Kaituna River Major Scheme Hydraulic Review

Prepared by Matt Surman, Design Engineer

Environment Bay of Plenty
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5 Quay Street
P O Box 364
Whakatane
NEW ZEALAND

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Contents

Chapter 1: Introduction

The hydrological design of the Kaituna River Scheme is based on work done up to 1983. The hydraulic design of individual structures has been ongoing as structures are built, however the majority of structures were built before 1990. The information available to define the flood frequency distribution for the Kaituna River and some of its tributaries has increased substantially since 1983.

In some places, there has been substantial settlement of stopbanks, which reduces the level of protection the stopbanks provide. Changes in river and streambed levels will alter the water level at a given flow. Prior to spending large amounts of money importing fill to bring the stopbanks back up to their original levels, a design review is justified.

The review has found that the 1% AEP design flood peak at Te Matai can be reduced from 580 m^3/s to 500 m^3/s, a reduction of 16%. The frequency distribution for the Waiari Stream remains similar to the 1983 design and the design for the Raparapahoe Stream has been reduced slightly. There is insufficient information on some of the tributaries to improve their design figures, however, because of the smaller scale of the streams and the satisfactory performance in recent flood events, retaining the existing design estimates is acceptable.

Calibration of the model with recent flood information has resulted in a model that generally predicts lower levels for a given flow than previous estimates. This is mostly related to the choice of a resistance factor, Mannings n. In the lower river, this has been reduced from about 0.03 in previous studies to 0.025. In contrast, the Mannings n chosen for some of the tributaries has risen significantly, based on recent flood information.

Under the recommended practice of topping up banks once they have lost more than half their freeboard, the total volume of the earthworks required is estimated to be only 3,000 m^3 plus allowance for stripping etc. Assuming material can be taken from the main river but not the tributaries, and allowing $11-18/ m^3 for this work, the cost to rehabilitate these banks is approximately $35,000 m, a tiny fraction of the costs estimated in the asset management plan.

Chapter 2: Hydrology

2.1 Estimation of Design Flood

2.1.1 Flow and Level Data

Good flow records exist at Mangorewa at Saunders. However, there is a very poor relationship between peak flows in the Mangorewa and peak flows at Te Matai. For instance, the peak flows in 1968 were 291 m^3/s and 119 m^3/s respectively, while in 1970, they were 157 m^3/s and 194 m^3/s respectively. It is clear that the Mangorewa can have very short, sharp peaks that may not translate into particularly high flows at Te Matai.

The peak flows at Te Matai were recorded until 1981. An analysis of gaugings since then indicates that the hydraulic characteristics at the site have changed considerably. In particular, there was a small drop (a few hundred millimetres) in water levels for a given flow between April 1982 and January 1985. There was a large drop (close to 1m for some flows), between January 1985 and January 1986. Since September 1986, levels appear to be relatively stable, with a range of about 100-150 mm for the mean flow.

It therefore appears possible to construct a rating curve that would be valid for high flows since September 1986. (Low flows are tidally affected). While peak flows from 1982 to 1984 cannot be known exactly, a reasonable estimate can be made using the previous rating, but giving weight to the 1983 gaugings. The peaks in 1985 and 1986 cannot be accurately known, but can be adequately estimated from gaugings near the time of the peaks.

The peak flow in the Mangorewa in 1986 was 313 m^3/s, the highest recorded flow (1968 to 1997), and was over 100 m^3/s for 11 hours, but a gauging at Te Matai 0.57 m below the peak gave 112 m^3/s, indicating the peak was less than 150 m^3/s (width about 35 m, velocity about 1.3 m^3/s)

An estimate of annual peak flows with measured levels at Te Matai is therefore as follows:

Year	1982	1983	1984	1985	1986
Level (Moturiki datum)	4.44	5.39	3.92	3.79	3.63
Relevant gauging	400850*	400847	400850*	400983*	400995
Gauged flow		133		84	112
Gauged level (Mot)		5.25		3.35	3.06
Average width at peak/gauged levels		41.8		35	34.5
Gauged velocity		0.885		0.975	1.26
Assumed peak velocity		0.90		1.05	1.35
Estimated peak flow	78	141	62	107	147

*The relevant gaugings shown are not from the same event as the peak.

Other relevant data from Clarkes for estimating the 1983, 1985 and 1986 peak flows:

The peak level in 1983 was only 62 mm higher than in 1981 (100 m3/s), while the lowest level recorded that year was 625 mm lower than in 1981.

The peaks in 1985 and 1986 were less than in 1989 (estimated at 82 m3/s), but lowest levels were around 100 mm lower. The peaks were around 200 mm lower than in 1990 (162 m3/s)

1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2.64	3.02	2.40	3.67	2.28	2.53	2.25	2.63	3.62	3.09		3.84	4.44
92	112	82	163	74	88	73	92	160	114	76	159	361

2.1.2 Correlation Between Mangorewa at Saunders and Kaituna at Te Matai

About one third of annual peaks in the Mangorewa and at Te Matai do not coincide with the same event.

While there is not a good correlation between peak flows at Te Matai and peak flows in the Mangorewa, the estimated flows do not look out of place when plotted against the Mangorewa peaks. (Although there is no linear relationship between the sites, the estimated flows fit in reasonably well with the previous recorded spread). The estimated peaks appear to be generally lower than the recorded peaks.

Several storms were analysed to see if there was a correlation between the length of time above 100 m^3/s at Mangorewa and the peak at Te Matai. Three storms above 100 m^3/s for 5hrs or more barely got above 100 m^3/s at Te Matai. Three storms above 100 m^3/s at Mangorewa for eight hours were around 150 m^3/s at Te Matai, while the one that got to 194 m^3/s at Te Matai was over 100 m^3/s for 10.5hrs. The 1986 event was over 100 m^3/s for 11hrs but only appears to have reached 147 m^3/s at Te Matai.

The 1995 and 1998 events, that were both over 100 m^3/s in the Mangorewa for more than 8 hours, gave higher flows at Te Matai than the 1983 event (that was similar in the Mangorewa). The 1990 event also gave higher flows at Te Matai than the 1983 event, despite being over 100 at Mangorewa for only four hours. These peaks (1990, 1995, 1998) may have been larger because of reduced upstream storage in this size event, as the bed had cut down. The 1970 event was over 100 m^3/s for 10.5 hours and produced larger flows at Te Matai than these three events, indicating storage may be less of a factor if the Mangorewa is over 100 m^3/s for over 8 hours. Six other events since 1968 have been above 100 m^3/s at Mangorewa for 3.5-6.5 hours, but none of these appear to have produced flows at Te Matai above 140 m^3/s.

2.1.3 Alternative Analyses; Unit Hydrograph Method

Rainfall-runoff relationships, of the type in the 1970 Major Scheme Report, could be investigated further to increase understanding of the hydrology of these catchments. These relationships do not need to be known to perform a statistical evaluation of the likelihood of a given flood size, but provide an alternative method for arriving at a design flood event, or a check on the statistical evaluation.

Previous stopbank designs have been based on one or other of these methods; initial design and construction work was done using the unit hydrographs developed in the 1970 report, while most work was done following a statistical review in the early 1980's. It should be noted that alternative methods of estimating the 100 year rainfall (e.g. HIRDS), indicate the design rainfall used in the 1970 report may be a significant overestimate, so the unitgraph approach is not necessarily inappropriate for this catchment, provided the appropriate rainfall is chosen.

The Kaituna River Major Scheme report analysed 5 large storms to create a unit hydrograph shape with an average time to peak of about 24 hours. A review in 1977 (concentrating on the changes in storage the works would bring), analysed 4 further storms, again coming up with unit hydrographs rising for 24-30 hours. A revised design hydrograph of the 48 hour storm was taken as the critical event. The largest recorded floods also had time to peak of around 48 hours.

Uncertainties in the low flow levels due to increased tidal influence make further unitgraph analysis impossible at this site (Assumptions could be made, but the possible errors would make the results subject to a wide margin of error). However, there is sufficient confidence in the previously derived hydrograph shape to use that as the design hydrograph, with the peak flow altered according to the frequency analysis.

A review of the design 48 hour rainfall, using the HIRDS program and scaling the average point source rainfall by 84% to represent the catchment below Okere (as per method for probable maximum rainfall), gave a catchment mean rainfall of 327 mm as the 1% AEP rainfall. The original design rainfall was 480 mm, but an increase in the design flow to allow for uncertainty due to a short period of record meant the design was based on an equivalent of 545 mm. Again, a major part of the difference is due to the addition of a period of record relatively devoid of extreme rainfalls when compared with the overall record. The peak flow derived from the original unitgraph analysis and the revised catchment mean rainfall is 520 m^3/s, including allowance for reduced floodplain storage due to stopbanking as in original report. The flows the unitgraph was derived from have since been amended downwards. An amendment to the unitgraph in proportion to the 1962 change (420 to 377 m^3/s) would give a peak of 467 m^3/s.

The 1951 catchment mean rainfall of 350 mm in 48 hours corresponds to greater than a 1% AEP event in terms of rainfall over the whole catchment, according to the HIRDS and PMP calculation.

The 30 April/1 May 1999 catchment mean rainfall (below Okere) was 231 mm, which is less than a 5% AEP event for the catchment as a whole for a 48hr rainfall (although individual tributaries were much higher than the 5% AEP level for shorter periods).

2.1.4 Statistical Analysis

1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
225	69	155	178	104	101	377	80	76	98	92	280	119
1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
123	194	137	156	72	124	98	132	106	86	120	66	100

An evaluation of all the above peak annual data, including the derived data 1982-1999 and the published record from 1956-1981, using the FRAN frequency analysis program, had the following results:

The best fit was found using the General Extreme Value distribution, indicating a 1% AEP flow of 519 m^3/s, with an EV2 type distribution. A good fit was also found using the Log-Pearson Adjusted method, with a 1% AEP flow of 448 m^3/s.

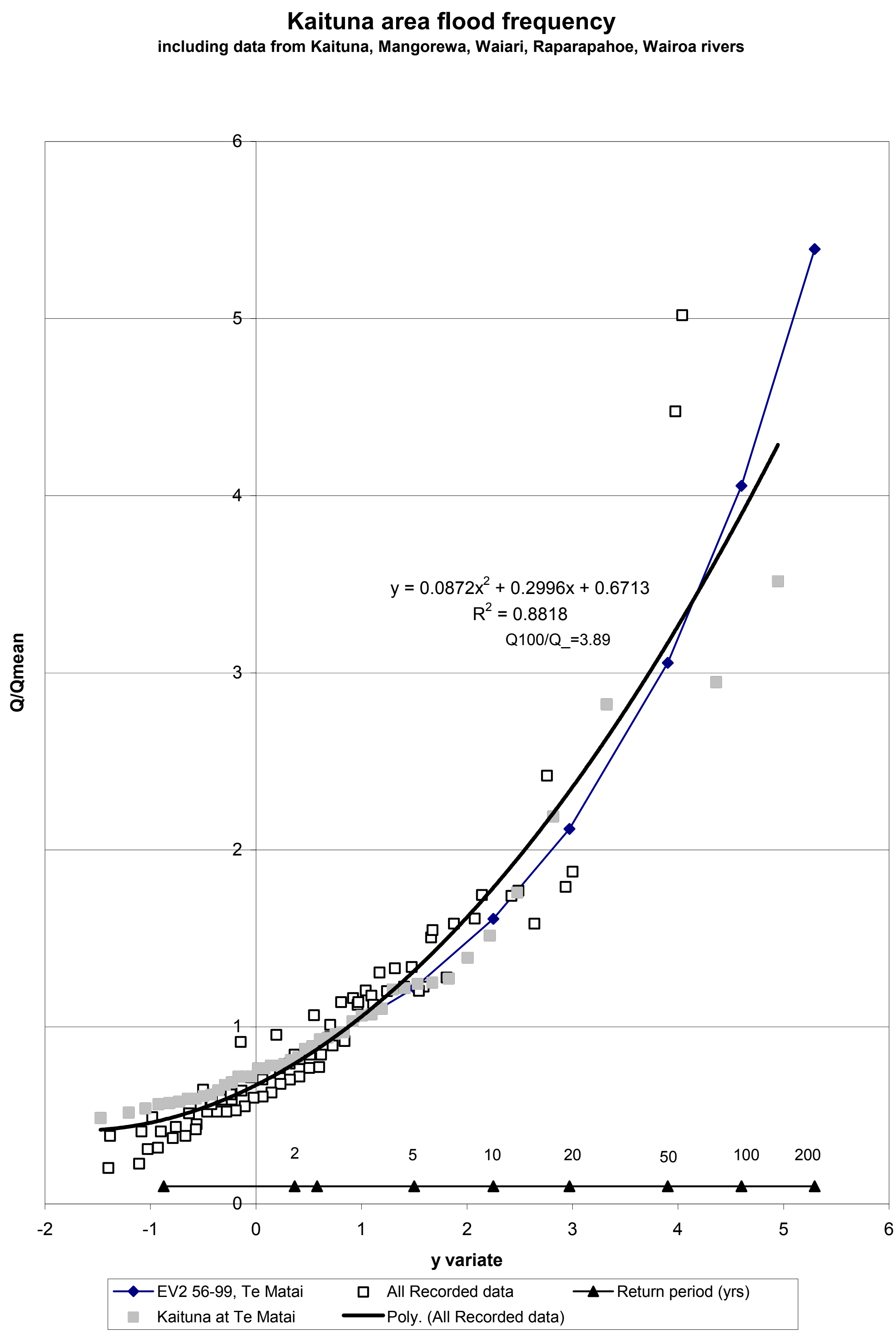
There is an upward skew of the top four floods in the Kaituna at Te Matai data. The skew is not evident in the Mangorewa at Saunders data except that the May 1999 flood was much greater than any previous recorded flood and may possibly be an "outlier". The closeness of the two sites may suggest geological rather than climatic differences.

Note that the Regional Flood Estimation analysis indicates that an EV2-type distribution is likely to fit better than an EV1 distribution in this area. The EV1 method gave a particularly poor fit to the data, especially for the largest floods.

2.1.5 Revised Regional Flood Estimation

The Regional Flood Estimation publication chapter on the Bay of Plenty compared flood frequency data in the wider "pumice" area including the southwestern Rangitaiki, Tarawera, Utuhina, Kaituna and Wairoa rivers. The data was normalised by taking the ratio of every annual flood peak with the mean annual flood in that river. A curve was drawn through all data from these rivers, with the result that the ratio of the 1% AEP flood to the mean annual flood was estimated to be 2.89 for the region.

The same method has been used with up-to-date data, specific to the Kaituna area. The results are shown on the following graph and indicate that for the Kaituna River and tributaries, a ratio of 1% AEP flood to mean annual flood (being 128 cumecs for the Kaituna at Te Matai) of 3.89 is more realistic. For the Kaituna River at Te Matai, this would indicate the 1% AEP flood to be around 498 m^3/s.


Kaituna area flood frequency
including data from Kaituna, Mangorewa, Waiari, Raparapahoe, Wairoa rivers
Q/Qmean
y variate
y = 0.0872x2 + 0.2996x + 0.6713
R2 = 0.8818
Q100/Q_=3.89
2
5
10
20
50
100
200
6
5
4
3
2
1
0
-2
-1
0
1
2
3
4
5
6
EV2 56-99, Te Matai
All Recorded data
Return period (yrs)
Kaituna at Te Matai
Poly. (All Recorded data)

2.1.6 The July 1951 Flood

Early reports (Murray, 1951 and Floods in New Zealand 1920-1953) gave this flood a peak flow of 140 m^3/s, based on extrapolation of a small number of gaugings at the State Highway bridge. The peak level was shown as 117 feet, in a datum where mean sea level at Maketu is reported as 97 feet. The level was taken at the highway bridge, and corresponds to about 6.17 m.

The Kaituna River Major Scheme Report shows the peak flow in 1951 as 495 m^3/s, based on a subsequent rating curve at the Te Matai site just downstream. It says the peak level was 6.28 m, but it is unclear whether a small correction has been made between the bridge measurement and the gauging site. The report also shows the 1962 flood as 420 m^3/s, but this figure has since been revised to 377 m^3/s. It is clear from the rainfall in the 1951 event, e.g. 425 mm at Te Ranga in 48 hrs, that it was an extreme event, however, the size of it is less clear. Taking the same ratio for the reduction of the 1962 event would give about 450 m^3/s. If no correction was made for the measurement site, it is possible that the 1951 flood was only as high as the 1962 flood at Te Matai. The rivermouth cut at Te Tumu was undertaken in 1957 and affected the rating curve, although the effect would be less at higher levels. It is therefore possible that the 1951 peak flow was less than the 1962 flood.

The Floods in New Zealand 1920-1953 summary describes several floods in the Kaituna catchment, but details are sparse. The 1951 flood appears to be the largest of these.

In summary, the size of the 1951 flood is uncertain, perhaps as high as 495 m^3/s, but perhaps lower than 380m3/s. For prediction purposes it has been assumed to be 450 m^3/s and the largest flood in the period 1920-1955.

2.1.7 Reanalysis Including the 1951 Flood

The statistical analysis was rerun including the 1951 flood as an historical peak, the largest in 35 years.

The EV2 analysis gave the 1% AEP flow as 526 m^3/s. The fit was not quite as good as the previous analysis. The points were then replotted using the Gringorten plotting positions on Gumbel paper and a line fitted manually. The 1% AEP flow by this method was 420-480 m^3/s. EV1 again gave a poor fit.

It was also considered to include the 1951 peak as an additional peak on the continuous data series 1956-1999. This effectively decreases the time period over which the 1951 peak is known to be the largest flood, and also increases the frequency of all the other peaks, so increases the 1% AEP flow significantly. The EV2 plot showed the 1% AEP using this method to be 655 m^3/s. It is considered that this manipulation results in overemphasising the largest floods and therefore represents an unrealistically high estimate of extreme values.

2.1.8 Changes to the Distribution of Floods

Two aspects of the scheme works will alter the frequency distribution of flood flows at Te Matai, particularly for small and moderate floods (to 10% AEP). These are the stopbanking upstream of Te Matai and the lowering of the bed along the river. The stopbanking has the effect of reducing floodplain storage, so peaks are likely to be higher and occur sooner. Deepening of the channel also increases the flow in the channel, which also increases the speed of water in the channel and reduces the volume of water on the floodplains. Major floods are less affected since the floodplains (upstream of Te Matai) would be inundated regardless. This effect can perhaps be seen in the fact that there have been three floods in the 1990's near 160 m^3/s (approximately 20% AEP), however this may be mere coincidence. This change is not regarded as significant enough to discard flood flow information prior to scheme works. Inclusion of the major peaks in 1962 and 1967 defines the distribution much better, although it should be recognised there are many variables in the dataset.

2.1.9 Design Flow

A conclusion to be drawn from the flood frequency distribution is that, prior to May 1999, there hadn't been a "ten year" (10% AEP) flood on the Kaituna for almost thirty years! The Mangorewa peak in 1986 clearly was greater than a 10% AEP event, but was not of sufficient duration to cause a major flow at Te Matai. The 1999 peak of 361 m^3/s was about a 2.5% AEP (40 year) event.

This is largely consistent with other rivers in the Bay of Plenty. Generally there has been a benign period when it comes to major floods over the last thirty years, broken by the major floods in the Waimana, Whakatane and Waioeka rivers in July 1998 and in the Kaituna catchment in May 1999.

From the above analysis, it is recommended that the 1%AEP design peak flow be amended to 500 m^3/s at Te Matai, based primarily on the revised regional flood curve drawn above. The 10% AEP flow from the EV2 method is 206 m^3/s and fits better than the regional curve at this point.

Reasons for adopting this flow rather than a lower one include:

- The largest recorded floods were in the 1950's and 60's and the accuracy of the information is not clear.
- Most of the recent record covers a "benign period", where large floods have not occurred.
- The downcutting of the bed and loss of storage from stopbanking will generally increase flood peaks at Te Matai (although extreme floods will be less affected than moderate floods).
- It is a relatively conservative figure given the range of distributions analysed.

Reasons for adopting this flow rather than the previous 580 m^3/s include:

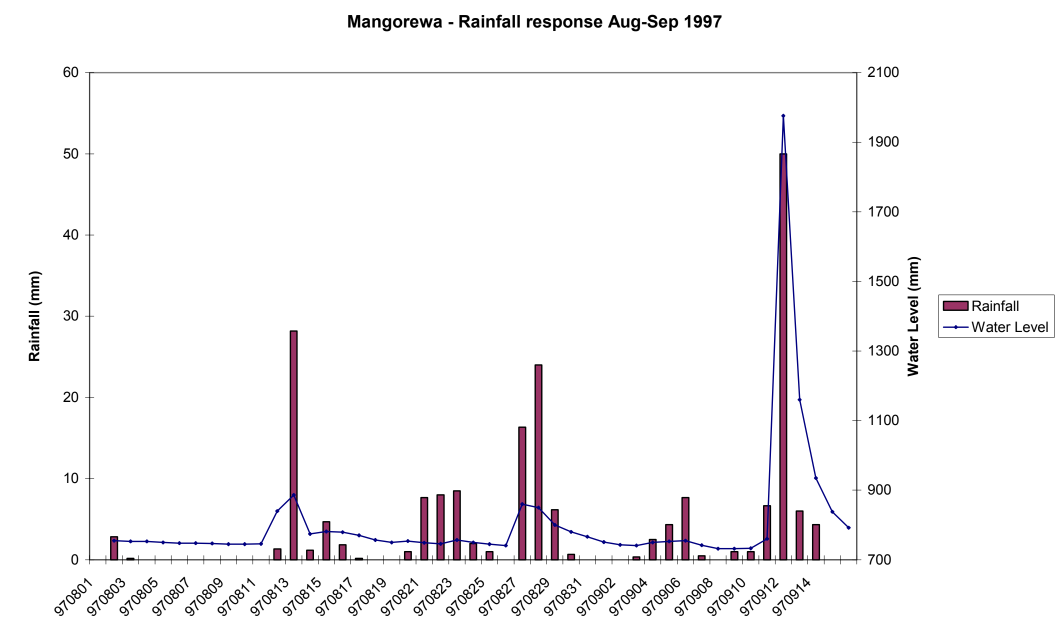
- There is considerably more rainfall and flow data available, with lower rainfall and flows experienced than those previously predicted
- The regional curve averages out anomalies in the data and the data fits the EV2 distribution well.

The recommenced design flows, based largely on the revised regional flood estimation are presented in the following table.

Kaituna at Te Matai Recommended Design Flows

Return Period (years)	Design Flow (cumec)
2	100
5	170
10	230
20	300
50	405
100	500
200	600

2.1.10 **Mangorewa Rainfall/Runoff Relationship**



The above graph illustrates the non-linear response to rainfall in the Mangorewa catchment. Two rainfall events, 29 mm on 12/8/97 and 40 mm on 26-27/8/97 gave very little increase (2 m^3/s) in flow rates in the Mangorewa River. A third event of 50 mm on 11/9/97 gave a much larger response, with flows increasing from 5 to 32 m^3/s. (Rainfalls are averages of three sites: 214628 - Mangorewa at Saunders, 769203 - Mangatoi Road and 768307 – Rangiuru Road). Runoff in the third event was equivalent to 8 mm. A closer look at the rainfall intensities at the Mangorewa site shows similar peak hourly intensities in the second and third events, but in the third event, these intensities lasted longer. This information suggests an appropriate rainfall-runoff model would include both an initial loss and a continuing loss component. Another short event in December 1997 had intensities over 10 mm/hr, but virtually no runoff. Perhaps an initial loss of 30 mm and a continuing loss of 5 mm per hour is a starting point from this information.

2.1.11 Kaituna at Maungarangi

The flow in the Kaituna River subcatchment between Taaheke near Lake Rotoiti and the confluence with the Mangorewa River is not recorded and is not well understood. This subcatchment covers 86 km^2. Observations at the Maungarangi Bridge are affected by the flow in the Mangorewa River, and much of the rest of the river is very difficult to access. It is believed that the geology of the area, with a higher proportion of breccias than the adjacent catchments, has a high infiltration capacity but a relatively low horizontal transmissivity of water and therefore a lower proportion of rainfall runs off.

Following the 1 May 1999 event, debris at the Ashe property in the gorge was observed about 5 m higher than the normal water level at a point where the channel is about 12 m wide with near vertical sides. Assuming the normal water flow (seen with Okere gates at 3 x 500) is about 3 m deep and 10 m wide, and assuming the velocity was around 2-3 m/s, gives a range for the peak flow of 180-270 m^3/s. This compares with 837 m^3/s estimated for the Mangorewa River.

A study in 1977 compared 8 storms in the Mangorewa River with the flow at Te Matai. It found the flow past Te Matai was between 1.1 and 2.4 times the flow in the Mangorewa River, excluding baseflow. The subcatchment between the lakes and Maungarangi Bridge is 79% of the remaining area above Te Matai, so it can be inferred that the flow at Maungarangi is likely to have been between 8% and 110% of the flow in the Mangorewa for those storms. This is not a very useful conclusion. Fortunately, the frequency analysis at Te Matai does not need this information and covers most of the scheme. However, design flows between Maungarangi and Te Matai cannot be well defined. They reduce significantly downstream as the floodplain storage causes significant attenuation.

2.1.12 Tributary Stream Flows

The Waiari Stream is the only other tributary with substantial continuous flow information, with peak flows available from 1967 to 1994 at Muttons Farm (94% of the catchment). The data fits the EV2 and Log-Pearson Adjusted distributions well – these give 1% AEP flows of 89.5 and 87.0 m^3/s respectively. Other methods also fit reasonably well and give 1% AEP flows ranging from 80 to 85 m^3/s. The trouble is, the May 1999 flow was estimated to be some 203 m^3/s at the peak, apparently greater than an 0.5%AEP (200yr) event. This event does not fit the pattern of recorded flows, but it should not be ignored when working out a design flow.

Flows on the Raparapahoe Stream have been recorded at the drop structure since 1990, although gaugings at high stages are limited. Prior to 1990, some level information is available at the Manoeka Road bridge. It is considered that there is insufficient information from this stream to make a reliable estimate of design flows from the recorded data only. A comparison can however be made with other methods to arrive at a reasonable design flow.

2.1.13 Tributary Stream Flows - Previous Approaches

The scheme report used unit graphs derived from individual storms to estimate peak flows for the tributary streams. It also compared these with the TM61 method.

A review in 1983 based designs on a “thunderstorm” rainfall for each individual catchment and scaled down these storms when combined with a flood in the main river, as the simultaneous occurrence of extreme floods is less likely than the individual events. The stopbanks downstream of State Highway 2 have been built to the combination that gives the greatest level; either the 1983 flows shown in combination with the 1% AEP flood in the Kaituna (generally the worst case), or the "thunderstorm" event with the Kaituna at "bankfull" flow.

The previously estimated 1% AEP events include (m^3/s):

Method	Area (km^2)	Unitgraph	TM61	Thunderstorm	Combined with River flood
Year		1970	1970	1983	1983
Parawhenuamea	32.7	152	163		
Waiari	72.9	371	275		120
Ohineangaanga	20.8	113	113	87	60
Raparapahoe	51.5	177	182	150	123
Kopuaroa	20.2	83	79	76	60
Bell Rd	18.9		31		

2.1.14 Tributary Stream Flows - Revised Flows

In light of the updated rainfall information from HIRDS (no area reduction factor applied except in "combined with river flood" column), the above calculations have been revised as follows (m^3/s):

Method	Unitgraph	TM61	Rational with C from unitgraph	Combined with River flood
Parawhenuamea	81	98	72	34
Waiari	211	96	116	95
Ohineangaanga	71	41	61	35
Raparapahoe	120	120	151	113
Kopuaroa	60	57	89	44
Bell Rd		11	37	28

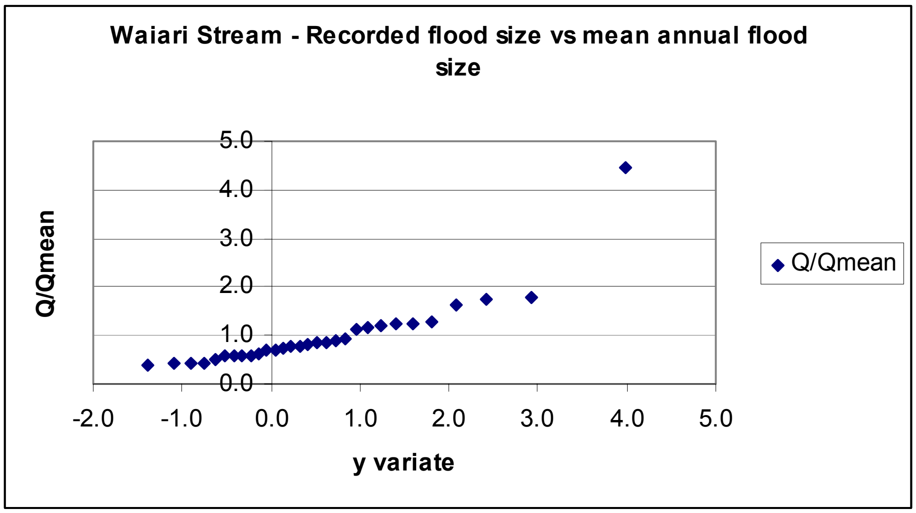
Note the unitgraphs are derived from 24hr rainfalls and are therefore less applicable to the smaller catchments, where the time of concentration is of the order of 3-6hrs.

The changes to the TM61 calculations relate mostly to rainfall differences and differences in the "shape" factor. They are very sensitive to the shape factor; the method for determining this factor has been modified (improved) since the original calculations were done. The Wic factor and slope calculation was not altered.

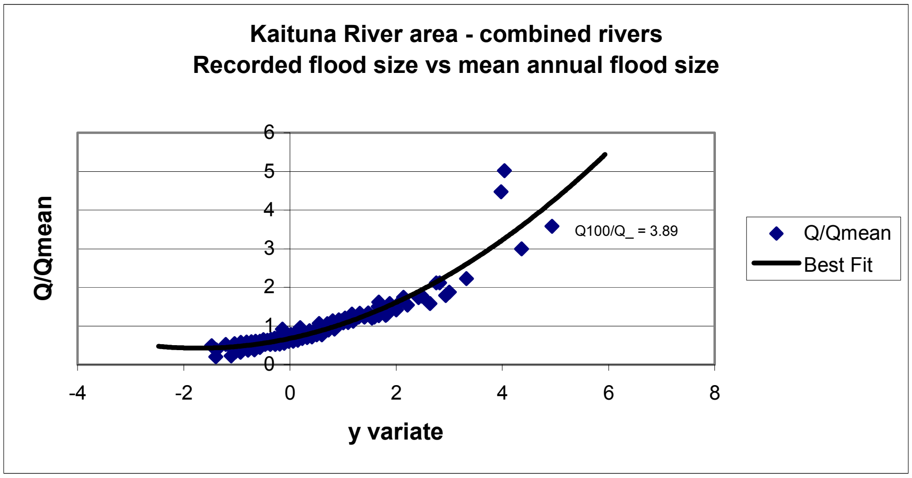
The calculation for the "combined with river flood" column was using the Rational method with a C factor as for the unitgraph method and a rainfall intensity of 18mm/hr for six hours. This rainfall intensity was derived from the 1977 48hr design rainfall event (plan K4265 sheet 5), scaled down by the total rainfall expected in a 1% AEP event (327 mm as opposed to 451 mm in the 1977 analysis). As a comparison, using the rainfall distribution in the Probable Maximum Precipitation publication (peak 20.2% of rainfall in 4.8 hrs), and the ratio of the 1% AEP rainfall event to the probable maximum rainfall event, gives intensities of 16 mm/hr for 4.8 hrs in a 48 hr event. (This distribution is based on the average variability of 20 of New Zealand's most extreme storms – less extreme storms tend to have more variability and may include bursts of rainfall with a higher proportion of the total rainfall than this distribution).

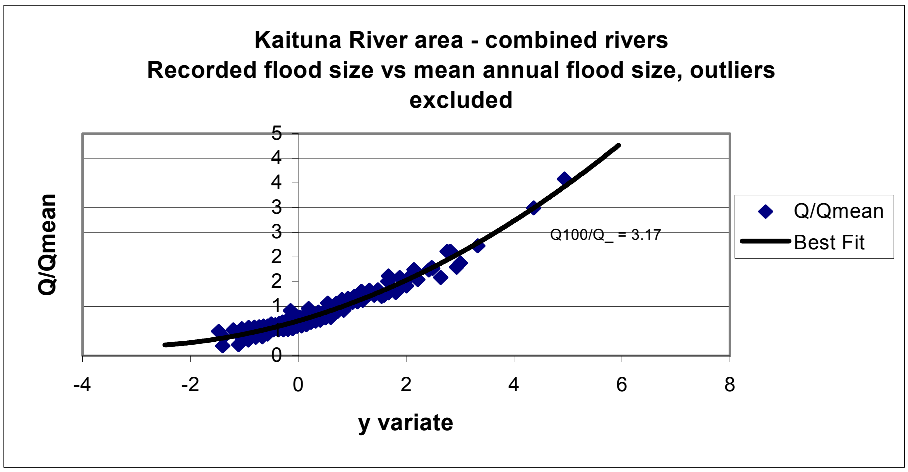
2.1.15 **Tributary Stream Flows - Regional Approach**

The Regional Flood Estimation method uses the approach that the distribution of floods in one river is likely to be similar to the distribution of floods in adjacent rivers. The available data for all rivers is combined to produce a type curve for a given region. The data is in the form of peak annual flows divided by the mean annual flow of each river. By combining several rivers, a more reliable relationship can be drawn between, say, the 1% AEP flood and the mean annual flood, than if only the one dataset were used. This is particularly useful for the tributary streams where limited information exists and the data does not follow a typical extreme value curve smoothly. This is shown below in the plot of the Waiari Stream, where the plot is relatively flat except for the last (1999) value, which does not fit the rest of the data. Without the last value, the 1% AEP flow appears to be around 2.5 times the mean annual flow, or around 90 m3/s. However, with the last value, it is difficult to say exactly where any curve should lie at the right of this plot. The 1% AEP flow corresponds to a “y variate” of 4.6.



However, the regional approach allows more confidence in drawing a curve through the points. In this instance, all available data from the Kaituna at Te Matai, Mangorewa at Saunders, Waiari at Muttons, Raparapahoe at Drop structure and Wairoa at Ruahihi is included. The third plot is the same data with two points excluded; the 1999 flood in the Mangorewa and Waiari rivers. This gives a much better fit, but is only achieved by manipulating the data. If the Waiari conforms to either of these plots, the 1% AEP flow is in the range 124 m^3/s to 152 m^3/s. Using this approach also gives a reasonable method of utilising the relatively short length of data from the Raparapahoe at Drop structure site. The recorded mean annual flood is 34 m^3/s, indicating the 1%AEP flood is likely to be in the range 108 m^3/s to 132 m^3/s. Further records from the Raparapahoe at Manoeka site, (discontinued in 1990), indicate the mean annual flood may be around 37 m^3/s, so the 1%AEP flow by this method would be 118 m^3/s to 144 m^3/s. Note that several of the other methods have given the Raparapahoe a larger 1%AEP flow than the Waiari Stream, despite the Waiari having a larger catchment area and slightly larger mean annual flow.





2.1.16 Tributary Stream Flows - Design Flows

Despite the 27 year record of much lesser flows, it is recommended to keep the Waiari Stream 1% AEP design flow at 120 m^3/s (3.1 times mean annual flood). In combination with a flood in the Kaituna, an appropriate reduction is 18 mm/hr divided by 22 mm/hr, giving a peak flow of 99 m^3/s in a 48 hr event.

It is recommended that the Raparapahoe flow be reduced to 120 m^3/s, or 3.53 times the mean annual flood recorded at the drop structure of 34.0 m^3/s.

For the Ohineangaanga and Kopuaroa streams, where no continuous flow records exist, it is not recommended to change the design flows at this stage. It is felt the design flow for the Ohineangaanga in particular may be a little high (the “combined with river flood” peak flow rate has a runoff equivalent to 58% of the design rainfall rate), but it may be prudent at this stage to allow for an increased flow from further development of Te Puke.

The Parawhenuamea Stream contribution is included in flow estimates at Te Matai. Some stopbanking exists above the confluence with the Brown Road drain – the recommended 10% AEP flow for this area (16.3 km^2) is 29 m^3/s.

The Bell Road area will not contribute significantly to the Kaituna River during the peak of extreme events except a small amount via the pumps. Determination of the flow in combination with these floods is therefore not critical to the river system. An analysis of the volume of runoff from this catchment will be more critical to flood levels in the area than the estimates of peak flow. This can be best done once the design hydrograph at the Bell Road floodgate outlet is known.

Recommended Design Flows (m^3/s):

Stream	Area (m^3)	Design 1% AEP flow, Kaituna at bankfull	Design 10% AEP flow (upper sections of some tributaries)	Design in combination with Kaituna at 1% AEP flow
Parawhenuamea	32.7	N/A	29	N/A
Waiari	72.9	120	N/A	99
Ohineangaanga	20.8	87	49	60
Raparapahoe	51.5	120	66	99
Kopuaroa	20.2	76	43	60
Bell Rd	18.9	37	19	33

2.1.17 Floodplain Flows

The areas that do not drain to the tributaries but are impounded behind stopbanks have been assessed as follows:

Name	Rural - High water table	Rural - Low water table	Urban	Total	Peak Flow Rate*
	Area (km^2)	Area (km^2)	Area (km^2)	Area (km^2)	(m^3/s)
Arawa wetland	0.32	0.8		1.12	1.8
Singletons drain	6.28	4.56		10.84	20.2
Maketu Rd/Ford Rd 1	8.16	4.4		12.56	24.0
Maketu Rd/Ford Rd 2	4.44	2.28		6.72	12.9
Right Bank floodplain	10.6	1.32		11.92	24.9
Parawhenuamea drain	2.56	1.41		3.97	7.6
Borough and Managhs drain	3.16		2.13	5.29	11.2
Marshalls drain	2.36	1.14	1.28	4.78	9.3
Kopuaroa pump	3.83			3.83	8.3
Bell Rd A pump	5.95			5.95	12.9
Bell Rd B pump	2.65	2.00		4.65	8.6
Total	50.31	17.91	3.41	71.63	141.7

*The peak flow rate has been assessed for the 72hr 1%AEP storm distribution developed from the Probable Maximum Precipitation publication. This is not the critical event for the peak flow in individual subcatchments, as more intense periods of lesser duration may cause higher flow rates, but is likely to be the critical event for ponding levels in some areas if combined with high river levels.

2.2 Design Tide Levels

(All levels below are in Moturiki Datum)

The original report assumed a peak tide level of 2.05 m coinciding with the peak 1% AEP flow and also allowed for a tide level of 2.74 m as a separate event.

The 1983 calculations were done assuming a peak tide level of 1.80 m. The works near the rivermouth for which the 2.74 m tide was critical were already completed by this stage.

Recent work by NIWA on 23 years of data from the Moturiki site identifies the 1% AEP tide level as 2.06 m, including the likelihood of combinations of wave set-up, storm surge, barometric pressure effects, coincidence of lunar and solar phases etc. Additional impacts of wave run-up and sea level rise are not considered. The 5% AEP tide level is given as 1.62 m.

The recommended design scenarios include:

As a check for existing works;

- 1% AEP flow plus 5% AEP tide level with 0.23 m additional allowance for possible differences between Moturiki and this site (called the estuary effect from observations of local variations within estuaries – also refer following postscript), and other imprecisions. (Peak tide level 1.85 m).

- 5% AEP flow plus 1% AEP tide with 0.33 m additional allowance (Peak tide level 2.39 m).

For areas where work is to be done, e.g. topping up of stopbanks, an additional allowance for sea level rise of 0.49 m (IPCC 1995 best estimate for sea level rise over the next 100 years);

- 1% AEP flow with 2.34 m peak tide level.

- 5% AEP flow with 2.88 m peak tide level.

Postscript: The addition of the “estuary effect” should only apply to Maketu Estuary to cover the dynamic effect of storm surge in the estuary – principally arising from differential wind stress across the estuary. This design water level estimates are marginally high in the lower reaches of the Kaituna River.

Chapter 3: Hydraulics

3.1 Cross-Sections

Kaituna River: The main river has established cross-sections, generally at 500 m intervals or less. These were last surveyed in April-June 1997. Forty-three surveyed cross-sections were used in the model, from the Maungarangi Bridge to the mouth. An artificial cross-section 3 km upstream of Maungarangi Bridge was included to allow for storage within this reach. Cross-section 1a was duplicated and shifted downstream by 80m to better define the restriction at the mouth. An additional cross section at sea was assumed to account for dissipation of energy beyond the mouth.

Mangorewa River: Three cross-sections are regularly surveyed, the last survey was in May 1997. The Mangorewa at Saunders recorder site is some six kilometres upstream of the uppermost cross-section. A series of artificial cross-sections was input into the model, based on the cross-section at the recorder site, for this 6 km stretch. The desired effect is to correctly model the time of travel from the recorder to the Kaituna confluence and any associated attenuation or increase of peak flows in the gorge section. Past records clearly show significant attenuation of some peak flows between the Mangorewa recorder and Te Matai (simplistically, a short sharp peak at Saunders, may translate into a longer flood with a lower peak flow by the time it reaches Te Matai). A clear example of this is in July 1998:

- on the 10th, a peak flow in the Mangorewa of 151 m^3/s was recorded, with over 100 m^3/s recorded for 9¾ hours and a peak of 153 m^3/s at Te Matai;

- on the 15th, a peak flow in the Mangorewa of 201 m^3/s was recorded, but greater than 100m3/s was recorded for only 4¾ hours, and a level 0.58 m lower was reached at Te Matai.

- the first flood was higher than the peak of the second flood for 15 hours at Te Matai.

Waiari, Ohineangaanga, Raparapahoe and Kopuaroa Canals: Cross-sections from the Kaituna River to SH2 (plus one above SH2 on the Waiari) were surveyed in August 1998, generally 1 km apart. These were compared with the design channels as constructed in the 1980’s, and generally found to be similar to the design. Some invert levels have risen by up to 1 m – this may have localised effects on drainage, but does not affect the flood capacity a great deal. Drainage was not studied in detail.

Additional sections were surveyed in 1999 following the May flood on some of the tributaries. Three sections on the Raparapahoe near Quarry Road plus two bridge cross-sections, six on the Ohineangaanga below Raymond Ave (including the three bridges in town), and eight sections on the Waiari near the old recorder site were surveyed, primarily to determine peak flows in that event. They have been included in the model. There is some distance between these sections and the previously surveyed sections, so information in between may not be accurate. The model is only intended for the sections with stopbanks. Including the upstream cross-sections will help improve the accuracy of the lead-in to each stop banked area.

The Kopuaroa Canal above SH2 and Quarry A drain were included using forty-three of the cross-sections as designed in 1990. These cross-sections only cover part of the floodplain, so were assumed to extend flat to the edge of the floodplain. The limits of the floodplains in this area were assumed from the original scheme report showing flooded areas for various storms.

Bell Road canal was modelled according to the design drawings from 2 km from the Kaituna River.

Floodplain areas and other inflows: e.g. Diagonal Drain, overflow from Bell Road Canal: These were modelled as very wide channels with appropriately scaled inflows. Levels are cross-sections pump stations were assumed to be working at full capacity throughout the flood for the purposes of river channel design.

Bridges and Culverts: Bridges on the Kopuaroa, Ohineangaanga and Raparapahoe streams have been included in the model as culvert restrictions. They are generally not major constrictions at the flows considered, unless they become clogged with debris. In the design cases, an allowance of 0.6m of debris has been included on the Ohineangaanga bridges, with 1.2 m of debris allowed on the Raparapahoe Stream bridges and the Ohineangaanga (Raymond Ave) culvert. It should be noted that it appears that considerably more than 1.2 m of debris collected on the Raparapahoe Railway bridge in May 1999 (refer Operations Report 2000/02). A relatively large drop in flood debris marks was recorded either side of the Kaituna Railway bridge in May 1999, but a rise in flood debris marks was recorded in the July 1998 flood. The data is conflicting and cannot be relied on. A Hybrid model of the railway bridge was run with a flow of 360 m^3/s, and indicated a drop of around 3-4 cm across the structure is likely, with no choking of the flow. It is unclear if any unusual hydraulics operate in this area, but there is no visual evidence of any major change in the channel characteristics in this section of the river compared with the section downstream of the railway bridge. There is no reason to suspect the railway bridge is a particular constriction.

3.2 Calibration

For a typical model calibration, for a particular flood event, the inflow would be known via a rated flow station, the tide level would be known or reasonably estimated, and several levels would be taken down the river so that the model could conform to those levels. Several floods could be modelled during calibration, with the desired outcome a model that predicts flood levels right down the river to a reasonable accuracy for any hydrograph.

The information available for this model is as follows:

Flow records from Mangorewa at Saunders and Kaituna at Taaheke. This excludes about 109km2 or 1/3 of the catchment between Taaheke and Te Matai, for which assumptions will need to be made.

Flow records at Te Matai prior to 1982. Post 1982, changes in bed levels were too great to allow a consistent rating curve to be continued. The water level also became tidally influenced, making the bottom of the rating curve variable depending on the tide, and therefore impractical. Peak annual flows since 1982 have been estimated from peak levels and associated gauging information. While bed levels were dropping between 1984 and 1986, gaugings are sufficiently close to the annual peaks that they can be reasonably estimated. Bed levels since 1987 appear to have stabilised, which may allow more certainty about the data since then if a (high level) rating curve is re-established.

Continuous river level recordings at Te Matai, Clarkes and Fords Cut (and Hicksons to 1989).

Continuous recordings at Moturiki Island. The dual recordings at Fords Cut and Moturiki Island are especially valuable in understanding and modelling the processes at the rivermouth.

Level marks along the length of the river for two floods: 10 July 1998 and 1 May 1999. Level recordings prior to 1986 would be very hard to interpret because there have been many changes in bed level and stopbank configuration since that time. They would certainly not be applicable for the model using the most recent cross-sections, i.e. a parallel model would need to be configured.

Thus, the calibration of the model is tied mostly to the two recent floods with adequate pegged flood level information, but there is a good record for verification at a few specific points for other floods.

The July 10 1998 flood was pegged and the flood marks levelled at every cross-section below Te Matai and generally every fourth section above Te Matai. In addition, levels were obtained on several of the tributary streams at the State Highway. It was gauged as 153 m^3/s at Te Matai near the peak – the peak has been estimated at 159 m^3/s. The Mangorewa River had reached a peak of 151 m^3/s 7½ hours before the peak at Te Matai, but was above 130 m^3/s for 7 hours.

The Mangorewa rose again to 201 m^3/s 5 days later, but was above 130 m^3/s for only three hours. This second flood produced a peak flow of around 90 m^3/s at Te Matai, some 570 mm lower than the first.

The May 1 1999 event was levelled at all sites between section 4 and Te Matai and most sites above Te Matai. In addition, about 20 levels were recorded on each of the Ohineangaanga, Raparapahoe and Waiari Streams. This is the most comprehensive record available for an event of this magnitude.

Calibration of the rivermouth used water level data from Fords Cut and Moturiki and allowed the model to calculate the flows. The resistance was then altered until the total volume passing through the rivermouth was correct. Modelled flows may not be precise because of differences between Moturiki and the site, but on average will allow reasonable calibration.

The calibration of the model with the two floods matches well in the Kaituna River above the confluence of the Waiari (except at the anomalous points near the Railway Bridge). Below the confluence of the Waiari, assumptions about the magnitude and the timing of the tributary inflows (the Raparapahoe is the only one recorded), mean the calibration is much more difficult. The best fit for the 1999 flood has a Mannings n of around 0.02 for a long section of the Kaituna below the Kopuaroa confluence, but the best fit for the 1998 flood has n = 0.025 in this section. In the final results, n = 0.025 has been used, despite the model over predicting some levels for the 1999 flood by about 400 mm. Earlier designs used n = 0.03 in this section. N = 0.025 is a relatively low resistance figure in river channel design, however, it is felt to be appropriate in the lower reaches of the Kaituna River. The tributary inflows are uncertain, and the 1 May 1999 flood stage graph recorded at Te Matai has had to be amended to fit observations taken on the day. Because of this, it would be of great benefit to record further flood levels on the tributaries if they become available, and for some estimate of their flow to be made, so a verification check on the model can be made. It is particularly important to have a good estimate of the timing of the peak of each tributary to allow a good comparison. Information from any flood over about 150 m^3/s at Te Matai would be of benefit.

3.3 Resistance

Mannings n resistance factors were initially assumed according to the following table (Ven Te Chow, 1959, after Cowan,1959):

n = (n0+n1+n2+n3+n4)*m5	Range	
n0 = bank material (earth)	0.02	0.028
n1 = degree of irregularity	0	0.02
n2 = variations in channel cross-section	0	0.015
n3 = relative effect of obstructions	0	0.06
n4 = vegetation	0	0.1
m5 = degree of meandering	1	1.3

	n0	n1	n2	n3	n4	m5	n
Kaituna Mangorewa to Waiari	0.02	0.01	0.005	0.005	0.005	1.1	0.050
Kaituna below Waiari – best	0.02	0	0.002	0	0	1	0.022
Kaituna below Waiari –worst	0.02	0.005	0.01	0	0.005	1	0.040
Waiari at Muttons in channel	0.02	0.01	0.01	0.01	0.002	1.1	0.057
Waiari at Muttons on berms	0.02	0.005	0.01	0	0.005	1	0.040
Waiari above stopbanks	0.02	0.015	0.005	0.015	0.002	1.3	0.074
Waiari floodplain	0.02	0	0	0.005	0.005	1	0.030
Waiari main channel above 2km	0.02	0.01	0.005	0.005	0.002	1.1	0.046
Waiari main channel below 2km	0.02	0.005	0.002	0	0.002	1	0.029
Waiari on berms	0.02	0	0	0	0.005	1	0.025
Ohineangaanga in town	0.02	0.015	0.01	0	0.005	1.1	0.055
Ohineangaanga below town	0.02	0.015	0.005	0.005	0.005	1	0.050
Ohineangaanga in channel	0.02	0.01	0.01	0	0.002	1	0.042
Ohineangaanga on berms	0.02	0	0	0	0.005	1	0.025
Raparapahoe above drop structure	0.02	0.015	0.005	0.01	0.005	1.2	0.066
Raparapahoe in channel	0.02	0.01	0.005	0	0.005	1	0.040
Raparapahoe on berms	0.02	0	0	0	0.005	1	0.025
Kopuaroa above SH2	0.02	0.005	0.002	0	0.005	1	0.032
Kopuaroa main channel	0.02	0.01	0.002	0	0.002	1	0.034
Kopuaroa on berms	0.02	0	0	0	0.005	1	0.025

Minor variation to the above figures were made for individual cross-sections for the calibration, in particular at the confluence of the Kopuaroa and the Kaituna where there is a large increase in depth and at the rivermouth where large energy losses occur. Design values are shown in Appendix IV.

Note that the Waiari Stream above the stopbanks in particular has a much shorter floodplain distance than channel distance, due to several meanders. The channel and floodplain have been modelled as joined cross-sections to keep the model simple. This has led to a high Mannings n being chosen for the channel to allow for the extra length (there will be a slight storage error from this configuration).

The flood berm resistances were achieved by adjusting the relative resistance across the width of each section.

Floodplain resistance has been assumed to be n = 0.030 throughout.

3.4 Results

The critical results of the various model scenarios are tabulated below. In general, the critical event is the 1% AEP flood in the main river, combined with a 5% AEP storm surge and peak flows in the tributary streams coincident with peak flows in the main river. Exceptions are below section 4 where a 1% AEP tide governs, and on the Ohineangaanga above 1 km from the confluence with the Raparapahoe and the Raparapahoe above 2 km from the Kaituna River, where the individual tributary flows govern.

Table _ Kaituna River Revised Stop bank Design Levels 1998, 1%AEP

Kaituna River

Section	Distance (km)	Mike 11 Distance	Design Water Level	Design Stopbank Level	Future DWL	Level to top up to
1	-0.070	21.970	2.39	2.89	2.88	3.38
1a	0.130	21.770	2.39	2.89	2.88	3.38
2	0.482	21.418	2.41	2.91	2.89	3.39
3	1.005	20.895	2.42	2.92	2.89	3.39
4	1.528	20.372	2.52	3.02	2.90	3.40
5	2.011	19.889	2.81	3.31	2.96	3.46
6	2.497	19.403	2.92	3.42	3.05	3.55
7	3.017	18.883	3.09	3.59	3.20	3.70
8	3.500	18.400	3.35	3.85	3.44	3.94
9	4.023	17.877	3.35	3.85	3.44	3.94
10	4.506	17.394	3.53	4.03	3.60	4.10
11	5.029	16.871	3.74	4.24	3.80	4.30
12	5.507	16.393	3.88	4.38	3.92	4.42
13	6.018	15.882	3.92	4.42	3.96	4.46
14	6.500	15.400	3.98	4.48	4.02	4.52
15	7.000	14.900	4.07	4.57	4.10	4.60
16	7.250	14.650	4.15	4.65	4.18	4.68
17	7.500	14.400	4.21	4.71	4.24	4.74
18	8.000	13.900	4.36	4.86	4.38	4.88

19	8.503	13.397	4.48	4.98	4.50	5.00
20	9.000	12.900	4.51	5.01	4.53	5.03
21	9.500	12.400	4.63	5.13	4.65	5.15
22	10.000	11.900	4.83	5.33	4.85	5.35
23	10.550	11.350	5.13	5.63	5.14	5.64
24	11.000	10.900	5.38	5.88	5.39	5.89
25	11.511	10.389	5.56	6.06	5.57	6.07
26	12.000	9.900	5.78	6.28	5.79	6.29
Gauge	12.300	9.600	5.99	6.49	6.00	6.50

Tributary Streams

Note: figures in italics denote levels controlled by stream flows, (not Kaituna River level)

Section	Distance (km)	Mike 11 Distance	Design Water Level	Design Stopbank Level	Future DWL	Level to top up to
Waiari Stream						
1	0.05	6.77	4.47	4.77	4.49	4.79
2	0.99	5.83	4.56	4.86	4.57	4.87
3	1.85	4.97	4.66	4.96	4.67	4.97
4	2.66	4.16	4.81	5.11	4.82	5.12
SH2	3.04	3.78	*5.28*	*5.58*	*5.28*	*5.58*
5	3.74	3.08	*6.12*	*6.42*	*6.12*	*6.42*
Ohineangaanga Canal						
1	0.00	3.48	*4.52*	*4.82*	*4.52*	*4.82*
		3.03	*4.66*	*4.96*	*4.66*	*4.96*
2	1.00	2.48	*4.92*	*5.22*	*4.92*	*5.22*
		2.13	*5.12*	*5.42*	*5.12*	*5.42*
		1.78	*5.34*	*5.64*	*5.34*	*5.64*
		1.68	*5.78*	*6.08*	*5.78*	*6.08*
3	2.00	1.48	*7.35*	*7.65*	*7.35*	*7.65*
Raparapahoe Canal						
1	0.00	5.47	4.21	4.51	4.24	4.54
2	1.03	4.44	*4.50*	*4.80*	*4.50*	*4.80*
	1.13	4.34	*4.52*	*4.82*	*4.52*	*4.82*
3	2.05	3.42	*4.91*	*5.21*	*4.91*	*5.21*
4	3.00	2.47	*5.62*	*5.92*	*5.62*	*5.92*
5	3.42	2.09	*5.98*	*6.28*	*5.98*	*6.28*
Kopuaroa Canal						
1	0.00	7.14	4.02	4.32	4.06	4.36
2	0.95	6.09	4.06	4.36	4.10	4.40
3	1.97	5.07	4.19	4.49	4.23	4.53
4	3.00	4.14	4.39	4.69	4.41	4.71
5	3.94	3.20	4.94	5.24	4.95	5.25

3.5 Kaituna River

The revised design indicates that lower stopbank levels are sufficient all the way down the main river except in the vicinity of the State Highway. This is partly due to a lower design flow rate and partly due to the assumption of lower resistance in the river channel (especially below the confluence with the Kopuaroa Canal).

These levels have been plotted against the measured stopbank levels (May-Aug 1998) and shown in long section plots. (Refer Ricoda plots). There are only a few spots lower than the new design level, with most of these having more than half the 500 mm freeboard remaining. This is a great deal better news than the 1980's design would suggest – in some places, the entire 500 mm freeboard has been lost by settlement.

Under the recommended practice of topping up banks once they have lost more than half their freeboard, the revised design indicates that the following approximate distance of topping up is required:

- 350 m of bank on the right bank (just below SH2).

The total volume of these earthworks is estimated to be 2300 m^3 plus allowance for stripping etc. Assuming material can be taken from the river, and allowing \$11/ m^3 for this work, the cost to rehabilitate these banks is approximately \$25,000. This is only a tiny fraction of the cost envisaged in the draft asset management plan for this work, scheduled for the year 1999/2000.

3.6 Tributary Streams

Design levels along the tributary streams are also substantially lower in most cases. Design levels in the lower reaches of the tributaries are around 0.5 m lower on average. Settlement also averages about 0.5 m but is variable, so some areas still require topping up. One stretch along both sides of the Raparapahoe Stream had settled about 1.1 m on average and was the area most susceptible to overtopping until it was topped up in early 2000. The following top-ups are currently required to meet the revised design levels:

- Waiari Stream: 40 m
- Ohineangaanga Stream: 250 m
- Kopuaroa Canal: 250 m

The total volume of earthworks required for the tributary streams is of the order of 600m^3. At \$18/m^3, assuming all material must be carted in, results in a cost of around \$10,000. This is again only a tiny fraction of the cost assumed for the draft asset management plan (the majority of which was for the Raparapahoe).

In places, the revised design on the Raparapahoe is, unfortunately, slightly above the level it has recently been upgraded to. At the major bend 400 m downstream of the drop structure, the revised design bank level is about 200 mm higher than calculated at the time of reconstruction. The design levels are highly dependant on the assumed resistance (assumed to be relatively high in this section), so some further flood level information in this locality would be of use. In addition, as more information is collected at the drop structure site, the design flow rate can be improved.

There is also a stretch of about 500 m on the Ohineangaanga where stopbank levels have not been measured. The model also indicates that the 100 year flow is very close to overtopping or may overtop the channel between the Washer Road Bridge and the start of the stopbank (approx 700 m). This area may need more investigation as the channel is steep and there are only a few cross-sections in the model above the stop banked section. Again, the choice of resistance factor is important and has been assumed to be relatively high in this section.

Peak ponding levels in selected floodplain areas for a 2%AEP rainfall:

Singletons Drain: 2.67m Susceptible to inundation by extreme tides
Maketu/Ford Rd drain at Kaituna Road: 1.25m
Diagonal Drain at Pah Road 1.25m
Between Waiari and Parawhenuamea (Parawhenuamea Drain): 2.99m
Could be much worse if banks overtopped
Between Waiari and Ohineangaanga Streams: 2.24m
Could be much worse if banks overtopped
Between Ohineangaanga and Raparapahoe Canals: 3.62m
Could be much worse if banks overtopped
Between Raparapahoe and Kopuaroa Canals: 2.01m
Could be much worse if banks overtopped
Kopuaroa above and adjacent to SH2: 4.50m Prudent to build well above road level Bell Rd Left Bank: 2.23m
Bell Rd Right Bank 1.85m Assumes bank levels are even left and right. Could be higher if more water spills from Bell Road drain across Bell Road

Appendices

Appendix I

Hydrology estimates, design hydrograph ordinates.

Kaituna River and Tributary design hydrographs - combined event

Time	Base	100yr combination						50yr combination					
		Kaituna	Waiari	Ohineangaanga	Raparapahoe	Kopuaroa	Bell Rd (upper)	Kaituna	Waiari	Ohineangaanga	Raparapahoe	Kopuaroa	Bell Rd
(hrs)	K4349	500	99	60	99	60	12	391	83	50	83	50	10.1
0	28	28	5	2	5	2	1.0	28	5	2	5	2	1.0
5	30	30	5	2	5	2	1.0	29	5	2	5	2	1.0
10	32	31	6	2	6	2	1.1	31	6	2	6	2	1.1
15	41	39	7	3	7	3	1.3	37	7	3	7	3	1.2
20	62	57	11	6	11	6	1.7	50	10	5	10	5	1.6
25	100	90	17	10	17	10	2.4	75	15	8	15	8	2.2
30	160	141	27	16	27	16	3.6	115	24	13	24	13	3.2
35	400	346	68	41	68	41	8.4	273	58	34	58	34	7.1
39	570	491	97	59	97	59	11.8	384	82	49	82	49	9.9
40	580	500	99	60	99	60	12.0	391	83	50	83	50	10.1
41	570	491	97	59	97	59	11.8	384	82	49	82	49	9.9
45	490	423	84	51	84	51	10.2	332	70	42	70	42	8.6
50	380	329	65	39	65	39	8.0	259	55	33	55	33	6.8
55	290	252	50	30	50	30	6.2	200	42	25	42	25	5.3
60	230	201	39	23	39	23	5.0	161	34	20	34	20	4.3
65	185	162	32	18	32	18	4.1	131	27	16	27	16	3.6
70	155	137	27	15	27	15	3.5	112	23	13	23	13	3.1
75	125	111	22	12	22	12	2.9	92	19	10	19	10	2.6
80	100	90	17	10	17	10	2.4	75	15	8	15	8	2.2
85	75	68	13	7	13	7	1.9	59	12	6	12	6	1.8
90	55	51	10	5	10	5	1.5	46	9	4	9	4	1.4
95	45	43	8	4	8	4	1.3	39	7	3	7	3	1.3
100	40	38	7	3	7	3	1.2	36	7	3	7	3	1.2

Tributary streams - design hydrographs, individual events

Time	Unitgraph shapes (K4100/32)		Waiari	Ohineangaanga	Raparapahoe	Kopuaroa	Upper section only				
							Bell Rd 5yr	Bell Rd 10yr	Bell Rd 20yr	Bell Rd 50yr	Bell Rd 100yr
(hrs)			120	87	132	76	5.2	7.1	9.3	12.6	15.5
0	0	0	4	1	2	1	1.0	1.0	1.0	1.0	1.0
1	0	0	4	1	2	1	1.0	1.0	1.0	1.0	1.0
2	0	0.5	4	2	5	3	1.1	1.1	1.2	1.2	1.3
3	0	1	4	3	7	4	1.2	1.3	1.3	1.5	1.6
4	0	1.5	4	4	10	6	1.3	1.4	1.5	1.7	1.9
5	0.5	2.5	7	6	16	9	1.4	1.6	1.9	2.2	2.5
6	1	3.5	9	9	21	12	1.6	1.9	2.2	2.7	3.1
7	1.5	4.5	12	12	26	15	1.8	2.1	2.6	3.2	3.7
8	2	5.5	14	15	32	18	2.0	2.4	2.9	3.7	4.3
9	3	6.5	19	18	37	21	2.2	2.7	3.2	4.1	4.9
10	5	7.5	29	24	43	24	2.3	2.9	3.6	4.6	5.5
11	8	12	44	38	67	39	3.1	4.1	5.1	6.8	8.3
12	13	18	70	58	100	57	4.2	5.6	7.2	9.7	11.9
13	18	24	95	78	132	76	5.2	7.1	9.3	12.6	15.5
14	23	22	120	87	121	70	4.9	6.6	8.6	11.7	14.3
15	20	20	105	74	110	64	4.5	6.1	7.9	10.7	13.1
16	15	18	80	61	100	57	4.2	5.6	7.2	9.7	11.9
17	11	16	59	50	89	51	3.8	5.1	6.5	8.7	10.7
18	8	12	44	38	67	39	3.1	4.1	5.1	6.8	8.3
19	6	10	34	30	56	32	2.8	3.6	4.5	5.8	7.0
20	5	8	29	25	45	26	2.4	3.0	3.8	4.9	5.8
21	4	7	24	21	40	23	2.2	2.8	3.4	4.4	5.2
22	3	6	19	17	35	20	2.1	2.5	3.1	3.9	4.6
23	2	5	14	14	29	17	1.9	2.3	2.7	3.4	4.0
24	1	5	9	12	29	17	1.9	2.3	2.7	3.4	4.0

20yr combination						10 yr	100		50		20	
Kaituna	Waiari	Ohineangaanga	Raparapahoe	Kopuaroa	Bell Rd	Kaituna	Kopuaroa	Quarry A	Kopuaroa	Quarry A	Kopuaroa	Quarry A
271	64	39	64	39	7.8	206	37.5	22.5	31.3	18.8	24.4	14.6
28	5	2	5	2	1.0	28	1.3	0.8	1.3	0.8	1.3	0.8
29	5	2	5	2	1.0	29	1.4	0.8	1.4	0.8	1.3	0.8
30	5	2	5	2	1.0	29	1.5	0.9	1.5	0.9	1.4	0.9
34	6	3	6	3	1.2	32	2.1	1.3	2.0	1.2	1.8	1.1
43	9	4	9	4	1.4	39	3.5	2.1	3.1	1.9	2.7	1.6
60	13	7	13	7	1.9	51	6.0	3.6	5.2	3.1	4.3	2.6
86	19	11	19	11	2.6	71	9.9	6.0	8.4	5.1	6.8	4.1
192	45	27	45	27	5.6	148	25.7	15.4	21.5	12.9	16.8	10.1
267	63	38	63	38	7.7	203	36.8	22.1	30.7	18.4	24.0	14.4
271	64	39	64	39	7.8	206	37.5	22.5	31.3	18.8	24.4	14.6
267	63	38	63	38	7.7	203	36.8	22.1	30.7	18.4	24.0	14.4
231	54	33	54	33	6.7	177	31.6	19.0	26.4	15.8	20.6	12.4
183	43	26	43	26	5.3	142	24.4	14.6	20.4	12.2	16.0	9.6
143	33	20	33	20	4.2	112	18.5	11.1	15.5	9.3	12.2	7.3
117	27	16	27	16	3.5	93	14.5	8.7	12.2	7.3	9.7	5.8
97	22	13	22	13	2.9	79	11.6	6.9	9.8	5.9	7.8	4.7
84	19	11	19	11	2.6	69	9.6	5.8	8.2	4.9	6.6	3.9
71	15	9	15	9	2.2	59	7.6	4.6	6.5	3.9	5.3	3.2
60	13	7	13	7	1.9	51	6.0	3.6	5.2	3.1	4.3	2.6
49	10	5	10	5	1.6	43	4.3	2.6	3.8	2.3	3.2	1.9
40	8	4	8	4	1.3	37	3.0	1.8	2.7	1.6	2.4	1.4
35	7	3	7	3	1.2	33	2.4	1.4	2.2	1.3	2.0	1.2
33	6	3	6	3	1.1	32	2.0	1.2	1.9	1.1	1.8	1.1
							2.0	1.2	1.9	1.1	1.8	1.1
							2.0	1.2	1.9	1.1	1.8	1.1

Bell Rd	Bell Rd	Bell Rd
2yr	5yr	10yr
3.1	4.9	6.3
1.0	1.0	1.0
1.0	1.0	1.0
1.0	1.0	1.0
1.0	1.1	1.1
1.1	1.2	1.3
1.3	1.5	1.7
1.5	1.9	2.3
2.4	3.6	4.6
3.1	4.8	6.2
3.1	4.9	6.3
3.1	4.8	6.2
2.8	4.3	5.4
2.3	3.5	4.4
2.0	2.9	3.5
1.8	2.4	2.9
1.6	2.1	2.5
1.5	1.9	2.2
1.4	1.7	1.9
1.3	1.5	1.7
1.2	1.3	1.5
1.1	1.2	1.3
1.1	1.1	1.2
1.0	1.1	1.1

			Combined event			Individual event				
Return period	y variate	Q/Q_ assumed Q_	Waiari + Raparapahoe	Ohineangaanga + Kopuaroa	Bell (upper)	Waiari	Raparapah	Ohineanga	Kopuaroa	Bell (upper)
			31.2	18.9	3.8	39.1	33.9	22.4	19.5	4.0
2	0.37	0.79	25	15	3.0	30	27	18	15	3.2
2.33	0.58	0.87	27	17	3.3	33	30	20	17	3.5
5	1.50	1.32	41	25	5.0	44	45	29	26	5.2
10	2.25	1.79	56	34	6.8	55	61	40	35	7.1
20	2.97	2.33	73	44	8.8	72	79	52	46	9.3
50	3.90	3.17	99	60	12.0	98	107	71	62	12.6
100	4.60	3.89	122	74	14.7	120	132	87	76	15.5
200	5.30	4.70	147	89	17.8	145	160	105	92	18.7

Bell Rd: Flats, dunes and drains straight to pumps:10.60km^2. Note uncertainty in catchment boundary (dunes).
Remaining area = 18.9-10.6 = 8.3km2 = 44% of area
Peak 100yr flow from dunes/flats = 21.5 cumecs
Same parameters gives 12.0cumecs for drain = 33.5 cumecs peak for PMP shape 72hr storm.
Alternative recommended gives total of 37, so for same plains flow, need 15.5 cumecs peak flow for "individual" event

Adopted extreme tide frequencies

Annual Exceedance Probability	50%	20%	10%	5%	2%	1%
Equivalent Return Period	2yr	5yr	10yr	20yr	50yr	100yr
NIWA report: tides at Moturiki	1.26	1.38	1.49	1.62	1.85	2.06
Estuary effect	0.13	0.16	0.19	0.23	0.33	0.33
NIWA + Estuary	1.39	1.54	1.68	1.85	2.18	2.39
NIWA + Sea Level Rise	1.75	1.87	1.98	2.11	2.34	2.55
NIWA + Estuary + SLR	1.88	2.03	2.17	2.34	2.67	2.88

Storm surge							Examples	
Recorded Fergus	Assumed design	Time	Standard	Neap	Spring	Spring+gh	100yr+est+gh	2yr
		Range	1.37	1.3	1.7	1.7	1.37	1.37
	0	01/01/90 00:00	-0.48	-0.54	-0.72	-0.22	0.01	-0.48
	0	01/01/90 01:02	-0.38	-0.44	-0.60	-0.10	0.11	-0.38
	0	01/01/90 02:05	-0.18	-0.25	-0.35	0.15	0.31	-0.18
	0.01	01/01/90 03:07	0.18	0.09	0.09	0.59	0.68	0.18
	0.03	01/01/90 04:10	0.55	0.44	0.55	1.05	1.08	0.56
	0.05	01/01/90 05:13	0.75	0.63	0.80	1.30	1.31	0.77
	0.07	01/01/90 06:16	0.85	0.72	0.93	1.43	1.44	0.88
	0.09	01/01/90 07:19	0.75	0.63	0.80	1.30	1.37	0.79
	0.11	01/01/90 08:22	0.55	0.44	0.55	1.05	1.20	0.59
	0.13	01/01/90 09:25	0.16	0.07	0.07	0.57	0.84	0.21
	0.15	01/01/90 10:28	-0.22	-0.29	-0.40	0.10	0.49	-0.16
	0.17	01/01/90 11:31	-0.42	-0.48	-0.65	-0.15	0.32	-0.35
0	0.19	01/01/90 12:34	-0.52	-0.58	-0.77	-0.27	0.25	-0.44
0	0.21	01/01/90 13:37	-0.42	-0.48	-0.65	-0.15	0.38	-0.34
0	0.23	01/01/90 14:40	-0.22	-0.29	-0.40	0.10	0.61	-0.13
0	0.25	01/01/90 15:43	0.16	0.07	0.07	0.57	1.02	0.26
0	0.27	01/01/90 16:46	0.58	0.47	0.59	1.09	1.47	0.69
0.02	0.29	01/01/90 17:49	0.8	0.68	0.86	1.36	1.72	0.92
0.05	0.31	01/01/90 18:52	0.85	0.72	0.93	1.43	1.80	0.97
0.06	0.33	01/01/90 19:55	0.8	0.68	0.86	1.36	1.78	0.93
0.07	0.35	01/01/90 20:58	0.58	0.47	0.59	1.09	1.59	0.72
0.08	0.37	01/01/90 22:01	0.18	0.09	0.09	0.59	1.22	0.33
0.09	0.39	01/01/90 23:04	-0.18	-0.25	-0.35	0.15	0.89	-0.02
0.11	0.41	02/01/90 00:07	-0.38	-0.44	-0.60	-0.10	0.72	-0.22
0.12	0.43	02/01/90 01:10	-0.48	-0.54	-0.72	-0.22	0.65	-0.31
0.11	0.45	02/01/90 02:13	-0.38	-0.44	-0.60	-0.10	0.78	-0.20
0.09	0.47	02/01/90 03:16	-0.18	-0.25	-0.35	0.15	1.01	0.01
0.08	0.49	02/01/90 04:19	0.18	0.09	0.09	0.59	1.40	0.38
0.07	0.51	02/01/90 05:22	0.55	0.44	0.55	1.05	1.80	0.75
0.06	0.53	02/01/90 06:25	0.75	0.63	0.80	1.30	2.03	0.96
0.05	0.55	02/01/90 07:28	0.85	0.72	0.93	1.43	2.16	1.07
0.08	0.57	02/01/90 08:31	0.75	0.63	0.80	1.30	2.09	0.98
0.11	0.59	02/01/90 09:34	0.55	0.44	0.55	1.05	1.92	0.78
0.14	0.61	02/01/90 10:37	0.16	0.07	0.07	0.57	1.56	0.40
0.17	0.63	02/01/90 11:40	-0.22	-0.29	-0.40	0.10	1.21	0.03
0.2	0.65	02/01/90 12:43	-0.42	-0.48	-0.65	-0.15	1.04	-0.16
0.22	0.67	02/01/90 13:46	-0.52	-0.58	-0.77	-0.27	0.97	-0.25
0.24	0.69	02/01/90 14:49	-0.42	-0.48	-0.65	-0.15	1.10	-0.15
0.26	0.71	02/01/90 15:52	-0.22	-0.29	-0.40	0.10	1.33	0.06
0.27	0.73	02/01/90 16:55	0.16	0.07	0.07	0.57	1.74	0.45
0.28	0.75	02/01/90 17:58	0.58	0.47	0.59	1.09	2.19	0.88
0.3	0.77	02/01/90 19:01	0.8	0.68	0.86	1.36	2.44	1.11
0.32	0.79	02/01/90 20:04	0.85	0.72	0.93	1.43	2.52	1.16
0.33	0.81	02/01/90 21:07	0.8	0.68	0.86	1.36	2.50	1.12
0.35	0.83	02/01/90 22:10	0.58	0.47	0.59	1.09	2.31	0.91
0.36	0.85	02/01/90 23:13	0.18	0.09	0.09	0.59	1.94	0.52
0.38	0.87	03/01/90 00:16	-0.18	-0.25	-0.35	0.15	1.61	0.17
0.4	0.89	03/01/90 01:19	-0.38	-0.44	-0.60	-0.10	1.44	-0.03
0.41	0.91	03/01/90 02:22	-0.48	-0.54	-0.72	-0.22	1.37	-0.12
0.5	0.93	03/01/90 03:25	-0.38	-0.44	-0.60	-0.10	1.50	-0.01
0.6	0.95	03/01/90 04:28	-0.18	-0.25	-0.35	0.15	1.73	0.20
0.7	0.97	03/01/90 05:31	0.18	0.09	0.09	0.59	2.12	0.57
0.81	0.99	03/01/90 06:34	0.55	0.44	0.55	1.05	2.52	0.94

0.92	1.01	03/01/90 07:37	0.75	0.63	0.80	1.30	2.75	1.15
1.03	1.03	03/01/90 08:40	0.85	0.72	0.93	1.43	2.88	1.26
1.13	1.03	03/01/90 09:43	0.75	0.63	0.80	1.30	2.78	1.16
1.23	1.03	03/01/90 10:46	0.55	0.44	0.55	1.05	2.58	0.96
1.32	1.03	03/01/90 11:49	0.16	0.07	0.07	0.57	2.19	0.57
1.4	1.03	03/01/90 12:52	-0.22	-0.29	-0.40	0.10	1.81	0.19
1.5	1.03	03/01/90 13:55	-0.42	-0.48	-0.65	-0.15	1.61	-0.01
1.57	1.03	03/01/90 14:58	-0.52	-0.58	-0.77	-0.27	1.51	-0.11
1.4	1.03	03/01/90 16:01	-0.42	-0.48	-0.65	-0.15	1.61	-0.01
1.25	1.03	03/01/90 17:04	-0.22	-0.29	-0.40	0.10	1.81	0.19
1.1	1.03	03/01/90 18:07	0.16	0.07	0.07	0.57	2.19	0.57
0.95	1.03	03/01/90 19:10	0.58	0.47	0.59	1.09	2.61	0.99
0.8	1.03	03/01/90 20:13	0.8	0.68	0.86	1.36	2.83	1.21
0.6	1.03	03/01/90 21:16	0.85	0.72	0.93	1.43	2.88	1.26
0.62	1.01	03/01/90 22:19	0.8	0.68	0.86	1.36	2.80	1.20
0.64	0.99	03/01/90 23:22	0.58	0.47	0.59	1.09	2.55	0.97
0.67	0.97	04/01/90 00:25	0.18	0.09	0.09	0.59	2.12	0.57
0.7	0.95	04/01/90 01:28	-0.18	-0.25	-0.35	0.15	1.73	0.20
0.72	0.93	04/01/90 02:31	-0.38	-0.44	-0.60	-0.10	1.50	-0.01
0.75	0.91	04/01/90 03:34	-0.48	-0.54	-0.72	-0.22	1.37	-0.12
0.65	0.89	04/01/90 04:37	-0.38	-0.44	-0.60	-0.10	1.44	-0.03
0.55	0.87	04/01/90 05:40	-0.18	-0.25	-0.35	0.15	1.61	0.17
0.45	0.85	04/01/90 06:43	0.18	0.09	0.09	0.59	1.94	0.52
0.35	0.83	04/01/90 07:46	0.55	0.44	0.55	1.05	2.28	0.88
0.25	0.81	04/01/90 08:49	0.75	0.63	0.80	1.30	2.45	1.07
0.17	0.79	04/01/90 09:52	0.85	0.72	0.93	1.43	2.52	1.16
0.22	0.77	04/01/90 10:55	0.75	0.63	0.80	1.30	2.39	1.06
0.28	0.75	04/01/90 11:58	0.55	0.44	0.55	1.05	2.16	0.85
0.34	0.73	04/01/90 13:01	0.16	0.07	0.07	0.57	1.74	0.45
0.4	0.71	04/01/90 14:04	-0.22	-0.29	-0.40	0.10	1.33	0.06
0.46	0.69	04/01/90 15:07	-0.42	-0.48	-0.65	-0.15	1.10	-0.15
0.52	0.67	04/01/90 16:10	-0.52	-0.58	-0.77	-0.27	0.97	-0.25
0.44	0.65	04/01/90 17:13	-0.42	-0.48	-0.65	-0.15	1.04	-0.16
0.35	0.63	04/01/90 18:16	-0.22	-0.29	-0.40	0.10	1.21	0.03
0.26	0.61	04/01/90 19:19	0.16	0.07	0.07	0.57	1.56	0.40
0.17	0.59	04/01/90 20:22	0.58	0.47	0.59	1.09	1.95	0.81
0.1	0.57	04/01/90 21:25	0.8	0.68	0.86	1.36	2.14	1.03
0.02	0.55	04/01/90 22:28	0.85	0.72	0.93	1.43	2.16	1.07
0.06	0.53	04/01/90 23:31	0.8	0.68	0.86	1.36	2.08	1.01
0.1	0.51	05/01/90 00:34	0.58	0.47	0.59	1.09	1.83	0.78
0.15	0.49	05/01/90 01:37	0.18	0.09	0.09	0.59	1.40	0.38
0.2	0.47	05/01/90 02:40	-0.18	-0.25	-0.35	0.15	1.01	0.01
0.24	0.45	05/01/90 03:43	-0.38	-0.44	-0.60	-0.10	0.78	-0.20
0.28	0.43	05/01/90 04:46	-0.48	-0.54	-0.72	-0.22	0.65	-0.31
0.23	0.41	05/01/90 05:49	-0.38	-0.44	-0.60	-0.10	0.72	-0.22
0.18	0.39	05/01/90 06:52	-0.18	-0.25	-0.35	0.15	0.89	-0.02
0.13	0.37	05/01/90 07:55	0.18	0.09	0.09	0.59	1.22	0.33
0.09	0.35	05/01/90 08:58	0.55	0.44	0.55	1.05	1.56	0.69
0.05	0.33	05/01/90 10:01	0.75	0.63	0.80	1.30	1.73	0.88
0	0.31	05/01/90 11:04	0.85	0.72	0.93	1.43	1.80	0.97
	0.29	05/01/90 12:07	0.75	0.63	0.80	1.30	1.67	0.87
	0.27	05/01/90 13:09	0.55	0.44	0.55	1.05	1.44	0.66
	0.25	05/01/90 14:12	0.16	0.07	0.07	0.57	1.02	0.26
	0.23	05/01/90 15:15	-0.22	-0.29	-0.40	0.10	0.61	-0.13
	0.21	05/01/90 16:18	-0.42	-0.48	-0.65	-0.15	0.38	-0.34
	0.19	05/01/90 17:21	-0.52	-0.58	-0.77	-0.27	0.25	-0.44
	0.17	05/01/90 18:24	-0.42	-0.48	-0.65	-0.15	0.32	-0.35
	0.15	05/01/90 19:27	-0.22	-0.29	-0.40	0.10	0.49	-0.16
	0.13	05/01/90 20:30	0.16	0.07	0.07	0.57	0.84	0.21
	0.11	05/01/90 21:33	0.58	0.47	0.59	1.09	1.23	0.62
	0.09	05/01/90 22:36	0.8	0.68	0.86	1.36	1.42	0.84
	0.07	05/01/90 23:39	0.85	0.72	0.93	1.43	1.44	0.88
	0.05	06/01/90 00:42	0.8	0.68	0.86	1.36	1.36	0.82
	0.03	06/01/90 01:45	0.58	0.47	0.59	1.09	1.11	0.59
	0.01	06/01/90 02:48	0.18	0.09	0.09	0.59	0.68	0.18
	0	06/01/90 03:51	-0.18	-0.25	-0.35	0.15	0.31	-0.18
	0	06/01/90 04:54	-0.34	-0.40	-0.55	-0.05	0.15	-0.34
	0	06/01/90 05:57	-0.48	-0.54	-0.72	-0.22	0.01	-0.48

Rainfall - runoff assumptions for plains areas of Kaituna River Model

Name	Arawa	Singletons	Maketu Rd/Ford Rd	Maketu Rd/Ford Rd 2	Right FP	WaiPar FP	WaiO FP	RapO FP	RapKop FF	Bell Rd A	Bell Rd B	Total
Rural - High water table	0.32	6.28	8.16	4.44	10.6	2.56	3.16	2.36	3.83	5.95	2.65	50.31
Rural - Low water table	0.8	4.56	4.4	2.28	1.32	1.41		1.14			2.00	17.91
Urban							2.13	1.28				3.41
Total	1.12	10.84	12.56	6.72	11.92	3.97	5.29	4.78	3.83	5.95	4.65	71.63
Peak Flow Rate (100yr 72hr)	1.8	20.2	24.0	12.9	24.9	7.6	11.2	9.3	8.3	12.9	8.6	141.7

Rainfall - runoff assumptions for plains subcatchments; from HIRDS @ Te Matai						
%AEP	50%	20%	10%	5%	2%	1%
Return Period	2yr	5yr	10yr	20yr	50yr	100yr
Total 72hr rainfall	172	229	266	303	349	384
Total 72hr runoff, high water t	76	133	170	207	253	268
Rate (mm/day), high water tal	25	44	57	69	84	96
Runoff coefficient, high water	44%	58%	64%	68%	72%	75%
Runoff coefficient, low water t	29%	39%	42%	45%	48%	50%
Runoff coefficient, urban	49%	59%	62%	65%	68%	70%

1. Maximum rainfall losses to storage, vegetation retention and evaporation over a three day period are 96.5mm as in previous reports (ref Whakatane Major Scheme Vol 2 App. 10)
2. Temporal distribution of rainfall as per 72hr event in "A Guide to Probable Maximum Precipitation in New Zealand (Thompson and Tomlinson, NIWA, 1995)[illegible]
3. Rainfall as per the HIRDS software (NIWA's High Intensity Rainfall Design System) at Te Matai. Note that recorded rainfalls are similar for 24hr events, but are less than HIRDS for longer duration events. The rainfall record at Te Matai is only 9 years long, so is not reliable for extreme events
Note also that it is anticipated that rainfall is progressively less closer to the coast, but the Te Matai figures have been used over all the plains. The scheme report showed a 48hr design isohyet map with about 40mm less rainfall at the coast than at Te Puke.

Time (hrs)	% of rainfall		2yr Arawa	Singletons	Maketu/Ford Rd 1	Maketu Rd/Ford Rd 2	Right FP	WaiPar FP	WaiO FP	RapO FP	RapKop FF	Bell Rd A	Bell Rd B	Total
		Runoff Volume (000's of m3)	64	704	838	450	867	264	419	344	289	449	301	4989
		Max flow rate	0.5	5.3	6.3	3.4	6.5	2.0	3.2	2.6	2.2	3.4	2.3	37.6
0	0.00	Flow rates (m^3/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.04		0.01	0.08	0.09	0.05	0.10	0.03	0.05	0.04	0.03	0.05	0.03	0.55
2	0.08		0.01	0.16	0.19	0.10	0.19	0.06	0.09	0.08	0.06	0.10	0.07	1.11
3	0.12		0.02	0.23	0.28	0.15	0.29	0.09	0.14	0.11	0.10	0.15	0.10	1.66
4	0.16		0.03	0.31	0.37	0.20	0.39	0.12	0.19	0.15	0.13	0.20	0.13	2.22
5	0.20		0.04	0.39	0.47	0.25	0.48	0.15	0.23	0.19	0.16	0.25	0.17	2.77
6	0.24		0.04	0.47	0.56	0.30	0.58	0.18	0.28	0.23	0.19	0.30	0.20	3.33
7	0.28		0.05	0.55	0.65	0.35	0.67	0.21	0.33	0.27	0.22	0.35	0.23	3.88
8	0.32		0.06	0.63	0.74	0.40	0.77	0.23	0.37	0.31	0.26	0.40	0.27	4.43
9	0.36		0.06	0.70	0.84	0.45	0.87	0.26	0.42	0.34	0.29	0.45	0.30	4.99
10	0.40		0.07	0.78	0.93	0.50	0.96	0.29	0.47	0.38	0.32	0.50	0.33	5.54
11	0.47		0.08	0.93	1.10	0.59	1.14	0.35	0.55	0.45	0.38	0.59	0.40	6.58
12	0.56		0.10	1.09	1.29	0.69	1.34	0.41	0.65	0.53	0.45	0.69	0.46	7.69
13	0.65		0.12	1.26	1.50	0.81	1.55	0.47	0.75	0.62	0.52	0.81	0.54	8.95
14	0.74		0.13	1.46	1.73	0.93	1.79	0.55	0.87	0.71	0.60	0.93	0.62	10.32
15	0.85		0.15	1.66	1.98	1.06	2.05	0.62	0.99	0.81	0.68	1.06	0.71	11.79
16	0.96		0.17	1.88	2.24	1.20	2.32	0.71	1.12	0.92	0.77	1.20	0.80	13.34
17	1.08		0.19	2.11	2.51	1.35	2.60	0.79	1.25	1.03	0.87	1.35	0.90	14.94
18	1.20		0.21	2.34	2.78	1.50	2.88	0.88	1.39	1.14	0.96	1.49	1.00	16.58
19	1.32		0.24	2.57	3.06	1.65	3.17	0.97	1.53	1.26	1.06	1.64	1.10	18.24
20	1.44		0.26	2.81	3.34	1.80	3.46	1.05	1.67	1.37	1.15	1.79	1.20	19.91
21	1.56		0.28	3.04	3.62	1.95	3.75	1.14	1.81	1.49	1.25	1.94	1.30	21.57
22	1.67		0.30	3.27	3.90	2.09	4.03	1.23	1.95	1.60	1.35	2.09	1.40	23.21
23	1.79		0.32	3.50	4.16	2.24	4.31	1.31	2.08	1.71	1.44	2.23	1.50	24.81
24	1.90		0.34	3.72	4.42	2.38	4.58	1.40	2.21	1.82	1.53	2.37	1.59	26.35
25	2.01		0.36	3.93	4.67	2.51	4.84	1.47	2.34	1.92	1.61	2.51	1.68	27.84
26	2.11		0.38	4.13	4.91	2.64	5.08	1.55	2.46	2.02	1.70	2.63	1.76	29.25
27	2.21		0.39	4.31	5.13	2.76	5.31	1.62	2.57	2.11	1.77	2.75	1.84	30.57
28	2.30		0.41	4.49	5.34	2.87	5.53	1.68	2.67	2.19	1.84	2.86	1.92	31.81
29	2.38		0.43	4.65	5.53	2.97	5.72	1.74	2.77	2.27	1.91	2.97	1.99	32.94
30	2.45		0.44	4.79	5.70	3.06	5.90	1.80	2.85	2.34	1.97	3.06	2.05	33.96
31	2.52		0.45	4.92	5.85	3.14	6.06	1.85	2.93	2.40	2.02	3.14	2.10	34.86
32	2.57		0.46	5.03	5.98	3.21	6.19	1.89	2.99	2.46	2.07	3.21	2.15	35.64
33	2.62		0.47	5.12	6.09	3.27	6.31	1.92	3.05	2.50	2.10	3.27	2.19	36.30
34	2.66		0.48	5.19	6.18	3.32	6.40	1.95	3.09	2.54	2.13	3.32	2.22	36.82
35	2.69		0.48	5.25	6.25	3.36	6.47	1.97	3.13	2.57	2.16	3.35	2.24	37.21
36	2.70		0.48	5.28	6.29	3.38	6.51	1.98	3.15	2.58	2.17	3.37	2.26	37.47
37	2.71		0.49	5.30	6.31	3.39	6.53	1.99	3.16	2.59	2.18	3.38	2.27	37.58
38	2.71		0.49	5.30	6.31	3.39	6.53	1.99	3.15	2.59	2.18	3.38	2.26	37.56
39	2.70		0.48	5.27	6.28	3.37	6.50	1.98	3.14	2.58	2.17	3.37	2.25	37.40
40	2.68		0.48	5.23	6.23	3.35	6.45	1.97	3.12	2.56	2.15	3.34	2.24	37.10
41	2.65		0.47	5.17	6.16	3.31	6.37	1.94	3.08	2.53	2.13	3.30	2.21	36.66
42	2.60		0.47	5.09	6.06	3.26	6.27	1.91	3.03	2.49	2.09	3.25	2.18	36.10
43	2.55		0.46	4.99	5.94	3.19	6.15	1.88	2.97	2.44	2.05	3.19	2.13	35.41
44	2.50		0.45	4.88	5.81	3.12	6.01	1.83	2.91	2.39	2.00	3.11	2.09	34.59
45	2.43		0.43	4.75	5.65	3.04	5.85	1.78	2.83	2.32	1.95	3.03	2.03	33.65
46	2.35		0.42	4.60	5.47	2.94	5.66	1.73	2.74	2.25	1.89	2.94	1.97	32.61
47	2.27		0.41	4.44	5.28	2.84	5.47	1.67	2.64	2.17	1.82	2.83	1.90	31.46
48	2.18		0.39	4.26	5.07	2.72	5.25	1.60	2.54	2.08	1.75	2.72	1.82	30.21
49	2.08		0.37	4.07	4.85	2.60	5.02	1.53	2.43	1.99	1.67	2.60	1.74	28.88
50	1.98		0.35	3.87	4.61	2.48	4.77	1.45	2.31	1.89	1.59	2.47	1.66	27.47
51	1.88		0.34	3.67	4.36	2.34	4.52	1.38	2.18	1.79	1.51	2.34	1.57	25.99
52	1.77		0.32	3.45	4.11	2.21	4.25	1.30	2.05	1.69	1.42	2.20	1.47	24.46
53	1.65		0.30	3.23	3.84	2.06	3.98	1.21	1.92	1.58	1.33	2.06	1.38	22.89
54	1.54		0.27	3.00	3.57	1.92	3.70	1.13	1.79	1.47	1.23	1.92	1.28	21.29
55	1.42		0.25	2.78	3.30	1.77	3.42	1.04	1.65	1.36	1.14	1.77	1.19	19.68
56	1.30		0.23	2.55	3.03	1.63	3.14	0.96	1.52	1.25	1.05	1.63	1.09	18.07
57	1.19		0.21	2.32	2.77	1.49	2.86	0.87	1.38	1.14	0.95	1.48	0.99	16.47
58	1.08		0.19	2.10	2.50	1.35	2.59	0.79	1.25	1.03	0.86	1.34	0.90	14.91
59	0.97		0.17	1.89	2.25	1.21	2.33	0.71	1.13	0.92	0.78	1.21	0.81	13.41
60	0.86		0.15	1.69	2.01	1.08	2.08	0.63	1.01	0.83	0.69	1.08	0.72	11.97
61	0.77		0.14	1.50	1.78	0.96	1.85	0.56	0.89	0.73	0.62	0.96	0.64	10.63
62	0.68		0.12	1.33	1.58	0.85	1.63	0.50	0.79	0.65	0.54	0.85	0.57	9.40
63	0.60		0.11	1.17	1.39	0.75	1.44	0.44	0.70	0.57	0.48	0.75	0.50	8.30
64	0.53		0.09	1.04	1.23	0.66	1.28	0.39	0.62	0.51	0.43	0.66	0.44	7.35
65	0.45		0.08	0.88	1.05	0.56	1.08	0.33	0.52	0.43	0.36	0.56	0.38	6.24
66	0.35		0.06	0.68	0.81	0.44	0.84	0.26	0.41	0.33	0.28	0.44	0.29	4.85
67	0.29		0.05	0.57	0.67	0.36	0.70	0.21	0.34	0.28	0.23	0.36	0.24	4.02
68	0.24		0.04	0.47	0.56	0.30	0.58	0.18	0.28	0.23	0.19	0.30	0.20	3.33
69	0.19		0.03	0.37	0.44	0.24	0.46	0.14	0.22	0.18	0.15	0.24	0.16	2.63
70	0.14		0.03	0.27	0.33	0.17	0.34	0.10	0.16	0.13	0.11	0.17	0.12	1.94
71	0.09		0.02	0.18	0.21	0.11	0.22	0.07	0.10	0.09	0.07	0.11	0.08	1.25
72	0.05		0.01	0.10	0.12	0.06	0.12	0.04	0.06	0.05	0.04	0.06	0.04	0.69
			0											

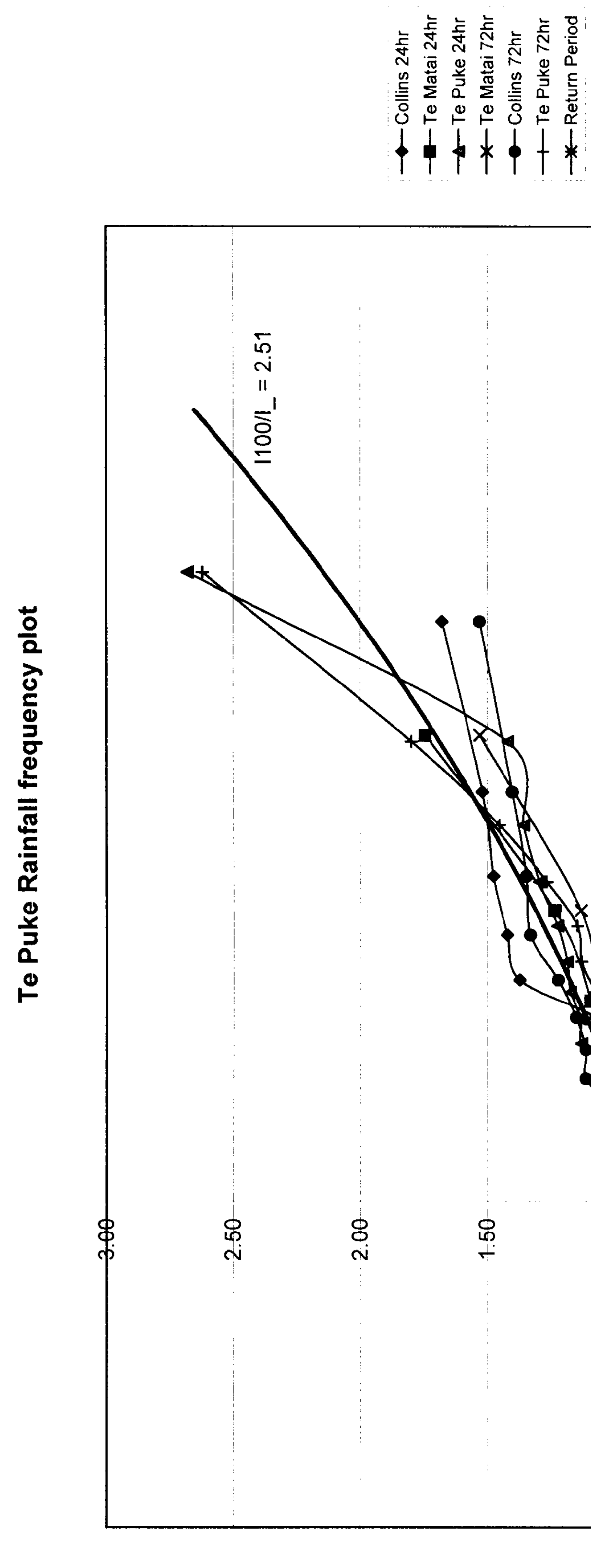
Time (hrs)	% of rainfall		5yr Arawa	Singletons	Maketu/Fo	Maketu Rd	Right FP	WaiPar FP	WaiO FP	RapO FP	RapKop FF	Bell Rd A	Bell Rd B	Total
		Runoff Volume (000's of m3)	113	1235	1470	790	1521	464	704	585	507	788	528	6178
		Max flow rate	0.9	9.3	11.1	5.9	11.5	3.5	5.3	4.4	3.8	5.9	4.0	65.6
0	0.00	Flow rates (m^3/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.04		0.01	0.14	0.16	0.09	0.17	0.05	0.08	0.07	0.06	0.09	0.06	0.97
2	0.08		0.03	0.27	0.33	0.18	0.34	0.10	0.16	0.13	0.11	0.18	0.12	1.93
3	0.12		0.04	0.41	0.49	0.26	0.51	0.15	0.23	0.20	0.17	0.26	0.18	2.90
4	0.16		0.05	0.55	0.65	0.35	0.68	0.21	0.31	0.26	0.23	0.35	0.23	3.87
5	0.20		0.06	0.69	0.82	0.44	0.85	0.26	0.39	0.33	0.28	0.44	0.29	4.84
6	0.24		0.08	0.82	0.98	0.53	1.01	0.31	0.47	0.39	0.34	0.53	0.35	5.80
7	0.28		0.09	0.96	1.14	0.61	1.18	0.36	0.55	0.46	0.39	0.61	0.41	6.77
8	0.32		0.10	1.10	1.31	0.70	1.35	0.41	0.63	0.52	0.45	0.70	0.47	7.74
9	0.36		0.11	1.23	1.47	0.79	1.52	0.46	0.70	0.59	0.51	0.79	0.53	8.71
10	0.40		0.13	1.37	1.63	0.88	1.69	0.52	0.78	0.65	0.56	0.88	0.59	9.67
11	0.47		0.15	1.63	1.94	1.04	2.01	0.61	0.93	0.77	0.67	1.04	0.70	11.48
12	0.56		0.17	1.90	2.27	1.22	2.35	0.72	1.09	0.90	0.78	1.22	0.81	13.43
13	0.65		0.20	2.22	2.64	1.42	2.73	0.83	1.26	1.05	0.91	1.41	0.95	15.62
14	0.74		0.23	2.56	3.04	1.63	3.15	0.96	1.46	1.21	1.05	1.63	1.09	18.01
15	0.85		0.27	2.92	3.47	1.87	3.60	1.10	1.66	1.38	1.20	1.86	1.25	20.58
16	0.96		0.30	3.30	3.93	2.11	4.07	1.24	1.88	1.56	1.36	2.11	1.41	23.27
17	1.08		0.34	3.70	4.40	2.36	4.55	1.39	2.11	1.75	1.52	2.36	1.58	26.07
18	1.20		0.38	4.10	4.89	2.62	5.06	1.54	2.34	1.94	1.69	2.62	1.75	28.93
19	1.32		0.41	4.52	5.38	2.89	5.56	1.70	2.58	2.14	1.86	2.88	1.93	31.84
20	1.44		0.45	4.93	5.87	3.15	6.07	1.85	2.81	2.34	2.03	3.15	2.11	34.75
21	1.56		0.49	5.34	6.36	3.42	6.58	2.01	3.05	2.53	2.19	3.41	2.28	37.65
22	1.67		0.53	5.75	6.84	3.67	7.08	2.16	3.28	2.72	2.36	3.67	2.46	40.50
23	1.79		0.56	6.14	7.31	3.93	7.56	2.31	3.50	2.91	2.52	3.92	2.62	43.29
24	1.90		0.60	6.52	7.76	4.17	8.04	2.45	3.72	3.09	2.68	4.16	2.79	45.99
25	2.01		0.63	6.89	8.20	4.41	8.49	2.59	3.93	3.26	2.83	4.40	2.95	48.58
26	2.11		0.66	7.24	8.62	4.63	8.92	2.72	4.13	3.43	2.98	4.62	3.09	51.04
27	2.21		0.69	7.57	9.01	4.84	9.32	2.84	4.32	3.59	3.11	4.83	3.23	53.35
28	2.30		0.72	7.87	9.37	5.03	9.70	2.96	4.49	3.73	3.24	5.03	3.36	55.50
29	2.38		0.75	8.15	9.70	5.21	10.04	3.06	4.65	3.86	3.35	5.20	3.48	57.47
30	2.45		0.77	8.41	10.00	5.38	10.35	3.16	4.79	3.98	3.45	5.37	3.59	59.25
31	2.52		0.79	8.63	10.27	5.52	10.63	3.24	4.92	4.09	3.55	5.51	3.69	60.83
32	2.57		0.81	8.82	10.50	5.64	10.87	3.31	5.03	4.18	3.63	5.63	3.77	62.20
33	2.62		0.82	8.98	10.69	5.75	11.07	3.37	5.13	4.26	3.69	5.74	3.84	63.34
34	2.66		0.83	9.11	10.85	5.83	11.23	3.42	5.20	4.32	3.75	5.82	3.90	64.25
35	2.69		0.84	9.21	10.96	5.89	11.35	3.46	5.25	4.36	3.79	5.88	3.94	64.94
36	2.70		0.85	9.27	11.04	5.93	11.42	3.48	5.29	4.39	3.81	5.92	3.96	65.38
37	2.71		0.85	9.30	11.07	5.95	11.46	3.49	5.31	4.41	3.82	5.94	3.98	65.58
38	2.71		0.85	9.30	11.07	5.95	11.45	3.49	5.30	4.40	3.82	5.94	3.97	65.54
39	2.70		0.85	9.26	11.02	5.92	11.40	3.48	5.28	4.39	3.80	5.91	3.96	65.26
40	2.68		0.84	9.18	10.93	5.87	11.31	3.45	5.24	4.35	3.77	5.86	3.92	64.74
41	2.65		0.83	9.06	10.80	5.80	11.18	3.41	5.18	4.30	3.73	5.79	3.88	63.98
42	2.60		0.82	8.94	10.64	5.71	11.01	3.36	5.10	4.23	3.67	5.70	3.82	62.99
43	2.55		0.80	8.76	10.43	5.60	10.80	3.29	5.00	4.15	3.60	5.60	3.75	61.78
44	2.50		0.78	8.56	10.19	5.48	10.55	3.22	4.88	4.06	3.52	5.47	3.66	60.36
45	2.43		0.76	8.33	9.92	5.33	10.26	3.13	4.75	3.95	3.42	5.32	3.56	58.72
46	2.35		0.74	8.07	9.61	5.16	9.94	3.03	4.60	3.82	3.32	5.15	3.45	56.90
47	2.27		0.71	7.79	9.27	4.98	9.59	2.92	4.44	3.69	3.20	4.97	3.33	54.89
48	2.18		0.68	7.48	8.90	4.78	9.21	2.81	4.27	3.54	3.07	4.77	3.20	52.72
49	2.08		0.65	7.15	8.51	4.57	8.80	2.68	4.08	3.39	2.94	4.56	3.06	50.39
50	1.98		0.62	6.80	8.09	4.35	8.37	2.55	3.88	3.22	2.79	4.34	2.91	47.93
51	1.88		0.59	6.43	7.66	4.11	7.92	2.42	3.67	3.05	2.64	4.11	2.75	45.36
52	1.77		0.55	6.06	7.21	3.87	7.46	2.27	3.45	2.87	2.49	3.87	2.59	42.69
53	1.65		0.52	5.67	6.74	3.62	6.98	2.13	3.23	2.68	2.33	3.62	2.42	39.94
54	1.54		0.48	5.27	6.27	3.37	6.49	1.98	3.01	2.50	2.17	3.36	2.25	37.15
55	1.42		0.45	4.87	5.80	3.12	6.00	1.83	2.78	2.31	2.00	3.11	2.08	34.34
56	1.30		0.41	4.47	5.32	2.86	5.51	1.68	2.55	2.12	1.84	2.86	1.91	31.53
57	1.19		0.37	4.08	4.85	2.61	5.02	1.53	2.33	1.93	1.68	2.60	1.74	28.75
58	1.08		0.34	3.69	4.39	2.36	4.55	1.39	2.11	1.75	1.52	2.36	1.58	26.03
59	0.97		0.30	3.32	3.95	2.12	4.09	1.25	1.89	1.57	1.36	2.12	1.42	23.40
60	0.86		0.27	2.98	3.53	1.90	3.65	1.11	1.69	1.40	1.22	1.89	1.27	20.89
61	0.77		0.24	2.63	3.13	1.68	3.24	0.99	1.50	1.25	1.08	1.68	1.12	18.55
62	0.68		0.21	2.33	2.77	1.49	2.86	0.87	1.33	1.10	0.96	1.48	0.99	16.40
63	0.60		0.19	2.05	2.44	1.31	2.53	0.77	1.17	0.97	0.84	1.31	0.88	14.48
64	0.53		0.17	1.82	2.17	1.16	2.24	0.68	1.04	0.86	0.75	1.16	0.78	12.83
65	0.45		0.14	1.54	1.84	0.99	1.90	0.58	0.88	0.73	0.63	0.99	0.66	10.88
66	0.35		0.11	1.20	1.43	0.77	1.48	0.45	0.68	0.57	0.49	0.77	0.51	8.46
67	0.29		0.09	0.99	1.18	0.64	1.23	0.37	0.57	0.47	0.41	0.64	0.43	7.01
68	0.24		0.08	0.82	0.98	0.53	1.01	0.31	0.47	0.39	0.34	0.53	0.35	5.80
69	0.19		0.06	0.65	0.78	0.42	0.80	0.24	0.37	0.31	0.27	0.42	0.28	4.59
70	0.14		0.04	0.48	0.57	0.31	0.59	0.18	0.27	0.23	0.20	0.31	0.21	3.39
71	0.09		0.03	0.31	0.37	0.20	0.38	0.12	0.18	0.15	0.13	0.20	0.13	2.18
72	0.05		0.02	0.17	0.20	0.11	0.21	0.06	0.10	0.08	0.07	0.11	0.07	1.21

Time (hrs)	% of rainfall		10yr Arawa	Singletons	Maketu/Fo	Maketu Rd	Right FP	WaiPar FP	WaiO FP	RapO FP	RapKop FF	Bell Rd A	Bell Rd B	Total
		Runoff Volume (000's of m3)	145	1580	1880	1010	1946	593	890	742	649	1009	675	11118
		Max flow rate	1.1	11.9	14.2	7.6	14.7	4.5	6.7	5.6	4.9	7.6	5.1	83.8
0	0.00	Flow rates (m^3/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.04		0.02	0.18	0.21	0.11	0.22	0.07	0.10	0.08	0.07	0.11	0.08	1.24
2	0.08		0.03	0.35	0.42	0.22	0.43	0.13	0.20	0.16	0.14	0.22	0.15	2.47
3	0.12		0.05	0.53	0.63	0.34	0.65	0.20	0.30	0.25	0.22	0.34	0.23	3.71
4	0.16		0.06	0.70	0.84	0.45	0.86	0.26	0.40	0.33	0.29	0.45	0.30	4.94
5	0.20		0.08	0.88	1.04	0.56	1.08	0.33	0.49	0.41	0.36	0.56	0.38	6.18
6	0.24		0.10	1.05	1.25	0.67	1.30	0.40	0.59	0.49	0.43	0.67	0.45	7.41
7	0.28		0.11	1.23	1.46	0.79	1.51	0.46	0.69	0.58	0.50	0.78	0.53	8.65
8	0.32		0.13	1.40	1.67	0.90	1.73	0.53	0.79	0.66	0.58	0.90	0.60	9.88
9	0.36		0.14	1.58	1.88	1.01	1.95	0.59	0.89	0.74	0.65	1.01	0.68	11.12
10	0.40		0.16	1.76	2.09	1.12	2.16	0.66	0.99	0.82	0.72	1.12	0.75	12.35
11	0.47		0.19	2.08	2.48	1.33	2.57	0.78	1.17	0.98	0.86	1.33	0.89	14.66
12	0.56		0.22	2.44	2.90	1.56	3.00	0.92	1.37	1.14	1.00	1.56	1.04	17.15
13	0.65		0.26	2.83	3.37	1.81	3.49	1.06	1.60	1.33	1.16	1.81	1.21	19.95
14	0.74		0.30	3.27	3.89	2.09	4.03	1.23	1.84	1.53	1.34	2.09	1.40	23.00
15	0.85		0.34	3.73	4.44	2.39	4.60	1.40	2.10	1.75	1.53	2.38	1.60	26.28
16	0.96		0.39	4.22	5.03	2.70	5.20	1.59	2.38	1.98	1.74	2.70	1.80	29.72
17	1.08		0.43	4.73	5.63	3.03	5.83	1.78	2.66	2.22	1.94	3.02	2.02	33.29
18	1.20		0.48	5.25	6.25	3.36	6.47	1.97	2.96	2.46	2.16	3.35	2.24	36.95
19	1.32		0.53	5.78	6.88	3.69	7.12	2.17	3.25	2.71	2.37	3.69	2.47	40.66
20	1.44		0.58	6.31	7.51	4.03	7.77	2.37	3.55	2.96	2.59	4.03	2.70	44.38
21	1.56		0.63	6.83	8.13	4.37	8.41	2.57	3.85	3.21	2.81	4.36	2.92	48.08
22	1.67		0.67	7.35	8.75	4.70	9.05	2.76	4.14	3.45	3.02	4.69	3.14	51.73
23	1.79		0.72	7.86	9.35	5.02	9.68	2.95	4.42	3.69	3.23	5.01	3.36	55.29
24	1.90		0.76	8.35	9.93	5.34	10.28	3.13	4.70	3.92	3.43	5.33	3.57	58.73
25	2.01		0.81	8.81	10.49	5.64	10.86	3.31	4.96	4.14	3.62	5.63	3.77	62.04
26	2.11		0.85	9.26	11.02	5.92	11.41	3.48	5.22	4.35	3.81	5.91	3.96	65.18
27	2.21		0.89	9.68	11.52	6.19	11.92	3.64	5.45	4.54	3.98	6.18	4.14	68.14
28	2.30		0.92	10.07	11.99	6.44	12.41	3.78	5.67	4.73	4.14	6.43	4.30	70.88
29	2.38		0.95	10.43	12.41	6.67	12.85	3.92	5.87	4.90	4.29	6.66	4.46	73.40
30	2.45		0.98	10.75	12.80	6.88	13.24	4.04	6.06	5.05	4.42	6.86	4.60	75.67
31	2.52		1.01	11.04	13.14	7.06	13.60	4.15	6.22	5.18	4.54	7.05	4.72	77.69
32	2.57		1.03	11.29	13.43	7.22	13.90	4.24	6.36	5.30	4.64	7.21	4.82	79.43
33	2.62		1.05	11.49	13.68	7.36	14.16	4.32	6.47	5.40	4.72	7.34	4.91	80.89
34	2.66		1.07	11.68	13.88	7.46	14.36	4.38	6.57	5.47	4.79	7.44	4.98	82.06
35	2.69		1.08	11.78	14.03	7.54	14.51	4.43	6.64	5.53	4.84	7.52	5.04	82.93
36	2.70		1.09	11.86	14.12	7.59	14.61	4.46	6.68	5.57	4.88	7.57	5.07	83.50
37	2.71		1.09	11.90	14.16	7.61	14.66	4.47	6.70	5.59	4.89	7.60	5.09	83.75
38	2.71		1.09	11.89	14.16	7.61	14.65	4.47	6.70	5.58	4.89	7.59	5.08	83.70
39	2.70		1.08	11.84	14.09	7.57	14.59	4.45	6.67	5.56	4.87	7.56	5.06	83.34
40	2.68		1.08	11.75	13.98	7.51	14.47	4.41	6.62	5.51	4.83	7.50	5.02	82.68
41	2.65		1.06	11.61	13.82	7.42	14.30	4.36	6.54	5.45	4.77	7.41	4.96	81.71
42	2.60		1.05	11.43	13.61	7.31	14.08	4.29	6.44	5.37	4.70	7.30	4.89	80.45
43	2.55		1.03	11.21	13.34	7.17	13.81	4.21	6.31	5.26	4.61	7.16	4.79	78.90
44	2.50		1.00	10.95	13.04	7.00	13.49	4.11	6.17	5.14	4.50	6.99	4.68	77.08
45	2.43		0.98	10.66	12.68	6.81	13.13	4.00	6.00	5.00	4.38	6.80	4.55	75.00
46	2.35		0.95	10.33	12.29	6.60	12.72	3.88	5.81	4.85	4.24	6.59	4.41	72.67
47	2.27		0.91	9.96	11.86	6.37	12.27	3.74	5.61	4.68	4.09	6.36	4.26	70.10
48	2.18		0.88	9.57	11.39	6.12	11.78	3.59	5.39	4.49	3.93	6.11	4.09	67.33
49	2.08		0.84	9.14	10.88	5.85	11.26	3.43	5.15	4.29	3.76	5.84	3.91	64.36
50	1.98		0.80	8.70	10.35	5.56	10.71	3.27	4.90	4.08	3.57	5.55	3.72	61.21
51	1.88		0.75	8.23	9.80	5.26	10.14	3.09	4.63	3.86	3.38	5.25	3.52	57.93
52	1.77		0.71	7.75	9.22	4.95	9.54	2.91	4.36	3.64	3.18	4.95	3.31	54.52
53	1.65		0.66	7.25	8.63	4.64	8.93	2.72	4.08	3.40	2.98	4.63	3.10	51.01
54	1.54		0.62	6.74	8.02	4.31	8.30	2.53	3.80	3.16	2.77	4.30	2.88	47.45
55	1.42		0.57	6.23	7.42	3.98	7.68	2.34	3.51	2.93	2.56	3.98	2.66	43.86
56	1.30		0.52	5.72	6.81	3.66	7.05	2.15	3.22	2.69	2.35	3.65	2.45	40.26
57	1.19		0.48	5.22	6.21	3.34	6.43	1.96	2.94	2.45	2.14	3.33	2.23	36.71
58	1.08		0.43	4.72	5.62	3.02	5.82	1.77	2.66	2.22	1.94	3.02	2.02	33.24
59	0.97		0.39	4.25	5.05	2.72	5.23	1.59	2.39	1.99	1.74	2.71	1.81	29.88
60	0.86		0.35	3.79	4.51	2.42	4.67	1.42	2.14	1.78	1.56	2.42	1.62	26.68
61	0.77		0.31	3.37	4.01	2.15	4.15	1.26	1.90	1.58	1.38	2.15	1.44	23.69
62	0.68		0.27	2.98	3.54	1.90	3.66	1.12	1.68	1.40	1.22	1.90	1.27	20.94
63	0.60		0.24	2.63	3.13	1.68	3.24	0.99	1.48	1.23	1.08	1.68	1.12	18.49
64	0.53		0.21	2.33	2.77	1.49	2.87	0.87	1.31	1.09	0.96	1.49	0.99	16.38
65	0.45		0.18	1.97	2.35	1.26	2.43	0.74	1.11	0.93	0.81	1.26	0.84	13.90
66	0.35		0.14	1.54	1.83	0.98	1.89	0.58	0.86	0.72	0.63	0.98	0.66	10.81
67	0.29		0.12	1.27	1.51	0.81	1.57	0.48	0.72	0.60	0.52	0.81	0.54	8.96
68	0.24		0.10	1.05	1.25	0.67	1.30	0.40	0.59	0.49	0.43	0.67	0.45	7.41
69	0.19		0.08	0.83	0.99	0.53	1.03	0.31	0.47	0.39	0.34	0.53	0.36	5.87
70	0.14		0.06	0.61	0.73	0.39	0.76	0.23	0.35	0.29	0.25	0.39	0.26	4.32
71	0.09		0.04	0.39	0.47	0.25	0.49	0.15	0.22	0.19	0.16	0.25	0.17	2.78
72	0.05		0.02	0.22	0.26	0.14	0.27	0.08	0.12	0.10	0.09	0.14	0.09	1.54

20yr Arawa	Singletons	Maketu/Fo	Maketu Rd	Right FP	WaiPar FP	WaiO FP	RapO FP	RapKop Fl	Bell Rd A	Bell Rd B	Total
176	1925	2291	1231	2371	723	1075	898	791	1229	823	13531
1.3	14.5	17.3	9.3	17.9	5.4	8.1	6.8	6.0	9.3	6.2	101.9
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.02	0.21	0.25	0.14	0.26	0.08	0.12	0.10	0.09	0.14	0.09	1.50
0.04	0.43	0.51	0.27	0.53	0.16	0.24	0.20	0.18	0.27	0.18	3.01
0.06	0.64	0.76	0.41	0.79	0.24	0.36	0.30	0.26	0.41	0.27	4.51
0.08	0.86	1.02	0.55	1.05	0.32	0.48	0.40	0.35	0.55	0.37	6.01
0.10	1.07	1.27	0.68	1.32	0.40	0.60	0.50	0.44	0.68	0.46	7.52
0.12	1.28	1.53	0.82	1.58	0.48	0.72	0.60	0.53	0.82	0.55	9.02
0.14	1.50	1.78	0.96	1.84	0.56	0.84	0.70	0.62	0.96	0.64	10.52
0.16	1.71	2.04	1.09	2.11	0.64	0.96	0.80	0.70	1.09	0.73	12.03
0.18	1.92	2.29	1.23	2.37	0.72	1.07	0.90	0.79	1.23	0.82	13.53
0.20	2.14	2.55	1.37	2.63	0.80	1.19	1.00	0.88	1.37	0.91	15.03
0.23	2.54	3.02	1.62	3.13	0.95	1.42	1.18	1.04	1.62	1.08	17.84
0.27	2.97	3.53	1.90	3.66	1.11	1.66	1.39	1.22	1.90	1.27	20.87
0.32	3.45	4.11	2.21	4.25	1.30	1.93	1.61	1.42	2.20	1.48	24.27
0.36	3.98	4.74	2.55	4.91	1.50	2.22	1.86	1.64	2.54	1.70	28.00
0.42	4.55	5.41	2.91	5.60	1.71	2.54	2.12	1.87	2.90	1.94	31.98
0.47	5.14	6.12	3.29	6.34	1.93	2.87	2.40	2.11	3.28	2.20	36.17
0.53	5.76	6.86	3.69	7.10	2.16	3.22	2.69	2.37	3.68	2.46	40.52
0.59	6.40	7.61	4.09	7.88	2.40	3.57	2.98	2.63	4.08	2.73	44.97
0.64	7.04	8.38	4.50	8.67	2.64	3.93	3.28	2.89	4.49	3.01	49.48
0.70	7.68	9.14	4.91	9.46	2.89	4.29	3.58	3.16	4.90	3.28	54.01
0.76	8.32	9.91	5.32	10.25	3.13	4.65	3.88	3.42	5.31	3.56	58.51
0.82	8.95	10.66	5.73	11.03	3.36	5.00	4.18	3.68	5.72	3.83	62.95
0.88	9.57	11.39	6.12	11.79	3.59	5.34	4.47	3.93	6.11	4.09	67.28
0.93	10.17	12.10	6.50	12.52	3.82	5.68	4.74	4.18	6.49	4.35	71.48
0.98	10.74	12.78	6.87	13.23	4.03	6.00	5.01	4.41	6.86	4.59	75.50
1.03	11.28	13.43	7.22	13.90	4.24	6.30	5.26	4.64	7.20	4.82	79.33
1.08	11.79	14.04	7.54	14.53	4.43	6.59	5.50	4.85	7.53	5.04	82.92
1.12	12.27	14.60	7.85	15.11	4.61	6.85	5.73	5.04	7.83	5.24	86.26
1.16	12.71	15.12	8.13	15.65	4.77	7.10	5.93	5.22	8.11	5.43	89.33
1.20	13.10	15.59	8.38	16.14	4.92	7.32	6.11	5.38	8.36	5.60	92.10
1.23	13.45	16.01	8.60	16.57	5.05	7.51	6.28	5.53	8.59	5.75	94.56
1.26	13.75	16.37	8.79	16.94	5.16	7.68	6.42	5.65	8.78	5.88	96.67
1.28	14.00	16.67	8.95	17.25	5.26	7.82	6.53	5.75	8.94	5.98	98.45
1.30	14.21	16.91	9.08	17.50	5.33	7.93	6.63	5.84	9.07	6.07	99.87
1.31	14.36	17.09	9.18	17.68	5.39	8.02	6.70	5.90	9.16	6.14	100.93
1.32	14.45	17.20	9.24	17.80	5.43	8.07	6.74	5.94	9.23	6.18	101.61
1.33	14.50	17.26	9.27	17.86	5.44	8.10	6.77	5.96	9.26	6.20	101.93
1.33	14.49	17.25	9.27	17.85	5.44	8.09	6.76	5.95	9.25	6.19	101.86
1.32	14.43	17.17	9.23	17.77	5.42	8.06	6.73	5.93	9.21	6.17	101.43
1.31	14.31	17.03	9.15	17.63	5.37	7.99	6.68	5.88	9.14	6.12	100.62
1.30	14.14	16.84	9.05	17.42	5.31	7.90	6.60	5.81	9.03	6.05	99.44
1.28	13.93	16.58	8.91	17.15	5.23	7.78	6.50	5.72	8.89	5.95	97.91
1.25	13.66	16.26	8.73	16.82	5.13	7.63	6.37	5.61	8.72	5.84	96.03
1.22	13.34	15.88	8.53	16.44	5.01	7.45	6.23	5.48	8.52	5.70	93.81
1.19	12.98	15.45	8.30	15.99	4.88	7.25	6.06	5.34	8.29	5.55	91.27
1.15	12.58	14.97	8.04	15.49	4.72	7.03	5.87	5.17	8.03	5.38	88.44
1.11	12.14	14.44	7.76	14.95	4.56	6.78	5.66	4.99	7.75	5.19	85.32
1.07	11.65	13.87	7.45	14.36	4.38	6.51	5.44	4.79	7.44	4.98	81.94
1.02	11.14	13.26	7.12	13.72	4.18	6.22	5.20	4.58	7.11	4.76	78.32
0.97	10.60	12.61	6.78	13.05	3.98	5.92	4.94	4.35	6.76	4.53	74.50
0.92	10.03	11.94	6.41	12.35	3.77	5.60	4.68	4.12	6.40	4.29	70.50
0.86	9.44	11.23	6.03	11.62	3.54	5.27	4.40	3.88	6.02	4.03	66.35
0.81	8.83	10.51	5.65	10.88	3.32	4.93	4.12	3.63	5.64	3.77	62.08
0.75	8.21	9.78	5.25	10.12	3.08	4.59	3.83	3.38	5.24	3.51	57.75
0.70	7.59	9.04	4.85	9.35	2.85	4.24	3.54	3.12	4.85	3.24	53.37
0.64	6.97	8.30	4.46	8.59	2.62	3.89	3.25	2.86	4.45	2.98	49.00
0.58	6.36	7.56	4.06	7.83	2.39	3.55	2.97	2.61	4.06	2.72	44.68
0.53	5.75	6.85	3.68	7.09	2.16	3.21	2.68	2.36	3.67	2.46	40.45
0.47	5.17	6.16	3.31	6.37	1.94	2.89	2.41	2.13	3.30	2.21	36.37
0.42	4.62	5.50	2.95	5.69	1.73	2.58	2.16	1.90	2.95	1.97	32.47
0.38	4.10	4.88	2.62	5.05	1.54	2.29	1.91	1.68	2.62	1.75	28.83
0.33	3.62	4.31	2.32	4.46	1.36	2.02	1.69	1.49	2.31	1.55	25.48
0.29	3.20	3.81	2.05	3.94	1.20	1.79	1.49	1.32	2.04	1.37	22.50
0.26	2.84	3.38	1.81	3.49	1.07	1.58	1.32	1.17	1.81	1.21	19.94
0.22	2.41	2.86	1.54	2.96	0.90	1.34	1.12	0.99	1.54	1.03	16.91
0.17	1.87	2.23	1.20	2.30	0.70	1.04	0.87	0.77	1.19	0.80	13.15
0.14	1.55	1.85	0.99	1.91	0.58	0.87	0.72	0.64	0.99	0.66	10.90
0.12	1.28	1.53	0.82	1.58	0.48	0.72	0.60	0.53	0.82	0.55	9.02
0.09	1.02	1.21	0.65	1.25	0.38	0.57	0.47	0.42	0.65	0.43	7.14
0.07	0.75	0.89	0.48	0.92	0.28	0.42	0.35	0.31	0.48	0.32	5.26
0.04	0.48	0.57	0.31	0.59	0.18	0.27	0.22	0.20	0.31	0.21	3.38
0.02	0.27	0.32	0.17	0.33	0.10	0.15	0.12	0.11	0.17	0.11	1.88

50yr Arawa	Singletons	Maketu/Fo	Maketu Rd	Right FP	WaiPar FP	WaiO FP	RapO FP	RapKop Fl	Bell Rd A	Bell Rd B	Total
215	2353	2801	1505	2899	884	1305	1093	967	1502	1006	16530
1.6	17.7	21.1	11.3	21.8	6.7	9.8	8.2	7.3	11.3	7.6	124.5
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.02	0.26	0.31	0.17	0.32	0.10	0.15	0.12	0.11	0.17	0.11	1.84
0.05	0.52	0.62	0.33	0.64	0.20	0.29	0.24	0.21	0.33	0.22	3.67
0.07	0.78	0.93	0.50	0.97	0.29	0.44	0.36	0.32	0.50	0.34	5.51
0.10	1.05	1.24	0.67	1.29	0.39	0.58	0.49	0.43	0.67	0.45	7.35
0.12	1.31	1.56	0.84	1.61	0.49	0.73	0.61	0.54	0.83	0.56	9.18
0.14	1.57	1.87	1.00	1.93	0.59	0.87	0.73	0.64	1.00	0.67	11.02
0.17	1.83	2.18	1.17	2.25	0.69	1.02	0.85	0.75	1.17	0.78	12.86
0.19	2.09	2.49	1.34	2.58	0.79	1.16	0.97	0.86	1.34	0.89	14.69
0.22	2.35	2.80	1.50	2.90	0.88	1.31	1.09	0.97	1.50	1.01	16.53
0.24	2.61	3.11	1.67	3.22	0.98	1.45	1.21	1.07	1.67	1.12	18.37
0.28	3.10	3.69	1.98	3.82	1.17	1.72	1.44	1.28	1.98	1.33	21.80
0.33	3.63	4.32	2.32	4.47	1.36	2.01	1.69	1.49	2.32	1.55	25.50
0.39	4.22	5.03	2.70	5.20	1.59	2.34	1.96	1.73	2.70	1.80	29.66
0.45	4.87	5.80	3.11	6.00	1.83	2.70	2.26	2.00	3.11	2.08	34.20
0.51	5.56	6.62	3.56	6.85	2.09	3.08	2.58	2.29	3.55	2.38	39.07
0.58	6.29	7.49	4.02	7.75	2.36	3.49	2.92	2.59	4.02	2.69	44.19
0.65	7.05	8.39	4.51	8.68	2.65	3.91	3.27	2.90	4.50	3.01	49.50
0.72	7.82	9.31	5.00	9.63	2.94	4.34	3.63	3.21	4.99	3.34	54.94
0.79	8.61	10.24	5.50	10.60	3.23	4.77	4.00	3.54	5.49	3.68	60.45
0.86	9.39	11.16	6.01	11.57	3.53	5.21	4.36	3.86	6.00	4.01	65.98
0.93	10.18	12.11	6.51	12.54	3.82	5.64	4.73	4.18	6.50	4.35	71.48
1.00	10.95	13.03	7.00	13.49	4.11	6.07	5.08	4.50	6.99	4.68	76.90
1.07	11.70	13.93	7.48	14.41	4.39	6.49	5.43	4.81	7.47	5.00	82.20
1.14	12.43	14.80	7.95	15.31	4.67	6.89	5.77	5.11	7.94	5.31	87.32
1.20	13.13	15.63	8.40	16.17	4.93	7.28	6.10	5.40	8.38	5.61	92.24
1.26	13.80	16.42	8.82	16.99	5.18	7.65	6.41	5.67	8.81	5.90	96.91
1.32	14.42	17.17	9.22	17.76	5.42	8.00	6.70	5.93	9.21	6.16	101.30
1.37	15.00	17.86	9.59	18.48	5.63	8.32	6.97	6.17	9.58	6.41	105.38
1.42	15.54	18.49	9.94	19.14	5.83	8.62	7.21	6.38	9.92	6.64	109.13
1.47	16.02	19.07	10.24	19.73	6.02	8.88	7.44	6.58	10.23	6.85	112.51
1.51	16.44	19.57	10.52	20.26	6.18	9.12	7.63	6.76	10.50	7.03	115.51
1.54	16.81	20.01	10.75	20.71	6.31	9.32	7.81	6.91	10.73	7.19	118.10
1.57	17.12	20.38	10.95	21.09	6.43	9.50	7.95	7.04	10.93	7.32	120.27
1.59	17.37	20.67	11.11	21.40	6.52	9.63	8.06	7.14	11.09	7.42	122.01
1.61	17.55	20.89	11.23	21.62	6.59	9.74	8.15	7.21	11.21	7.50	123.30
1.62	17.67	21.04	11.30	21.77	6.64	9.80	8.21	7.26	11.28	7.55	124.14
1.62	17.73	21.10	11.34	21.84	6.66	9.83	8.23	7.28	11.32	7.58	124.52
1.62	17.72	21.09	11.33	21.82	6.65	9.83	8.23	7.28	11.31	7.57	124.44
1.62	17.64	21.00	11.28	21.73	6.62	9.78	8.19	7.25	11.26	7.54	123.91
1.60	17.50	20.83	11.19	21.56	6.57	9.71	8.12	7.19	11.17	7.48	122.92
1.58	17.30	20.59	11.06	21.30	6.49	9.59	8.03	7.11	11.04	7.39	121.48
1.56	17.03	20.27	10.89	20.97	6.39	9.44	7.91	7.00	10.87	7.28	119.61
1.53	16.70	19.88	10.68	20.57	6.27	9.26	7.75	6.86	10.66	7.14	117.31
1.49	16.32	19.42	10.43	20.10	6.13	9.05	7.58	6.70	10.42	6.97	114.61
1.45	15.87	18.90	10.15	19.55	5.96	8.80	7.37	6.52	10.13	6.78	111.51
1.41	15.38	18.31	9.84	18.95	5.78	8.53	7.14	6.32	9.82	6.57	108.04
1.36	14.84	17.66	9.49	18.28	5.57	8.23	6.89	6.10	9.47	6.34	104.23
1.30	14.25	16.96	9.11	17.55	5.35	7.90	6.62	5.86	9.10	6.09	100.10
1.25	13.62	16.21	8.71	16.78	5.12	7.55	6.32	5.60	8.70	5.82	95.68
1.19	12.96	15.42	8.29	15.96	4.87	7.19	6.02	5.32	8.27	5.54	91.01
1.12	12.26	14.59	7.84	15.10	4.60	6.80	5.69	5.04	7.83	5.24	86.12
1.06	11.54	13.73	7.38	14.21	4.33	6.40	5.36	4.74	7.37	4.93	81.05
0.99	10.80	12.85	6.91	13.30	4.06	5.99	5.01	4.44	6.89	4.62	75.85
0.92	10.04	11.95	6.42	12.37	3.77	5.57	4.66	4.13	6.41	4.29	70.55
0.85	9.28	11.05	5.94	11.43	3.49	5.15	4.31	3.81	5.93	3.97	65.20
0.78	8.52	10.14	5.45	10.50	3.20	4.73	3.96	3.50	5.44	3.64	59.86
0.71	7.77	9.25	4.97	9.57	2.92	4.31	3.61	3.19	4.96	3.32	54.58
0.64	7.04	8.37	4.50	8.67	2.64	3.90	3.27	2.89	4.49	3.01	49.42
0.58	6.32	7.53	4.04	7.79	2.38	3.51	2.94	2.60	4.04	2.70	44.43
0.52	5.65	6.72	3.61	6.96	2.12	3.13	2.62	2.32	3.61	2.41	39.67
0.46	5.01	5.97	3.21	6.18	1.88	2.78	2.33	2.06	3.20	2.14	35.22
0.41	4.43	5.28	2.83	5.46	1.66	2.46	2.06	1.82	2.83	1.89	31.13
0.36	3.91	4.66	2.50	4.82	1.47	2.17	1.82	1.61	2.50	1.67	27.49
0.32	3.47	4.13	2.22	4.27	1.30	1.92	1.61	1.43	2.21	1.48	24.36
0.27	2.94	3.50	1.88	3.62	1.10	1.63	1.37	1.21	1.88	1.26	20.66
0.21	2.29	2.72	1.46	2.82	0.86	1.27	1.06	0.94	1.46	0.98	16.07
0.17	1.90	2.26	1.21	2.34	0.71	1.05	0.88	0.78	1.21	0.81	13.32
0.14	1.57	1.87	1.00	1.93	0.59	0.87	0.73	0.64	1.00	0.67	11.02
0.11	1.24	1.48	0.79	1.53	0.47	0.69	0.58	0.51	0.79	0.53	8.72
0.08	0.92	1.09	0.59	1.13	0.34	0.51	0.42	0.38	0.58	0.39	6.43
0.05	0.59	0.70	0.38	0.72	0.22	0.33	0.27	0.24	0.38	0.25	4.13
0.03	0.33	0.39	0.21	0.40	0.12	0.18	0.15	0.13	0.21	0.14	2.30

100yr Arawa	Singletons	Maketu/Fo	Maketu Rd	Right FP	WaiPar FP	WaiO FP	RapO FP	RapKop Fl	Bell Rd A	Bell Rd B	Total
245	2680	3189	1714	3301	1006	1480	1241	1101	1711	1145	18812
1.8	20.2	24.0	12.9	24.9	7.6	11.2	9.3	8.3	12.9	8.6	141.7
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.03	0.30	0.35	0.19	0.37	0.11	0.16	0.14	0.12	0.19	0.13	2.09
0.05	0.60	0.71	0.38	0.73	0.22	0.33	0.28	0.24	0.38	0.25	4.18
0.08	0.89	1.06	0.57	1.10	0.34	0.49	0.41	0.37	0.57	0.38	6.27
0.11	1.19	1.42	0.76	1.47	0.45	0.66	0.55	0.49	0.76	0.51	8.36
0.14	1.49	1.77	0.95	1.83	0.56	0.82	0.69	0.61	0.95	0.64	10.45
0.16	1.79	2.13	1.14	2.20	0.67	0.99	0.83	0.73	1.14	0.76	12.54
0.19	2.08	2.48	1.33	2.57	0.78	1.15	0.96	0.86	1.33	0.89	14.63
0.22	2.38	2.83	1.52	2.93	0.89	1.32	1.10	0.98	1.52	1.02	16.72
0.25	2.68	3.19	1.71	3.30	1.01	1.48	1.24	1.10	1.71	1.15	18.81
0.27	2.98	3.54	1.90	3.67	1.12	1.64	1.38	1.22	1.90	1.27	20.90
0.32	3.53	4.21	2.26	4.35	1.33	1.95	1.64	1.45	2.26	1.51	24.81
0.38	4.13	4.92	2.64	5.09	1.55	2.28	1.91	1.70	2.64	1.77	29.02
0.44	4.81	5.72	3.07	5.92	1.81	2.66	2.23	1.98	3.07	2.05	33.75
0.51	5.54	6.60	3.55	6.83	2.08	3.06	2.57	2.28	3.54	2.37	38.93
0.58	6.33	7.54	4.05	7.80	2.38	3.50	2.93	2.60	4.04	2.71	44.46
0.66	7.16	8.53	4.58	8.82	2.69	3.96	3.32	2.94	4.57	3.06	50.29
0.73	8.02	9.55	5.13	9.88	3.01	4.43	3.72	3.30	5.12	3.43	56.33
0.82	8.91	10.60	5.69	10.97	3.34	4.92	4.12	3.66	5.69	3.81	62.52
0.90	9.80	11.66	6.27	12.07	3.68	5.41	4.54	4.03	6.26	4.19	68.80
0.98	10.70	12.73	6.84	13.17	4.02	5.91	4.95	4.40	6.83	4.57	75.09
1.06	11.59	13.79	7.41	14.27	4.35	6.40	5.37	4.76	7.40	4.95	81.35
1.14	12.47	14.84	7.97	15.36	4.68	6.89	5.77	5.12	7.96	5.33	87.52
1.22	13.32	15.86	8.52	16.41	5.00	7.36	6.17	5.48	8.51	5.69	93.55
1.30	14.15	16.85	9.05	17.44	5.32	7.82	6.55	5.82	9.04	6.05	99.38
1.37	14.95	17.80	9.56	18.42	5.61	8.26	6.92	6.14	9.55	6.39	104.97
1.44	15.71	18.70	10.05	19.35	5.90	8.68	7.27	6.46	10.03	6.71	110.29
1.50	16.42	19.55	10.50	20.23	6.17	9.07	7.60	6.75	10.48	7.02	115.29
1.56	17.08	20.33	10.92	21.04	6.42	9.44	7.91	7.02	10.91	7.30	119.93
1.62	17.69	21.06	11.31	21.79	6.64	9.77	8.19	7.27	11.29	7.56	124.20
1.67	18.24	21.71	11.66	22.46	6.85	10.08	8.44	7.49	11.64	7.79	128.04
1.71	18.72	22.29	11.97	23.06	7.03	10.34	8.67	7.69	11.95	8.00	131.45
1.75	19.14	22.79	12.24	23.58	7.19	10.58	8.86	7.87	12.22	8.18	134.40
1.79	19.50	23.21	12.47	24.01	7.32	10.77	9.03	8.01	12.45	8.33	136.88
1.81	19.78	23.54	12.65	24.36	7.43	10.93	9.16	8.13	12.63	8.45	138.85
1.83	19.99	23.79	12.78	24.62	7.51	11.04	9.25	8.21	12.76	8.54	140.32
1.84	20.12	23.95	12.87	24.79	7.56	11.12	9.32	8.27	12.85	8.60	141.28
1.85	20.18	24.03	12.91	24.86	7.58	11.15	9.35	8.29	12.89	8.63	141.71
1.85	20.17	24.01	12.90	24.85	7.58	11.14	9.34	8.29	12.88	8.62	141.63
1.84	20.09	23.91	12.84	24.74	7.54	11.10	9.30	8.25	12.82	8.58	141.02
1.82	19.93	23.72	12.74	24.54	7.48	11.01	9.23	8.19	12.72	8.52	139.89
1.80	19.69	23.44	12.59	24.26	7.40	10.88	9.12	8.09	12.57	8.42	138.26
1.78	19.39	23.08	12.40	23.88	7.28	10.71	8.98	7.97	12.38	8.29	136.12
1.74	19.02	22.63	12.16	23.42	7.14	10.51	8.80	7.81	12.14	8.13	133.51
1.70	18.58	22.11	11.88	22.88	6.98	10.26	8.60	7.63	11.86	7.94	130.43
1.65	18.08	21.51	11.56	22.26	6.79	9.99	8.37	7.43	11.54	7.73	126.90
1.60	17.51	20.85	11.20	21.57	6.58	9.68	8.11	7.20	11.18	7.49	122.96
1.55	16.90	20.11	10.80	20.81	6.34	9.33	7.82	6.94	10.79	7.22	118.62
1.49	16.23	19.31	10.38	19.99	6.09	8.96	7.51	6.67	10.36	6.93	113.92
1.42	15.51	18.46	9.92	19.10	5.82	8.57	7.18	6.37	9.90	6.63	108.89
1.35	14.75	17.56	9.43	18.17	5.54	8.15	6.83	6.06	9.42	6.31	103.58
1.28	13.96	16.62	8.93	17.20	5.24	7.71	6.46	5.74	8.91	5.97	98.01
1.20	13.14	15.64	8.40	16.18	4.93	7.26	6.08	5.40	8.39	5.62	92.24
1.13	12.29	14.63	7.86	15.14	4.62	6.79	5.69	5.05	7.85	5.25	86.32
1.05	11.44	13.61	7.31	14.09	4.29	6.32	5.29	4.70	7.30	4.89	80.29
0.97	10.57	12.58	6.76	13.02	3.97	5.84	4.89	4.34	6.75	4.52	74.21
0.89	9.70	11.55	6.21	11.95	3.64	5.36	4.49	3.99	6.20	4.15	68.13
0.81	8.85	10.53	5.66	10.90	3.32	4.89	4.10	3.64	5.65	3.78	62.12
0.73	8.01	9.53	5.12	9.87	3.01	4.43	3.71	3.29	5.11	3.42	56.24
0.66	7.20	8.57	4.61	8.87	2.70	3.98	3.33	2.96	4.60	3.08	50.56
0.59	6.43	7.65	4.11	7.92	2.41	3.55	2.98	2.64	4.11	2.75	45.15
0.52	5.71	6.79	3.65	7.03	2.14	3.15	2.64	2.35	3.64	2.44	40.08
0.46	5.05	6.01	3.23	6.22	1.90	2.79	2.34	2.07	3.22	2.16	35.43
0.41	4.46	5.30	2.85	5.49	1.67	2.46	2.06	1.83	2.84	1.90	31.28
0.36	3.95	4.70	2.53	4.86	1.48	2.18	1.83	1.62	2.52	1.69	27.72
0.31	3.35	3.99	2.14	4.13	1.26	1.85	1.55	1.38	2.14	1.43	23.52
0.24	2.61	3.10	1.67	3.21	0.98	1.44	1.21	1.07	1.66	1.11	18.29
0.20	2.16	2.57	1.38	2.66	0.81	1.19	1.00	0.89	1.38	0.92	15.15
0.16	1.79	2.13	1.14	2.20	0.67	0.99	0.83	0.73	1.14	0.76	12.54
0.13	1.41	1.68	0.90	1.74	0.53	0.78	0.65	0.58	0.90	0.60	9.93
0.10	1.04	1.24	0.67	1.28	0.39	0.58	0.48	0.43	0.67	0.45	7.32
0.06	0.67	0.80	0.43	0.83	0.25	0.37	0.31	0.28	0.43	0.29	4.70
0.03	0.37	0.44	0.24	0.46	0.14	0.21	0.17	0.15	0.24	0.16	2.61


Te Puke Rainfall frequency plot
Collins 24hr
Te Matai 24hr
Te Puke 24hr
Te Matai 72hr
Collins 72hr
Te Puke 72hr
Return Period
I100/I_ = 2.51
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1.1
2
2.33
5
10
20
50
100
200
Return Period (years)
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
y variate

Appendix II

Model Structure, Calibration

The calibration run of the July 1998 and May 1999 floods use the following boundary files:
798+.bnd11
599adjj.bnd11

Graphs of the May 1999 event at Clarkes and Fords Cut water level recorder show the adopted design does not match low tide levels well before the event, but matches tide levels very well after the event. This suggests some changes to the riverbed and/or the river mouth during the flood.

Final design levels (below Te Matai) were based on the following model set-up, stored in R:\MikeZero\data\Kaituna\m99\:

River cross-sections: **Des00.nwk11**

Cross-section file: **Des00.xns11**

Boundary files and result files:
Boundary files are in the folder **K99 boundaries\Calibration, Design Tides, Long, Plains**
1% AEP flow plus 20% AEP tide level with 0.23 m additional allowance for possible differences between Moturiki and this site, and other imprecisions. (Peak tide level 1.85 m).
Des1.bnd11, Des1.res11
20% AEP flow plus 1% AEP tide with 0.33 m additional allowance (Peak tide level 2.39 m).
Des3.bnd11, Des3.res11

For areas where work is to be done, e.g. topping up of stopbanks, an additional allowance for sea level rise of 0.49m (IPCC 1995 best estimate for sea level rise over the next 100 years);
1% AEP flow with 2.34 m peak tide level. **Des2.bnd11, Des2.res11**
20% AEP flow with 2.88 m peak tide level. **Des4.bnd11, Des4.res11**

For floodplain areas, a 2% AEP rainfall on the plains has been modelled with a 5% AEP flow in the river and tributaries, with a 5% AEP tide level. **Des5.bnd11, Des5.res11**

Peak tributary flows are all modelled simultaneously with a 5% AEP flow at Te Matai and 1.85 m tide level. **Des6.bnd11, Des6.res11**
9

Slope -Area calculations

	Cross-sect	Distance b	Average	A	R	v	delS	Ss	Converging Se	Diverging Se	k	n	2gL^0.5	kSs^0.5	2gL	k/A2	k/A1	Direct Qconv	Direct Qdiv	Trial Qconv	Trial Qdiv	Trial esti
Waiari Stream 1/5/99																						
Note: 6 intermediate cross-sections were taken, but water levels showed an inconsistent slope. The best representation seems to be from the most distant cross-sections.																						
	1		12.27	125.26	2.05	1.69																
	5	563.3	13.75	122.59	2.93	1.73	0.0000	0.0026	0.0026	**0.0026**	4139.3	0.055	105.1	212	11052	1092	1140	213	**212**	212	**212**	212
	1		12.27	125.26	2.05	1.87																
	5	563.3	13.75	122.59	2.93	1.91	0.0000	0.0026	0.0026	**0.0026**	4553.3	0.050	105.1	233	11052	1321	1380	234	**234**	233	**234**	234
	1		12.27	125.26	2.05	2.32																
	5	563.3	13.75	122.59	2.93	2.37	0.0000	0.0026	0.0026	**0.0026**	5691.6	**0.040**	105.1	292	11052	2065	2156	293	**292**	293	**291**	291
Using area and radius from all sections																						
	1		12.27	125.26	2.05	**1.40**																
	2	150.7	13.10	**155.6**	2.23	1.12																
1b		36.9	12.53	152.5	2.44	1.15																
2b		56	12.27	101.9	1.79	1.72																
	3	32.7	12.38	102.44	1.73	1.71																
3b		23.3	12.53	**108.6**	1.73	**1.61**	Note: recorded velocities extrapolated to water level imply v should be about 1.35m/s at this section.															
	4	108.2	13.20	93.42	2.8	1.87																
	5	155.5	13.75	122.59	2.93	1.43	0.0000	0.0026	0.0026	**0.0026**	3404.1	0.060	55.2	175	3051	739	771	175	**175**	174	**175**	**175**
Waiari below SH2																						
	1		3.43	121.4	1.84	1.15																
	2	1000	3.84	129.4	1.65	1.08	0.00001	0.00041	**0.00040**	0.00041	6990.7	0.026	140.1	142	19620	3316	2919	**140**	141	**140**	142	140
	2		3.84	129.4	1.65	1.08																
	3	780	4.27	103.2	2	1.36	0.00004	0.00055	0.00051	**0.00057**	5828.3	0.030	123.7	137	15304	2029	3189	142	**140**	131	**140**	140
	3		4.27	103.2	2	1.36																
	4	710	5.10	120	1.96	1.17	0.00003	0.00117	**0.00113**	0.00119	4169.9	0.042	118.0	143	13930	1633	1208	**140**	141	**140**	144	140
	4		5.10	120	1.96	1.17																
	5	1060	6.62	82.5	1.65	1.70	0.00007	0.00143	0.00136	**0.00147**	3661.0	0.041	144.2	139	20797	931	1969	142	**140**	135	**140**	140
	1		3.43	121.4	1.84	1.15																
	2			129.4	1.65	1.08																
	3	1780	4.27	103.2	2	1.36	0.00001	0.00047	0.00046	**0.00048**	6373.4	0.028	186.9	138	34924	2756	3814	141	**140**	136	**140**	**140**

Raparapahoe Stream 1/5/99

Assume n = 0.055

Cross-sect	Distance b	Average Flood level	A	R	v	delS	Ss	Converging Se	Diverging Se	k	n	2gL^0.5	kSs^0.5	2gL	k/A2	k/A1	Direct Qconv	Direct Qdiv	Trial Qconv	Trial Qdiv	Trial esti
1		12.74	85.3	2.49	1.01																
2	56	12.81	76.9	1.97	1.12	0.0002	0.0013	0.0010	**0.0014**	2346.2	0.059	33.1	83	1099	757	931	90	**86**	76	**86**	**86**
3	56	12.76	101.2	2.69	0.85	0.0005	-0.0009	**-0.0014**	-0.0007	2652.7	0.059	33.1	#NUM!	1099	1190	687	**#NUM!**	#NUM!	**#NUM!**	#NUM!	
Alternative calculation using highest debris mark on upstream cross-section only																					
1		12.74	85.3	2.49	1.01																
3	112	12.80	102.5	2.72	0.84	0.0001	0.0005	**0.0004**	0.0006	4336.0	0.041	46.9	100	2197	2584	1789	**86**	92	**86**	107	86
Alternative calculation - n= 0.055																					
1		12.74	85.3	2.49	1.09																
2	56	12.81	76.9	1.97	1.21	0.0002	0.0013	0.0010	**0.0014**	2516.9	0.055	33.1	89	1099	871	1071	98	**93**	80	**93**	93
Alternative calculation using highest debris mark on upstream cross-section only and all area and radius measurements																					
1		12.74	85.3	2.49	1.01																
2			76.9	1.97	1.12																
3	112	12.80	102.5	2.72	0.84	0.0001	0.0005	**0.0004**	0.0006	4325.2	0.037	46.9	100	2197	2571	1781	**86**	92	**86**	107	86

Note: water level slope on survey date = 0.00125

Raparapahoe at Drop Structure

Peak water level at recorder	RLZ staff gauge	RL	Weir level	Depth y	Critical depth yc	Critical velocity	Water level	Area (ricoda)	Flow rate	Overflow ???	v at site approx	additional head	Critical depth yc	Critical velocity	Water level	Area (ricoda)	Flow rate	
3.530	2.452	5.982	4.23	1.75	1.17	3.38	5.40	19.45	**65.8**	6	1.99	0.20	1.30	3.58	5.53	22.27	**79.6**	**86**

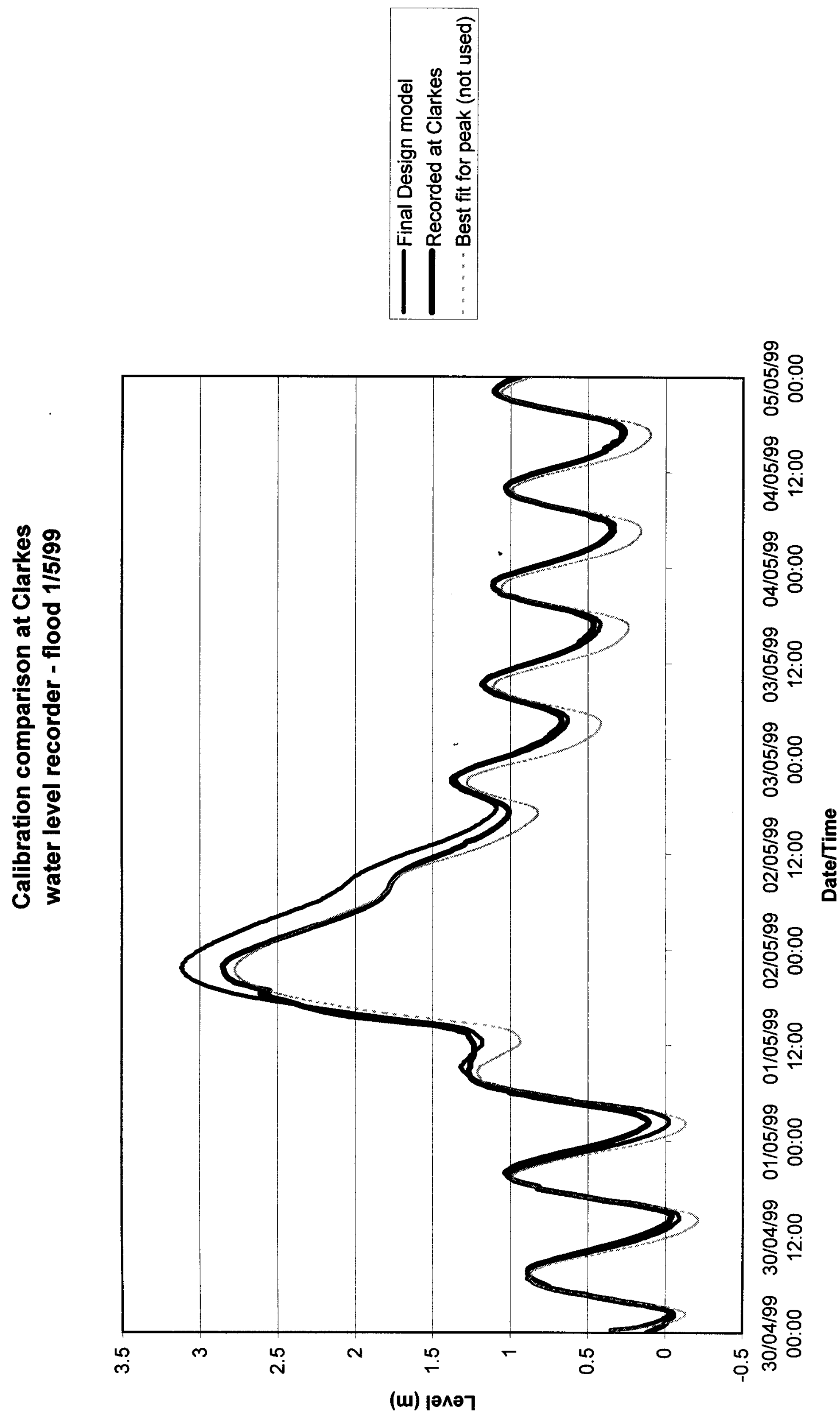
Notes on flow at weir:
Some velocity at measurement site, but also some headloss between the site and the weir.
Some flow bypassed the structure - across SH2 and over the stopbank above the railway bridge (see photos CN1836..), perhaps up to 6 cumecs.
The weir may have been partially drowned (CN 183615)

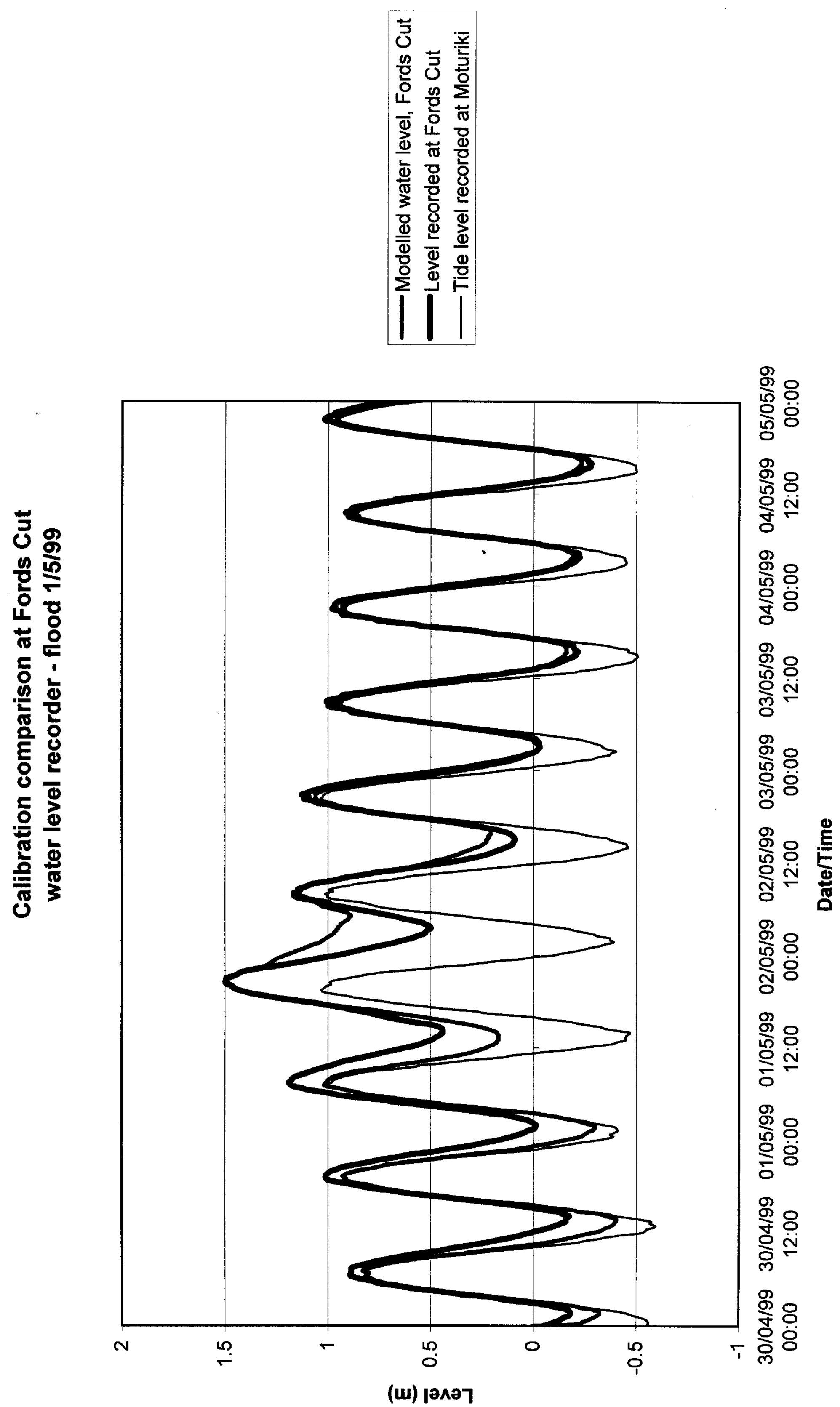
Ohineangaanga Stream 1/5/99

Assume n = 0.055

Cross-sect	Distance b	Average Flood level	A	R	v	delS	Ss	Converging Se	Diverging Se	k	n	2gL^0.5	kSs^0.5	2gL	k/A2	k/A1	Direct Qconv	Direct Qdiv	Trial Qconv	Trial Qdiv	Trial esti
1		10.29	42.82	2.03	2.13																
2	55	10.25	47.89	2.09	1.90	0.0008	-0.0006	**-0.0015**	-0.0002	1049.0	0.070	32.8	#NUM!	1079	600	480	**#NUM!**	#NUM!	**#NUM!**	#NUM!	
3	55	10.76	34.72	1.57	2.62	0.0030	0.0092	0.0062	**0.0107**	882.8	0.070	32.8	85	1079	340	647	100	**91**	69	**91**	**91**
Alternative calculation without middle section, using highest debris mark and average at each section																					
1		10.29	42.82	2.03	1.47																
3	110	10.87	36.94	1.62	1.71	0.0003	0.0053	0.0050	**0.0055**	850.8	0.070	46.5	62	2158	395	530	64	**63**	60	**63**	63
1		10.29	42.82	2.03	1.28																
3	110	10.76	34.72	1.57	1.58	0.0004	0.0043	0.0039	**0.0045**	819.6	0.070	46.5	54	2158	366	557	56	**55**	51	**55**	**55**
1		10.29	42.82	2.03	1.70																
2			51.61	2.20	1.41																
3	110	10.87	36.94	1.62	1.98	0.0005	0.0053	0.0049	**0.0055**	976.4	0.070	46.5	71	2158	520	699	74	**73**	68	**73**	**73**
1		10.29	42.82	2.03	1.49																
2			51.61	2.20	1.24																
3	110	10.76	34.72	1.57	1.84	0.0005	0.0043	0.0037	**0.0045**	954.4	0.070	46.5	62	2158	497	756	67	**64**	58	**64**	**64**
Alternative using highest debris level at each section, and highest level at middle section only																					
1		10.29	42.82	2.03	2.22																
2	55	10.43	51.61	2.20	1.84	0.0014	0.0026	**0.0012**	0.0033	1111.4	0.070	32.8	57	1079	674	464	**52**	54	**39**	64	
3	55	10.87	36.94	1.62	2.57	0.0030	0.0080	0.0050	**0.0095**	973.7	0.070	32.8	87	1079	356	695	105	**95**	69	**95**	**95**
2	55	10.43	51.61	2.20	1.55																
3	55	10.76	34.72	1.57	2.30	0.0027	0.0059	0.0032	**0.0073**	941.0	0.070	32.8	72	1079	332	734	91	**80**	53	**80**	**80**
Alternative calculation - n= 0.055																					
1		10.29	42.82	2.03	1.96																
2			51.61	2.20	1.63																
3	110	10.76	34.72	1.57	2.42	0.0009	0.0043	0.0033	**0.0047**	1214.7	0.055	46.5	79	2158	805	1224	88	**84**	70	**84**	**84**

Note: water level slope on survey date = 0.0135


Calibration comparison at Clarkes
water level recorder - flood 1/5/99
Level (m)
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
30/04/99 00:00
30/04/99 12:00
01/05/99 00:00
01/05/99 12:00
02/05/99 00:00
02/05/99 12:00
03/05/99 00:00
03/05/99 12:00
04/05/99 00:00
04/05/99 12:00
05/05/99 00:00
Date/Time
Final Design model
Recorded at Clarkes
Best fit for peak (not used)


Calibration comparison at Fords Cut
water level recorder - flood 1/5/99
Level (m)
2
1.5
1
0.5
0
-0.5
-1
30/04/99 00:00
30/04/99 12:00
01/05/99 00:00
01/05/99 12:00
02/05/99 00:00
02/05/99 12:00
03/05/99 00:00
03/05/99 12:00
04/05/99 00:00
04/05/99 12:00
05/05/99 00:00
Date/Time
Modelled water level, Fords Cut
Level recorded at Fords Cut
Tide level recorded at Moturiki

		Calibration for 1/5/99 flood	Calibration for 7/98 flood (used in model)
River	Distance	Mannings n	Mannings n
KAITUNA	9600	0.04	0.04
KAITUNA	9900	0.04	0.04
KAITUNA	10390	0.035	0.035
KAITUNA	10900	0.035	0.035
KAITUNA	11350	0.04	0.04
KAITUNA	11900	0.04	0.04
KAITUNA	12400	0.03	0.03
KAITUNA	12900	0.03	0.03
KAITUNA	13400	0.03	0.03
KAITUNA	13400	0.03	0.03
KAITUNA	13900	0.035	0.035
KAITUNA	14400	0.035	0.035
KAITUNA	14650	0.03	0.03
KAITUNA	14900	0.03	0.03
KAITUNA	14900	0.03	0.03
KAITUNA	15400	0.03	0.03
KAITUNA	15400	0.025	0.025
KAITUNA	15880	0.025	0.025
KAITUNA	16390	0.025	0.025
KAITUNA	16870	0.02	0.025
KAITUNA	17390	0.02	0.025
KAITUNA	17880	0.02	0.025
KAITUNA	18400	0.018	0.025
KAITUNA	18880	0.018	0.025
KAITUNA	19400	0.018	0.025
KAITUNA	19900	0.018	0.025
KAITUNA	20370	0.018	0.025
KAITUNA	20900	0.02	0.025
KAITUNA	21420	0.02	0.025
KAITUNA	21770	0.027	0.027
KAITUNA	21850	0.027	0.027
KAITUNA	21970	0.025	0.025
WAIARI	0	0.06	0.06
WAIARI	565	0.06	0.06
WAIARI	1140	0.074	0.074
WAIARI	2500	0.074	0.074
WAIARI	3080	0.046	0.046
WAIARI	3780	0.046	0.046
WAIARI	4160	0.03	0.03
WAIARI	4970	0.03	0.03
WAIARI	5830	0.03	0.03
WAIARI	6820	0.03	0.03
Raparapahoe	0	0.07	0.07
Raparapahoe	1440	0.07	0.07
RAPARAPAHOE	2040	0.07	0.07
Raparapahoe	2050	0.045	0.045
Raparapahoe	2470	0.045	0.045
Raparapahoe	3420	0.045	0.045
Raparapahoe	4340	0.045	0.045
Raparapahoe	4440	0.034	0.034
Raparapahoe	5470	0.034	0.034
Ohineangaanga	0	0.085	0.085
OHINEANGAANGA	1460	0.085	0.085
OHINEANGAANGA	1480	0.05	0.05
OHINEANGAANGA	1680	0.05	0.05
OHINEANGAANGA	1770	0.05	0.05
OHINEANGAANGA	1780	0.05	0.05
OHINEANGAANGA	2130	0.042	0.042
OHINEANGAANGA	2480	0.042	0.042
OHINEANGAANGA	3480	0.042	0.042
Quarry a	1662	0.032	0.032
Quarry a	2990	0.032	0.032
Kopuaroa	0	0.032	0.032
Kopuaroa	2990	0.032	0.032
Kopuaroa	3100	0.05	0.05
Kopuaroa	3200	0.05	0.05
KOPUAROA	3200	0.034	0.034
KOPUAROA	4140	0.034	0.034
KOPUAROA	5070	0.034	0.034
KOPUAROA	6090	0.034	0.034
KOPUAROA	7140	0.034	0.034
Estuary	0	0.025	0.025
Estuary	5	0.025	0.025
Estuary	160	0.025	0.025
Estuary	430	0.022	0.022

A list of the starting levels and flows used to help the model start calculations

River	Distance	Starting h	Starting Q
KAITUNA	9600	1.3	28.1
KAITUNA	9900	1.2	27.9
KAITUNA	10390	1.1	27.5
KAITUNA	10900	1	26.9
KAITUNA	11350	0.9	26.1
KAITUNA	11900	0.8	24.8
KAITUNA	12400	0.7	23.9
KAITUNA	12900	0.6	23.6
KAITUNA	13400	0.5	22.1
KAITUNA	13530	0.5	24.5
KAITUNA	13530	0.5	22
KAITUNA	13900	0.4	28.5
KAITUNA	14400	0.4	26.4
KAITUNA	14400	0.4	24.6
KAITUNA	14650	0.3	25.7
KAITUNA	14900	0.3	22.7
KAITUNA	15150	0.3	19.7
KAITUNA	15150	0.3	15.2
KAITUNA	15400	0.2	11.6
KAITUNA	15880	0.2	11.6
KAITUNA	16390	0.2	11.6
KAITUNA	16870	0.2	11.6
KAITUNA	17390	0.2	11.6
KAITUNA	17880	0.2	11.6
KAITUNA	18400	0.2	11.6
KAITUNA	18880	0.2	11.6
KAITUNA	19400	0.2	11.6
KAITUNA	19900	0.2	11.6
KAITUNA	20370	0.2	11.6
KAITUNA	20900	0.2	5
KAITUNA	21420	0.2	11.6
KAITUNA	21420	0.2	11.6
KAITUNA	21770	0.4	0
KAITUNA	21970	0.8	-10
KOPUAROA	3200	2.3	5
KOPUAROA	4140	1.8	5
KOPUAROA	5070	1.2	5
KOPUAROA	6090	0.5	5
KOPUAROA	7140	0.3	5
OHINEANGAANGA	0	10.8	5
OHINEANGAANGA	100	10.5	4.9
OHINEANGAANGA	1480	3	3.9
OHINEANGAANGA	2480	2.7	3.9
OHINEANGAANGA	3480	1.2	3.9
WAIARI	0	8	3.9
WAIARI	4160	1.3	3.9
WAIARI	2450	4	3.9
WAIARI	1400	6	3.9
WAIARI	5830	0.5	3.9
ESTUARY	0	0.5	3.9
ESTUARY	5	0.5	3.9
ESTUARY	160	0.5	3.9
ESTUARY	430	0.5	3.9
ESTUARY	605	0.5	3.9
ESTUARY	925	0.5	3.9
ESTUARY	1695	0.5	3.9
ESTUARY	2220	0.5	3.9
ESTUARY	2470	0.5	1.9
ESTUARY	2785	0.5	1.9
ESTUARY	3020	0.5	1.9
ESTUARY	3320	0.5	1.9
ESTUARY	3480	0.5	1.9
ESTUARY	3680	0.5	1.9
ESTUARY	3780	0.5	0
QUARRY A	1662	7.6	1.9
QUARRY A	1740	7.2	1.9
QUARRY A	1790	6.9	1.9
QUARRY A	1890	6.1	1.9
QUARRY A	1985	5.5	1.9
QUARRY A	2010	5.4	1.9
QUARRY A	2090	5.2	5
QUARRY A	2190	4.9	5
QUARRY A	2290	4.6	5
QUARRY A	2390	4.4	5
QUARRY A	2490	4.1	5

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Estuary	605	0.022	0.022
Estuary	925	0.022	0.022
Estuary	1695	0.022	0.022
Estuary	2220	0.022	0.022
Estuary	2470	0.022	0.022
Estuary	2785	0.022	0.022
ESTUARY	3020	0.022	0.022
Estuary	3320	0.022	0.022
Estuary	3480	0.022	0.022
Estuary	3780	0.022	0.022
Singleplain	-30	0.03	0.03
Singleplain	0	0.03	0.03
Singleplain	1000	0.03	0.03
Arawa wetland	0	0.1	0.1
Arawa wetland	600	0.1	0.1
Maketu Rd 1	0	0.03	0.03
Maketu Rd 1	20	0.03	0.03
Maketu Rd 2	0	0.03	0.03
Maketu Rd 2	20	0.03	0.03
Arawa overflow 1	0	0.03	0.03
Arawa overflow 1	5	0.03	0.03
Arawa overflow 2	0	0.03	0.03
Arawa overflow 2	5	0.03	0.03
Maketu/Ford Rd drain	0	0.03	0.03
Maketu/Ford Rd drain	10	0.03	0.03
Maketu/Ford Rd drain	4440	0.03	0.03
makout	0	0.03	0.03
makout	550	0.03	0.03
BELL B PUMP	0	0.03	0.03
BELL B PUMP	1000	0.03	0.03
BELL A PUMP	0	0.03	0.03
BELL A PUMP	100	0.03	0.03
bell lb fp	0	0.03	0.03
bell rb fp	0	0.03	0.03
bell rb fp	1950	0.03	0.03
bell	0	0.03	0.03
bell	2700	0.03	0.03
FORD PUMP	0	0.03	0.03
FORD PUMP	20	0.03	0.03
EMOUTH	0	0.025	0.025
EMOUTH	25	0.025	0.025
EMOUTH	25	0.1	0.1
EMOUTH	100	0.1	0.1

QUARRY A	2590	3.8	5
QUARRY A	2690	3.5	5
QUARRY A	2790	3.2	5
QUARRY A	2890	2.9	5
QUARRY A	2990	2.5	5
RAPARAPAHOE	0	8.4	5
RAPARAPAHOE	55	8.3	5
RAPARAPAHOE	110	8.2	5
RAPARAPAHOE	300	7.9	5
RAPARAPAHOE	530	7.6	5
RAPARAPAHOE	750	7.3	5
RAPARAPAHOE	970	7	5
RAPARAPAHOE	1200	6.6	9.9
RAPARAPAHOE	1400	6	9.7
RAPARAPAHOE	1600	5	3.1
RAPARAPAHOE	1800	5	3.1
RAPARAPAHOE	2050	4.3	3.1
RAPARAPAHOE	2070	2.3	3.1
RAPARAPAHOE	2090	2.2	3.1
RAPARAPAHOE	2470	2	3.1
RAPARAPAHOE	3420	1.4	3.1
RAPARAPAHOE	4440	1.1	7
RAPARAPAHOE	5470	0.4	7
KOPUAROA	0	7	3.1
KOPUAROA	200	6.5	3.1
KOPUAROA	400	5.9	3.1
KOPUAROA	600	5.4	3.1
KOPUAROA	800	5.2	3.1
KOPUAROA	1000	4.9	3.1
KOPUAROA	1200	4.7	3.1
KOPUAROA	1300	4.5	3.1
KOPUAROA	1400	4.4	3.1
KOPUAROA	1500	4.3	3.1
KOPUAROA	1600	4.1	3.1
KOPUAROA	1700	4	3.1
KOPUAROA	1800	3.9	5
KOPUAROA	1900	3.8	5
KOPUAROA	2000	3.6	5
KOPUAROA	2030	3.6	5
KOPUAROA	2100	3.5	5
KOPUAROA	2200	3.4	5
KOPUAROA	2300	3.3	5
KOPUAROA	2400	3.1	5
KOPUAROA	2500	3	5
KOPUAROA	2600	2.9	5
KOPUAROA	2700	2.8	5
KOPUAROA	2800	2.6	5
KOPUAROA	2900	2.5	5
KOPUAROA	2990	2.5	5
KOPUAROA	2990	2.5	5
KOPUAROA	3000	2.5	5
KOPUAROA	3053	2.4	5
KOPUAROA	3090	2.3	5
KOPUAROA	3100	2.3	5
KOPUAROA	3120	2.3	5
KOPUAROA	3150	2.3	5
KOPUAROA	3200	2.3	5
SINGLEPLAIN	0	0.1	0.1
SINGLEPLAIN	1000	0.1	0.1
MAKOUT	0	0.1	0.1
MAKOUT	550	0.1	0.1
ARAWA WETLAND	0	0.5	0.1
ARAWA WETLAND	600	0.5	0.1
MAKETU/FORD RD DRAI	0	0.2	-1.33
MAKETU/FORD RD DRAI	2000	0	0
MAKETU/FORD RD DRAI	4075	-0.1	0
OHINEANGAANGA	540	10	4.9
OHINEANGAANGA	550	8.6	4.9
OHINEANGAANGA	610	7.6	4.9
OHINEANGAANGA	670	7.1	4.9
RAPARAPAHOE	4340	1.22	3.1
RAPARAPAHOE	4380	1.2	3.1
BELL	0	0.4	0.2
BELL	2700	0.2	0.2
BELL RB FP	0	0.4	0.1
BELL RB FP	1950	0.4	0.1
BELL LB FP	0	0.4	0.1
BELL LB FP	500	0.4	0.1
BELL B PUMP	0	0.4	0.1
BELL B PUMP	1000	0	0
FORD PUMP	0	-0.1	0
FORD PUMP	20	-1	0

Appendix III

Level Books and plans used for floodplain information:
396 Singletons Drain area
398 Singletons Drain area
457 Kopuaroa Pump area
483 Singletons drain area
484 Singletons Drain area
520 Pah Rd area adjacent wetland
612 Lower Kaituna cross-sections
613 Upper Kaituna cross-sections
615 Lower Kaituna cross-sections
623 Flood profiles 7/98, Kopuaroa Canal stopbanks
627 Stop bank levels – RB below Te Matai,
628 Flood profiles 7/98
642 Flood profiles and tributary cross-sections, 5/99, Upper Kopuaroa GGL's, Kaituna Wetland spot levels
646 General floodplain cross-sections
Plan K4582 Raparapahoe/Ohineaangaanga drainage
Plan K4341 Upper Kaituna floodplain storage
Maketu Estuary DTM – refer GIS section, Environment Bay of Plenty

Appendix IV

Design stop bank levels, changes to design levels, stop bank repair volumes

1%AEP design levels

Ricoda or prev. distance	Mike 11 Cross-section	DWL	DBL	Future DWL	Future DBL
0	KOPUAROA 7140.00	4.02	4.32	4.06	4.36
	KOPUAROA 6090.00	4.06	4.36	4.10	4.40
	KOPUAROA 5070.00	4.19	4.49	4.23	4.53
	KOPUAROA 4140.00	4.39	4.69	4.41	4.71
	KOPUAROA 3200.00	4.94	5.24	4.95	5.25
SH2	KOPUAROA 3150.00	4.97	5.27	4.98	5.28
	KOPUAROA 3120.00	4.95	5.25	4.96	5.26
	KOPUAROA 3100.00	5.05	5.35	5.06	5.36
	KOPUAROA 3090.00	5.02	5.32	5.03	5.33
	KOPUAROA 3053.00	5.16	5.46	5.17	5.47
	KOPUAROA 3000.00	5.23	5.53	5.24	5.54
	KOPUAROA 2990.00	5.24	5.54	5.25	5.55
	KOPUAROA 2990.00	5.24	5.54	5.25	5.55
	KOPUAROA 2900.00	5.25	5.55	5.26	5.56
	KOPUAROA 2800.00	5.25	5.55	5.26	5.56
	KOPUAROA 2700.00	5.25	5.55	5.26	5.56
	KOPUAROA 2600.00	5.25	5.55	5.26	5.56
	KOPUAROA 2500.00	5.26	5.56	5.26	5.56
	KOPUAROA 2400.00	5.27	5.57	5.28	5.58
	KOPUAROA 2300.00	5.31	5.61	5.31	5.61
	KOPUAROA 2200.00	5.37	5.67	5.38	5.68
	KOPUAROA 2100.00	5.66	5.96	5.66	5.96
	KOPUAROA 2030.00	5.83	6.13	5.83	6.13
	KOPUAROA 2000.00	5.97	6.27	5.97	6.27
	KOPUAROA 1900.00	6.05	6.35	6.05	6.35
	KOPUAROA 1800.00	6.06	6.36	6.06	6.36
	KOPUAROA 1700.00	6.07	6.37	6.07	6.37
	KOPUAROA 1600.00	6.09	6.39	6.09	6.39
	KOPUAROA 1500.00	6.21	6.51	6.21	6.51
	KOPUAROA 1400.00	6.44	6.74	6.44	6.74
	KOPUAROA 1300.00	6.72	7.02	6.72	7.02
	KOPUAROA 1200.00	6.86	7.16	6.86	7.16
	KOPUAROA 1000.00	7.28	7.58	7.28	7.58
	KOPUAROA 800.00	7.44	7.74	7.44	7.74
	KOPUAROA 600.00	7.81	8.11	7.81	8.11
	KOPUAROA 400.00	8.11	8.41	8.11	8.41
	KOPUAROA 200.00	8.53	8.83	8.53	8.83
	KOPUAROA 0.00	8.86	9.16	8.86	9.16
0	RAPARAPAHOE 5470.00	4.21	4.51	4.24	4.54
	RAPARAPAHOE 4440.00	4.5	4.80	4.5	4.80
	RAPARAPAHOE 4340.00	4.52	4.82	4.52	4.82
	RAPARAPAHOE 3420.00	4.91	5.21	4.91	5.21
	RAPARAPAHOE 2470.00	5.62	5.92	5.62	5.92
	RAPARAPAHOE 2090.00	5.98	6.28	5.98	6.28
	RAPARAPAHOE 2070.00	5.95	6.25	5.95	6.25
Dropstructure	RAPARAPAHOE 2050.00	6.5	6.80	6.50	6.80
	RAPARAPAHOE 1800.00	7.74	8.04	7.74	8.04
	RAPARAPAHOE 1680.00	8.32	8.62	8.32	8.62
	RAPARAPAHOE 1600.00	8.97	9.27	8.97	9.27
	RAPARAPAHOE 1400.00	9.75	10.05	9.75	10.05
	RAPARAPAHOE 1200.00	10.54	10.84	10.54	10.84
	RAPARAPAHOE 970.00	10.93	11.23	10.93	11.23
	RAPARAPAHOE 750.00	11.32	11.62	11.32	11.62
	RAPARAPAHOE 530.00	11.98	12.28	11.98	12.28
	RAPARAPAHOE 300.00	12.53	12.83	12.53	12.83
	RAPARAPAHOE 110.00	12.87	13.17	12.87	13.17
	RAPARAPAHOE 55.00	13.04	13.34	13.04	13.34
	RAPARAPAHOE 0.00	13.17	13.47	13.17	13.47
0	OHINEANGAANGA 3480.00	4.52	4.82	4.52	4.82
	OHINEANGAANGA 3027.97	4.66	4.96	4.66	4.96
	OHINEANGAANGA 2480.00	4.92	5.22	4.92	5.22

	OHINEANGAANGA 2130.00	5.12	5.42	5.12	5.42
	OHINEANGAANGA 1780.00	5.34	5.64	5.34	5.64
	OHINEANGAANGA 1680.00	5.78	6.08	5.78	6.08
	OHINEANGAANGA 1480.00	7.35	7.65	7.35	7.65
	OHINEANGAANGA 1090.00	9.51	9.81	9.51	9.81
	OHINEANGAANGA 740.00	11.13	11.43	11.13	11.43
	OHINEANGAANGA 685.00	11.35	11.65	11.35	11.65
	OHINEANGAANGA 630.00	11.59	11.89	11.59	11.89
	OHINEANGAANGA 610.00	11.65	11.95	11.65	11.95
	OHINEANGAANGA 570.00	12.39	12.69	12.39	12.69
	OHINEANGAANGA 550.00	12.16	12.46	12.16	12.46
	OHINEANGAANGA 540.00	12.46	12.76	12.46	12.76
	OHINEANGAANGA 510.00	13.1	13.40	13.10	13.40
SH2	OHINEANGAANGA 490.00	13.26	13.56	13.26	13.56
	OHINEANGAANGA 120.00	14.92	15.22	14.92	15.22
	OHINEANGAANGA 100.00	15	15.30	15.00	15.30
	OHINEANGAANGA 0.00	15.47	15.77	15.47	15.77
0	WAIARI 6820.00	4.46	4.76	4.48	4.78
	WAIARI 6770.00	4.47	4.77	4.49	4.79
	WAIARI 5830.00	4.56	4.86	4.57	4.87
	WAIARI 4970.00	4.66	4.96	4.67	4.97
	WAIARI 4160.00	4.81	5.11	4.82	5.12
SH2	WAIARI 3780.00	5.28	5.58	5.28	5.58
	WAIARI 3080.00	6.12	6.42	6.12	6.42
	WAIARI 2450.00	7.1	7.40	7.10	7.40
	WAIARI 1940.00	8.36	8.66	8.36	8.66
	WAIARI 1400.00	9.55	9.85	9.55	9.85
	WAIARI 1150.00	10.44	10.74	10.44	10.74
	WAIARI 565.00	11.91	12.21	11.91	12.21
	WAIARI 415.00	12.11	12.41	12.11	12.41
	WAIARI 375.00	12.19	12.49	12.19	12.49
	WAIARI 320.00	12.22	12.52	12.22	12.52
	WAIARI 290.00	12.27	12.57	12.27	12.57
	WAIARI 265.00	12.33	12.63	12.33	12.63
	WAIARI 155.00	12.42	12.72	12.42	12.72
	WAIARI 0.00	12.79	13.09	12.79	13.09
0	KAITUNA 21970.00	2.39	2.89	2.88	3.38
	KAITUNA 21770.00	2.38	2.88	2.88	3.38
0.482	KAITUNA 21420.00	2.41	2.91	2.89	3.39
1.005	KAITUNA 20900.00	2.42	2.92	2.89	3.39
1.528	KAITUNA 20370.00	2.52	3.02	2.90	3.40
2.011	KAITUNA 19900.00	2.81	3.31	2.96	3.46
2.497	KAITUNA 19400.00	2.92	3.42	3.05	3.55
3.017	KAITUNA 18880.00	3.09	3.59	3.20	3.70
3.5	KAITUNA 18400.00	3.35	3.85	3.44	3.94
4.023	KAITUNA 17880.00	3.35	3.85	3.44	3.94
4.506	KAITUNA 17390.00	3.53	4.03	3.60	4.10
5.029	KAITUNA 16870.00	3.74	4.24	3.80	4.30
5.507	KAITUNA 16390.00	3.88	4.38	3.92	4.42
6.018	KAITUNA 15880.00	3.92	4.42	3.96	4.46
6.5	KAITUNA 15400.00	3.98	4.48	4.02	4.52
7	KAITUNA 14900.00	4.07	4.57	4.10	4.60
7.25	KAITUNA 14650.00	4.15	4.65	4.18	4.68
7.5	KAITUNA 14400.00	4.21	4.71	4.24	4.74
8	KAITUNA 13900.00	4.36	4.86	4.38	4.88
8.503	KAITUNA 13400.00	4.48	4.98	4.50	5.00
9	KAITUNA 12900.00	4.51	5.01	4.53	5.03
9.5	KAITUNA 12400.00	4.63	5.13	4.65	5.15
10	KAITUNA 11900.00	4.83	5.33	4.85	5.35
10.55	KAITUNA 11350.00	5.13	5.63	5.14	5.64
11	KAITUNA 10900.00	5.38	5.88	5.39	5.89
11.511	KAITUNA 10390.00	5.56	6.06	5.57	6.07
12	KAITUNA 9900.00	5.78	6.28	5.79	6.29
12.3	KAITUNA 9600.00	5.99	6.49	6.00	6.50

Kaituna Scheme Stopbank Volumes - Recommended top-ups							
Cross-section	Distance (m)	Depth (m)	Additional Future WL	Height (m)	Volume (m^3)		
Kaituna River below Te Matai							
Right Bank							
Rway to SH2	350	0.4	0	2.1	2250		
Subtotal	350			Subtotal	2250	$ 24,750	@ $11/m^3
Waiari							
	40	0.2	0	0	30		
Ohineangaanga							
	250	0.3	0	0	260		
Kopuaroa							
	250	0.3	0	0	260		
Subtotal	540			Subtotal	550	$ 9,900	@ $18/m^3
Total	890			**Total**	**2800**	**$ 34,650**	