

The geomorphology and radar facies of Kaitorete Spit, Canterbury,
New Zealand.

A thesis
submitted in partial fulfilment
of the requirements for the Degree
of
Master of Science in Geology
in the
University of Canterbury
by
Matthew Paul Andrew Holmes

University of Canterbury

1998



“Kaitorete”

Abstract

Kaitorete Spit is a mixed sand and gravel barrier beach complex that is located at the northeastern end of the Canterbury Bight. Kaitorete Spit was examined during this study using a combination of ground penetrating radar surveys, sedimentological and geomorphological examinations of the barrier beach complex.

The geomorphology formed on Kaitorete has developed in three different environments. At the northeastern end of Kaitorete low elevation spit recurves are formed. South of these are numerous parallel beach ridges, formed by the tops of prograded storm berms. Lacustrine geomorphic features have developed over the marine geomorphology. Small scale cusped ridges have formed in shallow lake water and associated with lake bottom sediments. Lacustrine beach ridges, lacustrine beach ridge plains and lacustrine spit complexes all formed along the shore of a higher lake.

Nine different radar facies were found developed in the radar profiles collected on Kaitorete Spit. The facies are defined on the basis of their internal reflector patterns. Generally, the reflector patterns could be predicted by interpreting the geomorphic features over which the radar profiles ran. Three of the radar facies revealed reflector patterns that could not be predicted using geomorphology alone.

At the eastern end of Kaitorete Spit, the radar profiles revealed that the marine spit recurves comprise a spit beach overlying a spit platform. It also reveals that the distal end of the spit platform was reworked by tidal currents into a series of seaward prograding foresets. The radar profiles also revealed that immediately the barrier beach reached the edge of the spit platform, a rise in the elevation of the beach crest occurred due to an increase in the wave energy expended on the beach.

In the centre of the barrier beach complex the radar profiles revealed that two long overwash barriers developed, which fill two long (up to 12 km), thin lake outlet lagoons. These lagoons developed as a result of breaching due to a large river overflowing the lake basin. After the initial breach, the longshore drift and lake outflow developed a dynamic equilibrium, resulting in the progressive eastward dislocation of the outlet mouth. The large volume of lake water acted to buffer the high flows of the river thereby, maintaining flow conditions at the outlet channel which were conducive to lagoon elongation.

Associated with the lacustrine spit complexes are scarp-like ridges which have steep reflectors which dip away from the lake. These developed in a similar way to shore-parallel bars, with material moving up the stoss side and avalanching down the lee side.

The combined application of ground penetrating radar and geomorphology reveals a much more complete geological history of an area where outcrop is sparse.

1. INTRODUCTION.....	1
1.1 STUDY AIMS.....	1
1.2 STUDY AREA.....	1
1.3 CLIMATE.....	3
<i>1.3.1 Vegetation.....</i>	<i>3</i>
<i>1.3.2 Regional Geology.....</i>	<i>4</i>
<i>1.3.3 Human Modification.....</i>	<i>6</i>
1.3.3.1 Pre–European Modification.....	6
1.3.3.2 Post–European Modification.....	8
1.4 PREVIOUS WORK.....	9
1.5 SAMPLE LOCATIONS.....	11
1.6 NOMENCLATURE.....	11
1.7 THESIS STRUCTURE.....	12
2. METHODOLOGY.....	14
2.1 BASEMAP PREPARATION.....	14
2.2 AERIAL PHOTOGRAPHIC INTERPRETATION.....	14
2.3 GROUND PENETRATING RADAR (GPR).....	16
2.4 SAMPLING STRATEGIES.....	17
<i>2.4.1 Radar Data Collection.....</i>	<i>18</i>
<i>2.4.2 Velocity Calculation.....</i>	<i>19</i>
<i>2.4.3 Ground Penetrating Radar Validation at Browns Pit.....</i>	<i>20</i>
2.4.3.1 Browns Pit West Wall.....	22
2.4.3.2 Browns Pit South Wall.....	25
<i>2.4.4 Radar line assembly.....</i>	<i>26</i>
<i>2.4.5 Topographic Correction.....</i>	<i>26</i>
<i>2.4.6 Interpretation.....</i>	<i>27</i>
<i>2.4.7 Chapter Summary.....</i>	<i>27</i>
3. OBSERVATIONS.....	28
3.1 GEOMORPHOLOGY AND SEDIMENTOLOGY.....	28
<i>3.1.1 Lacustrine Depositional Setting.....</i>	<i>28</i>
3.1.1.1 Modern Lakeshore.....	28
3.1.1.2 Taumutu Ridges.....	33
3.1.1.3 Dune Ridges.....	36
3.1.1.4 Ponds.....	38
3.1.1.5 Bayleys Ridges.....	40
3.1.1.6 Island.....	43
3.1.1.7 Speight Ridge.....	45
3.1.1.8 Trig Point Ridges.....	51
3.1.1.9 Golf Course Ridges.....	51
3.1.1.10 Railway Cutting Ridges.....	54
3.1.1.11 McIntosh Ridges.....	56
3.1.1.12 Birdlings Ridges.....	56
<i>3.1.2 Marine Geomorphology.....</i>	<i>57</i>
3.1.2.1 Marine Spit Ridges.....	57
3.1.2.2 Preserved Beach Geomorphology.....	58
3.1.2.3 Modern Beach Geomorphology.....	62
3.1.2.4 Overwash Barriers.....	64
<i>3.1.3 Drill Hole Data.....</i>	<i>66</i>
3.2 GROUND PENETRATING RADAR.....	70
<i>3.2.1 Regional Lines.....</i>	<i>70</i>
3.2.1.1 Kailine 5.....	70
3.2.1.2 Kailine 2.....	72
3.2.1.3 Kailine1.....	76
3.2.1.4 Kailine 3.....	78
3.2.1.5 Kailine4.....	81
<i>3.2.2 Smaller Selected Lines.....</i>	<i>83</i>
3.2.2.1 Transgressive Barrier.....	83
3.2.2.2 Dune Ridge.....	83

3.2.2.3 Ponds	85
3.2.2.4 Island	89
3.2.2.5 Trig Point.....	91
3.2.2.6 Jones Pit.....	93
3.2.2.7 Birdlings Valley Ridges.....	96
3.2.2.8 Browns Pit	96
3.3 CHAPTER SUMMARY	98
3.3.1 Geomorphology	98
3.3.2 Radar Facies.....	99
4. INTERPRETATION	101
4.1 GEOMORPHOLOGY.....	101
4.1.1 Marine Geomorphology.....	101
4.1.1.1 Hooked Ridges.....	101
4.1.1.2 Marine Beach Ridges.....	102
4.1.1.3 Overwash Barriers	103
4.1.2 Lacustrine Geomorphology	104
4.1.2.1 Lake bed.....	104
4.1.2.2 Lake Edge.....	105
4.2 RADAR PROFILES.....	109
4.2.1 Radar Facies Interpretations.....	109
4.2.2 Regional Lines	111
4.2.2.1 Kailine 5.....	112
4.2.2.2 Kailine 2.....	112
4.2.2.3 Kailine 1.....	115
4.2.2.4 Kailine 3.....	115
4.2.2.5 Kailine 4.....	117
4.2.3 Smaller Selected Lines	117
4.2.3.1 Transgressive Barrier	117
4.2.3.2 Dune Ridge	118
4.2.3.3 Ponds	118
4.2.3.4 Island	119
4.2.3.5 Trig Point.....	120
4.2.3.6 Jones Pit.....	121
4.2.3.7 Birdlings Ridges	122
4.2.3.8 Browns Pit	123
4.3 CORRELATION BETWEEN RADAR LINES.....	123
4.4 CHAPTER SUMMARY	127
4.4.1 Geomorphology	127
4.4.1.1 Marine Geomorphology.....	127
4.4.1.2 Lacustrine Geomorphology	127
4.4.2 Radar Facies.....	128
5. SUMMARY AND CONCLUSIONS.....	130
5.1 PRINCIPLE RESULTS	130
5.2 SYNTHESIS.....	132
5.2.1 Marine Development of Kaitorete Spit and Waihora Estuary.....	132
5.2.2 Formation of Barrier Beach and Lake.....	133
5.2.3 Development of Lake Ellesmere/Waihora.....	134
6. ACKNOWLEDGEMENTS.....	137
7. REFERENCES	138
8. APPENDICES.....	142
APPENDIX A SURVEY DATA.....	142
APPENDIX B CMPS	184
APPENDIX C HEADER FILES	225
APPENDIX D RADAR STATION SPACING CALCULATION.....	250
APPENDIX E PIT AND DRILL HOLE LOGS	251

APPENDIX F SHELL PHOTOGRAPHS	265
APPENDIX G AERIAL PHOTOGRAPH INFORMATION.....	271

Figure 1-1. Location Diagram of Kaitorete Spit.....	2
Figure 1-2. Figure showing parallel (A) and prograding (B) seismic reflector configurations. C shows the terminology for unconformable boundaries in a depositional sequence.	12
Figure 2-1: Figure showing the placement of interpretation lines on the marine and lacustrine geomorphology on Kaitorete Spit.	15
Figure 2-2. Figure showing the basic theory of GPR.	16
Figure 2-4. Figure showing the process of obtaining a CMP profile and a resulting profile.	19
Figure 2-3. Photograph of the ground penetrating radar in operation.....	21
Figure 2-5. Photograph of Browns Pit looking southwest from the top of Devils Knob.....	21
Figure 2-6. Photograph of the sedimentary structures in the west wall of Browns Pit.....	23
Figure 2-8. Photograph of the structures revealed in the south wall of Browns Pit.....	23
Figure 2-7. (Above) Radar profile situated c. 30 m west of Browns Pit western wall.	24
Figure 2-9. (Below) Radar profile taken south of the southern wall of Browns Pit.	24
Figure 3-1. Photograph showing the poor preservation of the estuarine shells on the mud bank at the west end of Kaitorete Spit (M37 619 074)	30
Figure 3-2. M37 619 074. Photograph of the shell layer in finely laminated muddy very fine sands.	30
Figure 3-3. M36 766 101. Sinuous small scale ridges developed on the lake floor.	32
Figure 3-4. South facing wall of large pit at M36 768 102.	32
Figure 3-5. Photograph of a section of the truncation developed in the well bedded gravels in the pit at M36 768 102.	34
Figure 3-6. Photo of the Taumutu Gravel Pit south wall showing eastward dipping sandy gravel layers which downlap a series of horizontal beds of sand and gravel.....	34
Figure 3-7. Photograph looking southeast at M37 626 063.....	37
Figure 3-8. Photograph at M37 626 063 taken looking west from the top of the overriding dune shown in figure 3-7.....	37
Figure 3-9. Photograph taken looking west across one of the depressions in the Ponds area.....	39
Figure 3-10. Photograph looking east showing the northern bounding ridge mantling a group of parallel curvilinear ridges at M37 656 073 in the Ponds area.	39
Figure 3-11. Photograph looking southwest at the rounded terminations of a group of parallel curvilinear ridges at M37 655 073 in the Ponds area.	41
Figure 3-12. Smaller scale rounded terminations of a group of parallel curvilinear ridges, in the Bayleys Ridges South area.	41
Figure 3-13. Photograph taken from M37 682 078 looking northeast at the plateau in the Island area. .	44
Figure 3-14. M37 682 080. Looking southeast at two small ridges in the northwest corner of the Island group.....	44
Figure 3-15. M37 695 081. Speight Ridge looking west, note the lack of ridge form.....	46
Figure 3-16. M37 758 094. Looking north, at the round terminations of some of the small, Speight Ridge subparallel, ridges.	46
Figure 3-17. M37 758 094. Speight Ridge looking west at southern margin of subparallel ridges.	48
Figure 3-18. M37 786 099. View looking west along the southern scarp-like face of Speight Ridge where it joins Trig Point Ridges.	48
Figure 3-19. M36 806 103. View looking west at the intersection of Speight Ridge and a marine barrier beach ridge.....	50
Figure 3-20. M36 824 105. Looking west along the southern margin of Speight Ridge.	50
Figure 3-21. M37 786 099. Looking east over the Trig Point Ridges.	52
Figure 3-22. M37 785 097. Photograph looking east over the Trig Point Ridges.	52
Figure 3-23. (Above) M36 838 106. A view west across the Golf Course Ridges, notice the curving ridge crests cutting across the picture.....	67
Figure 3-24. (Left) M36 854 110. Photograph looking east along the southern wall of Birdlings Valley. 55	55
Figure 3-25. (Above) M36 854 110. Photograph looking north across Birdlings Valley.....	55
Figure 3-26. M37 868 097. Looking south along the cliff which terminates the marine barrier beach ridges at their eastern ends.	59
Figure 3-27. M37 827 098. A view looking north at the subtle horn and cusps (marked) developed near the Kailine 3 radar survey line.....	59
Figure 3-28. M37 866 088. Horn and cusps developed on the modern beach at Birdlings Flat.....	61
Figure 3-29. M37 837 087. A view looking east along the beach at the scientific reserve.....	61
Figure 3-30. (Left) M37 865 088. A close up view of the layering developed in the beach at Birdlings Flat.....	63

Figure 3-31. (Above) M37 837 087. This section of eroded horn was found at the beach near the scientific reserve..... 63

Figure 3-32. Truncated overwash bedding exposed in the west facing wall of the outlet to Lake Forsyth. 65

Figure 3-33. A closer look at the overwash bedding in the wall of an old outlet to Lake Ellesmere..... 65

Figure 3-34. (Above) M37 613 057. View looking eastward down Kaitorete Spit. 67

Figure 3-35. M37 610 058. Photograph showing impact damaged root end from an 'insitu' stump on the washover barrier which stretches between Taumutu and Kaitorete Spit. 68

Figure 3-36. Selections of Kailine 3 radar profile showing plot with trace differencing option turned on (left) and the same selection after migration at 0.13 m/ns also with trace differencing turned on..... 80

Figure 4-1. Kirk's 1983 descriptive model of lagoon/barrier processes at the Rakaia River mouth. 125

1. Introduction

Kaitorete Spit is located on the east coast of the South Island of New Zealand at the north-eastern end of the Canterbury Bight. It is centred about 172°33'E 43°50'30"N (Figure 1-1). Kaitorete Spit is a mixed gravel–sand barrier–beach complex that separates Lakes Ellesmere (Waihora) and Forsyth (Wairewa) from the Pacific Ocean. It stretches about 30 km from the small settlement of Taumutu (NZMS 260 M37 586053) to the south-western shore of Lake Forsyth (NZMS 260 M36 882107). At the Taumutu end it is approximately 200 m in width and widens along its length until it reaches about 3.2 km width approximately 7 km from its eastern-most point. The majority of the subdued topography developed on Kaitorete Spit is below 10 m in elevation. The sand dunes developed along the coastal margin rise up to a maximum of 20 m in some places.

1.1 Study Aims

During this study new data from ground penetrating radar (GPR) surveys is examined, as well as aerial photo interpretations, and field observations of subfossil and sedimentology data. Data from previous studies, in the form of borehole data, C¹⁴ dates and subfossil data, will also be examined. The aim is firstly to interpret the radar data and gain new insights on the sedimentary structures developed on Kaitorete Spit. Then secondly to combine this data to give a refined geological history of Kaitorete Spit. I hope to show that the combination of these methods can produce insights into the processes and geological development of an area where outcrop is sparse.

1.2 Study Area

The study area was restricted to the Holocene sediment along Kaitorete Spit, excluding the Tertiary Volcanics of Banks Peninsula (Figure 1-1). The study included some photo interpretation of the geomorphology around Taumutu as well as a Ground penetrating radar survey at the mouth of Birdlings Valley.

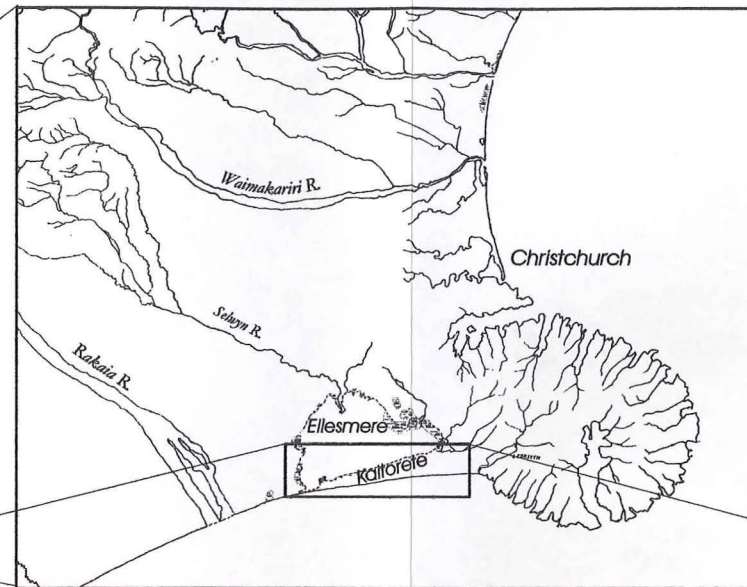
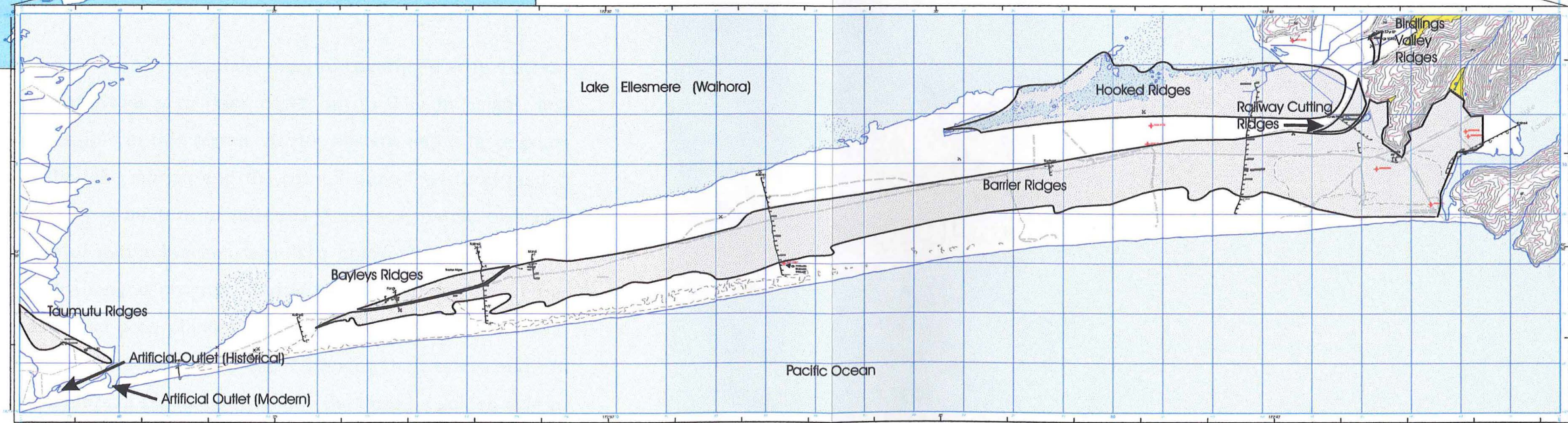


Figure 1-1. Location diagram of Kaitorete Spit. The right panel shows the location of the Canterbury Plains in New Zealand. The middle panel shows the major rivers of Canterbury, Lake Ellesmere and Kaitorete Spit are also shown. The bottom panel shows the location of various areas of interest on Kaitorete Spit itself. The greyed areas are geomorphic features that were named and described by Armon (1974). The small red dots are the locations of boreholes some of which have been discussed in other studies. Note the outlet to Lake Ellesmere, both the current one (Modern) and the outlet the Maori used (Historical). The rough black lines are the approximate locations of the radar surveys carried out during this study. (Figure compiled by H. Kellehan).



1.3 Climate

The coastal part of the Canterbury Plains that includes Kaitorete Spit receives a mean annual rainfall of around 510 mm/yr, mainly from the southerly storms (Mason et al., 1996). North-westerly storms produce high rainfalls in the Southern Alps and consequently high flows in rivers with their headwaters situated in the Alps (Leckie, 1994). During a southerly rain, the central two-thirds of Kaitorete Spit generally gets much less rain than the parts adjacent to the hills and Taumutu. This often allowed the collection of field data on days when it was raining hard in Christchurch.

The coastal region has three major strong wind directions: the south-westerly wind, the north-westerly wind and the north-easterly wind. The south-westerly wind tends to be the strongest and most predominant of the winds (Ryan, 1987). The north-easterly wind blows down Lyttleton Harbour and funnels over Gebbies Pass and out across Lake Ellesmere in a south-westerly direction, producing very strong local north-easterly winds at Motukarara (Mason et al., 1996). The shallowness of Lake Ellesmere means strong winds can cause the occurrence of set-ups in the lake. During the “Wahine” storm of 1968 a combination of very strong southwesterly winds and flood water combined to produce a mean rise of 2.17 m at the Kaituna end of the lake (Crawford et al., 1996).

1.3.1 Vegetation

Salt marsh ribbonwood grows along the lake margin, covering a strip 100 m–200 m wide. This shrub provides very thick cover, up to 2 m in height, and makes radar surveys impossible in this region. At the western end a large patch of flax grows. Between the lake margin and the coastal dunes, pastoral land is developed and is covered by a mixture of introduced grasses, native tussocks, sedges and a few patches of native bracken fern. The bracken patches in some areas are thick enough to impede progress during a radar survey. Numerous *Pinus radiata* windbreaks have been planted at fence lines along Kaitorete Spit, and a small block of *Pinus radiata* has been planted towards the western end. In the sand dunes, large amounts of pingao grow giving the dunes a golden colour.

The way in which the pingao grows means that radar surveys have to be carried out by lifting the antennae between readings. At the eastern end of the barrier-complex salt marsh ribbonwood grows in the swales formed during the development of Kaitorete Spit.

1.3.2 Regional Geology

At its eastern end Kaitorete Spit is attached to Banks Peninsula. The peninsula is formed from the remnants of two Miocene shield volcanoes (Weaver et al, 1990). Since the development of the volcanoes, erosion has greatly affected the landforms as evidenced by the drainage cut valleys, shore platforms, sea cliffs and sea stacks found all around the peninsula.

To the north the uplifted Mesozoic sandstone and mudstone sediments form the Southern Alps. The erosion of the Alps has provided the material from which the Canterbury Plains has been constructed. A combination of climatic fluctuations, resulting in glacial and interglacial periods, and tectonic uplift during the past 2.5 Ma led to the development of vast amounts of coarse grained sediment in the Southern Alps.

In the South Island there is evidence that the most recent series of glaciations began in the Pliocene. There is offshore drill hole evidence that since the Pliocene nine South Island glaciations have occurred during the past 700,000 yrs. Onshore landforms provide evidence for four glacial periods in the past 350,000 yrs (Table 1-1) (Suggate, 1990). The units formed during each glacial and interglacial have been assigned names from both outcrop studies and borehole studies.

The glacial periods were marked by the formation of extensive valley glaciers. As the amount of ice increased the global sea levels became lower. In areas which were not directly affected by glacier ice, frost-thaw action produced large amounts of scree which gravity dumped onto the surfaces of the valley glaciers adding to the lateral moraine.

Climatic Event (Suggate 1965 & 1985)	Formation Names (Wilson, 1988)	Years B.P. (Wilson, 1988)
Aranui Postglacial	Christchurch Formation Springston Formation	14,000 – 0 yrs B.P.
Otira Glaciation	Burnham Formation Riccarton Gravel	27,000 – 14,000 yrs B.P.
Kaihinu Interglacial	Bromley Formation	
Waimea Glaciation	Windwhistle Formation Linwood Gravel	70,000 – 40,000 yrs B.P.
Karoro Interglacial	Heathcote Formation	
Waimaunga Glaciation	Woodlands Formation Burwood Gravel	~ 150,000 yrs B.P.
Scandinavia Interglacial	Shirley Formation	
Nemona Glaciation	Hororata Formation Wainoni Gravel	~ 350,000 yrs B.P.

Table 1-1 Climatic Events of the late Quaternary and the Formations produced (After Moore and Weeber, 1996)

The glaciers produced plentiful meltwater which combined with the vast amount of moraine material led to the development of aggradational outwash fans. The aggradational fans reached their maximum size during the glacial maxima (Suggate, 1990). As the glaciers started to retreat, entrenchment in the upper aggradational fan surface started.

During the interglacial periods entrenchment continued as the glaciers melted and the sediment supply dwindled. The material released by the entrenchment was transported down the outwash fan surface and redeposited at the edge of the outwash fans. The rising interglacial sea levels led to the landward movement of marginal marine environments, resulting in the deposition of silts, muds, peats, shelly sands, and estuarine deposits over the previous glacial's outwash fan (Suggate, 1990; Wilson, 1988). Over the many glacial/interglacial cycles, the Canterbury Plains have developed as a series of gravel outwash fans interfingering with finer grained coastal sediments.

During the Otira (the last) Glaciation, the Rakaia and Waimakariri Rivers produced extensive outwash fan surfaces. The end of the glaciation, approximately 14,000 yrs B.P., led to a change in the depositional regime. The reduction in the sediment supply meant that both rivers began to incise their upper outwash fan surfaces. This incision resulted in sediment which was

transported by the rivers and redeposited at the seaward edges of their respective outwash fans. As the glaciers retreated and the sea levels rose, the resulting transgression meant that the deposits of the postglacial were deposited closer to the mountains. When the sea level reached its present level about 6,000 yrs B.P. (Gibb, 1986) the coastlines around the Christchurch Region were somewhat further inland than at present (Suggate, 1968).

The sediments of Kaitorete Spit are within the Christchurch Formation (Suggate 1958). A Canterbury Regional Council borehole located approximately halfway along Kaitorete Spit shows that the sediments of Kaitorete Spit directly overlie the Riccarton Gravel (Brown & Wilson, 1988) which in turn overlies the Bromley Formation (Brown & Wilson after Suggate, 1988).

The provenance of the sediments is ultimately the Torlesse Supergroup but the gravels are currently eroding from (and have been eroding from) the Springston Formation (Brown & Wilson, 1988; after Suggate, 1958) and the Burnham Formation along the coast of the Canterbury Bight. The various rivers draining into the Canterbury Bight also supply sediment to the coast for transport north-eastward.

1.3.3 Human Modification

It is currently thought that Kaitorete Spit has been a locus for various levels of human habitation since about 1 ka (Jacomb, 1994). This time-frame has seen anthropogenic modification of some of the geomorphology on Kaitorete Spit. Several of these minor changes place crucial constraints on the changing lake levels in early historic times.

1.3.3.1 Pre-European Modification

The rich resources of Lake Ellesmere were influential in locating significant Maori activity along Kaitorete Spit (Jacomb, 1994). In and around the lake Maori collected freshwater mussel, eel, flounder, mullet, several species of waterfowl, raupo pollen and flax. From Kaitorete Spit itself, gravel was dug for gardens and pingao was collected for weaving (Evison, 1994; Atkinson, 1994). The swampy northern margin of Lake Ellesmere meant Kaitorete Spit provided a viable alternative pathway for foot traffic.

Since c. 1 ka Kaitorete Spit has seen several groups of Maori come and go, starting with the Moa Hunters about 900 AD. Between 1100 AD and 1300 AD widespread fires, probably started by the Maori, destroyed most of the forests of Canterbury. Close to the time of the forest fires, the Te Rapuwai people replaced the Moa Hunters and in turn they were conquered by the Waitaha. About 1500 AD the Ngati-mamoe took over the resources of Lake Ellesmere. In the late 1620's to early 1630's the Ngai-tahu moved down the East Coast and replaced the majority of the Ngati-mamoe. When the Europeans arrived in the 1850's a small population of Ngai-tahu was left around Lake Ellesmere (Straubel, 1957).

The later Maori founded several settlements at the eastern end of Kaitorete Spit and at Taumutu. A large settlement and pa, named Waikakahi (water of the freshwater mussel), was situated near the site of Jones Pit (Andersen, 1927). The shell middens around the old pa site, and the name, indicate that freshwater mussels were probably plentiful in the lake near here.

In pre-European times the Maori used to let Lake Ellesmere out when the high water levels threatened the pa at Taumutu. This occurred when the lake reached ~ 2.9 m a.m.s.l. (Horrell, 1992; Atkinson, 1994). The opening was carried out at the western end of the regressive barrier developed between NZMS 260 M37 586053 and NZMS 260 M37 614058. A large channel resulted from the head of water released and the lake remained open to the sea for 3–6 months (Thomas, 1849). The lake is recorded as being let out by the Taumutu Maori in 1852, 1854, 1856, 1858, 1863, 1865 and 1867 (Andersen, 1927). Andersen (1927) also records an event in 1829 when the lake breached the barrier near Taumutu and this natural breaching destroyed large areas of sand hills, which have never reformed.

There are several archaeological sites on Kaitorete Spit, with the majority of recorded sites being umu (cooking ovens) (Jacomb, 1994). On the lakeward side of Kaitorete Spit there is evidence of mahinga kai (food gathering places) where extensive collections of freshwater mussel shells occur. In the sand dunes areas of blackened stones and stone-flake knives are common. An important adze cache was found on Kaitorete Spit with adzes showing characteristics of both Archaic and early Classic Maori periods (Jacomb, 1994). There is also thought to be evidence for Maori food storage huts which are built into a hollow excavated

into the ground; the result of this is scattered hollows 1.5 to 2.5 m in diameter and up to 1.5 m in depth.

1.3.3.2 Post-European Modification

With the arrival of Europeans, the flat relatively dry land between Lake Ellesmere and the sand dunes provided a suitable place to graze sheep. The timber industry on the southern side of Banks Peninsula constructed two loading points near the mouth of Birdlings Valley. Birdlings Point was used when the lake was high and Stony Point was used when the lake was low. A third loading point, approximately one third of the way along the southern lake shore, was used when the lake was extremely low. A tramway was constructed linking a jetty on the south western shore of Lake Forsyth with Birdlings Point (Andersen, 1927). The remains of this tramway can be seen on aerial photos, or from elevated points on the hills surrounding the eastern end of Kaitorete Spit.

As the land bordering the lake was settled the flooding of both farmland and recreation areas led to calls that the lake level be controlled by the local government. Proposals for lake level control appeared as early as 1867. In 1868 the lake was let out by Europeans to uncover the rich grazing along the northern lake shore. During the following years various schemes were carried out by different groups until the North Canterbury Catchment Board became responsible for managing the lake level in 1947 (Glennie and Taylor, 1996). Since this time the lake has been kept at a level of 1.05 m a.m.s.l. during summer and 1.13 m a.m.s.l. during winter. When the lake becomes higher than these levels it is opened when weather and tide conditions are favourable.

At some time during World War Two both the army and the airforce used Kaitorete Spit as training ground. The airforce used the spit as a bombing range and the bomb craters are clearly visible, both in aerial photos and on the ground.

Sand and gravel extraction has taken place on Kaitorete. A sand pit was located approximately 15 km along the spit in the sand dunes, with the removal of an estimated 274,384 m³ during the operation. There are several gravel pits beside the Akaroa Highway. The largest of these, Brown's Pit, is situated at the turn-off to Birdlings Flat settlement, and offers some of the best 'outcrop' exposed on Kaitorete Spit. Another gravel pit, Jones Pit, developed in the Railway Cutting Ridges, offers the only other 'outcrop' (although the cattle

which graze in this area have destroyed most of this outcrop during the time of this study). For approximately 300 m along Jones Road as it intersects the Akaroa Highway, there are patches of outcrop developed in the Railway Cutting Ridges.

Kaitorete Spit is currently used for farming both sheep and cattle. The ground is largely unmodified. Some time early in this century a farmer ploughed a section of land about 20 kilometres west of Birdlings Flat (Mike Bayley pers. comm., 1997). The traces of the ploughing can be seen in the 1940's aerial photographs.

Birdlings Flat settlement is situated on the seaward side at the eastern end of Kaitorete Spit, beside the outlet to Lake Forsyth. The settlement is made up of a mixture of holiday bachs and permanent dwellings. The homes are concentrated at the eastern end, and the only other dwelling which is currently occupied is the Bayley's house, "Kaitorete", about 18 kilometres west of Birdlings Flat.

1.4 Previous Work

Work by previous authors suggests the following sequence of events in the development of Kaitorete Spit and Lake Ellesmere. Southerly storm wave erosion of the coastal cliffs developed in the Pleistocene outwash gravels of the Rakaia and Rangitata rivers, provides the greywacke sand and gravel which form the sediments of Kaitorete Spit (Speight, 1930; Kirk, 1969). The prevailing southerly swell sets up a strong north-easterly longshore drift, which moves these erosion products along the coast towards Kaitorete Spit (Speight, 1930; Kirk, 1969; Gibb and Adams, 1982; Leckie, 1994; Soons et al., 1997).

The erosion and transport of sediment along the Canterbury Bight coast has been continuing since the post-glacial sea level started rising, approximately 14,000 years B.P. (Leckie, 1994). By c. 9,500 years B.P. some sort of marine barrier had formed to the south of the current Kaitorete Spit, as is shown by estuarine shells taken from a drill hole approximately halfway along Kaitorete Spit (Beau, unpubl. data). As the sea level neared its present level, around 6,000 years B.P. (Gibb, 1986), the marine barrier moved northward, and a west-southwest/east-northeast oriented spit started growing into the marine embayment where Lake Ellesmere is situated at present (Armon, 1970; Armon,

1974b). The continued erosion and longshore drift built the spit across the embayment, and eventually closed off the embayment when it reached Banks Peninsula, some time after 7558 ± 89 years B.P. (Armon, 1970; Armon, 1974b; Soons et al., 1997).

After the embayment closed the coast started prograding to the south-southeast. This is shown by the ridge and runnel structure which can be observed on Kaitorete Spit (Speight, 1930; Armon, 1974b). Concurrent with this coastal progradation, was the development of a lake in the old estuary basin behind Kaitorete Spit (Armon, 1970; Armon, 1974b).

Waves on the rising lake destroyed ridges which had developed on the westward extent of the spit (Armon, 1970; Armon, 1974b). As the lake rose higher the waves also formed several ridges, and sets of ridges, along the central portion of Kaitorete Spit (Armon, 1970; Armon, 1974b). Armon (1970) named these features Speight Ridge for the large ridge which runs along a large extent of Kaitorete Spit, Bayleys Ridges for the set of ridges which are developed approximately 10 km west-northwest of Taumutu, Railway Cutting Ridges for the set of ridges which the old Lincoln-Little River Railway cuts through about 0.5 km south of the Akaroa Highway, and Birdlings Valley Ridges for the set of ridges which stops just behind Lakeview (the Birdlings family house) just east of the Akaroa Highway (Figure 1-1). Speight (1930) described these features but attributed them to marine actions on a lowered landmass. More recently Soons et al. (1997) have described Railway Cutting Ridges and Birdlings Valley Ridges in terms of marine action, linked to a recent closing off of the Lake Ellesmere spit. Lake silt and mud up to 3 m in thickness is described by Armon (1970, 1974) as covering the spit recurves.

Two recent studies have suggested that the Waimakariri River may have changed its course and flowed down the west side of Banks Peninsula and into Lake Ellesmere near Motukarara (Soons, et al., 1997; Harvey, 1996). The effect of this on a closed Lake Ellesmere would be to raise the level until an outlet was established. Soons et al. (1997) suggest that the spit recurves developed at the northeastern end of Kaitorete Spit are evidence

According to Armon (1970), the higher lake level would have produced waves of an amplitude of 0.9 m and a period of 4.5 seconds. He attributed the erosion

of the loess deposited on the remains of basalt spurs on Banks Peninsula to these waves. The low cohesive strength of loess means that only very small waves are needed to remove the 'toe' of the loess deposit, when the loess hillside becomes saturated during rain. The lack of the 'toe' would lead to slumping occurring further up the slope (this may be seen happening currently up slope of any road cuttings through loess deposits). This has led to the characteristic loess cliffs in the valleys north and east of the old higher lake.

1.5 Sample Locations

Figure 1-1 shows the locations of the Ground penetrating radar surveys and the sites where shallow pits were dug. It also includes the locations of samples which have been dated for previous studies, and the location of boreholes described in previous studies.

1.6 Nomenclature

As noted by Armon (1970) the name 'Kaitorete Spit' is not technically correct and the role of Kaitorete Spit is actually as a 'barrier'.

Definitions of:

Beachface is defined here, after Massari and Parea (1988), as the whole sloping face of the beach, from the highest berm to the landward extent of the shoreface.

Berm is defined as the point on the beach profile at which the slope changes from seaward sloping to gently landward sloping, a berm may or may not have horn and cusps developed on the seaward slope.

The elevations stated in the thesis are all in reference to mean sea level.

The dip angles of reflectors and bedding planes are divided into three classes of steepness: gentle 1-5°, moderate 5-10° and steep >10°.

Radar profile :- the hardcopy of a radar survey consisting of a wiggle-trace plot.

Radar survey :- the surface line where the radar unit was used to image the subsurface

Radar facies :- a group of reflections in a profile that have distinct characteristics and extend over a significant area of the profile, generally with distinct bounding reflectors.

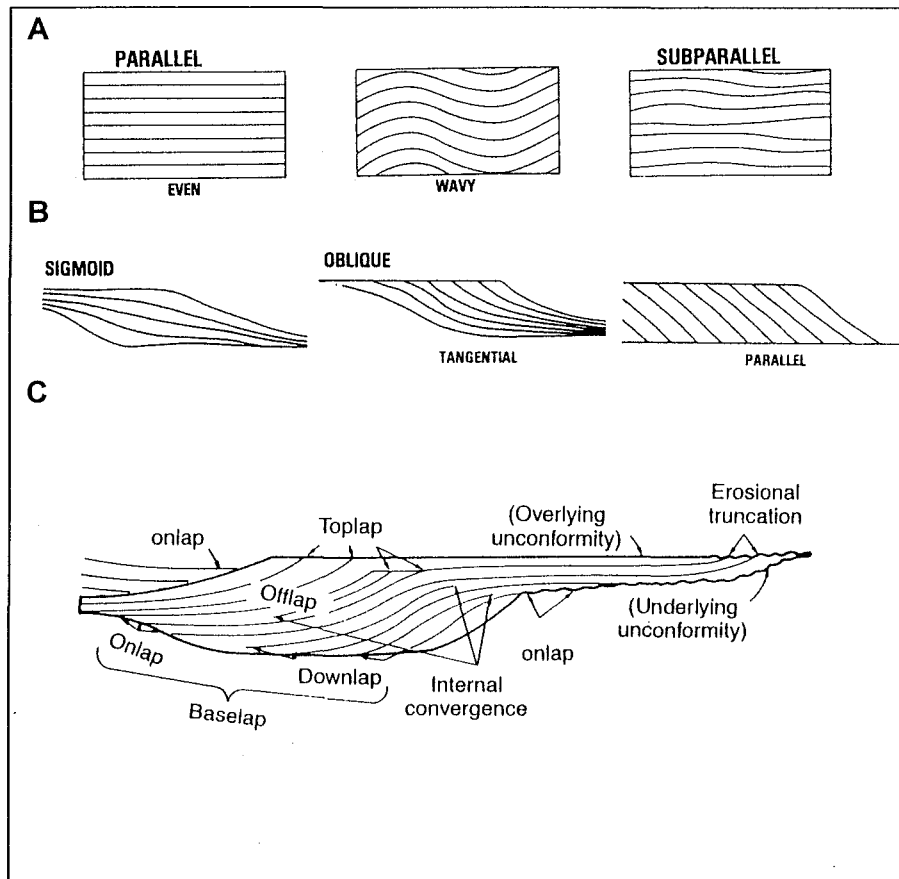


Figure 1.2. Figure showing parallel (A) and prograding (B) seismic reflector configurations. C shows the terminology for unconformable boundaries in a depositional sequence. The terms defined in the figures are used to describe similar radar reflector configurations and boundaries.. (After Boggs, 1987, and Mitchum et al., 1977).

The terms used in the radar profiles descriptions are illustrated in Figure 1.2.

1.7 Thesis Structure

In chapter 2, the methods used during the course of the study are described. Chapter 3 incorporates the descriptions of the GPR profiles, descriptions of the geomorphology and sedimentology from this study. The chapter also includes the sedimentology descriptions from earlier studies and introduces the C^{14} dates from other studies. In Chapter 4 interpretations of the observations made in chapter 3 and compares the results obtained from this study with results from other studies. Chapter 5 brings together the discussion in chapter 4 into a

cohesive story of the development of the structures on Kaitorete Spit and the development of the barrier-complex in relation to the described structures.

2. Methodology

The new data used in this study were obtained from numerous GPR surveys carried out during 1996 and 1997. The GPR surveys were supplemented by information obtained during field examinations of the present marine beach environment, as well as examinations of the geomorphology both in the field and on aerial photographs. Qualitative studies of the sediment textures and structures were made in several shallow pits and three shingle pits.

2.1 Basemap Preparation

The topographic base map used in this study was prepared by first scanning the relevant sections of New Zealand Map Series 270 sheets 36 Lincoln and 37 Taumutu. The scanning was carried out at foolscap size and the resulting bitmaps were joined together in Coreldraw7™. Any distortion in the bitmaps was removed by superimposing a grid over the map and stretching the scanned map until the map's grid fitted the superimposed grid. The corrected map was then traced and saved as a vector drawing. The corrected map has no more than 1% error from the original topographic map. For the final presentation of the geomorphologic interpretation the map is plotted at 1:25,000.

2.2 Aerial Photographic Interpretation

To get complete coverage of the field area it was necessary to use several different series of aerial photographs during this study, ranging from parts of a series flown in 1942, to parts of a series flown in 1984. It was decided for this study that the most recent aerial photographs were not needed, as the majority of the geomorphology being studied has not changed substantially in the past 50 years. The 1942 photographs are at a larger scale and have less cultural coverings (mainly windbreaks) than the 1984 photographs.

Initially the aerial photographs were studied using a Sokkia 4X pocket stereoscope and the major geomorphological patterns were traced. It was decided that the most accurate way to transfer the geomorphology to the topographic basemap, was to trace the geomorphology directly using the computer. The

individual photographs were scanned at a resolution of 300 dpi. These scanned images were then taken into Coreldraw7™. Firstly the scanned images were stretched until they had a linear scale similar to the basemap. Then they were placed underneath the topographic basemap and the scaling was fine tuned by aligning prominent features on the basemap with those on the photographs. After scaling it was found that due to the subdued relief of Kaitorete Spit, the photographs showed very little distortion in comparison to the basemap. When a ‘best fit’ was achieved, the geomorphology was traced on a layer and checked against both the original photos, and the initial stereo interpretation. Where possible the central third of the photograph was used to minimise any photographic (and scanning) distortion, however where the relevant photographs were not available, it was necessary to use more than the central third of some photographs.

The trends of the marine geomorphology were picked out by tracing the crest of the ridges developed. Where it was possible to see cusped ridge development in the aerial photographs, it was decided that both the accuracy of the line, and the scale of the map meant that tracing the embayments was a bit optimistic. In these cases the line was put along the backs of the embayments (Figure 2-1).

The aeolian geomorphology was restricted to tracing the crest of the erosion scarps of the dunes. The extent of the sand dunes was also traced from the aerial photographs.

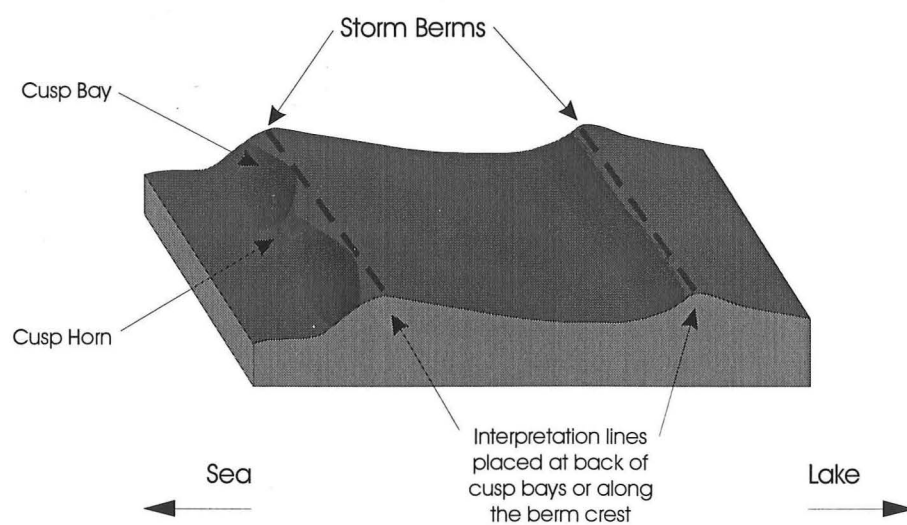


Figure 2-1: Figure showing the placement of interpretation lines on the marine and lacustrine geomorphology on Kaitorete Spit.

The lacustrine geomorphology consists mainly of the shoreline features developed when Lake Ellesmere was several metres higher. The features were dealt with in the same way as the marine beach ridges, with a line placed along the ridge crests (Figure 2-1).

Developed on the old lake bed were numerous geomorphic features, these were picked out again by placing a line along the crest (often sinuous) of the feature.

2.3 Ground Penetrating Radar (GPR)

Ground penetrating radar is an effective way of imaging the near surface stratigraphy, using non-invasive electromagnetic (EM) waves. The basic method employs a pulse of high frequency EM energy being transmitted into the ground. At interfaces where the bulk EM properties of the ground change rapidly a reflection is generated (see Figure 2-2).

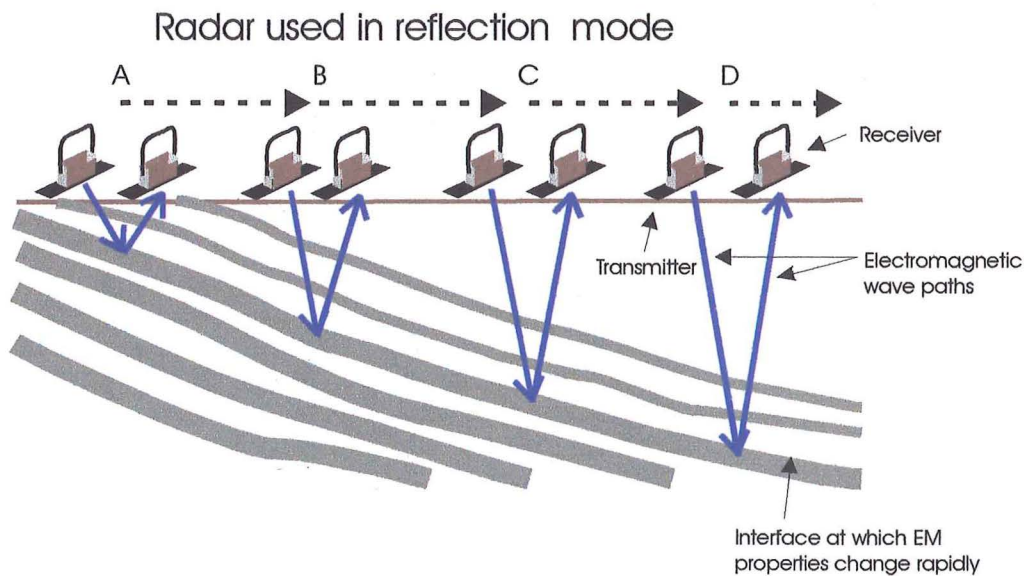


Figure 2-2. Figure showing the basic theory of GPR.

The electrical properties of the ground are controlled by several different factors including lithology, porosity, water content or air content in the pores. The factor which has the most effect on the velocity of the radio wave transmission is the **amount and quality of water**. Therefore if the ground is equally saturated the **porosity** will control the amount of water able to be held. This means that at rapid changes of porosity, e.g. from an open framework gravel to a well sorted granule layer, a reflection will be generated.

The radiowave velocity is found according to the formula :-

$$c = \lambda f$$

where c is the velocity of the EM wave (m ns^{-1}), λ is the wavelength (m) and f is the central frequency of the EM wave (Hz). The velocities of the radiowaves can be estimated in the field using common mid-point (CMP) experiments (Jol and Smith, 1991). On Kaitorete Spit subsurface velocities found ranged from $0.06\text{--}0.15 \text{ m ns}^{-1}$. According to Sheriff (1984) the ideal resolution resolvable is equal to $\lambda/4$, but Trabant (1984) points out that field uncertainties limit the practical resolution to about $\lambda/2\text{--}\lambda/3$. This means that on Kaitorete Spit the practical resolution using the 100 MHz antennae is limited to resolving beds 20–75cm apart.

The radar data was collected using a Software and Sensors pulseEKKO IV owned by the Department of Geological Sciences, University of Canterbury. The data was saved in the field on a Compaq laptop computer using pulseEKKO IV software V 4.1.

Five regional GPR survey lines were carried out. These regional lines were placed roughly perpendicular to the geomorphic features, and covered more than three quarters of the width of the barrier complex. In addition to these regional lines, several areas were looked at in more detail, with short lines placed in areas of special interest.

2.4 Sampling Strategies

The radar station spacing of 25 cm was calculated as being accurate for subsurface velocities ranging from $0.7\text{--}0.12 \text{ m ns}^{-1}$, which encompasses the majority of the velocities found on Kaitorete Spit (see Appendix D for the calculation). The sampling rate of 800 picoseconds is recommended for antennae frequencies of 100–200 MHz (Annan and Cosway, 1992).

With the radar station spacing of 25 centimetres the level of topographic detail needed was high. However collecting topographic information at every 25 centimetres would have been a case of oversampling, considering the radar sledge has a length of 1.35 m, and therefore averages the elevation at each station. It was decided that the sample spacing for the spot heights was dependent on the geomorphology developed at each individual site. For example

where the geomorphology consisted of lake ridges with a crest to crest spacing of approximately 10 m, a sampling interval of 5 paces should be adequate to resolve the topographic expression, as long as the crests and troughs were included in the sampling. Where the geomorphology consisted of the marine beach ridges, the crest to crest spacing was more in the order of 100 m and a sampling interval of 8–15 paces was used. The flattening of the water table after topographic correction suggests that these sampling intervals proved to be adequate.

2.4.1 Radar Data Collection

Due to the length of the regional lines a sledge was constructed to transport the radar unit. During the surveys a rope was attached to the sledge which put the person pulling at a distance of 6 m from the centre of the antennae. A 100 m fibreglass tape measure was laid between the pegs and then offset by 6 m, in the direction of travel. The person pulling the sledge could then read the distance travelled along the profile line by looking down at their feet. The person pulling the sledge kept the rope taut and took 25 cm steps between radar readings (Figure 2-3).

The location of the regional lines was chosen by visual inspection of the topographic map. The lines were placed to cover the main extent of the Barrier Complex width and spaced to try and cover most of the changes in the barrier length. The regional lines were pegged at 100 metre intervals, with the position chosen initially as perpendicular to the geomorphic structures and then each segment dependent on avoidance of vegetation and other obstacles.

The 100 MHz antennae were used with the 400 volt transmitter. The station spacing chosen was 25 cm. Initially the lines were collected using 64 stacks, but it was decided that for speed of collection 32 stacks gave more than adequate results. Radar collection was carried out using a common 1 metre offset, single fold and parallel broadside antennae configuration. The radar was run using continuous mode, an 800 picosecond sampling interval and a 400 nanosecond time window. This allowed enough time between readings, for the operator to move the sledge to the next station, and have it stationary for the next reading. As a check on position, the person with the computer and console read out every metre station. The first regional lines were collected in 300 metre line segments,

this allowed the data to be transferred to floppy disc and then to desktop computer. Later lines were collected as whole lines and transferred to a desktop computer via a serial cable.

2.4.2 Velocity Calculation

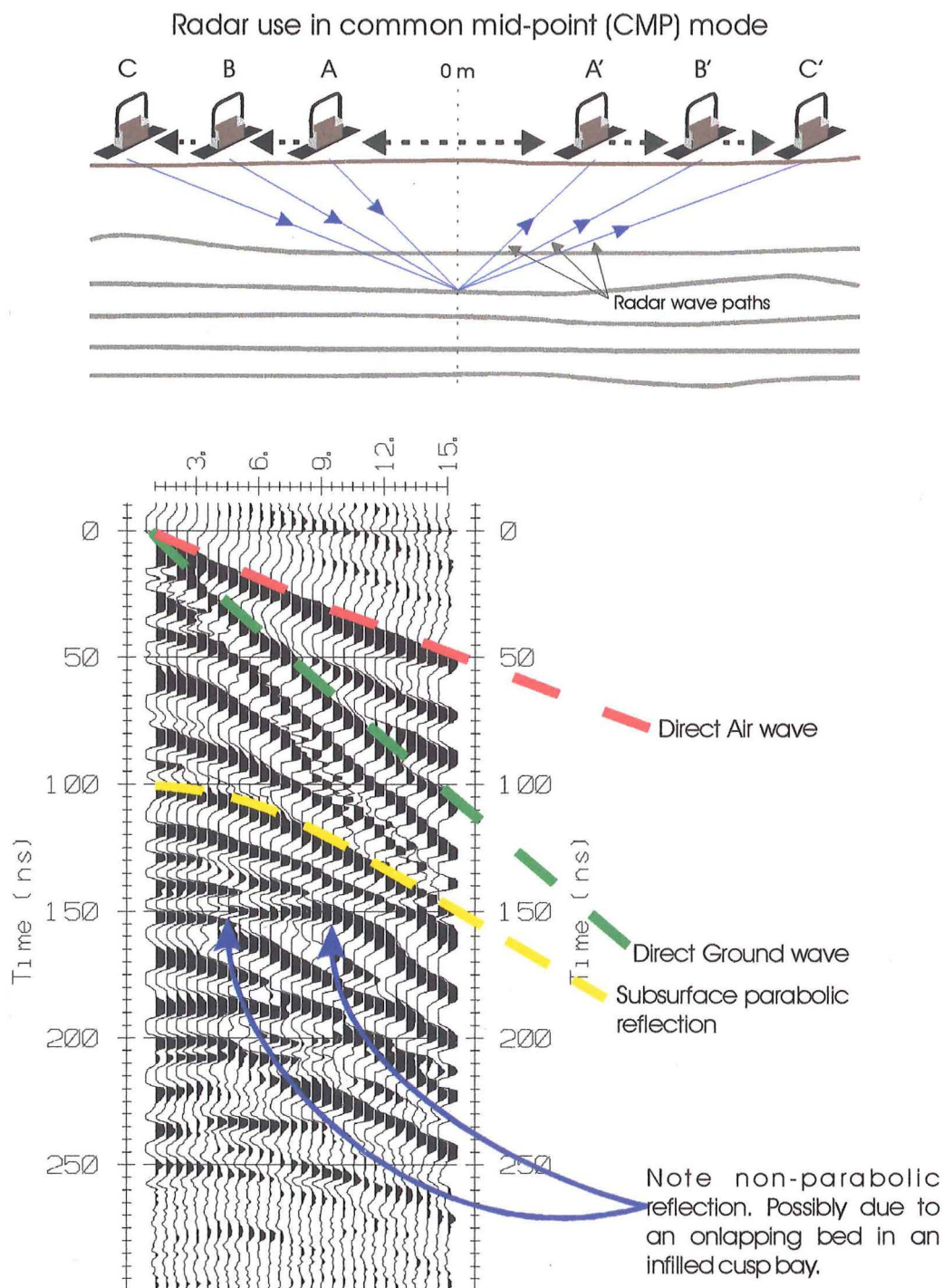


Figure 2-3. Figure showing the process of obtaining a CMP profile and a resulting profile. Marked on the profile are the direct airwave, the direct groundwave and one of the parabolic reflections which is used to calculate the subsurface velocity. Also marked is a discordant reflector that is due to a non-horizontal bed (After Annan and Cosway, 1992).

At selected sites along the radar lines common mid point (CMP) surveys were carried out. The resulting profiles can be used to calculate the velocities of the underlying beds. The method used assumes that the underlying beds are horizontally layered. In the case of Kaitorete Spit, lines taken along the strike of the geomorphology should have close to horizontal beds and any deviations can clearly be seen (Figure 2.4). To collect the CMP the antennae are stepped away from the central point at even increments. The resulting plot can be used to determine the 'root-mean-square' (RMS) velocity of the layers by taking each layer and picking the arrival time and the distance from the centre (Jol and Smith, 1991; Annan and Cosway, 1992). The time and distances are both squared then plotted against each other. The slope of the resulting plot is equal to the square root of the RMS velocity. The velocity for each reflector is an average of all the layers above it, and can be used to estimated depths to certain features. All the radar profiles on Kaitorete Spit suffer from a lack of velocity data along profile lengths, and some lines did not have adequate CMPs collected at all, in these cases an average of all the velocities was used or the velocity obtained from a lithologically similar setting.

2.4.3 Ground Penetrating Radar Validation at Browns Pit

At Browns Pit (Figure 2-5), a gravel pit located at the eastern end of Kaitorete Spit, a series of correlation lines were carried out where the radar profiles could be compared to the sedimentary structures exposed in the pit walls. The pit is located in an area of the spit which Armon (1970) interpreted as formed from marine barrier beach gravels. The south and west walls are best preserved, and therefore the most suitable for correlation purposes. The floor of the pit has several piles of foreign material dumped on it, but between these the floor consists of the gravel remaining after extraction. It is assumed that the disturbance to the gravel on the floor of the pit does not extend below 0.5 m, and that the structures preserved below the floor are primary structures.

The siting of the GPR lines was dictated by the fact that the radar profile needed to be as parallel as possible to the pit wall. Ideally the radar lines should have been run along the top of the pit wall as close to the edge as possible, but unfortunately vegetation and fences limited available sites for the radar lines.



Figure 2-5. (Above) M36 858 103. Photograph of Browns Pit looking southwest, from the top of Devils Knob. The location of the four radar survey lines is marked. Photo courtesy of Alistair Ritchie.



Figure 2-3. (Left) Photograph of the ground penetrating radar in operation.

This meant that to be parallel to the pit wall faces, the radar lines needed to be offset by 10–30 m from the pit wall.

2.4.3.1 Browns Pit West Wall

On the west wall of the pit an exposure of the gravel structure stretches for about 150 m (see Figure 2-6). The upper 3 to 4 m is apparently structureless, and loose, medium to fine gravels sit at their angle of repose (c. 30°). Underneath these loose gravels there is a well defined layer below which well bedded gravels are standing vertically. In the vertical gravels there are well developed pebble and sand layers. The pebble layers dip to the south at angles varying from 5–10° and strike at approximately 090°. Several south dipping truncation surfaces can be observed in the pit walls, with dip angles 6–8°.

The vertical gravels are composed of well sorted layers of fine, medium and coarse pebbles, some of which have a fine sand matrix. The individual beds range in thickness from 10–50 mm, with an average bed thickness of 25 mm. The eastern wall of the pit has been largely removed during gravel extraction, the remains of the wall also show southward dipping well developed beds.

The radar line located slightly west of the pit west wall (see Figure 2-5) runs essentially north–south and parallel to the adjacent west pit wall.

The resulting radar profile is shown in Figure 2-7. Below the air and ground wave it can be seen that there are two essentially horizontal reflectors shown. The first of these, reflector A, located between 68 and 92 ns, has a slightly undulating character with an apparent dip towards the south. When this reflector is compared to the photograph of the west wall, in Figure 2-6, the undulating nature of the interface between the upper loose gravel unit and the lower tight vertical sandy gravel unit can be observed. Therefore, the reflector A marked on the profile is interpreted to represent this loose/tight contact.

Below reflector A there are numerous subparallel south dipping reflectors shown. When the vertical exaggeration is accounted for the apparent dip shown on these interfaces is approximately 7°. The south dipping reflectors are truncated at reflector A. The lower ends of the south dipping reflectors pass through the lower horizontal reflector B, and appear to steepen in dip slightly.



Figure 2-6. Photograph showing the sedimentary structures revealed in the west wall of Browns Pit. A horizontal boundary marks the contact between the loose gravel unit above and the tight sandy gravel unit below. Note the south dipping truncation marked. Compared with radar profile in Figure 2.7. The vertical gravel face is c. 2 m high.

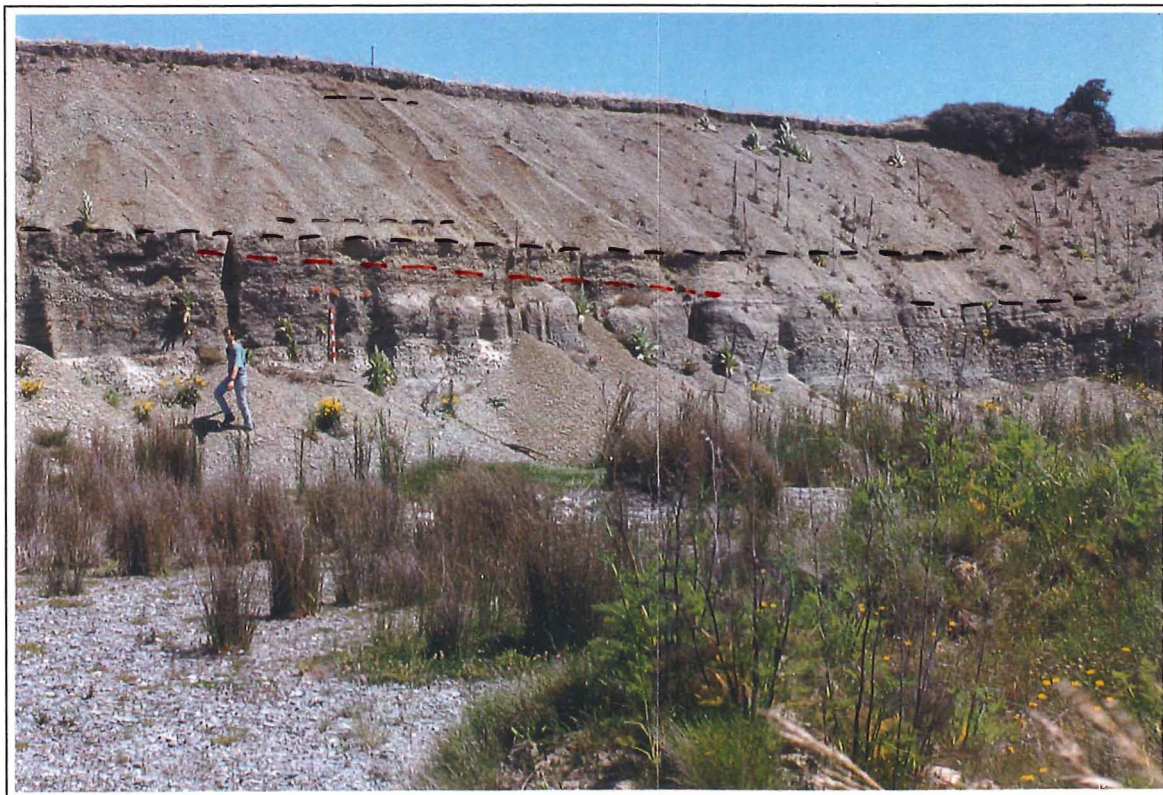


Figure 2-8. Photograph of the structures revealed in the south wall of Browns Pit. Note the layer which extends into the loose gravels above the tight sandy gravels, and also the westward dipping bed. Compare with radar profile in Figure 2-9. The scale shown is 1 m in length and has 0.1 m intervals marked.

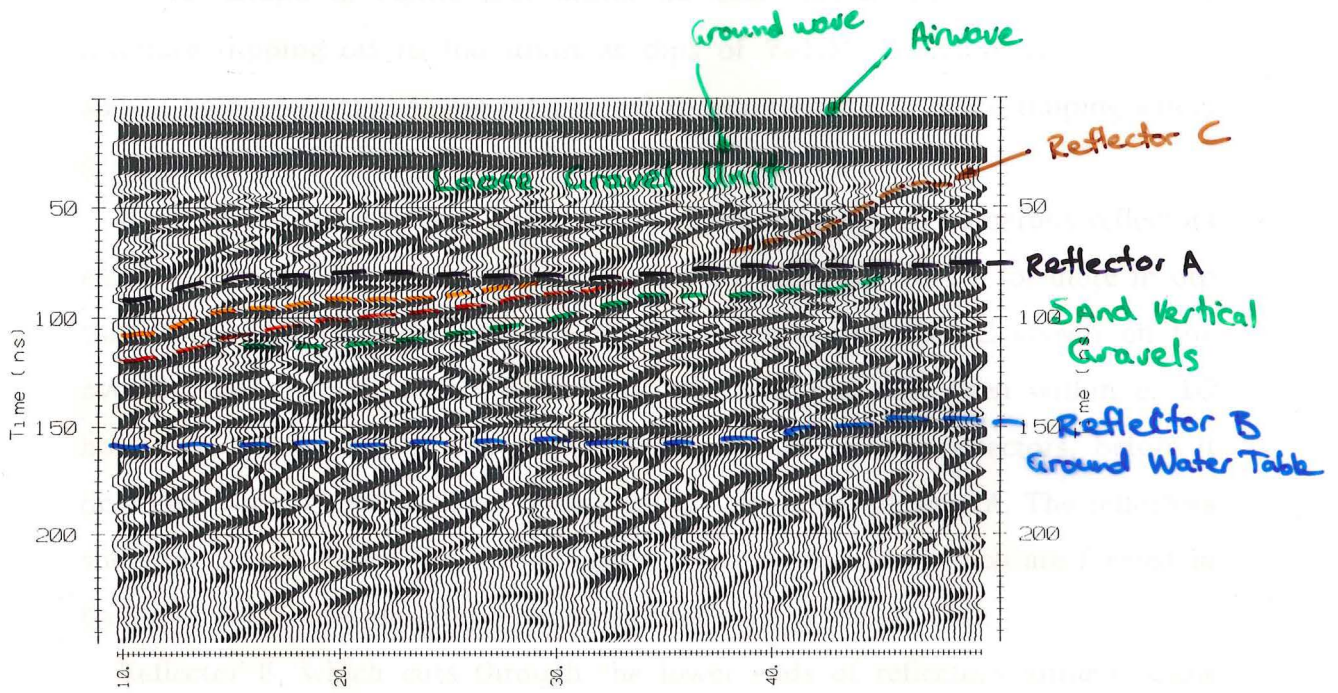
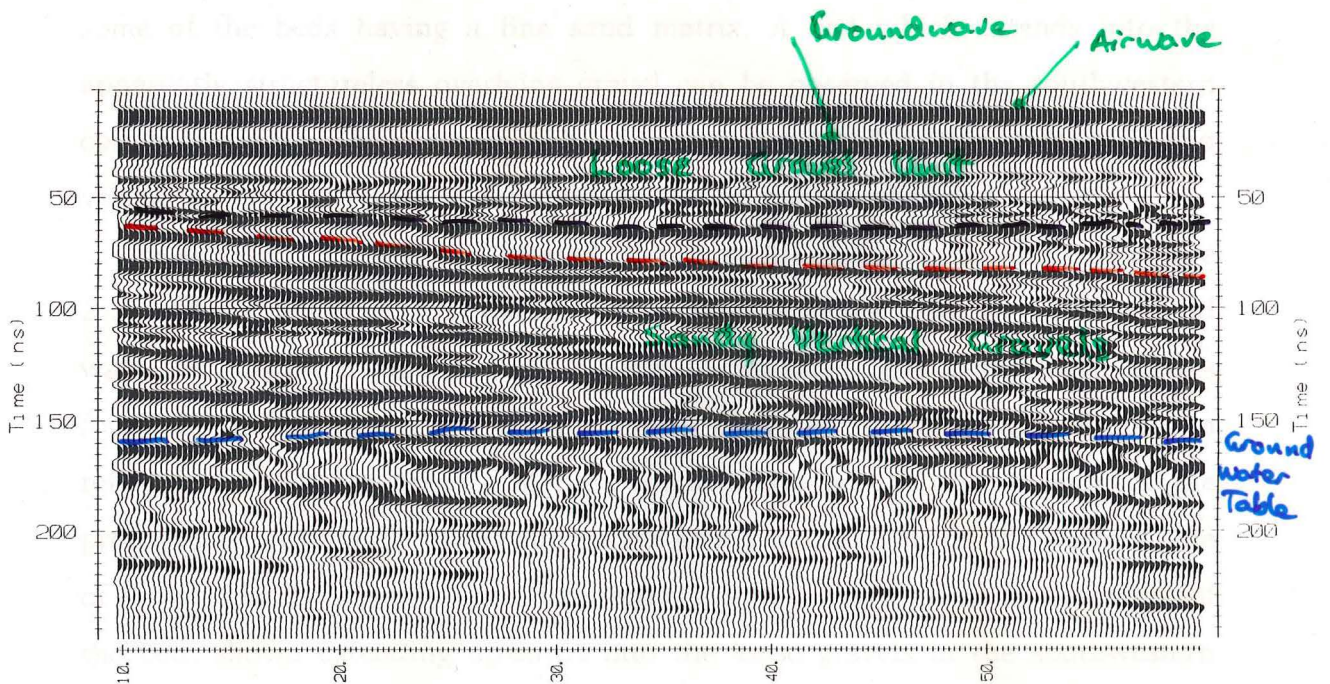


Figure 2-7. (Above) Radar profile situated c. 30 m west of Browns Pit western wall. The horizontal reflector at 70–95 ns depth is interpreted to be the top of the sandy gravels shown in Figure 2-6. Compare the marked reflectors in this figure, with the marked beds in Figure 2-6.

Figure 2-9 (Below). Radar profile taken south of the southern wall of Browns Pit. Compare the gently east dipping reflector with the gently dipping bed marked in Figure 2-8. The second reflector marked is interpreted to be a continuation of the bed shown in Figure 2-8, which extends up into the loose gravel unit.



The photograph in Figure 2-6 shows the beds below the loose/tight gravel interface dipping off to the south at dips of 7–10°. Therefore the reflectors shown below reflector A, are interpreted to represent these south dipping sandy gravel beds.

Between the ground wave and reflector A the radar shows numerous reflectors also dipping towards the south. The individual reflectors vary a lot more in dip than those shown below reflector A. For example, reflector C shown on the overlay starts at the surface with a nearly horizontal dip, then within c. 10 horizontal metres it steepens its dip and truncates several reflectors, before it downlaps onto a horizontal reflector located just above reflector A. The reflectors shown in above reflector A are interpreted to be structures which are formed in the apparently structureless loose gravel unit seen in the pit wall.

Reflector B, which cuts through the lower ends of reflectors formed below reflector A, is thought to be the reflection off the local unconfined water table.

2.4.3.2 Browns Pit South Wall

Figure 2-8 shows the south wall of Browns pit has c. 4 m of apparently structureless gravel, overlying vertical well bedded sandy gravel. The sandy gravel beds have a generally horizontal attitude. There are very gentle apparent dips, both towards the east and west. A truncation surface can be observed dipping to the east. The beds are composed of medium gravels to granule, with some of the beds having a fine sand matrix. A bed which extends into the apparently structureless overlying gravel can be observed in the southwestern corner of the pit. The northern edge of the pit is covered by the access road and vegetation, and therefore no structure or texture may be observed.

The second radar line was located slightly south of the south wall (see Figure 2-2) and the resulting radar profile is presented in Figure 2-9. Below the ground wave the horizontal reflectors are thought to represent beds in the loose gravels found in the upper part of the pit walls. These horizontal reflectors onlap a reflector with an apparent east dip, which starts on the eastern side of the profile at approximately 80 ns and curves gently up to 60 ns on the western side of the profile. This gently curved reflector is interpreted to be a continuation of the bed, shown extending upwards into the loose gravels in the southwestern corner of the pit (Figure 2-8). The reflectors below this reflector have gentle

eastward apparent dips and are interpreted to be the gently dipping beds shown in the tight sandy gravels, seen in the south pit wall. The flat horizontal reflector at 160 ns is thought to be the local unconfined water table.

The two profiles located on the pit floor are described later in the text.

2.4.4 Radar line assembly

The segments were repositioned so that each line started at the station after, the last station of the preceding line segment. The lines were 'added' together in pulseEKKO software V4.1 to form a continuous line. The continuous line was then dewowed to remove the low frequency noise from the signal. The line was inspected to find the amplitude of the first break, a first pick was applied and a first break shift applied. When the first break was lined up, the topography was added as mentioned below.

2.4.5 Topographic Correction

The topographic information for the radar lines was collected using a Wild Theodolite and distomat. The first radar line surveyed was Kailine 2, with the theodolite given an arbitrary compass bearing and elevation. The survey data was recorded manually as: vertical circle reading; staff height; height difference; bearing; and horizontal distance. This data was then converted into arbitrary northings and eastings using the co-ordinates 1000E,1000N for station 1. All the other surveys were carried out using actual compass bearings; arbitrary northings and eastings; and arbitrary elevations. The data was recorded using a Wild datalogger. The surveys were then converted to ASCII files with four columns: point number; easting; northing; and elevation.

The elevations of the lines were then corrected using Canterbury Regional Council coastal bench marks to their true elevations. The northings and eastings were corrected to the New Zealand Map Grid by placing the lines on the basemap and estimating the first northing and easting.

The topographic correction needed for the radar lines consists of a ASCII file with two columns, the first showing the distance along the radar line, the second showing the elevation. The ASCII survey files were converted to files suitable for input into the pulseEKKO software V4.1, using Microsoft Excel 5.0. The radar lines were then topographically corrected using pulseEKKO software V4.1.

2.4.6 Interpretation

The radar lines were printed from pulseEKKO software V4.1 and inspected. The interpretation and annotation was carried out by exporting the files as graphic files and importing these into Coreldraw7™. The interpretation was carried out on a different layer to the bitmap. The final profiles are plotted at a horizontal scale of 1:500, with the vertical scale being dependent on the velocity of the profile. The vertical exaggeration on the plots ranges from 2–3 times.

For interpretation purposes it was decided to break the lines into Radar facies and describe the deviations in the facies for each individual profile. Due to limitations of the pulseEKKO software V4.22 printer driver the radar lines had to be plotted on a page less than 36 inches long, this meant that the profile length had to be restricted to 400 m. The individual sections of those profiles which are longer than 400 m have been broken into 400 m lengths and the ends of these lengths are designated on the map by a letter and a dash (i.e. A—A'). These sections are plotted two to a sheet with the northernmost end of the profile at the left-hand side of the sheet and the first section at the top of the sheet. The interpreted profile is plotted directly below the wiggle trace profile and the major radar facies are marked as well as any important reflectors. The profiles are plotted looking east, for north–south oriented profiles, and looking north, for west–east oriented profiles. The only exceptions to this are the Browns Pit profiles, in section 2.4.3, which have been plotted so they can be compared directly to the photographs of the pit walls.

2.4.7 Chapter Summary

This study uses new data in the form of ground penetrating radar profiles collected during 1996 and 1997 and combines it with aerial photograph interpretations and field observations to refine the geologic history of Kaitorete Spit. The ground penetrating radar surveys utilised 100 MHz antennae with a 25 cm station spacing. The final map of the geomorphology is plotted at 1:25,000.

3. Observations

The interpretations presented in this study are derived from field observations and the results of the ground penetrating radar surveys carried out during 1996 and 1997.

3.1 Geomorphology and Sedimentology

Geomorphology was examined in the field and aided and supplemented by aerial photographs of the area. Topographic data was also collected for the ground penetrating radar survey lines. Armon (1970) isolated the geomorphology on Kaitorete Spit into several areas dependent upon the environment of formation. The approach here will similarly follow Armon's subdivision, and the observations are broken into the three main environments he established.

Sedimentological observations, consist of qualitative examinations of the structures and textures in the field. Several shallow pits were dug (up to 1 m deep) to examine the very near surface (0–0.75 m), information, in areas where structure cannot be resolved with the radar, using 100 MHz antennae. The pits were small, being about 0.5 m along each edge and from 0.4–1.1 m in depth. The commercial gravel pits located around the lake, also provided sections which were studied qualitatively.

3.1.1 Lacustrine Depositional Setting

Aerial photographs show clearly developed lacustrine geomorphology. Shoreline and lake bottom features can be recognised. Shoreline geomorphology is dominated by ridges developed parallel to the present shoreline, and were previously described by Speight (1930) and Armon (1970).

3.1.1.1 Modern Lakeshore

The present shore of Lake Ellesmere is covered for a large extent in marsh ribbonwood, which obscures much shoreline geomorphology. From M37 753 102 to M36 835 120 the shoreline is covered in a grass-like vegetation, which acts to baffle fine sediment when the lake is high, but the geomorphology is still

visible, if slightly muted. At the western end of the shoreline a large mud bank is developed, the top of which presently sits above lake level.

A thin layer of estuarine shells occurs along the western edge of the mud bank. The layer is c. 5 cm thick, and is c. 10 cm below the bank surface. There were two species of shell found *Mactra ovata* (Gray) and *Austovenus stutchburyi* (Wood). Generally the shells are poorly preserved, especially where they have been exposed to the atmosphere, and the majority of fragments comprise the hinges of both species (Figure 3-1). The edge of the mud bank shows that erosion is the present trend here, which has bank formed in the muddy very fine sands up to 0.4 m high (Figure 3-2). Rare granule to fine pebble clasts are associated with the shell layer. The shell layer rests above a blue brown mottled silty clay layer.

A pit dug near where the mud bank joins Kaitorete Spit, reveals that the top of the mud bank is 0.1 m of blue brown mottled clay (mottling developed adjacent to plant roots), overlying a blue moderately sorted muddy fine sand. Below this sand a blue clay occurs.

At M37 620 063 also on the lake shore, a second shell layer was found, again formed in a blue muddy medium sand layer approximately 0.3 m below the surface (elevation of shell layer is 1.5 m). There were four species of shell found (see Appendix F) *Paphies australis* (Gmelin), *Mactra ovata* (Gray), *Austovenus stutchburyi* (Wood) and *Amphibola crenata* (Gmelin). This shell layer was found developed underneath a small lake-formed ridge which is being eroded at its lakeward side.

Located 50 m east of this shallow pit, a second pit was dug on the lake shore. At a depth of 1 m paired freshwater mussel periostracums were found in the blue muddy medium sand. Stratigraphically this places the freshwater mussels c. 1 m below the estuarine shells.

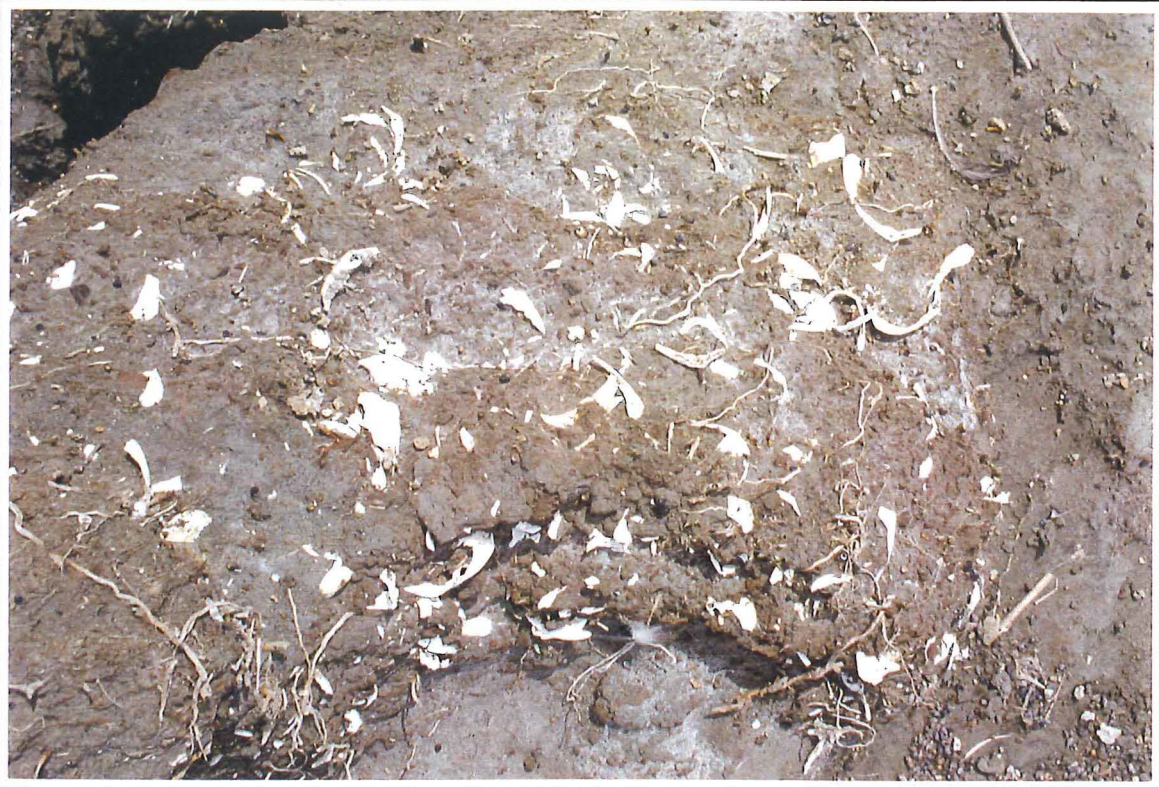


Figure 3-1. Photograph showing the poor preservation of the estuarine shells on the mud bank at the west end of Kaitorete Spit (M37 619 074). Photo width about 40 cm.



Figure 3-2. M37 619 074. Photograph of the shell layer in finely laminated muddy very fine sands. The shells have been exposed in the mud bank by lake wave erosion. The height of the bank is c. 20 cm. Photograph taken looking east.

On the lake shore just north of Kailine 2, another shallow pit revealed 250 mm of brown mottled, blue clay developed over sandy fine to medium gravels. During summer, when the lake level was low, it was observed that the present lake floor is covered with numerous coarse to very coarse pebbles, which have their long and intermediate axes oriented parallel to the slope of the lake bed. Several sinuous ridges also occur standing c. 0.25 m above the surrounding lake bed, with horns developed perpendicular to the ridge trend. Ridge tops were covered by coarse to very coarse discoid pebbles and the matrix between these pebbles was silty clay. During winter, when the lake was higher, ridges did not appear above the lake-level.

3.1.1.1.1 Lake Bed

Developed on the old lake bed are numerous small scale, geomorphic features. In some places (marked on Sheet 1) the lake bed structures are very small scale complex features that were too small in scale to trace, and it was decided tracing them would yield little useful information for the present study. Simpler structures, sinuous ridges, were traced on some of the lake bed, which stand no more than 1 m above the surrounding ground (see Figure 3-3). They have a cusate form in plan view, with elongate horns developed between shallow cusps. The horns trend between north-northwest/south-southeast and northwest-southeast. There are also numerous small linear ridges have less than 0.5 m relief developed subparallel to Speight Ridge.

The old lake bed has coarse to very coarse discoid pebbles scattered on the ground surface all with their long and intermediate axes oriented parallel to the ground slope. Medium to coarse pebbles are scattered over the tops of the small scale cusate ridges.

A large pit and several shallow pits were excavated on what was the lake bed of a higher Lake Ellesmere. In the south facing wall of the large pit located at M37 768 102 (see Figure 3-4), there is an irregular layer of poorly sorted, muddy, fine to medium gravel reaching a maximum thickness of 200 mm overlying a 250 mm thick layer of grey silty clay. Below the silty clay a series of moderately to well sorted gravel layers occur, ranging in size from granule to very coarse pebble. There are many discoid pebbles present. The layers all dip

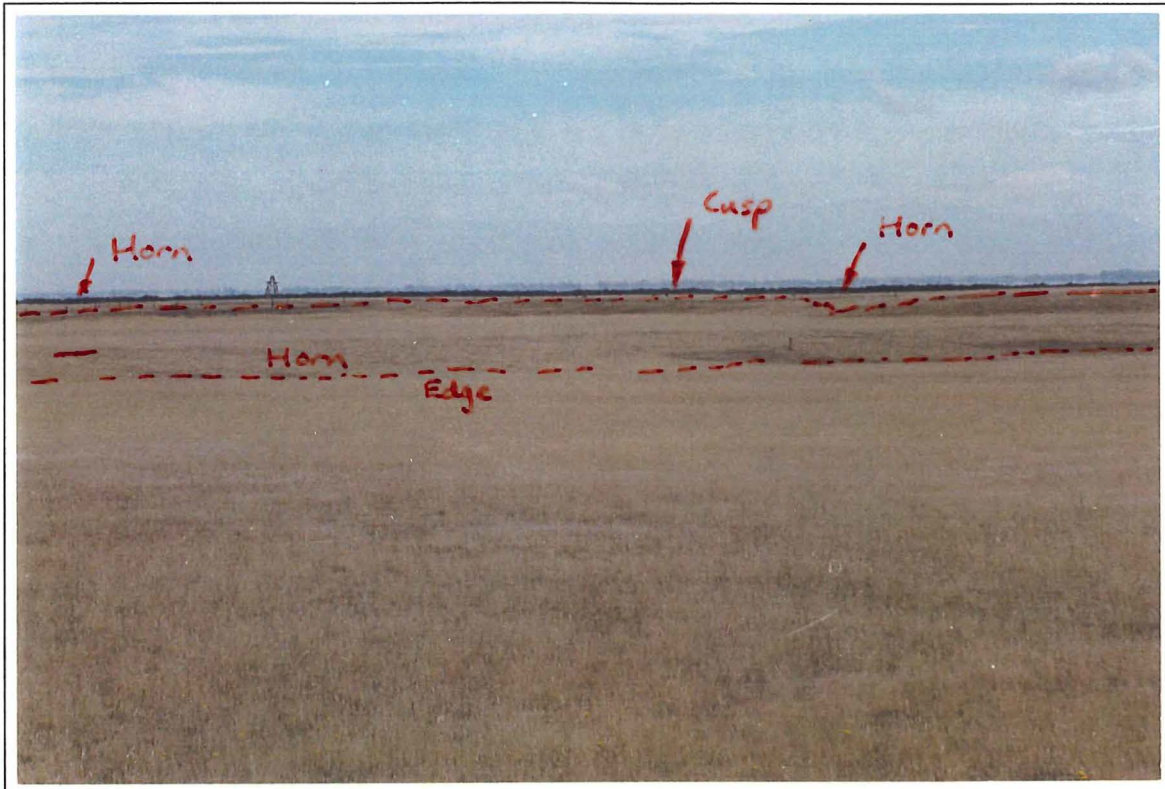


Figure 3-3. M36 766 101. Sinuous small scale ridges developed on the lake floor. The relief of the slopes visible is no more than 1 m. Photograph taken looking northwest.



Figure 3-4. South facing wall of large pit at M36 768 102. Note the muddy gravel overlying a silty clay layer, which appears to be sitting on a truncation surface developed on well bedded gravels. The height of the face is 1.6 m.

to the south at angles between 4 and 7°. A curved truncation is developed in the south wall, which also dips off to the south, but strikes at a slightly different angle and therefore truncates the lower beds (Figure 3-5). Above the truncation the bedding layers are parallel to the truncation surface.

Excavating one of these small scale cusped ridges revealed, that underneath the pebbles on the surface, the ridge was composed of very fine sand and silt, and was developed over top of a layer of coarse to very coarse pebbles, which was contiguous with the ground surrounding the ridge. At the eastern end of Kaitorete Spit Armon (1970) found silty clays developed to a thickness of 2.5 m over gravel. In an auger hole at M37 807 111 it was found that 1.2 m of blue silty clay was developed over a brown muddy medium gravel. The top c. 200 mm was brown mottled blue silty clay, the mottling associated with plant roots.

3.1.1.2 Taumutu Ridges

North of Taumutu settlement, a group of lacustrine ridges are divided into two main groups: 1) Group 1 is made up of ridges with crest elevations c. 4–5 m; 2) Group 2 ridges that truncate Group 1 ridges at their easternmost ends, of which the highest ridge reaches approximately 7 m elevation.

Group 1 ridges trend northwest–southeast, have crest elevations of c. 4–5 m, and their southeastern ends are truncated by several alluvial channels. A small triangle of ridges has formed with a more west–northwest/east–southeast trend at the southern end of this group, and these are truncated by the highest (and oldest) ridge of the Group 2 ridges. An area to the southwest has numerous alluvial channels, that either lead off to the south into Waikewai Creek, or are truncated by the cliff to the south. One of these channels has a Group 2 ridge developed over its northeastern end.

Group 2 ridges are generally more subparallel in character than those in Group 1. The general form is a gentle curve changing from a northwest trend at the limit of the field area (M36 580 070) to a west–northwest trend where the ridges are truncated at their southeastern ends. In the field, the ridges have a gentle topography, with the southwestern slopes slightly steeper than their corresponding lakeward slopes. The height difference between ridge crest and the intervening swale is generally in the order of c. 1 m, with crest to crest



Figure 3-5. Photograph of a section of the truncation developed in the well bedded gravels in the pit at M36 768 102. The truncation and overlying beds have an apparent dip of 4° east, the gravel beds below the truncation have an apparent horizontal attitude. All the beds are actually dipping to the south at $4-7^\circ$. Photograph height is 0.8 m.



Figure 3-6. Photo of Taumutu Gravel Pit south wall showing eastward dipping sandy gravel layers which downlap a series of horizontal beds of sand and gravel. Note the blue silty clay which occurs at bottom of the hole. The elevation at the top of the face is c. 6.5 m. Note spade for scale. Taken looking southeast at M37 588 065.

spacing varying from 20–100 m. The highest ridge crest in Group 2 reaches approximately 7 m elevation (Hemmingsen, pers. comm., 1997), with ridge crest heights gradually decreasing lakeward.

The southeastern ends of the group 2 ridges are truncated by a curved cliff. The cliff ranges in height up to a maximum of c. 4 m (which puts the cliff top at c. 6 m elevation). Between the cliff and the present lake shore there are much smaller ridges developed which parallel the trend of the cliff. This cliff is vertically cut into either marine beach or alluvial gravels, and ends at the point where Waikewai Creek joins Lake Ellesmere.

3.1.1.2.1 Taumutu Gravel Pit

Within the Taumutu Ridges a large sand and gravel pit is located at M36 588 O65. The pit showed good exposures of sedimentary structures in the walls. The centre of the pit corresponds to the crest of the highest ridge in the Group 1 Taumutu Ridges.

Figure 3-6 shows the south wall of Taumutu Gravel pit, where the pit wall is oriented roughly perpendicular to the strike of the ridge crests. Three of the four units developed are shown in the pit. The first unit occurs from c. 6.5–4 m elevation, and comprises of parallel well bedded sands and sandy gravels dipping at 5–7° to the northeast (lakeward). Minor truncations occur within the unit, and the beds downlap the top of the lower unit. Dipping sand and sandy gravel beds range from 1.5 to 60 mm in thickness. Sandy gravel layers are generally clast supported and have a poorly sorted medium to coarse sand matrix. Pebbles range from granule to medium pebble. In the fine to medium pebbles there are numerous discoid pebbles, most of which have their long and intermediate axes oriented parallel to the bedding plane. The sand layers tend to be moderately sorted medium to coarse sand. Several thick (60 mm) silty medium sand beds occur at the base of the unit.

The second unit occurs from c. 4–3 m elevation, and consists of horizontally bedded medium to coarse sands, there are also some beds with floating fine pebbles. The sand beds contain hummocky cross-bedding.

The third unit consists of poorly bedded poorly sorted clast supported muddy sandy medium gravel. The unit occurs from c. 3–2 m elevation.

The top of the fourth unit occurs at c. 2 m elevation, this puts the top of the fourth unit beneath the pit floor. It consists of blue silty clay and has a strong hydrogen sulphide odour when freshly dug.

Northeastern and southwestern pit walls, are roughly parallel to the strike of ridge crests and show subhorizontal bedding with minor truncations developed.

Armon (1974a) found a shellbed of the freshwater mussel *Hyridella menziesi* (Gray) in the Taumutu Ridges c. 2.5 elevation, and had one of the shells dated at 748±41 years B.P.

3.1.1.3 Dune Ridges

At the western end of Kaitorete Spit a small area of lacustrine shoreline ridges are mantled by aeolian dune deposits (M36 626 063, Figure 3-7). The ridge crests stand between 7 and 8 m in elevation. Their lakeward slopes are between 5° and 7° toward the north. Relief on the northern side is approximately 3 m, and to the south relief reaches a maximum of 2 m.

At the area of interest the lacustrine ridge disappears underneath two dunes, and reappears on the western side. In the westernmost dune, an area approximately 10 by 15 m at 7.8 m elevation is covered by medium to coarse pebbles (see Figure 3-8). A shallow pit c. 0.5 m deep was dug to examine the texture and structure of this area. The pit showed 0.1 m of medium to coarse pebble beds, dipping north (lakeward) at 2–5°, overlying 0.5 m of massive, poorly sorted, fine to medium sand. An interdune ‘blow-out’ (Armon, 1970) is developed just south of the over riding dune. The floor of the blow-out is characterised by a coarse discoid pebble pavement, overlying coarse to medium sand. The blow-out pavement surface is at c. 6.4 m elevation.

Approximately 200 m to the northeast, another pit was dug, in a sinuous lacustrine ridge that stands c. 0.4 m above the surrounding ground, with a crest elevation of c. 4 m. The pit revealed a layer of broken shells and coarse sand in a fine sand matrix, 300 mm below the surface. The shells on the basis of their nacreous lustre, muscle scar pattern, overall shape and the nature of the hinge line have been identified as *Hyridella menziesi* (Gray) (see Appendix F). Shell beds appear to be horizontal, but this may be an artefact of the small area exposed in the pit wall. Near the base of the hole at 400 mm was a layer of granules to very coarse pebbles in a fine sand matrix, the medium to very coarse



Figure 3-7. Photograph looking southeast at M37 626 063. Observe the lacustrine ridge disappearing beneath the sand dune in the centre of the photo. Ridge has approximately 3 m of relief.

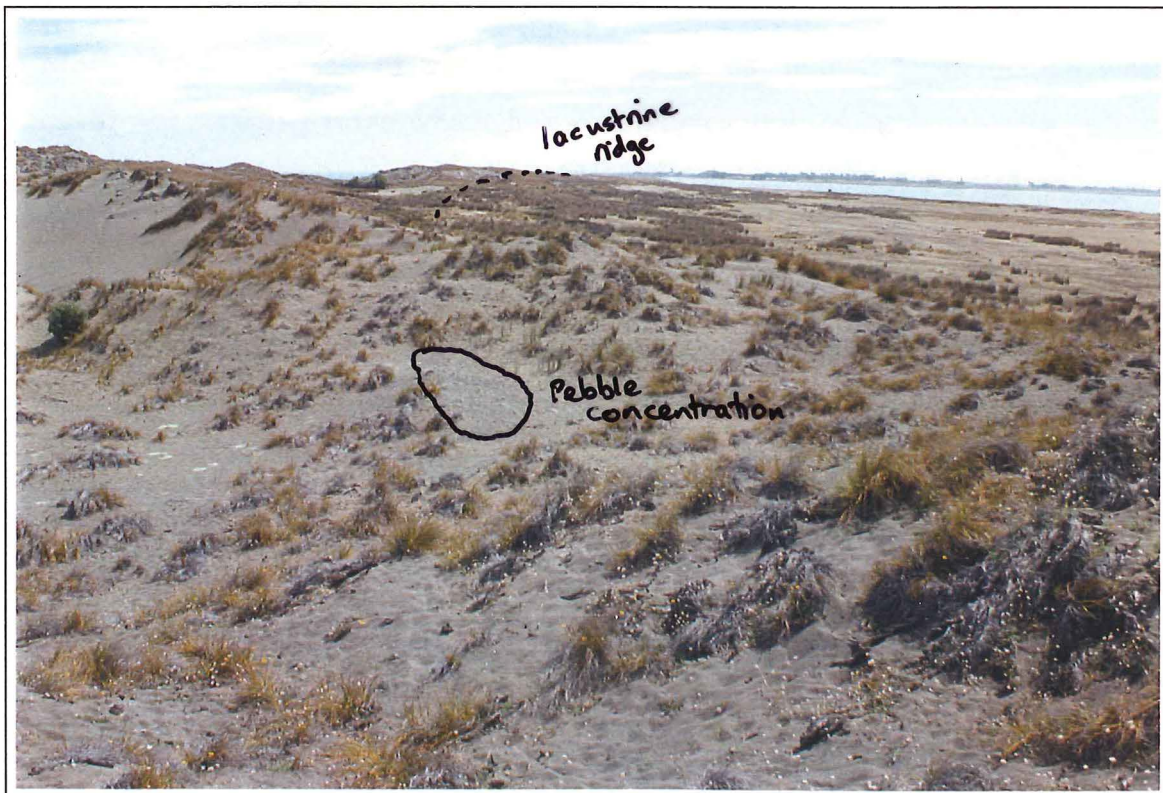


Figure 3-8. Photograph at M36 626 063 taken looking west from the top of the overriding dune shown in figure 3-7. Note the concentration of medium to coarse pebbles scattered on the surface at c. 8 m elevation (marked). The continuation of the lacustrine ridge can be seen in the distance.

pebbles being predominantly discoid in shape, with their intermediate and long axis oriented horizontally. Ground surrounding the ridge is covered by medium to coarse pebbles, with their intermediate and long axes parallel to the ground slope.

One kilometre east of Dune Ridge, a group of subparallel curvilinear ridges occur on the south side of a large lacustrine ridge. The easternmost curvilinear ridges trend north–south at their distal ends. At the northern side of the group the large ridge mantles the proximal ends of the curvilinear ridges. The easternmost ridges curve around a sand dune and their round ends sit above a dune ‘blow-out’, with coarse to very coarse pebbles scattered over a poorly sorted medium to coarse sand. South of the curvilinear ridges a bracken-covered small ridge occurs along the northern margin of the sand dunes.

3.1.1.4 Ponds

Three large, and several small semi-circular depressions dominate the geomorphology developed in the area of Ponds (Figure 3-9)(M36 651 071 to M36 664 076). Half of the southern margin is defined by a roughly west–southwest trending ridge which has a crest elevation of approximately 6–7 m. The other half of the southern margin comprises of a northeast–southwest trending cusped ridge, which forms the northern margin of Bayleys Ridges West (see section 3.1.1.5.3, below). The northern margin of Ponds, is defined by a ridge which also trends close to east–northeast/west–southwest, and reaches 4–5 m in elevation. The form differs from the other lacustrine ridges discussed so far, in that its lakeward (north–facing) slope is gentle (2–3°), but its corresponding seaward (south–facing) slope is very steep (12–15°). The toe of the south–facing slope ends very abruptly on the bottom of the adjoining depression, with the ridge crest standing 2.5–3 m above the depression floor. The southern outline of the ridge also differs from other lacustrine ridges formed on Kaitorete Spit in that it is not a smooth continuous margin, but is sinuate in nature. The ridge mantles the geomorphic features formed to the south (Figure 3-10). Down the lakeward slope of the northern margin, several smaller parasitic ridges have formed. These parallel the trend of the main ridge, but only stand 0.5 m above the surrounding slope.



Figure 3-9. Photograph taken looking west across one of the depressions in the Ponds area. Note the steep slope of the northern bounding scarp-like ridge, and the coarse material exposed. Several small scale ridges can be seen on the floor of the depression. The left centre of the photo shows the southern bounding ridge of the area. M37 662 075.



Figure 3-10. Photograph looking east showing the northern bounding ridge mantling a group of parallel curvilinear ridges at M37 656 073 in the Ponds area.

Separating the depressions are short northward trending ridges that are located at the horn apices of the cusped southern bounding ridge. These north trending ridges are 1.5–2.5 m above the floors of the surrounding depressions and consist of a single ridge which may have small parasitic, parallel ridges developed low down on the lateral margins. Northern ends of the ridges are truncated by the east–northeast/west–southwest trending northern ridge.

Several groups of curvilinear ridges occur in the Ponds Area (Figure 3-11). At their northern ends the ridges trend north–south and rotate toward a west–east trend at their southern ends. Ridge crests stand 2.5–3 m above the floors of the surrounding depressions and have very similar heights in each group, varying by no more than 0.5 m. At their southwestern ends, the curvilinear ridges are linked to the southern margin by ridges which trend roughly northeast–southwest and rotate toward the west where they join the southern margin.

Depression floors dip very gently lakeward and have small scale ridges, channels and depressions formed on them (see Figure 3-9). A 0.5 m pit was dug in the floor of one depression to reveal that the floor consisted of 100 mm of grey silty clay overlying very poorly sorted sandy medium gravels below.

A pit that was dug 75 m north of the crest of the northern bounding ridge revealing well developed beds of both sandy and open framework, fine to medium gravel, dipping at 6–7° north. Several pits were dug on the tops and down the sides, of the groups of curvilinear ridges. All revealed well developed beds, ranging from very coarse sand to fine pebble, dipping southwest at steep angles >25° (difficult to get an accurate measurement due, to the collapsing pit sides). Southern slopes of the northern bounding ridge have medium to very coarse pebbles cascading down them. The top of the ridge has coarse discoid pebbles scattered about on the surface (see Figure 3-9).

3.1.1.5 Bayleys Ridges

The area named Bayleys Ridges by Armon (Armon, 1970), has been further subdivided into the areas: Ponds (see section 3.1.1.4); Bayleys Ridges West; Bayleys Ridges North; and Bayleys Ridges South.

The northern margin of the Bayleys Ridges group comprises of a ridge slightly higher than the preceding ridges, with a crest elevation of 7.5 m and a lakeward

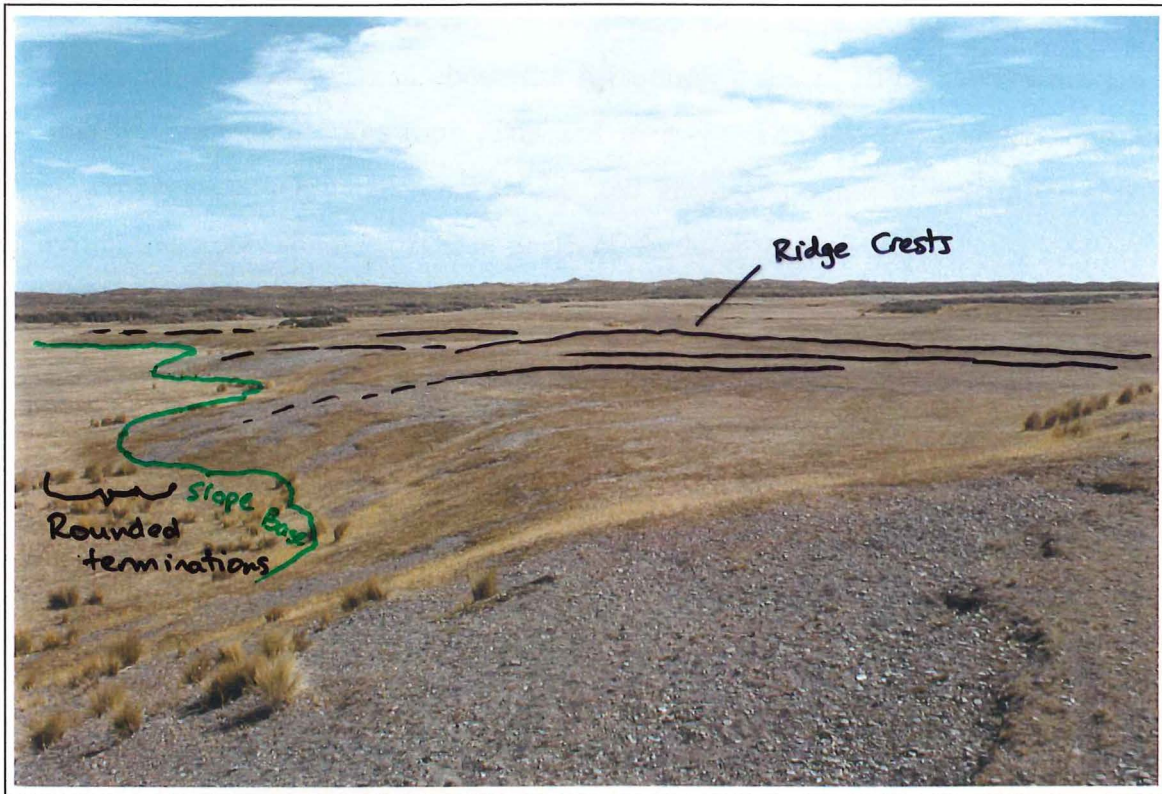


Figure 3-11. Photograph looking southwest at the rounded terminations of a group of parallel curvilinear ridges at M37 655 073 in the Ponds area.

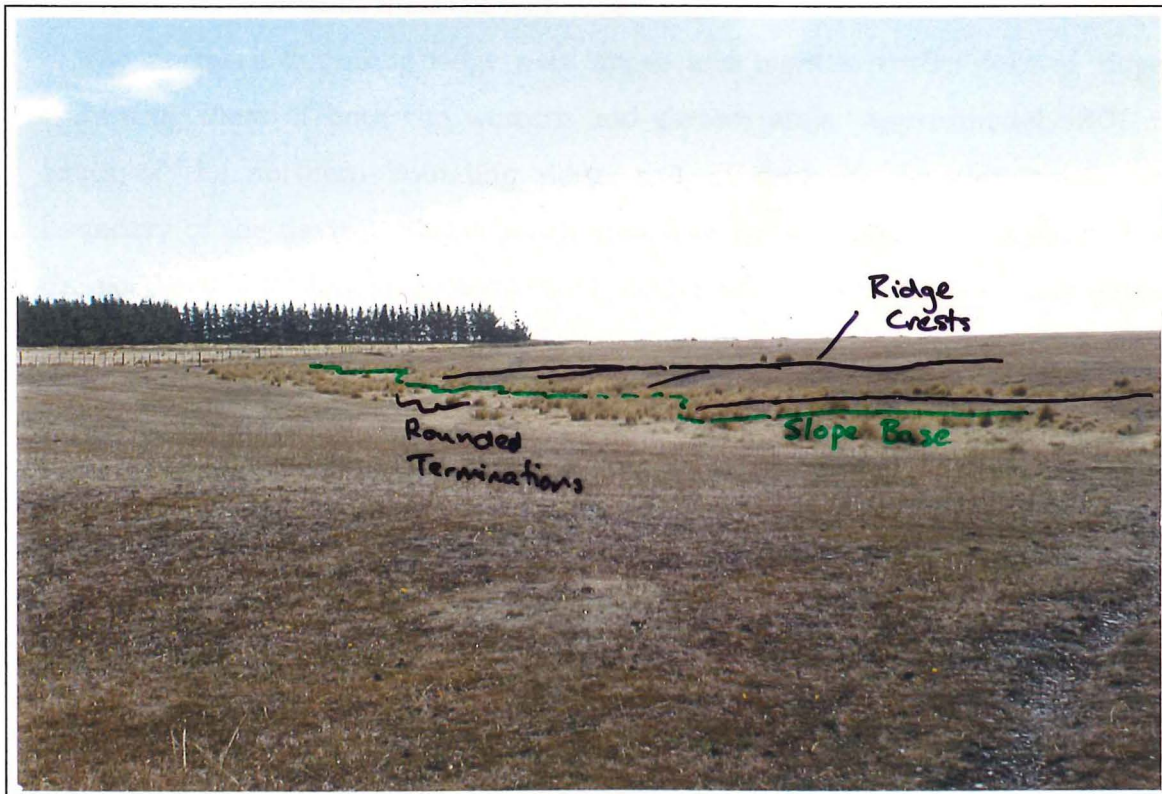


Figure 3-12. Smaller scale rounded terminations of a group of parallel curvilinear ridges, in the Bayleys Ridges South area. The photograph is taken looking west from M37 674 076.

slope of 5–7°. Halfway down the lakeward slope is a smaller parasitic ridge which stands about 0.5 m above the surrounding slope. The lakeward margin of this parasitic ridge also dips lakeward at 5–7°. The lakeward slope continues down progressively shallowing in dip and ending in some small, rather chaotic structures approximately 100 m north of the largest ridge crest.

A ridge formed on top of marine beach deposits forms the southern margin of the Bayleys Ridges group. The ridge tapers out approximately halfway along the area and is replaced by a gently (3–4°) lakeward sloping surface on the marine deposits. The crest of the ridge reaches 7–8 m in elevation.

3.1.1.5.1 Bayleys Ridges North

The majority of this area comprises of subparallel ridges trending east–northeast/west–southwest which have crest elevations of 6–7 m. At their western and eastern ends, the ridge trends rotate toward north. Crest to crest spacing is quite constant at about 10 m, with a relatively uniform crest to trough height of approximately half a metre. The cross–sectional shape of the ridges appears symmetrical in the field with slope angles of 2–3°.

The northern bounding ridge rises above and mantles earlier formed ridges truncating them at both the western and eastern ends. Approximately 200 m south of the northern bounding ridge, a 1 m drop in elevation marks the boundary of the Bayleys Ridges South area. The surficial sediment developed on the northern bounding ridge consists of coarse sand and medium to very coarse discoid pebbles.

3.1.1.5.2 Bayleys Ridges South

Ridge development in this area is similar to the curvilinear ridges developed in the Ponds area. The main ridges trend northeast–southwest at their northern ends, changing along their length to a roughly north–south trend at their southern ends. There are several groups of these curvilinear ridges formed. The southern ends of the ridges cease abruptly, standing 0.5–1 m above the surrounding ground with rounded terminations (Figure 3-12). The ridge crests stand 0.5–2.5 m above the surrounding low ground. In the west of the area the ridges tend to have less curvature, and ridge ends start to merge into the

southern margin. A triangular group of ridges along the boundary of Bayleys Ridges West, have west–northwest trends.

3.1.1.5.3 Bayleys Ridges West

Bayleys Ridges West area is triangular in plan view and bounded to the north by the Ponds area. The western margin is defined by a northeast–southwest trending ridge, which truncates the ridges developed in both the Bayleys Ridges South and Bayleys Ridges North areas. Younger ridges developed in this area progressively rotate away from the southern bounding ridge until a west–southwest/east–northeast trend is reached. North of the west–southwest/east–northeast trending ridge, the ridges begin to take on a cusped form, with the horn apices pointing to the north–northwest. At these apices the north–south trending ridges developed in the Ponds area, intersect the group (see section 3.1.1.4).

3.1.1.6 Island

The most noticeable feature of this area is the large elongate depression that is situated immediately north of Bayleys Road. The depression is approximately 1 km long, 150 m wide, 3.5 m deep, and its long axis runs roughly west–east (Figure 3-13). To the west, the depression runs into the southern margin of the Bayleys Ridges South area.

North of the depression, there is a relatively flat plateau of similar dimensions and orientation to the depression, but having an elevation of approximately 6 m. The northern boundary of the plateau is defined by the continuation of the northern bounding ridge of the Ponds and Bayleys Ridges areas. A small triangular area is defined by a west–southwest/east–northeast trending ridge which intercepts the northern bounding ridge about 500 m from the western end of the area. At the western end of this triangle is a smaller triangle of slightly lower elevation (4–5 m) than the rest of the plateau. Developed in this smaller triangle are several small ridges 1–2 m above the surrounding flat, and trending either north–south or northwest–southeast. These small ridges are mantled by the northern bounding ridge at their northern ends and join onto the edge of the plateau at their southern ends (Figure 3-14).

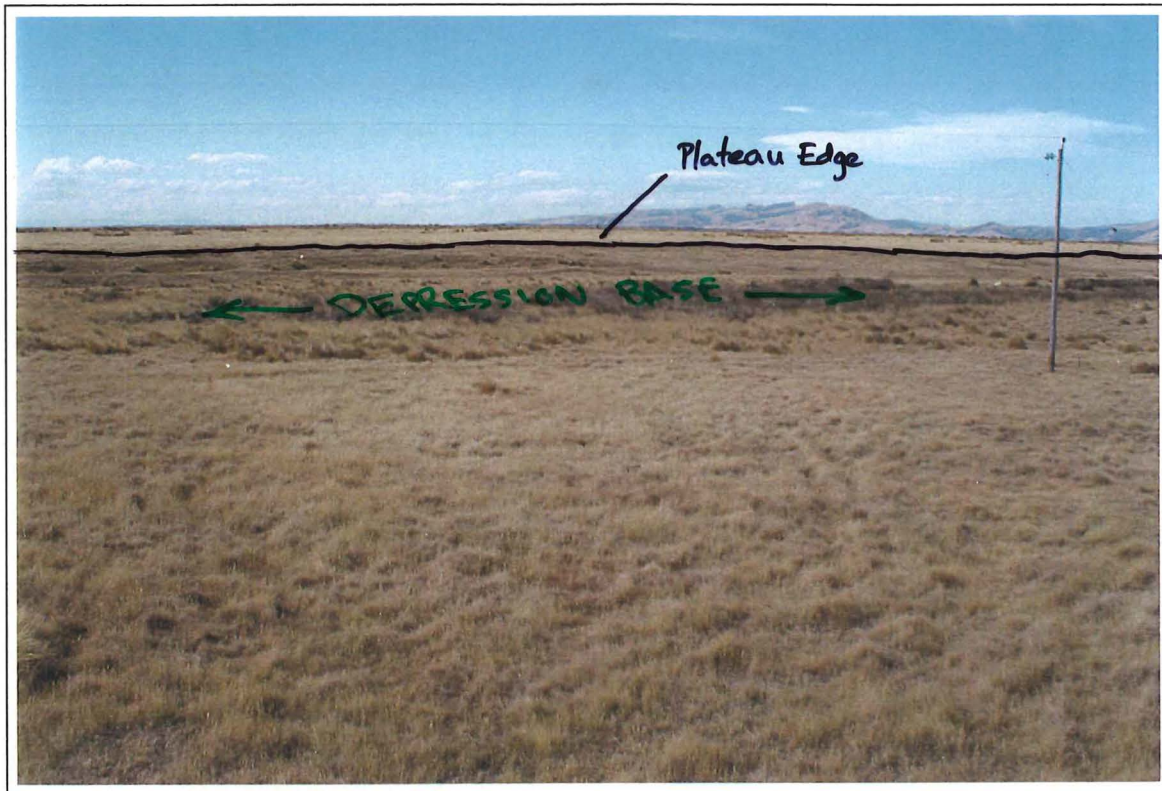


Figure 3-13. Photograph taken from M37 682 078 looking northeast at the plateau in the Island area. The edge of the plateau is marked. Note the bottom of the depression is covered in a darker tussock.



Figure 3-14. M37 682 080. Looking southwest at two small ridges in the northwest corner of the Island group. Note the steep southfacing slope of the northern bounding ridge and the nested rounded terminations on the farthest north-south trending ridge. The location of the radar profile Island northwest-southeast is marked.

Along the southern margin of the plateau the slope angle dips steeply to the south. Developed on the slope are small benches that parallel the trend of the plateau. At the western end of the slope there are several small slump scarps developed.

At the eastern end of the plateau a small northeast–southwest trending channel cuts both the plateau and northern bounding ridge. Beyond the channel the plateau is continued as a small finger of northwest–southeast trending land at c. 6 m elevation. The northern bounding ridge loses its relief and becomes part of the southern slope of a second, much smaller depression.

The smaller depression is approximately 300 m long and 100 m wide and trending roughly east–west. The northern margin of the small depression is similar in character to the ridge, which constitutes the northern boundary of Ponds area, so is very steeply dipping to the south, with an abrupt termination on the base of the depression. Developed on the slope are several slope parallel ridges. The northern margin has a sinuous outline, and the southern slope continues eastward as Speight Ridge (Armon, 1970) (see section 3.1.1.7).

Several small auger holes were drilled in the bottom of the depression, revealing at least 2 m of blue, silty clay, overlying sandy gravel. At the eastern end of the depression near the channel, several thin layers of fine gravel and granule occur within the clay. Several collections of broken freshwater mussel shells were found in the sandy gravels on the top of the plateau and along the fence line at the top of the slope, south of the depression. The floor of the small triangular area at the western end of the plateau is covered in coarse to very coarse, discoid pebbles lying with their long and intermediate axes parallel to the ground surface.

3.1.1.7 Speight Ridge

Speight Ridge was named by Armon (1970) and refers to a roughly west–southwest/east–northeast trending linear feature, which approximates the boundary between lacustrine–influenced and marine–influenced areas in the central region of Kaitorete Spit. In reality it is not a ridge for its entire length, but alternates between being a ridge and a scarp–like feature. At its western end it begins as the steep (10–12°) lakeward–dipping margin to the marine beach barrier complex (Figure 3-15). Further east the feature begins to take on a ridge



Figure 3-15. M37 695 081 Speight Ridge looking west, note the lack of ridge form. The second small depression of the Island area occurs just north of the ridge. Note darker tussock the on depression floor.

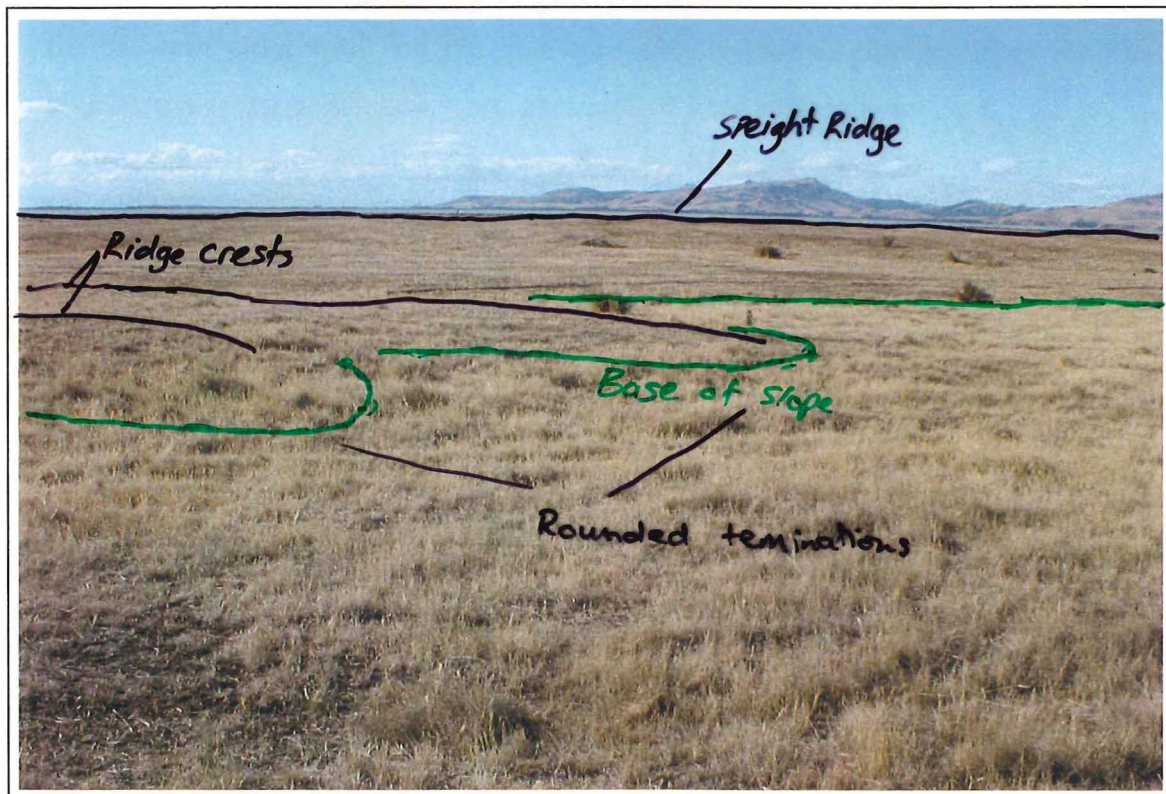


Figure 3-16. M37 758 094 Looking north, at the rounded terminations of the some small, Speight Ridge subparallel, ridges. Note slight vegetation change between ridges and they rest on (marked).

form, standing higher than the surrounding ground on both sides, with a relief of 2–2.5 m and a slope angle of 5–7° on the lakeward side, and a 1–1.5 m relief and a 10–12° slope angle on the seaward side.

At grid reference M36 722 087, the ridge loses relief against the seaward side as a result of an intersection with a marine beach ridge which is higher in elevation than previously intersected marine beach ridges. This loss of relief against the seaward side continues for several hundred metres due to the subparallel trends of the marine beach ridge and Speight Ridge. At the eastern end of this region, Speight Ridge abruptly changes trend to northeast–southwest for a length of about 400 m, before resuming its original east–northeast/west–southwest trend.

Speight Ridge remains a ridge for approximately 4 km eastward from the bend described above. It slopes lakeward from 5–7°, and the crest stands about 3.5 m above the gently sloping lake floor on the north side. On the south (seaward) side, the ridge stands approximately 1–2 m above the moderately sloping lower ground, with slope angles from 5–10°. The termination of the slope is abrupt on the seaward side, while on the lakeward side the slope changes from moderate lakeward sloping to a much more gentle (1–3°) lakeward slope.

In several places small ridges are developed seaward of the crest of Speight Ridge, and these generally parallel the trend of Speight Ridge, and stand only 0.5–1 m above the ground to the south. There is an area where a collection of these ridges have distinctive rounded terminations, very similar to the terminations of the ridges in Bayleys Ridges South (see section 3.1.1.4) and the Ponds (see section 3.1.1.5.2) areas (Figures 3-16 and 3-17).

At M37 771 097 Speight Ridge changes in form by losing its moderate slope on the lakeward side, replaced by the gentle lakeward slope extending to the crest of the ‘ridge’. The seaward slope becomes steeper with a slope angle of 10–12° (Figure 3-18). South of the ridge crest, several small ridges are developed running parallel to Speight Ridge. The relief on the south side increases eastward, from c. 1.5 m at M37 778 097, to c. 3 m at the Trig Point Ridges (see section 3.1.1.8). At Trig Point Ridges, Speight Ridge is replaced by several northeast–southwest trending short wide ridges.



Figure 3-17. M37 758 094 Speight Ridge looking west at southern margin of subparallel ridges. Note subtle north–south trending structures, with the rounded terminations again present. Note sheep for scale.



Figure 3-18. M37 786 099 View looking west along the southern scarp–like face of Speight Ridge where it joins Trig Point Ridges. Note the abrupt termination of the southern face of the ridge on the gently north sloping lower ground. The lower right corner of the photo shows coarse discoid pebbles covering the ridge crest. Note the shallow slope north of the crest. The relief from crest to ground is c. 3.2 m.

Approximately 150 m south of the point at which Speight Ridge disappears into the Trig Point Ridges, there is a small ridge approximately 0.5 m above the surrounding ground. Eastward of Trig Station Ridges the ridge quickly gains relief until it stands approximately 1.5–2 m above the seaward ground and 2–3 m above the gently sloping lakeward surface. Speight Ridge continues east-northeast until it crosses Jones Road where it begins to rotate toward the east. Around this point the marine beach ridge crests have elevations such that Speight Ridge loses much of its relief against the southern side and stands no more than 0.5 m above the southern ground (Figure 3-19). The ridge begins to change form again with a steepening of the southern slope to 12–18° (Figure 3-20). The lakeward slope stays moderately dipping at 5–7° with a rapid change to a gentle (1–3°) lakeward slope approximately 50 m from the ridge crest.

Approximately 1.5 km east of the point where Speight Ridge crosses Jones Road, it joins onto a group of curvilinear ridges named Golf Course Ridges (see section 3.1.1.9). The ridge crest elevation increases eastward from 9 m at the western end of the Golf Course Ridges, to approximately 10 m at the eastern end. The ridge wraps around the eastern end of the Golf Course Ridges and changes its trend from east-west to north-south. The ridge decreases in elevation towards the south until it ends with a relief of 0.5–1 m above the surrounding ground in the golf course.

North of Speight Ridge the ground gently (1–3°) slopes toward the north (lakeward) gradually shallowing in dip. South (seaward) of Speight Ridge the ‘ridge’ is marked by a steep (10–15°) dip south which abruptly meets with a moderately (4–5°) lakeward dipping planar surface.

On the lakeward side of Speight Ridge several excavations reveal thin (2–5 cm) beds of sandy granule to medium pebble dipping (5–7°) toward the lake, a peaty matrix is present with the majority of the beds. The seaward side of the ridge has corresponding seaward dipping beds. The lakeward side of the ridge again has medium to very coarse pebbles at the surface, with any discoid pebbles having their long and intermediate axes oriented perpendicular to the ground slope. Where the ridge loses its lakeward relief and becomes a southward dipping scarp-like feature (eg. Trig Point Ridges or west of Golf Point Ridges), the fine to

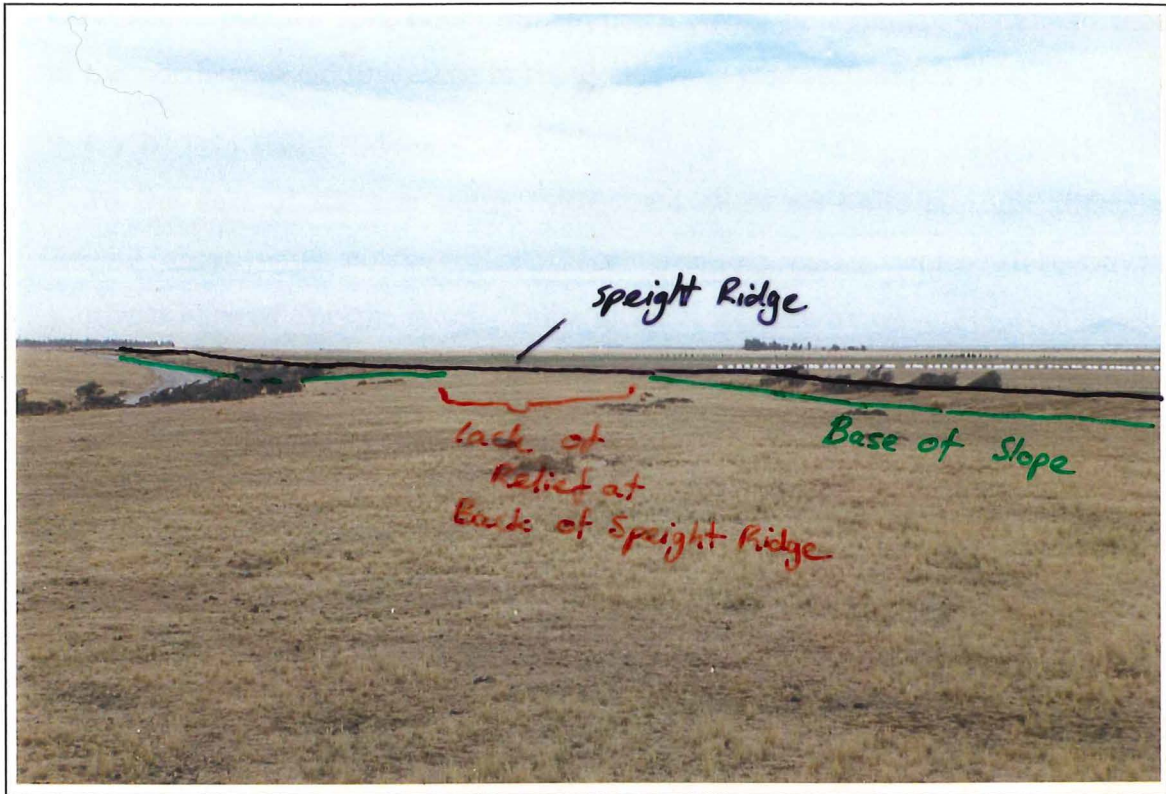


Figure 3-19. M36 806 103. View looking west at the intersection of Speight Ridge and a marine barrier beach ridge. Note the loss of relief on the southern side of Speight Ridge.

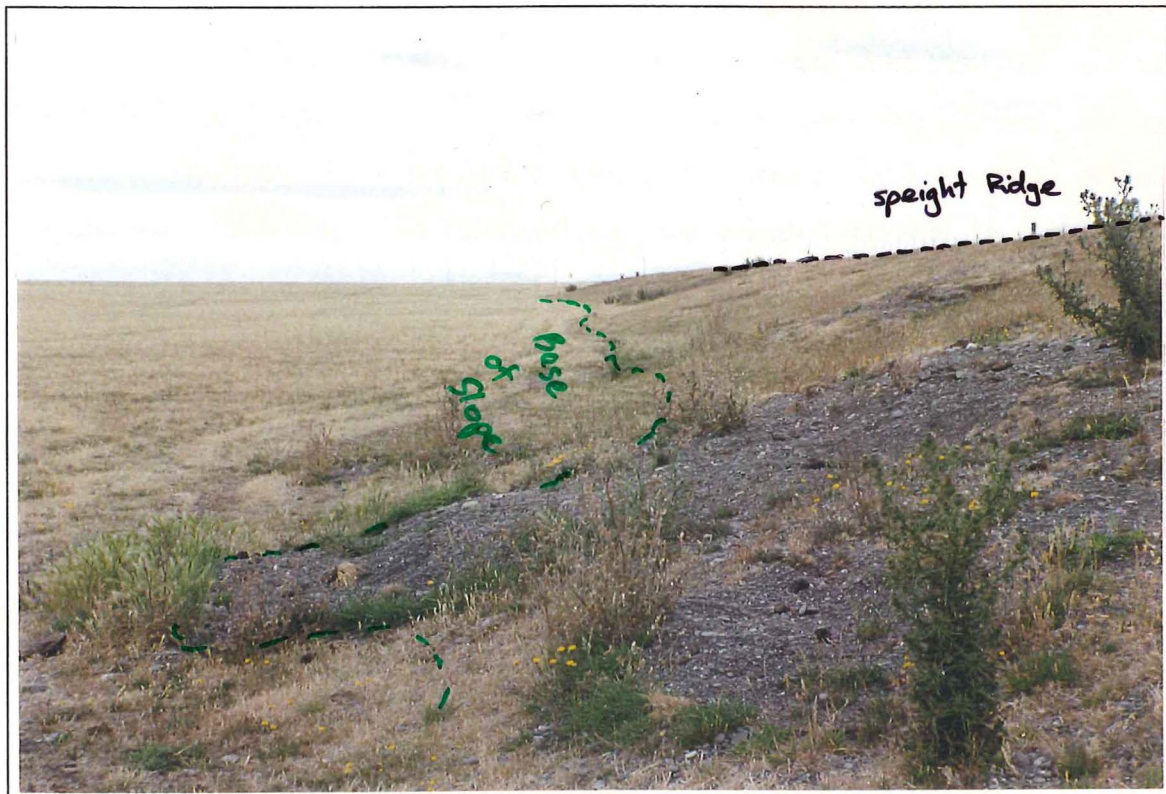


Figure 3-20. M36 824 105. Looking west along the southern margin of Speight Ridge. Notice the steep slope which terminates abruptly on the ground to the south. Compare with Figure 3-18. The relief here from crest to southern ground is c. 3 m.

very coarse pebbles spill down the southern slope, in a similar fashion to those in the northern bounding ridge in the Ponds area (see section 3.1.1.4).

3.1.1.8 Trig Point Ridges

To the east of the trig point (M36 784 098) on Kaitorete Spit there are several short wide northwest–southeast trending ridges which start on the southern edge of Speight Ridge. These short ridges are between 50–100 m wide and 50–150 m in length. They differ from other ridges formed on Kaitorete Spit in their cross-sectional shape. They have steep slopes on their west and east sides, with slope angles of 10–15°. Their relief is about 3 m from crest to surrounding low ground, and diminishes to the south as the lakeward sloping surface increases in elevation. The elevations of the ridge crests are between 4 and 5 m, and they are essentially horizontal. The ridges end in one of two ways: 1) the ridges terminate abruptly with the end being marked by a steep slope down to meet the moderately lakeward–dipping surface; 2) the ridges extend southeast, with nearly horizontal crests where the crest eventually meets the lakeward sloping surface farther to the south (Figure 3-21).

The ridges become smaller in size towards the east until they are no more than 5 m in length, 2 m in width and 0.25 m above the lakeward sloping surface. The tops of the ridges are covered by medium to very coarse pebbles lying with their long and intermediate axes oriented parallel to the ground surface. Down the slopes of the ridges, fine to medium pebble beds are revealed in small scarp-like features created by stock erosion.

Approximately 200 m east of the trig station, the continuation of Speight Ridge (see section 3.1.1.7) starts as a very small ridge (standing less than half a metre above the surrounding ground) trending east–northeast (see Figure 3-22). This small ridge rapidly gains relief to the east–northeast, until after 300 m, it stands 1.5 m above the ground to the south.

3.1.1.9 Golf Course Ridges

This area can be subdivided into three parts: 1) Southwest Golf Course Ridges; 2) Middle Golf Course Ridges; 3) Northeast Golf Course Ridges (Figure 3-23 on page 67).

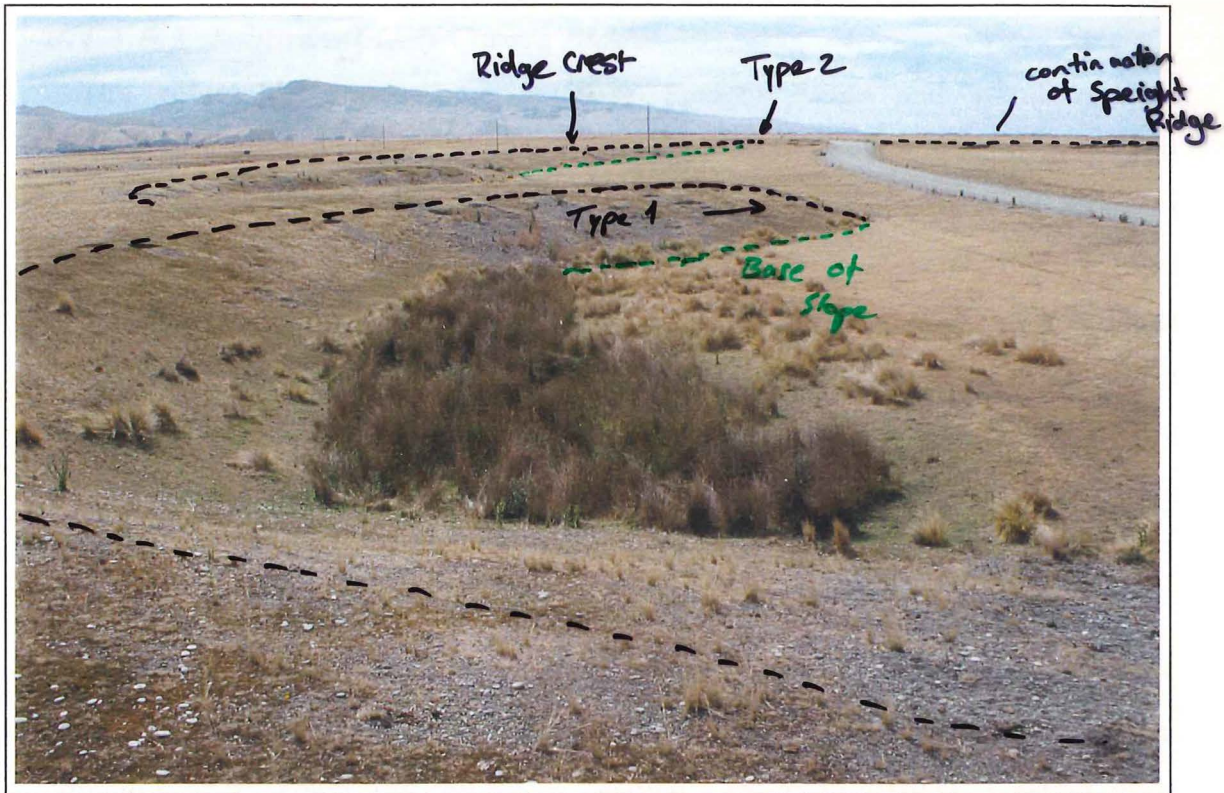


Figure 3-21. M37 786 099. Looking east over the Trig Point Ridges. Notice the closest ridge has a rounded termination that ends abruptly on the gently north sloping surface. A second type of termination is developed further east (marked) where the ridge crest is essentially horizontal and joins the gently lakeward sloping surface to the south. The continuation of Speight Ridge occurs at the top right of the photo. Compare the rounded terminations with the rounded terminations shown in Figure 3-11.

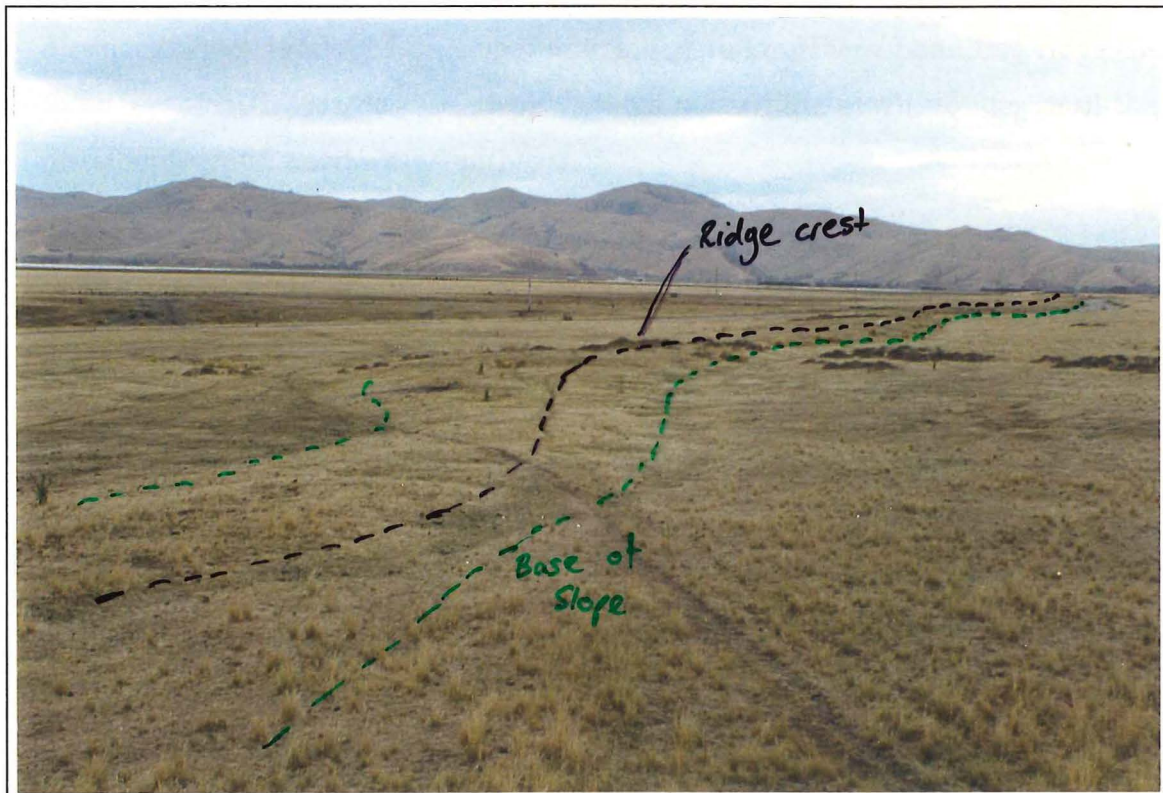


Figure 3-22. M37 785 097. Photograph looking east over the Trig Point Ridges. Notice how the continuation of Speight Ridge (marked) gains relief to the east.

3.1.1.9.1 Southwest Golf Course Ridges

The ridges developed here start at Speight Ridge and trend roughly southwest–northeast, with ridge crest elevations higher at the Speight Ridge end than the southern end. The ridges developed in this area are generally lower in elevation, and the topography is a lot more subdued than the ridges developed in the other two areas. The aerial photographs show that there is ridge development but the definition of the ridges is poor. The ridges end to the south by gradually losing relief and joining with the lakeward sloping surface. The northern margin is defined by a ridge which runs east–west along the northern margin of the group.

3.1.1.9.2 Middle Golf Course Ridges

The middle ridges have crest elevations of approximately 5–6 m, slightly higher than the Southwest Golf Course Ridges. The definition shown in the aerial photographs improves and the ridges become a lot more distinct. A larger ridge starts at Speight Ridge, trends west–east for 500 m, and then rotates to an east–southeast/west–northwest trend for the last 150 m. This ridge defines the northern boundary for the Middle Golf Course Ridges. The middle ridges have distinct curves developed on them. Starting at the northern bounding ridge they trend west–northwest/east–southeast, which toward the south, rotates until their distal ends trend northwest–southeast.

3.1.1.9.3 Northwest Golf Course Ridges

The northern margin of the Northwest Golf Course Ridges is defined to be Speight Ridge. The Northwest Golf Course Ridges have crest elevations of 8–9 m. The individual ridges start at Speight Ridge and trend west–northwest/east–southeast, with the distal ends of the easternmost ridges trending northwest–southeast. The ridge crests decrease in elevation away from Speight Ridge.

East of the point where Speight Ridge ends, a small north–south trending channel 20 m wide and 200 m long, dips to the south. This channel cuts a small west–east trending ridge, which extends from Speight Ridge to the Railway Cutting Ridges. This small ridge stands 1.5 m above the ground to the north and approximately 1 m above the ground to the south.

The surface is covered by patches of medium to very coarse pebbles, and where pits were dug beds of sandy fine to medium gravel were shown dipping to the northeast. Upon excavation a peaty matrix was found developed in the beds near the ground surface.

3.1.1.10 Railway Cutting Ridges

The ridges that make up the Railway Cutting Ridges area are dominated by the old Lincoln–Little River railway cutting on the aerial photographs. These ridges form a north–northeast/south–southwest trending group just over 1 km in length and 400 m wide. The group narrows at its southern end where it meets the small ridge extending from the northern edge of the Golf Course Ridges. The northern end of the group butts up against the volcanic rocks and loess deposits of Banks Peninsula. At the northeastern corner of the group, a beach extends around the rock spur and joins with a gravel beach developed on the southern side of Birdlings Valley (Figure 3-24).

The ridges can be separated into two smaller groups based on crest elevation. To the west is the Waikakahi group, with crest elevations which average at about 8 m, and to the east is the Jones group which has an average crest elevation of approximately 6.5 m. A distinctive channel like depression separates these two groups.

The Jones group has a steep seaward bounding ridge which slopes at 8–10° to the southeast and ends abruptly on a very gently (1–2°) lakeward dipping surface. At the southwestern end the ridges trend southwest–northeast, changing farther northeast to a more north northeast–south southwest trend.

The Waikakahi group has a steep 6–8° lakeward dipping, northern bounding ridge, whose crest stands c. 5 m above the gently lakeward dipping surface to the northeast. This lakeward ridge has been eroded in places to form small (2 m) cliffs of gravel. The ridges in the Waikakahi group are straighter than the ridges in the Jones group and roughly trend north–northeast/south–southwest.

3.1.1.10.1 Jones Gravel Pit

The pit is located on the southwestern side of the old railway cutting, and is cut into the gravels of both the Waikakahi group and Jones group. The gravel pit has not been used for several years and the running of cattle, in the paddock

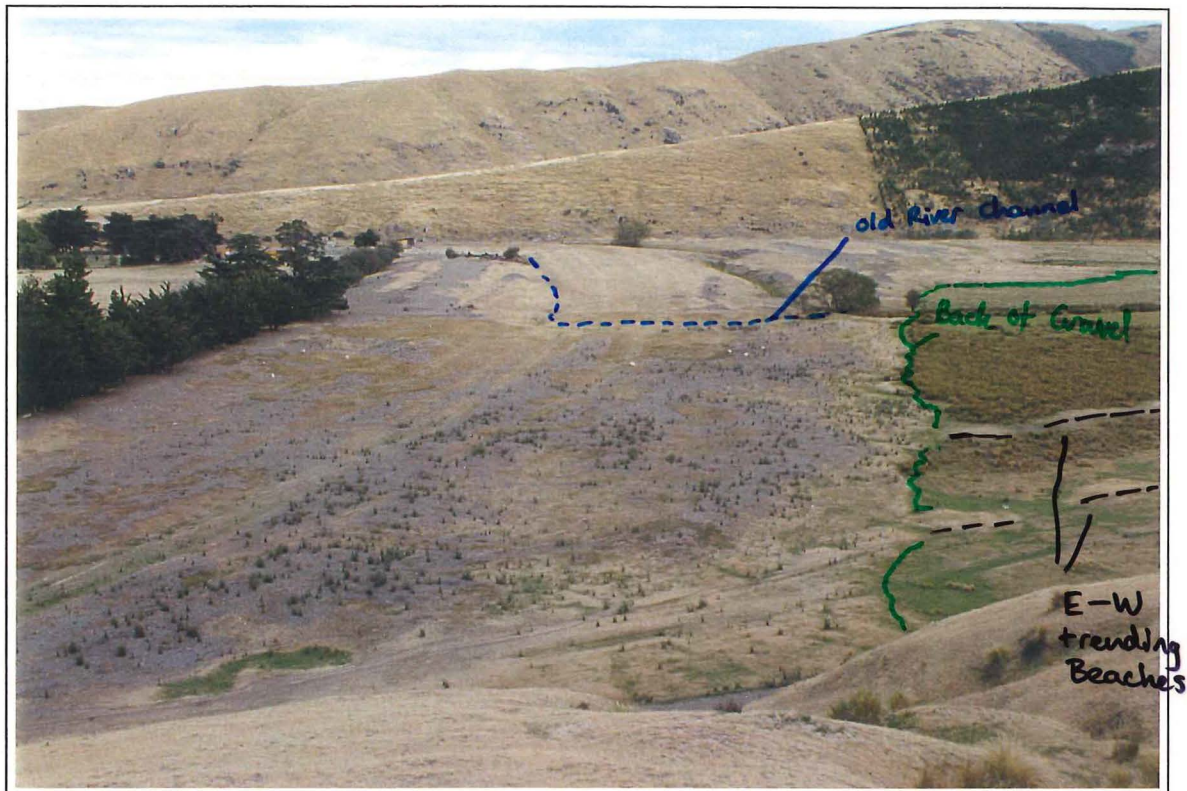


Figure 3-25. (Above) M36 854 110 Photograph looking north across Birdlings Valley. Note the curved north-south trending ridge complex. An old stream channel is marked cutting the ridges. Two east-west trending beaches appear at the bottom right of the photo (marked).

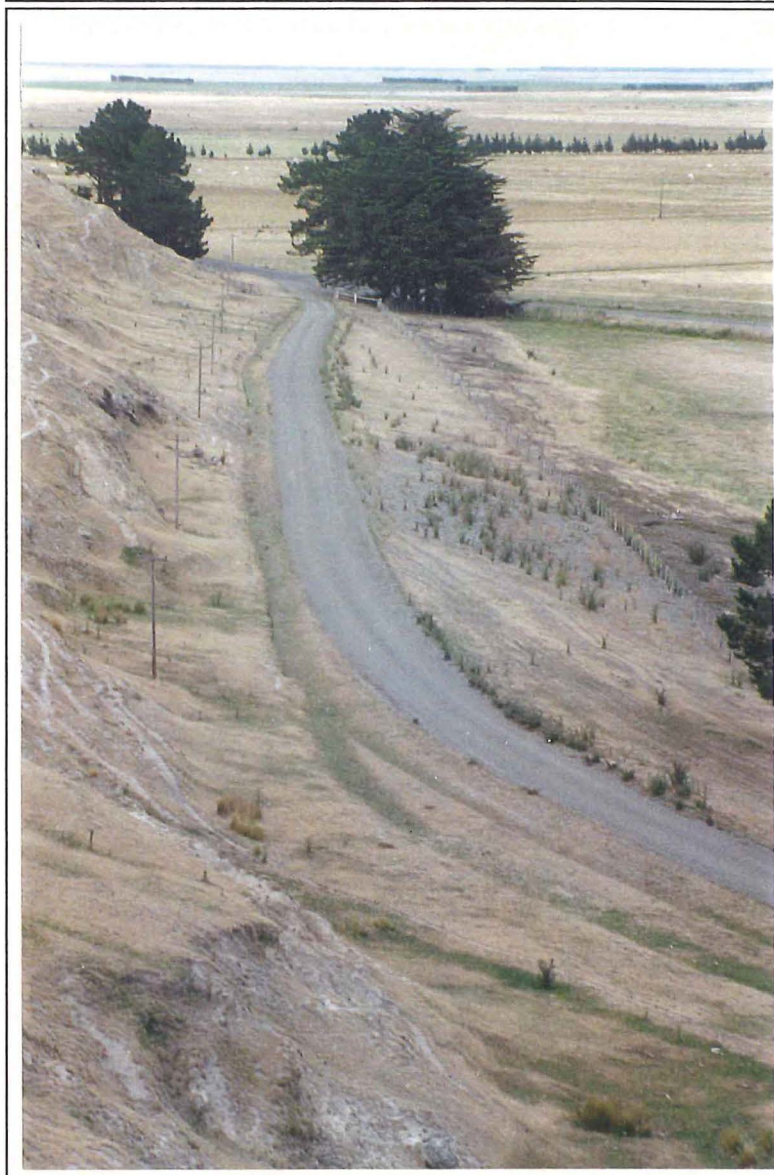


Figure 3-24. (Left) M36 854 110. Photograph looking east along the southern wall of Birdlings Valley. Notice the gravel beach onlapping the base of the volcanic rocks.

where the pit is located, has destroyed most of the pit wall. A small area remains which shows beds dipping lakeward at 5–8° and striking at c. 045°. The majority of the remaining outcrop is composed of well sorted, open framework, fine and medium pebble beds, between 5 and 20 cm thick. There are several beds of coarse discoid pebbles which are a single clast in thickness. The clasts lie with their intermediate and long axes parallel to the bedding plane.

Numerous nacreous shell fragments occur in the gravel apron at the base of the outcrop and broken shells occur in layers partially buried at the tops of the ridges. Soons et al (1997) found a layer of shells in the pit wall and had them identified as *Paphies australis* (Gmelin) (pipi) and carbon dated at 775±48 years B.P. The shells found at this site, during this study, were identified as *Hyridella menziesi* (Gray) (New Zealand freshwater mussel) (M James pers. Comm., 1997) (see Appendix F). Several areas of partially buried broken shells, bones and fire broken rocks, were also found on the tops of the surrounding ridges.

The small cliffs along the western margin of the Waikakahi group also show fine and medium gravel beds dipping toward the lake.

3.1.1.11 McIntosh Ridges

Between the Railway Cutting Ridges and the area of preserved marine geomorphology there is a small triangular depression. The floor of the depression is a very gently (1–2°) lakeward dipping surface, which has two sets of ridges developed on it. There is a regular poorly defined east–west trending set, with an irregular well defined sinuous set developed above the first set. Only a few of the ridges in the regular set can be seen in the field due to the poor definition.

The poorly developed ridges have medium to coarse pebble patches developed parallel to the strike of the ridge crests.

3.1.1.12 Birdlings Ridges

Across the mouth of Birdlings Valley a group of north–south trending slightly curved ridges occur (Figure 3-25). The westernmost ridge has a 0.5 m higher crest elevation than the more easterly ridges, and stands c. 5 m above the very gently (1–2°) west dipping ground to the west. The ridge crest elevations drop off eastward. The eastern margin of the ridges is marked by a slight drop down onto a flat subhorizontal surface. There is an old southwest–northeast trending

channel cutting the ridge group in the middle of the valley. The channel makes a sharp turn and occupies a runnel between two of the ridges. Further east the current stream has cut a channel between two of the ridges.

Along the southern wall of Birdlings Valley a gravel beach occurs linking Birdlings Ridges to Railway Cutting Ridges (Figure 3-24). East of the north-south trending ridges, on the south side of Birdlings Valley, there are two short northeast-southwest trending gravel beaches formed.

The surface of many of the ridges are covered in fine to medium gravel, and the western slope of the bounding ridge is entirely covered in loose fine to coarse gravel. In scarps along the edge of the current stream, west dipping beds of gravel occur. A 0.8 m pit was dug at the western toe of the bounding ridge, which revealed under 400 mm of fine to medium gravel, a yellow silty layer. At 700 mm several leaf like membranes were found, which were identified as the periostracums of *Hyridella menziesi* (Gray) (M. James pers. comm., 1997). Excavations into the ridges, beside the site of the old stream channel also revealed shell fragments of *Hyridella menszii* (M. Harvey pers. comm., 1997).

3.1.2 Marine Geomorphology

There are two main areas where marine geomorphology is preserved. These areas were defined by Armon (1970) and their locations are shown in Figure 1-1. The early formed spit recurves named the Hooked Ridges by Armon (1970) are preserved in an area on the northeastern end of Kaitorete Spit, and the later marine barrier beach ridges are well preserved between Speight Ridge and the current coast.

3.1.2.1 Marine Spit Ridges

Armon (1970) was the first to notice the recurved nature of the ridges developed in this region of Kaitorete Spit. The geomorphology shown in this area is generally poorly defined, and in the field it is very difficult to see the ridge and runnel form of the ground. The aerial photographs show a subtle ridge and runnel geomorphology. Generally the ridges developed in this area are very low relief, with the crest to runnel height less than half a metre. The ridge crests are difficult to pinpoint on the aerial photographs, but the general trend of the ridges can be observed.

The western spit ridges are quite straight and show east–northeast/west–southwest trends. At M37 778 112 a major truncation of these straight ridges is evident, and the truncating ridge curves from trending east–northeast/west–southwest, to a more northeast–southwest trend, cutting the ridges located to the north. East of this truncation there are well developed recurves which range in trend from north–northwest/south–southeast to northeast–southwest at their distal ends. The recurved ridges occupy a zone about 800 m wide and 7 km long. The east northeast–west southwest trending ridges, which appear to join to the recurves (although the lack of detail makes it difficult to pinpoint), move progressively southward as the recurves move eastward. At the southeastern side of the group it appears that the lacustrine Railway and Golf Course Ridges are developed over the spit geomorphology. In the depression southeast of the Railway Cutting Ridges, the regular, poorly defined set of east–west trending ridges (see section 3.1.1.10.1) appear to be continuations of the spit geomorphology developed on the lakeward side of the Railway Cutting Ridges.

Lakeward of Speight Ridge there are again small scale lacustrine features developed over the spit geomorphology (see section 3.1.1.11). The surface above the spit recurves is gently sloping lakeward and several fingers of the lake occupy the hollows between the ridge crests.

3.1.2.2 Preserved Beach Geomorphology

The aerial photographs show parallel ridges and runnels between Speight Ridge and the present coastline, trending roughly east–northeast/west–southwest and developed from M36 647 070 to M36 867 090. At the eastern end the ridge crests develop a curved form as they fill the area between Devil’s Knob and Lake Forsyth. The ridges straighten out as they are formed further to the south between Browns Pit and Birdlings Flat settlement. At the eastern ends of the ridges a cliff and a steep slope are formed, which abruptly end the ridges (Figure 3-26). The cliff is c. 6 m high and the ridge crests do not lose elevation as they approach this cliff. At the base of the steep slope Lake Forsyth has formed a moderately lakeward sloping gravel shoreline, there are several small ridges formed on this shoreline. At the elbow formed as Lake Forsyth runs around the base of the basalt cliff to the south, a lacustrine ridge c. 5 m high is formed at

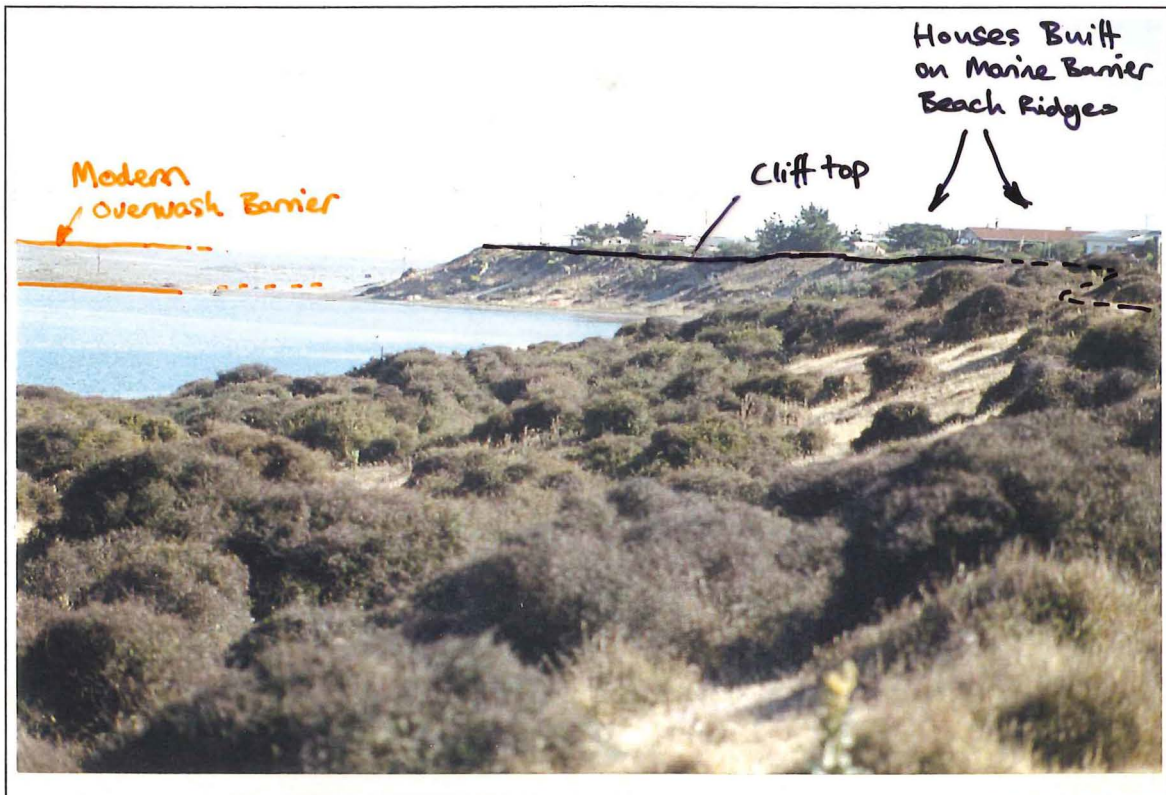


Figure 3-26. M37 868 097. Looking south along the cliff which terminates the marine barrier beach ridges at their eastern ends. Notice the ridge crests do not lose elevation as they near the cliff. In the distance the crest of the modern overwash barrier which fills the outlet to Lake Forsyth can be seen.

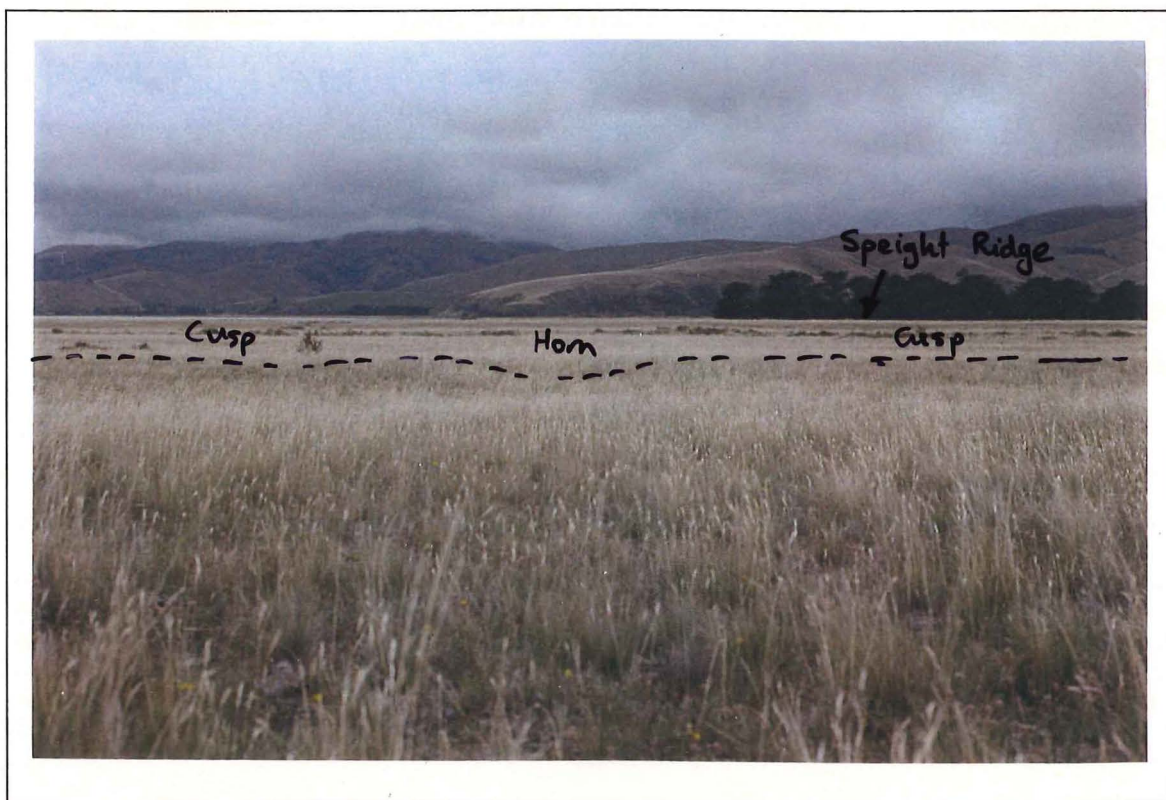


Figure 3-27. M37 827 098. A view looking north at the subtle horn and cusps (marked) developed near the Kailine 3 radar survey line. The horn to horn spacing measured here was c. 50 m. Several other marine crests can be seen further north, with Speight Ridge visible in front of the trees.

the northernmost extent of the shoreline. This lacustrine ridge overtops the regular ridge and runnel marine geomorphology to the north.

Armon (1970) traced the marine beach ridge crests, and noted that the trends of the ridges varied systematically from west to east, and that at the western end the ridge trends approached the present coast at angles such that they must be truncated by the present coastline. Armon (1970) also noted that the ridges at the eastern end show rise in crest elevation from north to south.

The aerial photographs reveal that towards the eastern end of Kaitorete Spit the ridge crests have a crenulated nature. In the field it is possible to see these crenulations developed on some of the ridges (see Figure 3-27). A horn to horn spacing of c. 50 m was observed at one locale.

At the eastern end, the 1984 photographs show the development of modern storm berms, when compared to the 1953 photographs. Along the rest of the coast, the shoreline shown on the aerial photographs has a good level of agreement with the map shoreline, including the dune washouts, which are indicated by the 10 m contour line, in the western third of Kaitorete Spit.

Along the southern margin shore parallel coastal dunes, described by Armon (1970), are developed over the marine beach ridges. The dune covered area reaches a maximum width of 1 km, and tapers off to the east until it disappears at the western end of Birdlings Flat settlement. In the western part of the spit the northern edge of the dunes has been eroded by the lake, as evidenced by the development of the lake ridge on the northern margin. In some places the dunes reach 20 m in elevation, but the majority stand between 6 and 15 m in elevation. The dunes' slip faces are on the northern sides with a northward dip of 10–20°. The interdune areas have blow-outs developed in them (Armon, 1970) which have medium to very coarse discoid pebble pavements overlying poorly sorted medium to very coarse sands. Along the seaward edge the sea has eroded the dunes, and in places has breached the dune front to form wash-outs which have long axes trending northeast–southwest. The wash-outs have medium to very coarse pebbles and driftwood covering their floors and ripples migrate to the northeast on the sides of the bordering dunes.



Figure 3-28. M37 866 088. Horn and cusps developed on the modern beach at Birdlings Flat. An old beach storm berm can be seen (marked) at the right of the photo. Notice the zone of coarse discoid pebbles at the base of the highest berm. Note the coarse nature of the surface sediment, with no visible sand. View looking west.



Figure 3-29. M37 837 087. A view looking east along the beach at the scientific reserve. Notice the appearance of sand on the beach surface, and that two sets of horns and cusps are visible. A coarse discoid pebble zone is again developed just seaward of the highest berm.

3.1.2.3 Modern Beach Geomorphology

The modern beach at Birdlings Flat is composed of medium to coarse greywacke pebbles (Figure 3-28). There are three main storm berms developed on the beach face. The highest berm, at c. 8 m elevation, marks the beginning of the beach face. The general profile of the beach is concave with three berms create steps in this profile. All three berms have horn and cusps developed on them, and the highest berm has horn to horn spacing exceeding 75 m in some places. From the berm, the beach slopes at 7–10° for a drop of 1.5 to 2 m. The beach then levels off to a 3–5° slope as it meets the crest of the second berm. At the crest of the middle berm the beach slopes off steeply again until it reaches the crest of the lowest and smallest berm. The middle berm has horn to horn spacing of approximately 60 m, while the lowest berm has horn to horn spacing of approximately 15 m. A beach step can be seen developed at c. 0 m elevation, and is the point at which the waves break on the beach.

On the beach near the scientific reserve there are still three berms, but the shape of the beach is quite different (Figure 3-29). The general beach slope is a shallower 5–7°, and the sediment has the addition of sand, which is modifying the beach response and therefore profile. The beach profile remains similar further to the west and the three main berms are still developed down at Taumutu. The horn and cusp nature of these berms also remains.

Excavations into the beach surface reveal seaward dipping layers which largely parallel the dip of the beach (Figure 3-30). The individual layers may be inversely graded as found in many beach laminations (Thompson, 1937; Clifton, 1969), or have normal grading. Figure 3-31 shows bedding developed in a horn cusp set which has been eroded by a later wave event.

At Birdlings Flat the beach is covered by an armouring layer of pebbles. Developed seaward of all three horn and cusp sets is a zone of discoid very coarse pebbles. Beneath the surface layer, the gravel tends to be finer and ranges from fine pebble to medium pebble with the odd coarse discoid pebble layer developed within the finer gravel. Further west on the beach, the coarse discoid pebble zones still occur, parallel to and seaward of, the horn and cusp sets (see Figure 3-29).



Figure 3-31. (Above) M37 837 087. This section of eroded horn was found at the beach near the scientific reserve. Compare the bedding and truncation to the pit north wall shown in Figure 3-5. The scale is 15 cm long.



Figure 3-30. (Left) M37 865 088. A close up view of the layering developed in the beach at Birdlings Flat. Note the relative fineness of the sediment in comparison to that shown on the beach surface in Figure 3-28. The scale is 15 cm long, with 5 and 1 cm markings.

3.1.2.4 Overwash Barriers

At the outlets to both Lake Ellesmere and Lake Forsyth, overwash fans have developed in the artificial cuts. These are characterised by their general steep seaward slope (5–8°) and their shallow lakeward slope (2–5°). In the cuts the beachface can be seen to truncate gently north dipping parallel beds (see Figure 3-32). The layering developed in these fans is parallel and single beds are continuous for more than 20 m. The beds are well defined and may be open framework or clast supported fine to coarse gravel, the matrix is generally fine sand (Figure 3-33).

Eastward of the Taumutu opening of Lake Ellesmere, there are overwash fans which coalesce to form the barrier which joins the beach at Taumutu to the beach of Kaitorete Spit. These fans initiate at cuts in the crest of the beach dunes (see Figure 3-34) and run down toward the lake at gentle angles of 2–5°. The distal ends of the overwash fans are characterised by small lobate deltas extending into the lake. Between the fans the lakeward slope is covered by marram grass, while the fans are distinct in their lack of vegetation. At present, from M36 602 066 to M36 614 068, the overwash barrier has pingao growing on the remains of the sand dunes at the seaward side of the barrier. In the 1942 aerial photographs the lakeward slope appears to have only pingao growing on it in the interfan areas behind the dissected sand dunes. West of M36 602 066 (where Lake Ellesmere is opened at present) the barrier is covered in marram grass only. In the 1942 aerial photographs the barrier west of M36 602 066 has only a small amount of vegetation growing along the lake shore.

Drift wood is present on the fan surfaces, along with several tree stumps which initially appear to be insitu. The tree stumps on closer examination show the borings of marine organisms and evidence of transportation and abrasion in energetic conditions (Figure 3-35). Excavations into the fans reveal subparallel bedded, sandy, medium to coarse gravels interbedded with coarse sand to granule layers all gently (3–5°) dipping lakeward.

3.1.2.4.1 Browns Gravel Pit

Browns Gravel Pit is located at the north-eastern end of Kaitorete Spit in an area of preserved marine barrier beach ridges. The pit is not being actively mined



Figure 3-32. Truncated overwash bedding exposed in the west facing wall of the outlet to Lake Forsyth. Note the gently north dipping layers, which are truncated at their southern ends by the beach profile. Beach crest c. 4 m above water level. Photo taken looking east from M37 867 088.



Figure 3-33. A closer look at overwash bedding in the wall of an old outlet to Lake Ellesmere. Note pencil for scale. Photo taken looking east from M37 601 056.

at present, hence an extensive gravel apron has developed around the edge of the pit.

The pit walls show two distinctive units developed. The upper unit has very poorly developed south dipping bedding. The unit is sitting at the angle of repose and actively adding to the gravel apron below. The unit consists of unsorted medium to coarse gravel.

The lower unit shows well developed bedding dipping at 5–10° south and striking at c. 090°. In the west and east walls (perpendicular to strike) there are several truncations dipping towards the south from 6.5–8°. The bedding planes above the truncations are developed parallel to the truncation surface. The south wall also shows several wavy truncation surfaces which have onlapping beds above the truncation surface (see Figure 2-8).

The beds in the pit are 0.1–0.5 m thick, average 0.25 m bed thickness, and are composed of well sorted fine to medium pebbles. Many of the layers are open framework, but several layers in the lower unit have a very fine sand matrix.

3.1.3 Drill Hole Data

There are a total of nine drill holes which have been looked at in this study (See Appendix E). Most of the drill holes are from Canterbury Regional Council bore holes, but there is one shallow drill hole that Soons, et al. (1997) had drilled for their study. The drill holes mainly contain clast size information although two contain dates taken from shells in the holes.

The holes M36 4829 and M36 4830 both show gravel is deposited to a thickness of at least 6 m. M36 4829 also has sand and silt mixed with the gravel shows in the top metre.

Data from hole M36 0271 shows that gravels are deposited to a thickness of at least 10.3 m, and a ground water table occurs at 8.8 m depth.

In drill hole M37 0094 there is clean medium gravel in the upper 3.8 m, below which fine and medium gravel with grey silt matrix occurs.

Hole M36 4300 shows 2.5 m of brown gravel deposited over nearly 3 m of grey clay. Below this clay another metre of gravel occurs, underlain by 4 m of

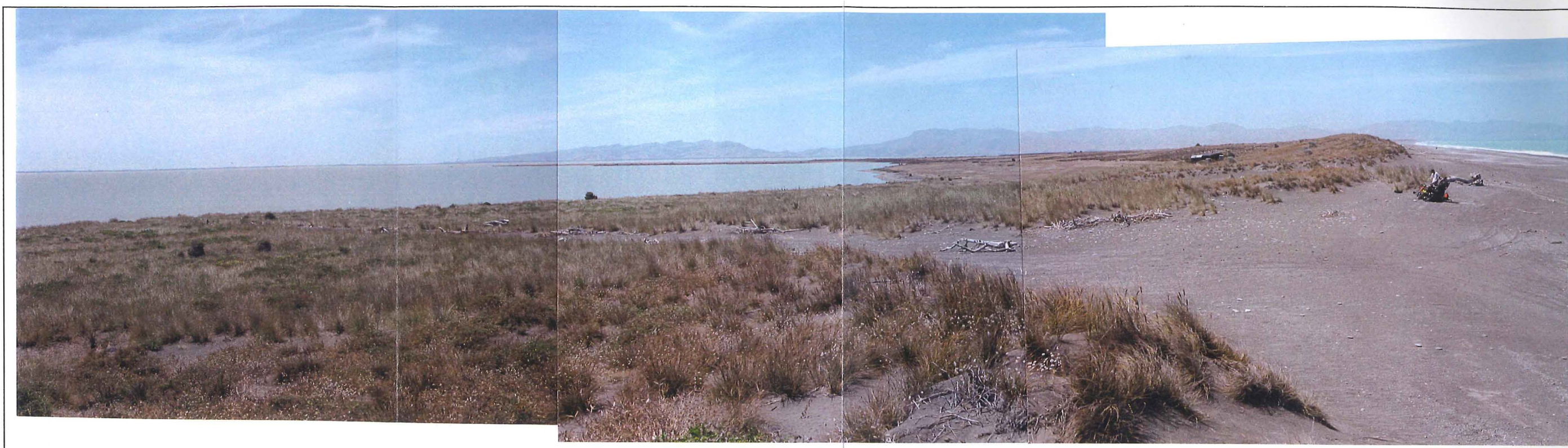


Figure 3-34. (Above) M37 613 057. View looking eastward down Kaitorete Spit. In the foreground a cut in the dune front marks the top of a washover fan. The fan can be seen dipping off to the north. Numerous bits of driftwood can be seen on the fan surface. Notice the vegetation change in the near foreground, from the orange coloured pingau to the green marram grass. The wave cut dune fronts can be seen beyond the cyclist. The beach sediment is sandy here (hence dune formation) with patches of coarse to very coarse gravel. The mud bank can be seen extending into the lake in the centre of the panorama.



Figure 3-23. (Above) M36 838 106. A view west across the Golf Course Ridges, notice the curving ridge crests cutting across the picture. The gravel patch at the extreme right of the photo is the north face of Speight Ridge.



Figure 3-35. M37 610 058. Photograph showing impact damaged root end from an 'insitu' stump on the washover barrier which stretches between Taumutu and Kaitorete Spit. Note root is also exposed well above the ground, indicating that the stump has been transported here and undergone heavy abrasion (probably in the surf along the beach).

sand, and 0.7 m of claybound gravel. The bottom of the hole has 1.7 m of loose gravel above the basalt basement.

M36 4109 shows 5 m of sandy gravels deposited above 3 m of blue fine sand. Below the sand another 4.5 m of gravel occurs.

M36 0730 shows 17.3 m of gravel over 13.7 m of blue sand, deposited over at least 2.5 m of blue gravel.

The regional council borehole M36 0287 shows 1 m of sand over 13.3 m of sandy granule to coarse gravels. From 15.2 to 19.3 m clayey sandy granular gravels occur. From 19.2 to 35.1 m there are bluey grey sandy gravels with layers of estuarine shells, clay and fragments of wood. At 27 m a C^{14} date of 7990 ± 50 years B.P. (M37/f4) on fragments of estuarine shells. At 35.1 m depth a C^{14} date of 8530 ± 63 years B.P. (M37/f8) again from a mixture of estuarine shells. From 35.1 to 52.5 m depth fine sands, silts and clays dominate the lithology. Associated with these are shells, wood fragments and peaty layers. At 44 m depth a C^{14} age 9483 ± 59 years B.P. (M37/f11) was obtained from another mixture of estuarine shell fragments. From 52.5 m to the bottom of the hole at 65 m, sandy granular to pebbly gravel layers occur interbedded with clayey and sandy layers (Brown unpublished data, 1991).

The hole located at the north end of Birdlings Ridges contains 2 metres of pebbly gravel, overlying a thin shell bed of fragments identified as *Paphies australis* (Gray) which have been C^{14} dated at 561 ± 57 years B.P. (NZA3791). The shell bed occurs at the top of a 3 m thick layer of grey clay, containing wood and finer organics. The bottom 3 m is composed of an olive brown silty clay with a gradational upper contact (Soons et al., 1997).

3.2 Ground Penetrating Radar

The ground penetrating radar surveys were carried out during the 1996/1997 field season and the lines described below give insights into the sedimentary structures formed beneath the geomorphology. The radar profiles show very similar packages of reflectors, so it was decided that the best way to describe the profiles was to break the individual profiles into radar facies, and describe each facies in the profile (Jol and Smith, 1991; Huggenburger, 1993) . It was found that 10 different radar facies can be identified in the lines collected on Kaitorete Spit, and each radar profile generally had 4 of the radar facies represented. In a profile description, the position of the feature in question will be given as a distance along the radar profile in m, and the depth in the profile in nanoseconds (ns). The profiles which run north–south (ish) are plotted looking east, and the west–east (ish) trending lines are plotted looking north. The horizontal scale is 1:500 and the vertical scale is shown for each sheet.

3.2.1 Regional Lines

Five regional lines were run and these are defined as covering the vast majority of the spit width (from lake shore to sea shore). None of the regional lines actually cover the entire distance due to vegetation, both at the lake shore and in the dunes, restricting the movement of the radar sledge. The longest regional line was Kailine 3 at c. 2.4 km length and the shortest was Kailine 5 at 500 m length. The lines were placed to run as near perpendicular to the strike of the geomorphic features as possible, but this was not always feasible due to vegetation and various cultural obstacles. The objective of the regional lines was to see what structures were developed in the various geomorphic areas. The regional lines are described in order of occurrence from the west, but the numbers in the line names reflect the order of line collection.

3.2.1.1 Kailine 5

Kailine 5 is the shortest regional line, as a result of the width of Kaitorete Spit at the western end. It runs from M36 636 069 to M36 637 064. The profile shown on sheet 2 is plotted looking east.

The air and ground waves parallel the topography, and the main topographic features are as follows: The small projection located between 62 and 80 m along the profile represents a small ridge. From 0–300 m the ground surface rises 2 m in elevation. The sharp elevation rise and fall between 300 and 355 m represents a large ridge. From 355–450 m the ground undulates gently and drops approximately 1 m in elevation. The gentle rise from 450–500 m represents the floor of a dune ‘blow out’.

The profile can be divided into 3 main radar facies. Several subhorizontal flattish reflectors can be observed between 120 and 160 ns, the highest of which disappears into the facies upper boundary at c. 250 m. The lower one disappears into the facies boundary at c. 187 m, and a possible continuation of this lower subhorizontal reflector extends from c. 150 to 0 m at c. 150 ns. These subhorizontal reflectors appear to have no effect on the reflectors or boundary reflectors of any of the radar facies they pass through.

3.2.1.1.1 Radar Facies 1

This facies occurs beneath the small ridge, in a hummock shaped subunit between 225 and 250 m and from 260–455 m. There are five subunits formed in this facies. Each of the ridges comprises a subunit of the facies. The facies consists mainly of short, north dipping, oblique, sigmoid reflectors. The boundary of the ridge subunits are horizontal reflectors, which appear to be contiguous with the ground surface topography either side of the ridges. Between c. 310 and 320 m a single reflector can be seen dipping towards the south. The northward dipping reflectors appear to downlap onto the reflectors below them. There are several short southward dipping reflectors between 330 and 350 m downlapping onto the subunit boundary.

Another, sliver shaped subunit starts at 250 m and 125 ns, and its upper surface reaches the surface at c. 390 m. The lower boundary dips slightly more gently than the upper boundary and surfaces at 450 m. From 350–420 m there are north dipping sigmoid reflectors. The remaining 30 m of the subunit is comprised of a south dipping irregular reflector.

3.2.1.1.2 Radar Facies 2

RF2 extends from 0–260 m. The facies boundaries are formed by the ground surface between 0 and 260 m, excluding the small ridge, and the lower of two northward dipping reflectors starting about 220 ns and 80 m along the profile. At its northern end the facies consists of parallel horizontal reflectors, which at their southern ends onlap the facies boundary. Between 120 and 162 m several north dipping reflectors can be observed within 15 ns of the surface. Between 225 and 250 m the interesting hummock shaped subunit of RF1 can be seen. The horizontal reflectors either side, onlap this hummock shaped reflector. Between 50 and 75 m steeply dipping parallel reflectors occur, dipping to the north on the north side of the ridge and to the south on the south side of the ridge, and are the result of airwave reflections of a fence situated on the ridge. Several subsurface diffractions can be seen between 75 and 105 m, with a well developed example occurring alongside the road.

3.2.1.1.3 Radar Facies 3

Volumetrically RF 3 is the largest radar facies represented in the Kailine 5 profile. A northward dipping truncation which starts at 200 ns, 105 m, marks the upper boundary of RF 3. The boundary reaches the ground surface 450 m along the radar profile. There is a predominance of south dipping subparallel oblique reflectors developed in RF 3. These reflectors have apparent dips of 5° to 10°.

The lower ends of the reflectors fade out at the limit of radar penetration. Several diffraction tails can be observed in the area of no signal below RF 3. Between 300 and 365 m several diffractions can be seen which have their point of origin in the line of some of the south dipping reflectors.

3.2.1.2 Kailine 2

Kailine 2 runs roughly north–northwest/south–southeast, starting at M36 673 084 (Sheets 3a and 3b). The profile runs over the geomorphic area of Bayleys Ridges as described in section 3.1.1.5. The profile line starts at the edge of the lakeside vegetation and stops at the edge of the coastal dunes.

The first 425 m of relief is a gentle rise in elevation from c. 1.5–3 m, before a sudden rise in elevation marks the beginning of the Bayleys Ridges geomorphic

area. Bayleys Ridges north is represented by an undulating topography around 6 m in elevation. A slight rise marks the transition into Bayleys Ridges middle, and at 700 m a drop of 1 m marks the Bayleys Ridges south area. Another small drop in elevation marks the southern boundary of the Bayleys Ridges south area, and a gradual rise in elevation for 190 m takes the elevation up to c. 8 m. The elevation drops back down to 6 m, and undulates around 5–6 m for the remaining 500 m.

Kailine 2 radar profile can be divided into 5 radar facies, three of which are described in section 3.2.1.1. The strong horizontal reflector which appears around 120 ns from c. 600 m southwards, does not have any effect on the reflectors it cuts through. There are several steep parallel dipping reflectors developed beside the fences and windbreaks at 55 m, 400 m, 480 m, 940 m and 1500 m.

3.2.1.2.1 Radar Facies 1

RF1 occurs from 400–790 m and reaches a thickness of 100 ns below the ground surface. RF1 only occurs under the geomorphic area of Bayleys Ridges. The base of the facies is a gently northward dipping reflector which truncates the reflectors in the units below. Between 410 and 485 m a lensoid shaped packet of southward dipping, oblique sigmoid reflectors occur, which downlap the facies boundary. Between 490 and 515 m, beneath the crest of the highest ridge in the Bayleys Ridges group, a horizontal reflector occurs. The rest of RF1 is characterised by north dipping oblique sigmoid reflectors.

3.2.1.2.2 Radar Facies 2

Between 75 and 440 m a facies occurs which is interpreted to be the equivalent of RF2 in the Kailine 5 profile. The upper boundary is the ground surface and the lower margin is not observed due to signal attenuation. The north boundary is not well defined, but shows up as a rapid shallowing of the dip of reflectors from the RF 3 to the north. The facies is dominated by two sections of nearly horizontal subparallel reflectors separated by the occurrence of a RF4 and RF 3 between 230 and 270 m.

There is a collection of prominent diffractions seen in the first section of subhorizontal reflectors, and many of these diffractions appear to start just

below the ground wave, which corresponds to about 0.3–0.75 m depth. The subhorizontal reflectors either onlap the RF4 reflectors or steepen their dips to reach the surface.

The second section of RF2 replaces a RF3, and a series of subhorizontal reflectors extends to onlap the boundary of a RF4 to the south. The reflectors in the northern end of the RF 1, described in section 3.2.1.2.1, downlap the top of this subunit.

3.2.1.2.3 Radar Facies 3

RF 3 is again the dominant facies type in this profile. The reflectors occurring in this facies are similar to the reflectors in the RF 3 in the Kailine 5 Profile. They are generally south dipping, oblique reflectors, whose lower ends are lost due to signal attenuation. In the southern section the reflectors can be seen to take on a more sigmoid nature. In places the reflectors start horizontally at or just below the surface (see between 1215 and 1230 m), and steepen in dip to the south.

The line starts in a patch of RF 3 which occurs from 5–75 m, where it is replaced by RF2. A very small section of RF 3 occurs between 250 and 330 m. The south dipping reflectors here are slightly divergent in character, and at their southern extensions they begin to steepen in dip. The reflectors of the adjoining RF2 onlap the southern margin.

RF 3 next occurs below Bayleys Ridges RF 1, between 525 and 625 m. The upper boundary appears to truncate the tops of the reflectors in this group. The northern margin is a change over from RF4, and at the southern margin another change to RF4 takes place.

At 825 m RF4 is replaced by RF 3, which continues until the end of the line at 1556 m. The northern margin shows some of the reflectors in RF4 continuing over the Facies boundary, and suddenly changing from a moderate northerly dip, to a much steeper southerly dip. The upper surface of the facies is mainly represented by the ground surface, except for two thin RF5 covers. Between 1200 and 1475 m there appears to be a horizontal reflector, onto which the reflectors of RF3 downlap.

3.2.1.2.4 Radar Facies 4

At c. 255 m along the profile, a small triangular shaped RF4 reaches the surface. The upper part of the facies is difficult to distinguish from the overlying RF2, due to the fact that both facies have gently northward dipping reflectors. The lower part of the unit differs in the development of steep north dipping oblique reflectors, which downlap onto a gently south dipping reflector at c. 310 ns. The southern margin of the facies is truncated by a steep south dipping reflector, which marks the beginning of a RF3.

From 385–525 m a second RF4 occurs below the Bayleys Ridges RF1. Here the subparallel, continuous, slightly wavy reflectors dip gently (1–2° corrected for vertical exaggeration) to the north. At c. 220 ns between 410 and 460 m steep short north dipping reflectors occur. Associated with these steep reflectors are several diffractions, making it difficult to see the extent of the reflectors. The steep reflectors appear to downlap onto very gently south dipping reflectors. The southern margin is a moderately (5–6°) dipping reflector which truncates several of the reflectors in RF4.

Still underneath Bayleys Ridges RF 1, at 675 m along the profile the next RF4 starts. The gently north dipping reflectors of RF4 onlap onto the moderately south dipping reflectors of RF3. From 750–850 m, at a depth of 260 ns, a subhorizontal reflector occurs which has steep northward dipping reflectors downlapping it at its northern end. The southern end of this subhorizontal reflector curves upwards. The southern boundary of the facies is marked by a moderately south dipping truncation.

3.2.1.2.5 Radar Facies 5

RF5 occurs from 940 m south. A thin triangular section overlies RF2 from 940–1050 m, in which the reflectors dip to the south paralleling the ground surface. Several small reflections are seen between the airwave and the groundwave from 1050–1556 m, and these are thought to represent RF5. The last section of RF5 occurs from 1465–1490 m and appears as a horizontal reflector over RF2 reflectors.

3.2.1.3 Kailine1

Kailine 1 runs from the edge of the lakeside vegetation at M36 729 097 south-southeast to the base of the coastal dunes at M36 733 078 (Sheets 4a, 4b and 4c). In this profile there are 3 recognisable RF, all of which have been found in the two radar profiles Kailine 5 and Kailine 2 above. The topography from 0 to c. 585 m shows a gentle rise in elevation from 2–4 m, before a sudden elevation rise to c. 8 m marks the crest of Speight Ridge (see section 3.1.1.7) at 620 m. 17 m south of the crest of Speight Ridge a second much smaller ridge occurs, with a crest elevation of 7 m. Further south the topography undulates around 7.5 m, until a low point is reached at c. 950 m of 7 m. From here the elevation quickly climbs to c. 8 m. The topography undulates between 7.5 and 9 m elevation until 1600 m. From 1600 m it undulates but loses elevation, until c. 6.75 m is reached at 1900 m. The elevation climbs up to 7.5 m by 2000 m.

3.2.1.3.1 Radar Facies 1

The RF1 developed in Kailine 1 is restricted to a small area beneath Speight Ridge. There are five reflectors developed in the facies, four of which dip moderately (c. 5°) north, and these are overtopped by the fifth reflector which dips steeply (c. 8°) to the south. The base of the unit is a north dipping reflector, which is parallel with the reflectors in the underlying RF4.

3.2.1.3.2 Radar Facies 3

RF3 forms the largest area of radar facies in this profile. Again the reflectors dip southward between 5° and 10°, the lower extent of the reflectors disappearing at approximately 240 ns. The upper part of the reflectors start with shallow dips of 5–6°, and steepen as they get deeper, with some reflectors undergoing several steepening and shallowings of dip. Where a single reflector is continuous from the ground surface (c. 7 m elevation) to c. 140 ns (c. 0 m elevation) the horizontal distance covered is c. 80 horizontal metres.

The first 470 m of the profile is all RF3, with subparallel 6–7° south dipping reflectors disappearing at about 240 ns depth. The reflector continuity is good, with many reflectors starting at the groundwave and disappearing at depth. There are also many shorter reflectors that are truncated at top and bottom.

There are several groups of diffractions formed at depth, for example at c. 220 ns between 230 and 240 m. At the southern end of the unit the boundary is lost in a series of diffractions, including several diffractions off the steel gate frame. The reflectors appear to steepen in dip, but the diffractions start both at the surface and at depth, and confuse the attitude of the reflectors. South of the diffraction zone a RF4 replaces this section of RF3.

At c. 655 m along the profile a moderately ($5-8^\circ$) south dipping reflector marks the start of the next RF3 section. The reflectors are similar in attitude to the reflectors found in the first RF3 section, however they differ from the first section in the appearance of short reflectors close to the surface, which are either horizontal or dip very slightly north or south. These subhorizontal reflectors are developed within 40 ns of the surface, and their northern ends tend to onlap the moderately south dipping reflectors to the north. Their southern ends either curve down to the south until they dip at $6-7^\circ$, or they are truncated by moderately southward dipping reflectors (see from 40–80 ns between 1210 and 1240 m). RF3 continues along the profile from 655 m to the end of the profile at 2001.25 m, and is interrupted only at the surface, between 960 and 1000 m, by a small section of RF4.

3.2.1.3.3 Radar Facies 4

There are two sections of RF4 developed in Kailine 2. The first section stretches between 470 and 655 m. The unit is bounded to the north by the zone of diffractions mentioned in section 3.2.1.3.2, and therefore, the northern ends of the reflectors are not clearly defined. The reflectors between c. 80–140 ns are subparallel gently ($0-2^\circ$) dipping to the north. The southern ends of the reflectors are either truncations, or the reflectors abruptly change to moderately ($5-7^\circ$) south dipping reflectors in the adjoining RF3

Below 150 ns the reflectors are steeply ($10-27^\circ$) north dipping, with lower ends that downlap a gently north dipping wavy reflector at c. 230 ns depth. Associated with these steep reflectors are several diffractions. Two prominent, gently northward dipping reflectors may be seen to cut through the steeply dipping reflectors. These gently dipping reflectors appear to follow the ground surface topography. Between 120 and 150 ns depth a prominent flat, horizontal reflector appears.

The second section of RF4 occurs between 960 and 990 m along the profile, and from c. 50 ns down to 150 ns. The base of the unit appears to be coincident with a prominent horizontal reflector at 150 ns. Below 150 ns, the reflectors appear to be part of the RF3 developed either side of them. Reflectors above 150 ns generally dip north at angles of 1–2°. The northern boundary is marked by the reflectors in the RF4 overlapping the reflectors in the adjacent RF3. Above the RF4 several gently southward dipping reflectors overlap the top of the highest reflector. The southern boundary is again characterised by either truncations, or abrupt dip changes from gentle north to moderate south.

3.2.1.4 Kailine 3

Kailine 3 is the longest radar profile collected on Kaitorete Spit and is 2365 m long (Sheets 5a, 5b and 5c). It starts on lake flats at M37 828 117 and heads south–southwest. The lake side flats are gently undulating, which is difficult to see in the field, but ponded lake water in the hollows helps define the runnels. There is a slight drop in elevation once off the lake side grasses and into the farm paddocks, before a gentle climb of 2.5 m to the base of Speight Ridge, mentioned in section 3.1.1.7. The ridge rises rapidly up to c. 8 m in elevation at the crest, and then drops down on the south side to an elevation of c. 5.5 m. The ground surface remains at 5.5 m elevation for a distance of 100 m, and then drops down to 4.5 m. For 300 m there is an elevation rise up to 7 m and then by 1450 m the profile drops down to 6 m. From 1500–1800 m the elevation rises to 10.5 m. The topography undulates between 9.5 and 10.5 m for a distance of 250 m, and then drops down to undulate between 8.5 and 9.5 m. Between 2300 and 2400 m an old sand dune occurs, which has an elevation of 10.5 m at its highest point. The remainder of the topographic profile rises up towards 10 m with a sudden drop down to c. 8.5 m elevation at 2700 m. The radar profile only extends from 35–2400 m.

3.2.1.4.1 Radar Facies 1

RF1 is restricted to a small section between 1145 and 1200 m underneath Speight Ridge (see section 3.1.1.7). In this facies, the reflectors are poorly developed. The base of the unit is a wavy reflector which starts at c. 1145 m is subhorizontal for 30 m, then dips down half a metre, before continuing on

subhorizontally until it reaches the ground surface at c. 1200 m. At the northern end, several small northward dipping reflectors are present, which downlap the basal reflector and are toplapped by a gently south dipping reflector. There are also two south dipping reflectors which reach the surface at the south edge of Speight Ridge. Above this group, two moderately south dipping reflectors downlap the reflectors below. The upper surface is defined by the topography.

3.2.1.4.2 Radar Facies 3

RF 3 is well represented in this profile, starting at c. 950 m and present in the remaining 1450 m of the profile. The reflectors extend from the surface to the lowest extent of the record, for most of the profile but between 930 and 1440, m and 2330 and 2400 m, sections of RF6 and RF5 overlie this unit respectively.

The reflectors generally dip south at angles ranging between 5° and 10°. There are some gently north dipping (1–2°) reflectors developed near the surface in several places, which onlap the northern reflectors and are truncated, or steepen in dip to the south (see between 2190 and 2210 m from surface to 90 ns depth). A small number of reflectors dip at c. 6° south for c. 10 m distance, then shallow to 1–2° for 10–20 m, before returning to a 5–6° southward dip. The subhorizontal parts of the reflector may have short reflectors downlapping onto it and may truncate reflectors underneath it (see between 1700 and 1725 m at 100 ns depth). Beneath the section of RF6, between 930 and 1440 m, the tops of the reflectors are truncated by a horizontal reflector.

3.2.1.4.3 Radar Facies 5

As mentioned above, a small section of RF5 occurs beneath the old sand dune, between 2330 and 2400 m. A horizontal reflector defines the base of the unit, and above this are several horizontal and subhorizontal reflectors. The ground surface defines the upper boundary of the unit.

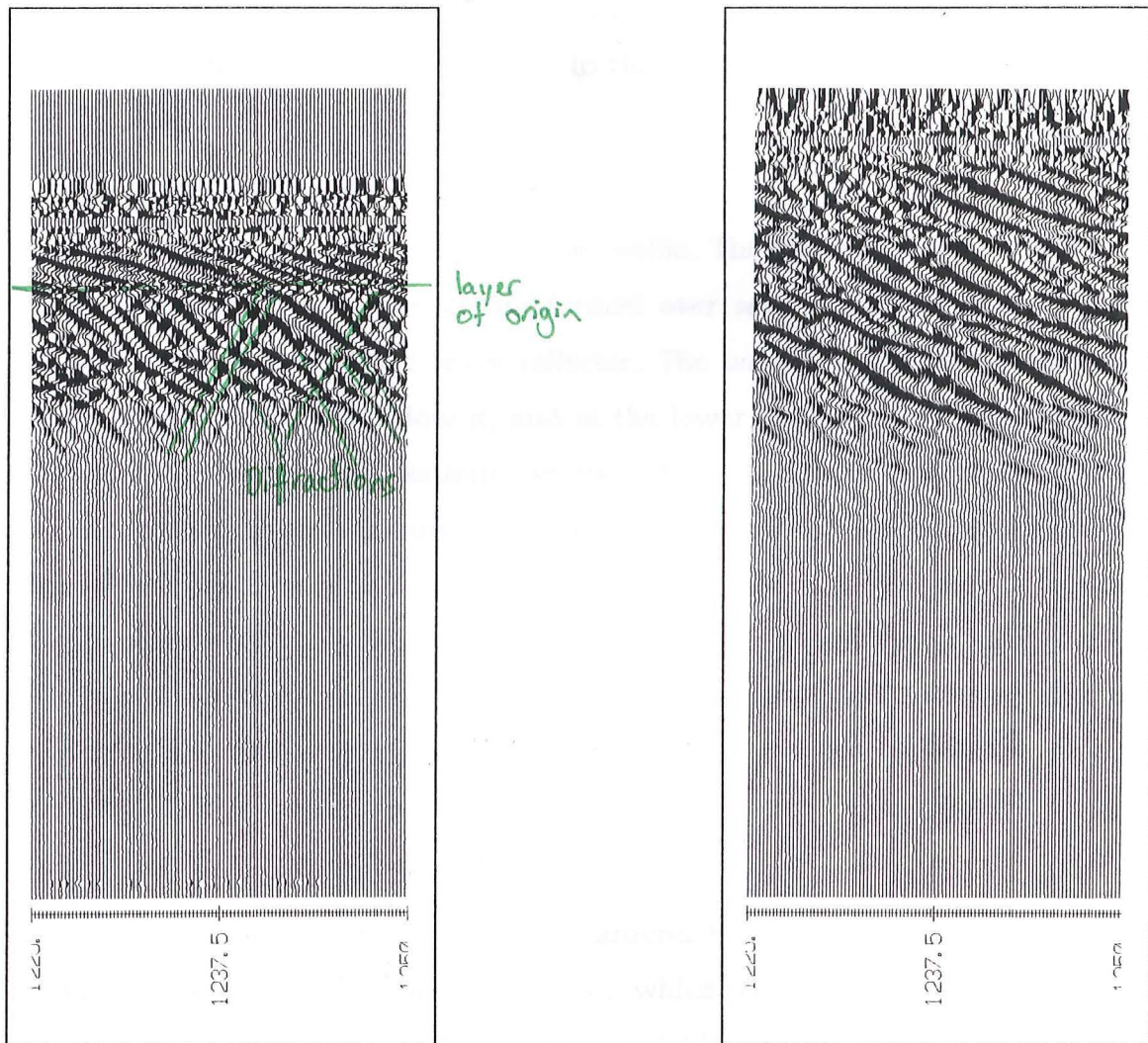


Figure 3-36. Selections of Kailine 3 radar profile showing plot with trace differencing option turned on (left) and the same selection after migration at 0.13 m/ns also with trace differencing turned on. Note the diffractions originate from a distinct layer.

3.2.1.4.4 Radar Facies 6

RF6 occurs in two sections on this profile, between 925 and 1250 m, and 1280 and 1425 m. In Sheet 5a the facies is bounded by a horizontal reflector at the base, while the ground surface defines the top of the unit, except for the section between 1145 and 1200 m where RF1 overlies the facies. When the profile is plotted with trace differencing, the horizontal reflector is lost, and it becomes apparent that the *reflector* is the result of coalescent diffraction snouts (see Figure 3-36). When the profile is migrated at a velocity of 0.13 m ns^{-1} , and plotted with trace differencing the true nature of the reflectors can be seen.

The unit consists of south dipping oblique tangential sigmoid reflectors, which downlap the tops of the truncated reflectors of the RF 3 below. In a few places, the reflectors of the facies appear to continue through the facies base and

into the RF 3 below. The northern and southern boundaries are defined by reflectors of the RF 3, which continue to the surface subparallel to the reflectors in the adjacent RF 6.

3.2.1.4.5 Radar Facies 7

RF7 occurs in the first 900 m of the profile. The facies is characterised by a convex reflector of variable length, formed over several steeply south dipping reflectors which downlap a wavy reflector. The wavy reflector has moderately south dipping reflectors below it, and at the lower ends of these south dipping reflectors a zone of diffractions occurs. There are several sections of RF7 developed which are surrounded by sections of RF8. The southern most RF7 becomes a continuous feature which ends against the RF3. As the facies nears the boundary with the RF3, the wavy reflector approaches the ground surface. The wavy reflector also starts to disappear for several metres, and the reflectors which start at the surface with steep south dips, become much shallower dipping features at their lower extents.

3.2.1.4.6 Radar Facies 8

RF8 is developed both between and around RF7, and it is characterised by having well developed 'railway tracks', which apparently run through any structures developed. Near the surface irregular subhorizontal reflectors are developed, some of which onlap the convex reflectors of RF7.

3.2.1.5 Kailine4

Kailine 4 (Sheets 6a and 6b) starts at the vegetation of the southwestern shore of Lake Forsyth, at M37 883 107, and runs southwest for 900 m, before heading northwest for 100 m, and taking a southwesterly course for the last 600 m. The profile covers what has been interpreted as marine beach ridges (Armon, 1970), and goes onto the present lake shore. The topography is briefly as follows. The lake shore is at c. 2 m elevation, and from 0–725 m the topography is irregular in form, with an elevation rise of 2 m. From 725–1075 m the topography starts to show an undulating nature and a 1 m rise in elevation. The high points at c. 1110 and 1250 m are the ridge crests developed on the shores of Lake Forsyth, while the intervening low point is the current lake shore. From 1300–1500 m, the undulating nature is resumed and the elevation

is between 5.5–6 m. Between 1550 and 1600 m a low point of c. 4.8 m elevation is reached, and from 1600–1950 m the topography makes a sawtooth rise up to 9.5 m elevation. From the last 50 m it appears that the undulating topography may continue further south.

The profile has 4 RF formed in it, a strong horizontal reflector occurs at c. 120 ns, from c. 400–1350 m this reflector appears to correspond to the contact between two RF's, but between 1350 and 1600 m this reflector appears to have little affect on the reflectors it passes through.

3.2.1.5.1 Radar Facies 3

A transition from RF6 and RF7 to RF3 occurs between 1350 and 1450 m. The elevation rapidly rises and the two sets of short moderately seaward dipping reflectors are replaced by a longer more continuous set of moderately seaward dipping reflectors. Concurrent with this the lowest undulating reflector disappears at about 1425 m. The RF3 has several strong gently dipping seaward reflectors which have short moderately seaward dipping reflectors downlapping them.

3.2.1.5.2 Radar Facies 6

RF6 occurs from 475–865 m and from 925–1350 m. The top of the facies is the ground surface and the moderately seaward dipping oblique tangential reflectors downlap a horizontal reflector which marks the top of the underlying RF7.

3.2.1.5.3 Radar Facies 7

From c. 450–860 m and from 1000–1470 m RF7 occurs. The top of the facies is marked by a horizontal reflection at 130 ns which is also the source of many diffractions. The facies has moderately seaward dipping reflectors which downlap a strong undulating reflector. Between 1000 and 1160 m the upper many of the upper reflectors appear to continue through this undulating reflector. Elsewhere the upper reflectors largely end at the undulating reflector.

Below the undulating reflector (which is also the source for many diffractions) the reflectors dip moderately seaward and are lost to attenuation at c. 200ns.

Between 500 and 750 m the diffractions mask the reflector patterns and there are three subparallel wavy reflectors developed.

3.2.1.5.4 Radar Facies 8

The first 400 m of this profile is dominated by RF8. There are numerous diffractions associated with the an undulating reflector in the first 400 m. Below c. 160 ns the 'railway tracks' mask any other reflectors.

The RF8 section developed between 850 and 940 m is where the radar profile kinks out on to the present lake shore.

3.2.2 Smaller Selected Lines

In addition to the regional lines, there were several areas which warranted further investigation. Smaller lines were run in these areas, in an effort to further illuminate the specific geomorphology of that area. In most of these areas there were several small lines run, with at least one of the lines being oriented parallel to the trend of the features in the area. The areas are discussed in the order they occur from the west.

3.2.2.1 Transgressive Barrier

A short line was run over the transgressive barrier formed between Taumutu and the end of Kaitorete Spit, to see if the radar would pick out the structures in the transgressive barrier. The results can be seen in the plot on Sheet 7. The profile is dominated by the 'railway tracks' below c. 60 ns. Above the 'railway tracks' a few poorly developed reflectors occur. The crest of the barrier shows several gently northward dipping reflectors from 140–160 m. A reflector which is subparallel with the surface occurs from c. 65–140 m. Between 65 and 100 m, three short reflectors are truncated by this surface subparallel reflector. From 40–65 m several diffractions occur, and the reflectors are still surface subparallel. From 0–40 m at c. 75 ns a horizontal reflector occurs which is interpreted to be the water table.

3.2.2.2 Dune Ridge

In section 3.1.1.2.1 it was observed that the sand dunes appeared to be developed over an earlier formed lake ridge. These two short radar profiles were run to clarify the situation (Sheet 7).

3.2.2.2.1 Dune Ridge north–south west

This profile was run down the junction between two sand dunes, over the place where a continuation of the lake ridge should be. The profile shows two radar facies developed. Note the strong horizontal reflector at c. 160 ns, which also corresponds to the limit of radar penetration.

3.2.2.2.2 Radar Facies 3

Beneath RF10, the characteristic south dipping reflectors of RF3 occur. The reflectors are very similar to RF3 formed, in many of the other profiles. The lower ends of the reflectors disappear, into the strong horizontal reflector, at c. 160 ns depth.

3.2.2.2.3 Radar Facies 10

From the ground surface to the gently north dipping reflector, which stretches from 0 m 90 ns to 38 m 70 ns, there is RF10 formed. Cutting through the facies is a strong reflection, stretching from 10 m 75 ns to 38 m 50 ns, which divides the facies into two sections, and truncates the reflectors in the lower section. The upper section has poorly developed, north dipping, reflectors downlapping the bisecting reflector, while the lower section has truncated north dipping reflectors downlapping the facies boundary.

3.2.2.2.4 Dune Ridge north–south east

This profile originates from the same point as *Dune Ridge north–south west*, and consequently has the same two radar facies developed. There is a strong irregular subhorizontal reflector between c. 160–180 ns, which appears to be a source of diffractions.

Again from the ground surface to a gently dipping northward reflector, stretching from 0 m, 100 ns to 42 m, 80 ns, RF 10 occurs. The bisecting reflector is also developed in this profile, and stretches from 5 m, 100 ns to 42 m, 70 ns, but a convex bulge in the reflector occurs between 20 and 40 m. The reflector is a source of several diffractions. The upper section of the facies has steeply north dipping reflectors from 10–25 m, and discontinuous moderately south dipping reflectors from 25–42 m. Both these sets of reflectors downlap the bisecting reflector. The lower section has truncated, south dipping reflectors which downlap the basal reflector. Beneath RF10, moderately south dipping

reflectors of RF3 occur, which disappear into the subhorizontal reflection between 160 and 180 ns.

3.2.2.3 Ponds

The Ponds area had several geomorphic features which warranted further investigation. Four radar lines were run to illuminate the structures developed underneath the various geomorphic features (Sheets 8 and 9).

3.2.2.3.1 Ponds north-south long

The profile for this line extended from M36 656 075 for 400 m to the south. The line starts 75 m north of the crest of the northern bounding ridge of the Ponds area (see section 3.1.1.4 above), and crosses a plateau, before dropping down c. 2 m, 125 m along the profile. From 130–300 m the elevation rises c. 3 m, with two small ridges rising above this surface. From 300 m the elevation rises rapidly to the crest of the southern bounding ridge, at 7 m elevation, and from 325–400 m the elevation undulates between 5.5 and 7 m.

A distinct horizontal reflection may be seen developed at c. 140 ns depth across the profile.

3.2.2.3.2 Radar Facies 1

There are four sections of RF1 developed on this profile, and all appear to be perched on top of the RF's formed below them.

The first section stretches from 5–85 m. The facies has mostly moderately north dipping, oblique tangential reflectors, that downlap the basal reflector. From 50–85 m, at about 60 ns, there is a wavy subhorizontal reflector which overlies the top of the oblique reflectors. Above the subhorizontal reflector are several small, gently south dipping reflectors, of which, the southernmost downlaps the subhorizontal reflector.

The second section of RF1 is developed between 165 and 230 m. The lower boundary is a very gently north dipping flat reflector, above which there are several moderately south dipping oblique tangential reflectors. The upper boundary is defined by the ground surface.

The third RF1 section is developed underneath a ridge, situated between 275 and 290 m. The only reflectors in this section are the flat very gently north dipping basal reflector, and the ground and air wave.

The fourth RF1 section occurs south of the crest of the southern bounding ridge of the Ponds geomorphic area (see section 3.1.1.4). The lower boundary is a concave reflector. Between the basal reflector and the ground wave, a south dipping reflector and a short north dipping reflector are developed.

3.2.2.3.3 Radar Facies 2

A section of RF2 is developed from 0–125 m. The southern end of the unit wedges out between an overlying RF9 and an underlying RF4. There are numerous diffractions developed in this section which mask the reflections in the unit, however, there are two types of reflectors which are still discernible. These are gently north dipping reflectors, and moderately south dipping reflectors which onlap the southern boundary. The southern boundary is a moderately north dipping reflector, subparallel to the reflectors in the RF4 developed to the south. A strong south dipping reflector, which starts at 0 m 120 ns and stretches to 37 m 150 ns, appears to be a second lower boundary, below which there appears poorly developed south dipping reflectors of an underlying RF3.

3.2.2.3.4 Radar Facies 3

There are two possible sections of RF3 developed in this profile; the first, mentioned above, has poorly developed south dipping reflectors below the RF2 from 0–37 m, while the second is well developed and stretches from 240 m to the end of the profile at 400 m. The sections consist of well developed moderately south dipping, oblique reflectors. Between 350 and 395 m, just below the surface, there is a group of gently north dipping reflectors, onlapping the reflectors to the north, and either being truncated to the south or changing their dip to the south.

3.2.2.3.5 Radar Facies 4

From 75–275 m a section of RF4 is developed. Above 150 ns there are gently north dipping subparallel reflectors. Between 110 and 205 m a subhorizontal reflector is developed at c. 200 ns depth. The north dipping reflectors of the RF4 unit onlap this reflector. Below this subhorizontal reflector, poorly developed gently north dipping reflectors can be seen, along with many 'railway tracks'. Between 240 and 275 m, and starting at c. 150 ns depth, several steep north dipping reflectors occur, which downlap a horizontal reflector at their

lower ends can be seen. Associated with these are several cross cutting 'railway tracks', and a few diffractions.

3.2.2.3.6 Radar Facies 9

From 60–125 m a section of RF9 occurs. This unit has a flat horizontal reflector at its base and a flat horizontal reflector for most of its top. The northern end is defined by a wavy north dipping reflector, while the southern end is defined by the ground surface. Moderately south dipping, oblique tangential reflectors form most of the unit. At the northern end, there are several subhorizontal reflectors. The south dipping reflectors appear to steepen in dip the further south they occur.

3.2.2.3.7 Ponds north–south short

This profile was run over the scarp–like ridge which comprises the northern boundary of the Ponds Geomorphic area. The line is oriented perpendicular to the strike of the surface geomorphology. There are 3 RF developed in this profile. A strong horizontal reflector stretches across the profile at c. 120 ns.

3.2.2.3.8 Radar Facies 2

From 0–70 m a wedge of RF2 occurs. The facies is dominated by subparallel very gently north dipping reflectors, which onlap the southern lower boundary. Numerous diffractions occur within the facies, many starting at the upper horizontal reflector.

3.2.2.3.9 Radar Facies 4

RF4 occurs from 0–100 m. As with other profiles, the facies is characterised by subparallel gently north dipping reflectors. The large number of diffractions from 0–70 m, makes the continuity of individual reflectors difficult to assess. Below 210 ns from 70–100 m, there are several steep north dipping reflections, which begin to shallow in dip and disappear at c. 320 ns.

3.2.2.3.10 Radar Facies 9

At the surface from 0–70 m a section of RF9 occurs. The unit is bounded by a subhorizontal basal reflector, and has characteristic moderate to steep south dipping oblique reflectors developed throughout it. Again the reflectors developed to the south appear to be steeper in dip.

3.2.2.3.11 Ponds west-east long

This profile line is oriented roughly along strike of any structure formed parallel to the beach. Some of the facies boundaries in this profile needed to be defined by looking at the two north-south profiles. There are 3 RF found in this profile (Sheet 9).

3.2.2.3.12 Radar Facies 2

A wedge of RF2 stretches from 0–220 m. The upper bounding surface of the unit is horizontal from 0–50 m, rises c. 2 m from 50–62 m, and is horizontal from 62–100 m, before dropping down c. 1 m from 100–108 m. It remains horizontal for the remaining 120 m, until it joins the ground wave at 230 m. The upper boundary is a source of diffractions which mask the reflectors in the unit. Two gently east dipping reflectors can be seen between 0 and 50 m at c. 100 ns depth. Several steeply east dipping reflectors can be observed between 50 and 60 m, which downlap the basal reflector. A strong horizontal reflector between 50 and 70 m forms a downlap surface for several other east dipping sigmoid reflectors. Another subhorizontal reflector from 75–105 m at c. 70 ns depth, forms the base of a set of west dipping oblique tangential reflectors.

3.2.2.3.13 Radar Facies 4

RF4 stretches across the entire profile, and due to the profile being almost parallel to the strike of the beds, the reflectors are generally subparallel and either subhorizontal or very gently east dipping. The upper boundary is essentially flat, apart from a hummock developed from 72–112 m. From 108–280 m below 140 ns, a wavy reflector marks a truncation surface. There are numerous diffractions originating in this unit.

3.2.2.3.14 Radar Facies 9

There are two sections of RF9 formed on this profile. The first stretches from 0–62 m, while the second stretches from 75–225 m. Both the sections mantle the RF formed beneath them, and have predominantly steep, west dipping, oblique reflectors internally. In the second section there are several relatively long sigmoid reflectors which have short reflectors developed between them and the basal reflector (see between 105 and 115 m or 115 and 130 m). The west

end of the second section has a concave reflector, which is formed above the sigmoid reflectors.

3.2.2.3.15 Ponds west-east short

Underneath the ridge, from 50–87 m, a section of RF1 is formed. The western half of the facies has short oblique west dipping reflectors developed, and the eastern half has horizontal reflectors, which are truncated at their eastern end.

Below RF1, a RF4 section is developed across the entire profile. This RF4 has the characteristic subhorizontal reflectors developed down to a depth of c. 160 ns. At 0 m 160 ns a strong convex irregular reflector appears. This reflector joins a second irregular reflector at 35 m 170 ns. Below these irregular reflectors there is an attenuation of the radar signal. Approximately 40 ns below the peak of the first irregular reflector, a second convex reflector appears which toplaps several steep east dipping reflectors.

3.2.2.4 Island

The Island profiles were run to investigate the high plateau and small ridges developed in the Island geomorphic area (Sheet 10) (see section 3.1.1.6). Three lines were run in total, the longest oriented north–south, with one of the short lines perpendicular to the north–south line (intersecting at 300 m along Island north–south). The other was oriented northwest–southeast and located over a small ridge, several hundred metres west of Island north–south.

3.2.2.4.1 Island north-south

This radar profile started north of the Island geomorphic area, at M36 683 083, and headed 500 m in a southerly direction. The line crosses the northern bounding ridge of the Island area, and the small west southwest–east northeast trending ridge which defines the large triangular area. The profile then crosses the plateau and follows the slope down into the depression, before crossing the depression and continuing up the northward sloping southern margin of the depression.

A flat horizontal reflector occurs across most of the profile at c. 120 ns. This reflector does not appear to affect any of the reflectors it crosses.

3.2.2.4.2 Radar Facies 1

RF1 occurs from 0–225 m. The lower boundary is a gently north dipping flat reflector, truncating the tops of the reflectors in the RF3 unit below its southern half, and running subparallel to the reflectors in the RF4 below its northern half. This RF1 consists of predominantly gently north dipping, oblique tangential sigmoid reflectors. There are also 2 long reflectors which mantle the reflectors formed below them.

3.2.2.4.3 Radar Facies 4

Underneath the RF1, a RF4 stretches from 0–125 m down to c. 240 ns. The southern boundary of the section is marked by a transition to the adjacent RF3, with some of the RF4 reflectors being truncated, and some changing their dip from north to south, to become RF3 reflectors. From 110–170 ns, gently north dipping subparallel reflectors are developed in the RF4. Below 170 ns the reflectors steepen their dip and downlap a prominent wavy reflector, occurring from 0–100 m between 200 and 240 ns. A second group of steep north dipping reflectors is developed below the wavy reflector. From c. 15–60 m, these appear to downlap a chaotic group of reflections.

Between c. 330 and 465 m a second section of RF4 occurs. The northern boundary is a transition from RF8, while the upper boundary is defined by the ground surface, and the southern boundary is a transition to RF3. At a depth of c. 150 ns the gentle north dipping subparallel reflectors become steep north dipping tangential reflectors, which downlap a subhorizontal reflector at 200 ns. Several diffractions are associated with these steep north dipping reflectors. A second short subhorizontal reflector occurs between 420 and 450 m at a depth of c. 260 ns.

3.2.2.4.4 Radar Facies 3

From 125–300 m the profile is dominated by a RF3 section. There are moderately south dipping, subparallel oblique reflectors, with minor truncations developed. The southern margin is a combination of the ground slope which truncates several reflectors, and a rapid change into RF8. A second, triangular shaped, section of RF3 occurs from 465 m and continues until the end of the profile at 500 m.

3.2.2.4.5 Radar Facies 8

The RF8 is developed in the bottom of the depression and has several irregular subhorizontal reflectors near the surface, but below c. 160 ns 'railway tracks' dominate the profile

3.2.2.4.6 Island west-east

This profile is oriented perpendicular to Island north-south. There are 2 radar facies developed in this profile. A strong horizontal reflector can be observed at 110 ns which stretches across the profile.

3.2.2.4.7 Radar Facies 1

A thin layer of RF1 stretches across the top of the profile, with the lower boundary being a continuous subhorizontal reflector at c. 40 ns depth. The other reflectors in the unit are very gently west dipping, oblique tangential reflectors.

3.2.2.4.8 Radar Facies 3

The profile runs close to the strike of the reflectors in this unit, shown in the flattish nature of the reflectors, with just a very gentle east dip. A truncation can be observed starting at 100 m 70 ns, and stretching down to 37 m 100 ns.

3.2.2.4.9 Island northwest-southeast

This profile again has RF1 and RF3 developed in it. The RF1 occurs underneath the ridge from 90-70 m, with the only reflector developed being a horizontal reflector, which stretches from one side of the ridge to the other. At the crest of the second ridge another small section of RF1 occurs. A horizontal reflector defines the base and two very small reflectors are developed above this.

The rest of the profile has RF3 developed in it, with the apparent dip on the reflectors being lower than the reflectors in the Island north-south profile due to the oblique angle this profile makes to the strike. The reflectors are quite continuous and a few truncations can be observed. A flat horizontal crosscutting reflector occurs at c. 100 ns depth.

3.2.2.5 Trig Point

These two radar lines were run to examine the internal structures of the geomorphic features found near the trig point on Kaitorete Spit (Sheet 11). The geomorphic features are described above in section 3.1.1.8. The location of the lines is shown on the sheet 1.

3.2.2.5.1 Trig Point north south

This radar line was placed to run between two of the northwest–southeast trending ridges mentioned in section 3.1.1.8. A strong horizontal reflector stretches across the profile at c. 120 ns. Note that numerous equally spaced, surface parallel, fine reflections can be seen, particularly in sections of RF3.

3.2.2.5.2 Radar Facies 3

There are two sections of RF3 developed in this profile. The first stretches from 0–50 m between 60 and 200 ns, the second from 165–250 m between 10 and 200 ns. Moderately south dipping subparallel reflectors constitute the bulk of the facies. There are also some short subhorizontal to gently north dipping reflectors formed in the upper parts of the facies.

3.2.2.5.3 Radar Facies 4

From c. 50–210 m, and between 80 and 220 ns, a section of RF4 is formed. The facies is dominated by gently north dipping to subhorizontal reflectors. A very strong, gently north dipping reflection marks the bottom of the facies between 60 and 200 m at 220 ns depth. Below this reflector several moderately south dipping reflectors can be seen. Numerous diffractions confuse the ground response between 25 and 60 m, and therefore the northern ends of the reflectors are lost. Below about 130 ns the facies has several diffractions formed from within the facies. The south margin of the facies is a transition to RF3 with some of the reflectors having truncated ends and others changing their dip angles from north to south.

3.2.2.5.4 Radar Facies 9

A reflector starting at 15 m 60 ns, dipping south and reaching the ground surface at 50 m, 100 ns, marks the base of the RF9 section formed on this profile. Steep south dipping oblique reflectors, which downlap the basal reflector, characterise this section. From 15–c. 30 m there are three diffraction snouts which mask any underlying reflectors. From 30–40 m a reflector which is parallel to the basal reflector occurs.

3.2.2.5.5 Trig Point west east

This profile runs over one of the northeast–southwest trending ridges described in section 3.1.1.8 and pictured in Figure 3-21. There are two radar

facies apparent in this profile. A horizontal reflector at c. 80 ns stretches across the profile.

3.2.2.5.6 Radar Facies 4

Below about 60 ns the profile is entirely RF4. The facies has several strong irregular subhorizontal reflectors, which sandwich short oblique tangential reflectors between them. Below the ridges, diffractions mask the reflectors and make it difficult to follow the individual reflectors. Between the ridges, the reflector patterns are much clearer and several truncations can be observed.

3.2.2.5.7 Radar Facies 9

Beneath the two ridges and above a horizontal reflector at c. 60 ns, which is contiguous with the ground surface, there are two sections of RF9 formed. The ridge from 10–45 m has short reflectors, some dipping east and dipping west, as well as some short subhorizontal reflectors. A diffraction starts at 37 m, 40 ns. The visible half of the second ridge from 80–100 m is dominated by west dipping oblique sigmoid reflectors.

3.2.2.6 Jones Pit

Jones Pit is located at the northeastern end of Kaitorete Spit just off Jones Road (Sheets 12 and 13). Two radar lines were run here: the first (Jones Pit north south long) looking at the Railway Cutting Ridges, and the second (Jones Pit north south short) looking at a ridge which marks a rapid change in ground surface elevation just north of Bayleys Road.

3.2.2.6.1 Jones Pit north south long.

This profile starts beside Jones road and heads roughly southeast. The ridges in the Railway Cutting Ridges group show up in the first 240 m. For the rest of the profile the topography gently undulates between 4 and 6 m. The fact that the profile runs oblique to the strike, means that the dip angles of the reflectors will be apparent dip angles. In the case of the lower units this means that the dips will be 5–7° shallower than true dip.

3.2.2.6.2 Radar Facies 1

Directly beneath the Railway Cutting Ridges Group is a RF1. The facies has the characteristic oblique tangential and oblique sigmoid tangential northwest dipping reflectors. There are 6 RF1 subunits, all with their own local basal

reflectors. The basal reflector of the southern most unit defines the base of the RF1. From 0–90 m between 120 and 160 ns there is a zone of diffractions developed in the RF1.

3.2.2.6.3 Radar Facies 6

RF6 occurs between the ground surface and a subhorizontal reflector between c. 300 and 800 m at a depth of 130 ns. The facies is dominated by gently southeast dipping oblique tangential reflectors. The strong horizontal reflector at c. 115 ns, which cuts across many of the reflectors in RF6, is interpreted to be the local unconfined water table. The basal reflector acts as the source of the many diffractions apparent in the RF7 below.

3.2.2.6.4 Radar Facies 7

At 90 m, 160 ns several subtle moderately southeast dipping reflectors appear. The strong reflector they start from seems to be a source of diffractions further to the southeast. The RF7 stretches from 90–800 m. At their northwest ends the moderately southeast dipping reflectors are poorly developed, and from 0–240 m numerous diffractions interfere with the reflectors. From 90–240 m the dominant reflectors are subhorizontal gently undulating reflectors, with very subtle southeast dipping reflectors at 90–115 m and 175–190 m below c. 150 ns. The dominant reflector type changes from 240 m onwards to a moderately southeast dipping reflector. The upper boundary of the facies is coincident with the local unconfined water table reflection, and has many diffractions originating from it. From about 370 m onwards the tops of the moderately dipping reflectors are mantled by strong concave down wavy reflectors which turn into moderately southeast dipping reflectors to the southeast. Several steeper southeast dipping reflectors may be seen to downlap the upper surface of the wavy reflectors. Some of the steep southeast dipping reflectors shallow in dip to the southeast, and become the moderately southeast dipping reflectors.

3.2.2.6.5 Radar Facies 9

From 125–245 m, between 80 and 120 ns, RF9 occurs and pinches out underneath the RF1 to the northwest. The unit has both oblique tangential and sigmoidal southeast dipping reflectors developed in it. The basal reflector is a very gently northward dipping flat reflector, which intersects the groundwave at

245 m c. 100 ns, at its southern end. The small kink in the ground/airwave is the result of a bomb crater.

3.2.2.6.6 Jones Pit north south short

This 200 m profile, which straddles a marked change in elevation and environment of deposition, shows 3 different radar facies developed (Sheet 13). A strong horizontal reflector stretches across the entire profile at c. 135 ns. Beneath the ridge numerous diffractions with subsurface velocities confuse the reflectors in this section. At c. 140 m, and 90 ns a fine surface parallel reflection appears which cuts across the reflectors in the RF3 here. This reflection appears to be a systematic hardware sampling error.

3.2.2.6.7 Radar Facies 3

From c. 125–200 m between 30 and 270 ns RF3 is well developed. The reflectors show the characteristic moderate south dip, with a steepening of dip at the reflectors lower ends (below c. 190 ns). Between 155 and 175 m from 30–60 ns there is a package of reflectors which show a subhorizontal to gently north dipping attitude, overlapping the reflectors to the north and steepening dip to the south.

3.2.2.6.8 Radar Facies 6

From 0–125 m between 30 and 130 ns a section of RF6 is formed. South dipping oblique tangential sigmoid reflectors occur in the facies. The basal reflector which they downlap is a gently north dipping reflector, which is coincidental with the water table reflection at its northern end. The south end of the facies is marked by a transition to RF3.

3.2.2.6.9 Radar Facies 7

Below c. 140 ns and stretching from 0–125 m is a RF7. Between 0 and 70 m from 130–165 ns several short steep south dipping reflectors can be seen, downlapping onto both wavy and flat subhorizontal reflectors. Below these flat and wavy reflectors, the reflectors become gently south dipping. At the south end of the facies there is a transition to RF3 reflectors, with the gentle dip angles steepening up to more moderate dip angles.

3.2.2.7 Birdlings Valley Ridges

The ridge complex formed at the mouth of Birdlings Valley shows very well developed RF1 sections, below which is a RF2 (Sheet 13).

The RF1 unit occurs from the ground surface to a roughly horizontal reflector at 70 ns depth. The basal reflector of the RF1 has several diffraction hyperbolas initiating at it, which mask the underlying reflectors. Moderately south dipping oblique tangential sigmoid reflectors dominate the facies. The RF2 has several subhorizontal irregular wavy reflectors developed in it.

3.2.2.8 Browns Pit

Browns Pit is a gravel pit located beside the Christchurch–Akaroa Road, at the east end of Kaitorete Spit. The pit is approximately 8 m deep and roughly rectangular in shape, with an east–west width of c. 200 m and a north–south width of c. 150 m. The south and west walls both show good sedimentary structure and are discussed in section 2.4.

Four radar lines were run in the Browns Pit area, the locations of which are shown in Figure 2-5 and on the Sheet 1. Two were run along the pit edge parallel to the pit walls and are discussed in sections 2.4.3.1 and 2.4.3.2. The other two were run on the bottom of the pit and are discussed below (Sheet 14).

3.2.2.8.1 Pit Edge north–south

This profile is discussed in the section 2.4.3.1, but a few further observations will be made. This profile shows two radar facies developed. A strong horizontal reflector occurs across the profile at 160 ns.

3.2.2.8.2 Radar Facies 3

A strong wavy reflector occurs stretching from 0 m, 70 ns to 54 m, 100 ns. Below this wavy reflector a RF3 occurs. The reflectors dip moderately to the south, and show minor truncations. The lower ends of the reflectors disappear at c. 240 ns.

3.2.2.8.3 Radar Facies 6

RF 6 is developed between the ground wave and the wavy reflector developed on the top of the RF3 unit. It consists of south dipping oblique tangential reflectors which downlap the wavy reflector.

3.2.2.8.4 Pit Bottom north-south

This profile runs from one edge of the pit to the other and is oriented perpendicular to the strike of the beds. There are numerous topography parallel fine 'reflections' that appear to interact with the south dipping reflectors. There is an even spacing between these 'reflections', and they are therefore more likely to be systematic equipment error, than reflections from subsurface reflectors. The effect of this equipment noise is to make reflectors which dip relatively evenly, and have a very steppy appearance. A subhorizontal reflector occurs just below the ground wave reflection, and interacts with it.

The profile shows only RF3 with characteristic moderately south dipping oblique reflectors. At approximately 170 ns the reflectors steepen in dip.

3.2.2.8.5 Pit Edge west-east

This profile has been discussed in section 2.4.3.2 but a few further observations will be made. The profile has two radar facies developed. A strong horizontal reflector stretches across the profile at 160 ns.

3.2.2.8.6 Radar Facies 3

RF3 occurs in the lower part of the profile below a eastward dipping reflector which stretches from 0 m 70 ns to 67 m 90 ns. This reflector appears to truncate a short reflector in the RF3 at c. 3 m 70 ns. The reflectors are very gently dipping to the east, with several minor truncations developed within the facies.

3.2.2.8.7 Radar Facies 6

The reflectors developed in this facies are essentially horizontal and onlap the eastward dipping reflector which marks the top of RF3.

3.2.2.8.8 Pit Bottom west-east

This profile line is oriented slightly oblique to the strike of the geomorphic structures in the area. Again the profile displays systematic equipment error, in the form of equally spaced surface parallel pseudo-reflections. These 'reflections' are not as prominent as those in *Pit Bottom north south*, probably due to the fact that the subhorizontal nature of the real reflectors masks the systematic horizontal 'reflectors'. The strong irregular reflector developed within 20 ns of the groundwave reflection is probably the unconfined water table.

As in *Pit Bottom north south*, the only radar facies developed is RF3. The apparent west dip on the reflectors is due to the oblique angle the profile cuts the structure of the area. The reflectors are subparallel, uniformly west dipping. There are several minor pinchouts between the reflectors. There is a flattening of dip between 0 and 25 m.

3.3 Chapter Summary

3.3.1 Geomorphology

From the material presented in this chapter, it is apparent that there are several geomorphologic features consistently occurring together, on Kaitorete Spit. At the beginning of the chapter the lacustrine geomorphology was divided into lake-bed geomorphic features, and lake-edge geomorphic features.

The lake bed geomorphic features consist of: i) the linear small scale ridges that are parallel; ii) the horn and cusp small scale ridges which form with very long horns and stand c. 0.5 m above the surrounding lake bed; iii) the lake bed itself, which has patches of discoid coarse to very coarse pebbles lying with their long and intermediate axes parallel to the ground slope.

The lake edge geomorphic features consist of: i) the linear ridges which are formed subparallel to the present lake shore, and mantle either older lake ridges or marine geomorphology away from the lake; ii) the curvilinear ridges which generally curve towards the south, from either a starting trend of northwest-southeast or from a starting trend of northeast-southwest, and have rounded terminations which stand between 1 and 3.5 m above the surrounding ground; iii) the scarp-like continuations of the ridges which have a gentle lakeward slope of 2–3° and a steep seaward slope of 10–18°, with a relief of 1.5 to 3.5 m; iv) several channel like features that cut the surrounding geomorphologic features are also found with the lake edge geomorphology.

The marine geomorphology can be subdivided into two groups: i) the long continuous subparallel ridges which are developed between Speight Ridge and the present coast; ii) the recurved very low relief ridges, which are developed in the northeastern part of Kaitorete Spit.

3.3.2 Radar Facies

The radar profiles are divided into 10 different radar facies defined on the basis of reflector geometry and surface geomorphology. The radar facies are summarised as follows:

Radar Facies 1:- RF1 is characterised by having mainly lakeward dipping oblique tangential reflectors, which downlap the RF developed below. There may also be subhorizontal reflectors developed within the facies. This facies is restricted to the area underneath lacustrine ridges.

Radar Facies 2:- RF2 is characterised by having flat subhorizontal reflectors but the reflectors may dip at very gentle angles towards the lake. The ends of the reflectors generally onlap the reflectors in the adjacent RF and may curve upwards to the surface for a short distance.

Radar Facies 3:- RF3 is the commonest facies in the profiles from Kaitorete Spit, and its reflectors predominately dip at angles from 5–10° to the south. There are also small areas, close to the ground surface, where short reflectors may be subhorizontal, or dip gently to the north and onlap the reflectors developed to the north. The southern ends of these subhorizontal reflectors are either truncated, or change to southerly dips. Where no erosion of the ground surface has taken place, and nothing has been deposited on top of the facies, there is a gently undulating topography developed over RF3.

Radar Facies 4:- RF4 has subparallel, long, gently (2–5°) northward dipping reflectors, the southern ends of which are either truncated or change to a southerly dip. Below these gently northward dipping reflectors are steep northward dipping, oblique, tangential reflectors, which generally downlap a strong horizontal reflector at depth.

Radar Facies 5:- RF5 reflectors are generally subparallel to the surface topography, and may occur between the airwave and groundwave. This facies occurs underneath sand dunes and surface accumulations of sand or gravel.

Radar Facies 6:- RF6 this facies has oblique, tangential, sigmoid reflectors, which downlap a horizontal reflector that may be a source for many diffractions. Some of the reflectors may continue through the lower reflector and become a reflector in the underlying RF. This facies, like RF3, is associated with undulating surface topography.

Radar Facies 7:– RF7 this facies has two sets of reflectors which occur together. A steeply south dipping set downlap a wavy reflector, which is developed over a set of moderately dipping reflectors.

Radar Facies 8:– RF8 occurs where there is wet clay or saline porewater, and consists of ‘railway tracks’ that are surface parallel, evenly spaced, reflectors.

Radar Facies 9:– RF9 is associated with the groups of curvilinear ridges and the scarp-like south facing ridges, developed in the Ponds and Trig Point areas, and has steep oblique sigmoid reflectors which downlap the lower boundary.

Radar Facies 10:– RF10 is associated with sand dunes and is characterised by steep north dipping reflectors in the northern half of the facies, and moderately south dipping reflectors in the southern half of the facies. The reflectors downlap the basal reflector.

4. Interpretation

The interpretations will be carried out by first interpreting the broad scale geomorphology and then interpreting the radar facies, and finally, radar profiles and geomorphology will be integrated.

4.1 Geomorphology

4.1.1 Marine Geomorphology

There are two areas of marine geomorphology recognised on Kaitorete Spit, the Hooked Ridges and the Marine Beach Ridges. Armon (1970) recognised both these areas, describing and interpreting them as marine environments.

4.1.1.1 Hooked Ridges

Armon (1970) interpreted the curved alignment of these ridges as representing the development of the distal end of a gravel spit. The linear ridges developed south of the recurves were interpreted as being the beach ridges formed on the seaward side of the spit. He interpreted the low elevation of the recurved ridge crests as indicative of a lower sea level when the ridges formed. The distal end of a spit forms with the distal end projecting below the water level in which it forms (Johnson, 1919; Soons, et al., 1997), therefore the need to have a lower sea level is removed, and these spit recurves were probably formed with a sea level close to the current one. The truncation at M37 778 112, is probably due to a pause in the development of the early spit, due to a deepening of the bay. Johnson (1919) points out that in shallow water a small amount of sediment is needed to build the subaerial portion of a spit. Consequently in areas of high sediment supply and shallow water a straight spit will build with relative rapidity. When the water depth increases a submarine platform must be built prior to the subaerial portion of the spit growing. These observations are backed up by the experimental work of Meistrell (1966). Meistrell found in wave tank experiments, that in deep water a submarine platform (which he called the 'platform') is built on the shelf (shelf = local sea bottom), prior to the subaerial spit being built, and that the depth of water

above the top of the platform remains constant, even when the shelf topography is irregular. He also found that when the water depth above the shelf is small enough, no platform was developed, and the spit built directly on the shelf. Meistrell (1966) also found that the growth of the platform and spit are inversely related.

When Kaitorete Spit slowed in growth (while a platform grew across the bay) the straight spit was eroded at its distal end. When spit growth resumed, the platform caused the waves to be refracted into the bay mouth and build the recurved ridges (Kumar and Sanders, 1974; Evans, 1942). The reflection of waves off the volcanic rocks of Banks Peninsula, may also have contributed to the angle at which the ridges formed. Kumar and Sanders (1974) describe the sedimentary structures found in a tidal inlet at the distal end of a spit, and found that the ebb tide modified Meistrell's split platform, by redepositing the material supplied by the beach drifting, as a Gilbert-type delta, with topsets, foresets and bottomsets. Foresets comprise a series of seaward prograding, parallel, planar cross-strata.

As the bay mouth closed the waves could no longer be refracted, and the spit recurves straightened, as can be seen by the set of regular ridges in the McIntosh area, and the spit became a barrier beach. The remaining platform modified the wave climate such that the waves forming the beach ridges could only form ridges with crest elevations c. 4 m.

4.1.1.2 Marine Beach Ridges

South of the spit recurves, Armon (1970) recognised the second area of marine formed geomorphic features. He interpreted the parallel ridges as old beach ridges. This interpretation is supported by the cusped ridges found at the eastern end of Kaitorete Spit. The cusps are interpreted to be the tops of old horn and cusp sets. The parallel bedded gravels and sandy gravels, found in Browns Pit and the large pit at M37 768 102, are very similar to the gravels found on the current beach at Birdlings Flat, both of which are similar in character to the beach laminations described by Thompson (1937) and Clifton (1969).

The loose gravel unit in Browns Pit is interpreted to be the upper beach face, formed when high energy storm waves break on the lower beach face, and coarse

material is either thrown, or carried to the top of the beach by the swash. Any sand transported to the top of the beach is likely to be removed by the backwash, and either re-entrained or deposited in the lower beach. If sufficient of material is thrown over the beach berm, the beach is raised in height and short, landward dipping, overtopping laminae occur (Carter and Orford, 1984). During a high energy storm event, cusps may be cut into the storm beach (Sherman, et al., 1993). The gently curved truncations present in both Browns Pit (Figure 2-8) and the large pit at M37 768 102 (Figure 3-5), are interpreted to be the truncations developed during cusp development. Lower energy waves produce berms lower down the beach profile, and these berms may also have cusps cut into them. This is evidenced by the two lower berms developed on the beach at Birdlings Flat (Sherman, et al., 1993).

4.1.1.3 Overwash Barriers

The gentle lakeward dipping gravel layers developed in the overwash barriers that seal the outlets to Lakes Forsyth and Ellesmere, are known to have developed over very short time scales, generally 1–3 weeks (although in very rare circumstances the outlets have been known to remain open for 6 weeks). Two factors influencing this short length of time are the narrow opening width, and the prevailing southwesterly airflow (Reid and Holmes, 1996).

At the Taumutu end of Kaitorete Spit, the transgressive barrier which stretches from M37 584 053 to M37 614 058, is interpreted to be an overwash barrier for its entire length. Vegetation changes along its length are thought to be indicative of different aged sections of the overwash barrier. The section from M36 602 066 to M36 614 058 with its pingao vegetation cover by 1942, is thought to be older than the section west of M36 602 066, which only has sparse lake-edge vegetation in the 1942 aerial photographs.

It is known that when the local Maori opened the lake it was close to M37 584 053, and remained open for 3–6 months, therefore the outlet when developed must have been quite sizeable. Horrell (1992) developed a water balance model which indicates that, under current hydrological conditions, an uncontrolled Lake Ellesmere, the lake would self breach every 4 years, after reaching a level of c. 4 m. The section from M37 584 053 to M36 602 066 is thought to be the area which Andersen (1927) records as having been destroyed

by a natural breach in 1829. The remaining section from M37 602 066 to M37 614 058 of the transgressive barrier probably developed in an area of lacustrine and marine barrier beaches which were destroyed by a natural breach in prehistoric times. This section of transgressive barrier has been established long enough to have pingao growing in the sand dunes on it. The crest heights of the lake-edge ridges at Dune Ridge and Taumutu, and the plan of the highest lacustrine ridge, suggest that this ridge must have continued through from Dune Ridge to Taumutu. If this was the case, the lake basin for Lake Ellesmere would have had a much higher margin, and therefore been able to have had a much higher lake level than at present. The lacustrine spit recurves suggest that the lake must have been at least 5 m deep, while the ridge heights could have contained a lake level of 6 to 7 m. If the lake had reached a level of 6 to 7 m, and a channel developed to the coast, then the resulting large head of water could easily have removed a large quantity of the gravel by down and lateral undercutting. Therefore the transgressive barrier is thought to be developed in the site of a large natural breach that developed prehistorically.

4.1.2 Lacustrine Geomorphology

The geomorphology thought to be lacustrine can be divided into two groups on the basis of its formation within the lake.

4.1.2.1 Lake bed

The gently dipping lakeward surface, with coarse to very coarse pebbles lying with their long and intermediate axes parallel to the slope, is interpreted to be an old lake bed. Cuspate, small scale ridges are thought to be analogous to the small ridges observed just offshore in the present lake. The possibility that this surface is a remnant marine surface is discounted on the basis of the large pit at M37 768 102, which shows that the beach laminated gravels have 450 mm of silty clay and muddy gravel formed on top of them.

In several of the pits a silty clay layer was found either at the surface, or a few hundred millimetres below a poorly sorted, muddy, sandy gravel. This silty clay is thought to have formed on the floor of a much deeper Lake Ellesmere, where the depths were such that gravel and sand could not be transported with the clays and silts. Where developed, the poorly sorted, muddy, sandy gravel is

interpreted to be evidence of a change in the energy of the environment, either by a shallowing of the lake or an extreme storm event. The latter situation is unlikely, as the poorly sorted gravels tend to form quite thick layers over top of the silty clay layer. This suggests a sustained change in environment, not an occasional event. Further, the silty clay layer generally has no coarse clasts in it, implying deposition in quiescent water.

It is possible that the clay layer is actually a marginal lake shore deposit, accumulated by sediment baffling plants, however the yellow colour of the silty clay, suggests that no decomposed vegetable matter is included in the sediment (the silty clay forming along the present lake shore is blue due to the decomposition of plant material included in it). Another possibility is that it is part of an estuary floor, but this is unlikely on the basis of its elevation, at c. 2.5 m. As the spit recurves are thought to have formed at a sea level similar to the present, any estuary formed in the Lake Ellesmere basin would have had an upper water level approximately equal to the highest spring tide, which is 0.92 m a.m.s.l. (Reid and Holmes, 1996).

4.1.2.2 Lake Edge

The lake-edge geomorphology is the most complex geomorphology developed on Kaitorete Spit. Several other authors have previously interpreted aspects of the lake-edge geomorphology (Speight, 1930; Armon, 1970; Soons, et al., 1997). The easiest way to deal with the geomorphology is to break it into groups of similar geomorphic features.

Curvilinear Ridge Groups

There are several areas where groups of curvilinear ridges are formed. These curvilinear ridge groups generally stand between 1 and 3.5 m above the surrounding surface and have distinctive rounded terminations. The distal ends of the ridges have characteristic spit recurve form, and the groups of curved ridges are interpreted to be lacustrine spit ridges formed by a higher level Lake Ellesmere. The lacustrine spit interpretation is supported by the fact that when they occur together they all have similar orientations, and they are formed across areas which would be bays, in a higher Lake Ellesmere.

The lacustrine spit recurves developed 1 km east of Dune Ridge, and in the Ponds, Bayleys Ridges South and Island areas, all indicate that the spits were growing to the southwest. Therefore the direction of sediment transport must have been a predominantly, east to west direction in these regions of the lake. Crest elevations of the lacustrine spit recurves in the last three areas are between 5.5 and 6 m, therefore it is thought that the lake level must have been at least 5 m and may have been higher during the formation of these features. The blow-out into which the ridges 1 km east of Dune Ridge project, must have been covered in water for these features to have formed, in which case the 'blow-out' interpretation, of interdune areas that have elevations close to 6 m, and border the lake-edge ridges, must be questioned.

The lacustrine spit recurves developed at the Golf Course area, indicate spit growth to the east, and therefore the sediment transport in this area must have been from west to east. Lower elevation ridges, in Golf Course Southwest (see section 3.1.1.9.1), appear to have poor geomorphic definition. This is thought to be caused by a fine sediment layer, which was deposited by a rising lake, over the early formed lacustrine spit recurves. The Golf Course Middle and Northeast Ridges, are slightly higher in elevation probably due a slightly higher lake-level. Where Speight Ridge reaches c. 10 m elevation at the northeastern end of Golf Course Northeast Ridges, it is not interpreted to mean that the lake-level had reached 10 m elevation, but that a combination of large waves and lake water setup during storms led to swash working the beachface up to this elevation.

The Trig Point ridges appear to be similar to the lacustrine spit recurves, but do not have the subparallel nature developed. Crest elevations here are c. 4.5 m, and the round ends are interpreted to have been formed at or near the level of the lake surface. These features also indicate a sediment movement direction from west to east.

The two directions of sediment transport at either ends of the lake (i.e. east-to-west at the western end of the lake, and west-to-east at the eastern end of the lake), are thought to be due to waves generated by the two dominant winds on the lake.

During times when Lake Ellesmere had a lake-level of c. 4 m, the northeasterly wind, which is funnelled down Gebbies Valley (Mason et al.,

1996), has a fetch of c. 30 km to the Island area. During the same wind, a wind shadow is developed in over the lake in the vicinity of the Trig Point and Golf Course Areas. So when a northeasterly wind is blowing, waves generated on the lake should move sediment along the southern lake shore in a westerly direction, the longer the fetch the greater the wave energy and therefore transport potential.

When Lake Ellesmere had a lake-level of c. 4 m, a northwesterly wind had an effective fetch of c. 30 km from the western lake-shore to the Trig Point Area and c. 45 km to the Golf Course Area, but no more than c. 25 km fetch to the Islands area. So in northwesterly wind conditions sediment movement on the southern shore should be from west-to-east, with the highest energy sediment transport occurring where the wind has the longest fetch. During sustained winds on the lake, a setup may occur in the down wind direction (Crawford et al., 1996).

Scarp-like Ridges

Scarp-like ridges occur in areas adjacent to the lacustrine spit recurved ridges. They have shallow lakeward slopes 2–3° and steep seaward slopes 10–18°, which terminate abruptly on the ground to the south (see Figures 3-18 or 3-20). The gravel on the seaward slopes is close to the angle of repose, the abrupt termination appears to be downlapping the ground to the south. It appears they have either formed as large gravel dune-like features with sediment being brought up the shallow lakeward slope and then avalanched down the southward face, or alternatively they have formed by lake erosion on the south side of an originally high feature.

Linear Shore Parallel Ridges

The linear and gently curved ridges developed around the margins of the lake are interpreted to be lacustrine barrier beach ridges. The areas where these ridges occur, are where high geomorphic features are formed on the seaward side of the ridges (i.e. they form where a higher level lake would have been lapping against a high feature). The ridges occur as a single ridge, e.g. Speight Ridge (where it is a ridge), or in areas where the shoreline was out of equilibrium, as a complex of ridges, e.g. Railway Cutting Ridges, Bayleys Ridges, Birdlings Valley

Ridges and Taumutu Ridges. The complexes of ridges are interpreted to have formed in a similar way to the Marine Barrier Beaches with the sediment being transported around the edge of the lake by beach drifting, and the beaches being built up by swash and backwash processes acting on the sediment. This interpretation is supported by the lakeward dipping, parallel bedded, sandy fine to medium gravels. The material which forms the beach ridges is thought to have been derived from reworked marine beach gravels. The finer clast sizing in the ridges, is due to the lower energy environment. The coarser gravels remain largely on the lake bed as a lag deposit, but the lake waves were able to transport the fine to medium gravels.

There has been some lacustrine erosion of the marine beach ridges, as evidenced by the truncations at M37 725 088, and between M37 802 102 and M37 823 105, and between M37 647 069 and M37 670 075. The dunes have also been eroded between M37 646 068 and M37 616 059. The very sandy nature of the lacustrine ridge sediments in the Taumutu Gravel Pit, indicates that some of this dune sand was transported in the lake to this location.

The Taumutu Group 1 ridges, have lower crest elevations than their counterparts, indicating that the lake had a lower level before reaching its 5 m elevation. The freshwater mussel shell bed found by Armon (1974a) in the Taumutu ridges, indicates that the lake was at least 2.5 m higher than present, 750 years B.P.

Channels

The channels developed at the southwestern end of the Taumutu Group 1 Ridges indicate that after ridge development a series of alluvial channels removed the ends and sides of some of these ridges. The facts that the lake basin occurs to the east, the channels indicate flow directions to the south and west, and one of the channels has its northeastern end blocked by a Group 2 ridge, indicates the channels may represent an outlet of the lake when it was forming the Taumutu Group 1 ridges. Subsequently it appears that an environmental change (possibly an influx of sediment) led to the Group 2 ridges developing and cutting off these channels.

The small, short channels developed in the lake–edge ridges are interpreted to have formed when relatively rapid lake–level changes took place in a lake basin which was surrounded by lake–edge beach ridges, with areas of low relief developed behind. At low points in the lake–edge ridges flows were concentrated and channels were cut when the flow velocities were high enough. The lake level changes may have been caused by sudden inflows of water or by lake water setups during strong winds.

4.2 Radar Profiles

An interpretation of each of the radar facies summarised in section 3.3.2 is made, and then the individual radar profiles are interpreted in the order they occur from the west. The regional lines are examined first followed by an examination of the shorter lines which were collected in areas of specific interest.

4.2.1 Radar Facies Interpretations

The 10 radar facies will be interpreted first and then an interpretation of the individual radar profiles will follow.

4.2.1.1.1 Radar Facies 1

The short lakeward dipping tangential sigmoid reflectors, which occur beneath the various lake–edge linear ridges, are interpreted to be reflections off the bedding planes in the lacustrine ridges. If the profile that shows Bayleys Ridges is compared to the photograph of Taumutu Gravel pit wall (Figure 3-6) the strong similarity of reflector geometry and bedding plane geometry can be seen.

4.2.1.1.2 Radar Facies 2

The horizontal reflectors developed in this facies are interpreted to be either lacustrine or estuarine deeper water beds, which formed in hollows left after erosion. The onlapping and parallel nature of the reflectors supports this. The diffractions developed in some of the units may be due to logs collecting in deeper water, or are possibly due to large gravel clasts being moved over the bottom of the water body during high energy events.

4.2.1.1.3 Radar Facies 3

This wide spread facies occurs across the entire spit and the similarity of the reflector geometry and the bedding plane geometry in Browns Pit, including the

truncation patterns, leads to this facies being interpreted as barrier beach face deposits. The upper gently dipping reflectors are thought to represent the bedding developed in overtopping deposits, where high energy storm waves throw sediment up over the tops of the preceding storm berms.

4.2.1.1.4 Radar Facies 4

The gently dipping lakeward upper reflectors in this facies leads to it being interpreted as a washover barrier deposit. The steeply dipping reflectors at depth are interpreted as being foresets in a gravel bar-like deposit formed below sea level before the washover barrier develops. A gravel bar is thought to form below sea level in the bottom of the opening prior to a subaerial washover barrier being formed. The waves directed onshore will cause the sediment to be deposited as a series of steeply dipping foresets. When the bar has emerged above the level of wave action then washover begins to occur, where only waves that are large enough can throw material over the bar. The result is a series of more gently dipping beds above the steeply dipping foresets of the bar.

4.2.1.1.5 Radar Facies 5

This facies is thought to be representative of dry sand and gravel deposits which occur above the soil horizon. Where collections of gravel occurred at the surface a strong reflector always appeared between the ground wave and air wave. When collecting radar profiles over sand and old sand dunes a very similar reflector appeared between the air and ground waves.

4.2.1.1.6 Radar Facies 6

This facies is thought to represent an upper beach face deposit, where gravels are deposited at the top of a beach by storm waves. The top of the lower beach remains due to sand packing between the gravels, as observed in the walls of Browns Pit. The layer of diffractions is thought to be due to large cobbles collecting at the top of the lower beach between high energy storm events, analogous to the coarse discoid zone appearing on the present beach (see Figures 3-28 and 3-29) It is thought unlikely that the diffractions could be resulting from driftwood on the top of the beach, as the only driftwood observed on the present beach was either on the washover barriers or on top of the highest storm berm deposits.

4.2.1.1.7 Radar Facies 7

These two reflectors occurring together are interpreted to be marine spit and platform deposits. The steep upper reflectors are interpreted to be the spit beach and the lower slightly shallower dipping reflectors are interpreted to be the spit platform. The spit platform is thought to be of the type described by Kumar and Sanders (1974) where the ebb tide currents developed in an inlet modify the platform end into a series of foreset beds of a Gilbert-type delta. Following this, the wavy reflector is thought to be topset beds, with the waves creating large structures on top of the foreset beds rather than the flat lying beds.

4.2.1.1.8 Radar Facies 8

The 'railway tracks' developed in areas of wet clay or saline pore water are not, strictly speaking a facies. The parallel reflections are internal multiple reflections of the signal between two highly conductive and reflective layers.

4.2.1.1.9 Radar Facies 9

Where associated with the scarp-like ridges, the steep reflectors developed in this facies are interpreted to be sands and gravels which are on slip faces of what are essentially large gravel bars. The sand and gravel travel up the lakeward surface and avalanches down the slip face onto the gently dipping surface to the south.

Where the facies occurs beneath the groups of curvilinear ridges the reflectors are interpreted to be the lakeward beach faces of the lacustrine spit complexes. The fact that no platform is present is interpreted as meaning that the water depths were shallow enough not to have needed platform growth before spit growth (Meistrell, 1966;).

4.2.1.1.10 Radar Facies 10

This facies is associated with the large sand dune at the Dune Ridge area and the reflectors are interpreted to be the internal bedding geometries of the sand dune.

4.2.2 Regional Lines

The regional lines are interpreted in the order they occur from west to east.

4.2.2.1 Kailine 5

The underlying RF3 indicates that marine barrier beach deposits form the local basement for this profile. The upper boundary of the facies indicates that some form of erosion has removed the tops of the reflectors in the north half of the profile. The onlapping RF2 unit has been deposited on top of the eroded surface, implying a period of either lake or possibly estuarine sedimentation took place some time after the erosive event. The hummock shaped subunit of RF1 indicates that there was lake–edge ridge development when the lake level was c. 4 m. After the formation of this ridge the lake appears to have deepened and the horizontal reflectors of RF2 were deposited again. The development of the large ridge appears to have happened in several phases. The lake level appears to have been c. m. The small ridge on the northern side of the profile appears to have developed after the large ridge when the lake level had dropped considerably and was c. 3 m.

So the sequence of events portrayed in Kailine 5 radar profile is as follows:

- 1) deposition of marine barrier beach, prograding to the south
- 2) truncation of northern barrier beach deposits, leaving a north dipping truncation surface
- 3) deposition of horizontal beds by estuary or lake
- 4) deposition of ridge at edge of lake with a level c. 4 m
- 5) further lake bottom deposition, possibly concurrent to development of large ridge, lake level c. 6 m.
- 6) development of small ridge at northern end of profile, lake c. 3 m deep

4.2.2.2 Kailine 2

RF3 again dominates the profile especially for the last 600 m. In the northern 900 m RF3 is interrupted by the appearance of three episodes of RF5. The implication of RF4 appearing is that an overwash barrier must have developed. The formation of an overwash barrier needs a pre-existing basement with a pre-existing sediment supply. This implies that a breach occurred from the northern side removing material from the top of the barrier beaches and depositing this material at sea. After the breach occurred a period of first bar formation, and then overwash barrier formation must have taken place.

The northernmost RF2 section appears to have developed onlapping a steep erosional truncation surface developed on the southern side of a series of beach face gravels. The reflectors appear to mantle the truncation surface and are developed to the lower limit of the profile. The diffraction zone developed in the central segment of this section implies this is an area which has a collection of large boulders, logs, or small conductive clasts. The development of the RF4 immediately to the south of the RF2 implies that the flat lying reflectors probably had a connection to the sea and the RF2 here is probably estuarine in character. The small and incomplete overwash barrier development suggests that whatever caused the initial truncation of RF3 to the north was still active in either advancing the beach face offshore, or removing another substantial volume of already deposited RF3. The incomplete development of the RF3 south dipping reflectors, and the truncations developed within the facies, suggests that the event which occurred was a movement in barrier location, rather than erosion of extensive RF3. The RF2 onlapping the RF4 unit to the south suggests that the washover barrier had developed to a reasonable size by the time either the lacustrine or estuarine beds reached this level. The top of the RF4 and RF3 units developed underneath Bayleys Ridges have been truncated.

A change over to prograding barrier beachface takes place at the junction of RF4 and RF3. The barrier beach progrades for a while and a third truncation of the beachface deposits takes place at 700 m along the profile. The development of a third overwash barrier takes place, the size of the overwash barrier preserved is probably quite close to the size it was formed at. There was then a third transformation to prograding beach face deposition, which continued to the end of the profile.

The small patches of RF5 developed at the surface are related to sand accumulations and are interpreted as being the remnants of old coastal sand dunes, mantling the barrier beach deposits.

Sometime after the development of the third washover barrier, extensive erosion must have taken place over the tops of the RF3 and RF4 units between 425 and 700 m. After this erosion the lake had reached a level such that it could deposit the small spits between 700 and 780 m. The size of the spit ridges is probably the reason that the reflector patterns do not look like the

lacustrine spits of the Ponds area. The spit formation was replaced by lake–edge ridge formation when the spits had grown long enough to form a high lake shore. A constant and plentiful sediment supply led to the development of an extensive lake–edge ridge plain. The small hummock–shaped southward dipping package of reflectors seen at the beginning of the RF1 unit may be an offshore bar, or may have been a lacustrine over wash deposit that developed as the lake was rising, prior to the development of the spit ridges. The very gently north dipping reflector which cuts the top of the ridge, is interpreted to be a result of an increased lake level after the development of the ridge plain. The small parasitic ridge developed at the toe of the large ridge is interpreted to be the ridge which developed after the lake had breached the marine barrier at Taumutu, and was restricted to reaching a lake level of c. m.

The sequence of events in Kailine2 are thus:

- 1) prograding barrier beachface
- 2) either erosion or dislocation of barrier formation offshore, leading to overwash barrier formation and concurrent estuarine/lacustrine horizontal bedded deposits
- 3) short resumption of beachface progradation
- 4) movement or erosion leading to second overwash barrier formation and second lacustrine/estuarine horizontal bedded unit
- 5) resumption of beachface progradation
- 6) Third erosion or barrier dislocation event leading to formation of third overwash barrier, this time without horizontal bedded lacustrine/estuarine deposit
- 7) resumption of beachface progradation
- 8) erosion of old marine beachface and washover deposits
- 9) deposition of small lacustrine spit recurves and possibly shore parallel bar or overwash barrier between 425 and 460 m
- 10) development of lacustrine beach ridge plain with elevation of approximately 6 m
- 11) increase in lake level leading to heightening of most lakeward ridge
- 12) drop in lake level to c. 4 m leading to development of small ridge at toe of large ridge

4.2.2.3 Kailine 1

The RF3 developed for the first 470 m of this profile indicates that steady southward beachface progradation took place. Then an erosive event removed the southern edge of the beach and marine barrier formation was dislocated 200 m to the south. A washover barrier formed as shown by RF4, followed by a resumption of southward beachface progradation. A small erosive event removed the upper beachface between 960 and 990 m, this area was then backfilled by overwash deposits. Southward beachface progradation again resumed and continued until the end of the profile. The small areas of gently north dipping reflectors in the upper parts of the profile, are interpreted to represent overtopping deposits, formed when high energy storm waves, overtop the beach berm and deposit material over the top of it.

The horizontal reflector developed from 50 to 2001.25 m at c. 140 ns depth is interpreted to be the unconfined water table reflection. The gently dipping reflector starting at 865 m 250 ns and stretching to 1000 m 280 ns, where it steepens in dip and disappears at 1040 m 360 ns, is an airwave reflection off a windbreak that was subparallel to the profile line approximately 50 m east.

The sequence of events in Kailine 1 are as follows:

- 1) southward prograding marine barrier beachface
- 2) an event of erosion took place removing the southern ends of the beachface reflectors
- 3) a washover barrier filled the area left by the erosion
- 4) southward marine beachface progradation resumed
- 5) a erosive event removed a small section of the beachface reflectors and overwash deposits filled this area
- 6) southward marine beachface progradation resumed

4.2.2.4 Kailine 3

The first 940 m of this profile consists of RF7 and RF8. The RF7 is interpreted to be the marine spit recurved ridge crests, which are overlain by RF8 which is interpreted to be saturated estuarine and lacustrine silts and clays. The high conductivity of these overlying deposits is leading to the development of the characteristic 'railway tracks'. Irregular reflectors can be seen developed

near the surface and in places can be seen overlapping the tops of the spit ridge crests and are interpreted to be beds of lacustrine or estuarine silt and clay.

The first section of RF7 appears as a series of faint reflectors, the subhorizontal wavy reflector can be seen in all the RF7 sections. The change in elevation of the ridge crests is a result of the changing position along the ridge crest, i.e. by 700 m along the profile the ridge crest corresponds to the spit beach ridge, not the spit recurve ridge. The subhorizontal reflector is essentially developed at -1 m elevation, and interpreted to be the topset beds reflection of the platform. This agrees with the environment that Kumar and Sanders (1974) found in their inlet sequence. The seaward dipping reflectors below this platform surface are interpreted to be similar to the Gilbert-type delta spit platform that Kumar and Sanders also found. The layer below the foreset reflectors is interpreted to represent the inlet base, and the numerous diffractions generated here could be due to logs or boulders on the inlet floor. The change over to RF3 at 940 m is thought to have resulted from the loss of the spit platform and the development of the marine beach, as noticed by Meistrell (1966).

RF3 continues for the rest of the radar profile indicating that southward beachface progradation was occurring after the development of the spit. The appearance of RF6 above RF3 between 930 and 1440 m is interpreted as the development of a loose upper beach related to the change in sedimentary environment.

The small section of RF5 occurring above the prograded beachface deposits is an old sand dune, which has subhorizontal flat reflectors developed, which may be the reactivation surfaces in the dune.

The lacustrine ridge RF1 is developed above RF7 and shows gently dipping seaward beds (RF9?) overlying a gently dipping truncation surface developed over gently dipping lakeward reflectors. The lakeward reflectors are thought to represent an initial lake-edge ridge, which was then eroded and became the locus (RF9?) for shore parallel bar deposition as indicated by the seaward dipping reflectors.

Kailine 3 shows the following sequence of events:

1) a marine spit platform was deposited on the local 'shelf' this was followed by a subaerial spit with possible fine estuarine sedimentation occurring concurrently in the interdigit bays

2) the spit and platform prograded to the south and the was replaced by a southward prograding marine beachface

3) some time later lake sedimentation replaced the estuarine and a lake-edge ridge developed on the marine beachface deposits

4.2.2.5 Kailine 4

The RF7 developed in the first 1460 m is thought to be due to beach development on the floor of a shallow embayment. The similarity between the reflectors developed in the first part of this profile and parts of *Kailine 3* and *Jones Pit north-south long* are thought to be due to the wave modifying effect of a shallow bottom. The transition to RF3 is interpreted to mark the arrival of the beachface at the edge of a local platform, and therefore an increase in available wave energy, resulting in a higher beach crest. The development of the numerous diffractions is thought to be partially due to infiltration of lake silts and clays. The horizontal reflector at 120 ns depth is interpreted to be both a facies boundary and the local ground water table. The water table is coincident with the facies boundary from 475–1350 m.

The 'railway tracks' of RF8 are interpreted to be a result of saturated lake silts and clays.

4.2.3 Smaller Selected Lines

4.2.3.1 Transgressive Barrier

The extensive 'railway tracks' developed in this profile are a result of saline pore water. During storm events large waves both wash over (hence a washover barrier) and drain through the gravel layers internally as small streams, so the salt content of the gravels is high.

Several reflectors can still be observed and the truncation of the gently north dipping reflectors by the beach face is interpreted to be the relationship of the beachface and overwash deposits seen in RF4 and in figure 3-32. The reflectors which dip away from the surface are interpreted as being a result of the barrier migrating towards the north, while the steeper reflectors are the ends of the

individual overwash fans. The horizontal reflector stretching from 0 m 70 ns to 40 m 80 ns is interpreted to be the unconfined water table.

4.2.3.2 Dune Ridge

Both the Dune Ridge lines show the same facies relationships. After the southward progradation of the marine beachface, coastal dunes developed over the resulting surface. When the lake rose it eroded the dunes and moved the sand (probably to the southwest) leaving a thin covering of coarse pebbles on the erosion surface in the dunes (the truncation reflection in both the profiles). After the lake level dropped the dunes remained active and migrated towards the northeast over the old lake-edge ridge.

4.2.3.3 Ponds

4.2.3.3.1 Ponds north-south long

South progradation of marine beachface was interrupted by an erosive event, a marine overwash barrier developed filling the hole left by the erosive event. The gently south dipping reflector at c. 200 ns between 110 and 205 m, is interpreted to be the top of the eroded bed. South progradation of the beachface resumed when the overwash barrier had grown large enough to stop the majority of the material over the top (c. 4 m).

Following development of an overwash barrier lacustrine/estuarine deposition took place to the north of the overwash barrier (RF2). A small amount of lacustrine erosion on the old overwash barrier and beachface deposits took place, followed by the development of spit ridges and lake-edge ridges. The development of the ridges was progressively moved northward until a spit complex developed between 50 and 125 m along the profile. With continued sediment supply the spit was replaced by a series of north prograding lacustrine beach face deposits. Later after the lake rose a shore parallel bar developed on top of the old lake-edge beachface deposits, the bar migrated to the south onto the old lacustrine spit complex.

4.2.3.3.2 Ponds north-south short

This line shows the distal end of the washover barrier and the associated RF2. Above this, the continuation of the shore parallel bar is developed growing from the north and increasing in height suggesting a rising lake level.

4.2.3.3.3 Ponds west-east long

This profile shows the nested overwash fans of the overwash barrier. Above the overwash deposits the mantling deposits of the lacustrine/estuarine unit occur. There appears to have been an erosive event before the deposition of the lacustrine/estuarine deposits leaving a hummock shaped high between 70 and 110 m. During the RF2 deposition several mantling deposits were laid down, the series of west dipping reflectors were laid on top of the high. The diffractions initiated at the top of the RF2 are interpreted to be from very coarse discoid pebbles with their long and intermediate axes horizontal.

The spit which appears in *Ponds north-south long* appears over top of these lake bed deposits and is growing towards the west. A second slightly higher spit appears also growing westward. The west end of the spit shows a beachface reflector developed over the last few spit beaches.

4.2.3.3.4 Ponds west-east short

This profile is interpreted as being the strike view of the overwash barrier reflectors. The wavy reflector is interpreted as being the truncation surface developed when the erosive event removed the beachface deposits.

A small lake ridge is developed on top of the overwash barrier which is interpreted as a small spit ridge which failed to develop into a spit complex.

4.2.3.4 Island

4.2.3.4.1 Island north-south

The northern end of *Island north-south* shows the development of a washover barrier, which is interpreted as a post-erosive deposit. Associated with the northern end of the washover barrier is a thin layer of lacustrine/estuarine deposition (as indicated by the RF2). Following development of the large washover barrier, southward beachface progradation resumed (RF3). A second erosive event took place, and a second washover barrier formed (RF4), after which southward beachface progradation resumed. The southern slope of the depression (see section 3.1.1.6) is interpreted to be the original slope of the washover barrier. The northern slope is a slightly modified erosion slope.

Some time after the resumption of southward beachface progradation the lake level rose to c. 5 m and erosion planed the top of the first washover barrier and

some of the barrier beachface deposits. Concurrent with the lake level rise, lake-edge ridge deposition began on top of the old marine surface, and the remaining high standing barrier beachface deposits remained as an island. The lake level remained at about 4–5 m and a series of lacustrine beachface deposits prograded to the northwest. A later lake level rise deposited subhorizontal beds over the old lacustrine ridge plain. Concurrent with this lake level rise, clays were deposited in the depression, to a maximum thickness of 2 m.

4.2.3.4.2 Island west east

The gently dipping truncation and onlapping reflectors shown in this profile are interpreted to be reflections from a cusp bay, infilled with later sediments. The lake-edge ridge sediments show that the reflectors dip gently to the east, this combined with the fact they dip north on the north south profile indicates that the true dip direction is north-northeast. The dip on the lake-edge reflectors in the north-south profile is steeper, therefore closer to the true dip, than the dip on the lake-edge reflectors in the east west profile.

4.2.3.4.3 Island northwest southeast

On this profile the lacustrine erosion surface is shown developed on top of the progradational beachface deposits. On top of this erosion surface two thin lacustrine ridge deposits are developed. The southeast dip of the beachface reflectors is lower than the reflectors in the north-south reflectors due to the angle at which the profile cuts the strike.

4.2.3.5 Trig Point

4.2.3.5.1 Trig Point north-south

An interruption to southward marine beachface progradation is shown between 40 and 60 m, the reflectors developed show a steepening which is interpreted to be slumping of the gravels due to erosion at the southern side. After this erosion a washover barrier developed to the south with the distal ends of the washover beds onlapping the toe of the slump beachface gravels. When the washover barrier reached c. 4 m then southward beachface progradation resumed.

Later when the lake had risen to a level something over 3 m, the waves developed on a northwest wind moved sand and gravel along the top of the high

left by the erosion. When sediment reached the top of this remnant high it would have avalanched down the southern side. As this process continued a linear dune-like sand and gravel ridge was built out. As the lake grew higher a second ridge was constructed on the southern slope.

4.2.3.5.2 Trig Point west-east

The ridges formed near the trig point are developed over overwash deposits, which show chaotic reflector development at their distal ends.

The ridges themselves are interpreted to have developed first as a series of spit ridges which then had their proximal ends truncated. Material could not then travel around the spit beach, but travelled along the ridge top to avalanche down the southeast face in a series of foreset beds. Their southern edges were reworked into a series of beachface deposits, by waves developed in the body of water between the shore parallel scarp-like ridge and the shore.

4.2.3.6 Jones Pit

4.2.3.6.1 Jones Pit northwest-southeast

Spit platform deposits form the local base of this profile, shown by the lower reflectors in RF7. The lower dip angles developed on these reflectors, when compared to RF7 lower reflectors on Kailine 3 are interpreted to be due to the oblique line of the profile in relation to the dip direction. The water table reflection cuts the spit beach reflectors at c. 120 ns. Above the steep spit beach the shallow seaward dipping reflectors of the upper beach downlap a horizontal slightly wavy reflector which has numerous diffractions starting at it. The diffractions are interpreted to be the result of cobbles dumped on top of the spit beach.

Above the spit beach at c. 200 m a small lacustrine spit or bar developed, migrating toward the south after the lake level rose. As the lake rose further, the spit/bar became the local lake shore and lake-edge ridge development started. A continued sediment supply led to steady northwest lacustrine beachface progradation. Several pulses in the sediment supply and/or changes in lake level left their mark as a series of subunit boundaries in the RF1. The beachface reflectors merge down dip into the gently dipping reflectors of the RF2 below,

this indicates that the RF2 reflectors are indeed the lower portions of the lake beachface and are therefore of lacustrine origin at this locality.

4.2.3.6.2 Jones Pit north-south

A transition from marine-spit platform facies to south prograding beachface facies is recorded between 50 and 125 m on the profile. Here it is thought that when the spit welded onto Banks Peninsula there was a transformation from spit beach to barrier beach. The radar profile shows that there is still the platform facies developed below what is interpreted to be early barrier beach, this is thought to be the platform which had developed in the last stages of the estuary inlet. The platform remained due to its position in the wave regime. The barrier beach then prograded across this remnant platform as sedimentary material was delivered by the longshore drift. The platform attenuated the waves approaching the beach and consequently the beach that developed had a crest elevation of c. 4 m. As the beach approached the edge of this platform the wave energy being delivered to the beach increased and the beach crest developed with higher elevations. The beach prograded beyond the edge of the platform. With the removal of the modifying affect of the platform the beach ridge crest increased in elevation, as shown by change in elevation between 50 and 125 m.

The water table reflection can be seen at 130 ns. Again the top of the beach shows the lower angled storm deposits until the change to a more reflective beach profile is reached (Wright and Short, 1984).

4.2.3.7 Birdlings Ridges

Data from a drill hole located at the northern end of Birdlings Ridges (Soons, et al., 1997) suggest that lake bottom silt and sand beds form the lower reflectors in this profile. The similarity of the reflectors in this profile to those in *Jones Pit northwest-southeast*, indicate that the lower subhorizontal reflectors are lake bottom deposits which form down dip of the lacustrine beachface reflectors. These are interpreted to be continuations of lacustrine beachface reflectors further east. As the sediment continued to be supplied along the front of Railway Cutting Ridges around the point and down the beach on the south side of Birdlings Valley, the lacustrine beachface prograded to the west, creating a beach ridge plain. Sediment or lake level interruptions led to the development of

several subunits in the RF1. The western most ridge series is interpreted to have developed at a higher lake level than the preceding ridges.

4.2.3.8 Browns Pit

The reflectors in Browns Pit are interpreted to be the beachface deposits found on the marine barrier beach. The upper RF6 is interpreted to be the loose gravel unit is thought to result from gravel being thrown to the top of the beachface during high energy storm events, any sand which makes it to the upper beachface is removed by backwash. The lower RF3 unit is interpreted to be the sandy gravels found in the lower unit. Representing lower energy beachface deposits. The sandy matrix would act to make the beach resistant to erosion during high energy storm events.

The gently curved truncating reflector seen in the profile taken along the southern pit wall is interpreted to be a cusp bay, with onlapping infilling deposits.

4.3 Correlation Between Radar Lines

The lateral continuity of the marine barrier beach ridges means it is possible to apply correlations between widely separated radar profiles. On the map sheet showing the geomorphology several lines of correlation have been marked on the marine barrier beach ridges. From these it is possible to establish that the overwash barrier deposits are in the same positions on several profiles.

Ponds north-south has one overwash barrier formed with its crest c. 225 m along the profile. The crest elevation, if the topmost overwash reflector and first beachface reflector are continued until they intersect, is c. 4 m. The overwash barrier has extensive overwash deposits, and has well developed beachface progradation deposits continuing southward.

Kailine 2 has three sets of overwash barriers formed along its length. The first is poorly developed and shows the development of a beachface, which is then replaced by a another 200 m wide section of RF2. The second section starts at 390 m and finishes at 570 m. Lacustrine erosion has removed the washover barrier crest, but if the beachface is continued up to meet the upper overwash bed then it becomes apparent the crest elevation must have been c. 4 m. A further 325 m south the crest of a third overwash barrier occurs. This third

overwash barrier also has a crest elevation of c. 4 m, and appears to have escaped major lacustrine erosion. To the south of the third overwash barrier, southward marine beachface progradation continued.

Island north-south radar profile shows 2 well developed overwash barriers. The first overwash barrier has its crest c. 100 m along the profile, and has a crest elevation of c. 4 m. The second overwash barrier occurs c. 350 m south of the first, at c. 450 m. It also has a crest elevation of c. 4 m, the fact that this surface has escaped large scale lacustrine erosion has been discussed in section 4.2.3.4.1.

Kailine 1 radar profile also has 2 overwash barriers. The first is a large well developed deposit which extends to the limit of the radar penetration, and has its crest c. 650 m along the profile (just south of Speight Ridge). The second overwash deposit differs from the first in that it only extends half way down the profile. It has a crest elevation of c. 6 m and occurs c. 340 m south of the first washover crest at c. 990 m along the profile.

The last profile which displays any overwash barrier formation is *Trig Point north-south* which has an overwash barrier crest 150 m along the profile, with the crest elevation again c. 4 m. The overwash barrier has well developed overwash reflectors. Again the northern slope of the overwash barrier is not thought to have suffered from much erosion from the lake.

The correlation line which starts at the crest of the third overwash barrier on *Kailine 2*, and runs parallel to the lacustrine lake-edge features, passes through the crest of the second overwash barrier on *Island north-south*. The eastern continuation of the correlation line still runs parallel to the lake-edge features and passes through the second small unit of overwash barrier on *Kailine 1*. These three overwash deposits are interpreted to have formed during the same period of washover barrier formation. If the correlation line is run west from *Kailine 2*, and kept parallel to the marine beach ridges developed south of the lake-edge features, it passes through the crest of the washover barrier formed on *Ponds north-south*. Therefore, the washover barrier formed on *Ponds north-south* is also interpreted to have formed during the same episode of washover barrier formation as the washover barriers mentioned above in *Kailine 2*, *Island north-south* and *Kailine 1*.

On *Kailine 2, Island north-south* and *Kailine 1* between 325 and 350 m north of the washover barrier discussed in the preceding paragraph, another well developed washover barrier occurs. A second correlation line can be run parallel to the southern correlation line, passing through the crests of these northerly washover barriers. If this second correlation line is continued eastward, it runs along just south of Speight Ridge, and eventually passes through the washover barrier crest developed on *Trig Point north-south*.

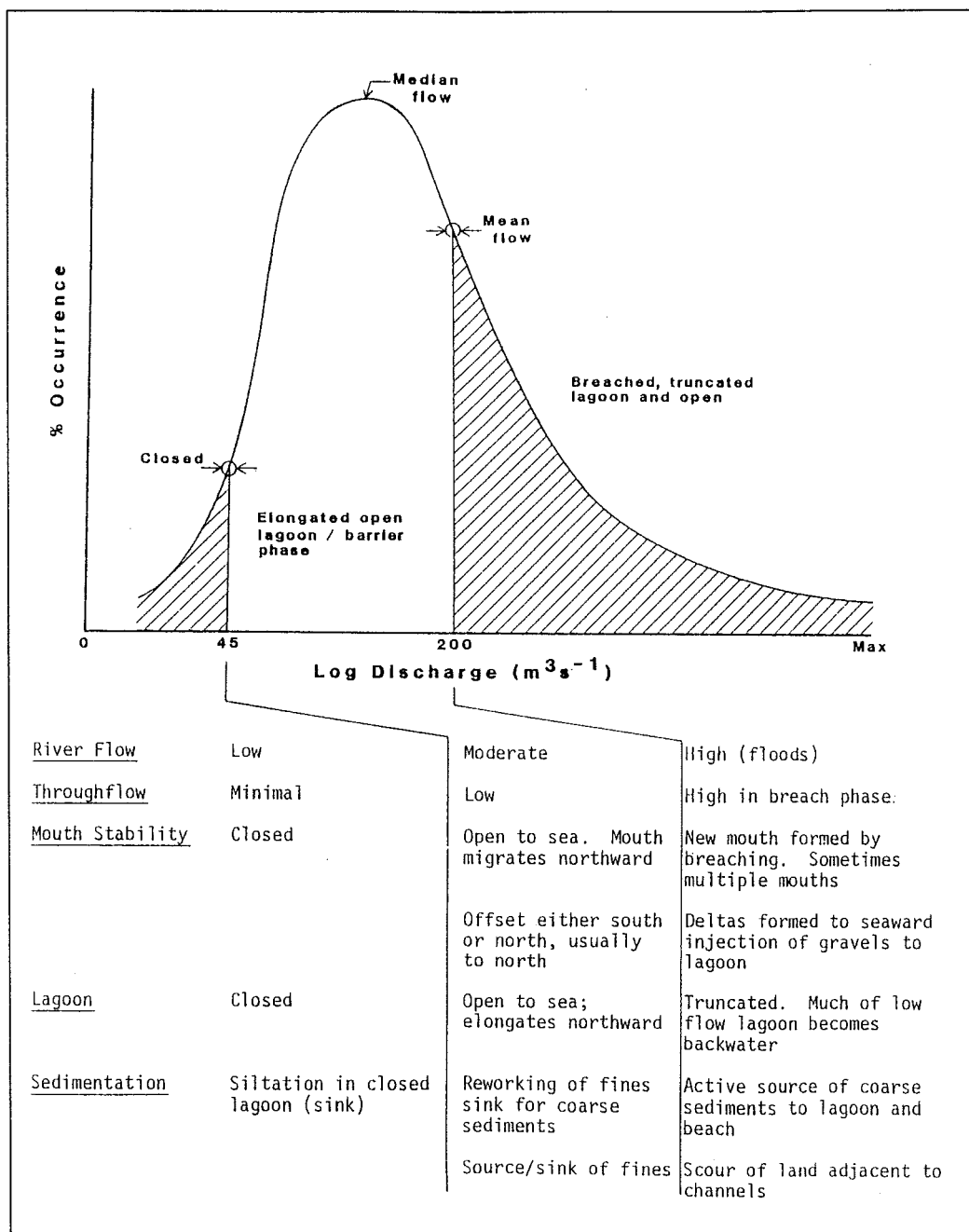


Figure 4-1. Kirk's 1983 descriptive model of lagoon/barrier processes at the Rakaia River mouth. It is thought at two early outlets to Lake Ellesmere, the flow conditions remained moderate (between 45 and 200 $m^3 s^{-1}$) for extended periods of time, resulting in the development of very elongated lagoons. From Kirk, 1983.

These two washover barriers must have developed in two long, (8–12 km) narrow (150–200 m), shore-parallel, depressions. The base of these depressions extends several metres below mean sea level. These depressions are interpreted to be shore-parallel outlet channels for an early Lake Ellesmere. These channels are thought to have been similar in character to the river mouth lagoon that develops currently at the Rakaia River mouth and is discussed by Kirk (1983). He proposed a descriptive model for the lagoon and barrier dynamics dependent on the amount of river flow. This model is presented in Figure 4.1.

If this channel is similar to the river mouth lagoon at the Rakaia River, a large continuous supply of water is needed to keep the channel open. The work of Soons, et al. (1997), Harvey (1996) and Basher (1988), all indicate that during the past 4000 years the Waimakariri River has flowed into Lake Ellesmere, probably on several different occasions. If the Waimakariri River maintained a continuous flow into the lake, then some form of outlet channel would need to exist. If none were present then a breach would occur and a channel would be cut.

Kirk's (1983) model suggests that the flow into the lagoon influences the how the lagoon outlet behaves. His model defines three situations which could occur for the Rakaia River mouth system. These are as follows: for low flows into the system ($<45 \text{ m}^3\text{s}^{-1}$), the longshore drift along the coast closes the lagoon outlet and ponding occurs behind the washover barrier; for moderate flows ($45\text{--}200 \text{ m}^3\text{s}^{-1}$) the lagoon mouth is kept open by the discharged water flow but the mouth is progressively moved northward by the longshore drift; for high flows ($>200 \text{ m}^3\text{s}^{-1}$) the overwash barrier is breached adjacent to the main flow into the lagoon (in the Rakaia system the southern channel).

If a large river (the Waimakariri) maintained a flow into Lake Ellesmere a breach would occur when the volume of water exceeded the lake-basin capacity. After initial breaching the river inflows, the lake outflows and the longshore drift would develop a dynamic equilibrium. It is thought that once equilibrium conditions were established at the breach site a lagoon would develop and the outlet mouth would be dislocated to the east by the longshore drift. The lagoon would behave as if there were continuous moderate flow ($45\text{--}200 \text{ m}^3\text{s}^{-1}$) conditions. The reason behind this is during times of high river inflow the large

volume of Lake Ellesmere would act as a buffering system and the outlet flows would only rise gradually, probably not exceeding the high flow conditions needed to breach the overwash barrier. Therefore the main control on the lagoon outlet would be the longshore drift movement. The result of extended moderate flow conditions in a lagoon system is the (eastward) dislocation of the lagoon mouth, and the development of a long, thin, shore-parallel lagoon. The channels developed on Kaitorete suggest that the lagoon/channels were up to 12 km long, far exceeding the 2 km lagoons found in the Rakaia River mouth system (Kirk, 1983). If the flows became too low the high sediment supply, due to longshore drift in this region of the coast, would rapidly fill the lagoon with washover deposits. The resulting bedding geometries would look very similar to the radar profiles. With continued sediment supply the washover barriers would be replaced by a progradational beachface and southward beachface progradation would resume.

4.4 Chapter Summary

4.4.1 Geomorphology

Within the two major geomorphic areas defined by Armon (1970) smaller distinct geomorphic groupings can be identified:

4.4.1.1 Marine Geomorphology

1) Armon's (1970) interpretation of the recurved ridges is kept as the distal end of a eastward growing marine spit complex.

2) The interpretation of the east-west trending linear ridges developed between the present coast and the lake-edge geomorphic features, are interpreted to be the tops of storm berms developed on a southward prograding marine barrier-beach, in agreement with Armon (1970).

4.4.1.2 Lacustrine Geomorphology

1) Lake bed features which include small scale cusped ridges, beds of very poorly sorted muddy gravels, and very coarse sediment lying on the old lake bed, are all interpreted as formed in 'shallow' water depths (within fair weather wavebase) in conditions similar to those present along the current southern shoreline of Lake Ellesmere. Beds of fine sediment deposited over the marine

barrier beach gravels and beneath the poorly sorted beds mentioned above are interpreted to represent 'deep' lake bottom deposits, when water depths were such that coarse sediment could not be transported (well below fair weather wavebase).

2) The lake-edge deposits consist of linear ridges, scarp-like ridges and groups of parallel curvilinear ridges. The linear ridges are interpreted to be lacustrine beach ridges, the scarp-ridges are interpreted to be either erosional features, or shore-parallel bar-like features, the groups of curvilinear ridges are interpreted to be lacustrine spit complexes. Both alluvial channels and short channels which indicate that rapid lake level changes occurred, resulting in flows developing from one area to another.

4.4.2 Radar Facies

The 10 radar facies developed on Kaitorete Spit have been interpreted on the basis of reflector geometry and the geomorphic features they are associated with. The facies interpretations are thus:

- 1) RF1 results from the development of lake-edge ridges and lake-beach ridge plains.
- 2) RF2 is formed by sediment deposition in relative low energy water bodies, resulting in subhorizontal bedding and therefore reflectors.
- 3) RF3 is the most common facies on Kaitorete Spit and is interpreted to represent marine barrier beachface progradation.
- 4) RF4 is interpreted to represent marine washover barrier development, formed where a breach into the sea has occurred.
- 5) RF5 is a widely occurring facies which is interpreted to represent sand and gravel accumulations above any soil horizon.
- 6) RF6 is interpreted to represent an upper gravelly marine beachface developed when the lower beachface has a sandy matrix .
- 7) RF7 is interpreted to be marine spit platform deposits.
- 8) RF8 is the result of highly conductive and reflective layers and is not really a facies.
- 9) RF9 is interpreted to be lacustrine shore-parallel bar-like features or the lakeward faces of lacustrine spit beaches.

10) RF10 is interpreted to be aeolian dune deposits..

The radar profiles show that there are several distinct episodes of sedimentation that can be correlated between lines. The area was built first as a marine spit, followed by a transition to southward prograding marine barrier beach. Landward of the barrier-beach, a lake replaced the estuary, and several phases of lake level change and marine barrier beach breaching are recorded.

5. Summary and Conclusions

5.1 Principle Results

Geomorphology

The geomorphology found on Kaitorete Spit can be subdivided into marine and lacustrine features.

1) Marine spit geomorphology

The marine spit geomorphology consisted of both straight and recurved ridges which have low elevation crests, most of which are covered by estuarine and lacustrine sediments

2) Marine Barrier Beach Geomorphology

The marine barrier beach geomorphology consists of storm berm ridges which are developed subparallel to the current coast and have moderate (5–10°) southward dipping sand and gravel beds and are formed by swash processes. The ridges seen on the aerial photographs represent high level storm berms which may have horn and cusps sets formed on them. Also washover barriers which currently form in the outlets to Lakes Ellesmere and Forsyth, and consist of gently (2–5°) north dipping sand and gravel layers, with a moderate (5–10°) southward dipping beachface..

3) Lacustrine Geomorphology

The lacustrine geomorphology is subdivided into two smaller groups:

Lake-edge features consisting of: *lacustrine beach ridges*, formed along the shore of a higher level Lake Ellesmere and were formed into beach ridge plains where the original lake shore left by the marine processes was not in equilibrium with the lake longshore drift; *lacustrine spit complexes* also formed along the shore of a higher Lake Ellesmere, and consist of groups of parallel recurved ridges with steeply (25–30°) dipping beachface deposits; *scarp-like ridges* occur often associated with the proximal ends of the lacustrine spit complexes and have shallow (2–4°) lakeward slopes with steep (10–18°) seaward slopes, with truncations on the seaward side which appear to downlap the surface they are formed on.

Lake–bottom features consisting of: *elongated horn and cusp ridges* which occur as low relief silty ridges with long horns, with medium to coarse pebble coverings.

Ground Penetrating Radar

The ground penetrating radar surveys revealed 10 different radar facies formed across Kaitorete Spit. These are as follows.

- Radar facies 1, formed beneath the lacustrine beach ridges and comprises of short lakeward dipping reflectors.
- Radar facies 2, formed where either lacustrine or estuarine sedimentation has taken place and comprises of subhorizontal subparallel reflectors.
- Radar facies 3, formed by the prograding marine beachface deposits and comprises of long moderately seaward dipping reflectors.
- Radar facies 4, formed by overwash barrier deposits and comprises long gently landward dipping reflectors near the surface and shore steeply landward dipping reflectors at depth.
- Radar facies 5, occurring where there is sand or gravel accumulations above any soil horizon and is generally a topographically parallel short reflector.
- Radar facies 6, representing coarse gravelly upper beachface deposits and comprises short moderately seaward dipping sigmoid reflectors.
- Radar facies 7, representing marine spit and spit platform deposits and comprises of short moderate to steeply seaward dipping reflectors developed over long moderate to gently dipping seaward reflectors.
- Radar facies 8, developed in areas of highly conductive and reflective bed materials and comprises of surface parallel reflections.
- Radar facies 9, formed on lacustrine spit complexes and their associated bar–like ridges and comprises of short steeply dipping reflectors which dip in the direction of spit growth.
- Radar facies 10, occurring beneath the larger sand dunes and comprising of moderate to steeply dipping reflectors both seawards and landwards..

The use of ground penetrating radar has confirmed many of Armon's (1970, 1974) geomorphic interpretations of the features developed on Kaitorete Spit.

The radar profiles have also revealed some new geomorphic features developed on Kaitorete Spit: the lacustrine shore-parallel bar-like ridges; the marine spit-platform deposits beneath the spit recurves; and the overwash-deposits developed in the central parts of the marine barrier-beach complex.

The correlation of the radar profiles using the lateral continuity of the barrier beach ridges revealed two long, lagoon-like channels, that formed early in the development of Lake Ellesmere.

With a combination of geomorphology and ground penetrating radar it is possible to obtain a detailed picture of the underlying sedimentary structure in an area of little outcrop. There are limitations, such as the poor results in areas of highly conductive ground materials; or the general lack of correlation material (i.e. boreholes), and these need to be taken into account when both planning an investigation and interpreting the resulting profiles.

5.2 Synthesis

5.2.1 Marine Development of Kaitorete Spit and Waihora Estuary

By about c. 9500 years B.P., a marine barrier had closed off an estuary in the basin which is now occupied by Lake Ellesmere. With the continuing rise in sea level the barrier migrated landward, and probably grew in length. With the stabilisation of the sea level close to the present level, and the large amount of material supplied by longshore drift, the barrier began to extend across the embayment. As the spit end reached deeper water a spit platform needed to be built across the shelf. The development of the platform modified the wave climate and led to the spit forming recurves into the embayment.

As the mouth of the estuary inlet narrowed, the ebb tide began to modify the distal end of the spit platform into a Gilbert-type delta deposit. Leaving a series of seaward prograding foresets with a topset formed just below sea level. The spit beach then built out over the topset beds.

As the spit grew eastward the high sediment supply meant the spit beach also prograded southward. The attenuation of the wave energy by the spit platform led to the spit beach crest being several metres lower than the current beach crest. When the spit platform reached Banks Peninsula sediment began to travel

around Devils Knob into the embayment of Lake Forsyth. The effect of this was to create a shallow embayment which was exposed to the southerly swells.

After the spit beach reached Banks Peninsula the Ellesmere/Waihora estuary was replaced by Lake Ellesmere/Waihora. Immediately after the closure the remaining Gilbert-type delta platform still modified the wave climate consequently the first barrier beach ridges developed in the McIntosh area, had much lower beach crests than those of the open beach. With the migration of the beach to the edge of the Gilbert-type delta platform, the amount of wave energy transferred to the beach increased, and a change in beach form and a rise in beach crest elevation took place.

5.2.2 Formation of Barrier Beach and Lake

If not before then, very soon after the closure of Ellesmere/Waihora estuary a large river (probably the Waimakariri) flowed into the basin. The river rapidly increased the lake level. As the lake reached the limit of the enclosing marine barrier beach, a breach occurred near Ponds and Bayleys Ridges.

The initial breach may have been quite large but the longshore drift and the lake outflow soon reached a dynamic equilibrium. When equilibrium conditions had been reached, a lagoon, similar to the lagoons that currently develop at the Rakaia River mouth, developed as the longshore drift and southerly waves started building a washover barrier extending eastward across the outlet.

The outflow from the lake was strong enough to keep the lagoon open, and the large volume of water in the lake acted to modify the high and low flows of the river thereby maintaining a moderate, even flow. This even flow combined, with the high sediment supply and the strong longshore drift on the coast, led to the development of a very long (c. 12 km) lagoon system running parallel to the coast and protected from the sea by a washover barrier. It is evident that some environmental change occurred leading to a reduction in flow along this lagoon, consequently strong southerly waves combined with the high sediment supply filled the lagoon channel with washover barrier deposits.

The continued sediment supply led to further southward beachface progradation. A relatively short time later a second breach was developed and another long thin coastal lagoon was formed. Again the lagoon channel was eventually filled with washover deposits and the marine beachface began

prograding to the south. After this second lagoon system development the beach face continued to prograde to the south, apparently uninterrupted by further lacustrine breaching.

Further east low elevation beach ridges formed in the shallow Forsyth/Wairewa estuary. The combined effects of wave refraction on the basalt headlands and wave attenuation on the shallow bay bottom led to the development of a series of southward-prograding, low elevation, gravel, barrier-beach ridges. After the closing of the Ellesmere/Waihora estuary an increase in the amount of sediment supplied to the beach led to the rapid southward progradation. Again as the beach face reached the edge of the shallow embayment (approximately in line with Devils Knob) there was an increase in wave energy reaching the beach and consequently a rise in the elevation of the beach crest.

When the beach closed off the Forsyth/Wairewa estuary and Lake Forsyth/Wairewa developed. As the lake rose breaching of the beach ridges at the base of the basalt cliffs on the southern shore of Lake Forsyth occurred. The result of this is the cliff which is cut into the eastern ends of the marine barrier beaches.

With continued longshore drift the western shoreline began to be eroded and a thinning in the barrier complex occurred. The beach at the eastern end of the complex continued to prograde towards the south.

5.2.3 Development of Lake Ellesmere/Waihora

When the spit had reached the Devils Knob the estuary became enclosed. A lake formed in the estuary basin and breaching occurred as evidenced by the overwash barriers infilling the lagoon channels. The beach face deposits preserved in the Island area indicate that this plateau escaped being flattened and remained as an island in the rising lake.

On Lake Ellesmere the breaching episodes had left several high points in the lake, which broke up the smooth shoreline. The largest of these (the Island plateau) formed a peninsula into the lake. The northern slopes of both the marine washover barriers formed part of the higher Lake Ellesmere's southern shore. As a result lake-edge ridge development occurs on top of these washover barrier deposits for most of the length of Speight Ridge.

As the lake level rose the winds acting on the lake water formed longshore currents. These longshore currents began to both erode and transport sediment along the southern shore of the lake. This rising lake eroded the top of the more westerly marine barrier beaches leaving a local transgressive erosion surface. As the lake deepened enough, this erosion surface became below fair-weather wave base and fine sediment was deposited over the eroded marine barrier beach gravels.

During northeasterly winds, waves developed on the lake refracted around the western end of the Island projection, and began to form southwest trending spits. As the spits reached the southern lake shore, ridges began to develop on the lakeward side of the spit beaches. Continued development of the ridges led to the development of a lake-beach ridge plain (Bayleys Ridges). West of the Bayleys Ridges further lacustrine spit development took place in the Ponds area.

Northwest winds developed eastward longshore wave currents, and spit development began at both the Trig Point Ridges and the Golf Course Ridges. The continued supply of sediment to the east, led to the Railway Cutting Ridges being developed. When the Railway Cutting Ridges had formed a beach ridge plain that extended the beachface around the end of the volcanic spur, gravel was transported into Birdlings Valley along the southern gravel beach. The continued supply of gravel led to the development of the Birdlings Valley Ridges.

As the lake level rose slightly higher sand dunes, which had developed on top of the marine beach ridges, began to be eroded by the lake, with the sand and gravel transported south to the Taumutu Ridges.

The lake reached a level where lake ridges achieved up to c. 8 m crest elevations. At this time a continuous ridge extended from the Dune Ridge area to the Taumutu Ridges, and there were marine barrier ridge deposits formed between this lake-edge ridge and the coast. The lake gradually rose in level, as indicated by the last formed ridges being the highest in Bayleys Ridges, Ponds, Island and Birdlings ridges areas.

The continued longshore erosion of the coast and the lacustrine erosion of the coastal dunes eventually led to a breach developing at the Taumutu end of the lake shore. The large head of water in the lake resulted in a c. 3 km wide breach. This breach removing sections of the coastal dunes, marine beach

deposits and the lake–edge ridges. This breach also formed the cliff which truncates the southeastern ends of the Taumutu Ridges. The timing of this breach can be given a maximum age, using the age of the youngest freshwater mussels found beneath the high lake–edge ridges of Birdlings Valley. The shell in question puts the breach at Taumutu sometime after 561 ± 57 years B.P. The outlet developed by this breaching took a significant time to close off and during this time estuarine development took place in the lake basin, with shell beds forming near the opening.

After this breach occurred a barrier formed between Taumutu and Kaitorete Spit. The barrier which initially filled the breach site was developed long enough to have sand dunes develop along the crest and to have pingao colonise these dunes. The continued erosion of the coast west of Taumutu led to the initial barrier being thinned. A lacustrine breach which removed the western half of this initial barrier is probably the c. 1829 breach that Andersen (1927) records. After this second breach the barrier that developed has not had any sand dune development nor any pingao colonisation, but has begun to move landward towards Taumutu. The crest elevation of the washover barrier put an upper limit to the lake level of c. 4 m.

Subsequently lake–edge ridge development was restricted to developing ridges along the base of the old, much higher lake edge ridges. Associated with this lower lake level of c. 4 m, the fine ‘deep’ lake bottom silty clay deposits, became reworked by the waves developed on Lake Ellesmere, resulting in the poorly sorted muddy gravels which occur beneath the gently lakeward sloping surface. Waves on this c. 4 m lake, also developed the elongated horn and cusp like ridges, found on the gently sloping surface.

When the Maori settled at Taumutu the necessity to keep the lake level below ~2.9 m led to the development of further lake–edge ridges close to this new controlled lake level. The European control of the lake has led to the development of new geomorphic changes including the erosion of the lakeshore in various places, such as the mud bank at the western end of Kaitorete Spit.

6. Acknowledgements

My wife Lyn for her help, love, support and patience during the last few years. Hazel and Sam for their love and distraction during their entire lifetime(s).

Mum and Dad for your support, encouragement and patience during the last few years and especially the last few weeks (Oh! and the proof reading).

Ian and Pam Carmichael for looking after the Hazel and Sam (and Lyn) when their distractions became too much, and for the support given during the past few years.

Thanks to Alistair Ritchie who put up with me and the machine that goes beeeeeep!!!! for far too many hours in one lifetime.

Thank you to Hamish Kellahan who has helped in innumerable ways.

Thank you to Mark Harvey for the interesting discussions on the development of Kaitorete Spit and the freely given help in the field.

Thanks to Adriaan Bal who suggested the topic of study (a big thanks from Lyn).

Thank you to Aaron Chapple for your help and contributions and Kane Inwood for your help.

Doug Lewis and David Nobes for the supervision they provided.

Thank you to the technical staff of the Geology Department especially Michelle Wright who patiently surveyed vast tracts of Kaitorete Spit. Arthur Nicol who help make the sledge and provide various other help. Thank you to Kerry Swanson for the photographs and helpful advice.

Thank you to Colin Mckay of the Zoology Department and Mark James of NIWA for the various shell identifications.

Thank you to the staff of the Canterbury Regional Council for providing me access to all sorts of material.

Thank you to Chris Jacomb at the Canterbury Museum for access to various material.

Thank you to Jane Soons for the aerial photographs and the discussions.

Thank you to Maree Hemmingsen for the help with the field work.

Thank you to Bob Kirk for the interesting field trip out to Kaitorete Spit and beyond.

Thanks to the Geography Department for providing access to their aerial photographs.

A big thanks to the farmers who allowed me access to their land (without whom the radar would have never got on the ground), especially: the Lewthwaites; the Birdlings; the Bayleys; the Hephannans; the Caleys; the Paveys; and the Macintoshs. Thanks to Selwyn District Council and Banks Peninsula District Council for allowing me access to their land .

7. References

- Andersen, J.C. 1927. Place-names of Banks Peninsula : a topographical history. Government Printer, Wellington. Reprint 1976, Capper Press, Christchurch, New Zealand.
- Annan, A.P. and S.W. Cosway 1992. Ground penetrating radar survey design: Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP) R.S. Bell (ed.), Vol. 2, 329–351.
- Armon, J.W. 1970. Recent shoreline changes in the North Canterbury Bight. Unpublished MA thesis in Geography. University of Canterbury, Christchurch.
- Armon, J.W. 1974a. Radiocarbon age for freshwater mussel shells from Taumutu, Lake Ellesmere, New Zealand (note). *N.Z. Journal of Marine and Freshwater Research* 8. 229–232.
- Armon, J.W. 1974b. Quaternary shorelines near Lake Ellesmere, Canterbury, New Zealand. *New Zealand Journal of Geology and Geophysics* 29 : 174–184.
- Atkinson, C. 1994. Waihora/Lake Ellesmere: a local Maori view. In Davies, J.D.G., L. Galloway and A.H.C. Nutt (eds.), 1994. *Waihora/Lake Ellesmere: Past, present future*. 21–25. Lincoln University Press and Daphne Brasell Associates Ltd, Lincoln University, Canterbury.
- Basher, L.R.; D.M. Hicks; M.J. McSaveney and I.E. Whitehouse 1988. The lower Waimakariri River floodplain: a geomorphological perspective: Soil Conservation Group Report, Ministry of Works and Development, Christchurch, New Zealand 33p.
- Boggs, S., Jr. 1987. Principles of sedimentology and stratigraphy. Merrill Publishing Company. A Bell and Howell Company. Columbus, Ohio.
- Brown, L.J.; Wilson, D.D. 1988. Stratigraphy of late Quaternary deposits of the northern Canterbury Plains. *New Zealand Journal of Geology and Geophysics* 31, 305–335.
- Carter, R.W.G. and J.D. Orford 1984. Coarse clastic barrier beaches: a discussion of the distinctive dynamic and morphosedimentary characteristics. *Marine Geology* 60. 377–389.
- Clifton, H.E. 1969. Beach lamination: nature and origin. *Marine Geology* 7. 553–559.
- Crawford, S.J., G.A. Griffiths and G.A. Horrell 1996. Chapter Seven: Surface Water Hydrology. . In Taylor (ed.), 1996. *The Natural Resources of Lake Ellesmere (Te Waihora) and its Catchment*. 85–104. Canterbury Regional Council Report 96/7.

- Evans, O.F. 1942. The origin of spits, bars, and related structures. In M.L. Schwartz (ed.), 1972. *Spits and Bars*. 53–72. Dowden, Hutchinson and Ross, Stroudsburg, P.A.
- Evison, H. 1994. Early Maori history. In Davies, J.D.G., L. Galloway and A.H.C. Nutt (eds.), 1994. *Waihora/Lake Ellesmere: Past, present, future*. 21–25. Lincoln University Press and Daphne Brasell Associates Ltd, Lincoln University, Canterbury.
- Gibb, J.G. 1986. A New Zealand regional Holocene eustatic sea-level curve and its application to determination of vertical tectonic movements. A contribution to IGCP-Project 200. *Royal Society of New Zealand, Bulletin 24* : 377–395.
- Gibb, J.G.; Adams, J. 1982. A sediment budget for the east coast between Oamaru and Banks Peninsula, South Island, New Zealand. *New Zealand Journal of Geology and Geophysics 25* : 335–352.
- Glennie, J.M. and K.J.W. Taylor 1996. Chapter Two: Catchment Location, Development and Population. In Taylor (ed.), 1996. *The Natural Resources of Lake Ellesmere (Te Waihora) and its Catchment*. 5–14. Canterbury Regional Council Report 96/7.
- Grimmond, N.M. 1968. Observations on growth and age in *Hyridella menziesi* (Mollusca: Bivalvia) in a freshwater tidal lake. Unpublished MSc thesis in Zoology, University of Otago.
- Harvey, M. 1996. A paleolimnological study of Lake Ellesmere (Te Waihora), South Island, New Zealand. Unpublished MSc thesis in Environmental Science, University of Canterbury, Christchurch.
- Horrell, G.A. 1992. Lake Ellesmere water balance model: Variable analysis and evaluation. Unpublished M.Eng.Sci. thesis in Civil Engineering, University of New South Wales, Sydney.
- Huggenburger, P. 1993. Radar facies: recognition of facies patterns and heterogeneties within Pleistocene Rhine gravels, NE Switzerland. In Best, J.L. and C.S. Bristow (eds.), 1993. *Braided Rivers*. Geological Society Special Publication No. 75. 163–176.
- Jacomb, C. 1994. The archaeology of Waihora/Lake Ellesmere. In Davies, J.D.G., L. Galloway and A.H.C. Nutt (eds.), 1994. *Waihora/Lake Ellesmere: Past, present, future*. 21–25. Lincoln University Press and Daphne Brasell Associates Ltd, Lincoln University, Canterbury.
- Johnson, D.W. 1919, Shore processes and shoreline development. John Wiley and Sons. New York.
- Jol, H.M. and D.G. Smith 1991. Ground penetrating radar of northern lacustrine deltas. *Canadian Journal of Earth Science 28*. 1939–1947.
- Kirk, R. M. 1969. Beach erosion and coastal development in the Canterbury Bight. *New Zealand Geographer 25* : 23–35.
- Kirk, R.M. 1983. Rakaia River mouth lagoon system and adjacent coast. In : Bowden, M.J.; Ayrey, R.B.; Lineham, I.W.; Duffield, D.N.; Saville-Smith, K.; Mason, R.R.; Talbot, J.D.; Weeber, J.H.; Glennie, J.M.;

- Moore, K.; Kirk, R.M.; Cowie, B.; Miskell, D.J. 1983. *Rakaia River and Catchment – A Resource Study. Volume 2*: 67–101. North Canterbury Catchment Board, Christchurch.
- Kumar, N. and J.E. Sanders 1974. Inlet sequence: a vertical succession of sedimentary structures and textures created by the lateral migration of tidal inlets. *Sedimentology* 21. 491–532.
- Leckie, D. A. 1994. Canterbury Plains, New Zealand–Implications for sequence stratigraphic models. *American Association of Petroleum Geologists Bulletin* 78 : 1240–1256.
- Mason, C.R., S.H. Larsen and J.H. Weeber 1996. Chapter Three: Physical Description of the Catchment. . In Taylor (ed.), 1996. *The Natural Resources of Lake Ellesmere (Te Waihora) and its Catchment*. 15–42. Canterbury Regional Council Report 96/7.
- Massari, F. and G.C. Parea 1988. Progradational gravel beach sequences in a moderate– to high–energy, microtidal marine environment. *Sedimentology* 35. 881–913.
- Meistrell, F.J. 1966. The spit–platform concept: laboratory observation of spit development. In M.L. Schwartz (ed.), 1972. *Spits and Bars*. 225–283. Dowden, Hutchinson and Ross, Stroudsburg, P.A.
- Mitchum, R.M., Jr.,; P.R. Vail and J.B. Sangree, 1977. Stratigraphic interpretation of seismic reflection patterns in depositional sequences. In C.E. Payton (ed.), *Seismic stratigraphy–application to hydrocarbon exploration*: American Association of Petroleum Geologists Memoir 26. 117–133.
- Moore, C.R. and J.H. Weeber 1996. Chapter Six: Groundwater. . In Taylor (ed.), 1996. *The Natural Resources of Lake Ellesmere (Te Waihora) and its Catchment*. 65–84. Canterbury Regional Council Report 96/7.
- Reid, R.E. and R.G. Holmes 1996. Chapter Five: Lake Level Control, Flood Hazard Management, and Drainage. . In Taylor (ed.), 1996. *The Natural Resources of Lake Ellesmere (Te Waihora) and its Catchment*. 51–64. Canterbury Regional Council Report 96/7.
- Ryan, A.P. 1987. The climate and weather of Canterbury. *New Zealand Meteorological Service Miscellaneous Publication* 115(17). Ministry of Transport, Wellington.
- Sewell, R.J.; Weaver, S.D.; Reay, M.B. 1992. Geology of Banks Peninsula. *Institute of Geological and Nuclear Sciences Map* 3. 1:100,000. Institute of Geological and Nuclear Sciences Ltd, Lower Hutt.
- Sheriff, R.E. 1984. Encyclopedic dictionary of exploration geophysics. 2nd edition. Society of Exploration Geophysics, Tulsa, OK.
- Sherman, D.J.; J.D. Orford and R.W.G. Carter 1993. Development of cusp–related, gravel size and shape facies at Malin Head, Ireland. *Sedimentology* 40. 1139–1152.

- Soons, J.M.; Shulmeister, J.; Holt, S. 1997. The Holocene evolution of a well nourished gravelly barrier and lagoon complex, Kaitorete Spit, Canterbury, New Zealand. *Marine Geology* 138 : 69–90.
- Speight, R. 1911. Preliminary account of the geological features of the Christchurch artesian area. *Transactions of the New Zealand Institute* 43 : 420–436.
- Speight, R. 1930. The Lake Ellesmere spit. *Transactions of the Royal Society of New Zealand* 61 : 147–169.
- Speight, R. 1950. An eroded coastline. *Transactions of the Royal Society of New Zealand* 78 : 3–13.
- Straubel, C.R. 1957. Maori and European to 1850, In Hight, J. and Straubel, C. R. (Eds.), *A History of Canterbury, Vol. I: to 1854*. Whitcombe and Tombs Ltd.
- Suggate, R.P. 1968. Postglacial sea level rise in Christchurch, New Zealand. *Geologie Mijnbouw* 47. 291–297.
- Suggate, R.P. 1990. Late Pliocene and Quaternary glaciations of New Zealand. *Quaternary Science Reviews* 9. 175–197.
- Thompson, W.O. 1937. Original structures of beaches, bars, and dunes. *Bulletin of the Geological Society of America* 48. 723–752.
- Trabant, P.K. 1984. Applied high-resolution geophysical methods. International Human Resources Development Corp., Boston.
- Wilson, D.D. 1988. Quaternary geology of the northwestern Canterbury Plains (Sheet L35 and parts sheets L36, M35, & M36) 1:100,000. *New Zealand Geological Survey Miscellaneous Series*, Map 14. Map (1 sheet) and notes. Wellington, New Zealand. Department of Scientific and Industrial Research.
- Wright, L.D. and A.D. Short 1984. Morphodynamic variability of surf zones and beaches: a synthesis. *Marine Geology* 56. 91–118.

Appendix A Survey Data

The following pages contain the survey data for all the radar survey lines on Kaitorete Spit.

The elevation corrections have been made off the following Canterbury Regional Council coastal benchmarks :

- ECE 3560
- ECE 2995
- ECE 2515
- ECE 1980
- ECE 1620
- ECE 1320

The accuracy of the survey data is ± 0.1 m.

Birdlings Ridges

Point ID	Easting	Northing	Elevation	pegs	Line Name & Comments
BR1	2485229.161	5712391.481	8.000	stn	
BR2	2485204.815	5712377.390	3.884	backsite	
BR3	2485204.794	5712377.382	3.879	peg	
BR4	2485210.474	5712379.109	4.631		
BR5	2485216.964	5712381.750	5.888		
BR6	2485223.085	5712384.338	6.966		
BR7	2485229.140	5712387.253	7.791		
BR8	2485235.676	5712389.616	7.967		
BR9	2485242.318	5712392.344	7.513		
BR10	2485249.354	5712394.932	6.944		
BR11	2485256.506	5712397.454	6.597		
BR12	2485258.197	5712398.588	6.696		
BR13	2485262.623	5712400.024	6.415		
BR14	2485266.729	5712401.587	6.365		
BR15	2485270.671	5712403.633	5.805		
BR16	2485276.449	5712405.543	4.988		
BR17	2485282.138	5712407.834	5.226		
BR18	2485286.911	5712409.382	6.034		
BR19	2485289.777	5712410.562	6.065		
BR20	2485291.715	5712411.201	6.307		
BR21	2485297.375	5712413.743	5.965		
BR22	2485303.317	5712416.333	5.897		
BR23	2485307.063	5712417.619	6.339		
BR24	2485312.056	5712419.744	6.605		
BR25	2485317.787	5712421.950	6.622		
BR26	2485320.739	5712423.147	6.277		
BR27	2485325.000	5712425.000	6.266	peg	

Transgressive Barrier

Point ID	Easting	Northing	Elevation	pegs	Line Name & Comments
TB1	2461800.338	5705824.705	7.430	stn	
TB2	2461918.963	5705898.829	2.470	well	
TB3	2461772.200	5705944.550	1.937	peg	
TB4	2461773.993	5705936.115	2.327		
TB5	2461774.548	5705930.321	2.554		
TB6	2461774.523	5705929.809	2.723		
TB7	2461774.831	5705922.455	2.909		
TB8	2461774.864	5705913.376	3.148		
TB9	2461775.103	5705903.415	3.534		
TB10	2461775.630	5705895.126	3.756		
TB11	2461776.517	5705885.677	4.005		
TB12	2461777.558	5705876.535	4.287		
TB13	2461778.045	5705866.453	4.572		
TB14	2461779.057	5705856.179	4.828		
TB15	2461780.485	5705845.051	5.159		
TB16	2461781.546	5705835.575	5.398		
TB17	2461782.785	5705825.618	5.717		
TB18	2461783.552	5705819.435	5.843		
TB19	2461784.212	5705814.196	6.023		
TB20	2461784.721	5705809.689	6.133		
TB21	2461785.193	5705805.074	6.192		
TB22	2461785.543	5705801.770	6.059		
TB23	2461786.282	5705797.754	5.795		
TB24	2461786.565	5705795.563	5.619	peg	
TB26	2461794.549	5705772.231	4.292		
TB25	2461795.391	5705744.652	2.483	surf	

Dune Ridge

DR53	2462902.640	5706193.338	8.064	spot ht	
DR54	2462915.389	5706192.606	8.099	spot ht	heights
DR55	2462931.348	5706189.448	8.132	spot ht	<---

Dune Ridge

Point ID	Eastings	Northing	Elevation	pegs	Line Name & Comments
DR1	2462671.545	5706194.959	12.403	stn	elevation
DR2	2462638.764	5706185.559	8.017	backsite	corrected
DR3	2462638.745	5706185.499	7.987	interdune lakeridge	
DR4	2462640.339	5706171.718	6.600	base of blowout	
DR5	2462638.526	5706153.953	6.540	base of blowout	
DR6	2462680.537	5706190.398	10.592	peg	<--
DR7	2462682.319	5706192.938	10.325		
DR8	2462683.633	5706194.253	9.873		
DR9	2462685.066	5706196.640	9.328		
DR10	2462686.212	5706198.117	9.091		
DR11	2462687.467	5706199.583	8.970		
DR12	2462688.471	5706201.077	8.523		
DR13	2462690.424	5706204.120	8.228		duneridw
DR14	2462692.231	5706206.902	7.861		
DR15	2462692.926	5706207.961	7.683		
DR16	2462693.186	5706208.526	7.528		
DR17	2462693.499	5706209.079	7.464		
DR18	2462693.687	5706209.439	7.353		
DR19	2462695.974	5706212.728	6.855		
DR20	2462698.590	5706216.721	6.370		
DR21	2462700.735	5706219.853	6.205		
DR22	2462701.770	5706221.350	6.180	peg	<--
DR23	2462701.508	5706217.309	6.381		
DR24	2462701.238	5706215.130	6.656		
DR25	2462701.310	5706213.790	6.969		
DR26	2462701.406	5706212.871	7.112		
DR27	2462701.471	5706212.153	7.408		
DR28	2462701.109	5706208.652	8.302		
DR29	2462701.015	5706205.822	9.241		
DR30	2462700.825	5706203.843	10.100		
DR31	2462700.535	5706200.194	11.304		
DR32	2462700.427	5706198.608	11.699		
DR33	2462700.029	5706195.703	11.671		duneride
DR34	2462699.252	5706192.723	11.372		
DR35	2462698.885	5706191.130	11.192		
DR36	2462698.275	5706188.534	11.384		
DR37	2462697.412	5706184.683	11.161		
DR38	2462697.403	5706184.152	10.969		
DR39	2462696.935	5706182.138	10.613		
DR40	2462696.265	5706179.536	10.260		
DR41	2462695.851	5706177.866	9.954		
DR42	2462695.420	5706175.929	9.906		
DR43	2462695.216	5706174.651	9.962	peg	<--
DR44	2462754.886	5706175.950	9.485	spot ht	<---
DR45	2462761.043	5706174.987	9.246	spot ht	lake
DR46	2462807.491	5706204.020	6.921	spot ht	
DR47	2462827.680	5706204.797	7.013	spot ht	
DR48	2462840.358	5706203.295	7.247	spot ht	ridge
DR49	2462855.373	5706202.244	7.393	spot ht	
DR50	2462870.552	5706201.146	7.626	spot ht	
DR51	2462872.017	5706192.344	8.287	spot ht	spot
DR52	2462885.582	5706193.975	8.206	spot ht	

Ponds

PD159	2465370.567	5707245.506	3.247		
PD160	2465366.326	5707242.061	3.262	peg4	<--
PD161	2465357.422	5707351.436	4.499	peg1	<--
PD162	2465358.709	5707346.801	4.589		
PD163	2465360.106	5707341.634	4.778		
PD164	2465361.318	5707336.753	4.968		
PD165	2465362.794	5707331.710	5.073		
PD166	2465364.128	5707326.903	5.278		
PD167	2465365.577	5707322.124	5.415		
PD168	2465367.084	5707317.271	5.628		
PD169	2465368.369	5707312.537	5.784		
PD170	2465369.527	5707307.788	6.012		pondssn
PD171	2465370.942	5707302.945	6.259		
PD172	2465372.135	5707298.419	6.474		
PD173	2465373.504	5707294.780	6.106		
PD174	2465374.460	5707291.735	5.530		
PD175	2465375.149	5707289.145	4.957		
PD176	2465375.931	5707286.179	4.084		
PD177	2465377.116	5707282.739	3.147		
PD178	2465378.918	5707276.532	2.991		
PD179	2465380.689	5707270.275	3.078		
PD180	2465382.781	5707263.400	3.050		
PD181	2465385.670	5707256.266	3.135	peg2	<--

Ponds

PD106	2465563.102	5707358.844	4.982		
PD107	2465559.664	5707357.613	4.952		
PD108	2465555.948	5707356.134	4.875		
PD109	2465552.567	5707354.860	4.725		
PD110	2465548.816	5707353.465	4.532		
PD111	2465545.421	5707352.145	4.170		
PD112	2465541.980	5707350.626	4.082		
PD113	2465538.194	5707349.293	4.653		
PD114	2465534.702	5707347.829	5.135		
PD115	2465531.074	5707346.424	5.504		
PD116	2465527.456	5707344.544	5.613		
PD117	2465523.661	5707342.675	5.657		
PD118	2465519.822	5707340.751	5.704		
PD119	2465516.918	5707339.158	5.635	peg2	<-
PD120	2465513.174	5707337.101	5.857		
PD121	2465509.512	5707335.057	5.909		
PD122	2465505.680	5707332.881	5.936		
PD123	2465502.120	5707331.039	5.934		
PD124	2465498.419	5707328.893	5.943		
PD125	2465494.860	5707326.725	5.942		
PD126	2465491.278	5707324.599	5.989		
PD127	2465487.710	5707322.529	5.951		
PD128	2465484.362	5707320.552	5.854		
PD129	2465480.873	5707318.716	5.839		pondswe
PD130	2465477.410	5707316.706	5.702		
PD131	2465473.978	5707314.726	5.711		
PD132	2465470.500	5707312.707	5.786		
PD133	2465466.975	5707310.655	5.891		
PD134	2465463.534	5707308.548	5.772		
PD135	2465459.972	5707306.326	5.645		
PD136	2465455.823	5707303.954	5.627		
PD137	2465452.263	5707301.721	5.675		
PD138	2465448.784	5707299.689	5.694		
PD139	2465445.112	5707297.437	5.717		
PD140	2465440.601	5707294.861	5.984		
PD141	2465437.144	5707292.718	5.901		
PD142	2465433.418	5707290.194	5.912		
PD143	2465430.858	5707288.485	6.099	peg3	<-
PD144	2465427.400	5707286.165	6.043		
PD145	2465424.242	5707283.839	5.709		
PD146	2465421.409	5707281.841	5.513		
PD147	2465418.771	5707279.941	5.314		
PD148	2465416.121	5707277.801	4.955		
PD149	2465413.217	5707275.764	4.316		
PD150	2465410.084	5707273.481	3.485		
PD151	2465406.633	5707271.185	3.256		
PD152	2465402.650	5707268.156	3.095		
PD153	2465398.979	5707265.669	3.098		
PD154	2465395.380	5707263.147	3.109		
PD155	2465391.729	5707260.525	3.081		
PD156	2465388.125	5707257.719	3.123		
PD157	2465382.065	5707253.404	3.151		
PD158	2465376.027	5707249.345	3.197		

Ponds

PD53	2465608.551	5707195.689	4.431		
PD54	2465609.275	5707191.800	4.818		
PD55	2465610.277	5707187.661	5.367		
PD56	2465611.479	5707182.598	5.660		
PD57	2465612.658	5707176.728	5.523		
PD58	2465613.482	5707171.705	5.277		
PD59	2465615.013	5707166.687	5.233	peg4	<--
PD60	2465616.909	5707162.523	5.297		
PD61	2465617.890	5707160.242	5.517		
PD62	2465618.696	5707158.210	5.804		
PD63	2465619.188	5707157.166	6.193		
PD64	2465619.804	5707155.363	6.721		
PD65	2465620.235	5707153.765	6.998		
PD66	2465621.105	5707151.601	7.240		
PD67	2465622.396	5707149.530	7.501		
PD68	2465623.495	5707147.240	7.461		
PD69	2465625.072	5707143.609	7.372		
PD70	2465628.469	5707138.397	7.096		
PD71	2465632.015	5707132.839	6.810		
PD72	2465635.075	5707126.915	6.635		
PD73	2465638.336	5707122.227	6.599		
PD74	2465640.727	5707118.315	6.720		
PD75	2465643.379	5707114.475	6.794		
PD76	2465646.418	5707108.925	6.796		
PD77	2465648.656	5707102.171	6.691		
PD78	2465651.575	5707096.075	6.573		
PD79	2465654.331	5707090.363	6.344		
PD80	2465657.492	5707084.241	6.047		
PD81	2465660.688	5707078.277	5.948	peg5	<--
PD82	2465605.155	5707313.611	2.925	peg1	<--
PD83	2465596.031	5707310.376	2.898		
PD84	2465585.133	5707306.630	2.891		
PD85	2465575.406	5707303.320	2.937		
PD86	2465564.620	5707299.562	2.990		
PD87	2465556.507	5707296.789	3.245		
PD88	2465551.449	5707295.221	3.112		pondsew
PD89	2465548.352	5707294.057	4.058		
PD90	2465544.477	5707292.754	5.094		
PD91	2465540.237	5707291.518	5.014		
PD92	2465535.196	5707289.605	4.781		
PD93	2465530.134	5707288.425	4.416		
PD94	2465526.182	5707287.957	4.127		
PD95	2465521.735	5707286.714	3.354		
PD96	2465517.163	5707285.796	3.082		
PD97	2465513.286	5707284.761	2.993	peg2	<--
PD98	2465609.454	5707376.426	5.418	peg1	<--
PD99	2465602.514	5707373.477	5.328		
PD100	2465590.861	5707368.902	5.075		
PD101	2465582.752	5707365.887	5.033		
PD102	2465578.603	5707364.720	4.973		
PD103	2465574.549	5707363.128	5.014		
PD104	2465570.635	5707361.584	5.001		
PD105	2465566.947	5707360.122	5.005		

Ponds

Point ID	Easting	Northing	Elevation	pegs	Line Name & Comments
PD1	2465607.182	5707149.885	7.458	stn1	elevation
PD2	2465410.785	5707309.363	6.993	stn2	corrected
PD3	2465615.101	5707166.868	5.217		backsite on peg 4 pondsns
PD4	2465572.452	5707361.371	4.983		backsite on peg 2 pondsns
PD5	2465553.000	5707459.000	3.803	peg1	<--
PD6	2465553.495	5707455.841	3.900		
PD7	2465554.404	5707451.148	4.178		
PD8	2465555.476	5707446.200	4.582		
PD9	2465556.751	5707440.762	5.060		
PD10	2465557.488	5707436.826	4.913		
PD11	2465559.319	5707427.598	5.073		
PD12	2465561.120	5707418.246	5.679		
PD13	2465563.180	5707408.389	5.844		
PD14	2465564.919	5707399.839	6.066		
PD15	2465566.475	5707391.328	6.242		
PD16	2465567.394	5707384.812	6.455		
PD17	2465568.613	5707379.923	6.012		
PD18	2465569.310	5707376.821	5.254		
PD19	2465570.060	5707372.898	5.153		
PD20	2465570.442	5707370.986	4.907		
PD21	2465571.124	5707367.872	4.937		
PD22	2465572.452	5707361.371	4.983	peg2	<-
PD23	2465573.268	5707357.438	5.025		
PD24	2465574.943	5707351.674	5.007		
PD25	2465576.860	5707343.814	4.895		
PD26	2465578.027	5707338.698	4.575		
PD27	2465578.736	5707335.504	3.902		
PD28	2465579.583	5707331.407	3.175		
PD29	2465580.190	5707328.582	2.840		
PD30	2465580.735	5707325.664	2.794		
PD31	2465582.315	5707318.097	2.827		
PD32	2465583.918	5707311.037	2.887		
PD33	2465585.090	5707304.587	2.937		
PD34	2465586.468	5707297.586	3.104		
PD35	2465587.156	5707293.752	3.563		
PD36	2465587.987	5707289.948	3.762		
PD37	2465588.634	5707286.984	4.014		
PD38	2465589.976	5707279.526	4.238		
PD39	2465592.119	5707270.916	4.330		
PD40	2465593.191	5707263.845	4.461	peg3	<-
PD41	2465594.545	5707259.428	4.911		
PD42	2465595.759	5707254.576	5.450		
PD43	2465596.499	5707251.147	5.815		
PD44	2465597.476	5707245.533	5.863		
PD45	2465598.844	5707239.482	5.010		
PD46	2465600.010	5707235.385	4.412		
PD47	2465600.753	5707232.212	3.808		
PD48	2465601.169	5707229.578	3.738		
PD49	2465602.252	5707223.121	3.797		
PD50	2465603.962	5707216.198	3.955		
PD51	2465605.861	5707208.781	3.997		
PD52	2465607.372	5707201.824	4.236		

Island

IS106	2467982.880	5707909.729	5.786		
IS107	2467979.611	5707910.407	5.830		
IS108	2467974.400	5707912.627	5.609		
IS109	2467970.963	5707914.083	5.295		
IS110	2467965.034	5707916.125	4.991		
IS111	2467958.410	5707918.382	4.638	peg	<--

Island

IS53	2468305.732	5707843.863	2.047		
IS54	2468307.306	5707838.346	2.249		
IS55	2468306.592	5707835.833	2.292		
IS56	2468307.951	5707830.792	2.480		
IS57	2468308.897	5707823.300	2.925		
IS58	2468310.239	5707816.499	3.316		
IS59	2468311.529	5707809.161	3.538		
IS60	2468312.332	5707802.018	3.663		
IS61	2468313.152	5707795.328	4.022		
IS62	2468313.708	5707788.198	4.453	peg5	
IS63	2468314.481	5707780.623	4.750		
IS64	2468314.990	5707778.049	4.800		
IS65	2468315.885	5707770.811	5.194		
IS66	2468316.401	5707766.388	5.360		
IS67	2468317.140	5707759.777	5.444		
IS68	2468317.475	5707757.169	5.400		
IS69	2468318.604	5707749.963	5.636		
IS70	2468319.043	5707743.028	5.719		
IS71	2468319.747	5707736.297	5.999		
IS72	2468320.473	5707729.709	6.113		
IS73	2468321.281	5707722.871	6.335		
IS74	2468322.189	5707716.237	6.445		
IS75	2468322.991	5707709.402	6.605		
IS76	2468323.665	5707702.500	6.706		
IS77	2468324.687	5707695.450	6.802		
IS78	2468325.327	5707688.548	6.888	peg6	<--
IS79	2468326.114	5707681.367	6.881	spot ht	
IS80	2468325.492	5707680.893	6.882	spot ht	
IS81	2468335.442	5707985.843	6.813	peg	<--
IS82	2468328.992	5707984.933	6.853		
IS83	2468318.682	5707983.303	6.806		
IS84	2468308.472	5707981.733	6.842		
IS85	2468298.562	5707979.953	6.854		
IS86	2468288.912	5707977.973	6.815	isldwe	
IS87	2468285.972	5707977.563	6.855		
IS88	2468278.652	5707976.503	6.848		
IS89	2468268.592	5707974.823	6.842		
IS90	2468258.742	5707972.943	6.793		
IS91	2468247.812	5707971.063	6.715		
IS92	2468236.892	5707969.133	6.621	peg	<--
IS93	2468052.328	5707885.268	5.802	peg	<--
IS94	2468050.046	5707886.313	5.823		
IS95	2468043.356	5707888.731	5.906		
IS96	2468036.557	5707891.079	6.224		
IS97	2468030.088	5707893.465	6.387		
IS98	2468023.694	5707895.767	6.322		
IS99	2468017.320	5707898.113	6.046		
IS100	2468012.824	5707899.726	5.477		
IS101	2468008.493	5707901.255	4.862	isldnwse	
IS102	2468003.757	5707903.049	4.481		
IS103	2467996.709	5707905.496	4.376		
IS104	2467989.822	5707908.025	4.368		
IS105	2467986.420	5707909.092	5.180		

Island

Point ID	Easting	Northing	Elevation	pegs	Line Name & Comments
IS1	2468064.092	5707992.593	7.341	bench mark	
IS2	2468051.983	5707646.043	6.791	backsite	elevation
IS3	2468033.538	5707643.320	6.766	backsite	corrected
IS4	2468282.000	5708184.000	2.857	peg1	<--
IS5	2468281.707	5708175.434	2.875		
IS6	2468281.162	5708168.049	2.926		
IS7	2468280.898	5708160.787	3.001		
IS8	2468280.458	5708153.376	3.089		
IS9	2468279.930	5708146.279	3.221		
IS10	2468279.211	5708139.107	3.274		
IS11	2468278.654	5708131.769	3.374		
IS12	2468278.311	5708124.344	3.520		
IS13	2468277.805	5708117.246	4.170		
IS14	2468277.617	5708112.955	4.772		
IS15	2468277.418	5708107.838	5.074		
IS16	2468276.785	5708100.094	5.050		
IS17	2468276.115	5708092.317	5.264		
IS18	2468275.772	5708084.534	5.564	peg2	
IS19	2468275.988	5708082.128	5.602		
IS20	2468276.114	5708074.286	5.655		
IS21	2468276.817	5708066.797	6.026		
IS22	2468277.277	5708059.565	6.410		
IS23	2468277.846	5708052.397	6.927		
IS24	2468278.490	5708045.507	7.176		
IS25	2468278.919	5708040.143	6.940		
IS26	2468279.812	5708035.101	5.860		
IS27	2468280.689	5708029.821	5.734		
IS28	2468281.676	5708022.076	5.851		
IS29	2468282.740	5708014.503	6.042		
IS30	2468283.658	5708007.342	6.212		
IS31	2468284.277	5708000.040	6.376		
IS32	2468285.352	5707992.838	6.712		
IS33	2468286.389	5707985.457	6.873	peg3	
IS34	2468285.895	5707977.950	6.853		
IS35	2468287.264	5707970.283	6.737		
IS36	2468288.200	5707962.956	6.381		
IS37	2468289.067	5707955.977	6.201		
IS38	2468289.907	5707949.117	6.123		
IS39	2468290.747	5707942.121	6.093		isldns
IS40	2468291.470	5707935.296	5.972		
IS41	2468292.271	5707928.473	5.961		
IS42	2468293.163	5707921.555	5.893		
IS43	2468293.901	5707914.294	5.573		
IS44	2468294.156	5707906.770	4.708		
IS45	2468295.690	5707899.472	3.976		
IS46	2468297.452	5707890.343	3.222		
IS47	2468297.752	5707886.943	2.842	peg4	
IS48	2468299.682	5707878.813	2.441		
IS49	2468301.462	5707868.803	2.006		
IS50	2468302.932	5707860.423	1.970		
IS51	2468304.562	5707851.833	1.907		
IS52	2468306.126	5707845.452	2.016		

Trig Point

BR53	2478664.299	5709934.015	1.249		
BR54	2478672.414	5709934.502	1.320		
BR55	2478680.806	5709934.409	1.338		
BR56	2478688.157	5709935.178	1.397		
BR57	2478691.561	5709935.671	1.878		
BR58	2478697.605	5709936.207	2.823		
BR59	2478703.993	5709935.794	3.686		
BR60	2478710.942	5709936.326	3.955	peg2	<--
BR61	2478688.750	5709752.768	5.813	spot ht	<--
BR62	2478614.963	5709808.332	6.240	spot ht	
BR63	2478713.414	5709830.791	6.166	spot ht	
BR64	2478687.037	5709828.717	6.287	spot ht	
BR65	2478716.452	5709838.383	6.130	spot ht	
BR66	2478718.293	5709950.420	4.231	spot ht	
BR67	2478660.197	5709949.770	3.994	spot ht	various
BR68	2478588.437	5709940.246	4.141	spot ht	spot
BR69	2478533.838	5709925.021	4.576	spot ht	heights
BR70	2478475.654	5709928.312	4.248	spot ht	
BR71	2478471.917	5709947.455	4.187	spot ht	
BR72	2478398.675	5709932.654	4.813	spot ht	
BR73	2478370.528	5709924.386	4.480	spot ht	
BR74	2478371.570	5709908.361	4.416	spot ht	
BR75	2478371.743	5709901.775	3.067	spot ht	
BR76	2478372.400	5709890.949	1.061	spot ht	<--

Trig Point

Point ID	Easting	Northing	Elevation	pegs	Line Name
BR1	2478705.124	5709828.570	6.242		stn1
BR2	2478388.924	5709743.429	6.274	trig point	stn2 on trig point
BR3	2478665.000	5710001.000	3.327	peg 1	<--
BR4	2478665.446	5709994.118	3.604		elevation
BR5	2478666.316	5709985.033	3.674		corrected
BR6	2478666.865	5709976.596	3.771		
BR7	2478667.178	5709968.140	3.800		
BR8	2478667.566	5709960.283	3.995		
BR9	2478667.976	5709955.909	3.652		
BR10	2478668.049	5709949.962	2.118		
BR11	2478668.177	5709945.125	1.128		
BR12	2478668.742	5709937.840	1.118		
BR13	2478669.083	5709930.813	1.420		
BR14	2478669.777	5709923.852	1.610		
BR15	2478669.889	5709922.028	1.551		
BR16	2478670.309	5709915.159	1.985		
BR17	2478670.550	5709909.224	2.199		
BR18	2478670.552	5709906.952	1.965		
BR19	2478670.631	5709905.191	1.599		
BR20	2478670.703	5709903.090	1.916		
BR21	2478670.879	5709901.526	2.258	peg 2	<-
BR22	2478671.318	5709898.635	2.609		
BR23	2478671.860	5709891.417	3.169		
BR24	2478674.344	5709884.766	3.359		breachns
BR25	2478675.077	5709878.837	3.225		
BR26	2478674.917	5709876.446	3.821		
BR27	2478674.756	5709868.043	4.129		
BR28	2478676.084	5709859.940	4.334		
BR29	2478677.061	5709851.447	4.705		
BR30	2478677.932	5709843.149	4.881		
BR31	2478678.302	5709835.748	5.094		
BR32	2478678.766	5709828.907	5.902		
BR33	2478679.444	5709825.753	6.246		
BR34	2478679.912	5709822.929	6.152		
BR35	2478680.359	5709818.978	5.803		
BR36	2478681.228	5709811.463	6.057		
BR37	2478681.842	5709805.894	6.283	peg 3	<-
BR38	2478682.361	5709798.041	6.337		
BR39	2478683.944	5709790.186	6.297		
BR40	2478684.229	5709781.988	6.309		
BR41	2478685.166	5709773.983	6.177		
BR42	2478687.288	5709766.455	5.976		
BR43	2478688.226	5709758.726	5.828		
BR44	2478688.750	5709752.768	5.813	peg 4	<--
BR45	2478611.833	5709930.887	1.237	peg1	<--
BR46	2478618.131	5709931.981	1.199		
BR47	2478623.802	5709933.667	2.476		
BR48	2478629.256	5709935.309	3.666		
BR49	2478636.163	5709935.086	4.131		
BR50	2478643.840	5709932.830	4.188		
BR51	2478650.146	5709933.122	2.943		
BR52	2478656.714	5709933.854	1.484		breachwe

Jones Pit

JP106	2484921.435	5710400.330	5.561		
JP107	2484922.995	5710391.858	5.710		
JP108	2484924.583	5710383.061	5.803		
JP109	2484926.081	5710375.448	6.023		
JP110	2484927.029	5710369.232	6.342		
JP111	2484928.070	5710361.148	7.056		
JP112	2484929.682	5710352.867	7.334		
JP113	2484931.096	5710344.973	7.697		
JP114	2484932.758	5710336.387	8.437		
JP115	2484934.016	5710327.899	8.885	peg2	jonespt2
JP116	2484934.723	5710324.023	8.949		
JP117	2484936.026	5710317.080	8.840		
JP118	2484937.248	5710309.047	8.523		
JP119	2484938.371	5710301.213	8.147		
JP120	2484939.649	5710293.387	7.721		
JP121	2484940.662	5710285.785	7.765		
JP122	2484941.938	5710277.533	8.054		
JP123	2484943.106	5710269.210	8.422		
JP124	2484944.451	5710260.616	8.626		
JP125	2484945.728	5710252.479	8.626		
JP126	2484946.673	5710245.129	8.716		
JP127	2484947.674	5710237.341	8.810		
JP128	2484948.544	5710229.095	8.886	peg3	<--

Jones Pit

JP53	2484754.287	5710787.435	3.827		
JP54	2484760.970	5710782.854	3.847		
JP55	2484767.921	5710777.890	3.664	peg4?	<-
JP56	2484774.922	5710772.857	3.808		
JP57	2484781.677	5710767.896	3.832		
JP58	2484787.994	5710762.873	3.882		
JP59	2484796.194	5710756.921	4.004		
JP60	2484802.835	5710752.107	4.020		
JP61	2484809.861	5710747.084	4.077		
JP62	2484816.576	5710742.230	4.131		
JP63	2484823.110	5710737.346	4.513		
JP64	2484829.444	5710732.380	4.675		
JP65	2484836.646	5710726.956	4.843		
JP66	2484843.975	5710721.520	4.989	peg5?	<-
JP67	2484850.930	5710716.765	5.254		
JP68	2484858.092	5710711.343	5.595		
JP69	2484864.891	5710706.337	5.591		
JP70	2484871.865	5710701.156	5.487		
JP71	2484878.570	5710696.237	5.488		
JP72	2484885.567	5710691.123	5.470		
JP73	2484892.376	5710686.215	5.343		
JP74	2484898.921	5710681.526	4.961		
JP75	2484905.656	5710676.440	4.738		
JP76	2484911.785	5710671.875	4.556		
JP77	2484919.332	5710666.335	4.315		
JP78	2484926.923	5710661.185	4.151	peg6	<-
JP79	2484934.585	5710655.524	4.240		
JP80	2484941.552	5710650.203	4.190		
JP81	2484948.714	5710644.991	4.217		
JP82	2484955.608	5710639.789	4.271		
JP83	2484962.423	5710634.740	4.244		
JP84	2484968.868	5710629.869	4.361		
JP85	2484975.138	5710625.333	4.468		
JP86	2484981.356	5710620.686	4.583		
JP87	2484987.838	5710615.900	4.659		
JP88	2484994.224	5710611.153	4.716		
JP89	2485000.454	5710606.595	4.810		
JP90	2485007.114	5710601.661	4.911	peg7	<-
JP91	2485014.236	5710596.154	5.077		
JP92	2485020.990	5710591.141	5.277		
JP93	2485027.576	5710586.288	5.431		
JP94	2485033.643	5710581.837	5.442		
JP95	2485040.436	5710577.021	5.371		
JP96	2485046.783	5710572.348	5.263		
JP97	2485053.279	5710567.562	5.181		
JP98	2485059.808	5710562.510	5.137		
JP99	2485066.296	5710557.808	5.093		
JP100	2485073.099	5710552.631	5.067		
JP101	2485080.185	5710547.291	5.086		
JP102	2485087.045	5710542.211	5.154	peg8	<--
JP103	2484916.395	5710426.001	5.287	peg1	<--
JP104	2484918.369	5710416.622	5.319		
JP105	2484919.774	5710408.954	5.411		

Jones Pit

Point ID	Easting	Northing	Elevation	pegs	Line Name & Comments
JP1	2484588.700	5710928.125	8.433	stn	elevation
JP2	2484948.548	5710229.087	8.883	backsite on peg2 jonespt2	corrected
JP3	2484534.000	5710965.000	4.845	peg1	<--
JP4	2484535.539	5710963.160	5.117		
JP5	2484538.629	5710959.970	5.773		
JP6	2484542.235	5710956.068	6.561		
JP7	2484546.017	5710952.098	7.390		
JP8	2484549.605	5710948.813	7.991		
JP9	2484552.766	5710945.419	8.164		
JP10	2484555.672	5710941.647	8.069		
JP11	2484558.735	5710938.816	7.816		
JP12	2484562.116	5710935.854	7.467		
JP13	2484565.334	5710932.788	7.414		
JP14	2484567.825	5710930.061	7.715		
JP15	2484570.234	5710927.402	7.661		
JP16	2484573.019	5710923.924	7.860		
JP17	2484576.458	5710919.650	8.310		
JP18	2484579.866	5710915.832	8.476		
JP19	2484583.362	5710911.398	8.097		
JP20	2484587.056	5710907.236	7.806		
JP21	2484590.381	5710903.430	7.797		
JP22	2484594.238	5710899.193	7.659		
JP23	2484597.340	5710895.405	7.380		
JP24	2484601.035	5710891.562	6.879	peg2	<-
JP25	2484605.234	5710889.028	6.360		
JP26	2484609.297	5710886.518	5.911		
JP27	2484613.531	5710883.750	5.695		
JP28	2484618.437	5710880.654	5.871		
JP29	2484623.619	5710877.440	6.378		
JP30	2484628.418	5710874.333	6.994		
JP31	2484632.974	5710871.512	7.197		
JP32	2484638.396	5710867.841	7.140		
JP33	2484643.463	5710864.157	6.836		
JP34	2484647.981	5710861.083	6.588		
JP35	2484652.622	5710857.790	6.433		
JP36	2484657.767	5710854.241	6.404		
JP37	2484663.303	5710850.423	6.730		
JP38	2484667.726	5710847.368	6.823		
JP39	2484672.298	5710844.027	6.507		
JP40	2484676.719	5710840.810	6.482		
JP41	2484683.702	5710835.915	6.580	peg3	<-
JP42	2484687.785	5710833.332	6.645		
JP43	2484694.456	5710828.753	6.672		
JP44	2484701.160	5710824.070	6.454		
JP45	2484707.244	5710819.835	5.776		
JP46	2484713.776	5710815.596	5.060		
JP47	2484717.740	5710812.860	4.038		
JP48	2484720.343	5710810.997	4.388		
JP49	2484726.331	5710806.856	3.889		
JP50	2484733.017	5710802.244	3.872		
JP51	2484740.454	5710797.234	3.843		
JP52	2484747.268	5710792.045	3.769		

Browns Pit

Point ID	Easting	Northing	Elevation	pegs	Line Name & Comments
BS1	2485644.128	5710169.733	10.942		stn
BS2	2485648.316	5710179.845	10.701		backsite
BS3	2485623.341	5710118.008	11.395	peg	<--
BS4	2485622.879	5710109.792	11.400		elevation
BS5	2485622.989	5710101.064	11.368		corrected
BS6	2485623.213	5710092.107	11.282		pitens
BS7	2485622.587	5710083.744	11.291		
BS8	2485622.263	5710074.270	11.256		
BS9	2485620.976	5710066.568	11.124	peg	<--
BS10	2485635.984	5710052.176	11.051	peg	<--
BS11	2485643.282	5710050.697	11.097		
BS12	2485651.478	5710049.462	11.098		
BS13	2485659.703	5710047.738	11.122		
BS14	2485668.628	5710045.597	11.131		pitewe
BS15	2485677.303	5710043.461	11.145		
BS16	2485686.306	5710041.844	11.133		
BS17	2485694.468	5710039.918	11.081		
BS18	2485700.995	5710038.983	11.119	peg	<--
BS19	2485640.537	5710126.442	4.007	peg	<--
BS20	2485648.188	5710127.174	4.126		
BS21	2485656.107	5710128.198	4.301		
BS22	2485663.757	5710129.073	4.344		
BS23	2485672.023	5710130.060	4.235		
BS24	2485680.104	5710131.133	4.281		
BS25	2485687.782	5710131.875	3.735		
BS26	2485696.167	5710133.204	3.665		
BS27	2485704.613	5710133.701	3.555		
BS28	2485713.188	5710134.676	3.440		
BS29	2485721.223	5710135.479	3.279		pitwe
BS30	2485729.915	5710136.705	3.178		
BS31	2485738.469	5710137.716	3.170		
BS32	2485747.581	5710138.377	3.160		
BS33	2485751.478	5710138.511	3.375		
BS34	2485754.362	5710138.984	3.101		
BS35	2485761.789	5710140.565	3.010		
BS36	2485770.331	5710141.694	2.912		
BS37	2485778.268	5710142.185	3.005		
BS38	2485783.078	5710142.571	2.959	peg	<--
BS39	2485708.000	5710162.000	3.123	peg	<--
BS40	2485705.461	5710154.918	3.192		
BS41	2485702.759	5710147.229	3.277		
BS42	2485701.154	5710141.997	3.225		
BS43	2485698.385	5710135.081	3.572		
BS44	2485697.150	5710131.475	3.674		
BS45	2485693.978	5710123.578	3.662		pitns
BS46	2485690.739	5710114.149	3.714		
BS47	2485687.836	5710106.444	3.608		
BS48	2485684.935	5710098.819	3.352		
BS49	2485681.735	5710090.884	3.216		
BS50	2485678.235	5710083.251	3.215		
BS51	2485675.020	5710074.877	2.865		
BS52	2485672.853	5710068.888	2.730	peg	<--

Kalline5

53K5	2463701.205	5706577.504	5.959		
54K5	2463703.173	5706570.811	6.002		
55K5	2463705.154	5706564.531	6.003		
56K5	2463707.236	5706558.264	6.144		
57K5	2463708.903	5706552.245	6.487		
58K5	2463710.868	5706545.938	6.655		
59K5	2463712.776	5706539.815	6.861		
60K5	2463714.687	5706533.784	7.112	peg 6	<--

Kailine5

Point ID	Eastings	Northing	Elevation	pegs	Line Name & Comments
1K5	2463693.098	5706704.841	8.312	stn	elevation
2K5	2462701.770	5706221.350	6.185	backsite on DR20?	corrected
3K5	2463548.499	5707003.833	2.856	peg 1	<--
4K5	2463552.514	5706993.329	3.021		
5K5	2463555.876	5706984.177	3.149		
6K5	2463559.253	5706975.557	3.358		
7K5	2463562.760	5706966.206	3.637		
8K5	2463566.784	5706956.363	3.771		
9K5	2463570.301	5706947.093	3.962		
10K5	2463573.619	5706939.777	4.637		
11K5	2463575.616	5706933.788	4.829		
12K5	2463578.135	5706927.245	3.896		
13K5	2463581.294	5706918.640	3.888		
14K5	2463584.546	5706910.852	3.803	peg 2	<--
15K5	2463587.699	5706903.038	3.925		
16K5	2463592.494	5706890.893	3.858		
17K5	2463596.755	5706879.669	3.964		
18K5	2463600.827	5706869.835	3.827		
19K5	2463605.869	5706856.428	3.993		
20K5	2463610.999	5706841.982	4.096		
21K5	2463616.635	5706827.378	4.109		
22K5	2463620.067	5706817.570	4.272	peg 3	<--
23K5	2463624.509	5706805.910	4.605		
24K5	2463628.075	5706796.385	4.972		
25K5	2463631.293	5706787.465	5.043		
26K5	2463635.333	5706775.726	4.999		
27K5	2463638.740	5706766.425	4.914		
28K5	2463642.125	5706756.603	5.085		
29K5	2463645.145	5706746.675	5.228		kailine5
30K5	2463648.204	5706737.905	5.089		
31K5	2463650.674	5706730.164	5.153		
32K5	2463653.050	5706723.593	5.249	peg 4	<--
33K5	2463657.272	5706711.607	6.680		
34K5	2463659.352	5706704.796	7.426		
35K5	2463661.161	5706698.553	8.043		
36K5	2463663.284	5706692.128	8.328		
37K5	2463666.916	5706682.554	7.947		
38K5	2463669.543	5706675.321	7.525		
39K5	2463671.679	5706668.864	6.716		
40K5	2463673.851	5706663.305	7.142		
41K5	2463676.049	5706656.435	7.117		
42K5	2463678.363	5706649.467	7.334		
43K5	2463680.630	5706642.356	7.358		
44K5	2463682.734	5706635.360	7.051		
45K5	2463684.659	5706629.035	7.116	peg 5	<--
46K5	2463686.832	5706624.190	7.206		
47K5	2463688.580	5706617.929	7.129		
48K5	2463690.683	5706611.244	7.187		
49K5	2463692.874	5706604.339	7.017		
50K5	2463695.004	5706597.673	6.863		
51K5	2463697.141	5706590.617	6.659		
52K5	2463699.300	5706583.949	6.098		

Kailine4

159K4	2486832.915	5710122.129	4.861	
160K4	2486828.347	5710117.170	5.215	peg18 <-
161K4	2486822.471	5710109.153	5.395	
162K4	2486816.420	5710100.547	5.493	
163K4	2486810.394	5710091.960	5.671	
164K4	2486804.899	5710083.769	5.923	
165K4	2486802.393	5710079.839	6.110	
166K4	2486800.636	5710077.678	5.915	
167K4	2486799.491	5710076.082	5.975	
168K4	2486797.202	5710072.716	6.206	
169K4	2486791.484	5710063.997	6.419	
170K4	2486785.463	5710055.223	6.882	
171K4	2486779.854	5710046.524	7.164	
172K4	2486774.653	5710038.110	7.056	
173K4	2486772.533	5710034.225	7.082	peg19 <-
174K4	2486769.490	5710024.442	7.315	
175K4	2486766.356	5710014.312	7.720	
176K4	2486764.621	5710009.915	7.604	
177K4	2486763.191	5710006.372	7.519	
178K4	2486760.575	5710000.172	7.367	
179K4	2486755.548	5709985.600	7.799	
180K4	2486750.189	5709971.577	8.232	
181K4	2486744.838	5709957.358	8.438	
182K4	2486739.083	5709939.904	8.768	peg20 <-
183K4	2486734.300	5709925.931	8.964	
184K4	2486731.664	5709916.700	9.187	
185K4	2486729.989	5709911.614	9.401	
186K4	2486726.869	5709900.447	9.560	
187K4	2486721.937	5709886.715	9.570	
188K4	2486716.580	5709871.679	9.362	
189K4	2486711.604	5709856.384	9.374	
190K4	2486708.774	5709844.706	9.182	peg21 <--

Kailine4

106K4	2487231.437	5710337.249	5.280	
107K4	2487222.455	5710332.763	5.094	
108K4	2487213.168	5710328.451	5.429	fence
109K4	2487209.329	5710326.121	5.548	
110K4	2487202.216	5710323.495	5.776	peg12 <-
111K4	2487195.172	5710318.453	6.167	
112K4	2487187.126	5710312.279	5.776	
113K4	2487178.810	5710306.368	5.226	
114K4	2487170.255	5710300.257	4.832	
115K4	2487162.728	5710294.630	4.609	
116K4	2487155.765	5710289.520	4.328	
117K4	2487146.333	5710282.568	4.086	
118K4	2487137.871	5710276.157	3.803	
119K4	2487129.763	5710270.216	3.666	
120K4	2487122.110	5710264.052	3.502	peg13 <-
121K4	2487113.322	5710271.286	3.872	
122K4	2487105.746	5710277.396	4.250	
123K4	2487097.779	5710283.482	4.809	
124K4	2487089.932	5710289.614	5.457	
125K4	2487083.598	5710294.929	6.292	
126K4	2487080.799	5710297.383	6.286	
127K4	2487078.180	5710299.504	5.941	
128K4	2487069.696	5710305.301	5.604	
129K4	2487060.865	5710311.302	5.611	
130K4	2487052.194	5710316.877	5.685	
131K4	2487043.238	5710322.649	5.722	peg14 <-
132K4	2487034.606	5710316.994	5.629	
133K4	2487025.861	5710311.120	5.516	
134K4	2487015.428	5710304.016	5.420	
135K4	2487006.071	5710298.351	5.789	
136K4	2486996.851	5710292.611	5.922	
137K4	2486988.326	5710286.795	5.880	
138K4	2486978.960	5710281.108	5.538	
139K4	2486969.735	5710275.255	5.653	
140K4	2486959.307	5710268.329	5.782	peg16 <-
141K4	2486953.319	5710260.378	5.829	
142K4	2486947.961	5710254.351	5.480	
143K4	2486941.947	5710247.602	5.347	
144K4	2486934.980	5710239.479	5.420	
145K4	2486928.161	5710231.519	5.654	
146K4	2486921.360	5710223.708	5.525	
147K4	2486914.434	5710215.277	5.644	
148K4	2486907.401	5710206.863	5.884	
149K4	2486901.071	5710199.738	5.777	
150K4	2486894.450	5710192.204	5.403	peg17 <-
151K4	2486887.753	5710184.178	5.250	
152K4	2486881.186	5710176.459	5.410	
153K4	2486874.511	5710168.895	5.284	
154K4	2486867.815	5710161.187	4.996	
155K4	2486860.982	5710153.208	4.959	
156K4	2486853.927	5710145.413	4.837	
157K4	2486846.435	5710137.546	4.800	
158K4	2486839.203	5710129.204	4.789	

Kailine4

53K4	2487681.923	5710565.240	3.363	
54K4	2487672.234	5710560.495	3.319	
55K4	2487662.719	5710555.923	3.319	
56K4	2487653.723	5710551.539	3.278	
57K4	2487648.647	5710549.132	3.243	peg7 <-
58K4	2487639.205	5710544.066	3.236	
59K4	2487629.838	5710539.141	3.174	
60K4	2487619.472	5710533.788	3.143	
61K4	2487610.411	5710529.150	3.115	
62K4	2487601.089	5710524.266	3.113	
63K4	2487591.438	5710519.447	3.162	
64K4	2487582.283	5710514.822	3.141	
65K4	2487572.479	5710509.763	3.214	
66K4	2487559.651	5710503.519	3.339	peg8 <-
67K4	2487550.772	5710498.831	3.481	
68K4	2487541.742	5710494.303	3.702	
69K4	2487532.974	5710489.881	3.881	
70K4	2487523.767	5710485.126	3.875	
71K4	2487514.657	5710480.450	3.850	
72K4	2487505.055	5710475.530	3.753	
73K4	2487495.325	5710471.045	3.607	
74K4	2487485.943	5710466.498	3.753	
75K4	2487477.114	5710462.127	4.077	
76K4	2487470.233	5710458.662	4.269	peg9 <-
77K4	2487463.887	5710454.979	4.387	
78K4	2487458.389	5710451.011	4.067	
79K4	2487449.323	5710446.403	3.896	
80K4	2487439.739	5710441.522	3.850	
81K4	2487429.945	5710436.622	3.858	
82K4	2487420.480	5710431.827	3.920	kailine4
83K4	2487411.184	5710427.359	4.017	
84K4	2487401.729	5710422.921	4.105	
85K4	2487392.394	5710418.529	4.232	
86K4	2487380.909	5710413.430	4.373	peg10 <-
87K4	2487372.168	5710408.641	4.421	
88K4	2487362.994	5710403.489	4.359	
89K4	2487354.104	5710398.219	4.172	
90K4	2487346.250	5710394.141	4.132	
91K4	2487336.714	5710389.211	4.536	
92K4	2487327.946	5710384.804	4.549	
93K4	2487319.116	5710380.305	4.370	
94K4	2487309.881	5710375.836	4.347	
95K4	2487299.705	5710371.073	4.727	
96K4	2487291.990	5710367.766	4.926	peg11 <-
97K4	2487288.838	5710366.210	4.932	
98K4	2487285.522	5710364.532	4.599	
99K4	2487281.254	5710362.239	4.513	
100K4	2487272.190	5710357.248	4.852	
101K4	2487263.977	5710353.076	5.117	
102K4	2487260.135	5710350.960	5.231	
103K4	2487257.767	5710349.787	5.130	
104K4	2487248.291	5710345.234	5.119	
105K4	2487239.710	5710341.089	5.115	

Kailine4

Point ID	Easting	Northing	Elevation	pegs	Line Name & Comments
1K4	2487166.917	5710317.688	6.957	stn	elevation based on point 3K4
2K4	2487122.034	5710264.197	3.519	backsite	being at lake level of 1.83m
3K4	2488184.000	5710820.000	1.830	peg1	<--
4K4	2488177.223	5710816.696	2.007		
5K4	2488170.323	5710813.070	2.112		
6K4	2488163.732	5710809.624	2.134		
7K4	2488155.137	5710805.239	2.212		
8K4	2488146.093	5710800.694	2.264		
9K4	2488146.096	5710800.690	2.227		
10K4	2488136.864	5710796.136	2.264		
11K4	2488122.972	5710789.012	2.197		
12K4	2488109.513	5710782.184	2.264		
13K4	2488109.517	5710782.215	2.254		
14K4	2488094.733	5710775.080	2.330	peg2	<-
15K4	2488077.051	5710765.754	2.410		
16K4	2488059.810	5710756.820	2.487		
17K4	2488042.316	5710748.106	2.532		
18K4	2488023.257	5710738.657	2.533		
19K4	2488014.048	5710734.600	2.567		
20K4	2488005.089	5710731.069	2.604	peg3	<-
21K4	2487986.605	5710720.704	2.685		
22K4	2487969.054	5710711.076	2.762		
23K4	2487949.527	5710701.509	2.956		
24K4	2487940.356	5710697.136	3.152		
25K4	2487930.636	5710692.193	3.145		
26K4	2487921.822	5710687.789	3.181		
27K4	2487916.182	5710685.141	3.138		
28K4	2487907.417	5710680.349	3.171	peg4	<-
29K4	2487898.681	5710675.736	3.179		
30K4	2487889.703	5710671.109	3.143		
31K4	2487879.946	5710665.880	3.185		
32K4	2487870.380	5710660.904	3.222		
33K4	2487861.171	5710655.915	3.202		
34K4	2487851.737	5710651.282	3.165		
35K4	2487842.231	5710646.550	3.207		
36K4	2487832.959	5710641.999	3.069		
37K4	2487827.287	5710639.285	3.106	peg5	<-
38K4	2487818.388	5710634.604	3.057		
39K4	2487808.600	5710629.415	2.897		
40K4	2487798.864	5710624.394	3.095		
41K4	2487789.705	5710619.807	3.274		
42K4	2487780.288	5710614.894	3.487		
43K4	2487771.359	5710610.419	3.527		
44K4	2487761.730	5710605.535	3.544		
45K4	2487751.913	5710600.871	3.371		
46K4	2487742.969	5710596.766	3.351		
47K4	2487737.763	5710594.558	3.379	peg6	<-
48K4	2487728.828	5710589.791	3.379		
49K4	2487719.683	5710584.704	3.399		
50K4	2487710.407	5710579.863	3.415		
51K4	2487701.007	5710574.878	3.389		
52K4	2487691.367	5710569.989	3.373		

Kailine3

318K3	2482543.608	5709415.658	9.316	peg26	<-
319K3	2482542.246	5709413.197	9.253		
320K3	2482538.762	5709406.965	9.107		
321K3	2482535.147	5709400.427	9.352		
322K3	2482531.999	5709393.388	9.337		
323K3	2482529.920	5709389.595	9.130		
324K3	2482526.106	5709382.040	9.222		
325K3	2482522.398	5709375.203	9.130		
326K3	2482519.081	5709368.616	9.276		
327K3	2482515.837	5709361.885	9.296		
328K3	2482512.855	5709355.327	9.609		
329K3	2482509.192	5709347.465	9.763		
330K3	2482505.339	5709339.718	9.725		
331K3	2482502.559	5709332.964	9.655		
332K3	2482499.579	5709325.954	9.758	peg27	<-
333K3	2482496.789	5709319.093	9.691		
334K3	2482494.096	5709311.535	9.517		
335K3	2482491.373	5709303.840	9.396		
336K3	2482488.895	5709296.467	9.555		
337K3	2482486.488	5709289.182	9.573		
338K3	2482484.256	5709282.108	9.502		
339K3	2482482.130	5709274.738	9.561		
340K3	2482479.578	5709267.064	9.819		
341K3	2482477.421	5709260.691	9.903		
342K3	2482475.072	5709253.566	9.646		
343K3	2482472.900	5709246.118	9.526		
344K3	2482470.818	5709238.564	9.193		
345K3	2482468.918	5709230.989	8.751	peg28	<--

Kailine3

265K3	2482622.118	5709814.479	9.586		
266K3	2482621.373	5709805.742	9.527	peg22	<-
267K3	2482620.058	5709797.671	9.471		
268K3	2482618.334	5709787.887	9.422		
269K3	2482616.999	5709779.889	9.296		
270K3	2482615.727	5709771.931	9.136		
271K3	2482614.502	5709763.631	8.938		
272K3	2482613.090	5709754.938	8.881		
273K3	2482611.690	5709746.671	8.932		
274K3	2482610.378	5709738.486	9.111		
275K3	2482609.260	5709730.119	9.108		
276K3	2482607.973	5709722.538	8.920		
277K3	2482606.874	5709715.014	9.035		
278K3	2482605.384	5709707.191	9.161	peg23	<-
279K3	2482604.065	5709698.843	9.198		
280K3	2482602.728	5709688.360	9.038		
281K3	2482601.178	5709678.200	8.823		
282K3	2482599.877	5709667.768	8.567		
283K3	2482598.441	5709657.802	8.662		
284K3	2482597.250	5709648.133	8.831		
285K3	2482596.347	5709639.481	8.980		
286K3	2482595.285	5709631.413	9.037		
287K3	2482594.440	5709623.662	8.937		
288K3	2482593.694	5709615.794	8.808		
289K3	2482592.959	5709608.057	8.822	peg24	<-
290K3	2482591.746	5709600.362	8.912		
291K3	2482590.718	5709592.692	8.985		
292K3	2482589.737	5709584.817	8.972		
293K3	2482588.550	5709576.247	9.059		
294K3	2482587.616	5709568.926	9.289		
295K3	2482586.995	5709561.272	9.803		
296K3	2482586.103	5709553.340	10.142		
297K3	2482585.088	5709546.493	10.413		
298K3	2482583.691	5709541.055	10.402		
299K3	2482583.066	5709535.502	10.102		
300K3	2482581.951	5709528.230	9.763		
301K3	2482581.501	5709523.739	9.658		
302K3	2482580.532	5709517.077	9.352		
303K3	2482579.223	5709508.916	8.848	peg25	<-
304K3	2482577.724	5709505.579	8.945		
305K3	2482574.918	5709498.066	9.070		
306K3	2482572.128	5709490.650	9.195		
307K3	2482569.272	5709483.349	9.200		
308K3	2482567.703	5709479.089	9.370		
309K3	2482566.429	5709474.595	9.139		
310K3	2482563.750	5709468.156	9.100		
311K3	2482562.228	5709464.904	9.384		
312K3	2482560.404	5709459.635	9.163		
313K3	2482557.677	5709451.872	9.413		
314K3	2482554.580	5709444.279	9.409		
315K3	2482551.720	5709436.860	9.391		
316K3	2482548.832	5709429.739	9.307		
317K3	2482546.331	5709422.740	9.421		

Kailine3

212K3	2482668.502	5710247.186	7.580		
213K3	2482667.358	5710239.832	7.391		
214K3	2482666.425	5710232.325	7.355		
215K3	2482665.971	5710225.402	7.644		
216K3	2482665.050	5710218.049	7.646		
217K3	2482664.352	5710210.330	7.820		
218K3	2482663.351	5710203.218	8.056	peg18	<-
219K3	2482661.968	5710192.775	8.186		
220K3	2482660.993	5710184.303	8.197		
221K3	2482659.910	5710176.190	8.366		
222K3	2482659.177	5710168.407	8.616		
223K3	2482658.501	5710161.234	8.848		
224K3	2482657.801	5710155.492	8.491		
225K3	2482657.366	5710151.406	8.652		
226K3	2482656.547	5710143.384	9.093		
227K3	2482655.980	5710135.180	9.451		
228K3	2482655.124	5710127.543	9.515		
229K3	2482654.550	5710120.008	9.597		
230K3	2482653.942	5710113.315	9.950		
231K3	2482653.739	5710109.319	10.504	peg19	<-
232K3	2482652.489	5710097.110	10.619		
233K3	2482651.508	5710088.557	10.747		
234K3	2482650.783	5710080.386	10.689		
235K3	2482649.954	5710072.193	10.404		
236K3	2482649.184	5710063.740	10.295		
237K3	2482648.639	5710055.075	10.276		
238K3	2482648.363	5710046.717	10.376		
239K3	2482647.744	5710038.318	10.507		
240K3	2482647.138	5710029.251	10.501		
241K3	2482646.451	5710020.556	10.484		
242K3	2482645.861	5710012.259	10.316		
243K3	2482645.391	5710004.128	10.253	peg20	<-
244K3	2482644.027	5709993.214	10.325		
245K3	2482643.312	5709984.546	10.348		
246K3	2482642.452	5709976.026	10.428		
247K3	2482641.483	5709967.886	10.478		
248K3	2482640.545	5709959.542	10.386		
249K3	2482639.959	5709951.413	10.200		
250K3	2482638.852	5709941.094	9.855		
251K3	2482637.958	5709932.925	9.496		
252K3	2482637.038	5709923.793	9.277		
253K3	2482636.102	5709914.837	9.283		
254K3	2482635.133	5709904.684	9.613	peg21	<-
255K3	2482634.320	5709899.090	9.800		
256K3	2482633.109	5709890.706	10.034		
257K3	2482631.941	5709882.621	10.080		
258K3	2482630.803	5709874.085	10.134		
259K3	2482629.423	5709864.968	10.325		
260K3	2482628.214	5709856.205	10.377		
261K3	2482626.979	5709848.044	10.430		
262K3	2482625.924	5709840.420	10.252		
263K3	2482624.908	5709832.435	9.946		
264K3	2482623.581	5709823.472	9.717		

Kailine3

159K3	2482703.912	5710655.229	5.644		
160K3	2482703.622	5710647.084	5.562		
161K3	2482703.475	5710639.526	4.644		
162K3	2482703.032	5710631.793	4.544		
163K3	2482702.814	5710624.076	4.585		
164K3	2482702.482	5710616.525	4.686		
165K3	2482702.081	5710608.681	4.943		
166K3	2482701.798	5710601.151	5.349	peg14	<-
167K3	2482700.729	5710590.337	5.864		
168K3	2482699.851	5710580.521	5.958		
169K3	2482699.422	5710572.538	5.986		
170K3	2482698.778	5710564.419	6.124		
171K3	2482698.171	5710556.457	6.290		
172K3	2482697.701	5710548.256	6.466		
173K3	2482697.345	5710540.519	6.554		
174K3	2482696.752	5710532.615	6.590		
175K3	2482696.205	5710524.955	6.648		
176K3	2482695.666	5710516.927	6.561		
177K3	2482695.172	5710509.100	6.646		
178K3	2482694.756	5710501.402	6.926	peg15	<-
179K3	2482693.824	5710494.169	7.043		
180K3	2482693.058	5710487.114	6.997		
181K3	2482692.302	5710479.409	6.610		
182K3	2482691.623	5710471.496	6.364		
183K3	2482691.056	5710463.862	6.376		
184K3	2482690.245	5710455.800	6.423		
185K3	2482689.582	5710447.938	6.235		
186K3	2482689.168	5710439.845	5.878		
187K3	2482688.641	5710432.210	5.826		
188K3	2482688.221	5710424.303	5.858		
189K3	2482687.741	5710416.518	5.996		
190K3	2482687.380	5710409.378	6.101		
191K3	2482686.959	5710401.765	6.069	peg16	<-
192K3	2482686.663	5710397.888	6.100	fence	
193K3	2482686.163	5710393.418	5.888		
194K3	2482685.480	5710387.964	6.052		
195K3	2482684.990	5710382.286	5.788		
196K3	2482684.979	5710381.204	5.898		
197K3	2482684.350	5710375.409	6.112		
198K3	2482683.327	5710365.090	6.264		
199K3	2482682.196	5710354.960	6.513		
200K3	2482680.808	5710344.278	6.657		
201K3	2482679.769	5710335.214	6.827		
202K3	2482678.710	5710327.065	6.974		
203K3	2482677.522	5710318.575	6.939		
204K3	2482676.684	5710310.349	6.966		
205K3	2482675.725	5710302.454	7.032	peg17	<-
206K3	2482674.194	5710291.288	7.442		
207K3	2482673.103	5710282.890	7.693		
208K3	2482672.148	5710275.132	7.768		
209K3	2482671.163	5710267.592	7.819		
210K3	2482670.044	5710259.731	7.759		
211K3	2482669.191	5710252.143	7.726		

Kailine3

106K3	2482752.966	5711066.444	2.557	fence	
107K3	2482752.690	5711058.108	2.546		
108K3	2482752.827	5711049.010	2.558		
109K3	2482752.854	5711048.986	2.566		
110K3	2482752.454	5711035.271	2.658		
111K3	2482752.150	5711021.422	2.740		
112K3	2482751.128	5711007.701	2.813		
113K3	2482749.774	5710996.568	2.857	peg10	<-
114K3	2482746.933	5710982.603	2.928		
115K3	2482744.207	5710968.621	3.021		
116K3	2482741.286	5710955.355	3.138		
117K3	2482738.324	5710941.145	3.268		
118K3	2482735.098	5710927.276	3.429		
119K3	2482731.829	5710913.952	3.501		
120K3	2482729.389	5710905.037	3.580		
121K3	2482727.592	5710899.157	3.572	peg11	<-
122K3	2482726.539	5710889.387	3.675		
123K3	2482725.482	5710879.612	3.742		
124K3	2482724.270	5710870.225	3.746		
125K3	2482723.064	5710860.382	3.871		
126K3	2482722.045	5710853.119	3.993		
127K3	2482720.849	5710845.715	4.023		
128K3	2482719.801	5710838.429	4.072		
129K3	2482718.782	5710830.852	4.097		
130K3	2482717.720	5710823.020	4.163		
131K3	2482716.465	5710815.569	4.236		
132K3	2482715.006	5710807.937	4.314		
133K3	2482713.616	5710800.256	4.506	peg12	<-
134K3	2482714.143	5710792.171	4.573		
135K3	2482713.490	5710784.404	4.657		
136K3	2482713.298	5710776.245	4.677		
137K3	2482713.314	5710768.613	4.837		
138K3	2482713.413	5710760.206	5.058	fence	
139K3	2482712.875	5710755.911	5.080		
140K3	2482713.132	5710751.062	5.561		
141K3	2482713.285	5710746.236	6.125		
142K3	2482713.507	5710741.260	6.735		
143K3	2482713.890	5710736.292	7.464		
144K3	2482713.810	5710733.603	7.795	fence	
145K3	2482713.128	5710730.450	8.316		
146K3	2482712.249	5710725.573	8.301		
147K3	2482711.191	5710720.926	7.734		
148K3	2482709.922	5710716.546	6.714		
149K3	2482709.199	5710711.708	5.737		
150K3	2482708.841	5710708.383	5.457		
151K3	2482708.216	5710703.997	5.442		
152K3	2482708.061	5710700.873	5.444	peg13	<-
153K3	2482708.076	5710700.842	5.436		
154K3	2482707.240	5710695.335	5.404		
155K3	2482706.348	5710687.253	5.509		
156K3	2482705.731	5710678.996	5.663		
157K3	2482705.054	5710671.068	5.739		
158K3	2482704.372	5710662.817	5.723		

Kailine3

53K3	2482889.692	5711438.970	1.993		
54K3	2482886.960	5711432.120	2.028		
55K3	2482883.947	5711424.871	1.996		
56K3	2482881.000	5711417.856	2.010		
57K3	2482877.949	5711411.183	1.997		
58K3	2482875.032	5711404.275	2.030		
59K3	2482871.982	5711397.094	2.023		
60K3	2482868.853	5711389.908	2.018		
61K3	2482865.704	5711382.930	2.013		
62K3	2482862.752	5711376.334	2.012		
63K3	2482862.094	5711374.873	2.083	peg6	<-
64K3	2482859.731	5711368.294	2.060		
65K3	2482856.845	5711361.375	2.070		
66K3	2482854.251	5711354.400	2.069		
67K3	2482851.627	5711347.201	2.024		
68K3	2482848.826	5711340.083	2.035		
69K3	2482846.008	5711333.021	2.041		
70K3	2482843.329	5711325.875	2.107		
71K3	2482840.619	5711318.323	2.126		
72K3	2482837.897	5711311.174	2.145		
73K3	2482835.026	5711303.572	2.133		
74K3	2482832.285	5711296.310	2.104		
75K3	2482829.535	5711289.237	2.174		
76K3	2482825.960	5711281.703	2.116	peg7	<-
77K3	2482822.797	5711275.216	2.055		
78K3	2482819.447	5711268.757	1.960		
79K3	2482816.210	5711261.960	2.037		
80K3	2482812.392	5711255.072	2.035		
81K3	2482810.602	5711251.710	1.996		
82K3	2482805.998	5711242.304	1.989		
83K3	2482802.206	5711234.899	2.071		
84K3	2482798.454	5711227.435	2.092		
85K3	2482794.792	5711220.911	2.083		
86K3	2482791.603	5711213.980	2.147		
87K3	2482788.006	5711207.811	2.253		
88K3	2482784.509	5711201.209	2.177		
89K3	2482780.639	5711194.784	2.206		
90K3	2482779.913	5711193.042	2.229	peg8	<-
91K3	2482777.901	5711185.713	2.202		
92K3	2482775.970	5711178.243	2.287		
93K3	2482773.866	5711170.327	2.326		
94K3	2482771.875	5711163.193	2.327		
95K3	2482770.130	5711155.447	2.357		
96K3	2482768.260	5711148.077	2.172		
97K3	2482766.518	5711141.456	2.263		
98K3	2482764.726	5711134.334	2.258		
99K3	2482762.598	5711126.937	2.262		
100K3	2482760.789	5711121.243	2.221	gate	
101K3	2482758.353	5711113.244	2.341		
102K3	2482756.512	5711105.243	2.383		
103K3	2482753.943	5711096.457	2.449	peg9	<-
104K3	2482753.803	5711087.051	2.474		
105K3	2482753.360	5711077.474	2.541		

Kailine3

Point ID	Eastings	Northing	Elevation	pegs	Line Name & Comments
1K3	2482719.988	5710735.604	7.770	stn1	elevation
2K3	2482653.578	5710103.782	9.179	stn2	corrected
3K3	2482867.050	5711843.840	2.947	peg1	<--
4K3	2482868.814	5711839.326	2.966		
5K3	2482870.302	5711834.902	2.947		
6K3	2482873.569	5711825.626	2.927		
7K3	2482877.017	5711815.921	2.926		
8K3	2482880.828	5711806.765	2.723		
9K3	2482884.008	5711797.763	2.711		
10K3	2482887.026	5711788.327	2.702		
11K3	2482890.231	5711779.116	2.743		
12K3	2482893.043	5711769.280	2.733		
13K3	2482895.964	5711759.811	2.711	peg2	<-
14K3	2482899.169	5711749.834	2.742		
15K3	2482902.409	5711739.874	2.744		
16K3	2482905.725	5711729.652	2.669		
17K3	2482909.085	5711720.192	2.660		
18K3	2482912.083	5711710.892	2.652		
19K3	2482914.968	5711701.315	2.703		
20K3	2482917.698	5711691.852	2.716		
21K3	2482920.321	5711681.887	2.572		
22K3	2482923.151	5711672.082	2.659		
23K3	2482924.956	5711665.165	2.698	peg3	<-
24K3	2482923.977	5711655.782	2.717		
25K3	2482923.083	5711646.523	2.705		
26K3	2482921.849	5711636.852	2.194		
27K3	2482920.848	5711627.677	2.229		
28K3	2482920.072	5711620.805	2.192		
29K3	2482919.883	5711618.696	2.210	fence	
30K3	2482919.161	5711609.561	2.188		
31K3	2482918.164	5711600.750	2.197		
32K3	2482917.151	5711591.768	2.225		
33K3	2482916.162	5711583.190	1.749		
34K3	2482915.049	5711574.473	1.752		
35K3	2482914.119	5711568.224	1.714		
36K3	2482913.991	5711565.852	1.731	peg4	<-
37K3	2482913.398	5711558.615	1.725		
38K3	2482912.301	5711551.070	1.740		
39K3	2482911.074	5711544.079	1.708		
40K3	2482910.111	5711537.018	1.652		
41K3	2482909.286	5711529.257	1.715		
42K3	2482908.264	5711521.810	1.713		
43K3	2482907.236	5711514.235	1.744		
44K3	2482906.221	5711506.380	1.870		
45K3	2482905.197	5711498.431	1.930		
46K3	2482904.215	5711490.442	1.927		
47K3	2482903.442	5711482.447	1.992		
48K3	2482902.680	5711474.671	1.925		
49K3	2482901.482	5711466.708	1.984	peg5	<-
50K3	2482898.546	5711459.895	1.970		
51K3	2482895.635	5711452.931	1.982		
52K3	2482892.737	5711446.106	1.892		

Kailine2

212K2	2467222.049	5707179.140	6.342	
213K2	2467221.499	5707170.622	6.209	
214K2	2467220.614	5707164.297	5.884	
215K2	2467220.056	5707158.813	6.035	
216K2	2467219.748	5707150.825	6.130	
217K2	2467219.256	5707145.760	6.053	Peg 13
218K2	2467217.762	5707131.916	5.883	
219K2	2467217.081	5707118.048	5.980	
220K2	2467215.510	5707105.099	5.993	
221K2	2467214.386	5707091.752	6.000	
222K2	2467214.097	5707079.936	5.959	CMP
223K2	2467212.573	5707065.931	6.010	
224K2	2467211.425	5707051.109	5.930	
225K2	2467211.276	5707046.248	5.986	
226K2	2467210.683	5707037.555	6.051	
227K2	2467210.111	5707024.335	6.036	
228K2	2467210.148	5707015.977	6.061	
229K2	2467207.723	5707007.241	6.398	
230K2	2467206.977	5707000.287	6.369	
231K2	2467206.674	5706995.610	6.307	
232K2	2467206.107	5706988.569	6.123	
233K2	2467205.265	5706981.253	6.291	
234K2	2467204.603	5706976.462	6.429	
235K2	2467204.078	5706967.557	6.281	
236K2	2467203.824	5706963.185	6.488	
237K2	2467203.881	5706955.549	6.413	
238K2	2467203.492	5706950.836	6.452	
239K2	2467203.212	5706946.550	6.356	Peg 15
240K2	2467202.155	5706936.384	6.588	
241K2	2467201.555	5706929.084	6.710	
242K2	2467200.801	5706915.331	6.581	
243K2	2467199.364	5706900.401	6.622	
244K2	2467198.944	5706890.714	6.713	
245K2	2467198.148	5706881.797	6.673	
246K2	2467197.319	5706869.781	7.035	
247K2	2467196.813	5706862.175	7.223	
248K2	2467196.306	5706851.926	7.000	
249K2	2467195.876	5706846.666	6.906	Peg 16
250K2	2467195.955	5706843.368	6.733	fence
251K2	2467195.674	5706834.218	6.540	
252K2	2467195.581	5706818.714	6.512	
253K2	2467195.547	5706813.702	6.575	
254K2	2467195.247	5706800.076	6.769	
255K2	2467195.446	5706790.868	6.885	Peg 17

Kailine2

159K2	2467245.075	5707583.340	5.909	
160K2	2467245.165	5707579.349	5.921	
161K2	2467246.031	5707570.238	6.051	
162K2	2467247.062	5707564.920	6.029	
163K2	2467247.414	5707561.825	5.736	
164K2	2467247.551	5707559.451	5.228	
165K2	2467247.770	5707557.741	5.435	
166K2	2467251.167	5707551.381	5.344	Fence
167K2	2467249.002	5707544.356	5.596	Peg 9
168K2	2467249.087	5707534.459	5.952	
169K2	2467249.147	5707525.386	6.179	
170K2	2467249.156	5707516.181	6.348	
171K2	2467249.067	5707507.050	6.435	
172K2	2467249.070	5707496.700	6.544	
173K2	2467249.691	5707484.649	6.766	
174K2	2467249.991	5707475.007	6.753	
175K2	2467249.993	5707464.787	6.851	
176K2	2467249.888	5707452.765	7.123	
177K2	2467250.060	5707444.544	7.326	peg 10
178K2	2467249.792	5707437.986	7.400	
179K2	2467249.670	5707428.666	7.544	
180K2	2467249.282	5707418.863	7.589	
181K2	2467249.008	5707409.721	7.788	
182K2	2467248.929	5707406.200	7.900	Windbreak
183K2	2467238.004	5707381.854	7.962	
184K2	2467237.484	5707375.658	7.901	
185K2	2467236.605	5707368.744	7.878	
186K2	2467236.284	5707361.822	7.768	
187K2	2467235.889	5707354.470	7.604	
188K2	2467235.616	5707349.305	7.638	
189K2	2467235.368	5707346.406	7.775	
190K2	2467235.297	5707344.781	7.728	Peg 11
191K2	2467235.310	5707341.065	7.697	
192K2	2467234.929	5707337.320	7.607	
193K2	2467234.633	5707333.793	7.286	
194K2	2467234.288	5707327.464	6.959	
195K2	2467233.004	5707320.457	7.008	
196K2	2467232.224	5707313.834	7.155	
197K2	2467231.750	5707307.895	6.636	
198K2	2467231.272	5707301.121	6.281	
199K2	2467231.012	5707292.505	6.205	
200K2	2467230.533	5707282.635	6.369	
201K2	2467230.017	5707272.454	6.478	
202K2	2467229.706	5707262.828	6.618	
203K2	2467229.060	5707252.580	6.505	
204K2	2467228.779	5707245.156	6.586	Peg 12
205K2	2467228.194	5707240.413	6.560	
206K2	2467227.121	5707231.625	6.472	
207K2	2467225.730	5707220.985	6.490	
208K2	2467224.471	5707211.997	6.622	
209K2	2467224.239	5707206.791	6.203	
210K2	2467223.636	5707197.308	5.992	
211K2	2467222.793	5707186.449	6.276	

Kailine2

106K2	2467239.498	5707830.852	7.125
107K2	2467239.034	5707826.052	6.618
108K2	2467238.936	5707821.531	6.367
109K2	2467239.209	5707816.694	6.250
110K2	2467239.257	5707811.266	6.212
111K2	2467239.355	5707806.143	6.022
112K2	2467239.363	5707801.601	5.949
113K2	2467240.311	5707796.479	5.976
114K2	2467240.626	5707792.198	6.250
115K2	2467240.991	5707787.422	6.320
116K2	2467241.045	5707782.331	6.341
117K2	2467241.000	5707777.457	6.559
118K2	2467241.198	5707774.845	6.755
119K2	2467241.350	5707770.811	6.706
120K2	2467241.007	5707766.171	6.582
121K2	2467240.841	5707761.460	6.439
122K2	2467240.501	5707756.768	6.589
123K2	2467240.005	5707752.256	6.711
124K2	2467239.880	5707747.310	6.759
125K2	2467239.901	5707743.644	6.589
126K2	2467239.872	5707739.284	6.621
127K2	2467239.740	5707734.243	6.538
128K2	2467239.853	5707729.771	6.823
129K2	2467239.911	5707725.161	6.557
130K2	2467240.114	5707720.943	6.110
131K2	2467240.236	5707716.563	6.244
132K2	2467240.470	5707712.288	6.121
133K2	2467240.413	5707708.731	6.300
134K2	2467240.528	5707703.649	6.667
135K2	2467240.646	5707698.912	6.714
136K2	2467240.591	5707695.148	6.792
137K2	2467240.689	5707690.805	7.260
138K2	2467240.820	5707686.157	7.131
139K2	2467241.079	5707679.382	6.876
140K2	2467241.464	5707671.603	6.715
141K2	2467241.664	5707667.398	6.631
142K2	2467241.794	5707663.067	6.497
143K2	2467242.180	5707660.216	6.352
144K2	2467242.090	5707656.171	6.406
145K2	2467242.236	5707651.412	6.320
146K2	2467242.237	5707647.179	6.174
147K2	2467242.355	5707643.890	5.765
148K2	2467242.368	5707639.827	5.315
149K2	2467242.733	5707635.698	5.241
150K2	2467242.685	5707627.568	5.331
151K2	2467243.037	5707623.070	5.318
152K2	2467243.411	5707618.612	5.395
153K2	2467243.677	5707614.514	5.451
154K2	2467244.008	5707610.313	5.685
155K2	2467244.306	5707603.876	5.744
156K2	2467244.629	5707597.240	5.947
157K2	2467244.930	5707592.169	6.128
158K2	2467245.015	5707587.534	6.074

Peg 7

Peg 8

Kailine2

53K2	2467264.980	5708071.087	2.508	
54K2	2467266.277	5708066.382	2.579	
55K2	2467267.525	5708061.675	2.623	
56K2	2467268.581	5708057.062	2.793	
57K2	2467269.627	5708052.708	2.934	
58K2	2467270.371	5708047.891	3.055	
59K2	2467270.900	5708043.522	3.160	
60K2	2467271.606	5708039.441	3.282	
61K2	2467272.006	5708036.592	3.359	
62K2	2467272.572	5708033.374	3.290	
63K2	2467272.861	5708031.110	3.097	Peg 4
64K2	2467273.983	5708023.239	3.036	
65K2	2467271.840	5708017.403	2.936	
66K2	2467275.154	5708014.132	2.952	
67K2	2467275.397	5708011.753	3.067	
68K2	2467276.052	5708006.156	2.998	
69K2	2467276.492	5708003.939	2.853	
70K2	2467277.409	5707998.540	2.747	
71K2	2467278.545	5707990.180	2.694	
72K2	2467279.570	5707982.111	2.769	
73K2	2467280.759	5707975.441	2.799	
74K2	2467281.205	5707972.077	2.704	
75K2	2467281.021	5707964.055	2.733	
76K2	2467283.566	5707955.666	2.813	
77K2	2467284.259	5707951.274	2.947	
78K2	2467284.786	5707946.860	3.156	
79K2	2467285.265	5707944.298	3.047	
80K2	2467285.723	5707940.670	3.084	
81K2	2467286.094	5707937.352	3.257	
82K2	2467286.651	5707932.154	3.232	Peg 5
83K2	2467285.457	5707929.657	3.368	
84K2	2467282.573	5707923.702	3.418	
85K2	2467279.803	5707917.862	3.481	
86K2	2467277.915	5707913.940	3.605	
87K2	2467275.956	5707910.146	3.856	
88K2	2467273.959	5707906.366	4.277	
89K2	2467272.049	5707902.546	4.770	
90K2	2467269.983	5707898.529	5.034	
91K2	2467268.195	5707894.977	5.111	
92K2	2467266.398	5707891.443	4.967	
93K2	2467264.454	5707887.995	4.867	
94K2	2467262.432	5707884.082	4.895	
95K2	2467260.386	5707880.054	5.008	
96K2	2467258.371	5707876.320	5.105	
97K2	2467256.327	5707872.502	5.144	
98K2	2467254.378	5707868.670	5.272	
99K2	2467251.956	5707863.914	5.515	
100K2	2467249.988	5707859.566	5.825	
101K2	2467245.396	5707851.493	6.462	
102K2	2467242.858	5707847.250	6.824	
103K2	2467240.995	5707843.463	7.214	Peg 6
104K2	2467240.804	5707840.493	7.422	
105K2	2467240.457	5707835.926	7.409	

Kailine2

Point ID	Eastings	Northing	Elevation	pegs	Line Name & Comments
1K2	2467241.303	5707397.086	7.988	Station 2	
2K2	2467198.275	5706842.119	5.930	spotht	
3K2	2467196.476	5706856.094	6.378	spotht	
4K2	2467241.000	5708323.000	1.328	Peg 1	Elevation Corrected
5K2	2467241.610	5708318.285	1.429		
6K2	2467242.292	5708312.830	1.490		
7K2	2467243.172	5708307.169	1.575		
8K2	2467243.831	5708302.240	1.605		
9K2	2467244.640	5708297.461	1.610		
10K2	2467245.693	5708292.273	1.621		
11K2	2467245.914	5708287.280	1.645		
12K2	2467246.179	5708282.169	1.683		
13K2	2467246.434	5708276.905	1.712		
14K2	2467246.528	5708275.093	1.696	Fence	
15K2	2467246.889	5708270.107	1.778		
16K2	2467247.388	5708265.482	1.785		
17K2	2467247.777	5708260.348	1.827		
18K2	2467248.478	5708254.125	1.875		
19K2	2467249.411	5708248.300	1.904		
20K2	2467249.951	5708242.018	2.121		
21K2	2467249.966	5708239.267	2.306		
22K2	2467249.905	5708235.235	2.322		
23K2	2467249.694	5708231.507	2.246		
24K2	2467249.278	5708228.459	2.227	Peg 2	
25K2	2467249.387	5708226.757	2.142		
26K2	2467249.512	5708224.712	2.296		
27K2	2467249.855	5708221.176	2.309		
28K2	2467249.995	5708217.052	2.124		
29K2	2467250.223	5708211.404	2.218		
30K2	2467250.154	5708205.372	2.280		
31K2	2467250.904	5708197.597	2.337		
32K2	2467250.552	5708192.648	2.322		
33K2	2467250.421	5708186.739	2.315		
34K2	2467250.344	5708179.672	2.256		
35K2	2467250.317	5708172.670	2.193		
36K2	2467250.415	5708168.050	2.177		
37K2	2467250.392	5708162.006	2.111		
38K2	2467250.387	5708157.939	2.083		
39K2	2467250.479	5708154.900	2.095		
40K2	2467250.491	5708148.544	2.100		
41K2	2467250.621	5708147.273	2.182		
42K2	2467250.743	5708145.347	2.062		
43K2	2467250.625	5708136.793	2.088		
44K2	2467250.454	5708128.516	2.137	Peg 3	
45K2	2467251.484	5708124.106	2.133		
46K2	2467252.659	5708120.124	2.158		
47K2	2467254.380	5708113.478	2.177		
48K2	2467256.558	5708104.853	2.279		
49K2	2467258.945	5708096.432	2.353		
50K2	2467261.043	5708087.790	2.329		
51K2	2467262.826	5708079.728	2.420		
52K2	2467263.791	5708075.160	2.516		

Kailine1

265K1	2473306.848	5707891.480	7.063	
266K1	2473308.100	5707882.984	6.899	
267K1	2473310.700	5707873.013	6.885	peg20 <-
268K1	2473312.463	5707865.601	6.811	
269K1	2473314.050	5707858.161	6.645	
270K1	2473315.868	5707850.806	7.004	
271K1	2473317.475	5707842.720	7.078	
272K1	2473319.233	5707835.284	7.225	
273K1	2473321.364	5707827.158	7.382	
274K1	2473323.368	5707818.657	7.356	
275K1	2473325.499	5707811.077	7.458	
276K1	2473327.404	5707803.458	7.465	
277K1	2473329.350	5707795.826	7.527	
278K1	2473331.437	5707788.096	7.567	
279K1	2473333.295	5707780.254	7.532	
280K1	2473334.351	5707775.937	7.617	peg21 <--

Kailine1

212K1	2473202.084	5708298.354	8.206	
213K1	2473203.643	5708290.863	8.263	
214K1	2473205.588	5708283.228	8.292	
215K1	2473207.329	5708275.906	8.287	
216K1	2473208.687	5708267.621	8.540	
217K1	2473210.700	5708259.009	8.684	peg16 <-
218K1	2473213.263	5708252.254	8.724	
219K1	2473216.252	5708245.201	8.730	
220K1	2473218.791	5708238.209	8.632	
221K1	2473221.135	5708231.245	8.417	
222K1	2473223.736	5708223.910	8.199	
223K1	2473226.866	5708216.799	8.277	
224K1	2473229.623	5708209.566	8.229	
225K1	2473232.528	5708202.288	8.340	
226K1	2473235.227	5708194.823	8.448	
227K1	2473237.820	5708187.784	8.649	
228K1	2473240.783	5708180.670	8.765	
229K1	2473243.522	5708173.168	8.949	
230K1	2473245.262	5708165.288	9.046	peg17 <-
231K1	2473246.521	5708161.347	9.036	
232K1	2473247.556	5708152.349	8.827	
233K1	2473249.288	5708145.344	8.627	
234K1	2473250.448	5708137.801	8.383	
235K1	2473252.290	5708130.281	8.194	
236K1	2473254.396	5708122.858	7.994	
237K1	2473255.979	5708116.010	7.888	
238K1	2473257.720	5708108.615	7.802	
239K1	2473259.564	5708101.282	7.762	
240K1	2473261.522	5708093.485	7.761	
241K1	2473263.387	5708085.856	7.866	
242K1	2473265.467	5708077.431	8.030	
243K1	2473267.776	5708067.933	8.069	peg18 <-
244K1	2473270.004	5708060.443	7.903	
245K1	2473272.095	5708052.831	7.778	
246K1	2473274.105	5708045.095	7.645	
247K1	2473275.950	5708037.178	7.492	
248K1	2473277.928	5708029.052	7.489	
249K1	2473279.840	5708021.478	7.482	
250K1	2473281.693	5708013.583	7.594	
251K1	2473283.593	5708005.587	7.678	
252K1	2473285.461	5707997.733	7.596	
253K1	2473287.384	5707989.700	7.582	
254K1	2473289.193	5707981.226	7.509	
255K1	2473291.624	5707971.014	7.455	peg19 <-
256K1	2473293.215	5707963.129	7.500	
257K1	2473294.668	5707955.591	7.615	
258K1	2473296.354	5707948.162	7.708	
259K1	2473297.840	5707940.174	7.763	
260K1	2473299.430	5707932.110	7.639	
261K1	2473300.856	5707924.280	7.546	
262K1	2473302.173	5707916.021	7.261	
263K1	2473303.473	5707907.983	7.273	
264K1	2473304.923	5707899.439	7.218	

Kailine1

159K1	2473138.000	5708698.771	8.047	
160K1	2473138.188	5708691.075	8.166	
161K1	2473138.439	5708683.346	8.242	
162K1	2473138.364	5708675.372	8.241	
163K1	2473138.277	5708667.706	8.164	
164K1	2473138.014	5708659.699	8.289	
165K1	2473138.492	5708651.937	8.328	peg12 <-
166K1	2473139.793	5708644.595	8.244	
167K1	2473141.113	5708636.866	8.203	
168K1	2473142.457	5708629.025	8.160	
169K1	2473144.297	5708621.257	8.189	
170K1	2473145.680	5708614.054	8.198	
171K1	2473147.036	5708607.188	8.136	
172K1	2473148.477	5708599.785	7.996	
173K1	2473150.088	5708592.092	7.861	
174K1	2473151.515	5708584.437	7.710	
175K1	2473153.148	5708576.381	7.641	
176K1	2473154.416	5708568.369	7.529	
177K1	2473155.472	5708560.377	7.457	
178K1	2473156.718	5708553.785	7.572	peg13 <-
179K1	2473157.826	5708546.587	7.708	
180K1	2473158.874	5708539.335	7.821	
181K1	2473160.436	5708531.526	7.955	
182K1	2473161.551	5708523.343	8.013	
183K1	2473162.722	5708515.071	8.025	
184K1	2473164.156	5708506.948	7.921	
185K1	2473165.470	5708498.959	7.869	
186K1	2473166.119	5708491.014	7.875	
187K1	2473167.033	5708483.491	8.027	
188K1	2473168.540	5708475.487	8.076	
189K1	2473169.622	5708467.543	8.174	
190K1	2473171.041	5708459.327	8.153	
191K1	2473171.997	5708455.055	8.217	peg14 <-
192K1	2473173.676	5708445.765	8.235	
193K1	2473174.687	5708438.363	8.246	
194K1	2473175.795	5708430.826	8.260	
195K1	2473177.054	5708423.244	8.158	
196K1	2473178.222	5708415.589	8.143	
197K1	2473179.686	5708408.282	8.117	
198K1	2473181.156	5708400.473	8.048	
199K1	2473182.504	5708392.909	7.970	
200K1	2473183.729	5708385.370	7.966	
201K1	2473185.541	5708377.775	8.047	
202K1	2473187.237	5708370.490	8.147	
203K1	2473188.969	5708362.778	8.282	
204K1	2473190.188	5708356.793	8.357	peg15 <-
205K1	2473191.519	5708349.836	8.378	
206K1	2473193.027	5708342.633	8.410	
207K1	2473194.768	5708335.344	8.339	
208K1	2473196.537	5708327.896	8.231	
209K1	2473197.851	5708320.329	8.101	
210K1	2473199.450	5708313.052	8.076	
211K1	2473200.850	5708305.814	8.107	

Kailine1

106K1	2473065.920	5709094.326	6.180	
107K1	2473068.289	5709086.021	6.309	
108K1	2473070.368	5709078.449	6.460	
109K1	2473072.291	5709070.750	6.643	
110K1	2473074.232	5709062.341	6.882	
111K1	2473076.084	5709054.022	7.176	
112K1	2473078.025	5709045.194	7.375	peg8 <-
113K1	2473079.888	5709037.426	7.484	
114K1	2473081.710	5709029.919	7.556	
115K1	2473083.516	5709022.380	7.415	
116K1	2473085.231	5709014.745	7.368	
117K1	2473086.890	5709006.982	7.286	
118K1	2473088.305	5708999.368	7.309	
119K1	2473089.540	5708991.737	7.303	
120K1	2473091.014	5708984.042	7.310	
121K1	2473092.549	5708976.543	7.256	
122K1	2473094.292	5708968.435	7.236	
123K1	2473095.806	5708960.876	7.398	
124K1	2473097.235	5708952.981	7.532	
125K1	2473098.198	5708947.360	7.561	peg9 <-
126K1	2473099.660	5708940.284	7.604	
127K1	2473101.104	5708932.845	7.680	
128K1	2473102.153	5708927.132	7.601	
129K1	2473103.601	5708920.408	7.535	
130K1	2473104.632	5708913.630	7.560	
131K1	2473106.012	5708906.004	7.622	
132K1	2473107.515	5708898.890	7.615	
133K1	2473108.777	5708891.534	7.532	
134K1	2473110.147	5708883.526	7.520	
135K1	2473111.618	5708876.085	7.517	
136K1	2473113.371	5708867.936	7.518	
137K1	2473114.692	5708860.540	7.538	
138K1	2473116.134	5708853.369	7.487	
139K1	2473117.042	5708849.329	7.485	peg10 <-
140K1	2473118.821	5708841.832	7.432	
141K1	2473120.500	5708834.645	7.398	
142K1	2473122.216	5708827.700	7.354	
143K1	2473123.833	5708820.027	7.326	
144K1	2473125.446	5708812.633	7.251	
145K1	2473127.255	5708805.054	7.093	
146K1	2473129.126	5708797.671	7.048	
147K1	2473130.849	5708790.163	7.206	
148K1	2473132.486	5708783.075	7.329	
149K1	2473134.196	5708775.901	7.513	
150K1	2473135.587	5708768.538	7.733	
151K1	2473137.227	5708761.272	7.898	
152K1	2473139.019	5708751.896	8.128	peg11 <-
153K1	2473138.613	5708744.586	8.252	
154K1	2473138.526	5708737.399	8.276	
155K1	2473138.149	5708730.104	8.370	
156K1	2473138.026	5708722.407	8.404	
157K1	2473138.039	5708714.564	8.297	
158K1	2473138.284	5708706.320	8.077	

Kailine1

53K1	2472991.715	5709418.530	4.426	
54K1	2472993.789	5709410.776	4.476	
55K1	2472995.875	5709402.543	4.542	
56K1	2472997.818	5709394.286	4.533	
57K1	2472999.984	5709385.639	4.483	
58K1	2473001.840	5709376.706	4.432	
59K1	2473004.022	5709368.284	4.475	
60K1	2473005.960	5709359.996	4.436	
61K1	2473008.030	5709351.509	4.505	
62K1	2473009.808	5709342.940	4.496	
63K1	2473011.230	5709336.671	4.538	
64K1	2473013.390	5709328.510	4.550	peg5 <-
65K1	2473015.880	5709320.834	4.638	
66K1	2473018.448	5709312.844	4.793	
67K1	2473020.745	5709304.959	4.920	
68K1	2473023.264	5709296.793	5.027	
69K1	2473025.352	5709288.732	5.151	
70K1	2473027.933	5709280.312	5.116	
71K1	2473030.166	5709272.342	5.222	
72K1	2473032.404	5709264.432	5.090	
73K1	2473033.934	5709259.595	5.065	
74K1	2473035.497	5709253.939	5.050	
75K1	2473036.848	5709248.826	5.137	
76K1	2473038.041	5709244.056	5.137	
77K1	2473039.075	5709240.769	5.042	
78K1	2473040.059	5709234.662	5.107	peg6 <-
79K1	2473040.865	5709229.298	5.096	
80K1	2473041.597	5709224.231	5.128	
81K1	2473042.485	5709219.049	5.180	
82K1	2473042.935	5709214.077	5.141	
83K1	2473043.909	5709208.485	4.988	
84K1	2473044.749	5709203.040	4.979	
85K1	2473045.474	5709197.705	5.019	
86K1	2473046.373	5709192.020	4.938	
87K1	2473047.247	5709186.488	5.052	
88K1	2473048.112	5709181.287	5.063	
89K1	2473048.981	5709175.587	5.026	
90K1	2473050.308	5709167.342	5.131	
91K1	2473051.456	5709159.597	5.276	
92K1	2473052.306	5709154.348	5.442	
93K1	2473053.230	5709149.516	5.805	
94K1	2473054.131	5709144.855	6.276	
95K1	2473054.943	5709142.217	6.504	
96K1	2473056.011	5709137.698	6.921	peg7 <-
97K1	2473057.277	5709132.638	7.574	
98K1	2473058.404	5709127.574	8.121	
99K1	2473059.358	5709122.650	8.397	
100K1	2473059.749	5709118.819	8.114	
101K1	2473060.913	5709113.620	7.265	
102K1	2473061.299	5709110.848	6.996	
103K1	2473061.264	5709109.900	6.947	
104K1	2473061.802	5709107.025	6.997	
105K1	2473064.000	5709102.483	6.365	

Kailine1

Point ID	Easting	Northing	Elevation	pegs	Line Name & Comments
1K1	2473245.461	5708165.281	9.657	stn	elevation
2K1	2472907.000	5709729.000	2.413		corrected
3K1	2472908.414	5709724.360	2.502	peg1	<--
4K1	2472909.751	5709719.264	2.549		
5K1	2472911.074	5709714.000	2.639		
6K1	2472912.482	5709708.385	2.754		
7K1	2472914.142	5709703.053	2.825		
8K1	2472915.515	5709697.566	2.935		
9K1	2472917.127	5709692.025	2.944		
10K1	2472918.638	5709686.511	2.951		
11K1	2472920.308	5709680.972	2.967		
12K1	2472921.998	5709675.442	2.990		
13K1	2472923.469	5709669.887	3.083		
14K1	2472924.946	5709664.533	3.085		
15K1	2472926.476	5709659.309	3.138		
16K1	2472927.976	5709654.135	3.236		
17K1	2472929.422	5709648.844	3.283		
18K1	2472930.799	5709643.257	3.332		
19K1	2472932.207	5709637.557	3.352		
20K1	2472933.612	5709632.706	3.395		
21K1	2472935.311	5709627.331	3.391	peg2	<--
22K1	2472936.998	5709621.917	3.395		
23K1	2472938.632	5709616.357	3.446		
24K1	2472940.224	5709610.587	3.513		
25K1	2472941.810	5709604.890	3.538		
26K1	2472943.546	5709599.285	3.587		
27K1	2472945.111	5709593.741	3.579		
28K1	2472946.579	5709588.286	3.585		
29K1	2472948.000	5709582.850	3.580		
30K1	2472949.501	5709577.138	3.595		
31K1	2472951.117	5709571.695	3.620		
32K1	2472952.570	5709566.741	3.641		
33K1	2472954.390	5709560.988	3.690		
34K1	2472955.917	5709555.303	3.729		
35K1	2472957.624	5709549.686	3.788		
36K1	2472959.130	5709544.125	3.812		
37K1	2472960.634	5709538.830	3.801		
38K1	2472961.156	5709536.628	3.825		
39K1	2472962.904	5709531.050	3.872	peg3	<--
40K1	2472965.135	5709522.564	3.906		
41K1	2472966.974	5709514.309	3.916		
42K1	2472969.176	5709506.098	3.978		
43K1	2472971.343	5709497.968	3.958		
44K1	2472973.615	5709489.512	3.908		
45K1	2472975.841	5709481.274	3.922		
46K1	2472978.142	5709473.169	3.936		
47K1	2472980.340	5709464.939	3.935		
48K1	2472982.427	5709456.977	3.943		
49K1	2472984.217	5709448.858	3.983		
50K1	2472986.112	5709440.646	4.104		
51K1	2472987.626	5709433.912	4.274		
52K1	2472989.514	5709426.513	4.352	peg4	<--

Appendix B CMPs

The following pages have the CMPs and header files from CMPs collected on the radar survey lines on Kaitorete Spit. There was no CMP collected for Birdlings Ridges. The CMPs marked with N.A. were not good enough quality to obtain any velocities from.

Profile Name	Number of CMPs	Velocities calculated
Kailine1	2	0.125
		N.A.
Kailine2	3	0.097
		0.107
		0.102
Kailine3	1	0.118
Kailine4	2	0.125
		N.A.
Kailine5	2	0.105
		0.127
Browns Pit	2	0.085
		0.127
Jones Pit	2	0.124
		0.126
Trig Point	1	0.128
Island	1	0.109
Ponds	2	0.121
		0.143
Dune Ridge	1	0.078
Transgressive Barrier	1	N.A.
Birdlings Ridges	0	N.A.

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\cmp1550.hd

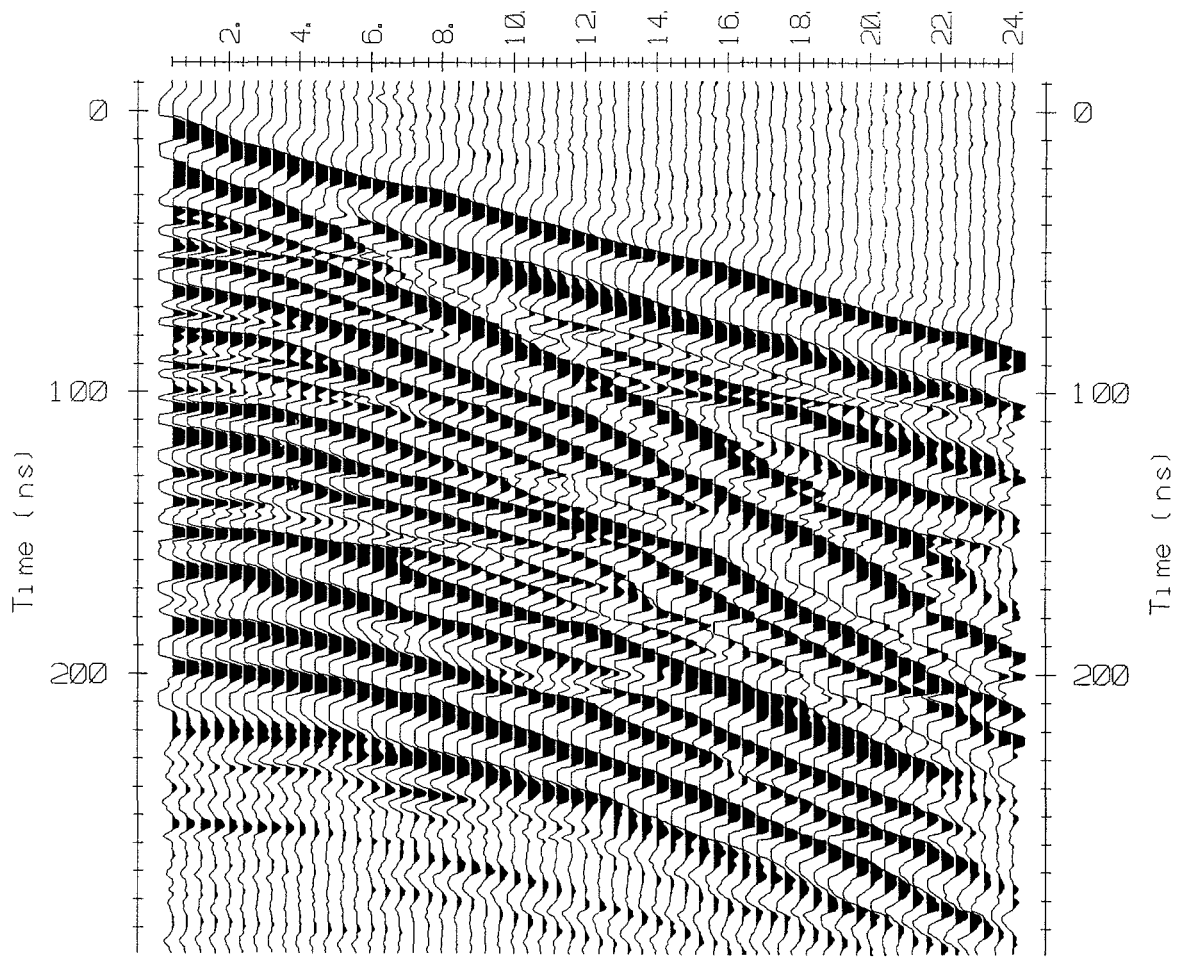
cmpat 1550
05/12/96
NUMBER OF TRACES = 60
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 62
TOTAL TIME WINDOW = 400
STARTING POSITION = 0.4000
FINAL POSITION = 24.0000
STEP SIZE USED = 0.4000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 0.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 64
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 60

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.075"
Trace Width : 0.141"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\k1cmp.hd

Kaitorete Spit - Digby and Kelly, 28/03/96
CMP parallel to Speight Ridge, centred at 75 m along line
28/03/96

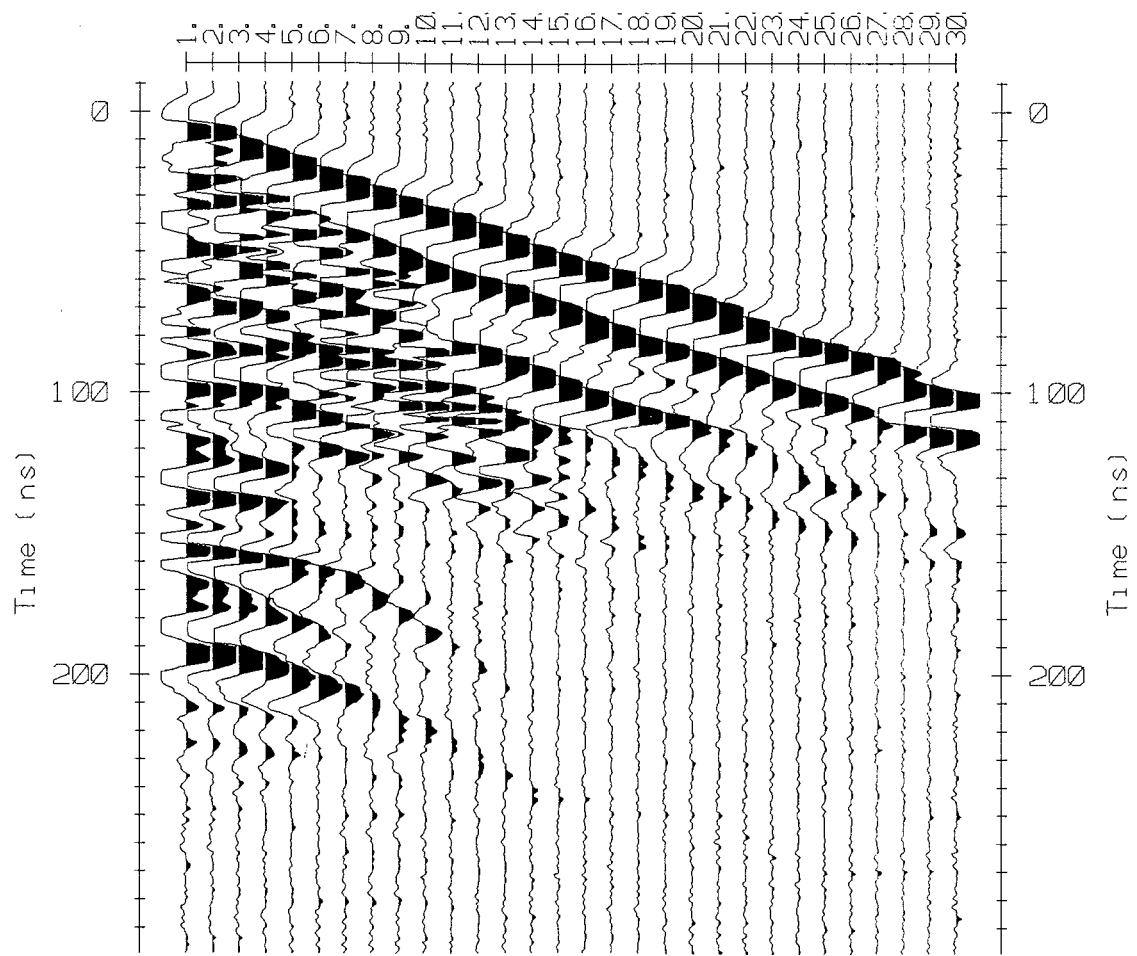
NUMBER OF TRACES = 30
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 52
TOTAL TIME WINDOW = 400
STARTING POSITION = 1.0000
FINAL POSITION = 30.0000
STEP SIZE USED = 1.0000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 64
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 30

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.140"
Trace Width : 0.262"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\klacmp.hd

Kaitorete Spit - Digby and Kelly, 28/03/96
CMP 1 at 175 m along line parallel to Speight Ridge
28/03/96

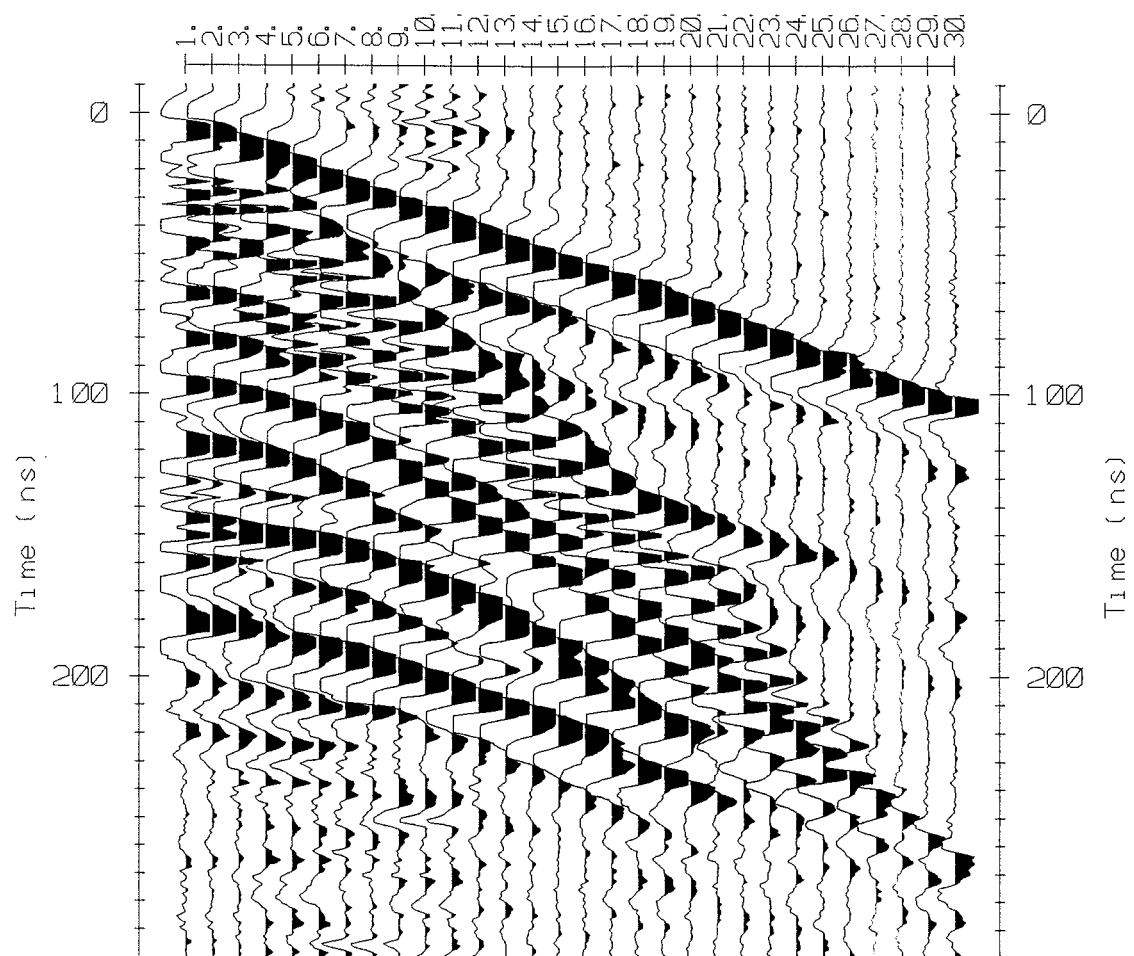
NUMBER OF TRACES = 30
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 54
TOTAL TIME WINDOW = 400
STARTING POSITION = 1.000000
FINAL POSITION = 30.000000
STEP SIZE USED = 1.000000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 64
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 30

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.140"
Trace Width : 0.262"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\cmp21265.hd

Kailine 2 CMP at c.1265m

22/07/96

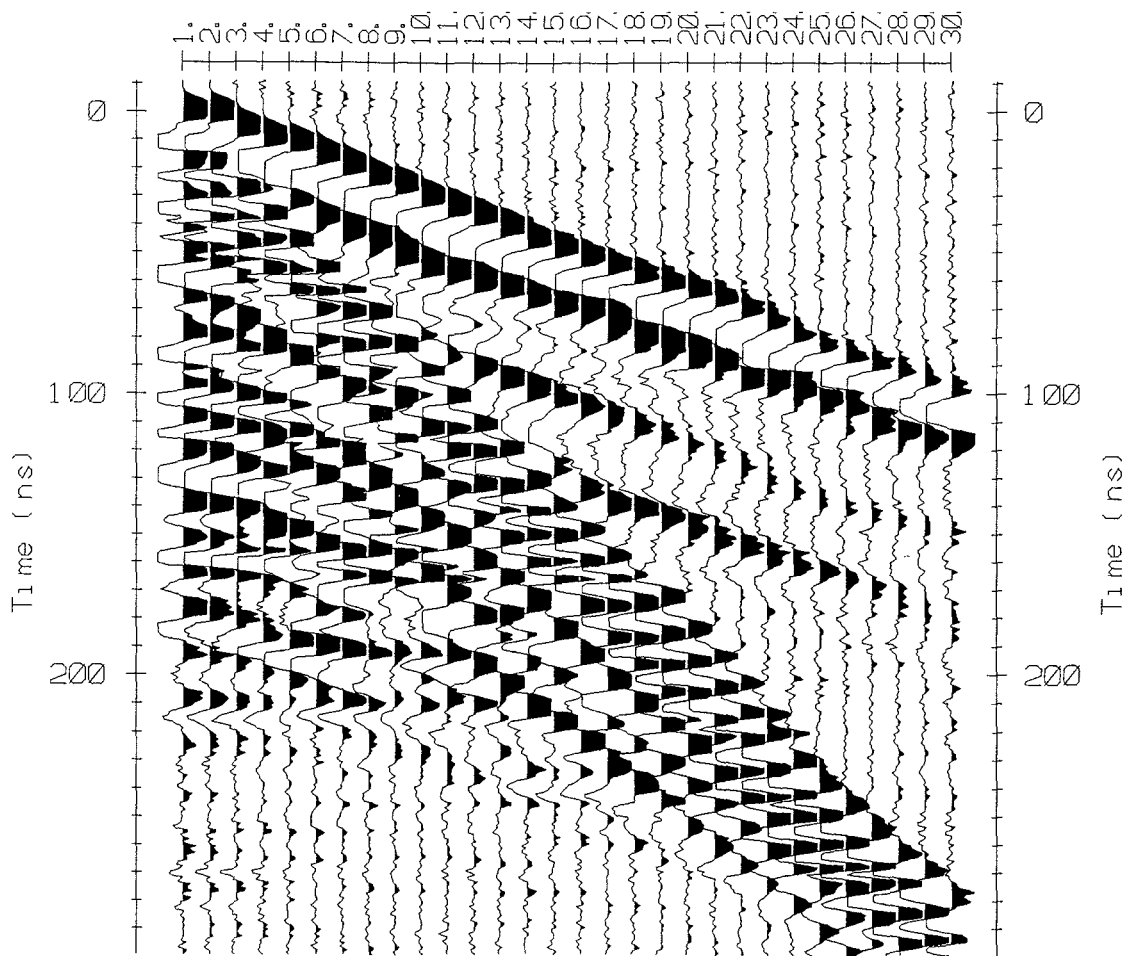
NUMBER OF TRACES = 30
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 46
TOTAL TIME WINDOW = 400
STARTING POSITION = 1.0000
FINAL POSITION = 30.0000
STEP SIZE USED = 1.0000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 30

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.140"
Trace Width : 0.262"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\cmp15k2.hd

CMP at 15m on Kailine2 100MHz

20/07/96

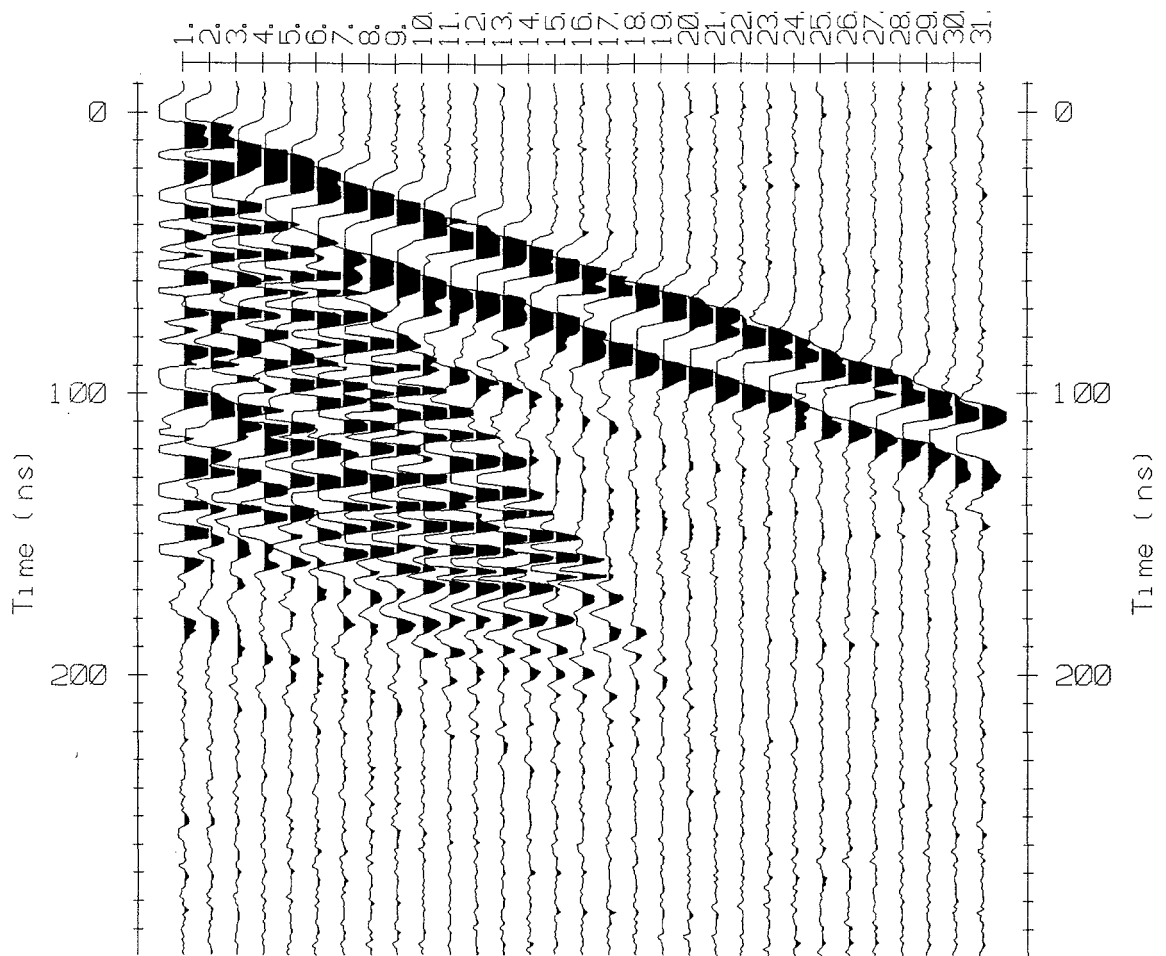
NUMBER OF TRACES = 31
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 47
TOTAL TIME WINDOW = 400
STARTING POSITION = 1.000000
FINAL POSITION = 31.000000
STEP SIZE USED = 1.000000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 64
SURVEY MODE = CMP/WARR
TRACES REPOSITIONED.

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 31

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.140"
Trace Width : 0.262"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\cmp2-595.hd

Kailine 2 CMP at 595

22/07/96

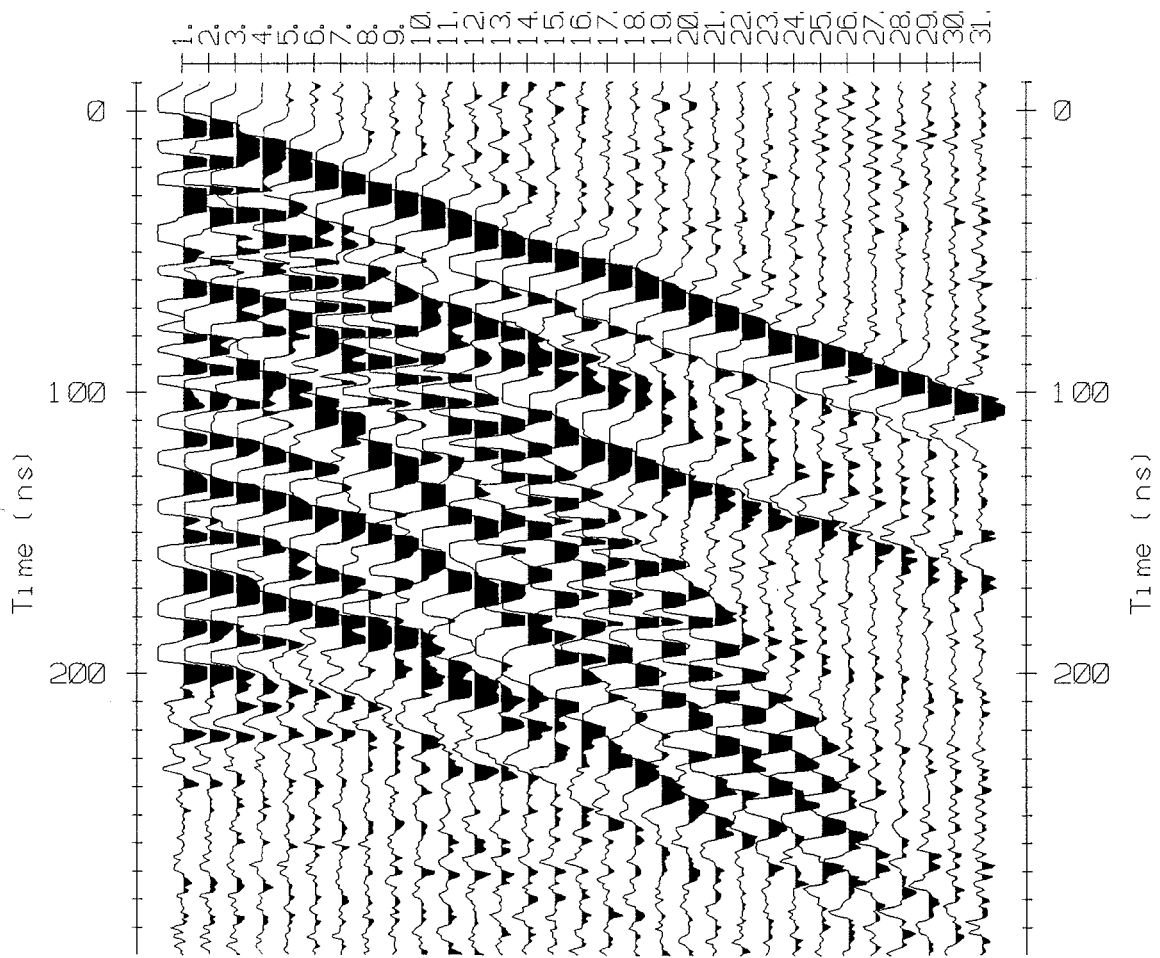
NUMBER OF TRACES = 31
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 59
TOTAL TIME WINDOW = 400
STARTING POSITION = 1.000000
FINAL POSITION = 31.000000
STEP SIZE USED = 1.000000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = CMP/WARR
POSITIONS RENUMBERED
TRACES REPOSITIONED.

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 31

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.140"
Trace Width : 0.262"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\rbcmp.hd

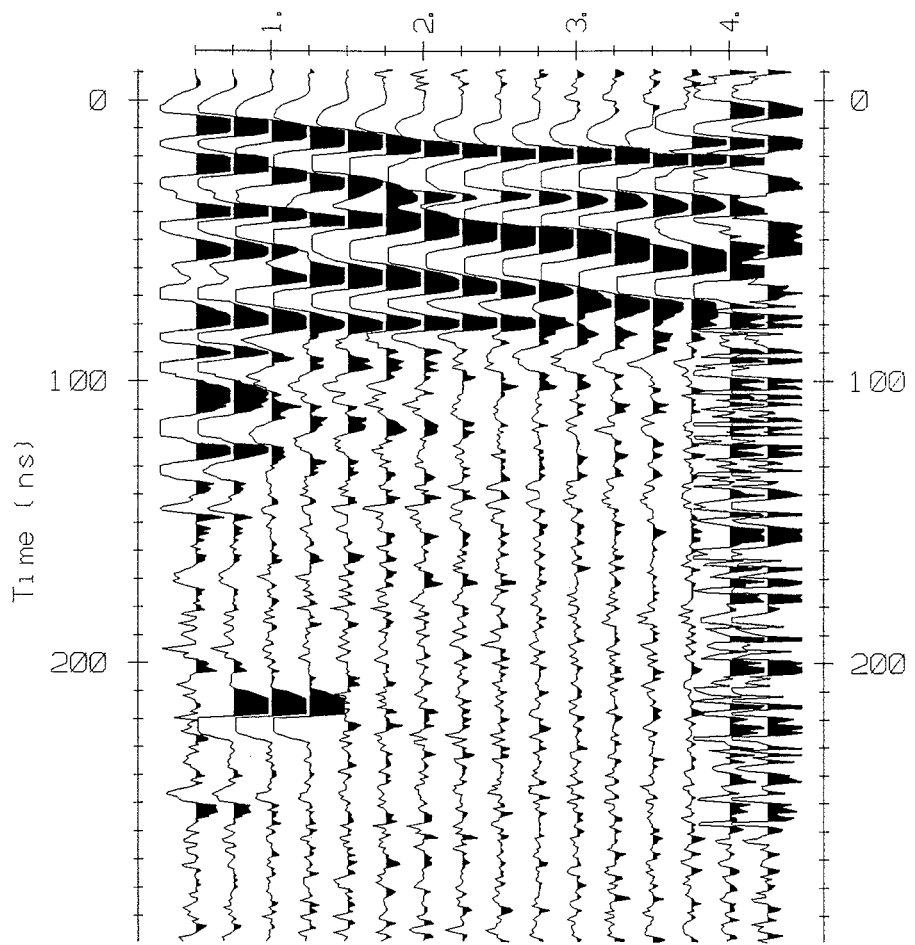
cmp on regressive barrier
17/04/97
NUMBER OF TRACES = 16
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 71
TOTAL TIME WINDOW = 400
STARTING POSITION = 0.5000
FINAL POSITION = 4.2500
STEP SIZE USED = 0.2500
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 16

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.200"
Trace Width : 0.375"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\drcmp.hd

cmp at dune engulfing ridge
17/04/97

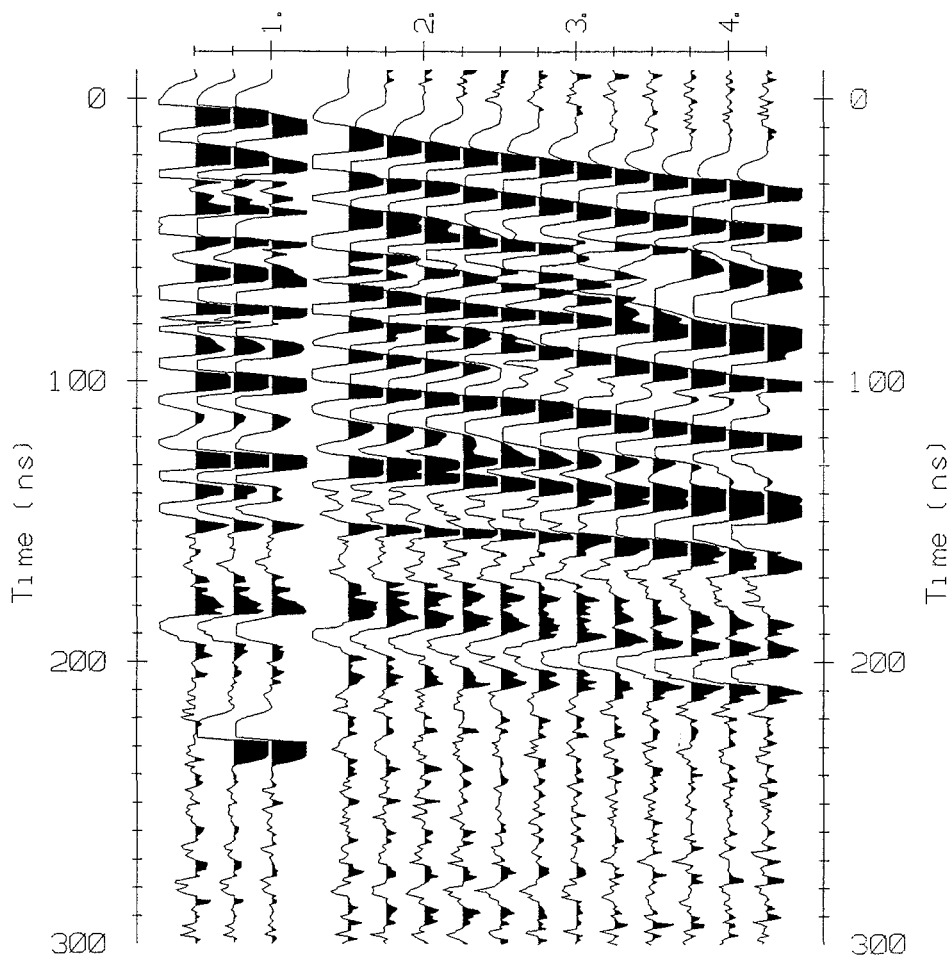
NUMBER OF TRACES = 16
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 60
TOTAL TIME WINDOW = 400
STARTING POSITION = 0.5000
FINAL POSITION = 4.2500
STEP SIZE USED = 0.2500
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 16

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.200"
Trace Width : 0.375"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\islldcmp.hd

CMP AT 200 ON RIDGEA

19/05/97

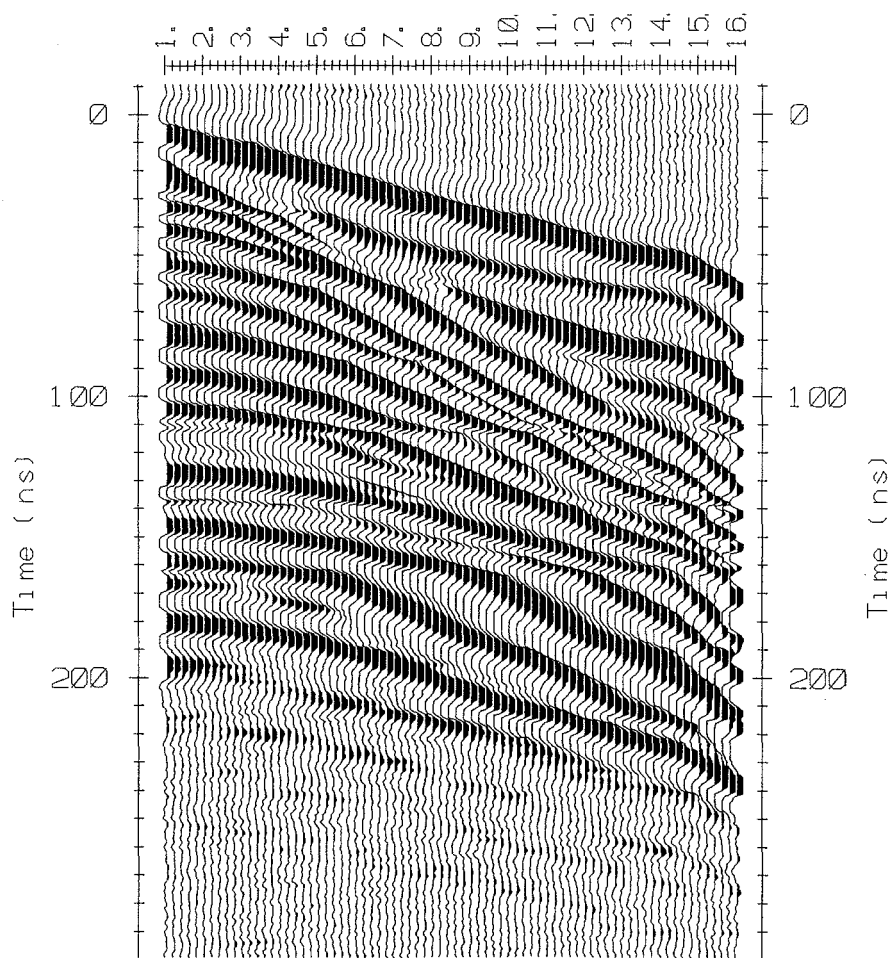
NUMBER OF TRACES = 76
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 52
TOTAL TIME WINDOW = 400
STARTING POSITION = 1.0000
FINAL POSITION = 16.0000
STEP SIZE USED = 0.2000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 76

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.040"
Trace Width : 0.075"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\cmpsn100.hd

cmp at 100m on pondssn

20/05/97

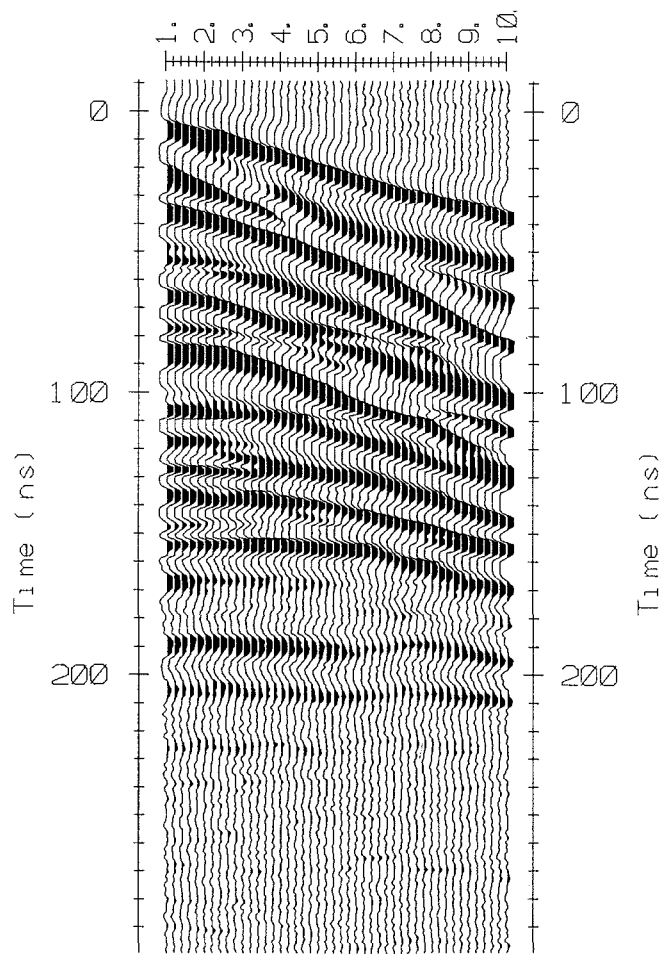
NUMBER OF TRACES = 46
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 56
TOTAL TIME WINDOW = 400
STARTING POSITION = 1.0000
FINAL POSITION = 10.0000
STEP SIZE USED = 0.2000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 46

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.040"
Trace Width : 0.075"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\cmp700.hd

cmp at 700m

06/05/97

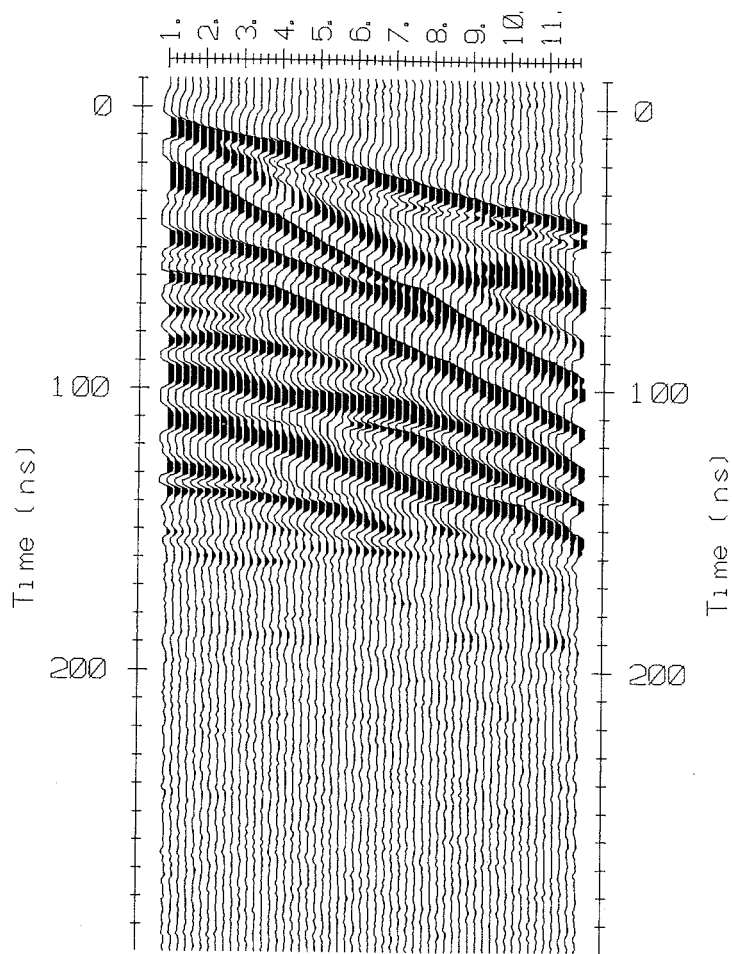
NUMBER OF TRACES = 55
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 49
TOTAL TIME WINDOW = 400
STARTING POSITION = 1.0000
FINAL POSITION = 11.8000
STEP SIZE USED = 0.2000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 55

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.040"
Trace Width : 0.075"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\bspcompew.hd

cmp on west side of pit

21/11/96

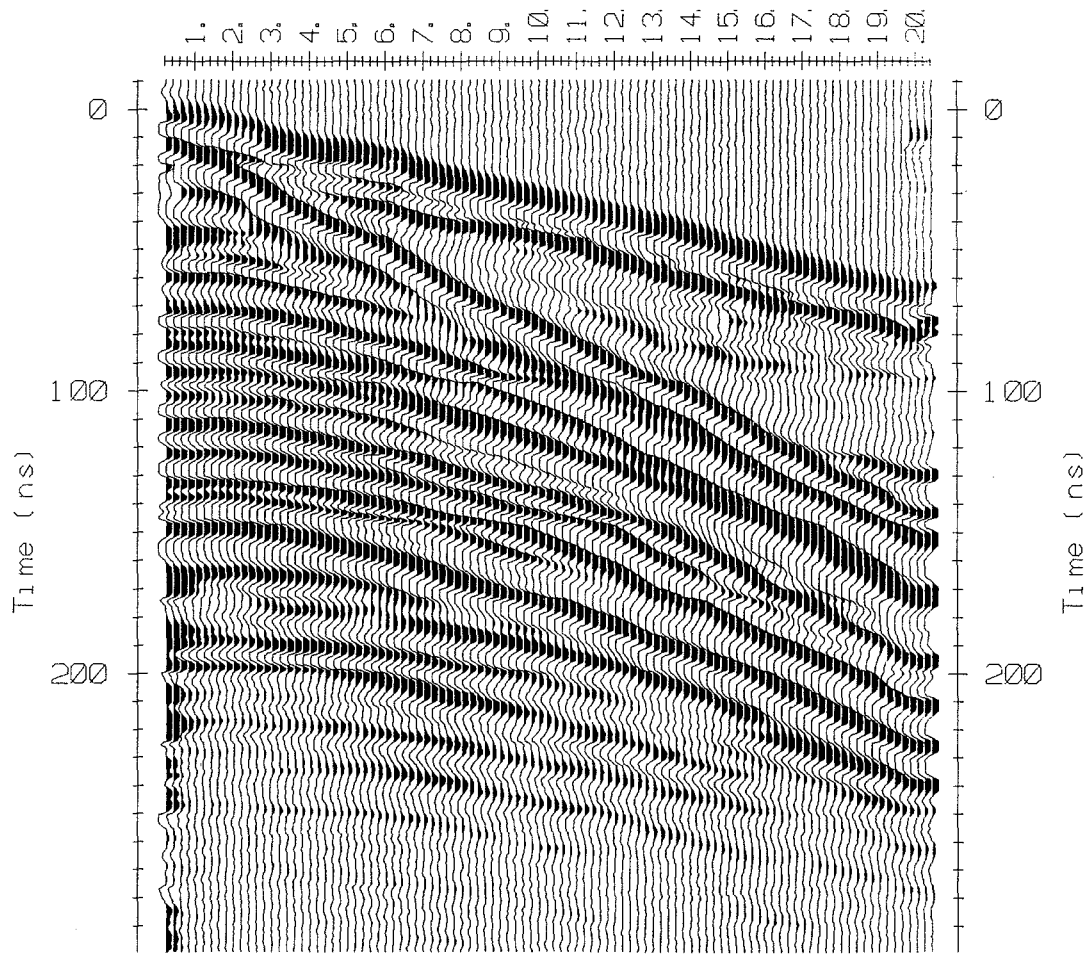
NUMBER OF TRACES = 102
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 72
TOTAL TIME WINDOW = 400
STARTING POSITION = 0.2000
FINAL POSITION = 20.4000
STEP SIZE USED = 0.2000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 64
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 102

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.040"
Trace Width : 0.075"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\bspmpm.hd

cmp in brown's pit

21/11/96

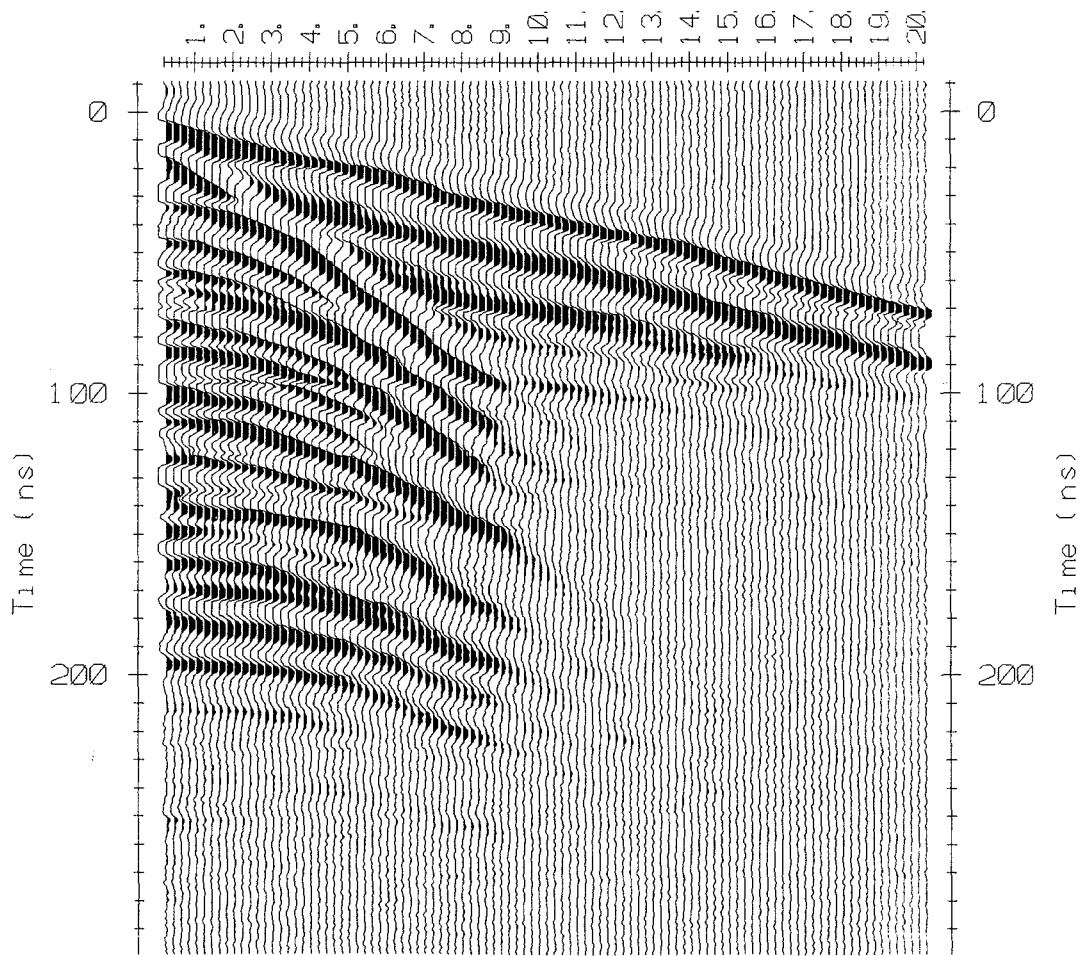
NUMBER OF TRACES = 101
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 71
TOTAL TIME WINDOW = 400
STARTING POSITION = 0.2000
FINAL POSITION = 20.2000
STEP SIZE USED = 0.2000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 64
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 101

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.040"
Trace Width : 0.075"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\brcmp.hd

cmp at beginning of breachns

03/01/80

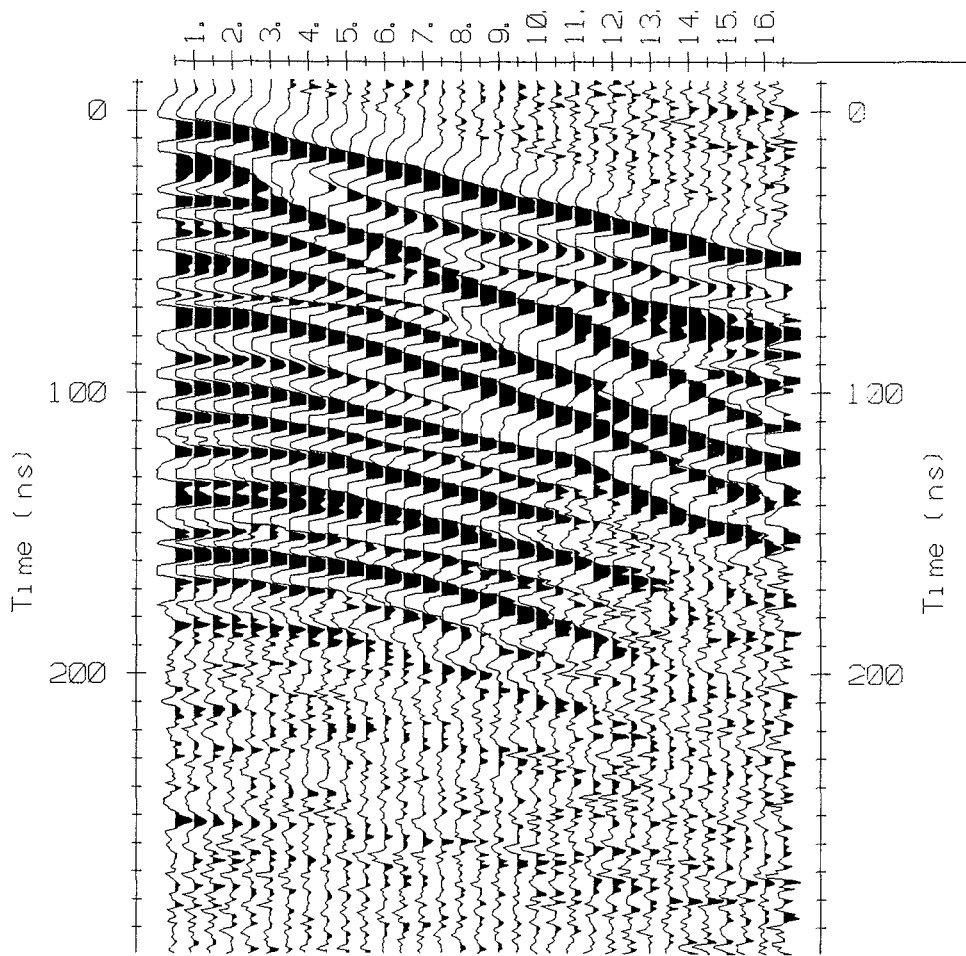
NUMBER OF TRACES = 34
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 41
TOTAL TIME WINDOW = 400
STARTING POSITION = 0.5000
FINAL POSITION = 17.0000
STEP SIZE USED = 0.5000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 34

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.100"
Trace Width : 0.188"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\cmp40.hd

cmp by forsyth

16/01/97

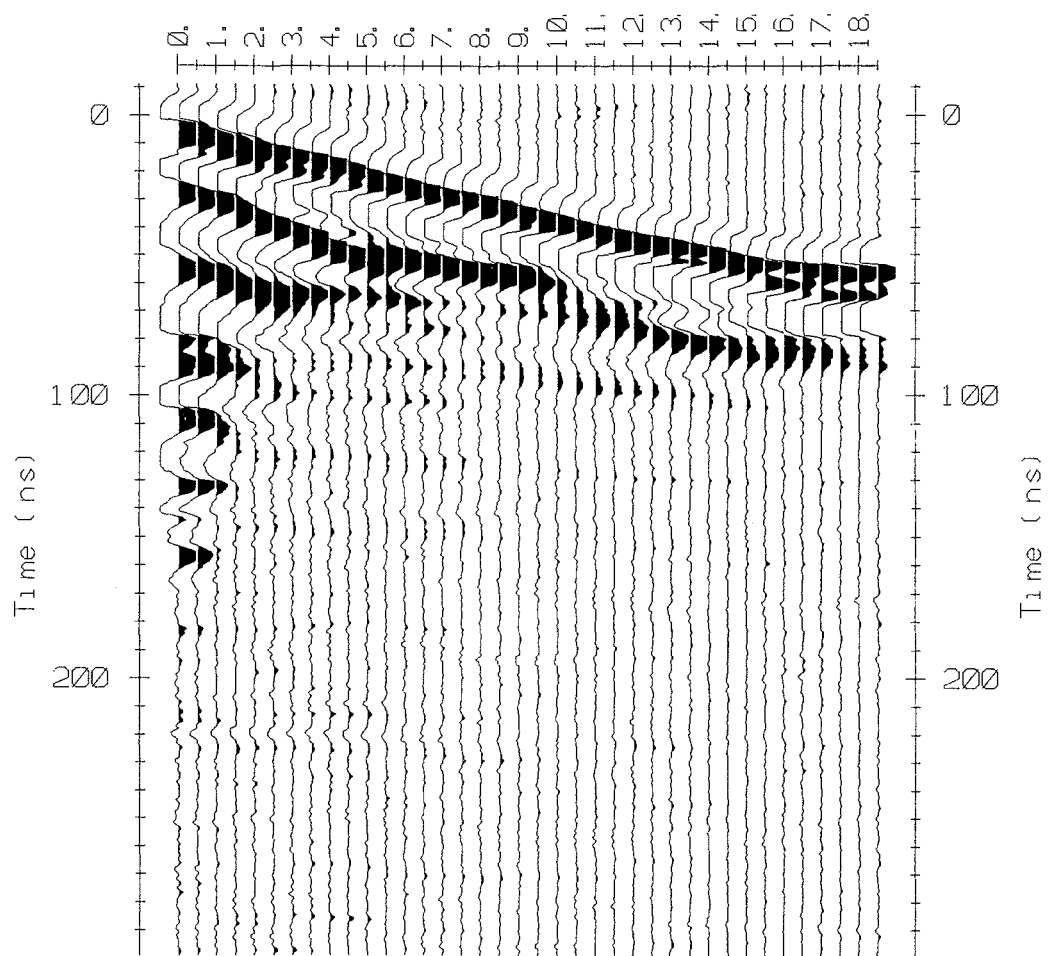
NUMBER OF TRACES = 38
NUMBER OF PTS/TRC = 625
TIMEZERO AT POINT = 61
TOTAL TIME WINDOW = 500
STARTING POSITION = 0.0000
FINAL POSITION = 18.5000
STEP SIZE USED = 0.5000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 64
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 38

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.100"
Trace Width : 0.188"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\fgcmp.hd

cmp for forsyth grid

21/01/97

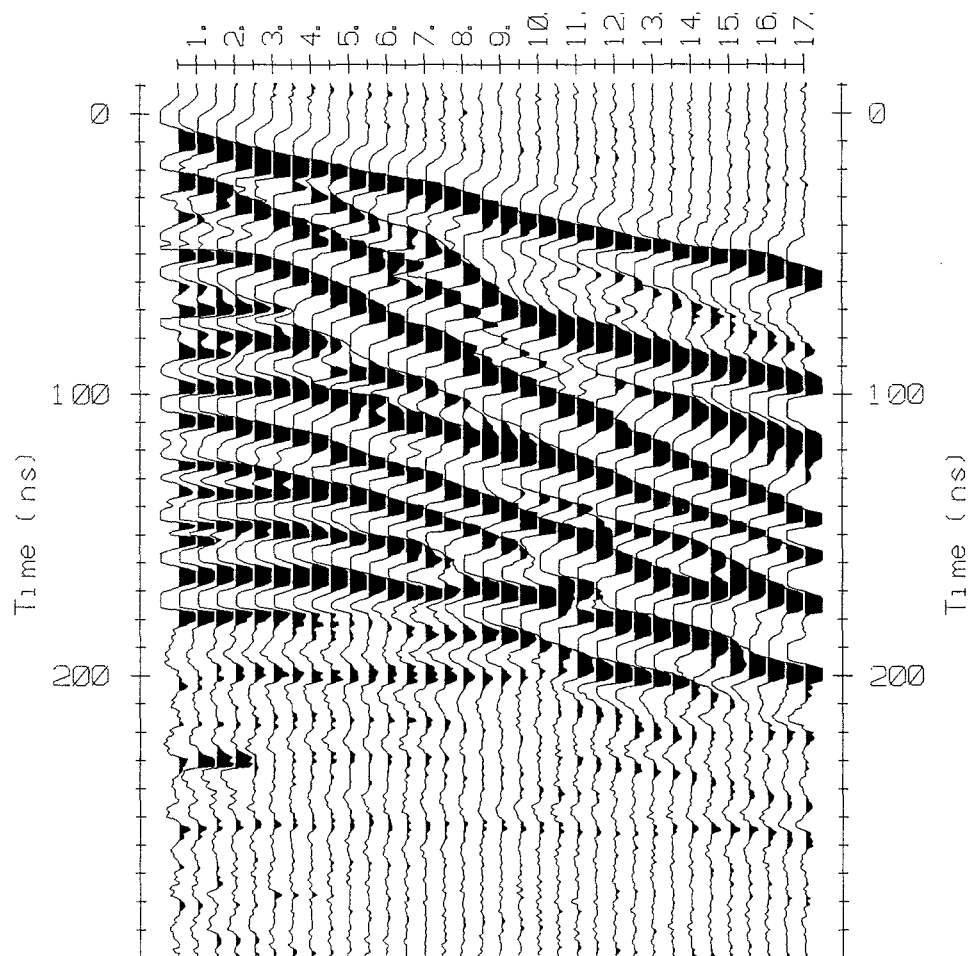
NUMBER OF TRACES = 34
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 67
TOTAL TIME WINDOW = 400
STARTING POSITION = 0.5000
FINAL POSITION = 17.0000
STEP SIZE USED = 0.5000
POSITION UNITS = metres.
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 34

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.100"
Trace Width : 0.188"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\cmplr78.hd

cmp at the end of lr7897 ie 200m
07/08/97

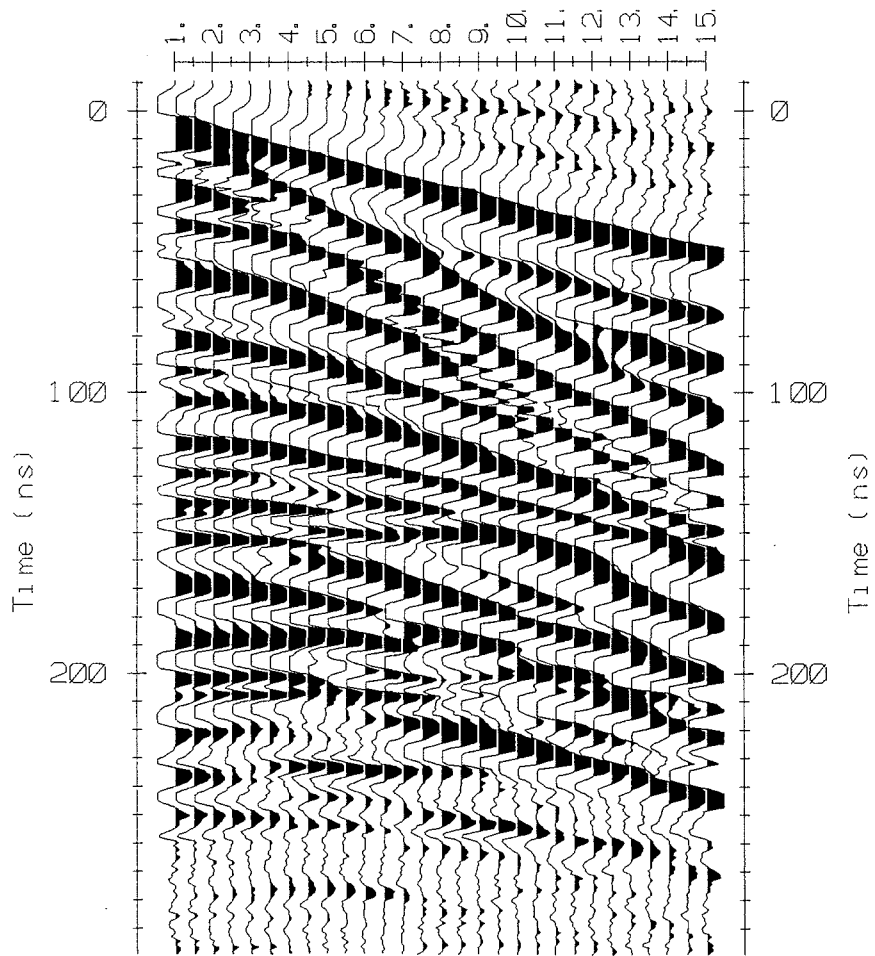
NUMBER OF TRACES = 29
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 62
TOTAL TIME WINDOW = 400
STARTING POSITION = 1.0000
FINAL POSITION = 15.0000
STEP SIZE USED = 0.5000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 29

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.100"
Trace Width : 0.188"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\cmplew1.hd

cmp at xm on line

03/01/80

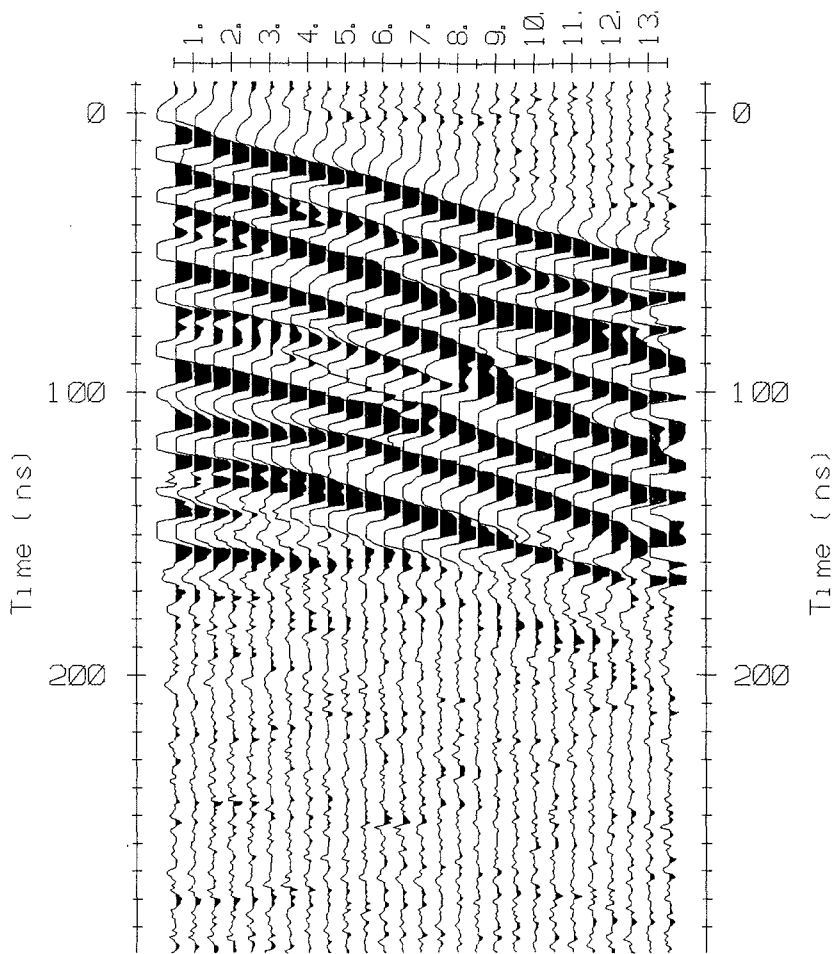
NUMBER OF TRACES = 27
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 31
TOTAL TIME WINDOW = 400
STARTING POSITION = 0.5000
FINAL POSITION = 13.5000
STEP SIZE USED = 0.5000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 27

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.100"
Trace Width : 0.188"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\k5cmp193.hd

CMP AT 192M ON TAURID1

24/07/97

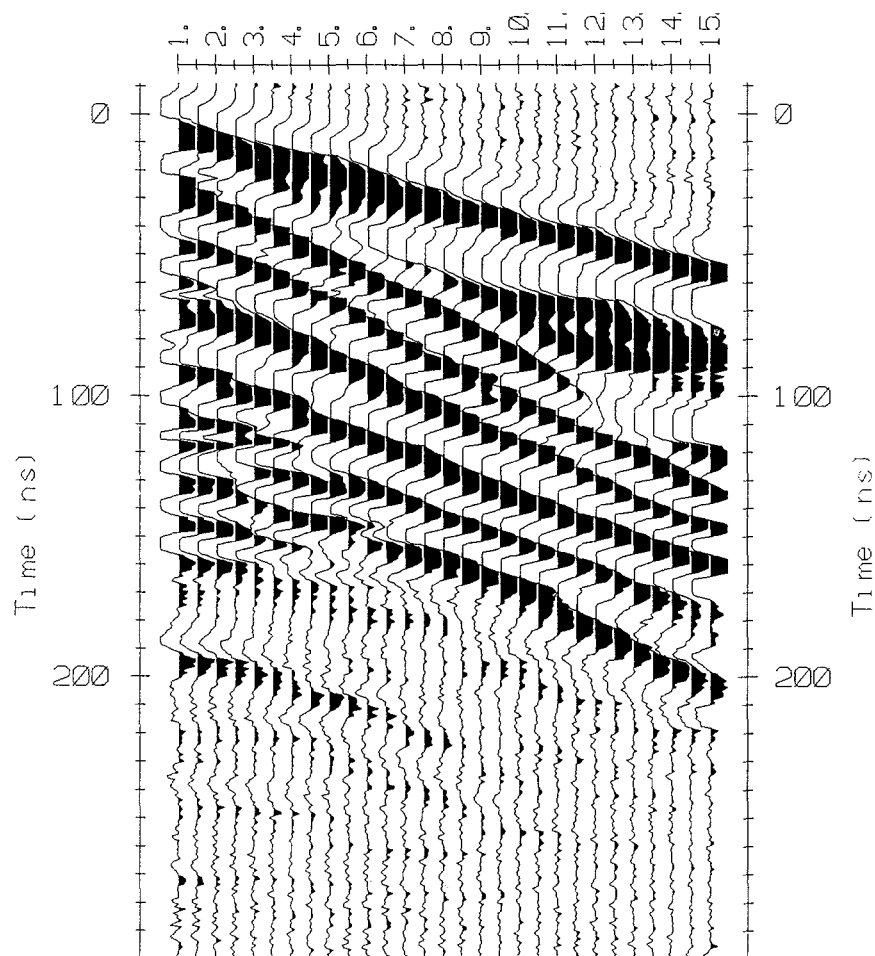
NUMBER OF TRACES = 29
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 46
TOTAL TIME WINDOW = 400
STARTING POSITION = 1.0000
FINAL POSITION = 15.0000
STEP SIZE USED = 0.5000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 29

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.100"
Trace Width : 0.188"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = c:\ampa\cmps\k5cmp361.hd

CMP AT 361M ON TAURID2

24/07/97

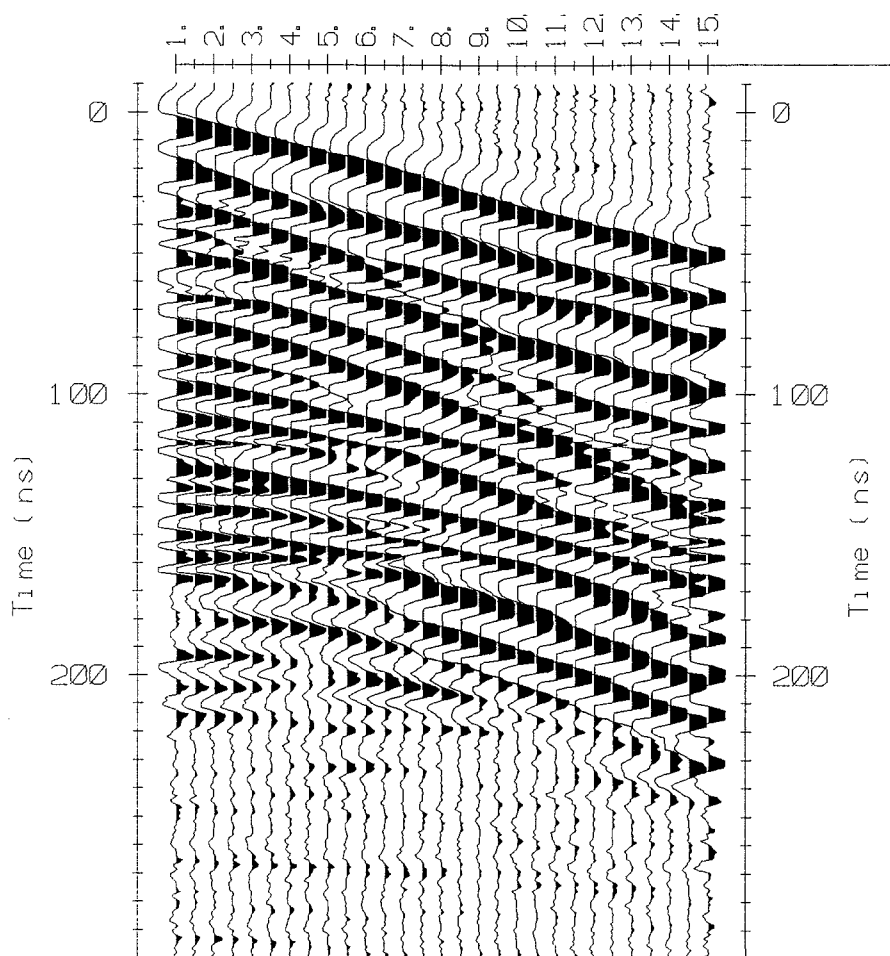
NUMBER OF TRACES = 30
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 44
TOTAL TIME WINDOW = 400
STARTING POSITION = 1.0000
FINAL POSITION = 15.5000
STEP SIZE USED = 0.5000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = CMP/WARR

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Gain Type : AGC
Window : 1.000 pulse widths
Amount : 1024 Maximum
Selection : Time = -10 to 300 ns
Trace = 1 to 30

PLOT LAYOUT PARAMETERS:

Trace Spacing : 0.100"
Trace Width : 0.188"
Trace Position : 3.000" to 7.500"
Left/Right Margin : 2.500" / 0.750"
Border Size : 0.400"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet II 300dpi



Appendix C Header Files

The following pages contain the pulseEKKO IV header files of all the radar profiles used in this thesis. They are listed in the follow order:

- Kailine1
- Kailine2
- Kailine3
- Kailine4
- Kailine5
- Browns Pit
- Jones Pit
- Trig Point
- Island
- Ponds
- Dune Ridge
- Transgressive Barrier
- Birdlings Ridges

The header files contain information on the plotting parameters for the profiles on Sheets 2 through to 14.

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\KAILINE1.hd

Kai line 1 lake side 2nd 100m. 100mhz
03/07/96

NUMBER OF TRACES = 8006
NUMBER OF PTS/TRC = 437
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 2001.250000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 64
SURVEY MODE = Reflection

SIGNAL SATURATION CORRECTION APPLIED

THIS FILE A MERGING OF \11 AND d:\radar\KAILINE1\R

FIRST BREAK POINT CORRECTED. THRESHOLD = -2000

FIRST BREAK SHIFT APPLIED.

THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.

ELEVATION DATA ENTERED : MAX = 9.045661 MIN = 2.5

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\KAILINE2.hd

Kailine 2 on Bill Lewthwaites land
20/07/96

NUMBER OF TRACES = 6205
NUMBER OF PTS/TRC = 438
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 5.000000
FINAL POSITION = 1556.000000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 64
SURVEY MODE = Reflection

THIS FILE A MERGING OF \10 AND d:\radar\kailine2\ra
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED.
THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
ELEVATION DATA ENTERED : MAX = 7.961838 MIN = 1.3

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 5.000 to 5.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\KAILINE3.hd

Kialine3 starting out on lake heading Seaward
24/07/96

NUMBER OF TRACES = 9461
NUMBER OF PTS/TRC = 437
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 35.000000
FINAL POSITION = 2400.000000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = Reflection
SIGNAL SATURATION CORRECTION APPLIED
THIS FILE A MERGING OF \12 AND d:\radar\KAILINE3\R
FIRST BREAK POINT CORRECTED. THRESHOLD = -1500
FIRST BREAK SHIFT APPLIED.
THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
ELEVATION DATA ENTERED : MAX = 10.746375 MIN = 1.

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 35.000 to 35.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\KAILINE4.hd

LINE FROM FORSYTH ACROSS BIRDLINGS FLAT
16/01/97

NUMBER OF TRACES = 6401
NUMBER OF PTS/TRC = 437
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 1600.000000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 64
SURVEY MODE = Reflection
THIS FILE A MERGING OF \6 AND C:\AMPA\KAILINE4\KAI4
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED.
THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
ELEVATION DATA ENTERED : MAX = 9.569615 MIN = 2.8

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\KAILINE5.hd

RADAR LINE AT TAUMUTU END OF KAITORETE FROM HIGH LE
BED OVER LAKE RIDGE TO BASE OF DUNES

24/07/97

NUMBER OF TRACES = 2001

NUMBER OF PTS/TRC = 437

TIMEZERO AT POINT = 0

TOTAL TIME WINDOW = 350

STARTING POSITION = 0.000000

FINAL POSITION = 500.000000

STEP SIZE USED = 0.250000

POSITION UNITS = metres

NOMINAL FREQUENCY = 100.000000

ANTENNA SEPARATION = 1.000000

PULSER VOLTAGE (V) = 400

NUMBER OF STACKS = 32

SURVEY MODE = Reflection

THIS FILE A MERGING OF \2 AND C:\AMPA\KAILINE5\KAI5
SIGNAL SATURATION CORRECTION APPLIED

FIRST BREAK POINT CORRECTED. THRESHOLD = -2000

FIRST BREAK SHIFT APPLIED.

THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.

ELEVATION DATA ENTERED : MAX = 8.324735 MIN = 2.8

PROCESSING SELECTED:

Trace Stacking : 3

Points Stacking : 3

Trace Differencing: N

Correction : DEWOW

Gain Type : AGC

Window : 1.000 pulsewidths

Amount : 500 Maximum

Selection : Time = 0 to 250 ns

Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800

Width/Spacing Ratio: 2.250

Trace Position : 1.000" to 6.000"

Left/Right Margin : 0.500" / 0.500"

Border Size : 0.500"

Page Length/Width : 10.900" / 7.900"

Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\PITENS.hd

n-s west side brown's pit

21/11/96

NUMBER OF TRACES = 217
NUMBER OF PTS/TRC = 438
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 54.000000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 64
SURVEY MODE = Reflection
SOURCE DATA FILE = d:\radar\BROWNSPT\RAWDATA\PIT
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED.
THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
ELEVATION DATA ENTERED : MAX = 11.399922 MIN = 11

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\PITEWE.hd

w-e south side brown's pit
21/11/96

NUMBER OF TRACES = 269
NUMBER OF PTS/TRC = 438
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 67.000000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 64
SURVEY MODE = Reflection
SOURCE DATA FILE = d:\radar\BROWNSPT\RAWDATA\PIT
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED.

THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
ELEVATION DATA ENTERED : MAX = 11.144999 MIN = 11

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\PITNS.hd

n-s in brown's pit

21/11/96

NUMBER OF TRACES = 381
NUMBER OF PTS/TRC = 438
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 95.000000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 64
SURVEY MODE = Reflection
SOURCE DATA FILE = d:\radar\BROWNSPT\RAWDATA\PIT
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED.
THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
ELEVATION DATA ENTERED : MAX = 3.713228 MIN = 2.8

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\PITWE.hd

w-e in brown's pit

21/11/96

NUMBER OF TRACES = 557
NUMBER OF PTS/TRC = 437
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 139.000000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 64
SURVEY MODE = Reflection
SOURCE DATA FILE = d:\radar\BROWNSPT\RAWDATA\PIT
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED.
THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
ELEVATION DATA ENTERED : MAX = 4.343309 MIN = 2.9

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\JONESPT1.hd

lake ridges next to jones' pit
400m long kinked at 100m
06/05/97

NUMBER OF TRACES = 3200
NUMBER OF PTS/TRC = 437
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 799.750000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = Reflection
THIS FILE A MERGING OF \3 AND d:\radar\JONESPIT\RAW
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED.
THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
ELEVATION DATA ENTERED : MAX = 8.471573 MIN = 3.6
TRACES REPOSITIONED.

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\JONESPT2.hd

line over lake ridge? north of bayleys road just ps
cattle stop, line 200m long

07/08/97

NUMBER OF TRACES = 801
NUMBER OF PTS/TRC = 437
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 200.000000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = Reflection
SOURCE DATA FILE = d:\radar\JONESPIT\RAWDATA\JONE
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED.
THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
ELEVATION DATA ENTERED : MAX = 8.948820 MIN = 5.2

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\TRIGPTNS.hd

lines over overtopped ridge?

03/01/80

NUMBER OF TRACES = 1001

NUMBER OF PTS/TRC = 438

TIMEZERO AT POINT = 0

TOTAL TIME WINDOW = 350

STARTING POSITION = 0.000000

FINAL POSITION = 250.000000

STEP SIZE USED = 0.250000

POSITION UNITS = metres

NOMINAL FREQUENCY = 100.000000

ANTENNA SEPARATION = 1.000000

PULSER VOLTAGE (V) = 400

NUMBER OF STACKS = 32

SURVEY MODE = Reflection

SOURCE DATA FILE = d:\radar\TRIGPNT\RAWDATA\BREA

SIGNAL SATURATION CORRECTION APPLIED

FIRST BREAK POINT CORRECTED. THRESHOLD = -2000

FIRST BREAK SHIFT APPLIED.

THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.

ELEVATION DATA ENTERED : MAX = 6.336406 MIN = 1.1

PROCESSING SELECTED:

Trace Stacking : 3

Points Stacking : 3

Trace Differencing: N

Correction : DEWOW

Gain Type : AGC

Window : 1.000 pulsewidths

Amount : 500 Maximum

Selection : Time = 0 to 250 ns

Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800

Width/Spacing Ratio: 2.250

Trace Position : 1.000" to 6.000"

Left/Right Margin : 0.500" / 0.500"

Border Size : 0.500"

Page Length/Width : 10.900" / 7.900"

Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\TRIGPTWE.hd

lines over overtopped ridge?

03/01/80

NUMBER OF TRACES = 400
NUMBER OF PTS/TRC = 438
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 99.750000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = Reflection
SOURCE DATA FILE = d:\radar\TRIGPNT\RAWDATA\BREA
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED.

THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
ELEVATION DATA ENTERED : MAX = 4.186634 MIN = 1.1

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\ISLDNS.hd

LINE OVER RIDGE ON LEWTHWAITES/BAYLEYS PROPERTY (IS
19/05/97

NUMBER OF TRACES = 1997
NUMBER OF PTS/TRC = 437
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 499.000000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = Reflection

THIS FILE A MERGING OF \2 AND d:\radar\ISLAND\RAWD
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED. THIS PROFILE CLIPPED FROM
THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
ELEVATION DATA ENTERED : MAX = 7.174081 MIN = 1.9

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\ISLDWE.hd

LINE PERPENDICULAR TO RIDGE & RIDGEA
CROSS PT AT 200 ON RIDGEA AND 50 ON RIDGEB
19/05/97

NUMBER OF TRACES = 401
NUMBER OF PTS/TRC = 438
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 100.000000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000 PULSER VOLTAGE (V) =
NUMBER OF STACKS = 32
SURVEY MODE = Reflection
SOURCE DATA FILE = d:\radar\ISLAND\RAWDATA\ISLDW
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED.
THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
PROFILING DIRECTION HAS BEEN REVERSED
TRACES REPOSITIONED.
ELEVATION DATA ENTERED : MAX = 6.854925 MIN = 6.6

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\ISLDNWSE.hd

eroded end of breach pt
20/05/97

NUMBER OF TRACES = 401
NUMBER OF PTS/TRC = 437
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 100.000000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = Reflection
SOURCE DATA FILE = d:\radar\ISLAND\RAWDATA\ISLDN
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED.
THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
TRACES REPOSITIONED.
PROFILING DIRECTION HAS BEEN REVERSED
ELEVATION DATA ENTERED : MAX = 6.386723 MIN = 4.3
PROFILING DIRECTION HAS BEEN REVERSED
TRACES REPOSITIONED.

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\PONDSSN.hd

line perpendicular to pondsew crosses at 250m ponds
pondssn

20/05/97

NUMBER OF TRACES = 401
NUMBER OF PTS/TRC = 436
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 100.000000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = Reflection
SOURCE DATA FILE = d:\radar\\PONDS\RAWDATA\PONDSS
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED.

THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.

PROFILING DIRECTION HAS BEEN REVERSED

TRACES REPOSITIONED.

ELEVATION DATA ENTERED : MAX = 6.470860 MIN = 2.9

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\PONDSWE.hd

ponds across pondsns checking strike
03/01/80

NUMBER OF TRACES = 400
NUMBER OF PTS/TRC = 438
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 99.750000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = Reflection
SOURCE DATA FILE = d:\radar\\PONDS\RAWDATA\PONDSW
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED.
THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
ELEVATION DATA ENTERED : MAX = 5.092815 MIN = 2.8

PROFILING DIRECTION HAS BEEN REVERSED
TRACES REPOSITIONED.

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\PONDSNS.hd

LINE OVER AREA OF OLD PONDS? ON LEWTHWAITES PROPERT
POSS. SIMILAR TO BREACH AREA

03/01/80

NUMBER OF TRACES = 1602

NUMBER OF PTS/TRC = 436

TIMEZERO AT POINT = 0

TOTAL TIME WINDOW = 350

STARTING POSITION = 0.000000

FINAL POSITION = 400.250000

STEP SIZE USED = 0.250000

POSITION UNITS = metres

NOMINAL FREQUENCY = 100.000000

ANTENNA SEPARATION = 1.000000

PULSER VOLTAGE (V) = 400

NUMBER OF STACKS = 32

SURVEY MODE = Reflection

THIS FILE A MERGING OF \3 AND d:\radar\\PONDS\RAWDA
SIGNAL SATURATION CORRECTION APPLIED

FIRST BREAK POINT CORRECTED. THRESHOLD = -2000

FIRST BREAK SHIFT APPLIED.

THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.

ELEVATION DATA ENTERED : MAX = 7.499547 MIN = 2.7

PROCESSING SELECTED:

Trace Stacking : 3

Points Stacking : 3

Trace Differencing: N

Correction : DEWOW

Gain Type : AGC

Window : 1.000 pulsewidths

Amount : 500 Maximum

Selection : Time = 0 to 250 ns

Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800

Width/Spacing Ratio: 2.250

Trace Position : 1.000" to 6.000"

Left/Right Margin : 0.500" / 0.500"

Border Size : 0.500"

Page Length/Width : 10.900" / 7.900"

Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\PONDSEW.hd

line over spit recurves in 'ponds' 280m long going west

20/05/97

NUMBER OF TRACES = 1121
NUMBER OF PTS/TRC = 437
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 280.000000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = Reflection
SOURCE DATA FILE = d:\radar\ \PONDS\RAWDATA\PONDSE
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED.
THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
ELEVATION DATA ENTERED : MAX = 6.098135 MIN = 3.0

PROFILING DIRECTION HAS BEEN REVERSED
TRACES REPOSITIONED.

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\duneride.hd

Line over lake ridge engulfed by dunes2
17/04/97

NUMBER OF TRACES = 194
NUMBER OF PTS/TRC = 437
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 48.250000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = Reflection
SOURCE DATA FILE = d:\radar\\DUNERID\RAWDATA\DUNE
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED.
THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
ELEVATION DATA ENTERED : MAX = 11.697867 MIN = 6.
PROFILING DIRECTION HAS BEEN REVERSED
TRACES REPOSITIONED.
TRACES REPOSITIONED.

TRACES REPOSITIONED.

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 2.000" to 6.100"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\DUNERIDW.hd

Line over lake ridge engulfed by dunes
17/04/97

NUMBER OF TRACES = 153
NUMBER OF PTS/TRC = 438
TIMEZERO AT POINT = 0
TOTAL TIME WINDOW = 350
STARTING POSITION = 0.000000
FINAL POSITION = 38.000000
STEP SIZE USED = 0.250000
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.000000
ANTENNA SEPARATION = 1.000000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = Reflection
SOURCE DATA FILE = d:\radar\DUNERID\RAWDATA\DUNE
SIGNAL SATURATION CORRECTION APPLIED
FIRST BREAK POINT CORRECTED. THRESHOLD = -2000
FIRST BREAK SHIFT APPLIED.
THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.
PROFILING DIRECTION HAS BEEN REVERSED
TRACES REPOSITIONED.
ELEVATION DATA ENTERED : MAX = 10.592000 MIN = 6.

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\TRANSBAR.hd

Line over 'transgressive' barrier near Taumutu
17/04/97

NUMBER OF TRACES = 701
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 53
TOTAL TIME WINDOW = 400
STARTING POSITION = 0.0000
FINAL POSITION = 175.0000
STEP SIZE USED = 0.2500
POSITION UNITS = metres
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 1.0000
PULSER VOLTAGE (V) = 400
NUMBER OF STACKS = 32
SURVEY MODE = Reflection
SOURCE DATA FILE = c:\radar\transbar\rawdata\tran
ELEVATION DATA ENTERED : MAX = 4.760872 MIN = 0.5
TIMEZERO DRIFT CORRECTION APPLIED
SIGNAL SATURATION CORRECTION APPLIED

PROCESSING SELECTED:

Trace Stacking : 3
Points Stacking : 3
Trace Differencing: N
Correction : DEWOW
Gain Type : AGC
Window : 1.000 pulsewidths
Amount : 500 Maximum
Selection : Time = 0 to 250 ns
Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800
Width/Spacing Ratio: 2.250
Trace Position : 1.000" to 6.000"
Left/Right Margin : 0.500" / 0.500"
Border Size : 0.500"
Page Length/Width : 10.900" / 7.900"
Printer Name : HP LaserJet IV 600dpi

PulseEKKO Data Sheet

DATA FILE #1 PARAMETERS:

Data File = C:\EKKO42\BRDLNGS.hd

birdlings ridges

11/06/97

NUMBER OF TRACES = 521

NUMBER OF PTS/TRC = 437

TIMEZERO AT POINT = 0

TOTAL TIME WINDOW = 349

STARTING POSITION = 0.000000

FINAL POSITION = 130.000000

STEP SIZE USED = 0.250000

POSITION UNITS = metres

NOMINAL FREQUENCY = 100.000000

ANTENNA SEPARATION = 1.000000

PULSER VOLTAGE (V) = 400

NUMBER OF STACKS = 64

SURVEY MODE = Reflection

SOURCE DATA FILE = d:\radar\BRDLNG\RAWDATA\BRDLN

SIGNAL SATURATION CORRECTION APPLIED

FIRST BREAK POINT CORRECTED. THRESHOLD = -2000

FIRST BREAK SHIFT APPLIED.

THIS PROFILE CLIPPED FROM ORIGINAL PROFILE.

ELEVATION DATA ENTERED : MAX = 7.965528 MIN = 3.8

PROCESSING SELECTED:

Trace Stacking : 3

Points Stacking : 3

Trace Differencing: N

Correction : DEWOW

Gain Type : AGC

Window : 1.000 pulsewidths

Amount : 500 Maximum

Selection : Time = 0 to 250 ns

Position = 0.000 to 0.000

PLOT LAYOUT PARAMETERS:

Traces per Inch : 50.800

Width/Spacing Ratio: 2.250

Trace Position : 2.000" to 6.100"

Left/Right Margin : 0.500" / 0.500"

Border Size : 0.500"

Page Length/Width : 10.900" / 7.900"

Printer Name : HP LaserJet IV 600dpi

Appendix D Radar Station Spacing Calculation

Using the formula:

$$c = \lambda f \text{ (in cm ns}^{-1}\text{)}$$

where c =velocity of the radar wave in the medium in cm ns^{-1} ; λ =wave length of the radar wave in the medium in m; and f =the radar wave frequency in MHz.

Rearranging it to give λ we have:

$$\lambda = \frac{c}{f} \text{ (in m)}$$

The Nyquist frequency n_x is equal to a quarter of the wave length therefore:

$$n_x = \frac{c}{4f} \text{ (in m)}$$

So for a velocity of 70 cm ns^{-1} (0.07 m ns^{-1}) using the 100 MHz antennae, the resulting Nyquist frequency is:

$$\begin{aligned} n_x &= \frac{70}{4 \times 100} \\ &= 0.175 \quad \text{m} \end{aligned}$$

and for velocity of 180 cm ns^{-1} (0.18 m ns^{-1}) using the 100 MHz antennae, the resulting Nyquist frequency is:

$$\begin{aligned} n_x &= \frac{180}{4 \times 100} \\ &= 0.45 \quad \text{m} \end{aligned}$$

Therefore it was decided that a station spacing of 0.25 m was an adequate compromise for the conditions encountered on Kaitorete Spit.

Appendix E Pit and Drill Hole Logs

Water well logs were obtained from the Canterbury Regional Council for the following wells: (map sheet no./water well no.)

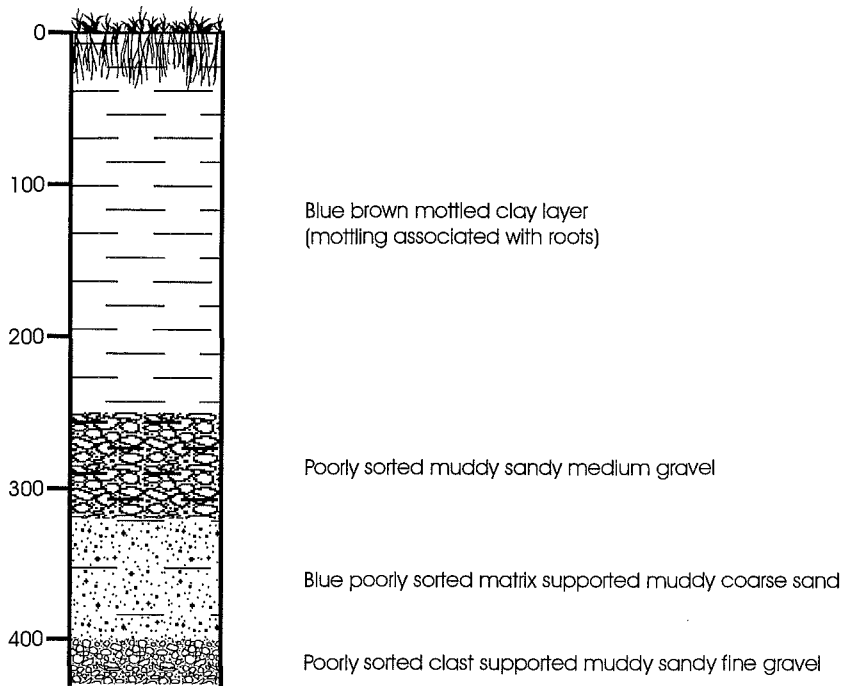
- M36/4109
- M36/4300
- M36/4829
- M36/0730
- M36/4830
- M37/0271
- M37/0094
- M37/0287

Presented below are the pit logs for the shallow pits dug in various places on Kaitorete Spit.

Lakeshore pit

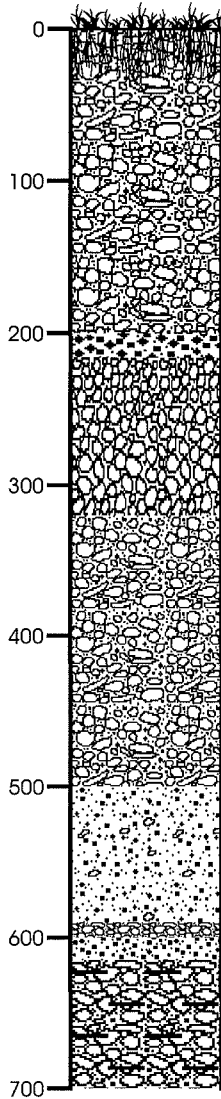
M37 673 085

Depth (mm)



Pit dug on Golf Course Lacustrine M37 837 106 Spit Complex

Depth (mm)



Very poorly sorted fine to coarse pebble gravel with a peaty matrix

Poorly sorted clast supported fine to medium sandy gravel
Matrix poorly sorted fine to coarse sand
The bed fines upward

Poorly sorted clast supported fine to coarse sandy gravel
Mode is medium
Matrix is poorly sorted fine to coarse sand
Mode is medium

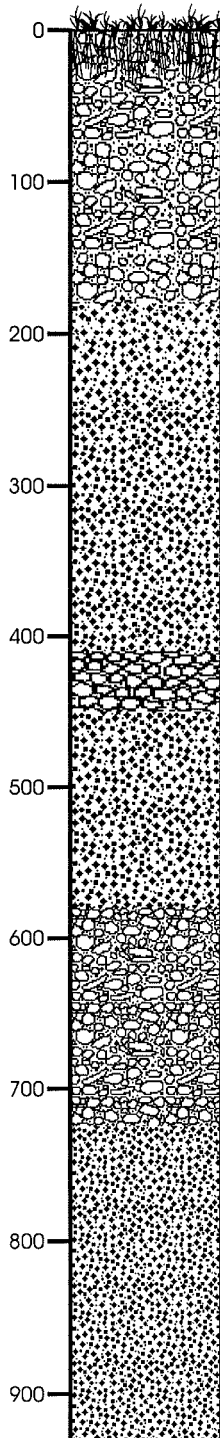
Moderately sorted matrix supported very coarse gravelly sand
~5% fine gravel

Moderately sorted medium sandy gravel with coarse sand matrix
Moderately sorted very coarse sand

Poorly sorted clast supported slightly muddy sandy medium gravel
Poorly sorted fine to very coarse sand matrix

Lake shore "recent" storm berm M37 616 061

Depth (mm)



Poorly sorted clast supported fine to coarse pebble sandy gravel with coarse to very coarse sand matrix (Poorly developed lakeward dipping imbrication)

Granule

Poorly sorted coarse sand to granule

Well sorted clast supported coarse pebble gravel

Poorly sorted coarse sand to granule

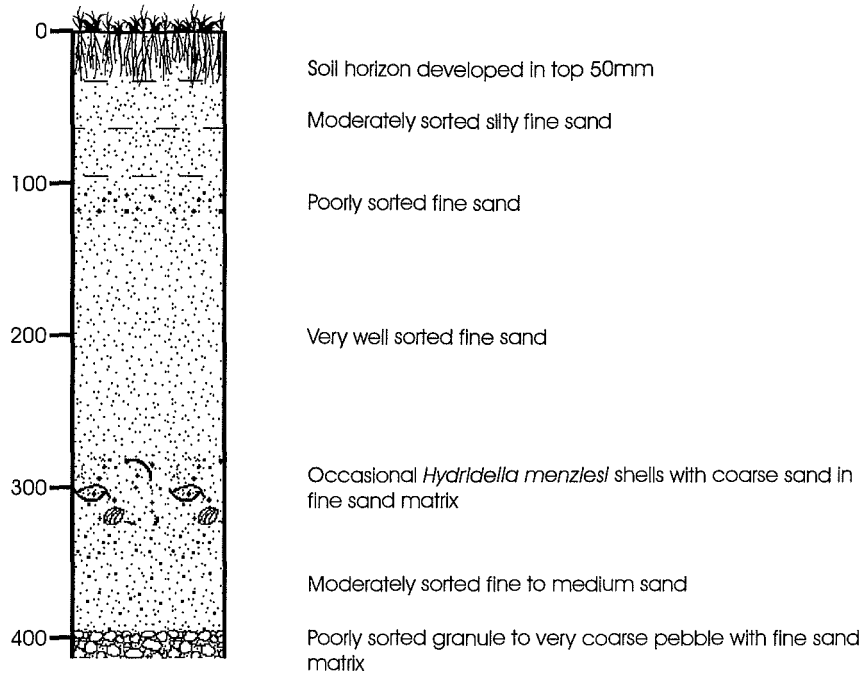
Moderately sorted clast supported clay coated medium pebble gravel

Blue poorly sorted medium sand to granule

Pit with Shells in it

M37 628 063

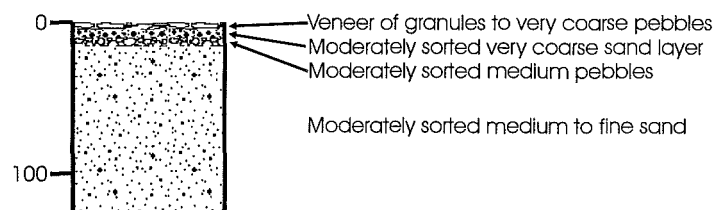
Depth (mm)



Dunerid

M37 627 062

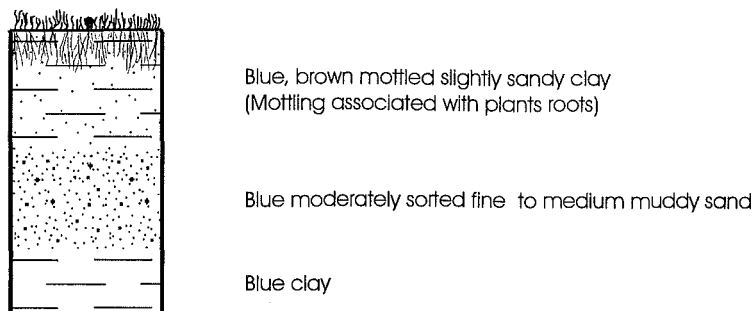
Depth (mm)



Mudflat

M37 628 072

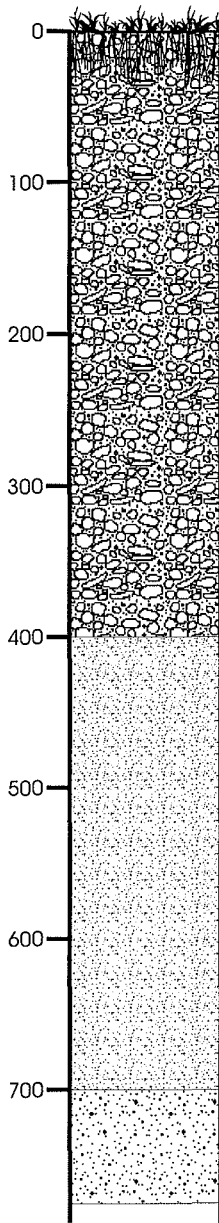
Depth (mm)



Birdlings Ridges

M36

Depth (mm)



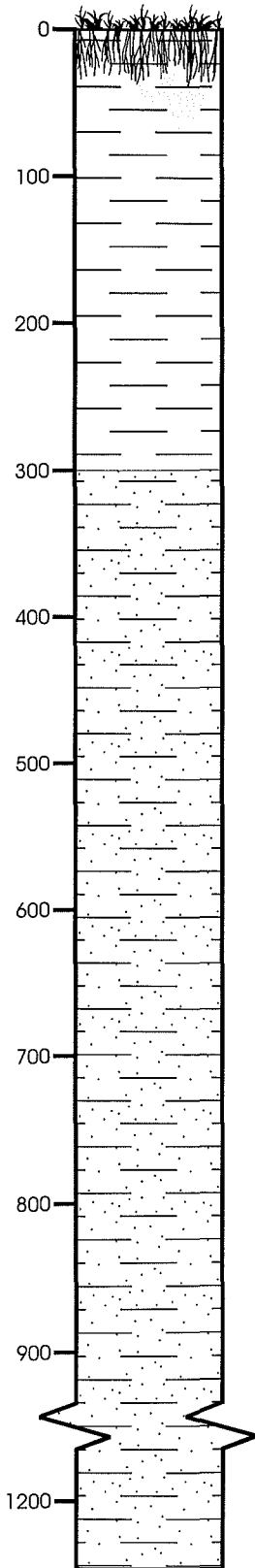
Structureless poorly sorted fine to medium gravels (slump material).

Yellow well sorted silt

Scattered periostracum fragments in yellow silt/very fine sand.

M37

Depth (mm)



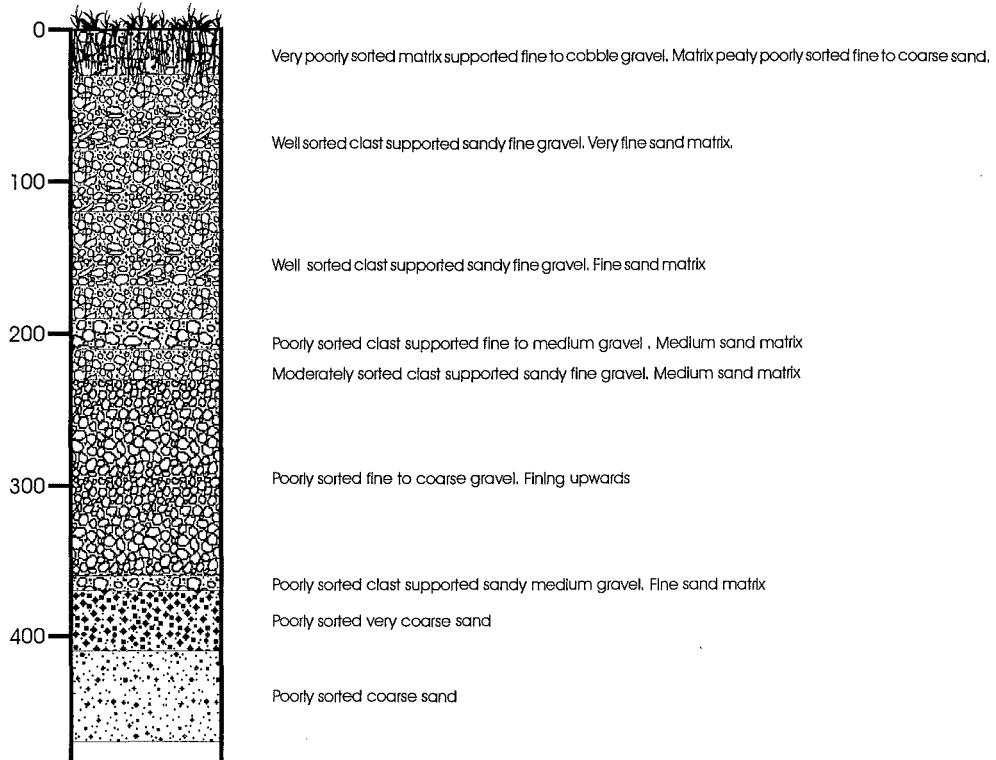
Brown blue mottled clay

Blue clay and silt

Peg 1 Kailine 1

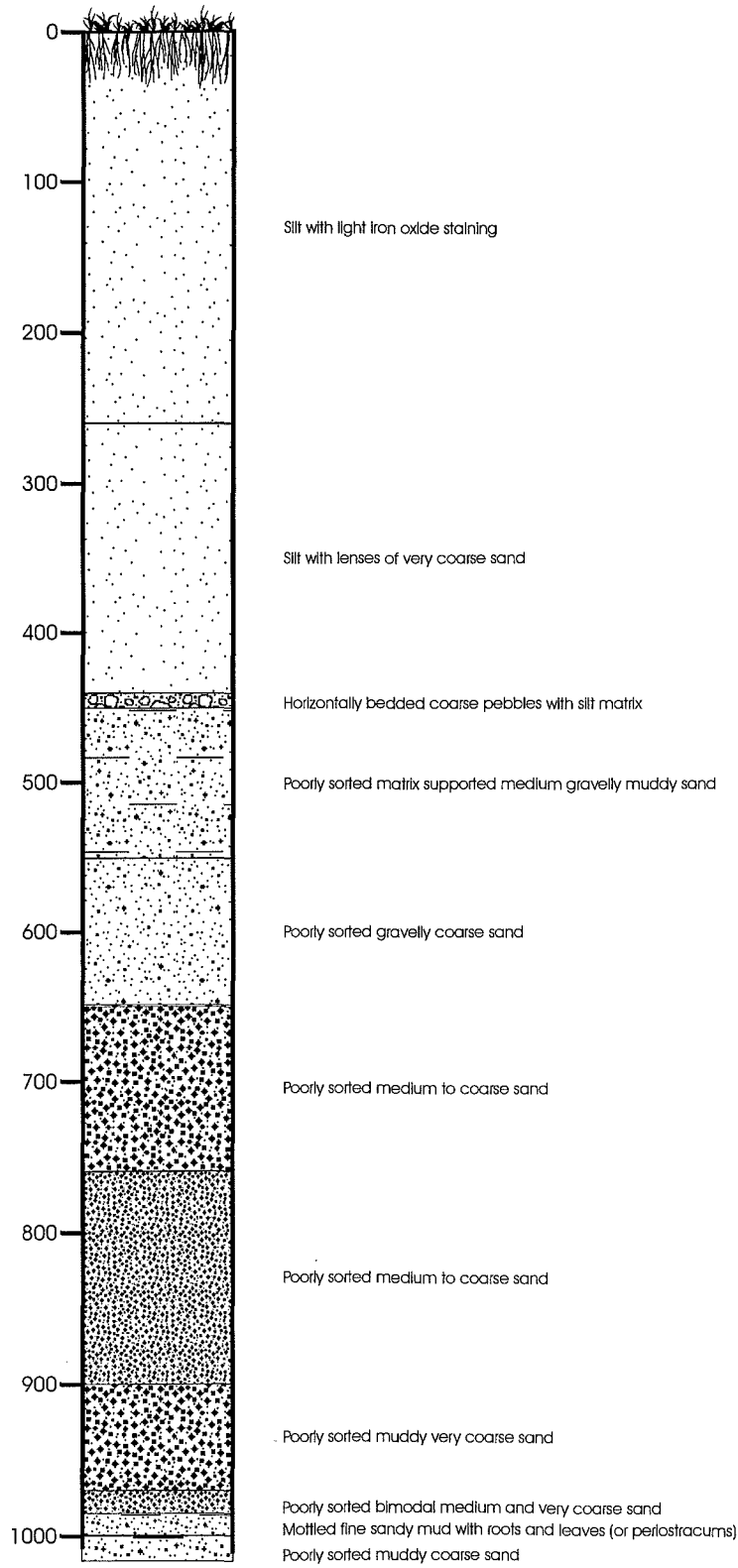
M37

Depth (mm)



On sinuous low relief ridge

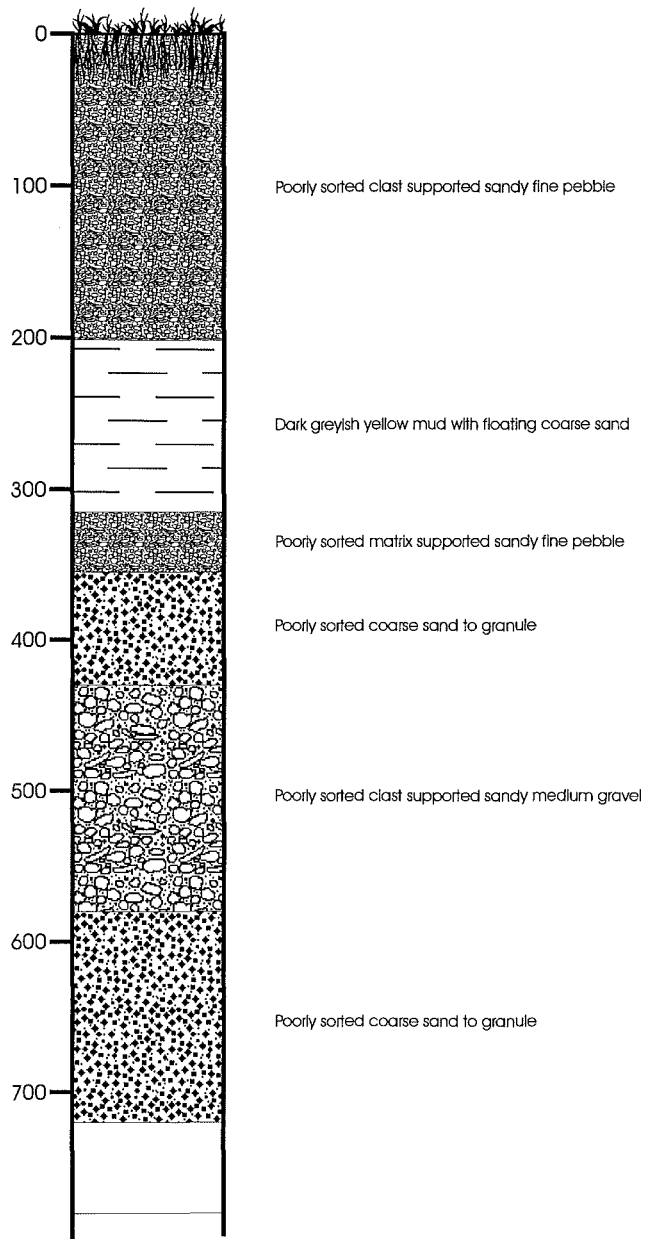
Depth (mm)



Ponds EW peg 2

M37

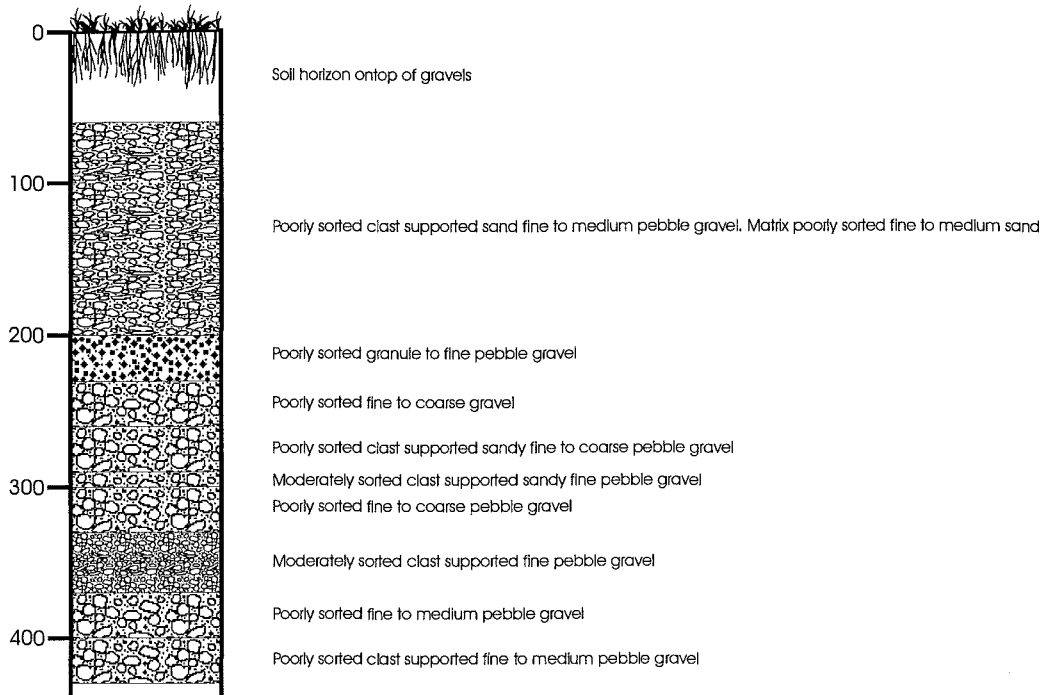
Depth (mm)



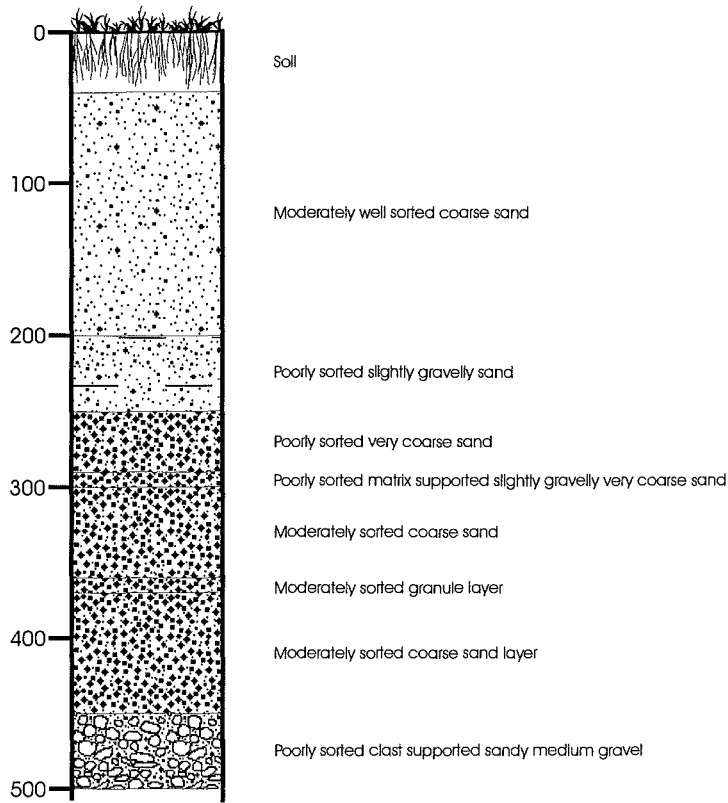
Pondsns Peg 1

M37 655 075

Depth (mm)



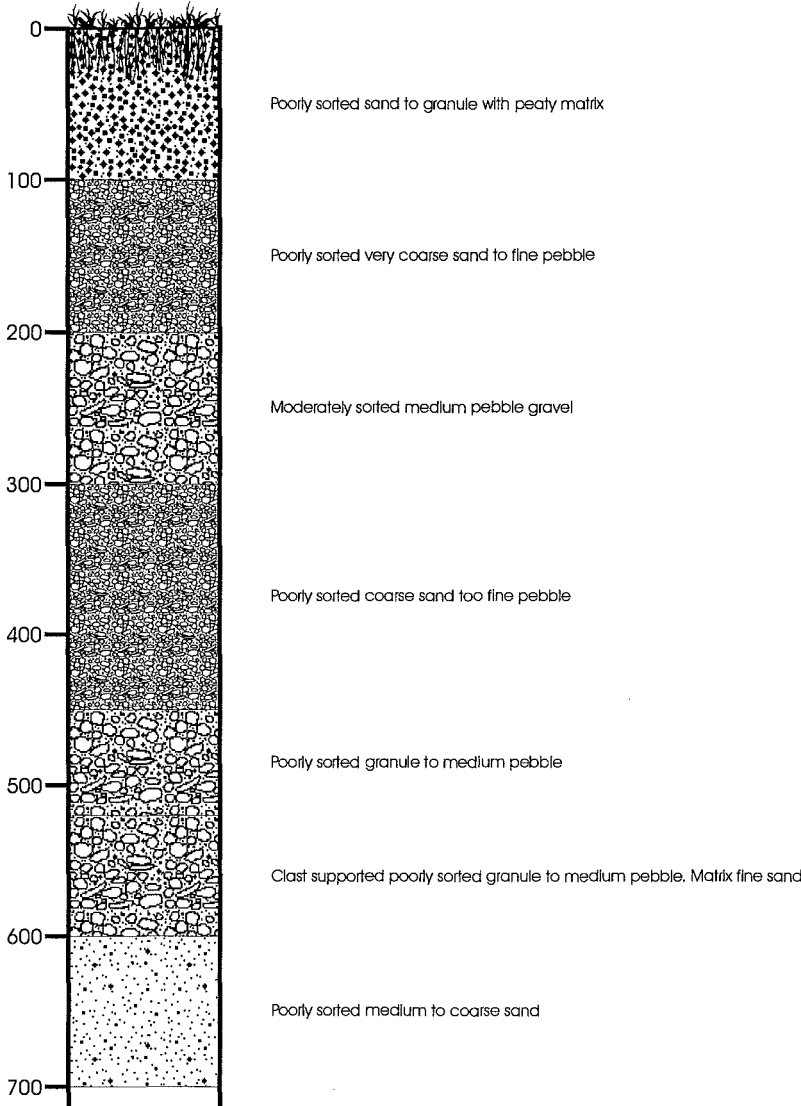
Depth (mm)



Peg 4 Pondsns

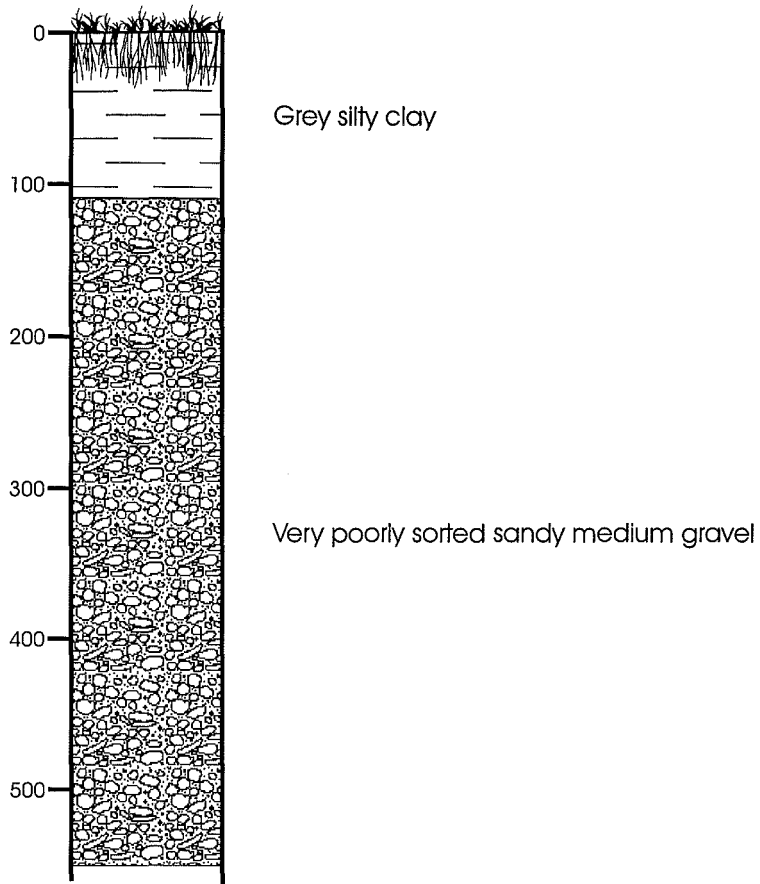
M37

Depth (mm)



East of peg 1 ponds we M37 656 073

Depth (mm)



Appendix F Shell Photographs

Below are representative photographs of the shell fragments found during this study.



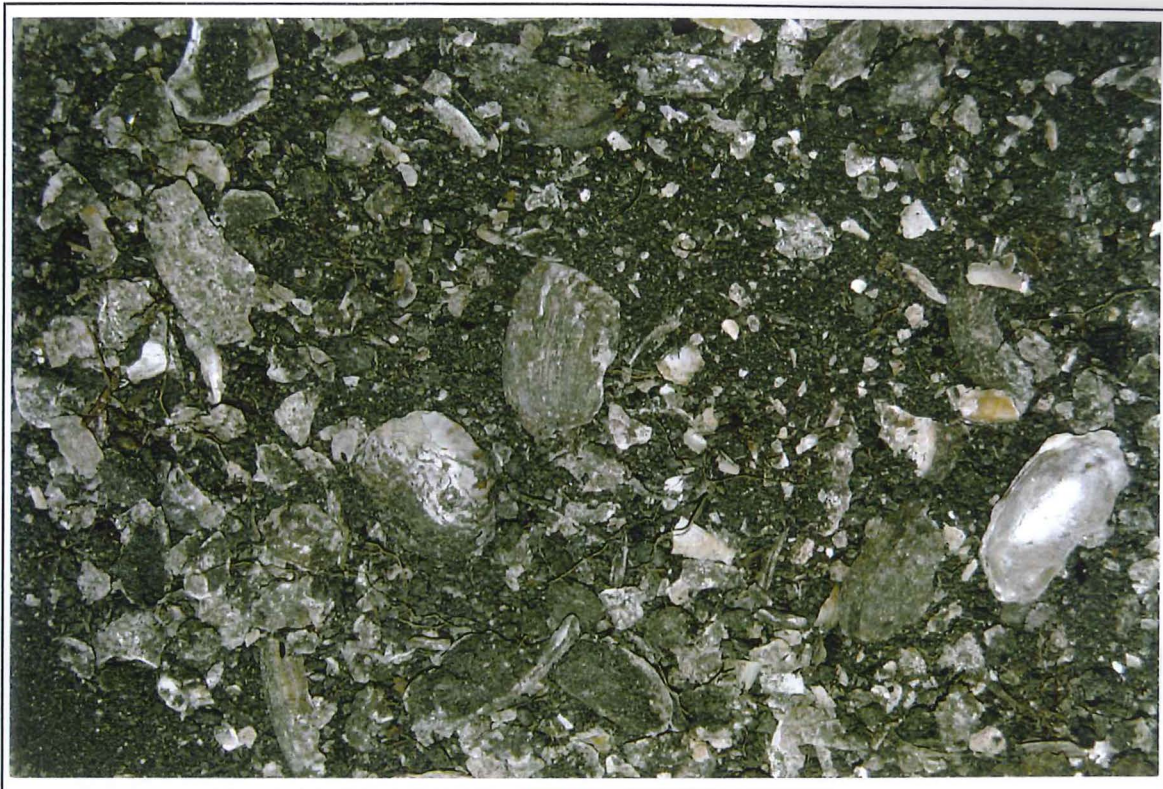


Figure F-1. Photograph showing a *Hyridella menziesi* shell hash. These fragments were found at the Island area. Note the nacreous lustre of the fragments, and the flecks of brown conchiolin appearing between the calcareous layers. Also note the way in which the shells break into thin flakes.



Figure F-2. Photograph of periostracm fragments collected from the shallow pit dug in front of Birdlings Ridges. Note the ligament still attached to two of the periostracms (marked). Photograph Dr. K. Swanson..

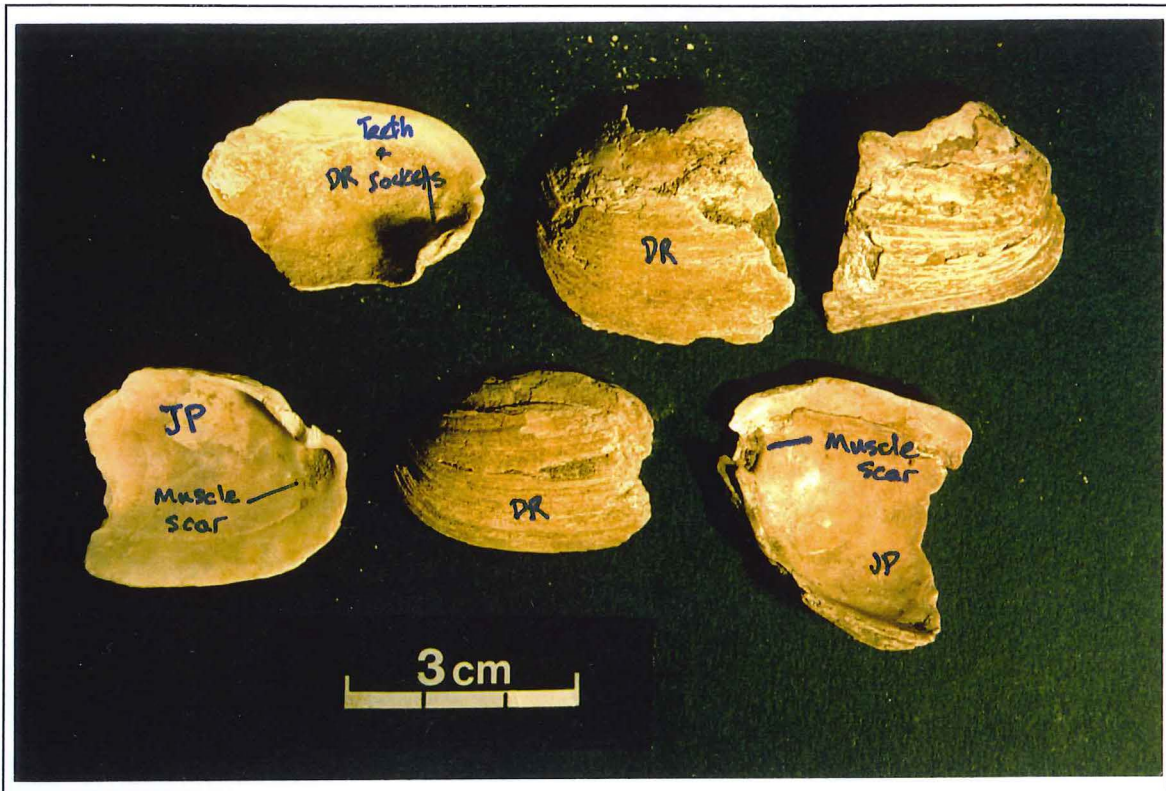


Figure F-3. Photograph of shells collected both from Jones Pit (JP) and from underneath a small ridge near Dune Ridge (DR). Note the distinctive muscle scar marked on several of the shells. Also note the asymmetry of the hinge line and the weakly developed teeth and sockets.

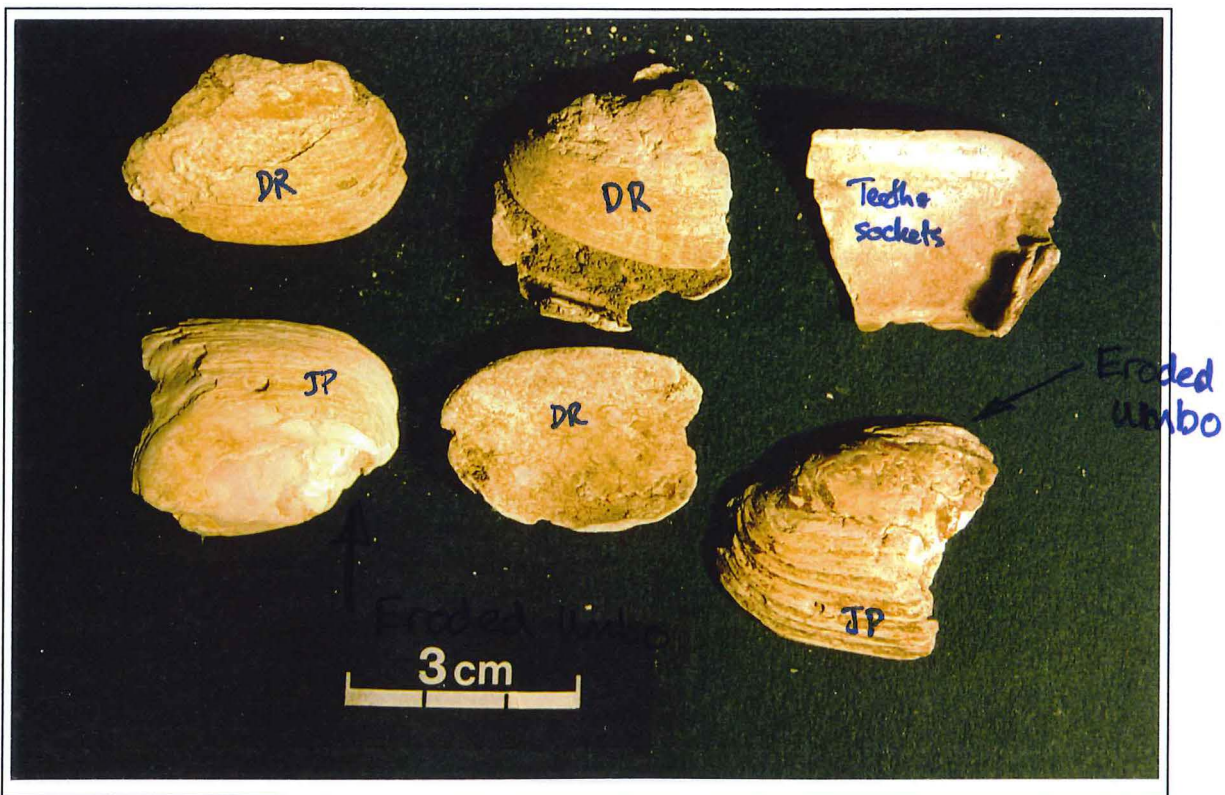


Figure F-4. Photograph of the reverse sides of the shells in Figure F-3. Note the eroded umbos (marked) which are common in *Hyridella menziesi* (Grimmond, 1968).

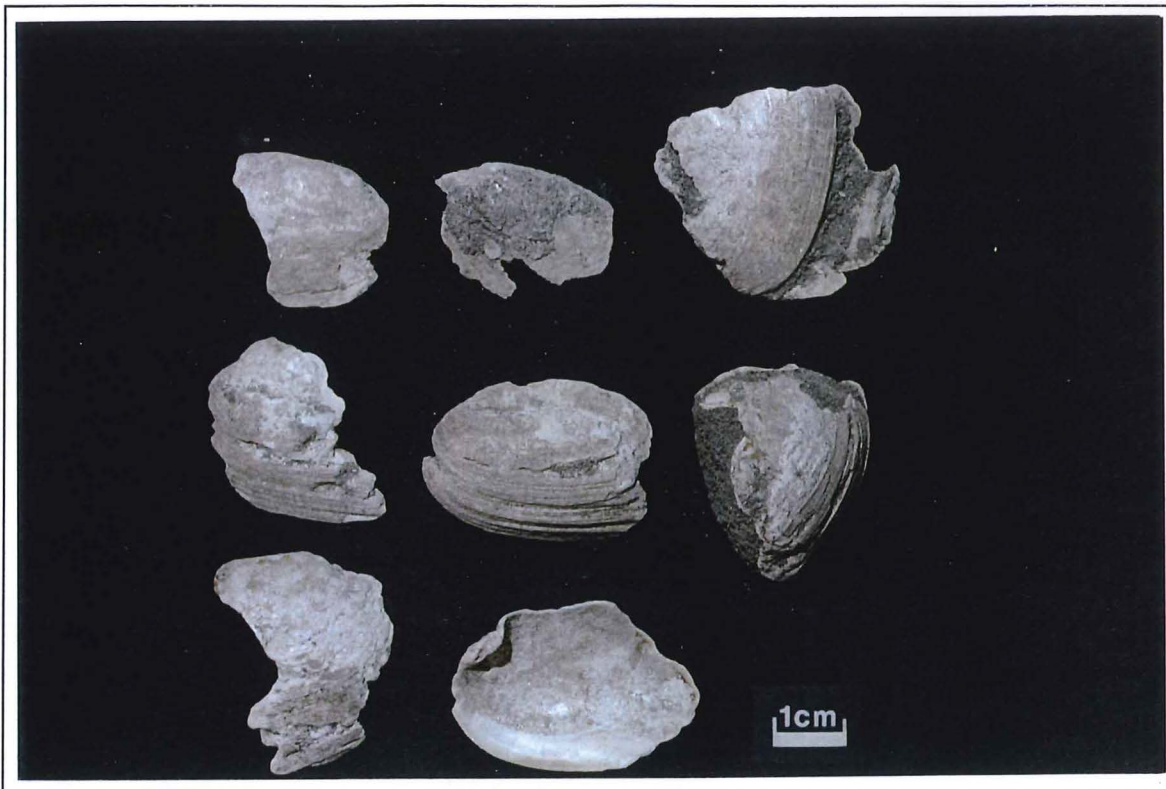


Figure F-5. Photograph of *Hyridella menziesi* shell fragments from beneath the small ridge near Dune Ridge (M37 646 083). Note the shell structure. (Photograph Dr. K. Swanson).



Figure F-6. Photograph of *Hyridella menziesi* shell fragments from Jones Pit. Again note the weakly developed teeth and sockets, and the nacreous lustre. (Photograph Dr. K. Swanson).

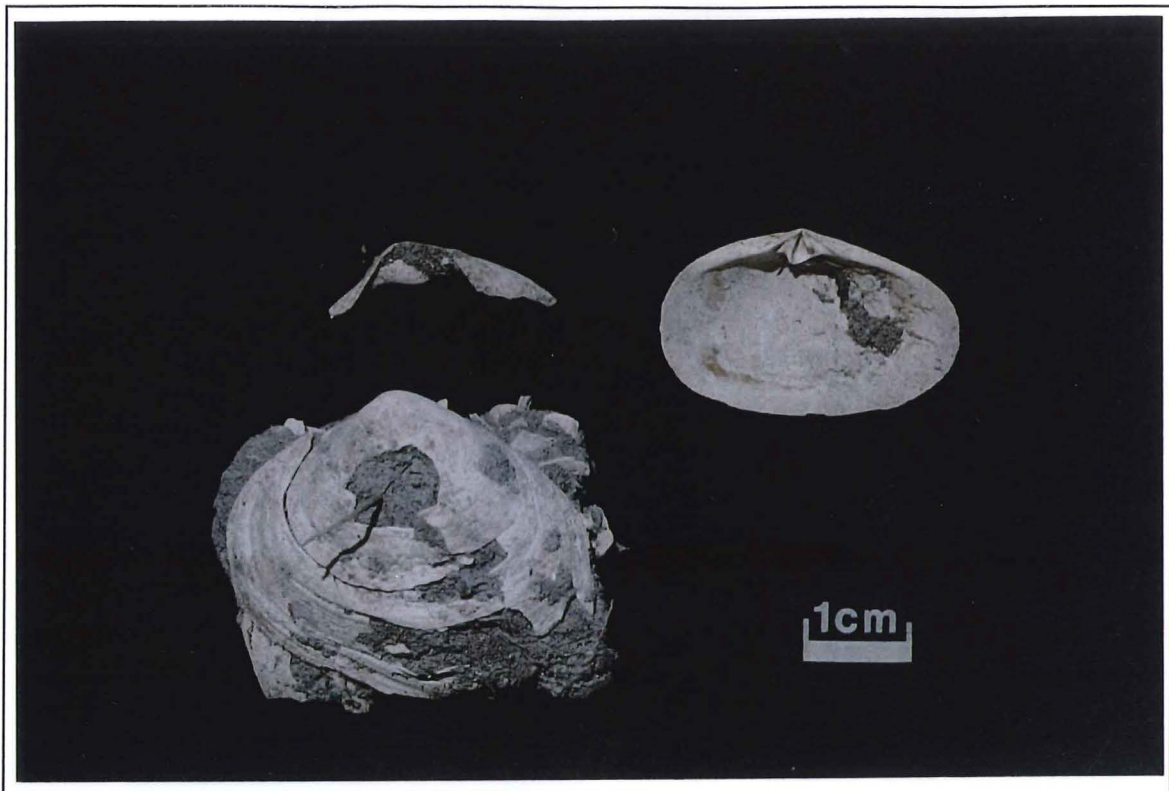


Figure F-7. Photograph of *Paphies australis* (Pa) and *Mactra ovata* (Mo) shells collected from the edge of Lake Ellesmere at M37 620 063. Note the well developed teeth and sockets, small round muscle scars (marked) and the bilateral symmetry of the *Paphies australis* shell. Note the general oval shape of the *Mactra ovata*. Also note the lack of nacreous lustre and the manner in which the *Mactra ovata* is disintegrating. (Photograph Dr. K. Swanson).

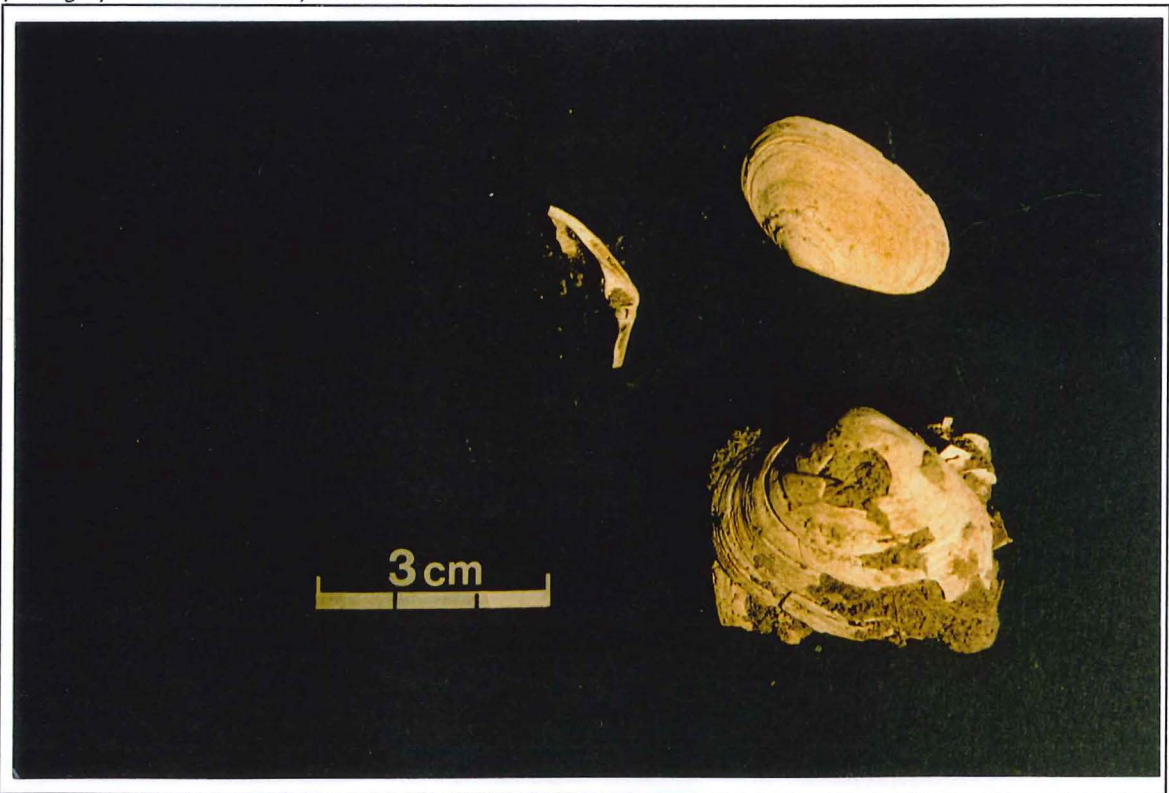


Figure F-8. Photograph of the reverse of the *Paphies australis* showing the general shell outline.



Figure F-9. Photograph of *Austrovenus stutchburyi* shells and fragments collected from the same site as the shells in Figures F-7 and F-8. Note the sculpture on the shell and the distinctive teeth and socket arrangement. A large oval muscle scar can be seen on the central fragment.



Figure F-10. Photograph of several *Amphibola crenata* shells also collected at M37 630 063.

Appendix G Aerial Photograph Information

The following table lists New Zealand Aerial Mapping aerial photographs used during this study.

Date Flown	Run number	Photos Used
6/5/1943	158	25-42
6/5/1943	159	20-27
20/5/1952	2116	68-86
20/5/1952	2117	76-90
28/10/1984	SN8389	N15-N17
28/10/1984	SN8389	O15-O17

The photomosaic maps NZMS 3 sheets S.93/6 and S.94/1 were also used.



The only way to study Kaitorete in the future !