Kaituna River to Maketu Estuary rediversion – recommended options

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Chapter 1: Objective

The objective of this report is to investigate and propose a preferred option for the diversion of Kaituna River flow into the Maketu Estuary based on the following criteria:

- Volume of inflow.
- Effects on local drainage and flooding.
- Cost.
- Flexibility (i.e. the ability to adapt the management of inflows, including the possibility of diverting further inflow to the estuary in the future).

It is noted that a range of other factors will finally decide the selected diversion option such as:

- Tangata whenua wishes and cultural issues.
- The morphological impact on river channels and estuary.
- Water quality impacts.
- Ecological impacts.
- Landscape impacts.
- Landownership issues.
- Resource consenting requirements.
- Affordability.
- Recreational and access issues.

These are not considered in this recommendation. It is anticipated that these other factors will be included as part of the public debate on selecting a diversion option or will be used in the adaptive management of the river flow diversion to best meet estuary ecological and other needs.

Chapter 2: Background

2.1 Diversion and Ford's Cut history

In the mid-1950s, the Kaituna River was permanently diverted out to sea at Te Tumu as a means of lowering river levels upstream, and the Papahikahawai Channel and Ford's Cut were both blocked off at their upstream end with a causeway. Thus the flow from the river to the Maketu Estuary was stopped. Years of concern about the closure of the river paths to the estuary, and the deteriorating state of the estuary followed. In response, a floodgate culvert structure was installed in 1996 to allow a small amount of flow back through Fords Cut into the Maketu Estuary (Figure 1).

Figure 1 Current layout, Kaituna River Mouth and Maketu Estuary

A summary of the works history of the Kaituna River diversion is given in Appendix I.

2.2 Hydraulic modelling history

The rediversion of flow through Ford's Cut was small and the concerns about the lack of flow to the estuary remained. Since 2001 a number of different options for rediverting more Kaituna River flow through to the Maketu Estuary have been assessed. These options are outlined in Appendix II.

In 2001 and 2002, Options A – L were identified. Hydraulic modelling of the options enabled the effects of each of the options on flood and drainage levels, and the effectiveness of each in diverting water to the estuary, to be compared.[1]

Modelling results showed that the most effective options at restoring flow through the estuary were those that involve blocking off the Te Tumu outlet (G, H). However these were predicted to have significant adverse impacts on farm drainage and flood levels in the river. The three most promising options were I, J and L; these increased the flow through the estuary without adverse effects on drainage and flood levels. The remaining options were predicted to provide no net increase (and in some cases a significant decrease) to estuary inflows.

Option M was tested in late 2006. This option was predicted to provide some increase to estuary inflows without compromising flood and drainage levels. The relatively small increase in inflow (of the order of 30%), together with the problems created for access to the river mouth, meant though that the option was not pursued further.

In 2007, the Maketu Estuary Focus Group selected several of the 2001-2002 options, and identified two more, P and R, that it wished to be further assessed. Updated modelling techniques and information (2006 bathymetry rather than 1996 data) were used in the re-assessment of these options.

Each of the 2007 rediversion options was assessed to estimate its effect on three key parameters: the volume of flow into the estuary and the drainage of the plains (both under normal conditions) and design flood levels. The resulting report[2] summarised the hydraulic effects of those options and presented indicative costings for each.

Subsequently, Option N was identified and it too was costed and assessed for its hydraulic effects.[3]

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[1] Environment Bay of Plenty (2001); Maketu Estuary Options – Ranking. Memorandum to Peter Blackwood from Phillip Wallace, 4 November 2001. File Reference 5600 05.

[2] Philip Wallace (2007); Rediversion of Kaituna River into Maketu Estuary: Hydraulic Modelling and Costing. Report prepared for Environment Bay of Plenty, June 2007.

[3] Email, Philip Wallace to David Phizacklea, Environment Bay of Plenty, 4 October 2007, Maketu Estuary Rediversion Options.

Chapter 3: Analysis of most likely options

Having regard to the criteria outlined in Chapter 1, findings of the 2007 investigations suggest that the most promising diversion options are Options A (status quo, Figure 1), H, J, L, N, and R. (Figures 2 – 6).

A description of all considered diversion options can be found in Appendix II.

3.1 Cost, inflow volume and flood/drainage impacts

Key findings from these 2007 investigations are presented in Appendix III. Results showed that blocking off the Te Tumu mouth would be the most effective way of increasing inflow to the Estuary (Options H and R), providing nearly 30 times more volume of inflow per average tidal cycle than the existing situation does under average flow conditions. Options N and L were shown to provide about four times the existing inflow, and option J about twice the inflow (Table 1).

Of the options that were shown to result in additional inflow to the estuary, the costs were estimated to range from around $500,000 (Option J) to $7,900,000 (Option H).

Options H and R, which redivert all normal flows through the estuary, are clearly the most effective of the options at rediverting flow. However they have substantial adverse impact on river flood levels and/or drainage. These impacts are likely to be unacceptable to landowners on the floodplain, and to mitigate the impacts will be costly. There may be an opportunity to partially mitigate the flood impacts by realignment of a portion of the river stopbanks to the proposed Tauranga Eastern Motorway embankment, thereby adding the Kaituna Wetland to the flood storage; further modelling and costing work is needed to quantify any such benefits and costs. Options H and R will also have an adverse effect on recreational fishermen who use the Te Tumu cut as an access to the ocean.

Of the options not adversely affecting flood levels and/or drainage, Option N is the most effective option, allowing over four times the existing inflow volume to the estuary under normal conditions. The estimated cost is around $900,000. Depending on the alignment a revived Papahikahawai Channel takes, Option N may lead to some impacts on the adjacent Brain property (e.g. bank erosion from waves in the channel, disruption during construction). Whatever option is selected negotiation with the landowner and permission to carry out works will be needed.

Option L is a slightly less effective version of Option N, and is estimated to cost a little less. For both options, a substantial power supply will be needed to work the gates, and the expected ongoing electricity costs are uncertain.

Option J is similar to Option L but less effective and less expensive. It is one of the simplest options to implement.

Figure 7 compares the cost and the effectiveness of various options.

Figures 2 – 6 Options H, J, L, N and R layout

Table 1 Comparison of most likely option

Option:			Option A	Option H	Option J	Option L	Option N	Option R
Effectiveness:	Net Inflow per tidal cycle (m^3)		105,000	2,887,000	200,000	383,000	449,000	2,856,000
Cost:			$0	$7,892,000	$490,000	$805,000	$920,000	$6,627,000
Flood Impact:	Increase in 1% flood level	Diagonal Drain	0	39cm	0	-7cm	0	-2cm
		Bell Road	0	25cm	0	-4cm	0	-2cm
Drainage Impact:	Increase in low tide river level	Diagonal Drain	0	95cm	0	0	0	116cm

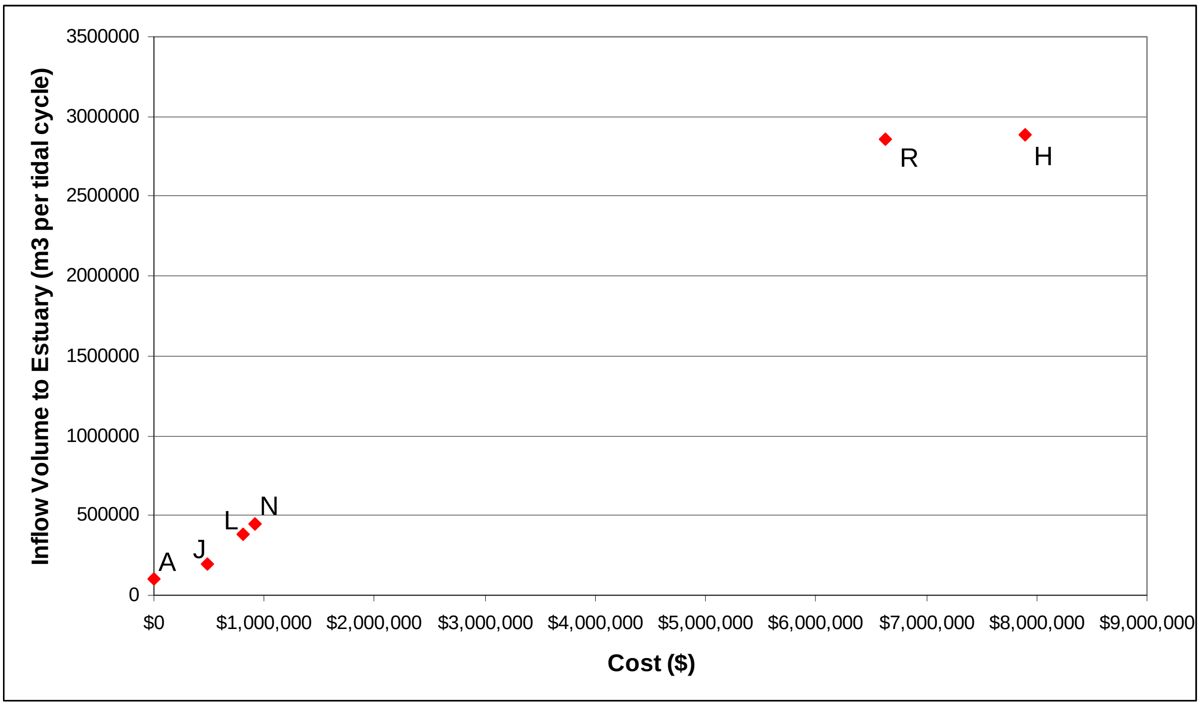

Figure 7 Cost versus diverted inflow volume of most likely options

3.2 Flexibility

Further to the cost, inflow volumes and impacts on flood levels and drainage, the flexibility of each of the most likely options in terms of a possible staged approach has been assessed.

Any option initially selected (Stage 1) could possibly later with adaptive management and additional funding be expanded to a further stage (Stage 2). Based on the desire for flexibility for adaptive management the six most likely options were investigated in terms of flexibility for future enhancement.

Options J, L, and N were identified as potential options for initial Stage 1 diversion, followed by Options H, J, L, N, and R as possible Stage 2 enhancements to diversion at a later time.

Each of the potential stage 1 options was evaluated in terms of stage 2 options that could be added to it to enhance the volume of inflow diverted in future. If a stage 2 option necessitated modifying or undoing work done in stage 1 then it was ruled out as an option for stage 2 in terms of flexibility.

The result of this analysis shown in Figure 8 clearly indicates that Option N has the greatest flexibility for adaptive management and later enhancement.

Stage 1	**Stage 2**
N	H
	J
	L
	R
L	N
	All others would involve undoing or modifying work undertaken in Stage 1.
J	N
	All others would involve undoing or modifying work undertaken in Stage 1.

Figure 8 Flexibility of options for future flow diversion enhancement using a staged approach

Chapter 4: Recommended Option

4.1 Stage 1

From the preceeding analysis of cost, inflow volume, effects on flooding and drainage and flexibility for adaptive management, **Option N** is recommended for further investigation for Stage 1 works. It involves opening the Papahikahawai Channel to the Kaituna River, installing floodgated culverts and removing a cut-off within the Papahikahawai channel. Option N would multiply the existing flow to the estuary fourfold (449,000 m^3 per tidal cycle) without any impacts on river flood levels or drainage performance. The estimated cost of this option is $920,000. It also provides flexibility for any of four options (H, J, L, R) to be implemented in the future (Stage 2).

4.2 Stage 2

The option selected in Stage 1 could with adaptive management and additional funding be later expanded as part of a Stage 2 diversion enhancement.

If Option N is implemented in Stage 1, further enhancement is possible in the future by implementing any of the options H, J, L, and R in Stage 2.

Stage 2 options can be broadly lumped into a lower cost relatively low inflow enhancement or a high cost higher inflow enhancement. The lower cost option would be to implement option J or L in Stage 2. Costs would vary from around $490,000 (Option J) to $805,000 (Option L) for a further increase in inflow of 200,000m^3 per tide cycle and 383,000m^3 per tide cycle respectively for options J and L.

The higher cost option would be to implement one of Options H or R in Stage 2. Costs would vary from $6.6 million (Option R) to $7.9 million (Option H) for a further increase in inflow of around 2,900,000 m^3 per tide cycle into the estuary. Both these options involve some form of blocking the Te Tumu cut out to sea.

All of these Stage 2 options involve modification of the Ford's Cut culverts – lowering or widening. The final configuration of stage 2 would need to be determined at a future time with further investigation.

It must be noted that the total benefit of combined options in Stage 2 will not equal the sum of the benefits of each option on its own since the increase in inflow is not linear. Further modelling and costing work would be required to optimise the combined options in Stage 2.

Chapter 5: Further Investigations

Although the hydraulic model was suitable for giving a clear indication of the relative effectiveness and impacts of each rediversion option, detailed assessment of the recommended options will require more detailed modelling. The hydraulic modelling undertaken to date has been based on a number of assumptions (for example, on the dimensions of the estuary and river mouths, in the absence of complete data at the time the model was built). The river model was also calibrated to historical flood events but not to normal or low flow conditions.

Water quality, salinity and ecological impact modelling has recently been commissioned by Environment Bay of Plenty. Results are expected around the middle of 2008. That modelling will require a detailed 2-d or 3-d hydraulic model of the Maketu Estuary and lower Kaituna River. Together with additional topographic and bathymetric information and updated river cross-sections now all available, and with recently completed work on the river hydraulic model, this will provide the tools to better predict the overall impacts of the rediversion options.

It should also be noted that the physical dimensions of the structures and channels, and the operating rules for opening and closing the gates under various flow and tide scenarios, for the preferred options have also been optimised to maximise effectiveness and minimise costs and impacts.

Finally, it must be emphasised that the above recommendation (for Option N) is based only on hydraulic modelling to date, and on practical engineering, cost and flexibility considerations. A range of other matters must be considered in the next stages. These will include, but not be limited to:

- Tangata whenua wishes and cultural issues
- The morphological impact on river channels and estuary
- Water quality impacts
- Ecological impacts
- Landscape impacts
- Landownership issues
- Resource consenting requirements
- Affordability
- Recreational and access issues

Chapter 6: References

Environment Bay of Plenty (2001); Maketu Estuary Options – Ranking. Memorandum to Peter Blackwood from Philip Wallace, 4 November 2001. File Reference 5600 05.

Environment Bay of Plenty (2008): Council Tour – May 2008.

Philip Wallace (2007); Rediversion of Kaituna River into Maketu Estuary: Hydraulic Modelling and Costing. Report prepared for Environment Bay of Plenty, June 2007.

Philip Wallace (2007); Maketu Estuary Rediversion Options. Email from Philip Wallace to David Phizacklea, Environment Bay of Plenty, 4 October 2007.

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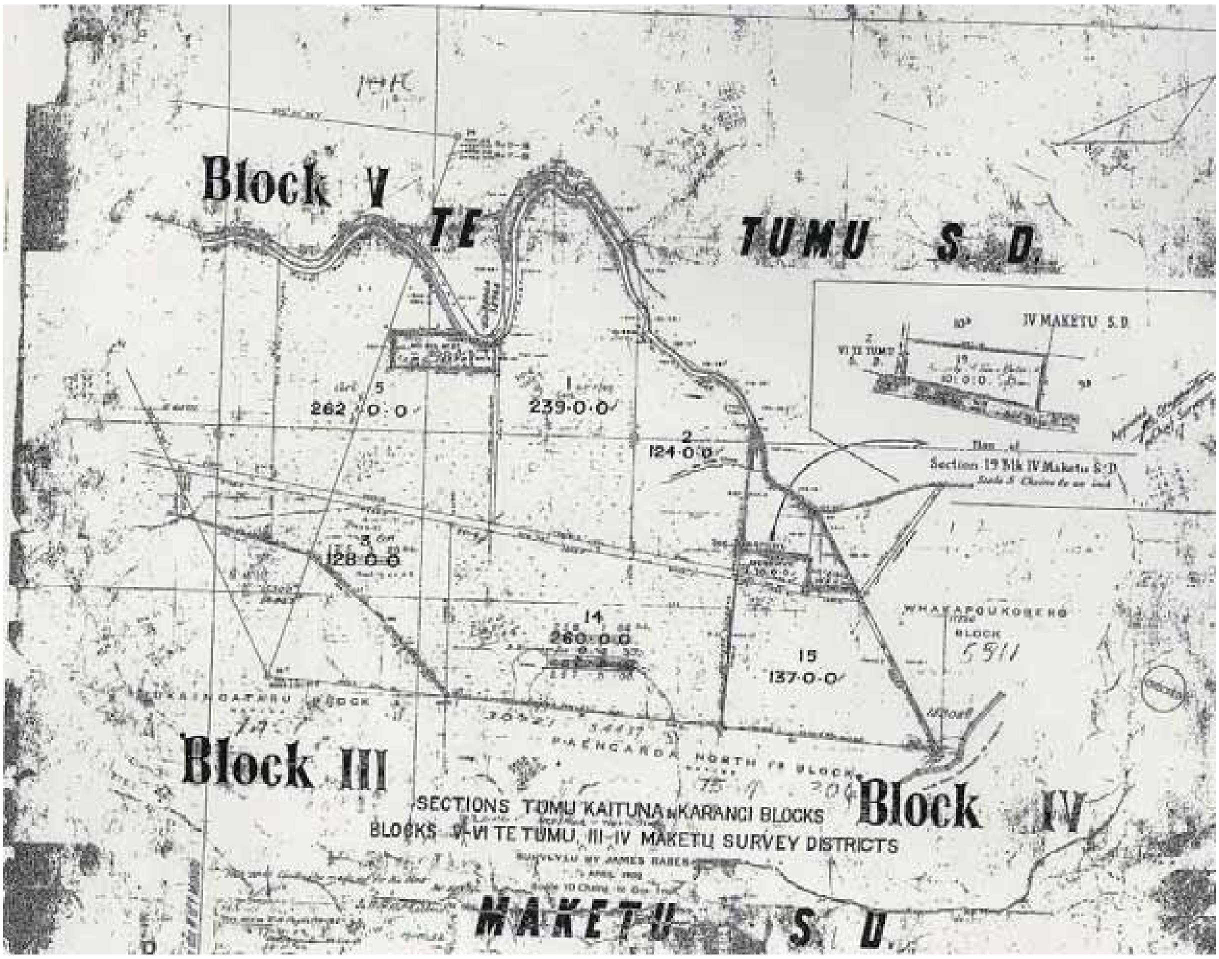
Appendices

Appendix I – Kaituna River Mouth and Maketu Estuary works history

1902	Kaituna River Pre-works flowed into Kaituna Estuary via Papahikahawai channel (see 1902 survey).
1907	River breakout at Te Tumu. Following breakout, plans to re-hydrate estuary with cut. At same time river mouth migrated eastward along Papahikahawai channel.
1925 – 1928	Ford's Cut (Twin Cut) made. Most likely reason was to divert the river back into the Maketu Estuary following breakout of the river at Te Tumu in 1907.
1928-1956	Flow into estuary through Fords Cut and Paphikahawai Channel (see 1948 photograph).
1956	Te Tumu Diversion to sea. Ford's Cut & Papahikahawai blocked. Diversion to reduce flooding to surrounding land (see photograph 13 November 1959).
to 1995	Seepage into Ford's Cut continues. (see photograph Fords Cut Causeway 1988).
1979	Start of Kaituna Catchment Control Scheme. Kaituna River Diversion to bypass River loop. Stopbank constructed on right bank from Ford's Cut to Te Tumu.
1992 – 1994	DoC consent application and tribunal. Re-diversion through Ford's Cut opened after approximately 40 years of closure.
1996	Flow diverted through Fords Cut. Construction of four flapgates completed in 1995. Gates temporarily closed following legal action by Brain family, then opened illegally (by unknown) then opened (May 1996) after rediversion allowed in high court ruling against the Brain family (see 2007).



1902 survey, showing the old river loop (blocked off and bypassed in 1979) and the Papahikahawai Channel, prior to Ford's Cut.

1948

13 November 1959

Ford's Cut causeway at spring high tide, 1988

2007

Appendix II – Kaituna River Diversion option layouts

- Option A: Status quo.
- Option B: Remove culverts and causeway between river and estuary at Fords Cut.
- Option C: As per B, plus open Papahikahawai Channel between river and estuary.
- Option D: As per A, plus remove the “block” in old river channel upstream of Fords Cut.
- Option E: As per D, plus place a weir at RL 1 m across the existing river channel at the cut.
- Option F: As per C, plus remove block in old river channel – i.e. a combination of C and D.
- Option G: As per F, plus a flood weir at RL 1.5 m at the existing river mouth (Te Tumu).
- Option H: As per F but with the existing river mouth completely blocked off.
- Option I: As per A, but with the number of culverts between Fords Cut and the estuary doubled to eight.
- Option J: As per A, but with the culverts lowered to be submerged at mid tide – i.e. an invert level of -1.6 m.
- Option K: As per B, but with the opening between Fords Cut and the estuary defined as two large culverts (to represent a bridge).
- Option L: As per K, but with the two large culverts between Fords Cut and the estuary floodgated to prevent backflow into the river.
- Option M: As per A, plus open Papahikahawai Channel and insert low level weir between it and the river.
- Option N: As per A, plus open Papahikahawai Channel and insert two large culverts between it and the river floodgated to prevent backflow into the river.
- Option P: Lower stopbank between Te Tumu Cut and Fords Cut to average flow levels, leave Te Tumu cut open, open Papahikahawai Channel.
- Option R: Control gates at both Te Tumu Cut and at Fords Cut – control gates at Te Tumu opened in flood events.

The recommended Option N, and alternatives J and L, are illustrated below.

Option N

Key features and assumptions

- The existing culverts and floodgates between the river and Fords Cut are left untouched.

- A bridged opening of 20 m width and 3 m depth is created from the river to Papahikahawai Channel. The structure has been modelled as twin 10 m wide culverts, with an invert level of -1 m RL. Floodgates are installed to allow flow only from the river to Fords Cut. The size of the gates is such that they would need mechanical control to open and shut properly.

- Papahikahawai Channel is reopened allowing flow from the river, parallel to the spit to enter the estuary. The assumed channel is 30 m wide in the upstream portion, and widens and depends slightly to fit recorded bathymetry downstream of the second block. In practice, the Papahikahawai Channel may scour or widen further over time after it is reopened.

Option J

Key features and assumptions

- The four culverts and floodgates (allowing flow only from the river to the estuary) are lowered, so that the invert level of the culverts becomes -1.6 m RL (the current invert level is approximately -0.5 m RL).

Option L

- The existing culverts and floodgates between the river and Fords Cut are removed, and a bridged opening of 20 m width and 3 m depth is created. The structure has been modelled as twin 10 m wide culverts, with an invert level of -1.5 m RL. Floodgates are installed to allow flow only from the river to Fords Cut. The size of the gates is such that they would need mechanical control to open and shut properly.

Appendix III – Summary of results for 2007 investigations

Volume of inflow to the estuary

The principal aim of the rediversion is to increase the inflow to the estuary from the river. To assess the effectiveness of each option in doing this, a mean river flow (40m^3/s at Te Matai) has been simulated in conjunction with several cycles of neap and spring tides (with current mean sea levels), and the average inflow per tidal cycle has been derived from the results. These are summarised in Table 1, ranked in terms of the effectiveness of restoring flow to the estuary (note the net inflow figures will differ if a different start point in the tidal cycle is assumed, but the relativity of options will be the same).

Table 1 Average net inflow per tidal cycle, typical river flow (over two neap tide cycles, one intermediate cycle and two spring tide cycles).

Option	Net Inflow (m^3)
Option H	2886921
Option R	2855535
Option N	448598
Option L	383118
Option J	199459
Option I	196973
Option P	160109
Existing	104893
Option K	57604

Design flood

The Kaituna Catchment Control Scheme is designed to provide protection against a 1% AEP[4] flood. Such an event may result from a 1% AEP river flood or from a 1% AEP sea level. For design purposes, Environment Bay of Plenty determines 1% AEP flood levels at any location from the highest level at the location of two scenarios:

- 1% AEP river flood plus 20% AEP sea level.
- 1% AEP sea level plus 20% AEP river flood.

[4] By definition, a 1% Annual Exceedence Probability (AEP) flood has a 1% probability of occurring in any one year. This is also known as a 1 in 100 year flood or simply as a 100 year flood. Likewise a 20% AEP flood has a 20% probability of occurring in any one year, and is also known as a 5 year flood.

Table 2 Peak design levels (1% AEP, with sea level rise) at selected locations on Kaituna River.

Option	21940m (downstream of Fords Cut)	19450m (Diagonal Drain outlet)	16390m Bells Rd Drain Outlet
Option P	2.59	2.95	3.91
Option K	2.66	3.07	3.95
Option L	2.66	3.07	3.95
Option I	2.66	3.12	3.98
Option R	2.69	3.12	3.97
Existing	2.67	3.14	3.99
Option N	2.67	3.14	3.99
Option J	2.67	3.14	3.99
Option H	3.20	3.53	4.24

Drainage

As river levels rise, drainage of the Plains becomes more difficult. To assess the impact of the rediversion options on drainage, the minimum river levels under normal flow and several cycles of neap and spring tide (i.e. the scenario modelled above) have been extracted from the results (in practice, lowest levels occur during spring tides, at low tide).

Table 3 Low tide river levels at selected locations on the Kaituna River

Option	21940m (downstream of Fords Cut)	19450m (Diagonal Drain outlet)	16390m Bells Rd Drain Outlet)
Existing	-0.32	-0.20	-0.06
Option I	-0.32	-0.20	-0.06
Option J	-0.32	-0.20	-0.06
Option L	-0.32	-0.20	-0.06
Option N	-0.32	-0.20	-0.06
Option P	-0.32	-0.20	-0.05
Option K	-0.27	-0.16	-0.02
Option H	0.72	0.75	0.80
Option R	0.94	0.96	1.00

Cost

Costs in terms of June 2007 dollars are summarised in Table 4. These are preliminary only. It is particularly worth noting that for options L, N and R, involving control gates, the very infrequent demand for such works within New Zealand could result in tender prices being quite different from estimates.

The additional pumping requirements, to restore the drainage level of service to the current situation for each of Option H and R are included in the costs.

Likewise, the cost of raising stopbanks to provide an equivalent standard of protection to the status quo has been estimated and included in the Option H cost.

On the other hand, there are potential savings in future stopbank works for Options K, L and P, due to lower flood levels resulting from the options, and these savings have been allowed for. Furthermore, Option P removes the stopbanks between Fords Cut and the Te Tumu mouth. The amount allowed in the Asset Management Plan for the next top-up of these banks has been deducted from Option P costs also.

Table 4 Summary of net cost of options (June 2007$)

Option	Net Cost
Option K	$234,000
Option P	$390,000
Option J	$490,000
Option I	$567,000
Option L	$805,000
Option N	$920,000
Option R	$6,627,000
Option H	$7,892,000