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SHORELINE PROFILES OF SELECTED SITES ON LAKES MANAPOURI AND TE ANAU

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J. Irwin

INTRODUCTION

A detailed survey of profiles at selected shoreline positions on Lakes Manapouri and Te Anau was carried out from 23-30 June 1973.

METHODS

At each profile position a 5-ft long steel post was driven into the ground at the top of the beach close to the bush line, leaving 6 in. to 1 ft of the post exposed. Numbered metal tags were attached to the post and to a nearby tree (Tables 1, 2). In a few places where a post could not be driven in, large trees were marked. The positions of these markers were located on enlarged aerial photographs.

On Lake Manapouri 50 profiles were measured (Fig. 1). Most were near the centre lines of beaches, but at Bullings Beach four profiles were measured. Ten profiles were measured on the north and south shore near the entrance of South Fiord, Lake Te Anau. (Fig. 2).

MEASUREMENTS

All references to lake levels with respect to hydro-electric purposes are stated in feet and tenths of a foot. To avoid introducing confusion here these units are retained. Metric units have been used for horizontal distances.

Above Water Level

Heights along profiles were measured to the nearest 0.1 ft from ground level at the marker post to the water level, along a bearing normal to the beach line. Generally the beaches had even slopes and measurements were made at 5 m or 2½ m horizontal intervals. On beaches with uneven slopes, measurements were made at closer intervals.

Underwater Measurements

The underwater section of each profile was measured on the same magnetic bearing as the beach profile. Depths were measured by lead line to the nearest 0.5 ft, at 5 m or 2½ m intervals along the transit line to a depth of over 30 ft (approximately 550 ft above sea level). In a few cases measurements were taken to a depth of 50 ft (approximately 530 ft above sea level).

The small boat used was rowed at constant slow speed. A marked line connected boat and shore and by this means accurate spacing of soundings along the line was possible. In the calm conditions at the time of survey the boat was readily kept on the transit line. The clarity of the water made it possible to distinguish the bottom surface material on some profiles out to 25 m from shore.

Using a Ferrograph Inshore Graphic echo sounder with a sounding rate of approximately six soundings per second, depths were obtained by sounding at a slow speed along the profile line. As a traverse took several minutes, detailed bottom configurations were obtained except at depths of less than 3 ft where the record became obliterated by the outgoing sound pulse. These profile echo sounder records are shown in Figs 3a, b for Lake Manapouri and Fig. 4 for Lake Te Anau.

Lake Levels

During the survey, the level of Lake Manapouri at the West Arm gauge was between 581.4 ft and 582.0 ft above sea level. The level of Lake Te Anau on the day of survey was 663.83 ft above sea level.

Lookout Beach and Bullings Beach

At Lookout Beach two lead line profiles and four offshore echo sounding traverses were measured. Contours at intervals of 1.0 ft have been drawn and the sketch bathymetry is shown in Fig. 5.

At Bullings Beach four lead line offshore profiles were measured at 2½ m intervals. Contours at intervals of 1.0 ft are shown in a sketch bathymetry (Fig. 6).

RESULTS

A. LAKE MANAPOURI

Characteristics of Beach and Offshore Profiles

The beach and underwater profiles for the 50 sites measured on Lake Manapouri (Fig. 1) have been drawn (Figs 7-17b). The following properties of these profiles have been examined -

1. Average beach gradient, from the top of the beach at the reference marker to the shoreline on the day of measurement.

2. Average 1st offshore gradient, measured from the shoreline to the first change in underwater slope, which in each case is quite well marked.
3. Average 2nd offshore gradient, measured from the break in slope to the 550 ft above sea level point.
4. Length of the 1st offshore gradient, from the shoreline to the 1st change in slope.
5. Fetch (km): the maximum distance over which wind could blow to cause wave action.
6. Beach sediments: 1. sand; 2. sand over mud* or peat; 3. mud; 4. boulders.
7. Rock types from the Geological Map of the area, (Sheet 24 Invercargill 1:250,000) in two main categories: 1. Fiordland complex; 2. Lower Tertiary conglomerates, sandstones and siltstones.

Beach Gradients

Of the 46 beaches measured, the majority (30) have average gradients of from 1 in 6 to 1 in 12, nine have very steep gradients greater than 1 in 6 (profiles 9, 22, 24, 25, 28, 29, 38, 39, 40, 41). Seven beaches have low gradients of less than 1 in 12 (profiles 6, 10, 14, 16, 21, 46).

Most beaches have an even slope; some show small steps (0.5 to 1 ft) caused by minor wave cutting at varying lake levels. Larger irregularities were noted on the following profiles - beach profile 29 at the south end of Lookout Beach, showed a major step cut in peat and mud; profile 35 in Surprise Bay exhibited small slump scars, and profile 42 near the Waiau River outlet shows a wave-eroded step; profile 45 at the east end of Circle Cove shows beach ridges formed by wave action.

Underwater Gradients

Underwater gradients can be divided into two distinct groups. The first offshore gradient is an approximate extension of the beach gradient and continues below water level to an average depth of 8.5 ft, for the 50 gradients measured when the lake level was between 581.4 ft above sea level and 582.0 ft above sea level. The depths of the ends of the 1st offshore gradients ranged from 3 ft to 32 ft but 80% fell between 6 ft and 11 ft, that is between 571 ft and 576 ft above sea level.

The majority of the 1st offshore gradients (for 35 beaches) are very steep to steep, 10 gradients being steeper than 1 in 8, and 16 between 1 in 8 and 1 in 16.

The second offshore gradients, measured from the change of slope to the 550 ft above sea level depth, are much steeper than the first offshore gradients, 37 of the 46 gradients being steeper than 1 in 4.

As with the beach gradients most of the 1st and 2nd offshore gradients are of even slope.

* 'mud' includes both silts and clays and refers to the Damsite Formation of McKellar (in press).

The 1st offshore gradients of profiles 1, 6 and 13 show the surface irregularities of complex delta forms; profile 35 in Surprise Bay shows the scars of successive rotational slumps (*see* McKellar 1973); the reversal of slope of profile 45 in Circle Cove is perhaps a submerged beach ridge.

Length of Offshore Gradient

Twenty-eight of the 1st offshore gradients are between 12 m and 36 m in length. Eleven are over 36 m in length. Profiles 1 and 46 off Garnock Burn near the river delta are the longest at 158 m and 156 m respectively and profile 3 in Monument Bay (126 m) and profile 45 (130 m) in Circle Cove are long, probably because these profiles are in narrow bays.

Fetch

The fetch affecting the beaches ranged from 0 to 14 km, 31 of the 46 beaches being subject to fetches of between 4 and 12 km. Eleven beaches had fetches of up to 4 km and only four had fetches of 12 to 14 km.

Sediments

The surface sediments of 30 of the 46 beaches are sand, 5 are sand over mud or peat, 8 are mud and 3 are boulders.

SUMMARY OF GRADIENT CHARACTERISTICS

		Beaches	Profiles
Average Beach Gradients			
Steep gradient	Greater than 1 in 6	9	10
Medium gradient	1 in 6 to 1 in 12	30	33
Low gradient	less than 1 in 12		7
Average 1st Offshore Gradient			
Very steep gradient	Greater than 1 in 8	19	22
Steep gradient	1 in 8 to 1 in 16	16	17
Low gradient	1 in 16 to 1 in 24		7
Very low gradient	less than 1 in 24		4
Average 2nd Offshore Gradient			
Very steep gradient	Greater than 1 in 2	21	22
Steep gradient	1 in 2 to 1 in 4	16	18
Low gradient	1 in 4 to 1 in 6	6	7
Very low gradient	less than 1 in 6		3
Length of 1st Offshore Gradient (m)			
Very short	0 to 12	7	8
Short	12 to 24	15	17
Long	24 to 36	13	14
Very long	more than 36		11

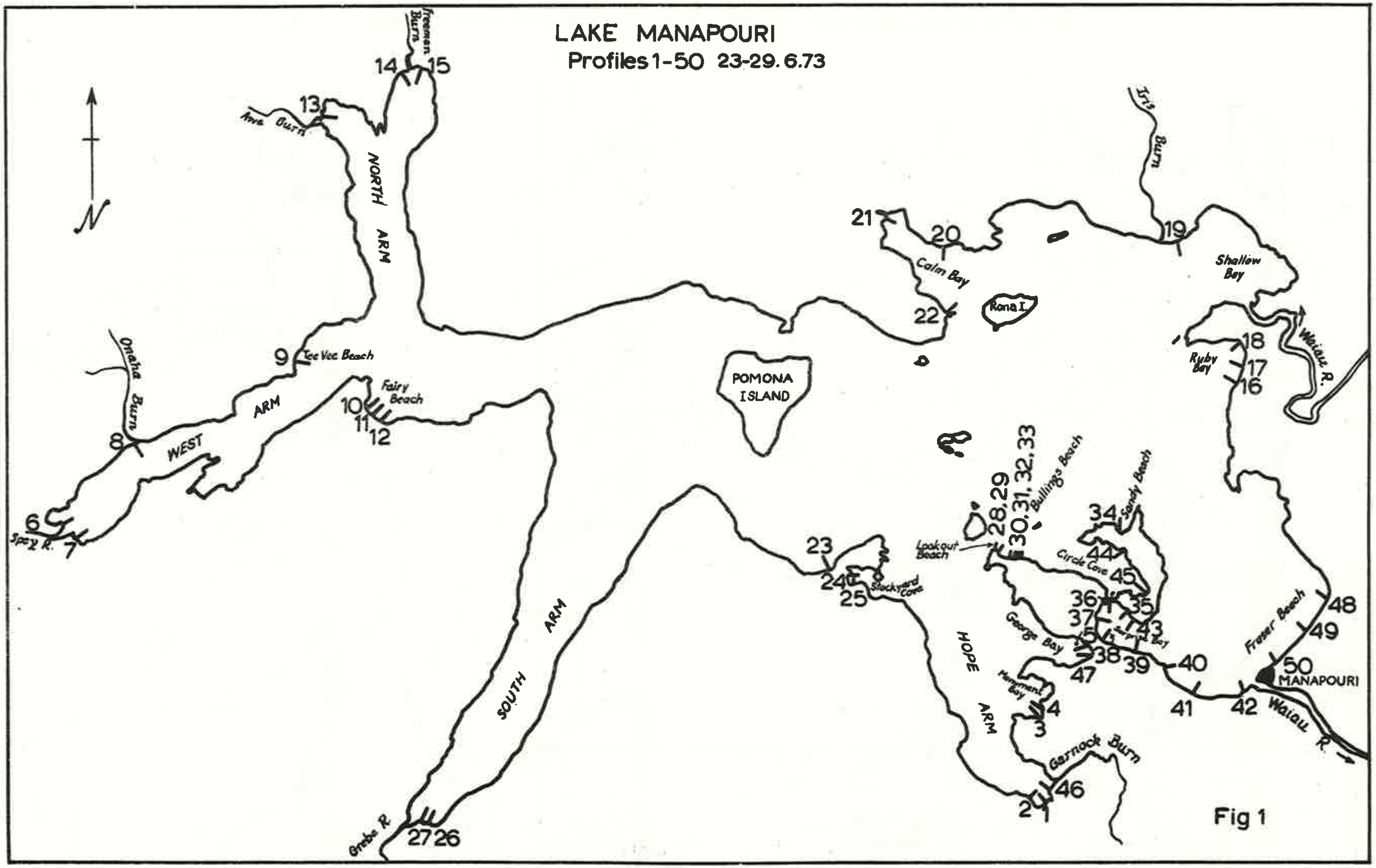


Fig. 1. Lake Manapouri showing positions of beach and underwater profile lines 1-50, June 1973.

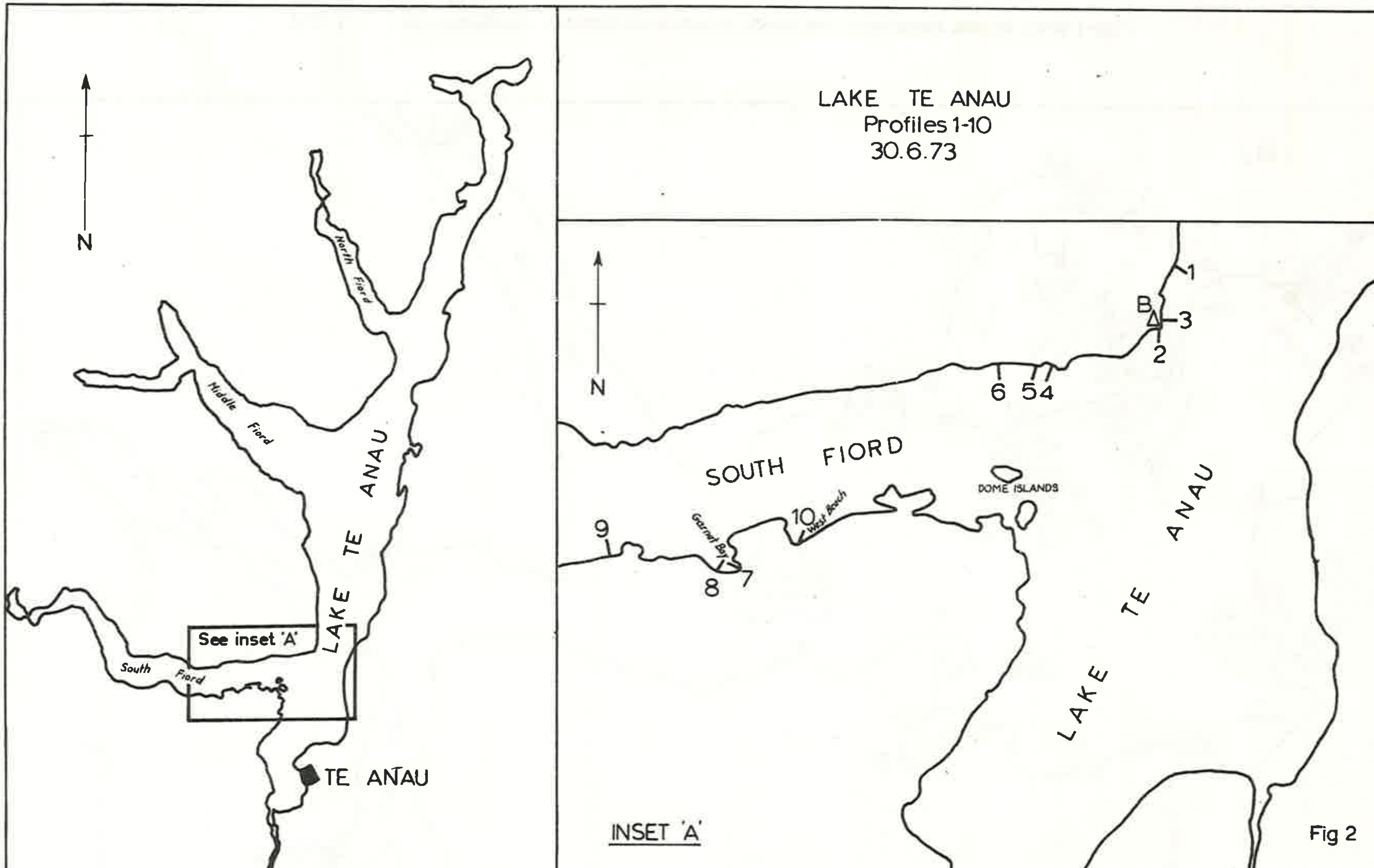
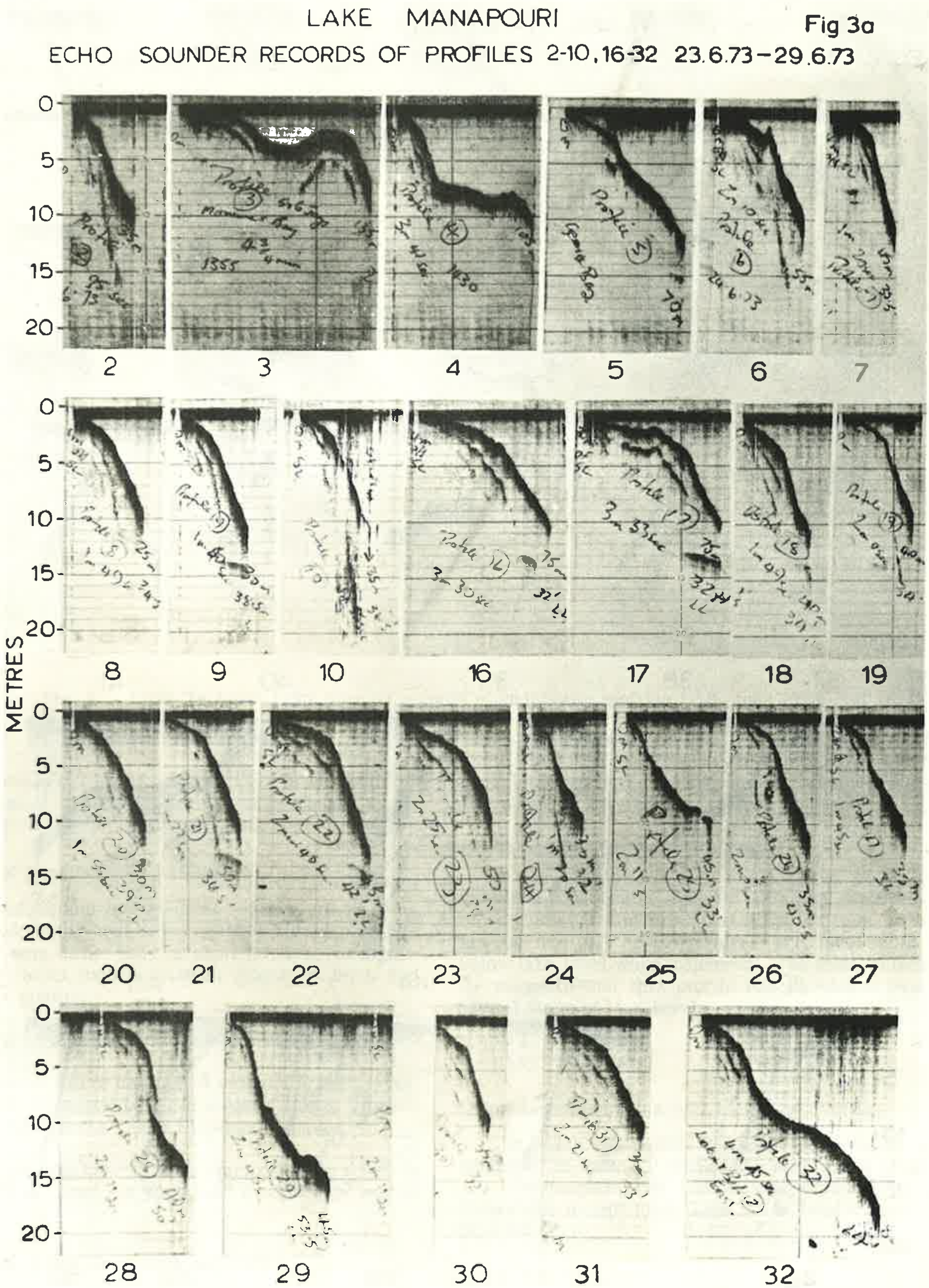


Fig. 2. Lake Te Anau showing positions of beach and underwater profile lines 1-10, June 1973.

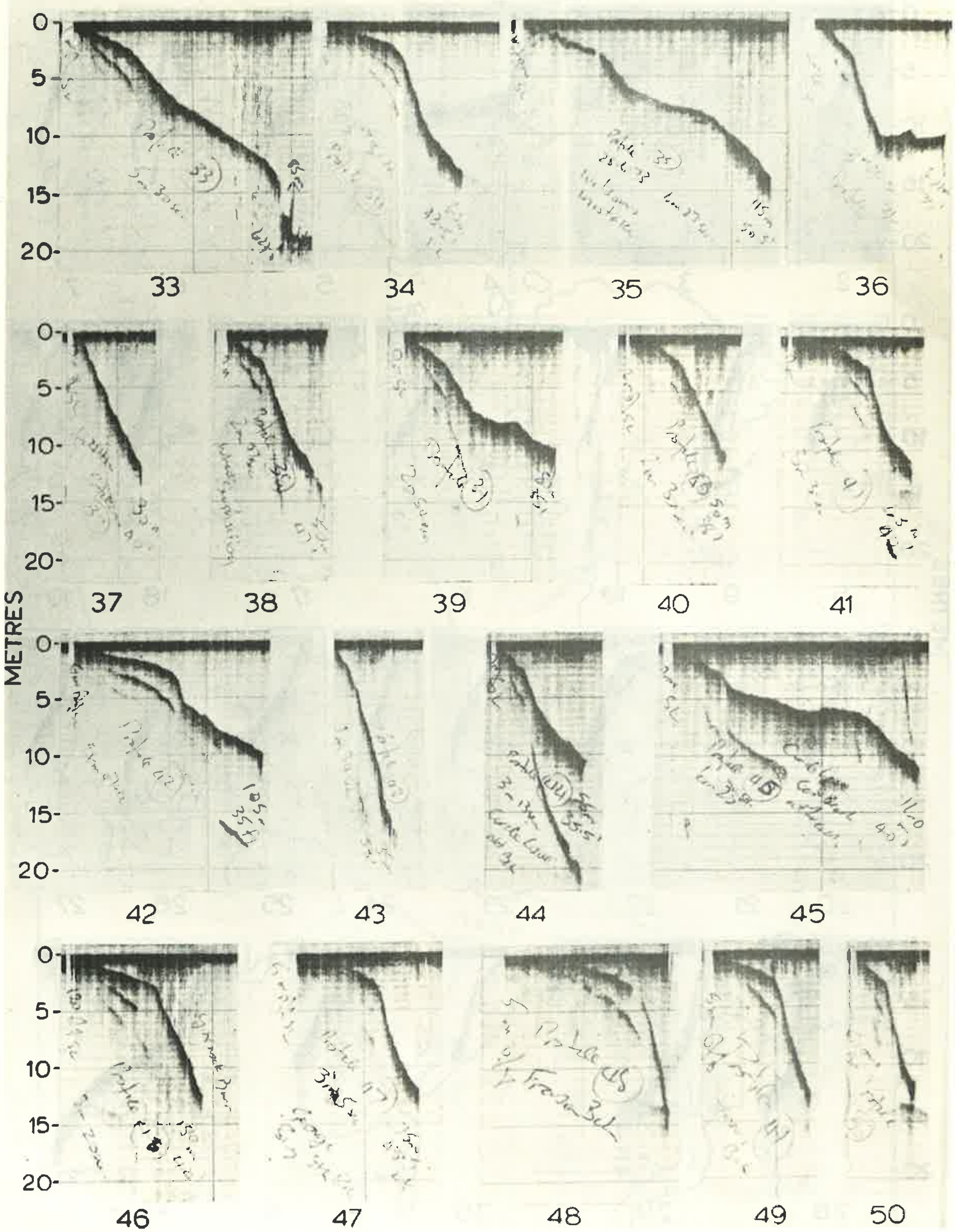


Figs 3a, 3b. Lake Manapouri. Echo sounder records of underwater profiles 1-50, June 1973.

LAKE MANAPOURI

Fig 3b

ECHO SOUNDER RECORDS OF PROFILES 33-50 23.6.73–29.6.73



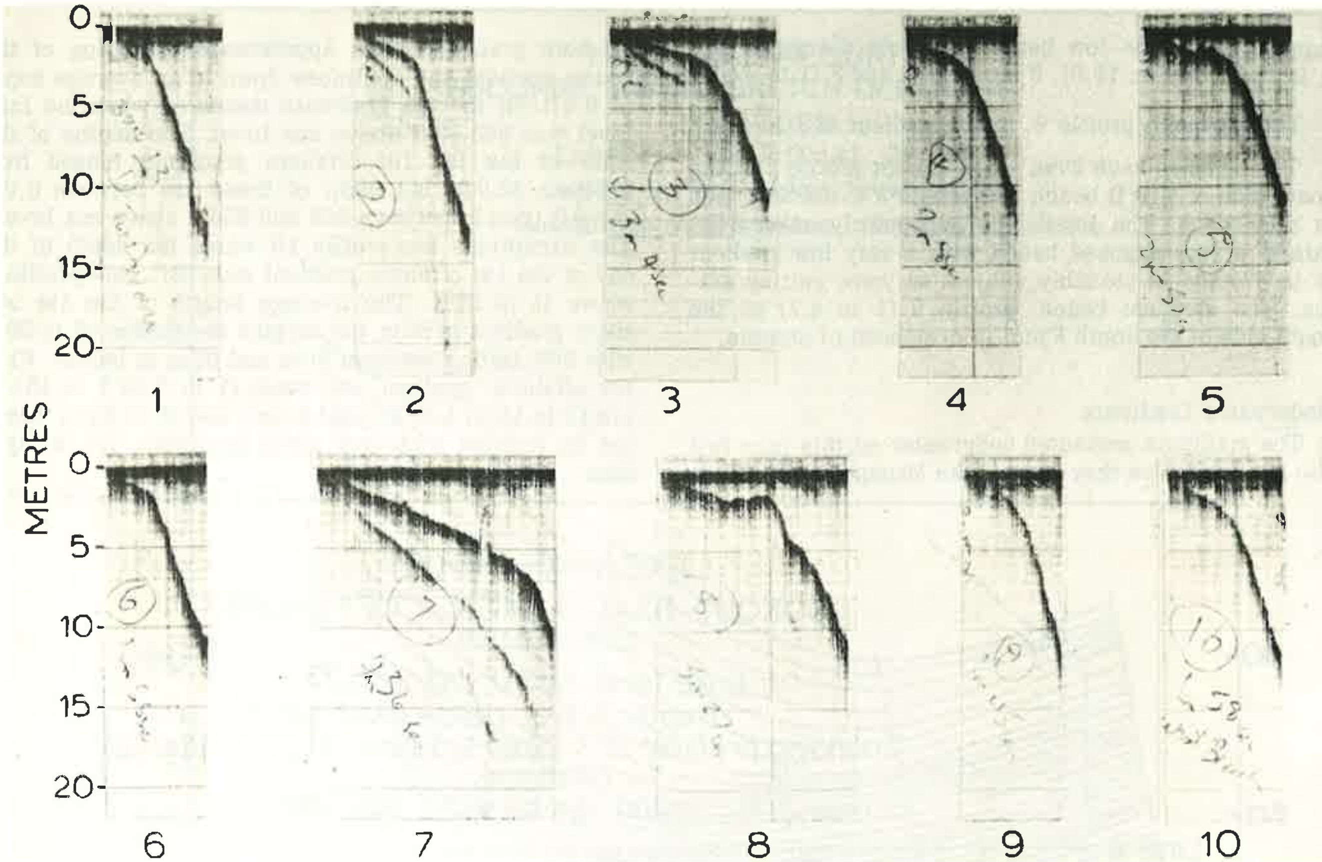


Fig. 4. Lake Te Anau. Echo sounder records of underwater profiles 1-10, June 1973.

CORRELATIONS

The possible effects of variation in intensity of wave action or in beach materials on beach and underwater gradients were examined using edge-clip cards.

Relation of Gradients to Fetch

Most medium and low gradient beaches are in areas exposed to long fetches. Steep beaches did not correlate positively with either long or short fetches. No significant correlation exists between length of fetch and underwater gradients.

Relation of Beach Gradients to Sediment

Sand beaches were not limited to specific rock types, 15 of the 30 examined being in areas of Lower Tertiary rocks and 12 in rocks of the Fiordland Complex.

Thirty beaches have medium gradients (1 in 6 to 1 in 12) and 20 of these are sand, and 3 sand over mud or peat.

Relation of Beach Sediments to Fetch

The possible correlation of sediment type with fetch was examined. Fourteen of 36 beaches with sand or sand over mud were exposed to fetches of 8 to 10 km. Six of eight mud beaches had fetches of 0 to 6 km. However the presence of sand on the beach is primarily dependent on its availability as a sediment.

Beach and 1st Offshore Gradients

As the profiles show at the majority of the sites examined the beach and 1st offshore gradients are closely similar and this total slope extends to levels ranging from 571 to 576 ft above sea level (6 to 11 ft below lake level when measured). The relative uniformity suggests that this profile has developed over the natural range of lake levels.

B. LAKE TE ANAU

Characteristics of Beach and Offshore Profiles

The beach and underwater profiles for the ten sites measured on Lake Te Anau have been drawn (Figs 18, 19). The properties of the profiles examined for Lake Manapouri, except Rock Type, have been examined for this lake.

Beach Gradients

Of the ten profiles measured, 5 have medium gradients of 1 in 6 to 1 in 12 and 4 have gradients less than 1 in 12. The low beach gradients are profiles 4 (1 in 12.2), 1 (1 in 12.8), 2 (1 in 20.8) and 3 (1 in 37.1).

The steepest, profile 9, had a gradient of 1 in 4.7.

The beaches have even slope except profile 2 at the south side of Trig B beach and profile 3 at the east side of this beach. The latter was particularly uneven but this is a very exposed beach with a very low gradient (1 in 37) and is probably subject to wave cutting action. The steepest beach, profile 9 (1 in 4.7) on the south side of the South Fiord is composed of shingle.

Underwater Gradients

The gradients measured underwater on this lake fall into two groups as they do on Lake Manapouri. The first offshore gradient is an approximate extension of the beach gradient and continues down to an average depth of 9.4 ft for the ten gradients measured when the lake level was 663.83 ft above sea level. The depths of the ends of the ten 1st offshore gradients ranged from 6.0 ft to 22.0 ft, but eight of these are between 6.0 ft and 9 ft (that is between 658 and 655 ft above sea level). The exceptions are profile 10 where the depth of the end of the 1st offshore gradient was 12 ft, and profile 7 where it is 22 ft. The average length of the 1st offshore gradient is 50 m, the lengths range from 26 to 90 m with 50% falling between 30 m and 67 m in length. Five 1st offshore gradient are steep (1 in 8 to 1 in 16), 3 low (1 in 16 to 1 in 24) and 2 very low (1 in 24+). There are no profiles with very steep gradients, i.e. steeper than 1 in 8.

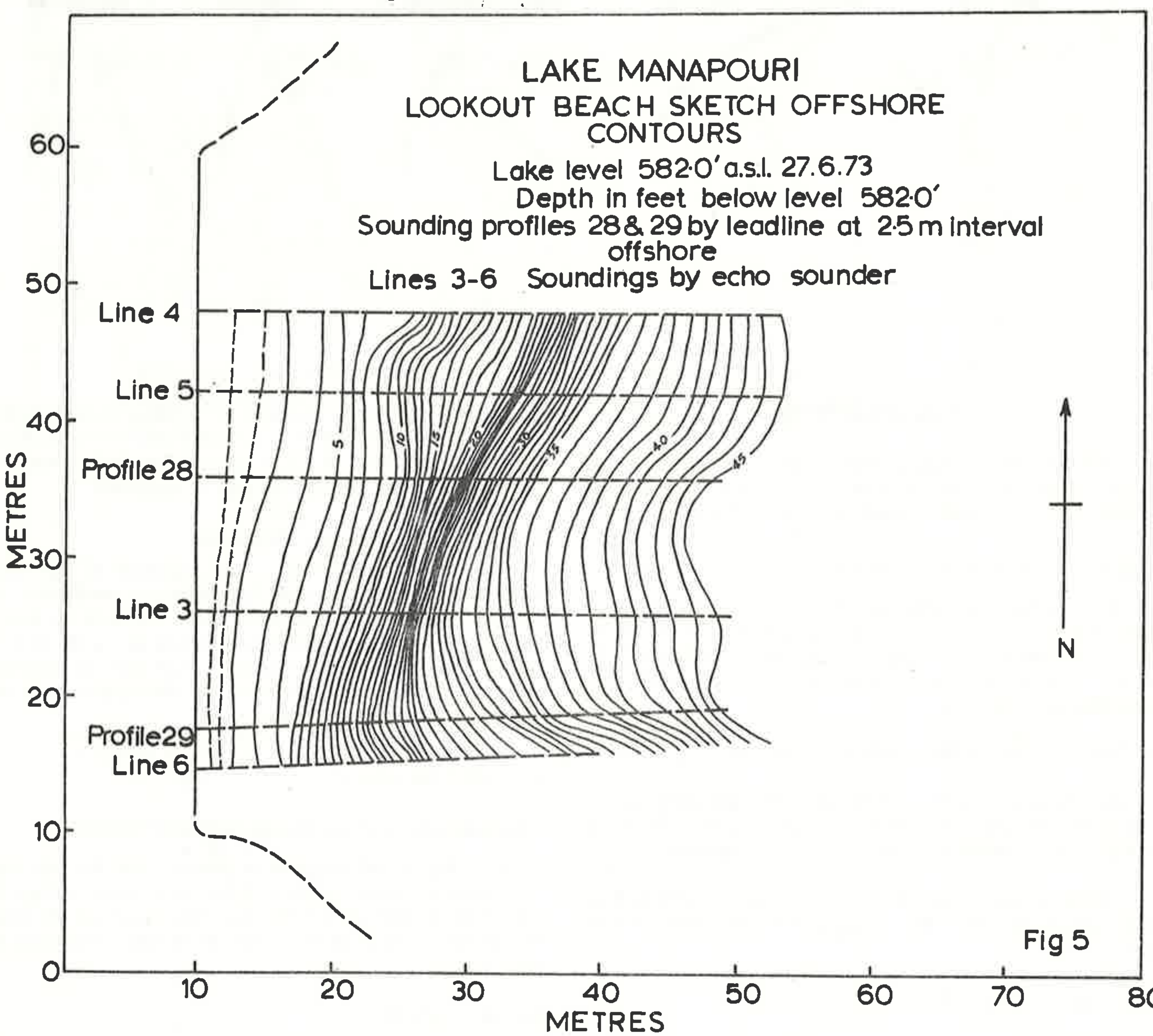


Fig. 5. Lake Manapouri, Lookout Beach. Sketch offshore contours from lead line and echo sounder depths.

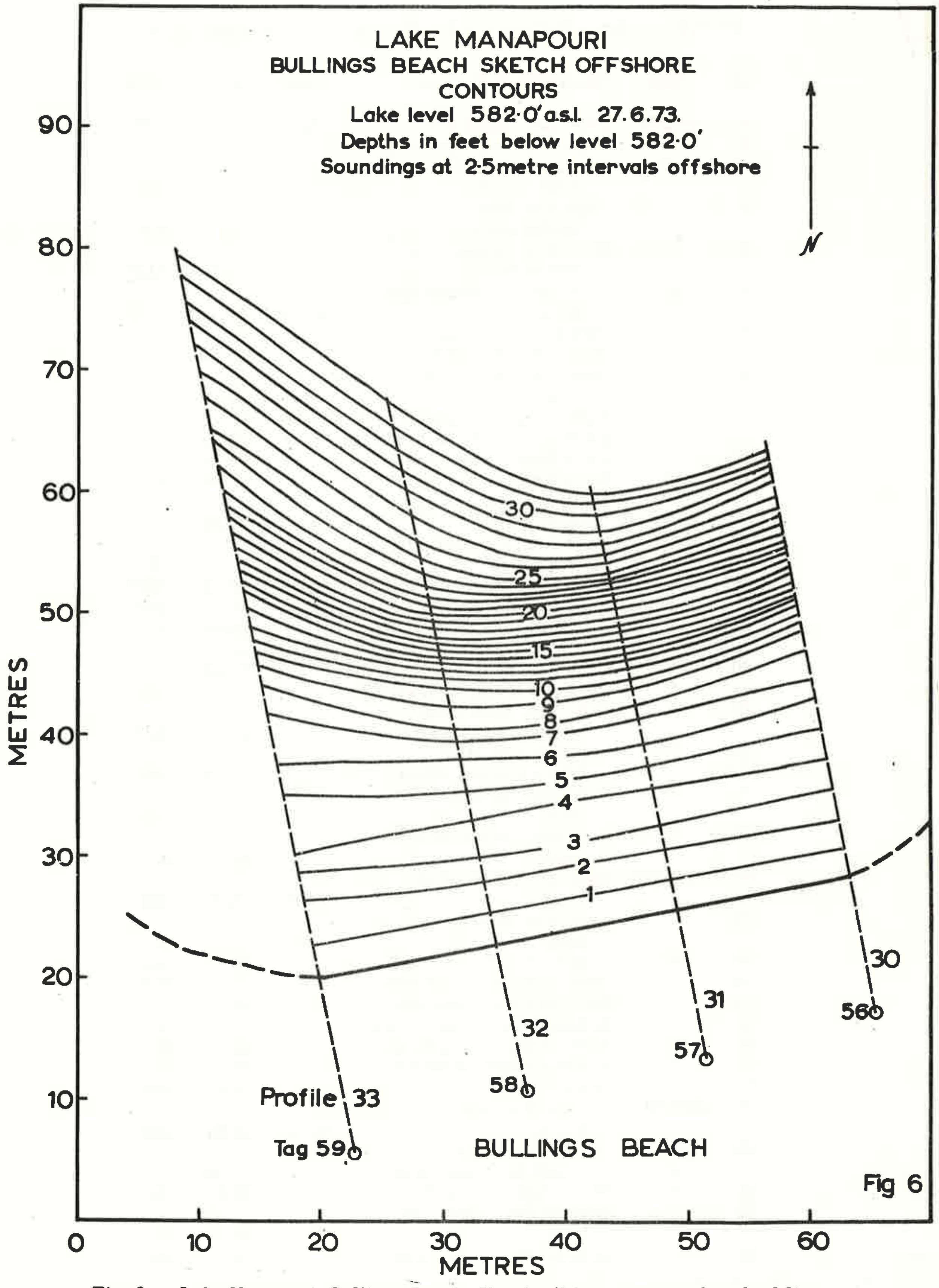


Fig. 6. Lake Manapouri, Bullings Beach. Sketch offshore contours from lead line soundings.

TABLE 1. Lake Manapouri - 23 to 29 June 1973 - Profiles 1 to 50.

No.	Date	Geographical Position	Lake Level	Tag Nos	(°M)*
1	23-6-73	Hope Arm, south beach	581.5	1,2	303°
2	"	Hope Arm, Head (west side)	"	3,4	031°
3	"	Hope Arm, Monument Bay south beach	"	5,6	301°
4	"	Hope Arm, Monument Bay middle beach	"	7,8	266°
5	"	Hope Arm, George Bay middle beach	"	9,10	247°
6	24-6-73	West Arm near Mouth Spey River	581.4	11	033°
7	"	West Arm, south side	"	12	349°
8	"	West Arm, off Onaha Burn	"	13,14	151°
9	"	West Arm, Tee Vee Point beach	"	15,16	067°
10	"	Fairy Beach, north end	"	17,18	050°
11	"	Fairy Beach, middle beach	"	19,20	022°
12	"	Fairy Beach, south end	"	21,22	017°
13	"	North Arm, off Awe Burn	"	23,24	087°
14	"	North Arm, Freeman Burn west beach	"	25,26	140°
15	"	North Arm, Freeman Burn east beach	"	27,28	178°
16	26-6-73	Ruby Bay, south end	581.9	29,30	270°
17	"	Ruby Bay, middle beach	"	31,32	263°
18	"	Ruby Bay, north end	"	33,34	226°
19	"	Shallow Bay, off Iris Burn	"	35,36	151°
20	"	Calm Bay, north side	"	37,38	190°
21	"	Calm Bay Head, west side	"	39	107°
22	"	Calm Bay, south side opposite Rona Island	"	40,41	050°
23	"	Opposite Hope Arm, facing Pomona Island	"	42,43	299°
24	"	Hope Arm, Stockyard Cove, west	"	44,45	077°
25	"	Hope Arm, Stockyard Cove, south	"	46,47	335°
26	27-6-73	South Arm, east end of beach	582.0	48,49	009°
27	"	South Arm, west end of beach	"	50,51	011°
28	"	Lookout Beach, north end	"	52,53	068°
29	"	Lookout Beach, south end	"	54,55	065°
30	"	Bullings Beach, east end	"	56	327°
31	"	Bullings Beach, centre east	"	57	327°
32	"	Bullings Beach, centre west	"	58	327°
33	"	Bullings Beach, west end	"	59	327°
34	"	Sandy Beach	"	60,61	342°
35	28-6-73	Surprise Bay, Wilsons Mistake beach	581.9	62,63	225°
36	"	Surprise Bay, opposite ismuth to Circle Cove	"	64,65	187°
37	"	Surprise Bay, west end	"	66,67	082°
38	"	Surprise Bay, south side jetty	"	68,69	354°
39	"	Surprise Bay, south shore	"	70,71	340°

* Profile bearing shore to lake (°Magnetic).

Table 1 (cont,)

No.	Date	Geographical Position	Lake Level	Tag Nos	(°M)*
40	28-6-73	Surprise Bay, Ritchers Rock beach	"	72,73	074°
41	"	Between Ritchers Rock beach and Waiau River	"	74,75	019°
42	"	Beach south side Waiau River outlet	"	76,77	312°
43	"	Surprise Bay, north side east off Wilsons Beach	"	78,79	201°
44	"	Circle Cove, north beach	"	80	231°
45	"	Circle Cove, east beach	"	81	287°
46	29-6-73	Hope Arm, south side of river Garnock Burn	581.7	82	249°
47	"	Hope Arm, George Bay, south beach	"	83	260°
48	"	Fraser Beach, north end	"	84	282°
49	"	Fraser Beach, middle	"	85	287°
50	"	Fraser Beach, south end	"	Manapouri Datum BM	297°

TABLE 2. Lake Te Anau - 30 June 1973 - Profiles 1 to 10.

No.	Date	Geographical Position	Lake Level	Tag Nos	(°M)*
1	30-6-73	Beach north of Trig B	663.8	86	093°
2	"	Trig B beach, south side	"	87	167°
3	"	Trig B beach, east side	"	88	082°
4	"	South Fiord north side Mark Point beach	"	89	177°
5	"	South Fiord north side 1st beach west of Mark Point beach	"	90	176°
6	"	South Fiord north side 2nd beach west of Mark Point beach	"	91	149°
7	"	South Fiord south side Garnet Bay east beach	"	92	273°
8	"	South Fiord south side Garnet Bay west beach	"	93	010°
9	"	South Fiord south side west of Garnet Bay	"	94,95	308°
10	"	South Fiord south side west beach (Eastern Beach)	"	96,97	348°

* Profile bearing shore to lake (°Magnetic).

The 2nd offshore gradients, measured from change in slope to 630 ft above sea level depth (34 ft below lake level when measured) are much steeper than the 1st offshore gradient; 9 out of the 10 measured showing gradients steeper than 1 in 4. Profile 7 in Garnet Bay has the lowest 2nd offshore gradient at 1 in 4.1.

With the exception of profile 8 (Garnet Bay west beach) all the 1st offshore and 2nd offshore gradients are of even slope.

Length of 1st Offshore Gradient

All are long or very long, four are from 24 m to 36 m (profiles 1, 6, 9 and 10) and six of 36 m+ (profiles 2, 3, 4, 5, 7 and 8). Those with lengths over 61 m are profiles 2 (61 m), 3 (84 m) and 7 (90 m).

Figs 7a-17b. Lake Manapouri. Beach and underwater profiles 1-50; vertical exaggeration x 3.3. Positions shown in Fig. 1.

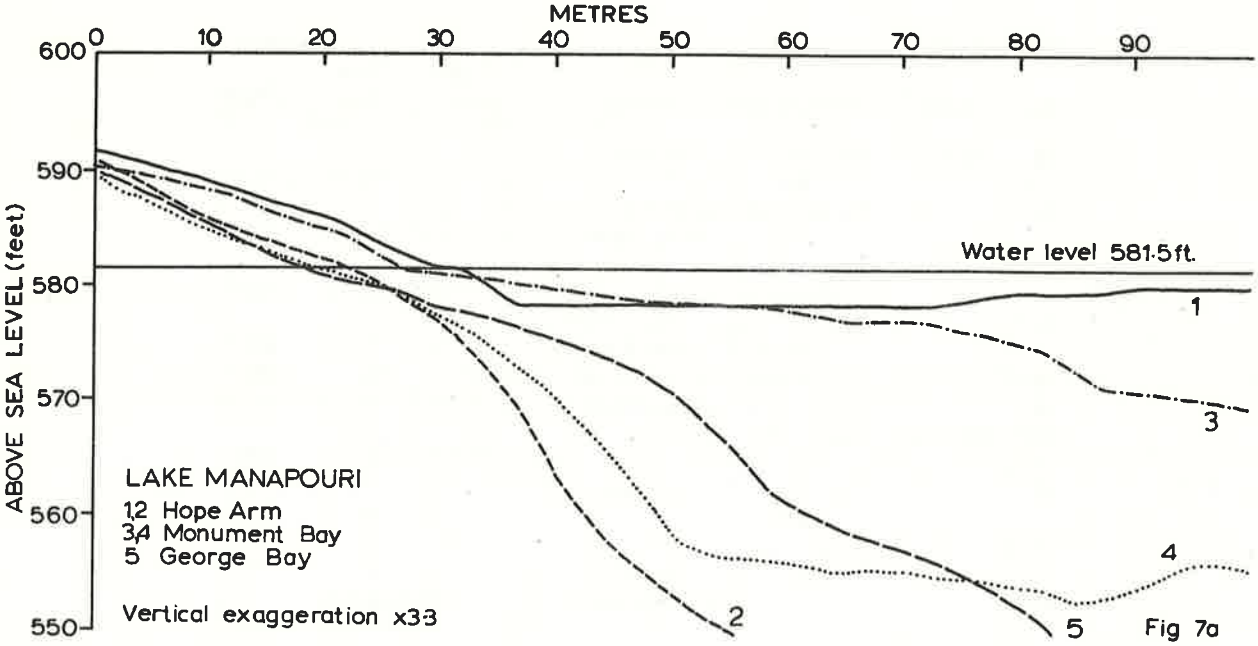
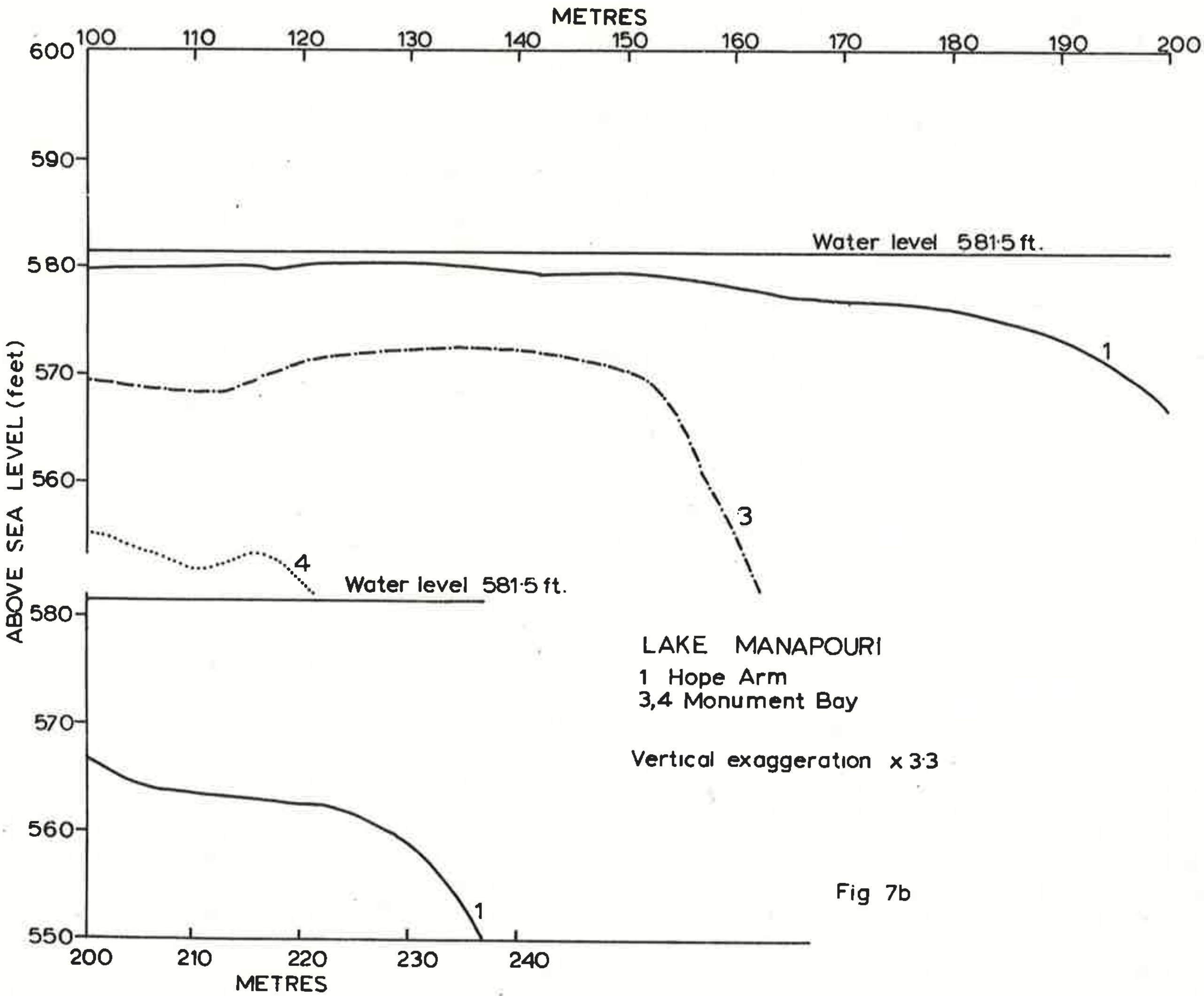

METRES
0
10
20
30
40
50
60
70
80
90
600
590
580
570
560
550
ABOVE SEA LEVEL (feet)
Water level 581·5 ft.
1
3
4
2
5
LAKE MANAPOURI
1,2 Hope Arm
3,4 Monument Bay
5 George Bay
Vertical exaggeration x3·3

Fig 7a


METRES
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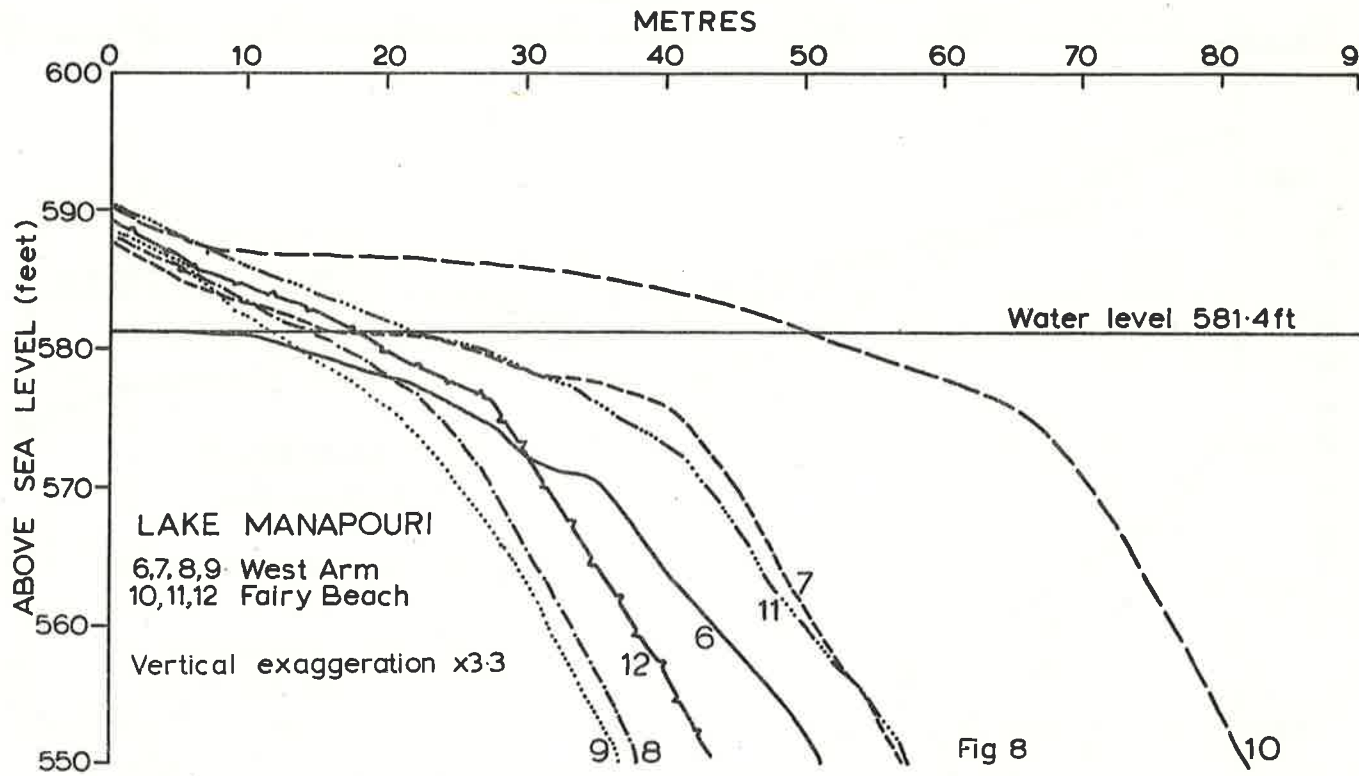
150
160
170
180
190
200
600
590
580
570
560
ABOVE SEA LEVEL (feet)
Water level 581·5 ft.
1
3
4
Water level 581·5 ft.
580
570
560
550
1
200
210
220
230
240
METRES
LAKE MANAPOURI
1 Hope Arm
3,4 Monument Bay
Vertical exaggeration x 3·3

Fig 7b


METRES
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600
590
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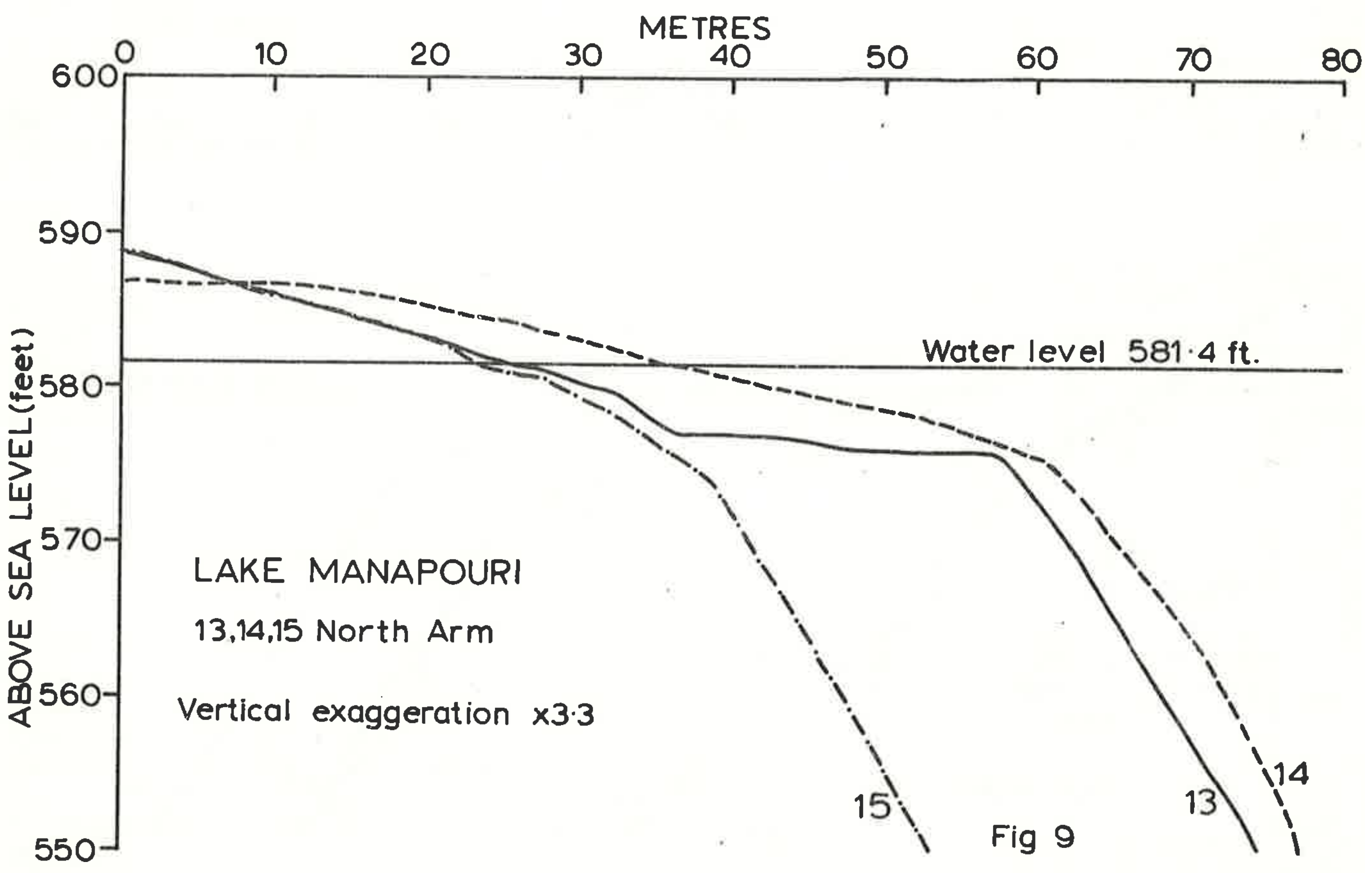
570
560
550
ABOVE SEA LEVEL (feet)
Water level 581·4ft
LAKE MANAPOURI
6,7,8,9 West Arm
10,11,12 Fairy Beach
Vertical exaggeration x3·3
7
11
6
12
9
8
10

Fig 8


METRES
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40
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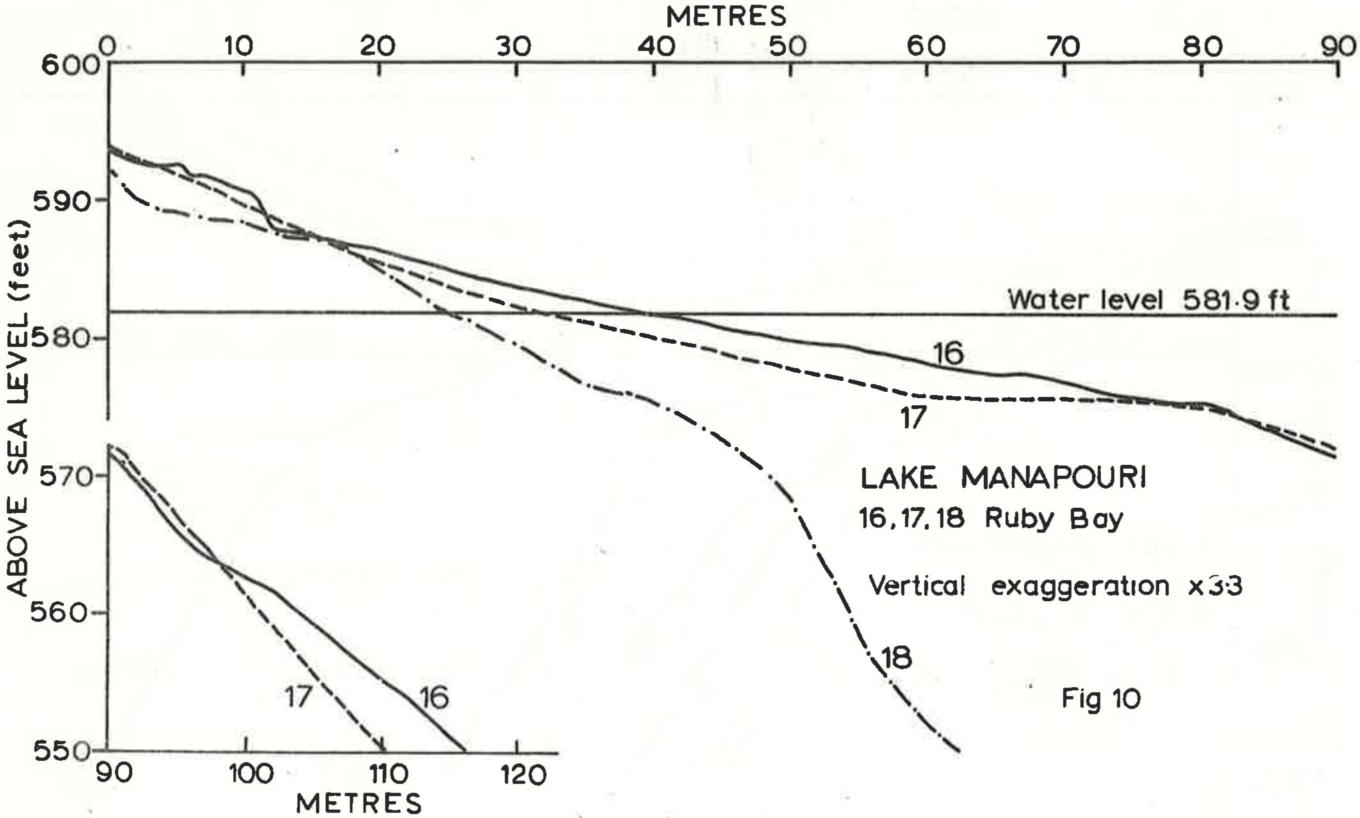
60
70
80
600
590
580
570
560
550
ABOVE SEA LEVEL (feet)
Water level 581·4 ft.
LAKE MANAPOURI
13,14,15 North Arm
Vertical exaggeration x3·3
15
13
14

Fig 9


METRES
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30
40
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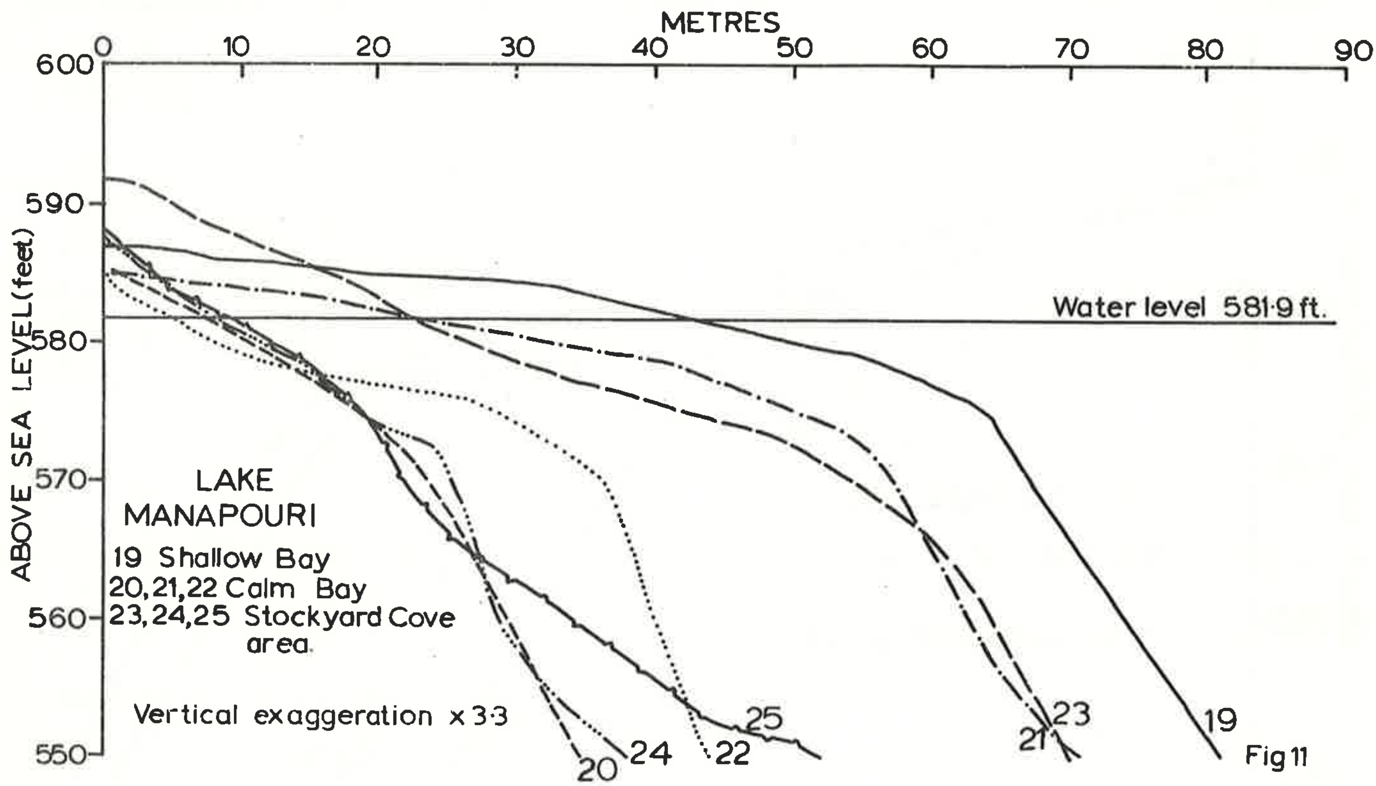
70
80
90
600
590
580
570
560
550
ABOVE SEA LEVEL (feet)
Water level 581·9 ft
16
17
18
LAKE MANAPOURI
16, 17, 18 Ruby Bay
Vertical exaggeration x3·3
100
110
120
METRES

Fig 10


METRES
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40
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600
590
580
570
560
550
ABOVE SEA LEVEL (feet)
Water level 581·9 ft.
LAKE
MANAPOURI
19 Shallow Bay
20, 21, 22 Calm Bay
23, 24, 25 Stockyard Cove area
Vertical exaggeration x 3·3
25
24
20
22
23
21
19

Fig 11

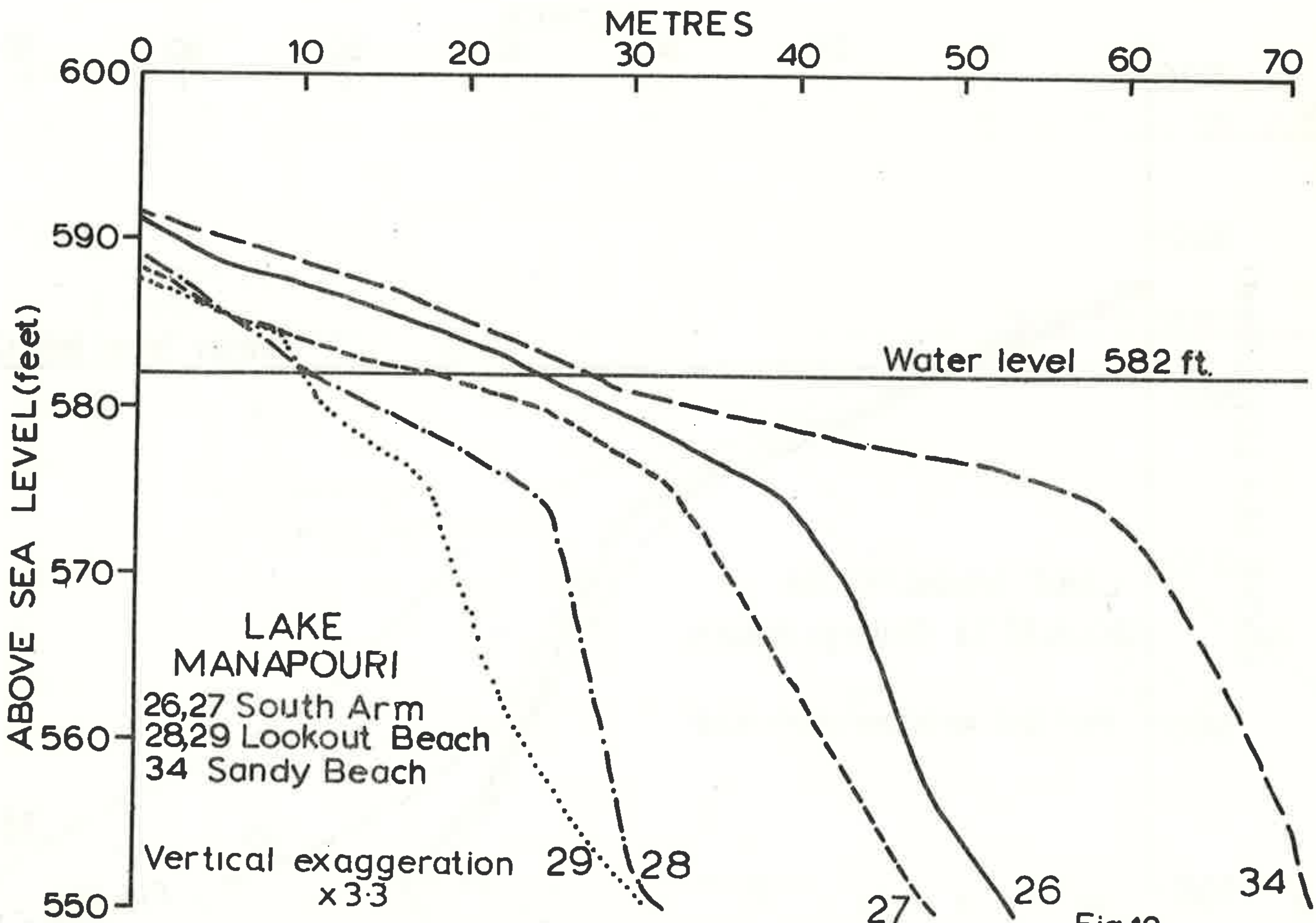


Fig 12

Fetch

The fetch affecting the beaches ranged from 3 to 35 km. Profile 8 has a fetch of 3 km, 10 (5 km), 6 (8 km), 9 (9 km), 7 (10 km), 4 and 5 (11.5 km), 2 (12 km), 1 and 3 (35 km).

Sediments

The surface sediments of eight of the ten beaches examined are sand, two are shingle (beaches 7 and 9).

SUMMARY OF GRADIENT CHARACTERISTICS

Average Beach Gradients

Steep gradient	Greater than 1 in 6	1 profile
Medium gradient	1 in 6 to 1 in 12	5 profiles
Low gradient	less than 1 in 12	4 "

(Group 10 is the gradient 1 in 37, profile 3)

Average 1st Offshore Gradient

Very steep gradient	Greater than 1 in 8	nil
Steep gradient	1 in 8 to 1 in 16	5 profiles
Low gradient	1 in 16 to 1 in 24	3 "
Very low gradient	less than 1 in 24	2 "

Average 2nd Offshore Gradient

Very steep gradient	Greater than 1 in 2	7 profiles
Steep gradient	1 in 2 to 1 in 4	2 "
Low gradient	1 in 4 to 1 in 6	1 profile
Very low gradient	less than 1 in 6	nil

Length of 1st Offshore Gradient (m)

Very short	0 to 12	nil
Short	12 to 24	"
Long	24 to 36	4 profiles
Very long	more than 36	6 "

CORRELATIONS

Relation of Beach Gradients to Fetch

The steepest beach (profile 9) is subject to a long fetch, 9 km. Of the five medium gradient beaches the

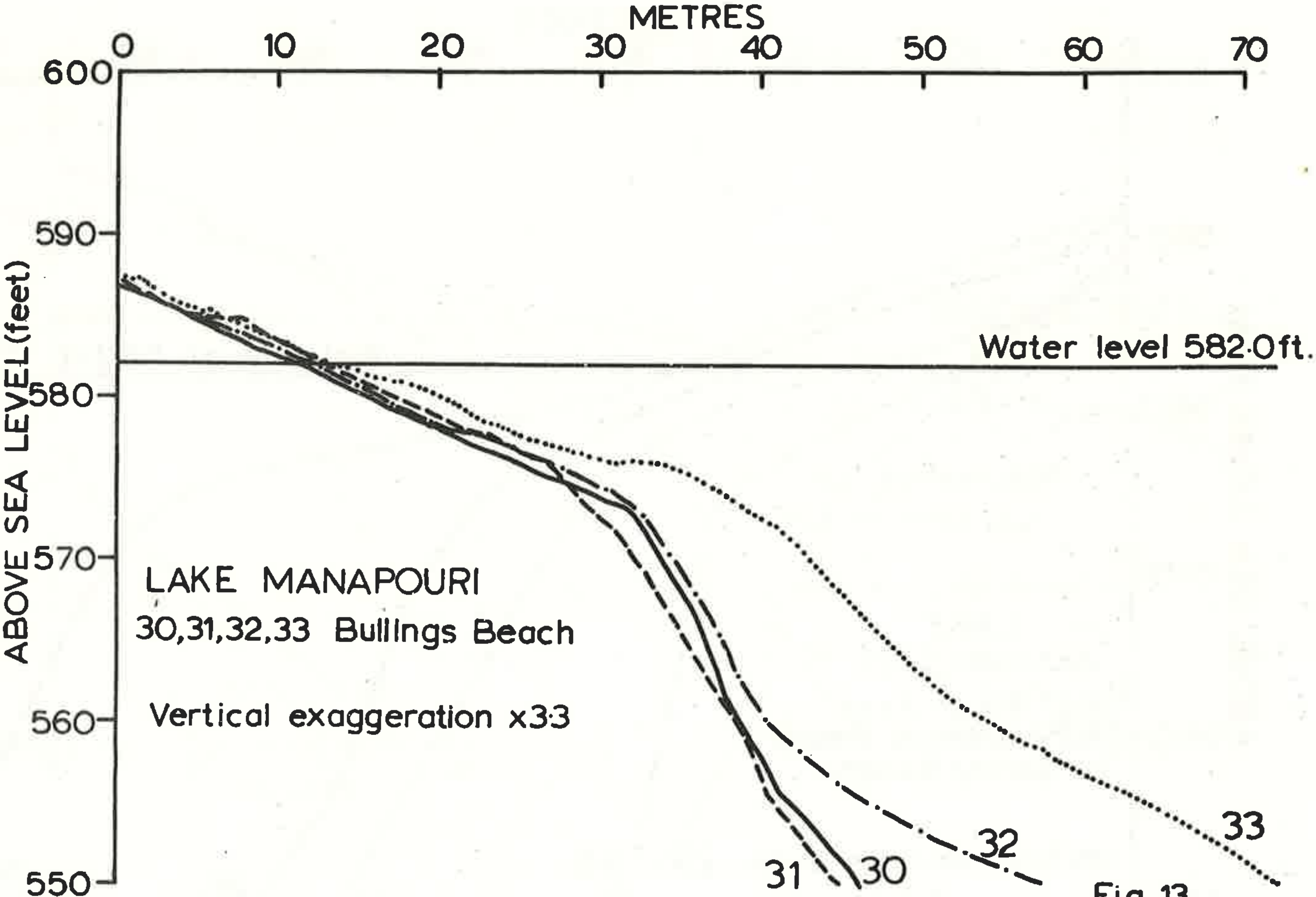

METRES
0
10
20
30
40
50
60
70
600
590
580
570
560
550
ABOVE SEA LEVEL (feet)
Water level 582·0ft.
LAKE MANAPOURI
30,31,32,33 Bullings Beach
Vertical exaggeration x3·3
31
30
32
33

Fig 13

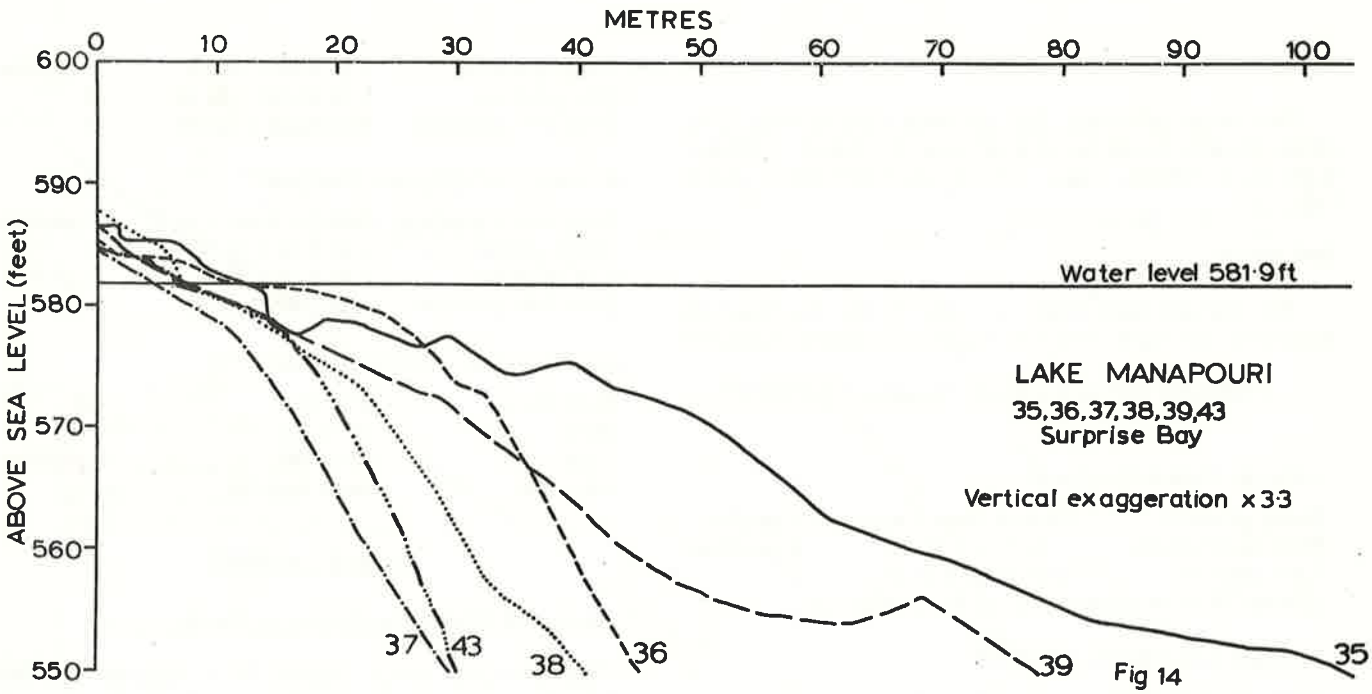
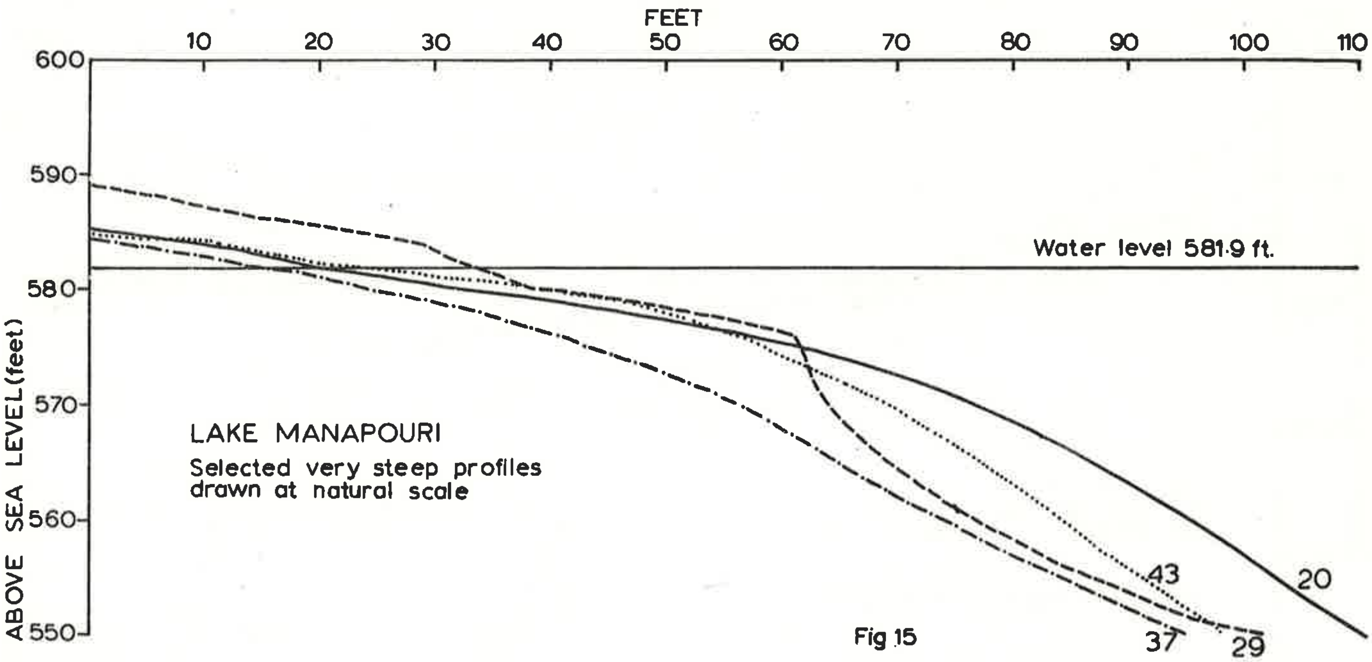

METRES
0
10
20
30
40
50
60
70
80
90
100
600
590
580
570
560
550
ABOVE SEA LEVEL (feet)
Water level 581·9ft
LAKE MANAPOURI
35,36,37,38,39,43
Surprise Bay
Vertical exaggeration x3·3
37
43
38
36
39
35

Fig 14


FEET
10
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30
40
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70
80
90
100
110
600
590
580
570
560
550
ABOVE SEA LEVEL (feet)
Water level 581·9 ft.
LAKE MANAPOURI
Selected very steep profiles
drawn at natural scale
43
20
37
29

Fig 15

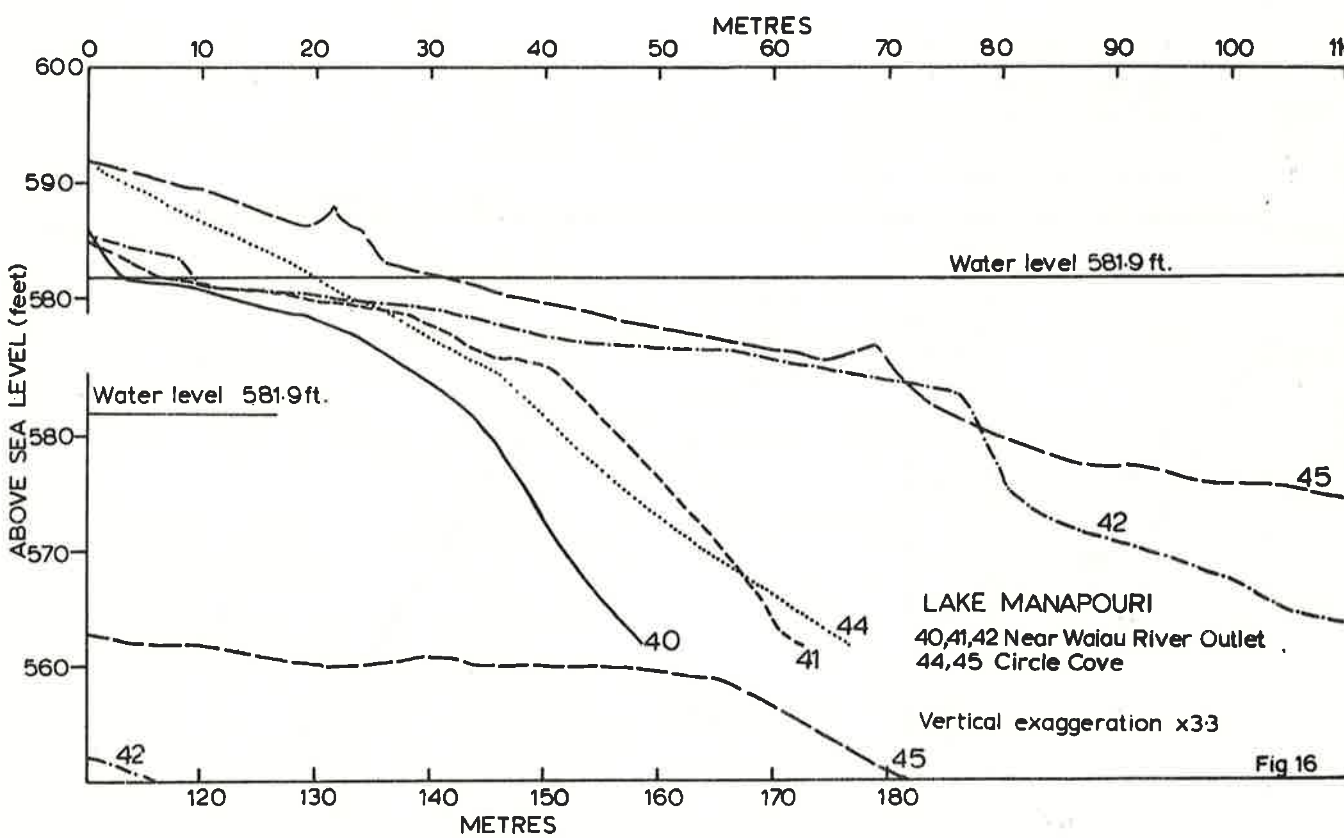

METRES
0
10
20
30
40
50
60
70
80
90
100
110
600
590
580
570
560
ABOVE SEA LEVEL (feet)
Water level 581·9 ft.
Water level 581·9 ft.
45
42
LAKE MANAPOURI
40,41,42 Near Waiau River Outlet
44,45 Circle Cove
40
41
44
Vertical exaggeration x3·3
42
45
120
130
140
150
160
170
180
METRES

Fig 16

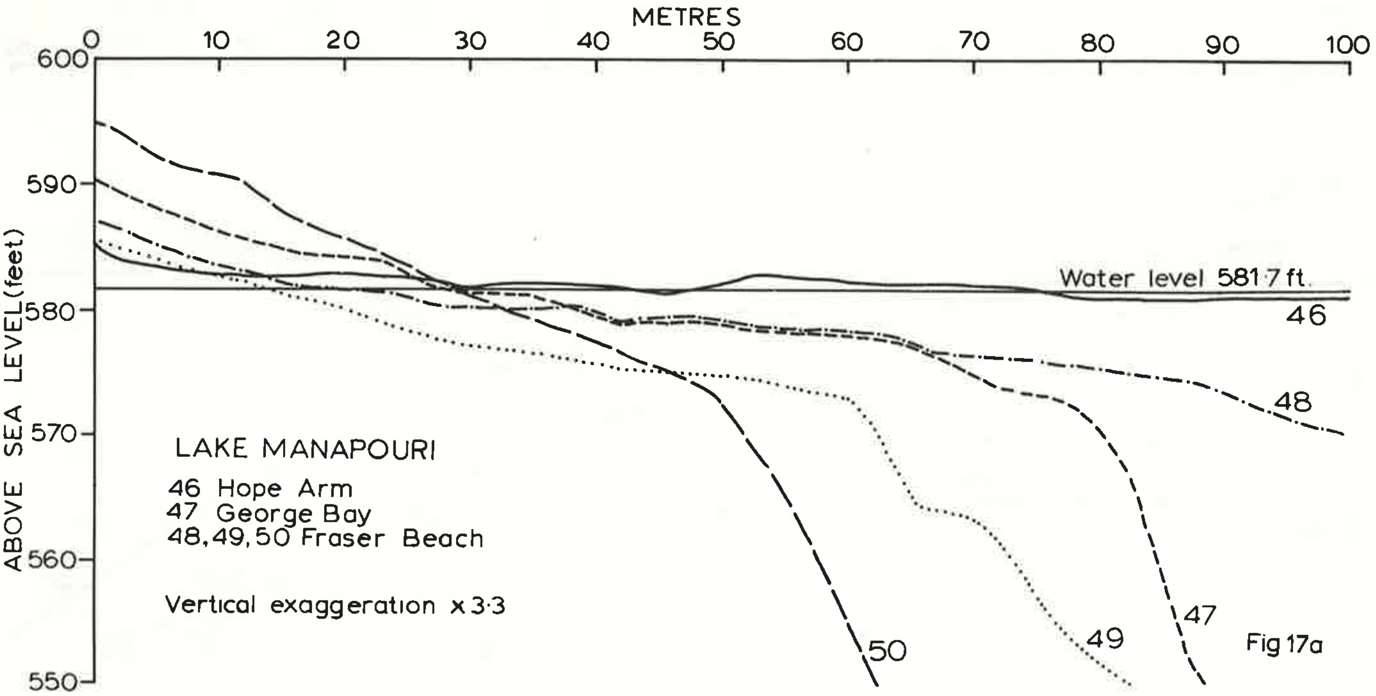


Fig 17a

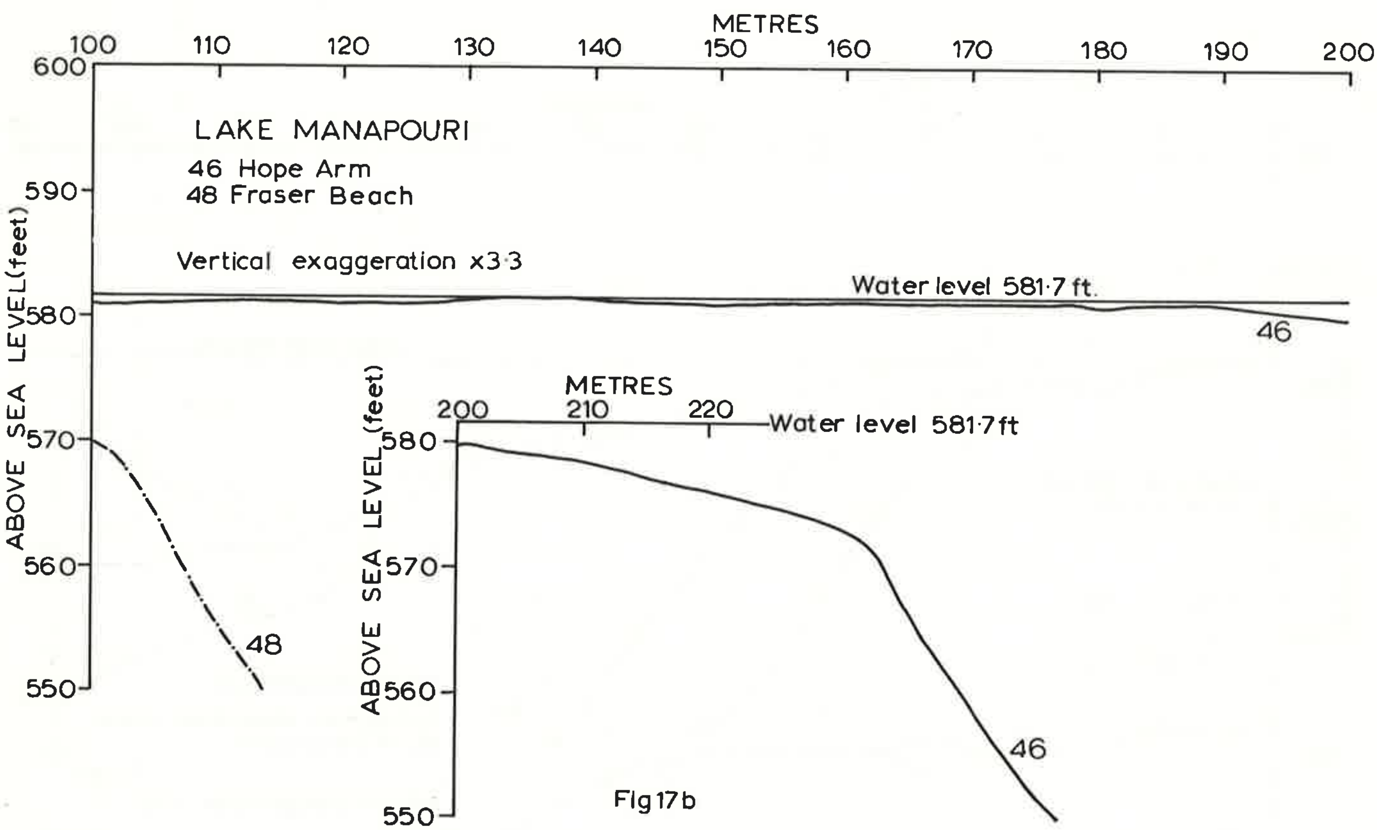
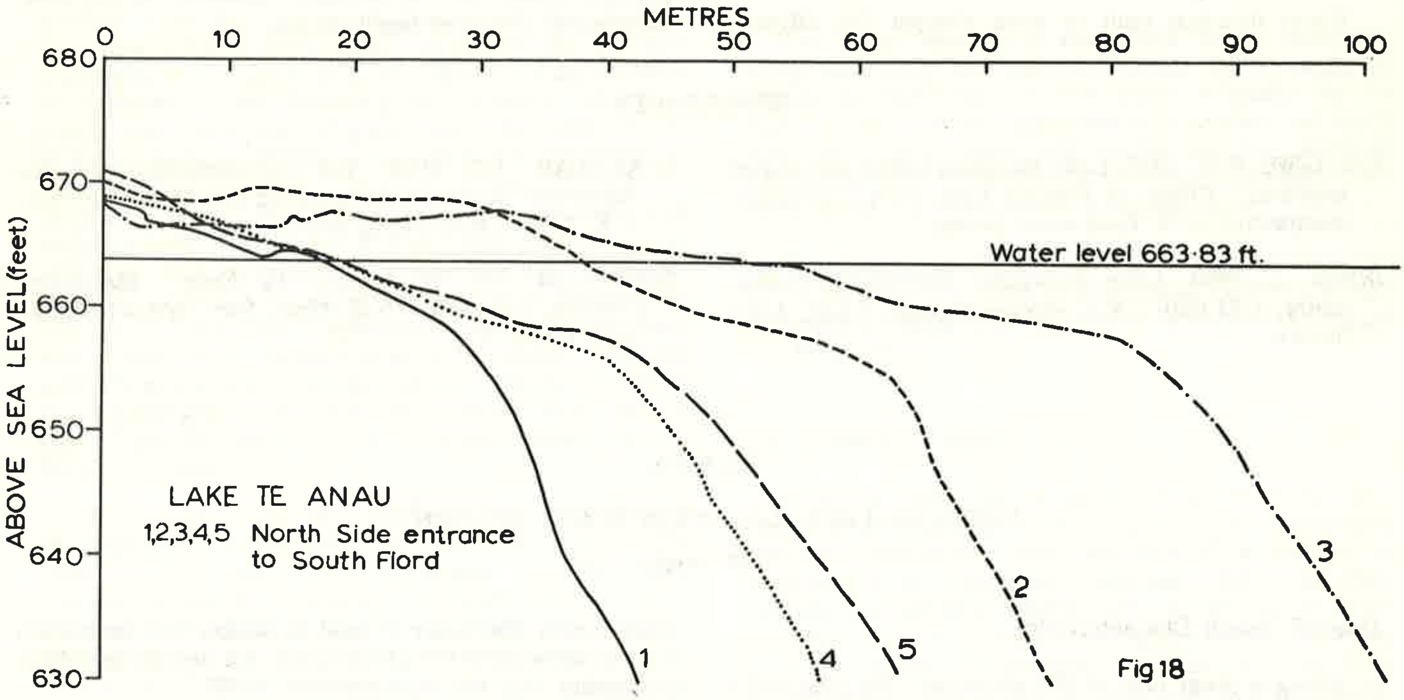
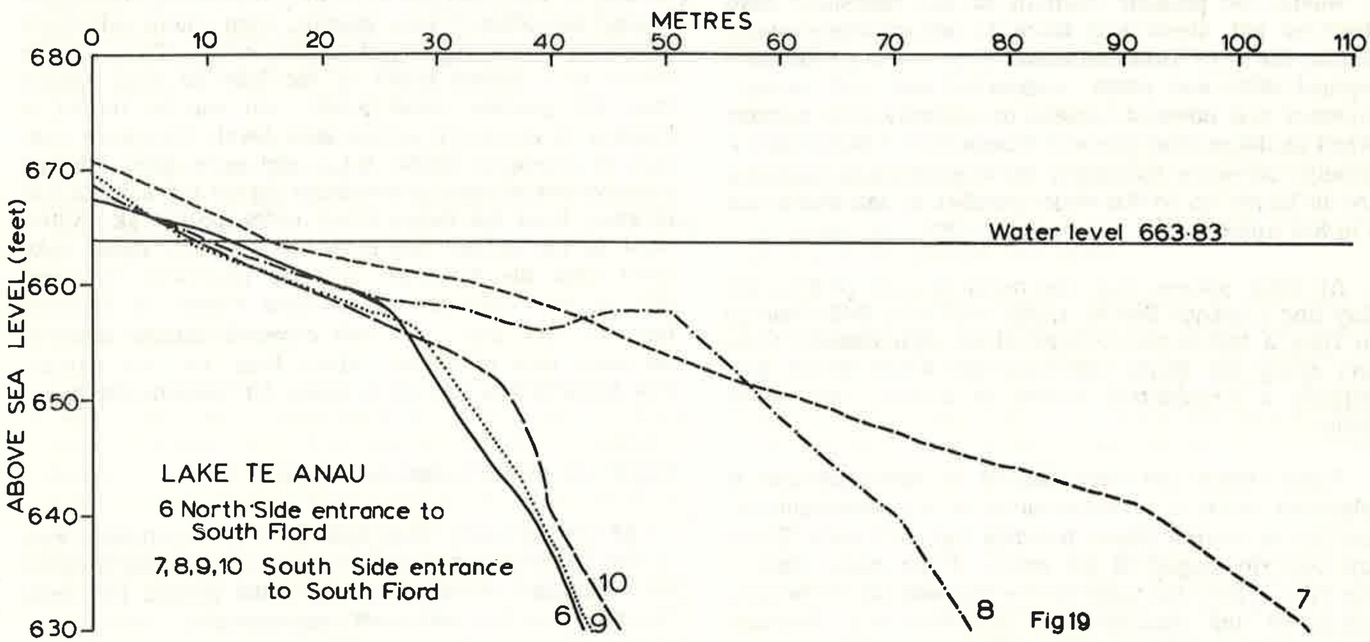


Fig 17b





Figs 18, 19. Lake Te Anau. Beach and underwater profiles 1-10; vertical exaggeration x 3.3. Positions shown in Fig. 2.

fetch. One of the lowest gradient beaches (profile 3) 1 in 37.1, is exposed to a fetch of 35 km.

Steep beaches tend to have steeper 1st offshore gradients; as with the beaches on Lake Manapouri most profiles show the 1st offshore gradient to be near-continuous with the beach slope.

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McKELLAR, I.C. (in press): Te Anau - Manapouri District, 1:50,000. *N.Z. Geol. Surv. Miscellaneous Series Map 4.*

Appendix

NOTES ON LAKE MANAPOURI BEACH SEDIMENTS

J.W. Brodie

General Beach Characteristics

Along a great part of the shoreline, the lake walls descend in steep ice-cut bare rock slopes directly into the water. The lower parts of these slopes are in places over-steepened to varying heights up to 200 ft above lake level. The underwater profiles below these cliffs are also commonly steep (Irwin 1969). Some steep lake-side slopes have a narrow rough beach of large boulders.

Where the present gradient of the nearshore lake floor is not steep and there is no emergent sandy beach, the lake floor sediment often consists of fine-grained silts and clays, compacted and stiff in consistency and covered closely or sparsely with medium sized boulders (the Damsite Formation of McKellar (in press)). At some localities the concentrated boulders are in bands up to 5 m wide parallel to the shore and 4 to 5 m apart.

At other places, e.g. the northern side of Surprise Bay and Lookout Beach, these stiff clay beds emerge to form a turf-covered slope often with manuka trees and along the south side near the Waiau outlet they support a substantial growth of several species of reeds.

Where there are indentations of the shoreline or wherever there is a watercourse of any consequence, medium or coarse sandy beaches can be found. These are best developed at the heads of the major arms of the lake, where the most active streams occur. In most instances the smaller-sized beaches, e.g. Bullings Beach (profiles 30 to 33) have only a thin cover of sand (0.15 to 0.7 m) over a surface cut in the compacted stiff clays or the uppermost peaty member of the beds. On the larger sandy beaches, e.g. Circle Cove, East Beach, the cover of sand is thicker (i.e. more than 1 m) in the centre but at the sides the underlying clays commonly crop out (*see* Andrews 1973).

The beaches of Lake Manapouri thus involve Post-Glacial fine-grained sediments of two distinct facies.

The Shoreline Clay and Silt Beds

The nearshore and shoreline lacustrine beds consisting of stiff clay and silts are extensively developed around the present lake margin, even where relatively steep bare-rock sub-aerial slopes occur. They clearly relate to a higher stand of the lake as they emerge from the present water level* and can be traced to heights of about 6 ft above lake level. The beds consist of cohesive layers 0.1 m and more thick, though massive not obviously stratified layers 0.8 m thick can be seen. Near the Waiau River outlet (profile 42 - 300 m west of the outlet) the beds are 3 to 4 ft above lake level near the waterline and dip lakewards at about 20°. In the sheltered, short-fetch waters of Surprise Bay the turf, fern, and tree covered surface extends for some tens of metres inland from the lake margin. The slope of this surface is about 10° towards the lake.

Upper and Lower Limits of the Beds

At Circle Cove, East Beach on the southwest side at the waterline, the beds can be seen resting directly on a marginal smoothed and striated glacial pavement cut in a massive indurated conglomerate.

* Where used in these notes, 'present' refers to the level, 581.5 ft at the West Arm Gauge that prevailed with a variation of ± 0.5 ft during this examination.

These shoreline clays and silts cannot be distinguished from the similar sediments of the Damsite Formation (McKellar, in press). However, the Damsite Formation in its lower part is Glacial, being overlain by moraines of the Ramparts ice advance. The geological map (McKellar, in press) uses the name for the shoreline beds described here, which are not likely to have survived through advances of the ice and are therefore Post-Glacial. The Damsite Formation thus includes both Glacial and Post-Glacial sediments and both tills and lake sediments. On the beaches examined, the clay beds are composed of sediments presumably laid down from the immediately Post-Glacial lake which must have stood significantly higher (perhaps at 600 ft above sea level) as indicated by the height of undisturbed claybeds above the present level of the lake. Thus the beds are the youngest members of the Damsite Formation.

At Lookout Beach the clay beds are succeeded by an apparently conformable horizon (the 'Lost Jetty Peat') and the succession terminates in these beds. The peat reaches a thickness of approximately 0.5 to 1.0 m and the top is about 3 to 4 ft above lake level at its highest point. The peat is composed dominantly of leaves and fibrous vegetable matter with many fragments of trunks and branches that principally lie parallel to the bedding plane.

From a position on the south shore 2000 ft southwest of the Waiau River outlet at the west end of the beach a partly carbonised wood fragment has been ^{14}C dated at 6070 ± 120 yrs B.P. (R. 2782 : NZ 1124). This wood fragment from a peaty horizon close to mean lake level (583 ft) was 1.5 ft below the ground surface and was considered to have been deposited when the lake level was R.L. 600 ft. (Notes from the collector, Mr I.C. McKellar in N.Z. Geological Survey records.)

The peats thus indicate a high lake level phase of sedimentation that followed the dominant deposition of the silts and clays produced by glacial erosion. In this phase vegetation had covered the lake walls and nearshore areas.

Variability in the Clay Beds

At profile 42 the clay beds, both above and below lake level, exhibit shrinkage phenomena and the formation of small ferric iron concretions that suggest an earlier period of drying out and exposure to atmospheric processes. Here individual beds show extensive development of shrinkage polygons through the thickness of individual layers, about 0.5 m across, rimmed with an aureole of segregated iron compounds, and now separated from each other by gaps about 10 to 25 mm. The small concretionary masses occur at intervals of about 25 mm. Fragments of the small concretions occur as a sparse coarse sand lag deposit after the continuing present-day removal of the clay matrix by shoreline erosion and its presumed redeposition in deeper water.

Primary Attitude of Deposition of the Clay Beds

The initial attitude of deposition on the relatively steep lake floor was governed firstly by the angle of repose for sediments of this grade, secondly by the angle of slope of the glaciated rock surface on which they were laid down and thirdly by the continual deposition and resuspension of those sediments laid down in the wave-influenced nearshore zone.

The present attitude of the beds (approximate dip 20° lakewards) may well be the initial attitude, though differential compaction could have increased the initial dip in places.

The Superficial Sands

At those places on the shoreline to which the products of post-glacial weathering can be transported either by streams or intermittent sheet flow and can be supported by an appropriately shallow offshore foundation, the present-day beaches are constructed at least superficially in a brown stained quartz sand of medium to coarse grade. These sands overlie the clay beds unconformably in a number of instances, and in general, residuals of the youngest Damsite Formation beds tend to have been preserved at the sides of bayhead beaches so the overlying sands can be thin or missing in these areas.

The sands are well-developed at the head of South Arm where grades up to very coarse are present. They are again prominent at Circle Cove East Beach where the beaches are steep : at the head of the bay the underwater profile, on which sand is the uppermost sediment, has a very low gradient. The beach is wide (more than 100 m) and minor changes in level or wave activity are reflected in steps in the beach profile. This bay is well exposed to winds from the northwest and looks out on a fetch of about 9 km. The beach also has horizons at which a substantial water seepage is occurring and presumably these reflect the occurrence of clay beds beneath the sands.

At many places where weathered quartz sand has accumulated on the lake-side clay beds, the quantity is yet so small as to form only a narrow strip (0.15 to 1.0 m wide for example), near water level, at points only a little distant from the immediate source. These sources are commonly not clearly defined watercourses, but often passages through and over vegetation.

Within the bays the sand is distributed laterally by long shore drift. Near the Waiau River outlet for example, a small low projection of emergent clay beds approximately 40 m long by 30 m wide is flanked on either side by a small beach on which sand cover is developing. However, between the vegetation-covered promontory and the hillside a narrow (6 m wide) sand beach has been formed 3 to 4 ft above present lake level.

The Beach Boulders

Boulders occur on steep, narrow beaches that rest on a clay bed foundation and as a scattered oover of variable density on both emergent and submerged clay bed surfaces.

The boulders in the southern part of the lake (commonly from 0.2 to 0.6 m diameter) are sub-rounded. This may have been caused by attrition, weathering, or in some instances, original form in parent conglomerates.

Where the cover of boulders is dense enough (for example profile 37), further erosion of the clay beds is prevented.

Stability of Beaches at Present Lake Level

Boulder Beaches : Those observed are stable insofar as the boulder component is concerned but the ultimate stability depends on that of the foundation which in many cases is Damsite Formation clays.

Sand Beaches : Those sand beaches on a shallow foundation of clay beds are dependent on the stability of the underlying foundation. Those to which large volumes of sediment are being supplied will undoubtedly maintain themselves. Those occupying areas from which the bulk or a substantial thickness of clay bed sediments had been removed before deposition of the sands began will be stable also, for while the sediments at the same depth will be moved by the waves, the sand will not be transported away as has occurred with the resuspended clays. Sand movements, both up and down the offshore slope, will occur, depending on lake level and wave action.

Clay Beds : None of the clay beds (and overlying peats) are, as sediments, related to present lake level, and a continuing process of adjustment to the present lake level is going on now. The degree of compaction and induration is relatively slight and offers small resistance to wave erosion. A large amount of material has already been eroded and all remnants of these beds that are exposed to significant wave attack will probably be removed in time by natural processes. Removal of the largest quantities will have taken place in areas most exposed to long-fetch waves.

Stability of Beaches at Lower Lake Levels

A depth of 571.5 ft above sea level (i.e. 10 ft below the level at the time of survey) is reached at distances not greater than 90 m offshore for 47 of the beaches examined in detail. Three were greater at 147 m, 194 m and 226 m, but at 41 beaches the 571.5 ft level is reached at a distance of less than 70 m offshore.

For beaches composed of substantial thicknesses of sand, e.g. Circle Cove East Beach, the effects of lowering of lake level will simply be the formation, by wave action, of a new beach profile similar to that of the present beach. This implies that where the present underwater gradient is less than that above water, a small degree of shoreward cutting will occur at the new water level. Even under relatively high energy wave situations the effects are probably minor. The largest disturbance of an above water sand beach noted (in South Arm) was the building up of a small beach ridge up to 1 m high, probably developed during a recent storm. This had only developed along a small part of the length of the beach. Very little effect on the stability of such beaches can be anticipated.

In the very low energy wave areas clay beds emerge from the water with no interruption to the surface gradient. As wave exposure increases a minor step is eroded ranging up to 0.8 m in height; with substantial exposure the near lake level beds have been removed.

This range of effects would be initiated at any lower lake level and the extent of these effects would depend on the duration of the lowered level.

The slumping that occurred at Surprise Bay following lowering of the lake in 1972 will have proceeded shoreward until a new stable position was arrived at. Similar reactions to earlier natural low levels have presumably been part of the natural process of readjustment of the clay beds to present-day lake level and its variations.

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