Uretara Stream Capacity Review

Prepared by Rachael Medwin, Engineering Assistant

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5 Quay Street
P O Box 364
Whakatane
NEW ZEALAND

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Chapter 1: Introduction

The Uretara stream is located at the Northern end of the Katikati Township; it flows under State Highway 2 and into the Tauranga Harbour. Due to heavy rain in the Uretara catchment on the 24 January 2006 the stream rose and lapped close to the top of the stopbanks and flooded some low lying areas. Some of the noted flooding was discovered to be due to poorly maintained floodgates. However the quantity of water that coursed through the stream caused current 100 year flood levels to be questioned and reassessed.

The stopbanks on the Uretara stream where built in the late 1970’s and were designed to contain a 2% AEP flood flow. Suspicions were raised following the 24 January event that the stopbanks were beneath the 2% AEP level. This report assesses these levels in relation to the revised flood level calculations.

The 25.3 km^2 Uretara Stream catchment has two main parts; a steep, densely vegetated hill sub-catchment covering roughly 60%; and a flatter pasture and orchard-covered area at the foot of the hills (40%). Appendix 1 shows the extent of this catchment. The soils are volcanic sandy loams with little to no cohesion. Although this would normally indicate a highly permeable surface, it is expected that weathering on the steep vegetated slopes has caused a reduced infiltration capacity in the upper catchment.

1.1 Method

1.1.1 Software

The Uretara stream model was constructed using the Hec-Ras (U.S. Army Corps of Engineers’ River Analysis System) modelling software package. This package was created by the US Army to model one dimensional steady and unsteady flow river hydraulic calculations. It is able to calculate the water volume at specified cross sections, given their location boundary conditions and distance between each section. It has the capacity to calculate a range of basic bridge and culvert flow data calculations.

1.1.2 Surveyed Cross Sections

Cross Sections were completed along the stretch of the stream bed protected by stopbanking; this involves the section from the stream mouth up to Rawaka Drive, a distance of approximately 3800 m. This was covered by a total of 17 cross sections and long sections taken of both the left and right side stream stopbanks. Debris marks were collected a month post the 24 January flood event and surveying was done a month later. Surveying was undertaken by Peter Vercoe, Carl Iverson, David Marven, Krystle Doney and Rachael Medwin. Locations of surveyed cross sections are shown in Appendix 2.

1.1.3 Bridges

There are two bridges crossing the Uretara stream in the region of the stream surveyed.

The first bridge being the State Highway 2 bridge 1850 m upstream of the harbour. This bridge is a flat concrete deck with one central pier. The model shows that the water would reach the central soffits. Provision of 0.6 m was added to the base of the bridge soffits to account for debris. An area 1.8 m wide was set as to account for the debris accumulation around the pier this equates to 0.6 m each side of the 0.6 m wide pier, and extending the height of the pier.

The second bridge was a walk bridge located 2460 m upstream of the harbour, with its rounded shape extending across the stream with no piers. A provision of 0.6 m was added to the base of the highest part of the bridge to allow for debris accumulation. However on this bridge it is less of an issue as the water doesn't reach this level.

1.1.4 Boundary Conditions

The Uretara stream runs into Tauranga Harbour setting the tidal level in the harbour as the downstream boundary condition. This being the case we are able to get a good indication of the level by looking at the levels of the tide in neighbouring sites where recording equipment is installed and then transferring the information with the addition of area knowledge of the Uretara stream situation.

The locations of the sites used to extrapolate the information required are shown in Appendix 3. These sites are known as Omokoroa, Hairini and Oruamatua.

Table 1 shows the tidal levels in the Uretara Stream at two specific design heights (based on design sea levels in Tauranga Harbour collated by Tonkin and Taylor Ltd). These design levels include 0.2 m for the mid-range estimated increase in sea level to 2050.

Table 1 Tidal levels at the Uretara Stream Mouth

Probability	Tidal Level (m)
2%	2.2
5%	2.05

For the upstream boundary condition the only data required was the flow because the flow down the stream was determined to be sub critical.

1.1.5 Hydrology

The hydrological data for the rainfall event was analysed by Environmental Engineer Peter West, his findings are set out in Appendix 4.

In reaching a conclusion the average of the Rational and TM61 methods was taken and the resulting data is displayed in Table 2.

Table 2 Uretara Hydrology

Exceedance Probability (%)	Flow (m3/s)
1	151
2	137
5	119
10	105
20	90

This calculation of 151 cumecs for a 1% AEP flood in the Uretara catchment is higher than the previous prediction of 138 cumecs in 2005 and 91 cumecs done by Matthew Surman back in 1995. Due to this increase in flood data it was important to reassess the stopbank design levels against this new information.

1.1.6 Design Flow Combinations

Design flow combinations of 2%AEP (1 in 50 year flood flow) and 5%AEP (1 in 20 year flood flow) were used, along with the 2% and 5% tidal levels. These are shown in Table 3.

Table 3 Combined event combinations used in Uretara Stream

Tidal level	Flood flow
2% (L50)	5% (Q20)
5% (L20)	2% (Q50)

1.1.7 Manning's n Values

Based on the knowledge of the streambed, size and average flow three Manning's n values were selected to best represent the stream reaches. Manning's n values are also chosen to represent the stream in its state of flood as this is what we are most interested in. Photos of cross sections are shown in Appendix 5 along with their allocated Manning's n value. A summary is shown in Table 4.

Table 4 Manning's n values applied

Cross Sections applied to	Manning's n Valve	Description
0-8A	0.035	Bed consists of mud and sand, side vegetation is mainly grass.
8B-14	0.037	Bed consists of gravel and cobbles, vegetation is mainly long grass.
15	0.040	Bed consists of cobbles and some small boulders; vegetation is mainly scrub and overhanging trees.
16	0.041	Bed consists of cobbles and boulders; vegetation is mainly grass with some overhanging trees.
17	0.042	Bed consists of mainly boulders; vegetation is mainly trees and scrub.

1.1.8 Freeboard

Stopbanks within the urban area of Katikati are owned by the Western Bay District Council, therefore Environment Bay of Plenty does not have these in an Asset Management Plan, in which stream specific stopbank freeboard levels would be set out. Due to this 0.5 m freeboard was used. This value is in line with the New Zealand Building Code floor level freeboard requirements.

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Chapter 2: Discussion

2.1 Cross section 0

Cross section 0 was a hypothetical cross section created to represent the down stream boundary condition where the stream meets Tauranga Harbour. The placement of this cross section, in terms of the distance from the stream mouth, was investigated (see Appendix 6) and found to have no affect on the resulting cross sections upstream. This being the case the cross section was placed at 0m, being the Uretara Stream Mouth.

2.2 Calibration

Because of the lack of stream data the only means of calibration was by considering the recorded debris marks left from the recent flood event on 24 January 2006. Available rainfall data and eyewitness accounts strongly suggest the flood did not have a large return period, at best 20 years. The model was partially calibrated with these levels, under the event specific boundary conditions.

2.3 Boundary conditions

Because the stream runs into the Tauranga Harbour the downstream boundary condition for calibration is thus set by the level of the tide in this portion of the Tauranga Harbour on the date in question. This being the case we are able to get a good indication of the level by looking at the levels of the tide on 24 January in neighbouring sites where recording equipment is installed and then transferring the information with the addition of area knowledge to the Uretara stream situation. On 24 January the sites recorded the data shown in Table 5.

Table 5 Data recorder at Recorders on 24 January

Recording Station	Tide Height (mm)	Time (hours)
Omokoroa	950	1450
Hairini	1049	1420
Oruamatua	870	1545

With this data in mind a downstream boundary condition of 1.0 m was applied to the Uretara stream when considering the even on 24 January 2006, in order to calibrate the model.

For the upstream boundary condition the only data required was the flow and this was taken to be 119 cumecs, the calculated flow of a 1 in 20 year event.

2.4 Debris levels

The debris levels recorded in the graph and Table 6 below were taken on 21 February 2006, and display the flood levels of 24 January 2006.

Table 6 Debris Levels Uretara 21 February 2006 post flood

RL	Distance upstream	Notes
2.93	76 m	
2.98	71 m	
2.97	60 m	
	Distance Downstream	
2.74	14 m	
2.79	18 m	
2.79	20 m	
2.79	28 m	
2.57	125 m	Low confidence
2.61	135 m	Reasonable confidence
2.66	155 m	Base of Humphrey (no debris found)

Note: Distances taken from the State Highway 2 bridge

Debris levels on structures were ignored during the calibration process, due to the time it takes debris to accumulate and the possibility that the high water marks were left early on in the flood event before debris has time to gather around the structures.

2.5 Discussion

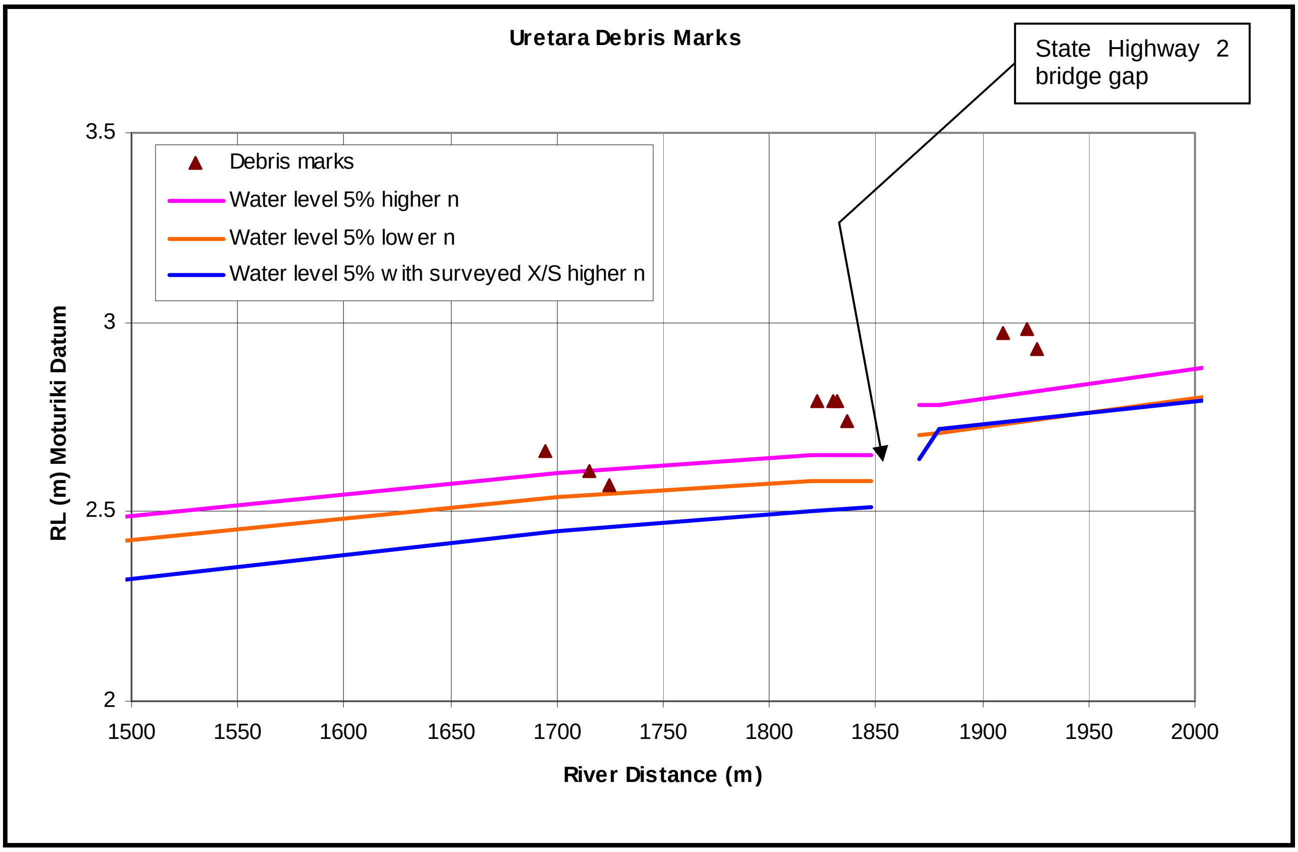


Diagram 1 Debris marks left around the State Highway 2 Bridge.

Comparisons were made with the current cross sections and an old set of cross sections surveyed in September 1995. The 1995 set of cross sections displayed a much higher bed level in the stream and this higher bed level is assumed to be the normal bed level in the stream, with the recorded lower bed levels in our cross sections showing the result of scouring due to the recent flood event. This being the case it is likely that the recorded debris levels were laid prior to this scouring taking place. To further investigate this the old cross section bed levels were related to the new cross sections and bed levels were altered in the Hec-Ras programme and modelled, to see if this would produce a better match with the recorded debris marks. Diagram 1 shows the results around the State Highway 2 bridge. This confirms that it is likely scouring occurred during the flood event and the debris marks were likely laid down prior to the scouring taking place.

Manning's n values were investigated and altered within realistic limits in order to obtain the most accurate model.

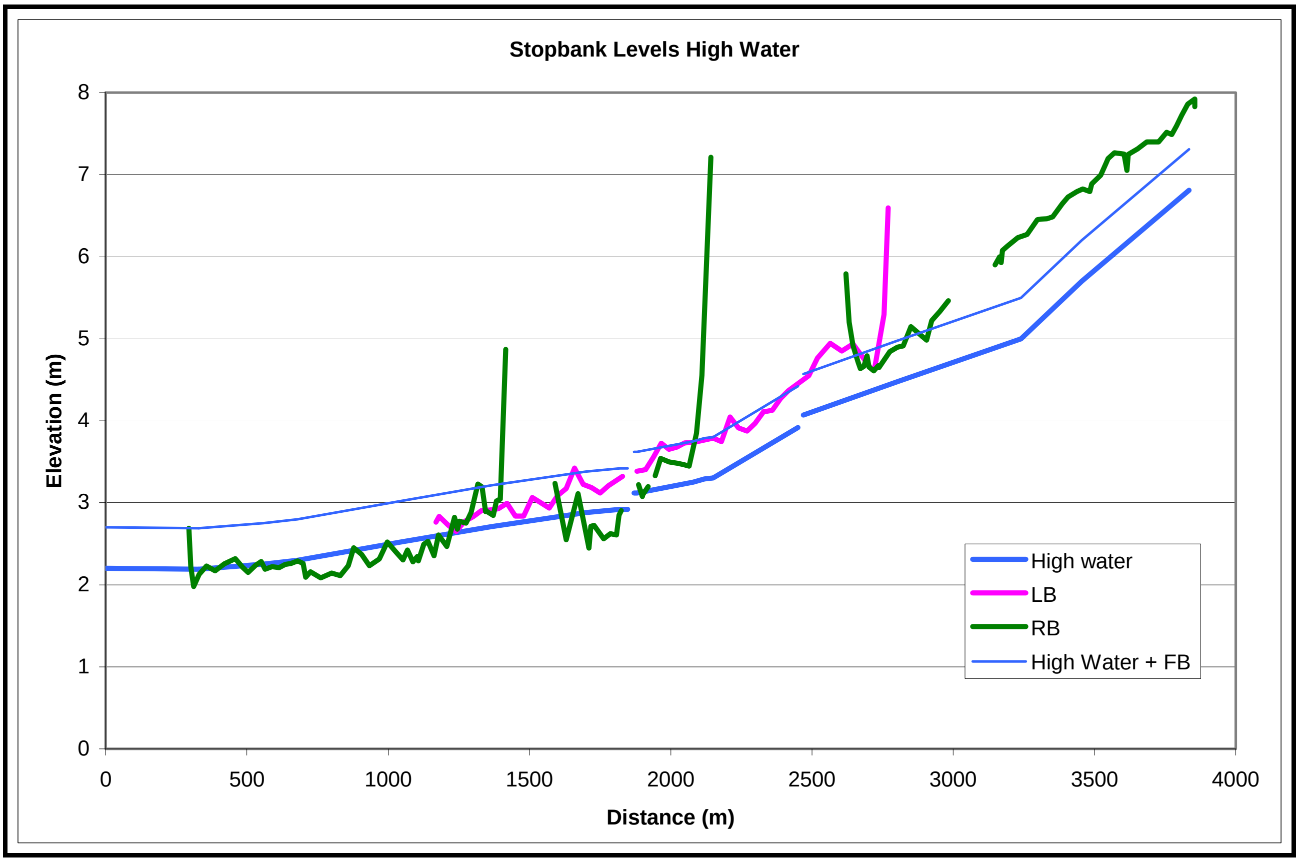
After consideration and comparison, it is suggested that the situation on 24 January 2006 was a mixture of the higher Manning's n value and also the higher cross sectional level. It is important to recognise that the under prediction using the current cross sections is within or very close to the accepted hydraulic modelling accuracy of +- 300 mm.

Chapter 3: Results

The results of running the model under the specific design conditions (this included using the pre scour cross sections) are set out in Appendix 7. An assessment of the information compiled in this investigation shows that the stopbanks are below the required levels in the section downstream of State Highway 2 bridge and in the first 1000 m upstream of this bridge.

3.1 Design flow results

The graph below shows the highest design water level, taken from the combined results of the Q50 L20 and Q20 L50 scenarios calculated without debris around bridges and the Q50 L20 scenario with debris accounted for. Freeboard was added to the highest design water level and the result plotted. The right and left stopbank levels are also shown. Details of all results are in Appendix 8.



Highest water level, combined scenarios

Cross Sections	River Station (m)	Water Level (m)	Water Level + FB (m)	LB Elev (m)	RB Elev (m)	LB Diff (m)	RB Diff (m)
17	3835	6.81	7.31		7.93		0.62
16	3455	5.7	6.2		6.956		0.756
15	3240	5	5.5		6.184		0.684
14	2805	4.48	4.98		5.018		0.038
	2470	4.07	4.57	4.606		0.036	
	2460						
13	2450	3.96	4.46	4.654		0.194	
12	2150	3.43	3.93	3.765	4.311	-0.165	0.381
11	2120	3.41	3.91	3.729	4.359	-0.181	0.449
10	2080	3.39	3.89	3.608	3.568	-0.282	-0.322
9	1880	3.28	3.78	3.379	3.104	-0.401	-0.676
	1870	3.27	3.77	2.79	2.61	-0.980	-1.160
8	1850						
	1848	2.92	3.42	2.74	2.56	-0.68	-0.86
7	1820	2.92	3.42	3.218	2.881	-0.202	-0.539
6	1700	2.88	3.38	3.405	2.649	0.025	-0.731
5	1365	2.71	3.21	2.956	2.967	-0.254	-0.243
4	1045	2.52	3.02		2.355		-0.665
3	680	2.3	2.8		2.252		-0.548
2	560	2.25	2.75		2.263		-0.487
1	330	2.19	2.69		2.22		-0.47
0	0	2.2	2.7				

The table above displays the stream stations and their corresponding stopbank height and design stopbank height, the numbers highlighted indicate where the heights are below those desired. Also listed are the differences between existing stopbank crest heights and design water levels, and where these are insufficient they are highlighted (negative values).

Chapter 4: Conclusions

This review of the stopbanks on the Uretara stream has shown that a considerable amount of protection provided by the banks is below the desired level. Taking freeboard into account the stream is currently offering less protection than is required for a 1 in 50 year flood. It would be desirable that the stopbanks be topped up to the 1 in 100 year flood protection level.

References

Tonkin and Taylor Ltd, May 1999. "Storm Surge Inundation Study for Tauranga Harbour". Report prepared for Tauranga District Council.

Tonkin and Taylor Ltd, November 2000. "Western Bay of Plenty Lifelines Engineering Group: 2% Design Inundation Levels", Plan No 18526, Figure 2.

Wallace P.L., July 2004. "Hydraulic Modelling of the Lower Whakatane River and Floodplain". Environment Bay of Plenty, Whakatane.

Appendices

Appendix 1..Map of Uretara Stream Catchment

Appendix 2... Cross Section Locations

Appendix 3...Aerial Maps

Appendix 4..Memorandum to Peter Blackwood

Appendix 5...Cross Sections

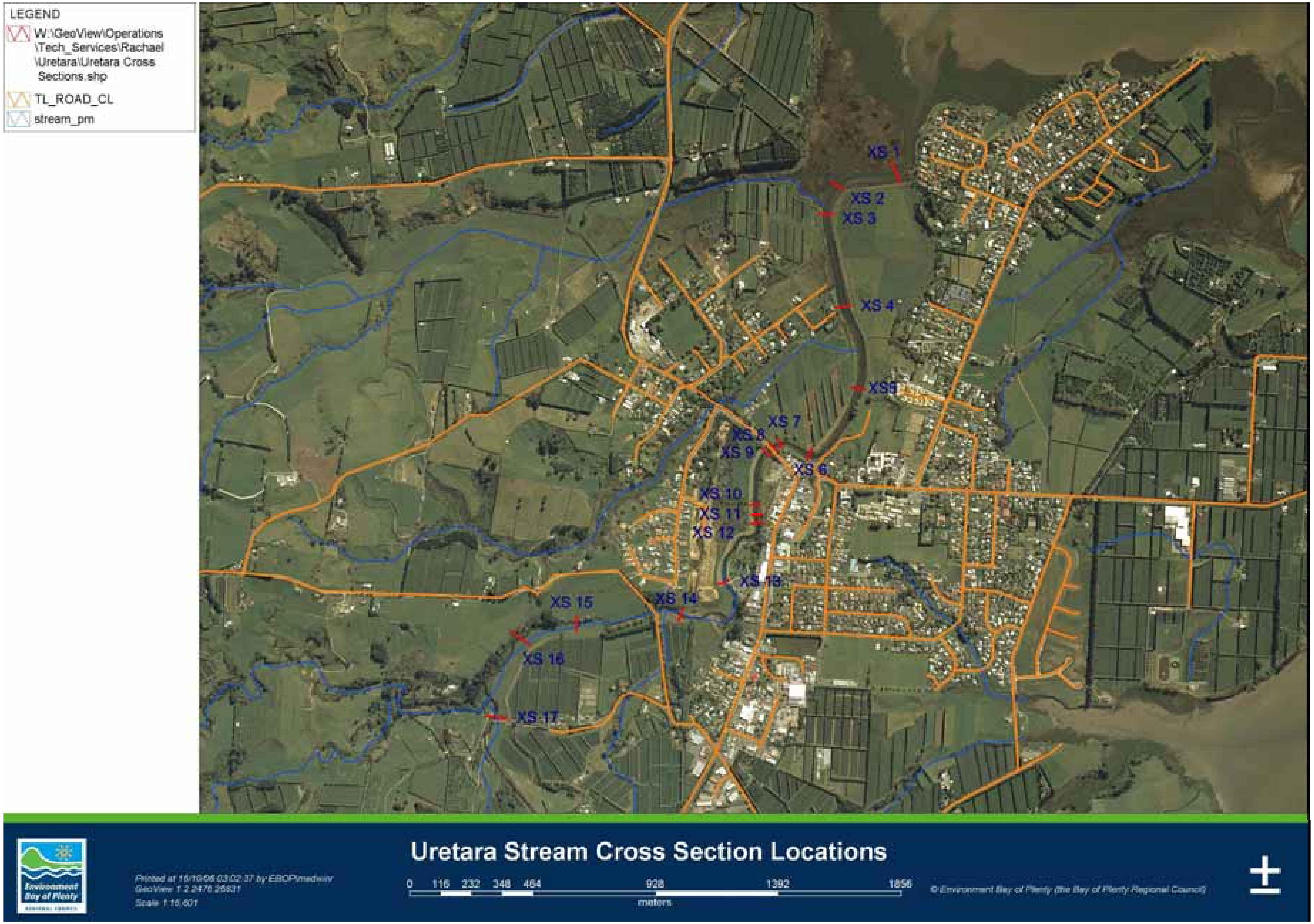
Appendix 6.. Graphs

Appendix 7... Model Results

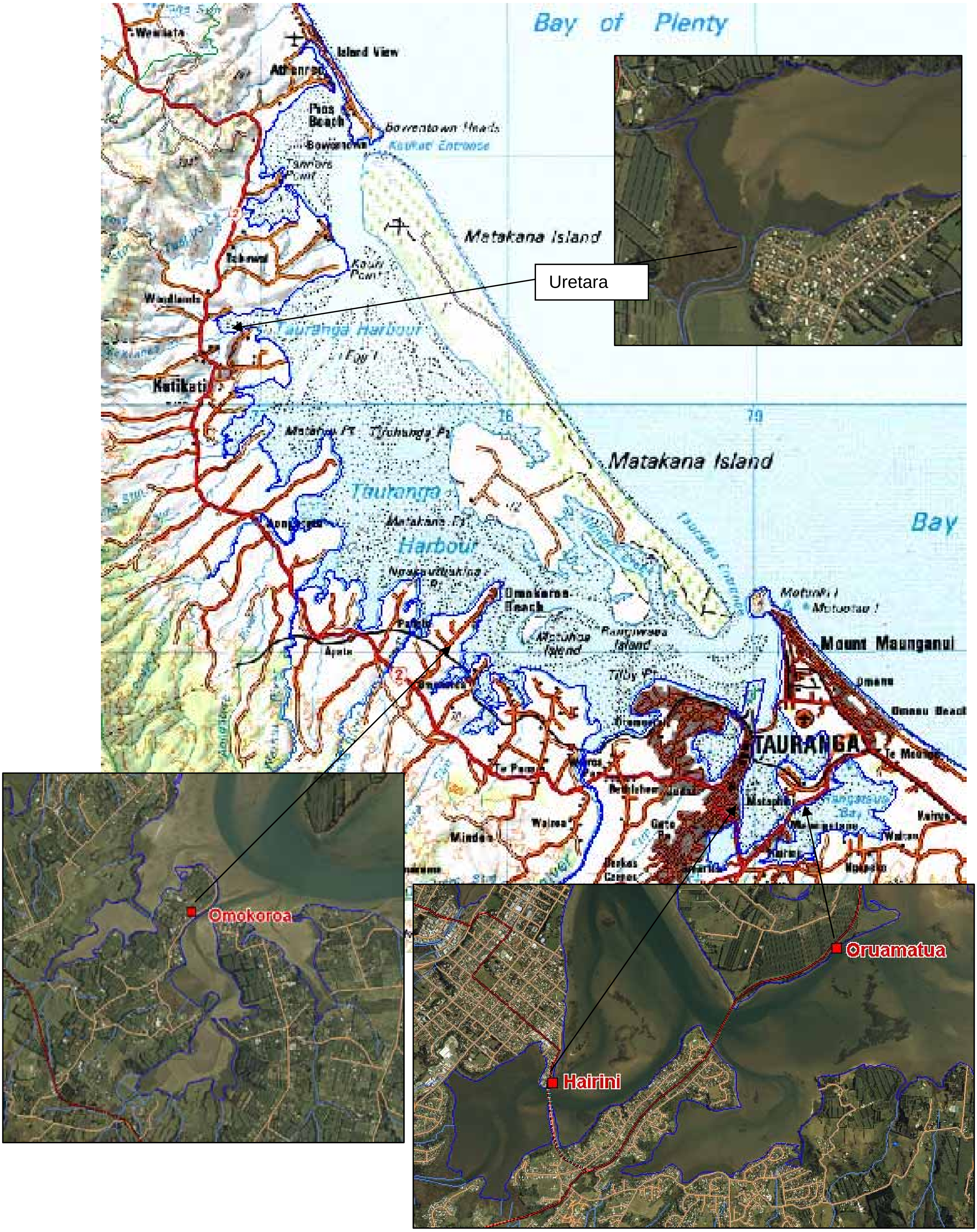
Appendix 8... Results

Appendix 1 – Map of Uretara Stream Catchment

Appendix 2 – Cross Section Locations



Appendix 3 – Aerial Maps



Appendix 4 – Memorandum to P Blackwood

MEMORANDUM

Environment Bay of Plenty
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To: Peter Blackwood
Manager Technical Services

From: Peter West
Environmental Engineer

Date: 14 March 2006

File Ref: 2160 04 08

Subject: **Hydrological Catchment Analysis; Uretara Stream, Katikati**

Peter,

As part of a review of the Uretara flood protection system, following flooding in February of this year, an hydrological assessment of the catchment to State Highway 2 has been carried out. Methods used include: TM61; Rational Method; McKerchar and Pearson's *Flood Frequency in New Zealand*; Petrus Herbst's *Regional Formula;* and transposition of nearby gauged catchments at Tuapiro and Waipapa. Results of these 5 methods vary considerably, with estimates for the 1% AEP flow ranging from 110 m3/s to 207 m3/s. After considering the results and the characteristics behind each method, design flow estimates were arrived at that adequately fit the available information.

Catchment Characteristics

The 25.3 km2 Uretara Stream catchment has two main parts; a steep, densely vegetated hill sub-catchment covering roughly 60%; and a flatter pasture and orchard-covered area at the foot of the hills (40%). The soils are volcanic sandy loams with little to no cohesion. Although this would normally indicate a highly permeable surface, it is expected that weathering on the steep vegetated slopes has caused a reduced infiltration capacity in the upper catchment. Previous Environment Bay of Plenty hydrological work has indicated that these steeper Kaimai catchments fit between the *impervious* and *moderately absorbent* classes of surface characteristic in the TM61 and Rational methods.

Discussion of results

The results of the various standard methods vary considerably as shown in

Table 1 below. Details of the various methods are attached.

Table 1: Estimates of 1%AEP flow for Uretara Stream by various methods

Method	1% AEP Flow Estimate
TM61	174
Rational Method	128
FFINZ	178
Regional Formula	207
Transposed Tuapiro	151
Transposed Waipapa	110

Of these it is considered that the TM61, Rational Methods and Transposition methods are the most reliable. The regional type methods rely on the plotting and selection of a regional variable that has a steep gradient at the location of interest. For the FFINZ method, figure 3.4, the plot of $Q_{bar}/A^{0.8}$ shows values ranging from 3 to 10 from one side of the catchment to the other. In Herbst's Regional Formula, contours of the regionally varying parameter in [his] figure1 vary from about 1.5 to 2.5 across the study area.

Of the transposed catchments, the Tuapiro is considered to better represent the study catchment. The Waipapa is much flatter and covered largely with broken scrub and cut-over bush. The Tuapiro at Woodlands road however lacks the large portion of flat farmland of the Uretara at SH2. and is expected to slightly over-predict in this regard. Although the period of record for the Tuapiro river gauge is only 21 years, it spans both phases of the Inter-decadal Pacific Oscillator and could be considered to give reasonable estimates.

The TM61 result is significantly higher than the rational method and the transposed values. This can not be disregarded although I feel that the surface characteristic parameter chosen (Wic = 0.83) may be slightly high. I feel that the average between the TM61 and Rational Methods would adequately represent the situation. Therefore the design flows used should be as given in table 2 below.

Exceedance Probability (%)	Flow (m3/s)
1	151
2	137
5	119
10	105
20	90

Peter West

Appendix 5 – Cross Sections

Cross Section 1 (n=0.035) (right side = on right when looking downstream)

Looking downstream

Across section L/R

Upstream

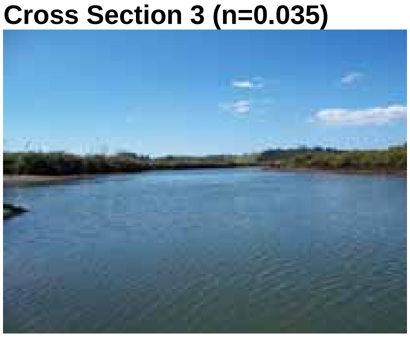
Cross section 2 (n=0.035)

Downstream

Across L/R

Upstream

Cross Section 3 (n=0.035)

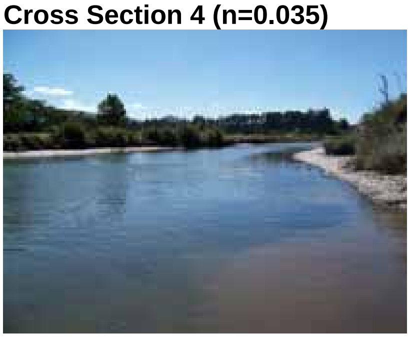


Downstream

Across L/R

Upstream

Cross Section 4 (n=0.035)



Downstream

Across L/R

Upstream

Cross Section 5 (n=0.035)


Downstream


Across L/R


Upstream

Cross Section 6 (n=0.035)


Downstream

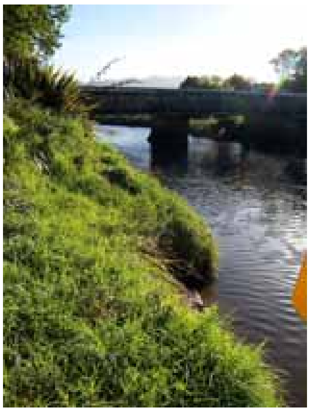

Across R/L


Upstream

Cross Section 7 (n=0.035)


Downstream


Across R/L


Upstream

Cross Section 8 (n=0.037)

Cross Section 9 (n=0.037)

Cross Section 10 (n=0.037)

Cross Section 11 (n=0.037)

Cross Section 12 (n=0.0.37)


Downstream


Across L/R


Upstream

Cross Section 13 (n=0.0.37)


From downstream

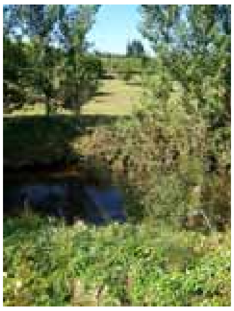

Across L/R


From upstream

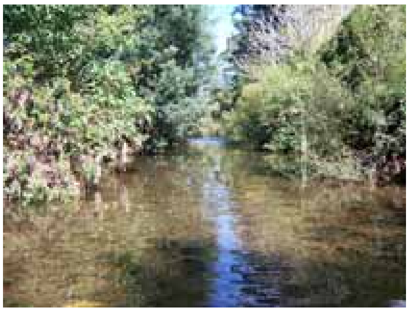
Cross Section 14 (n=0.037)

Cross Section 15 (n=0.040)


Downstream


Across L/R


Across R/L


Upstream

Cross Section 16 (n=0.041)


Downstream


Across L/R


Upstream

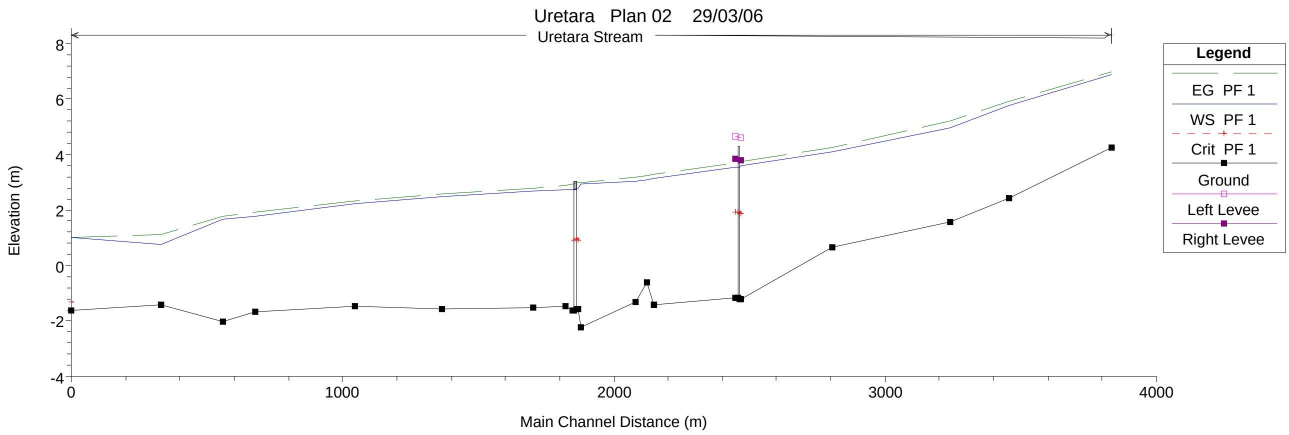
Cross Section 16 (n=0.042)


Across L/R


Across R/L

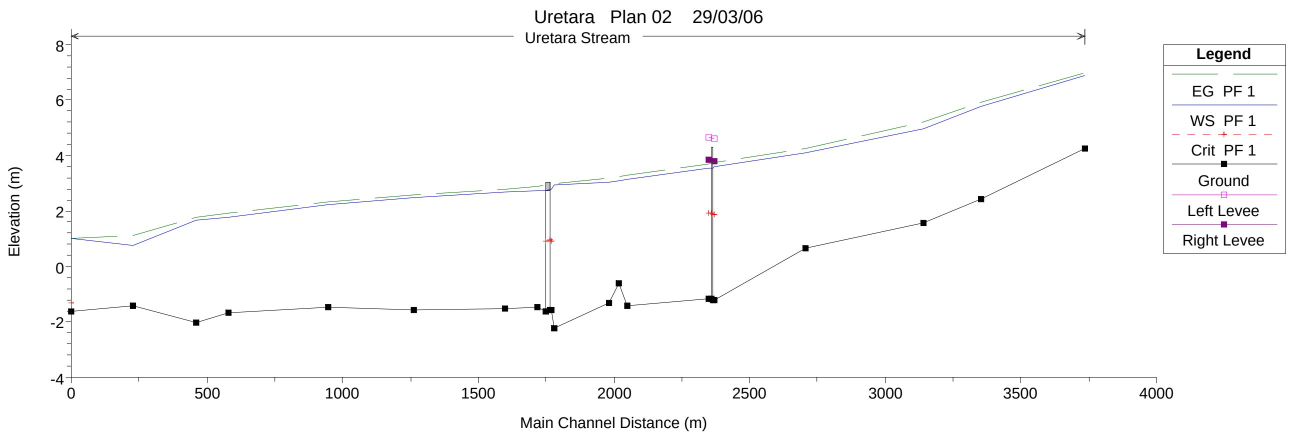

From upstream looking down

Appendix 6 – Graphs



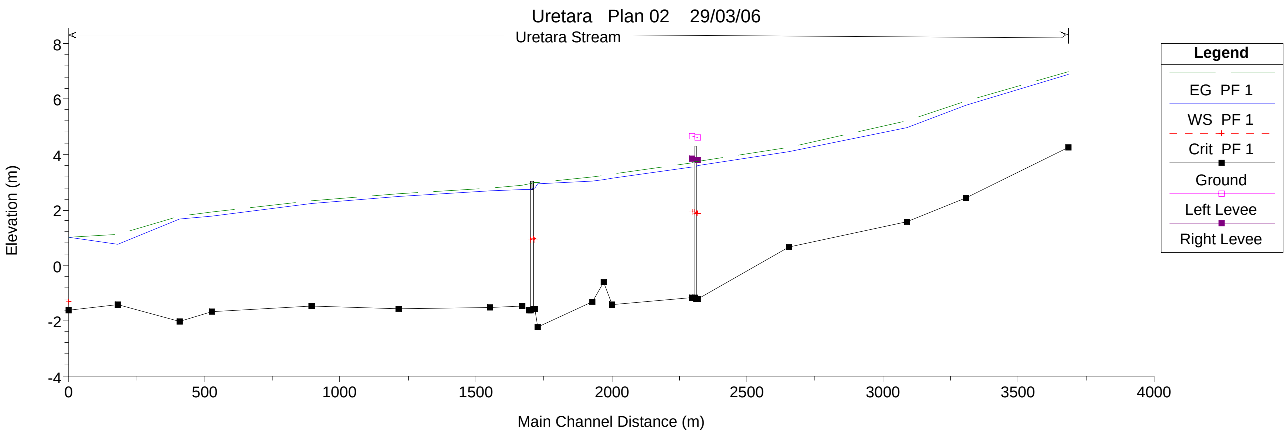
RAS Plan: Plan of Uretara River: Uretara Reach: Uretara Stream Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Uretara Stream	330	151.00	-1.41	0.78		1.11	0.007944	2.57	58.66	62.73	0.85
Uretara Stream	0	151.00	-1.60	1.00	-1.29	1.00	0.000010	0.15	991.98	495.00	0.03

1m tide at 0m, Stream Mouth



RAS Plan: Plan of Urer River: Uretara Reach: Uretara StreamReach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Uretara Stream	330	151.00	-1.41	0.77		1.11	0.007970	2.59	58.19	61.62	0.85
Uretara Stream	0	151.00	-1.60	1.00	-1.29	1.00	0.000010	0.15	991.98	495.00	0.03

1m tide at 100m Upstream of Stream Mouth



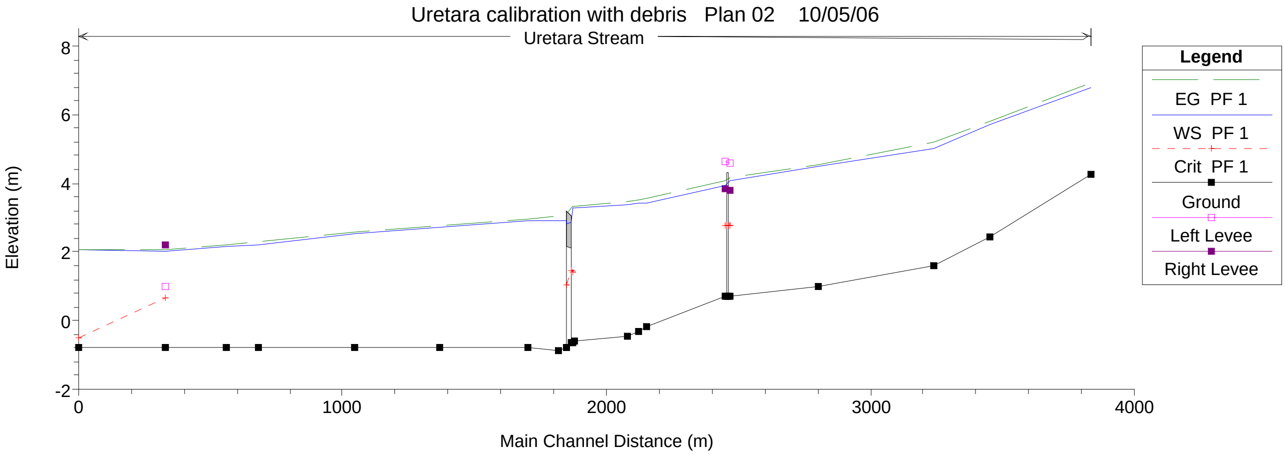
RAS Plan: Plan of Urer River: Uretara Reach: Uretara StreamReach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Uretara Stream	330	151.00	-1.41	0.77		1.11	0.007980	2.61	57.96	61.07	0.85
Uretara Stream	0	151.00	-1.60	1.00	-1.29	1.00	0.000010	0.15	991.98	495.00	0.03

1m tide at 150m Upstream of Stream Mouth

Appendix 7 – Model Results

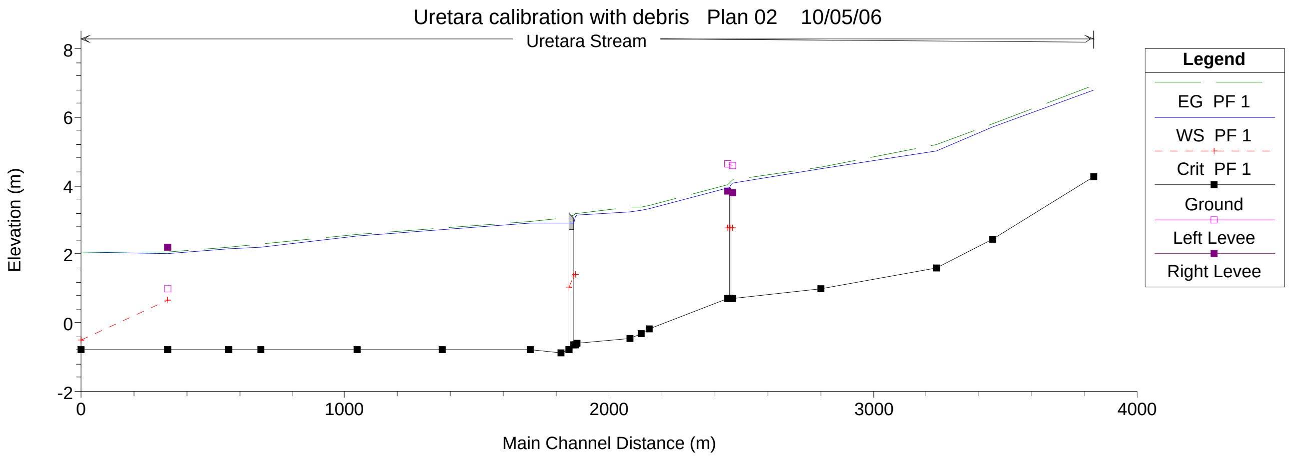
Model Results

Q50 L20 – with debris



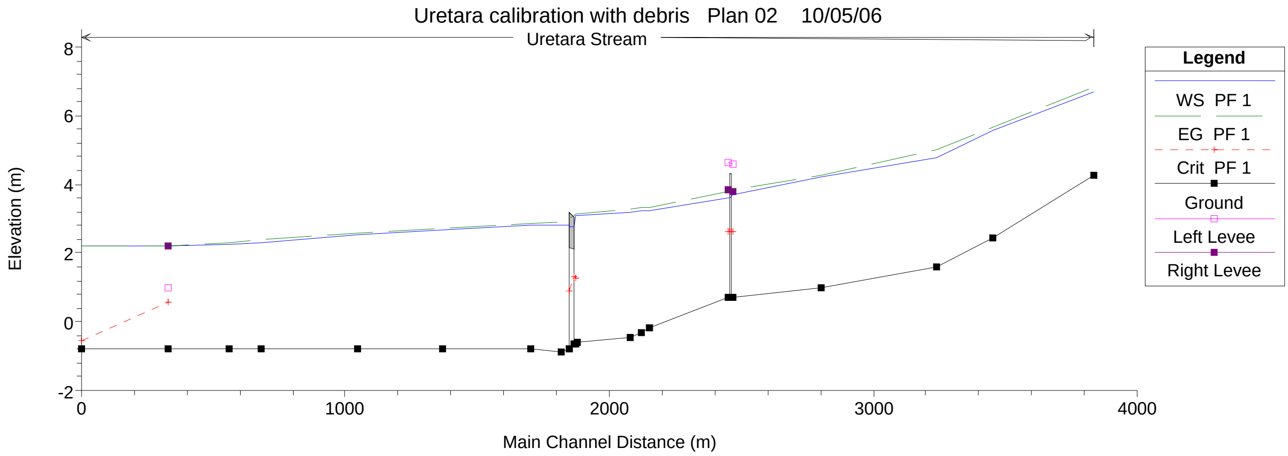
RAS Plan: Plan of Urer River: Uretara Reach: Uretara StreamReach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Uretara Stream	3835	137.00	4.24	6.81		6.92	0.004735	1.50	91.56	104.03	0.51
Uretara Stream	3455	137.00	2.45	5.70		5.81	0.001982	1.41	97.14	64.50	0.37
Uretara Stream	3240	137.00	1.59	5.00		5.20	0.004119	1.99	68.85	47.34	0.53
Uretara Stream	2805	137.00	1.00	4.48		4.55	0.000709	1.15	118.70	57.57	0.26
Uretara Stream	2470	137.00	0.72	4.08	2.77	4.16	0.002155	1.27	107.86	103.83	0.40
Uretara Stream	2460	Bridge									
Uretara Stream	2450	137.00	0.70	3.96	2.78	4.07	0.003767	1.50	91.06	103.48	0.51
Uretara Stream	2150	137.00	-0.20	3.43		3.54	0.001020	1.47	92.95	39.60	0.31
Uretara Stream	2120	137.00	-0.30	3.41		3.51	0.000793	1.34	102.12	41.55	0.27
Uretara Stream	2080	137.00	-0.45	3.39		3.47	0.000765	1.32	103.54	41.82	0.27
Uretara Stream	1880	137.00	-0.60	3.28		3.34	0.000544	1.07	128.26	56.46	0.23
Uretara Stream	1870	137.00	-0.62	3.27	1.43	3.33	0.000529	1.06	129.35	56.51	0.22
Uretara Stream	1850	Bridge									
Uretara Stream	1848	137.00	-0.80	2.92		3.07	0.000974	1.74	78.92	23.40	0.30
Uretara Stream	1820	137.00	-0.90	2.92		3.03	0.000867	1.44	95.09	39.87	0.30
Uretara Stream	1700	137.00	-0.80	2.88		2.94	0.000446	1.08	126.79	51.04	0.22
Uretara Stream	1365	137.00	-0.80	2.71		2.78	0.000545	1.20	114.34	45.64	0.24
Uretara Stream	1045	137.00	-0.80	2.52		2.59	0.000615	1.17	117.57	54.32	0.25
Uretara Stream	680	137.00	-0.80	2.22		2.32	0.000899	1.41	97.39	44.83	0.30
Uretara Stream	560	137.00	-0.80	2.14		2.21	0.000784	1.18	115.94	62.38	0.28
Uretara Stream	330	137.00	-0.80	2.03	0.66	2.07	0.000441	0.92	152.18	83.25	0.21
Uretara Stream	0	137.00	-0.80	2.05	-0.51	2.05	0.000004	0.11	1248.72	500.00	0.02

Q50 L20 – no debris



RAS Plan: Plan of Urer River: Uretara Reach: Uretara StreamReach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Uretara Stream	3835	137.00	4.24	6.81		6.92	0.004734	1.50	91.56	104.03	0.51
Uretara Stream	3455	137.00	2.45	5.70		5.81	0.001982	1.41	97.14	64.50	0.37
Uretara Stream	3240	137.00	1.59	5.00		5.20	0.004121	1.99	68.83	47.34	0.53
Uretara Stream	2805	137.00	1.00	4.48		4.54	0.000710	1.15	118.64	57.56	0.26
Uretara Stream	2470	137.00	0.72	4.07	2.77	4.16	0.002179	1.27	107.49	103.83	0.40
Uretara Stream	2460	Bridge									
Uretara Stream	2450	137.00	0.70	3.92	2.78	4.05	0.004319	1.57	87.36	103.40	0.54
Uretara Stream	2150	137.00	-0.20	3.30		3.43	0.001200	1.56	88.09	39.17	0.33
Uretara Stream	2120	137.00	-0.30	3.29		3.39	0.000924	1.41	96.91	40.87	0.29
Uretara Stream	2080	137.00	-0.45	3.25		3.35	0.000887	1.40	98.11	40.81	0.29
Uretara Stream	1880	137.00	-0.60	3.12		3.19	0.000680	1.15	119.42	56.04	0.25
Uretara Stream	1870	137.00	-0.62	3.12	1.43	3.18	0.000663	1.14	120.43	56.09	0.25
Uretara Stream	1850	Bridge									
Uretara Stream	1848	137.00	-0.80	2.92		3.07	0.000974	1.74	78.92	23.40	0.30
Uretara Stream	1820	137.00	-0.90	2.92		3.03	0.000867	1.44	95.09	39.87	0.30
Uretara Stream	1700	137.00	-0.80	2.88		2.94	0.000446	1.08	126.79	51.04	0.22
Uretara Stream	1365	137.00	-0.80	2.71		2.78	0.000545	1.20	114.34	45.64	0.24
Uretara Stream	1045	137.00	-0.80	2.52		2.59	0.000615	1.17	117.57	54.32	0.25
Uretara Stream	680	137.00	-0.80	2.22		2.32	0.000899	1.41	97.39	44.83	0.30
Uretara Stream	560	137.00	-0.80	2.14		2.21	0.000784	1.18	115.94	62.38	0.28
Uretara Stream	330	137.00	-0.80	2.03	0.66	2.07	0.000441	0.92	152.18	83.25	0.21
Uretara Stream	0	137.00	-0.80	2.05	-0.51	2.05	0.000004	0.11	1248.72	500.00	0.02

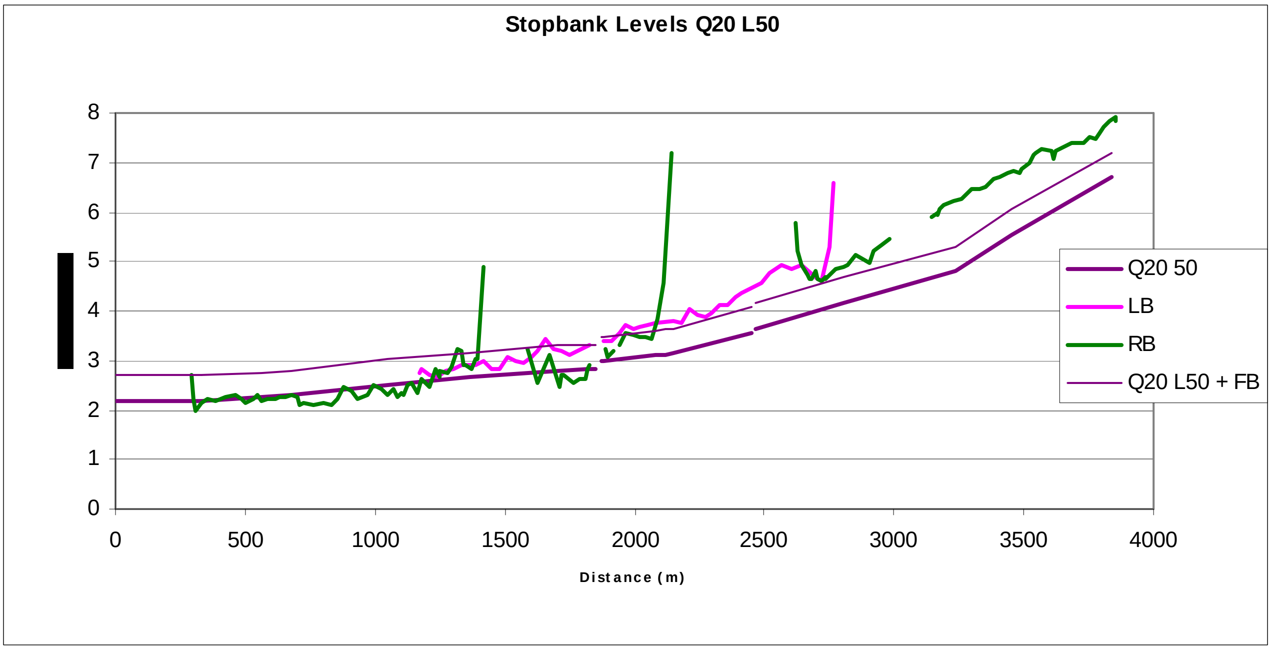
Q20 L50



RAS Plan: Plan of Urer River: Uretara Reach: Uretara StreamReach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Uretara Stream	3835	119.00	4.24	6.71		6.82	0.004973	1.45	81.85	100.81	0.52
Uretara Stream	3455	119.00	2.45	5.56		5.65	0.002079	1.36	87.56	63.83	0.37
Uretara Stream	3240	119.00	1.59	4.80		5.00	0.004601	2.00	59.52	44.05	0.55
Uretara Stream	2805	119.00	1.00	4.20		4.27	0.000797	1.15	103.09	54.59	0.27
Uretara Stream	2470	119.00	0.72	3.69	2.63	3.86	0.002009	1.79	66.66	35.80	0.42
Uretara Stream	2460	Bridge									
Uretara Stream	2450	119.00	0.70	3.61	2.64	3.79	0.002228	1.88	63.16	33.67	0.44
Uretara Stream	2150	119.00	-0.20	3.25		3.34	0.000981	1.39	85.77	38.96	0.30
Uretara Stream	2120	119.00	-0.30	3.23		3.31	0.000747	1.26	94.63	40.57	0.26
Uretara Stream	2080	119.00	-0.45	3.20		3.28	0.000707	1.24	96.12	40.43	0.26
Uretara Stream	1880	119.00	-0.60	3.10		3.15	0.000527	1.01	118.31	55.88	0.22
Uretara Stream	1870	119.00	-0.62	3.10	1.26	3.15	0.000514	1.00	119.40	56.04	0.22
Uretara Stream	1850	Bridge									
Uretara Stream	1848	119.00	-0.80	2.83		2.95	0.000795	1.55	76.89	23.40	0.27
Uretara Stream	1820	119.00	-0.90	2.83		2.92	0.000698	1.30	91.55	38.02	0.27
Uretara Stream	1700	119.00	-0.80	2.80		2.85	0.000373	0.97	122.57	50.78	0.20
Uretara Stream	1365	119.00	-0.80	2.66		2.71	0.000436	1.06	112.13	45.47	0.22
Uretara Stream	1045	119.00	-0.80	2.52		2.57	0.000470	1.02	117.15	54.32	0.22
Uretara Stream	680	119.00	-0.80	2.30		2.37	0.000611	1.18	101.08	45.37	0.25
Uretara Stream	560	119.00	-0.80	2.25		2.30	0.000502	0.97	122.95	63.74	0.22
Uretara Stream	330	119.00	-0.80	2.19	0.55	2.21	0.000255	0.74	165.37	83.60	0.16
Uretara Stream	0	119.00	-0.80	2.20	-0.54	2.20	0.000003	0.09	1323.40	500.00	0.02

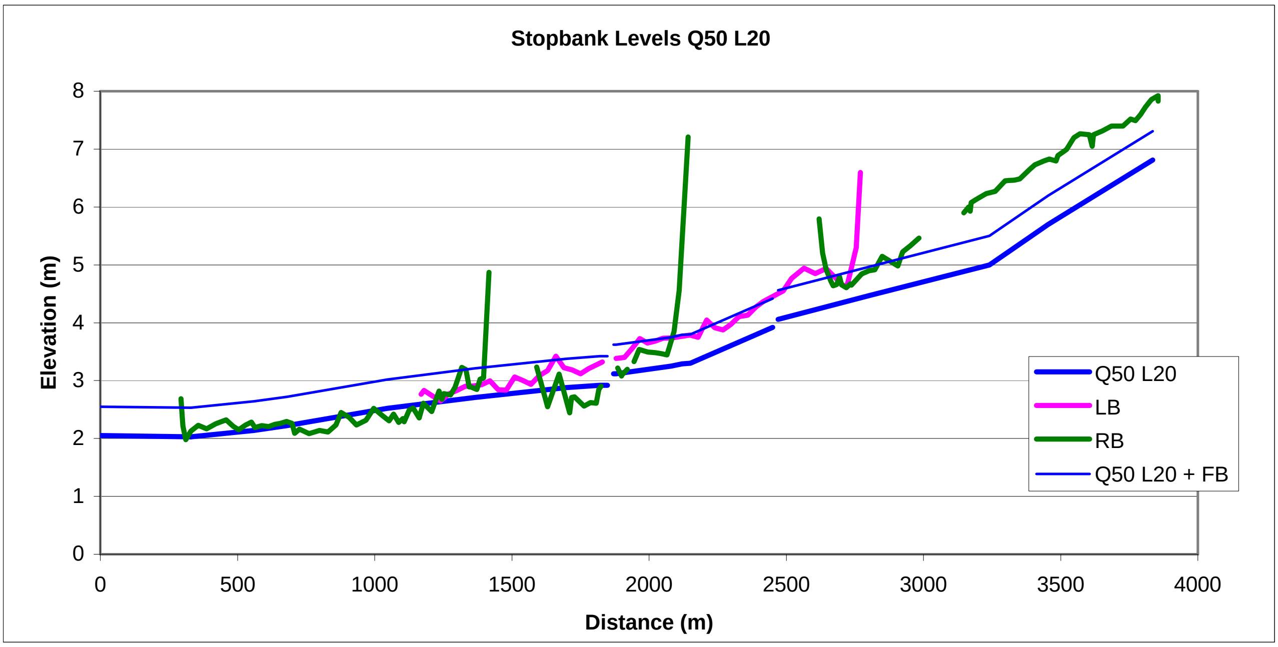
Appendix 8 – Results

Q20 L50 Results



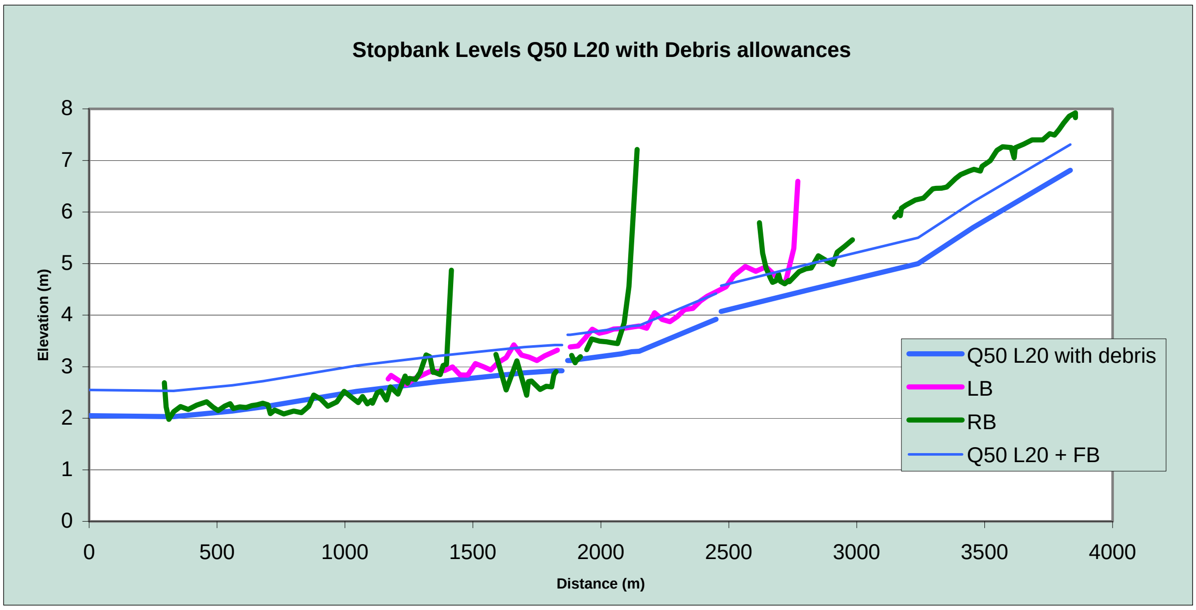
Cross Sections	River Station (m)	Water Level (m)	Water Level + FB (m)	LB Elev (m)	RB Elev (m)
17	3835	6.71	7.21		7.93
16	3455	5.55	6.05		6.956
15	3240	4.79	5.29		6.184
14	2805	4.17	4.67		5.018
	2470	3.65	4.15	4.606	
	2460				
13	2450	3.57	4.07	4.654	
12	2150	3.15	3.65	3.765	4.311
11	2120	3.13	3.63	3.729	4.359
10	2080	3.1	3.6	3.608	3.568
9	1880	2.98	3.48	3.379	3.104
	1870	2.98	3.48	2.79	2.61
8	1850				
	1848	2.83	3.33	2.74	2.56
7	1820	2.83	3.33	3.218	2.881
6	1700	2.8	3.3	3.405	2.649
5	1365	2.66	3.16	2.956	2.967
4	1045	2.52	3.02		2.355
3	680	2.3	2.8		2.252
2	560	2.25	2.75		2.263
1	330	2.19	2.69		2.22
0	0	2.2	2.7		

Q50 L20 Results – no debris



Cross Sections	River Station (m)	Water Level (m)	Water Level + FB (m)	LB Elev (m)	RB Elev (m)
17	3835	6.81	7.31		7.93
16	3455	5.7	6.2		6.956
15	3240	5	5.5		6.184
14	2805	4.47	4.97		5.018
	2470	4.06	4.56	4.606	
	2460				
13	2450	3.92	4.42	4.654	
12	2150	3.3	3.8	3.765	4.311
11	2120	3.29	3.79	3.729	4.359
10	2080	3.25	3.75	3.608	3.568
9	1880	3.12	3.62	3.379	3.104
	1870	3.12	3.62	2.79	2.61
8	1850				
	1848	2.92	3.42	2.74	2.56
7	1820	2.92	3.42	3.218	2.881
6	1700	2.88	3.38	3.405	2.649
5	1365	2.71	3.21	2.956	2.967
4	1045	2.52	3.02		2.355
3	680	2.22	2.72		2.252
2	560	2.14	2.64		2.263
1	330	2.03	2.53		2.22
0	0	2.05	2.55		

Q50 L20 with Allowance at Structures for Debris, Results



Cross Sections	River Station (m)	Water Level (m)	Water Level + FB (m)	LB Elev (m)	RB Elev (m)
17	3835	6.81	7.31		7.93
16	3455	5.7	6.2		6.956
15	3240	5	5.5		6.184
14	2805	4.48	4.98		5.018
	2470	4.07	4.57	4.606	
	2460				
13	2450	3.96	4.46	4.654	
12	2150	3.43	3.93	3.765	4.311
11	2120	3.41	3.91	3.729	4.359
10	2080	3.39	3.89	3.608	3.568
9	1880	3.28	3.78	3.379	3.104
	1870	3.27	3.77	2.79	2.61
8	1850				
	1848	2.92	3.42	2.74	2.56
7	1820	2.92	3.42	3.218	2.881
6	1700	2.88	3.38	3.405	2.649
5	1365	2.71	3.21	2.956	2.967
4	1045	2.52	3.02		2.355
3	680	2.22	2.72		2.252
2	560	2.14	2.64		2.263
1	330	2.03	2.53		2.22
0	0	2.05	2.55		