Hydraulic Capacity Review of the Waioho Stream and Canal

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Contents

Preface

Originally a model was set up for the Waioho Canal from Butler's Bridge to the Whakatane River confluence with the objective to assess the hydraulic capacity of the Canal. A draft report was written (by Ingrid Pak) in June 2003 but never finalised.

The model was later used after the July 2004 floods to estimate flows through the canal and into the Whakatane River during this flood. To do this accurately, the model was modified to model stopbank overflows.

In early 2006, a second model was set up for the Waioho Stream upstream of Butler's bridge and the Catchwater Drain, to assess the capacity in this reach. An investigation brought about by a complaint by one of the property owners on Station Road after the July 2004 flood, had pointed out that the reach upstream of Butler's Bridge is also part of the scheme.

The two separate models have now been merged into one final model, and the original report from 2003 has been superseded by this final report.

Chapter 1: Introduction

A Mike11 hydraulic model has been established for the Waioho Stream and Canal in order to review their capacity. The Waioho Canal is the lower reach of the Waioho Stream and is confined within stopbanks for a length of just over 4 kilometres before its confluence with the Whakatane River.

The original design standard was a 100 year (1% AEP) event with a freeboard of 600 mm.

The Waioho Stream drains a catchment of 88.5 km2 and additional flows from the Te Rahu Basin are pumped into the canal at times.

A cross-sectional survey was carried out in the canal in May 2003 and in the stream in April 2005.

Chapter 2: Hydraulic Analysis

Mike 11 hydraulic modelling software (version 2001) has been used to set up a status quo model of the Waioho Stream and Canal. A detailed description of the Mike11 software can be found in the Reference Manual (DHI, 2000) and the User Guide (DHI, 2000). All files used in the model are listed in Appendix 3.

Chapter 3: Extent of Model

The area modelled extends along the Waioho Stream/Canal from White Pine Bush Road (SH2) to the Whakatane River confluence with a stream length of approximately 5.4 km, including the Catchwater Drain between White Pine Bush Road and the Waioho Stream (length approx. 200 m). Additional inflows from the Te Rahu pumping scheme have been taken account of in the model. All other incoming drains are closed off by flood gates at the canal and are therefore ignored.

Chapter 4: Calibration

No calibration data is available for this canal. Therefore, the model established is limited to the design model. However, after the July 2004 floods, some observations and anecdotal references have been used to fine-tune the model where possible.

Chapter 5: Hydrology

The design flow of the original design was Q_{100}=133.0 m^3/s for the Waioho Canal (Bay of Plenty Catchment Commission). The hydrological analysis undertaken for the Mike11 model in 2003 resulted in a Q100=124.2 m^3/s at Butler's Bridge.

The 100yr design flow was reviewed again following the July 2004 floods. An investigation carried out by Opus found that the peak flow during the July 2004 floods was 258.0 m^3/s at the SH2 bridge, which suggests that the 100 year flow could be higher than previously estimated. The July 2004 flood was a very large and rare over design flood, probably twice the 100yr event (Peter Blackwood's email from 11 October 2006, files 5800 05 and 2320 04 16). The storm centre of convergence was over this catchment, and the event may have been as large as a 10,000 year event (based on the steepest dimensionless flood frequency curve available), although it is not thought that that was the case.

Following this review, the final 100yr design flow for the Waioho Stream at White Pine Bush Road (above the Catchwater Drain confluence) is Q_{100}=132.1 m^3/s. The 100 yr flow in the Catchwater Drain is Q_{100}=6.1 m^3/s, taken from a Transit NZ Resource Consent Application (file No. 1370 62577, Vol 1). This results in a total flow in the Waioho Canal of Q_{100}=138.2 m^3/s. Details of the hydrological catchment analysis are attached in Appendix 1.

Chapter 6: Design Model

6.1 Network and Cross-sections

The design model uses the cross-sectional data surveyed in May 2003 to define the Waioho Canal channel below Butler's bridge, and the cross-sectional survey from April 2005 and April 2006 for the Waioho Stream above Butler's Bridge and Catchwater Drain. The network is shown in Figure 1 and branch details are listed in Table 1.

Table 1 Branch details for design model

Branch Name	Chainage	Cross-sections	Description
Waioho	-5 to 4150	XS14 (Butler Rd bridge) to XS1 (near Whakatane River confluence)	Waioho Canal below Butler's Bridge
Waioho St	-1214 to -5	31 cross-sections between White Pine Bush Road and Butler's Bridge	Waioho Stream above Butler's Bridge
Catchwater	-991 to -777	Three cross-sections between SH2 culvert and Waioho Stream confluence	Catchwater Drain from SH2 to confluence

(Note: Negative chainages are the result of merging the two models without having to change the original chainages of the Canal model. Mike11 accepts negative chainages as long as the chainages are increasing in downstream direction.)

In September 2003, 18 cross-sections were surveyed on the Waioho Canal in the reach between Butler Road Bridge and the Whakatane River. Each cross-section covers the entire width of the channel and berm area from one stopbank crest to the other. The distance between the cross-sections has been chosen depending on the uniformity of the channel. Additional cross-sections were placed at each of the bridges crossing the canal.

The cross-sections in the Waioho Stream above Butler's Bridge and in the Catchwater Drain have been surveyed in April 2005 and April 2006. Due to some miscommunication they have been placed as close as approx. 20 m, and then further apart once the misunderstanding was resolved.

Cross-sections used in the design model are listed in Table 2.

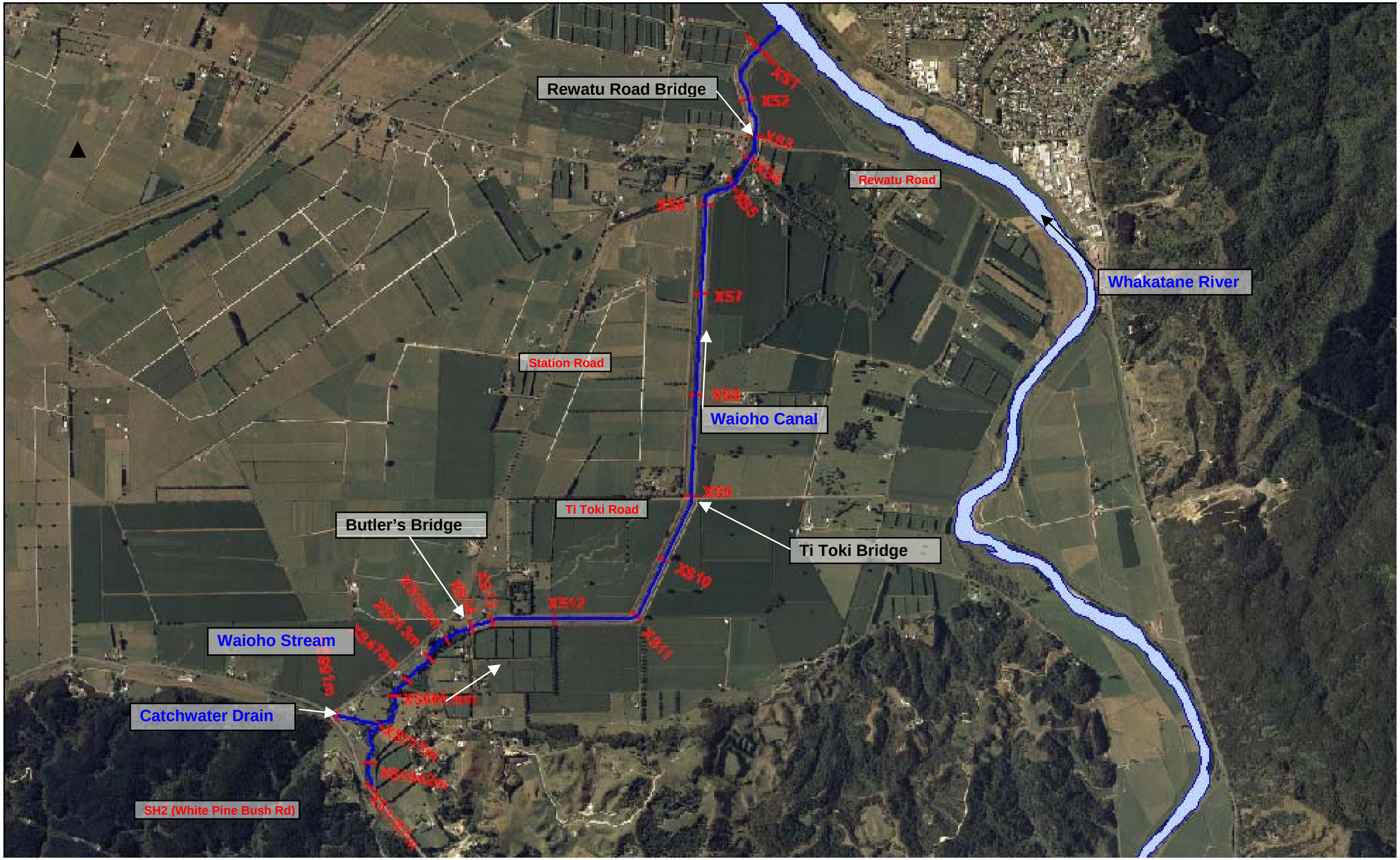

Figure 1 Model network

Table 2 Cross-sections used in the design model

Branch	Cross-section	Chainage	Survey date	Comment
Waioho	XS1	4150	May 2003	Near Whakatane R at farm bridge
	XS2	3850	May 2003	
	XS3	3620	May 2003	Rewatu Road bridge
	XS4	3470	May 2003	
	XS5	3310	May 2003	
	XS6	3100	May 2003	
	XS7	2580	May 2003	
	XS8	2060	May 2003	
	XS9	1540	May 2003	Titoki Road bridge
	XS10	1170	May 2003	
	XS11	850	May 2003	
	XS12	440	May 2003	
	XS13	120	May 2003	
	XS14	0	May 2003	d/s of Butler Road bridge
Waioho St	26.5m	-26.5	April 2005	
	57m	-57	April 2005	
	77m	-77	April 2005	
	110m	-110	April 2005	
	130m	-130	April 2005	
	150m	-150	April 2005	
	176m	-176	April 2005	
	196m	-196	April 2005	
	227m	-227	April 2005	
	243.5m	-243.5	April 2005	
	266m	-266	April 2005	
	292m	-292	April 2005	
	313m	-313	April 2005	
	338m	-338	April 2005	
	358m	-358	April 2005	
	415m	-415	April 2005	
	447.5m	-447.5	April 2005	
	478m	-478	April 2005	
	560.5m	-560.5	April 2005	
	581.5m	-581.5	April 2005	
	605.5m	-605.5	April 2005	
	632m	-632	April 2005	
	706m	-706	April 2005	
	777m	-777	April 2005	At Catchwater Drain confluence
	807m	-807	April 2006	
	938m	-938	April 2006	
	1042m	-1042	April 2006	
	1144m	-1144	April 2006	
	SH2 bridge	-1187	April 2006	At SH2 bridge
	1214m	-1214	April 2006	
Catchwater	794m	-794	April 2005	Above confluence
	892m	-892	April 2005	
	991m	-991	April 2005	d/s of SH2 culvert

6.2 Structures

Several bridges across the canal within the modelled reach potentially constrict flow. The bridges at White Pine Bush Road (SH2), Butler Road, Titoki Road, and Rewatu Road have been modelled as single irregularly shaped culverts. A weir has been modelled to represent the deck level of the Rewatu Road bridge. Note that once the water level reaches the deck level flooding will occur on the road in both directions, unless stop logs are put in place. The farm bridge at XS1, which is level with the berm area of the Whakatane River, has been ignored in the model for two reasons. Firstly, the channel is so wide at this location that any constrictions by the bridge are likely to be negligible. Secondly, the bridge is so fragile that it is likely to be washed away in a larger event.

For the 100 yr design event the bridge soffits have been lowered by 0.6 m to account for potential debris blockage.

Details of structures are listed in Table 3.

Table 3 Details of structures used in design model

Branch	Chainage	Structure	RL	Length	Width	Resistance
Waioho	0	"Culvert"	6.90m (soffit), 7.46m (deck)	9 m		0.03
	1540	"Culvert"	6.06m (soffit), 7.37m (deck)	5 m		0.03
	3620	"Culvert"	4.86m (soffit), 5.48m (deck)	5 m		0.03
	3620	"Weir"	4.58 m		30 m	
Waioho St	-1187	"Culvert"	8.72 m (soffit), 10.52 m (deck)	9 m		0.03

6.3 Boundary Conditions

The upstream boundary conditions are at the upstream end of the Waioho Stream and at the upstream end of the Catchwater Drain. At the Waioho Stream, design flows for the 100 year (1% AEP), and 50 year (2% AEP) and 20 year (5% AEP) events were used. At the Catchwater Drain, only the 100 year design flow was used due to its small contribution to the total flow in the Waioho Stream.

The hydrographs used as the upstream boundary conditions have been assumed based on the concentration time of six hours, and then scaled to the required design flow.

Additional inflows from the Te Rahu pumping scheme have been modelled as lateral inflows with a constant flow of 3.2 m^3/s. This is the total average maximum water discharge capacity of the three pumps located in the pump station on the left hand side of the Canal just downstream of XS6. The pumps operate automatically depending on the water level in the Te Rahu Basin. Pump operation is independent of the water level in the Waioho Canal so that they can start up at any time for extensive periods of time, with no regard to the water level in the Canal. The maximum pump discharge capacity is therefore assumed to be a constant inflow in the model.

The downstream boundary condition at XS1 at the Whakatane River confluence is the water level in the Whakatane River. The 20 year (5% AEP), 50 year (2% AEP), and 100 year (1% AEP) level in the Whakatane River have been used in the scenarios modelled. Both, the 20 year and 50 year Whakatane River levels have been taken from STOCKER (1985) by interpolation. The 100 year level has been taken from Wallace (2004), who has recently developed a new hydraulic model of the lower Whakatane River. His 100yr level is lower than previously estimated, and fitted in well with observations made during the July 2004 floods.

Details of all boundary conditions are listed in Table 4.

Table 4 Details of boundary conditions

Branch	Chainage	Flow	Level
Waioho St	-1214	132.1 m^3/s (100 year) 119.9 m^3/s (50 year) 103.7 m^3/s (20 year)	
Catchwater	-991	6.1 m^3/s (100 year)	
Waioho	3180	3.2 m^3/s (max. pump capacity)	
Waioho	4150		5.20 m (20 year) 5.50 m (50 year) 5.78 m (100 year)

The peaks of all boundary conditions coincide in time so that the peak flow in the Waioho Canal meats the peak level in the Whakatane River at the confluence.

6.4 Resistance

The Manning's *n* resistance factors as shown in Table 5 have been selected based on the channel conditions, and provided that the reach above Butler's Bridge be cleared and maintained in a tidy condition (NIWA, 1998).

Table 5 Resistance factors used in design model

Branch	Chainage	Manning's *n*
Catchwater	-991 to -782	0.04
Waioho St	-1214 to -26.5	0.04
Waioho	-5 to 440	0.03
	850	0.035
	1170 - 3100	0.03
	3310 - 4150	0.035
Waioho (Culvert)	0	0.03
	1540	0.03
	3620	0.03

Mike11 interpolates the resistance values for sections in-between the surveyed cross-sections.

Note that Manning's n in the Waioho Stream (0.04) has been chosen assuming that stream clearing work will be undertaken shortly, and regularly in the future, to improve the channel's capacity in this reach.

6.5 Computational Parameters

- Initial conditions: Water level = 1.00 m; Discharge = 2 m^3/s
- Wave approximation: High order fully dynamic
- Radius type: Total area, Hydraulic radius
- Time step: 5 seconds
- Delta: 0.75

Other values were as the Mike11 defaults.

6.6 Scenarios

The 100 year and 50 year design events have been modelled with different flow and level combinations. The scenarios and boundary condition details are listed in Table 6.

Table 6 Scenario details

Scenario	Waioho Stream flow	Catchwater Drain flow	Whakatane River maximum level	Pumps inflow
100 year (1% AEP)	100yr (132.1m^3/s)	100 yr (6.1m^3/s)	20 yr (RL_{max} = 5.20 m)	3.2 m^3/s
	20yr (103.7 m^3/s)	100 yr (6.1m^3/s)	100 yr (RL_{max} = 5.78 m)	3.2 m^3/s
50 year (2% AEP)	50 yr (119.9m^3/s)	100 yr (6.1m^3/s)	20 yr (RL_{max} = 5.20 m)	3.2 m^3/s
	20yr (103.7 m^3/s)	100 yr (6.1m^3/s)	50 yr (RL_{max} = 5.50 m)	3.2 m^3/s

Chapter 7: Results

According to the current Whakatane River Asset Management Plan the capacity of the Waioho Canal is required to be for a 100 year (1% AEP) event providing a freeboard of 600 mm. As there is no calibration data available to calibrate the model to, it is not justified to accept a freeboard lower than this.

The stopbank profiles along the Waioho Canal (downstream of Butler's Bridge) have been surveyed in September 2003. Stopbank profiles along the Waioho Stream (between White Pine Bush Road and Butler's Bridge) and Catchwater Drain have been surveyed in March 2006. The stopbank profiles have been plotted against the simulated water levels for the different events to assess the current channel capacity and to point out any low parts of the stopbanks which require topping-up (refer Figure 2). The simulated water level lines are the envelope of the two event combinations that make up the event; e.g. the 100 year simulated water levels are the higher level of each simulation run, the simulation runs being the 100 year Waioho flow combined with a 20 year Whakatane River level and the 20 year Waioho flow combined with the 100 year Whakatane River level. Generally, in the Canal below Butler's Bridge the Whakatane River level governs the water level in the Canal, while in the reach upstream of Butler's Bridge the flow governs the simulated water levels. Detailed results on water levels and available freeboard are listed in Appendix 2.

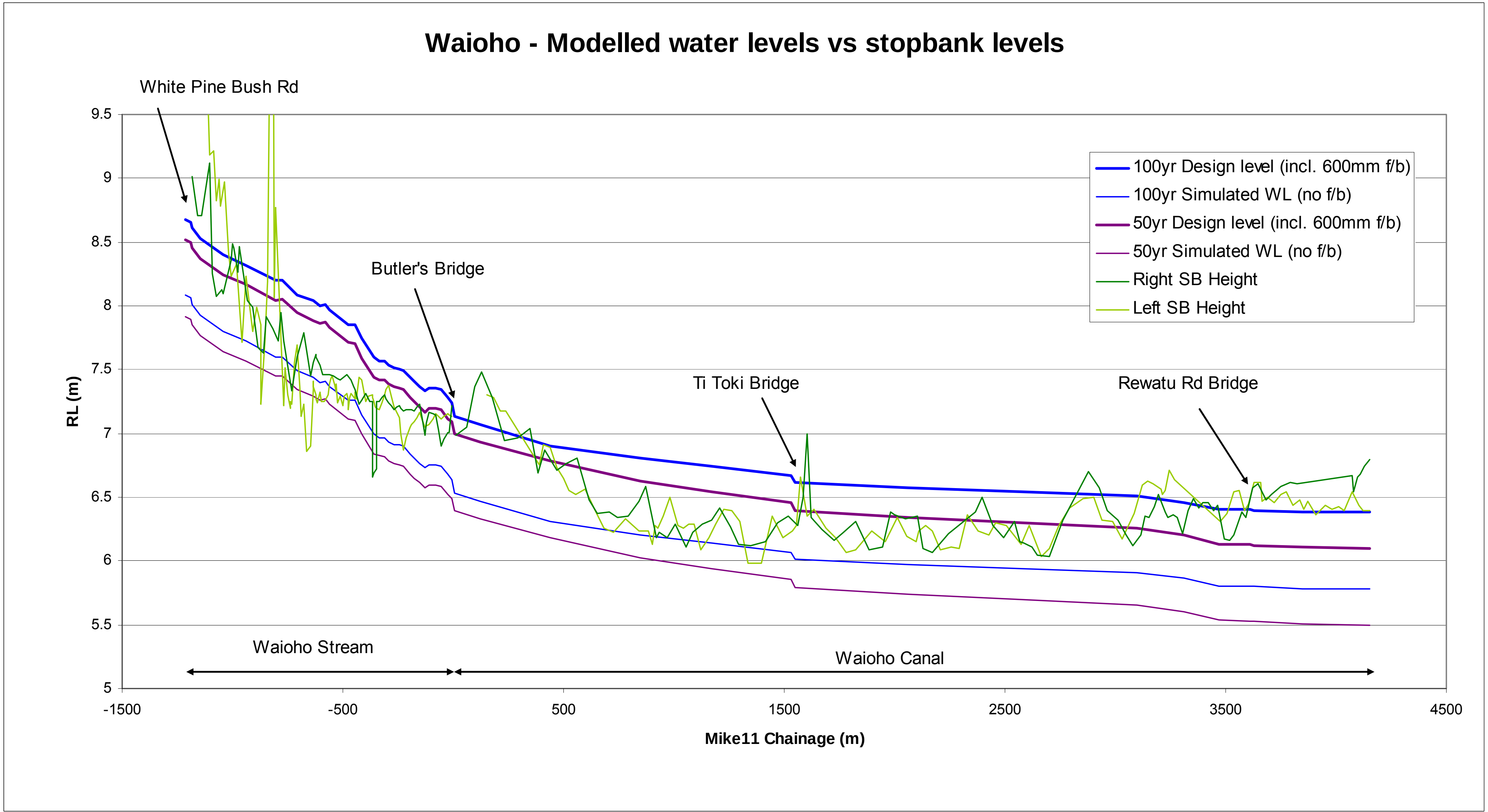

Figure 2 Waioho Stream and Canal - Modelled water levels, design levels and stopbank levels

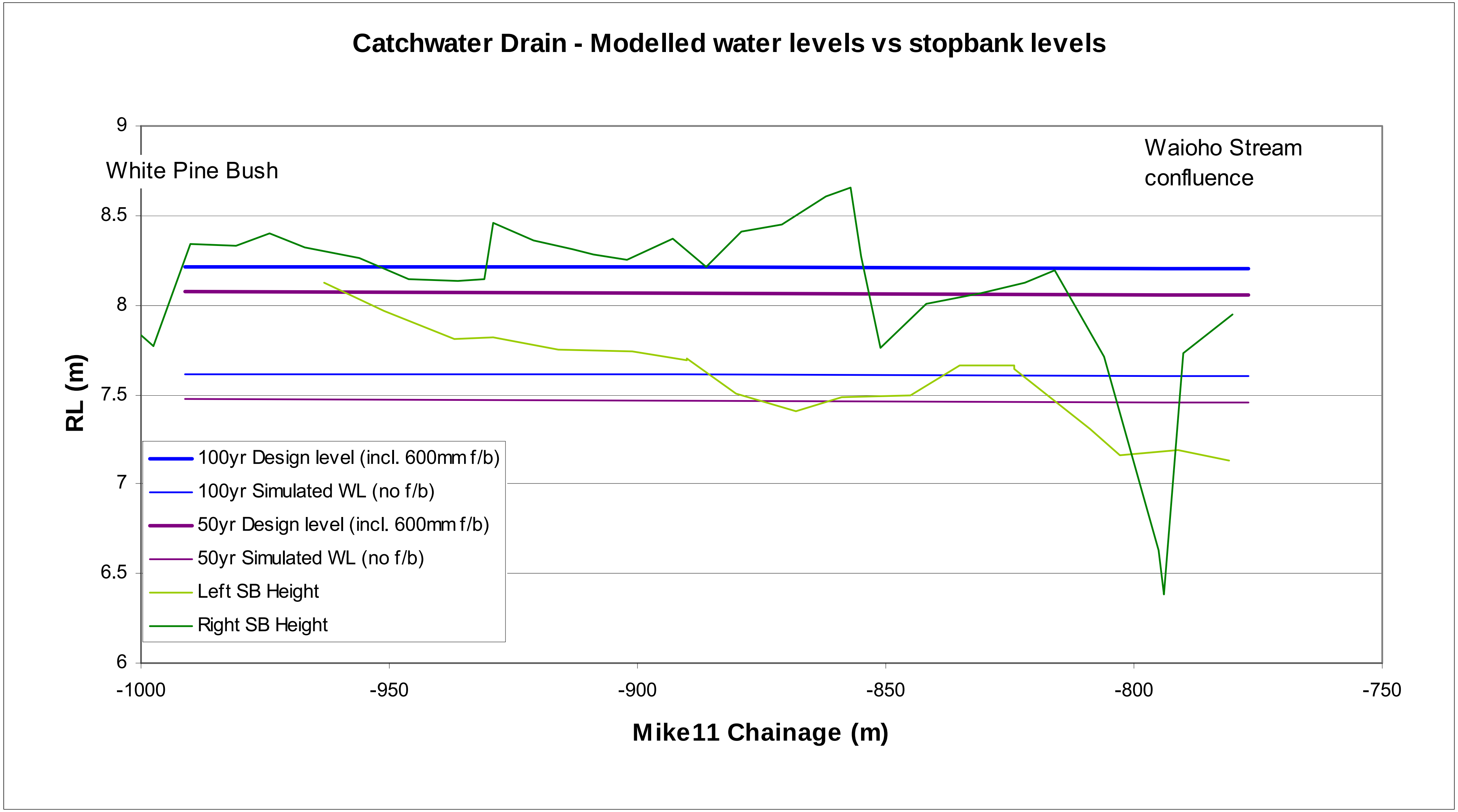

Figure 3 Catchwater Drain - Modelled water levels, design levels and stopbank levels

Key results are:

100 year event:

- At Butler Road Bridge (XS14) the water level stays clear of the bridge soffit level by approximately 0.26 m.
- At Titoki Road Bridge (XS9) the water level just reaches the bridge soffit.
- At Rewatu Road Bridge the water level drowns the bridge deck level by approximately 320 mm. This is the case under the assumption that stoplogs are in place to prevent water from the Canal flowing down onto the road. Water levels here are highly dependant on the Whakatane River levels rather than the Waioho flow.
- Water levels overtop the left bank stopbank along the Waioho Stream above Butler's Bridge in places.
- Water levels overtop the left bank stopbank of the Canal in places in the reach upstream of Titoki Bridge.
- Water levels overtop the left bank stopbank of the Catchwater Drain over most of its length.

Available freeboard is less than required on both banks along the entire modelled reach of the Waioho Stream above Butler's Bridge, and along most of the Canal, except in the reach below Rewatu Road Bridge where it is sufficient. Freeboard is also less than required on the left bank of Catchwater Drain and some of the right bank.

50 year event:

- At both Butler Road Bridge (XS14) and Titoki Road Bridge (XS9) the water level stays well below the bridge soffit level (by approx. 0.41m and 0.20 m respectively).
- At Rewatu Road Bridge the water level just drowns the bridge deck level by approximately 50 mm. This is the case under the assumption that stoplogs are in place to prevent water from the Canal flowing down onto the road. Water levels here are highly dependent on the Whakatane River levels rather than the Waioho flow.
- Water levels overtop the left bank stopbanks along the Waioho Stream above Butler's Bridge in places, but stay well within the Canal in the reach below Butler's bridge.
- Water levels overtop the left bank stopbanks along the Catchwater Drain in places.
- Available freeboard is less than required on both banks along most of the modelled reach of the Waioho Stream above Butler's Bridge, and along most of the Canal, except in the lower reach of approximately 1 km where it is sufficient. Freeboard is also less than required on the left bank of Catchwater Drain and some of the right bank.

Chapter 8: Conclusion

The model shows that in a 100 year (1% AEP) event the Waioho Stream and Canal will overflow its banks in places and available freeboard is less than required over a significant length of the scheme stopbanks.

Also in the case of a 50 year (2% AEP) event, the Waioho Stream and Canal will overflow its banks in places and available freeboard is less than required over a significant length of the scheme stopbanks.

In the reach of the Waioho Stream above Butler's Road Bridge the flow governs the peak water levels, while in the reach below Butler's Road Bridge the water level in the Whakatane River determines the peak water levels in the Canal.

According to the Asset Management Plan, Environment Bay of Plenty has an obligation to top up any stopbanks where the freeboard is reduced to less than 50% of the required freeboard, i.e. where the available freeboard is less than 300 mm. Therefore a total length of approximately 5.5 km of stopbanks requires topping up (refer Figures 4 and 5).

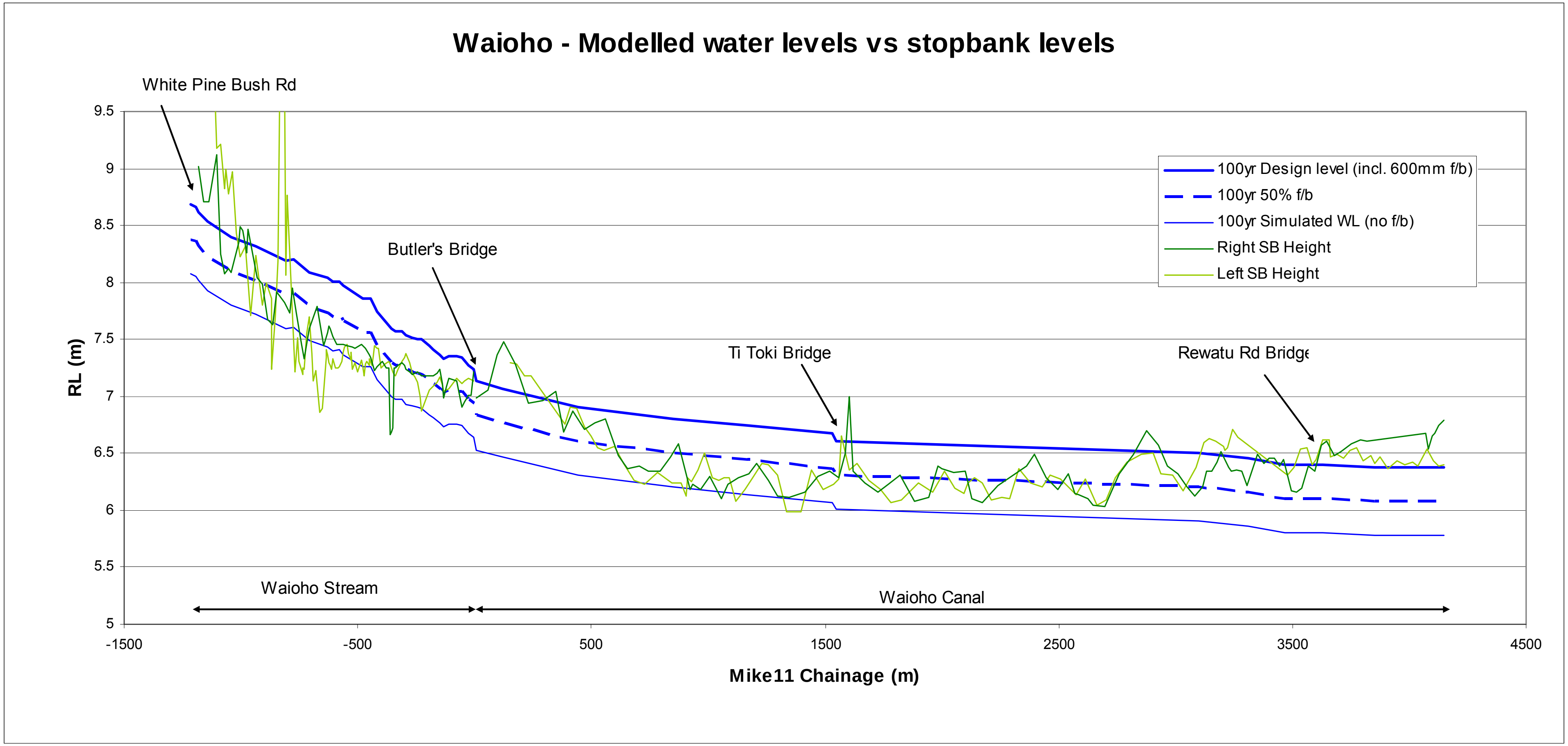

Figure 4 Waioho Stream and Canal – 100yr design levels and stopbank levels

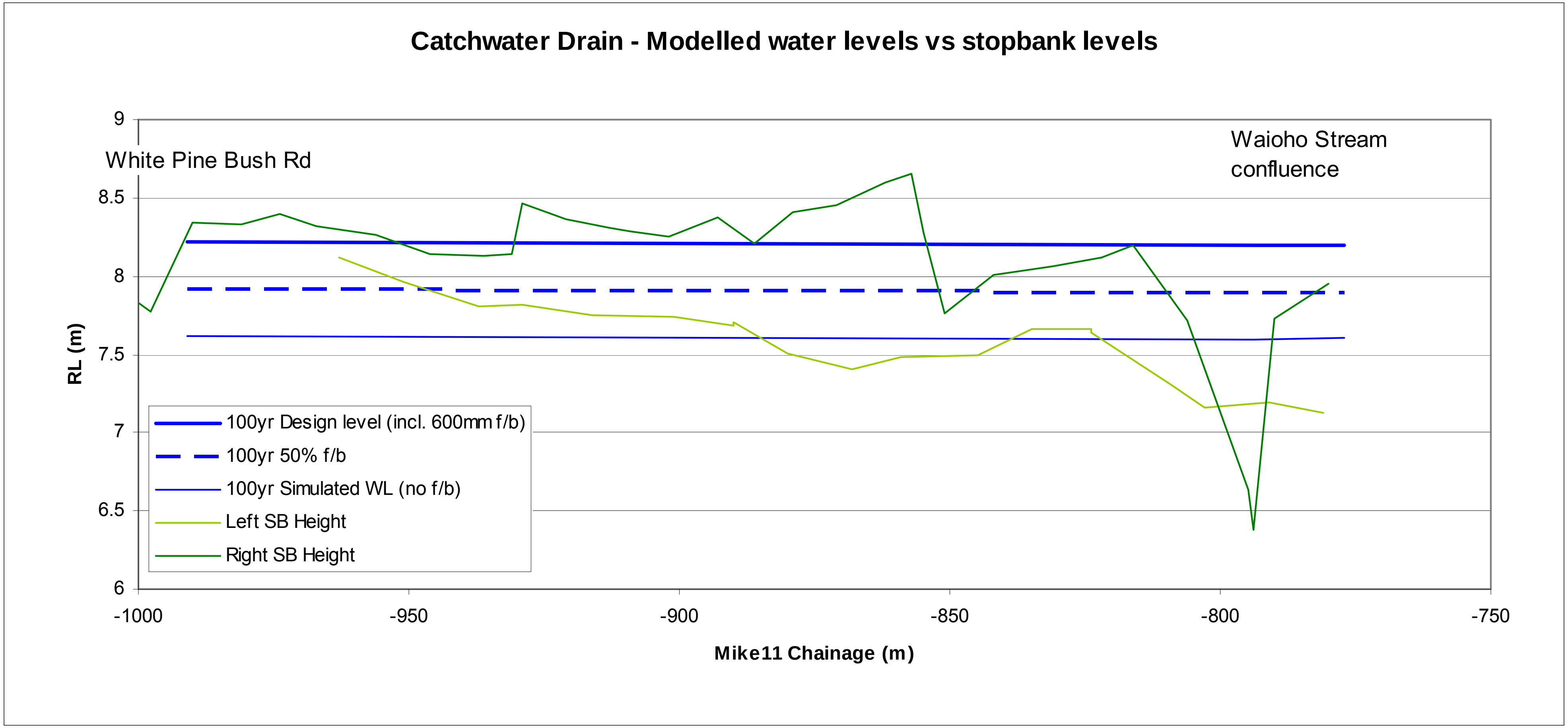

Figure 5 Catchwater Drain - 100yr design levels and stopbank levels

Chapter 9: References

Bay of Plenty Catchment Commission; Whakatane River Major Scheme (Volume 1)

H. Stocker (1985); Whakatane Major River Scheme Review, Evaluation of Lower Whakatane River Flood Protection Works, Bay of Plenty Catchment Commission.

M. Surman (1995); Whakatane River below Pekatahi Bridge – Model and Hydrology Review (Environment Bay of Plenty file 5800 03 1998 01).

National Institute of Water and Atmosphere (1998); Roughness Characteristics of New Zealand Rivers, reprinted 1998.

Environment Bay of Plenty (2001); Environmental Data Summaries, Environmental Report 2001/01.

OPUS (2004); Bay of Plenty Floods 18th July 2004. Volume 1 – Report.

P. Wallace (2004); Hydraulic Modelling of the Lower Whakatane River and Floodplain (Report prepared for Environment Bay of Plenty).

Appendices

Appendix 1– Hydrological Analysis

Appendix 2 – Mike11 results

Appendix 3 – Files used

Appendix 1 – Hydrological Analysis and Map of Catchment

Hydrological Catchment Analysis

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Stream Name: **Waioho Stream at SH2 (White Pine Bush)**

Reference: Excel File R:\Calculations\TM61-calcs\Waioho Stream.TM61.060207

Location: MAP GRID - NZMS260 U15:?????? **Date:** 7-Feb-06

Calculated: IP this is above the confluence with Catchwater Drain!

Technical Memorandum 61

Moderately abosrbant soils, 70% of area in long grass, scrub or bush; (0.8 chosen on the conservative side!)

Area	A	km^2	88.3
Direct length	L_d	km	14.9
Stream length	L	km	20
Average slope	S_a	m/m	0.0035
Height difference	H	m	390
Time of Concentration			
Ramser-Kirpich Eq.	Tc_1	min	351.2
Bransby Williams Eq.	Tc_2	min	403.3
U.S. Soil Con. Service.	Tc_3	min	182.0
	Ave.	min	312.2
	Use	min	360
Surface Characteristic	W_{ic}		0.8
Slope Factor	W_s		39.9
W_s x W_{ic}	W		31.9
Discharge coefficient	C		422
Standard rainfal depth		mm	205.3
A/L_d^2	K		0.398
Shape factor	S		0.90

Calculation of Average Slope
(Modified Taylor-Schwarz Method)

elevation (m)	distance (m)	slope (m/m)	li/Si^0.5
10	0		
20	8200	0.001	234812
40	11750	0.006	47296
80	13800	0.020	14676
120	16000	0.018	16316
160	18350	0.017	18012
200	19000	0.062	2620
300	19710	0.141	1892
400	19990	0.357	469
	Average slope (S_a)		0.0035
	S_a as %		0.35

Hirds data

Interpolation of Hirds — Version: 1995

Duration	100y	50y	20y	10y	5y	2y
	Design Rainfall Depth (mm)					
360	163	148	128	113	97	73
360	163	148	128	113	97	73
720	211	192	166	147	126	94

			100y	50y	20y	10y	5y	2y
Rainfall Factor	R		0.79	0.72	0.62	0.55	0.47	0.36
Peak Flow Rate	Q_p	m^3/s	**120.9**	**109.8**	**94.9**	**83.8**	**71.9**	**54.1**

Rational Method

Medium soakage soils; 70% bush and srcub cover; minus 0.05 adjustment for slope between 0-5%.

Area	A	km^2	88.3
Runoff Coefficient	C		0.215

			100y	50y	20y	10y	5y	2y
Rainfall Intensity	I	mm/h	27	25	21	19	16	12
Flow rate	Q_p	m^3/s	**143.2**	**130.1**	**112.5**	**99.3**	**85.2**	**64.2**

FFINZ

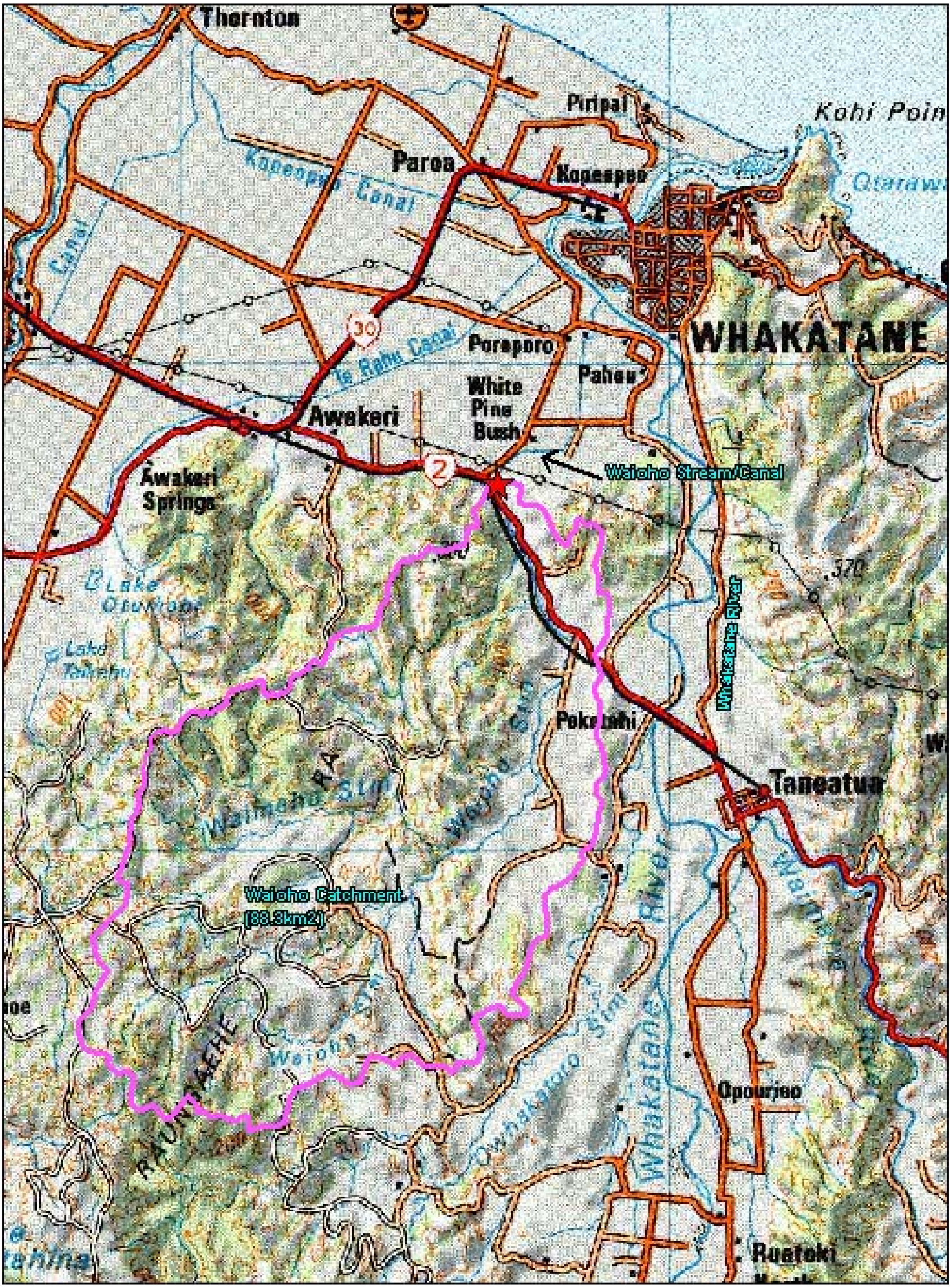
Area	A	km^2	88.3
$Q/A^{0.8}$ Contour			
Mean Annual Flood	Q_1	m^3/s	0.0
Q_{100} Flood Contour			
Peak Discharge	Q_{100}	m^3/s	**0.0**

Design Method Selected:

Average TM61 & Rational

	100y	50y	20y	10y	5y	2y
m^3/s	**132.1**	**119.9**	**103.7**	**91.6**	**78.6**	**59.1**

Map of Waioho Catchment



Appendix 2 – Mike11 Results

Waioho Mike11 simulation results 100year event					Envelope 100yr event	
		Q100H20_future.res11		**Q20H100_future.res11**		
		Simulated WL		Simulated WL	100yr Simulated WL (no f/b)	**100yr Design level (incl. 600mm f/b)**
Water Level	Mike11 chainage (m)	RL (m)		RL (m)	RL (m)	RL (m)
WAIOHOST -1214.00	-1214	**8.08**		7.715	**8.08**	8.68
WAIOHOST -1192.00	-1192	**8.059**		7.696	**8.059**	8.659
WAIOHOST -1182.00	-1182	**8.014**		7.658	**8.014**	8.614
WAIOHOST -1144.00	-1144	**7.93**		7.585	**7.93**	8.53
WAIOHOST -1042.00	-1042	**7.803**		7.476	**7.803**	8.403
WAIOHOST -938.00	-938	**7.721**		7.406	**7.721**	8.321
WAIOHOST -807.00	-807	**7.596**		7.302	**7.596**	8.196
WAIOHOST -777.00	-777	**7.601**		7.307	**7.601**	8.201
WAIOHOST -776.67	-776.67	**7.601**		7.307	**7.601**	8.201
WAIOHOST -776.67	-776.67	**7.601**		7.307	**7.601**	8.201
WAIOHOST -706.00	-706	**7.489**		7.212	**7.489**	8.089
WAIOHOST -632.00	-632	**7.437**		7.16	**7.437**	8.037
WAIOHOST -605.50	-605.5	**7.402**		7.141	**7.402**	8.002
WAIOHOST -581.50	-581.5	**7.412**		7.148	**7.412**	8.012
WAIOHOST -560.50	-560.5	**7.369**		7.113	**7.369**	7.969
WAIOHOST -478.00	-478	**7.257**		7.009	**7.257**	7.857
WAIOHOST -447.50	-447.5	**7.256**		7.006	**7.256**	7.856
WAIOHOST -415.00	-415	**7.144**		6.907	**7.144**	7.744
WAIOHOST -358.00	-358	**6.997**		6.785	**6.997**	7.597
WAIOHOST -338.00	-338	**6.97**		6.772	**6.97**	7.57
WAIOHOST -313.00	-313	**6.97**		6.774	**6.97**	7.57
WAIOHOST -292.00	-292	**6.933**		6.75	**6.933**	7.533
WAIOHOST -266.00	-266	**6.915**		6.729	**6.915**	7.515
WAIOHOST -243.50	-243.5	**6.907**		6.719	**6.907**	7.507
WAIOHOST -227.00	-227	**6.898**		6.713	**6.898**	7.498
WAIOHOST -196.00	-196	**6.841**		6.667	**6.841**	7.441
WAIOHOST -176.00	-176	**6.811**		6.644	**6.811**	7.411
WAIOHOST -150.00	-150	**6.768**		6.614	**6.768**	7.368
WAIOHOST -130.00	-130	**6.73**		6.583	**6.73**	7.33
WAIOHOST -110.00	-110	**6.752**		6.6	**6.752**	7.352
WAIOHOST -77.00	-77	**6.753**		6.602	**6.753**	7.353
WAIOHOST -57.00	-57	**6.742**		6.594	**6.742**	7.342
WAIOHOST -26.50	-26.5	**6.678**		6.545	**6.678**	7.278
WAIOHOST -5.00	-5	**6.642**		6.523	**6.642**	7.242
WAIOHO -5.00	-5	**6.642**		6.523	**6.642**	7.242
WAIOHO 5.00	5	**6.531**		6.45	**6.531**	7.131
WAIOHO 120.00	120	**6.468**		6.408	**6.468**	7.068
WAIOHO 440.00	440	6.303		**6.306**	**6.306**	6.906
WAIOHO 850.00	850	6.141		**6.208**	**6.208**	6.808
WAIOHO 1170.00	1170	6.026		**6.142**	**6.142**	6.742
WAIOHO 1530.00	1530	5.898		**6.071**	**6.071**	6.671
WAIOHO 1550.00	1550	5.782		**6.012**	**6.012**	6.612
WAIOHO 2060.00	2060	5.704		**5.975**	**5.975**	6.575
WAIOHO 2580.00	2580	5.629		**5.939**	**5.939**	6.539
WAIOHO 3100.00	3100	5.56		**5.906**	**5.906**	6.506
WAIOHO 3310.00	3310	5.466		**5.861**	**5.861**	6.461
WAIOHO 3470.00	3470	5.334		**5.806**	**5.806**	6.406
WAIOHO 3610.00	3610	5.32		**5.8**	**5.8**	6.4
WAIOHO 3630.00	3630	5.258		**5.798**	**5.798**	6.398
WAIOHO 3850.00	3850	5.215		**5.783**	**5.783**	6.383
WAIOHO 4150.00	4150	5.2		**5.78**	**5.78**	6.38
CATCHWATER -991.00	-991	**7.618**		7.34	**7.618**	8.218
CATCHWATER -892.00	-892	**7.609**		7.321	**7.609**	8.209
CATCHWATER -794.00	-794	**7.599**		7.305	**7.599**	8.199
CATCHWATER -777.00	-777	**7.601**		7.307	**7.601**	8.201

Waioho Mike11 simulation results 50year event					**Envelope 50yr event**	
		Q50H20_future.res11		**Q20H50_future.res11**		
		Simulated WL		Simulated WL (no f/b)	50yr Simulated WL (no f/b)	**50yr Design level (incl. 600mm f/b)**
Water Level	Mike11 chainage (m)	Maximum		Maximum		
WAIOHOST -1214.00	-1214	**7.916**		7.691	**7.916**	8.516
WAIOHOST -1192.00	-1192	**7.895**		7.672	**7.895**	8.495
WAIOHOST -1182.00	-1182	**7.851**		7.632	**7.851**	8.451
WAIOHOST -1144.00	-1144	**7.769**		7.557	**7.769**	8.369
WAIOHOST -1042.00	-1042	**7.645**		7.445	**7.645**	8.245
WAIOHOST -938.00	-938	**7.567**		7.371	**7.567**	8.167
WAIOHOST -807.00	-807	**7.447**		7.262	**7.447**	8.047
WAIOHOST -777.00	-777	**7.453**		7.267	**7.453**	8.053
WAIOHOST -776.67	-776.67	**7.452**		7.267	**7.452**	8.052
WAIOHOST -776.67	-776.67	**7.452**		7.267	**7.452**	8.052
WAIOHOST -706.00	-706	**7.345**		7.168	**7.345**	7.945
WAIOHOST -632.00	-632	**7.288**		7.111	**7.288**	7.888
WAIOHOST -605.50	-605.5	**7.261**		7.093	**7.261**	7.861
WAIOHOST -581.50	-581.5	**7.269**		7.099	**7.269**	7.869
WAIOHOST -560.50	-560.5	**7.229**		7.063	**7.229**	7.829
WAIOHOST -478.00	-478	**7.111**		6.95	**7.111**	7.711
WAIOHOST -447.50	-447.5	**7.107**		6.945	**7.107**	7.707
WAIOHOST -415.00	-415	**6.993**		6.835	**6.993**	7.593
WAIOHOST -358.00	-358	**6.843**		6.697	**6.843**	7.443
WAIOHOST -338.00	-338	**6.823**		6.687	**6.823**	7.423
WAIOHOST -313.00	-313	**6.822**		6.689	**6.822**	7.422
WAIOHOST -292.00	-292	**6.789**		6.666	**6.789**	7.389
WAIOHOST -266.00	-266	**6.765**		6.634	**6.765**	7.365
WAIOHOST -243.50	-243.5	**6.753**		6.621	**6.753**	7.353
WAIOHOST -227.00	-227	**6.744**		6.614	**6.744**	7.344
WAIOHOST -196.00	-196	**6.684**		6.559	**6.684**	7.284
WAIOHOST -176.00	-176	**6.653**		6.533	**6.653**	7.253
WAIOHOST -150.00	-150	**6.612**		6.499	**6.612**	7.212
WAIOHOST -130.00	-130	**6.569**		6.461	**6.569**	7.169
WAIOHOST -110.00	-110	**6.592**		6.482	**6.592**	7.192
WAIOHOST -77.00	-77	**6.593**		6.482	**6.593**	7.193
WAIOHOST -57.00	-57	**6.582**		6.473	**6.582**	7.182
WAIOHOST -26.50	-26.5	**6.517**		6.416	**6.517**	7.117
WAIOHOST -5.00	-5	**6.488**		6.395	**6.488**	7.088
WAIOHO -5.00	-5	**6.488**		6.395	**6.488**	7.088
WAIOHO 5.00	5	**6.399**		6.319	**6.399**	6.999
WAIOHO 120.00	120	**6.336**		6.265	**6.336**	6.936
WAIOHO 440.00	440	**6.181**		6.14	**6.181**	6.781
WAIOHO 850.00	850	**6.027**		6.021	**6.027**	6.627
WAIOHO 1170.00	1170	5.919		**5.94**	**5.94**	6.54
WAIOHO 1530.00	1530	5.805		**5.856**	**5.856**	6.456
WAIOHO 1550.00	1550	5.725		**5.792**	**5.792**	6.392
WAIOHO 2060.00	2060	5.657		**5.744**	**5.744**	6.344
WAIOHO 2580.00	2580	5.592		**5.7**	**5.7**	6.3
WAIOHO 3100.00	3100	5.533		**5.659**	**5.659**	6.259
WAIOHO 3310.00	3310	5.453		**5.605**	**5.605**	6.205
WAIOHO 3470.00	3470	5.343		**5.535**	**5.535**	6.135
WAIOHO 3610.00	3610	5.332		**5.528**	**5.528**	6.128
WAIOHO 3630.00	3630	5.248		**5.525**	**5.525**	6.125
WAIOHO 3850.00	3850	5.212		**5.506**	**5.506**	6.106
WAIOHO 4150.00	4150	5.2		**5.5**	**5.5**	6.1
CATCHWATER -991.0(	-991	**7.476**		7.304	**7.476**	8.076
CATCHWATER -892.0(	-892	**7.464**		7.282	**7.464**	8.064
CATCHWATER -794.0(	-794	**7.451**		7.265	**7.451**	8.051
CATCHWATER -777.0(	-777	**7.452**		7.267	**7.452**	8.052

Appendix 3 – Files used

Files used:

Scenario: 100yr flow, 20yr river level (bridge soffits lowered by 0.6m)	
.sim11	Waioho_merged&extd_Q100H20_future.sim11
.nwk11	Waioho_merged&extd_corrected soffits_loweredfordebris.nwk11
.xns11	Waioho_merged&extd_corrected soffits_loweredfordebris.xns11
.bnd11	WaiohoQ100H20.bnd11
.HD11	Waioho_merged&extd_0.04.HD11
.RES11	Q100H20_future_X_correctedsoffits_loweredfordebris.RES11
Scenario: 20yr flow, 100yr river level	
.sim11	Waioho_merged&extd_Q20H100_future.sim11
.nwk11	Waioho_merged&extd_corrected soffits_noRewatuBr.nwk11
.xns11	Waioho_merged&extd_corrected soffits.xns11
.bnd11	WaiohoQ20H100.bnd11
.HD11	Waioho_merged&extd_0.04.HD11
.RES11	Q20H100_future_correctedsoffits.RES11
Scenario: 50yr flow, 20yr river level	
.sim11	Waioho_merged&extd_Q50H20_future.sim11
.nwk11	Waioho_merged&extd_corrected soffits.nwk11
.xns11	Waioho_merged&extd_corrected soffits.xns11
.bnd11	WaiohoQ50H20.bnd11
.HD11	Waioho_merged&extd_0.04.HD11
.RES11	Q50H20_future_corrected soffits.RES11
Scenario: 20yr flow, 50yr river level	
.sim11	Waioho_merged&extd_Q20H50_future.sim11
.nwk11	Waioho_merged&extd_corrected soffits_noRewatuBr.nwk11
.xns11	Waioho_merged&extd_corrected soffits.xns11
.bnd11	WaiohoQ20H50.bnd11
.HD11	Waioho_merged&extd_0.04.HD11
.RES11	Q20H50_future_correctedsoffit.RES11

Spreadsheets:

Results_merged&extnd.xls