Northland Regional Council

Kaihu River Flood Management Scheme Concept

June 2009

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LIMITED
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Quality Assurance Statement	
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1. Summary

The Kaihu River floodplains downstream of Ahikiwi are narrow, and the river channel is small in relation to the size of the river floods. Protection against major floods is not considered economically justifiable. The river carries a high load of suspended sediment, which in the unmodified state of the river would be spread over the floodplains during floods. Containing the river and an adjacent floodway within high stopbanks is considered to be unsustainable because of probable high rates of sedimentation within the floodway. Because of these cost and sustainability constraints the best option for flood management in the Kaihu valley is to provide protection against nuisance floods, and to improve the discharge capacity of the Kaihu River to aid drainage after floods.

The principles of the proposed scheme are that it should be economically justifiable, environmentally sustainable, and treat all parts of the floodplains equitably. The basis for treating the floodplain areas equitably in the proposed scheme would be to maintain the distribution of flooding volume that would occur in a benchmark condition with unmodified river banks and with the river channel at a size that can be sustainably managed.

In order to treat all areas of the floodplains equitably from the beginning of the scheme, it is proposed to design the scheme for present day climate and sea level conditions, and to adjust the scheme in future as may necessary to take into account changes.

The elements of the proposed scheme are:

- It applies to the floodplains downstream of Ahikiwi
- The sustainable level of service will be defined in detailed design, but is expected to provide protection against a flood of between 6 months and 1 year Average Recurrence Interval (ARI)
- The scheme includes designated overflow crests, constructed, monitored, and maintained by Council, which will be designed to achieve equitable distribution of floodwaters, in floods that exceed the level of protection provided. The overflow crests would be designed to encourage the overflow of suspended sediment as well as water to farmland, in events that exceed the level of protection provided.
- The scheme design includes determining a sustainable river channel size, to be maintained and monitored by Council.
- The scheme design includes specification of floodgates for the various floodplain areas. It is proposed to the responsibility of landowners to install and maintain the floodgates.
- The scheme would allow private construction of stopbanks between the designated overflow crests.

- The scheme would control private construction of internal embankments, and may require adjustment of the crest levels of existing internal embankments, because stopbanked areas within a farm may influence the volume of overflow over the river banks, so that the scheme design proportions are not maintained.

- The scheme would maintain the special protection status of Dargaville and the land between Valley Road and the Kaihu River, accorded it by the Dargaville Borough scheme approved by the Soil Conservation and Rivers Control Council in 1965

- The scheme would include a specification for collecting flood level and suspended sediment data. This activity would be Council's responsibility.

- The scheme would be reviewed at 10 yearly intervals. Any adjustments found necessary, including adaptations to sea level rise and climate change, would be carried out under Council management.

2. Introduction

Barnett & MacMurray Ltd (B&M) was commissioned by Northland Regional Council to formulate a concept for a Kaihu River flood management system.

The offer of service was accepted by Bruce Howse on 12 June 2009.

This statement of the concept of a flood management scheme for the Kaihu Valley is intended to be circulated to stakeholders for comment. The principles underlying the concept are that it should be economically justifiable, environmentally sustainable, and should treat all parts of the valley fairly, so far as possible.

The sources of information used to formulate the concept scheme are:

- Two investigations by Barnett & MacMurray Ltd for Northland Regional Council, the first to establish the status quo of flooding the Kaihu Valley, and the second to quantify the effect of removing stopbanks and increasing the size of the lower river channel

- Discussions with Council, the Scheme Liaison Committee, and stakeholders at meetings in December 2008 and May 2009

- Reports on various earlier investigations, referred to below

- Reports describing flood management works in the Kaihu Valley, referred to below

3. Historical background

This statement of concept includes a brief review of the early history. More detail can be obtained from various reports held by Northland Regional Council and Kaipara District Council.

The early history of flood management works on the Kaihu River was summarised in a report by A Moores, Engineer to the Northland Catchment Commission, in April 1963. Moores described the Kaihu River scheme which included four parts:
Stage 1: Reconstruction of old diversions for 200m upstream and 2.8km downstream of Parore Road (originally constructed from 1927 to 1930), and drainage works.
Stage 2: Improvement of the Kaihu River channel from Parore to Rotu (5.6km)
Stage 3: Improvement of the Kaihu River channel from Rotu to Mamaranui (11.2km)
Dargaville Borough flood protection: This allowed for both tidal and river floods and included a concrete wall and embankments.
At the time of Moores' report, only the Stage 1 works had been completed (in 1957 and 1958).

K.D. Brennan, County Engineer for Hobson County Council, in a report dated July 1982 states that the Soil Conservation and Rivers Control Council approved the Dargaville flood protection works in 1965, and that the works were designed to protect the town and the rural zoned land in the vicinity of the river. Later in the report he indicates that the works included a stopbank along the Northern Wairoa. In a December 1985 report, Brennan states that the reconstruction of the Dargaville Borough section was carried out in 1969 and 1970. Bruce Judd Consultancy, in a report dated March 2001, identifies a stopbank that runs along the Kaihu River bank from Valley Road to the SH12 bridge as "the Dargaville stopbank". From the report it is clear that Judd understood the purpose of this bank was to protect Dargaville from both tidal and river floods. It is presumed that this bank is part of the works approved by the Soil Conservation and Rivers Control Council in 1965.

Brennan's 1982 and 1985 reports indicate that the Stage 2 and 3 works were completed after gaining approval of the Soil Conservation and Rivers Control Council, and that they were being maintained in 1985.

Most of the works described above were built with Government subsidy, at 2 for 1 or 1 for 1 rates – thus the Government contributed between 50% and 66.7% of the cost of works. Brennan's 1985 report includes a section on maintenance subsidies. It was stated that ricegrass control had a subsidy of 66.7% for many years, but Brennan said "Dropping the subsidy from 66.7% to 50% was serious enough and now we are told that this will be dropped to 30%. It should be very clearly understood that this will result in serious detriment to the whole system. It will result to great loss of benefit previously won at high cost with local and government money". On Giant Rush control, Brennan states "The subsidy for giant rush was 50%, and now we are told that this will reduce to 30%" and he considered it "imperative that the subsidy continue at 50% so that we can consolidate the gains we have made". On the removal of silt from the river, Brennan said "We are told that this subsidy is to be reduced from 50% to 30%. I can only assume that this is a purely arbitrary decision which can have no relevance to the conditions in the catchment area, the tidal problem, or the plain fact that silting is continuous and must be removed continuously. Double handling is inevitable. The subsidy should remain at 50%." None of those Government subsidies are available today. Thus the economic environment for scheme maintenance is very different from that before 1980, and this will affect the size of river channel that can be maintained in the present proposed scheme.

In various parts of the Kaihu valley there has been a practice of forming spoil heaps left on the river bank by river maintenance work, into continuous stopbanks. In some cases such embankments were authorised by officers of the relevant Council at the time. However stopbanks do not appear to have been part of the original scheme concept which was approved by the Soil Conservation and Rivers Control Council.

4. Cost constraints

The Kaihu River channel capacity, and the Kaihu Valley floodplain area, are both small in relation to the size of the floods that occur quite frequently. This means that expensive works would be required to protect the farmland to even a modest level of service (such as keeping a 5 year return period flood off farms). Such works are considered probably not justifiable, although it must be noted that in making this assessment, no supporting economic analysis has been done.

The Kaihu River is already substantially modified from its natural state. To maintain it in any kind of modified condition will require ongoing maintenance, and the greater the degree of modification, the greater the cost of maintenance is likely to be. This is discussed further below under **Sustainability constraints**.

5. Sustainability constraints

The Lidar survey undertaken by Northland Regional Council in 2006 showed that over much of the valley, the Kaihu river bank is 1 to 3m higher than the lower parts of the adjacent floodplain. The ground typically shows a gentle slope from the river bank towards the lower parts of the floodplain. This type of floodplain morphology is created during floods, by sediment falling out of suspension in the slower flows on the floodplain. The sediment deposition tends to occur more near the bank of the main channel, resulting in the observed gentle slopes across the floodplain. Raised river banks created in this way are sometimes known as natural levees. This morphology was clearly recognised by Brennan in his 1985 report, where he says: "we have, where appropriate, encouraged people to install floodgates on these drains so that the land will not flood as long as the river stays within its banks. If the river continues to rise, the water will go right over the top as it always has done."

Also clearly visible from the Lidar survey data is an old Kaihu River channel. About 1.5km north of Waihue Road, at some time in the past the river has clearly broken out of its old channel and taken a new course over the floodplain (the capture of the river by the new channel was probably a gradual process, occurring over several floods) . The old channel runs close to the west side of the valley, and joins the present day Taita Stream channel on the west side of State Highway 12. The present day Kaihu River channel rejoins the old channel at the Taita Stream junction. It is not known when the change of river course occurred, and it does not seem to have been mentioned in a 1917 Lands Department report referred to by Moores in his 1963 report. Between Frith Road and the Rotu Bottleneck there are two other clear examples of old river channels on the floodplain. River channel breakouts of the kind that has occurred upstream of Waihue Road occur when the river becomes perched above the surrounding floodplain by a process of sedimentation on its banks and bed.

The sedimentation that leads to perching of the river channel depends on a generous supply of sediment. In this regard it should be noted that the Kaihu River undergoes a relatively rapid transition from a steep river with a gravel or boulder bed, to a flat lowland river with a silt bed. This transition occurs approximately at Ahikiwi. The steep river reach can carry a very high suspended sediment load, thus there is likely to be a generous supply of silt at the upstream end of the Kaihu floodplain, limited only by supply from the upstream catchment area.

The Lidar survey shows the processes that have taken place on the floodplain, but at present little data is available to quantify the time scale of the floodplain sedimentation process. It would be possible to measure suspended sediment concentrations at the Kaihu Gorge flow recording station, and thus establish a suspended sediment rating for the site, but such measurements have not been made. Mr T. Newlove has stated that on his property near Mamaranui, only the tops of some fence posts put in by his grandfather now show, and that fence posts he put in 15 or more years ago have silt build up of about 100mm (Newlove 2008). It should be noted that the rate of sedimentation is quite variable over the floodplain, as the Lidar survey shows, with a tendency to higher rates of sedimentation near the river channel.

The ongoing maintenance of the lower river channel provides another qualitative indication of the sediment load carried by the river. Regular excavation of the river is found to be necessary to maintain a reasonable size of river cross section. However it seems that the records of excavation are not sufficient to quantify the rate of sedimentation. The contracts are let on the basis of metres of river bank cleaning, rather than cubic metres of spoil removed.

Upstream of the point where the present day river broke out of the old river channel (1.5km upstream of Mamaranui) the river shows a mature meander pattern. The new river channel is significantly less sinuous. It is likely that it will tend to develop a more sinuous course over time, unless prevented from doing so by human intervention. Thus even to maintain a naturally formed new channel in its original course on this kind of floodplain is likely to require significant maintenance work.

It is reasonable to assume that the Kaihu River continues to carry a relatively large load of suspended sediment, as it has in the past. Therefore the tendency for the river to become perched above the floodplain will probably continue.

A previous study by Bruce Judd Consultancy (dated October 2002) tested a proposal to set stopbanks 50m back from the river bank, thus creating a 100m wide floodway from the Rotu Bottleneck to the Parore Road bridge. A similar approach was also considered at the start of the present investigation into flood management options by Barnett & MacMurray Ltd. However such a system is considered unsustainable in the medium to long term, because experience shows that in most cases, such a system will accentuate sedimentation within the floodway, and thus speed up the perching of the river channel above the floodplain. In principle it is possible to maintain such a system, by excavating spoil from the river and floodway, and putting it on the floodplain. However a scheme that requires expensive stopbanks (built on soft soils away from the higher ground near the river bank), provides protection against a 2 or 5 year return period event, and has to be maintained at fairly high cost, is probably not economically justifiable. It should be noted that this assessment is not backed up by rigorous analysis at this stage, partly because of the lack of river suspended sediment data, as noted above. Such a scheme also commits future generations to an expensive maintenance program, and if for some reason that program stops, the system will eventually become unmanageable, with river water levels too high to allow good drainage from the land.

In the present day Kaihu River channel downstream of Ahikiwi, the flow capacity of the river is limited, compared with even frequent flood flows (more details are given below under **Design floods**). In the natural unmodified Kaihu River and floodplain system, the river channel capacity was probably even smaller. Thus to maintain the river channel at its present capacity or greater will require ongoing maintenance. The cost of this maintenance is an important parameter in the design of a sustainable flood management scheme. As a starting point it is reasonable to assume that the maintenance will be undertaken by a standard hydraulic excavator. The reach of the excavator is limited by its weight, and that is limited by the strength of ordinary unreinforced Kaihu River bank soils.

Guidelines produced by the Ministry for the Environment (MfE), recommend adopting a sea level rise of 0.5m by the 2090s. Average temperature rises of up to several degrees by the 2090s are also projected, with associated increases in peak rainfall intensities of 40% or more (MfE July 2008). In this context it is clear that a scheme designed for present day conditions may not give anything like the level of service it was designed for, in 20 or 30 years time. This is probably a good reason to err on the side of smaller rather than larger investment.

6. Outline of the concept

The proposed scheme is an adjustment of the status quo. It accepts that stopbanks have been built in various places, and adjusts those banks to make the distribution of floodwater equitable. It includes specification of floodgates so that some areas of land may be given slightly better flood protection than they have at present. It recognises the importance of an adequate Kaihu River cross section in providing drainage after a flood.

The scheme proposed:

- Protects land against nuisance floods rather than major floods. The level of protection proposed is described in more detail below under **Design floods**.

- Is limited to land downstream of Ahikiwi.

- Is designed for present day climate and sea levels, so that all areas of the floodplain are treated equitably from the beginning of the scheme.

- Includes overflow crests designed to achieve equitable distribution of flood waters, in floods that overtop the protection provided. The principles and method for achieving this in the design of the scheme are described below.

- Divides the floodplain downstream of Ahikiwi into 18 separate areas, each of which has one or more overflow crests to regulate the distribution of floodwaters.

- Allows private construction of stopbanks between the designated overflow crests.

- Controls private construction of internal embankments, and may require adjustment of the crest levels of such embankments, because stopbanked areas within a farm may influence the volume of overflow over the river banks, so that the scheme design proportions are not maintained.

- Includes specification of floodgates that will achieve satisfactory drainage of the floodplain areas.

- Includes ongoing maintenance of the Kaihu River channel between Dargaville and Mamaranui. The level of maintenance that is economically sustainable is an important parameter of the scheme design.

- Is designed to encourage the overflow of suspended sediment as well as water to farmland in events that exceed the level of protection provided.

- Maintains the special protection status of Dargaville and the land between Valley Road and the Kaihu River, accorded it by the Dargaville Borough scheme approved by the Soil Conservation and Rivers Control Council in 1965

- Includes monitoring of the river channel by regular survey of an adequate set of cross sections between Dargaville and Kaihu Gorge.

- Includes monitoring of the designated overflow crests.

- Includes increased monitoring of river levels and peak flood levels at the designated overflow crests. This will allow the performance of the system and the equitable distribution of floodwaters to be periodically checked.

- Includes provision for 10 yearly performance reviews, with adjustment of the designated overflow crests if necessary, under Council management. This may be necessary to adapt to climate change and sea level rise.

- Includes monitoring of suspended sediment load at Kaihu Gorge, to provide information for future river and floodplain management decisions.

7. Design floods

While it is accepted that all floods are different with regard to distribution of runoff, shape of hydrograph, antecedent conditions, and other factors, for the purpose of design it is necessary to adopt a standard pattern of flood. It is proposed to use the design flood hydrograph developed by Barnett & MacMurray Ltd in the present investigation. In this design flood, both the volume and the peak flow agree with the estimated frequency distributions for a given ARI. The distribution of runoff over the catchment is weighted towards the upper catchment, and there admittedly is little data to support this choice, except that the model calibrates reasonably satisfactorily against recorded flood levels. In future given more data it may be possible to make a more informed choice on this matter.

The size of flood against which the scheme should provide protection is one of the most important design parameters. Cost and sustainability factors relating to this choice have been discussed above. It is proposed that the scheme should protect against a flood of between 6 months and 1 year ARI, with the final level of protection to be set depending on detailed design considerations. At 1 year ARI, the annual exceedence probability is 0.63 – that means there is a 63% chance of this flow being equalled or exceeded in any year. At 6 months ARI, there is an 86% chance of the flow being equalled or exceeded in any year.

In a report dated October 1986 C.B. Judd stated that a flood in September 1986 peaking at 55m3/s at Kaihu Gorge “came up to the top of the river banks at many places and covered some low lying flats”. This observation followed fairly soon after Brennan’s December 1985 report in which he stated that: the Borough section was in excellent condition; the Stage 2 reach of the Kaihu River had previously had major silting problems due to major cleaning works in Stage3, but had been cleaned and was functioning satisfactorily; recent work at the Taita confluence was the final stage of bringing the Kaihu River to a condition that had not previously existed; and that the stretch of the Kaihu River from Mamaranui to Dargaville had by natural erosion increased its cross section from 20% to 65% in various places (drawings attached to the report indicate that the comparison was with the design cross sections). Brennan appeared in short to be well satisfied with the condition of the river.

In the 1986 report Judd further noted that floods exceeding 55m3/s peak flow had occurred 23 times during the 5 years from 1981 to 1985. Later in the same report Judd estimated that damage started to become significant in a flood peaking at 80m3/s at Kaihu Gorge.

The present computer model produced by Barnett & MacMurray Ltd indicates that the river banks (disregarding any stopbanks) would be overtopped in discharges between 50 and 80m3/s, depending on the location, and also that in a 2 year average recurrence interval (ARI) flood, there would be flooding on many parts of the floodplains, with the existing bank levels.

According to the flood frequency analysis by Barnett & MacMurray Ltd, flows of 55m3/s and 80m3/s at Kaihu Gorge would have ARI of 3.5 months and 5.4 months respectively, which is broadly in agreement with Judd’s 1986 assessment.

8. Principles for fair distribution of floodwaters

It is proposed to design the system so that in floods that overtop the designated overflow crests, the volume of flooding is distributed fairly between the 18 separate floodplain areas. The distribution of flood volume is to be as would have occurred in a benchmark condition with unmodified river banks, in the scheme design flood.

It is necessary to define the benchmark condition. Even before any settlement of the Kaihu valley, the floodplain was changing over time, with the river periodically changing course and floodplain levels tending to rise in most places by sedimentation and the formation of peat soils. It would not be practical or relevant to assess flood volume distribution under pre settlement conditions.

Since settlement of the Kaihu valley floodplain sedimentation has continued in some places, but in other places drainage and agricultural use have caused sinkage of peat land, while stopbank construction may have reduced floodplain sedimentation in some areas. To attempt to estimate ground levels over the floodplain at a previous time would be difficult and uncertain. Therefore with regard to land levels, it is proposed to use the Lidar survey of 2006 as the benchmark condition.

Setting stopbank crests back to unmodified river bank levels is an important part of establishing the benchmark condition. The available data sources for estimating unmodified river bank levels are: the Lidar survey data, on which it is usually possible to discern a break in slope at the toe of a constructed stopbank; inspection in the field with supplementary survey; and soil profiling, in which soil horizons indicating placement of additional material can often be distinguished in a test pit.

In the present investigation by Barnett & MacMurray Ltd, unmodified river bank levels have already been estimated in the context of assessing the effect of removing all stopbanks on flooding patterns. It is proposed to refine the representation of the unmodified banks, because the flooding volume proportions are to be the basis of equitable treatment of all properties, and should therefore be as accurate as possible.

At present the distribution of floodwaters is influenced not only by stopbanks adjacent to the river, but also (to some degree) by the State Highway 12 and old rail embankments, and by internal stopbanking on some properties. For the purpose of setting the flood volume proportions, it is proposed that these should be removed, so that the benchmark condition does not include any embankments. In practice the embankments for State Highway 12 at least must remain. In the detailed design process it may prove impossible to maintain the design flooding proportions with the highway embankments in place. If so the benchmark case may need to be adjusted to include the highway embankments. At this stage it seems best to make the benchmark represent unmodified topography, as far as possible.

It is proposed to treat floodgates in the same way as stopbanks, as they similarly alter the original flooding pattern. Therefore floodgates will be removed in creating the benchmark condition used to set the flooding volume proportions.

Tributary streams and old river channels contribute to flooding in some areas, by allowing backflow from the Kaihu River. These will be retained in the benchmark river and floodplain conditions that will be used to set the flooding volume proportions for the scheme.

The ponding volume available in side valleys has an influence on the volume of floodwater that overflows the river banks. For the benchmark case it will be assumed that there is no obstruction to flow into the side valleys.

The discharge capacity of the river, and its variation along the river, have an influence on the volume of overflow of the river banks in floods. The condition of the river channel is therefore an important part of the benchmark state that will be used to calculate the flooding volume proportions. Clearly the river has been greatly modified since settlement of the Kaihu valley, and as discussed above, it is expected that ongoing maintenance of the river will be necessary. The river channel geometry that is used for setting the flooding volume proportions should be as close as possible to that which will be maintained throughout the life of the proposed scheme. The design cross sections that were envisaged by the original Kaihu River scheme may not be achievable under present day economic conditions, when any subsidy from central Government is most unlikely. The present set of river cross sections, mostly surveyed in 1999, do not represent the river channel adequately in some areas. It is recommended that some extra river cross sections be surveyed to fill significant gaps. For setting the flooding volume proportions, it is proposed to estimate the maintainable river channel size, and to modify the presently available set of cross sections accordingly.

As noted above it is proposed that Dargaville and the land between Valley Road and the Kaihu River should maintain its special status, and be protected to a higher level against both tidal and river floods.

9. Calculating the flooding volume proportions

The benchmark condition of the system for calculation of flooding volume proportions has been discussed in the previous section. The features of the benchmark condition are:

- Floodplain ground levels according to the 2006 Lidar survey
- River bank levels before stopbank construction assessed from Lidar survey, supplemented by field inspection and survey, and perhaps soil profiling
- Railway, highway, and internal stopbanks removed
- River channel geometry that can be maintained at reasonable expenditure throughout the life of the scheme
- Floodgates removed
- Tributary streams and old river channels (other than those that were closed off in the old Kaihu River scheme) allowed to contribute to flooding of the floodplains

It is proposed to modify the computer model of the river and floodplain system to represent the benchmark condition. The number of overflow points may be increased so as to represent the river bank overflows as accurately as possible. The design flood will be simulated.

As the design flood rises, water may initially flow into a floodplain area by backflow up a drain, tributary stream or old river channel. Later water may flow over the river banks. As the flood recedes water may flow back to the Kaihu River over the river banks and through the drains, tributary streams, and old river channels. At some time during the flood the volume on any floodplain area and its attached side valleys will reach a maximum. The maximum volumes of water originating from the Kaihu River are proposed to be used to calculate the overflow volume proportions for the proposed scheme.

The proposed scheme relates to protection from the Kaihu River. Therefore in calculating the maximum flooding volume on each floodplain area (including its attached side valleys), the volume of tributary runoff will be discounted.

10. Design process to achieve fair distribution of floodwaters

In the design flood the water will just touch the crests of the overflow spillways, but there will be no overflow to the floodplain areas. It is proposed to design the overflow spillways so that in a spillway design flood slightly larger than the design flood (but in other respects having the same characteristics, such as hydrograph shape and distribution of runoff over the catchment area), the overflow volumes to the floodplain areas will be in the correct design proportions.

This will be achieved by adjusting the width and number of the overflow spillways. Some of the larger floodplain areas will need more than one overflow crest in order to distribute the overflow within the area.

The size of spillway design flood is to be established in detailed design, but it is expected to be not more than 50% larger than the design flood. It may not be possible to maintain the design flooding volume proportions in significantly larger floods. In large floods it is generally accepted that the whole valley will be flooded. Under these conditions it is expected that the scheme stopbanks will have relatively little influence on the distribution of floodwater amongst the floodplain areas.

11. Treatment of less floodprone areas

It is expected that in the benchmark condition (as described above) some areas will not be flooded by overflow from the Kaihu River in the design flood. It is proposed that such areas should maintain overflow spillways at the unmodified river bank level, so that they continue to take a share of floodwater in larger events. Private construction of floodgates would be allowed in such areas, as it would in the more flood prone areas.

12. Management of river sediment load and floodplain sedimentation processes

The sustainability issues associated with the river sediment load and the floodplain sedimentation process have been discussed above. It is proposed where possible to place overflow spillways on the inside of river bends, so that the water flowing into the floodplain areas will have a high suspended sediment concentration. This may reduce the volume of excavation needed to maintain the river channel, as well as allowing the floodplain sedimentation process to continue.

13. Council's and landowners' roles in construction, maintenance and monitoring

Council will be responsible for:

- Design of the scheme, including designated overflow crests, river channel cross sectional area, and specification of adequate floodgates to ensure drainage of the floodplain areas is limited by river levels only
- Construction of the overflow spillways
- River channel maintenance
- Monitoring the river channel by 10 yearly resurvey of an adequate set of river cross sections between Dargaville and Kaihu Gorge
- Monitoring the levels and widths of the overflow spillways
- Making suspended sediment measurements at Kaihu Gorge, and establishing a suspended sediment rating
- Establishing a network of peak flood level recording devices at the designated overflow crests, on the Kaihu floodplains, and in major side valleys, and recording the resulting information
- 10 yearly review of scheme performance, to adapt to climate change and sea level rise as necessary, and to take into account new data as it becomes available.

Landowners will be responsible for:

- Construction of stopbanks between the overflow spillways
- Construction and maintenance of floodgates
- Maintenance of farm drains

14. Effect of the proposed scheme in large floods

The effect of the proposed scheme on flood levels, extent and duration in the 10 year and 100 year ARI floods will be tested as part of the scheme design, to ensure that there are no significant adverse effects.

15. Conclusions

1. Quantitative investigation including computer modelling, and discussions with Council staff and the Kaihu River Scheme Liaison Committee, have clarified the requirements and constraints and allowed a flood management scheme concept to be formulated.
2. Some details of the concept remain to be resolved in the detailed design process, including the level of service to be provided, and the treatment of existing embankments (such as the old rail embankment) on the floodplains.
3. Economic conditions have changed since the original Kaihu River Scheme, in particular with the removal of Government subsidies. This will constrain the scale of both construction and maintenance works.
4. The economic assessments made in formulating the concept are not supported by quantitative analysis.
5. The assessment of floodplain sedimentation made in formulating the concept scheme is not supported by quantitative analysis, and there is at present a lack of basic data for such analysis.

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