheep and cattle fattening, dairying, market gardening, and grape growing. Because of a plentiful supply of moisture in summer, fruit trees grow well where the subsoil is a beach sand; but the area of sandy subsoil is 400 ac and limited to Gisborne city.

A **firm topsoil phase of Kaiti silt loam** is mapped where the topsoil has a well developed structure. It occurs in small shallow depressions that were once swampy and is distributed in one piece of over 200 ac in the Hexton locality and in a few smaller pieces of about 100 ac at Tamarau. The total area is 640 ac of which about 200 ac is in the city.

At Hexton the top 8 in. is a black firm silt loam with a well developed nutty structure; there is a strong turf 4 in. thick produced by paspalum grass, which grows vigorously in this soil. The topsoil passes sharply into a 2 in. layer of pale yellow loose coarse sand (pumice), and this passes abruptly to a massive, white mottled sandy clay. Below 18 in. is a pale yellow sticky clay with red mottles. The red mottling of the subsoil indicates that artificial drainage has improved soil aeration. The topsoil is waterlogged in winter and, in consequence, puddles and poaches very badly, more so than the main type; in a wet winter, even sheep puncture the surface. The land reverts easily to sedges and buttercup.

Chemically, the phase is not as fertile as the type; in a profile at Hexton, the topsoil is moderately acid (pH 5·4) and is low in phosphorus and in potassium.

Land use includes stud sheep and cattle breeding, dairying, hogget fattening, maize cropping, and grape growing.

Kaiti heavy silt loam (1,170 ac) is not as poorly drained as the other Kaiti soils and it has responded better to artificial drainage. The type is confined mainly to the western margin of the plains, where it is distributed in pieces of 25, 40, and 100 ac; near Patutahi is a large piece of 200 ac. The surface is flat and is now divided by a fine pattern of shallow, open drains.

It occurs in lower lying parts of the old flood plain where the soil has consolidated; it contains less clay than Kaiti clay loam, which occurs in lowest lying parts. A 6 in. pumice layer commonly occurs between 3 ft and 5 ft, and underneath is a sticky clay upon which drainage waters tend to perch. The pumice layer is water bearing in winter.

There are wide fluctuations in ground-water level, which may rise to within 16 in. of the surface in October of a wet winter and fall to below 8 ft in the following February; ground water is within 3 ft to 5 ft of the surface from September to November, which is a much shorter period than for Kaiti clay loam.

Under grass at Patutahi the top 7 in. is a black firm heavy silt loam with a coarse blocky and cast granular structure. There is a firm turf to 2 in. and the topsoil contains many partially decayed rootlets. The topsoil merges downward into 17 in. of pale grey friable heavy silt loam with porous aggregates. Old tree-root channels encase both decayed roots and grey worm casts, and these extend into a grey crumbly clay loam layer below 24 in.

Under pasture, infiltration through the topsoil is slow because of few passages between the large dense aggregates, but the subsoil is more permeable by reason of old tree-root channels and porous aggregates. In winter the top 3 in. is often saturated when the remainder of topsoil is moist. The topsoil does not dry out as in Kaiti silt loam, nor does it crack as badly as Kaiti clay loam, but in cultivated fields surface aggregates become hard in a dry summer. Profiles indicate that there is aeration to depths of between 21 and 30 in., below which the subsoil is permanently moist.

The best function that surface drains can perform is to clear the land of storm water as quickly as possible; to wait for water to soak through the slow draining topsoil is to court the possibility of poached pastures and, as water will lie about for a long time, deteriorated swards. To encourage better drainage in the topsoil the large aggregates of closely packed worm casts need to be broken up, preferably by deeper rooting grasses; paspalum is one such grass and it has the advantage of providing a strong turf to carry animals in winter. When ploughed out of grass this soil tills to a fine friable seed bed.

At Makaraka Racecourse there is a small piece of about 40 ac underlain by sand at 9 to 15 in.

The land is used for sheep and cattle fattening, for dairying, and for production of perennial ryegrass and clover seeds.

Kaiti clay loam (2,640 ac) is high in plant nutrients, but its use is limited by excessive wetness in winter and spring. Also, it is a heavy soil and cannot be tilled properly until the moisture content is suitable.

This soil is distributed along the margin of the plains in pieces of 20, 50, and 100 ac, with larger pieces of 200 and 400 ac in the Patutahi locality. The surface is flat but is dissected by many artificial drains. The soil occurs in small low-lying depressions, which are naturally swampy and difficult to drain; even with artificial drainage the soils are still poorly drained. During major floods parts may be inundated with muddy water.

Ground-water level is within 18 in. of the surface in winter and spring but may fall to below 5 ft in a dry summer. A water-bearing layer of coarse pumice sand about 6 in. thick is common at about 24 in. from the surface.

In a profile along Kaimoe Road, Patutahi, the top 9 in. is a black firm clay loam with a well developed fine blocky structure and many weakly decayed rootlets. There is a shallow turf to 2 in. The topsoil merges gradually into 9 in. of pale grey firm clay that becomes sticky and plastic when wet. Old tree-root channels are filled with topsoil now turned grey by waterlogging. Between 23 and 30 in. the clay is greenish grey, and underneath is a seam of loose, coarse pumice sand; below 36 in. to a depth of more than 5 ft the clay subsoil is friable with a well developed blocky structure.

Though the soil is frequently wet, ground water is not necessarily stagnant; shrinking and swelling create openings through which water slowly moves.

In a dry summer the structural blocks form large prisms with fissuring and cracking in the soil. Fissuring is not as marked as in Makauri soils, but movement is sufficient to unsettle building foundations. Fissuring seems to encourage consolidation when the land is heavily stocked with cattle; when trampled on, prisms vibrate noticeably and, perhaps, realignment of aggregates causes the surface to sink a little.

Land with this soil is not suitable for dairying or cattle fattening unless associated with hill country for running stock in winter. In growing maize the farmer frequently has to prepare a seedbed in a wet soil so as to be able to harvest the crop on firm ground during April or May of the next year. Often in spring and early summer drying westerly winds bake the top 2 in. and leave the lower part of the topsoil still wet, and to avoid a cloddy seedbed it is good practice to roll within a few hours of discing.

Present land use includes maize cropping, fat-lamb and hay production, stud-sheep breeding, and a small amount of dairying. Best use is fat-lamb production with cropping as a rotation.

A **shallow topsoil phase of Kaiti clay loam** (2,250 ac) is mapped in large and small units in the Patutahi, Muriwai, and Tamarau localities; small units are of 30 to 60 ac, and there is a larger one of 200 ac at Tamarau, one of 400 ac at Muriwai, and one of 800 ac at Patutahi.

It is the oldest surface of the plains, and the soil is naturally consolidated and, in places, the subsoil compacted. The topsoil is about 6 in. thick, is slightly peaty, and has a strongly developed structure of very firm blocky aggregates that do not disintegrate under excessive cultivation or under beating by heavy rains. A profile is described in detail on p. 84.

To exploit the natural fertility fully, strict attention must be paid to management of the soil. In arable farming it must be shallow ploughed to avoid contaminating the seedbed with sticky intractable subsoil, and to get a friable tilth it must be worked neither too wet nor too dry. If worked too wet, apart from producing a coarse cloddy tilth, the clods eventually fuse into a cultivation pan about 3 in. from the surface. Such a pan induces perching of water, and in summer it encourages severe cracking, with cracks 1 in. wide, 9 in. deep, and 12 to 24 in. apart (even when the surface is shaded by a dense cover of maize). If worked too dry, furrows cannot be cut properly with the discs. In grassland farming the soil poaches badly, leaving a rough and lumpy surface, and the top 2 to 3 in. becomes compacted and easily waterlogged with stagnant water; when pasture is subsequently ploughed in this compacted surface layer tends to form a pan in the lower part of the topsoil.

The surface is flat, but is dimpled by shallow holes left after tree stumping, is lightly etched by meandering water courses that are dry for most of the year, and is cut by many artificial drains. A dimpled surface introduces a range of topsoil thickness from 6 to 9 in.; stands of maize are thus rather uneven, and this crop thrives better in the deeper topsoil of Kaiti clay loam.

The subsoil may be sufficiently dense to restrict root penetration of grass and crops and it is not certain that the conventional mould-board plough and the disc are suitable implements for working up this soil. An implement fitted with spikes or chisels to rip through and lift the soil rather than turn it over would perhaps be more effective.

There are a few variations not plotted on the soil maps. Along both sides of Waikanae Creek, between Lytton and Stanley Roads, are small pieces, aggregating 60 ac, with a sand stratum at 18 to 24 in.; in patches nearer the stream a peaty stratum takes the place of sands. At Rakaukaka Rehabilitation Farm Settlement near Tansley Road, Patutahi, peaty soils occur in the bed of a partly drained raupo swamp; the top 9 in. is a loamy peat, which overlies grey sticky clay. Around the periphery of the swamp the peaty soils are now becoming mineralised. In 1950 such soils were markedly peaty, but in 1953, after the land had been disced, grassed, and stocked, soils were much less peaty, perhaps because of the activities of earthworms, which were particularly numerous at that time. Between 19 and 24 in. are peat and timber, and at 24 in. a thick stratum of coarse pumice sands, always carrying a great deal of water and always tending to choke any open drain that may be constructed. The area of loamy peats is 20 ac and that of peaty loams 80 ac.

Land use is mainly fat-lamb and beef production and maize cropping. The soil is best suited to grassland farming without cattle and with cropping as a rotation.

Soils of the Tidal Flats

Muriwai Soils

Muriwai soils (1,170 ac) are restricted to the tidal flats in Awapuni Lagoon and at Muriwai. They are saline and poorly drained and can grow only the most salt-tolerant plants. The tidal flats are the idle land of Gisborne Plains and are gradually being reclaimed for agricultural use. Reclamation work in Awapuni Lagoon began in 1958.

The land stands about 3 ft above mean sea level and is traversed by many tidal channels that overflow at spring tides. Sea water left after flooding soaks away slowly, leaving salt in the soil. The surface is so flat that there is no run-off, and ground-water level is high over most of the year. In a wet winter water may lie on the surface. Over the years the floor of the tidal flats has gradually been raised by successive floodings of the Waipaoa River, which leave residues of clay up to 3 in. thick at each flood. This has gradually reduced the area inundated with sea water.

The two types, Muriwai clay loam, which is moderately saline, and Muriwai clay, which is strongly saline, usually lie side by side on the tidal flats, but can be distinguished one from the other by the vegetation – Muriwai clay loam has a dense cover of sea rush or sea aster, and Muriwai clay may be bare or partly covered with salt weed. Vegetation boundaries are quite distinct (fig. 14).

Muriwai clay loam (490 ac) occurs in small pieces of about 10 and 50 ac. The soil is heavy and, when wet, is sticky and plastic. The top 8 to 10 in. is a massive clay loam, mottled grey, pale blue, and pale brown. It passes downward into a dark greyish brown clay loam in which are embedded many weakly decayed roots and stems of sea rush. These roots and stems provide fissures for the free passage of ground water. In Awapuni Lagoon is a pale blue plastic clay or pale blue sand at 30 in., and in the Muriwai locality there is sand at 18 in. The ground-water level reaches the surface in winter and falls to 30 in. in summer.

Analysis of a typical profile shows the soil to be strongly alkaline (pH 8·4) and high in soluble salts (table 4), which make it toxic to any but salt-tolerant plants. Organic matter is low. There are also large amounts of exchangeable magnesium and sodium. The latter inhibits the formation of soil aggregates, which are so necessary to good drainage. Ground water is high in soluble salts (table 5).

Photo, A. P. Underhill

Fig. 14. Awapuni Lagoon, showing vegetation/soil boundaries. In the foreground is salt weed on strongly saline soil; in the middle distance, sea rush on moderately saline soil; and the lighter strip in the background is old man twitch on weakly saline soil

In 1955 the plant cover in Awapuni Lagoon was principally sea rush with a few patches of *Selliera* and salt weed. In 1949 the rush cover was less dense and more open, and in the open spaces *Selliera* flourished. These changes suggest that the soil is becoming less saline, possibly owing to leaching of soluble salts during the wet years of 1950 and 1951 and to the raising of the surface by the 1950 flood to a level just beyond the reach of all but the highest spring tides.

Muriwai clay (680 ac) occurs in two large pieces of about 350 ac in Awapuni Lagoon and about 300 ac at Muriwai. The lowest lying portions are flooded daily with sea water, but as it may become practicable to shut off the tidal waters in any reclamation scheme these portions are included in this type.

The soil is sticky when wet. In a typical profile the top 4 in. is a grey laminated clay with a very coarse prismatic structure that breaks into coarse blocks. Many yellowish brown mottles on the faces of blocks indicate periodic wetting and drying near the surface. Underneath is a 12 in. layer of greyish brown sticky plastic clay with a weak coarse blocky structure. This layer is penetrated by many fine living roots enclosed in bluish grey sheaths indicating permanent wetness. Below is a 4 in. layer of greyish brown sticky massive clay on a wet viscous greenish grey clay that continues to over 5 ft. A profile is described in detail on p. 85.

In a typical profile the soil is moderately alkaline (pH 7·8) and is extremely high in soluble salts (table 4), particularly sodium and magnesium chlorides, so that it can grow only the most salt-tolerant plants such as salt weed, or nothing at all. Soluble salts are much higher than in the moderately saline soil, Muriwai clay loam, but exchangeable sodium and magnesium are not as high. Laboratory measurements (table 6) show 44% of clay in the top 3 in. and the clay to be poorly aggregated and easily dispersed; but, even so, the surface soil has a better structure than that in Muriwai clay loam. This is due to an excess of soluble salts, which it is known prevent the clay from forming a solid mass. Organic matter is low to very low.

Ground water is very high in salts (table 5). As the ground water moves slowly through the soil the free level cannot be measured easily; in summer it is about 42 in. from the surface and in winter about 30 in.

Steps in the reclamation of Muriwai soils are (1) exclude tidal waters, the source of the salts; (2) lower the ground water level; (3) eliminate salts from the soil; and (4) add nitrogen to assist in establishment of a grass cover.

Tidal waters are usually shut off by an automatic gate, and this has already been done for Awapuni Lagoon. Then the salt has to be washed out of the soil by leaching with fresh water, and to do this the ground-water level must be lowered appreciably. The drainage system, to be efficient, must keep the level sufficiently low to prevent salts returning to the surface soil in summer and should be so arranged that drainage waters carry the salt leachates away from the site. As the land is low-lying, conventional gravity drains may not suffice and pumping will probably be necessary.

It is important to know the kinds and amounts of soluble salts present at each stage in reclamation as well as the proportions of cations in the exchange complex, as there is a danger that a structureless sodium-magnesium clay might form. The danger period, however, is not likely to be long because free lime in the soil will, in time, convert such a clay into a granular calcium clay with well structured aggregates.

In bringing this land into production, the soils should be disturbed as little as possible so as to preserve their structure: to improve the structure a grass cover is best, but to establish grass nitrogen will have to be added to the soils. Muriwai clay loam should be brought in first and Muriwai clay later.

For reclamation, use should be made of characters inherent in the soils. In Muriwai clay loam soluble salts are partly leached, and this has allowed the soil clay to disperse and so to decrease permeability; but this natural tendency is offset by the large numbers of partially decayed roots and stems, which help to break up the soil and allow water to move freely. There is also a sand stratum near the surface, and if the ground water can be lowered to this stratum the leachates can be removed readily. Surface water can be drained by digging sink holes to the sand stratum. In Muriwai clay the excess soluble salts are sufficient to give some aggregation to the soil, but when these are removed the structure will tend to deteriorate for a time. There are no buried stems and roots to assist the drainage and there is no shallow sand stratum. Trench drains encourage the development of fissures or cracks, which increase the permeability.

Salts are more harmful in soil with a low organic-matter content, and in Muriwai clay the organic-matter level is low. Also, effective salt concentration in the surface soil is greater in summer and becomes more marked in clays that dry out badly (e.g., Muriwai clay).

Soils of the Beach Lands

Opoutama Soils

Opoutama soils are formed from sands of the new beach bordering the coast. Along Poverty Bay the beach lands are continuous but follow an irregularly shaped plan; they are a few chains wide at Young Nick's Head and about 1 mile wide in Gisborne city. At Wainui they follow a strip 5 ch wide parallel to the shore line. The soils are not important agriculturally as much of the land is built over. The total area is 2,250 ac, of which only about 1,000 ac are available for farming.

Two types are mapped – Opoutama sand and Opoutama loamy sand.

Opoutama sand is formed from the beach deposits nearest the shore line. These include the storm beach at Muriwai and parts of the foredune along Waikanae Beach, both of which have been built up by the sea within the last 20 to 30 years. In its natural state the land is hummocky or ridgy, and at the abattoirs a prominent foredune rises steeply from Awapuni Lagoon to a height of nearly 20 ft.

The sands are stabilised by a close cover of weeds, sand grasses, and shrubs, including harestail, sicklegrass, yellow sand coprosma, evening primrose, and pohuehue. The moss, *Bryden*, carpets the foredune, and the native sandbinder, *Spinifex*, is rapidly invading new ridges and storm beach.

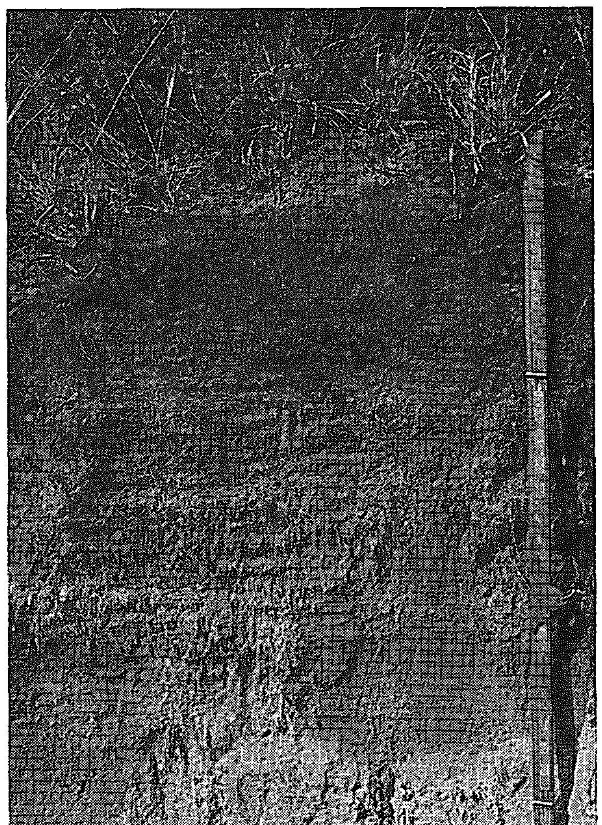
The soil (fig. 15) on the foredune under natural cover has a ½ in. mat of dead roots, underlain by a 2 in. horizon of pale brown sand held together by a strong fibrous mat of both living and dead roots. Underneath is grey loose sand in which roots penetrate to 10 in. At Muriwai, where a ridge was once sown in grass but is now covered with tree lupin, the top 5 in. is a brown and white loose sand underlain by 7 in. of greyish brown and white loose sand. Below is grey loose sand. Both of these profiles show that from time to time on-shore winds have been strong, for the top horizons in each instance are new sands that have buried the vegetation.

In a typical profile the top 6 in. is near neutral (pH 6·8) and is medium in phosphorus, high in potassium, but low in carbon and nitrogen; below 15 in. there is free lime and the subsoil is moderately alkaline (pH 8·0). As plant nutrients are associated largely with the organic topsoil, it is essential to maintain a high level of organic matter in this sandy soil. Opoutama sand dries out badly in summer and productivity is limited more by deficiencies of moisture than by mineral nutrients.

The area is 1,080 ac, of which 670 ac is available for farming. The land is used mainly for rough grazing. In winter the soil drains freely and the consolidated sands provide a strong, firm surface. It is thus an excellent soil for wintering cattle.

Opoutama loamy sand is formed from the older beach deposits 30 to 60 ch from the shore line and inland of Waikanae Creek, Awapuni Lagoon, and the Karaua Stream at Muriwai. The topsoil and subsoil are more distinct than in Opoutama sand.

The land comprises a series of long, continuous, closely spaced ridges each about 2 ch wide and 3 to 5 ft high. The ridge tops are about 2 ch apart, and ridges and hollows are smoothly moulded. Sands are finer and more consolidated than those of Opoutama sand and the soil is well stabilised



Photo, A. P. Underhill

Fig. 15. Soil profile of Opoutama sand on foredune fronting Poverty Bay

with such grasses as ratstail, perennial rye, Indian doub, meadow grass, and goose grass. On a well drained ridge under a perennial ryegrass, cocksfoot, and paspalum pasture, the topsoil is a dark greyish brown loamy sand, which changes sharply to a brownish yellow loose sand at 8 in. The topsoil has a weakly developed coarse blocky structure and there is a strong root mat to 3 in. from the surface.

The topsoil is slightly acid (pH 6·0) and rather low in organic matter; it is also low in phosphorus but is high in potassium. Minute shell fragments at about 18 in. give the subsoil a strongly alkaline reaction (pH 8·3). The soil dries out in summer but retains moisture longer than does Opoutama sand.

This type includes a number of variations too small to be mapped. Among these are the 400 ac deep coarse pumice sands in the vicinity of Darton Field. These sands dry out very rapidly, grasses wilt early in summer, and pasture runs out quickly. The soil in this locality is best suited to deeper rooting plants like lucerne, whose roots can search for ground water at between 6 and 10 ft. Another variation is 80 ac of poorly drained soil around the Intermediate School, where the ground water level may rise to within 30 in. of the surface in winter. The topsoil is darker than usual and contains more partly decayed organic matter. Some trees, like macrocarpa, do not thrive at all well in this locality, probably because of the high ground-water level in winter and spring.

In Awapuni Lagoon and at Muriwai are small wet low lying areas with soils of a sandy loam texture; these are useful adjuncts to the drier Opoutama soils, as they carry pasture into the summer. The area is about 140 ac.

Although the total area of this type is 1,170 ac, the land now available for farming is only 420 ac and is used chiefly for sheep and cattle grazing. Like Opoutama sand it is an excellent soil for carrying stock in winter.

Te Hapara Soils

Te Hapara soils are associated with the raised beach. They are formed from rhyolitic pumice, which is up to 11 in. thick and is underlain by fine beach sand. Their distribution is restricted to Gisborne city and to parts of the Taruheru Makaraka, and Wainui localities. On these soils, there is now little land left for farming and it is likely that within the next decade much of the remainder will be built over.

There are two types, Te Hapara sandy loam, which is excessively drained, and Te Hapara mottled sandy loam, which is poorly drained. The topsoils are moderately acid (pH 5·6) and are medium in nitrogen, phosphorus, calcium, and potassium. With farming, however, there are likely to be early responses to phosphate and potash (see p. 46). The nutrient level is higher than usual for a pumice soil, which suggests that there is an admixture of other mineral matter, either as dust from the roads or as sediment from muddy flood waters in the past; such additions, however, cannot be distinguished in the field. In contrast, the beach sands underneath are very low in plant nutrients.

Te Hapara sandy loam (1,630 ac) occurs mainly in the Taruheru and Makaraka localities, where beach ridges are well formed and lie in groups. One group starts at Darton Field and follows closely upon the Taruheru River in a 20 ch wide strip through the business sector of Gisborne city; other groups lie between Taruheru River and Hansen Road, where they are separated by old and new courses of Hapara Stream.

The top 7 in. is a black very friable sandy loam with a weakly developed structure of fine granules; it is, however, reinforced with a strong grass-root mat. Underneath is a 4 in. layer of loose coarse sand, pale yellow to white in colour and resting on a brownish yellow fine sand. A profile is described in detail on p. 85.

The soil is free draining to about 6 ft, so that in winter the surface is firm and in spring the topsoil warms quickly. In summer, however, the soil dries out badly, except in the deeper troughs where there may be enough moisture to carry pasture. After a dry spell much rain is required to recharge the sands with water. At Taruheru and at Makaraka the troughs are floored with poorly drained alluvial soils whose ability to retain moisture in summer offsets the droughtiness of the neighbouring ridges. The soil tills to a fluffy powder and is susceptible to blowing by westerly winds.

On the banks of Taruheru River the beach sands are 6 to 15 ft thick and overlie clay. About Dalrymple Road, Mangapapa, hard siltstone comes to within 2 ft of the surface. In the Mangapapa and Taruheru localities a plentiful supply of water for irrigation can be pumped from a shelly sand bed at 12 to 16 ft. This water, however, is unsuitable for drinking.

Only 630 ac of the 1,630 ac of this type are now devoted to farming; about 320 ac are in small holdings of 5 to 10 ac, principally in the Taruheru locality. Farming land is used for lamb and cattle fattening, stud-sheep breeding, poultry farming, pig raising, dairying, and maize cropping.

Te Hapara mottled sandy loam (1,090 ac) is associated with areas where the ground water is permanently near the surface. It occurs chiefly in the Te Hapara suburb and in the business sector of Gisborne where there is a continuous strip of about 900 ac between Gladstone Road and Childers Road. Here the type is wedged between the ridgy Te Hapara sandy loam inland and the Opoutama loamy sand on the coastal side. The transition is so smooth that the soils can be identified only by finding the pumice mantle. In the Taruheru and Wainui localities small scattered pieces of 20 to 50 ac total 180 ac.

The land is naturally corrugated by shallow inconspicuous ridges no more than 2 to 3 ft high and about 1 ch wide, but in the city these are now smoothed over. In early times, the soil was waterlogged and the land swampy.

The soil is poorly drained, with ground water levels at 3 to 5 ft from the surface in winter. The top 9 in. is a black friable sandy loam with a weakly developed crumb structure. Underneath is a 4 in. layer of loose coarse pumice sand, brown to dark brown in colour. This passes into a pale yellow fine sand conspicuous by its red lumps of iron-coated sands. At Te Hapara the fine sand below 3 ft is blue, indicating permanent waterlogging. At Taruheru lightly compacted iron-coated sands occur at 14 to 21 in. from the surface, and a soft iron-cemented pan at 21 to 36 in. is sufficiently dense to impede soil drainage. The red and yellow colours in the subsoil indicate that the water table has been lowered 1 to 3 ft by artificial drainage, but this is insufficient in a wet year when ground-water levels rise appreciably. In the city, therefore, it is important to lead storm water from buildings into sealed channels and not allow it to enter the soil.

Where cultivated, the soil aggregates break up easily under beating rains and fuse to produce a firm flat skin on the surface. In home gardens frequent hoeing is necessary to open up the soil for drainage and aeration.

In the Te Hapara locality shells and driftwood are common at a depth of 5 ft, and out of the thin layer of these materials flows a copious supply of water sufficient to interfere with the digging of deep drains by conventional methods like sheet piling. This shelly layer, as well as another at 10 to 12 ft, can be tapped and pumped for permanent water supplies. Near the abattoirs fine sands are over 100 ft deep, and at Taruheru, Mangapapa, and Wainui beach deposits are underlain by a clay stratum at 5 to 10 ft from the surface.

The land now available for farming is less than 200 ac, most of which is farmed in conjunction with the well drained Te Hapara sandy loam.

SOIL ANALYSES

General Soil Chemistry

By A. J. Metson, Soil Bureau

In order to describe the chemical properties of soils in a quantitative way it is necessary to introduce a number of technical terms, some of which are briefly described in the following notes (for a more detailed account of soil chemical properties and soil analyses, see Metson (1956)). Quantitative results are given in table 3.

pH. This is a measure of the acidity or alkalinity of the soil. On the pH scale a figure of 7 means "neutral", i.e., neither acid nor alkaline. The usual range of pH in soils extends from about 4 (very acid) to 9 (very alkaline). Soils with pH values greater than 7·0 usually contain calcium carbonate. pH values from 6 to 7 may be regarded as optimal for pasture soils in general. Plants differ to some extent in their pH requirements although almost all will grow satisfactorily over a range of 1·5 to 2 pH units, provided the various plant-nutrient elements are in adequate supply.

"Available" Phosphorus. There is no universally accepted criterion of availability; methods satisfactory for one group of soils may fail with another. In this bulletin the solubility of soil phosphorus in 1% citric acid has been used as the measure of availability.

Organic Carbon and Total Nitrogen. In the usual analysis no attempt is made to fractionate the soil organic matter, but organic carbon and total nitrogen are determined. If required, total organic matter can be calculated from the organic carbon figure by multiplying by 1·73 (since soil organic matter contains approximately 58% carbon). Organic matter tends to be low in some recent soils because of the limited time the organic cycle has been in operation. Moreover, soils regularly cultivated do not accumulate organic matter as do soils under an undisturbed cover of vegetation, whether this be forest, native grassland, or permanent pasture.

Carbon/Nitrogen Ratio (C/N). The C/N ratio provides a good index of the extent of decomposition of organic matter present. If C/N is high, say 20 or more, as in most peats, forest litters, and other partly decomposed organic materials, the indication is that organic matter is comparatively raw. C/N ratios of 14 to 18 indicate that breakdown of the organic matter is well advanced, while ratios of 10 to 12 are normal for the topsoils of cultivated soils such as occur on the Gisborne Plains. The lower ratios mean that accumulation and breakdown of organic matter have reached the stage of equilibrium. Continued cultivation without addition of organic residues would tend gradually to "burn up" this organic matter rather than lower the C/N ratio still further.

Cation exchange in soils originates through the existence of net negative charges on the clay minerals and on organic matter; these charges are in turn due to chemical irregularities or imperfections in the crystal lattice of the mineral. For example, the substitution of divalent magnesium (Mg^{2+}) for trivalent aluminium (Al^{3+}) and trivalent aluminium for quadrivalent silicon (Si^{4+}). The net negative charges are balanced by positive ions, called *exchangeable cations* or, more commonly, *exchangeable "bases"*. The cations that occupy the so-called "exchange positions" on the clay mineral are held in close contact with the surface of the mineral, but may be readily replaced or exchanged by other ions of equivalent charge by the process of cation exchange (base exchange). As *cation exchange* is essentially a surface reaction, it is the clay fraction and the organic matter, both of which have very large effective surface areas, that are most active in exchange reactions. In contrast, sand and silt particles are almost inert.

Soil clays from different sources exhibit wide variations in their physical and chemical properties, so that it is not sufficient simply to know the amount of clay in a soil to estimate its cation exchange properties. Some clays have a very high inherent charge and so bind a large number of cations; these are chiefly the clays of the montmorillonite group, which are fairly abundant in the recent soils of Gisborne Plains, and the clay-vermiculites. Clays of the illite or hydrous-mica group, which are also abundant in these soils, are intermediate in this respect, while clays of the kaolinite group are the least active, i.e., have the lowest *cation exchange capacity* (CEC) as this property of binding cations in exchangeable form is termed. Organic matter, on a unit weight basis, has an extremely high cation exchange capacity, usually more than twice that of the montmorillonite clays, and this is one reason for its important influence on soil properties.

Cations held in the exchange positions are not washed out by percolating rainwater but are exchangeable with other cations with which they may come in contact, e.g., hydrogen ions from the root-hairs of plants, soluble cations in the soil solution, cations added in soluble fertilisers, and calcium ions from limestone.

The principal exchangeable cations found in soils are hydrogen, calcium, magnesium, potassium and sodium. The proportions of these cations present vary with the kind of soil, but in fertile soils (like the recent soils of Gisborne Plains) the largest number of exchange positions on the soil colloid are occupied by the "basic" cations, calcium, magnesium, potassium, and sodium, with calcium greatly predominating. In acid infertile soils on the other hand, the hydrogen ion, often associated with aluminium, is dominant. The ratio of TEB to CEC provides an approximate index of fertility called the *percentage base saturation*. This quantity is calculated from the formula,

$$\frac{\text{total exchangeable "bases" (TEB)}}{\text{cation exchange capacity (CEC)}} \times 100 = \text{\% base saturation (\%BS).}$$

Total exchangeable "bases" (TEB) (more correctly, total exchangeable metal cations) may be thought of as the sum of exchangeable calcium, magnesium, potassium, and sodium (exch. Ca + Mg + K + Na). The difference, CEC − TEB, may be regarded, for practical purposes, as exchangeable hydrogen (exch. H). To enable calculations to be made and results to be reported unambiguously the various properties just described are usually expressed in chemical units called milliequivalents. Soil analyses are commonly reported as milliequivalents per cent (me.%), meaning milliequivalents per 100 grams of soil.

The addition of lime to the soil, either by top-dressing or by natural floodings with calcareous sediments, is a means of supplying exchangeable calcium so necessary for the maintenance of high chemical fertility. Besides calcium, magnesium and potassium are the other major cations required for satisfactory plant growth; the determination of exchangeable magnesium and exchangeable potassium is normally sufficient to assess the status of these two plant-nutrient elements in the soil. In recent soils of Gisborne Plains there is unlikely to be a magnesium deficiency because of a strong reserve of weatherable minerals in the soil and because of rejuvenation of some soils (Waipaoa soils) by flooding.

The exchangeable potassium (exch. K) figure usually provides a good indication of the immediate potassium status of the soil, but because the amount of potassium held in the exchangeable (i.e., available) form at any one time is sufficient only for a very few crops, exchangeable potassium gives little indication of the potassium-supplying power of the soil over a long period. This latter property is determined by the mineralogical composition of the soil. Soils with a high content of potassium-bearing micaceous clay minerals (hydrous micas) have a high capacity to replenish the exchangeable potassium as it is taken up by the crop or pasture. The recent soils of Gisborne Plains are of this type and, generally speaking, appear to be well endowed

TABLE 3: Chemical Analyses

By J. A. Robertson, L. C. Blakemore, and G. G. Claridge

Soil Type	Depth In.	pH	Citric-sol. Phosphorus mg. P/100g	Organic Matter: Organic C %	Organic Matter: Total N %	Organic Matter: C/N	Cation Exchange Properties: Exchange Capacity me.%	Total Bases me.%	Base Satn. %	Exch. Ca me.%	Exch. Mg. me.%	Exch. K me.%	Exch. Na me.%	CaCO₃ %	Lab. No.	Location of Sample: Grid Ref. Sheet N98	Locality
1. WAIPAOA silt loam ..	0–3	8·3	13	0·6	0·06	10	17·3	..	..	..	2·5	0·40	..	3·4	4921	282547	Waipaoa (1948 flood)
1b. WAIPAOA clay loam ..	0–4	7·7	11	1·2	0·13	9	24·6	..	..	..	2·1	1·0	0·6	3·4	6700	288513	Waituhi: Tangihanga Station (1954 flood layer)
1c. WAIPAOA mottled clay loam	0–3	8·3	14	1·0	0·13	8	29·7	..	..	..	4·0	0·80	..	3·9	4920	274439	Patutahi (1948 flood)
2. MATAWHERO silt loam ..	0–6	6·6	..	4·4	0·50	9	29·1	32·2	100	..	..	..	..	..	6397A	331385	Matawhero: T. Smellie
	15–18	7·1	..	2·0	0·16	13	29·2	31·0	100	..	..	..	..	..	6397B		
2a. MATAWHERO silt loam, friable topsoil phase	0–3	6·0	31	7·7	0·62	12	35·4	31·3	88	23·2	3·7	1·95	0·1	..	6072A	253355	Manutuke: Kawenga, Papatu Rd.
	7–10	5·7	19	1·0	0·12	8	21·1	18·0	85	13·2	3·0	1·45	0·1	..	6072B		
	14–17	5·8	9	0·8	0·10	8	20·3	17·8	88	12·7	2·3	1·15	0·1	..	6072C		
2b. MATAWHERO heavy silt loam	0–6	7·0	..	..	..	..	40·3	46·9	100	..	..	..	..	..	5517A	332386	Matawhero: opposite "Jolly Stockman" Hotel
	11–16	7·4	..	..	..	..	30·9	30·5	99	..	..	..	..	..	5517B		
	22–25	7·2	..	..	..	..	24·7	23·9	97	..	..	..	..	..	5517C		
	31–36	7·3	..	..	..	..	22·1	21·5	97	..	..	..	..	..	5517D		
2c. MATAWHERO heavy silt loam, friable topsoil phase	0–6	6·4	17	4·1	0·41	10	30·8	29·5	69	26·3	2·8	0·90	..	..	5025	308388	Matawhero: R. D. Rice, Bloomfield Rd. (composite sample)
2e. MATAWHERO clay loam ..	0–6	7·4	17	2·8	0·31	9	28·3	..	..	..	2·9	1·30	0·1	1·25	6075A	310458	Waerenga-a-Hika: C. Robcke
	10–16	6·9	15	1·4	0·21	7	26·1	25·5	98	21·2	1·9	0·85	0·1	..	6075B		
	19–22	6·9	16	0·7	0·12	6	22·2	21·7	98	17·4	1·8	0·50	0·1	..	6075C		
2f. MATAWHERO clay loam, friable topsoil phase	0–3	6·0	5	5·4	0·42	13	37·3	30·6	82	22·4	4·1	1·0	..	..	2012	350382	Darton Field, S. extension (composite sample)
3a. WAIHIRERE silt loam, gravelly topsoil phase	0–6	5·9	15	3·4	0·33	10	21·1	15·3	72	12·1	2·9	0·65	..	..	4925A	308391	Matawhero: R. D. Rice, Bloomfield Rd.
	9–12	6·1	14	0·9	0·12	8	18·5	15·1	82	11·2	3·6	0·70	..	..	4925B		
	12–18	6·0	15	0·5	0·08	6	17·6	15·8	90	11·5	3·9	0·60	..	..	4925C		
	18–23	6·1	15	0·4	0·07	6	17·8	15·7	88	11·6	3·8	0·50	..	..	4925D		
	24–28	6·2	15	0·4	0·05	8	18·6	16·6	89	12·7	3·8	0·40	..	..	4925E		
WAIHIRERE heavy silt loam	0–5	5·8	56	6·7	0·57	12	32·1	24·2	75	13·6	4·5	4·4	0·1	..	6074A	311476	Waihirere: R. B. Jones Gisborne-Opotiki highway
	11–15	5·0	20	0·9	0·12	8	20·4	13·6	67	7·2	2·9	3·3	0·1	..	6074B		
	18–22	5·1	13	0·5	0·08	6	17·7	12·8	72	6·8	2·5	2·8	0·1	..	6074C		
3e. WAIHIRERE heavy silt loam, mottled subsoil phase	0–6	5·8	22	3·5	0·30	12	19·1	13·7	72	10·8	2·6	1·2	..	..	3771	270363	Papatu Rd: Manutuke Research Station
3f. WAIHIRERE clay loam ..	0–6	7·3	16	4·4	0·40	11	41·2	..	..	..	..	..	..	2·2	5522A	324392	Matawhero: Presbyterian Manse glebe
	11–15	7·6	16	1·3	0·25	6	38·1	..	..	..	..	..	..	..	5522B		

4a. MAKARAKA clay loam ..	0–6	6·9	14	4·5	0·44	10	46·6	..	..	..	4·0	1·1	..	0·22	5514A	334393	Makaraka: W. J. White, Bushmere Rd.
	9–12	6·6	13	2·3	0·25	9	41·7	39·4	98	34·5	3·5	0·6	..	..	5514B		
	15–18	7·2	13	1·0	0·15	7	35·7	36·5	100	30·4	1·8	0·45	..	..	5514C		
	21–24	7·5	17	..	0·09	..	31·6	32·3	100	25·5	1·7	0·35	..	..	5514D		
	30–34	8·0	12	..	0·04	..	13·9	14·9	100	12·2	3·0	0·35	..	..	5514E		
4b. MAKARAKA clay loam, saline phase	0–3	7·9	..	2·1	0·18	12	31·1	..	..	..	6·5	0·70	0·2	3·1	6175A	346366	Awapuni Lagoon: near Matawhero Railway Station
	15–18	8·2	..	0·9	0·08	12	17·6	..	..	..	8·5	0·80	0·1	2·6	6175B		
	33–36	8·4	..	0·4	0·04	10	11·0	..	..	..	5·5	0·65	0·1	1·9	6175C		
5. MAKAURI clay loam ..	0–5	5·6	..	5·3	0·53	10	33·6	24·8	74	..	..	..	..	..	6396A	348430	Makauri: J. E. V. Simpson, Kings Rd.
	12–18	5·9	..	1·0	0·12	8	31·0	28·1	91	..	..	..	..	..	6396B		
5a. MAKAURI clay loam, friable subsoil phase	1–5	5·8	18	7·2	0·67	11	38·5	35·0	91	28·7	5·1	1·9	0·15	..	5764A	276378	Opou: Clarke Estate
	12–18	6·7	18	1·4	0·17	8	33·8	34·0	100	29·2	3·9	0·7	0·20	..	5764B		
6. KAITI silt loam	0–6	6·1	68	6·9	0·62	11	30·7	26·4	86	19·3	4·1	4·0	0·1	..	5765A	288400	Patutahi: substation
	14–18	6·5	12	0·3	0·07	4	17·0	17·3	100	11·4	3·8	2·5	0·3	..	5765B		
6a. KAITI silt loam, firm topsoil phase	0–4	5·4	5	5·1	0·39	13	20·1	12·0	62	8·5	2·9	0·50	..	..	5515A	362429	Hexton: C. Harding, Haisman Rd.
	7–10	5·5	4	2·2	0·23	10	17·1	10·3	58	6·9	2·9	0·40	..	..	5515B		
	11–14	6·2	4	0·2	0·06	3	13·9	11·6	83	6·2	3·8	0·30	..	..	5515C		
	17–20	6·5	4	..	..	..	23·6	21·6	93	11·7	8·1	0·40	..	..	5515D		
	32–37	6·9	14	..	..	..	19·0	18·0	95	10·4	5·5	0·45	..	..	5515E		
6b. KAITI heavy silt loam ..	0–5	5·8	27	5·1	0·48	11	29·8	21·9	73	12·9	4·5	3·8	0·1	..	6073A	317477	Waihirere: D. F. Hair
	11–15	5·7	11	0·7	0·11	6	22·6	17·9	79	11·3	4·3	1·55	0·1	..	6073B		
	18–22	5·8	12	0·6	0·09	7	22·2	18·3	82	12·6	4·1	0·65	0·1	..	6073C		
6c. KAITI clay loam ..	0–6	7·0	18	7·7	0·72	11	58·6	62·0	100	59·1	4·5	0·95	0·3	0·4	5762A	278397	Patutahi: J. A. Butler, Butler Rd.
	13–18	7·6	16	1·0	0·16	6	41·8	46·4	100	44·8	3·6	0·70	0·4	0·05	5762B		
6d. KAITI clay loam, shallow topsoil phase	0–6	6·2	15	5·8	0·61	10	48·8	44·8	92	..	..	0·85	..	..	6395A	532275	Muriwai: East Coast Commission
	12–18	6·8	17	1·1	0·16	7	41·5	43·2	100	..	..	0·75	..	..	6395B		
7. MURIWAI clay loam ..	0–3	8·4	..	1·3	0·13	10	28·7	..	..	..	9·4	0·75	6·5	3·5	6174A	350365	Awapuni Lagoon: near Matawhero Railway Station
	15–18	8·5	..	1·0	0·10	10	27·4	..	..	..	10·3	1·10	6·3	3·2	6174B		
	33–36	9·0	..	0·9	0·07	13	19·5	..	..	..	6·9	2·45	5·9	3·5	6174C		
7a. MURIWAI clay ..	0–3	7·8	..	1·3	0·11	12	27·3	..	..	..	7·4	0·35	2·3	3·3	6173A	350364	Awapuni Lagoon: near Matawhero Station
	15–18	8·1	..	0·7	0·06	12	19·1	..	..	..	4·3	0·40	0·7	3·3	6173B		
	38–36	8·3	..	0·9	0·05	18	17·9	..	..	..	0·5	0·30	0·9	3·4	6173C		
8. OPOUTAMA sand ..	0–5	6·8	15	1·5	0·13	12	9·5	6·9	73	4·1	1·3	0·80	0·0	..	6235A	314308	Muriwai: A. H. Wall, Old coach road
	15–18	8·0	3	0·3	0·03	10	6·1	..	..	..	1·1	0·10	0·0	2·0	6235B		
8a. OPOUTAMA loamy sand ..	0–6	6·0	7	3·5	0·23	15	14·3	10·9	76	..	..	0·55	..	..	6398A	393377	Gisborne city: Intermediate School
	18–24	8·3	1	..	..	..	..	..	..	..	..	0·20	..	Much shell	6398B		
9. TE HAPARA sandy loam ..	0–6	5·6	14	5·4	0·42	13	17·3	9·1	53	6·9	1·5	0·70	0·2	..	6234A	382402	Mangapapa: Cnr Lytton Rd. and Stout St.
	15–18	6·3	2	0·2	0·02	10	5·1	4·0	79	2·1	1·4	0·15	0·0	..	6234B		

TABLE 4: Soluble-Salt Analyses*

Soil Type	Depth In.	Total Soluble Salts† % (g/100g soil)	Cations: Ca^{2+} me.%	Mg^{2+} me.%	K^+ me.%	Na^+ me.%	Total me.%	Anions: Cl^- me.%	SO_4^{2-} me.%	HCO_3^- me.%	Total me.%	Lab. No.	Location of Sample: Grid. Ref. Sheet N98	Locality
4b. MAKARAKA clay loam, saline phase	0–3	0·18	0·7	0·6	0·5	1·0	2·8	0·9	1·0	0·9	2·8	6175A	346366	Awapuni Lagoon: near Matawhero Railway Station
	15–18	0·26	0·4	0·8	0·5	1·0	2·7	2·3	0·5	0·7	3·5	6175B		
	33–36	0·15	0·4	0·3	0·3	0·5	1·5	1·1	0·4	0·6	2·1	6175C		
	0–3	0·20	1·1	0·7	0·3	0·5	2·6	0·9	1·3	0·7	2·9	6176A	346368	„
	15–18	0·13	0·5	0·3	0·2	0·4	1·4	1·2	0·4	0·3	1·9	6176B		
	33–36	0·20	1·4	0·7	0·3	0·4	2·8	0·3	2·3	0·3	2·9	6176C		
	0–3	0·56	0·9	0·4	0·2	5·8	7·3	4·2	2·4	0·9	7·5	6701	328347	„
7. MURIWAI clay loam ..	0–3	0·50	0·4	2·1	0·4	8·6	11·5	4·4	1·5	1·0	6·9	6174A	350365	Awapuni Lagoon: near Matawhero Railway Station
	15–18	0·55	0·4	1·8	0·4	7·0	9·6	4·9	1·1	1·1	7·1	6174B		
	33–36	0·24	0·3	1·3	0·5	3·4	5·5	2·0	0·9	1·3	4·2	6174C		
7a. MURIWAI clay	0–3	1·9	2·1	6·2	1·0	23·2	32·5	22·4	3·4	0·6	26·4	6173A	350364	Awapuni Lagoon: near Matawhero Railway Station
	15–18	2·2	1·7	9·9	1·2	25·8	38·6	25·5	4·4	0·7	30·6	6173B		
	33–36	2·7	1·4	13·8	1·4	32·3	48·9	31·7	4·7	0·7	37·1	6173C		

*For ground-water analyses, see table 5.
†Obtained from the conductivity of the 1 : 5 extract by means of the approximate relation $K_{25}°$(millimho/cm) × 0·350 = Total soluble salts (%).

TABLE 5: Ground-Water Analyses

Soil Type	Depth In.	Conductivity $K_{25}°$ mmho/cm	Total Soluble Salts*: % (g/100 ml)	me./l	Cations: Ca^{2+} me./l	Mg^{2+} me./l	K^+ me./l	Na^+ me./l	Total me./l	Anions: Cl^- me./l	SO_4^{2-} me./l	HCO_3^- me./l	Total me./l	Lab. No.	Location of Sample: Grid Ref. Sheet N98	Locality
4b. MAKARAKA clay loam, saline phase	at 24	2·29	0·16	23	7·1	7·8	1·3	9	25	7·0	4·8	14·8	27	6175A/C	346366	Awapuni Lagoon: near Matawhero Railway Station
	at 36	0·70	0·05	7	5·9	1·0	0·2	1	8	1·1	0·4	6·4	8	6176A/C	346368	„
7. MURIWAI clay loam ..	at 30	9·26	0·65	93	4·5	9·2	2·3	80	96	66	9·1	22·4	98	6174A/C	350365	Awapuni Lagoon: near Matawhero Railway Station
7a. MURIWAI clay ..	at 45	79·5	5·6	795	71·8	215	11·0	675	973	930	116	9·2	1055	6173A/C	350364	Awapuni Lagoon: near Matawhero Railway Station

*Obtained from the conductivity by means of the approximate relations
$K_{25}°$ (millimho/cm) × 0·07 = total soluble salts (%)
$K_{25}°$ (millimho/cm) × 10 = total soluble salts (me./l)
NOTE—Sea water contains about 3·5% total salts.

TABLE 6: Mechanical Analyses

D. C. McDonald, L. C. Blakemore, and Jean A. Sutton

Soil Type	Depth In.	Particle Size: Coarse Sand* 2–0·2 mm %	Particle Size: Fine Sand* 0·02–0·2 mm %	Particle Size: Silt 0·002–0·02 mm %	Particle Size: Clay <0·002 mm %	Lab. No.	Location of Sample: Grid Ref. Sheet N98	Location of Sample: Locality
		(Results expressed on the oven-dry basis)						
2. MATAWHERO silt loam ..	0–3	0	44	39	17	6873	331384	Matawhero: T. Gambrill
2a. MATAWHERO silt loam, friable topsoil phase	0–3	56		28	16	6072A	253355	Manutuke: Kawenga, Papatu Rd.
2b. MATAWHERO heavy silt loam	0–6	14		53	33	5517A	332386	Matawhero: opposite Jolly Stockman Hotel
	11–16	17		52	31	5517B		
2c. MATAWHERO heavy silt loam, friable topsoil phase	0–6	12		42	46	5521	320389	Matawhero: market garden
2e. MATAWHERO clay loam ..	0–6	28		42	30	6075A	310458	Waerenga-a-Hika: C. Robeke
2f. MATAWHERO clay loam, friable topsoil phase	0–6	7		46	47	5520	321390	Matawhero: Henry Moore
3c. WAIHIRERE heavy silt loam ..	0–5	40		35	25	6074A	311476	Waihirere: R. B. Jones
4a. MAKARAKA clay loam ..	0–6	7		48	45	5514A	334393	Makaraka: W. J. White, Bushmere Rd.
	30–34	79		17	4	5514E		
4b. MAKARAKA clay loam, saline phase	0–3	0	1	48	51	6175A	346366	Awapuni Lagoon: near Matawhero Railway Station
	33–36	36	30	18	16	6176C	346368	,,
6a. KAITI silt loam, firm topsoil phase	0–6	15	16	47	22	6268	360424	Hexton: A. R. Smith, Haisman Rd.
	7–10	47		34	19	5515B	362429	Hexton: C. Harding, Haisman Rd.
6b. KAITI heavy silt loam ..	0–5	29		43	28	6073A	317477	Waihirere: D. F. Hair
7. MURIWAI clay loam	33–36	6	24	36	34	6174C	350365	Awapuni Lagoon: near Matawhero Railway Station
7a. MURIWAI clay	0–3	0	3	53	44	6173A	350364	,,
8a. OPOUTAMA loamy sand ..	0–3	42	37	11	10	6893	396374	Gisborne city: Intermediate School
9. TE HAPARA sandy loam ..	0–6	24	39	23	14	6234A	382402	Mangapapa: Cnr. Lytton Rd. and Stout St.

*Where only one figure is given for sand it represents coarse and fine sand.

5

with exchangeable and reserve potassium. The position may change with intensive cropping, but unless the need for potassium is clearly indicated it would appear advisable to withhold it, or use it only in small amounts. Soils derived mainly from rhyolitic volcanic ash (Te Hapara soils), however, are lacking in micaceous clay minerals and so have no mechanism for the rapid release and fixation of potassium. Although these latter soils are high in total potassium this is practically all unavailable to plants, so that they rapidly exhaust their meagre reserves and from that point on require repeated potash applications. It is important, therefore, to consider the class of soil when interpreting potassium analyses. Hogg (1957) considers that in the North Island in general, potassium responses are improbable where exchangeable K is above 0·6 me.% and probable below 0·5 me.%. However, because of their inherent capacity to release potassium, it appears likely that in the recent soils of the Gisborne Plains even low values for exchangeable K would not necessarily indicate potassium deficiency. Such a situation exists in the recent and associated yellow-grey earth soils of the drier parts of Canterbury where the soils are minerologically similar to those of the Gisborne Plains.

Calcium carbonate ($CaCO_3$). Soils formed in semi-arid to arid climates, or soils derived from calcareous parent materials, usually contain more or less calcium carbonate or "free lime". Although this carbonate is rather insoluble it is sufficiently reactive to keep the soil 100% base saturated, and so long as it is present, the pH remains above 7. Indeed, free lime constitutes a reserve of calcium ions. Because they are derived from calcareous (lime-bearing) sedimentary rocks, some recent soils of Gisborne Plains contain small and rather variable amounts of calcium carbonate (see table 3).

Soluble Salts. Soils formed in semi-arid or arid climates, or soils recently affected by flooding with sea water, contain various soluble salts. In this work, the salt content of the 1 : 5 extract (1 part of air-dry soil to 5 parts of water) has been determined; the results are reported as % total salts, and as me.% for individual cations and anions (table 4).

The boundary between "saline" and "non-saline" soils is commonly set at 0·1% total salts and at about 1·5 me.% total soluble salts, but a great deal depends on the texture and organic matter content of the soil. There is only a small area of saline gley soils on Gisborne Plains, and both soils and ground waters (table 5, p. 44) were analysed for soluble salts. The effect of soluble salts on these soils (Muriwai clay and Muriwai clay loam) requires to be understood when they come to be reclaimed for agriculture.

Chemical Analyses

Chemical analyses enable quantitative, numerial expression to be given to certain soil properties or characteristics. Analyses of type samples such as those given in table 3, are intended to show the general chemical status of the soils. No one analysis can be considered fully representative of a soil type; strictly, an analysis can only represent the chemical status of a particular site at the time of sampling. Fortunately, from the practical point of view, the chemical variability within each soil type is not very great; furthermore, some of the important chemical properties of a soil are rather stable ones, being determined largely by the mineral composition. This means that the determination of a comparatively small number of chemical properties for a few sample profiles of the type, along with other relevant information about the soil – particularly its physical characteristics – is sufficient to give the agriculturist a fairly good idea of its capabilities.

In addition to the chemical analyses the proportions of sand, silt, and clay were also measured for some of the soil types (table 6). In general, the amount of clay present is a good indication of the chemical fertility, and the amount of coarse sand is an index of permeability and workability. But in recent soils of Gisborne Plains, however, the proportions are not commonly in good balance because there is too little coarse sand and too much clay for good drainage and workability. When top-soils are wet the fine sand is of little benefit to workability. There is also insufficient coarse sand or fine gravel to prevent sealing of the surface. In summer fine sand does not hold any moisture and clay soils tend to crack badly.

Trace Element Analyses

The main soil types have been examined for "available" copper, samples being taken from non-topdressed soils at a depth of 0–3 in. A bio-assay method using *Aspergillus niger* was employed; it is similar to that described by Donald, Passey, and Swaby (1952), except that the incubation period was for six days at a temperature of 25°c. Results are given in table 7.

On overseas standards, the only soils low in "available" copper are Opoutama sand and Te Hapara sandy loam. There is, however, no evidence of copper deficiency in stock grazing on these soils.

TABLE 7. "Available" Copper in Soils of Gisborne Plains
By Esme M. Guy

Soil Type	"Available" Copper p.p.m. Range	Average
Waipaoa heavy silt loam	4·0–5·0	4·6
Waipaoa clay loam	5·0–6·0	5·5
Matawhero silt loam, friable topsoil phase	3·2–3·6	3·4
Matawhero heavy silt loam	3·6–5·0	4·1
Waihirere silt loam, gravelly topsoil phase	4·0–5·0	4·5
Waihirere heavy silt loam	4·8–6·0	5·1
Makaraka clay loam	3·6–4·0	3·8
Makauri clay loam	3·6–5·0	4·1
Kaiti silt loam	2·8–3·2	3·0
Kaiti clay loam, shallow topsoil phase	3·6–5·0	4·4
Muriwai clay	4·0–7·0	5·5
Opoutama sand	2·0–2·4	2·2
Te Hapara sandy loam	2·0–2·4	2·2

Samples of surface soil (0–4 in.) were collected in 1951 and examined at Rukuhia Soil Research Station for molybdenum content. Analyses showed 0·12 p.p.m. in Makauri clay loam, 0·32 p.p.m. in Waihirere heavy silt loam, 0·40 p.p.m. in Waipaoa clay loam, and 0·48 p.p.m. in Matawhero silt loam, friable topsoil phase. Except for Makauri clay loam, molybdenum is high for New Zealand conditions but is not at a toxic level.

In April 1951 pasture samples were collected and examined for copper and molybdenum at the Animal Research Station, Wallaceville. Results, listed according to the soil types from which the pastures were collected, are given in table 8.

TABLE 8. Copper and Molybdenum in Pastures

Soil Type	Copper p.p.m.	Molybdenum p.p.m.
Makauri clay loam	9·6	5·7
Waihirere heavy silt loam	10·1	6·2
Waipaoa clay loam	12·2	2·8
Matawhero silt loam, friable topsoil phase	10·2	2·5

It is considered that copper is in adequate supply in the pasture for stock but that molybdenum in pasture growing on Makauri clay loam and Waihirere heavy silt loam is rather high for April. Samples of pasture from the same soil types were further examined in September 1953, but the levels of molybdenum were much lower at 3·3 and 2·8 p.p.m. respectively.

According to Wells (1956), who has used sweet vernal (*Anthoxanthum odoratum*) to assess element availability, there is likely to be a pasture response to molybdate topdressing on Kaiti silt loam and Te Hapara sandy loam. It is inferred that on other recent soils plant molybdenum levels are high. In general, there is no fixation of molybdenum in recent soils in New Zealand.

Clay Minerals

Clay minerals not only provide an important source of plant nutrients but are also largely responsible for the way a soil "behaves" in the field, e.g., swelling in winter and cracking and fissuring in summer. Examples of these properties of clay minerals have been quoted previously

TABLE 9: Mineralogical Analyses of Clay Fractions
By L. D. Swindale

Soil Type	Illite	Montmorillonite	Vermiculite	Iron Oxides, Crystalline	Alumina	Quartz	Feldspar	Sampling Notes
Waipaoa clay loam	..	m	..	..	..	M	m	Sample 0–3 in. from sediment of 1950 flood.
Makauri clay loam	M	M	m	m	m	m	m	Samples 0–4 in. and 12–16 in.
Waihirere heavy silt loam	M	M	m	..	..	M	m	Samples from 0–5 in., 11–15 in., and 18–22 in.
Kaiti clay loam, shallow topsoil phase	M	M	m*	m	m	m	m	Samples 0–5 in. and 13–18 in.
Kaiti silt loam, firm topsoil phase	M	M	M	m	m	m	m	Samples from 0–4 in. 9–15 in., and 15–18 in.

*0–5 in. horizon only.

(pp. 19, 31) and the following section provides the detailed mineralogical analyses of the clay fractions.

In table 9 the clay minerals are arranged as an assemblage; major constituents (30–50% of clay fraction) are given as M and minor constituents (less than 10%) as m. The soils are set out in order of increasing age.

The soils have a similar mineralogical composition except for Waipaoa clay loam, which has much smaller amounts of montmorillonite and illite. While these clay minerals give recent soils their high chemical fertility, they also cause pronounced swelling and fissuring in heavy soils like Makauri clay loam and Kaiti clay loam and explain why such soils are difficult to farm.

In all soils examined the primary mineral feldspar is a common minor constituent in the clays, but is probably a major constituent of the coarser fractions. It can be considered as a long-term reserve of plant nutrients because these are not available until feldspar weathers to secondary (clay) minerals.

Soil Structure

By NANCY B. AUSTIN, M. W. GRADWELL, and W. A. PULLAR, Soil Bureau

Field observations indicate that soil properties such as infiltration (water entering the soil), permeability (water through the soil), surface sealing (breakdown of soil aggregates at the surface), and kind of tilth (cloddy or fine) are related to the soil structure (arrangement of soil particles into aggregates): in particular, to the stability of the aggregates when the soil is wet. To investigate this relationship, the following properties were studied in the laboratory: (1) aggregate stability by sieving the soil in water, (2) permeability of a column of aggregates.

For optimum crop growth a soil should break down to aggregates (preferably crumbs or porous aggregates) of 0·5 to 3·0 mm diam.; the aggregates should persist for a long time and must also resist stresses set up both by raindrop impact and by a sudden rewetting of a dry soil. This specification is seldom found in practice but it gives the standard of reference.

Waipaoa clay loam, Makauri clay loam, Waihirere silt loam, and Waihirere silt loam, gravelly topsoil phase were selected, and samples of the top 3 in. were taken from croplands in different localities (table 10) during January 1957. Five samples were collected from each sampling site.

In the first test samples were prepared by selecting air-dry aggregates ranging from 2·0 to 3·35 mm diameter. Each sample was submerged by pouring water around the aggregates and was then transferred to a bottle and shaken end over end for 5 min. The contents were then sieved under water using a 0·70 mm sieve and the residue again sieved on an 0·25 mm screen. Sieves were raised and lowered 1½ in. 50 times in approximately 1½ min. The water-stable aggregates held on each sieve were then weighed, and, by definition, the degree of aggregation is:

$$\frac{\text{weight of aggregates held on sieve} \times 100}{\text{weight of sample}}$$

In the second test – permeability of a column of aggregates – the time was noted for a certain quantity of water to drain through a column of soil composed of aggregates between 0·85 and 2·05 mm diam. packed in an air-dry state and subsequently wetted. The more readily the aggregates break down due to dispersion and slaking, the slower becomes the rate at which water will drain through the column. As it is difficult to duplicate laboratory procedures exactly, figures are best regarded as relative. Comparisons are therefore made between the soils concerned.

Waipaoa clay loam and the Waihirere silt loam, gravelly topsoil phase, have a lower degree of aggregation than Makauri clay loam and Waihirere silt loam; Waipaoa clay loam also drains much more slowly than the others. The poor stability of aggregates of Waipaoa clay loam under pasture (Waerenga-a-Hika) makes it appear improbable that grass rotations will give it a structure as good as Makauri clay loam. The latter soil, when broken down to a fine tilth, has better structural stability and drainage, but a major difficulty is likely to be in the breaking down of large clods. The test figures also indicate that the fine aggregates into which Waihirere silt loam readily falls down can have a high degree of water stability and permeability despite the lower clay content of this soil. For the gravelly phase of this type the low degree of aggregation may be inherent because of the high proportion of fine gravel, but the reduced permeability, particularly noted under intensive market gardening, provides a warning that the structure will deteriorate under continuous cropping unless grass rotations or green manure crops are introduced.

Samples of the soils examined in the laboratory were also left out in the open and exposed to the weather for nine months. After that time the surfaces of clods were compared. Waipaoa clay loam had a very smooth, plaster-like surface and an undesirable massive structure, because aggregates had run together. In Waihirere silt loam and Waihirere silt loam, gravelly topsoil phase, only a few fine aggregates (1 mm diam.) were to be seen, and there was a thin skin at the surface through which fine gravel protruded. The clods, however, were very firm and did not collapse under pelting by raindrops. Makauri clay loam had easily the best surface structure; a large number of fine blocky aggregates (1 to 2 mm diam.) were scarcely rounded or broken by the weather.

In this simple field test the time of exposure is longer than that for which crops are usually in the ground or that for which fields are normally tilled. It amply confirms the results of laboratory examination of structure and as well supports observations made during the three years of the soil survey.

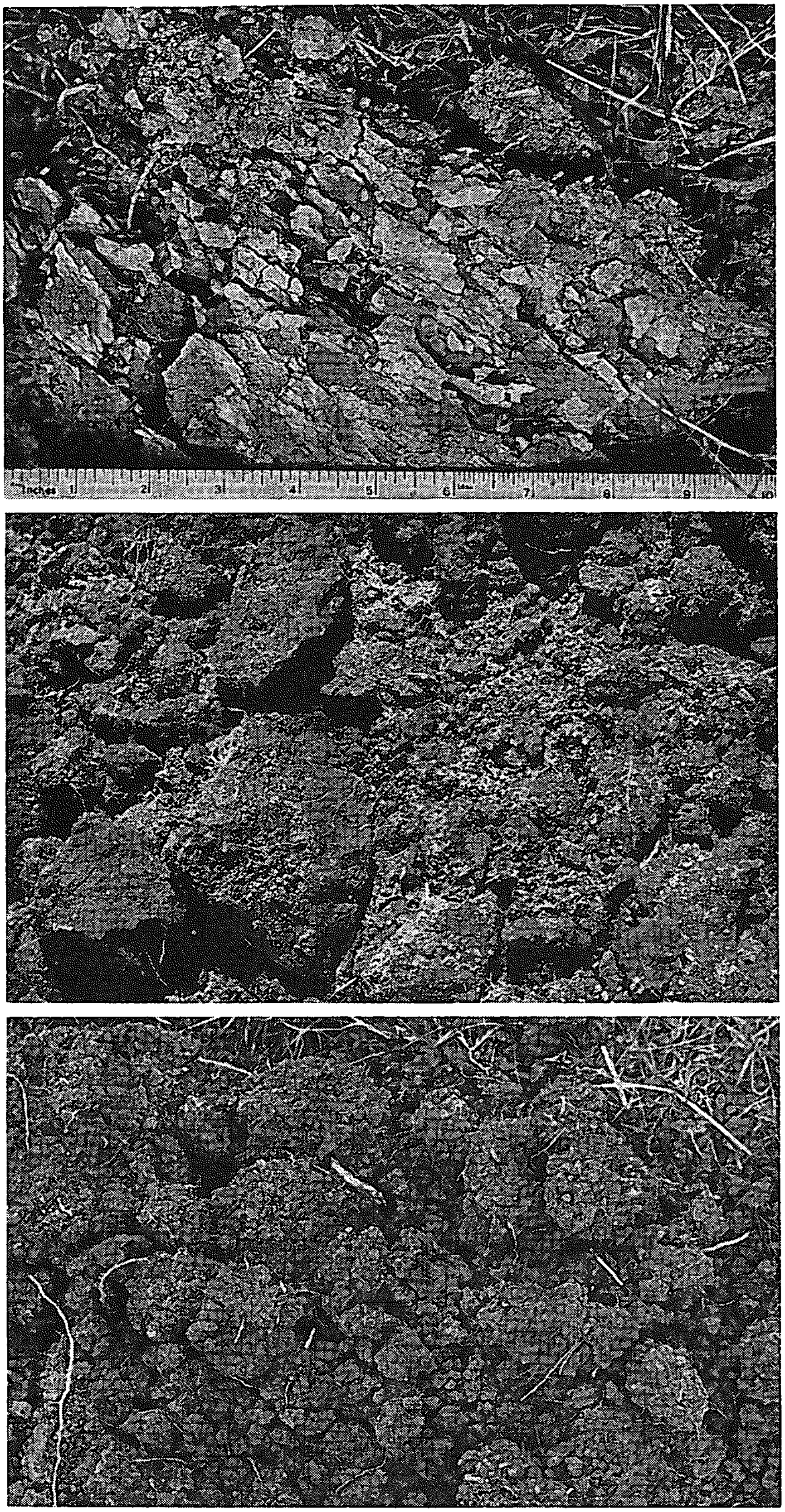
A comparison of soil structures under grass was also made (fig. 16). For cropping, most paddocks are ploughed out of grass, but not much attention is paid to the structure at that time; it is usually assumed that the growing of grass improves soil structure. Yet Waipaoa heavy silt loam has a weakly developed coarse nutty structure that is insufficiently developed to break up thin laminated beds formed by flooding. Laminations are not desirable for they slow up drainage through the soil. Kaiti silt loam at Wainui has a moderately developed fine granular structure. The clods (fig. 16) fall down easily to granules, which, however, are too soft for cropping; they run together during rain to form a surface crust. With adequate moisture and frequent cultivation the soil makes an excellent seedbed. Again, Makaraka clay loam has a strongly developed structure of firm aggregates but there is no grading of aggregates, which is a highly desirable feature for moisture control in cropping, i.e., there is too high a proportion of coarser aggregates of the same size and too low a proportion of fine aggregates. As a result the top 3 in. is very loose and dry in summer and is even too droughty for grass. Because of their structure the above-mentioned soils are among the most difficult for cropping.

The tilth in seedbeds on a number of recent soils was inspected during September 1956. All paddocks were ploughed out of grass. Makaraka clay

TABLE 10: Measurements of Stability and Permeability of Aggregates
(Samples 0–3 in.)

Soil Type	Locality	Aggregate Analyses: % of Water-stable Aggregates Held on Sieve, 0·70 mm Mean	Aggregate Analyses: % of Water-stable Aggregates Held on Sieve, 0·25 mm Mean	Permeability Tests: Time in Min. for Water to Drain From Surface of Column, Mean	Previous History
Waipaoa clay loam	Bushmere	16	19	4·7	Mainly maize year by year
	Willows	15	23	10·9	Mainly maize since 1950 flood
	Waipaoa	6	9	12·0	1950, major flood; 1951 to 1953, clover and grass; 1954 to 1956, crops
	Manutuke	13	21	16·5	Crops every year; no grass
	Waerenga-a-Hika	11	16	20·2	Pasture since 1950 flood
Waihirere silt loam	Kaitaratahi	20	30	1·3	Cropped for 3 years; previously under pasture for many years
	Manutuke	43	51	0·8	Cultivated intermittently; otherwise fallow
Waihirere silt loam, gravelly topsoil phase	Matawhero	9	13	2·2	14 years' continuous cropping
	Waerenga-a-Hika	8	17	6·5	Market garden under continuous cropping
Makauri clay loam	Makauri	33	38	1·4	Cropped for last 5 years
	Ormond	33	38	4·9	Mainly grass
	Patutahi	32	37	3·0	1950 to 1955, grass; 1956 to 1957, maize (best tilth of all sites)
	Hexton	37	43	3·4	Vegetables cultivated for last 5 years
	Manutuke	23	26	2·4	Mostly maize

Fig. 16. Structures developed in topsoils under grass. (*Photos, A. P. Underhill.*)—(All photos on same scale.)



Waipaoa heavy silt loam

Kaiti silt loam

Makaraka clay loam

loam in the Willows locality had been ploughed rather moist and the tilth was distinctly cloddy for a depth of 3 to 6 in. The clods ranged from ½ to 3 in. diam. and were moist to dry on the surface but wet inside. Matawhero heavy silt loam, friable topsoil phase, in the same locality had also been ploughed moist, but on this soil a fine tilth had been obtained. In Waihirere heavy silt loam, Muriwai locality, the tilth tended to be cloddy, but, even so, the soil was moist to within 1 in. of the surface. Kaiti silt loam in the Patutahi locality tilled to a fine, friable seedbed through which rainwater drained freely.

It seems that soils that have not been subject to flood accumulations for a long time have better structures and finer seedbeds than those that are flooded periodically.

EFFECTS OF FLOODING AND STOPBANKING ON SOILS

The sediments of present-day floods contain lime, which makes the soils of flooded lands slightly to moderately alkaline. Such a soil reaction may not be the best for high-production grasses, and it also may induce disorders in fruit trees, such as manganese deficiency. Nitrogen is likely to be deficient where deposits are thick, as in Waipaoa soils.

Because flood sediments contain montmorillonitic clay, they have a marked tendency to surface sealing in wet weather, swelling in winter, and cracking and fissuring in summer. These are undesirable properties, which on one hand allow little latitude in cultivation during a wet spring and on the other bring about severe droughtiness in clay loams in a dry summer. Even where flood layers are thin and are not disturbed by ploughing, surface sealing causes water to lie on the surface and encourage puddling.

Too frequent flooding is not immediately beneficial to the land, particularly when sediments are more than 3 in. thick at each flood. On Waipaoa soils, for instance, there has been insufficient time for an organic topsoil to be built up before the next flood smothers the newly formed soil with raw sediment, and the result is a poorly structured soil low in organic matter. However, when flood layers are 1 in. thick they appear to be readily assimilated with buried soils by worm mixing, root penetration, and by ploughing. Thus, in Matawhero soils there is a very deep, friable topsoil It seems that 1 in. of sediment deposited every five years is about the optimum for soil building, during which there is little time for natural consolidation.

For intensive cropping of land smooth surfaces are very important and one advantage of flooding is that depressions are filled in. On Makaraka and Matawhero soils surface smoothing is now almost complete.

Matawhero soils are highly productive because in pre-European times general floodings were infrequent, flood layers were thinner, and there was a forest vegetation; intervals between floodings were sufficiently long for flood layers to be converted into soil before new layers were deposited. Also, organic residues from forest litter built up a high chemical fertility and encouraged friability and a good structure. With cessation of flooding recent soils mellow with age, but, after about 100 years, natural productivity is slightly lowered by consolidation and later by leaching.

At the completion of the Waipaoa River Flood Control Scheme, flooding will be confined to a channel between stopbanks in the southern part of the plains and to low-lying land between terraces in the northern part. The area that will still be flooded will amount to 6,400 acres, as against 23,000 acres in the 1948 flood when there was no flood control scheme.

In soils protected from flooding small but definite changes can be expected. If legumes, like lucerne, are grown on Waipaoa silt loam and Waipaoa heavy silt loam, these soils will in time become more like Matawhero soils, which are deep, well drained, and friable. In Waipaoa clay loam the sediment accumulations are too thick and dense for deep root penetration and it is likely that humification will be restricted to the top 6 in.

Makaraka soils will tend to become like Makauri soils as accumulations are mixed by ploughing with older soils underneath. Artificial drainage will encourage quicker mineralisation of organic residues on both Makauri and Makaraka soils, except in the Makaraka, Willows, and Muriwai localities, where the level of ground water is permanently high.

There will be little change in both Waihirere and Kaiti soils as these are older than the others and they have been out of flood reach for a long time; they are consolidated, which is a good quality in Waihirere soils but not in Kaiti soils, and they have good structures, which should be preserved. As it is difficult to draw water out of Kaiti soils, care must be taken with storm-water disposal.

With the removal of the threat of flooding, the farmer can improve his soils by paying attention to the content of organic matter and to soil structure, and the best way to do this is by a judicious mixture of grassland and arable farming.

Organic matter has constantly to be replenished, and the ploughing in of soft, bulky crops, like green maize or lupins, helps to keep the surface springy and to buffer extremes of wetness and droughtiness. Continued cultivation without replenishment of organic matter results in lower yields. Good structure is necessary for both aeration and drainage and is built up and maintained under pasture. Unfortunately, however, the surface strength of all recent soils is weak in winter, and the surface tends to puddle when large numbers of stock are grazed. Puddling compacts the soil, and, subsequent ploughing exposes many big clods that are difficult to break down.

Natural compaction can be restricted by lifting the soil with special implements rather than by merely turning it over. While earthworms are necessary to develop a structure in new soils such as the Waipaoa soils, it is possible to have too many worm casts. In the older Kaiti and Waihirere soils the worm casts fit so closely together that drainage is slowed; the cast granules can be loosened, however, by periodic cultivation. The farmer cannot, of course, regulate development of poorly drained soils unless the main drainage system is efficient.

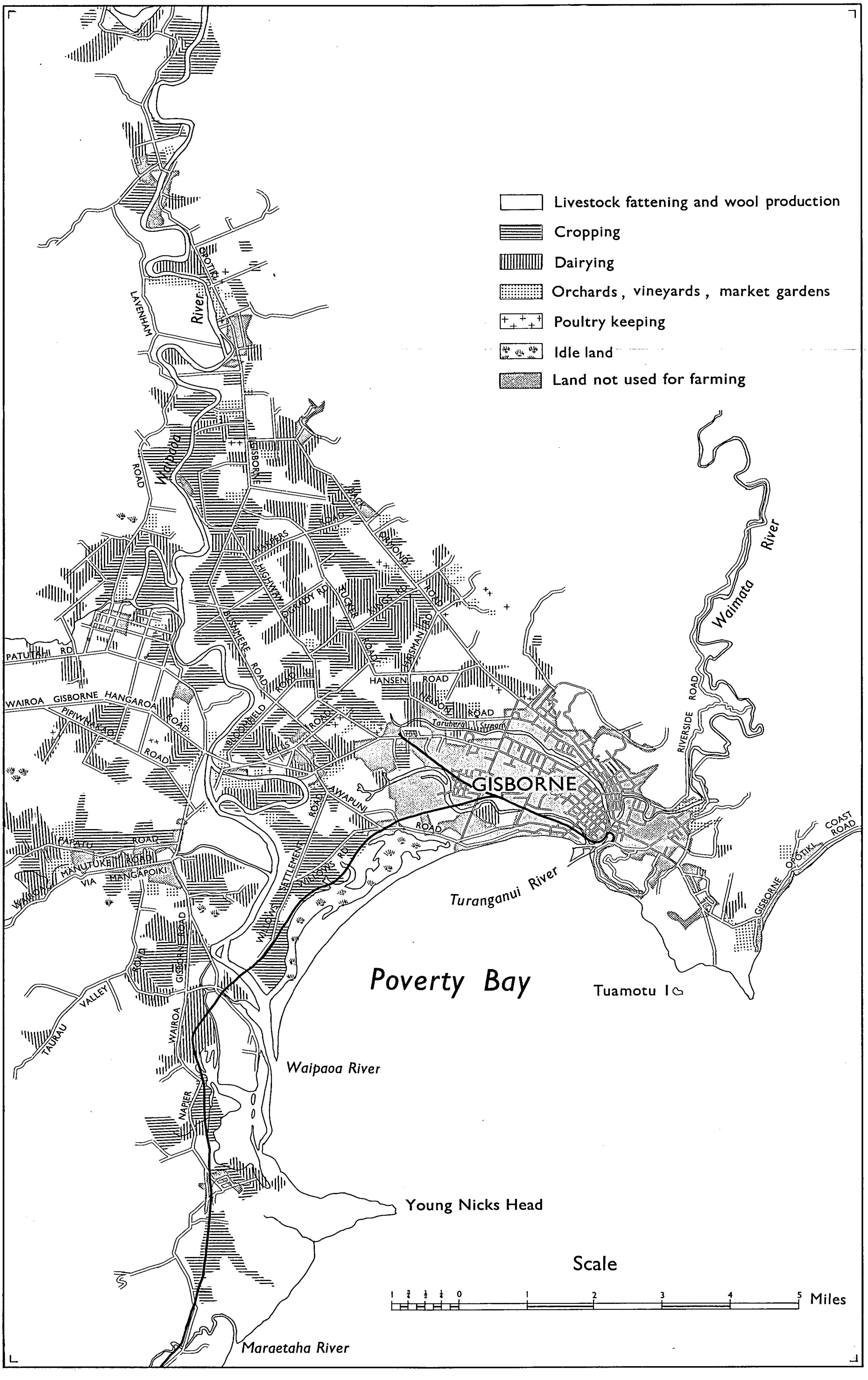


Fig. 17. Map of land use on Gisborne Plains, 1958

LAND USE

AGRICULTURE

By H. de O. Chamberlain, Department of Agriculture, Gisborne

Farming Pattern

Mixed farming is the basis of agriculture on the Gisborne Plains. Cropping, fat-lamb and fat-cattle production, grass- and clover-seed production, and dairying are all carried out in various combinations. Pigs are raised and poultry kept, generally as a single activity but sometimes as part of a mixed farm.

Soil and climate conditions permit a wide variation of farming practice according to the preference of the individual farmer, and considerable diversity of pattern has developed. The relationship of this pattern to soil type is not immediately apparent except as it refers to soil drainage. A better understanding of soil characters affecting drainage could lead to developing farming practices better suited to individual pieces of land. For example, the heavy, slow-draining Makauri and Kaiti clay loams puddle badly when grazed by cattle in winter. Pastures are damaged and, in consequence, less feed is available in the spring and early summer. When adequately drained, however, these soils are suitable for summer crops and fat-lamb production. Drainage alone can lift their potential production by 2 or 2½ times under either stock or crops.

Dairying is carried out on all soils of the flood plains but none is ideally suited to this purpose. However, adequate drainage, improved grassing management, and wider use of lucerne and special pastures for summer grazing could greatly increase production as well as decrease the cost per production unit.

Fig. 17, depicting the land-use pattern at 1958, illustrates the diversity of farming on the Gisborne Plains.

Pastures

The largest proportion of the land is used for pasture production. Though, in the past, Poverty Bay perennial ryegrass seed was in great demand by farmers of other districts, improved strains of ryegrass have since been developed by research stations and there is now little demand for the original Poverty Bay strain.

Perennial ryegrass and white clover is the most common pasture, but short-rotation ryegrass (also known as H.1. ryegrass), either alone or mixed with perennial ryegrass and white and red clover and sometimes cocksfoot, is becoming an increasingly popular pasture on dairy farms. Short-rotation ryegrass is also being grown more on sheep and cropping farms where a high-producing pasture of a relatively short life fits in with the farm programme. It is used in place of Italian ryegrass to produce quickly the feed required in the autumn/early winter period, enabling new paddocks to be stocked much earlier than with other grasses, but because of high summer soil temperatures this grass is very short-lived and requires careful management. Grazing must be controlled carefully to maintain a satisfactory grass/clover balance by preventing the fast-growing ryegrass from overshading the clovers and by preventing stock from eating out the clover as soon as it appears. The best balance seems to be maintained by the use of controlled grazing techniques employing heavy stock concentrations for short periods. This method is also effective in checking the growth of weed seedlings, which can be a serious problem following crops.

Despite sowing the best seed on thoroughly prepared seedbeds it does not seem possible in practice to maintain a high-producing pasture for a long period on the Gisborne Plains. Though improved stock management, especially the use of smaller paddocks and careful rotational grazing, could contribute considerably to pasture longevity, soil conditions are the limiting factor on some soil types. In winter and spring some soils are too wet, in summer some are too dry. For example, Waipaoa and Makaraka clay loams crack badly in summer, and Makauri clay loam sets hard and fissures deeply. In such soils grasses die out easily. After two years or so white clover dominates the sward and weeds invade bare patches where grasses have died. For this reason pastures should not be left longer than six years before ploughing up and re-sowing. It is better for the pasture that the soils be not cropped between breaking up and sowing, but if a cash crop is taken it should be followed by a green crop for ploughing in before the land is sown down.

Pasture growth and management is further discussed on pp. 69–71.

Grass and Clover Seeds

Seed production from both perennial and short-rotation ryegrasses and from red and white clovers is on a small scale. The area given over to it varies considerably from season to season, depending mainly on price and on the weather in spring and early summer, which determines whether there is a surplus of grass available to shut up for seed. Unpredictable heavy falls of rain during the harvesting period makes seed cropping uncertain. Although the quality of both grass and clover seed is very high, average yields are lower than from districts with a lower summer rainfall.

Lucerne

Lucerne is a good insurance against winter and summer feed shortage on dairy and fat-lamb farms. Though it is grown to limited extent on the Gisborne Plains, a considerable extension of its use would seem to be warranted. It can be readily established if sown in autumn on clean cultivated land and, if well managed, is satisfactorily persistent on well drained soils such as Waihirere and Matawhero silt loams. On gleyed recent soils with high winter water tables lucerne does not persist longer than about 5 years – too short a time to justify the costs of its establishment.

Cash Crops

Maize

Maize (fig. 18) is by far the most important crop grown on the Plains. It is also the safest in that the grower always gets some return. Since the introduction of hybrid maize the average yield has risen from about 60 bushels to 100 bushels per acre, with occasional yields up to 140 bushels. It is

Photo, A. P. Underhill

Fig. 18. Maize on friable topsoil phase of Matawhero heavy silt loam at Manutuke

likely that yields will be raised still further with the employment of more suitable hybrids bred for high yield and disease resistance. At the present time, however, the farmer can increase maize production even further by maintaining organic matter in the topsoil, preparing fine seedbeds, and controlling weeds. The most effective practical way of increasing organic matter is to plough in green crops.

Each year about 5,000 acres is sown to maize for grain, but of this only 4,700 acres is harvested. Insects and fungous diseases, bad weather, and bad farming are responsible for these losses. It is rare for any season to pass without some reseeding of paddocks where plants are lost through these causes.

For some time farmers have grown maize year after year in the same paddocks and, because the soils are chemically fertile, yields have remained high. This practice is not recommended as it encourages a steady depletion of humus, excessive build up of weeds on cropping land, and breakdown of soil structure. The result is a mounting cost of cultivation before and after the maize is sown; the extra cultivation brings no increase in yield and reduces net profit. Poor structure slows up soil drainage and in the early part of the season just after germination of the seed, excessive water in the soil can induce a nitrogen shortage. The plants receive a check in growth and, if wet conditions are prolonged, the leaves take on a yellowish tint. Growing maize year after year in the same paddock also results in the build up in the soil of a high population of spores of undesirable fungi, which are responsible for maize smut, maize blight, and stalk rots. These diseases not only reduce the yield but also increase the cost of harvesting.

For these reasons, to grow maize for profit it is necessary to spell the land frequently. By a system of crop rotation, including grass and green crops for ploughing in, such as peas, organic matter can be built up in the soil. The treatment of cropping land is also discussed on p. 67.

In early times there were several popular varieties of maize, including Horsetooth, Silver Queen, Marigold, and Early Butler. In 1941 Mrs A. L. Kemp, of Ruatoria, imported Pfister hybrid maize seed from U.S.A. This maize was an immediate success because of its high yield, small grain, and easy-shelling properties. Insistent demand by growers, coupled with import restrictions after the Second World War, forced the Department of Agriculture to grow its own seed at Gisborne, so in 1947 the first double-hybrid Pfister 360 seed was produced from first-crose parents supplied by the Pfister Company of U.S.A. By 1955 Pfister maize had ousted Marigold as the main commercial variety. Nowadays Marigold is grown chiefly for green feed, for which purpose it is excellently suited. Also in 1955 the Department of Agriculture released the first supplies of double-hybrid Wisconsin 643, which, because of its stronger stem, higher average yield, and greater resistance to *Helminthosporium* disease has now largely superseded the Pfister variety.

Fertilisers are little used, even on much cropped land, because it has not yet been shown that the expense is warranted. Experience indicates that there is no increase in yield from light dressings of fertilisers, but it is likely that heavier dressings, especially on second and subsequent crops, may give a higher return. Optimum rates of application are not yet available.

Peas and Sweetcorn

Details of these crops are given on pp. 67–8.

Pumpkins

About 250 acres of pumpkins of all varieties are grown. Crops of cattle pumpkins yielding 48 tons per acre have been reported, but the average yield is about 25 tons. The yield of table pumpkins is about 8 tons per acre.

Barley

The area in barley varies considerably year by year, the average being about 350 acres. Only feed barleys are grown, as high-quality malting barleys have not been successfully produced on Gisborne Plains.

Drainage

Over 43% (about 21,000 acres) of the soils of Gisborne Plains require artificial drainage, and early in the period of European settlement a major drainage system was constructed consisting of large drains at Muriwai, Taurau Valley, Opou, Repongaere, and Ormond. These were enlarged and deepened in the 1920s and again in 1957. Smaller drains track across country from one depression to another and often follow roadsides. To assist the quick discharge of storm water the Pakowhai Stream and the Taruheru River have been straightened.

Though this network of drains appears to be sufficient to provide outfalls for all land requiring drainage, the overall efficiency of the scheme has been limited by excessive weed growth blocking the channels. A cheap and effective means of controlling these weeds would contribute greatly to improved land utilisation.

Rapid removal of excess water from the soil is very important, for lack of adequate aeration can seriously limit plant growth. Also, a fine tilth can be produced on a well drained, aerated soil much more readily than on a poorly drained soil; this allows crops to be grown earlier, so avoiding many of the diseases that appear late in the season.

Successful soil drainage is difficult to achieve for three reasons. Firstly, the land is flat with little fall for open drains; secondly, the surface is dimpled with small depressions in which water collects, and thirdly, the natural through drainage in the subsoil is very slow, particularly in Kaiti soils.

Narrow, shallow, open drains are not efficient for removing soil water quickly. A more successful method is to cultivate the soil deeply to a fine tilth and then smooth the surface of the paddock with a grader or land leveller into a very low-convex ridge. The fall, after allowing for consolidation, should be only sufficient to lead water off the surface. Wide, shallow drains are then scooped along each side of the paddock and are grassed over. The only maintenance required of such drains is keeping the grass short by mowing or grazing. This method has proved especially successful for paddocks of less than 10 acres.

On Makauri soils where depressions are not too large the land surface should be levelled and deep drains dug. Surface depressions reduce yields of crops because plants mature more slowly in the depressions than on the warmer, higher parts of the paddock.

Special drainage treatment is required on Kaiti soils. The surface should be levelled and side drains dug sufficiently deep to tap a pumice layer 2 to 3 ft below the surface. This porous layer will lead water freely from the surrounding soils into the drains.

Mole drains have not been experimented with on the Gisborne Plains. Tiles have not been used to any extent, and since they have to be imported into the district would be extremely expensive to install.

Topdressing

In the past observational topdressing experiments carried out on some soils of the Gisborne Plains have shown no responses to lime, phosphate, or potash. However, more accurate trials in which responses are measured by mowing are now beginning to yield results. In one on Waihirere heavy silt loam near Muriwai there was no response to 2 and 4 cwt dressings of superphosphate until after 2 years, when an increased yield of 10% was recorded on the 2 cwt plots and 20% on the 4 cwt plots. No response to lime has been detected.

Present indications are that the occasional use of superphosphate may aid pasture production. Potassic fertilisers are not required at this stage. Soil tests at Rukuhia Soil Research Station show that there is no diminution of chemical fertility after many years of grassland farming. Soils long out of flood reach are still highly fertile. Where the soils have been repeatedly topdressed with superphosphate there appears to be a build up of residual phosphorus. On gleyed recent soils (Makaraka, Makauri, and Kaiti soils) nitrogen levels are low in late winter and early spring.

Copper and Molybdenum

Copper and molybdenum have been measured in both soil and pastures and values are reported on p. 47. On present knowledge there is no evidence of molybdenum excess or copper deficiency. Copper in animals' livers appears to be adequate. However, molybdenum levels in sweet vernal growing on Kaiti silt loam and Te Hapara sandy loam are low, and a response to molybdate topdressing may be obtained.

Climate and Agriculture

Compared with other parts of New Zealand, winter and spring at Gisborne are not very wet. There is, however, sufficient rain to keep the soils wet, and in this condition they cannot be cultivated satisfactorily. On cultivated land the surface soil puddles badly during heavy rain but dries out quickly if fine weather follows. Surface water collects in minor hollows and depressions and young plants may receive a check through lack of soil aeration or may even be killed by waterlogging.

It appears that the weather in September determines the physical state of the soil for the following season and hence the nature of the crop to be grown, its area, and its yield. In the main there are four sets of climatic and soil conditions:

1. A mild winter and not too wet; a dry September followed by some rain in November and December; optimum conditions and a bumper harvest assured of any crop. In the year 1956 two crops in succession were grown on Matawhero silt loam.
2. A wet winter and wet in September; the soil may be so wet that it cannot be tilled or, if it can be tilled, only a rough seedbed can be prepared. This is conducive to low germi-

nation and encourages an increased area in maize at the expense of other crops.

3. A wet winter followed by strong drying westerly winds in September and October. At this time much care is required in cultivation. The winds dry out the top 1 to 3 in. but the soil underneath is still wet. Plants germinate and strike well but encounter a check in growth. Nitrogen deficiencies are common. Under this set of conditions maize is more susceptible to disease.
4. A mild winter with little rain from September to December. Plants germinate and strike well but yields are light. Peas are liable to disease.

Conditions 2 and 3 are the most difficult for agriculture. They seem to occur when wet or dry springs follow wet winters. Reference to table 18, (p. 79), shows that in the past 83 years there have been 16 wet winters of which four were followed by wet springs, two by very wet springs, and four by dry springs. The table, however, has no predictive value.

Agriculture Potential

At the present time the main land use is the fattening of livestock brought off the surrounding hills, and it is unlikely that this emphasis will change in the foreseeable future. It is certain, however, that major improvements in farming practice will come. For instance, the growing of special fattening food is virtually unknown; trials conducted at Manutuke Research Station over the past five years have proved conclusively that pure white-clover paddocks will fatten lambs by an average of 9 lb heavier than by feeding off the normal ryegrass-dominant pasture. The fattening of beef cattle is still conducted along inexact lines. Experimental work at Ruakara Animal Research Station is already showing how better returns may be obtained, and these findings will gradually be applied in Gisborne. Artificial insemination and herd improvement will bring about improved butterfat yields in dairying.

The climate and soils are suitable for growing of maize for grain. The search for higher yielding varieties is continuing, but there is, however, much scope for development of means for combating plant diseases and for maintaining humus and structure in soils.

The area of cash crops for processing is gradually increasing, but it is not likely to be large. High yields can be sustained only by combining cropping with grassland farming, and the units have to be sufficiently large for cropping paddocks to be changed every two years. The production of grass seed is still largely at the mercy of the weather, but the element of risk may be reduced by the application of chemical desiccants. For instance, rain damage to clover seeds may be much reduced by cutting the drying time in the field from a week to 24–36 hours.

As irrigation is little practised no mention of it has been made in this discussion. It is likely, however, that with more intensive development arising from a desire for higher crop yields some form of irrigation will eventually be adopted in drier seasons. On present knowledge the best aquifers lie underneath the middle third of the plains, where also occur well drained soils like Matawhero and Waihirere silt loams and heavy silt loams. It is therefore unlikely that irrigation will have a general application, but the abovementioned soils when irrigated should produce more and with greater regularity than they do today.

HORTICULTURE

By R. S. Viney, Department of Agriculture, Gisborne

With its equable climate and fertile soils the Gisborne Plains are suitable for fruitgrowing, but, because of isolation and distance from markets, the industry has not been highly developed. The fruits most widely grown are citrus, pip, and stone fruits. Subtropical fruits can also be grown, but small fruits, such as gooseberries and black currants, have not been a success. In recent years there has been a distinct trend towards a greater production of citrus fruit, mainly sweet oranges and standard lemons, and it is likely that Gisborne Plains will become more important as a source for these fruits. In 1960 the Gisborne district produced 25% of the lemons grown in New Zealand and 46% of the oranges.

Market gardening, with which there has always been risk of large-scale flooding, is still on a small scale, but early potatoes and kumaras find a ready market in the southern centres of the North Island, and other vegetables are sent to Bay of Plenty towns. The establishing of a canning factory in Gisborne has tended to increase the variety of crops grown by most farmers.

Fruitgrowing

History*

The first peach and apricot trees were planted in 1831, and the apple, pear, and cherry were introduced in the 1830s. Grapes were first grown in 1840. By the 1860s the Maoris had planted large numbers of peach trees at Opou and Repongaere, as well as on the banks of Waimata River near Gisborne. In 1880 J. W. Johnston was reputed to have had the finest orchard of the district at Maraetaha. In 1887 there was a large orchard of nearly 3,000 trees at Repongaere.

Citrus trees were planted at Manutuke in 1885, at Repongaere in the 1890s, and at Ormond in 1891. Prunes were also grown at Ormond in the 1890s, but the enterprise did not pay. Other orchards were laid out in 1909, 1912, 1914, and 1915; then there was a lull in development until 1948, when returned servicemen of the Second World War were settled on new land in the Manutuke and Matawhero localities, where about 80 acres were subdivided into eight orchards and four vineyards. In 1956 citrus groves were laid out in the Taruheru locality near Gisborne.

Soils

Established orchards, whose main crops are pip and stone fruit, are sited wholly on Matawhero and Waihirere soils. There are small citrus groves on Matawhero soils and larger ones on the gravelly phase of Waihirere heavy silt loam. Vineyards are laid out on gravelly phases of Waihirere silt loam and heavy silt loam, Te Hapara sandy loam, and Kaiti silt loam, and subtropical fruit trees, boysenberries, and strawberries are also grown on the same soils. Avocados are grown successfully on the gravelly phase of Waihirere heavy silt loam. Recent plantings (new orchards) for pip and stone fruit are confined to the friable topsoil phase of Matawhero silt loam, and those for citrus on the gravelly phase of Waihirere heavy silt loam and on Te Hapara sandy loam.

All of the soils, except Kaiti silt loam, are well drained to moderately well drained, the oldest established orchards being on Matawhero and Waihirere soils. The poorly drained Makauri clay loam has proved to be unsatisfactory for commercial orchards.

Soils from established orchards have been analysed for free lime, potassium, and phosphorus. Nutrient levels are commonly high, but the ratio of potassium to phosphorus is rather variable; it is considered that a ratio of 1 to 3 is best for fruit trees.

On citrus trees leaf symptoms of manganese deficiency are widespread, but the symptoms are only mild and the deficiency is not of serious importance. It is known, however, that manganese sulphate sprays are beneficial to trees growing on Matawhero soils where the pH ranges from 6·8 to 7·5. Only one case of severe symptoms of typical manganese deficiency has been reported: the leaves of New Zealand grapefruit trees growing on Waihirere heavy silt loam in the Patutahi locality were almost devoid of green pigment and the trees were also in poor condition. After being sprayed with manganese sulphate plus hydrated lime (3:4:50) the trees became green again and resumed normal growth.

No serious symptoms of magnesium deficiency have been reported, but both Matawhero and Waihirere soils have a high level of exchangeable potassium, and Matawhero soils (except the friable topsoil phases) have a high level of calcium, caused by flooding. Where it is desired to raise the phosphorus level but not the calcium level serpentine superphosphate should be used in preference to "straight" superphosphate. Nitrogen deficiency in citrus trees growing on the gravelly phase of Waihirere heavy silt loam is suspected, but this may be a seasonal effect.

On present knowledge it is doubtful whether manuring of fruit trees is economic on deep recent soils such as the Matawhero and Waihirere soils. It is probable that the height of the water table plays a more important part than manuring; efficient subsoil drainage is needed on mottled phases of these soils, especially during years when the annual rainfall approaches 50 in.

Fruits

In 1957 there were more than 70 fruitgrowers, occupying an area of more than 430 ac. As well, there were eight nurseries, aggregating 20 ac. Fruitgrowing localities are fairly well defined (fig. 17) and include Manutuke, Matawhero, Waihirere, Patutahi, and Hexton, each locality having about the same number of growers. Pip and stone fruit are grown principally at Matawhero and Manutuke, where there are long-established orchards, and citrus is grown in all localities, Waihirere having the most trees. Grapes are produced mainly in the Manutuke and Hexton localities. There is no strict specialisation in fruit production as most orchardists who grow pip and stone fruit as their main crop also grow small areas of oranges, lemons, and grapefruit.

*Drawn freely from *Historic Poverty Bay and East Coast, N.I., New Zealand*, by J. A. Mackay, 1949, p. 332.

The size of orchards ranges from ½ ac to 22 ac; 40% are less than 5 ac and there are only six orchards larger than 10 ac. Since 1948 a common size is 8 ac but it is considered that 10 ac is desirable for pip, stone, and citrus fruits.

With apple and pear trees it is usual to plant on a 20 ft square, the trees being intercropped with vegetables until they come into production. Sweet orange and standard lemon trees are planted on a 20 or 22 ft square and are usually interplanted with Meyer lemon or peach trees; the latter are removed when they are six to 10 years old. The sale of Meyer lemons and peaches gives the grower some income until the other trees come into bearing.

Most orchards are poorly sheltered, mainly because the fruit trees are planted long before the shelter belts. Poplars are commonly grown to shelter pip- and stone-fruit orchards, and *Cupressus* species for citrus groves and vineyards.

Generally, orchards are clean cultivated, but the land is tilled only when weed growth is excessive. Tractor-drawn discs are used on the larger orchards and a rotary hoe on the smaller ones, including vineyards. Very little cover cropping is done and growers rely on weeds, natural clovers and prairie grass; but occasionally blue lupins, oats, and barley are sown to increase the organic matter of the soil. Even though the mechanical condition of the soil appears to be good some form of deliberate cover cropping would be an advantage in maintaining soil fertility. There is an increasing interest in grassing down of orchards and, so far, two citrus groves, two pip-fruit orchards, and three vineyards are in permanent grass. Mulching is not practised to any extent, but it is strongly recommended for citrus groves.

No consistent programme of manuring is carried out, but most growers supply some form of nitrogen. Manures used are blood and bone and sulphate of ammonia and, on citrus orchards, fowl manure has been tried with good results. On Matawhero soils, where the pH is high (more than 6·5), sulphate of ammonia is recommended.

Because of an equable climate undesirable fungi are active and insect pests abound; the most troublesome are red mites on apple trees, aphids, brown rot, and silver leaf on peach and nectarine trees, and hard-wax scale on citrus trees. There is an absence of verrucosis in lemons, a disease that is a problem in lemon groves in other parts of New Zealand. Disease control is generally good, but the standard of equipment could be raised. Over 75% of all the trees are vigorous and healthy and are classified as A grade for this district.

Apple and peach trees and grape vines are pruned annually and citrus trees occasionally. Standard practice now is to renew fruiting laterals and spurs on pip fruit every five years, except for Winter Cole and Winter Nelis pears for which the period is three years. Vines for table grapes are pruned to one or two buds next the old vine, and those for wine are kept to stumps so that they fruit on new laterals each year. Insufficient attention is given to the pruning of citrus trees, with the result that older trees have become too dense for adequate control of disease and pests; pruning is best done during September and October.

Orchards producing mixed fruits are harvesting all the year round; pip fruit from January to June, citrus from April to December, stone fruit from November to February, and grapes from January to March. All pip and stone fruit are graded and packed by growers, but citrus fruit is packed by Gisborne Markets Ltd. for the Citrus Marketing Authority.

Apple varieties include Delicious, Ballarat, Sturmer Pippin, Dougherty, Cox's Orange Pippin. Pears are mainly Winter Nelis, P. Barry and Winter Cole. Over 40% of the apple trees are less than five years old, and nearly 50% of the pears are in the same age group. In a favourable season apple yields may be as high as 1,000 bushels per ac but the crop is insufficient to meet local demand. The shortage is likely to continue well into the future and, in view of this, pip-fruit growing is well worth while.

Plums, nectarines, and peaches are also in short supply, though production is gradually increasing. Since plums and peaches mature seven to 10 days earlier than those in Hawke's Bay, increased plantings of early varieties suitable for bottling are worth consideration. Golden Queen peaches are grown for canning and extensive plantings have been made on Matawhero soils since 1954.

The first plantings of citrus trees were made with rough lemon and citronelle stocks, but, on these, the production of sweet oranges was disappointing. This fruit is now grown more successfully with *Poncirus trifoliata* and sweet-orange stocks. Increased plantings of Washington navel and Carter navel on these stocks are worth considering.

Subtropical fruits include feijoa, tree tomato, passionfruit, chinese gooseberry, loquat, persimmon, guava, pawpaw, and cherimoya, but they are grown commercially by only a few growers in the Waihirere, Manutuke, and Hexton localities. Production is probably supplemented to some extent from home gardens in Gisborne.

The avocado (*Persea gratissima*) has been grown successfully by one grower in the Waihirere locality and is marketed mainly in Auckland city and other centres where there is a strong demand. The first seedlings were planted in 1922 and began fruiting in 1932; a further 19 trees (10 varieties) were imported from California in 1941 and, of these, Mexicola, Fuerte, and Nabal are the most promising. As an example of their productivity 255 fruits, weighing 3 cwt, were harvested from one Nabal tree in 1951, and 300 fruits, averaging 1½ lb each, were picked from one of the first trees planted. The avocado is very popular in California, but it is not yet well known in New Zealand. Further plantings have recently been made.

The climate is suitable for the production of outdoor grapes and, in a favourable season, grapes from this district are some of the earliest to reach the market. The total area of vineyards is 42 ac, made up of small 5 – 10 ac holdings in the Waihirere, Hexton, and Manutuke localities. Grapes are grown for both table and for wine making, the main variety of table grape being Albany Surprise. The average annual yield of table grapes is 5 tons per ac, though in the Hexton locality a yield as high as 8 tons has been obtained. Here, grapes usually mature two weeks earlier than in other localities; the soil is Kaiti silt loam, which is not as chemically fertile as the Matawhero and Waihirere soils on which other vineyards are sited (fig. 19). Over 30,000 lb of table grapes are sent to other parts of New Zealand by air.

Market Gardening

Commercial gardening is still on a small scale. Besides the usual vegetables there are special crops of early potatoes and kumaras. Excluding crops grown for processing, the area of market-garden crops was 60 ac in 1920, and 240 ac in 1957. Gardens range from ½ ac to 14 ac and 60% of them are 5 ac and less.

Early vegetables, including potatoes, beans, lettuce, and cabbage, are produced at Waerenga-a-Hika and at Wainui, where there is little risk of frost. Potatoes are usually planted from mid June onward, but on Opoutama loamy sand at Wainui (fig. 19) they are planted as early as April-May and harvested during August-September. Yields may be up to 5 tons per ac. Owing to a high population of potato-tuber moth there are no large-scale plantings of late potatoes.

Kumaras are grown fairly extensively at Maori settlements at Waihirere, Waituhi, and Manutuke, and also at Waerenga-a-Hika and at Wainui. At Waerenga-a-Hika they grow well on Waipaoa heavy

Photo, A. P. Underhill

Fig. 19. Vineyards on Matawhero and Waihirere soils at Manutuke

silt loam and Waipaoa clay loam. Yields of 6 to 12 tons per ac have been obtained in Waipaoa heavy silt loam and from 8 to 20 tons in Kaiti silt loam. Average yields on the plains are between 5 and 6 tons per ac, and from variety trials in 1952 it is concluded that New Zealand varieties give the highest yields.

Pumpkins, including Hubbard Squash, Triamble, and Whangaparaoa Crown, are grown fairly extensively and yields of up to 22 tons per ac have been obtained. Matawhero and Waihirere soils have given the best yields for processing crops; peas have yielded up to 3 tons per ac, sweet corn up to 8 tons per ac, and tomatoes 20 tons per ac. The growing of tomatoes under glass is not widely practised, but interest in this method is increasing.

Most market gardens are on early soils such as Waihirere silt loam, gravelly phase, Matawhero silt loam, Matawhero heavy silt loam and Te Hapara sandy loam, mainly in the Ormond, Waerenga-a-Hika, Matawhero, Manutuke, and Wainui localities. Chinese-owned gardens are now concentrated at Matawhero, where Matawhero silt loam and its friable topsoil phase are much sought after. Orchardists at Matawhero and at Manutuke also grow vegetables. To overcome drought in summer Chinese gardeners draw upon ground water, which is pumped from beach sands at 12 ft. After five years of market gardening, the structure of Matawhero silt loam appears to be maintained and good tilth is assured on all soils used for market gardening because moisture content can be controlled by sprinkler irrigation. Periodic additions of organic matter are necessary to counteract surface sealing.

Soil tests on Matawhero soils show that pH values are high (7·1 to 7·5), free lime is excessive, and potassium and phosphorus are at high levels; the potassium/phosphorus ratio varies from 1 : 2 to 1 : 5. To acidify these soils the addition of sulphur has been suggested. There appears to be a shortage of nitrogen in late winter/early spring and this may be due to delay in nitrification brought about by cool temperatures and wet soils. On the slightly alkaline Matawhero soils sulphate of ammonia should be used in preference to organic manures as a source of nitrogen. On the Waipaoa and Kaiti soils phosphorus must be kept at a high level for the sustained production of kumaras.

Horticulture Potential

Soil types suitable for horticulture are listed in order of merit in table 11. They are grouped into two categories: (i) first class, where the soils are deep, friable and well-drained; and (ii) second class, where subsoils are mottled and the soil is heavy. Mottling indicates a high water table in a wet year, and heavy soils are not easy to keep open for good drainage and aeration.

The total area of the soil types is 22,200 ac, but when allowance is made for Gisborne city and built-up areas, as well as for established orchards, vineyards, market gardens, and nurseries, the balance suitable for expansion of horticulture is about 17,000 ac.

Opoutama and Te Hapara soils have not yet been proved suitable for commercial fruit-tree growing, although in 1956-57 a number of new citrus groves were laid out on Te Hapara sandy loam. They have strong assets in good drainage and a firm surface in winter and spring and, though not as chemically fertile as the recent soils, the difference can be made up by manuring. Ground-water supplies are sufficient for irrigation in summer. For these reasons they have been included in the first-class soil category. On Kaiti silt loam fruit trees are known to grow well where beach sands are within 3 ft of the surface, but sand subsoils are restricted to Gisborne city where the area of them is about 400 ac. This soil is also used for market gardening at Wainui, but elsewhere its suitability for horticulture has not been proved. It is recommended that no more land be used for horticulture until the soil is drained and trials made.

Established orchards, vineyards, and citrus groves are in the Ormond, Waihirere, Matawhero, and Manutuke localities, where the land surface is relatively high, being 30 to 80 ft above mean sea level. Localities with the lightest frosts appear to be Kaitaratahi, Ormond, and Waihirere, where the land is 50 to 80 ft above mean sea level and where down-valley breezes on winter nights are more noticeable. Even so, such breezes are selective, for on 4 June 1957 an orchard on the bank of Waipaoa River was hard hit by frost, while another orchard 10–20 chains away escaped damage. Another potentially suitable locality is Maraetaha, but as yet there are no established orchards; here Matawhero soils are more sandy than elsewhere.

There is a range of fruits and crops that the plains can produce easily and well. These include, in order of importance, citrus fruits, early vegetables, pip and stone fruits, grapes, subtropical fruits, strawberries, cut flowers, and flower and vegetable seeds. Early crops are worth trying, but the plains are rather exposed to southerly winds, which bring with them a sharp drop in temperature. Increased shelter and the use of cloches to keep the soil temperature high might be ways to make use of well drained soils for this purpose. Pip and stone fruits are difficult to market outside Gisborne because of great distance from southern cities. But marketing of crops for processing has been made possible by the erection of a food-processing factory in Gisborne, and isolation is now no obstacle. Subtropical fruits seem worth developing, especially avocados, since this fruit is high in protein.

TABLE 11: Land Suitable for Horticulture (as at 1957)

Soil Type	Area (ac)			
	Total	Gisborne City Plus Built-up Areas; Floodway, Waipaoa River	Established Orchards, Vineyards, Market Gardens and Nurseries	Remainder
FIRST-CLASS SOILS				
Waihirere silt loam, gravelly topsoil phase	500	70	–	430
Waihirere silt loam	1,430	220	20	1,190
Matawhero silt loam, friable topsoil phase	2,530	320	110	2,100
Matawhero silt loam	500	20	10	470
Waihirere heavy silt loam, gravelly topsoil phase	500	70	60	370
Waihirere heavy silt loam	2,450	170	80	2,200
Matawhero heavy silt loam, friable topsoil phase	1,880	100	70	1,710
Matawhero heavy silt loam	2,200	120	20	2,060
Opoutama loamy sand	1,170	710	0	460
Te Hapara sandy loam	1,630	1,020	10	600
	14,790	2,820	380	11,590
SECOND-CLASS SOILS				
Waihirere silt loam, mottled subsoil phase	580	30	5	545
Waipaoa heavy silt loam (after Waipaoa scheme is completed)	1,370	420	20	930
Matawhero heavy silt loam, mottled subsoil phase	1,120	50	20	1,050
Waihirere heavy silt loam, mottled subsoil phase	1,950	180	50	1,720
Matawhero clay loam, friable topsoil phase	240	20	20	200
Matawhero clay loam	1,440	90	60	1,290
Kaiti silt loam	670	550	120	0
	7,370	1,340	295	5,735

MAORI HORTICULTURE

By H. CONWAY, Department of Maori Affairs, Gisborne

There are no reports of early Maori agriculture on the Gisborne Plains, but the Maoris of the East Coast appear to have been good cultivators. When the *Endeavour* called at Tolaga Bay in 1769, Cook, Banks, and Solander were impressed by the methodical manner in which the plantations were laid out, and also by the high degree of tidiness with which they were tended. According to Banks (in Mackay, 1949):

"Their plantations were now hardly finished, but so well was the ground till'd that I have seldom seen, even in the ground of Curious people, Land better broken up. In them were planted sweet Potatoes, Cocos and some of the Cucumber kind . . . The sweet potatoes were planted on small hills, some in rows and others in quincunx, and all laid out most regularly in line. The Cocos were planted on flat land and had not yet appear'd above ground. The Cucumbers were set in small hollows or ditches, much as in England. These plantations were from one to two to 8 or 10 acres each. In the Bay, there might be 150 or 200 acres in cultivation, though we did not see 100 people in all. Each distinct Patch was fenced in, generally with reeds placed one by another so that scarce a mouse could creep through."

There is evidence from the soils of early Maori occupation on the plains – along the high banks of the Waipaoa River, particularly at Kaitaratahi, Waihirere, Waituhi, and at Matawhero, there are patches of coarse gravels and intensely black topsoils, and at Waihirere and Matawhero there are many shell fragments. Extremely high levels of phosporus and potassium in Waihirere, Matawhero, and Kaiti topsoils in these areas suggest sites of early Maori settlement.

Today the area of Maori land on Gisborne Plains is about 5,700 ac; of this, 310 ac is used for residential purposes within Maori settlements, and 2,290 ac. is leased to European farmers. Of the balance, 1,340 ac is used for livestock farming in

TABLE 12: Size Classes and Numbers of Occupiers of Maori Land

—	Size of Holdings (ac)							Total
	2–10	11–20	21–30	31–40	41–50	51–60	>60	
Number of occupiers ..	116	22	11	4	–	3	3	159
Total area occupied (ac) ..	616	397	199	148	–	166	249	1,775
% occupiers	73	14	7	2	–	2	2	100
% total area	35	22	11	8	–	10	14	100

large units (Maori incorporations) and 1,775 ac is in small holdings (table 12) with which this section is particularly concerned.

Small holdings are concentrated around Maori settlements in the Manutuke, Waituhi, Muriwai, Waihirere, and Wainui localities, with most holdings in the first three settlements. The settlements are sited on a variety of recent soils. Matawhero and Waihirere soils are considered to be first class, and Waipaoa, Makauri, and Kaiti soils are second class. Waipaoa soils at Waituhi are subject to flooding, and Makauri clay loam and Kaiti silt loam require to be drained.

Manutuke settlement has the highest proportion of first-class land, and Waituhi will always have problems associated with flooding and the draining of low-lying land. At Wainui Kaiti silt loam is not as chemically fertile as other recent soils, but the land has been made highly productive by drainage, windbreaks, and good husbandry.

The chief interest of Maori small holders is in growing vegetables, particularly kumaras, which grow very well in the Gisborne - East Coast region. Before 1947 there was little commercial growing and any surplus was marketed in Gisborne, but of recent years the production of a large quantity of high-quality vegetables has been encouraged. The volume of production for sale is now over 500 tons, and vegetables, principally kumaras, are marketed in the main centres of the North Island; kumaras and pumpkins are sometimes sent to Christchurch for distribution in the South Island. The value of Maori-grown produce sold from the Gisborne Plains in 1950 was nearly £9,000, including £7,000 for kumaras, and for 1957 exceeded £10,000. Wet seasons and floods have greatly reduced production in subsequent years.

Kumaras

Prior to 1949 the annual commercial production was less than 50 tons; in 1957 more than 300 tons of tubers were produced by a small number of growers, 12 at Manutuke, 10 at Wainui, eight at Waihirere, three at Waituhi, and two at Muriwai, but since then wet conditions have reduced crops.

The kumara is frost tender and, for sustained growth and a high yield of tubers, it requires sunny days and warm nights for at least four months. Preferably the soil should be well drained sandy loam over a heavy silt loam subsoil and the surface should be smooth and level. The best sites are on gentle slopes with a northerly aspect for maximum sunshine, and all fields should be sheltered from strong winds by belts of shrubs.

On the plains these specifications are easily met, except that the land is flat. Suitable soils are Waihirere silt loam and its gravelly phase, Matawhero silt loam and its friable phase, and Kaiti silt loam (if drained).

Growers usually raise their own plants. For this, good, medium-sized tubers are selected, and they are sprouted in warm, sunny beds covered with clean, sharp sand. For protection against rain and cold, glass or plastic lights are used; such covers are also easily handled when attending to the beds, pulling plants from tubers, and hardening them off. The beds should be sheltered by a manuka brush wall to keep the air still and hot, and they should be irrigated, but not excessively so, with warm water. To enable plants to develop a full root system while living on the tuber, the latter must not be allowed to rot.

The preparation of fields for planting out must be thorough, as no amount of after-cultivation will take the place of good initial preparation; a deep, fine tilth giving free drainage and ample aeration is required. Now that tractors, rotary hoes, and other implements are available the grower can open up the soil at its correct moisture content for optimum tilth and as quickly as possible while good soil conditions last.

Planting is done eight to ten weeks from setting of the tubers. On very favourable sites, planting out may be as early as September, but the main crop is usually planted in October, November, and early December. November is the best month for the main or stored crops as there are few cold winds then. Planting out must be done immediately after pulling from the tubers. Plants are set out on slight ridges about 15 in. apart with the stem bent in the form of a letter J, the bottom of the J being pushed into the ground: rows are at least 30 in. apart (fig. 20) but may be more to suit the grower's equipment. Watering-in of the plants settles the soil around their roots and helps to establish them firmly. Shallow planting encourages more tubers.

In kumara growing, cultivation not only destroys weeds and keeps the soil open, it also checks the vines from digging in new rooting systems and for this reason should be carried on for as long as possible.

Kumaras require a high level of potassium and, while most recent soils have adequate natural reserves of this element, these may be insufficient for this plant over a period. Potassium should be added to Waipaoa soils and Kaiti silt loam. In some gardens potassium deficiency has been observed on Kaiti silt loam.

A high potassium uptake appears to increase the yield, to induce better keeping qualities, and to have an influence on the flavour. It also results in the production of a shorter and more squat or chunky tuber, liked by consumers and better for packing. As kumara-plant roots are very sensitive to fertiliser injury, fertiliser should be worked well into the soil a week or two before planting.

Kumaras should be well matured before digging. Tubers from early plantings are harvested in February and March, and those from late plantings are dug in April. The present method of harvesting is to roll out the tubers by ploughing and then scratch them on to the ridges to lie until they have lost some of their moisture. After a few days they are packed in boxes carefully and without bruising and brought into the storehouse. The use of tractors and trailers has enabled growers with large areas to lift the crop quickly. Kumaras must be stored before the wet and cold weather sets in.

Photo, H. Conway

Fig. 20. Kumaras on Kaiti silt loam at Wainui

Because the skin of the kumara is very delicate and because there is no natural rest period, the long keeping of kumaras is very difficult. A fundamental condition in the storehouse is that the air should be dry and uniformly warm, and when the air has to be changed it must be done quickly. For temperature control, artificial heating may be necessary. Windows should be few, as excessive light favours sprouting, and large areas of glass permit loss of heat and so cause fluctuating temperatures.

In curing, a loss of 6 to 8% of the original weight is aimed at and the period required varies with the amount of curing occurring in the field and with the humidity. To prevent decay the curing should be done as soon as possible.

Kumura growing has always been a payable venture, but today it can be highly profitable. Yields range from 2 tons to 16 tons per acre with many of 10 to 12 tons.

Other Vegetables

A wide variety of other vegetables has been grown, including early potatoes, pumpkins, cabbages, cauliflowers, tomatoes, beans, marrows, carrots, peas, onions, cucumbers, sweet corn, maize, melons, and asparagus. There has always been a demand for early potatoes, the earliest of which grow best in Wainui and Waerenga-a-Hika localities. Mid-season varieties grow well in the Manutuke and Waihirere localities. Pumpkins thrive in all localities, especially at Manutuke. In 1949, 100,000 tomato plants were grown, and about 50,000 in 1950, but European growers have predominated since 1951 with the establishment of a large cannery in Gisborne. Apart from early potatoes and pumpkins, production is not sustained, but waxes and wanes with the grower's interest.

Seedlings

Tomato seedling plants have been grown for sale to chain stores. Onion plants can also be grown well, particularly on Kaiti silt loam, and large numbers of strawberry runners are grown for sale throughout New Zealand. One grower is producing flower and vegetable seedlings out of doors. The plants are in rows and not in trays, and during inclement weather are protected with plastic covers; windbreaks are carefully placed. When the plants are ordered the grower simply digs them out and rolls them into packets for dispatch to various parts of the North Island.

Small Fruits

From time to time feijoas, tree tomatoes, cane fruits, grapes, and citrus have been produced for marketing in small quantities, but the most successful and sustained venture has been strawberry growing. This has proved highly profitable and is particularly successful on Kaiti silt loam. The Gisborne market is supplied largely by Maori growers, and in the Wainui locality roadside sales are a speciality, yielding a high return.

Protection from strong, dry, north-westerly winds and cold southerly winds is necessary for satisfactory small-fruit production. Adequate windbreaks smooth out surface-temperature fluctuations and help to conserve moisture, and the effect on a field extends from the shelter a distance up to 15 times the height of the trees. It is said that 75% of a field, with the other 25% in trees, will produce as much as or more than the whole area without trees.

Trees, such as acacia species, pine species, cypress species, pohutukawa, hakea, pittosporum species, and eucalyptus (*E. gunnii*, *E. saligna*, and *E. botryoides*) grow well on the Gisborne Plains. Expert advice should be sought in choosing the species most suitable for a particular locality.

Home Gardens

The Maori people are great lovers of flowers, and efforts to improve the quality of home gardens have met with considerable success. Garden competitions, with awards for high standards, have brought a ready response and some very fine displays have been achieved. Many Maori gardeners do not begrudge expense on flowers and shrubs, and once a good garden is established reach a very high standard of maintenance.

Potential of Commercial Horticulture

Maori growers could gain the benefits of a longer growing season by adopting a balanced programme of early crops, such as potatoes, beans, peas, cucumbers, and melons, followed by storage crops, such as kumaras, pumpkins, and potatoes, and by late crops, such as beans. By planting a wider variety of crops growers could spread their returns over a longer period and be less dependent on price fluctuations of a main crop. Now that efficient kumara storing is quite practicable, attention should be given to the storing of pumpkins, which, if released from August onwards will fetch good prices.

The Maori people have a preference for small areas of 1 to 2 ac. For commercial cropping, however, larger units allow better use of machinery.

SOILS AND CROPS FOR PROCESSING

By L. R. RENOUF, J. Wattie Canneries Ltd., Gisborne

Since 1951 an area of 1,200 to 1,600 acres within a radius of 16 miles of Gisborne has been used annually for the growing of peas, tomatoes, sweet corn, and beans for canning and freezing. In order to maintain a steady flow of products to the factory, the crops are spread-planted; peas are sown from mid August to the end of October, tomatoes are planted from mid October to early November, sweet corn sown from mid October to early December, and green beans from end of October to end of November. As the cannery requires the farmer to cultivate earlier than he was previously accustomed to, much attention was first devoted to soil management, but now that growers are becoming familiar with the cannery's specifications, emphasis is being shifted to crop management. The following notes are based on field experience during the period 1951–1960.

Suitability of Soils for Cropping

Crops have been grown on a variety of soils and, under proper management and a favourable climate, such as moderate rainfalls and absence of long dry spells, there is little difference in production. There is, however, considerable variation in the periods over which soils can be used and there are also large differences in the way soils react to adverse climatic conditions such as heavy and continued rainfall or long dry spells. The adaptability of Gisborne Plains soils for special crops is therefore rather limited.

Table 13 shows the relative importance of the soils used for processed crops over the period 1953–57.

During the period 1957–60, 85% of the total processing crops have been grown on Matawhero, Waihirere, and Makaraka soils, and the balance on Kaiti, Waipaoa, and Makauri soils.

Matawhero soils (40%) have grown more crops than any other soil. Sweet corn, tomatoes, and beans produce well when grown throughout the scheduled planting periods, but late-planted peas are not a success. For this crop the silt loams are suitable for plantings during August to mid September, and heavy silt loams for planting to the end of September. Silt loams are readily worked at will, are fairly retentive of moisture, and also withstand adverse climatic conditions well.

Waihirere soils (21%) have proved the equal of Matawhero soils for all crops, but, because of widespread surface undulations, the land cannot be utilised over the same period as for the Matawhero soils.

Makaraka soils (16%) in the main have given good results, but like Waihirere soils their surfaces are not smooth. Furthermore, because of poor drainage and cloddy tilth the land is unsuitable for early cropping. As the soils tend to crack badly in dry summers they are more suitable for row crops, such as beans, tomatoes, and sweet corn.

Waipaoa soils (8%) have been used mainly for pea and sweet-corn production, but, with occasional exceptions, results have not been as good as those from other soil types. This has been partly due to maize blight in corn and footrot in peas, and the incidence of these diseases appears to be higher than on other soils. Although Waipaoa soils will possibly not be used to the same extent in future, there are some localitites that are favourable for late September and October plantings of peas and November plantings of sweet corn.

Makauri soils (8%) are also poorly drained, and few areas are free from depressions and old stream courses, which in wet seasons become filled with water to the detriment and even loss of crops. In dry seasons extensive fissuring also occurs. For

TABLE 13: Production of Crops for Processing (1953–57)

Soil Series	Peas		Sweet Corn		Tomatoes		Green Beans	
	% of Area	% of Production	% of Area	% of Production	% of Area	% of Production	% of Area	% of Production
Matawhero	38·5	42·3	38·5	37·2	55·7	60·1	33·5	28·5
Waihirere	18·0	18·5	17·0	16·5	19·1	16·2	31·0	34·5
Waipaoa	16·4	15·3	15·5	15·5	..	..	..	..
Makaraka	13·8	12·7	14·9	14·8	5·6	5·2	27·4	29·1
Kaiti	10·7	8·6	6·0	7·9	..	..	3·5	4·6
Makauri	2·6	2·6	8·1	8·1	19·6	18·5	4·6	3·3
	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0

these reasons their suitability is limited and only carefully selected fields are used.

Kaiti soils (7%) are generally very poorly drained and, although under favourable conditions production has compared well with that of other soils, they are restricted to late plantings.

Soil Management

Maximum production is obtained if the soils are used at their most suitable period of the season, if the land is smooth and level, and if fine seedbeds are prepared.

In early spring Waipaoa, Matawhero, and Waihirere heavy silt loams are temporarily slow draining, and Makaraka, Makauri, and Kaiti soils are either wet or waterlogged. Thus, spread planting is also necessary to suit the soils, and it is now standard practice to start the season in August with Matawhero and Waihirere silt loams and end in November with Makauri or Kaiti clay loams. A soil problem at this time is surface sealing, which is natural to the heavier soils; water may lie on the surface but the topsoil is merely moist. Infiltration is further retarded by the surface being compacted by cattle or by heavy trucks and harvesting equipment, particularly during wet weather. Slow storm-water clearance by main drains is also too common, and this keeps the soils unnecessarily wet.

Another important problem is unevenness in the surface caused by small depressions and old stream courses; though these are shallow they carry water late after a wet winter and, even though a large part of a paddock may be dry, the working of this paddock is often governed by the small area traversed by depressions. Instances have been noted of paddocks with friable well drained soils and only 3 to 5% of the area in depressions being up to four weeks later than level paddocks of similar soil. Production from these depressions, even in favourable seasons after planting of crops, has always been poor; if they are wet in spring and early summer they are also the driest in late summer and, in consequence, uneven maturity, particularly of peas, has reduced the yield.

Apart from Matawhero and Waihirere silt loams the soils need great care in working for cropping and, in order to ensure good tilth, few paddocks are now accepted that have been cropped for more than two years in succession. Heavy silt loams and clay loams dry out rapidly when tilled during warm and windy periods in late September, October, and November, and, unless cultivation is carried out quickly, large clods are merely battered down to smaller ones. For quick cultivation and a fine seedbed the farmer must employ more equipment than is normally required for other forms of agriculture.

Crops and Yields

Trials carried out over a number of years have demonstrated the varieties of each crop most suitable for the Gisborne Plains, and experimental work is continuing on the control of weeds, insect pests, and diseases in the field. The following crops are those most commonly grown for processing:

Peas

Land suited to high production of peas is rather more limited than that suited to maize or sweet corn production. There has, however, been a gradual increase in the area cropped for peas and, generally, good results have been obtained. The average yield for the period 1953–60 has been 1·4 tons per acre, and the yield giving the highest financial return, taking quality grading into account, has been 1·87 tons per acre of high-quality freezing peas. This crop was grown on Matawhero soils.

Weed control is still a major problem in growing peas, but during the last few years weedicides and application techniques have been greatly improved and efficient control can now be achieved. DNBP sprays are generally used and, to a lesser extent, combinations of MCPB and DNBP.

Tomatoes

Tomatoes are an important crop and do well on the better drained soils of the Gisborne Plains. Matawhero soils have proved especially suitable for high production. The average yield from 1953–60 has been 14·7 tons/acre with a peak yield of 22·25 tons/acre on a Matawhero soil.

Sweet Corn

This crop is produced for both canning and freezing. It is grown from Golden Cross hybrids, but other varieties are now under trial. The aim is to select those that will give a high production, that can be readily harvested mechanically (fig. 21), and that are equally suitable for processing as whole kernel, cream style, or corn on the cob. Indications are that some of the new hybrids will supersede Golden Cross.

The growing of sweet corn requires more care than that of maize. Best results are from a fine seedbed 3 to 4 in. deep on a slightly firm undersoil. Seed at the rate of 8–10 lb per ac is planted in rows 3 ft apart, and a nitrogenous fertiliser (2 cwt blood and bone or 1 cwt sulphate of ammonia) may be added to older cropped paddocks, but not to new land out of grass. Weeds are controlled by spraying before cultivation and when plants are no more than 4 to 6 in. high. Cutworm, wireworm, and wheat-stem borer are the most active pests; methods of control experimented with are by broadcasting aldrin-superphosphate or 50% DDT wettable powder or by spraying aldrin into rows made by the planting machine. Weeds that markedly reduce the production of sweet corn are barnyard and foxtail grasses, and these are now becoming a problem.

Sweet corn takes from 100 to 117 days to mature for early plantings and down to 100 days for later plantings; when soil moisture is low the cobs take much longer to mature. The average yield over the period 1955–60 was 4·7 tons/acre, and the peak yield of 7·75 tons/acre was produced on Matawhero soils.

Green beans

Dwarf varieties of green beans have been grown on most of the soil types, but the best production has come from Makaraka, Matawhero, and Waihirere soil types. When grown on Waipaoa soils results have been very disappointing.

The average yield per acre over seven years to 1960 has been four tons while the highest yield of eight tons was produced on Makaraka soil type.

Peaches

Extensive plantings of peaches have been made since 1954 on Matawhero and Waihirere silt loams.

The land really suitable for peach growing is limited in the district and is confined to these two soil types.

Asparagus

Some plantings of asparagus have been made over recent years and further planting is contemplated in the future. Matawhero and Waihirere soils are proving the most suitable for this crop.

Conclusions

From experience gained in the growing of crops for processing over the past nine years it is clear that the major areas of processing crops will probably be grown on Matawhero and Waihirere soils. However, to spread maturing dates the level portions of other soils will be utilised for late plantings.

Photo, J. Wattie Canneries Ltd.

Fig. 21. Harvesting sweet corn on Matawhero silt loam

The highest production of all crops is achieved during the first two years out of pasture, total production being up to 30% higher than for older cropped paddocks. By limiting cropping to two years before regrassing it appears that soil structure and fertility can be maintained over a long period.

While there is a large area of land that will give a high production of crops there is also an equally large area that could be greatly improved for cropping by better drainage and by surface levelling.

PASTURE GROWTH ON THE GISBORNE PLAINS

By D. P. SINCLAIR, Manutuke Research Station, Department of Agriculture

On the Gisborne Plains there are many and diverse forms of agriculture but, apart from pasture farming, most are practised on a relatively small scale. A major portion of the plains is still devoted to fattening store lambs, winter hoggets, fat-lamb production from aged ewes, and to dairying. Supplementary feeding with green crops or planned feeding from the surplus pasture saved at various times of the year is not widely practised, and production appears to be almost wholly dependent upon the vagaries of natural pasture growth. Hence the available information on pasture growth in relation to rainfall and temperature has been examined in an attempt to determine whether in most seasons a system of pasture management and conservation would be better than uncontrolled feeding.

Data on pasture growth on the plains are recorded at the Manutuke Research Station. There, measurements have been made at one- or two-weekly intervals without interruption since January 1945 on a permanent pasture consisting of perennial ryegrass and a poor type of white clover. By district standards it is similar to much of the permanent pastures, although, as a result of controlled grazing, perennial ryegrass has become dominant and the pasture can be regarded as above average. It has produced approximately 12,000 lb dry matter per annum, but owing to the lack of a high-yielding clover its potential summer production is limited. The comparative merits of an improved pasture will be discussed later.

The measurements of pasture production were made by weighing total green growth obtained between two set mowings of a known area over a given interval. An aliquot sample of green material was dried to obtain the percentage of dry matter, and from this the total dry-matter production per acre was calculated. Frames of a known fraction of an acre were used to enclose the mown area from grazing by livestock, and the frames were moved at random over the pasture. This technique has limitations, as close mowing checks growth during the flush periods when the grass is long and, in the final mowing during a dry summer when the pastures go to seed stalk, dead material could not be entirely excluded. The technique does, however, provide a useful indication of seasonal variations in pasture growth, and these variations are most important.

Records of rainfall, air, and earth temperatures have been kept at the station since January 1945. These measurements and those of dry-matter production are plotted as averages for an all-year period, 1945–55 (fig. 22). The year has been divided into half-monthly periods, i.e., 1st to 15th and 16th to 30th. Rainfall is expressed as the total for each period and temperatures and dry-matter production are derived from daily averages. The pasture samples were grown on Kaiti heavy silt loam.

The graphs reveal the relationship between low summer rainfall and low winter temperature and low dry-matter production; but there are variations in the same period over the several years and no clear-cut pattern emerges. Low production seems to be associated with earth temperatures of less than 50°F, but the period is relatively brief; it does not usually extend beyond six weeks and varies in time from early May to mid August.

The spring flush is dependable. It begins in early August, is well under way before the end of the month, and continues until early December. Contrary to popular opinion, summer dry spells with low pasture production are the exception rather than the rule on the Gisborne Plains. In only three out of 11 years has there been any significant feed shortage during December, January, and February. The autumn period of flush pasture growth is extremely variable and may occur at any time from February to early June. In general, periods of growth producing less than 20 lb dry matter per acre per day are relatively rare throughout the year, which explains why feed conservation is not widely practised.

Consideration of the graphs in relation to sheep farming on the Gisborne Plains is difficult. It is not possible to recommend one system of feed conservation that would fit all local needs, as no consistent type of farming is practised. There is a plentiful supply of store sheep at the weekly Matawhero sale, where prices, because of dependence on buyers from outside markets, are generally below average North Island rates. This gives the farmer ample opportunity to buy hoggets or wethers and so take advantage of a favourable feed situation. It is difficult to recommend autumn-saved pasture for wintering hoggets when it may be as profitable to fatten lambs on the autumn feed rather than to save it.

When the fat-lamb flock is considered, autumn-saved pasture is necessary for maximum carrying capacity during the winter. The occasional summer feed shortage is relatively unimportant, as early weaning and disposal of fat lambs and culled ewes eases the need for summer feed. In most years it is possible to save sufficient feed from mid April onwards to carry the ewes through the winter shortage. Lambing on the plains starts in late July, a little in advance of the onset of spring growth, and provision of saved feed must be made for the last month of pregnancy and for the first few weeks of lactation for the early lambing ewes.

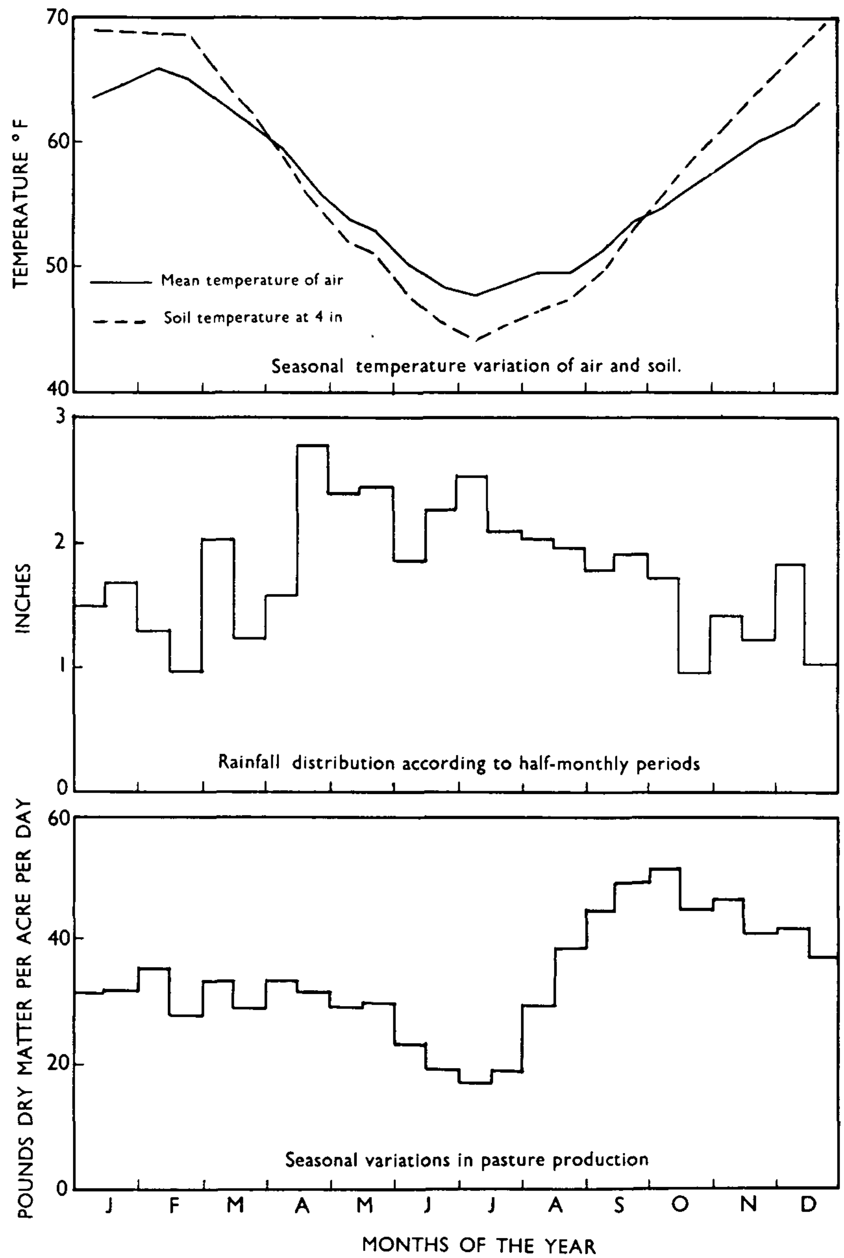


Fig. 22. Graphs of dry-matter production, rainfall, and soil temperatures at Manutuke Research Station

Although some growth might be taking place in August, pastures that have been grazed short during the winter require a spell to establish a good cover of feed suitable for ewes and lambs.

Theoretically, the magnitude of spring and autumn growth as shown in the graphs should permit at least eight ewes per acre to be carried if provision of autumn-saved pasture were made for the brief winter shortage. However, owing to poor surface drainage on a large part of the plains, topsoils become waterlogged and, with heavy stocking, feed is trodden into mud before it can be consumed. This severely limits carrying capacity and it would be inadvisable to recommend farming practices based on the complete utilisation of spring and autumn growth with breeding ewes.

With provision of autumn-saved pasture and lucerne hay, six ewes per acre have been carried at the Manutuke Research Station for several seasons. The station is less subject to the accumulation of surface water than are most parts of the flats, but extensive bogging of saved pastures occurred during the wet winters of 1955 and 1956. Only plentiful supplies of lucerne hay prevented a serious feed shortage in the month before lambing and possible heavy losses from pregnancy toxaemia. Early-lambing ewes suffered from the shortage of clean feed as the bogged pastures were slow to recover, and early lambs did badly. Thus six ewes per acre seems to be too high a figure; five per acre would be about the safe maximum rate for the winter months, even when pastures are supplemented by saved feed and hay. During summer and autumn, when requirements of the ewes are low, this number would result in a surplus of feed, which can be utilised efficiently only by the fattening of bought-in store lambs.

The pasture used for making growth measurements was predominantly perennial ryegrass, a type that, although it provides suitable feed for a fat-lamb flock in winter and spring, cannot be used with any success for fattening store lambs, as they have been found to become unthrifty on it during periods of flush autumn growth (Sinclair, Clarke, and Filmer, 1956). In contrast it has been found (Sinclair and Simpson, 1954) that lambs thrive on dense white-clover pastures during summer and autumn. Thus a system of sheep farming that combines store-lamb fattening with fattening on the mother requires pastures dominant in white clover during summer and autumn and dominant in grass during winter and spring. This can be achieved where a programme of pasture renewal is carried out (as would be so on a property on which crops are grown) by including the improved strains of certified white clover in the pasture mixture as paddocks are sown down. The new pastures will provide excellent grass for winter and spring feed and then, if they are grazed leniently during early summer, the white clover will dominate and provide a deep cover of feed, which will carry eight to 10 lambs per acre from January to May and allow fattening of several consecutive drafts of stores.

Under this management, unless care is taken, the ryegrass can be smothered out, with subsequent loss of winter feed production, and it is necessary to provide for wintering ewes a sufficient area of the best drained land available by either oversowing or opening up by heavy grazing. Either method is effective, but oversowing clover paddocks with 10 lb short-rotation ryegrass in April and May has been found to ensure a good supply of grass in July.

Disadvantages of white-clover pastures are that they lose vigour and require renewal every four-five years and that they are low winter producers. However, they solve the main problems of fattening young sheep; if they are used for that purpose in combination with a fat-lamb flock of aged ewes limited to a safe winter carrying capacity they provide for a method of sheep farming that suits the climate and pasture-growth conditions of the Gisborne Plains.

FLOODING AND PASTURES

By J. G. McKee, formerly of Grasslands Division, Department of Scientific and Industrial Research, Gisborne

On the Gisborne Plains regrassing of land covered with new flood sediment has met with indifferent success. To investigate this, trials were conducted immediately after the 1948 and 1950 floods and observations were made on flooded lands in the Puha, Waipaoa, Ormond, and Repongaere localities. Altogether, 35 farms were inspected, most of them sited on Waipaoa soils, mainly Waipaoa clay loam.

Pasture Trials

Up to the time of the 1948 flood there was little knowledge available as to the best way to conduct systematic trials, so plots in three localities were sown with a "shotgun" mixture of different species and manured with superphosphate and sulphate of ammonia in bands across each plot. The 1948 flood trials showed that:

1. Italian ryegrass made the best growth, and clovers, with the exception of red clover, struck poorly.
2. There was a response to superphosphate and sulphate of ammonia applied at the rate of 3 cwt per acre; in both grasses and clovers, the early response to superphosphate by itself was most marked.
3. Wetness or stickiness of the surface was most important in getting a strike; if the surface was dry at time of sowing, the strike was poor.
4. Different regrassing practice was required for clays, silts, and sands.
5. Birds consumed much of the seed.

After the 1950 flood another set of trials was laid down, with the object of answering questions posed by the 1948 flood trials. The main objectives were: to determine the best time to sow after a flood for each of clays, silts, and sands; to see if the strike of clovers could be improved, firstly, by innoculating the seed, and secondly, by not sowing with the grass seed but by oversowing later when grass was established; to see if smaller quantities of fertiliser than used in the 1948 trials would produce the same results. It was also desired to provide early feed. In this particular trial wheat was included because farmers were contemplating replacement of peas with this crop. The 1950 trials showed that:

1. The time of sowing is more important with clovers than with grasses. On silty sands and sandy silts, clover seeds struck best immediately the land was clear of flood waters; on clays and clay loams best strikes were obtained three weeks after the flood when the surface was slightly firm but soft and sticky. With grasses, earlier sowings did best on silty sands and sandy silts, but on clay loams no differences were observable between sowings a week after the flood and three weeks after. It is possible to sow too early in clays and clay loams, when the seed either sinks or floats away.
2. No results could be attributed to the inoculation of clover seed.
3. Plots given applications of fertiliser (superphosphate and sulphate of ammonia) showed better strikes, with better colour and more vigorous growth of plants, than the unmanured plots. Responses were most marked on sandy sediments. A superphosphate dressing of 1½ cwt per acre was necessary to achieve worth-while results.
4. The establishment of barley, wheat, and oats was generally not a success; some of the seed was eaten by birds.

General Observations on Regrassing After Flooding

The Sediment: The distribution of sediment commonly followed a pattern, with sands near the banks and with clays in ponding areas remote from the channel. Clays were fairly uniform in texture, but sands and silty sands were variable in texture and depth, largely because of obstructions to the flow of flood waters. Obstructions included fences (often lined with maize stubble) and hedges, which acted as small dams. It was common to find slightly thicker, finer sediments immediately up stream of an obstruction and coarser sediments immediately down stream.

Speed of drying out was influenced mainly by texture and partly by depth of sediment; sands dried out immediately after flooding, and silty sands and silts were moist under a dry surface skin for many days; clays took weeks to become firm. With the exception of clays, the surfaces of flood sediments were not smooth; silts and silty sands were slightly rippled with small indentations 1 in. deep and 6 in. apart, and sands were corrugated. After heavy rain, sheet erosion tended to be severe; on clays, parts of the top ½ in. were washed into cracks and, on silts and sands, sediment and seed were washed from high spots into small depressions.

All observations confirmed the finding of the 1948 trials that the original stickiness of the surface was most important. Once the surface had dried, rewetting with rain did not give the same degree of stickiness though it appeared to do so (McKee and Graham, 1952).

Smothering Effect of Sediment: The smothering of plants, including grasses, clovers, and weeds growing at the time of the 1950 flood, depended partly on the depth to which the plants were covered, partly on the texture of sediment, and partly on the type of plant (table 14). Where grasses were not wholly covered, many of them survived by elongating their leaf stems and by forming new roots about 1½ in. below the new surface. The minimum length of leaf above sediment necessary to carry on growth was not measured.

Had the flood occurred during summer months, the chances of survival of buried plants would have been greater, largely because of more rapid drying out and earlier cracking of the clay loams and clays. As the 1950 flood occurred in winter, the sediment was excessively moist for a long period.

In an attempt to save pasture buried by 1 to 2 in. sediment, it was a common practice to harrow the sediment or trample it with stock. This treatment tended to cut the surface into ridges and hollows and so uncover some of the plants but, unfortunately, rains during the month following beat down the ridges and so levelled the surface again. On some farms the sediment was treated too early, before it was sufficiently dry to stand up in ridges.

Methods of Sowing: The sowing of new sediment was done mainly by hand (on foot or from horseback) but about 500 ac was sown from the air. By the aerial method the clover seeds were spread evenly, but the grass seeds tended to drift. This drifting was partly corrected by flying in a light crosswind. Sowing from the air resulted in a more even strike than sowing by hand.

Growth of Pasture Plants on New Sediment: The outstanding plant was short-rotation ryegrass. It struck well, was able to establish itself during the prolonged wet and cold period after the flood, and also continued to grow during the following summer. Perennial ryegrass and red clover also struck well but did not make the same growth. Cocksfoot, timothy, and subterranean clover gave poor results, and white clover was patchy. On one farm lucerne was added to the seed mixture, and this plant flourished noticeably in new sediment.

The year 1950 was a wet one and it was not until the middle of December that sediment began to dry out; clay loams and clays shrank into hard blocks about 24 in. square with cracks 2 in. wide, and they clove easily from the buried soil; silty sands retained a firm surface skin but were dry and powdery underneath. The resultant poor physical condition and tendency towards droughtiness thus offered little encouragement for root growth. Perennial ryegrass plants were badly rusted and red clover plants, which were just beyond the five- and six-leaf stage, wilted. The sediment under short-rotation ryegrass was more moist owing probably to shading from extra top growth.

Evenly spaced rains fell in the following January and February and all plants picked up well. Had the summer been drier it is likely that perennial ryegrass and red clover would have fared badly.

TABLE 14: Observations on Survival of Buried Plants

	Max. Depth of Sediment
A. *Plants that Emerged Successfully Through Sediments After Complete Burial:*	
white clover (*Trifolium repens*)	5 in. sand and silty sand
paspalum (*Paspalum dilatatum*)	3 in. clay
lucerne	3 in. sand and silty sand
broad-leaf dock (*Rumex obtusifolius*)	6 in. clay
Californian thistle (*Cirsium arvense*)	6 in. clay
old man twitch (*Agropyron repens*)	11 in. sand and silty sand
hoary cress (*Cardaria draba*)	1 in. clay
B. *Plants That Emerged Successfully Through Cracks in the Sediments:*	
strawberry clover (*Trifolium fragiferum*)	2 in. clay
white clover	5 in. sand and silty sand
red clover (*Trifolium pratense*)	4 in. clay
lucerne	5 in. sand and silty sand
tall fescue (*Festuca arundinacea*)	5 in. sand and silty sand
C. *Plants Observed Surviving Partial Burial:*	
red clover	3 in. clay
white clover	3 in. sand and silty sand
young autumn-sown perennial ryegrass (*Lolium perenne*)	1 in. clay
perennial ryegrass	4 in. sand and silty sand
Italian ryegrass (*Lolium multiflorum*)	4 in. sand and silty sand
cocksfoot (*Dactylis glomerata*)	5 in. sand and silty sand
tall fescue	5 in. sand and silty sand
prairie grass (*Bromus unioloides*)	5 in. sand and silty sand
barley	2 in. clay
mallow (*Malva.* spp.)	1 in. clay
buttercup (*Ranunculus* spp.)	1 in. clay
oxtongue (*Helminthia echioides*)	1 in. clay
speedwell (*Veronica arvensis*)	1 in. clay
hedge mustard (*Brassica nigra*)	1 in. clay
wild turnip (*Brassica campestris*)	1 in. clay
shepherd's purse (*Capsella bursapastoris*)	1 in. clay
burr clover (*Medicago hispida*)	1 in. clay

NOTE—All plants in A and B, though still alive, had failed to emerge after two months when the sediments were 1 in. deeper than the maximum depth quoted in this table.

Worms: Worms were found on the surface of buried soils close to cracks in the sediment above, where they were presumably feeding on the decaying grass. After stock were brought on to the flooded areas, worms came to the surface and collected underneath the stock droppings.

Conclusions and Recommendations

Trials and observations indicate that the stickiness of the surface is the most important factor affecting the strike of seed sown on flood sediment. Because the surface of silty sands and sandy silts often dries out before farmers have recovered from the shock of a flood, sowing of such sediments presents greater problems than does the sowing of either clays or sands. The surface of clays remains sticky for some time after a flood and so a successful sowing can be made later, whereas sandy sediments dry out quickly and can be tilled early.

If the first opportunity of sowing silty sands or sandy silts has been lost, then it is best to wait until cultivation is possible. In the case of a winter flood, this means waiting for the spring, and, as spring is not a suitable time to sow a pasture, a crop has to be sown if the land is not to lie waste over the summer. The addition of phosphate and nitrogen either together or alone gave improved strikes with better colour and more vigorous growth, particularly on silty sands and sandy silts. A suitable rate of application of superphosphate is 1½ cwt per acre. Time of sowing is more important with clovers than with grasses. Establishment of white clover is a problem for which no easy solution is offered. Even though poor strikes were observed it is considered that clover seed should not be left out of the mixtures, and where a few plants are established they can be encouraged to survive and spread by regular dressings of superphosphate and by lenient grazing during their growth period. More plants can be introduced by oversowing in the autumn.

Lucerne can also be successfully established and it is suggested that this plant could be grown more extensively after a flood.

Short-rotation or Italian ryegrass is a success and seed of these plants should be included in mixtures where early grazing is intended.

Most pasture plants survive partial smothering by sediment and some survive even complete burial. It is recommended, therefore, that on lands frequently flooded, lenient grazing should be practised. Stands of pampas grass are also worth while.

The poor structure of flood sediments and their consequent droughtiness is the main reason for the slow growth of plants that have managed to establish themselves. Any practice that will build up organic matter in the soil will increase moisture in the top inch or so. The growing of plants best suited to sediments, the use of phosphatic and nitrogenous fertilisers, and the early feeding off of the growth produced are obvious suggestions. Another way of increasing organic matter is by ploughing and bringing to the surface the buried soils. This is not always practicable, however, as flood-stricken farmers have most need for feed at the lowest cost; moreover, buried soils may be too deep.

With the implementation of the Waipaoa River Flood Control Scheme, general flooding will be prevented and only 6,400 ac will be subject to flooding, so that in time the recommendations for regrassing will apply to a limited area of the Gisborne Plains. But these recommendations are of particular value to a farmer who wishes to raise the surface of his land by controlled flooding. The principles can also be applied to other parts of the Gisborne - East Coast region.

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APPENDIX 1. CLIMATE

By J. F. de Lisle, N.Z. Meteorological Service

The climate of the Gisborne Plains is largely influenced by the geographical position of the area and the topography of the surrounding country. The situation in a river valley oriented north-west to south-east, on an east coast in a latitude of prevailing westerly winds, and with high country on all sides except the valley mouth to the south-east, has an important effect on all climatic elements.

There are two climatological stations on the plains and one on the adjoining hill country. There are also a number of places at which rainfall records are kept (fig. 23).

Temperature

Table 15 contains a summary of temperature records kept at Gisborne Aerodrome, at Manutuke, and also at Waerenga-o-Kuri. Waerenga-o-Kuri, 12 miles west of Gisborne Aerodrome, is included so that comparison can be made with the hill country, but data relating to extreme conditions at both Manutuke and Waerenga-o-Kuri should be used with caution because of the shortness of the records. Mean air temperatures [$\frac{1}{2}$ (max. + min.)] show that July is the coldest month and February the warmest. Temperatures at various depths in the soils indicate that, except in late autumn and winter months, soils on the plains are several degrees warmer at all measured depths than those in the hill country. In winter and late autumn the temperature difference is small.

Frost, Hail, and Snow

Table 15 shows that frosts have occurred in all months except January and February, but that the frequency is not great. A ground frost is recorded when the reading of a minimum thermometer placed 1 in. above the grass is less than 30·4°F, while a "frost in screen" is recorded when the thermometer mounted in a standard screen

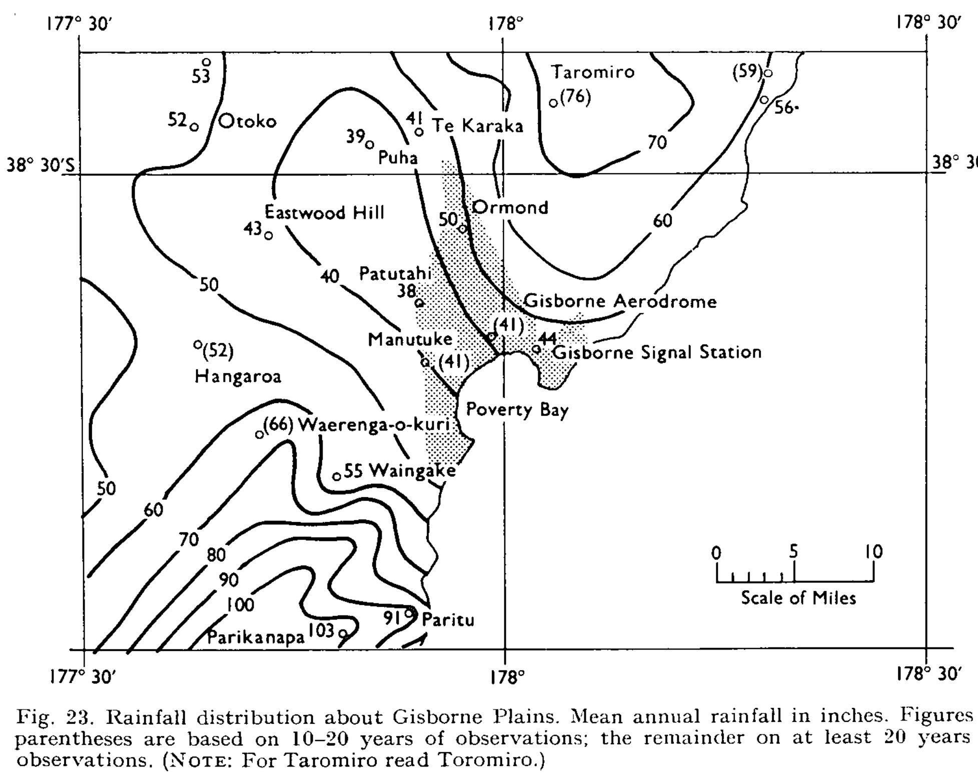

Fig. 23. Rainfall distribution about Gisborne Plains. Mean annual rainfall in inches. Figures in parentheses are based on 10–20 years of observations; the remainder on at least 20 years of observations. (Note: For Taromiro read Toromiro.)

and about 5 ft from the ground registers less than 32°F.

Hail, which may fall in any month, is infrequent, there being on the average less than three falls a year at Gisborne Aerodrome. Only one fall of snow has been reported at Gisborne Aerodrome and Manutuke since observations were begun.

Rainfall

Rainfall data for all stations on the plains and surrounding hill country for which records of more than 10 years are available are given in table 16. The monthly rainfall is highest in late autumn or mid winter, and lowest in November or December. A notable feature of the rainfall regime is the great variability, which is illustrated by the highest and lowest rainfall for each month and year and the rainfall of the wettest day (table 16). The mean number of raindays given in table 11 does not show very great variation from month to month, and the mean annual number over the plains varies from about 120 to 150. There is a rainday maximum in winter.

The distribution of the annual rainfall is shown in fig. 23. The influence of topography is demonstrated by the pronounced maxima over the high country north-east and south-west of the plains, e.g., average annual rainfall rises from 40 in. at Gisborne Aerodrome to over 100 in. at Parikanapa in a distance of about 20 miles (fig. 23). Although orographic effects cause more rain to fall over high country, heavy falls are just as likely over the plains as over the hills. The highest daily fall for the district, more than 11 in., was recorded on the plains at Ormond. The heavy falls are usually due to low-pressure systems, sometimes of tropical origin, moving over northern New Zealand or down the east coast of the North Island. The erratic occurrence of tropical cyclones affecting the Gisborne area from November to March, and of extra-tropical depressions originating in the north Tasman Sea during late autumn, is the cause of the variability in these months.

TABLE 15: Temperature Observations (°F)

—	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Gisborne Aerodrome													
Lat. 38° 40′ S., Long. 177° 59′ E., Alt. 25 ft													
Mean temp. (19 yr)	65·0	65·7	62·7	58·3	53·4	49·3	48·2	49·6	52·7	55·9	60·0	63·1	57·0
Mean daily grass min. temp. (14 yr)	49·8	51·3	48·1	44·2	40·2	36·5	35·0	36·0	37·8	41·2	45·1	47·8	42·8
Soil temp., 9.30 a.m. (Te Hapara sandy loam)—													
At 4 in. (14 yr)	69·7	68·8	63·8	57·0	51·0	46·4	44·6	46·5	51·3	57·5	64·1	68·7	57·4
8 in. (8 yr)	69·3	69·7	65·5	58·7	54·0	49·2	46·8	48·9	52·5	57·7	63·4	67·9	58·6
12 in. (19 yr)	70·1	69·8	66·2	60·3	54·3	49·5	47·7	49·1	52·8	57·3	63·0	68·0	59·0
36 in. (19 yr)	66·6	67·5	66·1	62·5	57·9	54·0	51·5	51·5	53·4	56·3	59·9	63·9	59·3
Days of ground frost (14 yr)	0	0	0·1	0·9	3·3	6·8	9·8	8·0	5·4	2·8	0·4	0·2	37·7
Days of frost in screen (14 yr)	0	0	0	0·1	0·4	2·8	2·7	1·2	0·3	0·3	0·1	0	7·9
Manutuke													
Lat. 38° 41′ S., Long. 177° 54′ E., Alt. 100 ft													
Mean temp. (12 yr)	63·8	65·2	62·1	57·5	53·2	49·0	48·0	49·6	52·5	55·6	59·3	62·2	56·5
Mean daily grass min. temp. (12 yr)	48·2	49·7	47·2	42·8	38·3	34·0	32·5	34·7	36·3	39·6	43·1	47·3	41·1
Soil temp., 9.30 a.m. (Kaiti heavy silt loam)—													
At 4 in. (11 yr)	68·8	68·4	63·7	57·0	51·5	46·7	44·8	46·7	51·6	57·7	63·0	68·2	57·3
8 in. (11 yr)	68·6	68·9	65·0	59·1	53·7	48·8	47·0	48·7	52·8	57·7	63·0	67·3	58·4
Days of ground frost (11 yr)	0	0	0·3	1·8	5·5	10·3	13·3	10·9	5·3	3·2	1·0	0·1	51·7
Days of frost in screen (11 yr)	0	0	0	0·1	0·9	2·9	4·2	1·7	0·7	0·2	0	0	10·7
Waerenga-o-Kuri													
Lat. 38° 41′ S., Long. 177° 48′ E., Alt. 1030 ft													
Mean temp. (8 yr)	61·2	63·2	59·5	55·2	51·4	47·2	45·6	46·9	50·1	53·2	56·8	59·7	54·2
Mean daily grass min. temp. (8 yr)	47·9	50·3	46·9	42·8	39·2	35·0	33·3	34·9	36·5	40·7	44·1	46·6	41·5
Soil temp., 9.30 a.m. (Gisborne sandy loam)—													
At 4 in. (8 yr)	63·8	64·2	60·3	54·2	49·9	45·6	43·6	45·8	49·7	53·9	58·7	62·8	54·4
8 in. (8 yr)	64·6	65·4	62·7	57·6	53·2	48·3	46·2	48·0	51·4	55·2	59·4	63·0	56·2
12 in. (8 yr)	64·7	65·3	63·4	58·9	54·5	50·1	47·7	48·7	51·7	55·7	59·7	63·2	57·0
36 in. (8 yr)	62·3	63·2	63·3	60·9	57·4	54·1	51·1	50·5	52·0	54·3	57·4	60·3	57·2
Days of ground frost (8 yr)	0	0	0·6	0·9	2·4	7·3	11·3	9·3	5·3	1·1	0·6	0·4	39·2
Days of frost in screen (8 yr)	0	0	0	0	0·1	1·4	2·1	0·7	0·4	0	0	0	4·7

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TABLE 16: Rainfall Data (Inches)

(a) Mean monthly and annual rainfall. (b) Highest rainfall each month and year. (c) Lowest rainfall each month and year. (d) Rainfall of wettest day. (e) Mean raindays per month.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Toromiro – 21 yr	(a)	3·75	4·45	3·88	4·90	5·53	4·21	5·68	5·18	4·76	4·04	3·43	3·16	52·97
	(b)	6·07	12·51	15·01	12·96	19·84	8·08	13·62	11·55	12·58	8·56	6·64	6·99	71·01
	(c)	0·03	0·15	0·55	0·66	0·83	1·90	3·31	2·86	1·47	0·68	1·19	1·09	37·22
	(d)	3·48	3·68	2·58	4·07	8·00	2·40	2·89	2·91	2·76	3·42	1·85	3·19	8·00
	(e)	11·9	11·0	12·6	14·8	15·1	15·0	17·2	17·0	16·2	14·7	13·2	11·3	170·0
Otoko – 42 yr	(a)	3·71	3·40	4·28	4·39	5·44	5·03	5·20	5·17	4·10	4·10	3·45	3·22	51·49
	(b)	10·09	13·36	20·66	12·14	15·18	12·89	17·15	11·61	13·15	12·29	8·89	7·67	67·53
	(c)	0·05	0·08	0·64	0·48	1·07	1·53	1·35	1·45	0·90	0·48	0·34	0·27	33·56
	(d)	3·82	4·90	3·35	3·66	4·69	4·42	5·35	3·84	3·46	3·76	2·11	3·33	5·35
	(e)	11·3	10·2	11·7	12·7	14·1	13·9	14·5	15·9	14·0	13·8	13·4	11·2	156·7
Puha – 39 yr	(a)	3·29	3·12	3·49	3·41	4·14	3·54	4·10	3·85	2·71	2·56	2·37	2·38	38·96
	(b)	7·59	13·22	18·28	12·29	16·67	10·32	12·98	8·50	8·41	7·33	7·12	6·90	50·72
	(c)	0·08	0·03	0·08	0·15	0·72	0·79	0·67	0·74	0·15	0·47	0·15	0·17	22·42
	(d)	2·67	5·06	6·57	3·78	7·57	2·55	4·35	3·35	2·71	2·86	1·98	3·42	7·57
	(e)	8·2	8·1	9·2	9·8	11·1	11·6	12·6	12·3	9·9	9·6	8·7	7·6	118·7
Te Karaka – 43 yr	(a)	3·09	3·27	3·80	3·55	4·64	3·76	4·32	4·00	2·71	2·61	2·50	2·32	40·57
	(b)	8·91	16·21	17·69	12·58	17·26	11·59	14·54	8·30	9·31	8·25	6·96	6·96	52·89
	(c)	0·17	0·04	0·36	0·27	0·77	1·04	0·67	0·77	0·39	0·57	0·12	0·11	25·73
	(d)	3·17	6·95	6·57	4·21	8·10	2·91	4·31	3·55	4·64	3·32	2·28	4·54	8·10
	(e)	10·8	10·2	12·1	13·0	14·4	14·4	15·6	16·2	12·7	12·5	11·6	10·2	153·7
Hangaroa – 19 yr	(a)	3·88	3·29	4·10	5·05	5·00	5·04	6·55	5·52	3·77	3·74	3·50	2·82	52·26
	(b)	7·58	11·57	16·29	14·92	13·26	11·05	19·03	9·79	11·73	11·46	9·59	7·85	71·82
	(c)	0·23	0·08	0·45	0·51	1·53	1·83	1·03	1·62	0·33	1·34	0·73	0·84	34·76
	(d)	3·75	4·17	3·17	6·22	3·54	3·45	5·67	2·07	3·10	2·58	2·60	1·91	6·22
	(e)	10·0	9·3	10·3	13·9	13·7	13·8	14·1	15·3	11·2	13·6	13·2	10·6	149·0
Eastwood Hill – 35 yr	(a)	3·27	3·35	3·65	3·88	4·52	3·84	4·76	4·24	3·29	3·01	2·57	2·33	42·71
	(b)	9·44	15·05	18·07	10·63	14·70	11·20	15·95	8·00	8·93	9·29	6·52	6·00	57·84
	(c)	0	0·02	0·28	0·33	0·83	1·29	0·77	1·09	0	0·66	0·10	0	29·15
	(d)	3·85	6·33	6·50	4·35	5·85	3·65	6·02	2·30	3·50	2·65	2·33	2·25	6·50
	(e)	9·1	8·0	9·5	10·7	12·5	12·6	14·2	15·2	12·1	10·1	10·1	9·4	133·5
Ormond – 27 yr	(a)	3·83	3·06	5·43	4·67	6·53	4·50	5·36	4·92	3·04	3·27	2·70	2·32	49·63
	(b)	8·47	9·53	22·09	11·29	24·17	12·50	17·42	11·96	11·26	14·29	10·52	8·61	84·83
	(c)	0·02	0	0·32	0·37	0·93	1·37	0·55	0·84	0·35	0·56	0·10	0·03	25·04
	(d)	4·95	4·13	7·99	5·00	11·56	3·08	4·60	4·55	3·77	3·41	3·73	2·71	11·56
	(e)	8·4	9·6	10·4	11·6	12·8	13·0	13·2	15·1	10·9	11·4	9·5	8·5	134·4
Patutahi – 55 yr	(a)	2·63	3·36	3·86	3·45	4·10	3·58	4·42	3·55	2·82	2·38	1·97	2·14	38·26
	(b)	8·42	14·09	17·38	10·69	11·51	10·04	11·73	9·82	8·30	5·89	6·58	7·32	55·55
	(c)	0·06	0·12	0·24	0·48	0·82	0·54	0·53	0·70	0·34	0·32	0·13	0·15	22·80
	(d)	4·02	4·33	7·55	4·12	4·32	3·60	4·09	3·20	3·65	2·91	3·28	2·47	7·55
	(e)	8·2	8·5	10·2	9·7	11·4	11·2	12·5	12·8	10·5	9·3	9·0	7·8	121·1
Manutuke – 11 yr	(a)	3·19	2·40	3·30	4·38	4·93	4·13	4·61	4·00	2·69	2·69	2·66	1·81	40·79
	(b)	6·28	7·25	8·33	9·05	13·49	9·38	11·63	7·37	7·13	8·45	7·62	5·60	53·98
	(c)	0·25	0·02	0·48	0·54	0·73	1·71	0·83	1·57	0·21	0·92	0·15	0·53	28·48
	(d)	1·82	2·52	1·89	3·55	5·49	3·19	4·84	2·35	2·66	2·11	1·46	2·12	5·49
	(e)	10·0	8·9	10·5	14·9	15·3	16·5	13·8	15·5	10·2	12·5	11·0	10·0	149·1
Gisborne Aerodrome – 19 yr	(a)	3·12	2·49	3·77	4·67	4·40	3·94	4·60	4·13	2·82	2·72	2·25	1·91	40·82
	(b)	6·22	9·51	14·80	8·15	13·51	8·99	12·64	5·82	7·49	9·38	7·98	3·13	56·35
	(c)	0·16	0·11	0·70	0·39	0·71	1·57	0·75	1·50	0·70	1·02	0·10	0·56	28·22
	(d)	2·06	2·38	3·09	4·15	4·44	3·17	4·75	2·56	2·09	2·41	2·18	3·61	4·75
	(e)	9·9	9·3	10·9	14·4	13·3	15·4	15·4	15·9	11·6	12·9	10·5	9·4	148·9
Waingake – 41 yr	(a)	3·58	3·98	4·28	4·62	6·63	5·79	6·96	6·15	4·09	3·48	2·81	2·80	55·17
	(b)	10·38	15·95	19·41	18·09	23·30	23·26	20·61	14·00	10·92	10·95	11·00	9·40	90·14
	(c)	0·31	0·12	0·45	0·37	0·97	0·59	0·88	0·77	0·58	0·60	0·22	0·08	32·79
	(d)	3·35	3·43	4·03	4·44	7·35	6·46	7·09	3·68	3·56	2·96	3·00	2·21	7·35
	(e)	11·0	9·7	11·1	15·0	15·3	17·3	16·3	18·1	11·9	14·9	14·1	12·1	166·8
Paritu – 32 yr	(a)	5·44	6·63	8·30	9·25	11·05	9·27	10·32	9·01	7·29	5·33	4·91	4·56	91·36
	(b)	10·01	34·90	22·44	28·78	25·94	29·57	24·14	16·73	19·18	13·91	17·53	12·84	123·82
	(c)	0·67	0·36	0·63	0·59	3·04	2·44	2·84	2·31	1·21	0·68	0·29	0·32	54·04
	(d)	4·34	8·55	9·65	11·22	10·40	8·90	5·73	5·61	6·20	4·90	3·98	6·02	11·22
	(e)	9·7	9·9	14·4	13·4	14·6	15·0	15·4	14·9	11·7	11·5	10·6	9·9	148·0

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Parikanapa – 13 yr	(a)	4·25	3·91	5·09	6·58	8·49	6·50	8·08	7·14	4·36	4·67	3·87	2·64	65·58
	(b)	9·69	11·90	18·74	11·25	25·37	13·36	19·00	13·04	11·14	8·37	11·85	7·01	91·97
	(c)	0·54	0·28	1·62	0·98	1·77	2·92	0·96	2·85	0·89	1·99	0·07	0·80	46·23
	(d)	3·35	4·40	3·49	7·38	6·34	3·48	3·98	2·81	1·54	2·26	2·26	3·28	7·38
	(e)	11·7	9·8	12·3	15·2	16·1	16·8	17·2	17·2	13·7	14·0	12·6	10·9	167·5
Gisborne Signal Station – 78 yr	(a)	2·87	3·36	4·17	4·18	5·14	4·63	4·94	4·31	2·95	2·65	2·80	2·20	44·21
	(b)	7·83	12·01	20·16	10·28	18·15	16·62	14·15	13·60	9·02	10·81	8·06	8·76	64·33
	(c)	0·20	0·13	0·23	0·33	0·95	0·61	0·79	0·61	0·55	0·26	0·08	0·06	25·84
	(d)	3·42	4·64	7·68	4·92	6·10	7·50	4·35	4·90	3·57	2·61	4·30	3·41	7·68
	(e)	8·9	9·5	11·7	12·4	15·0	15·5	16·0	15·5	12·1	11·3	10·6	8·7	147·2

For agricultural purposes it is useful to know the seasonal rainfall characteristics of the area, especially for the seasons spring and summer. The relations between winter rainfall and that of the following spring, and of spring rainfall and that of the following summer are also important.

To illustrate the seasonal rainfall characteristics, the 83-year averages for the winter, spring, and summer rainfalls for the Gisborne Signal Station were calculated, and the individual seasonal falls from 1878 to 1960 were expressed as percentages of the averages. The frequencies were found with which the percentages for each season fell within the following rainfall categories.

Type of Season

(% of the 83-year seasonal average)

Less than 25	exceptionally dry
25–54	very dry
55–84	dry
85–114	average
115–144	wet
145–174	very wet
More than 175	exceptionally wet

TABLE 17: Sunshine, Relative Humidity, and Vapour Pressure

(a) Duration of bright sunshine (hr) (b) Relative humidity (%) at 9.30 a.m. (c) Vapour pressure (mb) at 9.30 a.m.

——		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Gisborne Aerodrome	(a)	251	210	200	157	141	133	132	151	183	205	229	250	2242
	(b)	64	68	72	77	81	81	82	79	72	68	64	62	72
	(c)	15·5	16·2	15·1	13·7	11·7	9·7	9·4	9·9	10·6	11·7	12·8	13·8	12·5
Manutuke ..	(a)	240	198	198	156	133	117	136	152	187	206	216	228	2167
	(b)	68	69	74	80	83	82	84	79	72	67	66	65	74
	(c)	15·9	16·5	15·4	14·1	11·9	9·6	9·4	9·9	10·7	11·8	13·3	14·6	12·8
Waerenga-o-Kuri	(b)	70	74	76	78	78	80	81	80	74	73	73	70	76
	(c)	14·0	15·6	14·0	12·5	10·6	9·0	8·7	9·1	9·8	11·1	12·6	13·6	11·7

TABLE 18: Frequencies of Winter-Spring Seasonal Rainfalls at Gisborne Signal Station

(Rainfalls given as percentage of 83 year means)

Winter	Spring						Total
	25–54	55–84	85–114	115–144	145–174	175 and Greater	
25–54	1	0	2	1	0	1	5
55–84	4	12	2	3	1	3	25
85–114	4	8	4	6	4	1	27
115–144.. ..	1	4	4	4	2	1	16
145–174.. ..	0	3	6	0	1	0	10
Total ..	10	27	18	14	8	6	83

TABLE 19: Frequencies of Spring-Summer Seasonal Rainfalls at Gisborne Signal Station

Spring	Summer							Total
	Less Than 25	25–54	55–84	85–114	115–144	145–174	175 and Greater	
25–54	0	3	3	1	1	1	1	10
55–84	1	3	8	6	7	1	1	27
85–114	0	2	4	4	4	3	2	19
115–144	1	1	6	1	3	0	0	12
145–174	1	2	0	2	0	1	2	8
More than 175 ..	0	1	1	0	3	1	0	6
Total	3	12	22	14	18	7	6	82

Table 18 shows (a) the number of winters of each type (totals in the right-hand column) and of springs (horizontal totals), and (b) the number of times a winter of a certain type was followed by a certain type of spring. For instance, the table shows that there have been five very dry (25% – 54%) winters in the last 83 years and, of these, one was followed by an exceptionally wet spring, another by a very dry spring, and the remaining three lay between these extremes.

Table 19 shows similar data for spring and the following summer.

Although the tables do give the frequencies with which each type of season has occurred in Gisborne over the past 83 years they have no predictive value.

Knowing the rainfall for one season, it is not possible to forecast what type of season the following will be.

Sunshine, Humidity, and Wind

The monthly and annual means of hours of bright sunshine as recorded at Gisborne Aerodrome and Manutuke by Campbell-Stokes instruments are shown in table 17 together with the average relative humidity and vapour pressure (in millibars) at 9·30 a.m.

The frequency of winds from different directions, taken from three-hourly values from the aerodrome anemometer records illustrated in fig. 24 show that for a quarter of the observations the wind is less than 4 m.p.h. Of the remainder, north-westerlies are by far the most frequent. Strong winds are not very frequent – only 12% of the total exceed 16 m.p.h.; occasional gales are experienced, mainly from the south but also at times from the north-west. During the summer months a south-easterly sea breeze is a regular daytime occurrence in periods of settled weather. Monthly figures show a small variation with a maximum of mean speed in the spring.

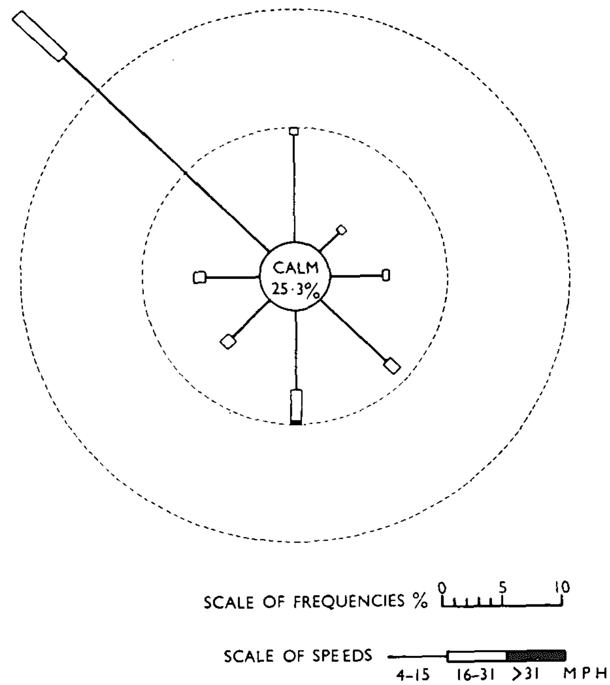

Fig. 24. Wind direction and frequency at Gisborne Aerodrome

APPENDIX 2. GLOSSARY OF PLANT NAMES

PLANTS OF THE FLOOD PLAINS

cabbage tree (*Cordyline australis*)
coprosma (*Coprosma sp.*)
flax (*Phormium tenax*)
hangehange (*Geniostoma ligustrifolium*)
kahikatea (*Podocarpus dacrydioides*)
kanuka (*Leptospermum ericoides*)
karaka (*Corynocarpus laevigatus*)
kawakawa (*Macropiper excelsum*)
kiekie (*Freycinetia banskii*)
lace bark (*Hoheria populnea*)
mahoe (*Melicytus ramiflorus*)
manuka (*Leptospermum scoparium*)
mapou (*Myrsine australis*)
matai (*Podocarpus spicatus*)
miro (*Podocarpus ferrugineus*)
ngaio (*Myoporum laetum*)
nikau (*Rhopalostylis sapida*)
pigeonwood (*Hedycarya arborea*)
pukatea (*Laurelia novae-zelandiae*)
puriri (*Vitex lucens*)
raupo (*Typha* species)
rimu (*Dacrydium cupressinum*)
rushes (*Juncus polyanthemos, Juncus vaginatus*)
tarata (*Pittosporum eugenioides*)
tawa (*Beilschmiedia tawa*)
titoki (*Alectryon excelsum*)
toe toe (*Arundo conspicua*)
totara (*Podocarpus totara*)
white maire (*Gymnelaea lanceolata*)
wineberry (*Aristotelia serrata*)

PLANTS OF THE TIDAL FLATS

old man twitch (*Agropyron repens*)
salt weed (*Salicornia australis*)
sea aster (*Aster subulatus*)
sea rush (*Juncus maritimus*)
sedge (*Scirpus nodosus*)
selliera (*Selliera radicans*)

PLANTS OF THE BEACH LANDS

bracken fern (*Pteridium aquilinum* var. *esculentum*)
cocksfoot (*Dactylis glomerata*)
evening primrose (*Oenothera* species)
goose grass (*Bromus mollis*)
harestail (*Lagurus ovatus*)
Indian doab (*Cynodon dactylon*)
meadow grass (*Poa trivialis*)
paspalum (*Paspalum dilatatum*)
perennial rye (*Lolium perenne*)
pohuehue (*Muehlenbeckia complexa*)
ratstail (*Sporobolus indicus*)
sickle grass (*Pholiurus incurvis*)
spinifex (*Spinifex hirsutus*)
tree lupin (*Lupinus arboreus*)
yellow sand coprosma (*Coprosma acerosa*)

APPENDIX 3. CLASSIFICATION OF SOILS OF GISBORNE PLAINS IN RELATION TO PUBLISHED CLASSIFICATIONS OF NEW ZEALAND SOILS

Soils of Gisborne Plains (Soil Bur. Bull. 20)	Soil "Set" in Which Type Included in North Island Survey (Soil Bur. Bull. 5)	Soil Groups of Genetic Classification*
Waipaoa silt loam		
Waipaoa heavy silt loam		
Waipaoa clay loam		
Waipaoa mottled clay loam		
Matawhero silt loam		
Matawhero silt loam, friable topsoil phase		
Matawhero heavy silt loam		
Matawhero heavy silt loam, friable topsoil phase	Manawatu loam, sandy loam, silt loam, and clay loam	
Matawhero heavy silt loam, mottled subsoil phase		
Matawhero clay loam		
Matawhero clay loam, friable topsoil phase		
Waihirere silt loam		
Waihirere silt loam, gravelly topsoil phase		
Waihirere silt loam, mottled subsoil phase		
Waihirere heavy silt loam		Recent soils from alluvium
Waihirere heavy silt loam, gravelly topsoil phase		
Waihirere heavy silt loam, mottled subsoil phase		
Waihirere clay loam		
Makaraka heavy silt loam		
Makaraka clay loam	Not recognised	
Makaraka clay loam, saline phase		
Makauri clay loam		
Makauri clay loam, friable subsoil phase		
Kaiti silt loam	Kairanga silt loam and clay loam	
Kaiti silt loam, firm topsoil phase		
Kaiti heavy silt loam		
Kaiti clay loam		
Kaiti clay loam, shallow topsoil phase		
Muriwai clay loam	Meeanee-Farndon complex	Saline gley soils
Muriwai clay		
Opoutama sand	Patea sand	Yellow-brown sands
Opoutama loamy sand		
Te Hapara sandy loam	Gisborne sandy loam	Yellow-brown pumice soils
Te Hapara mottled sandy loam		

*In 1948 the *Soil Map of New Zealand* was published on a scale of 32 miles to an inch and on this the soils are arranged in a genetic classification.

APPENDIX 4. SOIL PROFILES

Detailed profiles of important soil types are described below. Pits were dug on the least disturbed sites and usually under grass. Colours were matched with the Munsell Soil Colour Charts when the soil was moist.

Waipaoa Heavy Silt Loam

Site: along Nelson Road at junction with Tietjen's cut-off, Bushmere. Grid reference, 295433 on N98.

1 in. olive (5Y 5/3) heavy silt loam; firm; weakly developed medium nutty structure; aggregates soft; little organic matter but sheaths of cocksfoot decaying; grass partly buried but new tillers growing from clover (1950 flood);

5 in. olive (5Y 5/3) crumbly heavy silt loam; moderately developed fine blocky structure: dense grass-root mat with roots vigorous to 2 in. and large roots to 5 in.; some very faint yellowish brown mottling in lines along old root channels but no staining around live roots (1948 flood);

3 in. olive (5Y 5/3) crumbly heavy silt loam; moderately developed medium blocky structure; aggregates finely laminated and porous; brown staining about old root channels: a few worms; near top of layer is an abundance of decayed leaves from grass killed by 1948 flood and near bottom are many distinct dark brown (7·5YR 4/4) mottles associated with organic matter;

2 in. olive grey (5Y 5/2) crumbly heavy silt loam; moderately developed coarse blocky structure; decayed leaves of grass near top of layer; old root channels coloured reddish brown;

1½ in. olive (5Y 5/3) heavy silt loam; firm; weakly developed coarse blocky structure; soft aggregates; old root channels filled with decayed grass roots; many partly decayed grass leaves and stalks;

2 in. olive (5Y 5/4) heavy silt loam; friable; moderately developed medium nutty structure; aggregates soft and brittle; partly decayed roots leaves and stems of grasses abundant; old root channels coloured reddish brown; sharp boundary to

(There is a marked change in the colour, structure, and consistence of the following layers deposited before 1932)

2½ in. dark greyish brown (2·5Y 4/2) heavy silt loam; friable; moderately developed fine nutty and cast granular structure; decayed leaves and roots abundant; live fibrous roots bind the soil;

2½ in. pale olive (5Y 6/3) crumbly heavy silt loam; weakly developed medium blocky structure; aggregates finely laminated and very soft; layer devoid of visible organic matter;

3 in. dark greyish brown (2·5Y 4/2) heavy silt loam; very friable; strongly developed fine nutty and cast granular structure; fine partly decayed rootlets abundant;

2 in. olive (5Y 5/3) heavy silt loam; friable; moderately developed fine nutty structure; few cast granules; many partly decayed roots leaves and stalks of grasses;

2 in. pale olive (5Y 6/4) heavy silt loam; friable; moderately developed fine nutty and cast granular structure; aggregates very soft; partly decayed rootlets common;

5 in. very dark greyish brown (2·5Y 3/2) heavy silt loam; very friable; moderately developed fine nutty and cast granular structure; aggregates soft; partly decayed rootlets abundant;

2 in. olive (5Y 4/3) silt loam; friable; weakly developed medium nutty and strongly developed cast granular structure; old root channels stained yellowish brown;

6½ in. olive (5Y 4/3) heavy silt loam; firm; weakly developed medium nutty structure much modified by black worm casts which contrast strongly with other porous aggregates; decayed rootlets abundant; sharp boundary to

2½ in. layer of poorly sorted well rounded gravels of ⅛ to 1½ in. diam. mainly fine-grained sandstone and mudstone;

on 12 in. very dark grey (5Y 3/1) silty clay loam; very friable; strongly developed fine blocky and cast granular structure; visible organic matter abundant; surfaces of aggregates mottled dark reddish brown mainly in the lower half of the horizon; (old soil).

Matawhero Heavy Silt Loam

Site; R. M. Newman's farm, Patutahi. Grid reference, 282444 on N98.

¼ to ½ in. grass litter mixed with mineral matter;

2 in. olive grey (5Y 5/2) clay loam; very firm; plastic (wet); weakly developed coarse nutty structure; (1950 flood) grass roots growing mainly on top of layer; lower 1 in. devoid of live roots and visible organic matter;

½ in. grey (5Y 4/1) silty clay loam; firm; abundant decayed grass roots and leaves; sharp boundary;

2 in. olive (5Y 5/3) silty clay loam; firm; moderately developed medium blocky structure; aggregates (1948 flood) firm dense and weakly laminated; occasional worm casts; grass roots restricted mainly to top of layer; distinct boundary;

(no sediment deposited from 1944 flood)

2½ in. dark greyish brown (2·5Y 4/2) heavy silt loam; friable; strongly developed fine blocky and cast granular structure (worm-cast granules in patches); partly decayed roots, leaves and twigs abundant; a few live grass roots;

3½ in. pale olive (5Y 6/4) soft crumbly heavy silt loam; moderately developed medium blocky structure; aggregates finely laminated; occasional worm casts; a few partly decayed tree roots;

2 in. very dark greyish brown (2·5Y 3/2) and pale olive (5Y 6/4) heavy silt loam; friable; strongly developed fine blocky and cast granular structure (much mixing by worms); partly decayed grass roots and leaves abundant;

4 in. olive (5Y 5/3) heavy silt loam; friable; moderately developed medium blocky structure; aggregates firm; structure modified in patches by dark grey worm casts which incorporate much fine organic matter;

on 6 in. very dark greyish brown (2·5Y 3/2) and very dark grey (5Y 3/1) clay loam; very friable; loose; strongly developed fine blocky and cast granular structure; aggregates firm dense and porous; worm casts irregular and ill defined and well fused to blocky aggregates; fine partly decayed rootlets abundant; occasional fine yellowish brown concretions; (old soil).

Waihirere Heavy Silt Loam

Site; State highway Gisborne to Opotiki, near junction with Back Ormond Road. Grid reference, 312480 on N98.

3 in. dark olive grey (5Y3/2) heavy silt loam; friable; strongly developed fine granular and cast granular structure; partly decayed rootlets abundant; firm turf;

6 in. black (5Y2/1) heavy silt loam mixed with small amount fine well-rounded gravel; soft friable; strongly developed fine blocky and cast granular structure; decayed rootlets abundant; many live grass roots; boundary diffuse and regular;

4 in. black (5Y2/1) and pale olive brown (2·5Y5/4) heavy silt loam; friable; strongly developed fine blocky and cast granular structure; partly decayed roots abundant; many live roots;

9 in. pale olive brown (2·5Y5/4) silty clay loam; few medium distinct yellowish brown and grey mottles; firm; compound weakly developed coarse prismatic and moderately developed medium nutty structure; aggregates dense; few worm casts; partly decayed rootlets plentiful; few live grass roots; horizon lightly compacted;

6 in. pale olive brown (2·5Y5/4) soft crumbly heavy silt loam; few faint fine yellowish brown and grey mottles; moderately developed medium nutty structure; few pores; occasional worm casts;

on olive brown (2·5Y4/4) soft crumbly silt loam; many distinct medium yellowish brown and grey mottles in a 1 in. reticulate pattern.

Makaraka Clay Loam

Site: M. L. Dunstan's property near Willows Road. Grid reference, 335362 on N98.

2 in. olive grey (5Y4/2) clay loam; firm; sticky (wet); moderately developed fine nutty structure; partly decayed grass rootlets abundant; strong turf; (1948 flood);

5 in. very dark greyish brown (2·5Y3/2) clay loam; friable; strongly developed fine blocky and cast granular structure; dead grass roots abundant; old root channels lined with orange; many live grass roots;

5 in. olive grey (5Y4/2) clay loam; some aggregate faces light grey (2·5Y7/0); crumbly; sticky (wet); moderately developed fine nutty structure; partly decayed rootlets abundant;

6 in. grey (2·5Y6/0) clay loam; fine yellowish brown mottles distinct in some aggregates and faint in others; firm; sticky and plastic (wet); moderately developed medium nutty structure; fine dead rootlets abundant; (old soil);

5 in. grey (5Y6/1) clay; fine prominent yellowish brown mottles regular in outline and with sharp boundaries; sticky and plastic; moderately developed medium blocky structure; aggregates porous; many fine dead grass rootlets and a few decayed tree roots;

on 12 in. + as above but mottles fewer and more prominent; permanently moist.

Makauri Clay Loam

Site: J. E. V. Simpson's farm, Kings Road, Makauri. Grid reference, 351432 on N98.

4 in. very dark grey (5Y4/1) clay loam; few fine faint blue mottles; firm; slightly sticky (wet); strongly developed fine granular structure; very dense mat of dead rootlets; strong turf; rusty staining along old root channels;

6 in. very dark grey (2·5Y3/2) clay loam; many fine diffuse brown, yellow, and grey mottles of regular outline; firm; slightly sticky (wet); strongly developed fine granular and cast granular structure; rusty staining along old root channels; partly decayed rootlets abundant; a few worms and some mycelia;

11 in. grey (5Y6/1) clay; some very fine prominent strong brown (7·5Y5/8) mottles with sharp boundaries; friable; sticky and plastic (wet); compound weakly developed coarse prismatic and strongly developed medium blocky structure; scattered grains of coarse white pumice; (old soil);

4 in. as above but structure weakly developed medium nutty; mottles fewer; wet;

5 in. white (5Y8/1) loose coarse pumice sand;

on pale grey (5Y7/1) clay; many dark brown (7·5Y4/4) fine mottles of sharp regular outline; tough sticky and plastic; strongly developed fine blocky structure.

Kaiti Clay Loam, Shallow Topsoil Phase

Site: East Coast Commission's property, Muriwai; main road, Gisborne to Napier via Morere. Grid reference, 300277 on N98.

1½ in. black (5Y2/1) clay; very firm; sticky and very plastic (wet); strongly developed fine blocky structure; fine decayed rootlets in dense mat; strong turf;

4½ in. black (2·5Y2/0) clay with similar consistence as above; compound weakly developed coarse prismatic and strongly developed medium blocky and cast granular structure; many live roots and numerous worms; distinct boundary;

3 in. black (2·5Y2/0) and greyish brown (2·5Y5/2) clay; very firm; dense; mainly cast granular and a little moderately developed medium blocky structure;

11 in. pale olive grey (5Y6/2) clay; few fine yellowish brown concretions in clusters; firm sticky and very plastic; moderately developed medium blocky structure; aggregates porous; aggregate faces glazed with organic staining;

6 in. white (5Y8/1) loose coarse sand (pumice); water running freely;

on pale yellow (5Y8/3) clay; many prominent strong brown (2·5Y5/8) mottles regular and sharp; very sticky and plastic; strongly developed fine blocky structure; water perches on clay below pumice layer.

Muriwai Clay

Site: in Awapuni Lagoon. Grid reference, 342353 on N98. Land flooded with sea water at spring tides; soil wet. Vegetation: salt weed *Salicornia australis*.

4 in. olive (5Y5/1) clay; many faint coarse white and distinct yellowish brown mottles; laminated; slightly sticky and plastic; weakly developed very coarse prismatic structure which breaks down easily to very coarse blocky; fine concentric rings of blue and brown around root channels; many fine live roots; distinct boundary;

13 in. olive-grey (5Y5/2) clay loam; many distinct medium white and few faint strong brown mottles; sticky and plastic; weakly developed very coarse blocky structure; many fine live roots; some roots of ½ mm. diam. are enclosed in a pale blue sheath up to 3 mm. diam.; indistinct boundary;

4 in. olive-grey (5Y5/2) clay loam; many coarse prominent white mottles; very sticky and plastic and sticks to the spade but with less moisture, is slightly sticky and plastic; massive; old root channels are enclosed in successive sheaths of grey, orange, olive and grey; fine brittle yellowish red tubes (probably iron oxide) 3 in. long are common; very wet; diffuse boundary;

40 in. + greenish grey (2·5Y5/0) clay loam; very sticky and plastic; soft; massive; very wet; bore sunk to 5 ft but no water table; after 24 hours free water level at 42 in. from surface. 152 cm

Te Hapara Sandy Loam

Site: cutting in Nelson Road, opposite cemetery, Taruheru. Grid reference. 358405 on N98.

2 in. dark greyish brown (10YR4/2) sandy loam; very friable; fluffy; very weakly developed fine crumb structure; dense root mat; indistinct boundary;

5 in. black sandy loam; very friable; fluffy; very weakly developed fine and medium crumb structure; many roots which bind aggregates and which end at 7 in.; sharp boundary;

4 in. pale yellowish brown (10YR6/4) fine and coarse sand; loose; single-grain structure; rhyolitic pumice; distinct boundary;

36 in. + brownish yellow sand (10YR6/6); loose; single grain; beach sands; numerous roots to 18 in.

APPENDIX 5. GROUND WATER*

By T. L. GRANT-TAYLOR, N.Z. Geological Survey, D.S.I.R.

Ground-water Supply

On Gisborne Plains, ground water is required chiefly for livestock watering and for irrigation. For livestock watering, quantities required are not great and sources that will meet these needs are reasonably common at shallow depths. But for irrigation requiring large quantities of water continuously for several months the possible sources are limited. Water supplies are not as bountiful as under Heretaunga Plains. Aquifers and their distribution are shown in fig. 25.

Sources of Water

For Livestock Watering

Supplies for this purpose may be obtained at depths of less than 40 ft over most of the plains. On the map (fig. 25) areas marked "beach sands" will yield adequate quantities while those marked "very little water" will yield quantities of the order of 1,000 gal per day from cavities in shallow alluvium formed by buried stems and roots of trees.

Thin pumice-ash beds also form a useful shallow source of water. There appear to be four separate layers of pumice although not more than two or three are usually encountered in one hole. These beds are tapped more frequently on the western side of the valley but are unreliable sources as they dry up from time to time.

For Irrigation

Quantities of water of the order of several thousand gallons per hour can be tapped from the following sources:

Beach Sands (fig. 25): In this aquifer fresh water is perched on salt water. The average thickness of the fresh water is 25 ft, rather less near the coast and more inland. The well must not be placed at too great a depth, otherwise brackish water will be drawn in with the fresh.

15–100 ft Zone About Waipaoa River: This is a body of alluvium, 2½ miles wide, in which lenses of coarser sediments have been deposited over the last 15,000 years while sea level was rising during the post-glacial climatic recovery. The channels are filled with gravel, grit, and sand, but their courses are irregular. Neighbouring wells may therefore differ in both depth and yield.

Deeper Than 100 ft Zone: At depths ranging from 100 ft in the east to 200 ft beside the line of Waipaoa River, there is an artesian aquifer of medium permeability. Because the water in this aquifer is strongly corrosive it should not be tapped until technical advances enable wells to be fitted with inert liners. Corrosion is so intense that ordinary steel well casing is dissolved in three to five years. The result is a leaking well, water from which gives rise to a boggy patch around the well head.

Quality of Water

Chemical: The least mineralised water (100 p.p.m. of calcium carbonate) is obtained from the upper portion of the beach sands in the 0–20 ft aquifer. Water from other sources is very hard, 250 to 600 p.p.m. of calcium carbonate, and that from the deep aquifer (200 ft) is so mineralised as to be of limited use.

Bacteriological: Water from shallow sources less than 40 ft deep is likely to be contaminated with bacteria from the surface and should be treated with bactericidal agents before it is used for human consumption. Water from deep aquifers is uncontaminated. Because of air-borne contamination and seepage from the surface, water from dug wells is unsatisfactory for domestic use.

Irrigation Problems

The proper use of irrigation water is to supply sufficient to replace losses in the soil from evaporation and transpiration. Leaching of nutrients out of the soil is considered to be negligible. The best manner in which to apply water is through spray systems and this method has merit in conserving supplies as well. There is not nearly enough water in the aquifers for irrigation to be practised as widely as in Heretaunga Plains.

1. *Salts in the Soil:* In using ground water for irrigation there may be danger of accumulation of salts in the soil. The waters are high in calcium and magnesium salts, which will tend to concentrate in the topsoil and so make non-flooded soils less acid and flooded soils more alkaline; except for

*A fuller treatment of sources of ground water is published as Ground Water in the Poverty Bay Flats, by T. L. Grant-Taylor, in *N.Z. J. Sci. Tech. B 38* : 763-72.

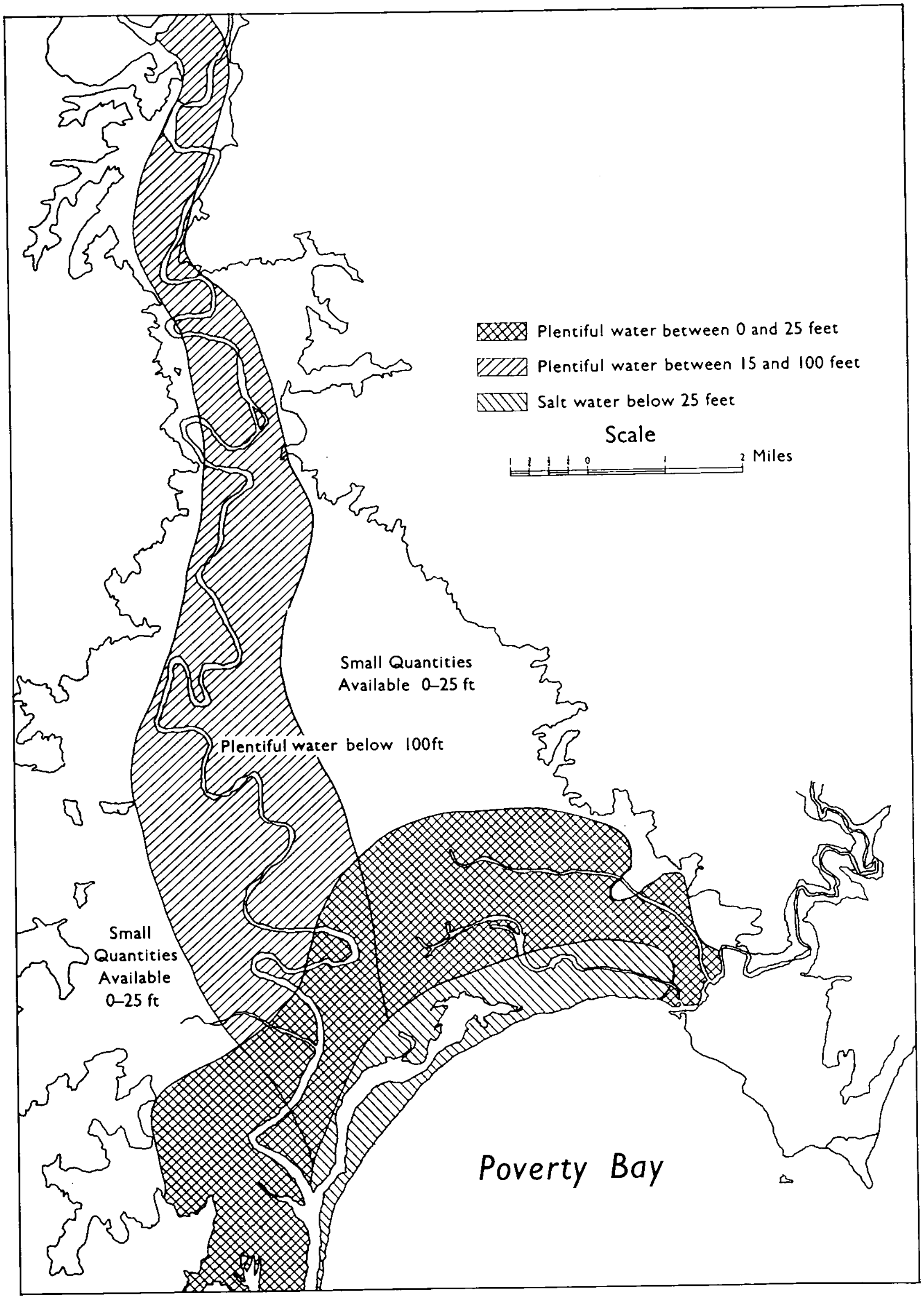

Fig. 25. Aquifers under Gisborne Plains

Waipaoa and Muriwai soils they will not become strongly alkaline, but, at the same time, soils that are naturally moderately acid or near neutral may be difficult to maintain in this condition.*

2. *Size of Well:* The selection of the right size of well for irrigation by modern high-pressure overhead spray units is most important. In these units a centrifugal pump is commonly employed and, as the efficiency of a centrifugal pump is greatly reduced by high suction lifts, it is better that the well be slightly too large than too small. The minimum size of well for a high-pressure irrigation unit is considered to be 4 in. diameter, and optimum sizes range from 6 to 8 in.

As the beach sands (0–20 ft aquifer) will not yield enough water for large, high-pressure irrigation units, a 3 in. well would be large enough to obtain the full safe yield from this very shallow depth.

The following examples illustrate the losses of head in a well pipe of different diameters on the suction side of the pump. It is assumed that the quantity of water required is 12,000 gal per hour, the depth of the aquifer is 100 ft, and the static water level in summer is 8 ft below the surface.

Pipe Diam. In.	Friction Loss (Well Pipe) (Feet of Water)	Friction Loss + Static Head (Feet of Water)
4	5·2	13·2
6	1·1	9·1
8	0·3	8·3

These losses are those occurring in the well pipe only. A drawdown must be applied to the water level to make the water flow into the well. This drawdown is proportional to the amount of water to be extracted and will certainly not be negligible in these aquifers. Therefore a 6 in. well must be used to obtain water in quantity if the suction lift is not to exceed 15 ft. The use of smaller wells would either greatly reduce the efficiency of pumping and hence operating costs, or would require a much more expensive pump. For an aquifer at a depth of 50 ft, the figures are:

Pipe Diam. In.	Friction Loss (Well Pipe) (Feet of Water)	Friction Loss + Static Head (Feet of Water)
4	2·6	10·6
6	0·5	8·5
8	0·15	8·15

In this case a choice would lie between a 4 in. and a 6 in. well. It is possible that a 4 in. well would prove adequate in the more permeable parts of the 20–100 ft aquifer.

3. *Well Screens*: In an aquifer composed of unconsolidated materials a screen must be installed to make the most efficient use of the well pipe that leads water to the surface. In the past it has been customary to use slotted or perforated pipe, and this type of screen proved quite satisfactory when small quantities of water were being pumped. But when large volumes are being pumped, as is required for irrigation, such a screen greatly restricts the flow of water. The most efficient screen is a helical wound wire, and when this is employed the aquifer can be more thoroughly developed to increase well yields by a further 25 to 50%. Indeed, the yield from a well fitted with a helically wound wire screen is often double that of the same well fitted with a slotted screen. As screens are carefully designed to match the character of the aquifer, it is important to fit the correct size of screen to the well. The length of screen is, of course, chosen in relation to the diameter of the well, i.e., the larger the well, the longer the screen should be.

The fitting of screens is also necessary to protect the pump from damage by gravel and sand.

Ground-water Control

To conserve ground-water supplies in the beach sands and to prevent entry of salt water into this aquifer (0–20 ft), it is recommended that a Ground-water Control Authority be set up. In this connection it is noted that the cut-off drain along the northern side of Awapuni Lagoon designed to drain parts of the lagoon is also tapping ground water from the beach sands. Drawing off of ground water is equivalent to a serious leakage from the aquifer, particularly during summer months, but loss of ground water could be controlled by blocking the drain temporarily.

Ground-water Levels and Perched Water Tables

By W. A. Pullar

During the wet year of 1950, when the rainfall was 55·05 in., ground water levels were recorded in the Taruheru, Awapuni, Makaraka, Manutuke, and Patutahi localities. In poorly drained soils such as Kaiti clay loam and Makauri clay loam the levels rose from 3 ft in July to 1 ft in November, and in a well drained soil like Waihirere silt loam the respective levels were 15 ft and 5 ft below the surface. Highest rainfall occurred in October but ground-water levels did not rise appreciably until November.

Within the plains there are several thin pumice beds, the shallowest of which may be buried at

*Waipaoa and Muriwai soils are already alkaline (pH 8·3); Matawhero and Makaraka soils are slightly acid to slightly alkaline (pH 6·0 to 7·4) and may become near neutral to moderately alkaline; other soils are moderately acid to near neutral (pH 5·6 to 7·0) and may become slightly acid to slightly alkaline.

depths of 1 to 20 ft; the bed rests on compacted, relatively impervious clays, which allow the drainage waters to perch and so build up in the soil. There appears to be a correlation between soil drainage and depth of the shallowest of these pumice beds; e.g., in well drained soils such as Waihirere and Matawhero the bed is 10 ft and more below the surface, and in poorly drained soils such as Kaiti and Makauri the bed is within 1 to 5 ft of the surface; within this range of 1 to 5 ft, the nearer the bed is to the surface, the more quickly is the soil waterlogged in winter.

The pumice is also an aquifer, which, when cut by an open trench, can be used to drain the subsoil. Many main drains are dug in approximately the best positions to tap subsoil water from the pumice.

There are special cases of perched water tables at the foot of small alluvial fans at Waiohika and Hexton. At Waiohika there are small seepage patches where the soil is waterlogged in a wet winter; water comes to the surface from the pumice bed, which acts as an underground drain within the fans. At Hexton, fans are built up of loose porous material through which water moves freely, and lower lying land nearby (Makaraka and Kaiti soils) is wet for long periods.

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