Rangitaiki River Scheme Post 1987 Earthquake

Bay of Plenty
Catchment Board
and
Regional Water Board

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SUMMARY

1. The March 1987 earthquake caused significant landform changes to and adjacent the Rangitaiki River reducing flood protection to an unacceptable standard. The flood protection system is now capable of handling about a 20 year flood compared to 100 year flood capability pre-earthquake.

2. Approximately 2500ha of land is highly suspectable to flooding with a further 850ha having drainage restrictions. This area is mostly farmland but includes a signifcant portion of Edgecumbe township and some industrial areas.

3. A comprehensive hydrological review has evaluated the 100 year flood at 755 cumecs compared to 796 cumecs used in the original scheme.

4. Hydraulics of the river/floodway system have been analysed with three alternatives to reinstate 100 year flood protection.

5. The 40 year floodway option as provided in the original scheme is technically supported.

6. Flood protection proposals involving upgrading stopbanks on the river and floodway to restore the 100 year standard are estimated to cost $2.4m.

7. The cost of the proposed scheme shows an internal rate of return from the national viewpoint of 10.58%.

CONCLUSIONS

1. The March 1987 earthquake caused severe damage to the Lower Rangitaiki River/floodway works reducing flood protection from one in 100 year to one in 20 year standard.

2. Since the earthquake, the Board's work on the Rangitaiki Plains, both in its own right and as consultants to the Rangitaiki Drainage Board and the Bay of Plenty Earthquake Restoration Committee has clearly identified a desire among the scheme participants to have the full scheme protection reinstated.

3. Hydrological and hydraulic investigations indicate that it is feasible from a technical point of view to achieve that reinstatement.

4. An economic analysis indicates that restoration of the scheme is economically feasible when assessed according to classic indicators.

CONTENTS

RANGITAIKI RIVER SCHEME POST 1987 EARTHQUAKE

1. INTRODUCTION

A major earthquake on 2 March 1987 damaged flood protection and drainage works built under the Rangitaiki-Tarawera Rivers Major Scheme. Damages were in two categories:

(i) Physical damage including slumping and fracturing of stopbanks, river banks, culverts and pumping stations.

(ii) Loss of scheme performance standards due to land subsidence.

(i) above has largely been repaired following cabinet approval March 1987 for so-called "phase 1" funds, based on a report submitted by the Board shortly after the earthquake. That document emphasised a further request for assistance would be forthcoming hence this report which addresses (ii) above, in particular the costs and value to the nation of restoring the scheme to its original standard.

2. BACKGROUND

2.1 General

Rangitaiki Plains are situated with a northerly aspect in the Eastern Bay of Plenty. The plains are the focal point of population and industry for the wider area. The main communities are Whakatane (12,800), Kawerau (8,311), Edgecumbe (1,825) Te Teko (572) and Matata (567). The area enjoys a mild climate with high sunshine hours and average annual rainfall of just over 1300 mm. Because of its aspect and inland high country behind, the area is subject to high rainfalls from moist sub-tropical air masses which occasionally move southward.

Bay of Plenty is well established as the leading forestry region in New Zealand; it has a traditionally strong dairy industry and an expanding horicultural output. The towns have developed on this rural base and continue to be strongly dependent on that sector.

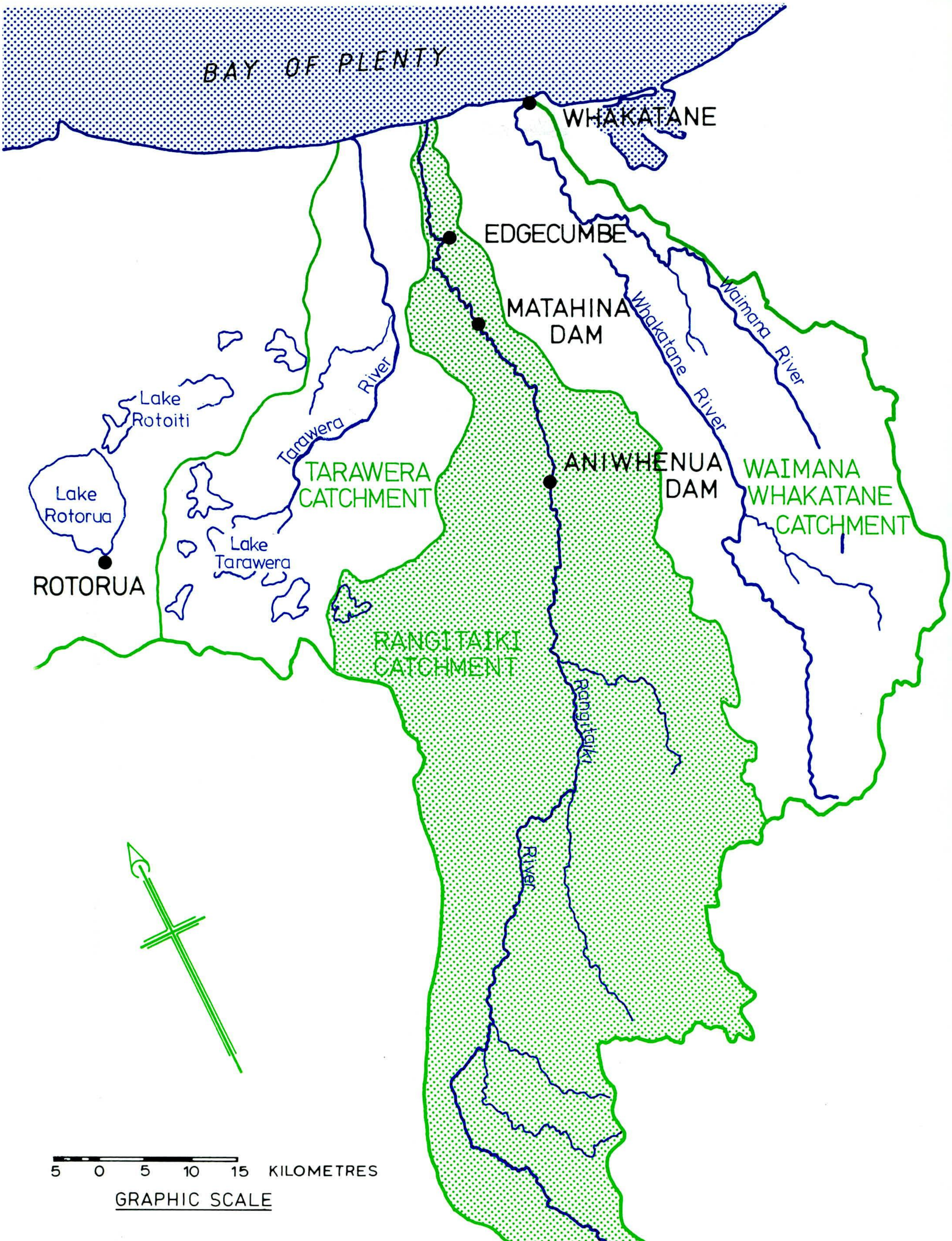
Rangitaiki River is one of three major rivers crossing the plains. It has a catchment area of approximately 4000 sq. km. including the central volcanic Kaingaroa plateau region of the North Island. Its main tributaries rise in the bush covered greywacke country of the Ikawhenua Ranges.

Another tributary - the Wheao - is harnessed for electricity generation. The river flows through Galatea area then through a gorge where it is again used for electricity generation at Aniwhenua and Matahina dams. It then flows across Rangitaiki Plains passing the townhips of Te Teko, Edgecumbe and Thornton (refer fig. 2-1).

Unless otherwise specified, Rangitaiki River in this report refers to the lower or northern portion of the river crossing Rangitaiki Plains.

2.2 Physical Description

The Plains cover an area of approximately 27,000 hectares. Geologically they are described as a graben, infilled by a combination of alluvial and marine processes. In many areas substantial swamps have deposited thick peat layers. In broad terms the plains consist of a number of northeast-southwest ridges (old foreshore sand dunes), with peat basins between them. Between the layers of peat are alluvial sediments deposited by the three rivers flowing northwards.



RANGITAIKI RIVER CATCHMENT

LOCATION PLAN

FIG. 2-1

Whakatane River is situated on the extreme eastern side of the plains, and originates in the greywacke mountains of the Urewera. The bed load is coarse gravel and only at depth on the plains is there much evidence of substantial infilling from this source. The top layers consist of finer sediments, which may have been deposited by either the Whakatane or Rangitaiki River systems (refer fig. 2-2).

Rangitaiki River flows across the central part of the plains. It has a very high bed load of coarse pumice sands and has undoubtedly been the major contributor of alluvial sediments to the plains. It is perched above the surrounding plains making flooding an ever-present threat.

Tarawera River is situated on the extreme western side of the plains and is sourced on the northern edge of the volcanic plateau. Large quantities of pumice sands have been deposited by this river to on the plains. Rangitaiki and Tarawera Rivers as recently as 1914 had a common outlet and so are considered as a single river system; one branch of the Rangitaiki River in recent times had an outlet to the Whakatane River. Up until about World War I, coastal scows could sail inland between Matata and Whakatane.

2.3 History of Flood Protection Works

Early attempts to provide flood protection and drainage of the Rangitaiki Plains were begun around the turn of the century by the Rangitaiki Drainage Board. That Board was taken over in 1911 by the Lands and Survey Department and by 1914 a new mouth had been cut for the Rangitaiki River. That project had a significant effect on lowering the water table and discharging floodwaters to sea faster than previously.

Additionally, a number of drainage canals were constructed using floating draglines. Because of the perched nature of the rivers, canal outlets had to be as close as practicable to the sea. This network of drainage canals is still in use today.

In 1962 the Eastern Bay of Plenty Catchment Commission was set up in response to flood problems on the Plains. In 1964 it became the Bay of Plenty Catchment Commission and in 1988 the Bay of Plenty Catchment Board (hereafter called "the Board"). During the period 1944 to 1964, 15 floods occurred on the Rangitaiki River which caused extensive inundation to the surrounding areas. The Board

undertook a major study of the entire river system and produced a comprehensive report setting out proposals for 100 year flood protection for the whole of the Rangitaiki Plains. That report was approved in April 1970.[11] A scheme for the Whakatane River had been approved earlier.

Note that in describing flood sizes this report uses the following terminology: a "100 year flood" is a flood which over a long period of time occurs on average once in 100 years. Similarly a "twenty year flood" ... occurs on average once in 20 years (etc.).

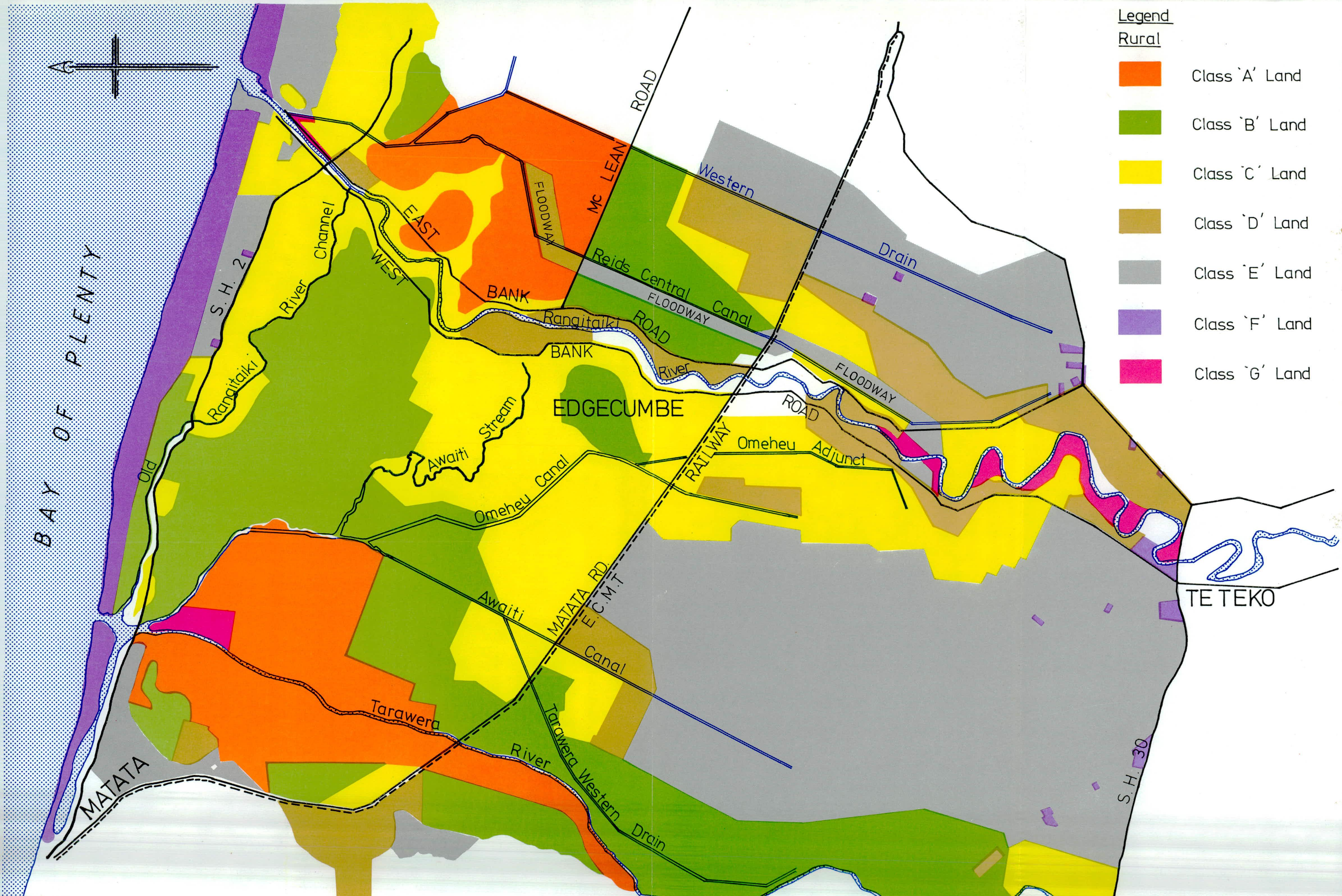
2.4 Summary of Works

(i) Flood Protection

From 1971 through to the present, flood protection and drainage works, as set out in the Rangitaiki-Tarawera Rivers Major Scheme report (hereafter referred to as the "scheme"), have been completed by a series of large contracts. The works have involved stopbanking of the Rangitaiki and Tarawera Rivers, stopbanking of a major floodway on the right bank of the Rangitaiki (refer fig 2-3) and "return" banking of the major drainage canals. The materials used have largely been won from the adjacent river as the cheapest source available. This caused some problems particularly on the Tarawera River where coarse pumice sand allowed excessive seepage and prevented a grass cover from growing. Subsequently this has been overcome by "toe loading" (foundation widening) of the stopbanks, and by the use of kikuyu grass, whose stolon growth habit helps armour the stopbanks.

At isolated locations on Rangitaiki River, underseepage and potential for a piping failure required both toe-loading plus special surcharge areas to be constructed. In some areas specially imported material was used to strengthen the stopbanks.

Daily fluctuations of water levels due to electricity generation has caused bank stability problems. To control this both Electricorp and the Board have installed rock protection over extensive sections of the river.



RANGITAIKI - TARAWERA RIVERS
MAJOR SCHEME
CLASSIFICATION PLAN FIG. 2-3

(ii) Drainage

The Board had upgraded all drainage outfalls and canals to scheme standard. The Rangitaiki Drainage Board had upgraded on-farm drainage to the scheme standard (pastoral) of 28mm per day. This involved installation of pumping stations in areas of lower contour on the northern half of the plains. In the higher areas floodgated culverts provide gravity drainage into the main outfall channels. The Drainage Board administers thirty seven communal pumping schemes, many funded for construction by NWASCA* through the Board.

The plains area has been classified and rated according to benefits received from the scheme. The classification plan is shown in fig. 2-3.

Present value (September 1987) of total scheme works is $23m.

2.5 Scheme Operation

Since installation of the scheme there has not been a flood event of significant magnitude to fully test the scheme works. Minor floods slightly in excess of the five year event (as in 1983) have largely gone unnoticed whereas prior to any scheme works would have caused significant flooding. The floodway has not been used nor has the Matahina Dam been required to provide extra storage during a large flood.

The drainage works have been tested to scheme requirements (again in 1983) having to discharge against five year flood levels in the outfall canals. The scheme works operated as designed under these conditions. Some problems were related to higher performance expectations than provided for in the design; this in part was due to recent horticultural development on the plains for which a higher drainage standard is required.

2.6 Land Development

Construction of flood protection works has given confidence to producers for more intensive and diverse development on the plains. Dairying is the major land use; the area is ideally suited for such pastoral farming. The generally low lying

*National Water and Soil Conservation Authority (abolished 31/3/88)

areas of the plains have high water tables encouraging grass growth in the drier months and high overall productions are achieved of up to around 650 kg milkfat per hectare per annum.
There has been a significant amount of horticultural development carried out over the past fifteen years. This is confined to the higher better drained areas, being adjacent to rivers, or on old sand ridges or on the southern half of the plains. Significant areas of the plains are also used for crops such as maize and asparagus (refer fig 2-4).

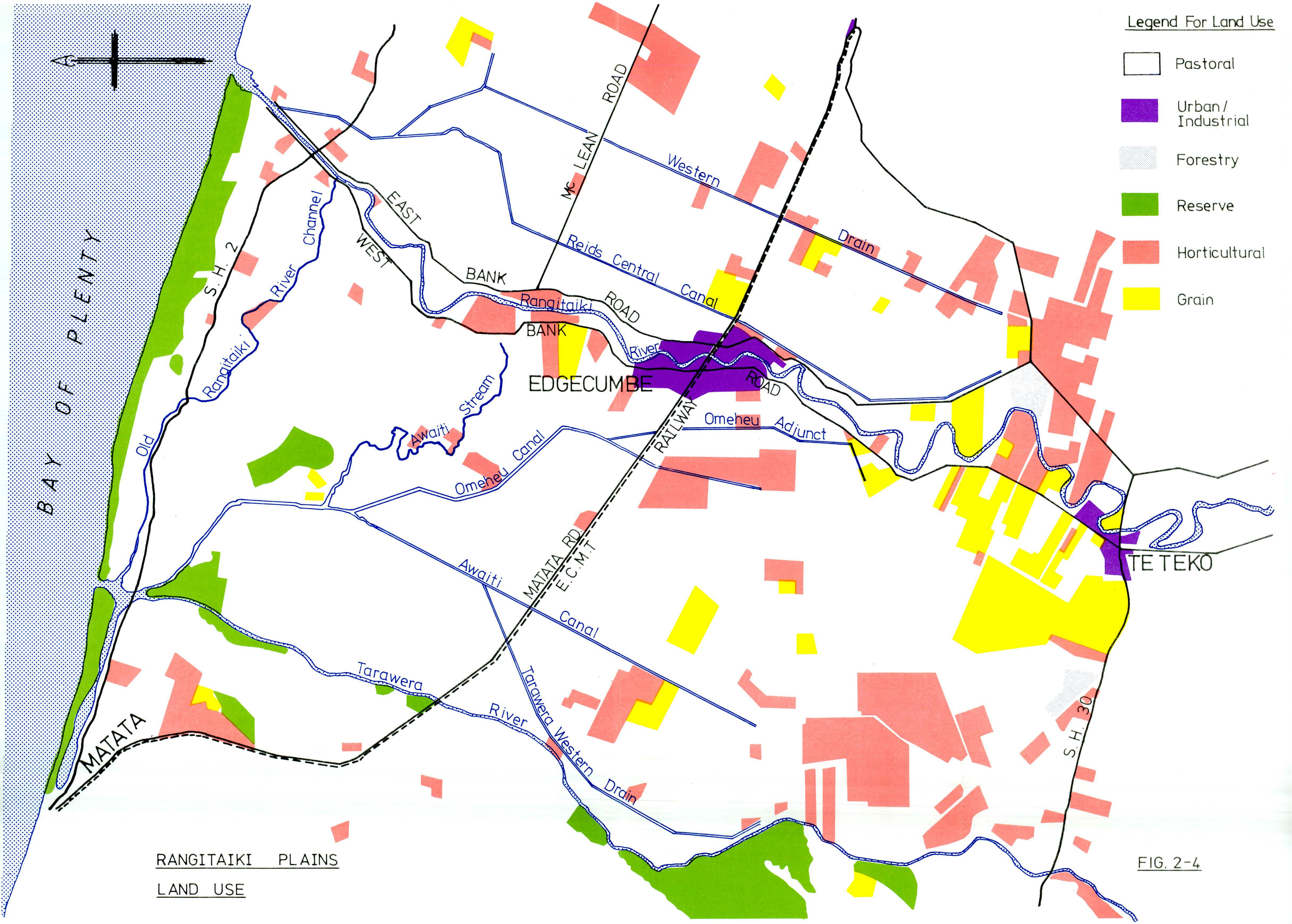
Along with the increase of primary production support industries and communities have grown. Bay Milk Products Dairy factory is the most significant large industry on the Plains and relies heavily on milkfat production from the surrounding high producing areas which are also the areas most prone to flooding.

Since construction of the original scheme, small communities such as Edgecumbe have expanded into areas which previously had severe flooding problems.

2.7 Edgecumbe Earthquake

On March 2nd 1987 at 1.42 p.m. an earthquake of magnitude 6.3 occurred with an epicentre just north of Edgecumbe. The depth of the earthquake was estimated to be 12 km. The earthquake occurred after a week of seismic activity in the general area, and was followed by numerous aftershocks, four of which registered greater than 5.0 on the Richter Scale. The main shock produced a complex series of surface scarps with the longest approximately 7km known as the Edgecumbe fault. That scarp strikes north-east from an area north of Te Teko to east of Edgecumbe. Up to 1.5m of lateral extension across the scarp has been measured and the north-west side has been downthrown by as much as 1.5 metres.

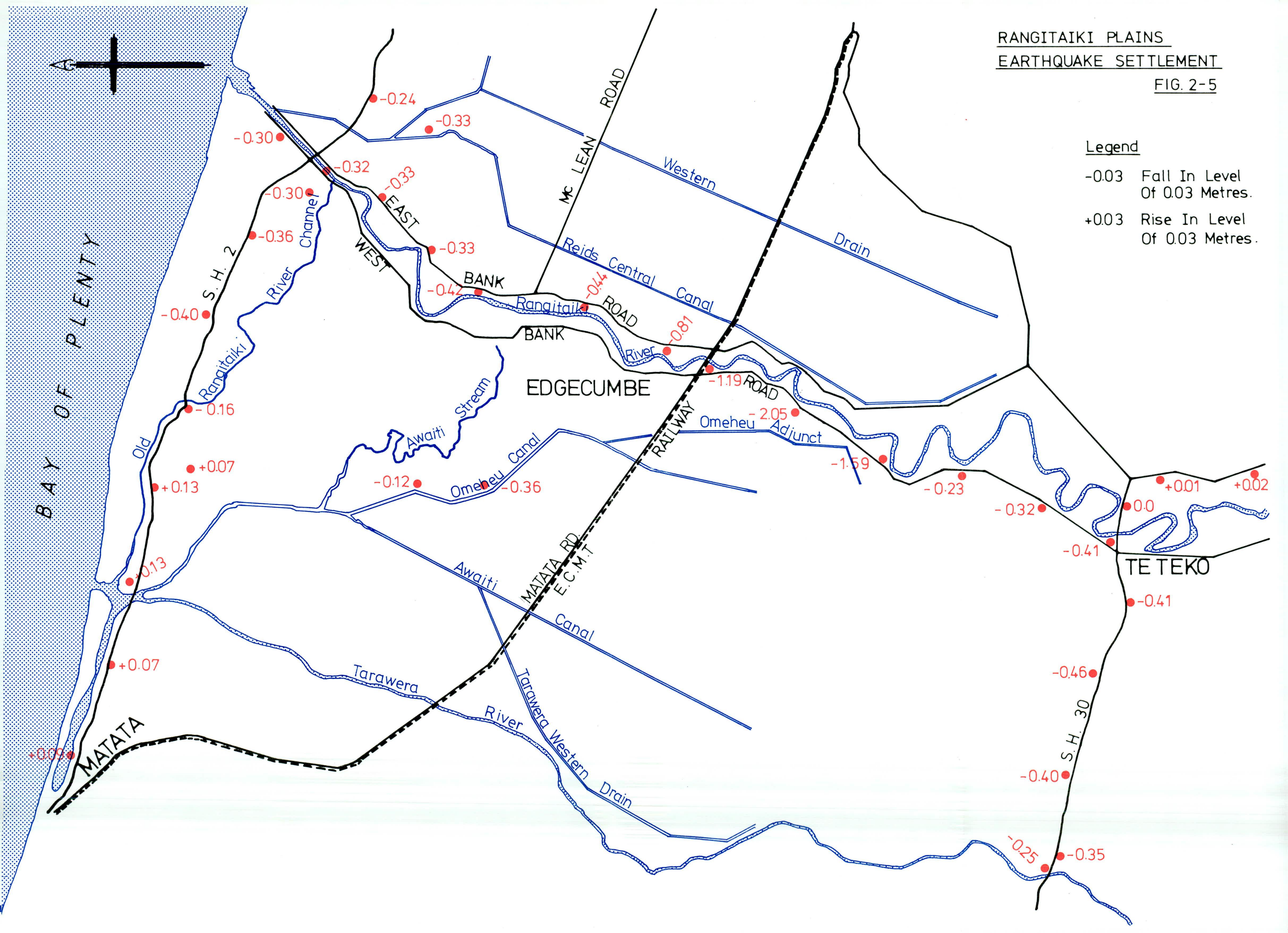
General regional subsidence of up to 2.0 metres has been measured (fig 2-5). Some small areas near Matata were upthrust. Flood protection works on the Plains suffered significant damage in the form of slumping, cracking and general subsidence. The stopbanks in particular suffered from severe cracking along sections of the Rangitaiki and Tarawera Rivers. Stopbanks that were known to have permeable foundations and where special techniques (refer section 2.4 (i)) were applied in the construction process, suffered the most damage.



RANGITAIKI PLAINS

LAND USE

FIG. 2-4



RANGITAIKI PLAINS
EARTHQUAKE SETTLEMENT
FIG. 2-5

Liquefaction of the underlying sands caused lateral spreading or relative displacements of the stopbanks from their foundations. The result was extensive cracking associated with numerous sand boils. The extent of stopbank damage is set out in the BOPCC report of April 1987[2]. Most of the emergency works proposed in that report have been attended to. However, extensive regional subsidence means flood overflows are more likely and also the drainage system has reduced ability to cope with them.

2.8 Existing Flood Protection and Drainage

(i) Flood Protection

The Rangitaiki River Model, as discussed in Section 3, indicates the present flood protection system is able to discharge $523m^3/s$*, which is approximately the 20 year flood. At this flow the floodway will be in use whereas its original design proposed that at the 40 year flood it would come into operation. Should flows in the river increase up to approximately the 50 year return period level the floodway itself will be unable to cope and its stopbanks will be breached flooding large areas of low lying land. The side-flow spillway which discharges water from the river into the floodway has also been damaged; uneven settlement has occurred and there is a real danger that flows concentrated over certain lengths of the grassed spillway could cause a failure leading to a major disaster.

During a flood sized between a 20 and 50 year event the section of river downstream from the fault line to Edgecumbe bridge would experience overflows on both sides from which water would discharge to lower lying areas away from the river. Depending on the point of overflow it is possible that water would run through a large part of Edgecumbe township, Electricorp's sub-station and Bay Milk Products factory. Water would not pond in these areas apart from some smaller low-lying areas of Edgecumbe.

The Tarawera River suffered no overall subsidence and its 100 year standard of protection has been restored in one operation with the completion of the earthquake repairs.

* Cubic metres per second, or cumecs

(ii) Drainage

Capacity of the various drainage systems has been adversely affected most notably in that there are now reduced gradients available to discharge water to the outlets. In many areas the water table is closer to land level than previously and hence a higher pumping requirement is needed. (refer fig 2-6).

Details of the inadequacies of the flood protection are set out in later sections.

2.9 Proposed Standards

2.9.1 Flooding

It is proposed that flood protection on the Rangitaiki Plains be restored to the 100 year standard. That standard facilitated the present development on the plains; it is what the community is rated for, and desires. An economic analysis (sec. 4) shows the investment in restoration of the scheme to 100 year standard has a satisfactory rate of return.

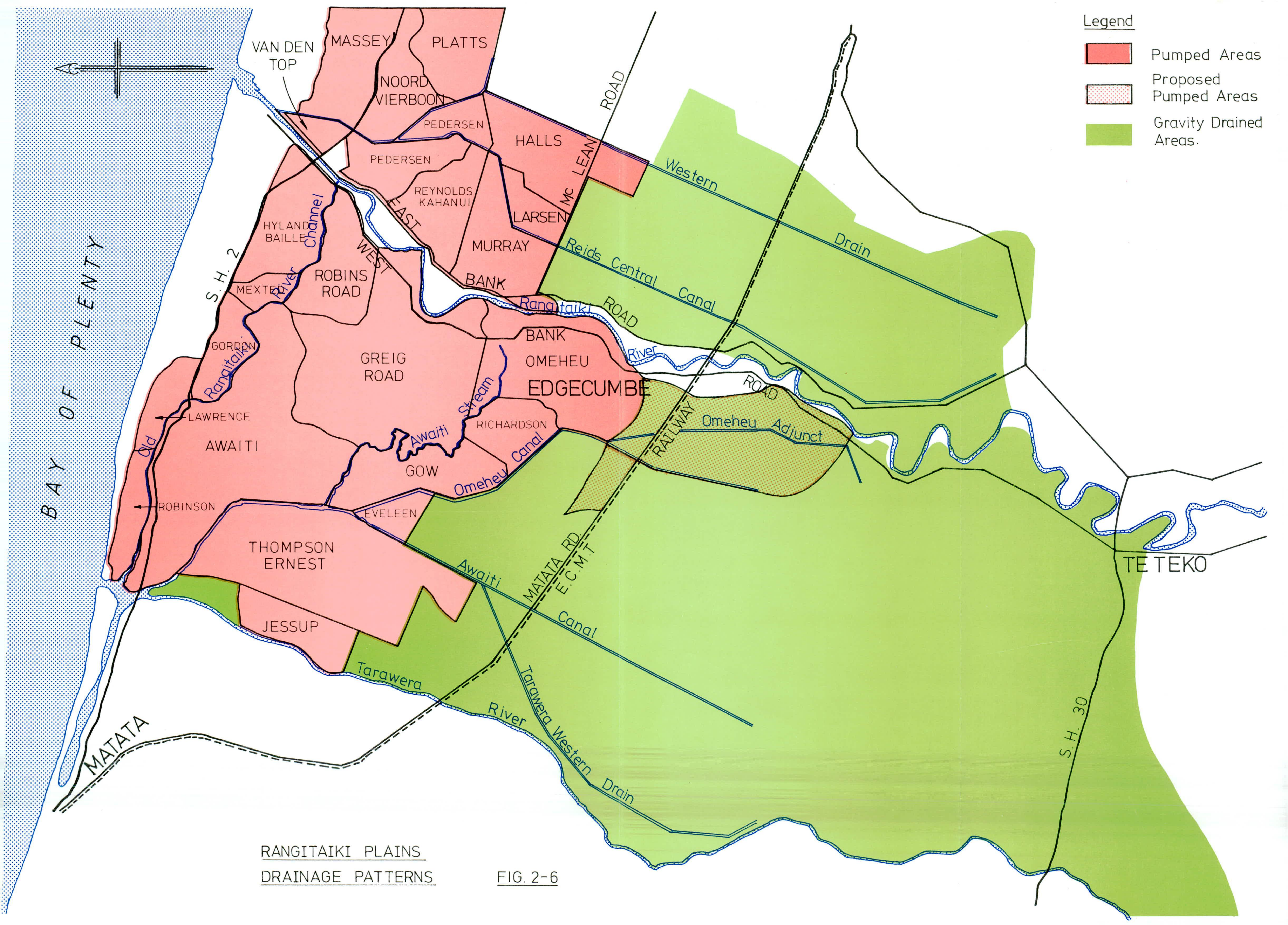
2.9.2 Drainage

The original drainage construction on the plains was to the 5 year standard. This equated to 28mm per day for a period of three days. This has proved to be successful for pastoral farming whose production has greatly increased since implementation of the scheme.

There has been a trend over recent years towards horticulture which requires a higher standard of protection. In particular ponding for more than one day is not permissible, and a lower water table is also usually required. In some areas it is impracticable to provide such a drainage standard and also unwise as low water tables in peat areas will induce settlement. Outfalls have been designed taking into account the type of land use possible - i.e. a higher standard for areas with horticultural potential and the traditional pastoral standard for other areas.

2.10 Sea Level Rise

One aspect of the proposed scheme standards is consideration of the effects of a rising sea level due to the "greenhouse effect". It is generally agreed amongst the scientific community that sea levels will rise over the next 50 years. The debate is centred around how much it will rise. No national policy exists at this stage as to what



RANGITAIKI PLAINS
DRAINAGE PATTERNS

FIG. 2-6

allowance flood protection works should make for such a scenario. It is prudent that structures with a long design life (e.g. stopbanks) should be built with an allowance for sea level rise. Structures with a shorter design life (e.g. pumping stations) should be designed for present conditions as such units would require upgrading by the time significant effects of rising sea level were noticed. After a comprehensive literature survey, .14m sea level rise (corresponding to projections for year 2020), has been incorporated where relevant.

2.11 Bay of Plenty Earthquake Assistance Steering Committee

This Committee (also known as the Adverse Events Committee) was set up by Cabinet Minute after the Edgecumbe earthquake to provide rural drainage relief. That Committee found the best solution to drainage problems was (where possible) to restore commmunal drainage systems to their former capacity. The Committee agreed to fund these projects via the Rangitaiki Drainage Board and as at October 1988, most of those works are being or have been constructed by the Board. However the complete benefits of the scheme could not be realized without drainage restoration. The economic analysis (sec. 4) therefore includes the cost of drainage restoration works related to Rangitaiki River although those works have already been funded by the above Committee.

2.12 Summary

The Edgecumbe earthquake of 1987 affected the flood protection and drainage systems of the Rangitaiki Plains to the extent that without restoration future development would be severely restricted. The present flood protection standard of 20 years is unacceptable for Edgecumbe and rural areas. Overall proposals for restoration of the 100 year standard of flood protection are set out in this report. Required drainage works are being carried out by the BOP Earthquake Assistance Steering Committee. However apart from works completed under "phase 1" repairs[2], flood protection restoration works presently do not have any source of funding.

3. HYDROLOGY AND HYDRAULICS

3.1 General

The following evaluates the river system following landform changes to the Plains caused by the earthquake. Several combinations of floodway and main channel discharge have been investigated which in turn have been analysed to determine the cheapest overall solution.

A channel in the floodway (Reids Central Canal) serves as the drainage outlet for and between the main river and Kopeopeo East drainage system. Layout of the lower river and floodway is shown on Fig 3-17.

3.2 Flood Control System

The flood protection system relies initially on flood forecasting methods to determine the expected flood size, which enables an assessment of the amount of storage Matahina Dam may need to provide. Flood estimates must initially be based upon rainfall as the river gauges (Aniwhenua, Whirinaki and Murupara) peak too late to enable full storage to be provided in the dam. Storage needs to be provided in the dam for floods greater than about the 20 year level of 500 cumecs. A controlled release of water from the dam is specified under existing operating rules.

From the dam the floodwave passes along 11.3km of natural channel where it attenuates slightly then enters the stopbanking system immediately upstream above Te Teko bridge. The main channel is required to transmit the full 100 year flow down to the spillway (river distance 14,860m). From this point the floodway comes into operation at a pre-determined discharge which thereby limits peak flow in the lower section of river. The floodway, relying on storage, discharges against a tidal cycle back into the main river 1,000m from the river mouth.

The spillway level determines the division of flow between the main river channel and floodway, and is a critical element in otimising downstream stopbank earthworks quantities in the post-earthquake scheme.

The floodway also provides a drainage outlet for 3,700ha of the plains, the main drainage systems being Reid's Central Canal (2,490ha), Kopeopeo West Canal and Western Drain (1,237ha).

3.3 Hydrology

A re-assessment of the river's hydrology was desirable in order that the system be designed using all available data. The original scheme works were designed with continuous data available over only a short period of time; the 100 year flood was then estimated at 796 cumecs.

3.3.1 Data

Continuous flow records for the Rangitaiki River at Te Teko since 1949 are available, stored on The Ministry of Works and Development (MWD) central computer in the TIDEDA system (site no 15412). However, since 1967 Matahina Dam has modified the natural discharge on the lower section of the river and therefore the series is not homogeneous. The effect of the dam on flood discharges is not great as at normal lake level the extra available storage is not large. It is only when a major flood is expected and drawdown of the lake is requested by BOPCB that sufficient storage can be made available to significantly affect the peak flood discharge (refer section 3.4.5). It is noteworthy that the largest and third largest floods recorded have occurred since construction of the dam.

3.3.2 Hydrologic Analysis

The annual flood series (1949 to 1986) was analysed by the Ministry of Works and Development computer program "FRANCES" which fits extreme value distributions to the data by the maximum likelihood method. The fit of the various distributions to the data was very good up to the 20 year flood of approximately 520 cumecs. Above the 20 year level there was a wide scatter ($586m^3/s$ to $788m^3/s$ for the 100 year event) in the results. This is because whilst a range of events up to $400m^3/s$ have been recorded, only three events greater than $500m^3/s$ have occurred during the 37 years of continuous record. Further, two of these events have been modified by Matahina Dam.

The Chi-square test statistic was applied to each of the distributions to test the significance level of the 100 year discharge as given in the analysis. The Log-Pearson method tested at a significant level of 0.0025 whereas the Gumbel method tested at a

significance level of 0.10. This means that in any 100 year period the Log-Pearson generated discharge (755m^3/s) has a 2.5% chance of being exceeded whereas the Gumbel generated discharge (684m^3/s) has a 10% chance of being exceeded. Adopting the Log-Pearson adjusted distribution is recommended and has been used in all analyses. Results are summarised in the following table.

Table 3a - Rangitaiki River Discharges (Fig 3-1)

Return Period (yrs)	Te Teko Discharge (m^3/s)
2.33	257
5.00	342
10.00	425
20.00	523
30.00	576
40.00	610
50.00	645
100.00	755

3.3.3 Regional Flood Estimation

As an approximate check on the 100 year flood discharge, the Regional Flood Estimation procedure was applied to the catchment. The major problem in applying this technique at Te Teko is that the upper catchment consists of two distinct regions. However, by coincidence, at the 100 year level the "regional curves" for both the North Island East Coast and Bay of Plenty coincide. The 100 year discharge is calculated to be 748m^3/s with an error estimate of 183m^3/s.

3.4 Hydrograph Derivation

For analysis of the floodway-river system it was important that a 100 year design hydrograph be developed. The largest flood recorded was in August 1970 from which records are available at both Te Teko and Matahina Dam, along with reliable rainfall data throughout the catchment. This flood forms the basis of the derivation of the design 100 year event.

3.4.1 Rainfall - August 1970

Rainfall depths for the period 11 to 14 August 1970 have been plotted on a map of the Rangitaiki Catchment (fig 3-3). The storm was widespread throughout the area.

By way of comparison fig. 3-2 shows a similar storm during June 1970. The August 1970 storm was considered typical of widespread rainfall events so the hydrograph it produced was used as a basis for the design hydrograph.

3.4.2 Te Teko Hydrograph

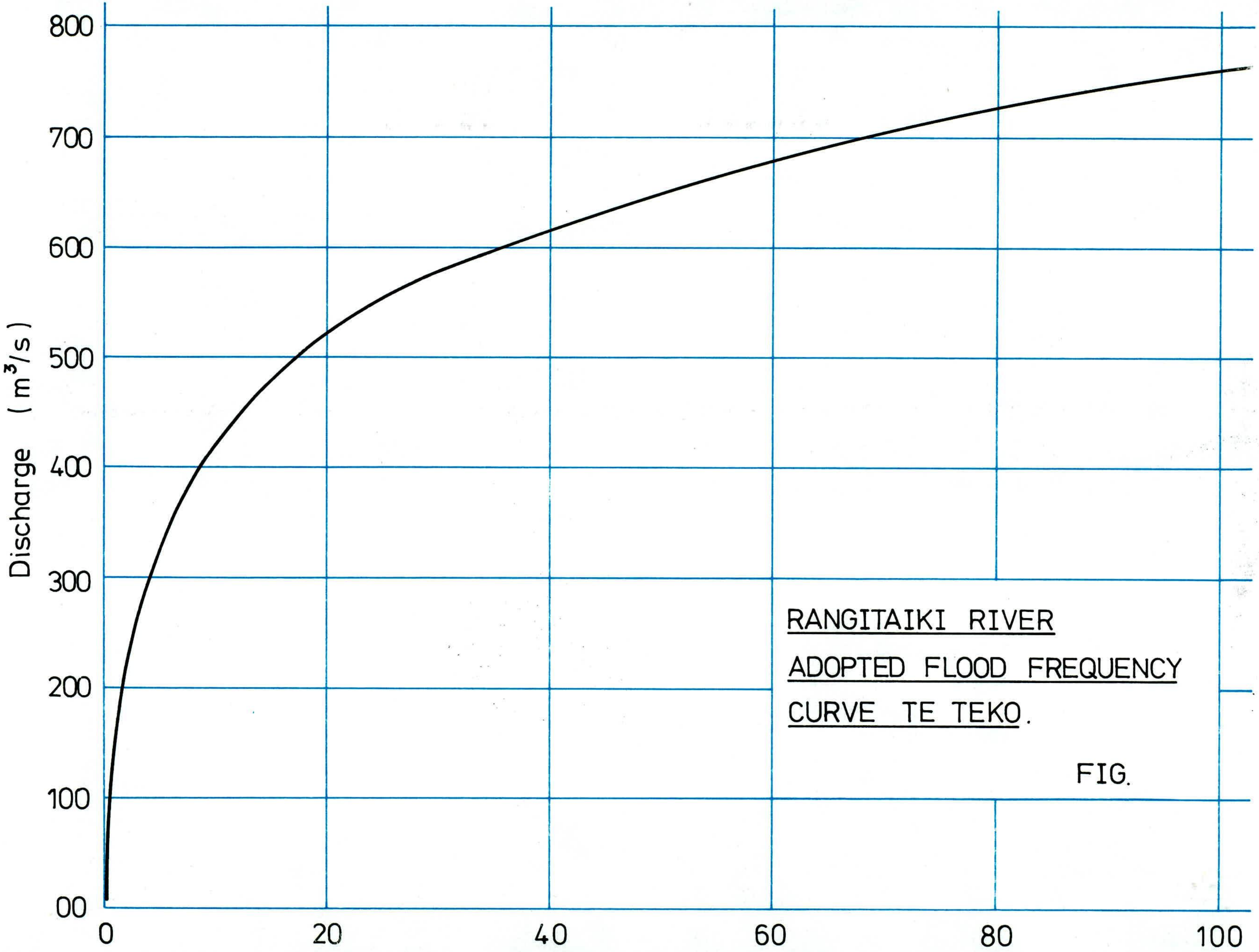
The hydrograph at Te Teko (13 August 1970 to 18 August 1970) was been extracted from TIDEDA records, plotted and the total flood volume calculated. The amount of runoff is far from evenly distributed throughout the entire catchment; however the average catchment runoff was used as a comparison with other storm events.

3.4.3 Unitgraph Analysis

This is a method which reduces runoff from a storm to a single unit (in this case one centimetre) hydrograph of excess runoff. The shape of the hydrograph embodies the physical characteristics of the catchment and therefore, within limits, hydrographs from other storms can be derived from the unitgraph. In this case the August 1970 storm was used to develop a unitgraph at Te Teko, which formed the basis of the design 100 year hydrograph. Firstly, rainfall from seven sub catchments were determined from the isohyetal map. (fig. 3-3). Runoff was calculated by assuming similar run-offs occurred as during previous analysed storms. Details of the hydrology of each sub-catchment in the August 1970 storm are as follows:

Table 3b

Sub-Catchment	Area (km^2)	Rainfall (mm)	Runoff (mm)	Runoff Coeffic.	Total Catchment Runoff Coefficent
Upper Rangitaiki	1190	140	7	0.05	
Whirinaki	531	150	41	0.27	
Horomanga	220	180	90	0.50	
Waihau	207	255	117	0.46	0.17
Kaingaroa	595	130	13	0.10	
West Matahina	122	230	20	0.09	
East Matahina	60	255	95	0.37	



800
700
600
500
400
300
200
100
00
0
20
40
60
80
100
Discharge (m³/s)
Return Period (Years)
RANGITAIKI RIVER
ADOPTED FLOOD FREQUENCY
CURVE TE TEKO.
FIG.

FIG. 3-1

In comparison total catchment run-offs from previous storms are as follows:

Table 3c

Storm Date	Rainfall (mm)	Runoff (mm)	Runoff Coefficient
February 1965	208	55	0.26
July 1964	122	25	0.20
March 1964	114	19	0.17
February 1967	202	39	0.19

Using the runoff figures of Table 2b the expected hydrograph at Te Teko was calculated. The actual and calculated hydrographs are plotted on figure 3-4 and show a close comparison. In general, the unit hydrograph method has underestimated the flood, as reflected in its low runoff coefficient value of .17 compared to other storm values up to .26. However, runoff coefficient values are dependent on antecedent moisture conditions and change with season, intensity and distribution of the rainfall and with vegetation.

In summary, the results from the unitgraph analysis however are considered realistic and provide the further basis for the 100 year design hydrograph.

3.4.4 Design Hydrograph

The derived hydrograph (fig. 3-4) was projected so that its peak value matched the statistically derived 100 year flood (755m^3/s). The rainfall distribution required to produce this flood would be similar to that shown in fig. 3-3.

The adopted design 100 year hydrograph is shown in fig. 3-7, together with the 1970 flood hydrograph (which could be used directly as a design 50 year hydrograph).

This 100 year hydrograph has been used in the design of the lower river and floodway proposals.

3.4.5 Effect of Matahina Dam

The dam has the capability of reducing the peak of the flood, providing storage is made available well before the peak enters Lake Matahina A notable aspect of floods is the

very high volume of discharge of which the da is capable of storing only a small portion.

Analysis of the 1970 flood showed the dam wa capable of storing, between minimum drawdow level (RL* 73.15) and design flood level (R 77.05), only 10% of the flood volume. Durin the 100 year flood this figure decreases t around 6%. To achieve reduction in peak flow minimum drawdown level must be reache approximately 12 hours before the flood pea reaches the dam. Prior to that approximately 1 hours is required to attain the minimum level i the dam. Early estimation of the size of th flood is therefore vital to maximise the use o the dam in a flood event. This is an area wher both Electricorp and BOPCB are keen to refin flood forecasting techniques.

The August 1970 flood has been analysed in som detail as to how the dam modified the lowe river flow. This was important to justify th use of the annual flood series at Te Teko in th frequency analysis, and also for development o the 100 year design hydrograph. From the da discharge data and known lake level change during the flood the inflow hydrograph to th dam could be calculated. These hydrographs ar plotted in fig 3-8.

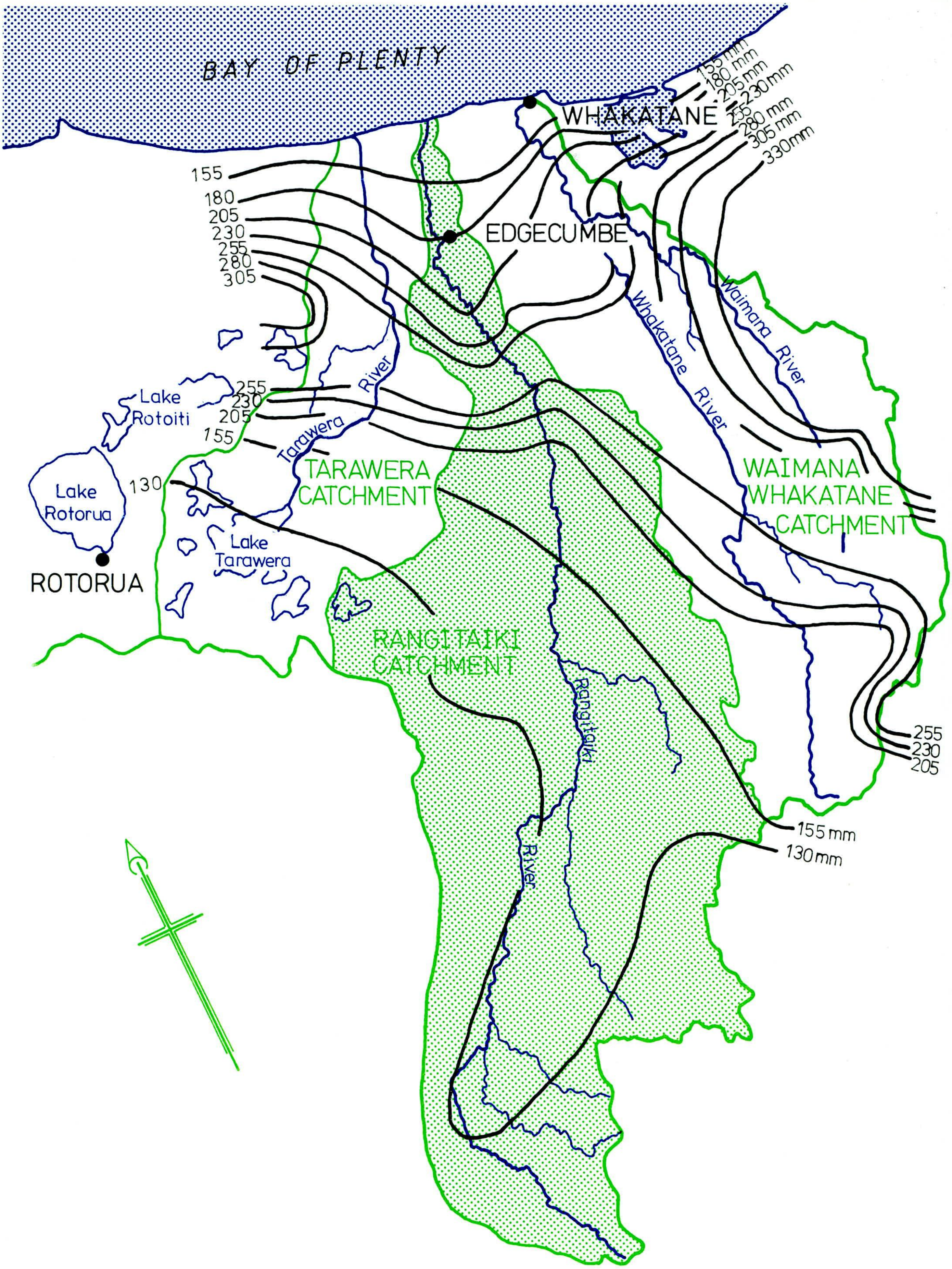
Analysis of this flood has shown:

(i) The peak of the flood was reduced onl $19m^3/s$ (2.9%) by the dam.
(ii) This had further attenuated by 7 cumecs t Te Teko.
(iii) The dam was not lowered below the maximu operating level and for that reason the peak discharge was not significantly reduced.

The small reduction in flood peak gives furthe confidence in the use of the frequency analysi at Te Teko as a method of predicting desig flows. Also the 1970 flood is considere representative of larger floods in the rive system (1965 and 1967 had similar shapes) and s provides a good basis for the design hydrograph

In summary: Matahina dam has a small effect o reduction of flood peaks such that the Te Tek peak flows record can be considered statisicall homogenous.

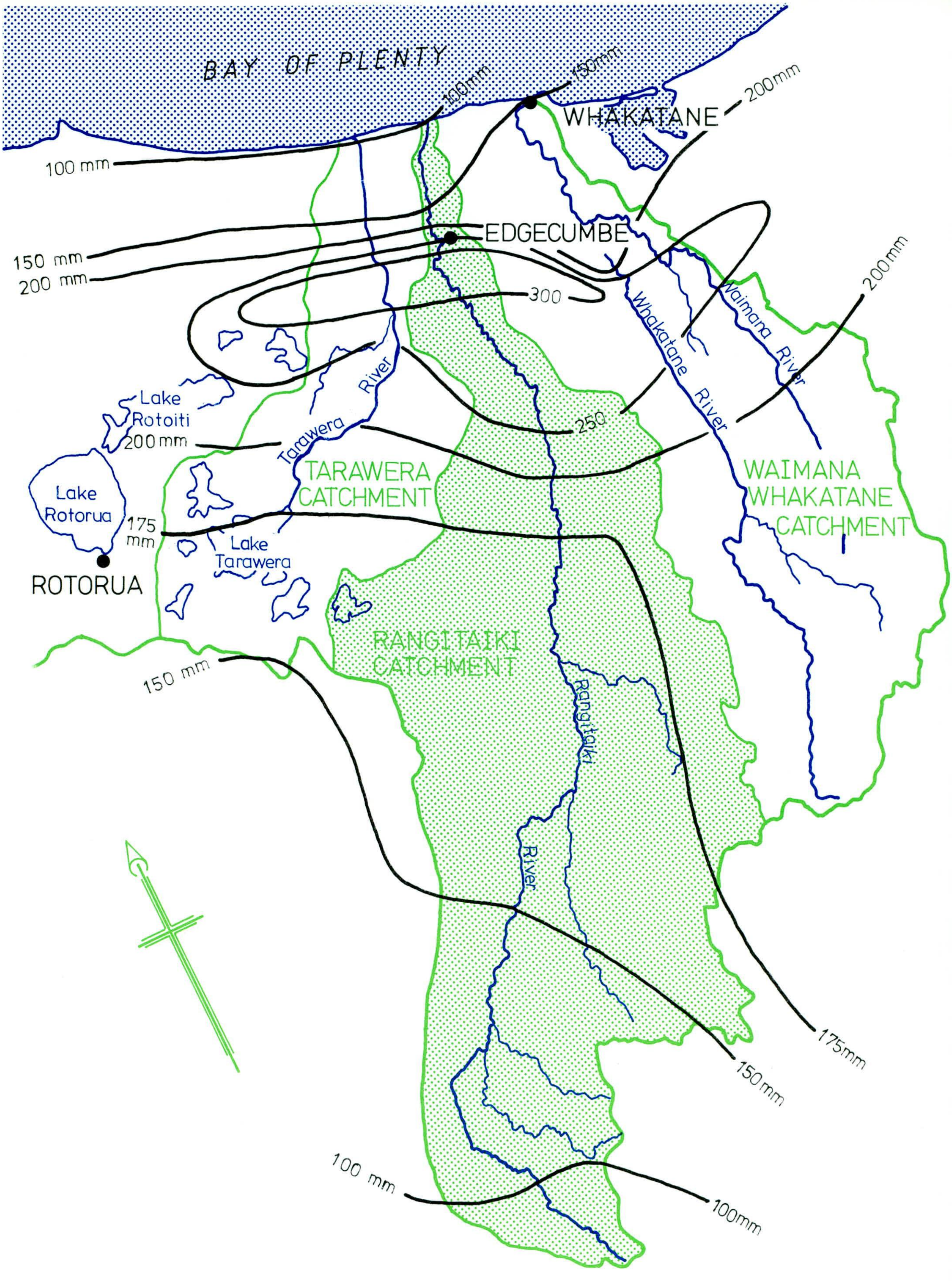
* Relative Level in metres above Mean Sea Level datum of 0.0 metres.



STORM ISOHYETS

JUNE 3 - JUNE 7 1970

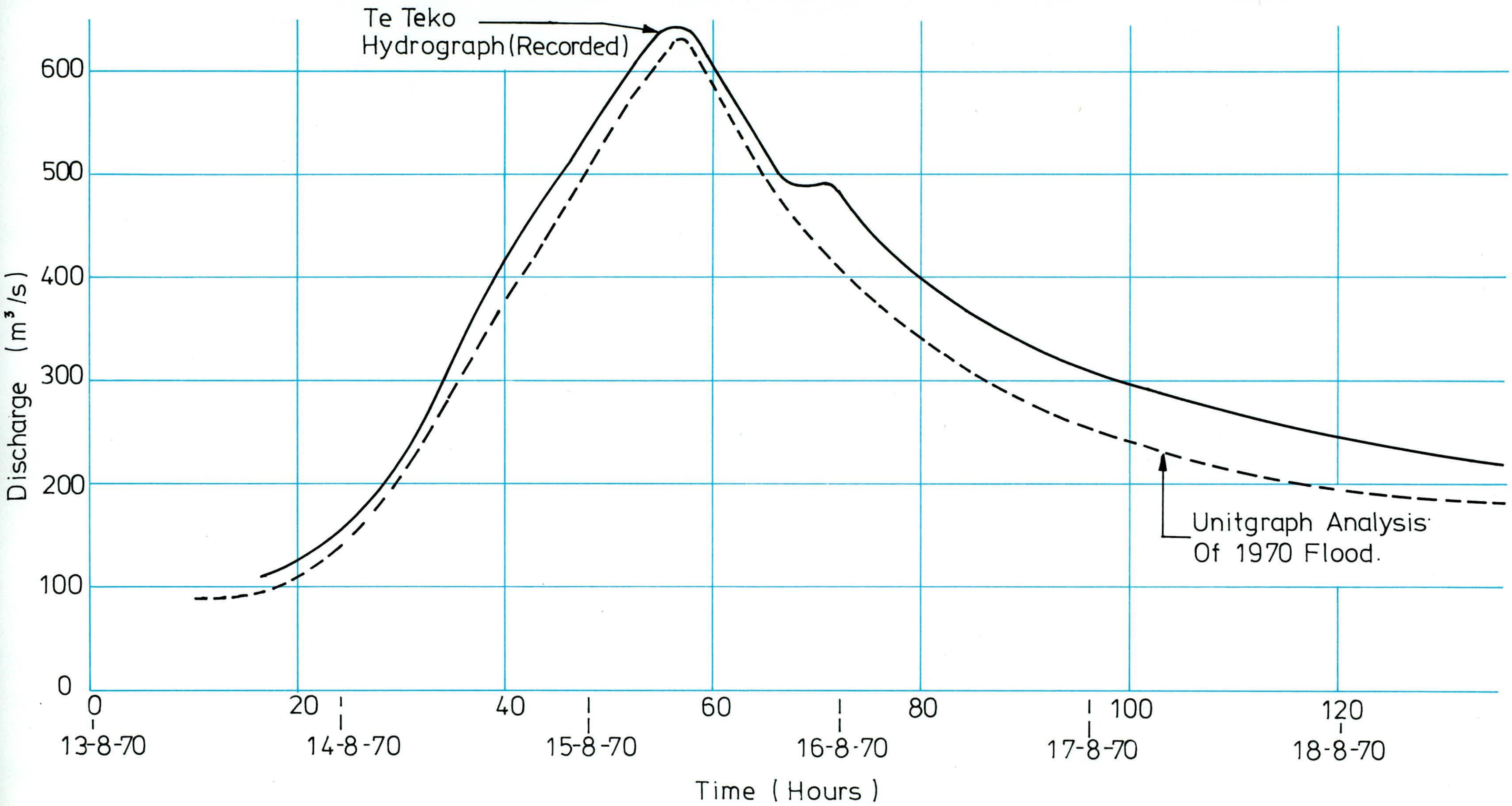
FIG. 3-2



STORM ISOHYETS

AUGUST 10 - AUGUST 12 1970

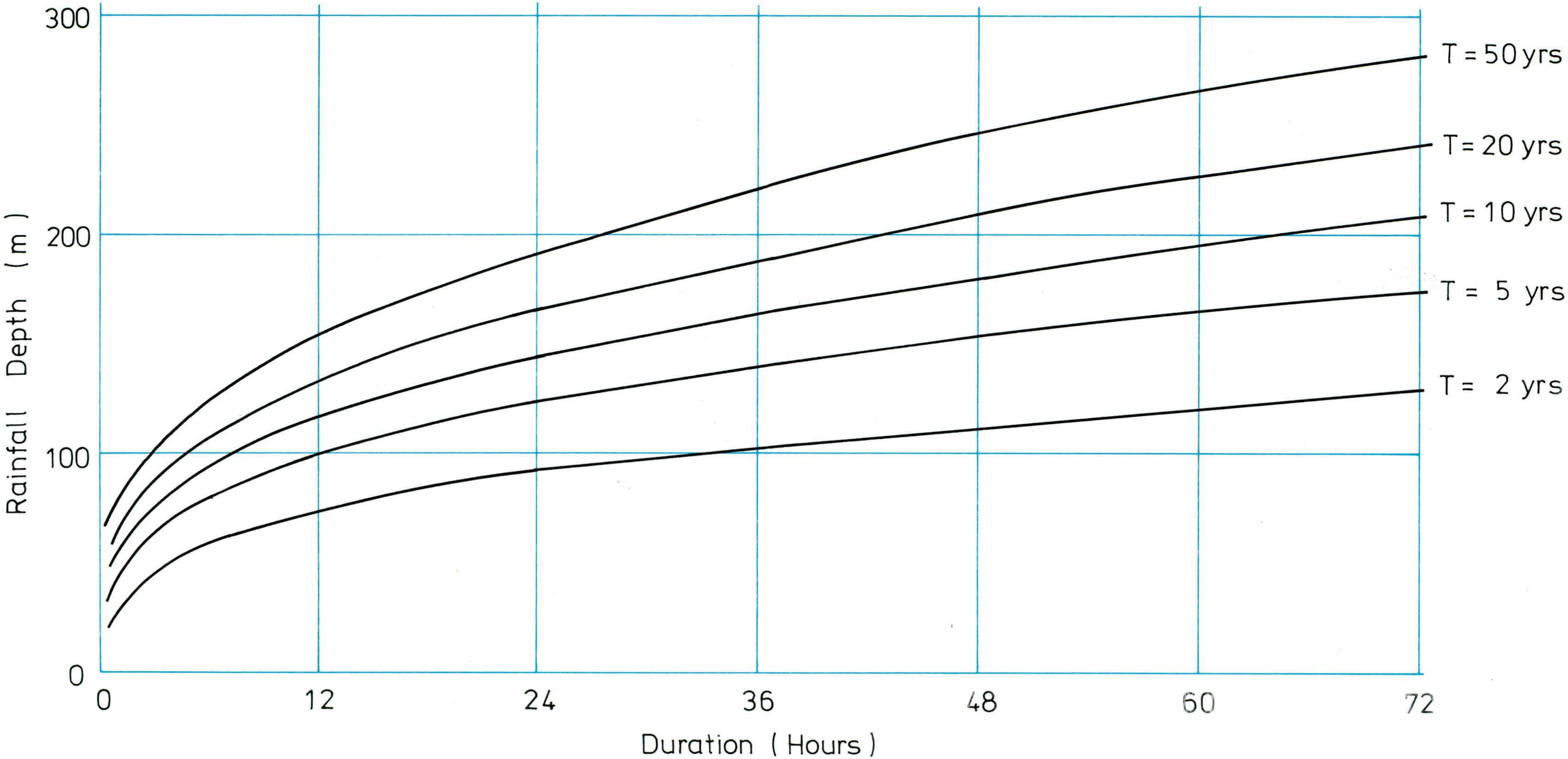
FIG. 3-3



RANGITAIKI RIVER

COMPARISON OF ACTUAL AND DERIVED HYDROGRAPHS AT TE TEKO

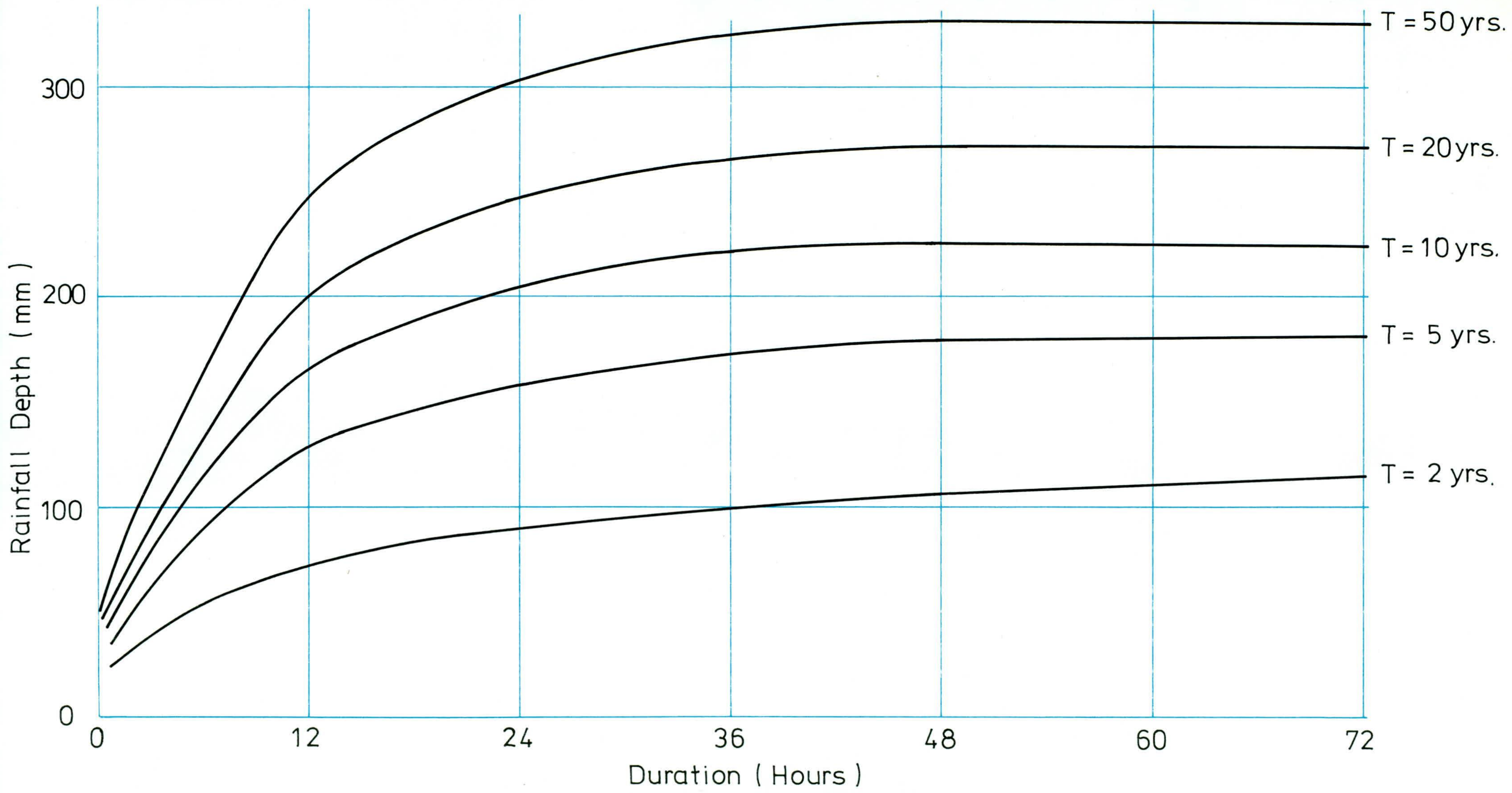
FIG. 3-4



RAINFALL DEPTH, DURATION, FREQUENCY CURVES

THORNTON

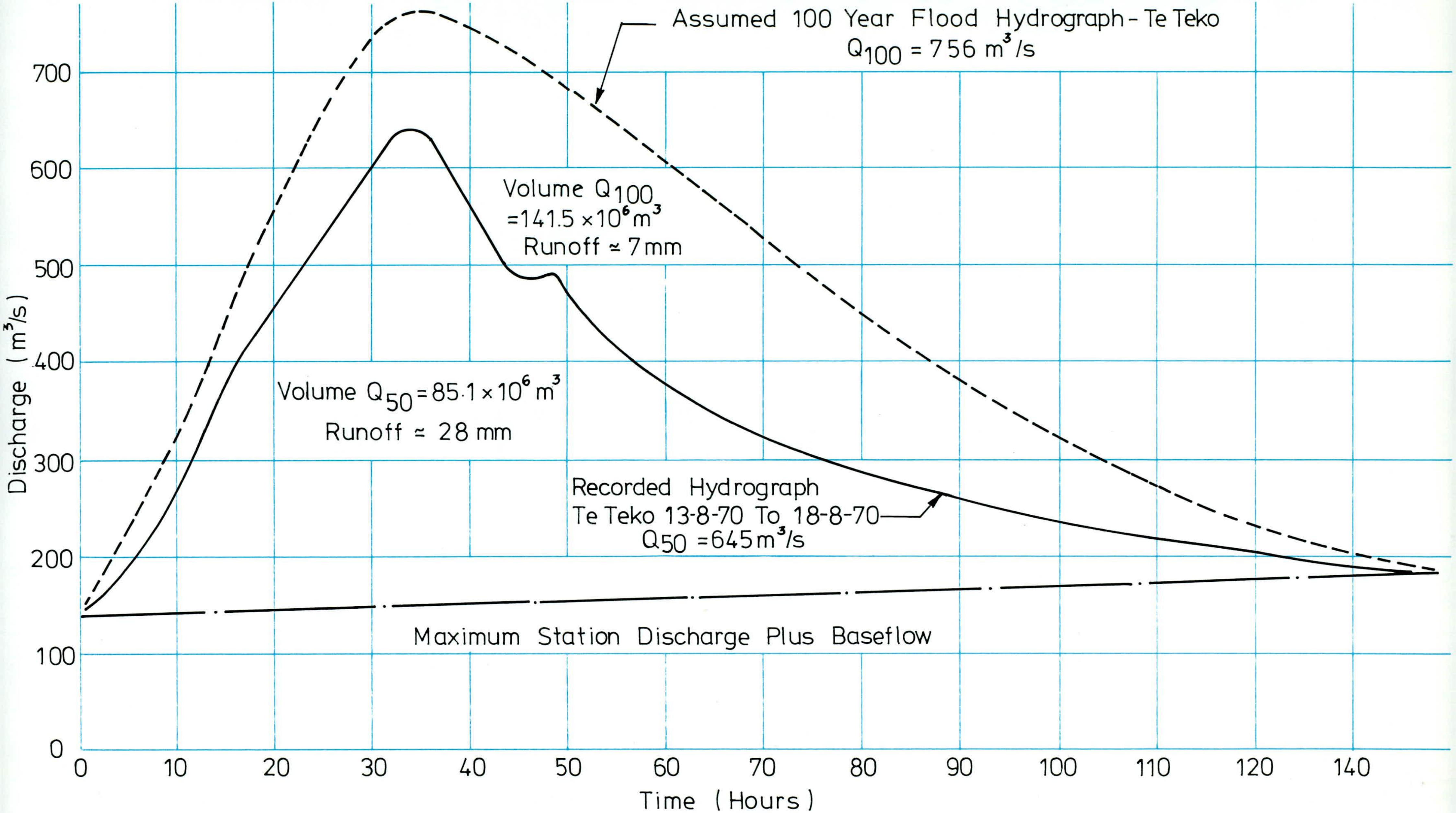
FIG. 3-5



RAINFALL DEPTH, DURATION, FREQUENCY CURVES

GRANT ROAD (GALATEA)

FIG. 3-6



RANGITAIKI RIVER - DESIGN 50 YEAR (RECORDED) AND DESIGN 100 YEAR (ASSUMED) FLOOD HYDROGRAPH - TE TEKO

FIG. 3-7

3.5 Hydraulic Analysis

Hydraulic design involved analysing the flow at the spillway then subsequently the main river and the floodway individually. For the river the upstream boundary condition was the hydrograph at Te Teko. Upstream boundary conditions at the floodway are determined by spillway hydraulics. Downstream boundary conditions for both river and floodway are determined by tidal conditions.

3.5.1 Boundary Conditions

(i) Spillway

The spillway is situated on the right bank of the Rangitaiki River at river distance 14,510 metres. The spillway used in this analysis is 240 metres long and acts as a sideflow weir. Calculation of the flow profile along the length of the spillway is a "spatially varied flow with decreasing discharge" problem. This requires analysis by the method of numerical integration as set out in Chow[7]. Detailed analysis is important in order that overflow into the floodway is distributed evenly along the length of the spillway and does not become concentrated. This analysis has not been included here as the final decision on the level at which the spillway will operate has yet to be made. (refer fig. 3-9 and 3-10 for spillway hydraulics)

Flow over the spillway, however, can be treated in isolation from flow in the river by treating the river as a headwater lake. This ignores the exchange of momentum which occurs with flow transferred sideways towards the spillway, (and which is best analysed by physical model studies).

To construct a rating curve for discharge spillway an equation developed by the Rangitikei-Wanganui Catchment Board for grassed spillways on detention dams has been used (ref. 9). This enabled determination of upstream boundary conditions for the floodway, and partitioning of flows downstream into the river channel and floodway. With grassed spillways flow depths are relatively shallow and

retardance very high, and are also variable depending on the season and amount of grazing. Depth over the spillway is also critical in order that shear stress be kept below values at which erosion would occur. In summary features of the spillway should include:

- being parallel to the direction of flow in the river to avoid any effects of crossfall

- being as short as possible to minimise the possibility of concentration of flow at one point

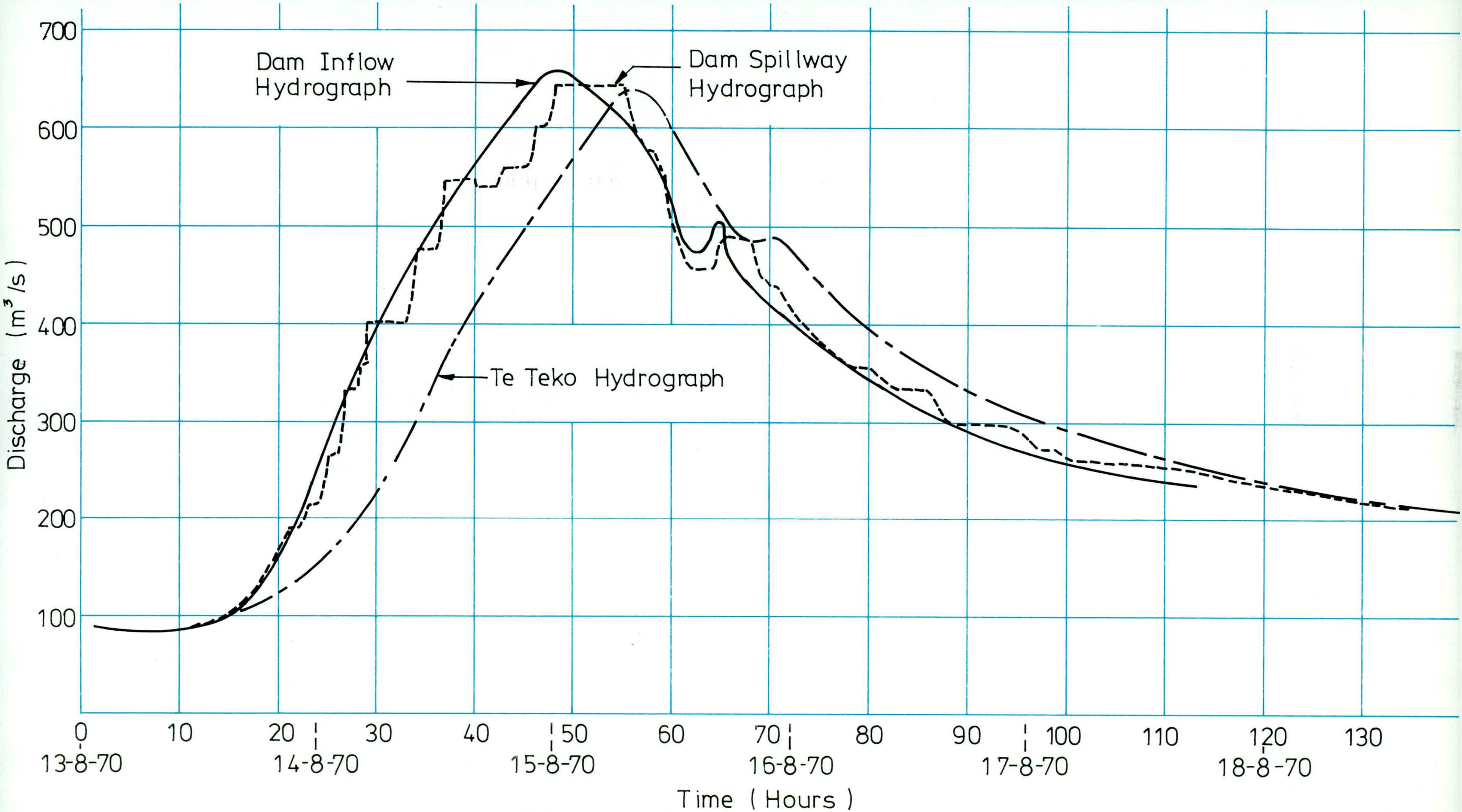
- having a slope to match the water surface slope developed in the river (to prevent concentration of flows)

- being limited in depth to prevent scour.

The spillway is the most critical aspect in controlling larger floods in the system. Further, the consequences of failure of the spillway particularly with a washout would be severe. Lining of the spillway with a non-erodible medium (e.g. gobi-mat) is now considered desirable to ensure its proper operation. (A lined spillway will slightly alter the weir discharge formula, hence floodway hydrograph used for this report).

(ii) Floodway

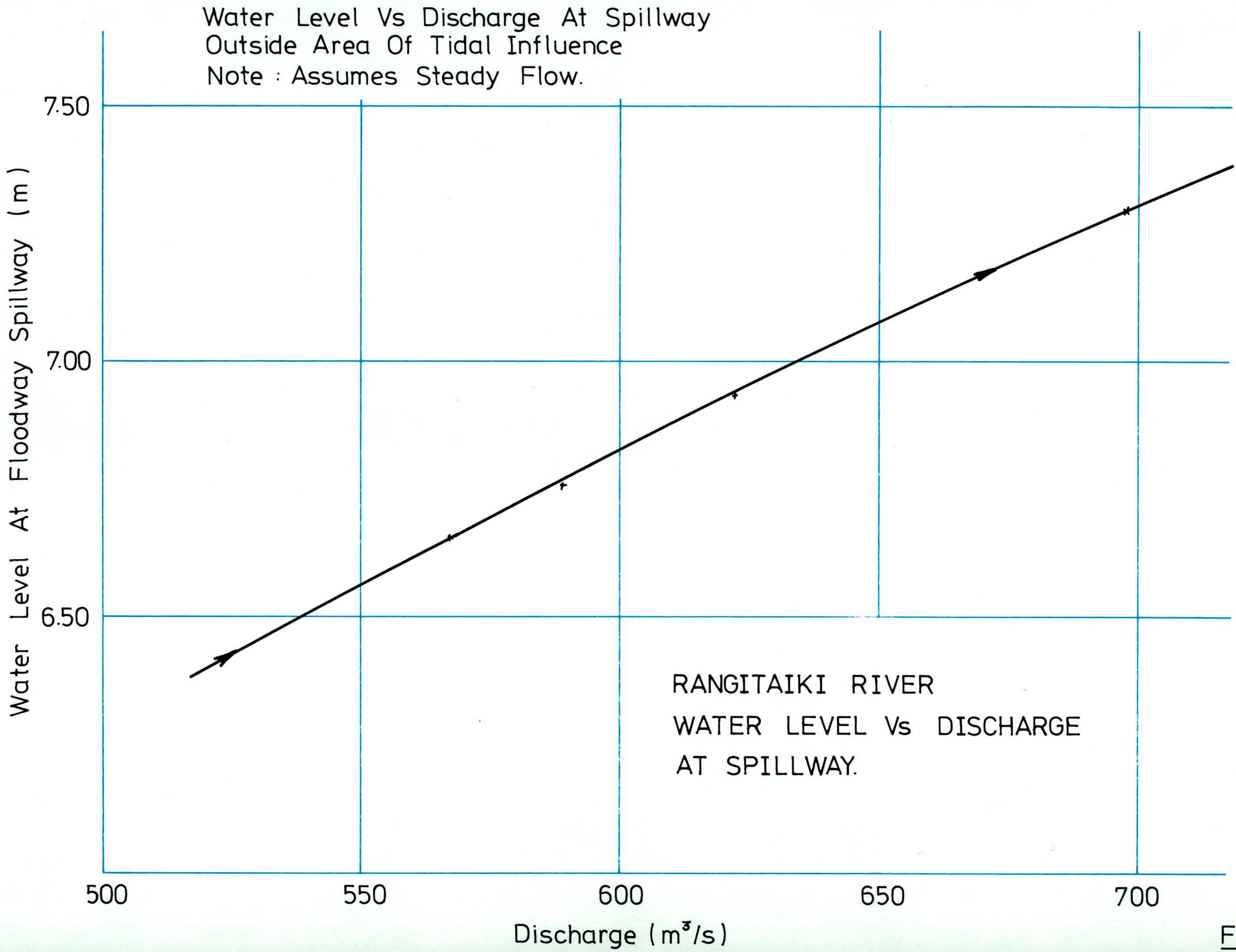
Downstream boundary conditions are the stage-time hydrograph at the outlet of Reid's Central Canal to the Rangitaiki River. This point is approximately 1,000 metres from the mouth of the river in the section strongly influenced by the tide. The Rangitaiki Drainage Board have taken a set of water level records at the site for the period 1961 to 1968. Several major storm events have been recorded. Three of these events are shown as fig 3-11 to 3-13.



RANGITAIKI RIVER - COMPARISON OF HYDROGRAPHS

SHOWING OPERATION OF MATAHINA DAM FROM 13-8-70 TO 18-8-70

FIG. 3-8



Water Level Vs Discharge At Spillway
Outside Area Of Tidal Influence
Note : Assumes Steady Flow.
7.50
7.00
6.50
Water Level At Floodway Spillway (m)
500
550
600
650
700
Discharge (m³/s)
RANGITAIKI RIVER
WATER LEVEL Vs DISCHARGE
AT SPILLWAY.

FIG. 3-9

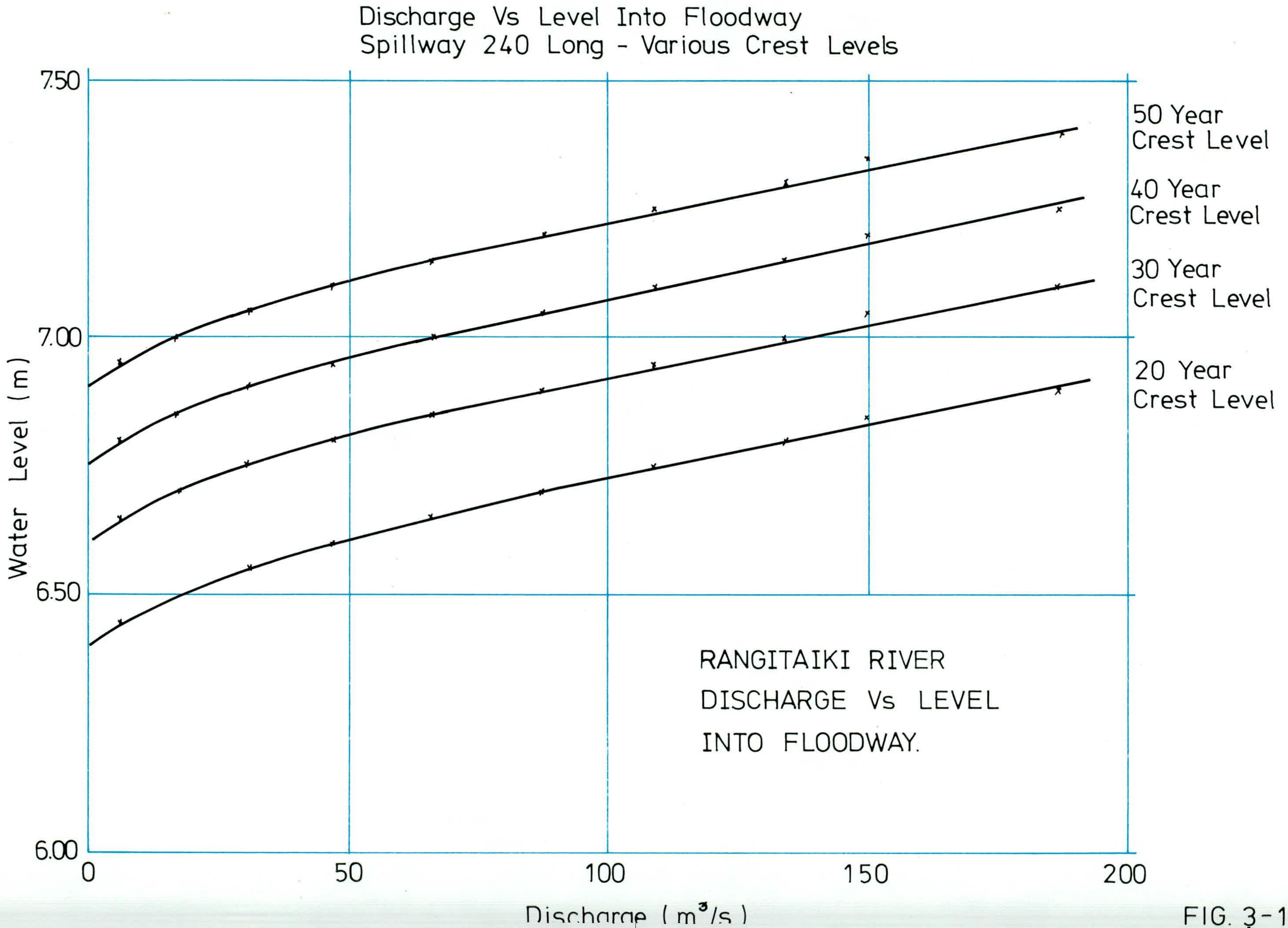

Discharge Vs Level Into Floodway
Spillway 240 Long - Various Crest Levels
7.50
7.00
6.50
6.00
Water Level (m)
0
50
100
150
200
Discharge (m³/s)
50 Year Crest Level
40 Year Crest Level
30 Year Crest Level
20 Year Crest Level
RANGITAIKI RIVER
DISCHARGE Vs LEVEL
INTO FLOODWAY.

FIG. 3-10

i) <u>April 1968 Event Fig - 3-11</u>
This event, known as Hurricane Dinah or the Wahine storm, caused extreme onshore sea set-up due to low barometric pressure and strong northerly winds. River discharge was normal. There is insufficient data available to assign a frequency to this event, but it is considered to be of 100 year or greater magnitude with respect to sea flooding. Analysis is further complicated by long-term changes in sea levels and also the constantly changing river bar. It is considered appropriate to rank this event, with account given to long-term rises in sea-level (refer sec. 2.10), as the 100 year sea-flood The probability of a major river flood coinciding with such an event is very remote.

ii) <u>February 1965 Event Fig 3-12</u>
This event had a maximum discharge at Te Teko of $596m^3/s$ and occurred before construction of Matahina Dam. It also occurred before construction of the flood protection system and consequently large volumes of water flooded onto the plains. This had the effect of significantly lowering the discharge at Thornton and also of maintaining a steady, relatively high outflow for a long period of time. A similar shaped hydrograph is apparent in other flood events such as (iii).

iii) <u>February 1967 Event Fig 3-13</u>
This event had a maximum discharge of $567m^3/s$ at Te Teko and occurred after construction of Matahina Dam. Again no flood protection works were in place and the Thornton peak discharge would have been very much less than 567 cumecs. A storm surge

(sea tide) occurred two tidal cycles (25 hours) before high river discharges. This is the typical northerly storm situation and has been incorporated in scheme design.

(iii) River Mouth
Comparison of 1960's water levels to the present shows similar values during high tide but a change at low tide. Analysis of very limited data indicates river levels at low tides are 300 to 400 mm lower now than during the period 1961 - 1968. This can likely be attributed to:

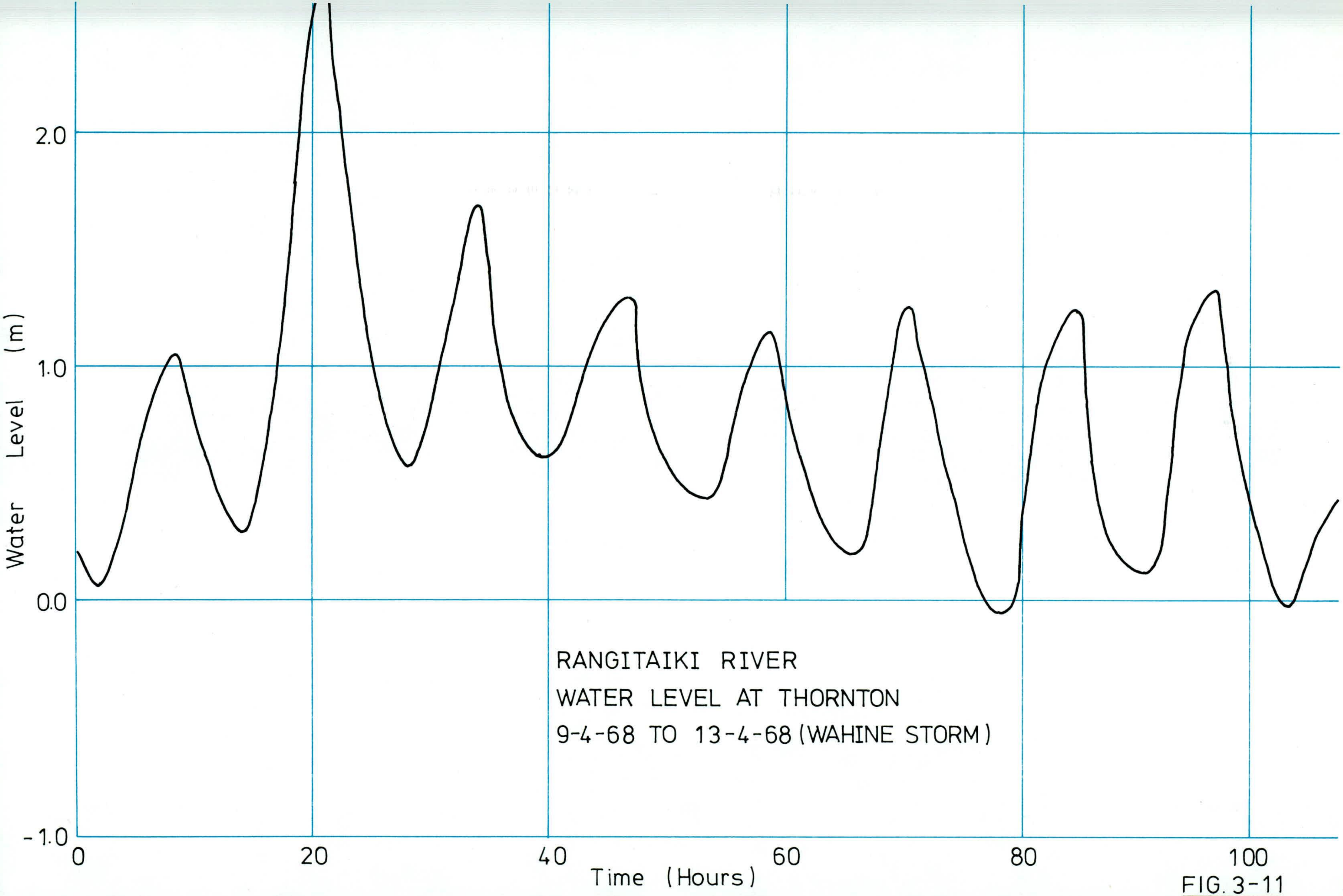
(i) Changes in the river channel.

(ii) Changes in the bar conditions.

Since 1968 the sediment supply has been cut off by Matahina dam; also stopbank construction utilized as much as possible fill won from the river. These factors together with river bank stabilization works have probably led to lowering of the mean river bed level.

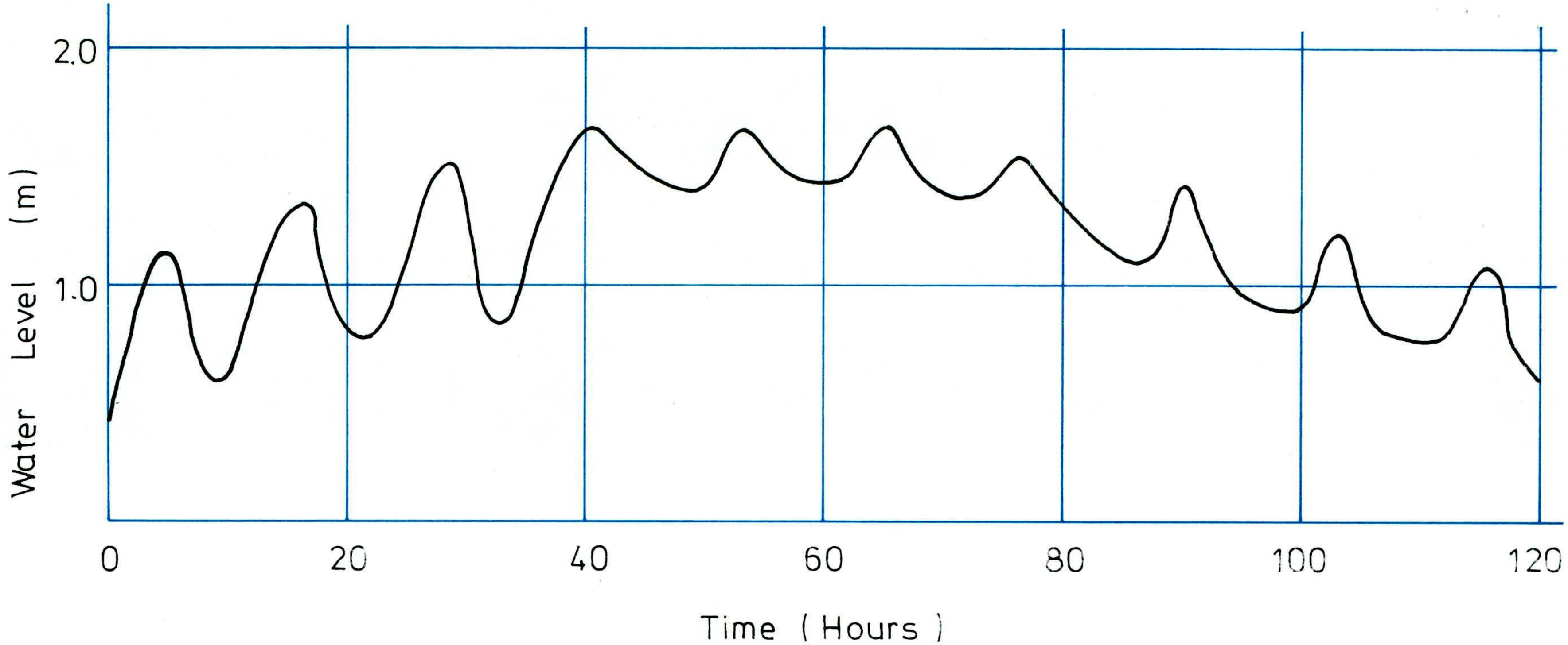
Bar formation at the mouth is caused by a combination of sediment discharge, river discharge, material type and littoral drift along the coast-line. To evaluate these complex inter-actions is a study within itself; it suffices here to note that there has been some change to the riverbed and mouth which has lowered low water levels.

- River Flood Conditions
Typical flood hydrographs at the river mouth provide the basis of the design hydrograph, consisting of a storm surge two tidal peaks before the maximum level followed by a gradual attenuation of the peak with each tide. The peak has a maximum level of RL 1.80m and is attenuated at a slightly steeper rate than occurred in the 1965 and 1967 floods, because no ponding will occur on the plains as happened in those floods, and the



2.0
1.0
0.0
- 1.0
Water Level (m)
0
20
40
60
80
100
Time (Hours)
RANGITAIKI RIVER
WATER LEVEL AT THORNTON
9-4-68 TO 13-4-68 (WAHINE STORM)

FIG. 3-11

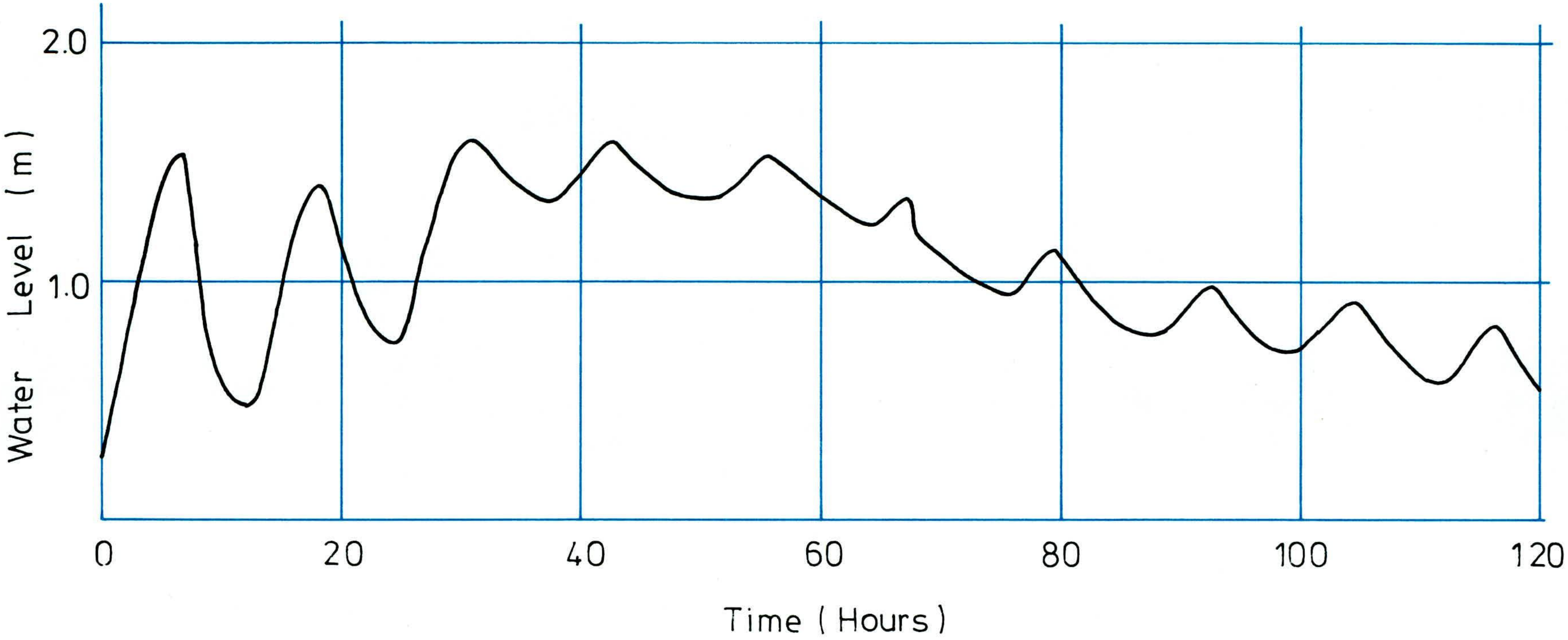


RANGITAIKI RIVER

RECORDED HYDROGRAPH - THORNTON

12-2-65 TO 17-2-65 Qp = 596 m^3/s

FIG. 3-12



RANGITAIKI RIVER

RECORDED HYDROGRAPH - THORNTON

3-2-67 TO 8-2-67 Q = 567 m^3/s

(POST MATAHINA DAM)

FIG. 3-13

channel is nowdays relatively more efficient. The design hydrograph is shown in figure 3-14.

This hydrograph has been used to run the non-steady models of the floodway, and could be used in future if a non-steady model of the main river was developed.

- Sea Flood Conditions
  This is the second design condition which affects the lower section of river in extreme tidal events. These events are associated with storm conditions which may or may not be accompanied with heavy rainfall and subsequent flooding. This storm surge however occurs before the river flood and has been taken into account with the boundary conditions for the river flood condition as described above.

  The sea flooding condition used is as described for the floodway (refer sec. 3.5.1.(ii))

3.5.2 River Channel

The river channel was modelled using a fixed bed, steady flow numerical model. The model was set up using the CHANEL program on the BOPCB's PDP 11/73 computer.

The function of the model was to simulate flow in the river channel by the calculation of backwater curves. Various flows and starting levels were input and the model predicted corresponding water levels.

(i) Input Data

The physical description was input as surveyed cross-sections taken from a comprehensive post-earthquake survey of 66 sections measured May/June 1987. (A major survey of the river was underway before the earthquake and while all the cross-sections were completed some sections unfortunately did not have the benchmarks levelled to enable a pre-post earthquake comparison).

A second set of data representing energy losses to channel friction and eddies was required to complete

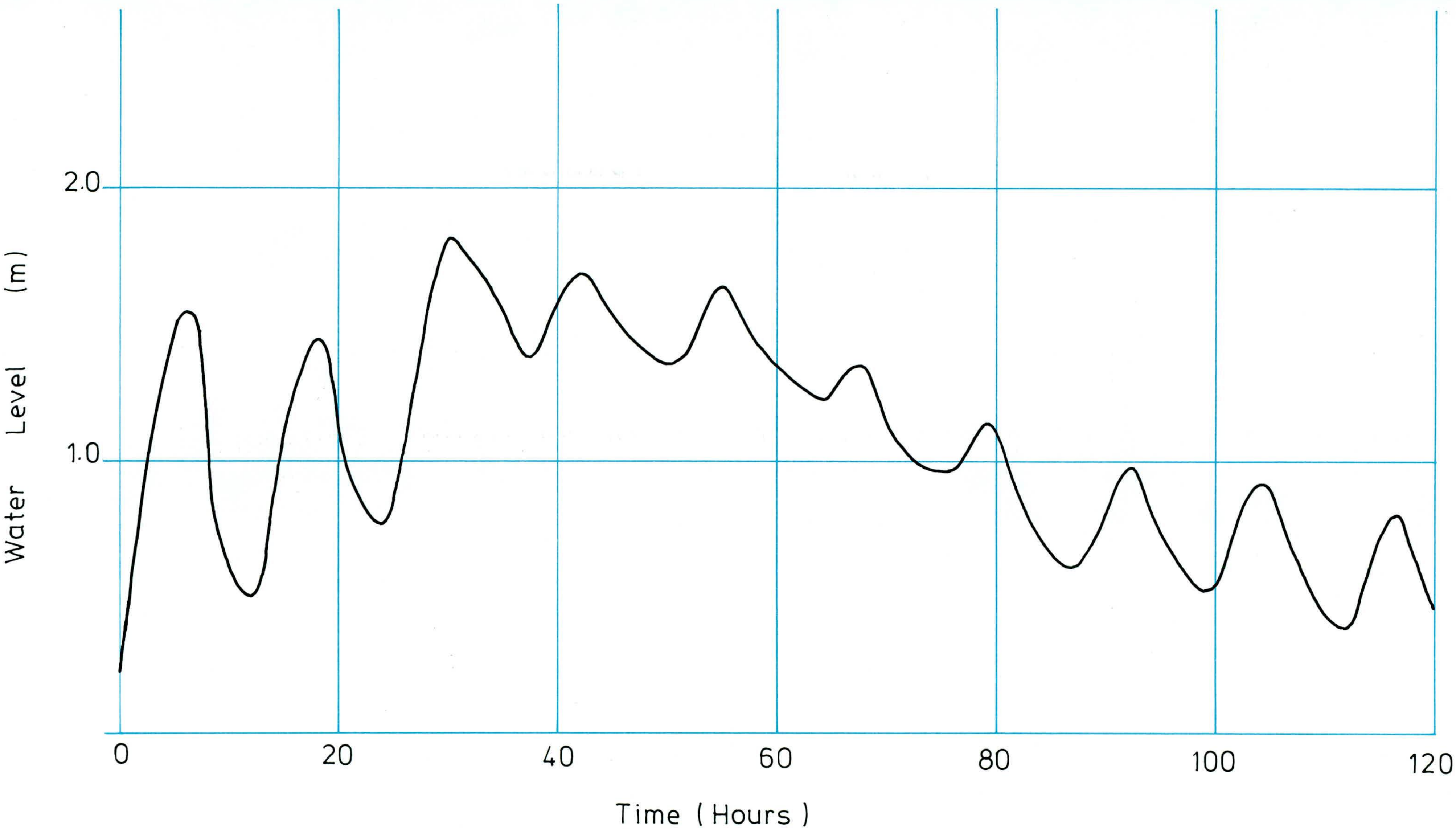
numerical description of the channel. Friction losses represent resistance to flow and eddy losses represent bend, expansion and contraction losses. To determine the magnitude of these they must be calculated from observed flow data or if not available, assessed from experience.

Henderson[6] recommends that eddy losses be treated by increasing the channel resistance coefficient, ('n') hence combining two loss coefficients into one. However that method is too coarse for high eddy loss sections such as across the fault scarp and the tight bends in the upper reaches. (refer fig. 3-17). Conversely, quantifying eddy losses is difficult; however channel 'n' values have a high degree of certainty and once fixed the balance of losses are due to eddies.

To overcome these difficulties two versions of the model were developed, one treating all losses under friction and one separating out the two head-loss coefficients. This provided a useful cross-check.

Only low-flow data was available for calculation of the channel resistance. With Matahina dam holding a steady outflow, water level gradient was measured in half hour periods during a high (16 June 1987) and low tide (26 June 1987). The tide did not allow a strictly steady flow situation but the measurements were the best practicable. In calibrating the model at low flows it was necessary to allow for channel storage effects caused by the tidal cycle.

Since developing the original model a flood of peak flow 223 m^3/s occurred when Electricorp quickly lowered Lake Matahina (after concern with earthquake damage to the dam). Further model calibration was done resulting in general agreement within 200mm between water levels measured and modelled.



RANGITAIKI RIVER

DESIGN TIDAL HYDROGRAPH (DOWNSTREAM CONDITIONS)

100 YEAR RETURN FLOOD DESIGN

FIG. 3-14

(ii) Results

The model was run with flows ranging from the 2.33 year to the 100 year values. Starting levels used for the final results were RL 1.00m for the 2.33 year flood, RL 1.30m for the 5 year flood, RL 1.50m for the 10 year flood and RL 1.80m for the 100 year flood. This compares to RL 2.00m adopted in the original scheme and which is now considered too conservative.

In the lower range of discharges (5 year and less) the starting level had a significant effect on flood levels upstream to Edgecumbe bridge. (river distance 11,167m). With greater flow the effect of the starting level became insignificant between 5000 and 6000 metres above the mouth.

The size of mouth section also markedly affects upstream levels. It was assumed this section would be fully scoured out during major floods by removal of the left bank (sandspit).

The model is most accurate for higher steady flow conditions particularly when Matahina dam releases constant flow for long periods. The model is not valid for low flow conditions because the flow is non-steady; although not necessary for this study a non-steady version could easily be set up using an alternative programme known as RIVERS.

Results of the various runs are shown in fig. 3-15.

A complete description of this work is given in ref. 8.

(iii) River Stability at Fault Trace

The river reach from 16,160m to 16,970m is where the Edgecumbe fault trace resulting from the earthquake crossed the river. There is now a steep gradient of 1:250 through this reach which had to be approximated in the computer model in order to prevent

near critical flows and hence unreliable results. Calculations indicate that velocities are likely to exceed 4m/s and very high bed shear stresses develop. It is likely that headward erosion and hence bank instability will progressively work upstream. Fortunately a buried forest which has been exposed in the bed is helping to prevent this headward erosion occurring. Over time and particularly with higher discharges bank instability will increase. The best solution is to let the river develop its own natural slope rather than to try and stabilise it in its present state. Therefore continuing maintenance over a number of years will be required.

3.5.3 Floodway

The floodway is situated on the right bank of the Rangitaiki River starting at river distance 14860m and discharging back into the river at distance 1000m (refer fig. 3-17). The waterway is bounded by stopbanks and has a much flatter gradient than the main river. Most of it is farmed. It has a significant storage component which affects hydraulic performance and therefore must be analysed using a non-steady flow approach with a fixed bed.

The RIVERS programme was used and calculated steady and non-steady state backwater profiles.

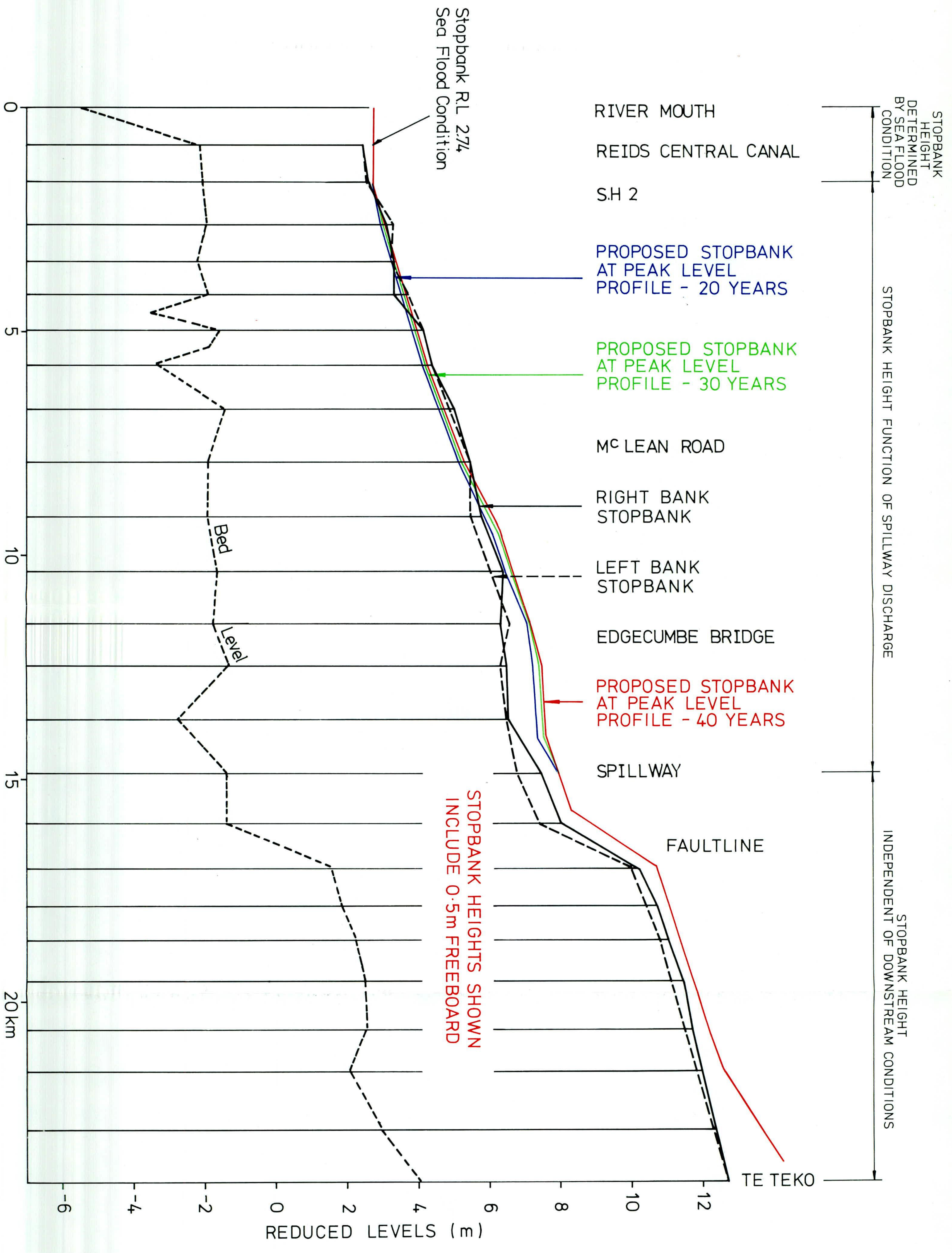
(i) Input Data

The floodway shape was input as a series of surveyed cross-sections taken at intervals along the channel.

The floodway has never operated so no flow data exists from which channel friction factors could be calculated directly. Friction factors therefore had to be estimated. In some sections particularly above the Edgecumbe-Awakeri road, cross fences and hedges offer high resistance to discharge and this was reflected in the values assigned for the mannings 'n' throughout the length of the channel.

(ii) Model Results

The model was run using the downstream boundary conditions against the upstream



RANGITAIKI RIVER
LONGITUDINAL SECTION

FIG. 3-15

hydrograph produced by having the spillway commence operation at the 20 year, 30 year and 40 year flood levels. Upstream hydrographs were routed through the floodway using combinations of timings with downstream conditions in order to cover all possibilities. Some combinations produced instability as the floodwave travelled down the canal. This occurred when high upstream levels coincided with a rapidly changing downstream water level, resulting in steep slopes and high instantaneous discharges. This depleted upstream storage and a wave effect was set up. It was partly overcome by reducing the time increment in the model but care was needed in interpretation of results.

(iii) Peak Levels
Peak level profiles generated in the analysis have been plotted on a long section (fig 3/16). These have been plotted for the spillway at the 20 year, 30 year and 40 year flood levels.

(iv) Maximum Velocities
High localised velocities will occur at McCracken and McLean Road which will act like spillways. High velocities also occur in Reid's Central Canal proper until water levels rise enough to spill out into the floodway. Both these areas are not expected to give any concern. Of concern is the high velocities that are generated at the Edgecumbe-Awakeri Road (Section 8778m). This is due to the severe restriction caused by the railway and road bridges. Large head losses occur through this section, with flow being supercritical at some stages. A high potential for erosion occurs particularly at the road bridge and immediately downstream and threatens the right stopbank of the floodway. Scour protection will be required in this area.

Table 3d summarises river and floodway flows modelled for the three options.

Table 3d - Main River and Floodway Discharges

Spillway Level (yrs)	Spillway Discharge (m^3/s)	River Mouth Discharge (m^3/s)	River Discharge Spillway to Reid's Central (m^3/s)	Reid's Central Canal (m^3/s)	Te Teko Discharge (m^3/s)
40	103	748	653	95	756
30	124	747	632	115	756
20	152	744	604	140	756

3.5.4 Optimisation of Works

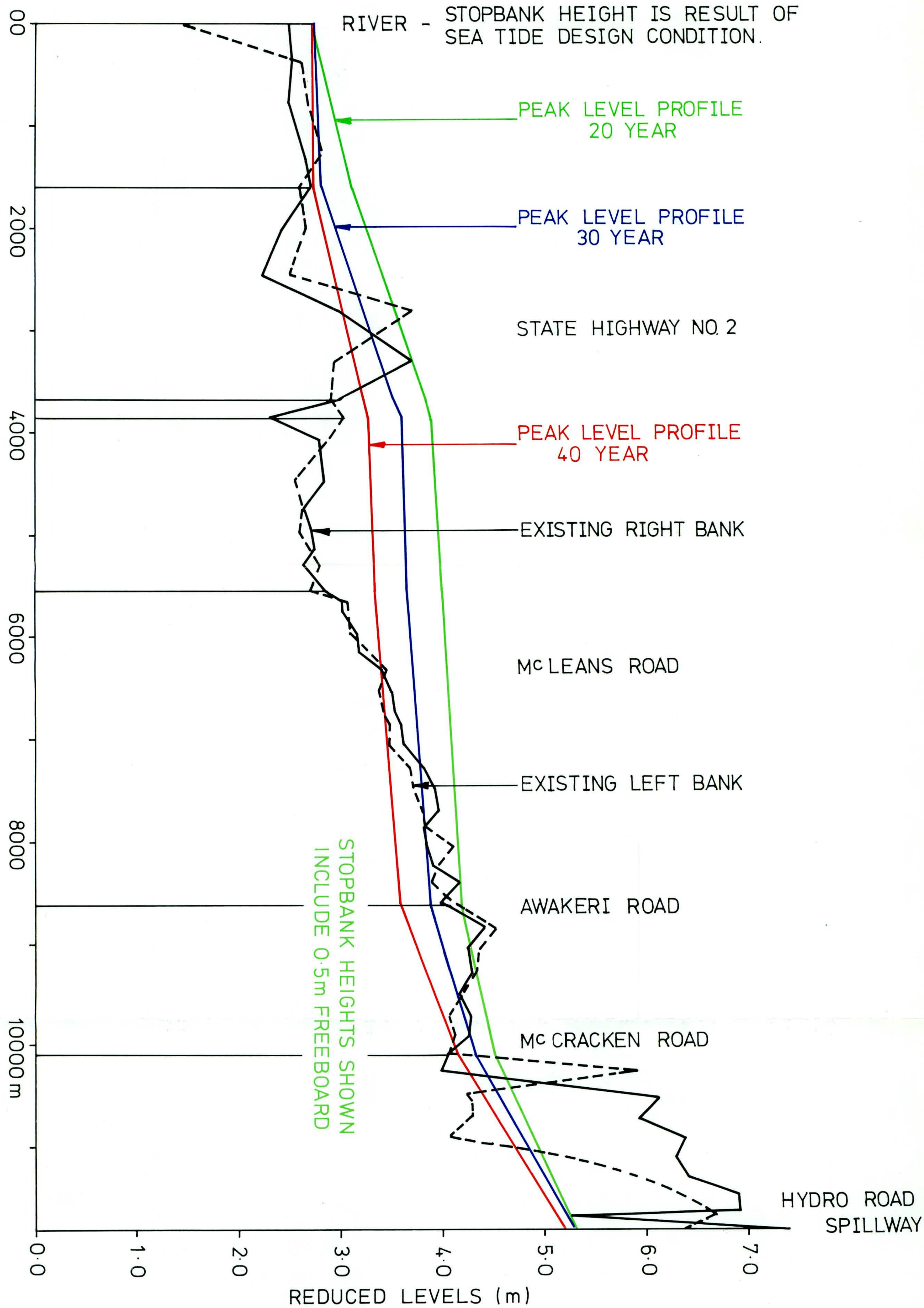
Original scheme design set spillway operating level at the 40 year flood. With the landform changes that have occurred it was appropriate to review this. In particular earthworks for scheme restoration will be made up of stopbanks to be raised on the river and stopbanks to be raised on the floodway. Unit earthwork costs on the floodway are more than double those on the river because fill must be carted to site whereas much of the riverworks fill can be won from the river and placed on site by dragline.

Estimated costs associated with each spillway level are presented in Table 3e.

Table 3e - Summary of Costs

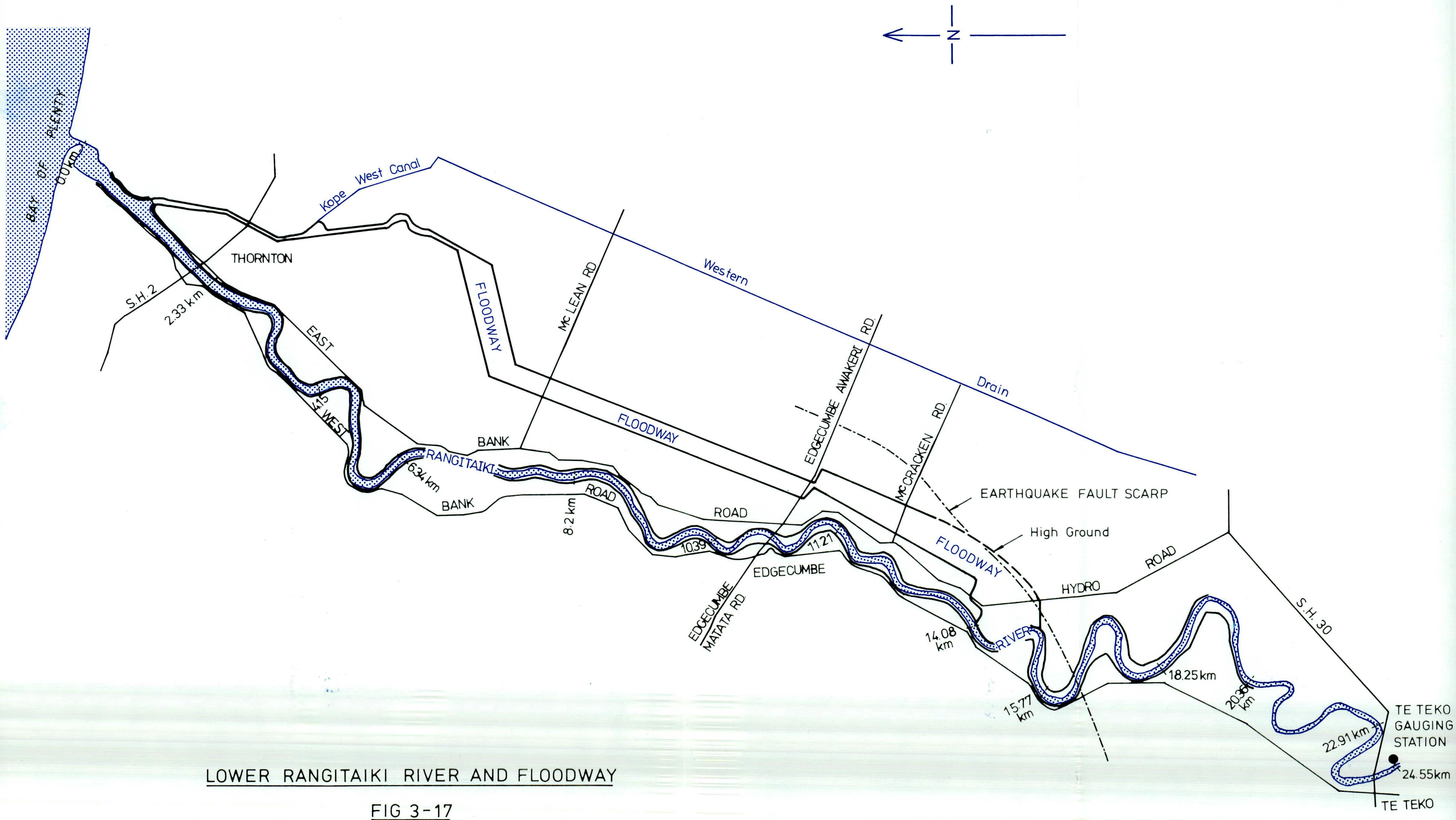
Spillway Level	River Costs $	Floodway Costs	Service 20% ($)	Total Costs $
40 yr	1,065,880	656,350	344,446	2,066,676
30 yr	1,034,790	863,975	379,753	2,278,518
20 yr	1,022,820	1,156,700	435,904	2,615,424

The 40 year floodway standard is therefore the least cost, and favoured, option.



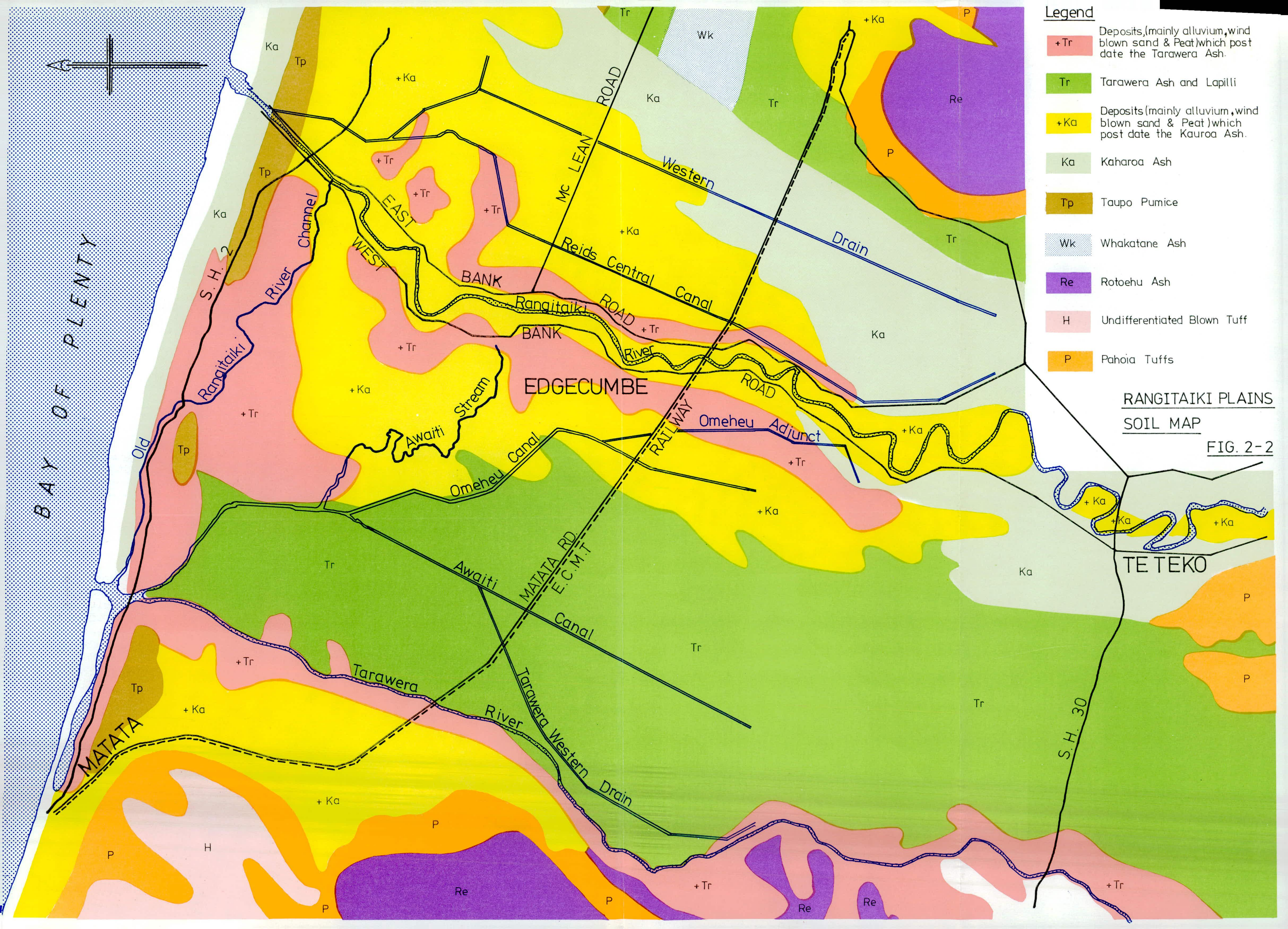
FLOODWAY LONGITUDINAL SECTION SHOWING
DESIGN STOPBANK HEIGHTS FOR VARIOUS
SPILLWAY LEVELS

FIG. 3-16



LOWER RANGITAIKI RIVER AND FLOODWAY

FIG 3-17



RANGITAIKI PLAINS SOIL MAP

FIG. 2-2

3.6 Estimate of Costs

The following are the estimated costs, (September 1987 dollars), to restore the system to provide the scheme standard 100 year flood protection with the spillway set at the 40 year flood level. All costs are exclusive of GST.

3.6.1 River Channel Works

RIVER SECTION (metres)*	BANK	DESCRIPTION	QUANTITY	RATE $	TOTAL $
1430 to 4000	RB	Upgrading Stopbanks	8200m3	3.50	28,700
		Trimming etc	2570m	7.50	19,275
1430 to 4400	LB	Upgrading Stopbanks	10600m3	3.50	37,100
		Trimming etc	2970m	7.50	22,275
8900 to 11190	RB	Upgrading Stopbanks	19600m3	3.80	74,480
		Trimming etc	2490m	7.50	17,175
8700 to 11190	LB	Upgrading Stopbanks	15600m3	3.80	59,280
		Trimming etc	2490m	7.50	18,675
10500m	LB	Concrete Wall	L.S.		10,000
11190 to 13230	LB	Upgrading Stopbanks	16800m3	3.50	58,800
		Trimming etc	2040m	7.50	15,300
11190 to 13230	RB	Upgrading Stopbanks	21700m3	3.50	75,950
		Trimming etc	2040m	7.50	15,300
13230 to 16160	LB	Upgrading Stopbanks	33700m3	3.50	117,950
		Trimming etc	2930m	7.50	21,975
14860	RB	Spillway Construct. (allow for gobi-mat)	240m	200.00	48,000
16160 to 16970	LB	Upgrading Stopbanks	3100m3	3.20	9,920
		Trimming etc	810m	7.50	6,075
16160 to 16970		Channel Stability Rock, planting etc Over 10 year period	L.S.		80,000
16970 to 19700	LB	Upgrading Stopbank	14500m3	3.50	50,750
		Trimming etc	2730m	7.50	20,475
16970 to 19120	RB	Upgrading Stopbanks	17800m3	3.50	62,300
		Trimming etc	2150m	7.50	16,125

Fencing and Grassing L.S.	60,000
Contingencies	120,000
	1,065,880
Service Charges 20%	213,176
Sub total	1,279,056

* for location refer fig. 3-17

3.6.2. Floodway Works

FLOODWAY SECT. (metres)	BANK	DESCRIPTION	QUANTITY	RATE $	TOTAL $
0 to 2700	LB	Upgrade Stopbanks	15100m3	4.50	67,950
		Trimming etc	2700m	7.50	20,250
0 to 2800	RB	Upgrade Stopbanks	18100m3	4.50	81,450
		Trimming etc	2800m	7.50	21,000
3200 to 6350	LB	Upgrade Stopbanks	27500m3	5.50	151,250
		Trimming etc	3150m	7.50	23,625
3300 to 6350	RB	Upgrade Stopbanks	26900m3	5.50	147,950
		Trimming etc	3050m	7.50	22,875
5600		Reconstruct McLeans Road	L.S.		20,000
		Fencing and Grassing			50,000
		Contingencies			50,000
					$656,350
		Plus 20% Services Charge			$131,270
		Total			$787,620

Grand total 3.6.1 and 3.6.2. $2,066,676

: As discussed in sec. 2.11 details of drainage works are included in this report. However drainage costs are included in economic analysis (sec. 4) in recognition of their being an rgral part of scheme restoration.

4. ECONOMIC ANALYSIS*

4.1 Introduction

4.1.1 Appraisal Approach

This analysis is on a "with" minus "without" scheme basis from the national viewpoint. This involves the comparison of two situations expected to occur over the life of the project (and is not always the same as the "before" and "after" situations).

In this analysis the "with" scheme situation is the full restoration to original scheme standards.

The "without" scheme scenario considers the damage and loss of production a 100 year flood would cause under present circumstances. This would involve damage to homes, services (e.g water supply, sewage), roads, disruption of milk supply to the Bay Milk factory at Edgecumbe, disruption and damage to electricity supply, as well as damage and loss of production from agriculture and horticulture.

The benefit of the scheme, therefore, is in prevention of this damage and loss of production.

4.1.2 Land Use

The main area at risk from flooding is north of the Matata-Edgecumbe highway, and between the Awaiti canal in the west and the Western drain in the east.

The predominant land use within the at-risk area is intensive dairying, with some permanent horticulture (e.g. kiwifruit), and some annual cropping (eg maize, vegetables). The areas which would be affected by a 100 year flood are shown on Figure 4-1.

Total area which would be affected by water ponding for various periods is 2580 ha. In addition there would be a further 850 ha (on the periphery of the ponding areas) which would have its drainage capacity adversely affected.

The areas of each land use affected by ponding are:

2060 ha	dairying
340 ha	beef (and some deer)
80 ha	kiwifruit
60 ha	maize
10.0 ha	pipfruit, garlic, shallots, stonefruit, and avocado.

* prepared by Philip Journeaux, MAF Tech

850 ha affected with drainage problems is predominantly in dairying.

Parts of Edgecumbe township are also at risk from a 100 year flood, particularly the south and west.

4.1.3 Costs and Prices

Output prices used in this report are in December 1986 basedate terms (being the latest available), and are medium term projections based generally on international prices, rather than current prices. All costs have been indexed to basedate terms by using the Ministry of Works Construction Cost Index (CCI). The index at December 1986 = 2700. The September 1987 CCI (latest available) = 2880. Costs given in the text have been indexed back to basedate terms in the Cost Benefit cashflow. The results are presented with all flows discounted to the beginning of the scheme construction (1989). This is year 0 of the analysis.

The results of this analysis are presented in Nett Present Value (NPV) terms and also as an Internal Rate of Return (IRR). The project analysis assumes that the scheme will continue long enough to regard the project life as being infinite and that there will be no salvage value at the end of the scheme life.

4.1.4 Seasonal Flood Probability

From rainfall data and previous flood records, the probability of a flood occurring during the seasons of the year are considered to be:

Winter	0.1
Spring	0.5
Summer	0.1
Autumn	0.3
Total	1.0

Where	Winter:	June, July, August
	Spring:	September, October, November
	Summer:	December, January, February
	Autumn:	March, April, May

The main risk period is July to October, from generally heavy winter/spring rains. The second most at-risk period is February to April, due to tropical cyclones moving south across the Pacific. Given this, the probabilities given above could be represented as:

Winter/Spring 0.6
Summer/Autumn 0.4

These are the weightings given to the damage/loss of production costs in the Cost Benefit cash flow.

The probability of a 100 year flood occurring in any one year is 0.01.

4.2 Cost and Benefits

4.2.1. Scheme Capital Costs

Total cost is estimated at $2,792,136. This is split up as follows:

i) Restoration to Scheme Standard of Stopbanks and Drainage on Rangitaiki River: $1,642,956. (refer 3.6.1)

ii) Restoration Works to Rangitaiki Floodway: $787,620. (refer 3.6.2)

iii) Restoration Works Drainage: $361,560

These costs are expected to be incurred evenly over the first two years of the scheme life.

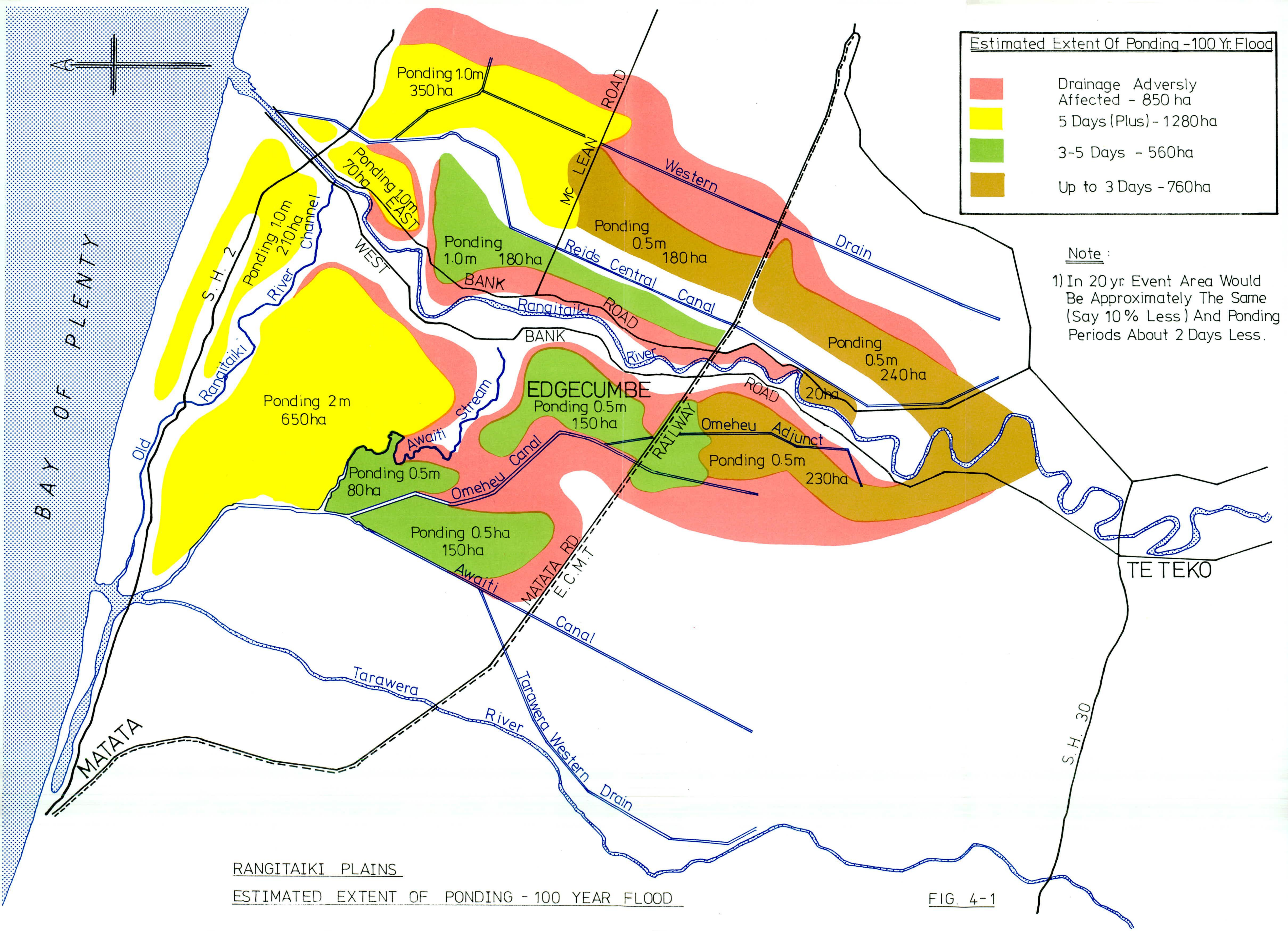
4.2.2 Scheme Associated Costs

It is expected that annual expenditure on repairs and maintenance on the extended stopbanks will be very similar to that expended currently. Hence no allowance is made for this in the analysis.

4.2.3 Saved Agricultural Damage and Production

The amount of damage to pasture caused by flooding is a function of the time the water ponds for and its temperature. It is expected the majority of the areas covered in water for more than 3 days would require regrassing. There would also be additional areas requiring regrassing where water ran over the land and deposited silt and pumice. Previous floods have deposited up to 900 mm of silt, mud, and pumice on pastures. These regrassing costs would be the same for either a spring or autumn flood.

There would be additional costs involved in grazing stock away for a period to allow for pastures to recover, for repairs to drains, fences, raceways, etc, increased week control costs, and numerous miscellaneous costs - eg repairs to electric motors, travelling to check stock, etc.



RANGITAIKI PLAINS

ESTIMATED EXTENT OF PONDING - 100 YEAR FLOOD

FIG. 4-1

Details of these costs (derived by local MAFTech Consultants) are given in Appendix I.

Total costs are:

Regrassing	$546,800
Stock grazing	$371,000
Drain Cleaning	$119,500
Miscellaneous	$350,000
Weed Spraying	$74,000

Loss of production from dairy farms would be dependent on the timing of the flood throughout the year. If the flood occurred in late winter-early spring, ie at the onset of calving, production losses in that year would be major. This would be due to the effects of pasture damage, cows aborting in the rush to get them away from properties, and insufficient feed on the farms which were not affected to sufficiently feed brought-in stock. There would also be a carry-over effect into the next season, due to a low in-calf rate resulting from poor spring feeding, and lower production from new pastures.

An autumn flood would have a lesser effect on production in the first year, in that the bulk of the production for that season would have already been produced. However, there would be a carry-over effect into the next year, due to cows calving in poor condition as a result of under-feeding over the winter, and new pastures being at a low level of production.

Dairy production <u>losses</u> assumed in this analysis are:

Spring flood:	75% in first year 20% in second year
Autumn flood:	10% in first year 45% in second year

There would also be a lifetime effect on replacement heifers not being able to be grown to target weights due to insufficient feeding. This is not accounted for in this analysis.

Loss of production form the area affected with poor drainage as a result of the flood, is difficult to assess accurately. While there would be restrictions on grazing for a short period, damage to pastures would generally be low and little re-grassing required. For the purposes of this analysis it is assumed a 10% loss in production

would occur in the first year only, with no re-grassing costs incurred.

Details of dairy production from each area is given in Appendix I, while an example of the Gross Margin used to calculate losses is shown in Appendix III.

Total loss of production from dairying is:

Spring flood:	$4,096,674
Autumn flood:	$2,431,706

Loss of production from bull beef units is also difficult to determine in that animals could be grazed off for the duration of the flood and at the end of the season be at a lesser-than-normal weight due to poorer feeding. Alternatively, they could either be sold off or bought in at earlier or later than normal times. For the purposes of this analysis it is assumed the farmers lose half their normal production.

A bull beef gross margin is shown in Appendix III.

Total loss from bull beef: $199,750

Loss of production from maize growing would be total in either a spring or autumn flood. A spring flood would mean that the crop could not be planted in time, if at all, while an autumn flood would generally occur before the crop was harvested.

A gross margin for maize is given in Appendix III.

Total loss from maize: $ 39,520

It is assumed that there would be sufficient warning of a flood to allow time to shift stock to higher ground. In this case stock losses would be minimal, and no account has been made for this.

4.2.4. <u>Saved Horticultural Damage and Production</u>

The bulk of the horticulture within the area, is kiwifruit.

Recent trials by MAFTech scientists indicate that kiwifruit are highly susceptible to damage following water logging.

A vine placed in anerobic conditions for 3 hours will be severely damaged. Wilting and senescence of leaves will occur. This is a result of root damage as well as production of chemicals toxic to the plant. Death can occur following 24 hours of water logging.

Wilting symptoms may not show up until hot/dry conditions place the plant under water stress. The vine is unlikely to be able to carry the crop through to harvest because of leaf death; replacement growth for the following season may be affected and the plants performance will be affected in the following year due to root death.

A flood in either spring or autumn would cause significant damage to kiwifruit. The spring flood will limit the plants uptake of nutrients at a crucial time and also limit performance during the season. A flood in autumn will kill the leaves limiting the vines ability to hold the fruit until harvest.

Further, highly saturated soil, resulting from flooding, will continue to damage kiwifruit.

In summary, it is probable a number of the kiwifruit vines would die and need replacing as a result of a flood. However, this is very difficult to quantify accurately in that the general health of the plant, especially its roots, prior to the flooding, has a large bearing on its survival. For this analysis it is assumed there would be a production loss of 100% in the first year, 50% in the second year, but no actual loss of vines. It is also assumed that equal damage/loss of production would occur in either a spring or autumn flood.

The respective areas in kiwifruit and their production levels, are detailed in Appendix II. An example of a kiwifruit gross margin used to determine the value of the loss is shown in Appendix III.

Total value of saved kiwifruit production:
$1,141,374

There are also some small areas growing other horticultural crops as outlined in Section 4.1.2. These are detailed in Appendix II.

Total saved damage/production of other horticultural crops:

Spring	$29,329
Autumn	$20,880

4.2.5 Damage to Services and Roads

A flood of 100 year return period would be expected to do severe damage to the infrastructure within the at-risk area. This could include physical damage to, and silt deposits into, the sewage system, water supply system, storm water system and roading network. The railway line running through Edgecumbe is not expected to suffer any major damage, being built well above the surrounding countryside. The bridge over the Rangitaiki River at Edgecumbe is also not expected to suffer major damage.

Based on costs incurred in the 1987 Whakatane earthquake, and costs incurred in recent flooding in Southland, the District Council Engineers and the local Civil Defence Officer estimate the cost of repairs to services and roads, and general civil defence costs, given a 100 year flood, at $6.0 to $8.0 million. A median value of $7.0 million is assumed in this analysis.

4.2.6 Damage to Industry

i) Dairy Factory

A major dairy factory - Bay Milk Products Limited - is sited at Edgecumbe. This factory is currently being rebuilt after the 1987 earthquake. It is not expected that a 100 year flood would affect the factory directly as such; the factory site is a few centimetres above the surrounding land on the eastern side, and some 3.0 metres above on the western side. Any flood waters would be expected to flow through or mostly around the factory without damaging or putting it out of action. During the last flood in 1970, the factory kept working. The main problem which would arise would be the disruption to its milk supply, its water supply and its effluent disposal. Bay Milk officials estimate that the median milk flow in spring and autumn would be very similar at 1.6 million litres/day (compared with 2.8 million litres/day at the spring peak). At this median flow they estimate the costs to the factory in terms of lost sales and compensation paid to farmers, at $650,000 per each day the factory is unable to work. For this analysis it is assumed that the factory would be forced to close for 2 days.

ii) Edgecumbe Substation

Approximately 2km south of Edgecumbe is situated an Electricorp substation, which feeds power to a large area of the eastern Bay of Plenty. It is sited next to the Rangitaiki River, in an area in which it is considered most likely that the present stopbanks would fail. Electricorp

officials (conservatively) estimate the cost of flood damage and loss of sales to the substation at $250,000/day. Again it is assumed that the substation would be knocked out by a 100 year flood, for 2 days.

The immediately adjacent Bay Power Board substation would also be affected, with costs estimated at $6,000.

4.2.7 Saved Repair Costs to Stopbanks
Stopbanks along both sides of the river for a 2km stretch between Edgecumbe and Te Teko will overtop and breach under 20 year flood conditions. Strengthening and raising these stopbanks would prevent this. The cost of repair of such a break is put at $100,000, and this is a saved cost in the "with" situation. The flooding would also damage a number of drainage pumping stations. The cost of repair of these is put at $50,000.

4.2.8 Saved Insurance Costs
A 100 year flood would also cause considerable damage to houses and other buildings throughout the at-risk-area. The amount of damage caused to houses is dependent on the height of the water within the house, and the materials out of which the house is constructed. Insurance Assessors estimate the average cost per house, based on the Paeroa flood in 1985, and assuming 0.5 metres of water through the house, at $12,000 for structural damage and $9,000 for content damage.

The census indicates 700 dwellings within the at-risk area, of which Civil Defence estimate 600 would be inundated with water in a 100 year flood. The saved insurance cost in the "with" situation, with respect to dwellings, would therefore be $12.6 million.

The damage to other buildings is difficult to assess, given that many, such as cowsheds would be built of concrete, and most would not be lined, and hence not require stripping. It is also likely, given adequate warning, that plant and machinery could be moved out of danger.

The assessed saved insurance cost for this category is put at $700,000.

4.2.9. Other Factors
i) Decreased production

It is quite possible that decreased protection from flooding (as in the current situation), would result in a decrease in the intensity

and production levels of current farming operations, as farmers adjusted to the new risk situation. For example, after the initial stopbank construction there was an increase in production and intensity of farming, as farmers perceived the lesser risk from flooding. However this possible production decrease in the "without" scheme scenario is very difficult to quantity and has not been accounted for in this analysis. Such costs are a benefit to the "with" scheme.

ii) Social Impact

As in all cases of flooding, there is a social cost resulting from disruption to normal living. It is felt that there would considerable physchological effects throughout the district, especially as much of the at-risk area was badly affected by the 1987 earthquake. In addition, after floodwaters had receded and with the pre sent economic climate, many farmers would be under severe pressure to bring stock home quickly, which would reduce the ability of pastures to recover. These costs are considered a secondary benefit to the scheme, and are not included in this analysis.

4.3 Results

Table 4a
Rangitaiki River Stopbank Scheme 1988
(Cashflow indexed to December 1986 basedate)

Year	Capital Cost	Saved Agric Costs	Saved Hort Costs	Saved Other Costs	Cash Flow
0	1,141,271				-1,141,271
1	1,141,271	36,496	7,396	209,206	- 888,173
2		48,234	10,973	209,206	268,413
3		48,234	10,973	209,206	268,413
.		"	"	"	"
.		"	"	"	"
.		"	"	"	"
100		48,234	10,973	209,206	268,413

Analysis yields a Net present Value, using a 10% discount factor of $457,941.

The internal rate of return is evaluated at 12.30%. This is a favourable result particularly in view of the long term of the schemes benefits. On the basis of traditional economic indicators the scheme is worthy of investment.

Appendix I: AGRICULTURAL DAMAGE BY AREA

1. McLean Road 350 ha
This area is predominantly dairying, with some bull beef. Les than 10% of stock units are non-dairying. Milkfat productio 400 kg/ha average. Top 600 kg/ha

(i)	heifers grazed out 6 months (stock rate 2.6/ha) say, 230 heifers @ $2.50/week	15,000
(ii)	regrassing 350 ha aerial application or undersowing, say 9000 kg seed @ $10	90,000
(iii)	drain cleaning and race repairs fence repairs @ $30/ha	10,000
(iv)	winter grazing 900 dairy cows 900 @ $5/head/week for 10 weeks	45,000
(v)	weed spraying 350 ha, MCPB or 24DB @ $35/ha applied	12,000

2. Putiki Road 180 ha

Area is mainly dairying with approximately 40 ha maize. This is an older more established area than McLeans Road. Productior average 450 kg MF. Top level to 630 kg/ha.

(i)	heifer grazing (stock rate 2.9/ha) 100 heifers (approx 30 already grazed out) 70 heifers 6 months grazing @ $2.50/week	4,500
(ii)	regrassing approx 60 ha (about 30 ha would have to be regrassed but as farmers are more well established than other areas they would undersow most of it); say 60 ha @ $250	15,000
(iii)	drain cleaning, fence & race repairs 140 ha @ $20/ha	3,000
(iv)	winter grazing 60% of cows 240 for 6 weeks @ $5/week	7,000
(v)	weed spraying 140 ha MCPB or 24DB + low drift @ $40/ha	5,600

Little other damage would occur; however a few older flood pumps may be at risk.

3. Hydro Road 240 ha

This area would receive significant initial debris. It is predominantly dairying with small area of horticulture. It is more at risk following earthquake than previously and farmers are not as aware of the risks of and ways of handling flooding. Milkfat production - 400 kg/ha.

(i)	Regrassing would be needed on heavily silted areas - say 25% = 60 ha @ $250/ha	15,000
(ii)	heifer grazing - a number do this already so taken mainly as cows grazed out for winter	0
(iii)	winter grazing 40% cows 250 cows @ 6 weeks @ $5/week	7,500
(iv)	winter spraying - would be as normal, some extra MCPB or 24DB may be used, but not significant, say	500

Other damage would be minimal - one cowshed is in the middle of the floodway and this could have real difficulties with silt removal, restoration of oxidation ponds, racing and fences. An estimate is $2,000 extra. (However, following earthquake and some structural damage, a build-up of debris (if it occurred) could flatten the walls of the shed).

4. Te Teko Road 320 ha.

This area is mainly dairying with some areas in maize. The earthquake has also increased the flooding risk in this area. Approximately 40 ha maize, remainder dairying.

A number of small blocks of deer and various totalling about 40 ha. 240 ha dairy, 40 ha maize, 40 ha other. Milkfat production 380 kg/ha.

(i)	regrassing needed on approximately 50% of area 140 ha @ $250/ha	35,000
(ii)	heifer grazing additional (2.7 cows/ha) 60 heifers for 6 months @ $2.50/week	4,000

(iii)	winter grazing 50% cows 300 @ $5/week for 6 weeks	9,000
(iv)	drain cleaning etc. Due to dry weather last 15 years and earthquake, many are unaware of drainage that will be required in wet year. Many unattended drains will need attention. Existing only	5,000
(v)	winter spraying 140 ha @ $40	6,000

5. Awaroa 180 ha

The majority of this is dairy company farm, all in dairying. Ave production 550 kg/ha; top 680 kg/ha

(i)	regrassing: total grass area included say 90% total. Some would have to be regrassed by air. 160 ha @ $270/ha	43,000
(ii)	drain cleaning - much of the area is underground drainage. Main drain cleaning would be needed plus some sub-soiling to allow water away in waste ponded areas 160 ha @ $40/ha minimum	6,500
(iii)	winter grazing - some grazing off for winter	16,500
(iv)	heifers grazed off normally 130 calves grazed off 6 months @ $2.50/week	8,500
(v)	weed spraying 160 ha @ $40	6,500

6. East Bank - Thornton 70 ha

The area is basically dairy with 8 ha horticulture and small blocks. Milkfat production - 550 kg/ha

(i)	regrassing 60 ha by air @ $285 applied	17,000
(ii)	drainage - all would need total re-cleaning and floodgates, etc 60 ha @ $80	5,000
(iii)	winter grazing 180 cows 10 weeks @ $5/week	9,000
(iv)	heifer grazing. 40 heifers for 12 months @ $2.50/week	5,000
(v)	weed spraying 60 ha @ $40	2,500

7. Edgecumbe 160 ha

This area is predominantly dairy with about 20 ha in drystock bulls etc. Parts of some horticulture blocks may be in this area since earthquake but are not included in cost. 140 ha Dairy and 20 ha other. Milkfat production 450kg/ha

(i)	regrassing 140 ha @ $250/ha	35,000
(ii)	drain cleaning - race repairs, pump bay cleaning 140 ha @ $50	7,000
(iii)	heifer grazing - 90 heifers 6 months @ $2.50/week	6,000
(iv)	winter grazing - 400 cows 6 weeks @ $5/week	12,000
(v)	weed spraying 140 ha @ $35/ha	5,000

8. Brownless-Gow 150 ha + 80 ha

A part of this is a wild-life reserve for which no damage has been allowed.

Production - this is a particularly highly productive area. Top production 1/2 area over 720 kg/MF/ha. Ave 650 kg/ha.

(i)	heifers grazed out. Most are at present. 60 @ $2.50 @ 52 weeks.	8,000
(ii)	winter grazing 500 cows @ $5/week - 12 weeks	30,000
(iii)	regrassing by air 200 ha @ $280/ha	56,000
(iv)	weed spraying 200 ha @ $280/ha	8,000
(v)	drainage - since earthquake drainage has altered and not all drain yet in place, including re-siting of flood pumps 200 ha @ $60	12,000

9. Greigs Road 660 ha

Much of this is recent settlement ex Lands and Survey Department mid 70's. This area is a mixture of dairying and bull beef. 500 ha dairy and 160 ha bull beef

Production: Dairy @ 400 kg/ha. Beef. 500 bulls - 1/2 production cycle

(i)	graze out 300 heifers @ $2.50 x 52 500 bulls @ 2 x 40 (sold as stores at various times) 1000 cows @ 12 @ $4 (winter)	 39,000 39,000 60,000
(ii)	drainage. Most would be silt and little real debris 660 ha @ $40 + main board drains	60,000
(iii)	regrassing 660 ha @ $280	184,000
(iv)	weed spraying 500 ha @ $40	20,000

Salt water would also be a problem if high seas occur at same time. This is not accounted for as it takes longer for pastures to recover.

10. West Bank - Thornton 210 ha

This area is approximately 40:60 dairy + dry stock. Bulls and deer plus a limited area of horticulture. 80 ha dairy 120 ha other 10 ha horticulture. Milk production - 350 kg/ha

(i)	grazing heifers - grazed out at present 300 bulls 40 weeks @ $2 100 deer 52 weeks @ $2.00 cows winter 190; 12 weeks @ $5	 24,000 10,000 12,000
(ii)	drainage 200 ha @ $40	8,000
(iii)	regrassing 200 ha @ $280/ha	56,000
(iv)	weed spraying 200 ha @ $40	8,000

The drainage difficulties at present experienced post earthquake will be improved once new system is in place.

11. Miscellaneous

Additional spot spray for weeds, cleaning sheds and races of silt, cost of travel to check stock off farm, stock freight costs, flood pump and other electric motor repairs - drying and cleaning. Cost of increased animal health expenditure, buying in hay and meal

350,000

12. Drainage Affected Area

Average production 380 kg/ha.

Appendix II: Horticultural Damage by Area

1. McLean Road

   3 hectares producing garlic and shallots. Average production for this area is 4 tonne, selling at $6.12 a kilogram.

   100 year Flood

   A flood of this magnitude in September may kill the crop. A flood in January is likely to result in no crop loss as harvest should be complete.

2. State Highway 2 and Smith Road

   Orchards here include a pip and stonefruit orchard, citrus, kiwifruit and avocados.

   100 year Flood

   Flooding in September and January will severely affect the 9 hectares of kiwifruit. Production of 36,000 trays may be reduced by 100% in the first year and by 50% in the subsequent year.

   5% of the 3./35 hectares of pipfruit, 2.2 hectares of stonefruit and 1 hectare of avocado (not producing yet) would die as a result of root disease.

   Cost of replanting would be around 260 trees at around $10 each i.e. $2,600.

   Production loss from these trees is likely to be 6 tonnes of pipfruit and 2 tonne of stonefruit.

   A flood in January may limit the orchardists ability to harvest some of the stonefruit. A possible loss of production in the stonefruit could be 25% of 40 tonnes, that is, 10 tonne.

3. East Bank Road

   There are around 7 hectares of poorly performing kiwifruit in the flood zone. Possible 10,000 trays production presently.

4. West Bank Road

   Approximately 4 hectares of kiwifruit orchard producing around 4000 trays per hectare.

5. Poplar Lane and Otakiri Road

   This area totals around 40 hectares of kiwifruit canopy area producing around 150,000 trays.

Appendix III: Gross Margin Examples

DAIRY GROSS MARGIN

Revenue

	Quantity	Price	Total
Milkfat	150	4.69	703.50
Cull Cows	.17	374	63.58
Bobby Calves	.70	34	23.80
			$790.88
Animal Health			21-00
Breeding Expenses			10.00
Dairy Shed Expenses			10.00
Electricity			18.00
Feed			31.00
Freight			8.00
Freight (Milkfat)			31.50
			$129.50

GM/cow = $ 661.38
GM/su = $ 87.95
GM/ha = $1846.95

KIWIFRUIT GROSS MARGIN (PER HA)

Revenue

	Total
20 T export fruit @ $2050/T (5500 trays)	41,000
Costs	
Weed and Pest Control	1,100
Fertiliser	700
Pollination	600
Grade and Packing	14,420
Coolstore	4,120
Market Levy	1,905
	$22,845

GM/ha = $18,155

BULL BEEF GROSS MARGIN (PER HECTARE)

Revenue

	Quantity	Price	Total
20 month bulls	3.88	482	1,870

Costs

Purchase Weaner Bulls 4 @ $108	432
Feed	84
Animal Health	44
Freight	133
	693

GM/ha = $1,177

MAIZE GROSS MARGIN (PER HECTARE)

Analysis based on 10 ha

Revenue

10 T grain @ $190/T	19,000

Costs

Weed & Pest	2,160
Cultivation	1,750
Seed	1,400
Planting	500
Fertiliser	2,294
Lime	160
Harvest	2,200
Test & Advice	100
Cartage & Weighing	1,000
Drying	2,500
	$14,064

GM/ha = $4,940.00

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Test & Advice	100
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Drying	2,500
	$14,064

GM/ha = $4,940.00

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