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BEACH CHANGES ON LAKES MANAPOURI AND Te ANAU, AUGUST 1988 TO FEBRUARY 1989

- A report to the Guardians of Lakes Manapouri and Te Anau

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CONTENTS

	Page No.
1. INTRODUCTION	3
2. SURVEY PROCEDURES AND METHODS	4
3. BEACH CHANGES, AUG.'88 TO FEB. '89, LAKE MANAPOURI	6
4. BEACH CHANGES, AUG.'88 TO FEB. '89, LAKE TE ANAU	10
5. UPGRADING THE MONITORING NETWORK	12
5.1 Lake Manapouri	12
5.2 Lake Te Anau	13
6. DISCUSSION AND CONCLUSIONS	14
7. REFERENCES	15
8. APPENDIX 1. LOCATION NOTES FOR PROFILE SITES ON LAKES MANAPOURI AND TE ANAU.	17

1. INTRODUCTION

This report is the fourth in a series completed since 1985 concerning measured changes in the beaches of Lakes Manapouri and Te Anau, together with their connections to a variety of natural events and management issues. Kirk (1975) discussed planning and management related matters for the urban foreshore of Lake Te Anau. Several of the recommendations made in that report have been implemented and so bear on the work to be discussed here.

Kirk and Single (1988) examined the results of a beach profile re-survey carried out in February 1988 that established longer term changes in beaches over 12-15 years back to the inception of detailed monitoring in 1973. Particular attention was paid in that report to the relationships between beach change and the Operating Guidelines for the levels of the two lakes.

A substantial earthquake centered on the North Arm of Lake Te Anau in June 1988 led to a further re-survey of the beach profiles in August (Kirk, Single, Gurnsey and McGown 1988) in order to document locally significant shoreline change and to provide a base-line for assessment of longer-term earthquake-related adjustments of beaches.

It will be important to bear in mind as this report proceeds that the results to be presented and discussed here thus contain some measure of post-earthquake change (particularly for Lake Te Anau), as well as the effects of more recent events.

The present report arises for two main reasons. First, the weather in the Spring of 1988 was unusual for a sustained procession of westerly wind systems that brought an extended period of high rainfall from mid-September to early November. Very strong winds occurred in late October - early November when lake levels were close to their peak thus resulting in appreciable shoreline erosion at higher than usual elevations. Damage to services and assets occurred at both Manapouri and Te Anau townships. Allen and Mark (1989) in a parallel report to this detail the effects on vegetation around the shorelines of both lakes. They also note that prolonged flooding around Lake Te Anau in 1975 (when levels exceeded the Operating Guidelines) resulted in mortality of shoreline scrub and forest. For the Spring of 1988 Allen and Mark (1989) state that Lake Te Anau reached a record high level on November 4th at 205.11m,which is +0.81m above the Guideline maximum. A day later Lake Manapouri reached 181.52m, also a new record, +1.02m above the Guideline maximum.

A re-survey of the beach profiles was necessary to document the physical effects of these events.

Secondly, the beach profile survey network has been installed now for a very long time. Vandalism and loss of the profile site markers by erosion has made steady inroads into the coverage and continuity of the record provided by the system, particularly on Lake Te Anau and especially on beaches within easy reach of the township. It was therefore decided in April 1988 to update and refurbish the network with the intention of re-measuring it either every 5 years or after significant events. This work is also presented here.

Finally, during February 1989 an investigation was made of wake waves from a catamaran, the "Fiordland Flyer" in order to determine their significance in shoreline change under typical observed operating conditions. The results of this work are presented in a further parallel report (Kirk 1989).

2. SURVEY PROCEDURES AND METHODS

Fieldwork was carried out between 17th and 24th February 1989 in variable weather and at generally very low lake levels. Lake Manapouri stood at and slightly above 175.9m (bottom of the Low Operating Range). Lake Te Anau stood at 201.59m (in the Low Operating Range). While these low levels are ideal for survey purposes since they expose all the beach and a substantial portion of the nearshore, they are themselves a cause for concern in respect of shoreline erosion, especially on Lake Manapouri and particularly where they are protracted in time because this presents a greater likelihood that beach sediments will be transported by wave action into deep water via the nearshore shelf edge.

Beach profiles with intact marker posts were re-located and re-surveyed using the same methods and equipment employed for the earlier surveys and detailed in the respective reports. Briefly, a line at right angles to the water line was surveyed across the beach and nearshore contours using a Sokkisha DT 20E digital Theodolite and staff. The peg position and the prevailing water level provide height controls. The data are computer reduced and profiles are overlaid on earlier ones to enable calculation of erosion distances and rates, beach form changes, and beach sand volume changes. The latter step involves digitisation of the areas enclosed by pairs of profiles.

At the same time as the line survey is carried out notes are made on relevant shoreline features (such as backshore erosion scarps, sand transport into vegetation, rilling, longshore effects etc.), and the beaches are photographed in both directions along the shore from the site.

This system depends vitally on successful marking and re-location of sites. Removal of the tagged, steel fencing Waratahs used to fix the sites destroys the continuity of data from the sites and so accurate information on behaviour of the shore extending back to 1973 (in many cases) is lost or thoughtlessly destroyed. Over time, and especially during 1988/89 there has been a steady decrease in the number of Waratahs remaining. This is particularly true on Lake Te Anau. In some cases erosion or damage from floating logs has clearly been responsible, but in the majority of situations the most likely cause is simple vandalism. Where the steel cannot be readily removed people will content themselves with removing the numbered identification tags and/or bending the Waratah.

In February 1988 it proved possible to re-survey only 23 sites. Only 8 could be relocated on Lake Te Anau for recreationally important beaches near the township and none were located in the urban area.

The refurbishing work has provided a total of 33 profiles in the active network, with a further 4 that are detailed to act as alternates on the larger beaches. Some 15 of these occur on Lake Manapouri and 18 on Lake Te Anau. Five new sites have been established at critical points of the Te Anau urban foreshore.

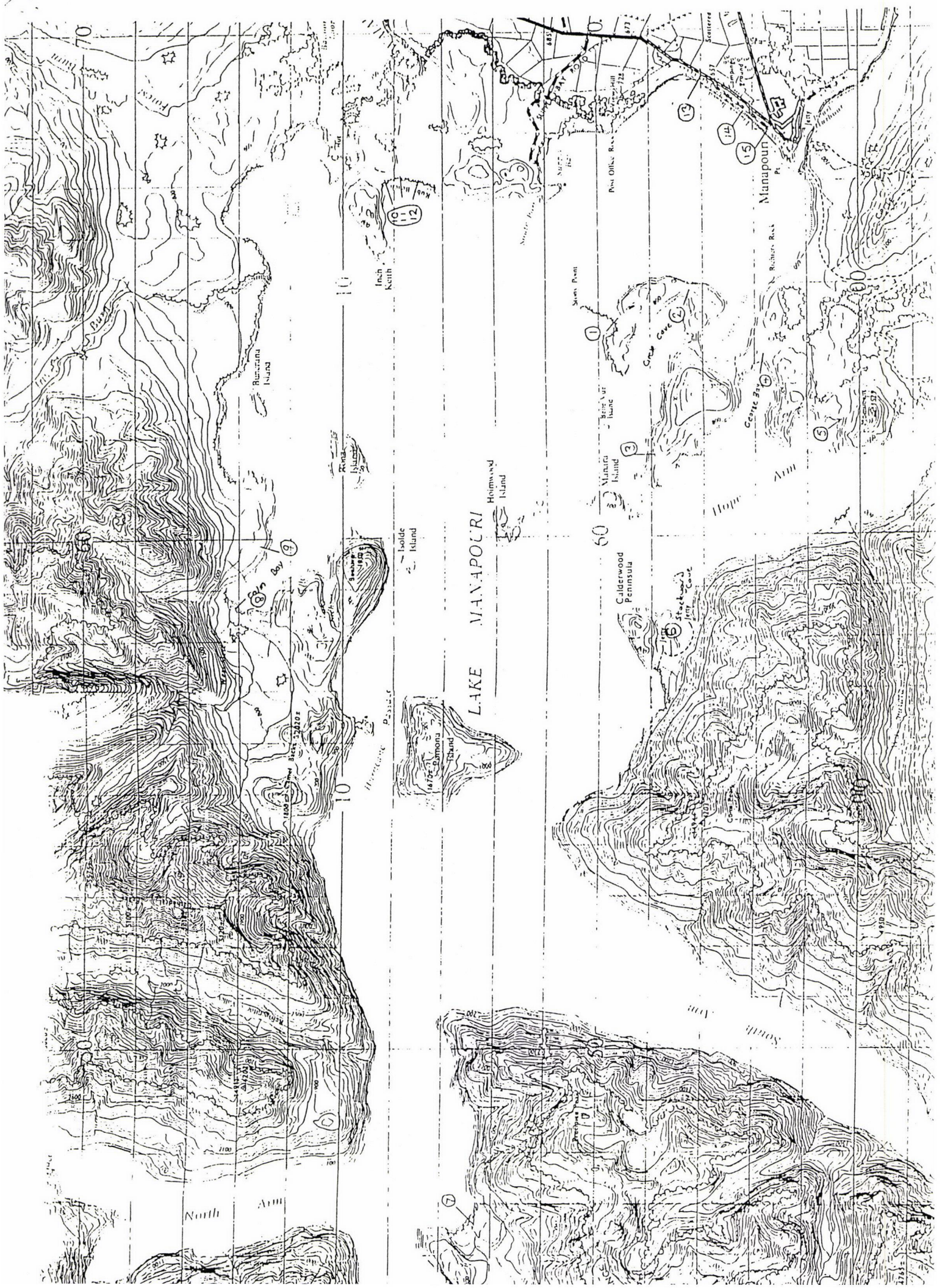
Unfortunately, the Manapouri bench mark (south end of Frasers Beach) which provides an important height and location control was removed by erosion in November 1988. This has been drawn to the attention of D.O.C., Te Anau and a makeshift control has been established to a new Waratah at the site using data held by the writers.

New profile sites have been established using steel Waratahs with stamped,numbered aluminium tags steel-wired to their tops, much as in the original system. In most cases the Waratahs have also been concreted in place below the beach surface. As well, a series of bearings and location notes provide an independent means of re-establishing the Waratah heights and positions when the vandalism inevitably recurs.

Because different annotation systems were used by earlier workers there has been confusion in the location details that has hampered comparison of re-surveys. For this reason <u>all</u> the sites currently in use have been re-numbered on a simple system for each lake. Details of this are presented later.

The work was funded in total by Electricorp who also again provided a radio-equipped jet-boat used on both lakes.

Figure 1. Locations of beach profiles on Lake Manapouri.


LAKE MANAPOURI
Manapouri
Pearl Harbour
Post Office Rock
Scott Point
Scott Cove
Bare Island
Manuka Island
Home Island
Calderwood Peninsula
Stockyard Cove
Jetty Cove
Isolde Island
Ramsay Island
Burnett Island
Inch Keith
Pomona Island
Deep Cove
North Arm
Pomona Passage
Hope Arm
Richies Rock
Cascade Bay
Seaforth Bay
Mistletoe Bay
Shag Rock
Shag Rock Passage
Reid River
Duncan Passage
Duncan Bay
Duncan Hill
Mt Hall
Mt Titiroa
Mt Hamilton
Mt Hamilton Saddle
Mt Hamilton Ridge
Mt Hamilton Creek
Mt Hamilton Stream
Mt Hamilton Track
Mt Hamilton Hut
Mt Hamilton Track

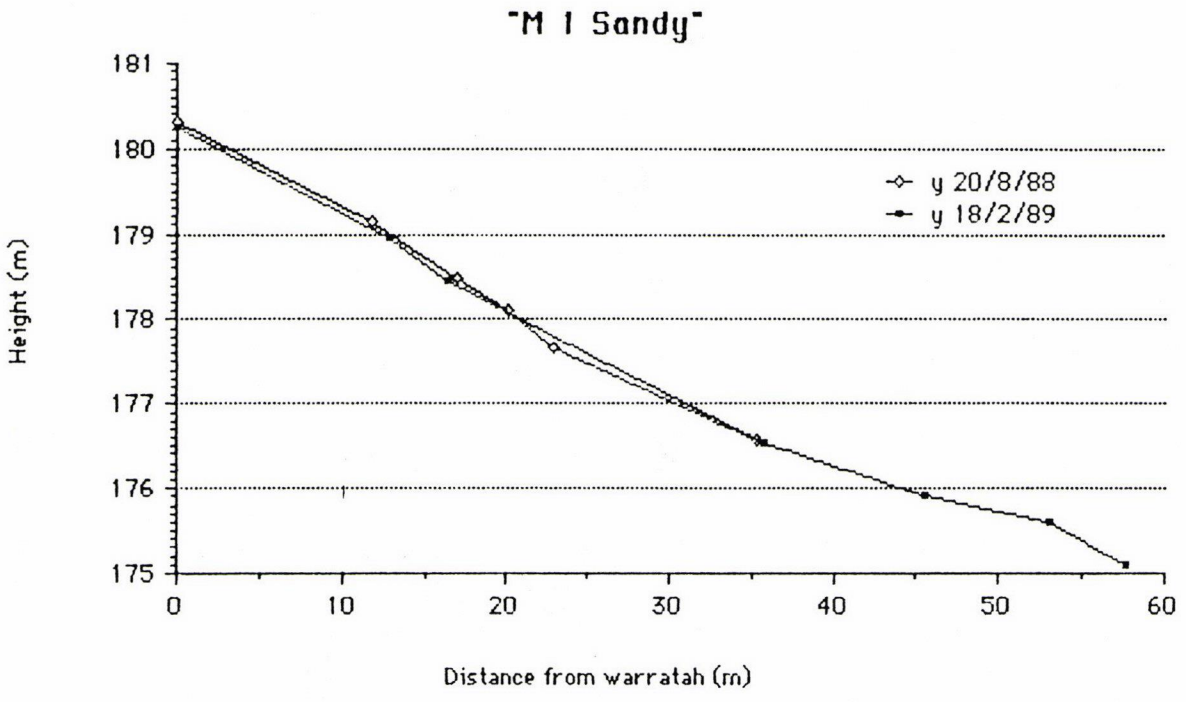
3. BEACH CHANGES . AUG.1988 TO FEB.1989. LAKE MANAPOURI.

As noted above, caution is warranted in ascribing all the change to be detailed here to the high water levels and strong winds of Spring 1988. Some part of it is due to post-earthquake adjustments of beaches, particularly on Lake Te Anau, and some further portion relates to the very low lake levels obtaining prior to and during the survey (especially on Lake Manapouri).

Figure 1 shows the locations of the beach profiles in the new numbering system. Corresponding numbers in the earlier system are indicated in the first column of Table 1 which also presents the measured beach volume and form changes for the various surveys. Figures 2A - 2G show the 15 profiles now current on Lake Manapouri. Where appropriate these have been overlaid on the equivalent surveys of August 1988 to reveal the changes that have occurred over the spring and summer.

Table 1 shows that beach volume changes have been appreciable, but variable as a result of the high water levels and strong wave action. Six of the profiles sustained accretionary gains of sediment while 8 suffered net erosional loss. At one site (Frasers south) there was no net change. It is worth noting that none of the changes were large by comparison with those that occurred throughout 1988 (including the earthquake effects of June and subsequent changes). It is also apparent from Table 1 that none of the changes over the spring and summer are especially large with respect to net changes over the 15 years from 1973 - 1974. These findings are important because they provide context and scale for the events of October/November 1988. Though water levels and winds may have combined in an unprecedented fashion, the resulting beach change on Lake Manapouri has clearly, (and fortunately) not been commensurately severe.

However, it is quite clear from the surveys and from observations made during the field work that this situation exists because the brunt of the attack was borne by backshore deposits of various kinds (and the vegetation) to landward of the beaches, rather than by the beaches themselves. It is for this reason that a good proportion of the profiles have sustained net gains of sediment rather than net erosional losses. Sand and gravel quarried by waves from the backshore have been drawn down the profiles ("combed down") as lake levels fell from the peak level. Though the resulting beach profiles are "healthy" in terms of the amounts of sand they contain, there has nonetheless been a net retreat of these beaches at their highest elevations. In some cases there has also been a net loss of sand inland from the beach by storm washover.



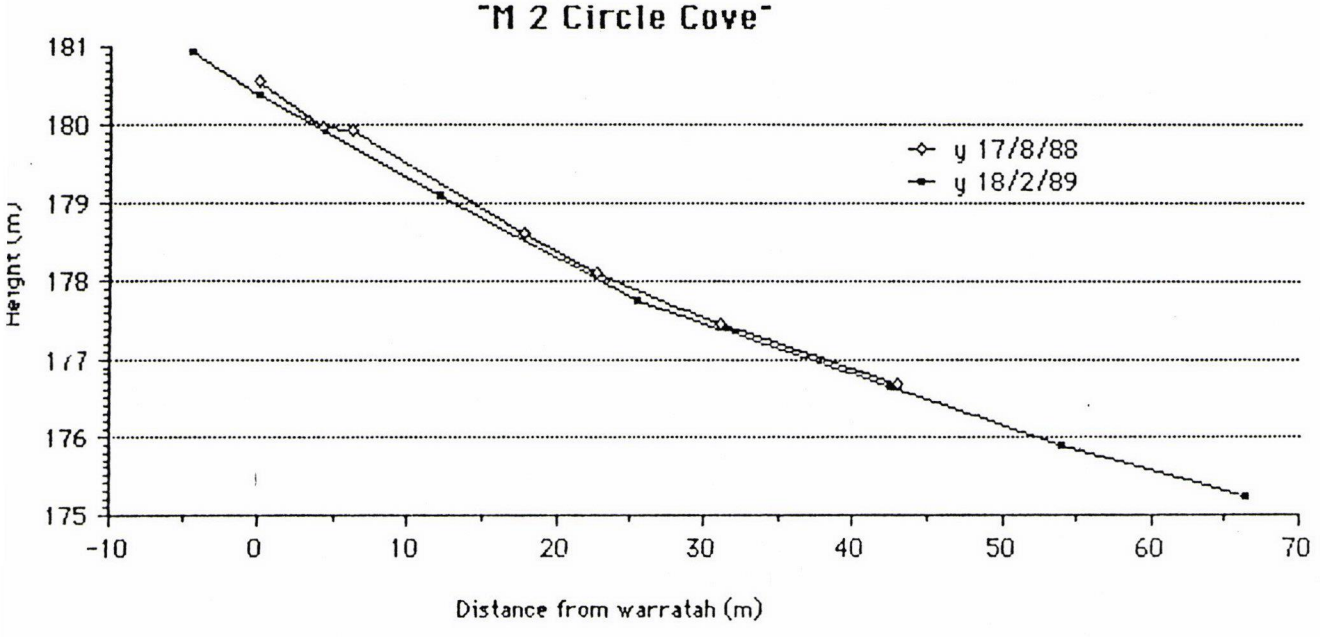
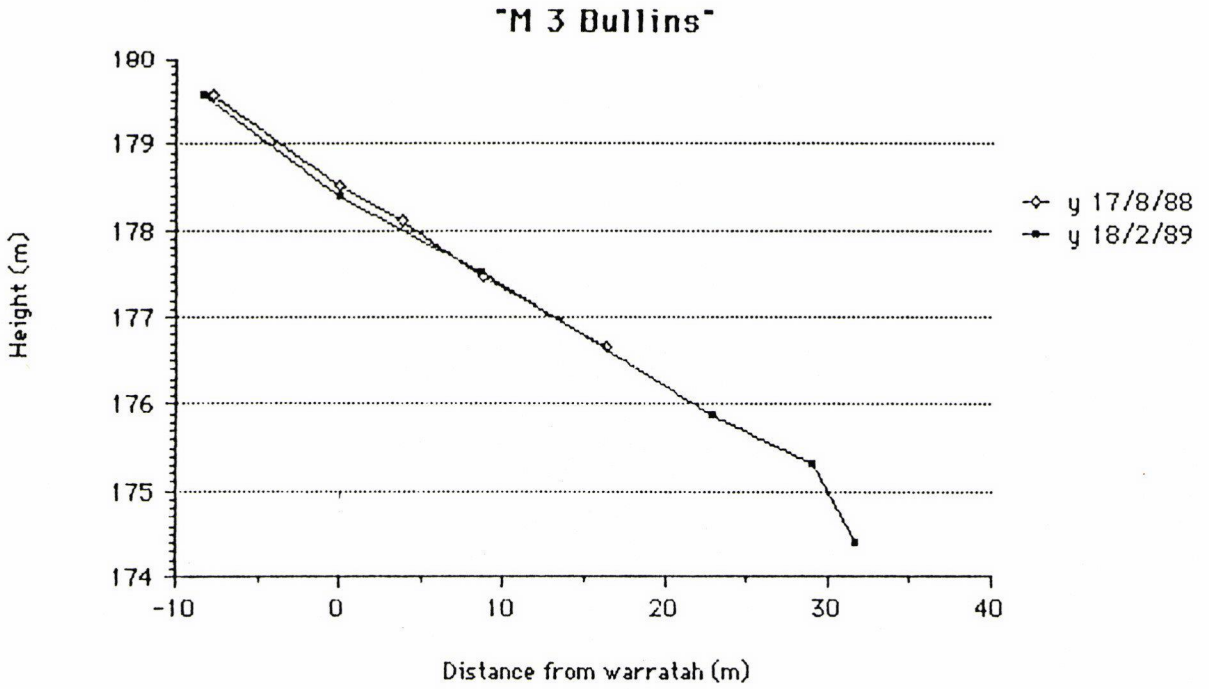


Figure 2. A. Beach profile changes from August 1988 to Fenruary 1989, Lake Manapouri. Locations as given on Figure 1.



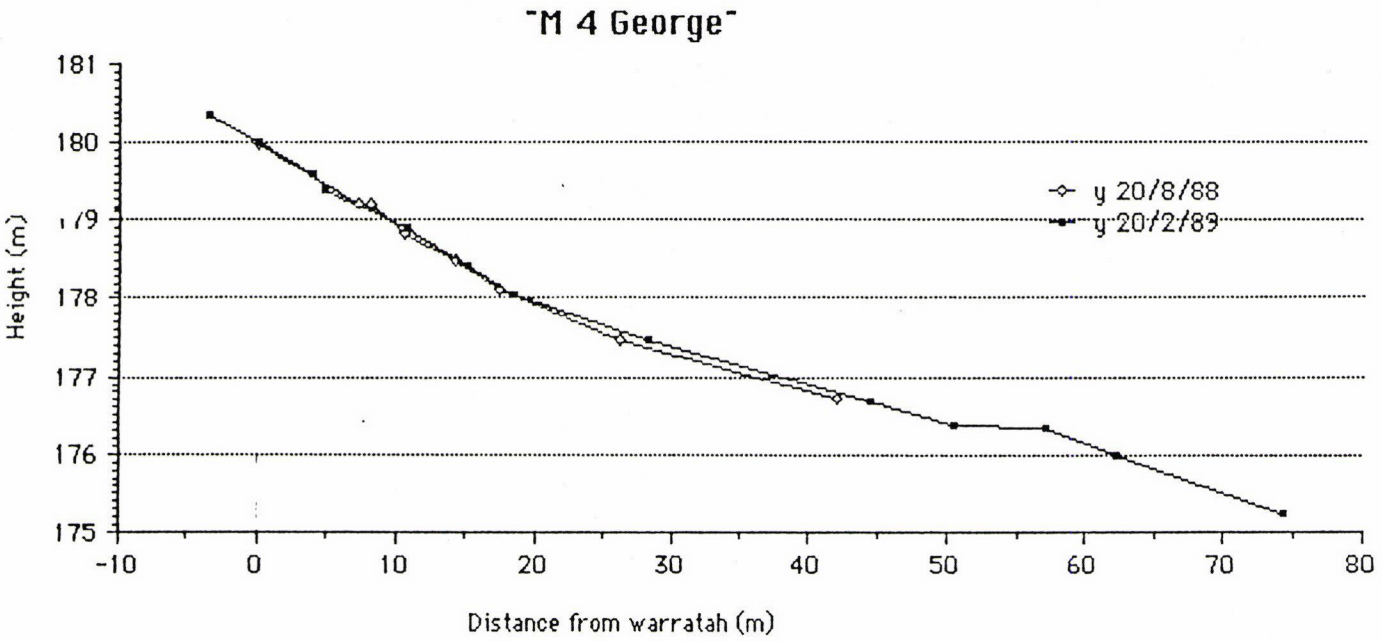
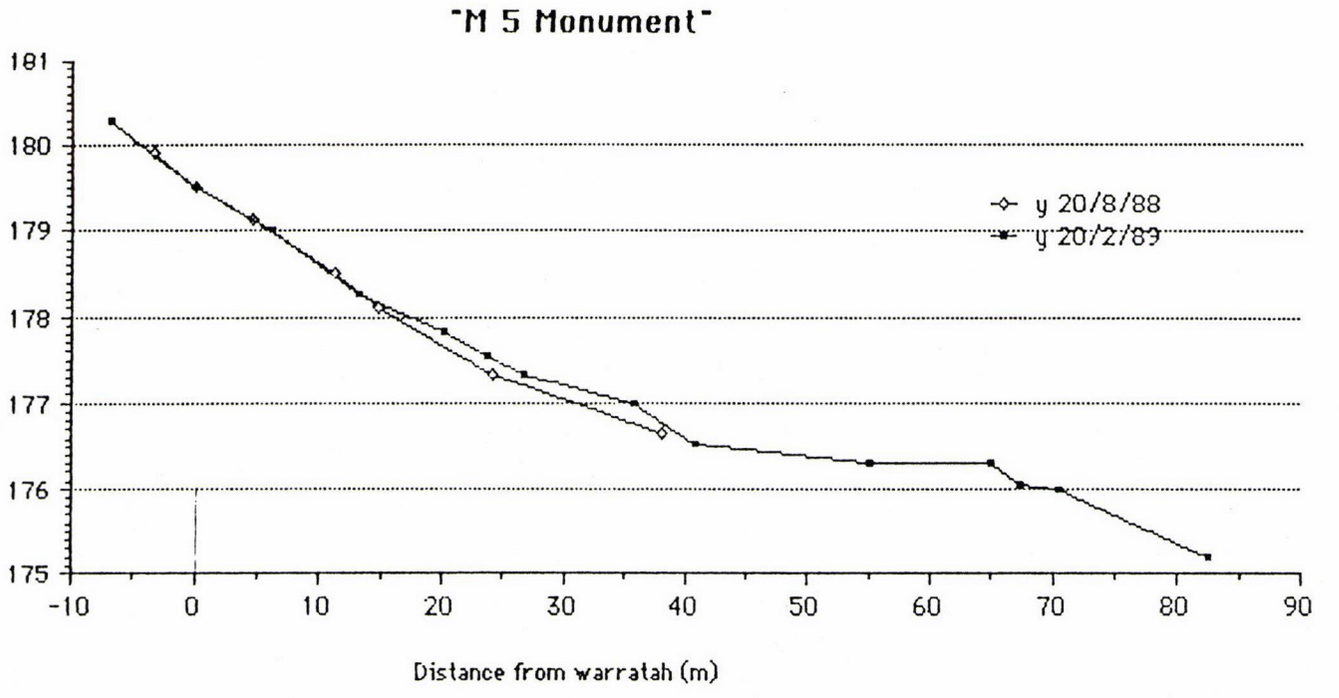


Figure 2. B. Beach profile changes from August 1988 to Fenruary 1989, Lake Manapouri. Locations as given on Figure 1.



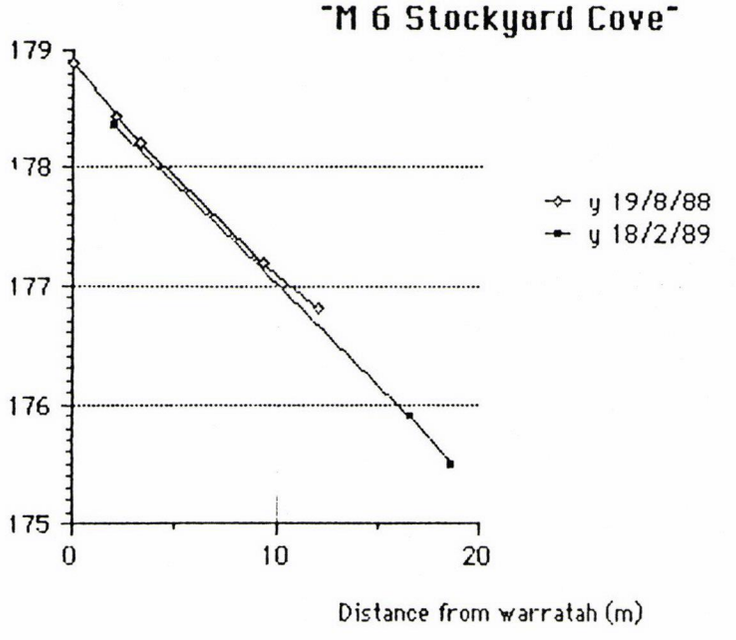
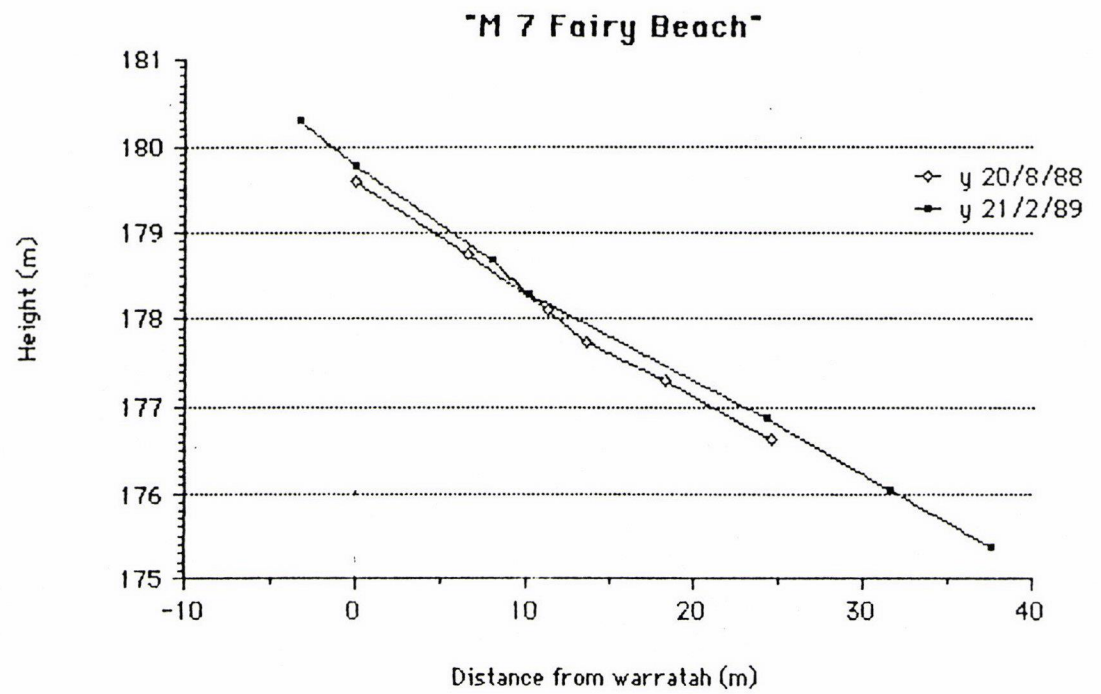


Figure 2. C. Beach profile changes from August 1988 to Fenruary 1989, Lake Manapouri. Locations as given on Figure 1.



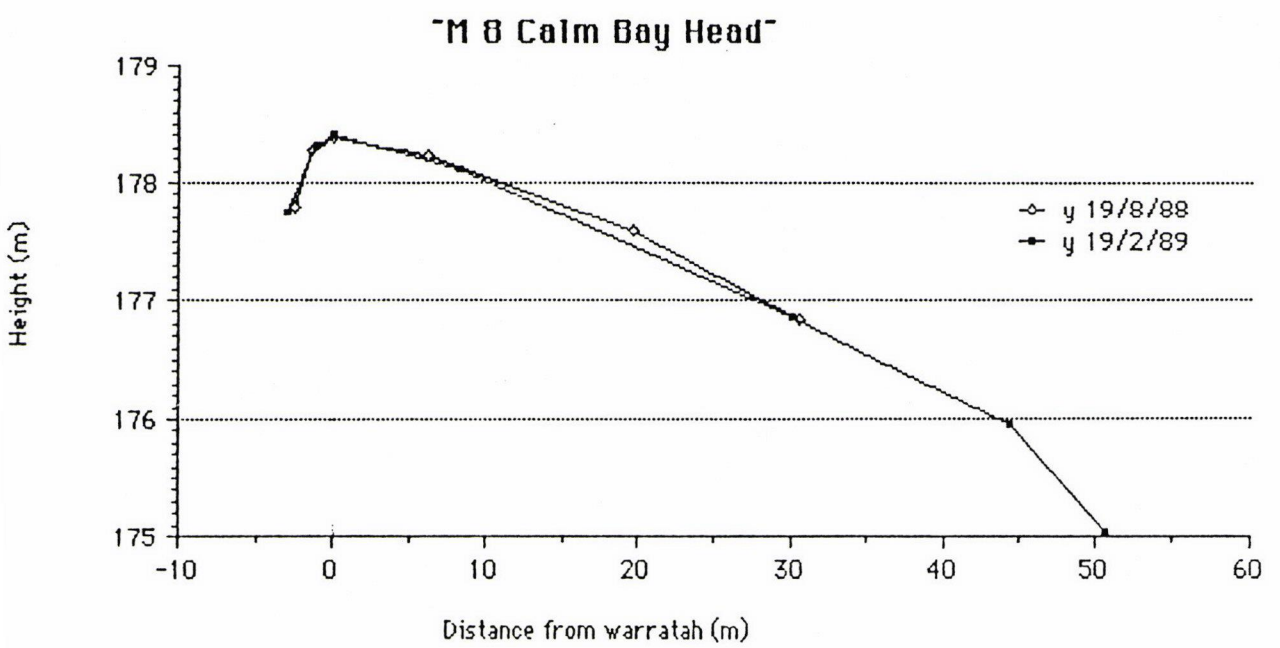
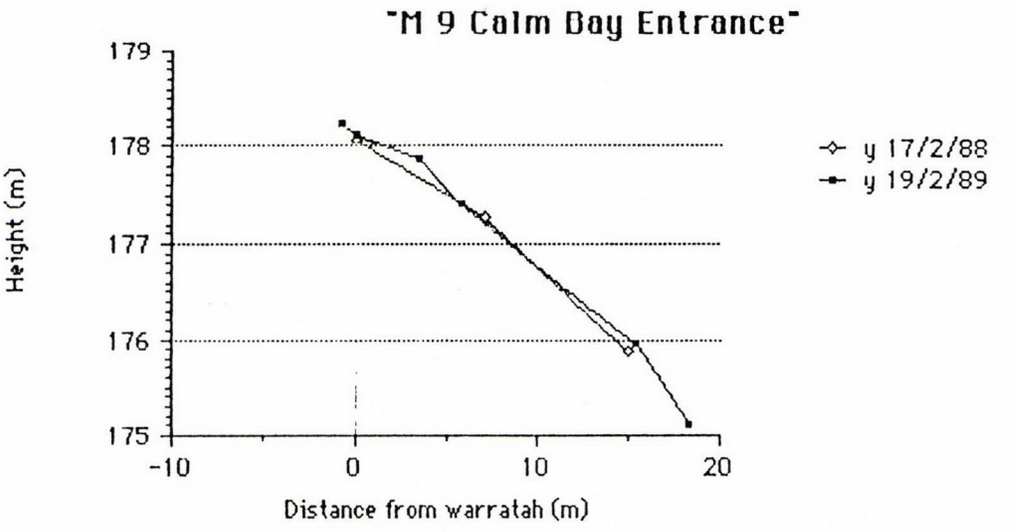


Figure 2. D. Beach profile changes from August 1988 to Fenruary 1989, Lake Manapouri. Locations as given on Figure 1.



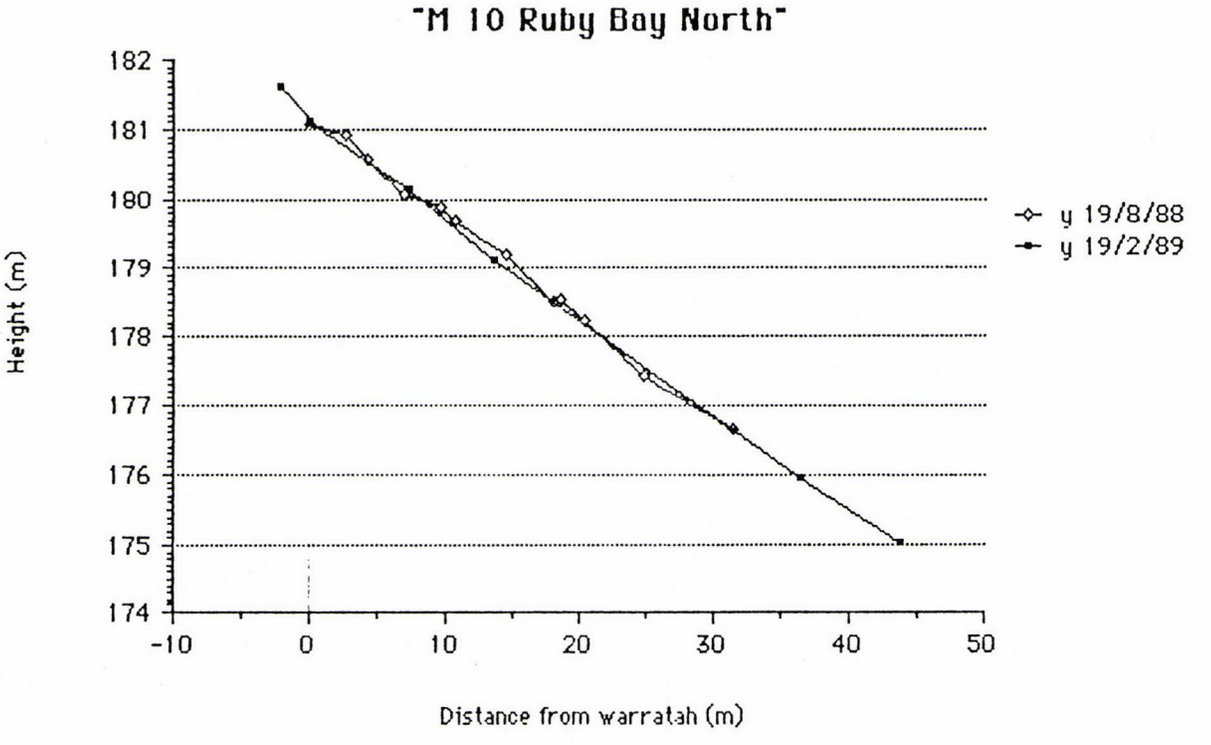
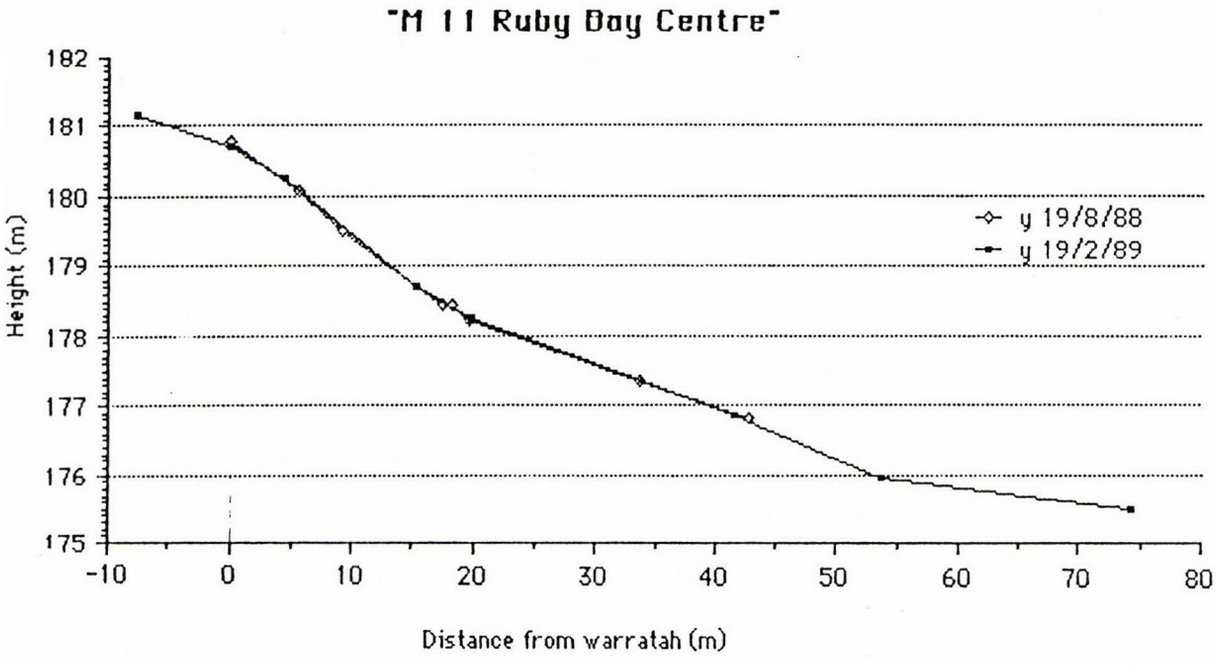


Figure 2. E. Beach profile changes from August 1988 to Fenruary 1989, Lake Manapouri. Locations as given on Figure 1.



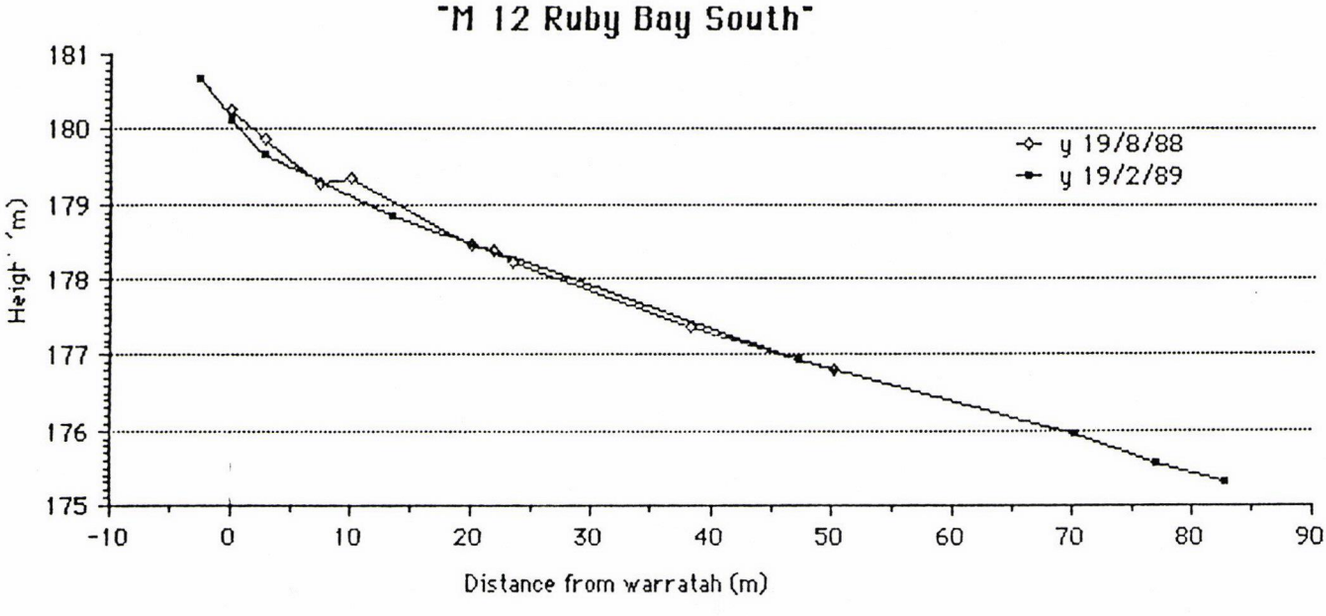
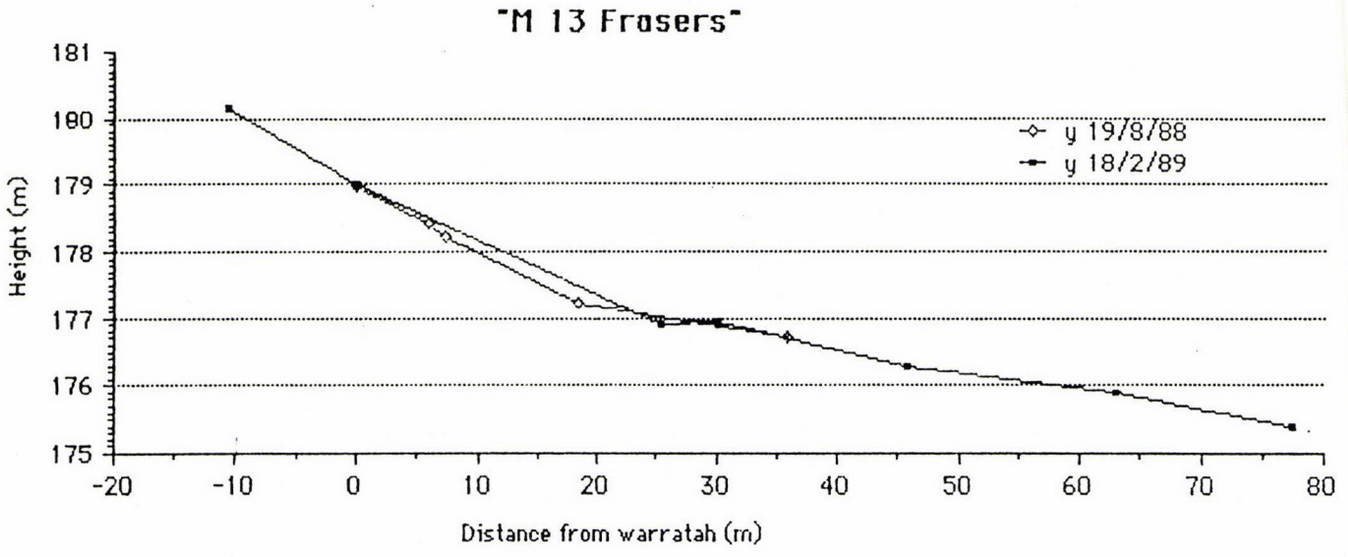
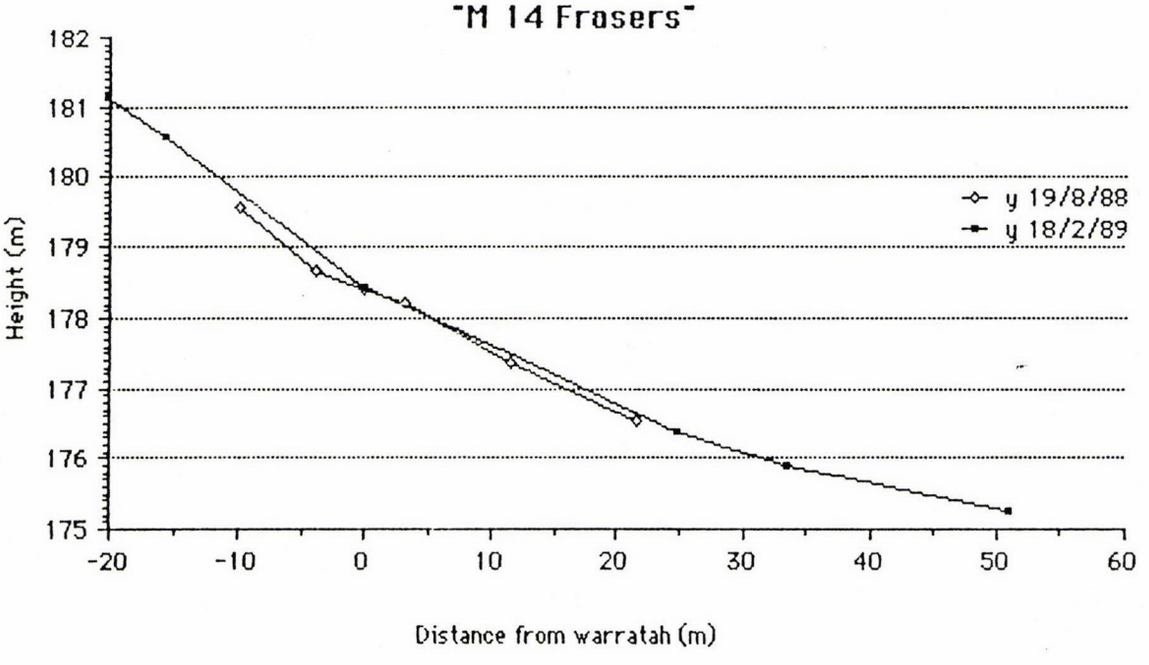


Figure 2. F. Beach profile changes from August 1988 to Fenruary 1989, Lake Manapouri. Locations as given on Figure 1.





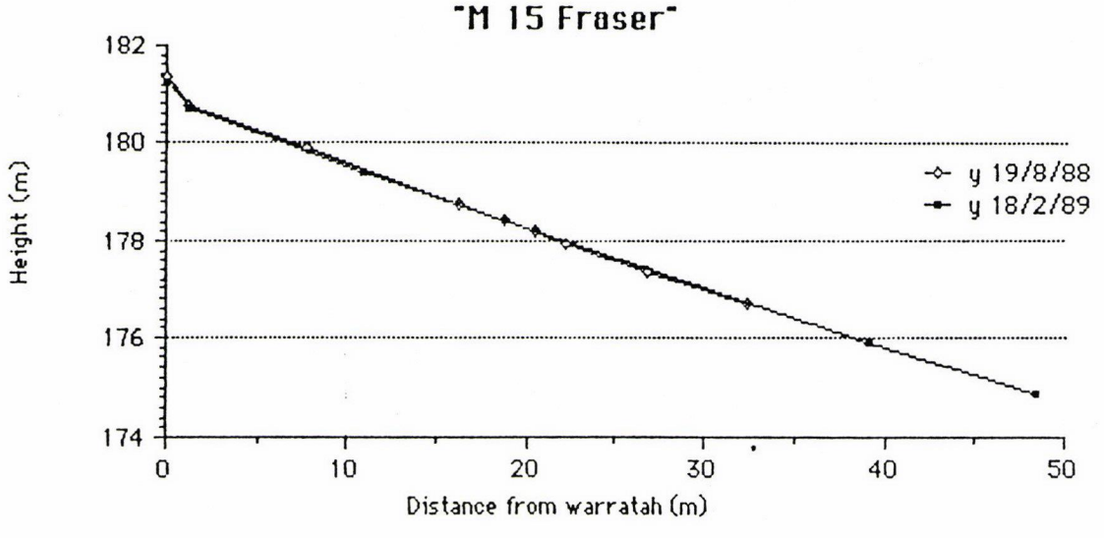


Figure 2. G. Beach profile changes from August 1988 to Fenruary 1989, Lake Manapouri. Locations as given on Figure 1.

Table 1. Lake Manapouri Beaches. Beach volume and form changes from August 1988 to February 1989 in comparison to changes in other periods.

Profile No. and site	New No.	Volume Ch. 73/74-2/88 (Full Period) cubic m/m	Volume Ch. 2/88-8/88 (Earthquake) cubic m/m	Volume Ch. 8/88-2/89 (High Levels) cubic m/m	Form Change 8/88 -2/89
Frasers BM-sth	15	-12.27	+3.11	0	b/sh ero.
Frasers (49) m.	14	-3.06	+1.71	+5.75	"
Frasers (48) nth	13	-6.62	+2.86	+3.99	"
Sandy Bch. (34)	1	+0.50	-3.60	-0.64	"
Circle Cove (45)	2	-7.89	-6.29	-5.27	whole p.
Bullings Bch (32)	3	-7.82	-0.84	-1.70	b/sh ero.
George Bay (47)	4	+9.52	-3.50	+4.14	Combed
Monument (3)	5	-44.30	+10.16	+4.17	"
Stockyard Cove(24)	6	-0.81	+ 1.24	-1.27	whole p.
Fairy Beach (19)	7	-10.74	-1.48	+1.22	Combed
Calm Bay (21)	8	+0.76	-0.64	-0.51	Whole p.
Calm Bay (20)	9	-3.59	No Data	+1.21	b/sh. ero
Ruby Bay (18) nth	10	+9.55	-3.19	-1.32	Whole p.
Ruby Bay (17) m.	11	-4.03	-0.56	-0.14	b/sh ero
Ruby Bay (16) sth	12	+1.87	-4.67	-1.70	" "

Notes:

[1. Location numbers in brackets are as given in earlier reports.

[2. positive values denote accretion

[3. negative values denote erosion.

[4. Form changes: whole p.= lowering across whole profile, b/sh ero = erosion of backshore only, Combed = sand combed from high to low on the beach.

As can be seen from Figure 2A Sandy Beach has suffered from such a washover loss, there having been net lowering of the foreshore over the whole width of the beach. Net erosional retreat (measured in the horizontal) at the crest of the beach is in the range 0.5-1.0 meter.

Figure 2A reveals a similar situation at Circle Cove, the crest erosion being of a similar order to that at Sandy Beach, but the net loss of sand volume being almost 8 times as great.

Figure 2B shows the changes at Bullings Beach where sand was removed from the upper half of the profile and washed back into the bush. A 10cm scarp was also eroded into the backshore. The net volume losses were moderate at -1.70 cubic meters per meter length of foreshore.

At George Bay sand eroded from the backshore has been combed down to form prominent berms on the lower foreshore. Sand has also been washed up to 15 m back into the bush. Monument Bay Beach has a similar exposure to wave action and has sustained similar changes (Figure 2C), the lower foreshore berms being anchored by substantial accumulations of driftwood. On the upper beach sand has been washed 6 m back into the bush. The net volume change is remarkably similar for the two beaches which suggests a common response to the severe westerly conditions. Table 1 makes it clear that large internal sand changes can occur from time to time in both beaches but that they are generally robust, simply changing shape to accommodate conditions.

Stockyard Cove Beach is also shown in Figure 2C. This beach enjoys considerable shelter from westerlies and so the net erosion evident there is unlikely to be due to the high water levels and severe wave action. Rather, the site has a steep profile adjacent to deepwater and was much affected by seismic events in June 1988, after which there was an apparent net gain of sediment that has now been removed. Post-seismic adjustment is thus the most probable explanation of the change there.

Figure 2D shows net gains of sediment to the centre of Fairy Beach near West Arm. These have occurred both at the top of the beach and over the lower foreshore. Field inspection shows that the eastern end of the beach (which is exposed to westerlies) has sustained erosion while the western end (which is more sheltered) has been less affected. The gains to the centre of the beach thus result from longshore sand transport along the gradient in wave energy.

On the northern shores of the lake two profiles at Calm Bay are shown in Figures 2D and 2E. M8 in the head of Calm Bay is sheltered from severe wave action and so has sustained little change apart from some flattening of the central foreshore. Profile M9 is on the exposed eastern promontory to the bay and occurs in Damsite Formation so that it has the form of a veneer of coarse, angular boulders overlying Tills with a jelly-like consistency. The diagram shows that the profile is narrow and that strong erosional attack of the backshore has caused gains to the upper profile. There have also been gains at the outer end where gravels are in process of transport into deep water.

Ruby Bay is very exposed to westerly conditions and is a long beach on which three profiles are sited (see Figures 2E and 2F). Net longshore drift is from south (from profile M12), through profile M11 to north (profile M10). As can be seen from the Figures the beach is generally well adjusted to even severe wave action, the net volume and form changes being of a low to moderate order. Erosional retreat and gravel washover into Manuka have occurred all along the crest of the beach, most severely at the (eroding) southern end, the intensity of attack declining northward in a downdrift direction (as expected). Washovers occur for 10 m back into the vegetation at the southern end and there was excavation of tree roots.

Finally, Figure 2G presents a similar series of three profiles from Frasers Beach at Manapouri Township. This beach is the most exposed of all to westerly conditions and like Ruby Bay it is strongly characterised by longshore drift. This beach displays very marked scour of the backshore deposits with corresponding gains of the products lower down on the foreshore. There is thus no net loss of beach but considerable loss to materials landward. These losses included the removal of the benchmark at M15, loss of 40 m+ of the lakeshore road and substantial erosion into vegetation further north.

In summary, it can be seen that almost every beach surveyed displays some evidence of recent erosion to backshore materials. However, the net beach changes are for the most part moderate so that beaches *per se* have generally weathered the storms quite well while their immediate hinterlands have borne the brunt of the attack.

The principal exceptions are the longer beaches having full exposures to the west (Frasers and Ruby particularly, but to lesser extents also George, Monument, Bullings and Sandy). Frasers Beach has the greatest exposure and has sustained the greatest backshore loss. As distinct from the damage to vegetation reported by Allen and Mark (1989), it is evident that severe physical change is localised to the area of the Township foreshore.

Figure 3. Locations of beach profiles on Lake Te Anau.


Te Anau Glowworm Caves Jetty
Deshmans Pt
Garden Pt
Mark Pt
Moonlight Beach
Honeymoon Beach
The Bluffs
Dome Is
Driftwood Cove
Mystery Cove
Jetty
Boat Ramp
Lookout
Dog Kennels
Fast Cove
Bond Bay
Bluegum Pt
Te Anau Pt
Sewage Ponds
Park HQ
Camping Ground
Control gates
GOLF COURSE
Golf House
CHARLES MAJOR RD
WILLIAM STEPHEN RD
Reservoir (tanks)
No 2 Lookout
KAKAPO RD
SINCLAIR RD
RAMPARTS
Scattered scrub
Scattered trees
Wheat crop
Pasture
Stream
Hut
Track
Cairn
Cable
Canal
Lake Control
Dock
Jetty
Beach
Hills
Cliffs
Contours
Roads
Buildings
Power lines
Fences
Gates
Tracks
Boundaries
Vegetation
Water
Land
Survey marks
Place names
Features
Symbols
Lines
Areas
Points
Text
Numbers
Letters
Colours
Shapes
Sizes
Scales
Grids
Coordinates
Projections
Datums
Units
Measurements
Data
Information
Maps
Charts
Graphs
Tables
Figures
Images
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Sketches
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Simulations
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Introductions
Abstracts
Summaries
Keywords
References
Bibliography
Appendices
Tables of contents
Indexes
Glossaries
Acknowledgements
Dedications
Prefaces
Forewords
Afterwords
Epilogues
Prologues
Chapters
Sections
Subsections
Paragraphs
Sentences
Words
Letters
Punctuation
Spelling
Grammar
Style
Tone
Voice
Point of view
Narrative
Dialogue
Description
Exposition
Argument
Persuasion
Rhetoric
Logic
Reasoning
Evidence
Facts
Opinions
Beliefs
Values
Ethics
Morality
Aesthetics
Beauty
Truth
Knowledge
Wisdom
Understanding
Meaning
Purpose
Intention
Motivation
Emotion
Feeling
Thought
Perception
Cognition
Memory
Learning
Education
Training
Skills
Abilities
Talents
Gifts
Virtues
Vices
Habits
Customs
Traditions
Culture
Society
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Relationships
Love
Hate
Fear
Joy
Sadness
Anger
Surprise
Disgust
Contempt
Shame
Guilt
Pride
Envy
Jealousy
Gratitude
Forgiveness
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Sympathy
Antipathy
Apathy
Indifference
Curiosity
Interest
Boredom
Excitement
Anticipation
Hope
Despair
Faith
Doubt
Belief
Disbelief
Trust
Distrust
Confidence
Insecurity
Self-esteem
Self-image
Identity
Personality
Character
Temperament
Mood
Attitude
Disposition
Behavior
Action
Reaction
Interaction
Communication
Language
Speech
Writing
Reading
Listening
Seeing
Hearing
Touching
Tasting
Smelling
Sensing
Feeling
Thinking
Knowing

4. BEACH CHANGES. AUG. '88 - FEB. '89. LAKE TE ANAU.

Data for profile volume and form changes for sites around Lake Te Anau are set out in Table 2. The locations of the sites (new number system) are shown on Figure 3 while the earlier numbering system is again set out in the first column of Table 2. Figures 4A - 4I set out the 18 sites now in the survey network including those for which overlays have been possible.

Table 2 also shows the steady decline in re-locatable sites on Lake Te Anau. Vandalism and natural losses of markers had proceeded to the point where the usable re-survey record was becoming both small and poorly representative of beach types.

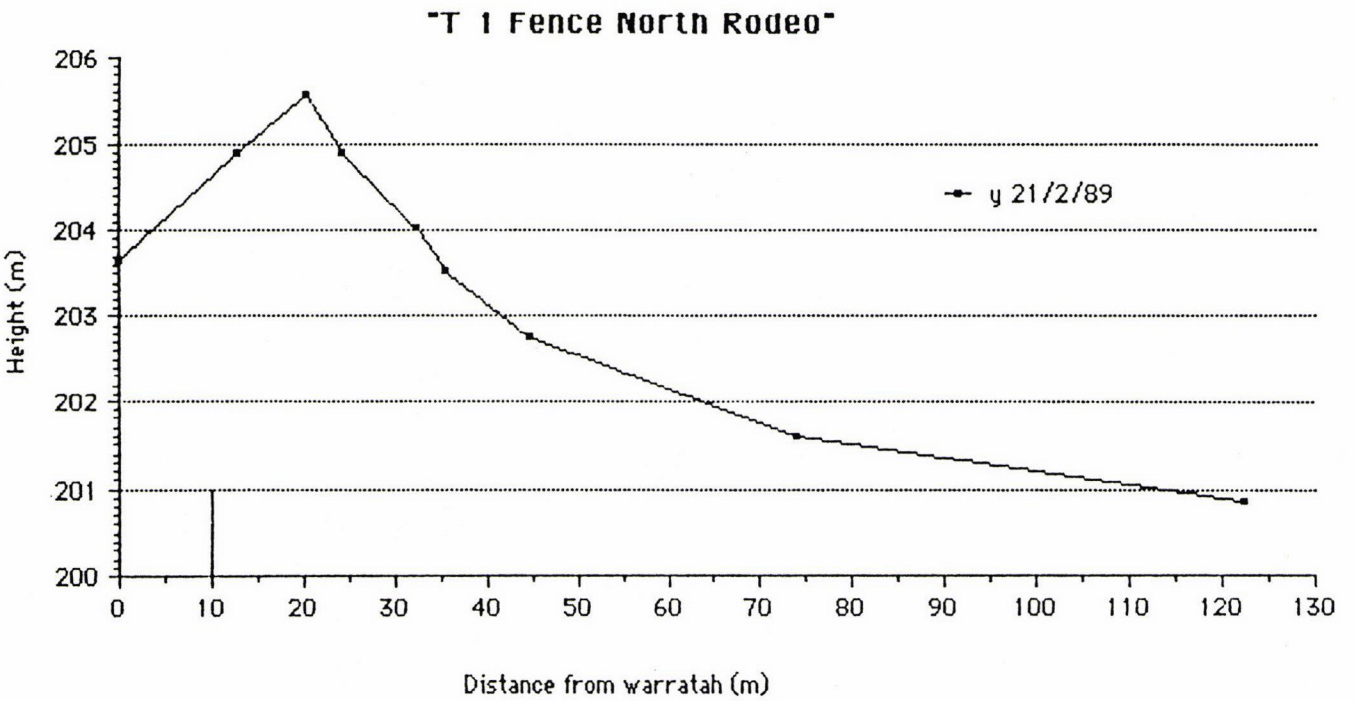
Inspection of the Table and the Figures reveals that the beaches of Lake Te Anau have undergone a very similar pattern of changes to those of Lake Manapouri. None of the net changes recorded are of dissimilar scale to those recorded in earlier periods.

Figures 4A, 4B, 4C, 4D and 4E all record the forms of new profiles, mainly in the Te Anau urban area. These are discussed further in the next section of this report.

Figure 4F shows two profiles (T11, T12) in Garnet Bay, South Fiord. Because the marker peg for T11 was destroyed by storm-tossed logs it has been replaced and there is some uncertainty in the overlay. The accretion shown in Figure 4F and Table 3 are thus more apparent than real. Field inspection showed that the bouldery foreshore had changed little but there had been strong scour of the backshore. Profile T12 was similarly eroded on the backshore and there were substantial amounts of driftwood driven back into forest.

Profile T13 (Moonlight Beach - incorrectly marked "Honeymoon" on the diagram) is a steep sandy beach adjacent to deepwater and sheltered from westerlies. There has been erosional retreat of the backshore and sand washover into the forest. Sand has also been combed down from the upper beach to the lower foreshore from whence it will be permanently lost into deepwater.

Deadmans Point (T 16 - Figure 4G) is a steep, stoney beach facing northwest so that it is subject to the full force of westerly storms. Strong erosion of the backshore into forest has occurred and the material combed down to the lower foreshore, there being a net gain to the beach overall.



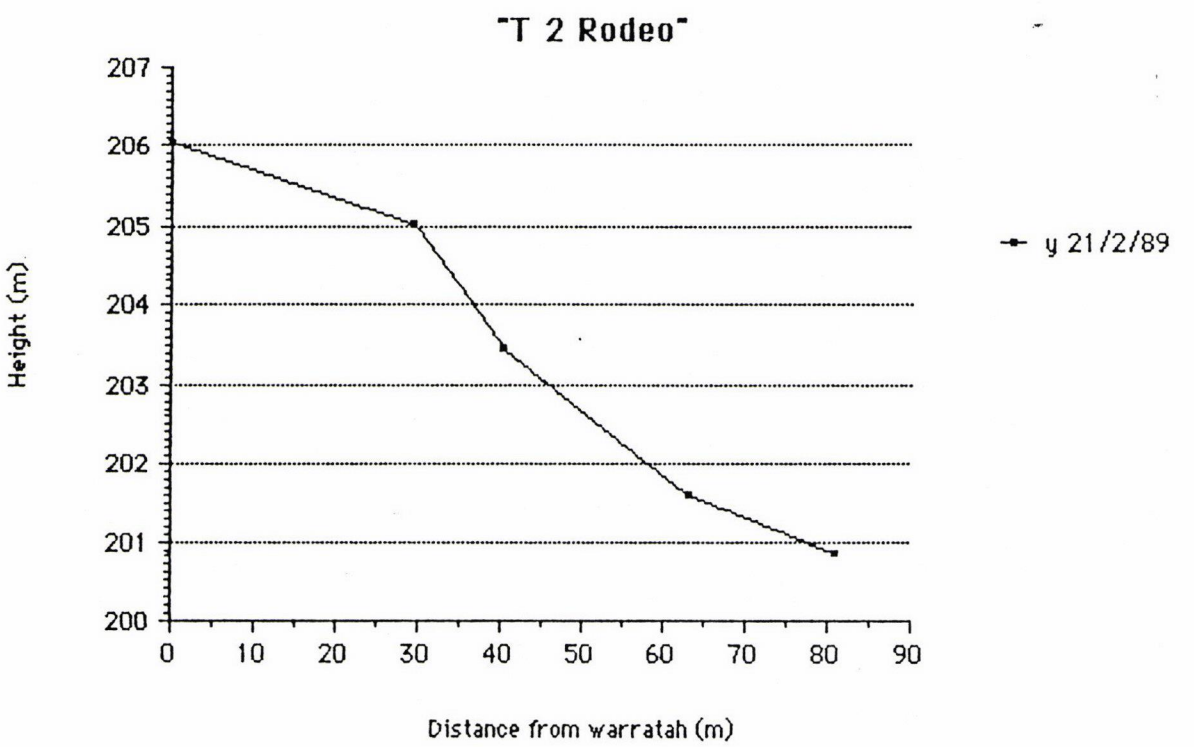
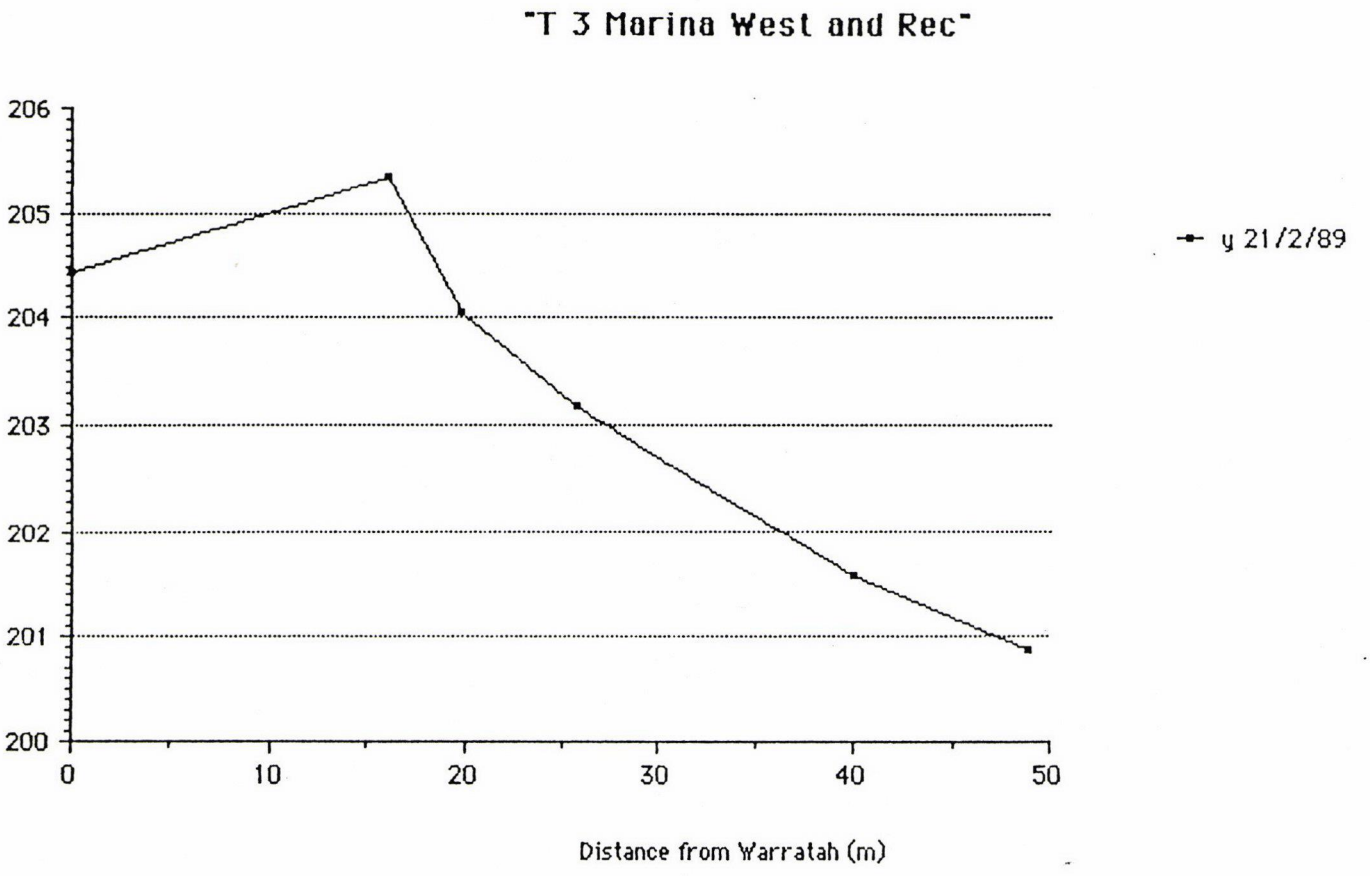


Figure 4. A. Beach profile changes from August 1988 to February 1989, Lake Te Anau. Locations as given on Figure 3.



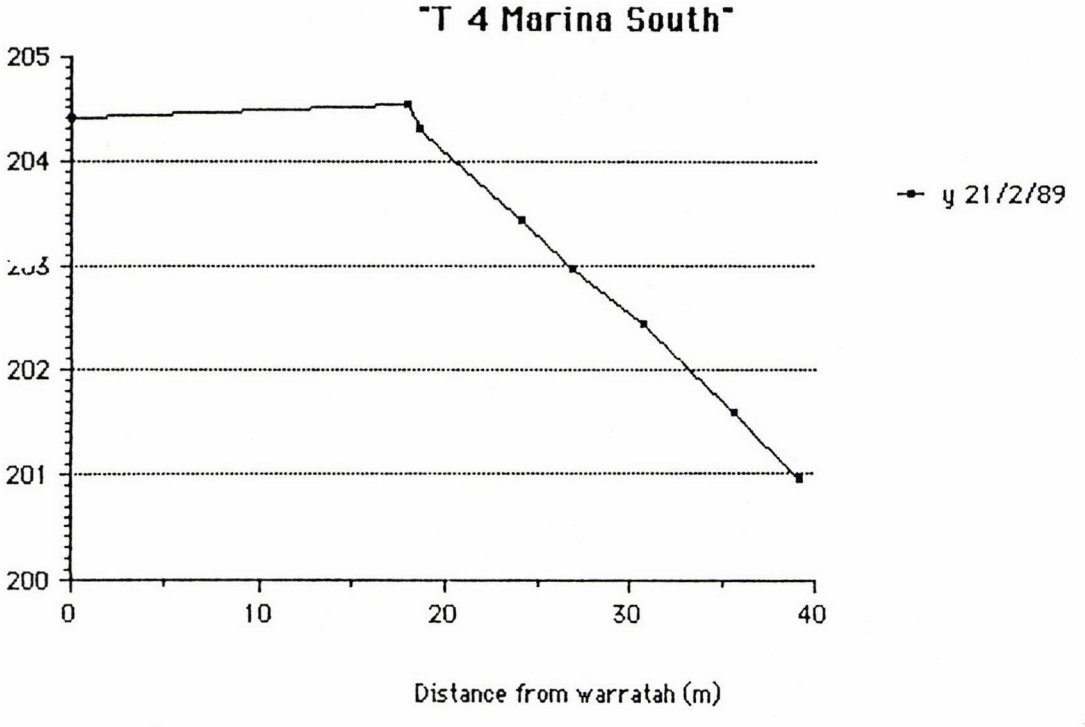
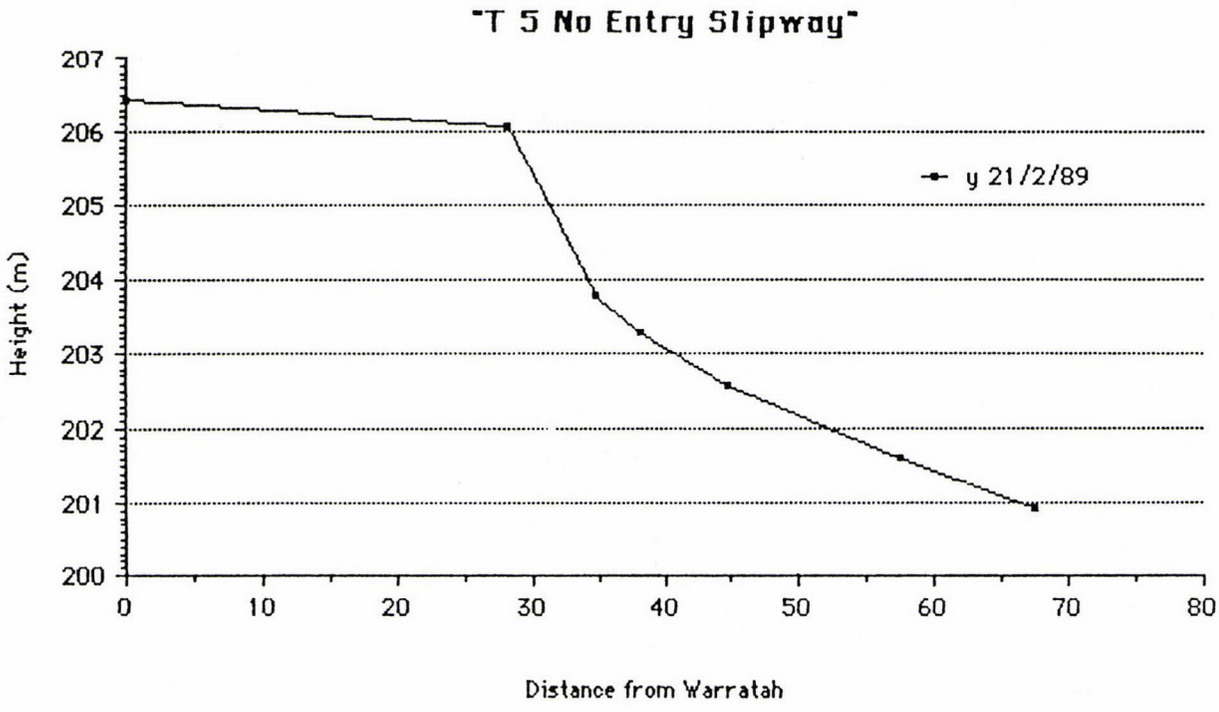


Figure 4. B. Beach profile changes from August 1988 to February 1989, Lake Te Anau. Locations as given on Figure 3.



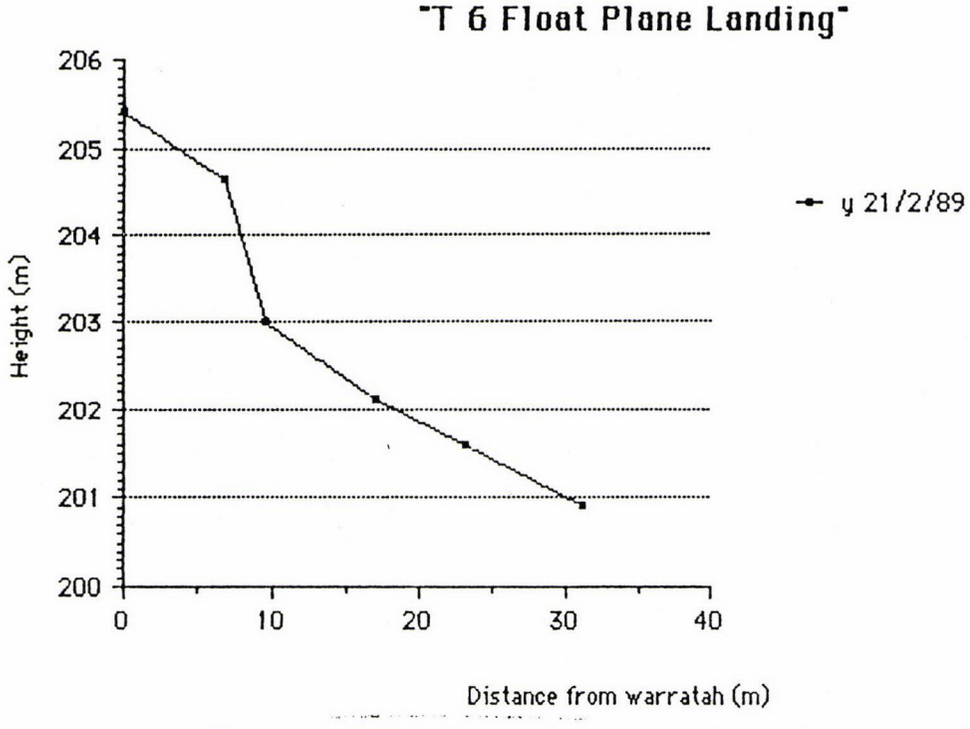
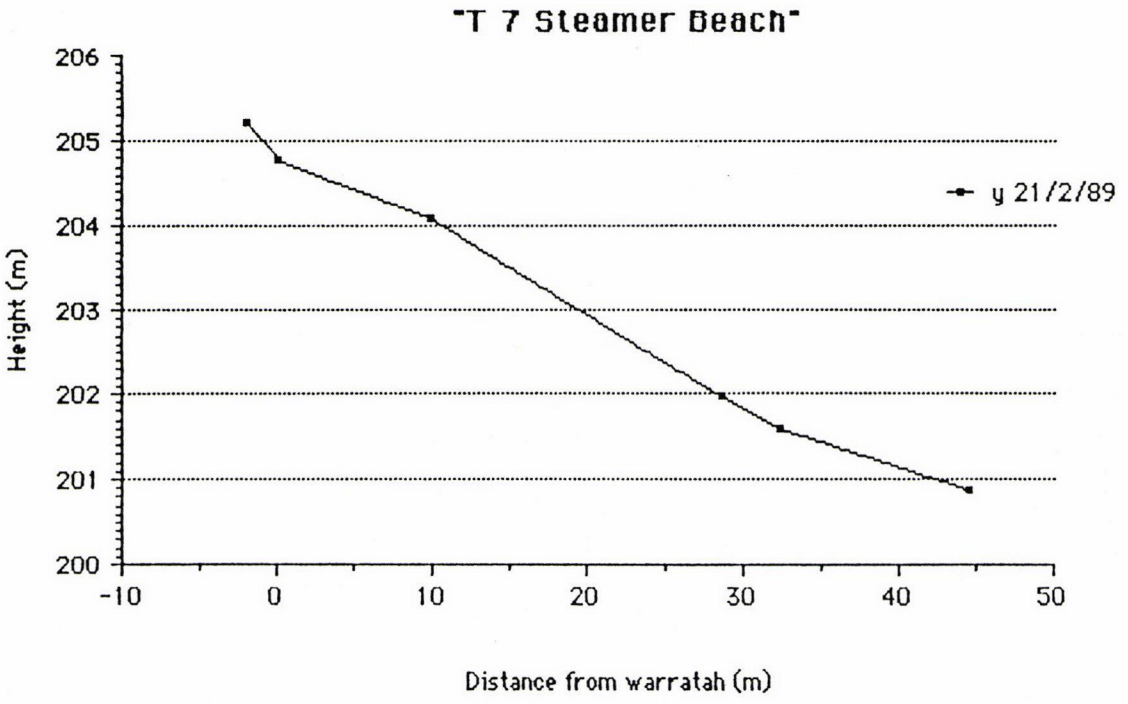


Figure 4. C. Beach profile changes from August 1988 to February 1989, Lake Te Anau. Locations as given on Figure 3.



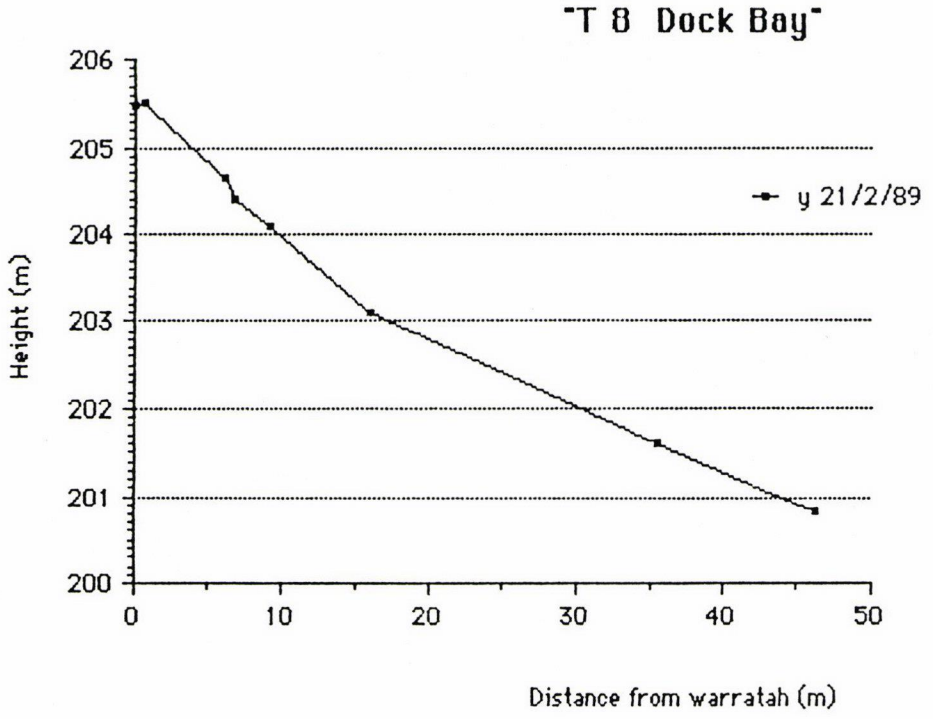
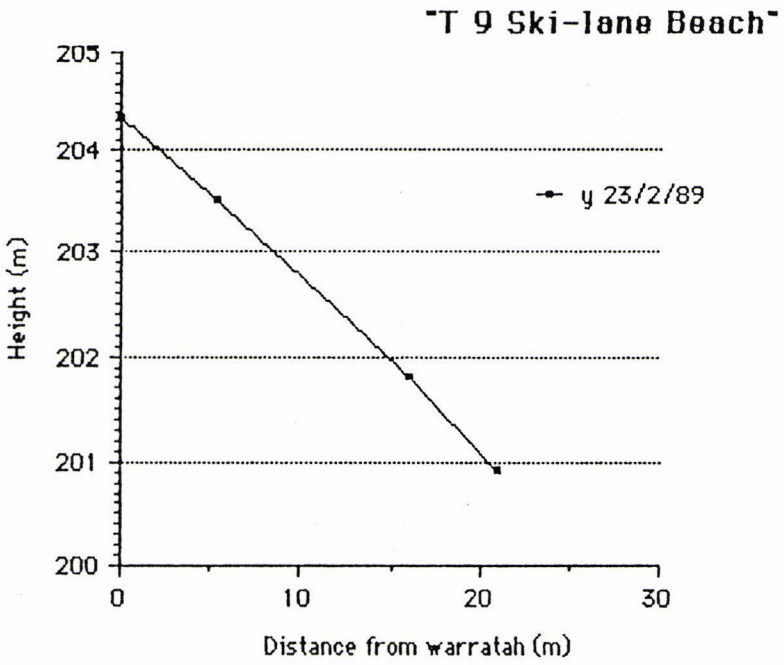


Figure 4. D. Beach profile changes from August 1988 to February 1989, Lake Te Anau. Locations as given on Figure 3.



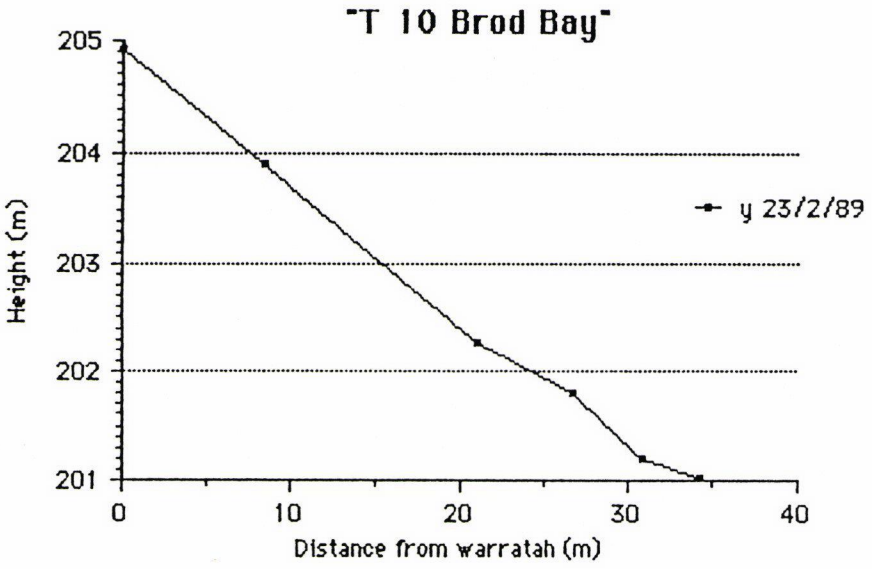
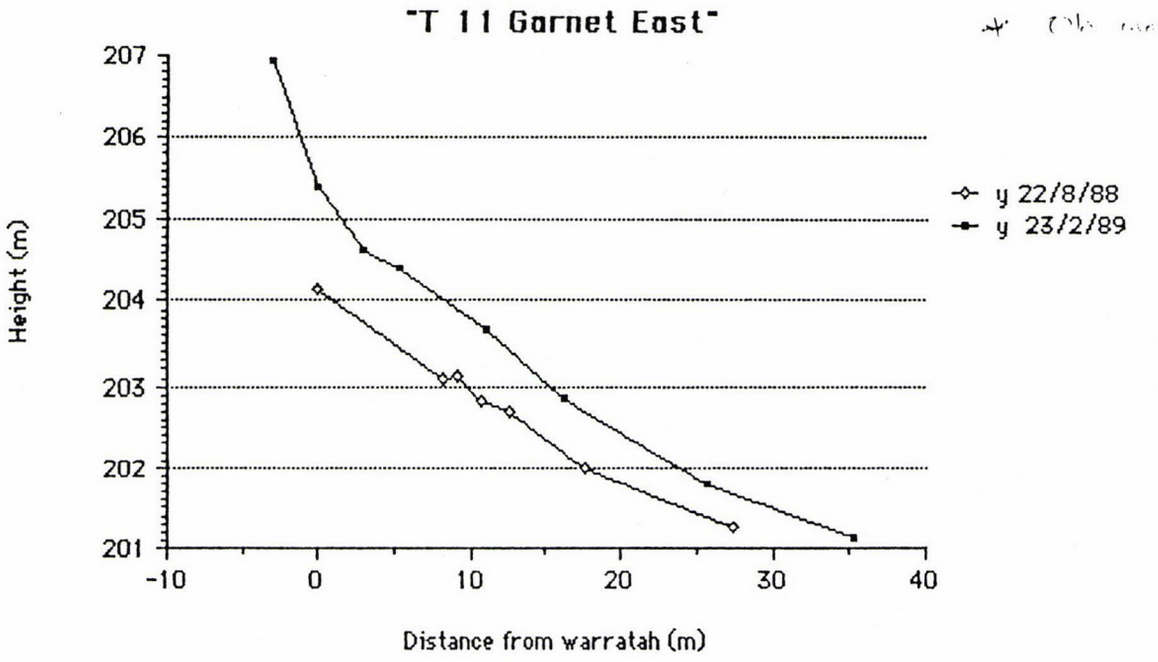


Figure 4. E. Beach profile changes from August 1988 to February 1989, Lake Te Anau. Locations as given on Figure 3.



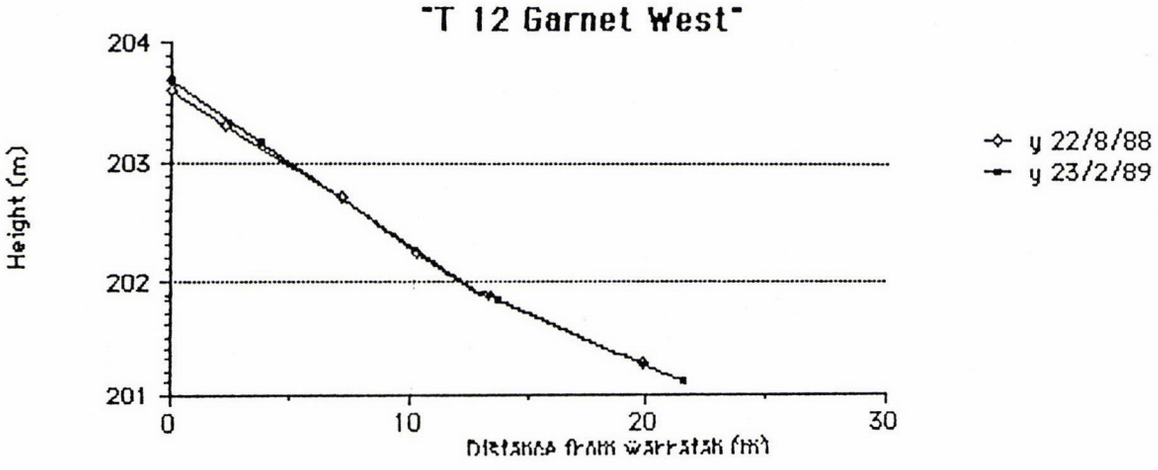
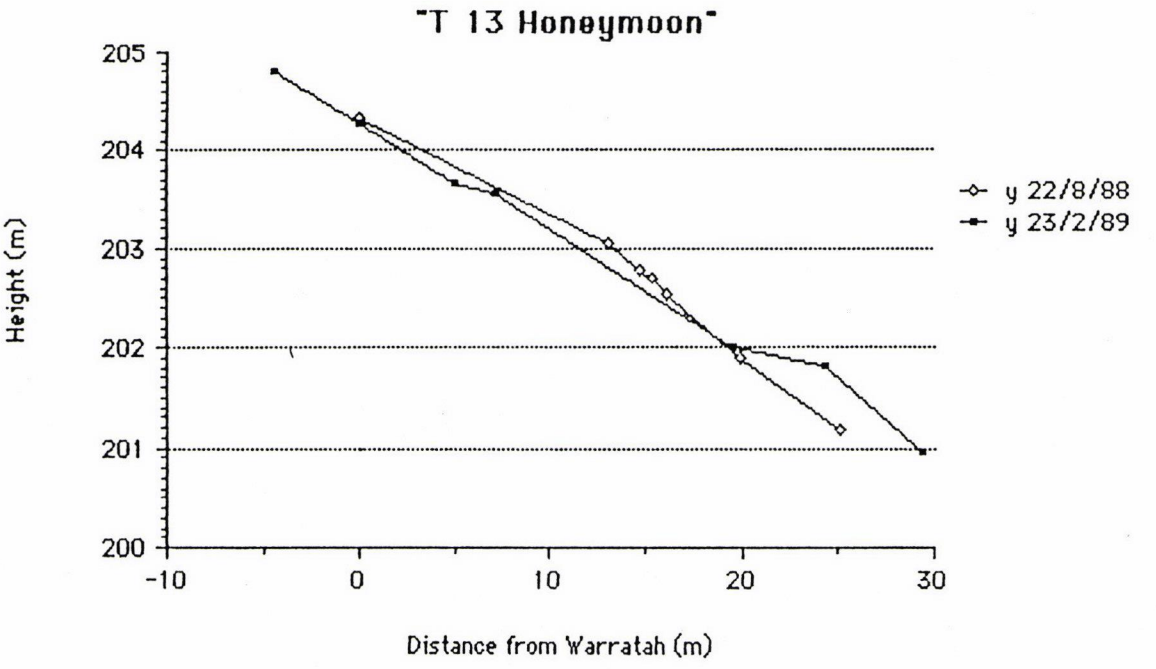


Figure 4. F. Beach profile changes from August 1988 to February 1989, Lake Te Anau. Locations as given on Figure 3.



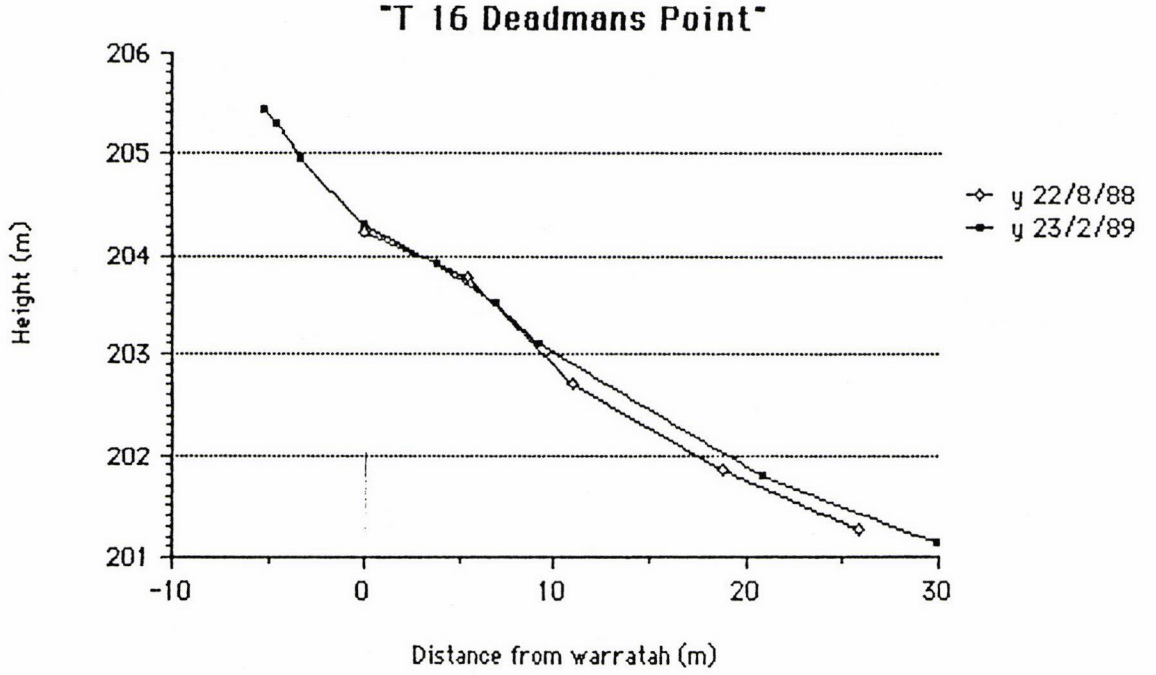
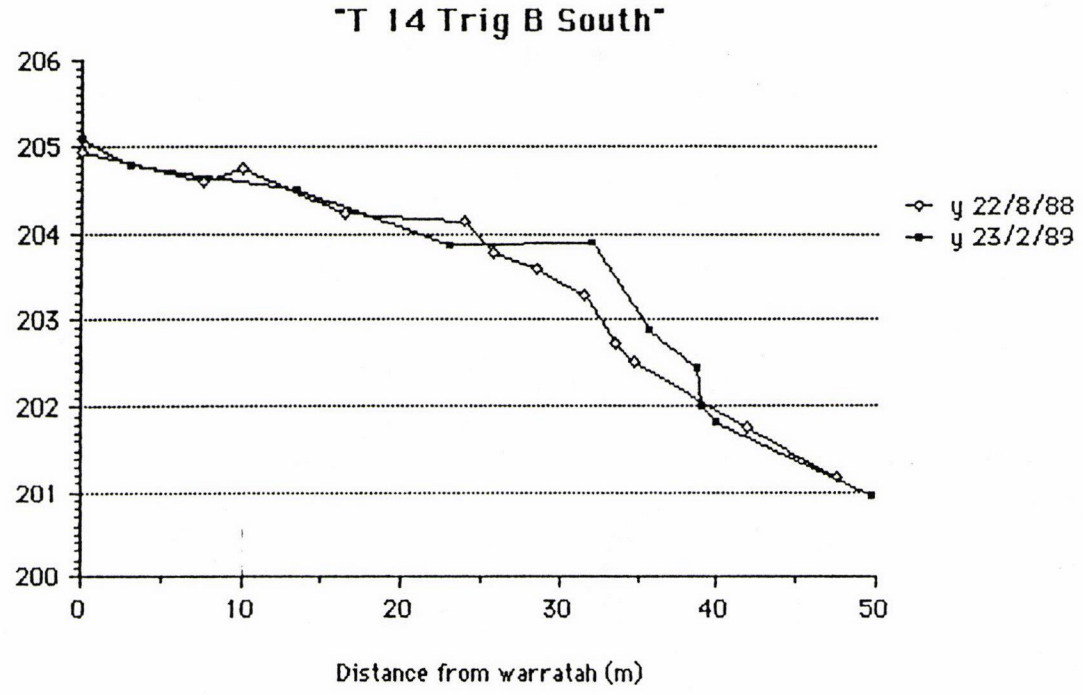


Figure 4. G. Beach profile changes from August 1988 to February 1989, Lake Te Anau. Locations as given on Figure 3.



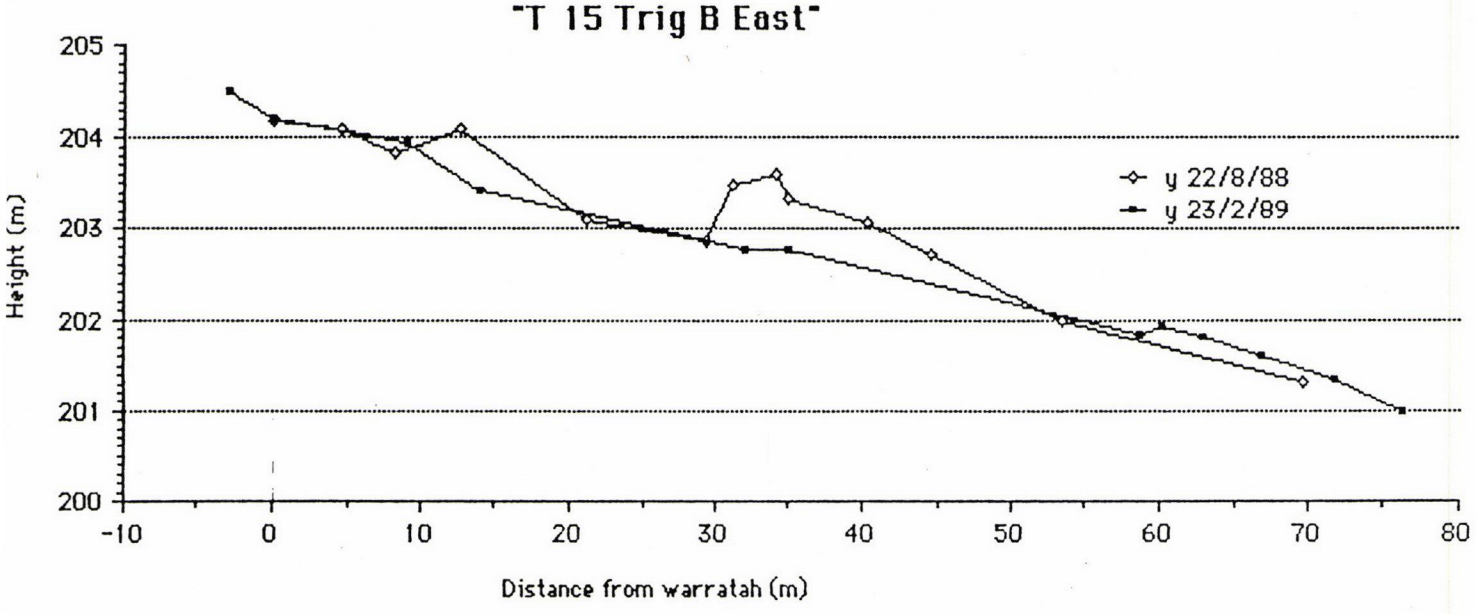
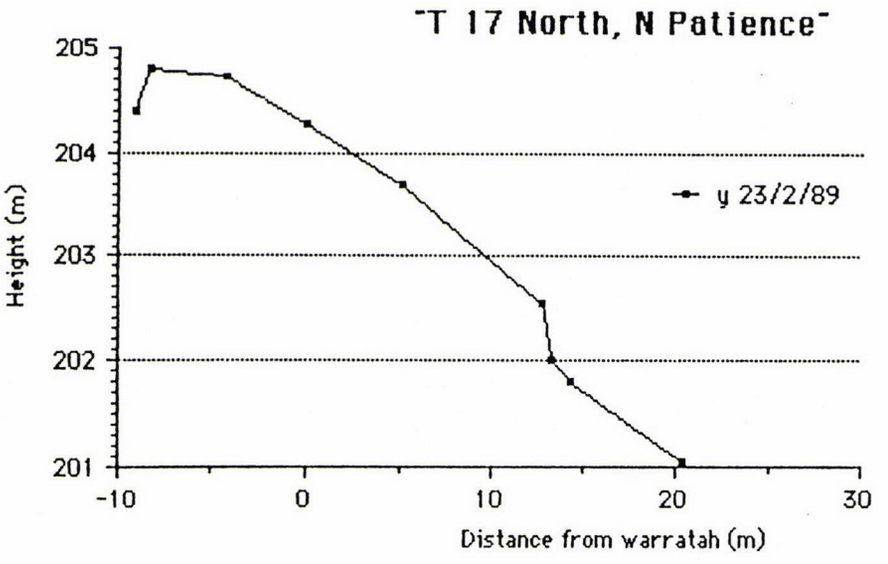


Figure 4. H. Beach profile changes from August 1988 to Fenruary 1989, Lake Te Anau. Locations as given on Figure 3.



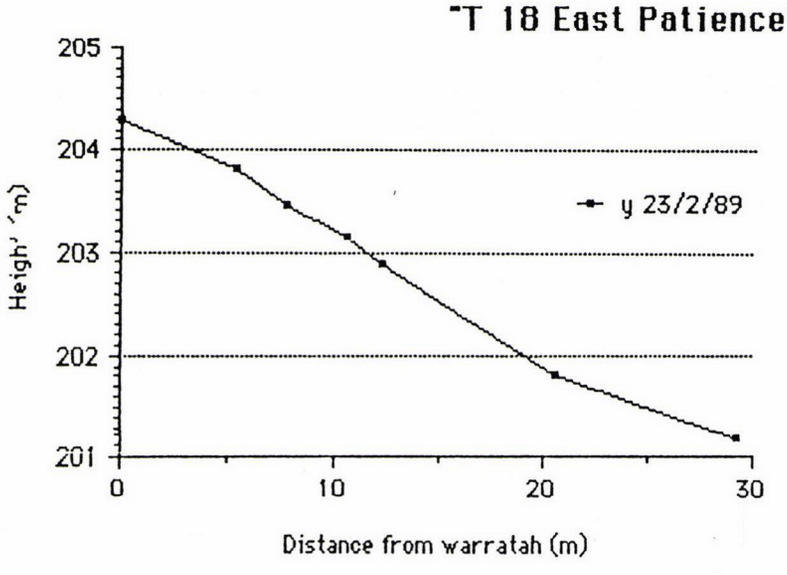


Figure 4. I. Beach profile changes from August 1988 to February 1989, Lake Te Anau. Locations as given on Figure 3.

Table 2. Lake Te Anau Beaches. Beach volume and form changes from August 1988 to February 1989 in comparison to changes in other periods.

Profile No. and Site	New No.	Volume Ch. 73/74-2/88 (Full Period) cubic m/m	Volume Ch. 2/88-8/88 (Earthquake) cubic m/m	Volume Ch. 8/88-2/89 (High levels) cubic m/m	Form Change 8/88-2/89
Garnet East(7)	11	+3.58	-7.73	Peg Lost.	-
Garnet West(8)	12	+2.38	-4.08	+0.43	b/sh ero
Mark Point (4) Moonlight	13	+10.28	-8.53	+0.23	Combed
Trig, B? (2)	14	+33.67	-27.3	+3.86	Relocated from nth.
Trig. B.? (3)	15	+20.18	-10.69	-8.78	Eroded fr. here
Deadmans (1)	16	-17.38	-5.54	+3.05	Combed
N. Patience (53) Bay	17	-9.28	-4.44	Peg Lost.	b/sh ero.
Patience Bay (52)	18	+3.44	No data	Peg Lost.	" "

Notes:

[1. Location numbers in brackets are as given in earlier reports.

[2. positive values denote accretion

[3. negative values denote erosion

[4. Form changes: b/sh ero. = backshore erosion, Combed = sand combed from high to low on the beach, Relocated = transferred alongshore from an exposed (west) site to a more sheltered (east) site.

Figure 4-H presents a complementary pair of profiles from Trig-B, a sandy foreland that is fully exposed to westerlies on its northwest flank. As can be seen, considerable volumes of sand were eroded from the exposed side (T15) and transported to the lee side (T14) appreciable volumes of sand were also combed down to form a prominent bar in the nearshore zone (see T 15). There has been little backshore erosion. These changes can be regarded as internal re-distributions of sand, the foreland merely changing shape and re-orienting itself in response to the changing incidences of westerly and southerly storms.

Figure 4 I again shows two sites in Patience Bay for which there are no previous survey records. Field inspection of this shore shows severe erosion of headlands and strong scour of backshore deposits along most of the shore.

Because there were no sites within the urban area it has not been possible to accurately assess foreshore erosion there. However, field inspection and the damage sustained to assets make it quite clear that the situation there is closely analagous to that on Lake Manapouri. Thus, the most severe erosion has occurred on long beaches having the greatest exposure to westerly wave action. As with Manapouri, it happens that such beaches form the township foreshore so that damage to assets has both been maximised and is localised in that area. This situation is discussed further in the next section of the report.

It must also be borne in mind that Kirk (1985) detailed a number of features of management of the Te Anau Township foreshore that have contributed to the damage sustained. Conversely, implementation of some of the recommendations of that report has helped to offset the severity of attack in some locations.

5. UPGRADING THE MONITORING NETWORK

As explained earlier, upgrading the survey network had become a pressing matter in order to ensure an adequate coverage of accurate information about ongoing shoreline changes on both lakes.

5.1 Lake Manapouri.

As can be seen from Table 1 and Figure 1 refurbishing the network involved establishment of no new sites on that lake. Rather, it was necessary to secure existing markers, re-tag all of them, concrete the bases and establish offset lines in some cases. Comprehensive location data were also compiled for each site and alternate marked profiles exist on some beaches. These are presented in note form as Appendix 1. In all,

Profile T6 (Figure 4C) has been sited to monitor developments around the upgraded rock revetment at the Floatplane Wharf (see Kirk 1985).

Profile T7 (Figure 4D) is sited to monitor ongoing accumulation of gravels on Steamer Beach at the downdrift end of the township foreshore system. Substantial accumulations were evident lower on the foreshore at the slipway and south of it.

Profile T8 (Figure 4D) is sited toward the centre of Dock Bay. Erosion of backshore deposits has occurred there as well as landward loss of gravels from the beach by washover.

Profile T9 (Figure 4E) is sited at Ski-Lane Beach where moderate erosion has occurred. However, the principal changes to this beach involved loss of a foreland which cracked off and slumped into deepwater in the earthquake of June 4th, 1988 (see Kirk, Single, Gurnsey and McGown 1988).

Profile T10 is sited at the centre of Brod Bay Beach. There substantial combing down of the profile is evident, as well as backshore erosion and washover of sand for 5-7 m back into forest.

Finally, two new profiles (T 17, T18 - Figure 4I) were established in Patience Bay to replace pegs removed during the last year.

Unless there are further significant shoreline modifying events that raise management concerns in the meantime, it is recommended that these sites be re-surveyed and assessed in 5 years time. It is an important characteristic of the system that, provided the locators remain intact, data can be obtained for a wide variety of purposes at any time.

6. DISCUSSION AND CONCLUSIONS.

There is widespread evidence of shoreline erosion on both lakes. However, beaches *per se* have sustained little long-term damage except for those most exposed to the westerlies. Indeed, many beaches have gained sediment as a consequence of the fact that erosion was most intense on higher level backshore deposits. It is backshores that have borne the brunt of the attack.

Because it happens that the most exposed beaches are also the sites of the two townships and parts of the backshores have been developed, damage to both backshores and assets is maximised in the township localities.

Elsewhere, it is very probable that the longer term consequences of the storms and high water levels of October/ November 1988 will be seen mainly in effects on vegetation communities. Such a conclusion is in keeping with earlier research utilised in formulation of the Operating Guidelines. For those purposes high water levels were seen principally as a threat to vegetation while low levels were seen as more of a threat to the physical stability of beaches. The generally low levels obtaining during February 1989 were of concern in this respect, though they greatly facilitated re-survey.

The survey network on both lakes has been upgraded and will hopefully remain mostly intact for a useful time span. Particular attention has been paid in the upgrade to a selection of sites within the Te Anau urban area,coverage of popular beaches near the town, and known sites of recent appreciable change. Further erosion to re-construction sites in Te Anau is inevitable because of the manner in which the work has been carried out.

7. REFERENCES.

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_____; Gurnsey, P.F.; McGown, A.C. (1988): " Lakes Manapouri and Te Anau:- Beach Changes February to

August, 1988 With Special Reference to Earthquake -Related Effects On and After June 4th."
Unpublished Report to Electricity Corporation of New Zealand and to The Guardians of Lakes Manapouri and Te Anau, September 1988: 17pp.

APPENDIX 1

LOCATION NOTES FOR PROFILE SITES ON LAKES MANAPOURI AND TE ANAU.

Profile Location Notes

Figures 1 and 3 show the approximate locations of the profiles. Apart from profiles 5 and 6 on Lake Te Anau, the profile marker is an iron warratah standard 2m in length.

Tables 1 and 2 list information relevant to re-profiling a given profile. All bearings are True, with the magnetic variation taken as 20° 18' (20.3°) East of True North. The profile bearing was taken from the marker looking lakeward, and should give a profile line approximately perpendicular to the lakeshore at that point. It must be appreciated that this may vary with different lake levels, and errors could made if comparing profiles from different dates if a shore perpendicular line was taken every time. This is especially relevant for profiles 13, 14 and 15 on Lake Te Anau.

Following are additional notes to help pinpoint the markers in the field.

Lake Manapouri

- **1** Sandy Beach. Profile is in the centre of the beach with the marker about 1m lakeward of a large Beech tree.
- **2** Circle Cove. Profile is in the centre of the beach above the present vegetation line.
- **3** Bullings Beach. Four warratahs are spaced along the edge of the vegetation, with the southernmost labelled 3a being on the edge of a rocky outcrop. The profile runs from marker 3c.
- **4** George Bay. Profile is in the centre of the right-hand (western) beach in George Bay, directly in front of a cluster of Manuka at the edge of the vegetation line.
- **5** Monument Bay. Profile is to the left of centre of the right-hand (western) beach in Monument Bay, near the highest storm berm.
- **6** Stockyard Cove. Profile is approximately 50m south of picnic tables, left of large tree trunk lying down the beach. Old marker is adjacent to the tree trunk and amongst the vegetation. New marker is 1.6m south of, and 2m lakeward of the old marker.
- **7** Fairy Beach. Three warratahs are spaced along the beach at the vegetation edge. The profile is from marker 7b which is 50m West of the westernmost boulder spur about 150m East of the western end of the beach. Marker 7a is 40-50m East of easternmost boulder spur 3m lakeward of Beech trees beside an angled Mahoi. Marker 7c is at the western end of the beach where the vegetation curves back up a river valley.
- **8** Calm Bay Head. Marker is towards the northern end of the beach about 25m south of stream mouth, and is about 1m lakeward of lagoon or barrier beach rear scarp.
- **9** Calm Bay Entrance. Marker is about 1m lakeward of scarp at vegetation edge and the profile is also marked by two sticks jammed into the beach in line with the profile. The marker is underwater when the lake level is greater than 178m.
- **10** Ruby Bay North. Marker is approximately 60m from the north end of the bay at the vegetation edge. New marker is 2.5m shoreward of highest beach berm and old marker. Old marker has two labels.
- **11** Ruby Bay Centre. Profile is approximately 150m South of profile 10, and 25m south of lone Kowhai. Marker is near the vegetation edge.
- **12** Ruby Bay South. Profile is approximately 250m South of profile 11. Marker is amongst vegetation and on the southern section of boulder fan.
- **13** Frasers Beach North. Profile is approximately 60m North of the end of vehicle/ walking track and picnic area. Marker is amongst vegetation, turf and ground water streams.
- **14** Frasers Beach Centre. Profile is 40m South of track down to beach from road below Manapouri Motor Inn. Marker is among tussock and turf near area of large boulders.

- **15** Frasers Beach Benchmark. Profile is at south end of beach below where the road turns and levels out behind the beach. Marker is next to large rock in vegetation 1m behind scarp amongst tree roots.

Lake Te Anau

- **1** Fence North Rodeo. Marker is near two gates with fence seperating paddocks.
- **2** Rodeo. Marker is 1.5m in front toilet wall, in line with baton beneath chimney.
- **3** Marina West. Marker is by Cabbage tree on Marina side of road opposite three Poplar trees on lake side of road.
- **4** Marina South. Marker is located lakeward of large tree stump with car park rail attached.
- **5** No Entry Slipway. Marker is northern concrete gatepost of 162 ??? Drive. Profile runs to the north of Kowhai at beach scarp. Profile label is at base of gatepost.
- **6** Float Plane Landing. Marker is concrete marker with 'Live Cables Underground' on face, oppposite Mokoroa Street just South of drainage water outlet. Profile label is at base of concrete marker.
- **7** Steamer Beach. Marker is in group of Poplar trees lakeward of single Cabbage tree.
- **8** Dock Bay. Marker is in grass lakeward of bush approximately 30m West of track that runs down to lake from Kepler Track sign.
- **9** Ski-lane Beach. Marker is lakeward of large double trunked Beech tree, which is the second large Beech West of Ski-lane Point.
- **10** Brod Bay. Profile is in the centre of the bay. Marker is 5m East and 3m shoreward of easternmost ski-lane pole, in front of bar-b-que area.
- **11** Garnet East. Marker is amongst vegetation, North of stream. A second warratah is sited 3m further into the bush up steep slope.
- **12** Garnet West. Marker is in the centre of the beach among fallen trees about 2m lakeward of vegetation.
- **13** Honeymoon Mark Point. Marker is located East of stream, in vegetation near large Beech trees approximately 25m West of easternmost bar-b-que area.
- **14** Trig B South. Marker is 20m East of 'Toilet' sign and rubbish bin, at vegetation edge.
- **15** Trig B East. Marker is 2m North of blank sign at vegetation limit. Profile runs between single Manuka to the south and two Manuka close together to the north.
- **16** Deadmans Point. Profile is about 30m West of Deadmans point. Old marker is beside fallen trees and is bent at right-angles to the ground. New marker is 3m shoreward.
- **17** North, North Patience. Profile is 50m South of eroded scarped sand-and-gravel point opposite the entrance to South Arm. Marker is on the lakeward edge of low terrace.
- **18** East Patience. Profile is located below second wind-break from the north on Lookout Hill, or first wind-break North of the Upokororo River. Marker is North of small stream near vegetation edge and at the foot of a Ribbon-wood tree.

Lake Manapouri Profile Information, February 1989

Profile Label	Profile Name	Profile Bearing°	Length of Marker Exposed (m)	Bearing ° to Fixed Locations From Marker	
1	Sandy Beach	357.5	0.440	To Stony Point	35.5
2	Circle Cove	306.5	0.380	To Beehive	320
3a			1.430	3c » 3a	62.5
3b			0.710	3c » 3b	66
3c	Bullings Beach	356	0.630	To island beacon	335
				To rock beacon	308
3d			0.600	3c » 3d	258
4	George Bay	277	0.446	To west bay head	277
				To east bay head	294
5	Monument Bay	216.5	0.320	To small island	310
6	Stockyard Cove	96	Old 0.850 New 0.850		
7a			0.710		
7b	Fairy Beach	46	0.603		
7c			0.570		
8	Calm Bay Head	130	0.268	To Beehive	164
9	Calm Bay Entrance	208	0.710	To Beehive	200
10	Ruby Bay North	256	Old 0.130 New 0.438		
11	Ruby Bay Centre	286	0.483	To Beehive	279
12	Ruby Bay North	307	0.770	To Beehive	285
13	Frasers Beach North	294			
14	Frasers Beach Centre	310			
15	Frasers Beach Benchmark	316			