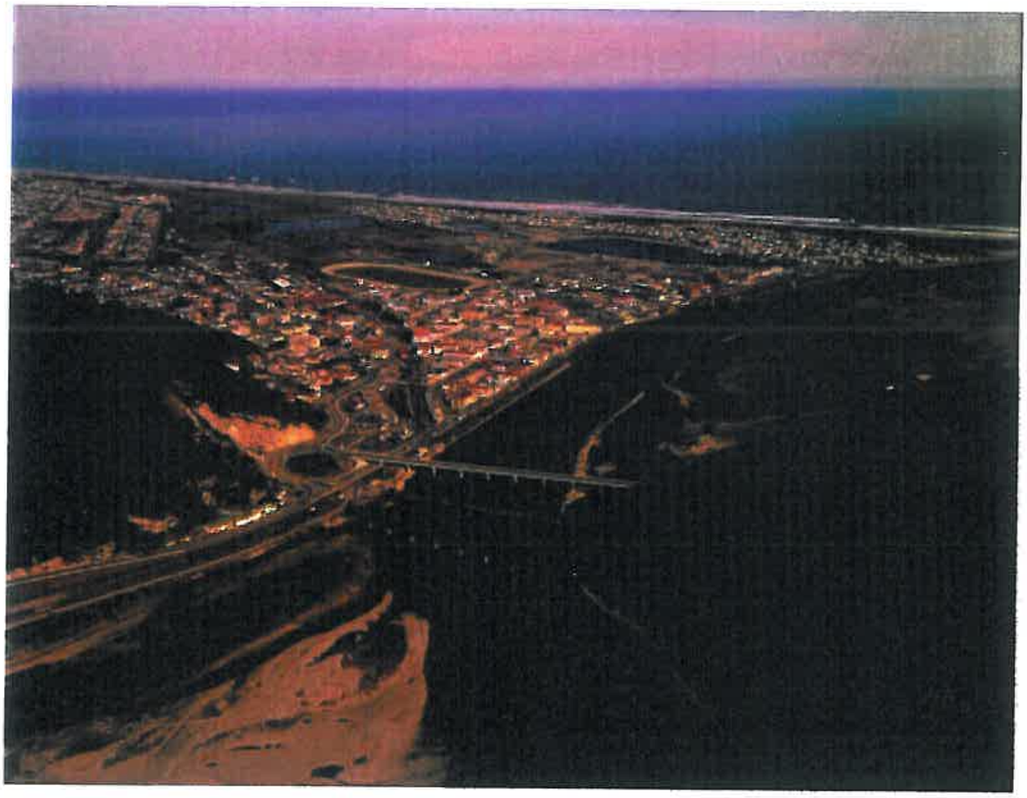
Grey River at Greymouth

Hydraulic Review and Assessment of Effects of Options to improve Flood Capacity for estimated T50 & T150 flood discharges



September 2002

Report for the West Coast Regional Council and Grey District Council

Report 3/2002

CH FLOOD MODELLING LTD

1.0 Introduction

This report examines:

1) Four options to improve flood protection to Cobden, Greymouth and Blaketown as follows:

a) T50 estimated at 6600 m^3/s + 600 mm freeboard
b) T150 estimated at 7400 m^3/s + 600 mm freeboard
c) As for a) with Cobden Island cleared
d) As for b) with Cobden Island cleared

2) The effects at Kaiata of the four options given above under bankfull conditions (or zero freeboard). To assess the effects, the flood levels at Kaiata with the present stopbanks were compared with the flood levels of each of the four options. The model of the present situation included both the northern and southern flood plains i.e. the Cobden and Commercial/Blaketown areas respectively.

2.0 Background 2001 report

This work compliments the February 2001 report that used the water flow model Hydro2de to model flood levels on the Grey River at Greymouth.

The 2001 report calibrated models for the 1988 flood and the 1998 flood on the Grey River. The 1988 flood parameters were more conservative and therefore were used with the present riverbed (with the Greymouth Flood Wall constructed) to calculate design levels for the stopbanks for a discharge of 6600 m^3/s.

Finally the 2001 report assessed the effect of the construction of the Greymouth Flood Wall on the flood levels at Kaiata.

The work for this new report (2002) used a more recent hydraulic model; called 'flumen' that is a better model for this type of channel. Due to time constraints, the model developed was based on the 1988 flood levels (to obtain the more conservative design parameters) modified using the 1998 riverbed.

This was possible, as the Hydro2de modelling for the 2001 report had assessed the effect or modification of the flood levels resulting from changing from the 1988 riverbed to the 1998 riverbed. There were two main differences between the 1988 situation and the present (and 1998) situation. These were that the Greymouth Flood Wall was built (hence there were no overflows to the flood plains as occurred during the 1988 flood) and also the area of Cobden Island that blocked the secondary channel in 1988 had been excavated (which improved the conveyance of the river in this area).

Appendix A examines the differences between the flumen results and the observed flood levels and also discusses the differences with the Hydro2de flood levels.

The 1998 flood levels were also useful to assess the model performance as these flood levels occurred with the river in its present situation.

3.0 Results and discussion

3.1 Flood levels for 6600 m^3/s

Table 1 shows the flood levels and freeboards for the 6600 m^3/s flumen model.

Cross-section or point	Left Bank			Right Bank		
	Model water level (m)	Stopbank level (m)	Available freeboard (m)	Model water level (m)	Stopbank level (m)	Available freeboard (m)
Sec01	1.9	7.4	5.5	1.8	8.85	7.05
Sec02	2.4	7.49	5.09	2.5	7.50	5.0
Sec03	3.31	6.61	3.20	3.97	4.47	0.50
Sec04	3.88	4.41	0.53	4.10	4.50	0.4
120 m upstream sec04	4.03	4.61	0.58			
200 m upstream sec04	4.55	4.88	0.33			
Sec05	4.65	4.90	0.25	4.56	5.07	0.50
Sec06	4.98	5.23	0.25	4.95	5.42	0.47
Sec07	5.52	5.7	0.18	5.11	5.7	0.59
75 m upstream of Sec 07	5.73	5.8	0.05			
Sec08	5.71	6.2	0.49	5.47	6.0	0.53
Sec09	5.98	6.5	0.52	5.64	6.5	0.86
Sec10	6.36	6.73	0.37	6.54	8.4	1.86
Cobden Bridge	6.65	6.9	0.35	6.55	NA	
Erua Lagoon	4.45	4.9	0.45			
Lake Karoro	4.45	5.0	0.55			

Table 1: Freeboards for 6600 m^3/s on the Greymouth Flood Wall at present

(This table can be compared with Table 4 of the 2001 report, and see figure A7 in appendix one for the positions of the cross-sections.) The flood levels need 600 mm freeboard and the stopbanks will need to be raised where the freeboard is less than 600 mm. The analysis shows that the average freeboards for 6600 m^3/s are:

Left Bank Average	0.36 m	Range 0.05 to 0.59 m
Right Bank Average	0.55 m	Range 0.40 to 0.86 m

Figures 1 to 3 show graphically how these flood levels and their associated stopbank levels with 600 mm freeboard compare with the present stopbank heights and therefore where the stopbanks need raising. Note that the Hydro2de results were adopted for the levels in Erua Lagoon and Lake Karoro. (See discussion in the Appendix in section A2.4.)

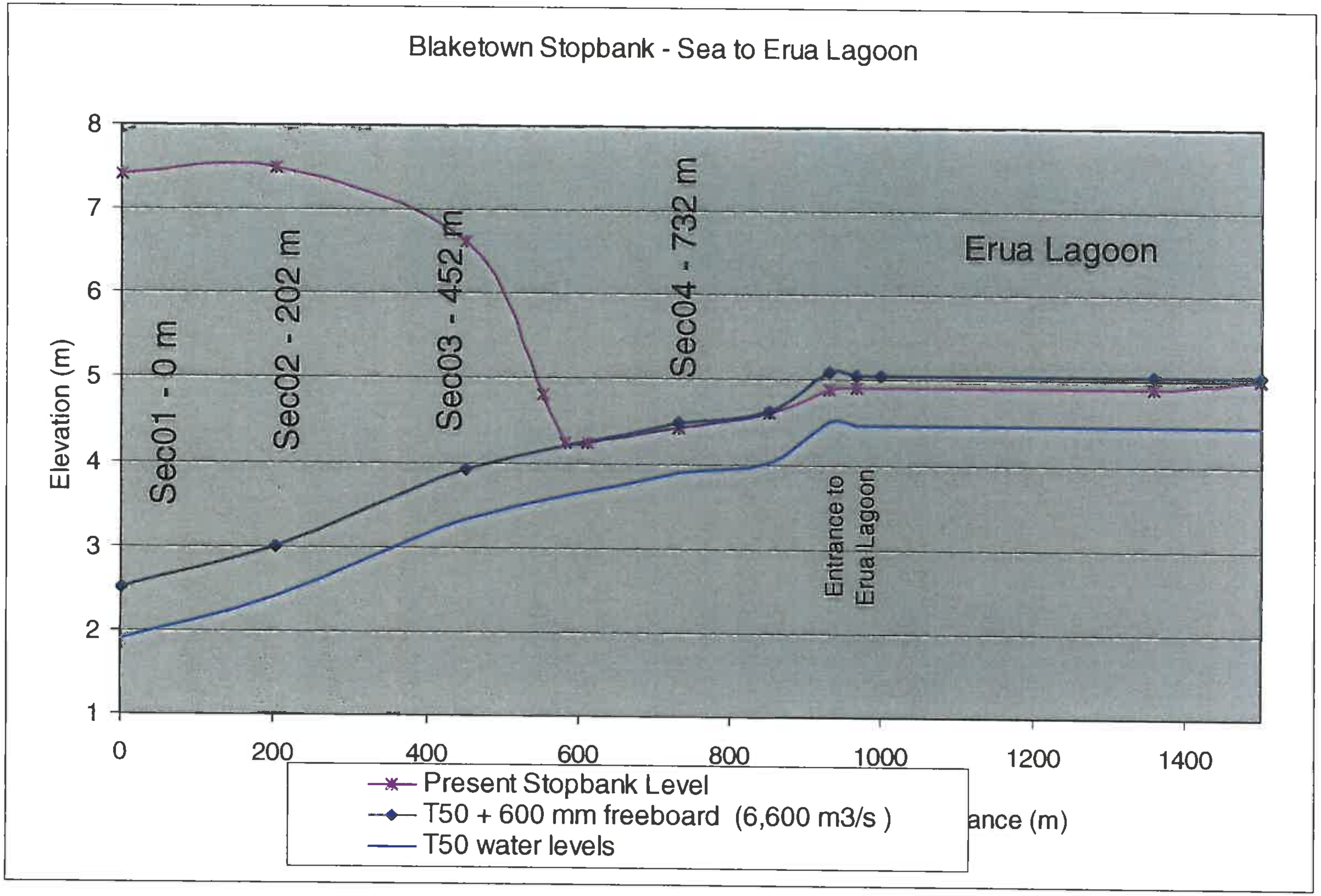


Figure 1: Long Section of Blaketown Area Stopbank showing T50 + 600 mm freeboard levels (6,600 m^3/s)

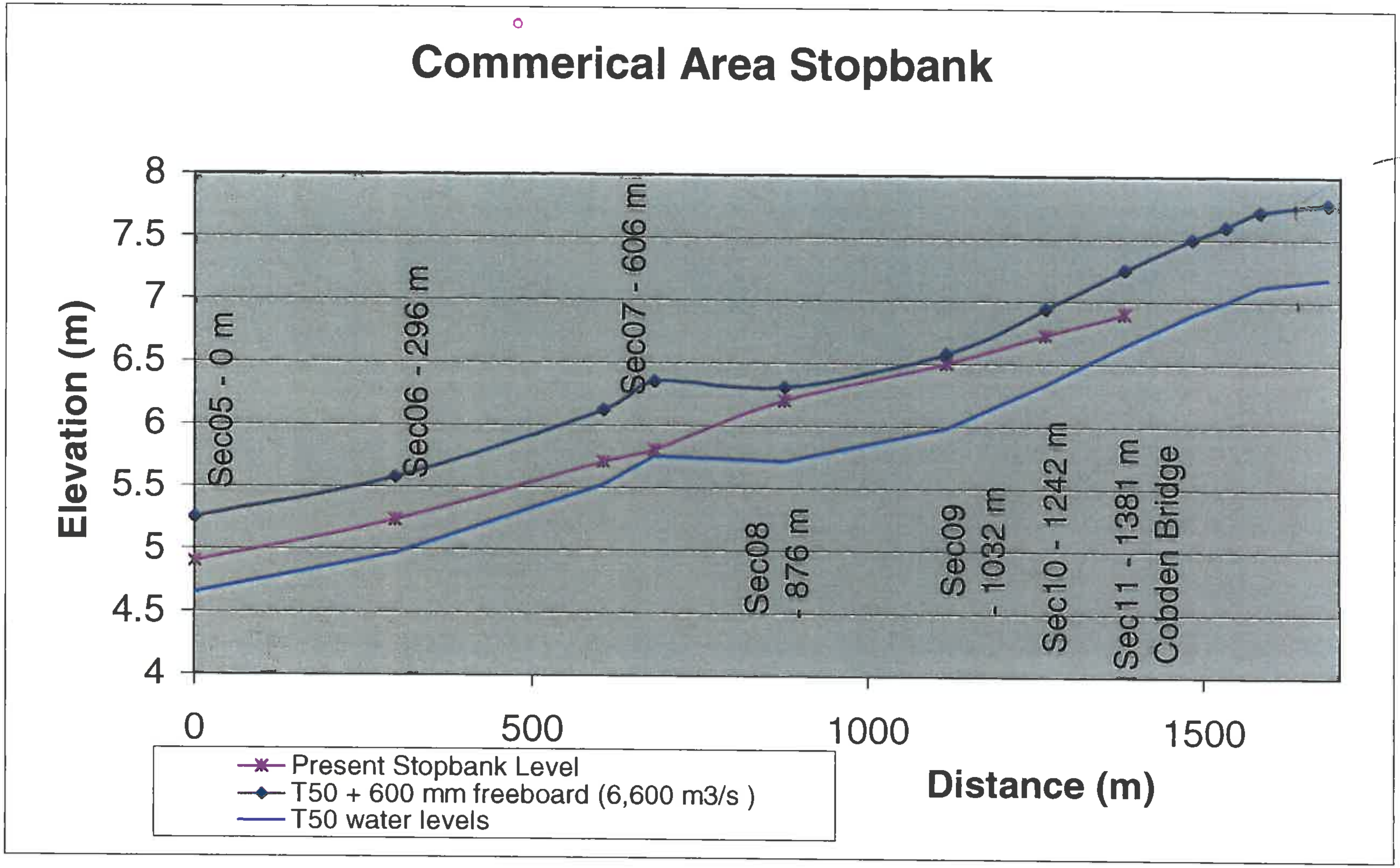


Figure 2: Long Section of Commerical Area Stopbank showing T50 + 600 mm freeboard levels (6,600 m^3/s)

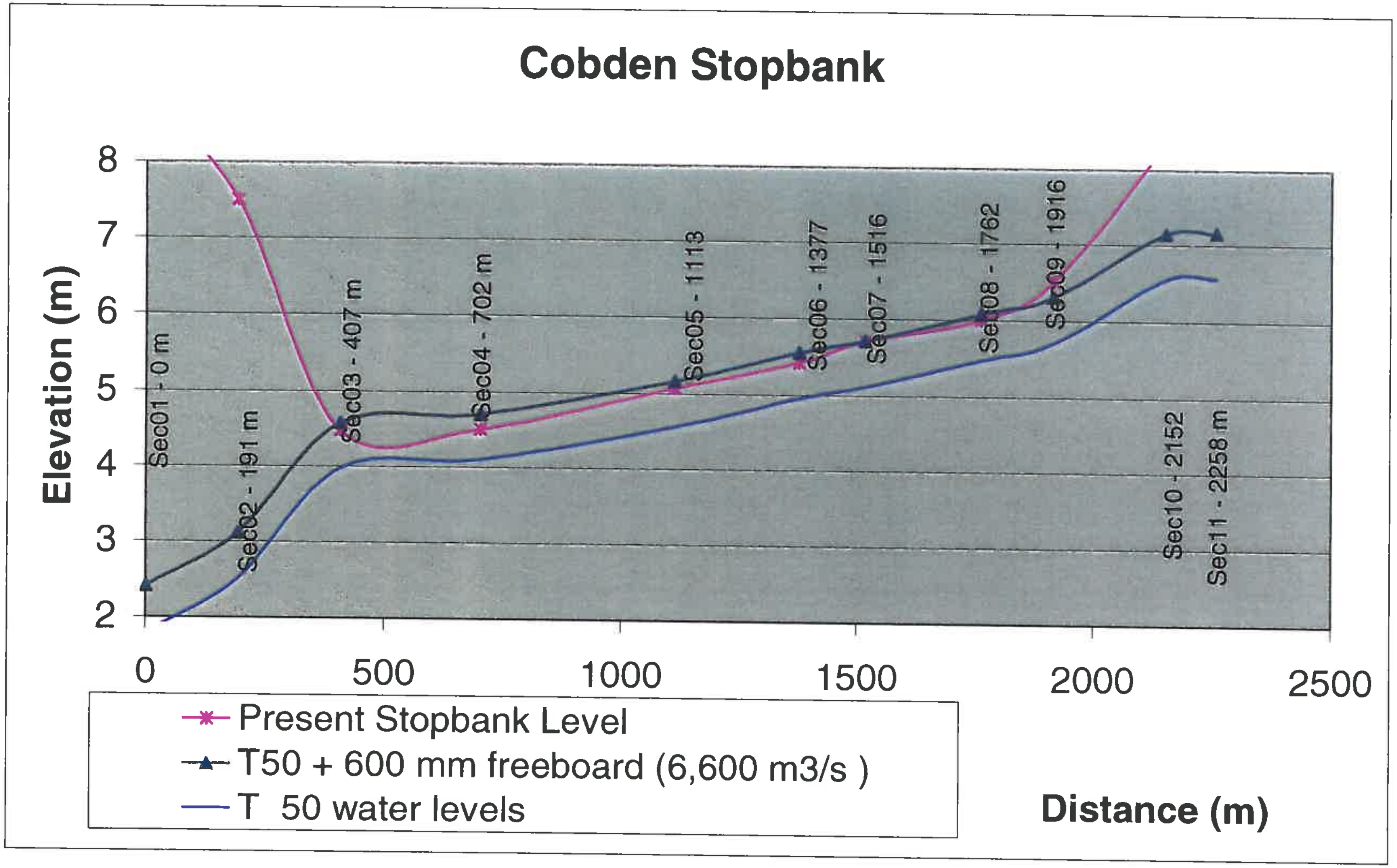


Figure 3: Long Section of Cobden Stopbank showing T50 + 600 mm freeboard levels (6,600 m^3/s)

3.2 Raising Required for 7400 m^3/s the Estimated 150 year return period flood.

Table 2 shows the flood levels and freeboards for the 7400 m^3/s flumen model.

Cross-section or point	Left Bank			Right Bank		
	Model water level (m)	Present Stopbank level (m)		Model water level (m)	Present Stopbank level (m)	
Sec01	1.9	7.4	5.5	2.0	8.85	6.85
Sec02	2.4	7.49	5.09	2.9	7.50	4.6
Sec03	3.87	6.61	2.74	4.29	4.47	0.18
Sec04	4.49	4.41	-0.08	4.64	4.5	-0.14
120 m upstream CS 4 Blaketown	4.60	4.61	0.01			
200 m upstream CS 4 at Blaketown	5.02	4.88	-0.12			
Sec05	5.15	4.90	-0.25	5.12	5.07	-0.05
Sec06	5.51	5.23	-0.28	5.51	5.42	-0.09
Sec07	6.08	5.7	-0.38	5.67	5.7	0.03
75 m upstream Sec 07	6.28	5.8	-0.48			
Sec08	6.27	6.2	-0.07	5.99	6.0	0.01
Sec09	6.52	6.5	-0.02	6.16	6.5	0.34
Sec10	6.87	6.73	-0.14	7.06	8.4	1.34
Cobden Bridge	7.19	6.9	-0.29	7.07	NA	NA
Erua Lagoon	5.05	4.9	-0.15			
Lake Karoro	5.05	5.0	-0.05			

Table 2: Stopbank levels for 7400 m^3/s the estimated 150 year return period discharge

The flood levels need 600 mm freeboard and the stopbanks will require raising where the freeboard is less than 600 mm. The analysis shows that the average freeboards for the design flood of 7400 m^3/s are:

Left Bank Average	-0.18 m	Range 0.01 to -0.48 m
Right Bank Average	0.06 m	Range 0.34 to -0.09 m

Figure 4 shows a plan of the flood levels for 7400 m^3/s.

Figures 5 to 7 show how these flood levels and proposed stopbank levels (with 600 mm freeboard) relate to the present stopbank levels. Where the proposed stopbank levels are above the present stopbank levels the stopbanks will need to be raised.

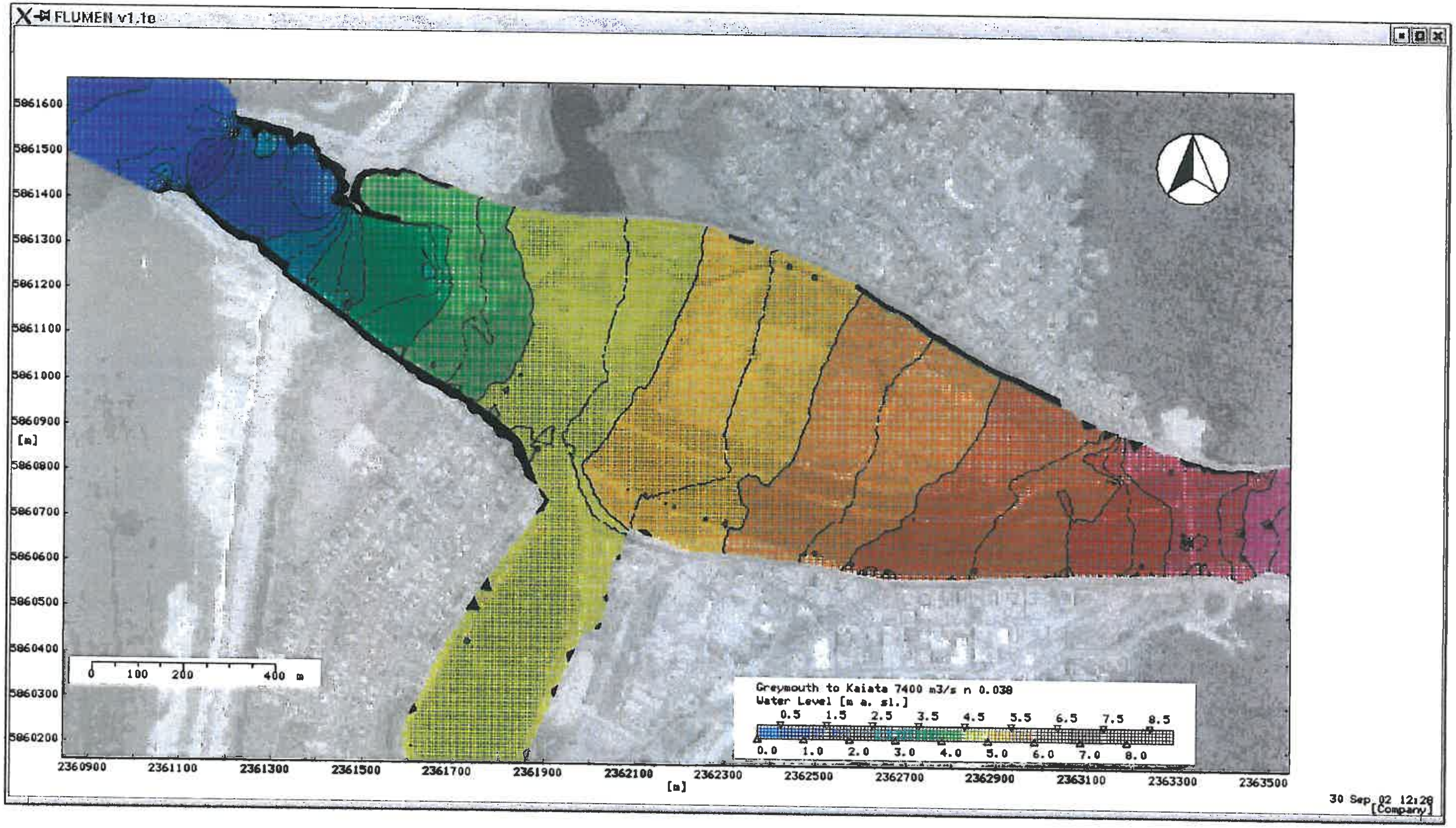


Figure 4: Water levels with the proposed stopbanks for 7400 m^3/s (Cobden Island not cleared).

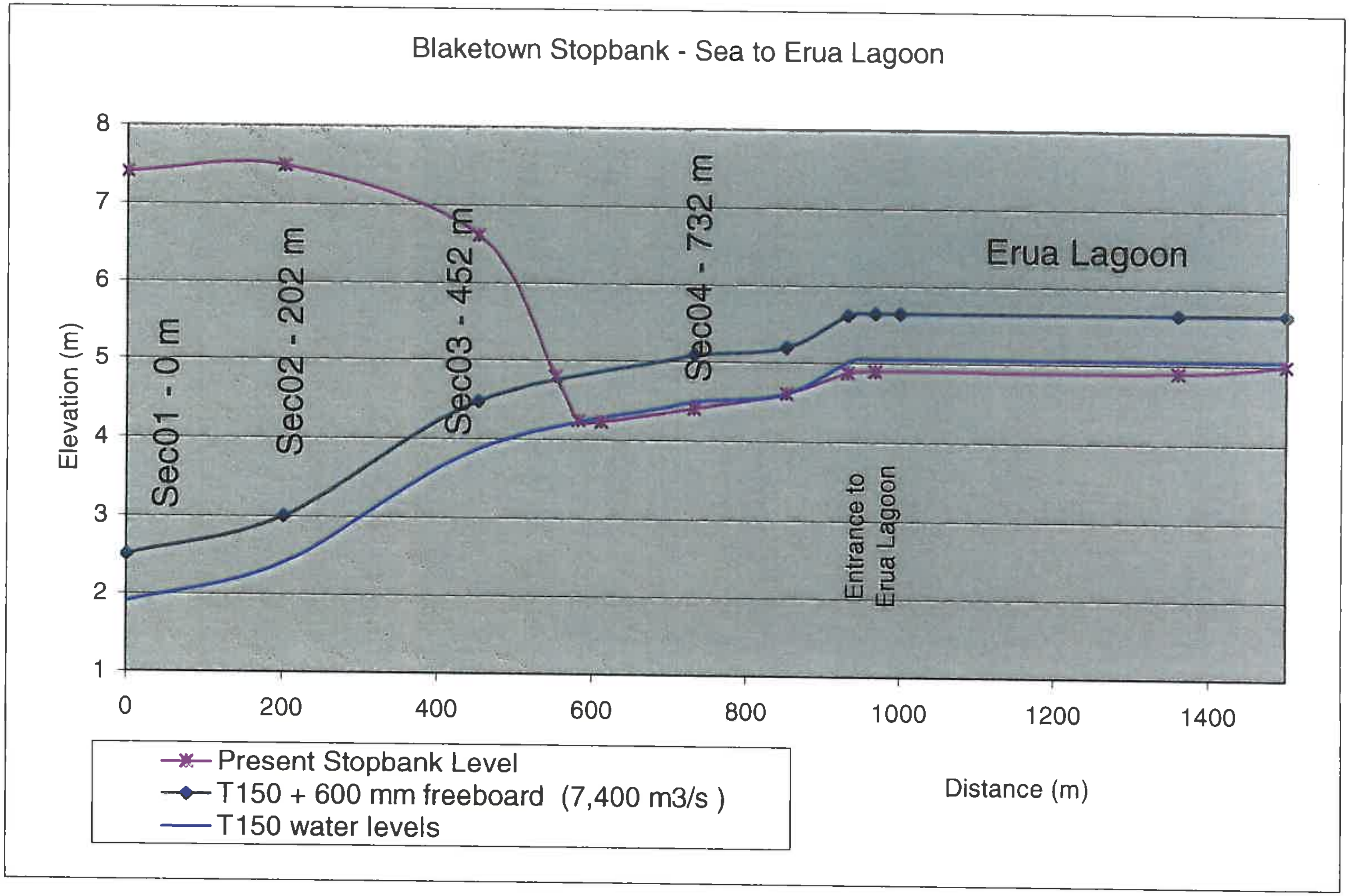


Figure 5: Long Section of Blaketown Area Stopbank showing T150 + 600 mm freeboard levels (7,400 m^3/s)

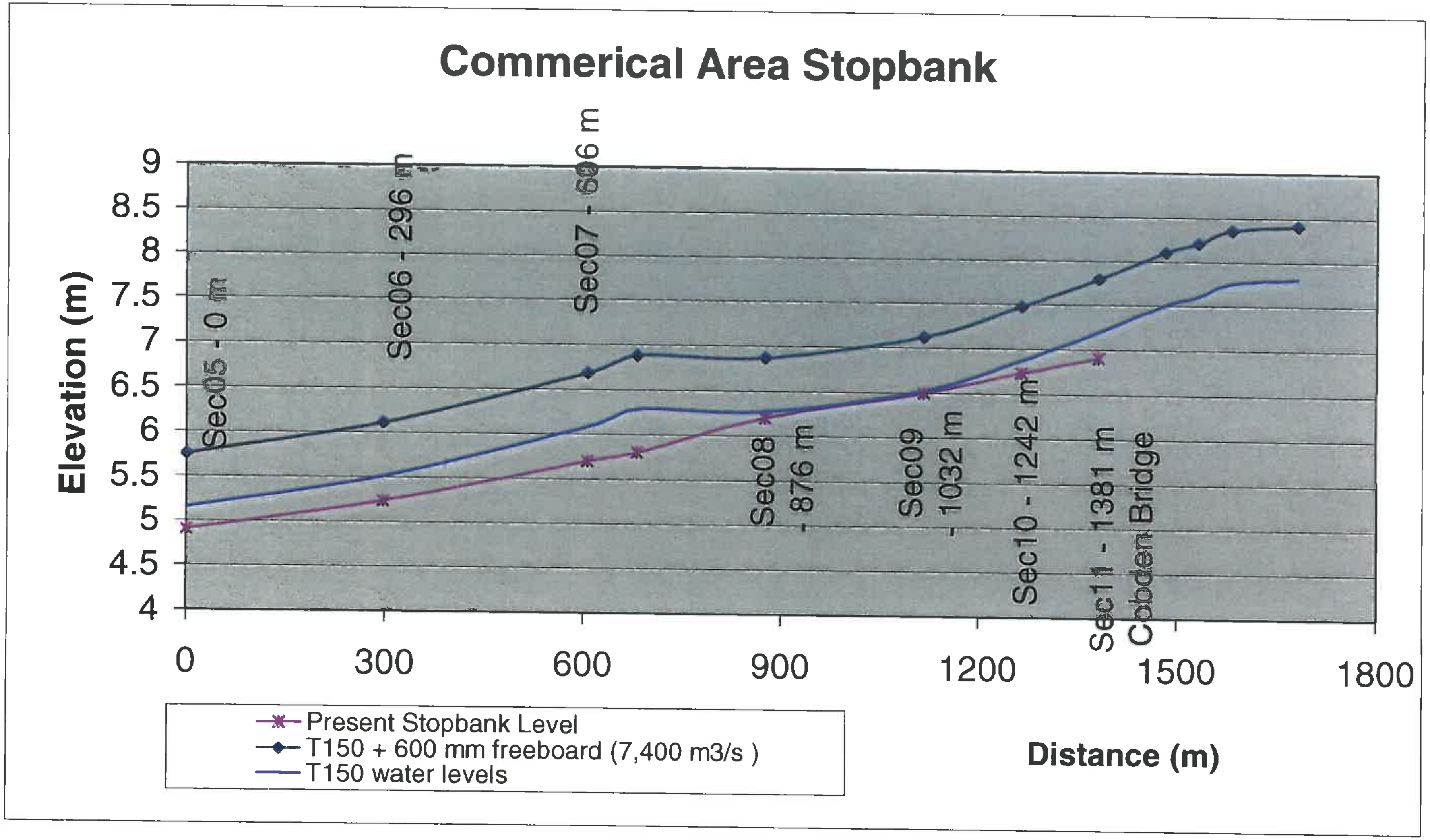


Figure 6: Long Section of Commerical Area Stopbank showing T150 + 600 mm freeboard levels (7,400 m^3/s)

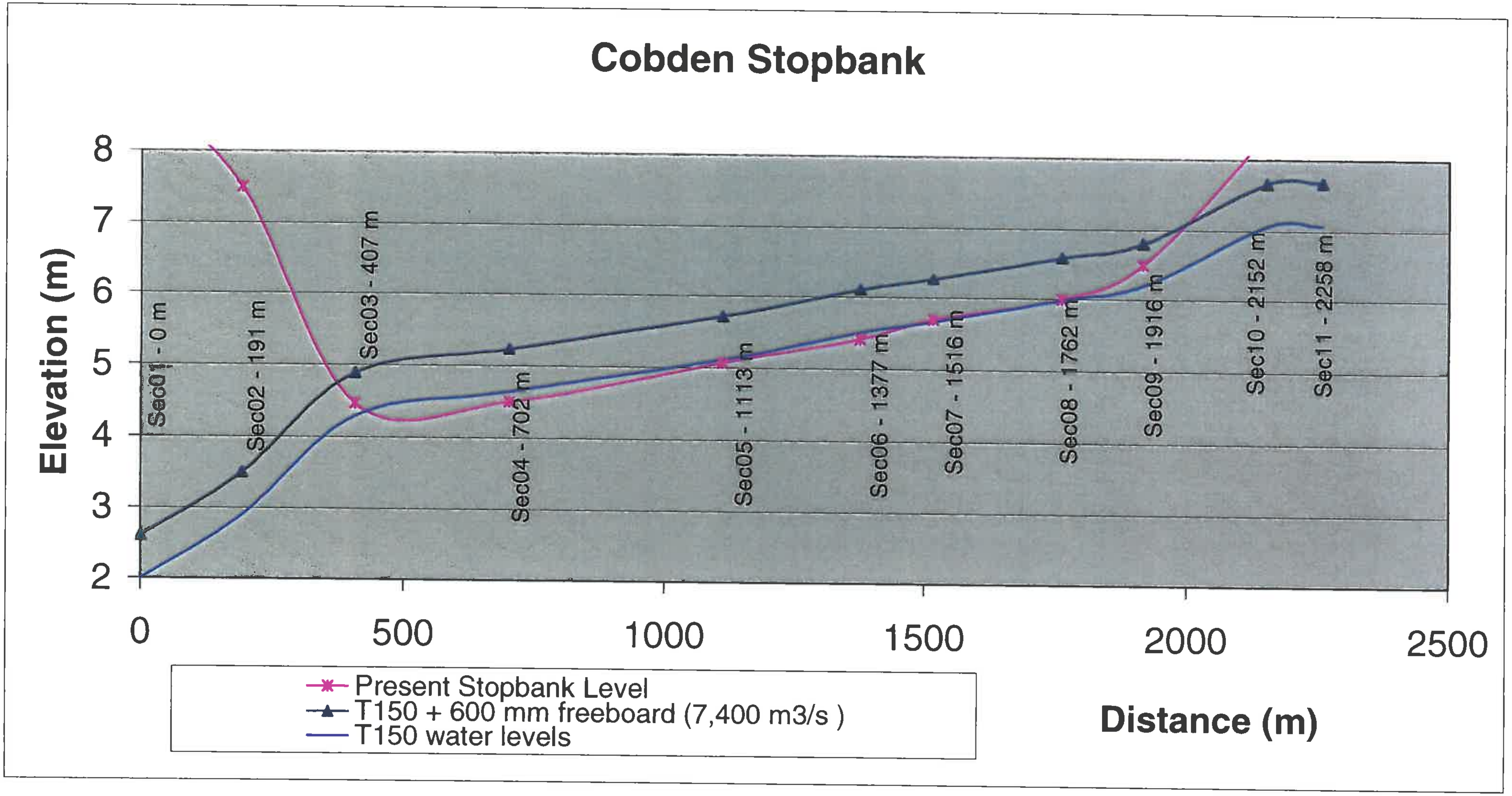


Figure 7: Long Section of Cobden Stopbank showing T150 + 600 mm freeboard levels (7,400 m^3/s)

3.3 Flood levels with Cobden Island cleared

For the purposes of modelling the area of Cobden Island that was cleared is shown in Figure 8 below.

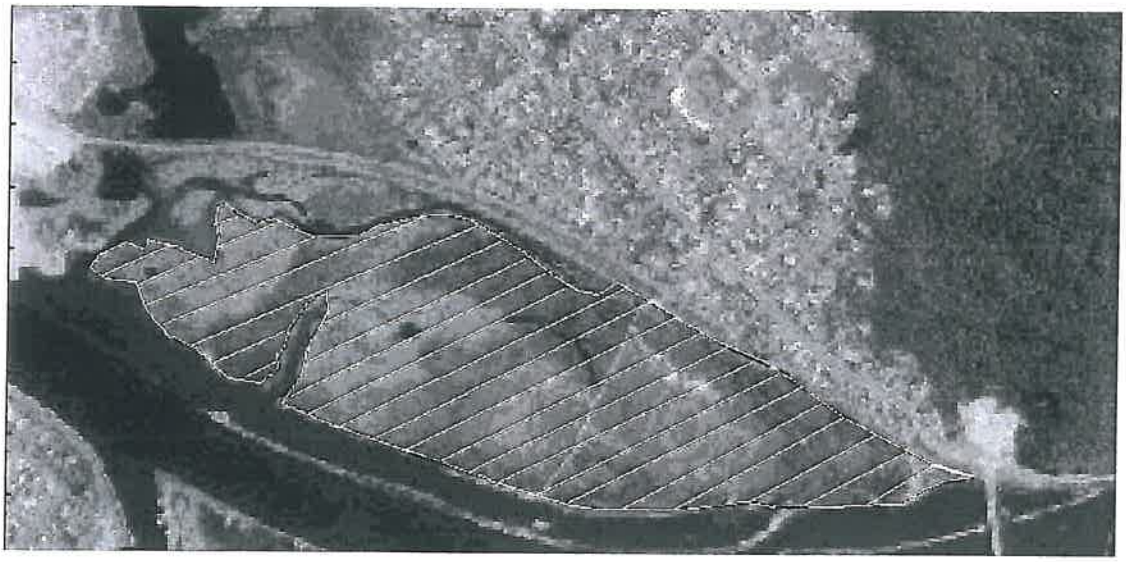


Figure 8: Clearance of Cobden Island used in Modelling.

The flood levels and freeboards for the 6600 m^3/s with Cobden Island cleared are given in Table 3 overleaf.

The flood levels need 600 mm freeboard and the stopbanks will require raising where the freeboard is less than 600 mm. The analysis shows that the average freeboards for the design flood of 6600 m^3/s with Cobden Island cleared are:

Left Bank Average	0.43 m	Range 0.18 to 0.75 m
Right Bank Average	0.57 m	Range 0.19 to 1.07 m

Figures 9 to 11 show how these flood levels and proposed stopbank levels (with 600 mm freeboard) relate to the present stopbank levels. Where the proposed stopbank levels are above the present stopbank levels the stopbanks will need to be raised.

Cross-section or point	Left Bank			Right Bank		
	Model water level (m)	Stopbank level (m)	Available freeboard (m)	Model water level (m)	Stopbank level (m)	Available freeboard (m)
Sec01	1.9	7.4	5.5	1.8	8.85	7.05
Sec02	2.4	7.49	5.09	2.5	7.50	5
Sec03	3.37	6.61	3.14	4.08	4.47	0.39
Sec04	4.01	4.41	0.40	4.31	4.50	0.19
120 m upstream CS 4 Blaketown	4.19	4.61	0.42			
200 m upstream CS 4 at Blaketown	4.61	4.88	0.27			
Sec05	4.72	4.90	0.18	4.71	5.07	0.36
Sec06	4.98	5.23	0.25	4.91	5.42	0.51
Sec07	5.37	5.7	0.33	4.98	5.7	0.72
75 m upstream Sec 07	5.58	5.8	0.22			
Sec08	5.48	6.2	0.72	5.28	6.0	0.72
Sec09	5.75	6.5	0.75	5.43	6.5	1.07
Sec10	6.14	6.73	0.59	6.35	8.4	2.05
Cobden Bridge	6.45	6.9	0.45		NA	
Erua Lagoon	4.45	4.9	0.45			
Lake Karoro	4.45	5.0	0.55			

Table 3: Freeboards for 6600 m^3/s on the Greymouth Flood Wall with Cobden Island cleared

There are several points that need to be made about the differences in the levels with Cobden Island cleared. Firstly the levels at Cobden Bridge are about 0.2 m lower. However downstream at Cobden Raceway the water levels are up to 0.21 m higher. The reason for this is that more water is flowing over Cobden Island at the downstream end resulting in higher levels here (0.21 m difference at Sec04). These higher levels raise the levels in the main channel on the opposite bank by 0.17 m. Therefore the overall effect of more water flowing over Cobden Island is that the effectiveness of the ‘whole channel’ is less at the downstream end as less water is in the main channel.

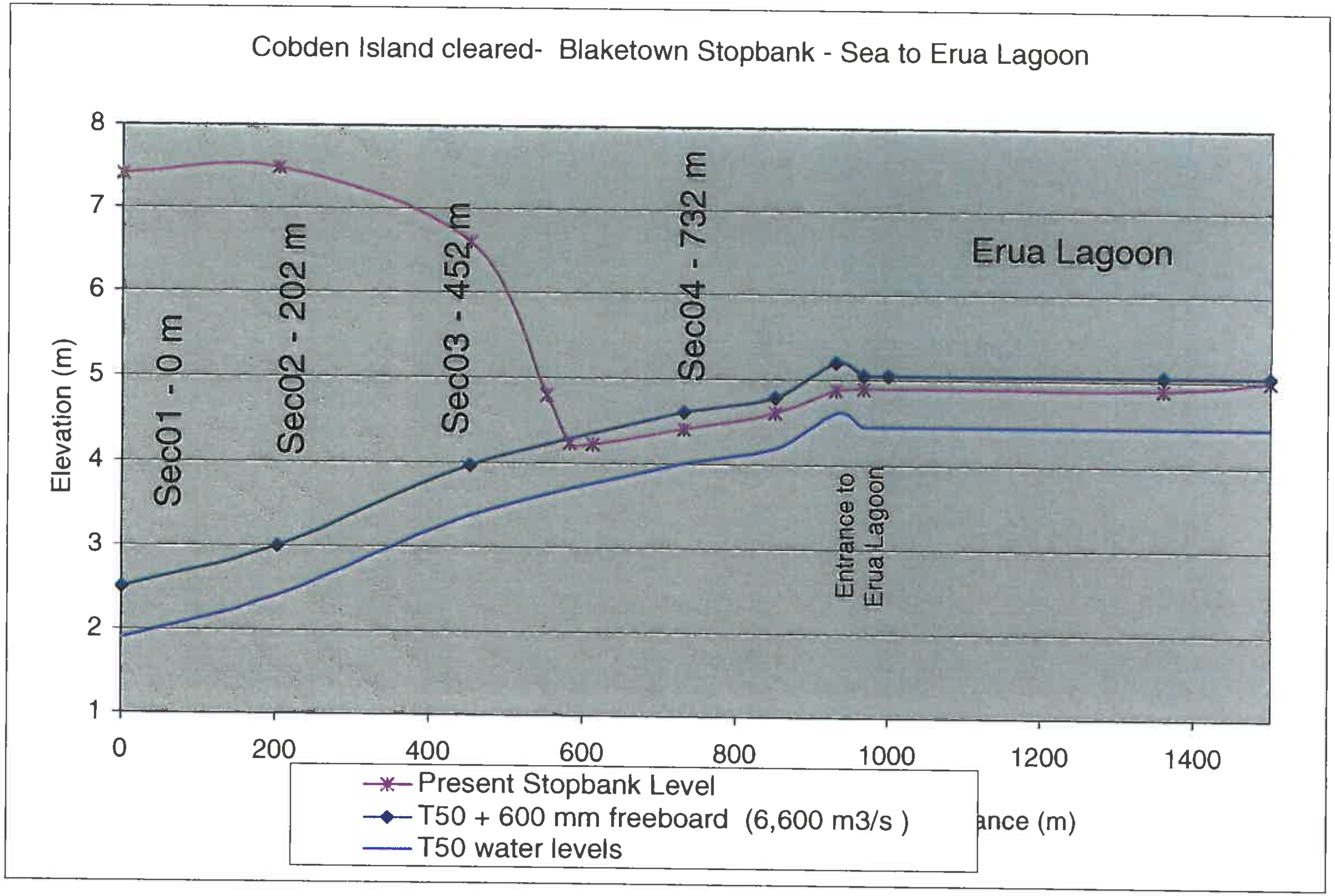


Figure 9: Cobden Island cleared Long Section of Blaketown Area Stopbank showing T50 + 600 mm freeboard levels (6,600 m^3/s)

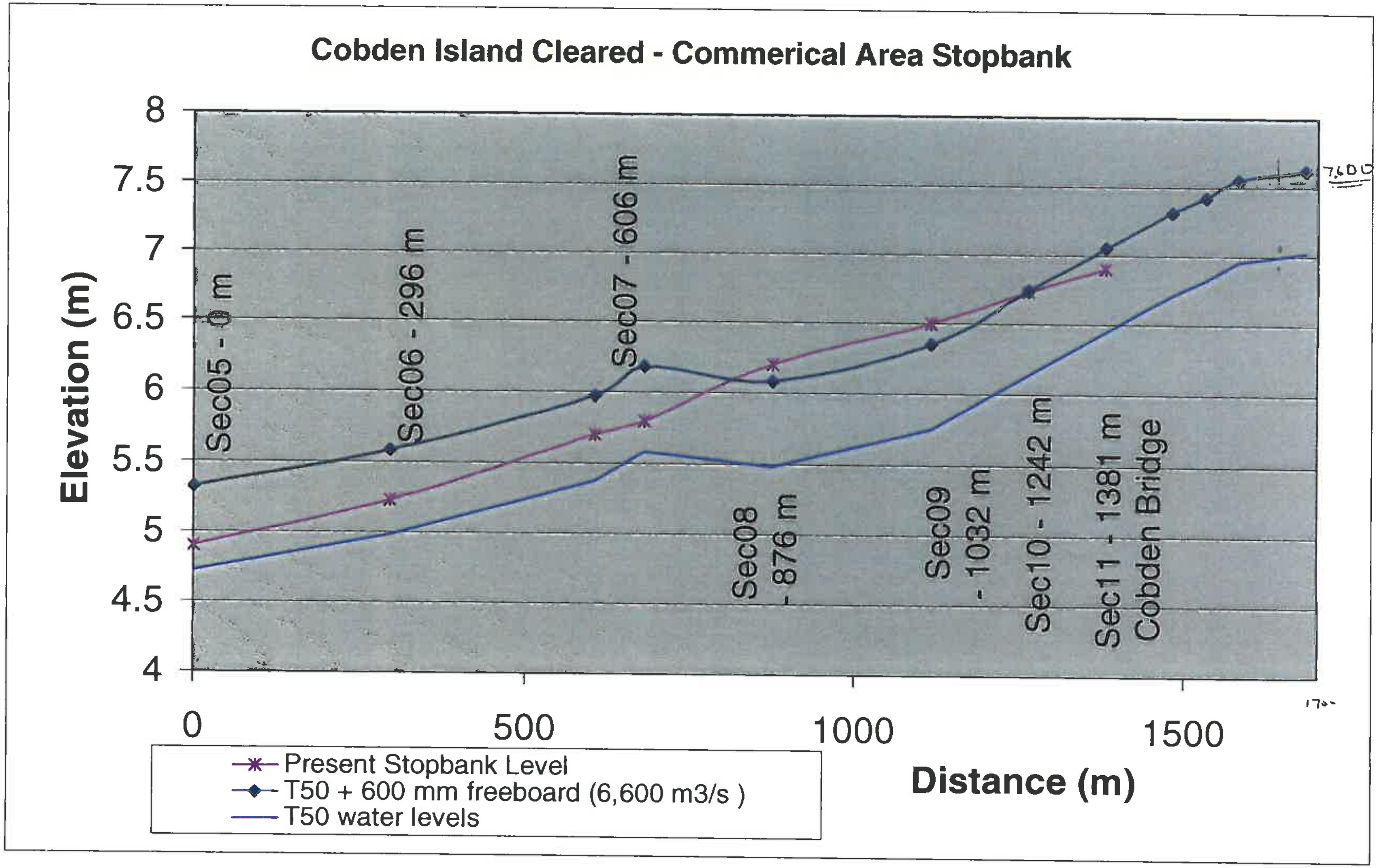


Figure 10: Cobden Island cleared - Long Section of Commerical Area Stopbank showing T50 + 600 mm freeboard levels (6,600 m^3/s)

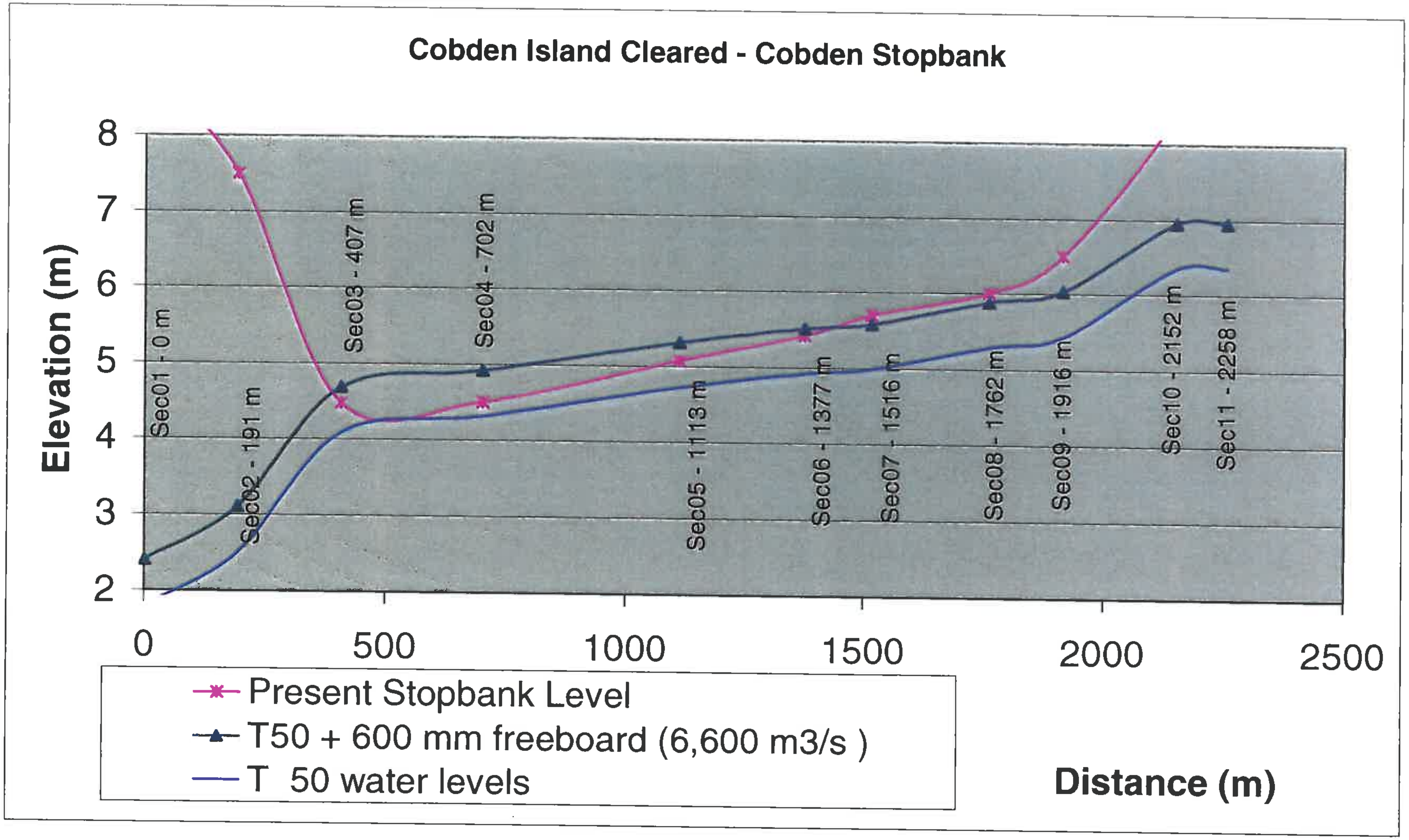


Figure 11: Cobden Island Cleared - Long Section of Cobden Stopbank showing T50 + 600 mm freeboard levels (6,600 m^3/s)

Table 4 below gives the stopbank levels for 7400 m^3/s with Cobden Island cleared.

Cross-section or point	Left Bank			Right Bank		
	Model water level (m)	Present Stopbank level (m)	Available freeboard (m)	Model water level (m)	Present Stopbank level (m)	Available freeboard (m)
Sec01	1.9	7.4	5.5	2.0	8.85	6.85
Sec02	2.4	7.49	5.09	2.9	7.50	4.6
Sec03	3.88	6.61	3.73	4.34	4.47	0.13
Sec04	4.58	4.41	-0.17	4.81	4.5	-0.31
120 m upstream CS 4 Blaketown	4.73	4.61	-0.12			
200 m upstream CS 4 at Blaketown	5.08	4.88	-0.20			
Sec05	5.19	4.90	-0.29	5.22	5.07	-0.15
Sec06	5.46	5.23	-0.23	5.42	5.42	0.00
Sec07	5.88	5.7	-0.18	5.49	5.7	0.21
75 m upstream Sec 07	6.05	5.8	-0.25			
Sec08	6.03	6.2	0.17	5.72	6.0	0.28
Sec09	6.21	6.5	0.29	5.86	6.5	0.64
Sec10	6.56	6.73	0.17	6.77	8.4	1.63
Cobden Bridge	6.91	6.9	-0.01	6.78	NA	NA
Erua Lagoon	5.05	4.9	-0.15			
Lake Karoro	5.05	5.0	-0.05			

Table 4: Stopbank levels for 7400 m^3/s the estimated 150 year return period discharge with Cobden Island cleared

The flood levels need 600 mm freeboard and the stopbanks will require raising where the freeboard is less than 600 mm. The analysis shows that the average freeboards for the design flood of 7400 m^3/s with Cobden Island cleared are:

Left Bank Average	-0.08 m	Range -0.29 to 0.29 m
Right Bank Average	0.11 m	Range -0.31 to 0.64 m

Figures 12 to 14 show how these flood levels and proposed stopbank levels (with 600 mm freeboard) relate to the present stopbank levels. Where the proposed stopbank levels are above the present stopbank levels the stopbanks will need to be raised.

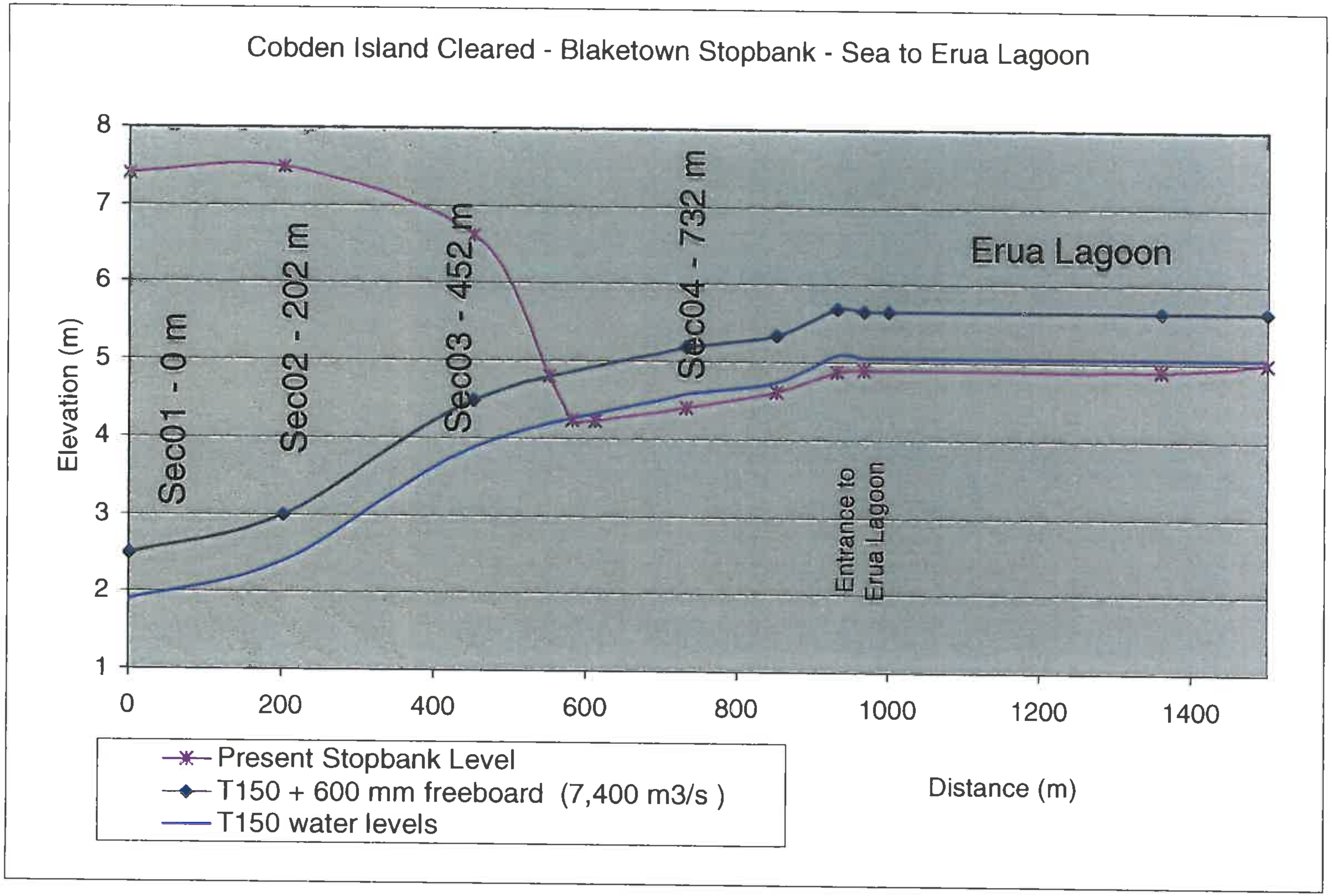


Figure 12: Cobden Island Cleared - Long Section of Blaketown Area Stopbank showing T150 + 600 mm freeboard levels (7,400 m^3/s)

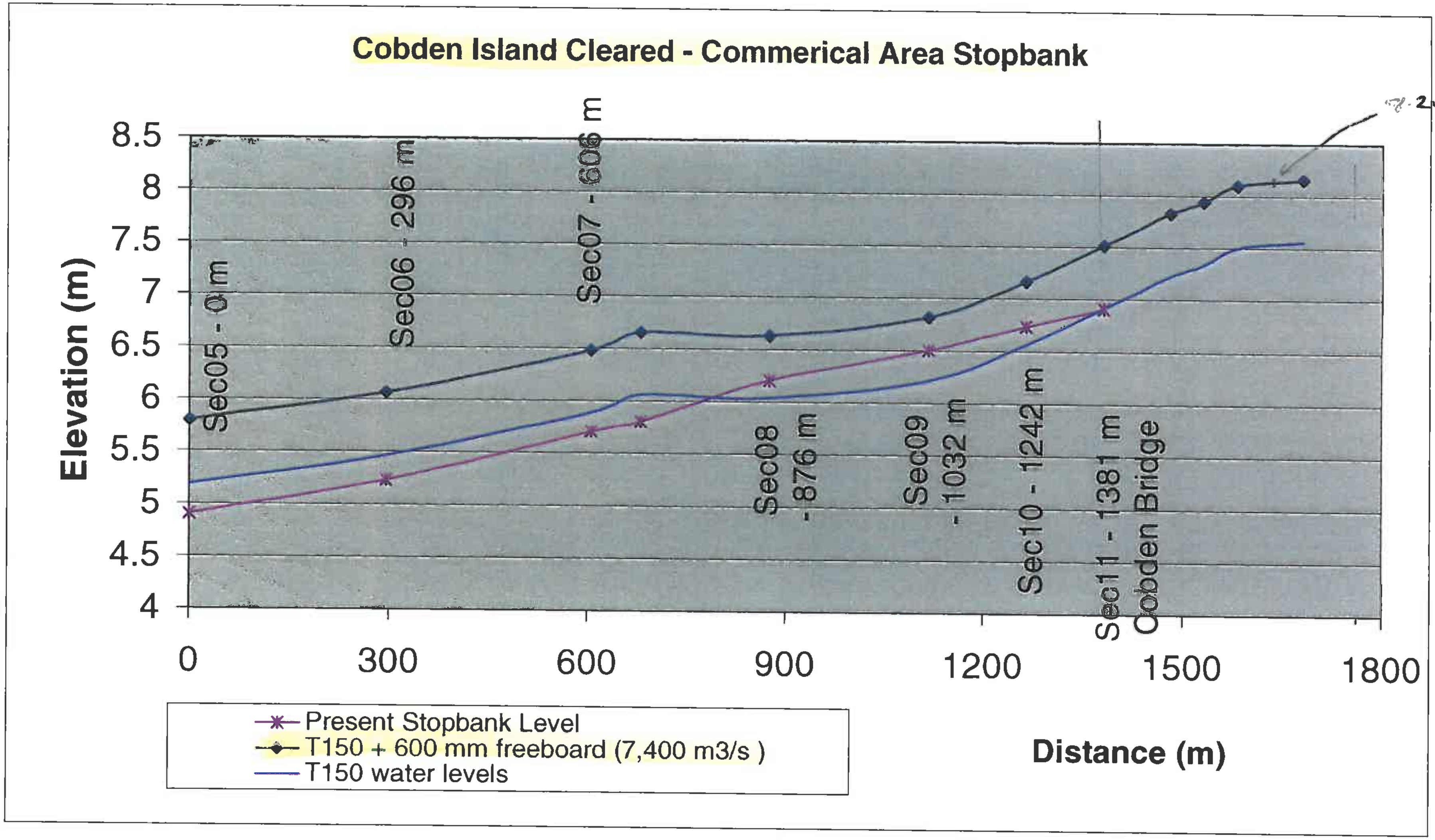


Figure 13: Cobden Island Cleared - Long Section of Commercial Area Stopbank showing T150 + 600 mm freeboard levels (7,400 m^3/s)

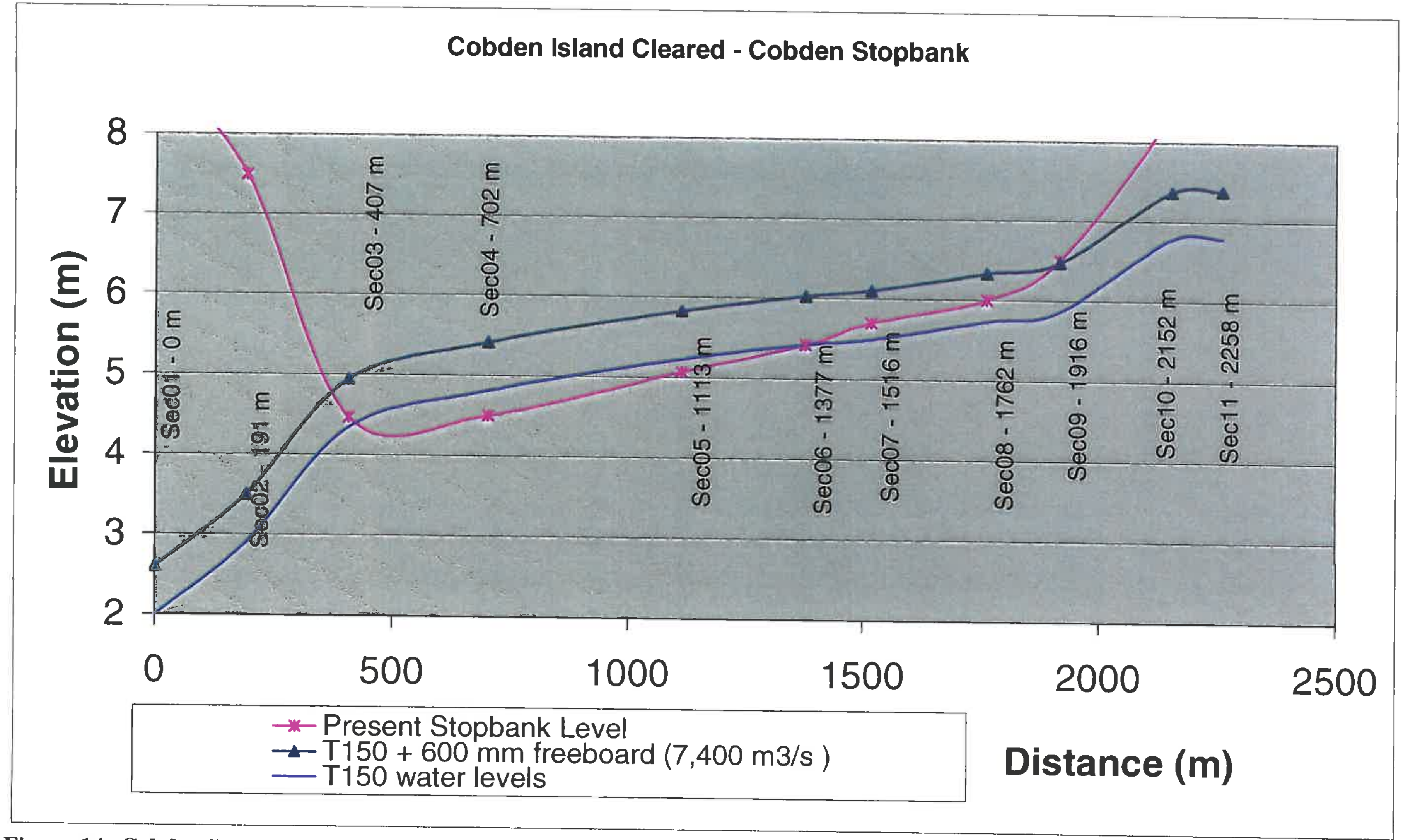


Figure 14: Cobden Island Cleared - Long Section of Cobden Stopbank showing T150 + 600 mm freeboard levels (7,400 m^3/s)

4.0 Discharge for Zero Freeboard Conditions

4.1 6600 m^3/s stopbanks.

To assess the discharge with zero freeboard, the model discharge was increased until the flood levels increased by 600 mm over the 6600 m^3/s flood levels. The discharge that achieved this was 7460 m^3/s. Table 5 below shows the water levels and the range of increase over the river.

Cross-section or point	Left Bank			Right Bank		
	Model water level 6600 m^3/s (m)	Model water level 7460 m^3/s (m)	Difference (m)	Model water level 6600 m^3/s (m)	Model water level 7460 m^3/s (m)	Difference (m)
Sec01	1.9	2		1.8		
Sec02	2.4	2.5		2.5	2.9	
Sec03	3.31	3.91	0.60	3.97	4.32	0.35
Sec04	3.88	4.46	0.58	4.10	4.68	0.58
120 m upstream CS 4 Blaketown	4.03	4.64	0.61			
200 m upstream CS 4 at Blaketown	4.55	5.05	0.60			
Sec05	4.65	5.19	0.56	4.56	5.15	0.59
Sec06	4.98	5.54	0.57	4.95	5.55	0.60
Sec07	5.52	6.12	0.60	5.11	5.71	0.60
75 m upstream Sec 07	5.73	6.32	0.59			
Sec08	5.71	6.30	0.59	5.47	6.03	0.56
Sec09	5.98	6.56	0.58	5.64	6.20	0.56
Sec10	6.36	6.91	0.55	6.54	7.10	0.56
Cobden Bridge	6.65	7.23	0.58	6.55	7.11	0.56
Erua Lagoon	4.15	4.81	0.66			

Table 5: The difference in water levels between 6600 m^3/s and 7460 m^3/s.

It could have been possible that this higher discharge could show that the 600 mm freeboard could favour one the three individual areas, i.e. Cobden, Greymouth or Blaketown. However this is not the case. The largest difference between 6600 m^3/s and 7460 m^3/s was 0.61 m, 120 m upstream of Sec 04 on the Blaketown stopbank and 0.60 m on both the Greymouth (Commercial area) and Cobden stopbanks. The difference of 0.01 m between 0.61 m and 0.60 m is minimal. However the difference in Erua Lagoon is 0.66 m. Hydro2de flood levels have been adopted on this reach for the flood levels in the lagoon (see discussion in Appendix section A2.4). These are thought to be conservative (see discussion in appendix section A2.4) and therefore translate to a value of less than 0.60 m. The Hydro2de level is 4.45 m means that 4.81 m in Table 5 above gives a difference of 0.36 m that is much less than 0.60 m.

4.2 7400 m^3/s stopbanks.

The discharge that resulted in the levels rising 600 mm from the 7400 m^3/s levels was 8150 m^3/s. Table 6 below shows the water levels and the range of increase over the river.

Cross-section or point	Left Bank			Right Bank		
	Model water level 7400 m^3/s (m)	Model water level 8150 m^3/s (m)	Difference (m)	Model water level 7400 m^3/s (m)	Model water level 8150 m^3/s (m)	Difference (m)
Sec01						
Sec02						
Sec03	3.87	4.47	0.60	4.29	4.68	0.39
Sec04	4.49	5.07	0.58	4.64	5.19	0.55
120 m upstream CS 4 Blaketown	4.60	5.18	0.58			
200 m upstream CS 4 at Blaketown	5.02	5.48	0.46			
Sec05	5.15	5.65	0.50	5.12	5.67	0.55
Sec06	5.51	6.03	0.52	5.51	6.04	0.53
Sec07	6.08	6.61	0.53	5.67	6.19	0.52
75 m upstream Sec 07	6.28	6.79	0.51			
Sec08	6.27	6.76	0.49	5.99	6.49	0.50
Sec09	6.52	7.00	0.48	6.16	6.65	0.49
Sec10	6.87	7.36	0.49	7.06	7.56	0.50
Cobden Bridge	7.19	7.70	0.51	7.07	7.55	0.48
Erua Lagoon	4.78	5.43	0.65			

Table 6: The difference in water levels between 7400 m^3/s and 8150 m^3/s.

The differences are higher near the mouth where the channel is the narrowest giving the highest rise in levels. The differences were less upstream (averaging about 0.5 m) as the channel is wider due to Cobden Island. This effect for the 6600/7460 m^3/s set was not as pronounced (averaging about 0.56 m). The reason for this is that there is a greater percentage of the water in the main channel in the 6600/7460 m^3/s set (compared to the above 7400/8150 m^3/s set) and therefore the widening of the channel effect due to Cobden Island (that lowers the differences in flood levels) is not so pronounced.

The reason that the levels at cross-section 3 on the right bank (for both the 6600/7460 m^3/s and 7400/8150 m^3/s sets) do not rise as much as the other levels is that in this case the water levels on the right bank are higher than those on the left bank (see Figure 4). The higher levels on the right bank occur because some of the water flows onto this higher area where the stockcar track is located before returning back to the main channel. Therefore a higher discharge does not raise the levels in this area as much.

5.0 Effects at Kaiata

5.1 Extension of model

5.1.1 Extension to Kaiata

The model was extended to Kaiata to assess the effects of options 1 to 4 on the flood levels at Kaiata. The model was calibrated for a discharge of 5810 m^3/s that was the discharge for the highest flood level at Kaiata. The modelled level was 8.81 m whereas the surveyed flood level was 8.765 m. During this flood there was very little flow over the inside of the bend at Kaiata that was not included in the model (see Figure 15 for the model extent). Therefore the model at a discharge of 5810 m^3/s gave a reasonable representation of the flood levels at Kaiata.

However for the larger floods used to assess the effects of 7400 m^3/s and 8150 m^3/s, in there will be considerable flow over this area on the inside of the bend. As a consequence the flumen model flood levels tended to over estimate the flood levels at Kaiata for these discharges. This means that the effects that were calculated using these discharges were also slightly larger than what would occur in reality.

5.1.2 Extension of model to include flood plains of Urban Areas

To model the present situation the stopbanks and flood plain topography i.e. the township and Cobden urban areas were added to the models as there would be flooding at the discharge of 7400 m^3/s and 8150 m^3/s that were used to assess the effects.

The data for this area was not detailed and only approximate as the datum for the township was under review at the time the model was built for the 2001 report. (For a plan of this topography see Figure 15). The present stopbanks were added into this model and the likely breaches were also included as outlined in the next section below.

5.2 Details of scenarios modelled

The worse case option would be for the banks full discharges for:

a) T50 stopbank carrying zero freeboard flood of 7460 m^3/s
b) T150 stopbank carrying zero freeboard flood of 8150 m^3/s.

Therefore the present situation was modelled with these discharges to assess the effects of all four options under consideration.

5.2.1 T50 Stopbank Scenarios (Zero freeboard flood flow 7460 m^3/s)

For the 7460 m^3/s (T50 stopbanks) situation two scenarios were modelled. These were breakouts on the south side only and then with breakouts on both sides.

The breakouts were assumed to occur at the points where the freeboards were the least as calculated in section 3 above. On the south side this would be a breach from Cobden Bridge to 200 m downstream (sec10) m and a 200 m breach at the bend starting from the Dolphin Watch shed as shown in Figure 15.

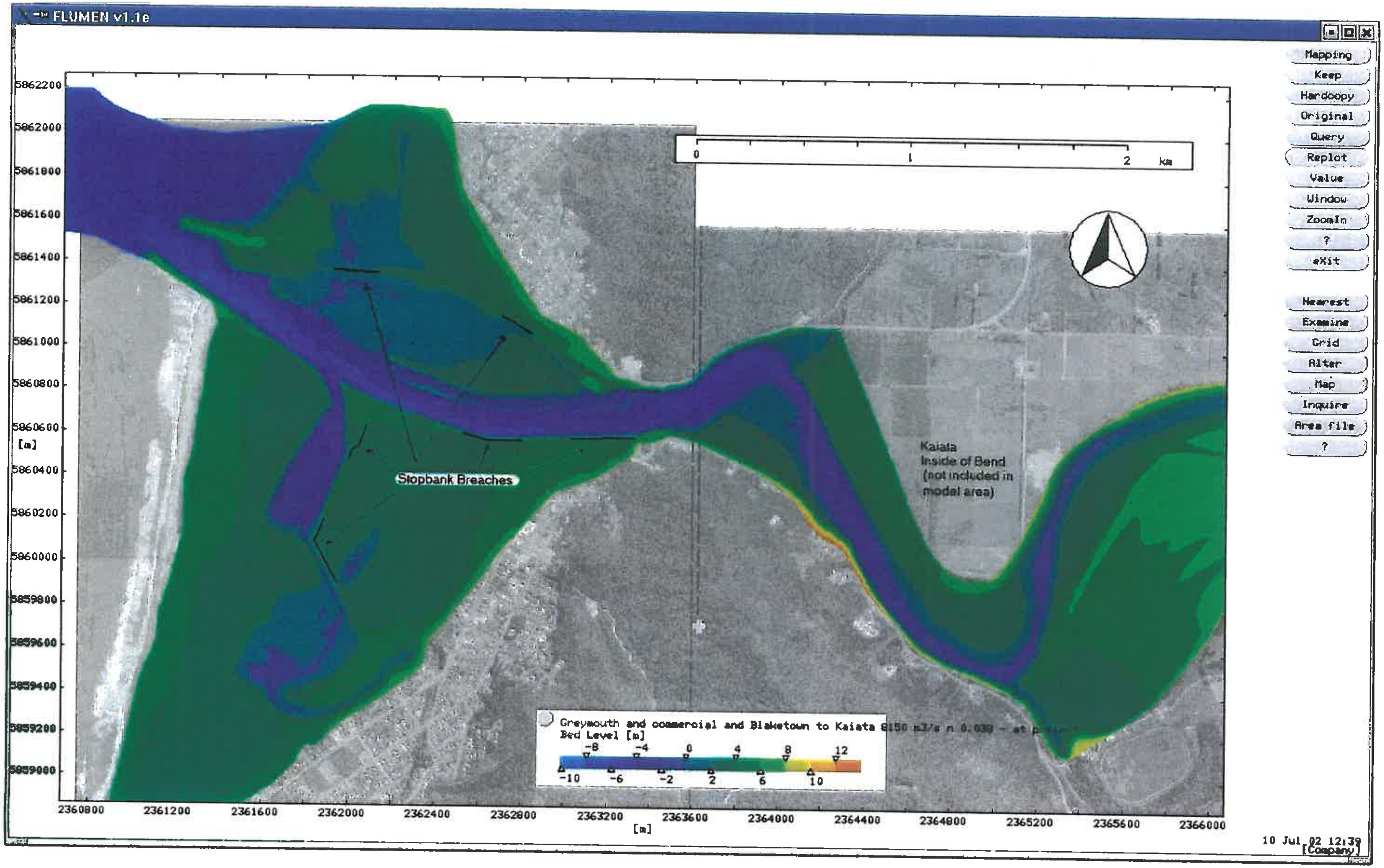


Figure 15: Ground topography to Kaiata showing the 8150 m^3/s stopbank breaches for the present situation modelled

The scenario where the breakouts were on both sides, assumed that in addition to the above breakouts on the south side there would be breakouts on the Cobden Side just upstream of the Cobden Raceway and near the upstream end of the stopbank between sec07 and sec08. These are also shown on Figure 15.

5.2.2 T150 Scenario (zero freeboard flood flow 8150 m3/s

For the 8150 m^3/s (T150) option breakouts were assumed to occur on both sides. These were the same length as the T50 breakouts.

The stopbanks on the upstream side of Erua Lagoon and Lake Karoro were assumed to remain intact for both the 7460 m3/s and 8150 m3/s scenarios, although there is a possibility that the Erua Lagoon stopbanks could breach with the 8150 m3/s scenario. The effect of these breaches on water levels at Kaiata is discussed in section 5.4.2.

5.3 Results

The changes in flood levels that occur at Kaiata arising from the raising of stopbanks from the current level to a T50 + 600 mm freeboard standard and T150 + 600 mm freeboard standard for bankfull condition (zero freeboard flood flows) is as follows:

T50 case - 7460 m^3/s modelled. (6600 m^3/s Design flow)

Raising the stopbanks to T50 + 600 mm	0.05 m increase.
Clearing Cobden Island and raising the stopbanks to T50 + 600 mm	0.03 m decrease.

T150 case - 8150 m^3/s modelled. (7400 m^3/s Design flow)

Raising the stopbanks to T150 + 600 mm	0.10 m increase.
Clearing Cobden Island and raising the stopbanks to T150 + 600 mm	0.005 m decrease.

Figure 16 shows the flood levels with a discharge of 8150 m^3/s with both flood plains flooding.

5.4 Discussion

5.4.1 Effect of Cobden Island Clearance

The reason that the levels decrease at Kaiata by clearing Cobden Island is that the clearance work drops flood levels at Cobden Bridge below the flood levels that would occur in the present situation with the stopbanks overtopping and breaching.

From this point upstream the river is the same. Whilst this effect gradually reduces upstream it never the less extends upstream to Kaiata to give the water level changes shown in section 5.3 above. At some point far enough upstream beyond Kaiata there would be no difference in water level between any of the options.

If Cobden Island is not cleared the water levels increase at Cobden Bridge and therefore increase at Kaiata as indicated by the results.

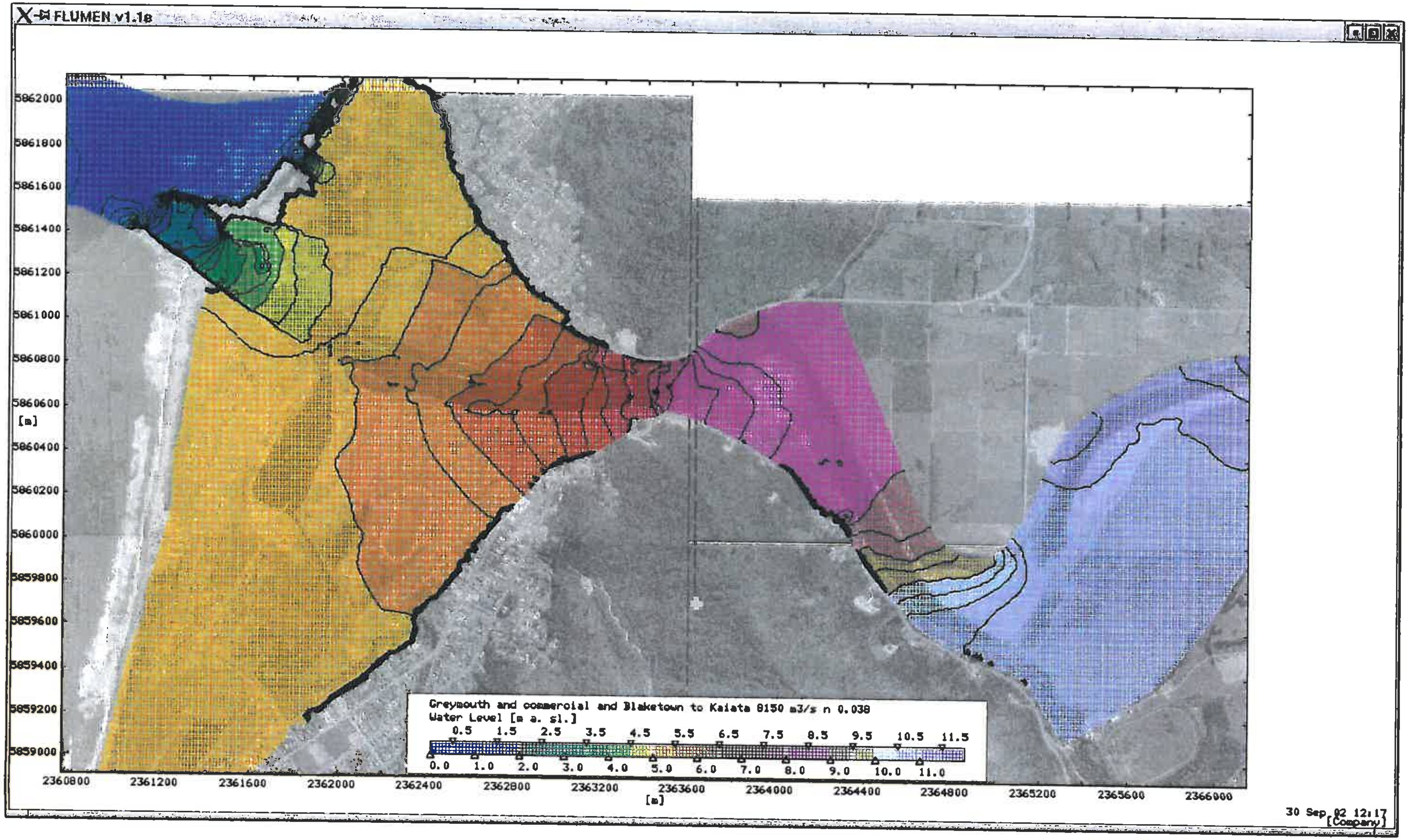


Figure 16: Water levels for 8150 m^3/s with the present situation (Stopbanks overtopped and breached).
Note:This plot gives the flood surface contours only. It does not represent depths of flood water on the flood plain

5.4.2 Erua Lagoon and Lake Karoro Stopbanks

It was assumed that the stopbanks surrounding Erua Lagoon and Lake Karoro would not breach for the above results. A run assuming they do breach in the 8150 m^3/s present situation (see Figure 15 for the positions) indicates that the levels will be 0.001 m lower at Kaiata. This will not change the results for the effects at Kaiata i.e. they will be the same as it section 5.3 as the values have already been rounded to the nearest 0.005 m or ½ cm. The actual decrease in level shown for the 8150 m^3/s Cobden Island clearing case to three decimal places changes from a 0.004 m decrease to a 0.003 m decrease i.e. the rounded figures to the nearest ½ cm remain unchanged.

5.4.3 Effect of full Kaiata flood plain in analysis

As discussed in section 5.1.1 above, upstream of Cobden Bridge the analyses have only used the river area and not the area of land on the inside of the river bend opposite Kaiata. This means that the above differences in flood level at Kaiata are higher than would occur if the whole flood plain were included in the model.

5.4.4 Effect of more detailed Urban Area flood plain in analysis

The topography in the urban area or flood plains has been built from limited data and as a consequence is only approximate in some areas. There are good levels at overflow points (these are from the stopbank profiles). Any corrections to the approximate levels will not change the slope of overflows greatly therefore that if the urban area topography is improved with better data, it will not change the flood level effects calculated at Kaiata significantly.

6.0 Summary of Results

1) A model of the Grey River stopbanks has been developed using flumen. This model gives better results than Hydro2de used in the 2001 report over this reach of the river.
2) The stopbank levels for the T50 flow of 6600 m3/s with 600 mm freeboard, the estimated T50 discharge are presented. This indicates that the current stopbank heights will not meet this flood standard over its entire length.
3) The stopbank levels for the T150 flow of 7400 m3/s with 600 mm freeboard, the estimated T150 discharge are presented. This indicates that the current stopbank heights will not meet this flood standard over its entire length.
4) The stopbank levels for both the T50 and T150 levels with Cobden Island cleared are also presented.
5) The zero freeboard capacity with the proposed 6600 m^3/s with 600 mm freeboard stopbanks is 7460 m^3/s.
6) The zero freeboard capacity with the proposed 7400 m^3/s with 600 mm freeboard stopbanks is 8150 m^3/s.
7) Without clearing Cobden Island the proposed stopbanks will raise flood levels at Kaiata for the T50 and T150 options.
8) Clearing Cobden Island the proposed stopbanks will lower flood levels at Kaiata for the T50 and T150 options.

Appendix A Comparison and Discussion of Flumen and Hydro2de results

A1.0 Background – 2001 Analysis

In the February 2001 report, the September 1988 flood (5840 m^3/s) and the October 1998 flood (5670 m^3/s) were calibrated using Hydro2de. The water levels during the September 1988 flood were higher than the October 1998 flood by about 300 to 400 mm in the main channel and 600 mm in Erua Lagoon and Lake Karoro.

Note that some of the level differences between the 1988 and 1998 floods in the main channel were larger than 400 mm as the excavation in the main channel affected them. For example, the point at 'the Pump Shed at top end of Wharf' that was opposite this excavation, the difference was 650 mm.

However the 400 mm difference levels cannot be explained by the difference in discharges between the 1988 and 1998 floods that only 170 m^3/s. The expected difference in floods level should have been 150 mm and not 400 mm. This meant that the higher flood, in September 1988 flood had more conservative model parameters. The more conservative parameters could be the result any number of factors including higher bed levels, more overflows to the flood plains (which tend to reduce the conveyance of the main channel) and even errors in estimating the discharges at the rating station (these typically have about a 7% standard error).

Therefore in the 2001 report, these higher parameters were adopted for the design model. The calibration of the September 1988 flood using Hydro2de is given in Table A1 below. (This is a reprint of Table 2 of the February 2001 report).

13th September 1988 flood - 5840 m3/s		Description of position	Observed Level 1988 (m)	Hydro2de Modelled Level (m)	Hydro2de Difference (m)
Position NZ map grid		**Left Bank –Blaketown and Commercial Area**			
2361715	5860998	Blaketown just U/S Parking Area -	3.38	3.37	0.01
2361857	5860881	Just D/S Entrance Erua Lagoon -	3.53	3.81	0.28
2362496	5860632	Just below Pump Station at top end of Wharf	4.65	4.84	0.19
2362655	5860594	Dolphin Watch Shed at 675 m -	4.84	5.04	0.20
2363330	5860636	Under Cobden Bridge -	5.72	5.66	-0.06
		Right Bank - Cobden Side			
2362862	5861031	Three blocks up from Sturge St	4.59	4.69	0.1
2362745	5861092	Two blocks up from Sturge St	4.54	4.56	0.02
2362490	5861240	Sturge Street -	4.27	4.19	-0.08
2362436	5861264	Corner Nelson Quay -	4.09	4.08	-0.01
2361899	5861364	200 m upstream of Raceway	3.59	3.62	0.03
2361704	5861384	Just upstream of Cobden Raceway	3.50	3.35	-0.15
2361728	5860433	Erua Lagoon Blaketown side	3.8	3.74	-0.06
2361489	5859491	South end of Lake Karoro	3.96	3.81	-0.15

Table A1: Hydro2de Model Calibration Results for the 13th September 1988 flood

Tme constraints with this work did not allow a model of the 1988 flood to be constructed and run. This will be done at a later stage to refine the model developed for this report to give final stopbank levels for the option that is ultimately promoted.

As a consequence, the calibration of the 1988 flood using flumen had to be done using the 1998 flumen model that had been built since the Hydro2de work in 2001 report. This could be undertaken as the expected differences in flood level from the changes between 1988 and 1998 using Hydro2de were calculated in the 2001 report (Table 3 of the 2001 report, reproduced below as table A2). Column 5 of Table A2 below gives the modified observed flood levels that flumen model was calibrated against.

Comparison of results with 1988 flood and 1998 topographies						
Position NZ map grid	Description of position	Observed Level 1988 (m) (1)	Hydro2de modelled level - 5840 m^3/s 1988 topography (m) (2)	Hydro2de modelled level - 5840 m^3/s 1998 topography (m) (3)	Difference in Hydro2de modelled flood level 1998 to 1988 topography (m) (4)	Modified Observed Levels to calibrate the models (m) (5) = (1) + (4)
	Left Bank					
2361715 5860998	Blaketown just U/S Parking Area -	3.38	3.37	3.42	0.05	3.43
2361857 5860881	Just D/S Entrance Erua Lagoon -	3.53	3.81	3.97	0.16	3.69
2362496 5860632	Just below Pump Station at top end of Wharf	4.65	4.84	4.78	-0.06	4.59
2362655 5860594	Dolphin Watch Shed at 675 m -	4.84	5.04	5.03	-0.01	4.83
2363330 5860636	Under Cobden Bridge -	5.72	5.66	5.75	0.09	5.81
	Right Bank					
2362862 5861031	Three blocks up from Sturge St	4.59	4.69	4.69	0	4.59
2362745 5861092	Two blocks up from Sturge St	4.54	4.56	4.62	0.06	4.60
2362490 5861240	Sturge Street -	4.27	4.19	4.37	0.18	4.43
2362436 5861264	Corner Nelson Quay -	4.09	4.08	4.31	0.23	4.32
2361899 5861364	200 m upstream of Cobden Raceway	3.59	3.62	3.63	0.01	3.60
2361704 5861384	Just upstream of Cobden Raceway	3.50	3.35	3.36	0.01	3.51
2361728 5860433	Erua Lagoon Blaketown side -	3.8	3.74	3.81	0.07	3.87
2361489 5859491	South end of Lake Karoro	3.96	3.81	3.86	0.05	4.01

Table A2: Hydro2de - Comparison of September 1988 flood levels using the 1998 topography. (This includes part of Table 3 of the February 2001 report)

The main differences in levels shown in Table A2 arose from the construction of Greymouth Flood Wall and the removal of part of Cobden Island where it extended into the secondary channel (see figure 12 of the 2001 report). This mean that using the

1998 topograph y increased the water levels in most areas, because water that flowed over the flood plains in 1988 was now confined to the river channel. However the flood levels reduced in area where part of Cobden Island was excavated.

It is concluded once the nature of these changes are appreciated, the model results are comparable; this is discussed further in section A2.0 below.

A2.0 Flumen Analysis and Comparison with Hydro2de Results

The results for the best calibration using flumen are given in Table A3 below.

13th September 1988 flood - 5840 m3/s			Flood Levels to calibrate flumen model (1) = (5) of Table 2	Flumen modelled level (2)	Flumen difference (3)	Difference flumen vs Hydro2de (4)
			(m)	(m)	(m)	(m)
Position NZ map grid		**Left Bank –Blaketown and Commercial Area**				
2361715	5860998	Blaketown just U/S Parking Area -	3.43	3.39	-0.04	-0.03
2361857	5860881	Just D/S Entrance Erua Lagoon -	3.69	3.80	0.11	-0.17
2362496	5860632	Just below Pump Station at top end of Wharf	4.59	4.76	0.17	-0.02
2362655	5860594	Dolphin Watch Shed at 675 m -	4.83	5.22	0.39	0.19
2363330	5860636	Under Cobden Bridge -	5.81	6.10	0.29	0.35
		Average Difference			0.18	
		Right Bank - Cobden Side				
2362862	5861031	Three blocks up from Sturge St	4.59	4.80	0.21	0.11
2362745	5861092	Two blocks up from Sturge St	4.60	4.67	0.07	0.05
2362490	5861240	Sturge Street -	4.43	4.32	-0.11	-0.05
2362436	5861264	Corner Nelson Quay -	4.32	4.25	-0.07	-0.06
2361899	5861364	200 m upstream of Cobden Raceway (Range Creek)	3.60	3.58	0.02	0.04
2361704	5861384	Just upstream of Cobden Raceway	3.51	NA	NA	
		Average Difference			0.02	
2361728	5860433	Erua Lagoon	3.87	3.58	-0.29	-0.23
2361489	5859491	South end of Lake Karoro	4.01	NA	NA	NA

Table A3: Flumen Calibration for 13th September 1988 Flood

The differences shown in Table A3 can be more clearly seen in the long sections of the three stopbanks at Greymouth as shown in Figures A1 to A3. Note that the levels shown in the figures are plotted against the modified observed flood levels

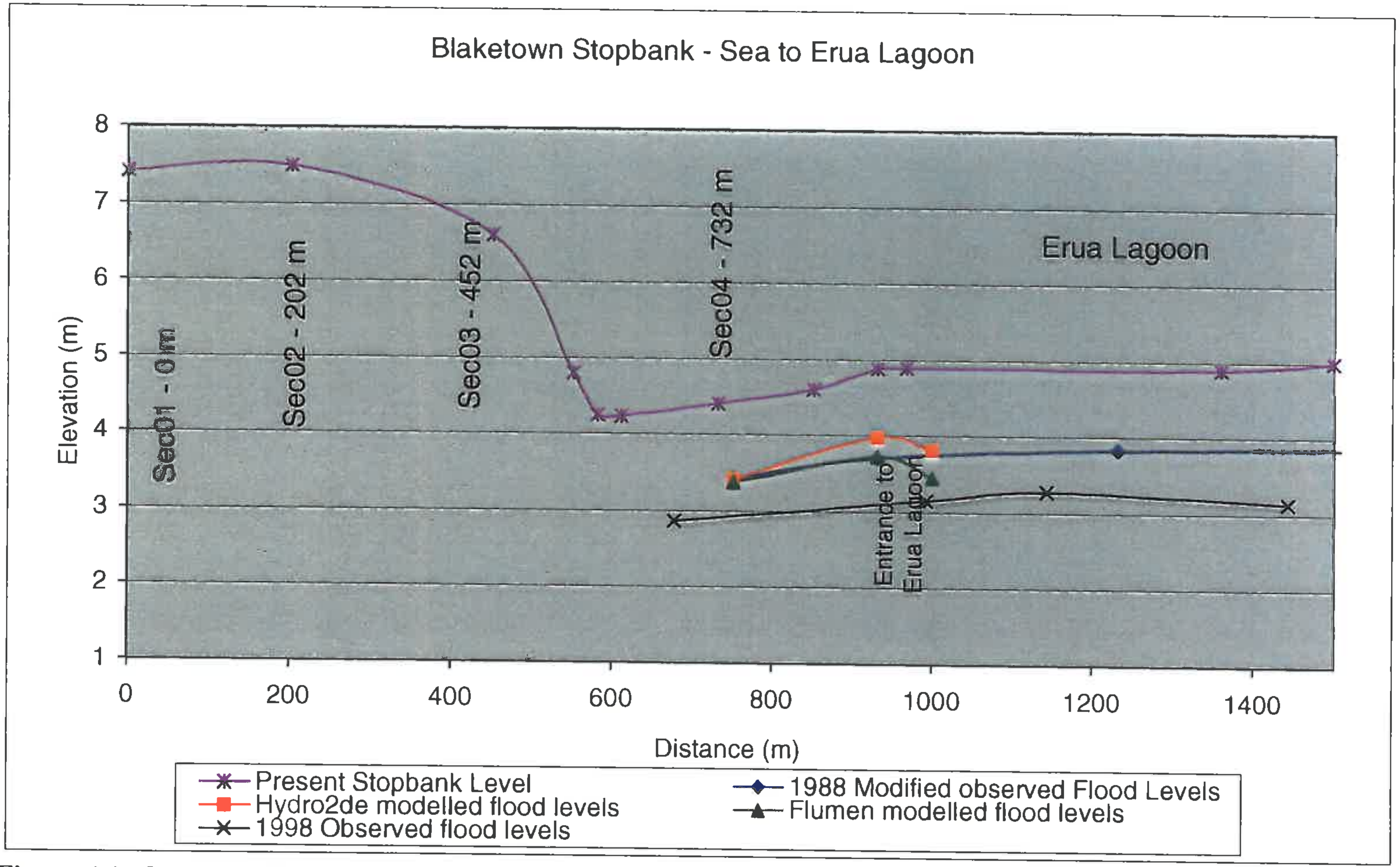


Figure A1: Observed flood levels vs Hydro2de and Flumen Calibrations – Blaketown Stopbank – Sea to Erua Lagoon

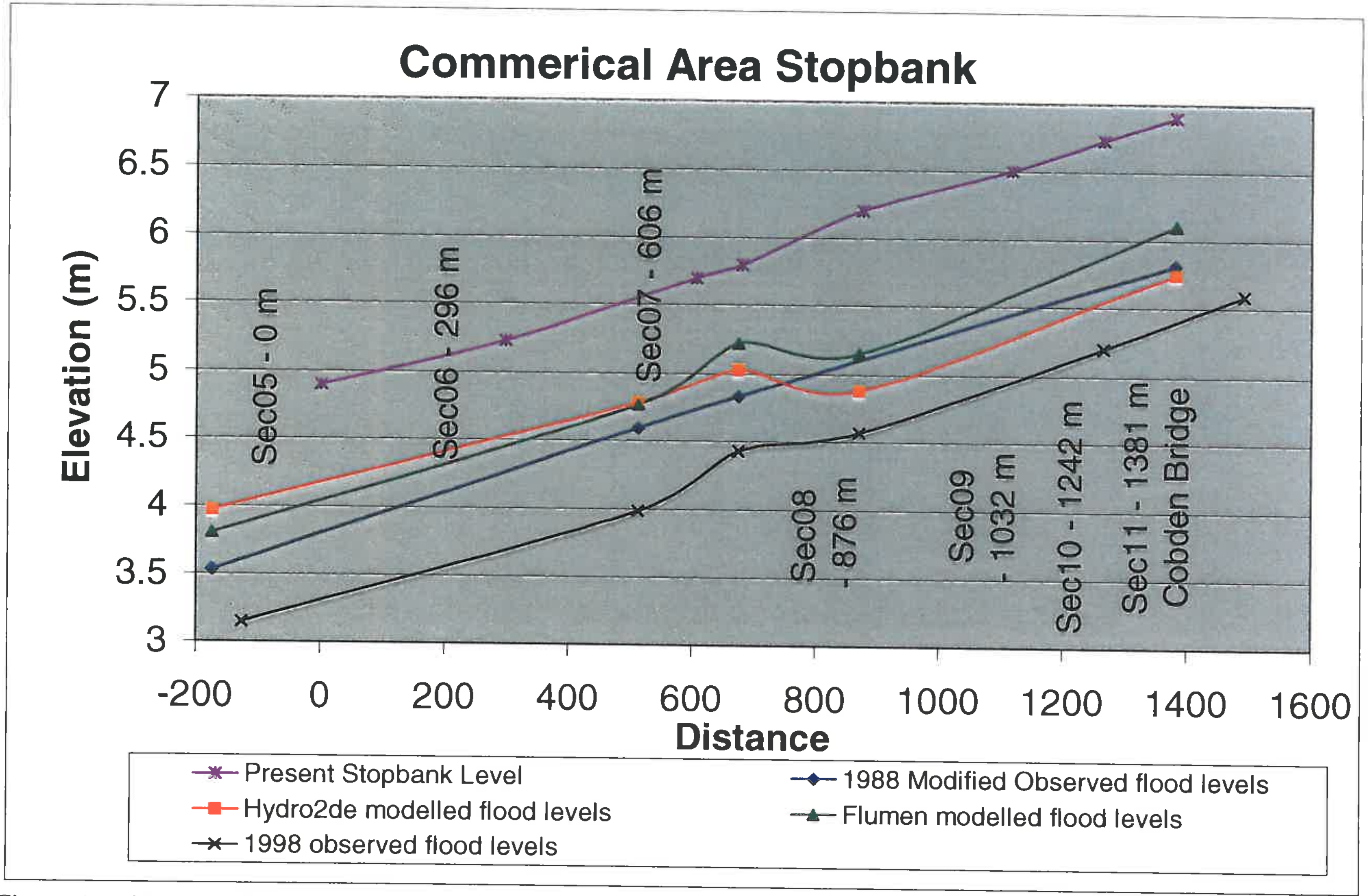


Figure A2: Observed flood levels for September 1988 flood vs Hydro2de and Flumen Calibrations - Commerical Area Stopbank

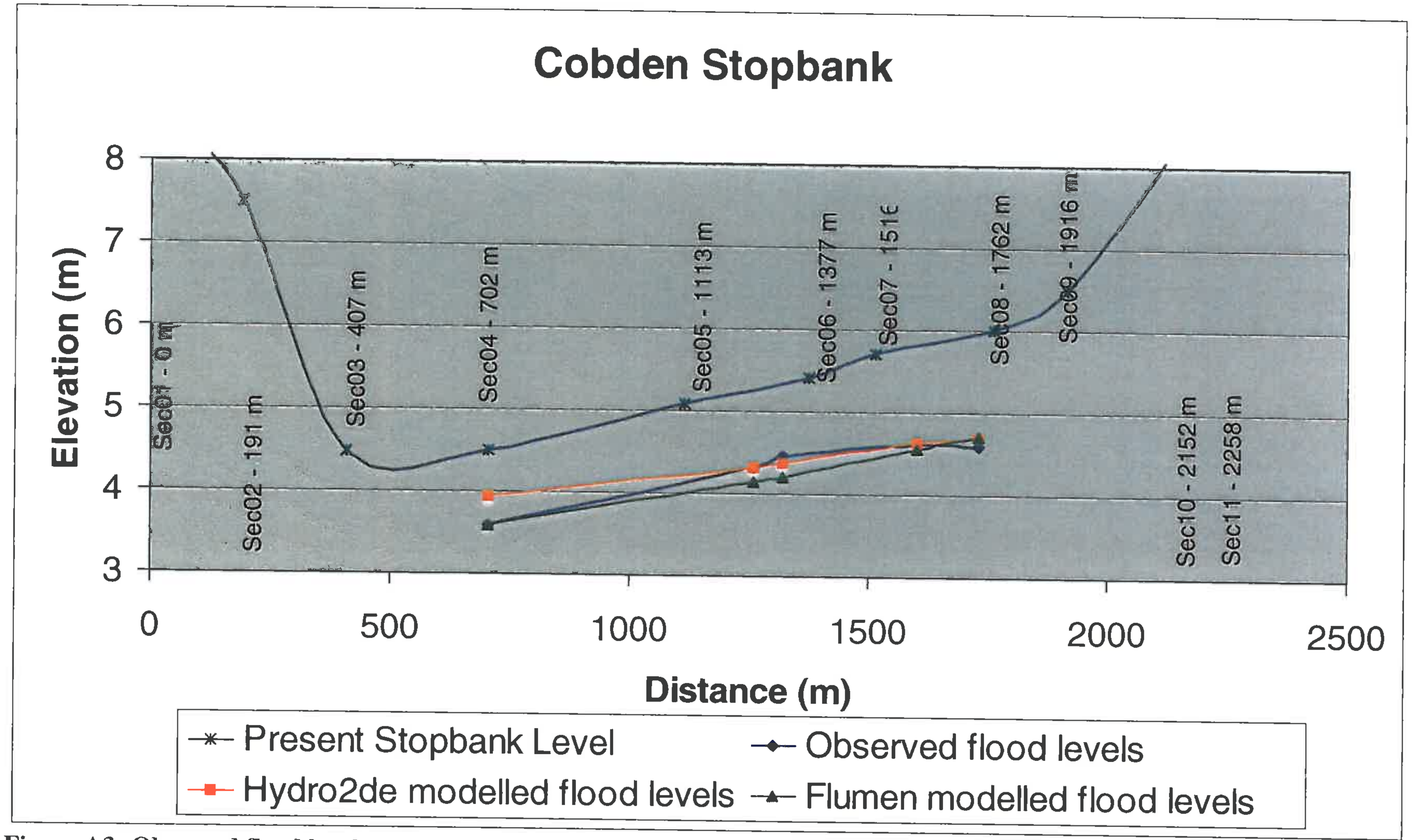


Figure A3: Observed flood levels vs Hydro2de and Flumen Calibrations - Cobden Stopbank

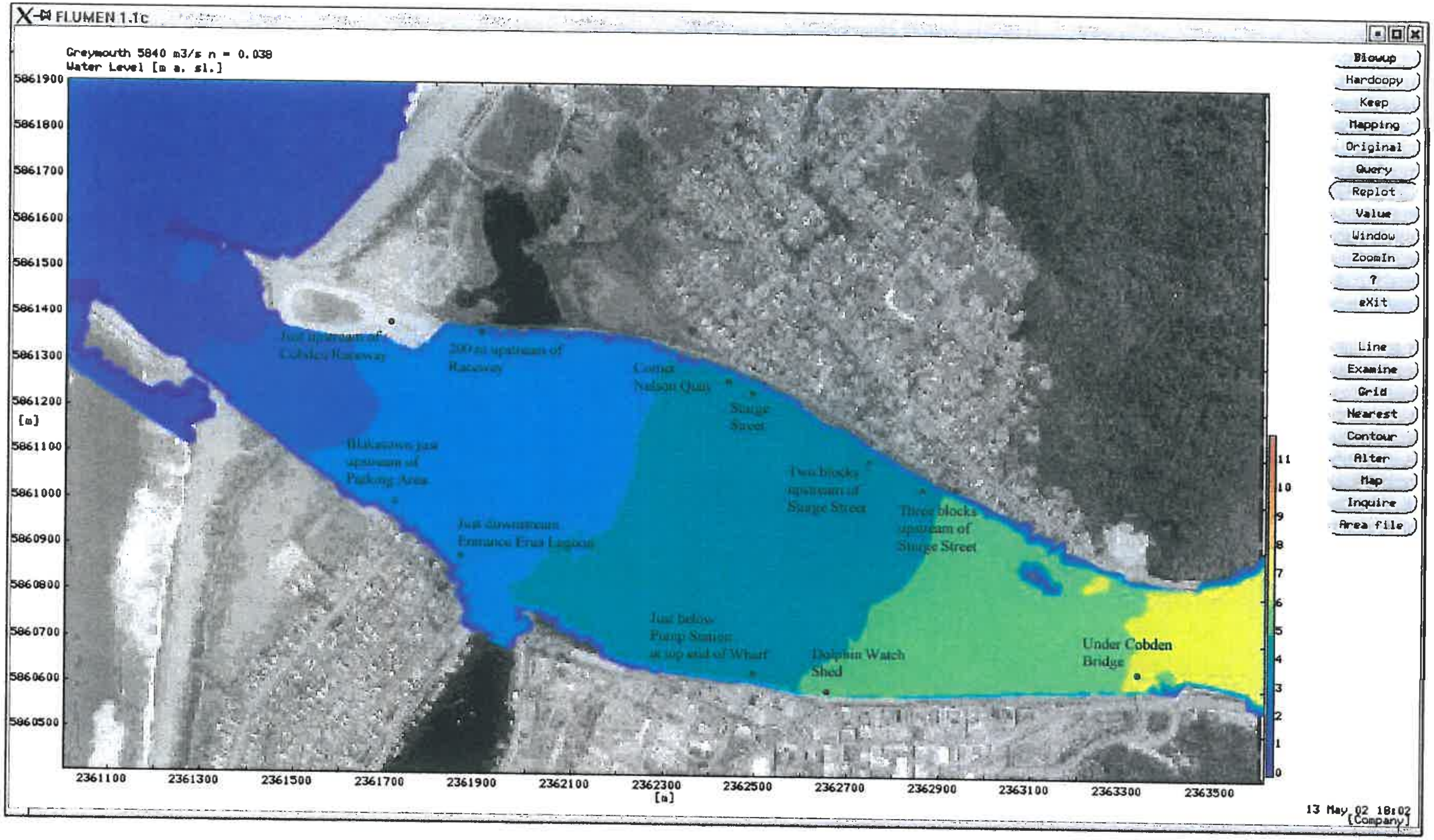


Figure A4: Flood Levels and Calibration Point Positions for the 13th September 1988 flood with the 1998 river topography

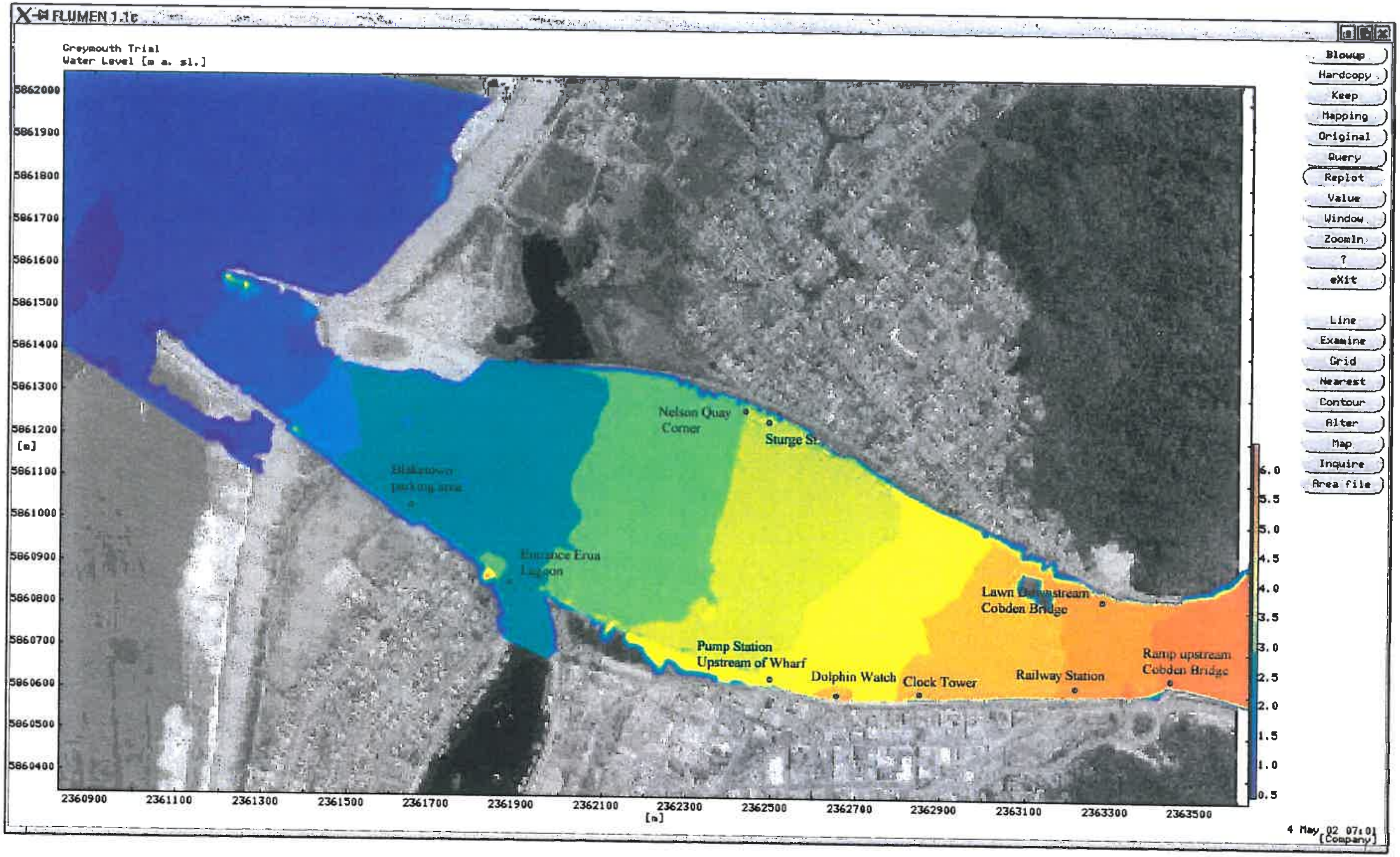


Figure A5: Flood Levels and Calibration Point Positions for the 19th October 1998 flood

column (1) of Table A3. Figure A4 shows the positions of the flood levels for the 1988 flood and figure A5 shows the positions for the 1998 flood (see section 2.2 below where this profile is discussed.)

The main differences in the flumen results and the Hydro2de results were:

i) Compared to the modified observed flood levels, the average left bank model level was 0.16 m higher than the average right bank model level
ii) The bar at the Cobden Raceway was required with the flumen model to obtain a good calibration with the modified observed flood levels (This could also have been done using a higher resistance factor from this point to the river mouth).
iii) The flumen flood levels at the upstream end of the Commercial area (upstream of Dolphin Watch shed) are higher than the Hydro2de levels for this location.
iv) The flumen flood level in Erua Lagoon was lower by 0.23 m that the Hydro2de levels for this location.

A2.1 Left bank and Right Bank water levels

Relative to the observed levels, the average left bank (Greymouth) model levels were 0.16 m higher than the right bank (Cobden side) model levels. This could imply that the design is more conservative on the left bank than the right bank. However this result is for a calibration using only 1988 information and verification using another flood was desirable. This was possible as data was available for the 1998 flood.

Comparing the 1998 flood levels with the modelled levels (that were calculated using the 1998 topography) showed that the converse was true. The difference in observed and modelled flood levels is given in Table A4 below.

NZ map grid X-coordinate	NZ map grid Y-coordinate	1998 observed flood level point	1998 Observed Flood Level (m)	Difference from 5840 m^3/s Hydro2de (m)	Difference from 5840 m^3/s flumen (m)
		Left Bank			
		Just down stream of Erua Lagoon	3.15	0.90 approx	0.7 approx
2362496	5860632	Pump Station U/S wharf	3.98	0.80	0.78
2362655	5860594	Dolphin Watch	4.35	0.61	0.80
2362850	5860600	Clock Tower	4.57	0.31	0.58
2363215	5860616	Railway Station	5.20	0.41	0.62
2363440	5860636	Ramp U/S Cobden Bridge	5.59	0.43	0.82
		Average Difference			0.72
		Right Bank			
2363280	5860823	Lawn D/s Cobden Bridge	5.16	0.42est	0.82
2362536	5861220	Sturge St.	3.5	0.87	0.73
2362424	5861272	Nelson Quay Corner	3.48	0.82	0.82
		Average Difference			0.79

Table A4: Difference in Hydro2de and flumen 5840 m^3/s levels from the 1998 Observed flood levels

The model levels on the right bank (Cobden side) average 0.79 m higher than the 1998 flood levels, whereas on the Commercial side the design flood levels are only 0.72 m higher, ie the difference is 0.07 m with the modelled levels on the Cobden side being higher, i.e. the converse of the 1988 calibration.

A2.2 Cobden Stopbank Calibration

The levels on the Cobden Side upstream of Cobden Raceway on the initial runs were lower than the observed levels. In the final calibration using the 1998 topography, the bar just upstream of the track (see photographs 1 and 2 of the 2001 report and Figure A6 below) was reinstated into the model. This gave a better fit to the observed levels shown in Figure A6.

However a run (with the no bar upstream of the track) and adding the Cobden Flood Plain to the flumen model gave a level of 3.58 m at the lower end of the Cobden Flood Plain against the beach dune (assuming no breach of this dune). This was very close to the 3.586 m level in Figure A6 below and indicates that the bar may have breached in the 1988 flood. (It is assumed that this run would give the correct levels at this point, as all the water on the opposite (Commercial Area and Blaketown) flood plain would have had to return to the river at the Cobden Raceway.)

Figure A6: Observed flood levels 13th September 1988 flood on lower Grey River (part of plan by Wayne Moen 1998).

Therefore runs with both the bar and no bar beside the Cobden Raceway were undertaken and the worst case used for the design.

A2.3 Commercial Stopbank

The analysis (see Figure A2) shows that the flumen levels were higher at the upstream end of this stopbank. It was difficult to assess whether the 2de or the flumen profile was better when comparing the model results against the modified 1988 observed profile.

However a comparison of the profiles of the flumen model results against the observed 1998 profile showed there was a much better correlation. (See figure A2 and Table A4 below). Upstream of sec08 (see Figure A2), the 1998 profile had the same slope as the both the Hydro2de and flumen profiles, while the modified 1988 profile had a flatter slope. (The Hydro2de profile is flatter if the calibration points in table A4 above are compared i.e. from sec07 (see Figure A2) to Cobden Bridge as this is how this model was developed).

This table shows that the flumen results had a lesser spread than the Hydro2de results when compared to the 1998 profile slope. The Hydro2de differences drop from 0.9 m at the entrance to Erua Lagoon (where the model results are considered high) to 0.4 m at Cobden Bridge. The flumen differences do not change significantly at all.

The 1998 profile is considered to be a better profile shape to use with the present riverbed topography and therefore the flumen calculated profile is better in this respect. The flumen profile is also higher and therefore more conservative than the Hydro2de profile.

Confirmation of this conclusion could be undertaken by modelling the 1988 flood using the Flumen model.

A2.3.1 Afflux at bend at sec07 in Commercial Area

Both models show the afflux of about 0.4 m at the bend at sec07. The observed afflux from the 1998 profile was 0.2 m. The expected afflux, using the formula based on Newton's second law, afflux = wV^2/gr (where w =width, V = velocity, g = gravitational constant and r = radius of bend), over the main channel would be about 0.3 m.

However it is reasonable to expect that the afflux will be nearer 0.2 m to 0.3 m as the bend is not large at this point. Therefore some refinement of the model in this area could be undertaken.

A2.4 Erua Lagoon

The flumen flood levels for Erua Lagoon (and also Lake Karoro) are lower than the Hydro2de levels by about 0.23 m for this flood discharge of 5840 m^3/s.

Analysis of the processes in this situation, outlined below, indicated that the flumen level could be better than the Hydro2de, however modelling of the 1988 flood with both flood plains inundated is required to confirm the flumen flood levels and the expected change resulting from the Greymouth Flood Wall in the lagoon.

At this stage an overview of the processes in the 1988 and 1998 floods was done. The 1998 profile in the lagoon is shown on Figure A1. The profile shows the two differences between the level at the entrance of the lagoon and points 150 m and 450 m further along the Blaketown stopbank in the lagoon. One of the levels is 0.13 m higher while the level 450 m away is 0.01 m lower.

The 1988 observed flood level profile shows levels increasing from the entrance of the lagoon by 0.22 m at 300 m upstream (point on Greymouth side) and by 0.27 m at the southern end of the lagoon, about 800 m upstream. (See Table A2, Erua Lagoon Blaketown side.)

The reason that the levels increased by about 0.2 m – 0.3 m is that only a small flow must have re-entered the main channel of the river in 1988. This difference is only a fraction of the velocity head in the middle of the main flow that is nearly 1 m (velocity of 4.3 m^3/s). The small discharge would only need to displace a small portion of the flow at the side of the main flow which has a velocity head of 0.2 m – 0.3 m to give the difference in water levels.)

However with the flood wall in place, it would be expected that flood levels in Erua Lagoon would be the same as at the entrance as indicated by the 1998 differences. This would mean that the level 450 m upstream should be 0.01 m lower (in reality the same), and not the 0.3 m increase as indicated by the observed 1988 flood levels. The model of the 1998 flood also gave little difference from the observed level points at the entrance to the lagoon and 450 m upstream (if the 1988 position is used it could be an increase as the 1988 point is downstream of the 1998 point).

The reason that Hydro2de model levels in Erua Lagoon were above the observed levels is the weakness that Hydro2de had in modelling the river reach at the entrance of Erua Lagoon. If the Hydro2de level at the entrance to Erua Lagoon in table A1 is examined it is 0.28 m higher than the observed level. This weakness in Hydro2de is explained in section 3.2 above.

If Hydro2de had modelled the correct level at the entrance to the lagoon, the model levels would have been 0.28 m lower and 0.21 and 0.23 m below the observed flood levels instead of 0.07 and 0.05 m higher (See Table A2). This would mean that Hydro2de would have given low levels in the lagoon as well. Therefore the model process at the entrance to Erua Lagoon needs to be examined closely before final design levels are developed that may reduce the levels given in this report. This is the case for the Hydro2de model of 1998 flood where the levels in the lagoon are 0.14 m too low (and 0.18 m too low in Lake Karoro) as shown in Table 1 of the 2001 report.

The flumen flood level at the entrance to Erua Lagoon is 0.11 m higher than the modified observed level. It could be 0.1 m lower if a level is taken away from the local rise due to water flows heading up against this point. This lower level (0.22 m lower) is level that flumen has calculated for the lagoon. This heading up is due to water at the downstream end of the wharf not flowing straight down the river channel here but at an angle towards the lagoon as the water level in lagoon is much lower than the level at the downstream end of the wharf. This would need to be checked with photographs taken during the 1998 and 1988 floods to be sure that the observed level was away from any localised water build up.

If the observed level were away from any build up then the model would have to becalibrated to give a higher flood level at the entrance to the lagoon which would increase the levels in the lagoon that flumen would calculate by 0.1 - 0.2 m.

Modelling the 1988 flood using flumen will also provide a check of the process to give the 0.27 m increase in flood levels (3.53 m to 3.80 m) between the river and the upstream end of the lagoon. It will also provide better differences in flood levels between the 1988 and 1998 topographies and also a better calibration the in the area at the entrance to the lagoon. And therefore enable better analysis of all the processes taking place that are discussed above. This would also check the process of the model in this area that may need to be improved.

Therefore in conclusion the flumen level was considered better at this point, but before the stopbank levels in the Lagoon and Lake Karoro could be reduced this would need to be assessed by modelling the 1988 flood using flumen, as there is possibility that they could be low.

A2.4 Conclusion

After considering all these factors the flumen model was adopted to calculate the design levels for the stopbank raising (except in Erua Lagoon and Lake Karoro) as it modelled the processes better and gave a closer fit to the 1998 flood profile shape. Further work to calibrate the 1988 flood using flumen would be valuable and would also confirm the flood levels in Erua Lagoon and Lake Karoro. A 1988 calibration using flumen, together with improving the model at the bend at sec07 (using the 1998 observed levels and model) would also confirm or improve the model in this area that was used to calculate the design levels in this report.

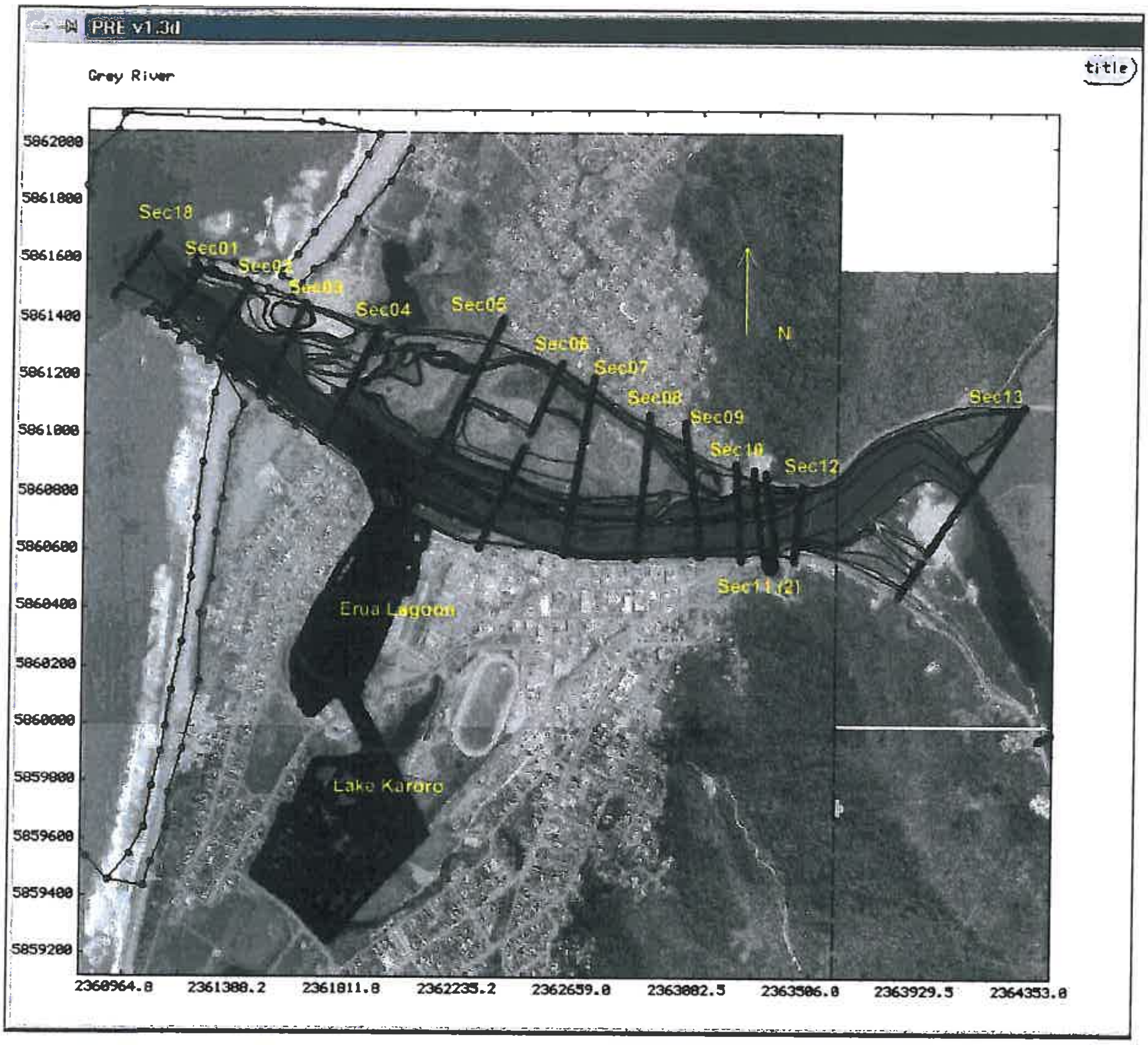


Figure A7 surveyed points and breaklines built for the DTM. (Figure 2 of 2001 report)