Northland Regional Council

Kaihu Flood Control Scheme Investigation Report on Stage 3a

May 2009

BARNETT & MACMURRAY LIMITED

Computational Hydraulics Specialists

Quality Assurance Statement	
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Cover picture: *Kaihu River at Kaihu (above) and near Mamaranui*

Northland Regional Council
Kaihu Flood Control Scheme Stage 3a

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1. Introduction

Barnett & MacMurray Ltd (B&M) was commissioned by Northland Regional Council (NRC) to model the Kaihu River and its floodplain to answer questions posed before design options are considered for a flood control scheme.

The offer of service was accepted by Bruce Howse, Land/Rivers Senior Programme Manager for NRC on 2 March 2009.

In the previous Stages 1 and 2, a hydrologic model for the catchment was upgraded, and hydrologic and hydraulic models of the Kaihu valley were calibrated to recorded flood events. A baseline for flooding was established under existing conditions for the 2, 5, 10 and 100 year average recurrence interval (ARI) floods. The aim of this project, Stage 3a, is to investigate the effects of changes to the river and floodplain system on flood extent and duration during a range of flood events. These will provide valuable background information towards evolving a flood control scheme for the valley.

This document is the report on the Stage 3a investigations.

1.1 Scope

The project consists of the following steps:

1. Modify the existing Mike 11 hydraulic model to reflect two new cases. These cases are:
   a) Kaihu valley with all farming stopbanks removed
   b) Kaihu valley with the river capacity downstream of Parore Rd increased by widening of the main channel.
2. Simulate floods of 2, 5, 10 and 100 year ARI with each modified hydraulic model.
3. Compare maximum flood extent and flooding duration at a number of reference points on the floodplains with the existing case for the four flood events.
4. Report on the effects of removing stopbanks and excavating the lower Kaihu River.

Selected flood duration plots and flood extent maps can be found in the appendices of this report.

1.2 Source data

The 2, 5, 10 and 100 year ARI design flood hydrographs developed in Stages 1 and 2 of the investigation are applied for this investigation. It was discovered that in order to track the full flood duration in some lower floodplain areas, a longer simulation period was needed. Extended tidal boundary series have been generated by Mulgor Consultants (2008), who performed the tidal study for Stages 1 and 2. In the case of the 2 year maximum tidal cycle, this has resulted in changes to the amplitude and frequency of the tidal cycle over the whole simulation period. This is because the tidal cycles are generated from real data. For the period in question, some data is missing from the record. Filling the gap in the record has altered the characteristics of the tidal cycle slightly. This affects the 10 year ARI event, which is matched with the 2 year tidal boundary. All of the models, including the existing model have been run with the new extended boundary condition. The other tidal boundaries are identical to those used in Stages 1 & 2, except that they are longer.

The existing hydraulic model as calibrated in Stages 1 and 2 has been used as the basis for the simulations here, with changes as described in the sections below.
Flood maps have been prepared using the same 10x10m terrain grids generated from LIDAR survey data used in the first stages of the project. For more information on these items, refer to the report on Stages 1 and 2 (B&M 2008).

NRC staff supplied 20 widened Kaihu River cross sections for use in the wider lower river model.

2. No stopbanks model

The aim of the no stopbanks model is to show the effects on flooding if all the farming stopbanks were removed. It also reflects how flooding would have occurred in the valley prior to the erection of the stopbanks. Banks believed to be natural features, such as natural levees which occur in many places or those which carry roads, such as SH12, have been retained in the model.

2.1 Lowering the stopbanks

Stopbanks are represented in the model by 82 overflow links from the main river channel to the floodplain, or from one floodplain area to another. In the no stopbank model the crests of 62 overflow links have been lowered to adjacent ground levels. The overflow crest levels in the existing model and the no stopbanks model are shown in Table 1 below.

Link branch	Upstream branch	Upstream chainage (m)	Downstream branch	Downstream chainage (m)	Stopbank level (m)	Ground level (m)
7774r	Kaihu	7774	maropiu	520	25	25
9398r	Kaihu	8398	maropiu	965	23	22
9404r	Kaihu	9404	maropiu	1725	21	21
10380r	Kaihu	10380	maropiu	2325	19	17.5
11509r	Kaihu	11509	maropiu	3110	18	17.5
12637r	Kaihu	12637	maropiu	3495	16	15.5
10136l	Kaihu	10136	settlement	575	19	19
11791l	Kaihu	11791	settlement	975	17	17
12073l	Kaihu	12073	settlement	1315	16.5	16.5
13201l	Kaihu	13201	settlement	1875	15	15
14608l	Kaihu	14608	settlement	2400	12.5	12.5
14608r	Kaihu	14608	maitahi	0	13	12.5
15441r	Kaihu	15441	maitahi	620	11.5	10.5

Link branch	Upstream branch	Upstream chainage (m)	Downstream branch	Downstream chainage (m)	Stopbank level (m)	Ground level (m)
16274r	Kaihu	16274	maitahi	1308	9.5	9
17070r	Kaihu	17070	maitahi	1925	8.5	8.25
17773r	Kaihu	17773	maitahi	2570	7.25	7
18560r	Kaihu	18560	maitahi	3265	6.75	6.5
19070r	Kaihu	19070	maitahi	3875	6.5	6.5
19325r	Kaihu	19325	maitahi	4145	6.25	6
12919r	Kaihu	12919	mamaranui	0	15.5	15
14048r	Kaihu	14048	mamaranui	740	14	13.5
17070l	Kaihu	17070	waihue	930	8.75	8.25
18035r	Kaihu	18035	waihue	1945	7.25	7
19325l	Kaihu	19325	waiatua	2015	6.5	6.25
taita3285l	taita	3285	maitahi	3875	8	8
taita3935r	taita	3935	cemetry	0	7.5	7
19890r	kaihu	19890	cemetry	400	7	6.5
20445r	Kaihu	20445	cemetry	1080	6.25	4.75
21180r	Kaihu	21180	cemetry	1335	5.75	5.75
22025r	Kaihu	22025	cemetry	2030	5.5	4.75
waiatua2180l	waiatua	2180	frith	0	7	6.5
19840l	Kaihu	19840	frith	140	7	6.25
20445l	Kaihu	20445	frith	680	6.5	5.5
20690l	Kaihu	20690	frith	930	6	5.25
21180l	Kaihu	21180	frith	1145	6.25	5.25
22290l	Kaihu	22290	frith	1965	5	4.75
23080l	Kaihu	23080	frith	2610	5	4.25
frith1055l	frith	1055	ndl	395	5	4.75
cemetry2515r	cemetry	2515	bush	0	4.5	4.5
23080r	Kaihu	23080	bush	180	4.75	4
23340r	Kaihu	23340	bush	380	4.75	4.25
24260r	Kaihu	24260	bush	1245	4	3.75
dip1785r	dip	1785	cemetry	2180	6.25	6.25
bush1555r	bush	1555	pouto	0	5.3	4.5
25614r	Kaihu	25614	pouto	335	5	4
26630r	Kaihu	26630	pouto	1060	4.25	3.5
27147r	Kaihu	27147	pouto	1170	3.5	3.5
27922r	Kaihu	27922	pouto	1650	4	3.25
28340r	Kaihu	28340	pouto	2000	4	3.25
pouto635r	pouto	635	poutowest	560	4	4
25360l	Kaihu	25360	pouto-east	110	4.5	4
25868l	Kaihu	25868	pouto-east	420	4.25	3.5
27147l	Kaihu	27147	pouto-east	1255	3.75	3
27663l	Kaihu	27663	spillway	300	4	3.5
28920l	Kaihu	28920	spillway	875	3.75	3.25
29570l	Kaihu	29570	spillway	1365	4.25	3.25
30560l	Kaihu	30560	spillway	1770	3.25	3.25
31220l	Kaihu	31220	spillway	2295	3	3
29137r	Kaihu	29137	antispillway	325	3.75	3.5
29818r	Kaihu	29818	antispillway	545	2.75	2.75

Link branch	Upstream branch	Upstream chainage (m)	Downstream branch	Downstream chainage (m)	Stopbank level (m)	Ground level (m)
30065r	Kaihu	30065	brown	265	3	3
31000r	Kaihu	31000	brown	915	3.25	3
31540r	Kaihu	31540	brown	1425	2.75	2.75
32290r	Kaihu	32290	brown	1930	2.25	2.75
32550l	Kaihu	32550	antibrown	150	4.2	3
32843r	Kaihu	32843	parore-rb	95	3.75	3
33660r	Kaihu	33660	parore-rb	840	3.25	3
34470r	Kaihu	34470	parore-rb	1510	2.5	2.75
35610r	Kaihu	35610	parore-rb	2530	2.75	2.25
36460r	Kaihu	36460	parore-rb	2945	2.75	2.5
37425r	Kaihu	37425	parore-rb	3465	3	2.25
33117l	Kaihu	33117	Parorelb	1015	3	2.5
parorelb895r	parorelb	895	Antibrown	500	2.75	2.75
scottys1035r	scottys	1035	parore-rb	558	3.25	3.25
baylys1120r	baylys	1120	parore-rb	2530	3	3
mangatara4950l	mangatara	4950	parore-rb	3465	3	3
35880l	Kaihu	35880	beach	200	3.25	2.5
37220l	Kaihu	37220	beach	700	2.75	2.75
38290l	Kaihu	38290	beach	1260	2.75	2.25
38520r	Kaihu	38520	mangawhare	540	2.5	2.5
33390l	Kaihu	33390	parorelb	1155	3	3
34200l	Kaihu	34200	valley	780	3.75	3

Table 1: Existing and no stopbank levels on overflow links

Where the level has not been changed, the links are shaded in light grey. The adjustments have been made on the basis of land contour maps. They have been judged by eye and are accurate to the contour divisions, which were 0.5 – 1.0m upstream of Mamaranui and 0.25m downstream of there. This level of detail is consistent with that used to set the existing stopbank levels and is sufficient for the purposes of this exercise. The average decrease in stopbank level was 0.4m.

In a few places where interpretation of the contour maps was difficult, NRC undertook supplementary survey to define the "no stopbanks" ground level. In two places these ground levels were higher than the stopbank crest level estimated for the existing case model. These links were on the right bank just upstream and 1.5km downstream of Parore Road, and the supplementary ground survey indicates that the original estimates were too low by 0.5m and 0.25m respectively. The first of these points would have very little effect on the results, because that part of the floodplain can be flooded by backflow through the western Parore Road bridge. In the second case (1.5km downstream of Parore Road), the contour plan indicates that there is no significant stopbank, so there would be little or no change on removing the stopbanks. An error of 0.25m in the bank level in the existing case model is unlikely to have a significant effect on the overall flooding pattern.

It should be noted that estimation of the "no stopbanks" ground level is a subjective judgement. Inspection of the contour plans shows that the Kaihu River tends to form significant natural levees, but it is not easy to judge what part of a raised river bank is due to natural processes, and what part is due to the deposition, and reworking in various ways, of material dredged from the river. The “no stopbanks” case that we have created is therefore one of many possible interpretations. Nevertheless, we consider that ours is a reasonable interpretation, and therefore that our simulations give a reasonably accurate indication of the effect of removing the farming stopbanks.

Similarly, the discretisation of the stopbank overflows has an influence on the accuracy of the simulations. As noted in the report on Stages 1 and 2 of this project, the 82 link branches in the model provide for bank overflow at an average spacing of 1km on both sides of the river. In addition there are 28 main drain outfalls which also provide hydraulic connections between the river and floodplain. This number of hydraulic connections will not reproduce all the details of the interaction between the river and the floodplain, but we consider it is sufficient to give a good indication of the overall pattern of flooding and drainage.

2.2 Flood extent

Maximum flood extent in the no stopbank case has been compared to the existing case for each event. These flood extents are mapped for all events in Appendix D.
The changes in maximum flood extent due to removing the stopbanks are summarised for each flood event below.

2.2.1 Two year ARI event

Flood extent appears quite similar in the lower reaches, and has increased significantly in the upper reaches. The surrounding low channel on the east side of river downstream of Parore Rd has water all the way around; flood extent south of this has increased slightly. Patches of higher ground on the east side of the river upstream of Parore Rd between Opanake Rd and the river are now flooded. Flooding in the upper reaches north of Waihue Rd on the west bank of the river is wider spread and extends up the valley approximately 500m further. Flooding covers remaining patches of high ground between Frith Rd and Waiatua Stream outlet and in the area currently behind the Northern Dairylands stopbank. Flood extent from Ahikiwi down to SH12 bend south of Maropiu has spread to the north and east and is significantly larger.

2.2.2 Five year ARI event

There are significant increases to flood extent in the uppermost and lower reaches of the valley; but a similar flood extent through the mid reaches. Flooding has increased all through the area downstream of Parore Rd on the east side of the river. Flooding in valley south of Scottys Camp Rd extended to the valley edges. There is a little more flooding downstream of Parore Rd on the west side of the river. The flood extent through the middle reaches is similar to existing, except north of Waihue Rd on the west side of the river, where flooding is more widespread and extends up the valley approximately 600m further. Near the top of the valley, flood extent has spread towards the river between Maropiu and Maropiu Rd on the west bank of the river.

2.2.3 Ten year ARI event

There are some increases in flood extent in the lower valley, much the same extent in the mid reaches, and increases in the upper valley. Patches of high ground south of Parore Rd on the east side of the river would be covered in the no stopbanks case. Flood extent south of Scottys Camp Rd has reached the sides of the valley. The flood extent north of Waihue Rd on the west side of the river is twice as wide as existing. The flood extent is slightly less between Maitahi Settlement Rd and the river, and slightly greater north of Maropiu on the west side of the river.

2.2.4 One hundred year ARI event

The flood extent is significantly greater in the lower reaches, not much different in the mid reaches and smaller increases in extent are seen in the upper reaches of the valley. The whole area between Valley Rd and the river loops to the south is also flooded, rather than just the old waterway. The whole area south of Parore Rd on the east bank is now flooded, rather than just the upper region. Water overtops SH12 just north of Baylys Coast Rd in both existing and no stopbank cases. Flood extent has decreased a fraction in the Taita Stream valley and those of its tributaries, around Maitahi Rd to the west of the valley. The flood extent is a little wider north of Waihue Rd on the west side of the river. The flood extent has reduced slightly between the east bank of the river and Maropiu Settlement Rd, but there is increased flooding over higher ground on the west bank south of Maropiu township.

2.3 Flood duration

Flood durations have been calculated for a range of locations in the valley. These are summarised in Appendix B. The floodplain locations where flood durations were calculated are shown in Figure 1, Appendix C. A nominal ground level was chosen by study of the floodplain cross section at each point. Flooding duration was defined as the amount of time the water level exceeded the nominal ground level. Flood durations for a selection of points are plotted in Appendix C to demonstrate the effect of removing the stopbanks on water levels. At two locations; Maitahi 3875m and Waiatua 1020m; the initial water level in the existing case exceeded the nominal ground level, so an alternative level just above the initial water level was selected in order to compare flood durations.

Removing the stopbanks caused flood duration to increase or decrease in different parts of the valley. In some areas the level at which water could overflow to the floodplain changed significantly, while in others the level didn't change at all. An example of this is the area on the east side of the river downstream of Maropui Rd until the 90 degree bend in the river. None of the levels for the five overflow links to this floodplain area were lowered for the no stopbanks model. Correspondingly, flood durations in this region didn't change by more than an hour from the existing case.

Removing the stopbanks affects how the parts of the system interact. It changes how much water overflows where, and when, how much water is left in the Kaihu and how quickly the flood waters can drain back to the river during a flood event. This means that patterns in flood effects were not clear. Flood durations increased by a maximum of 57.5 hours and decreased at most by 25.5 hours. Despite this, in 15 of the 32 locations investigated, the change in flood duration was less than 4 hours for all flood events. Water levels often rose significantly more rapidly in the "no stopbanks" case.

Upstream of Waihue Rd on the west side of the Kaihu, more water overflowed further north, and correspondingly less overflowed closer to Waihue Rd. This caused flood durations in the upper area to increase (in some instances where there had not been any flooding in the existing case) and flood durations in the lower area to decrease. Elevated water levels on the floodplain 1 km upstream of Waihue Rd prevented the water flowing more freely out of the region just downstream of Maropiu on the west bank.

Generally flood durations upstream of the Rotu Bottleneck didn't change by more than five hours, but any change tended to be an increase in flood duration. Exceptions were a decrease of 7-9 hours in flooding just upstream of Mamaranui between SH12 and Mamaranui Rd, and a decrease of up to 23 hours on the west side just upstream of Taita Stream outlet. A flood duration decrease of 9.5 hours in the Northern Dairylands area occurs with an increase of 8 hours in the area north of Frith Rd.

Downstream of the Rotu Bottleneck, the trend is increased flood duration in smaller flood events and decreased duration in larger events. This is because now more flood water can enter the floodplains in a smaller event, and may take longer to drain. However, in larger events, this means that flooding is more evenly distributed over a larger area, with more efficient drainage owing to outflow directly over the lowered stopbanks.

The greatest increases in duration were where flooding of the nominal ground level occurred in the no stopbanks simulation, but no flooding was recorded in the existing simulation. An example is downstream of Parore Rd on the east side of the river in the 2 year ARI event, where flood duration increased by 57 hours. The greatest decrease was 22.5 hours from Mangatara Flat to 2km north of Baylys Coast Rd west of SH12.

3. Wide lower river model

3.1 Widening the river

The purpose of this model was to see the effect on flooding of widening the main river channel in the lower reaches. It was thought that increasing the capacity of the lower river in this way might improve drainage of the floodplains during and after flood events. Twenty suitable guidance cross sections were generated by NRC staff, taking into account local restrictions and practicality. The channel has been widened from Parore Rd to the mouth. In the model, this is the reach Kaihu chainage 32570 – 40050m, measuring around 7.5km. The total excavation volume was approximately 680,000m^3.

3.2 Flood extents

Maximum flood extent for the widened lower river case has been compared to the existing case for each event. These flood extents are mapped for all events in Appendix D.

The overall effect of widening the lower river was to reduce flood extent in the lower river, with the effect extending further upstream in the minor events, and limited to downstream of Parore Rd in the larger flood events. Flood extent in the upper valley is barely changed. Significant changes in maximum flood extent due to widening the lower river are summarised for each flood event below.

3.2.1 Two year ARI event

Flood extent decreased significantly on the west side of the river between Parore Rd and Babylon Coast Rd, and by about a quarter on the east side of the river upstream of Parore Rd. Minor flooding downstream of Parore Rd on the east bank was further reduced. Upstream of Rotu Stream the flood extent is very similar to the existing flood extent.

3.2.2 Five year ARI event

Downstream of Parore Rd on the east side of the river, flood extent is slightly less. For 1 km upstream of Parore Rd on the west bank, flood extent is reduced. Patches of higher ground near the east bank of the river upstream of Parore Rd escape flooding. Upstream of Rotu Stream, flood extent appears the same as in the existing case.

3.2.3 Ten year ARI event

Flood extent between Baylys Coast Rd and Parore Rd on the west side of the river is reduced significantly. Flood extent for approximately 1km downstream of Parore Rd on the east bank is restricted to the low old channel areas, compared to completely flooded in the existing case. Upstream of Parore Rd, the flood extent is very similar to the existing flood extent.

3.2.4 One hundred year ARI event

Significant reductions in flood extent can been seen on the Mangatara Flats and in valleys to the west of SH12 between here and Parore Rd, in particular just north of Baylys Coast Rd. On the east side of the river downstream of Parore Rd there is some decrease in flood extent, but only from approximately 1km downstream of the road. The first kilometre downstream of the road is completely flooded in both cases. Upstream of Parore Rd, the flood extent for the widened lower river is virtually identical to the existing.

3.3 Flood duration

Flood durations have been calculated for a range of locations in the system. These are summarised in Appendix B. Figure 1 in Appendix C shows the location on the floodplain where each of the flood durations has been calculated. Flood durations are based on the time taken for the bulk of the flooding to drain. A nominal ground level was chosen by study of the floodplain cross section at each point. Duration was then the amount of time the water level exceeded the nominal ground level. Selected water level timeseries for the widened lower river model are plotted together with existing and no stop bank timeseries in Appendix C. Here the effects of the different cases on flood water level can be compared.

Upstream of Maitahi in the valley, compared flood durations remained the same as or within 4 hours of existing durations. Downstream of this, the wider lower river caused flood durations to decrease at every location tested. The effect tends to be greater further downstream, and tends to be greater for larger flood events. For example, approximately 1km downstream of Maitahi on the west side of the river (location Cemetry 1080m in the model) the flood duration decreased by 2.5hrs in the 2 year ARI flood, and by about 10 hours in the 100 year ARI flood. Mid river, about 1.8km north of Babylon Coast Rd on the west bank (Pouto 1250m), duration decreased by 15 hours in the 2 year ARI event and almost 22 hours in the 100 year event. Further downstream, about 1.25km north of Baylys Coast Rd on the west bank of the river (Parore-rb 2080m), the flood duration decreased in the 2 and 100 year ARI events by 18 and 35 hours respectively. The greatest decreases in flood duration occurred just downstream of Parore Rd on the east bank (ParoreLb 590m), where the increased lower river capacity prevented the nominal ground level from being exceeded in the 5 and 10 year ARI events, reducing the flood duration by 74 and 111 hours respectively The 100 year ARI event flood duration was also reduced by more than 73 hours.

4. Discussion

4.1 No stopbanks case

Removing the stopbanks from the model affected different parts of the valley in different ways. Flood extent mainly increased or remained the same, but flood duration increased or decreased depending on location. The interlinked nature of the valley floodplains means that the distribution of flood waters is governed by fairly complex interactions. There are no obvious patterns due to removing the stopbanks. The interaction between the river and its floodplain increased. More water overflowed to various floodplain branches, and entered and left the floodplains at more locations.

During the peak of a flood, when the water level in the Kaihu is high, water cannot escape from the floodplains where it has ponded. However, once the river levels started to fall, the water often drained more quickly because some of the water was able to return to the river through the lower overflow links. In some locations the redistribution of flood water meant that local Kaihu River levels were lower, also aiding drainage. There was a tendency for flooding to be more evenly distributed through the valley, which also reduced flooding load on some locations.

Flood durations tended to be increased in the smaller flood events, as the water could enter the floodplains where stopbanks were removed. Downstream of Parore Rd on the east side of the river, this caused flooding in the 2 year event which had not occurred in the existing case. However, faster drainage in the 10 and 100 year events meant that there was actually a 7 hour reduction in flood duration here. In the larger flood events, water was already overflowing at a significant number of points to the floodplain in the existing case, so the relative extra volume of overflow due to removing the stopbanks was less important. More important was the improved ability of the floodwaters to drain back to the river once the flood peak had passed. The improved drainage (generally resulting in reduced flood durations) is apparent on the duration plots for locations from the Waihue Stream valley down to Mangatara Flat.

Of specific note is that the region to the south of Valley Rd between the river and Dargaville flooded in the 100 year event for over a day longer than in the existing case, and covered the whole area, not just the old waterway.

The overall balance of more water overflowing to the floodplains and generally faster drainage off them has resulted in small or moderate changes to flood durations in most locations, but improvements in flood duration of up to a day in some lower valley areas.

4.2 Wide lower river case

Widening the lower river had the effect of decreasing flood duration for the floodplain downstream of Maitahi to the mouth. Just downstream of Maitahi, the reduction in duration for the 100 year flood was about 10 hours. Towards the lower end of the river it the reduction had grown to more than 40 hours. The area on the east bank to the south of Parore Rd benefitted particularly, with a decrease in flood duration of almost 3 days. Most of the improvement in flood duration is due to faster drainage of the floodplains due to the improved capacity of the lower river to carry water away, and the resulting lower water levels in the river on the falling limb of the flood. From a point approximately 2km north of Babylon Coast Rd the lower river water level also means that less water overflows into floodplains downstream of this point. The peak water levels in the floodplain upstream of this are not affected.

To create the widened lower river channel as simulated, would require excavation of approximately 680,000m^3 of earth. This gives an indication of the scale of works required to achieve the effects on flooding reported here. Maintenance of such an enlarged river channel could be a significant expense, as sedimentation may be fairly rapid. Environmental issues related to the greater extent of tidal incursion would need to be investigated before such a project was undertaken. It is possible that a tidal barrage could help to achieve a similar effect with a smaller volume of river excavation.

The simulations of both cases demonstrate that improved drainage can have a significant positive effect on flood extent and duration in the Kaihu valley. It would be worth considering other aids to drainage, such as larger drain channels parallel to the main channel or a tidal barrage.

5. Conclusions

1) Removing the stopbanks affected the flood extent in the upper and lower valley more than the mid reaches. Between Waihue Rd and Parore Rd, there was little effect on flood extent. Upstream of Waihue Rd flood extent increased significantly in the 2 year and 5 year ARI events, moderately in the 10 year event and did not change much in the 100 year event. Downstream of Parore Rd, significant increases in flood extent occurred in the 5, 10 and 100 year ARI events, but not in the 2 year event.
2) Due to the complex interactions between the Kaihu River and its floodplain, it is difficult to discern any general pattern in the effect of removing stopbanks on flood duration.
3) In about half the locations investigated, removing the stopbanks changed flood duration by 4 hours or less. Upstream of the Rotu Bottleneck, flood duration generally increased by up to 5 hours (with a few exceptions). Downstream of the Rotu Bottleneck flood duration increased for smaller flood events but decreased for larger events.
4) Removing the stopbanks meant that flooding was more evenly and widely distributed, reducing river flood levels in some areas, and drainage on the falling limb of a flood was improved for the majority of the locations investigated.
5) Removing the stopbanks led to larger volumes of water overflowing to the floodplain, and to improved drainage. These effects balanced out in some locations, so that the net difference in flood duration was relatively small.
6) Widening the lower river significantly reduced flood extent in the lower valley. Major effects were limited to downstream of Rotu Stream in the 2 and 5 year ARI events, and downstream of Parore Rd in the 10 and 100 year ARI events.
7) The wider lower river model reduced flood durations downstream of Maitahi, with the greatest reductions occurring at the downstream end of the valley.
8) The increased capacity of the lower river meant river flood levels receded faster and the floodplains started to drain earlier and drained faster than in the existing case.
9) To widen the lower Kaihu as in the model, approximately 680,000m^3 of earth would need to be excavated. The significant cost of this work needs to be considered together with maintenance costs and the possible negative effects of increasing the lower river capacity.
10) The simulations demonstrate that improved drainage can have a significant positive effect on flood extent and duration in the Kaihu valley. It would be worth considering other drainage aids, such as larger drain channels parallel to the main channel or a tidal barrage.

6. References

Barnett and MacMurray Ltd, 2008, *Kaihu Flood Control Scheme Investigation report on Stages 1 and 2*, prepared for Northland Regional Council
Mulgor Consulting Ltd, 2008, *Extreme Sea Levels at Dargaville, Client report 2008/5 for B&M*