THE FORMATION, CONTROL, AND UTILISATION
OF THE COASTAL SAND DUNES
BETWEEN THE WAIMAKARIRI RIVER AND
THE SUMNER ESTUARY

T H E S I S

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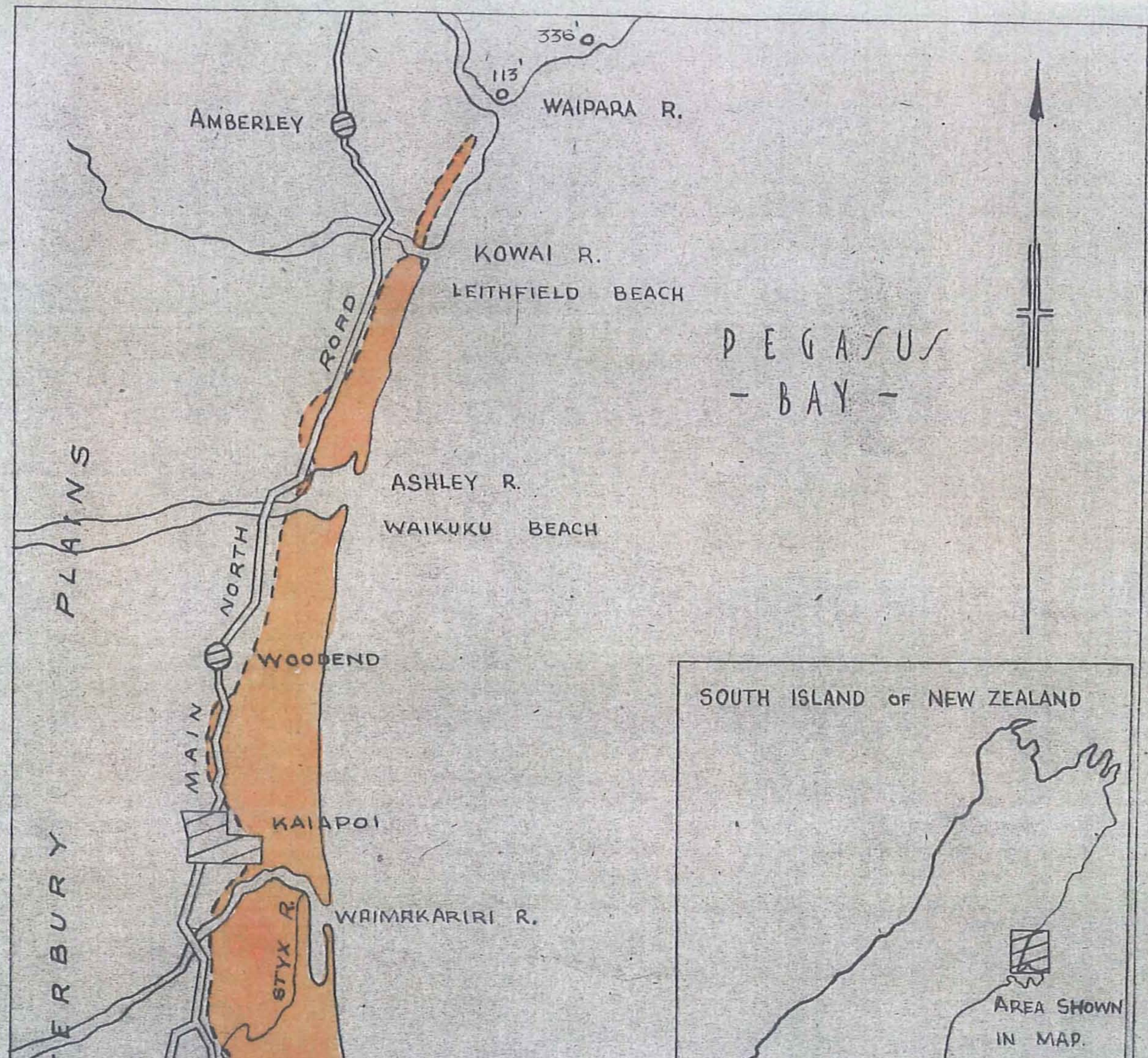

Fig. 1 SITUATION MAP:

The North Canterbury Coastline between Banks Peninsula and the Waipara River.

INTRODUCTION

Gently sloping sand beaches and coastal dunes extending inland are a distinctive feature of the North Canterbury coast of Pegasus Bay. The Waimakariri and the Ashley Rivers have not carried their shingle fans to the sea, and the coastline is now being built forward or being prograded by sand deposited on the shore. The sand dune coastal fringe is not a part of the alluvial plain, which consists of vast overlapping shingle fans, originating in the destruction and disintegration of the interior highland. It constitutes a beach ridge foreland of more recent development built out in front of the shingle plain, smoothing out the margins of the shingle cones into a curving sweep of coastline between Banks Peninsula and the Waipara River.

The dunes extend for 24 miles, from Banks Peninsula to the Leithfield Beach four miles north of the Ashley River. In the south, the sand beaches are terminated by the cliffed spurs of the Port Hills, and in the north, they change to shingle beaches at Leithfield. Four miles north of Leithfield at the mouth of the Waipara River, the North Canterbury uplands reach to the sea. Thus the association of sand beaches and sand dunes is restricted to the coast within the radius of supply of the Waimakariri and Ashley Rivers. At the northern and southern extremities of the sand dune coast, farthest from the river mouths, the dune belt narrows in width. In the central region between New Brighton and Waikuku Beach, the belt is wider, reaching three miles inland.

The coastal dunes to be discussed extend for eleven miles, from the estuary of the Avon and Heathcote Rivers at the foot of the Port Hills, to the mouth of the Waimakariri River. There is a belt of dunes from one to two miles wide adjacent to the sea. These dunes are of comparatively recent origin, and the success of all utilisation projects hinges on their control and stability. Separated from this seaward belt by a swamp which is now drained, is an inner line of dunes, older, lower and smoother in outline, With the passage of time and the development of a thick cover of vegetation, the sand has become consolidated and these dunes are not so prone to movement having in some cases, a thin loam covering.

The object of this paper is to account for the presence of this coastal fringe; to outline the major topographic features under natural conditions; to discuss the measures necessary to control and stabilise the dunes, and to describe their present utilisation.

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PART I

CHAPTER I

THE ORIGIN OF THE SAND COMPRISING THE DUNES

Three natural transporting agents play a part in supplying the coast with sand, viz., the Waimakariri River; the ocean currents in Pegasus Bay; and the Canterbury easterly wind.

The Waimakariri River: The initial sources of the sand are the eastern ridges of the Southern Alps, in which the river originates and through which it flows towards the bordering plain. The mountains rise to heights of 6,000 - 7,500 feet above sea level. The valleys were once occupied by a dendritic glacier which reached a maximum length of fifty miles, the major stem filling the relatively gently inclined main valley. Where the river leaves the mountains it has cu a trough 200-300 feet into its former bed, and flows across the alluvial plains to the sea.

Melting snow and the melting of the valley head glaciers contribute towards the volume of the river, but the higher floods are due to heavy north-west rainfall in the catchment area. An annual precipitation of nearly 200 inches is averaged on the main divide, but to the east this diminishes rapidly. The average annual precipitation for the whole of the catchment area has been estimated at

68.7 inches, but this may be an underestimate.[+] The average flow of the river is approximately 3,000 cusecs. The lowest recorded flow at the Main North Road bridge is 900 cusecs, while 176,000 cusecs was registered during the biggest flood so far recorded.

The mountains of the catchment area, comprising approximately 1,000 square miles, consist mainly of highly jointed and steeply dipping fine grained sandstones and argillites, both commonly termed "greywacke". The jointed nature of the rocks makes them yield readily to erosive forces, and the higher ridges are covered by downward creeping shingle scree. The load of the river is derived from these sources. During the melting of the valley glaciers, great masses of shingle debris were transported. With the retreat of the glaciers and the gradual lengthening and flattening of the river course, the necessary impetus to move heavier materials to the outer margin of the plains has been lost. Today, over its lowest reaches the river carries lighter materials such as fine gravels, and near the mouth only silt and sand. The sand is derived from the chipping and fluvial abrasion of the shingle and larger rocks upstream, and consists of the more resistant constituents of the original sandstone. Fine grains of quartz

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+ Benson, W.N.: Notes on the suspended load of the Waimakariri River.

TABLE NO. 1

CHANGES IN THE LOAD OF THE WAIMAKARIRI RIVER

FROM THE GORGE TO THE MOUTH

ures supplied by the North Canterbury Catchment Board)

to Percentage Retained on Half inch Screen 3 inches	2 inches	1 inch	½ inch	Percentage passing ½ inch screen
0	1	7	20	72
0	12	15	30	43
1	11	19	28	41
3	12	16	31	38
3	28	20	20	29
6	19	19	21	25
15	22	16	15	32
19	14	20	15	32
26	22	14	17	39
38	19	13	11	19

At the gorge, 39 miles from the sea, large form the major load of the river, viz., 38% of 3 in diameter as against 19% less than ½ inch. As is approached this position is reversed, till 3 rom the mouth, none of the load is above 2 inches, 2% is smaller than ½ inch. At the river mouth the ısists of only silt and sand and 100% would pass the half inch screen.

which are not so susceptible to weathering and decomposition survive in loose incoherent form as sand.

The changes in the river load, from large rocks in the headwaters, to shingle, and finally to silt and sand near the mouth, are due to changes of grade and the subsequent slowing up of the waters. The grade from the gorge to Coutts Island is $27\frac{1}{2}$ feet to the mile. It then lessens quickly to $13\frac{1}{2}$ feet to the mile, while from the seaward end of the island to the mouth, the drop is only 6-7 inches to the mile. Associated with this change of grade is a decrease in water velocity. During a flood a surface velocity of 9.6 feet per second at the top of Coutts Island dropped to 8.1 feet per second at the road bridge. Gravel is carried as far as the railway bridge at Stewarts Gully two miles from the mouth, and is present at the mouth only in small quantities after a flood. As a result the river carries only silt and sand into the sea. The annual discharge has been estimated at approximately three million tons, of which one million tons is sand.

The Pegasus Bay Ocean Currents:

The sand has been ground down from the parent rock by fluvial abrasion, and in the sea marine abrasion carries the process still further. The waste is carried

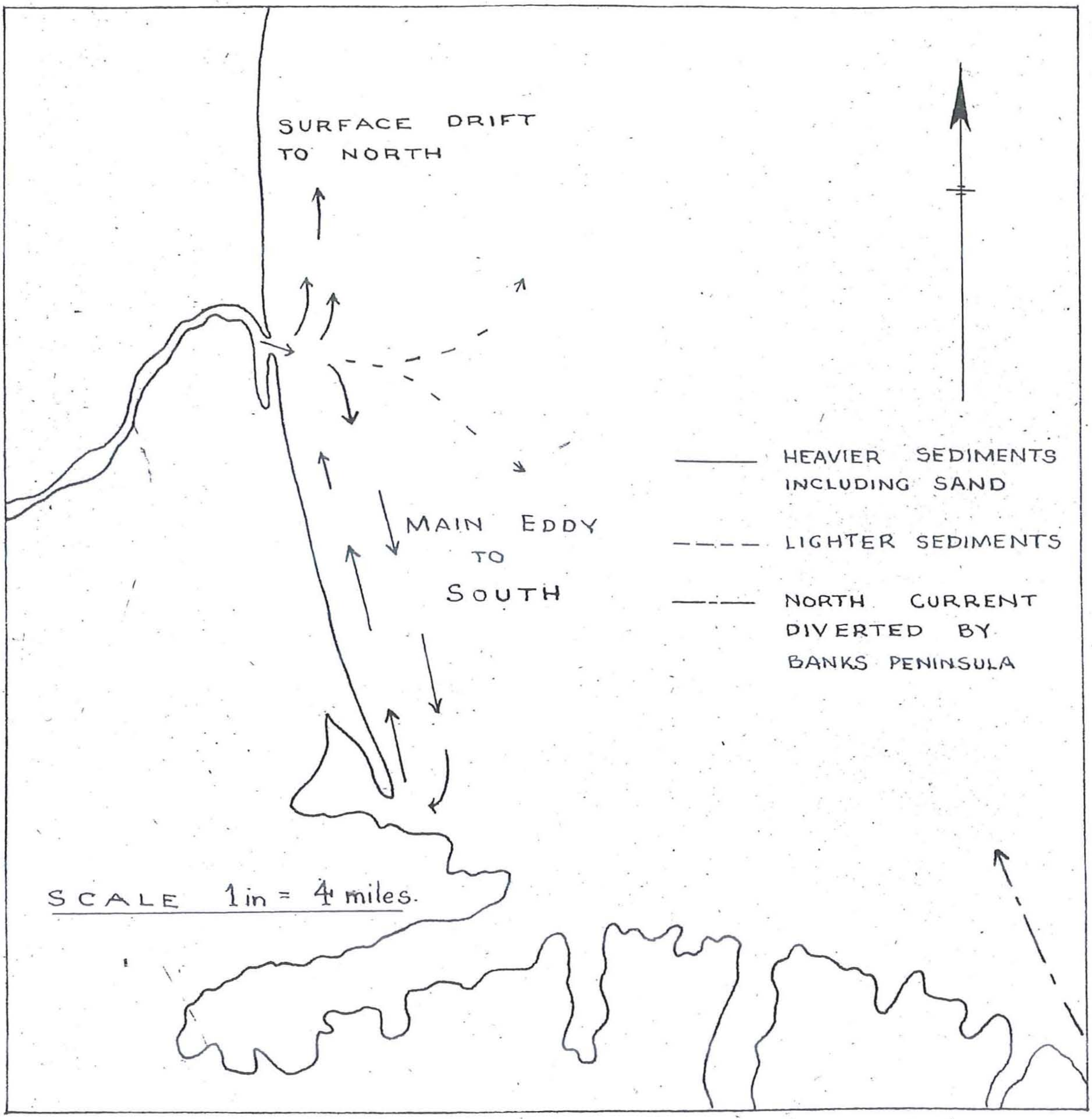

Fig. 2. THE SHOREDRIFT OF SAND FROM THE WAIMAKARIRI RIVER

into the sea by the river, but only a small part of the sand, together with the finer silts, spreads well out to sea, to be dropped to form the ocean bed. As sand is heavier than the finer materials in suspension, upon the slowing of the waters as they mix with the sea, by far the greater portion is carried and deposited as shore drift.

The ocean currents in Pegasus Bay immediately north of Banks Peninsula are variable, but there is a tendency to carry on in diminished form the 1-1½ knot current which sweeps up to the peninsula from the south. However, this current, with much of its momentum lost, is diverted seaward by the peninsula while an eddy develops inshore. The surface waters of the eddy may vary slightly with wind conditions; for instance, at times there is a slight drift to the north. But these are merely surface variations and the main body tends to move towards Banks Peninsula, inshore of the diverted northerly current. The southerly drift is especially evident from the Port Hills when the river is in flood. The loaded, dark water can be traced from the mouth of the river, south to the peninsula which turns it towards the coast and diverts it northward. As the peninsula acts as a barrier to the southerly drift of sand, there has been some sand accumulation in the valleys between the estuary and the Lyttelton Harbour heads.

The bulk of the sand carried as shoredrift by this eddy, is dropped temporarily on the sea bed. The deposition of excess debris shallows the offshore bottom and upsets the established equilibrium of the shore bed slope, thus favouring abrasion by wave action. This action lifts the sand clear of the bottom and as the waves in this littoral zone are waves of translation, with the forward movement of the water, the sand is moved towards the shore. When a wave breaks, the water which flows up the shore slope carries its load landward, while the "backwash" tries to transport it seaward again. The push landward is the stronger. The return current lacks the initial thrust of the breaking wave, it suffers a loss of velocity due to friction which acts continually, and a loss of volume due to the percolation of water into crevices. If the shore slope was steep, the seaward current would be the more effective of the two, as then the landward thrust must propel the sand up the slope against a strong pull of gravity. But as the slope is very gradual, the water retreats leaving the sand behind.

Assuming that the above process is taking place at high tide, with the ebb of the tide the fresh layers of sand are left exposed for some hours. The damp sand dries before it is re-covered with water, and it is ready for the wind to move it inland. Thus only a narrow strip of beach supplies the dunes with sand: the strip, some twenty yards

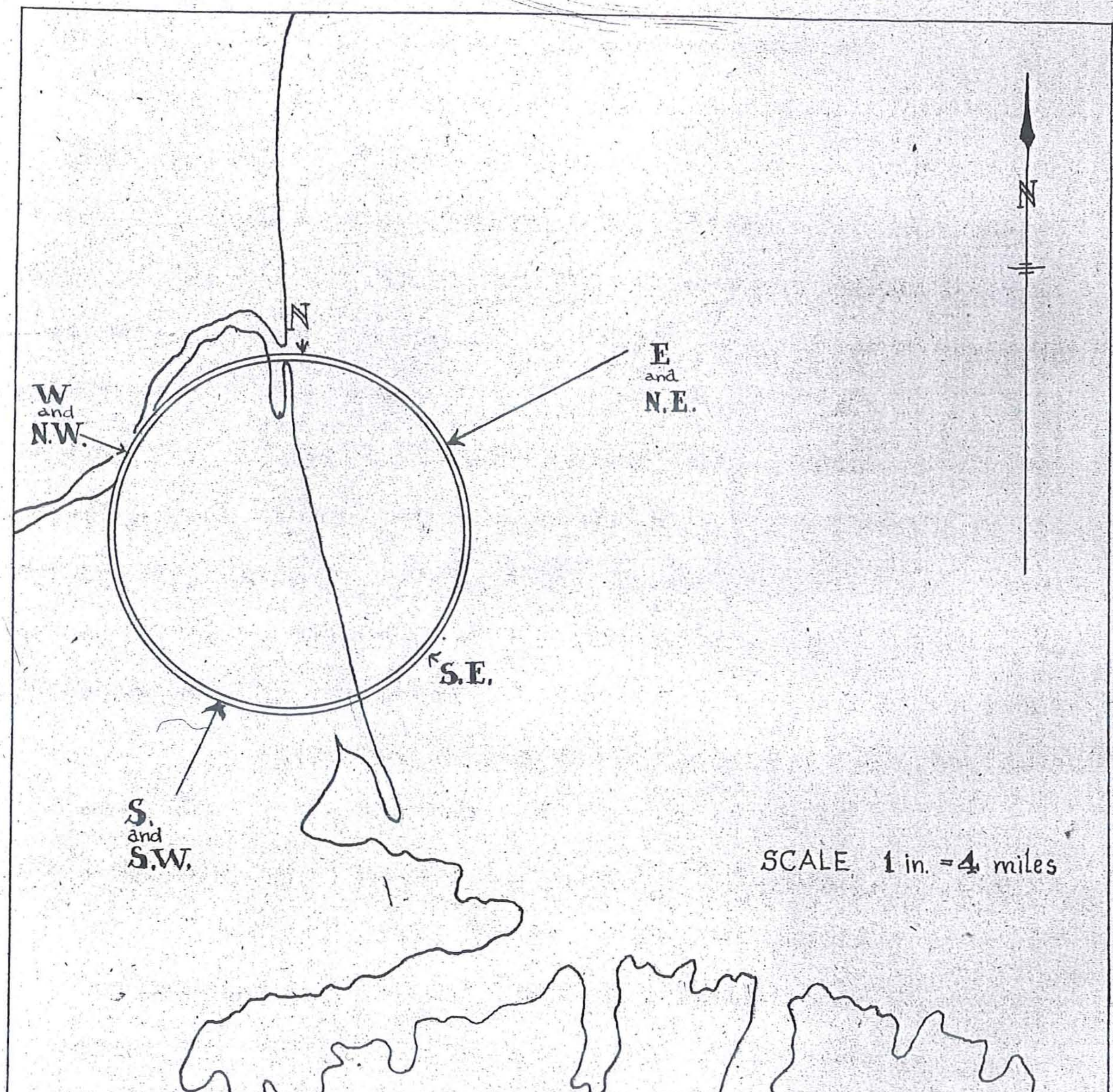

Fig. 3. MEAN WIND DIRECTION:

Winds over 3 m.p.h. The arrows reading towards the centre of the circle are proportionate to the frequency.

wide, which is left dry between the ebb and flow of the tide.

Relevant Features of the Canterbury Climate:

Various factors in the climate of this part of Canterbury combine to facilitate the movement of sand by wind from shore to dune. Constant periods of frost will freeze sand and prevent its movement by wind force. The average annual temperature in Christchurch is 51.7° F., with an average maximum of 61.13° F. in January, and an average minimum of 42.09° F. in July. The average number of frosts per month reaches a maximum of 21.4 in July and a minimum of .06 in January. The hardest frost registered during 39 years has been 20.1°. Frost at night however, is usually followed by a bright day, and the sun soon raises the temperature well above freezing point. Rarely if ever, has the temperature remained below freezing point during the day.

Sunshine to dry the sand and permit its free movement is liberal for these latitudes. The average total hours of sunshine annually over 17 years is 1970 hours, reasonably well spread over the year, with a maximum in January of 209 hours, and a minimum in June of 108 hours.

The average annual rainfall is 26.02 inches, with no month averaging less than 1.8 inches in February, and a maximum of 2.88 inches in May. Continual damping of the sand prevents movement, and so the duration of rainfall

TABLE NO. 2

THE AVERAGE OVER FIVE YEARS, 1938-1942 OF THE NUMBER OF WINDS OVER 3 m.p.h.

Taken at Three-hourly intervals at Wigram Aerodrome, Christchurch.

	East to North-east	South to south-west	West to North-west
Jan.	113	50	23
Feb.	103	36	19
March.	113	44	33
April	88	38	24
May	79	42	24
June	65	57	21
July	54	64	37
Aug.	86	40	31
Sept.	92	67	37
Oct.	106	52	26
Nov.	115	50	15
Dec.	106	60	26
Total	1140	600	316
Average Monthly	95	50	26.4
Percentage	55%	29.6%	15.4%

rather than the amount is the decisive factor to be considered in studying its effect. Christchurch has an average of 126 rain days in the year, and so on only approximately one third of the days is dampness a restricting factor.

Weather conditions generally are such that sand movement is not unduly impeded for any great length of time. The wind carrying the sand inland from the shore is the prevalent easterly, varying from north-east to east. This wind is an estremely steady, cool sea breeze usually rising about 10 a.m., reaching its maximum about 2 or 3 p.m., and often falling to a complete calm overnight. A study of data at the Meteorological Station, Wigram Aerodrome, Christchurch, revealed the following facts. Based on averages for the last ten years, 98% of all winds were, east to north-east, south to south-west, or west to north-west. The remainder, south-easterly and northerly winds constituted only 2% of the total, and hence are relatively unimportant.

Table No. 2 based on averages for five years shows that of all winds over 3 m.p.h.:- east to north-east = 55%; south to south-west = 29.6%: and west to north-west = 15.4%.

Of all winds, 20.3% were above 15 m.p.h., divided as follows:- east to north-east = 10%; south to south-west = 7.6%; west to north-west = 2.7%.

Thus, even of the stronger winds, in frequency

TABLE NO. 3

A COMPARISON BETWEEN THE EASTERLY AND SOUTHERLY WINDS ASSOCIATED WITH RAIN

An Average over three years, 1944-1946. Winds over 3 m.p.h. at Three-hour intervals, Wigram Aerodrome, Christchurch.

	Easterly	With rain	Southerly	With Rain
Jan.	124	10	50	7
Feb.	87	1	33	2
Mar.	96	7	47	18
April	72	1	41	18
May	65	11	45	32
June	58	12	61	40
July	69	3	58	13
Aug.	92	0	42	21
Sept.	103	5	62	23
Oct.	115	7	56	23
Nov.	108	3	59	30
Dec.	122	7	51	22
Total:	1111	67	605	249
Proportion:	Rain with one wind in 16.5		Rain with one wind in 2.5	

the easterlies almost equalled the southerlies and westerlies combined.

Rain may be more frequently associated with one wind than another, resulting in consolidation of the sand and little movement. The westerlies are of the föhn wind type, nearly always hot and dry, and Table No. 3 shows that rain is much more frequently experienced with the southerlies than with the easterlies.

Thus the sand will tend to move inland under the influence of the easterly winds because, of all winds the easterlies are the most common; damping of the sand occurs with approximately only one easterly wind in sixteen; these winds have a clearer approach to the shore and coastal area, as they come in from the sea.

At this stage the sand changes in shape. In the river and sea it is angular in shape, being protected by a film of water, but on land abrasion is rapid and round grains develop. The method of movement is dependent on size. The coarsest grains roll along the ground, finer grains hop, and the finest are blown completely into the air even in winds of moderate force.

CHAPTER 2

THE FORMATION OF THE DUNE COMPLEX

Progradation of the Coast:

There have been three phases in the progradation of the coast. During the first phase the shingle plain behind the coastal foreland was built by the spread of great shingle fans, formed by large glacially-fed rivers. The second phase resulted in the formation of the beach ridge foreland. A sand spit developing offshore enclosed a lagoon which filled up with swamp deposits and wind-blown sand. The topography of the coastal dune area took the form of a series of sand ridges, behind each of which there was a swamp. These dune ridges have not remained fixed. They have been cut into by the wind, and have developed into a complex of hollows and dunes. The growth of vegetation intensifies wind action, resulting in a diversity of dune shapes. Settlement too, has obliterated the original form of the dune lines.

Three major dune belts are still discernible, each separated by a drained swamp. The first forms a continuous belt of dunes adjacent to the sea. Some two to

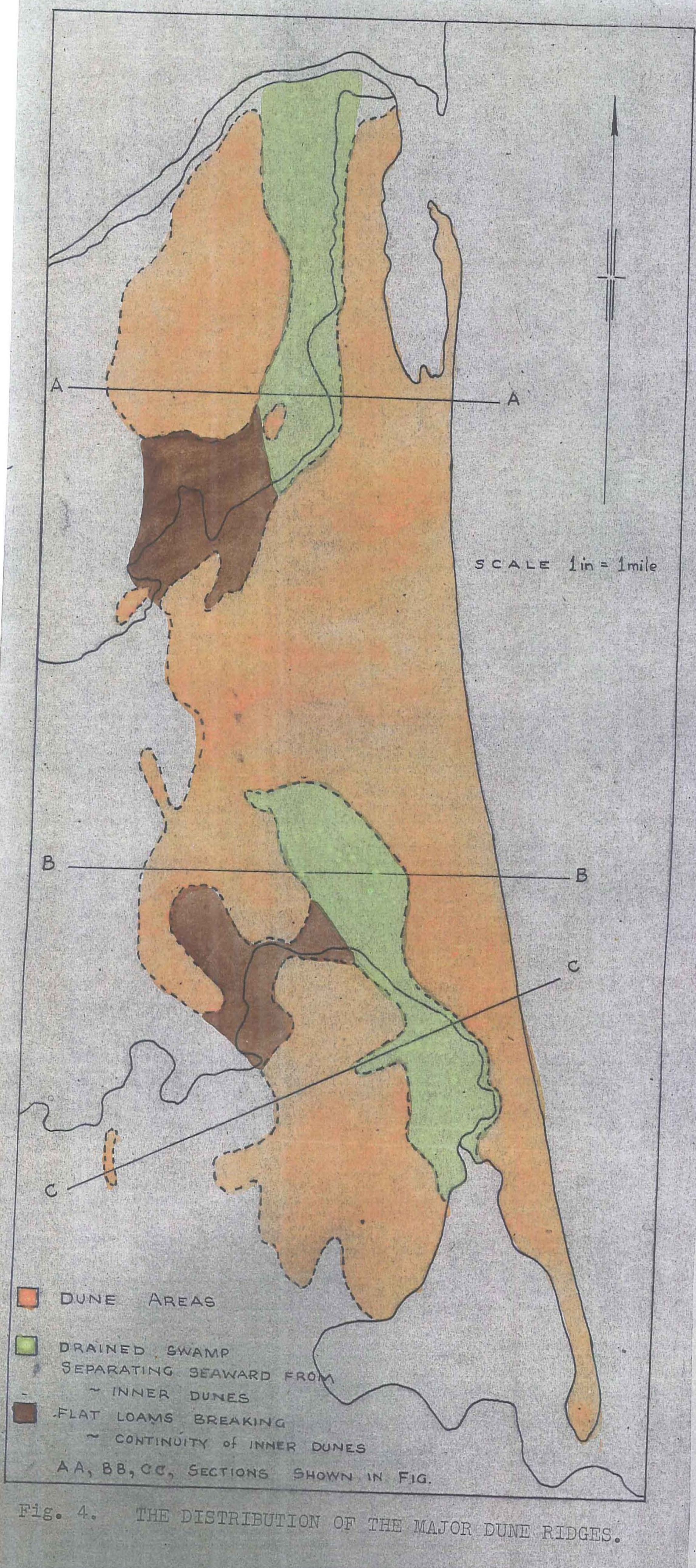

Fig. 4. THE DISTRIBUTION OF THE MAJOR DUNE RIDGES.

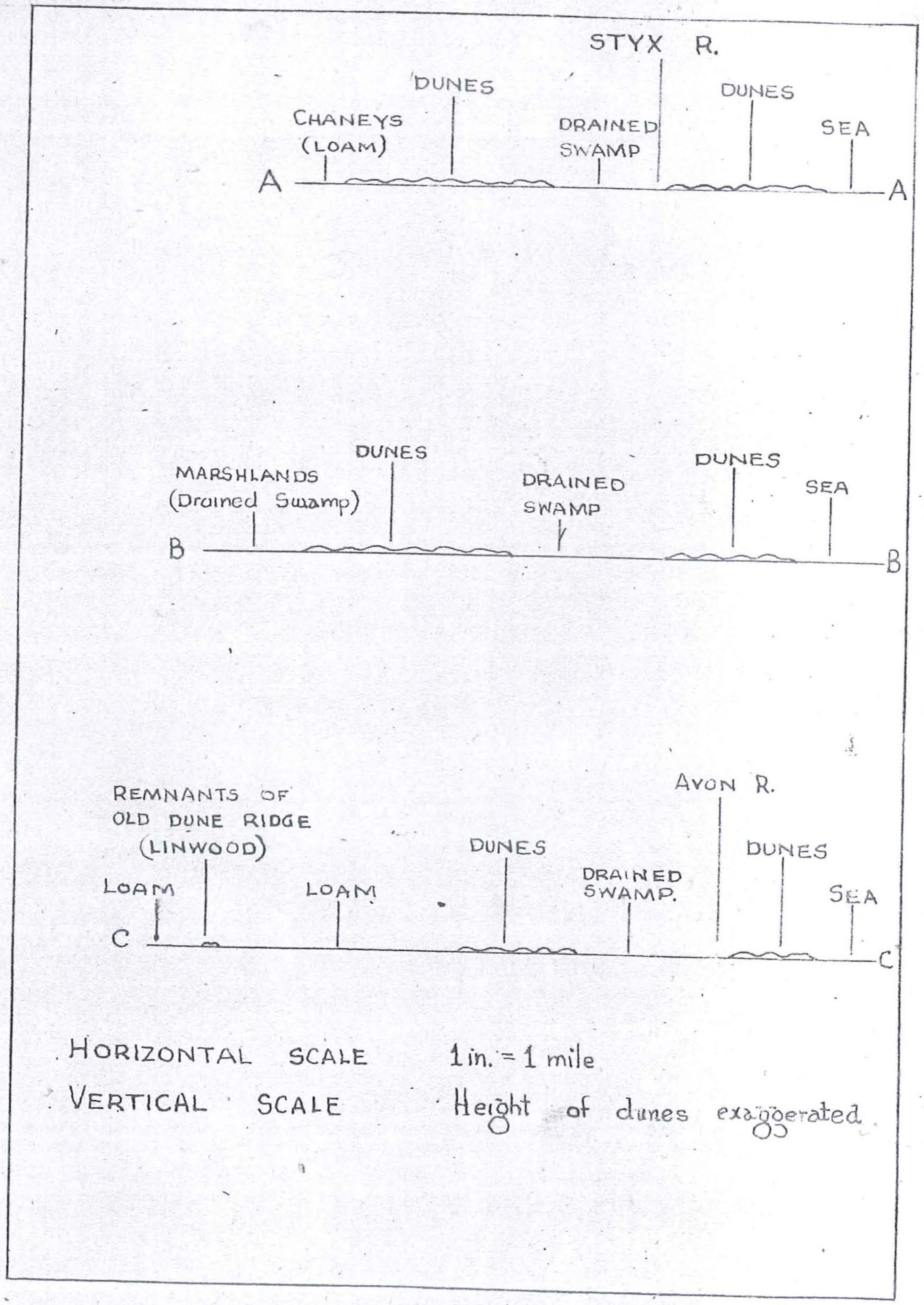

Fig. 5. THREE SECTIONS ACROSS THE DUNE RIDGES.

three miles inland is a second series, now consisting of a discontinuous zone of isolated dune areas. Behind this series the remnants of a third and very old dune ridge are still evident at Linwood, a suburb of Christchurch.

The third and present phase is due to the deposition of the Waimakariri sands on the shore. An excess supply of waste is fed into the sea by the Waimakariri River, and owing to the gradually sloping offshore profile, much of the sand is thrown up on to the shore. The prevailing wind, blowing onshore, carries the sand inland.

The sand moves inland until some obstacle, a piece of driftwood, seaweed, a plant, or any irregularity in the surface, arrests the drift. As the sand accumulates, a small dune is formed. This usually occurs a short distance above the high water mark, and as the dune grows, it becomes a natural foredune. These undulations in the surface almost invariably develop transversely to the direction of the wind, the line of dunes running roughly north to south in alignment with the coast. The foredune has a fairly gentle windward slope, a sharp crest unless rounded with vegetation, and a steep drop to leeward. The sand is blown up the gentle windward slope, but as an eddy forms to leeward in the shelter of the dune, it falls about and just over the crest.

The coastline advances simultaneously with the growing of the foredune. With a low incipient foredune, only a small proportion of the sand is retained, but as the

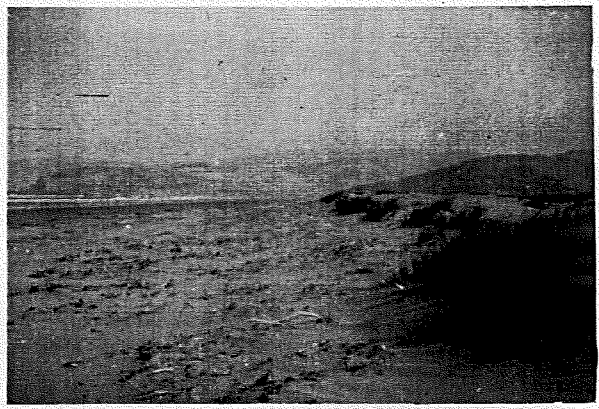

Fig. 6. PINGAO PLANTS BUILDING AN INCIPIENT FOREDUNE ON THE SPIT OF THE AVON RIVER ESTUARY.

Fig. 7. MOIST FLAT BEHIND FOREDUNE BOTTLE LAKE AREA.

dune becomes higher, the slope of the beach is built up, and with this raising of the profile, the coastline is advanced. As the distance between the foredune and the high water mark increases, another foredune develops nearer the sea. Tidal and seepage waters lie in the space between the two ridges. Portions of this swamp are filled with sand or by shifting dunes, and eventually only small patches remain scattered throughout the dune complex. Thus within the major dune belts which are separated by a zone of swamp, there has developed a complex of dunes and swampy hollows.

Borings made by the Waimakariri River Trust reveal a remarkable depth of sand. On the Waimakariri River spit, typical of the seaward margin of the area, a depth of 80 feet was reached and the machine was still in sand. At Stewarts Gully two miles inland sand changed to shingle at 68 feet; above the road bridge, three miles inland, the covering of sand was 30 feet; while at Coutts Island, four miles inland, shingle was only 12 feet below the surface. The last two locations are beyond the coastal dune area, the sand underlying a thick layer of loam.

Sand Movement:

A dune which is unfixed by vegetation moves forward in a direction with the prevailing wind. The sand

Fig. 8. SAND RIPPLES:

A large dune prior to artificial fixation. Bottle Lake area.

is dropped on the leeward side, and as this continues the dune besides building up at its crest, moves forward, its rate of advance depending on the supply of sand available to windward and the height of the dune. A low dune advances more quickly, needing less sand to move the same distance as a higher dune.

The sand moves in the form of ripples, except in a very high wind. Cockayne explains sand ripples by drawing attention to the different size of the sand grains.+ With the exception of a very strong wind, strong enough to lift all grains clear of the ground irrespective of size, the large grains are rolled forward. An eddy is formed to leeward of the larger grains, and this eddy lifts the smaller grains clear of the ground to deposit them further on in a hopping fashion. As the smaller grains are winnowed away a hollow forms, and the slower moving large grains form a ridge till they are moved into the hollow. These ridges and hollows give the surface its rippled appearance. Cockayne further records that at New Brighton, in a strong east wind, sand ripples have advanced at a rate of an inch a minute. The rapidity of advance varies with the strength of the wind, and the grade of the slope up which the sand

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\+ Cockayne, L.: Report on the sand dunes of New Zealand.

is moving.

The advance of a dune, unfixed by vegetation, is usually slow, but occasionally a high east wind will cause rapid movement. In one instance a dune with a ten feet high lee slope at New Brighton, was noted to advance two feet horizontally in ten hours.

CHAPTER 3

THE NATURAL VEGETATION OF THE DUNES

The plant environment of the dunes has distinctive characteristics. At first, only a few species of plants can establish themselves on the dunes, but as the sand becomes more stable, more species can enter the plant association. In moving sand, damp hollow or semi-fixed dune, the following conditions exist in varying degrees. Where there is an unstable surface, the sand may cover the plants in the more exposed locations and propogation by seeding is virtually impossible. The drifting sand may bruise the plants and the young buds if these are unprotected. Due to the paucity of vegetation, there is a lack of shade, an intense reflection of heat and light, and accelerated transpiration and evaporation. The low specific gravity of the sand results in quick changes in temperature and temperature extremes. The general dryness associated with the conditions already mentioned leads to rapid oxidation, delaying the formation of humus. The slow accumulation of humus and the initial poverty of the sand in plant minerals, results in a lack of many vital plant minerals such as phosphates. These extreme conditions would not have been universal. The environment would diminish in adversity with distance from the sea, becoming less exposed to the wind, with a more stable surface and with conditions generally becoming more congenial for growth.

On the beach itself there is even now, little or no plant cover, as it is too exposed to the wind, and the sand is constantly in motion. However with the development of the natural foredune, there was some protection to leeward, and it was behind this shelter that there was any vegetation of consequence. The coastal dunes could be divided into two broad zones. First, the zone of active wind erosion and instability, merging inland to the zone of lower dune formations with a comparatively stable surface.

Following Cockayne's major subdivisions, the plant covering of the first zone could be grouped into, "sand binders", "sand collectors", and the "plants of the moist hollows". The "sand binders" are distinguished by their adaptability to unstable sand conditions, and in some cases they flourish only in moving sand. The pingao (Scirpus frondosus) was the outstanding and dominant plant of this type. It has a great length of stem, but it is its special power to grow upwards seeking the surface light as it is buried by advancing sand, that enables it to survive. In common with the others in the group, as it grows in unstable sand it has a great power of vegetative increase, long and

Fig. 9. PINGAO IN UNSTABLE SAND.
Note the spreading ~~rhizomes~~ roots.

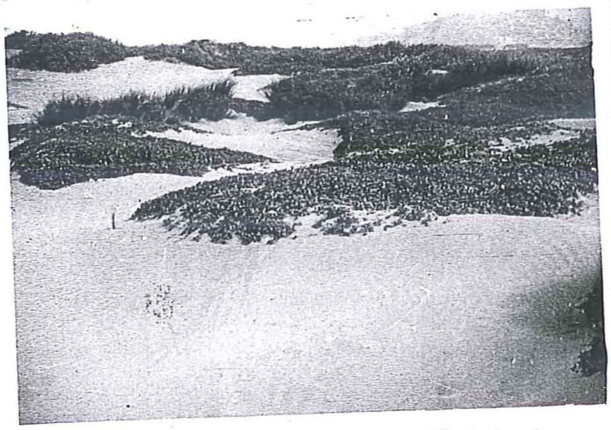

Fig. 10. GREEN CARPETS OF SHORE CONVOLVULUS, FOREGROUND.

strong rhizomes spreading over wide areas. The young stem and leaves are protected by the overlapping of broad leaf bases, and the leaf texture is tough to withstand sand blast. It was the major "sand binder" and in the transition from instability to stability would almost invariably be the first plant to establish itself. Associated with the pingao, but not so tolerant of moving sand conditions would be minor binding plants, the sand spurge (Euphorbia glauca); the sand sedge (Carex pumila) in the dry sand hollows; and the shore convolvulus (Calystegia soldenalla) which exhibited many of the characteristics of the binder group, but required slightly more sheltered and stable conditions.

The next group, the "sand collectors" are low spreading shrubs with many wiry and flexible branches. Unlike the binding plants, they cannot cope with continual burial by sand, but act rather as sand traps, catching moving sand and accumulating it in the shelter of their branches. Lacking the tolerance towards instability noticeable in the binders, they would be common on more stable dunes. They cannot vegetate and spread over a wide area, as they can extend their shoots to only a limited degree. The more common species would be the sand coprosma (Coprosma acerosa); Tauhinu (Cassinia fulvida); the small sand pimelia (Pimelia arenaria), as the major types, and sand fescue grass (Festuca littoralis); and sand bent (Agrostis billiardieri), in a minor role.

The third group, the "wet sand plants", would be located in the moist hollows. With the movement of dunes, these hollows developed into patches of moist ground, scattered at irregular intervals in the dune area. The most common plants would be the sand gunnera (Gunnera arenaria), forming large circular mats; Selliera radicans, with its green leaves forming thin, winding tracks over the sand; the common club rush (Scirpus nodosus); the dwarf club rush (Scirpus cernuus); and various salt meadow plants including the jointed rush (Leptocarpus simplex).

The second zone, as in the first, would become more stable moving inland, and the association would broaden as fixation became more widespread. With the protection of the dunes and the vegetation to windward, the wind struck with less power, the sand had a decreasing tendency to move, and many other than the typical dune plants of the seaward zone could grow. The following plants would be common:- manuka (Leptospermum scoparium); the cabbage tree (Cordylina australis); silver tussock (Poa caespitosa); and in the swampy areas, New Zealand flax (Phormium tenax), and some toe toe (Arunto conspicuo). On the landward margin of the zone, the dunes would be of such age that they would have developed a thin layer of humus, and under natural conditions, anticipating no human interference, could be regarded as fixed. It is difficult to say exactly what the natural vegetation would be. A considerable variety of plants would be covering the dunes, including silver tussock, manuka, flax, and the cabbage tree, but the association would be broadened by the appearance of wild irishman (<u>Discaria toumatu</u>); tutu (<u>Coriara sarmentosa</u>); the New Zealand broom (<u>Carmichaelia subalata</u>); and the small bushy trees, ngaio (<u>Myoporum laetum</u>), mahoe (<u>Melicytus ramiflorus</u>) and mapau (<u>Rapamca urvillei</u>). Raupo (<u>Typha angustifolia</u>) and niggerhead (<u>Carex secta</u>) would be established in the swampy areas.

The delineation of the area into zones for descriptive purposes does not mean that these zones were by any means fixed or exact. The basic factor restricting the plant association was instability. Many plants were able to stand up to excessive wind, a dry and poor soil and strong insolation, but only a true dune plant could withstand sand drift. The vegetation of sand binders, collectors, or manuka and wild irishman on the more stable scrub dunes, was an exact indication of the stability of the sand. The degree of stability was in turn, an exact indication of the degree of exposure to wind force. The growth first of pingao allowed the lesser binders to gain a foothold. In turn, with increasing stability, the collectors came in. Finally, on stable sand, xerophytes other than sand plants could establish themselves and a scrub and tussock heath resulted.. These latter plants added humus to the sand and a much greater variety of plants flourished. The natural sequence was a gradual change of plant types, in harmony with the stability of the sand.

PART II

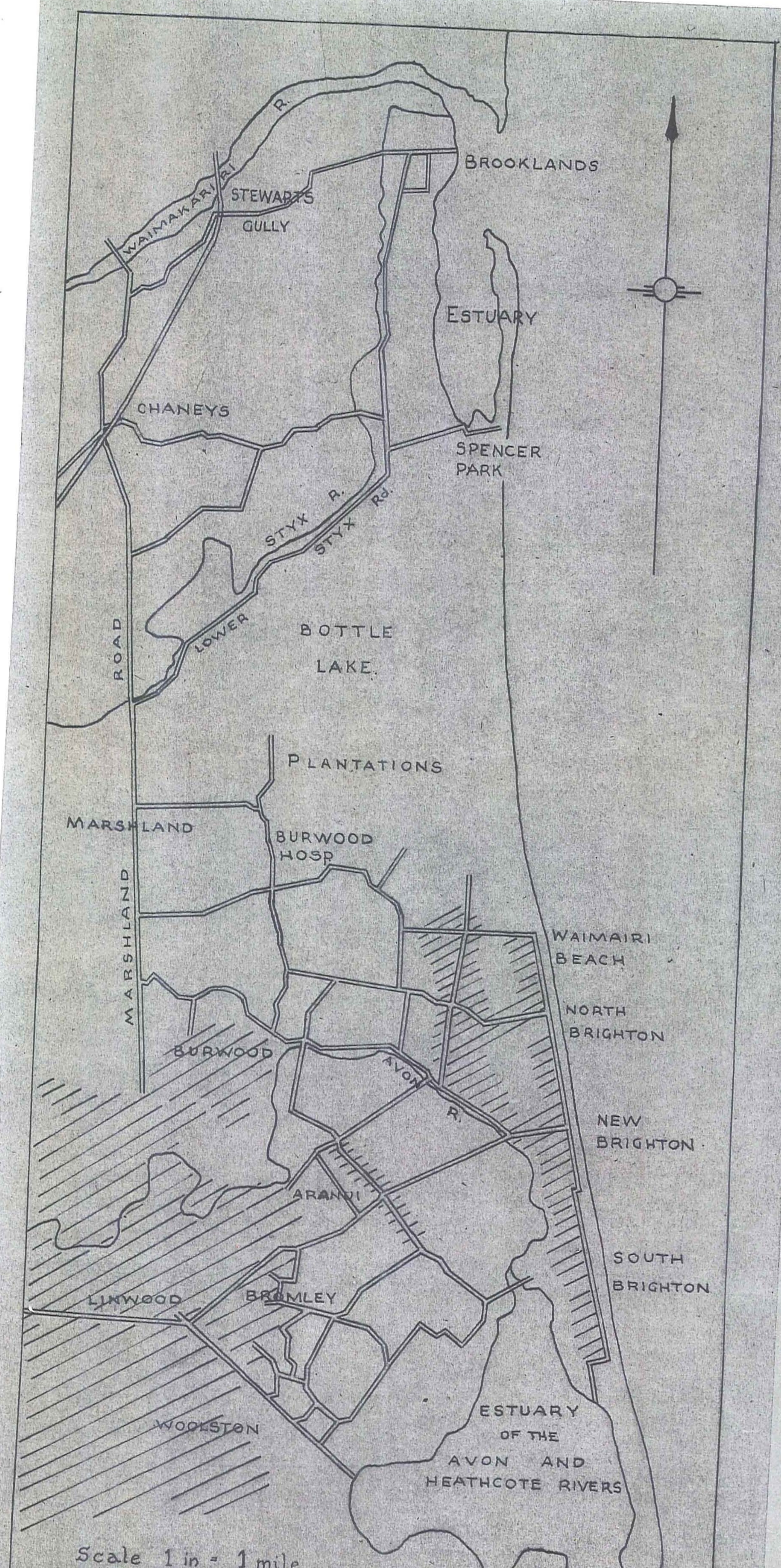

Fig. 11 SITUATION MAP:
The Coastal area between the Waimakariri River and the estuary of the Avon and Heathcote Rivers.

CHAPTER 4

THE CONTROL OF SAND MOVEMENT

Under natural conditions the sand was moving until held by the growth of vegetation. The natural sequence of fixation was a slow and increasing gripping of the loose sand as a greater variety of plants established themselves. But though much of the dune area was well covered with vegetation, there was, especially nearer the sea, only a delicate balance between stability and instability.

The Maoris had little interest in the area. There was a pa at Woodend, seventeen miles north of the present site of Christchurch, and others near Lake Ellesmere to the south. The flax in the swamps may have been used for clothing purposes, but as there were ample supplies much closer to the settlements, it is doubtful whether it was ever utilised. After the arrival of the white colonists in 1850, the coastal dunes were taken up in 1852 as a part of the Sandhills Run, which included Runs 9, 72, ,and 239. Runs 9 and 72 consisted of the more stable inner dunes and swamp. Run 239 was bounded in the north by the Waimakariri River, in the west by the Styx and Avon Rivers, and in the south by the estuary. It consisted approximately of the seaward belt of dunes, and was considered of little value. The complete Sandhills Run was worked as a dairy station, supplying early Christchurch with milk.

The inner dunes of Runs 9 and 72, with the exception of a block between Chaneys and Stewarts Gully, were soon cut up into smaller units for farming and building purposes. The seaward dunes of Run 239 continued to be grazed as a unit but after 1880 the southern section about New Brighton developed as a residential area. However in the north the area between Waimairi Beach and the Waimakariri River was a sheep run until the early 1900's. An old inhabitant of the district has estimated that at the most 2,000 sheep were carried. Under the Borough of Christchurch Reserves Act of 1878, 817 acres about Bottle Lake were vested in the city for sanitary and planting purposes, and a further 516 acres were granted in 1884. This block was leased out as part of the sheep run.

The continual grazing of sheep in the northern section of the seaward belt of dunes resulted in a general deterioration in the surface cover, and a drift of sand inland. This movement has been controlled and pine plantations established. Control in the southern section of seaward dunes has been aimed at preventing the sand moving from the shore into the townships of North Brighton, New Brighton and South Brighton. No comparable control measures have been necessary in the inner belt of older dunes.

The Establishment of the Bottle Lake Plantations:

As early as 1883 fifty acres of pines, Pinus laricio, and Pinus radiata were planted under contract for the Christchurch City Council near the sea in the Bottle Lake area, but the plantation was neglected. Only a few trees survived, the rest being destroyed by fire or covered by drifting sand. No steps were taken to prevent the grazing of the dunes. As a result the condition of the vegetation deteriorated, till dunes that had been naturally stabilised reverted to their original unstable state. Pingao, the major natural sand binder, is palatable to stock. As the pingao was eaten out, the other dune plants could not cope with the increasing sand movement. Wandering dunes developed with a smooth gently sloping surface and a sharp drop from the crest. These dunes were destitute of plant life and presented a bare surface to the wind. As wind has a greater velocity over smooth ground, sand movement was speeded up. The danger lay not only in the fact that hitherto stable dunes were in movement. In their advance they smothered well vegetated areas and if unchecked, may have eventually moved into the fertile Marshlands district to the west. The wandering dunes reached almost to the Lower Styx Road, a distance of 1½ miles from the sea, while further south they were more than 2 miles inland.

Soon after 1900 this rapid deterioration of conditions was appreciated and the City Council withdrew the lease on the area. In 1909 a policy of afforestation was decided upon, in order to stabilise the dunes and check their advance. Sample plots of trees were planted, and by 1911, 12,000 pines had been planted on the landward margins of the unstable dunes. Different species were tried in an attempt to discover which were best suited to the conditions. Among these were Pinus austriaca, Pinus muricata, Pinus laricio, Pinus ponderosa, and the maritime pine (Pinus pinaster) which had been used with success in many dune fixation projects overseas. In 1912 the Douglas fir and Norway spruce were planted, but both proved a complete failure. Pinus radiata was used only as a shelter tree as it was then considered of little commercial value.

In 1915 however, the quick growing qualities of P. radiata were realised, and until 1922 it was almost the only tree planted. Between 1922 and 1929 there was another experimental period, and further species were tried. Thuya plicata, sycamore, ash, Douglas spruce, redwoods, oaks and many varieties of the eucalyptii were planted, but all failed. Some Cupressus macrocarpa and poplars grew but they were not a complete success. Of all the species planted, P.radiata proved by far to be the most suited to the conditions. P. laricio showed good promise, but its rate of growth was only half that of P. radiata. P. pinaster, the most common tree used under similar conditions overseas, was not a success. P. radiata has been the main tree for planting since 1929.

Fig. 12. DUNES PRIOR TO PLANTING OF MARRAM GRASS.

Fig. 13. MARRAM GRASS SHORTLY AFTER PLANTING.

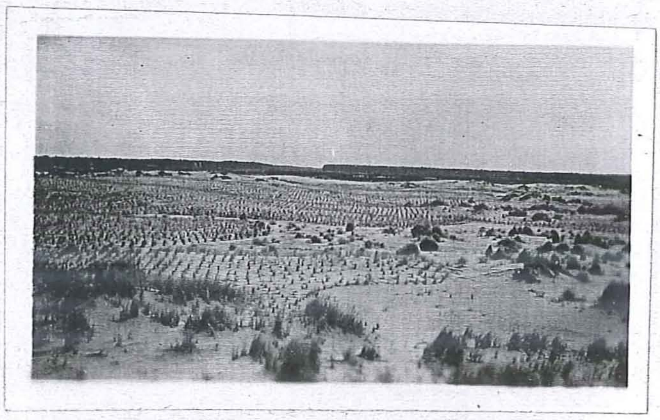

Fig. 14. PLANTED DUNES.
Note the regularity of the rows.

It grows twice as fast as any other species, and this quality makes it especially suitable for sand fixation. The tree is very adaptable, thriving in pure sand if the surface is sufficiently stable to allow it to make a start.

In establishing the pines, some measure of stability was necessary as the young trees could not withstand continual movement. To stabilise the surface, marram grass (Ammophila arenaria) was first planted, usually at about three feet intervals, and then lupin (Lupinus arboreus) was sown to ensure rapid stability. The lupins are shot-lived plants, and as they died, they added some humus to the sand. Branches of manuka scrub or broom were laid on the surface in some parts to break the smooth contours of the dunes. Marram grass has all the characteristics of the native pingao, with wide-spreading rhizomes and an ability to withstand sand movement. It has a major advantage in that it is unpalatable to stock. Its ease of transplantation makes it ideal for large scale fixation purposes, as one plant broken up produces many to plant out.

In later years the practice of using only marram as the pre-requisite for afforestation has been followed. Lupins quickly formed a dense covering and the pines were planted in lines cut through the bushes. It was found that as the pines took two years to consolidate and commence growing, the lupin often grew over and smothered the young trees. The advantage of the lupin was that it supplied

Fig. 15. PINUS RADIATA PLANTED THROUGH MARRAM GRASS TWELVE MONTHS AFTER THE MARRAM HAS BEEN PLANTED IN MOVING SAND.

Fig. 16. YOUNG PINUS RADIATA.

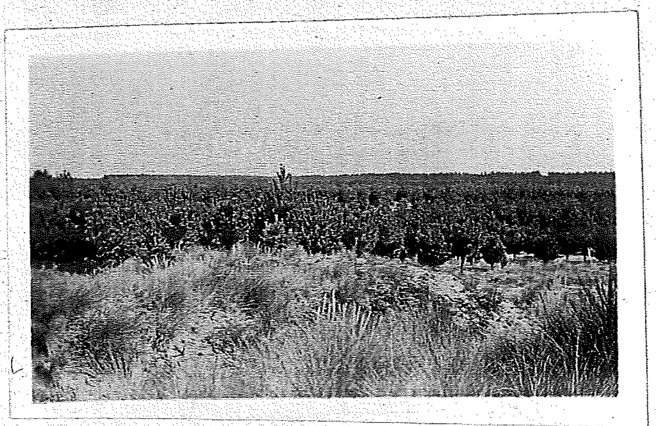

Fig. 17. WELL ESTABLISHED PINES.

some humus to the sand, but with *P. radiata* this was not necessary as the tree grew in pure sand providing the sand was reasonably stable. Recently pines have been planted out in sand that has been only one year in marram grass. Following the continental practice with the pinaster, the trees were first spaced four feet apart. With the fast growing *P. radiata* this proved much too close, unless a systematic and vigorous policy of thinning was carried out from the time suppression started, about nine years after planting. After trying six feet, eight feet, and nine feet spacing, experience has shown that the eight feet spacing is the most suitable.

Sand Fixation on the Beach North of Waimairi:

The landward fringes of the Bottle Lake dunes were planted first, and between 1909 and 1930 the plantation was slowly advanced into the unstable dune area. About 1930 it became obvious that even though the trees were stabilising the area planted, there was an inland drift of sand from the unplanted dunes which threatened to invade the established forest. There were still some 1800 acres of unstable dunes to seaward. The trees to the west were sheltering these dunes from the westerly and southerly winds, and movement inland from the east was greater than might normally be expected. Dunes some forty feet high which have banked up against the few surviving trees of the block

Fig. 18. A DUNE BANKED UP AGAINST TREES PLANTED SIXTY YEARS AGO.

This considerable accumulation was caused by the inland movement of sand before the foredune was built.

planted sixty years ago, are still visible. Fixation was becoming increasingly difficult as the frontage of the plantation moved nearer the sea.

The natural foredune was affording little protection. The coastline was serrated, with tongues of sea water extending inland at high tide. As a result the foredune had not developed in a straight line. This allowed the wind to scour into it and gullies were formed. The wind had eaten into the dune through these gullies till in many places the foredune was flattened. The wind velocity was unchecked as it moved into the dunes behind, and there was such a mass of sand constantly in motion that the establishment of a plant cover was impossible without protection. An artificial foredune was necessary to shelter the dunes and prevent the continual inland movement of sand. Dependent on the success of this dune, it was intended to bring the plantation as near to the sea as possible. As there was plenty of relief labour available, planting was continued as the foredune was constructed.

In such an exposed location, the wind strikes against unyielding objects such as a lump of wood or a solid fence, and an eddy develops, resulting in scouring at the base. A young pingao or marram plant has a different effect. The plant is flexible, and it breaks, rather than completely checks the force of the wind. Sand accumulates in the

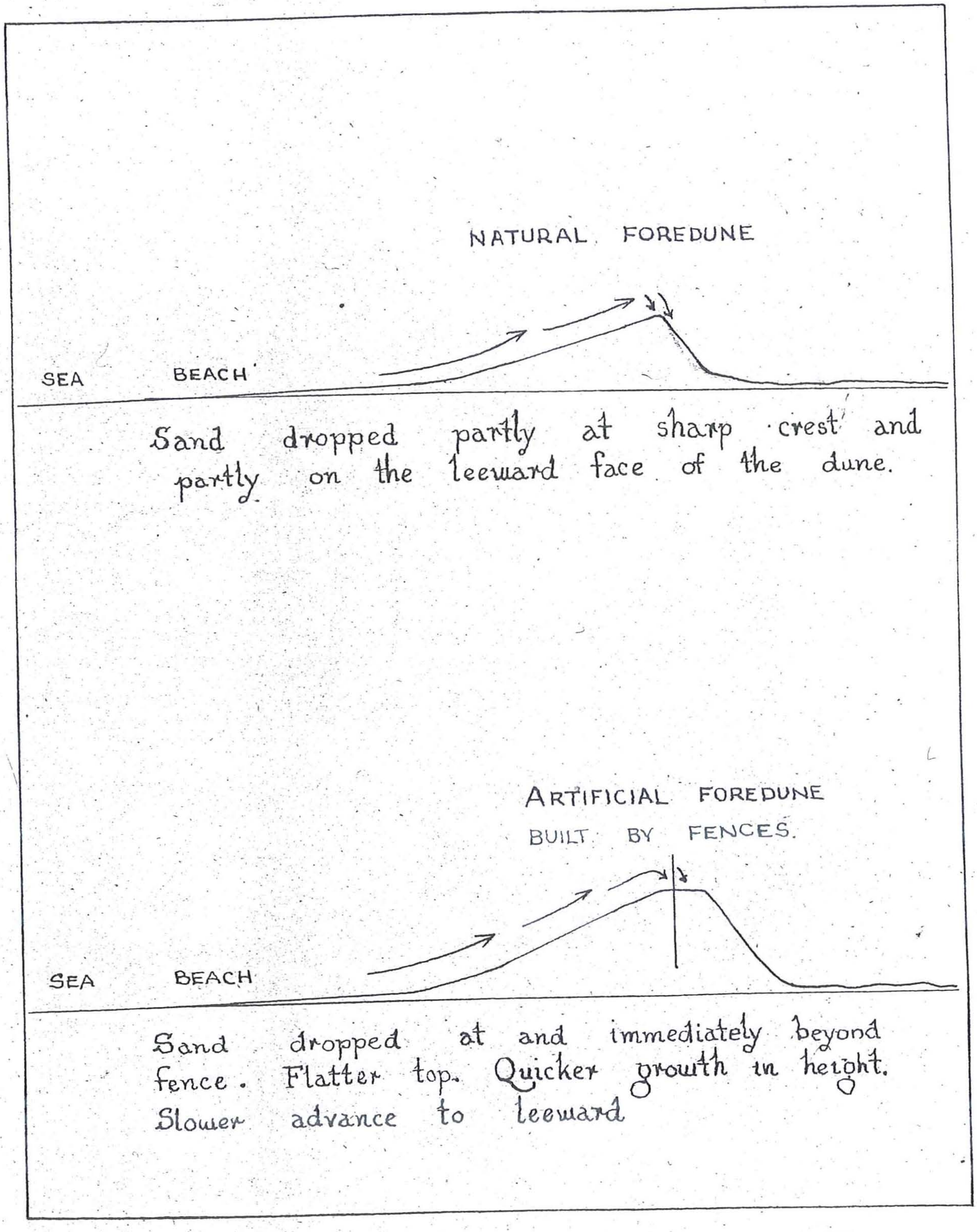

Fig. 19. THE SHAPE OF A NATURAL FOREDUNE COMPARED WITH THAT OF AN ARTIFICIAL FOREDUNE.

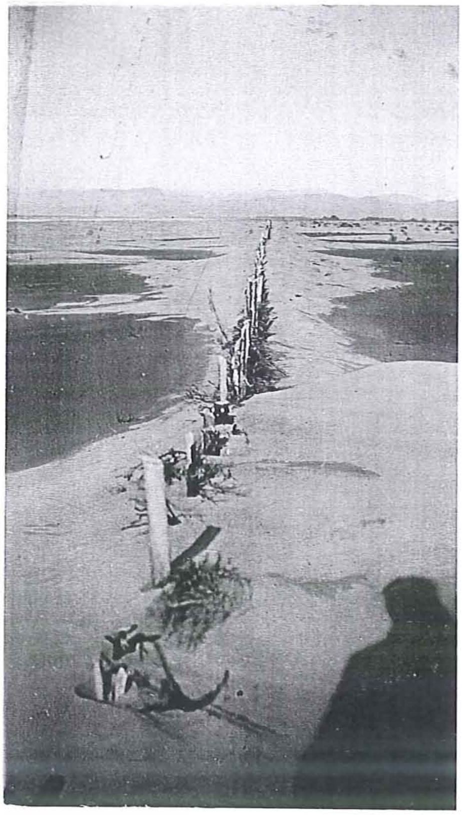

Fig. 20 Fig. 21.

THE FOREDUNE SHORTLY AFTER THE COMPLETION OF THE FIRST SCRUB FENCE.

Tongues of damp sand are visible on either side of the fence as at high tide the sea covered the dune.

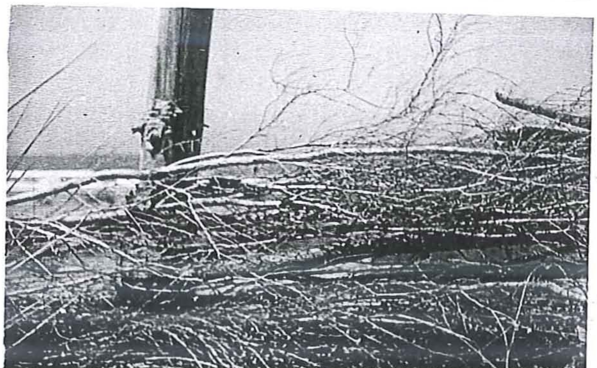

Fig. 22. THE LOOSELY INTERLACED SCRUB COMPRISING THE FENCE.

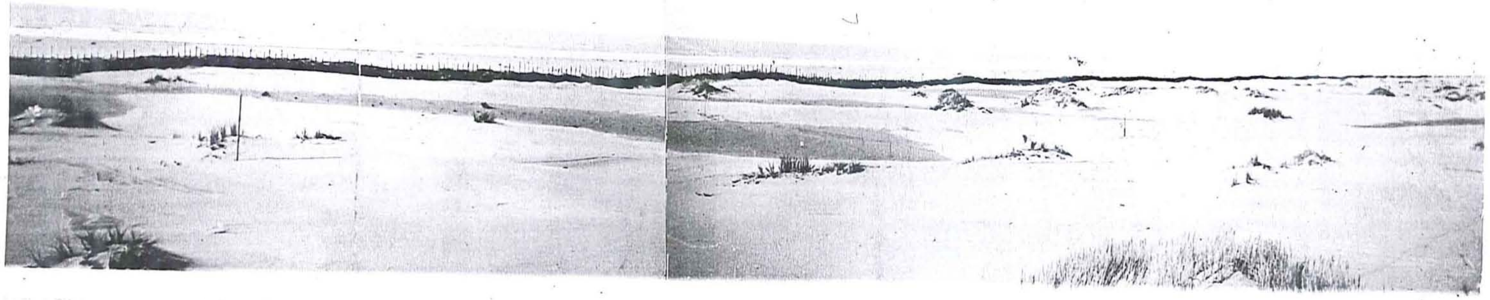

Fig. 23. PANORAMA OF THE FOREDUNE SHORTLY AFTER THE COMPLETION OF THE FIRST FENCE.

Fig. 24. THE FOREDUNE (BACKGROUND) AFTER THE CONSTRUCTION OF THE FIRST FENCE

Fig. 25.   FROM SEAWARD

Fig. 26.   FROM LANDWARD

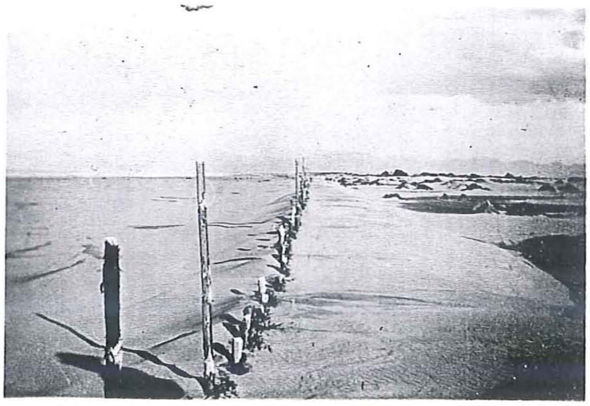

Fig. 27

Fig. 28

THE GROWING FOREDUNE IN THE 1930's.
In Fig. 28 note how the dune is building over and to leeward of the fence.

interior of the plant to form a tongue-like mass to leeward. The structure required to accumulate sand and form an artificial foredune must be a compromise between these two types of obstacles. It must be sufficiently solid to break the wind partially, yet sufficiently open to prevent scouring at the base, and eventual collapse.

To build the foredune, a loosely knit brush fence was constructed. This type of fence checked the wind only sufficiently to cause a deposition of sand at, and immediately behind the fence. As the sand accumulated, the dune grew to take the same form as a natural foredune, though the fence accelerated its growth in height. There was a gradual windward slope and a steep drop immediately to leeward of the fence. The fences were built in a straight line along the shore, in places being covered with water at high tide. Each fence was five feet high, with stakes driven well into the sand, and manuka brushwood loosely interlaced. In all, six were built, a new one being added as the old fence was buried, till the dune is now nearly thirty feet high. Such was the mass of sand to be checked that a five feet high fence was once covered in a day.

The foredune was constructed along the plantation frontage from Waimairi Beach almost to Spencer Park, between the years 1932 and 1940. Marram grass was planted on the foredune to add further stability. With this protection from the wind and incoming supplies of sand, the

Fig. 29 SAND SCOURED AWAY AT THE BASE OF TIGHTLY LACED FENCES.

Fig. 30.

Fig. 31.

COLLAPSED FENCES
Caused by wind scouring at the base.

dunes inland were stabilised with marram and ultimately planted in _P. radiata._

South of Waimairi:

The fact that there must be some protection from sand blowing in from the sea was realised soon after New Brighton was settled. It has been difficult to discover the exact date a foredune was first built, but in the "Lyttelton Times" of 1906, some mention is made of an artificial foredune at New Brighton. It was probably constructed some years prior to that date. The foredune first covered only New Brighton, but as houses extended along the coast, it was necessary to protect the whole area between Waimairi Beach and South Brighton. The same principles of construction were applied as with the foredune in front of the Bottle Lake plantations. The first fences built at South Brighton were laced too tightly, and many sections were undercut by the wind and eventually collapsed. After the amalgamation of the New Brighton Borough with the city in 1941, these fences were rebuilt by the Christchurch City Council and an effective foredune was built up.

To the south of New Brighton houses and roads are 200 yards from the foredune, leaving room for the dune to spread forward as it builds. Between Waimairi Beach however, and New Brighton, the Esplanade is close to the sea

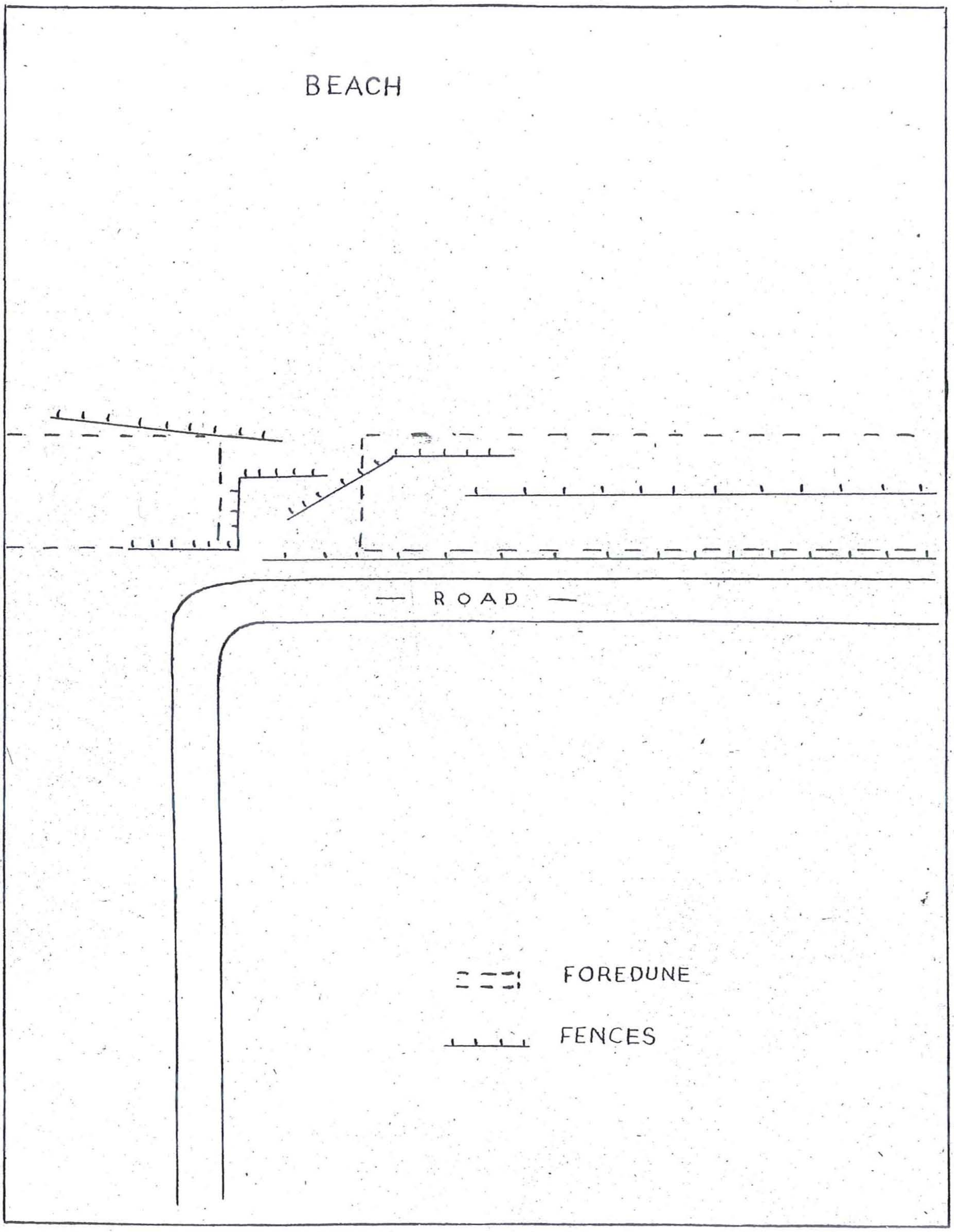

Fig. 32. FENCES COVERING A GAP IN THE FOREDUNE, WAIMAIRI BEACH.

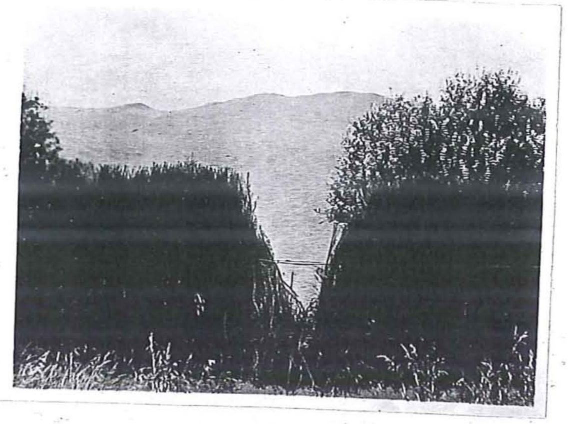

Fig. 33 THE FOREDUNE MOVING ON TO THE FENCE PROTECTING THE ESPLANADE

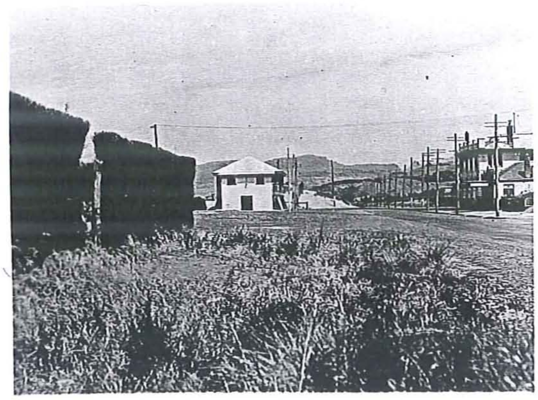

Fig. 34. THE FOREDUNE SPILLING ON TO THE ESPLANADE, NORTH BRIGHTON.

Fig. 35. PROTECTING FENCE BROKEN AS THE DUNE MOVES ON TO THE ESPLANADE.

Fig. 36 THE FOREDUNE, NORTH BRIGHTON
In the foreground the dune is building over the fence, but in the background collapsed fences have allowed the sand to move through.

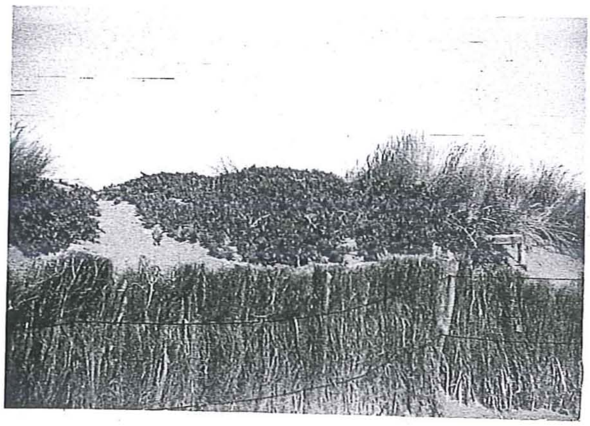

Fig. 37. ICE PLANT COVERING THE FOREDUNE, NORTH BRIGHTON

immediately behind the foredune. Considerable difficulty has been experienced in stopping the dune from spreading on to the road and into the houses opposite. A double fence was used in an attempt to confine the dune within strict limits. The first fence was constructed in the usual manner, loosely laced to check the wind and accumulate the sand. The second, some ten yards away on the down slope, was more tightly laced to hold the sand as it spilled towards the road. This fence was protected from the wind by the dune, there was no scouring at its base, but any large scale sand movement down the lee slope resulted in a collapsed fence, and the dune spread on to the road. Marram and lupins were planted on the dune to give it greater stability, but constant maintenance is still needed to keep the dune back from the road. The numerous holiday-makers trampling over the foredune have caused many of the slips.

In order to give bathers easy access to the sea, gaps were left in the foredune at the main holiday centres, Waimairi, North Brighton and New Brighton. The wind may scour a clear passage through such openings, and to cover these a series of fences and brick walls were built. These break the force of the wind, prevent the sand moving through, and protect the ends of the foredune. With the exception of these breaks, the foredune is continuous along the coast from South Brighton to within one mile of Spencer Park in the north.

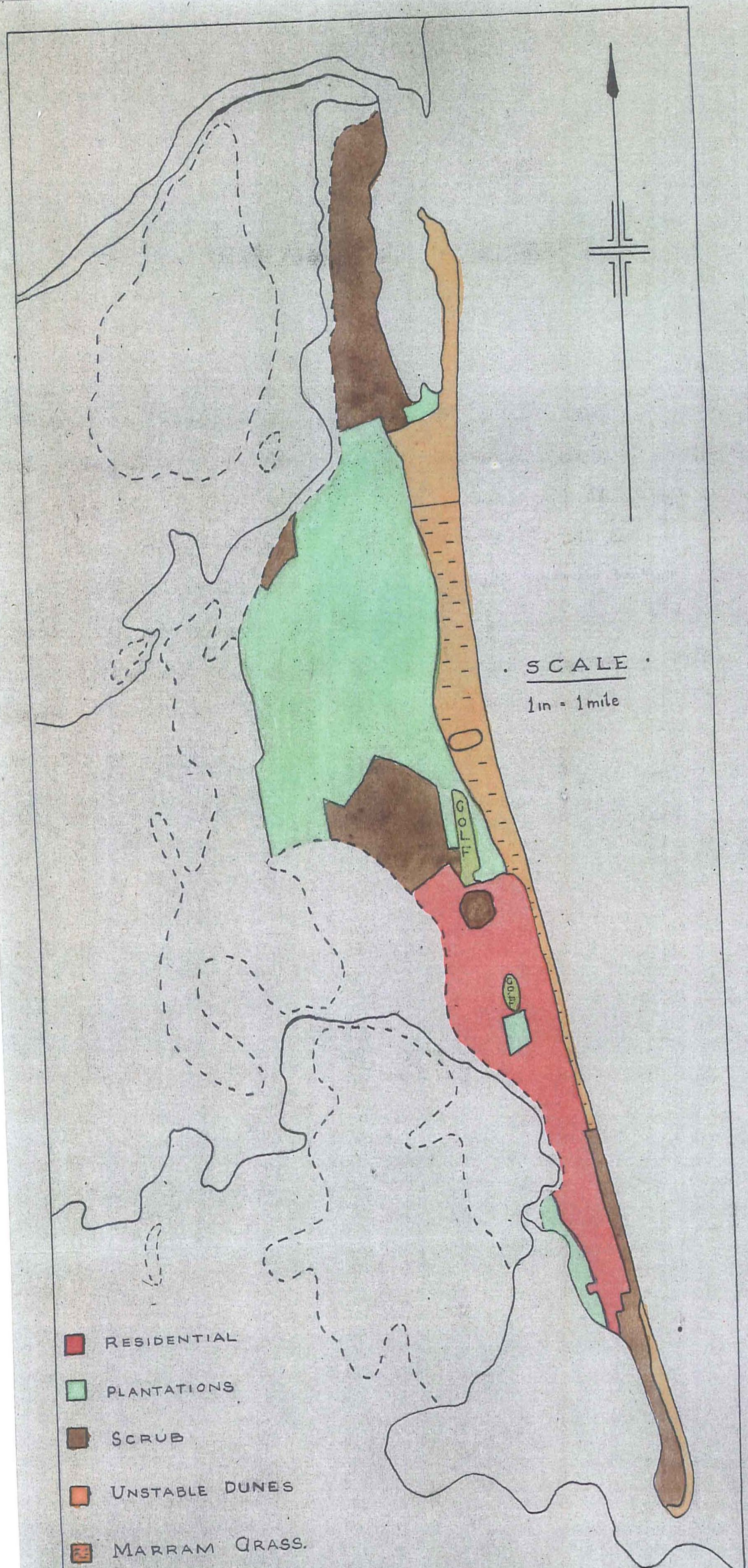

Fig. 38. UTILISATION OF THE SEAWARD DUNES

CHAPTER 5

THE UTILISATION OF THE SEAWARD DUNES

Introduced Vegetation:

Native dune plants in any abundance are today limited to areas which have not been planted in marram grass and are still unstable. Pingao is the dune binder and tauhinu and the shore convolvulus are also common. The planting of marram grass associated with dune fixation has driven out the native binders and collectors, and increased stability has allowed many introduced xerophytic plants to grow among dunes sometimes quite close to the sea. A great variety of introduced plants has mingled with the natives in the dune hollows and moist flats, and marram grass is the dominant binder. Haresfoot trefoil is common on dunes well fixed with marram. The dandelion, yarrow, thistles, silver poplar, barren brome and English hairgrass are growing in sheltered dune hollows. Yorkshire fog, sorrel and clovers are present in damp hollows. The ice plant is common about New Brighton.

On stable dunes which are not covered with houses or trees, there is a dense cover of scrub. The

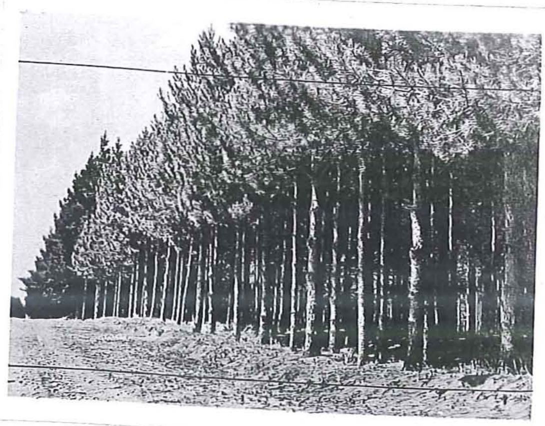

Fig. 39. PINUS LARICIO TWENTY-TWO YEARS AFTER PLANTING, BOTTLE LAKE PLANTATIONS.

The Pinus radiata in the background though the same age, are almost twice as high.

native scrub association has given place to a mixed scrub consisting of the introduced lupin and gorse, and broom and bracken. Lupin is most common. Under the pines in the plantations there is little growing except for a few colonies of bracken and broom. The grass Yorkshire fog forms a close carpet in some of the sheltered open spaces within the plantations.

<u>Afforestation:</u>

There are approximately 2,500 acres of pines at Bottle Lake, and 130 acres in small blocks at New Brighton and South Brighton. The City Council plantations at Bottle Lake have been extended to more than 2,000 acres by purchase of land during the last 18 years. Smaller blocks of pines fringe the plantation to the west and south. In the north-west there is a small privately owned block. In the south-west about the Burwood Hospital is the Hospital Board plantation of 150 acres. To the south-east is a block of 70 acres leased by the Canterbury Education Board.

<u>P. radiata</u> is the dominant tree, though some other varieties are present. In the Council plantations there are small blocks of <u>P. ponderosa</u>, <u>P. pinaster</u>, <u>P. laricio</u> <u>P. muricata</u>, <u>P. austriaca</u>, and some <u>Cupressus macrocarpa</u>. Under the cover of the pines the sand has become completely stabilised. The dunes have flattened and smoothed out till

they remain only as slight undulations in the surface. Beneath the trees, pine needles have accumulated and a layer of dark humus covers the sand.

After the trees have established themselves in the newly consolidated sand, they are thinned out at 15 feet, to 200 trees per acre, and kept pruned until ready for milling. The fast growing P. radiata is ready for milling when it is between 28 and 30 years old. The thinnings are sold for firewood and the trees are sold standing on a royalty basis. The contractor is obliged to clear the milled area and leave it ready for re-planting.

During the last nine years, as more trees have reached maturity, the revenue of the Council plantations has considerably exceeded expenses. In 1918 some very optimistic reports were made concerning the future economics of the plantation. It was estimated that in fifteen years the trees would be worth £800-£1,000 an acre, bringing in an income of about £50,000 per annum for many years. This was obviously an overestimate, even though P. radiata which was once considered only suitable for box-making, is now being used for some building purposes. That the growing of pines on the dunes is a profitable venture is illustrated by the following statements:-

\+ "Last year (1945)......... a few acres of standing *Pinus radiata* sold on a royalty basis of 6s 6d a hundred superficial feet, netted £260 an acre - quite good for trees not more than 28 years old."

"Two *Pinus radiata* .... estimated at 53 years old, yielded about 8,000 superficial feet of timber, which sold, in log lengths on the ground, at 9s a hundred feet and produced a revenue of £32."

"Some straight clean macrocarpa........ yielded excellent timber which is now being used for building and has been pronounced as good as rimu."

This last statement is of special interest as it illustrates the timber potential of the dunes. Macrocarpa is not suitable for planting in freshly stabilised sand, but would probably thrive in areas a little distance from the sea, which have been stabilised with *P. radiata.*

The Effect of Close Settlement:

The southern portion of the area was developing as a seaside resort and residential district within forty years of the Canterbury settlement. Houses were first

\+ Barnett, M.J.: The History and Development of Tree Planting in Canterbury.

built at New Brighton, and the township extended along the coast to include North and South Brighton. With the spread of Christchurch the township has become a city suburb, and in 1941 it was amalgamated with the city. From Waimairi Beach to within 1½ miles from the end of the estuary spit to the south there is almost continuous settlement. There are some holiday baches, but the greater number of the houses are permanent residences.

The dunes have been stabilised and made productive by the labour of residents in their gardens. Each gardener has spent some years in converting the top layer of sand into loam. When a new section is occupied it is sown with lupin to establish a more fertile soil. All manner of waste and compost is added to the sand. Under these intensive methods, the dunes have been flattened and the sand has been covered with a layer of light soil, in which vegetables and flowers can be grown. Houses and fences have acted as windbreaks, and surface instability is no problem, except in a few neglected sections, and then never on a wide scale. In most unoccupied sections there is a dense growth of lupins, seeded from neighbouring gardens.

Some large areas have been grassed. On the Waimairi Golf Links and the Rawhiti Domain and Golf Links, the sandy waste of lupin, broom and gorse was cleared, levelled and covered with a top soil before being sown. Yarrow grass, brown top, chewings fescue and twitch, all

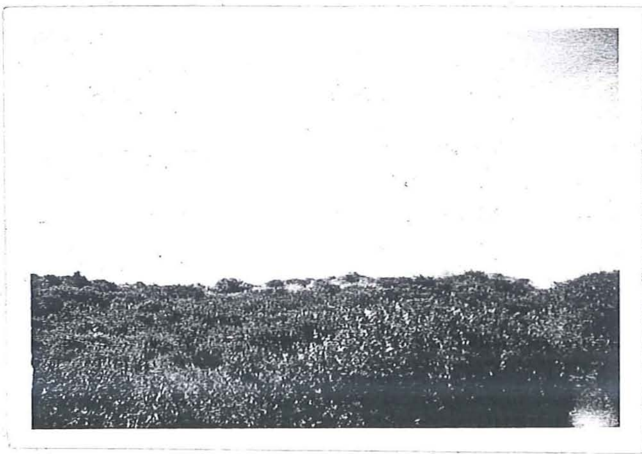

Fig. 40. SCRUB COVERED DUNES, BROOKLANDS.

good grasses on a dry hungry soil, were used to form a turf. In some cases a turf was brought from other parts and laid. Constant attention is needed to heal any opening in the sward.

Scrub:

Scrub-covered dunes are a common feature. All well stabilised dunes if untouched will eventually be covered with lupin, broom, gorse and bracken. The dunes are well fixed, but largely unproductive. There are many small areas, but three major regions can be distinguished. The dunes between the Lower Styx Road and the Waimakariri River estuary were first stabilised with marram grass, and there is now a cover of scrub. The dunes are low as there is not a considerable accumulation of sand. Much of the sand that is deposited on the estuary spit is carried by the wind into the estuary and this surface, when not covered with tidal water,is moist, and little loose sand moves inland.

South of the Council plantations, between the block of pines about Burwood Hospital and the Waimairi Golf Links is another area of scrub. This is the only part of the seaward dunes still grazed. There is very poor foraging among the scrub for only a few cows. The passage and pasturage of cattle is thinning out the scrub. In some open patches the sand is bared to the wind and there is a little movement.

Fig. 41. MARRAM GRASS

The plant is accumulating a small knoll of sand.

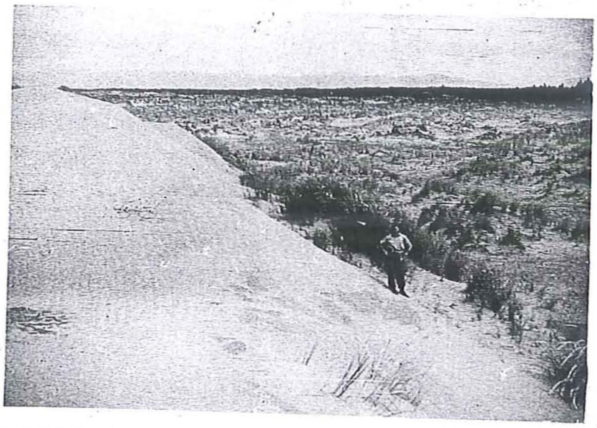

Fig. 42 DUNES PLANTED IN MARRAM GRASS BEHIND THE FOREDUNE, BOTTLE LAKE AREA.

The steep leeward slope of the foredune in the foreground, and the typical hillocky landscape behind.

Fig. 43. YOUNG PINUS RADIATA RECENTLY PLANTED BEHIND THE FOREDUNE, BOTTLE LAKE AREA.

The spit of the Avon and Heathcote River estuary is in many parts covered with scrub. There is a thick growth of introduced grasses on the damp flats, sufficient to graze a horse in one area.

Marram Grass:

The dunes between the Bottle Lake plantations and the artificial foredune were planted in marram in 1940, and there has been as yet no growth of scrub. With the exception of an area to the north, the foredune completely protects these dunes from invasion by sand. As the sand blown in from the shore is now retained by the foredune, there has been an acceleration in the rate of progradation. In 1930 the high tide mark in many places was several chains inside the present line of the foredune. With the growth of the dune and the straightening of the coastline, sand which was formerly carried inland is now built into the dune. The slope between the shore and the foredune has thus been built up till today, the high tide mark is now some 50 yards from the foredune.

Behind the foredune, a hummocky landscape has developed with the growth of marram grass. Each plant has accumulated sand till a small knoll has been formed. In an exposed position these knolls might be scoured by wind, but with the protection of the foredune to windward, wind erosion is not serious. To ensure complete fixation, *P. radiata*

Fig. 44. THE END OF THE FOREDUNE SOUTH OF SPENCER PARK.

In the foreground the sand is moving inland unchecked. In the background behind the established foredune, marram grass covers the dunes.

Fig. 45. DUNES PROTECTED BY THE FOREDUNE.

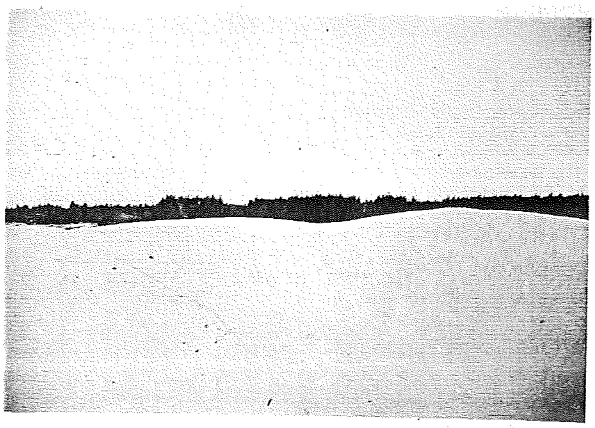

Fig. 46. UNPROTECTED DUNES.

Wandering dunes moving inland.

were planted out among the dunes in 1946, and a fair proportion should survive. As yet they have barely established themselves, but in another year they should be thriving. In the salt-charged air so close to the sea, the trees will probably be stunted, but with their growth, the sand will be further stabilised. As a protective belt of these pines becomes established along the frontage of the plantation, and with the protection of the foredune to windward, the dunes should be permanently fixed.

Unstable Dunes:

The construction of the northern part of the foredune just south of Spencer Park, was not commenced until 1939. At that time, as there was no protection from the easterly winds, wandering dunes were moving into the north-eastern corner of the plantations. There was such a considerable movement of sand to check that it was necessary to construct two fences parallel to each other, about twenty yards apart, to ensure a successful artificial dune. During the war, as the area was considered of strategic importance, work on the series of fences was discontinued. The fence was destroyed by army bulldozers and the dunes behind were also flattened, removing what little vegetation was already established. Today the area stands out in sharp contrast

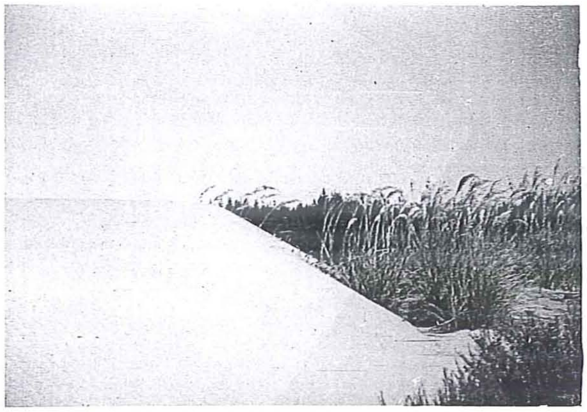

Fig. 47. WANDERING DUNE MOVING INTO SCRUB.

Note the sharp crest and steep leeward face of the dune.

Fig. 48. WANDERING DUNE MOVING INTO A BLOCK OF FIVE-YEAR OLD PINUS RADIATA.

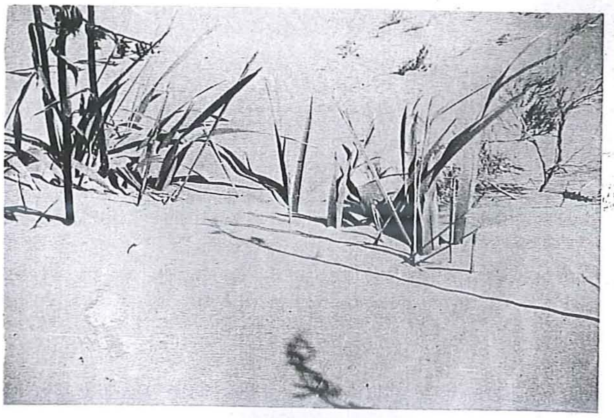

Fig. 49. THE TOPS OF SMOTHERED FLAX AND MANUKA BUSHES SHOWING ABOVE THE DUNE.

to the dunes behind the established foredune.

The broken fences have been completely covered with sand, and there is no check to the wind as it moves the sand in from the shore. The unprotected dunes are in constant motion. There are large wandering dunes moving inland. The flat surface is only broken here and there by a knoll of vegetation or a wind trough. The dunes have the full power of the wind developing over the smooth surface behindtheir advance. In 1942 a block of P. radiata was planted in the northern corner of the plantation, and these, though now twelve feet high, are being invaded and smothered by the dunes. When the trees were planted the nearest dunes were approximately seventy yards away, separated from the young trees by a growth of flax and manuka. Only the dead tops of these bushes now show above the advancing dune.

The few patches of pingao or marram grass that still exist are being destroyed, not by drifting sand, but by the erosion of the wind. The plant soon raises a knoll of sand, and the accumulation of sand accelerates its growth. The knoll becomes of such proportions that it constitutes a solid obstacle to the wind. With the developmeht of an eddy at the base, a trough is formed and the wind velocity expends itself at the base and sides. Wind scouring increases till the plant is undercut and it dies. When two plants are raised, the wind scours through the valley in between

Fig. 50. PINGAO PLANTS ON MOVING SAND

Fig. 51. SAND ACCUMULATING ABOUT THE PLANT

Fig. 52. AN EARLY STAGE IN WIND SCOURING. A trough has been formed at the base of the hillock.

Figs. 50-55. WIND SCOURING OF PLANTS IN EXPOSED DUNE LOCATIONS.

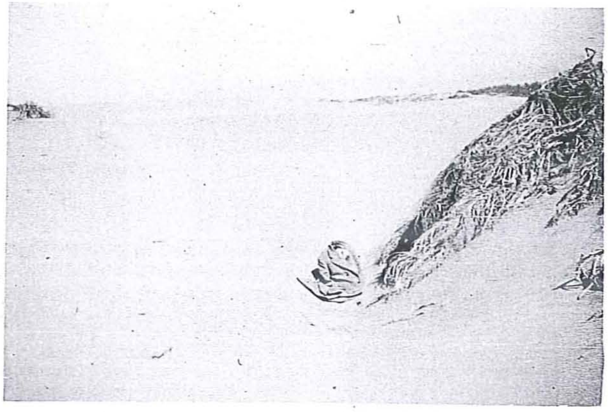

Fig. 53.

Fig. 54 LATER STAGES
The upstanding hillock is open to wind erosion.

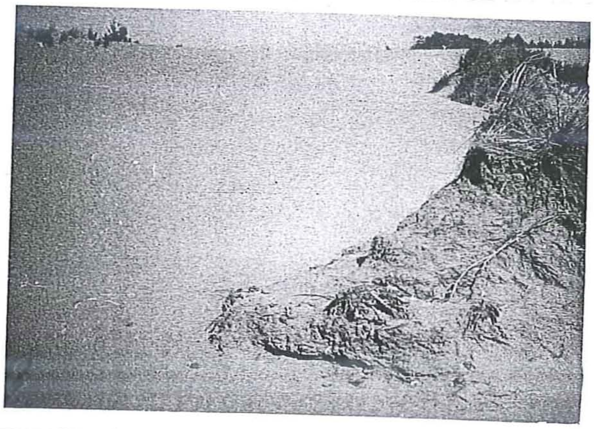

Fig. 55. LAST STAGE
The wind is eating into the hillock at the base and sides, and the plant at the top will soon be undercut.

and cuts into the knolls at the sides. If the sand binding plants formed a close enough cover, with some protection to windward such erosion would not be so active. On these sparsely vegetated dunes, with no protection to windward, the growth of sand binders is increasing the erosive power of the wind, and eventually causing their own destruction. Artificial fixation with marram grass is necessary, and if the foredune were extended to cover the area, the sand would eventually be stabilised.

The sand is also unstable behind the foredune in a small privately owned block one mile north of Waimairi Beach. The dunes have not been planted in marram grass, but as the foredune is holding the sand blown in from the shore, some marram and lupin have established themselves. These plants are checking wide scale movement into the plantations, but the planting of marram grass would ensure stability.

On the estuary spit in the south, dunes near the sea are still in motion. The artificial foredune is not continued past South Brighton, and there has been no marram planted. The natives pingao, tauhinu and the shore convolvulus are the most common dune plants. Pingao growing on the beach is building small dunes and a natural foredune is growing, but as yet it affords little protection. In the extreme south some dunes twenty feet high are advancing into scrub. However the southerly winds have a clear approach over the estuary, and as the effects of the easterlies and southerlies are here more closely balanced, most dunes are low, of complex shapes, and moving in different directions. There is a more common tendency to move with the easterly winds.

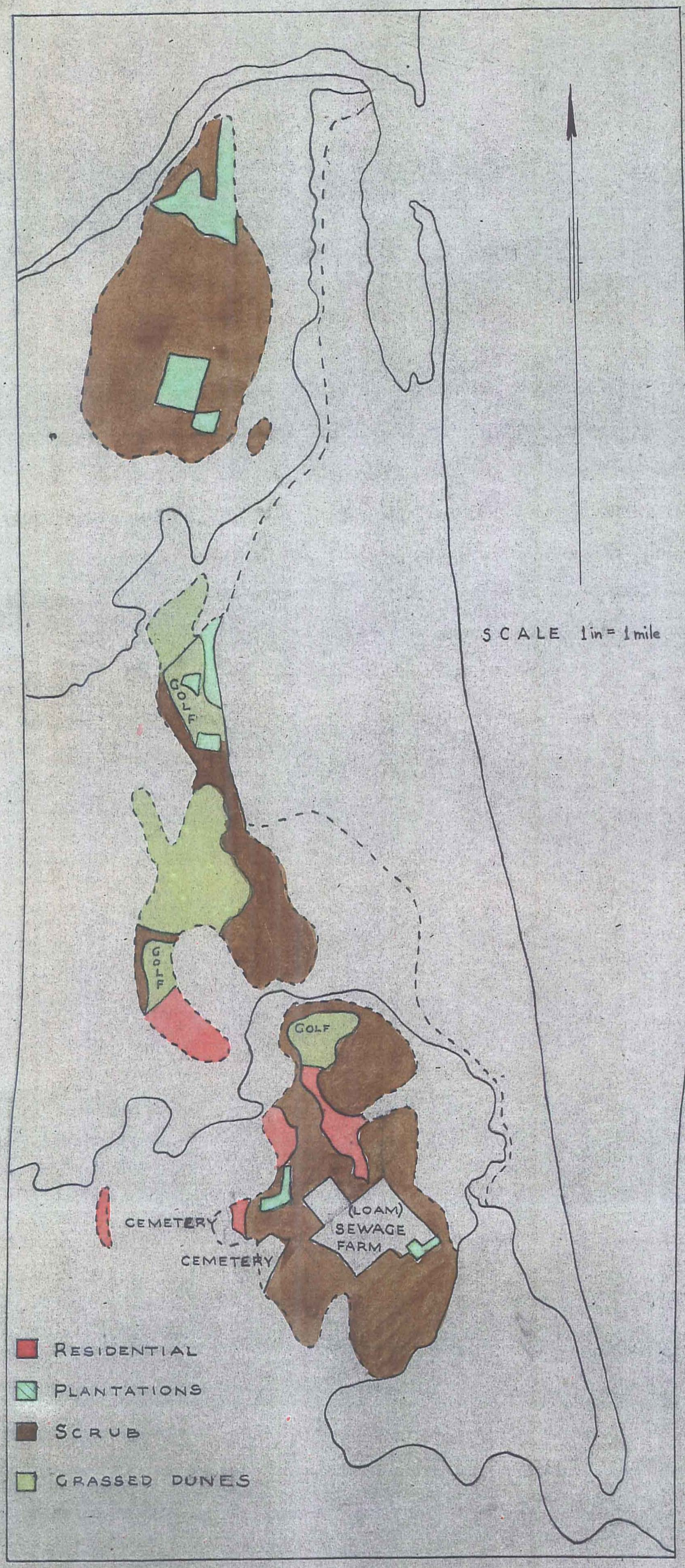

Fig. 56. UTILISATION OF THE INNER DUNES.

CHAPTER 6

THE UTILISATION OF THE INNER DUNES

The inner dunes are separated from the seaward dunes by a drained swamp. As the dunes are of ancient origin, a close cover of vegetation had consolidated the sand before the settlement in 1850. With any deterioration of the surface cover, though the sand may be bared, the vegetation will soon re-establish itself if given the opportunity. The natural vegetation of manuka, broom, wild irishman, and tussock has been replaced by numerous introduced plants. Among these, lupin, broom and gorse scrub are dominant. The continuity of the inner dune belt is broken in two places by the narrow flood plains of the Styx and the Avon Rivers, which divide it into three separate blocks. The first between the Styx and the Waimakariri Rivers; the second between the Styx and the Avon Rivers; the third between the Avon River and the estuary to the south. Interspersed among the dunes are extensive areas of flat loamy ground.

North of the Styx River, apart from two pine plantations, the dunes are scrub covered. They are in some cases grazed with cows from the dairy farms situated on the

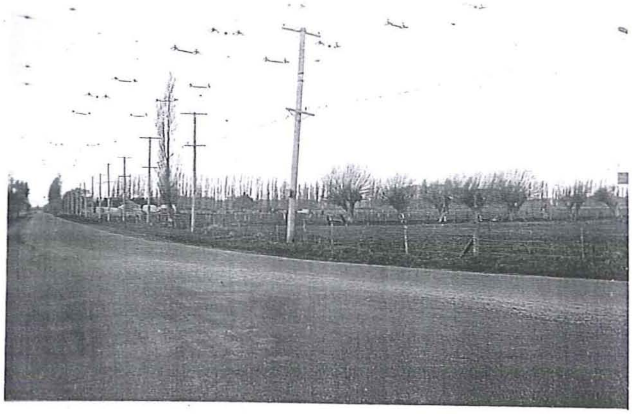

Fig. 57. DRAINED SWAMP SEPARATING THE INNER DUNES FROM THE SEAWARD DUNES; NORTH BRIGHTON.
In winter, this area is often under water.

Fig. 58. THE LANDWARD MARGIN OF THE INNER DUNES, BROMLEY.
To the left of the road - dunes, Bromley Cemetery.
To the right of the road - flat loams, swampy in parts.

low-lying land to the east and west, and among the dunes. South of the Styx River, about the outskirts of Christchurch, the pattern of land use becomes complex and diversified. Small dairy farms and market gardens are located on the loams among the dunes. In a few instances, grass has been sown on dunes which now support reasonably heavy stocking. Settlement becomes closer, merging into the outer suburbs of the city. Tillage is restricted to house gardens. Farm houses are often situated on dunes overlooking the low-lying dairy farms. In most cases however, the dunes are covered with scrub among which there is some foraging for stock.

Afforestation:

Small plantations, some privately owned, are scattered through the area. The two largest blocks are at Stewarts Gully and Chaneys. The plantations at Stewarts Gully are of *P. radiata*, 18 and 12 years old. Prior to planting, the dunes were covered in dense gorse scrub, and the sand was well consolidated. At Chaneys, the pines have been planted by the Christchurch City Council. A block of 1100 acres of dunes between Chaneys and Stewarts Gully was granted to the city in 1880 for use as cattle yards, abbatoirs and sewage disposal. As it was not required for these purposes, the land was leased out and grazed with sheep. The vegetation of native tussock, scrub, and introduced grasses became so seriously depleted, that in places the bared sand

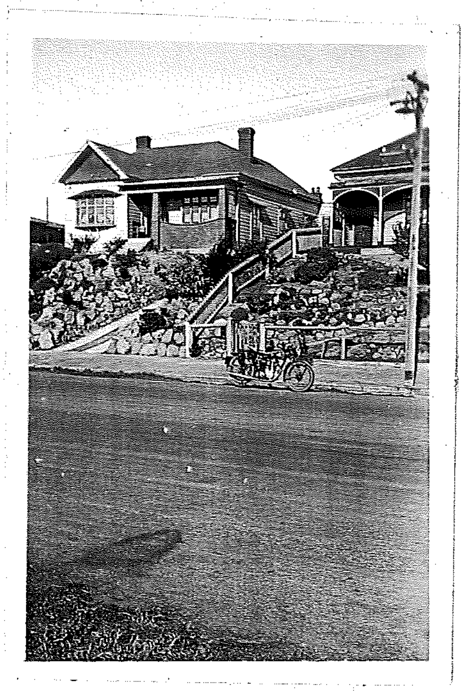

Fig. 59. HOUSES ON OLD DUNES,
LINWOOD.

was in movement. In 1938 the City Council adopted a policy of taking 100 acres a year from the lease, to plant in P. radiata. Though much of the vegetation had been removed, there was no large-scale movement as at Bottle Lake. The task of planting was much simplified, and there are now 300 acres of young pines. A shortage of labour has prevented the extension of the plantation.

Residential:

The suburbs of Christchurch are spreading over the dunes at Bromley, Aranui, and Burwood. It is perhaps preferable that the city should expand to the east, into this less valuable land, than to the west into high class farming land. Much the same process is operating as at New Brighton, but the more stable sand can be made fertile in a very short time. The remnants of an older dune ridge are still evident at Linwood, a suburb nearer the city centre. The long established suburban settlement has obscured the original outline of this ridge, but in places houses stand on dunes some 10 feet to 20 feet above the road.

Scrub:

As amongst the seaward dunes, scrub has invaded waste areas, and among the inner dunes is areally the major dune cover. The sand is consolidated beneath the scrub,

Fig. 60. AN ISLAND OF GRASS IN A SEA OF SCRUB.
One of the small dairy farms on the outskirts of Christchurch. Tha small flat among the dunes has been cleared, grassed, and now carries stock.

Fig. 61. GRASSED DUNES, BURWOOD.
Gently undulating dunes now covered with a firm sole of pasture.

Fig. 62. CHANEYS AREA.
Overgrazing bared the sand and caused instability ten years ago, but with the removal of the stock, scrub has returned. When labour is available, this area will be afforested.

and in most cases, is under a layer of accumulated humus. A few dairy farmers have enlarged their grazing by clearing the scrub and sowing grass, but the firm sole of pasture must be maintained to cover the sand and to prevent the return of of the scrub weeds. The expense and labour involved in such improvement has largely proved too much. Most dunes are left in scrub and cattle occasionally forage amongst the bushes. This intermittent grazing has caused no instability of consequence. Even between Chaneys and Stewarts Gully, where ten years ago there was some instability, the removal of the sheep has allowed the scrub to re-cover the dunes, and there is at present a dense covering of scrub. In the inner dune belt there is little danger of mass instability, but at present these large areas of scrub are virtually waste.

CONCLUSION

The coastline is prograding as sand carried into the sea by the Waimakariri River is being thrown up on to the shore. With this advance, the coastal area has developed a distinctive topography consisting of two major dune ridges separated by a swamp. A similar sequence of foredune and swamp existed within the major dune ridges which have been moulded by the wind into a complex of dunes, dune hollows and swamp. The prevalent onshore wind carried the sand inland, until the drift was halted by the growth of vegetation. Prior to interference by white settler and introduced animal, the natural vegetation of the dunes was well suited for its task of first fixing, and then covering the sand with a protective layer of humus. The growth of each species paved the way for a more varied plant association. Unwise utilisation, as in many other similar parts of New Zealand, has caused an inland drift of sand which is now checked.

The effect of and problems attendant on occupation can be considered from three major aspects as illustrated in the region; close settlement, afforestation and grazing. The township of New Brighton is expanding along the coast, and city suburbs are extending eastwards on to the dunes. Such settlement has rapidly consolidated the sand even close to the sea. Protective works have been necessary on the beach to prevent sand moving into the built up districts.

The plantations at Bottle Lake show that even dunes exposed to seaward can be productive. The success of all schemes of improvement in such situations is dependent on shelter to leeward. Prior to the building of the foredune, there was considerable difficulty in stabilising the dunes. Today, the only major region of instability is without the protection of the foredune. It seems apparent that the construction of an artificial foredune and the stabilisation of the dunes adjacent to the sea should be a primary step in similar programmes of utilisation.

The planting of marram grass has been only an intermediate step towards productive utilisation, i.e., afforestation. Stability is permanent, as the regular alignment of pines, even when young, prevents the raising of plant hillocks of sand, open to wind erosion. With the accumulation of pine needles beneath the trees, a cover of loam is developing. Owing to the fast growth of P.radiata, afforestation becomes economic in a comparatively short time, but as the initial capital outlay is high, large scale planting seems a local body or state enterprise.

Continual grazing, especially of sheep, on dunes in an exposed location has caused instability and the subsequent mass inland movement of sand. Even on the more stable dunes at Chaneys, two miles from the sea, the grazing of sheep caused a serious deterioration in the plant cover, but in this case, with the removal of the stock, the scrub vegetation has returned. The only dunes that are reasonably productive and still stable under stock are those that have been grassed. They are situated among the inner dunes.

It appears that the development and maintenance of a close grass cover should be an essential pre-requisite to successful grazing. The seed can be sown on a slightly stirred surface in the winter months. A suitable basic grass would be subterranean clover, and thus initial growth is assured when weather conditions are unfavourable for instability. +Saxby has shown by his experiments in Otago, that a mixture of grasses like Yorkshire fog, cocksfoot and sorrel, associated with heavy phosphatic manuring, can gain a foothold. There should be no grazing for at least a year, while the grasses become established and form a close sward. Thereafter the dunes should be grazed only in the winter months, when any openings in the grass sole will be less

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+ Saxby, S. H.: The Grassing of Maritime Dune Country in Otago.

liable to spread. Cattle are preferable to sheep as they would help to consolidate the sand underneath.

The possibility of the successful grazing of dunes under these conditions is dependent on the degree of exposure to wind force. In the seaward dunes this is a critical factor. Shelter from the wind and careful maintenance would be essential, as even small openings in the sward might result in movement. Grazing would be possible behind the shelter of pine plantations, or within open spaces among the trees. On the inner dunes however, many of the areas now covered with scrub could be cleared and sown. The juxtaposition of swamp and dunes makes a cattle grazing rotation possible. The dunes could be grazed in winter when the low-lying land is often under water, and rested in summer when the cattle are moved on to the flats.

In the region studied, there is some scope for more efficient utilisation. Afforestation could be extended to occupy many of the waste scrub dunes, especially among the seaward dunes and among the inner dunes to the north. About the outskirts of Christchurch, many of the scrub dunes could be cleared and grazed in conjunction with the dairy farms already established on the loam flats. In New Zealand there are today large areas of coastal dunes. Many of these regions are considered as waste, to be ignored if they provide no threat to better land. Schemes of improvement, aiming first at fixation and then at productive utilisation are possible, especially if once again there is a supply of idle labour as in the 1930's.

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