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Preliminary Flood Study of the Buller River at Westport

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NOTE: with regard to this:

Preliminary Flood Study of the Buller River at Westport by Connell Wagner Ltd

Only Sections 1- 6 are included in this e-document.

Appendices A – E (maps, diagrams etc), all A2 sized, are

Available with the paper copies of this report (2) in the Buller Flood Hazard Information File Box.

M Trayes
WCRC EI Officer
August 2011

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1. Introduction

This report summarises work undertaken on behalf of the West Coast Regional Council to carry out a preliminary assessment of the flood risk to Westport from storm flows in the Buller River. The scope of the work involved is defined by the West Coast Regional Council brief for contract 2000/ 16.

Current flood hazard maps are based on both historical research and a study of the landforms surrounding Westport. However much of the current information appears to be based on personal accounts and this type of information can be unreliable. Since the flood maps were published Buller District Council have identified several anomalies between what has been observed and what has been recorded on the flood maps[1]. Although these differences are generally small, they can potentially have a significant impact in urban areas. This study goes part way toward more closely identifying flood extents in Westport – the proposed detailed phase of the study, which may or may not proceed after this phase, is intended to take water levels computed in the Buller River and define overland flow paths and top water levels associated with a major flood.

The study covers three main headings:

(i) A qualitative flood history,

(ii) An analysis of changes in river bed profile and sediment deposition patterns,

(iii) The development of a calibrated Mike11 hydraulic model of the lower reaches of the Buller River.

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[1] personal communication with BDC staff

2. Background and Flood History

In terms of mean annual discharge, the Buller River ranks as the third largest river in New Zealand, with a total catchment area of 6,350 km^2, draining a large part of the northwest of the South Island. First settled in the early 1860's, Westport is located on the eastern banks of the Buller River, close to the mouth of the river. Located close to the coal and gold fields of the Northern West Coast, Westport quickly developed as port facility.

Littoral drift at the Buller River mouth is in an West to East direction and before major port development began the river mouth location varied between a northern alignment and the present location of the Orowaiti River mouth, with a littoral drift sand spit forming between the river and the ocean, causing the river to periodically flow through what is now the Orowaiti lagoon. Port development saw the river trained with the aid of rock walls, forced straight out into the ocean in a Northerly direction. Considerable accretion has occurred on either side of the training walls, estimated over the period 1870 – 1979 to be 13.4 million cubic metres. The training walls have been periodically extended, the last occasion being 1966. Despite the attempts to concentrate channel flows, the port operation requires constant dredging in order to maintain required water depths.

A major overflow channel exists on the lower reaches of the Buller River, called the Orowaiti Overflow, which links the back channel at Organs Island with the Orowaiti Lagoon. Excess flow spills from a secondary river channel that runs behind Organs Island – this was originally the main river channel until the late 1920's when a diversion channel was formed (the approximate location of the present main channel). Water spilling from this secondary channel flows overland before passing across Nine Mile Road and underneath the Westport-Stillwater railway line via two wooden trestle bridges. Although this overflow occurs naturally, the large flood in 1926 (reputedly the largest since European settlement) prompted works to maximise flow through overflow, including increasing the span of the rail bridges and the State Highway 67 bridge crossing the overflow and removing some of the willows congesting the channel. Willow growth continues to be a major issue for the overflow, and control work appears to have been infrequently carried out.

The earliest documented large flood in the Buller River occurred in 1873. This event is recorded as having damaged or destroyed much of the northern end of Westport. Attempts to regulate flow through the Overflow using a stopbank (in an attempt to prevent the river using the overflow as its permanent channel) met with failure in the next major flood event in 1876. The following year also saw a major flood with subsequent large events occurring in 1877, 1882, 1890, 1892, 1896, 1900, 1905, 1924 and 1925. There is little documented damage associated with these floods and it is therefore not possible to rank these events. However two similar sized floods are recognised as being the largest since European settlement - the 1877 and 1926 events. Photographs of the 1926 event show much of the town center under 0.5 – 1m of water with river levels close to the top of the wharf. The 'old' Buller Bridge was damaged during this flood, with one pier being shifted downstream due to the force of water acting on accumulated debris and another sinking due to scour at the upstream pile.

Subsequent events were recorded in 1931, 1933, 1936, 1942 and 1949, with the 1933, 1936 and 1942 events flooding parts of Westport. The next major event after the 1926 flood occurred in 1950. Although not as severe as the '26 event this flooded part of Westport. Little is recorded between 1950 and 1970, suggesting that no extreme events occurred during this period. Flow records at Te Kuha begins in 1964 and from 1964 – 1969 maximum flows were typically less than the estimated mean annual flow.

The 1970 event is ranked as the largest since the 1926 event. Water depths through Westport were typically 0.5m deep, flooding buildings and houses in Gladstone Street (northern end of the town). Based on current analyses of flow data recorded at Te Kuha, since 1970 events larger than an estimated ten year Return Period flow have occurred in 1983, 1988 and 1993. Of these floods the 1993 event has the largest estimated Return Period of just over 20 years, compared with the estimated Return Period of the 1970 event of 41 years. No documented records of property damage in Westport were found for the 1993 event, although the bridge on the Seddonville Branch railway line spanning the Overflow was damaged.

In terms of recorded maximum flood extents, the existing flood hazard maps are likely to have been based to a large extent on photographs and anecdotal information related to the 1926 event. The extents of inundation in the overflow are reasonably easily determined by the surrounding topography, and much of the urban inundation is recorded in a series of photographs held by the Westport News.

3. *Cross Section Profile Changes and Sediment Issues*

3.1 Methodology

Surveyed cross-sections of the Buller River between Te Kuha and the river mouth have been analysed with the main objective being to determine mean bed levels for every surveyed cross-section at each bench mark location along the main river channel. Summary calculations of this analysis are presented in Appendix B - graphs illustrating the magnitude of the changes are presented on the following pages.

Mean bed level and other associated calculations were made using Microsoft Excel, with the mean bed level calculations made using a Visual Basic for Applications (VBA) programming routine. The steps involved in this analysis are as follows:

(i) Orientate cross-sections to ensure they are relative to one another. Datums were assumed to be the same and therefore relative vertical positions were not altered on any of the sections. However the 1999 data required reversing to be in a right bank to left bank[2] format (consistent with the 1972, 1983 and 1994 formats). The 1999 data in some cases also required correcting along the horizontal axis in order to match the channel location of the other sections. Note that the 1999 survey has presumably been undertaken for modelling purposes, hence the left to right bank orientation and the extension of some of the sections on to the river berms.

(ii) Determine a suitable level at each bench mark location to enable representative mean bed level calculations to be made. The VBA program uses the same reference level for all the surveys at each bench mark location, calculating the area between consecutive survey points across the channel, summing these areas together and dividing by the section width to calculate the average depth, which is then subtracted from the reference level. Note that in a few cases sections were extended/modified slightly to ensure an accurate comparison with the other sections at that location, (generally where the survey has only covered the main channel and not extended far enough up one or both banks of the channel). Note also that the 1983 survey focussed on the 3.5 mile - 6.5 mile reach of the river.

These calculations also determined changes in section area enabling an overall volume change calculation for the main river channel to be made.

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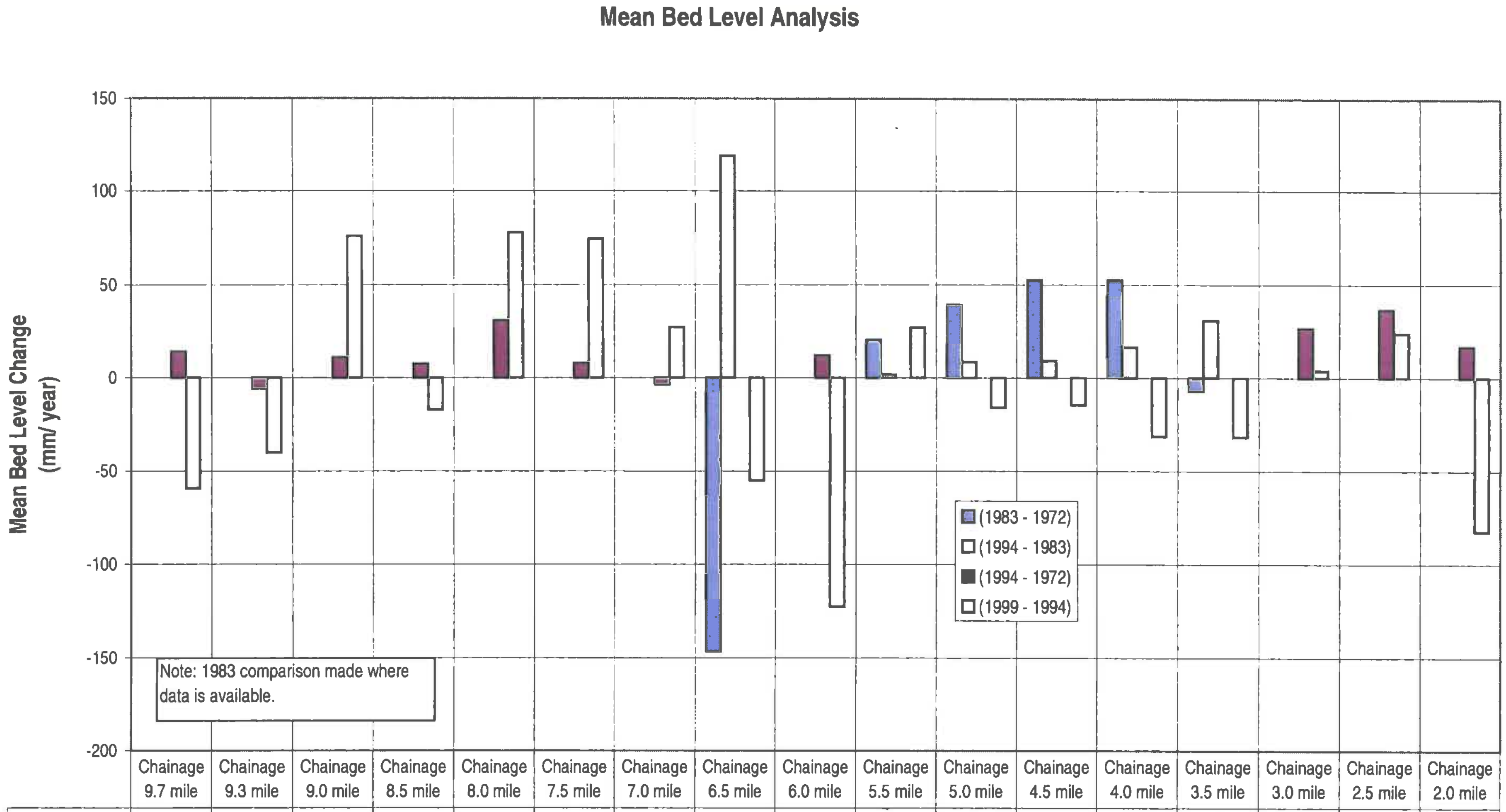
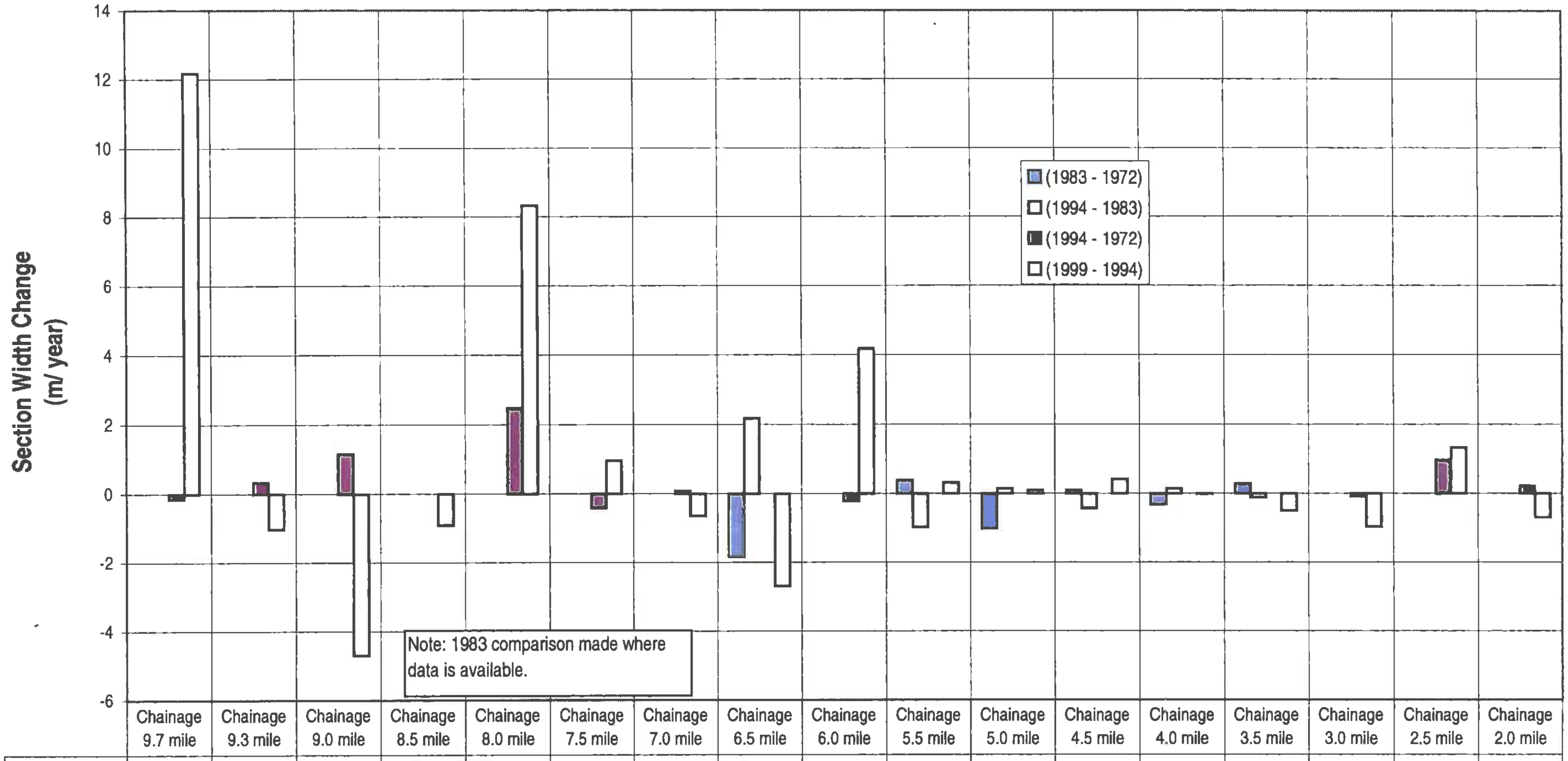
[2] all channel bank references are in ‘true’ format, that is, left bank on the left hand side when facing downstream.



	Chainage 9.7 mile	Chainage 9.3 mile	Chainage 9.0 mile	Chainage 8.5 mile	Chainage 8.0 mile	Chainage 7.5 mile	Chainage 7.0 mile	Chainage 6.5 mile	Chainage 6.0 mile	Chainage 5.5 mile	Chainage 5.0 mile	Chainage 4.5 mile	Chainage 4.0 mile	Chainage 3.5 mile	Chainage 3.0 mile	Chainage 2.5 mile	Chainage 2.0 mile
■ (1983 - 1972)								-147		20	39	53	53	-7			
☐ (1994 - 1983)								119		2	9	9	17	31			
■ (1994 - 1972)	14	-6	11	8	31	8	-4		12						27	37	17
☐ (1999 - 1994)	-59	-40	76	-17	78	74	28	-55	-122	27	-16	-14	-31	-32	4	24	-82

Section Width Analysis



	Chainage 9.7 mile	Chainage 9.3 mile	Chainage 9.0 mile	Chainage 8.5 mile	Chainage 8.0 mile	Chainage 7.5 mile	Chainage 7.0 mile	Chainage 6.5 mile	Chainage 6.0 mile	Chainage 5.5 mile	Chainage 5.0 mile	Chainage 4.5 mile	Chainage 4.0 mile	Chainage 3.5 mile	Chainage 3.0 mile	Chainage 2.5 mile	Chainage 2.0 mile
🟦 (1983 - 1972)								-1.84		0.39	-1.01	0.09	-0.32	0.28			
☐ (1994 - 1983)								2.18		-0.98	0.15	-0.43	0.15	-0.12			
■ (1994 - 1972)	-0.16	0.34	1.16	0.00	2.48	-0.41	0.08		-0.23						-0.09	0.97	0.22
☐ (1999 - 1994)	12.17	-1.02	-4.70	-0.91	8.33	0.96	-0.65	-2.71	4.17	0.32	0.09	0.42	-0.01	-0.51	-0.96	1.34	-0.69

3.2 Results

Referring firstly to the graphs summarising mean bed level calculations, there clearly is an overall trend toward aggradation in the river downstream of Te Kuha. Long section profiles show a change in grade at chainage 6 mile (the bend in the river approximately 1.5 kms downstream of Organs Island) and this point would also appear to differentiate between two overall mean bed level trends. Ignoring the extremes of the 6.5 and 6.0 mile results, where the nature of the section profile and the effects of the bend have exaggerated changes, above 6.0 mile an average rate of aggradation of 9mm/year was recorded between 1972 and 1999. Over the subsequent five-year period 1994 to 1999 changes become larger and less consistent, suggesting an increased rate of aggradation between 9 mile and 7 mile, while above 9 mile there has been appreciable degradation. Note that the 1999 survey at chainage 9 mile appears to have shifted position slightly, as the profile is quite different to those recorded in 1994 and 1972. Given the time interval the change may well be a small cycle rather than a long-term trend. However the 27 year interval between the first recorded and most recent survey would suggest a medium to long term trend toward aggradation. It is worth noting that flood events over this period have been no larger than a 23 year Return Period event – the 1970 event may have led to a significant decrease in mean bed levels , and this upward trend may be part of a larger cycle. Looking at sections width changes over this reach, the rate of increase between 1972 and 1994 is 0.5m per year, presumably the result of a more active meander in response to aggradation of the bed.

Between chainage 5.5 mile and the Buller Bridge trends are generally more consistent than above chainage 6.0 mile, most probably due to the flatter, more even grade of the channel; theory suggests that with less energy the river should adopt a more stable alignment, and the negligible section width change over this reach supports this. Where 1983 survey data is available, the analysis clearly shows appreciable aggradation. However the 1994-1983 comparison shows a reduction in the rate of increase and over the interval 1999-1994 an overall degradation trend becomes evident. The significant builds-ups evident between 9 and 7.5 mile may well explain this trend - small flood events have relatively low gravel/ sand transport potential, depositing much of the material immediately downstream of the gorge (where the widening in channel width reduces the transport capacity of the river), resulting in a sediment deficit and consequent degradation below the bend at 6.0 mile. Again these changes are symptomatic of a period when no large floods have occurred, the smaller events having insufficient energy to mobilise bed deposits in significant volumes or transport mobilised material through the lower reaches of the river and out to sea. Vegetation colonising gravel deposits, especially introduced species such as willow and tree lupin, may compound the problem, 'locking' up gravel in beach deposits which the river cannot easily mobilise.

Immediately below the bridge the trend toward degradation over the last five years is not repeated. This is possibly due to tidal effects causing sand-sized sediment to settle out. Chainage 2.0 mile becomes influenced by dredging, preventing any conclusions from being reached.

3.3 Extraction Policy

Records for volumes of sediment dredged annually in the port are as follows:

Year	Quantity Dredged at the Port	Quantity Extracted by Contractors
1991	341,650 m^3	-
1992	399,750 m^3	-
1993	397,650 m^3	-
1994	309,800 m^3	-
1995	-	1,750 m^3
1996	316,200 m^3	5,300 m^3
1997		7,750 m^3
1998	194,950 m^3	5,750 m^3
1999	282,875 m^3	2,250 m^3

Table 1 – Sediment Quantities Removed from the Buller River

Dredged quantities given are actual returns submitted to the Regional Council in accordance with the resource consent conditions. Returns appear not to be required for beach extraction carried out by Contractors, and therefore the numbers given are consent allocations rather than actual quantities removed. There are no records for the dredging prior to 1991 or for beach extraction prior to 1995. Records show that beach mining is carried out at two main locations; near the State Highway Bridge and at Organs Island. Based on these numbers on average just under 285,000 m^3 of material is removed from the river each year. Volumes dredged depend on buildups at the wharf and conditions at the mouth of the river, and in years with big floods volumes required to be extracted are likely to be less than the average. The current consent allows for a maximum of 400,000m^3 to be removed per annum.

In terms of beach extraction, Contractors obviously prefer locations with easy access and minimal haul distances. The preferred location in terms of river management is generally at a point where the channel is unable to transport the material mobilised, typically the transition from gravel to sand phase. However in large floods the Buller River has sufficient energy to transport gravel completely out of the system, so in effect there is no gravel/ sand phase transition. With this in mind it would seem prudent for Council to offer incentives to target reaches of the river where gravel is accumulating. The 1994 – 1999 comparison indicates that at present a two kilometre section of the river above Organs Island would benefit the most, stabilising bed levels and therefore reducing the mobility of the channel and consequent bank erosion. However this may change depending on flow regime – a series of large floods could cause the channel to degrade at this location and aggrade further downstream. Council should therefore consider more regular channel surveys (say 5 yearly intervals) to monitor points of accumulation.

3.4 Sediment Sources

Work done by Kirk, Haste and Lumsden[3] put the average annual sediment yield for the Buller at just over 1 million cubic metres per year. Obviously there are significant fluctuations year to year due to the exponential relationship between river flow and sediment transport rate, that is, once velocities are sufficient to mobilise the bed, further increases in flow cause successively larger increases in gravel/ sand volumes being transported. There has been a suggestion that the net aggradation of much of the river bed between Te Kuha and the Buller Bridge is at least in part due to:

1. New Zealand Rail's 'daylighting' of a tunnel in the Buller Gorge.

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[3] "Sedimentary processes operating around the entrance to a river mouth port, Westport, New Zealand", *New Zealand Journal of Marine and Freshwater Research*, 1987, Vol. 21 : 337 – 347.

2. Earthquake triggered landslides feeding gravel into the system.

An inspection of the Buller River in mid-June of this year showed the section of daylighted tunnel to be clearly evident. Although the exact date that the work took place has not been established, vegetation growth on the cut face and debris below the railway line would suggest that this took place in the earlier 1990's. At the time much of the broken rock excavated was dumped into the river channel and concerns have been expressed that this material may be a contributing factor to aggradation of the channel. This would seem to correlate with the mean bed level increases over the last five years at sections 9.0-mile, 8.0 mile and 7.5 mile. However the total decrease in channel volume between the gorge and chainage 6.5 mile over the interval 1994 and 1999 (ignoring the results for chainage 9.7 mile) is estimated at 230,000m^3, and a conservative (conceivable maximum) estimation of the percentage coming from the tunnel works would be 20%. The identification of this material on beaches downstream of the former tunnel site was intended to confirm this (the presence of angular rock indicating minimal transportation distance from source) but high river levels prevented an inspection being made.

The second potential source of additional sediment is earthquake-generated landslides. Two significant earthquakes have struck the Buller/ Kahurangi region during the 20th century. The most severe of these was the 1929 Murchison Earthquake, which generated landslides over a 7,000 km^2 area. The 50 largest landslides generated ranged in volume from 1 to 200 million m^3, although the bulk of these were concentrated in the Karamea River catchment. The Matiri River was the most severely affected part of the Buller River catchment, although the effects in terms of sediment load on the Buller were minimal as most of the slides were above Lake Matiri. Most of the other major landslides in the Buller catchment were concentrated along the Buller River between Lyell and Murchison. One of these slides blocked the river at Fern Flat, temporarily damming the river. However the largest landslide in the Buller catchment occurred in the Matakitaki catchment, killing five people and temporarily damming the river. This landslide had an estimated volume of 18 million cubic metres. A slightly smaller landslide occurred on the lower reaches of the Maruia River, killing four people and also briefly damming the river.

Although smaller in both intensity and landslide affected area than the 1929 event, the 1968 Inangahua Earthquake had an epicentre located in the Buller catchment. Landslides generated were restricted to the Buller downstream of the Maruia River confluence and the lower reaches of the Inangahua River, with the main concentration around Lyell and Inangahua. The landslide most commonly associated with the '68 earthquake is the 'Big Slip' that occurred approximately five kilometres upstream of Lyell. Estimated to have a total volume of 5 million cubic metres, this slide temporarily dammed the river.

Although this has undoubtedly added significant volumes of sediment to the river, there are several factors that make it unlikely for landslides generated by the '68 event to be a major contributor to current bed level increases downstream of Te Kuha:

1. The nature of the failures. Slide debris that constricted or blocked rivers and streams in the Buller catchment generally consisted of weathered mudstone or Granite[4]. Recent photos of the debris at the toe of some of the larger slides shows that much (possibly as high as 90%) of it is sand sized or smaller – the movement of the slide itself may have broken down some of the larger material. Once mobilised by the watercourse it is likely that a significant portion of the larger debris material was broken down under saltation, coming into contact with the sounder alluvial gravel already in the system, reducing much of the debris to its constituent components (mainly a quartz sand).
2. The nature of the channel between Lyell and Te Kuha. The Buller River over this reach is generally an incised and confined channel, with relatively small in-channel beach deposits. The exceptions to this are small meanders at Inangahua and Walkers Flat. Therefore in-channel storage capacity is relatively small, and in a medium to large sized flood gravel in suspension at Lyell could reasonably be expected to pass right through the system.

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[4] Personal communication with Graham Hancox, Institute of Geological and Nuclear Sciences.

3. The 1970 flood event. Estimated to have a Return Period of 41 years, this event is likely to have had the energy and the duration to transport much of the landslide debris generated by the '68 earthquake right through the system.

Based on the above points, and given that the Inangahua Earthquake occurred some 32 years ago, it is unlikely that the landslide debris generated by this event has significantly contributed to the 'recent' bed level increases below Te Kuha. Indeed the 1929 event is likely to have had a proportionately greater long term effect on sediment loads in the Buller River than the 1968 event, as the landslide volumes associated this earthquake were much larger.

As discussed, 'recent' bed level increases are more likely related to the lack of 'large' (ARI <2.5%) floods over the last 20 to 30 years. The 1970 event almost certainly lowered bed levels throughout the main channel, and although the perception is that the present accumulations will cause higher flood levels, an event of similar size will almost certainly have a similar degrading effect on bed levels. This trend is supported by bed level records between chainage 2 mile and 2.7 mile over the period 1927 and 1947[5] – rates of aggradation over this period were in the order of 80 to 100 mm/ year, despite an average of 230,000m^3 of material per year being dredged at the port. Given the size of the 1926 event bed levels could be expected to have been appreciably lowered, leading to relatively rapid aggradation afterward (no major floods occurred between 1927 and 1947).

However in our opinion it is undesirable to let excessive aggradation occur in the lower reaches of the Buller River, especially where it is relatively localised. Aggradation generally leads to more active meanders by the river, requiring bank protection works to prevent loss of alignment control (rock groynes between the State Highway and the river between chainage 8 mile and 8.5 mile illustrate the aggradation and consequent more active meandering of the channel over this reach).

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[5] Correspondence with the former Harbourmaster, Bob Gower.

4. Hydraulic Modelling

4.1 Model Construction

The third stage of the study involved the construction and calibration of an unsteady state hydraulic model of the Buller River from Te Kuha to the river mouth, analysing overbank flow thresholds and quantifying flows along major secondary flow paths (where channels are able to be defined) for a range of tidal and flood conditions. As stated in the methodology section of our proposal, we have used Mike11 for this task. Summarising the model construction, the steps involved are as follows:

1. Load cross-section data,
2. Define branches ,
3. Estimate roughnesses,
4. Add relevant controls.

The Regional Council provided cross-section data for the model, surveyed July/ August 1999. This information was supplemented where necessary with a long-section profile of the top of the right bank (surveyed March/ April of this year), and bench mark levels throughout Westport. Based on this information the model incorporates three branches; the primary Buller River channel, the back channel behind Organs Island and the Orowaiti Overflow. Although the brief referred only to the main channel, in large floods the Overflow carries 10 – 15% of the total flow, and without it the model would overpredict maximum water levels in the main channel. The Overflow branch runs as far as Soapworks Road, roughly 1.5km upstream of the Orowaiti Lagoon, extending well passed the main control on the Overflow, the Westport – Stillwater railway line, to avoid drawdown effects at the boundary influencing water levels at the railway bridges.

Input format for entering channel roughnesses into Mike11 involves entering a global roughness and factoring this as required for each surveyed point in each cross-section. A global Manning's 'n' of 0.03 was used for the main channel, with 0.04 used for the secondary channel at Organs Island and for the Orowaiti Overflow, both factored where necessary to allow for vegetation effects. 0.03 for the main channel is based on the back analysis of a section of the Buller River located approximately four kilometres upstream of the rail bridge at Inangahua (known as 'Woolfs')[6]. Photographs of this reach show that both the channel profile and bed material are similar to the reach between Te Kuha and the Buller Bridge. Bed roughness is a function of channel characteristics, particle size distribution and flow, generally trending toward a base value with increasing flow. The Buller River at Woolfs clearly shows this trend, and above 500 m^3/s Manning's 'n' is relatively consistent at 0.03. The increase to 0.04 for Organs Island and the Orowaiti Overflow represents the greater influence that roughness has on flow – the hydraulic radius of the main channel (ratio of area to wetted perimeter) is typically 4 times that of Organs Island and the Overflow. Values of 0.035, 0.04, 0.05, and 0.1 were used to approximate the effects of progressively denser vegetation on the banks and berms of the channel, 0.035 used for open farmland and 0.1 used for bush. Values for Organs Island and the Overflow were typically 20 – 30% higher. An artificially high roughness was used on the first section of the Overflow, to allow for losses associated with the Overflow joining Organs Island at right angles.

Once roughnesses had been approximated along all the branches of the network, points of control were added. With the present extents of the model there are two major controls, the two trestle bridges crossing the Orowaiti Overflow and the State Highway 67 'Buller' Bridge. Surveyed cross-sections of the rail bridges were obtained from TranzRail and entered into the model. These bridges were approximated in the model as a weir and culvert, with the weir a height/ width relation and the culvert referencing the cross-section database. Losses for the culvert were then adjusted in order to closely match hand calculations and calibration data.

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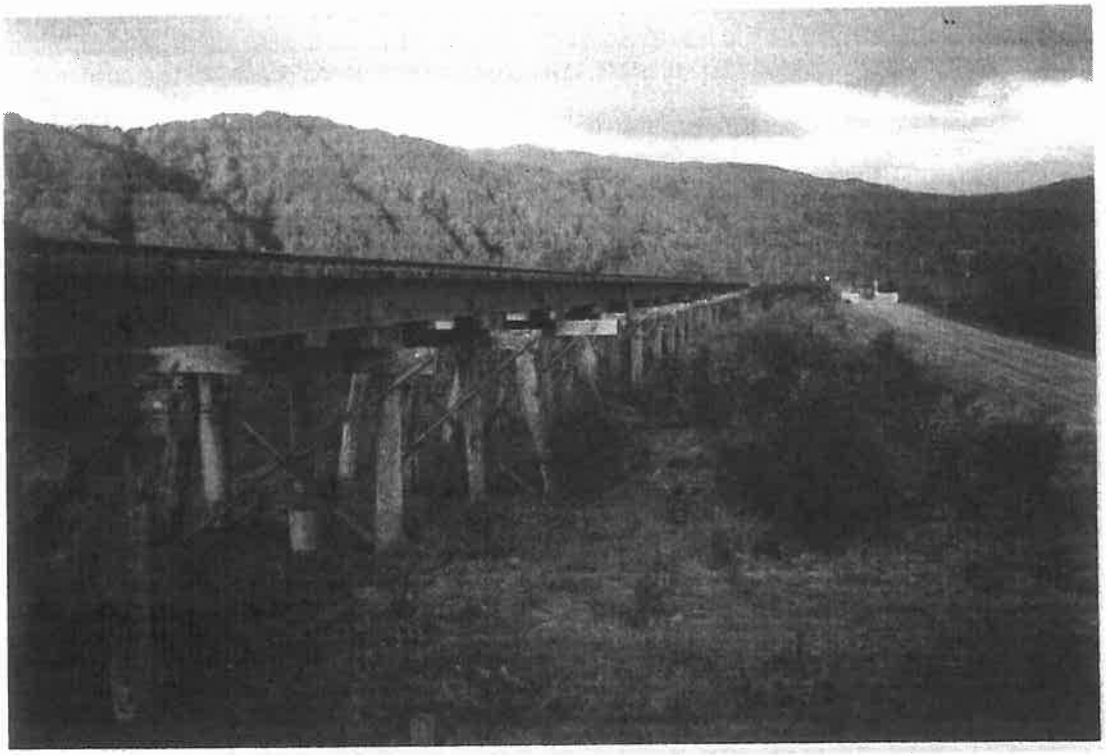
[6] "Roughness Characteristics of New Zeland Rivers"by DM Hicks and PD Mason, published by NIWA.



Photograph 1 - Railway Trestle Bridges Spanning the Orowaiti Overflow

Note that New Zealand Rail decreased the available waterway area of the bridge in the mid-1980's, replacing a section of the bridge with an embankment and thereby splitting the one trestle bridge into two separate structures. The model has been adjusted to allow for this.

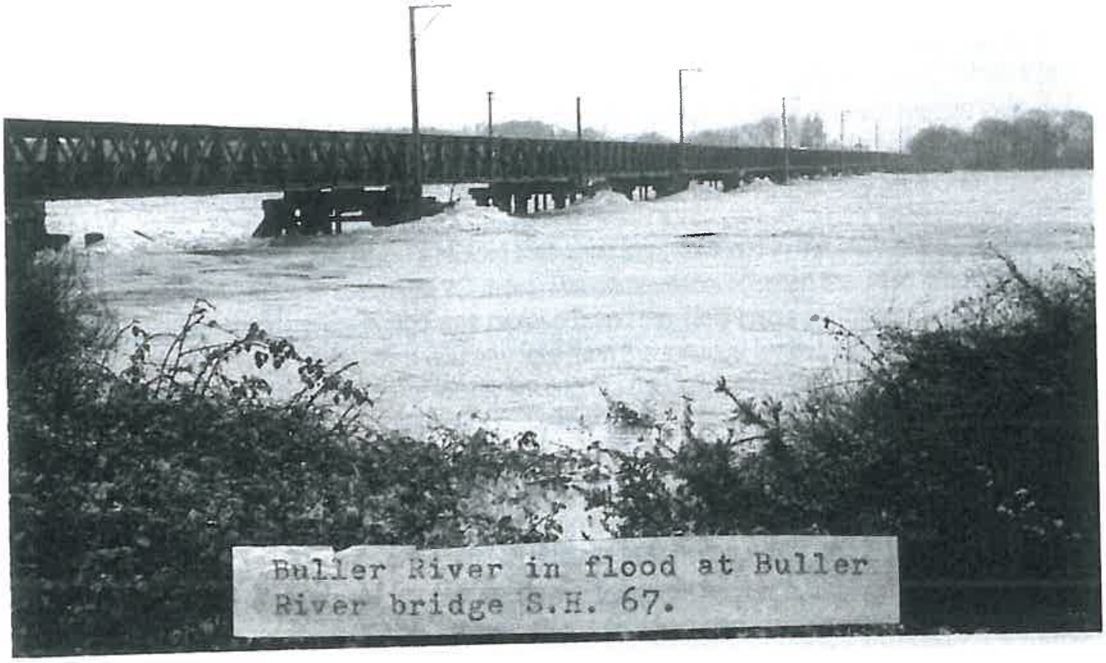
The second major control is the Buller Bridge. Originally constructed in the 1880's, the structure was replaced in the mid 1970's with a standard, pre-cast Ministry of Works structure. This bridge was approximated in the model in a manner similar to the Orowaiti Rail bridge – entered as a weir/ culvert, with inlet losses adjusted to match head losses indicated by hand calculations and photographs/ debris levels.

Two dummy sections were added to the bottom end of the model, extending it out into the Tasman Sea, enabling a tidal cycle to be added to the model. This tidal cycle is based on predicted levels from the relevant nautical almanac, with a storm surge component added. Storm surge data was based on previous Connell Wagner work at Westport – the surge profile has been superimposed on the design tide cycles for the 1970 and 1979 events, the graphs of which are presented in Appendix C. Note that the initial intention was to use actual recorded data from the Harbour Board recorder. However almost the entire data set is in an unprocessed state.

4.2 Model Calibration

In order to fine tune the model, selected historic flood events were simulated and compared with actual recorded flood heights. Two recorded flood events were selected for this purpose – the 1970 and 1979 events. The period of record available from the Te Kuha gauge (jointly operated by NIWA and the West Coast Regional Council) is from July 1963 to the present day, and the largest recorded flow over this period was on the 31st of August 1970, the most recent statistical analysis putting the Return Period of this event at 41 years. The second event occurred in 1979, estimated to be a 10 year Return Period event. These events were selected because they represent a major and a more common flood event and each has relatively good calibration data associated with it.

However the drawback with using historical events is that channel characteristics have often changed since this time. In the case of the Buller these are the replacement of the Buller Bridge in 1976, the rise in mean bed levels and changes in vegetation type along the river berms.



Photograph 2 - The 1970 Flood at the old Buller Bridge (taken from the left bank facing slightly downstream)

Photograph 3 - The 1979 Flood at the new Buller Bridge (taken from the right bank facing upstream)

The two photographs above illustrate the reduction in pier losses associated with the new bridge. To account for the replacement of the bridge two models were developed, the first including losses associated with the old bridge (pre-1976), and the second with smaller losses associated with the new bridge (post 1976).

As concluded in Section 3, mean bed levels over much of the lower reaches of the Buller have risen between 1972 and 1999. The constructed model has utilised cross-sections surveyed in 1999, as the power of a hydraulic model is in it's present day predictive capabilities. However running historical events through this model will give water levels higher than those that actually occurred. While it is possible to substitute the 1999 cross-sections with the 1972 cross-sections, this will require the construction of virtually a whole new model (bank/ berm roughnesses will need to be adjusted for the conditions at the time of the event), making it redundant for present day predictive purposes.

With this in mind, there are a number of factors that need to considered in the calibration process:

(i) bed level changes at Chainage 2.7 mile. The comparison between the 1975 cross-section (immediately before the bridge was replaced) and the 1999 cross-section shows a net increase in mean bed level of 380mm, less than the average for this section of the river. This is most likely due to pier scour locally limiting the bed level increase,

(ii) not all of the bed level increase will translate through to the maximum water level (the percent reduction on the flow area at high water levels will be much smaller than at lower water levels), and

(iii) the recorded level for the 1970 event was probably a static debris level on a pier (Photograph 2 illustrates the difference between water levels in front of the pier and the average water level across the river) and the average maximum water level was probably 200 – 300mm lower.

For the 1970 flood the computed top water level was 5.53m above Mean Sea Level compared with the recorded level of 18.3ft[7] (5.58m) – given the above points the predicted level would seem to match well with that recorded. Hand calculations gave estimated head losses at 250mm, less than Photograph 2 would indicate - the final model has a maximum head loss of 360mm. A debris mark was recorded along Nine Mile Road at the bridge crossing the Overflow. The recorded level at this location was 9.23m, compared with a computed top water level of 9.28. Hand calculations suggest minimal head losses and the model has been adjusted to match this.

Given that point (iii) above is not relevant to the 1979 event, the greater over prediction by the model (a computed top water level of 4.69m compared with that estimated from Photograph 3 of 4.5m) would seem to give a close match once bed level increases are allowed for. Head losses through the bridge are estimated from hand calculations to be in the order of 150mm, matching well with that indicated by Photograph 3. Head losses in the model have been adjusted accordingly to match these.

Longsections showing computed top water levels for the 1970 and 1979 events are presented in Appendix D.

4.3 Modelling Results and Conclusions

Conclusions that can be taken from the modelling to date are limited to the extents of the surveyed cross-sections. Most affected is the floodplain on the right berm, including Westport, where there are at present no surveyed cross-sections or spot height information. Although the contribution to total flow from the right berm will be negligible (and therefore the accuracy of the current model is essentially unaffected by not having this berm area included in the model), this area is relatively intensively developed, and therefore of great interest. Aerial photogrammetry and the development of a Digital Terrain Model (DTM) would permit an accurate determination of overland flow paths and flood

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[7] Supplied by the retired Harbour Master, Bob Gower.

extents during large floods. Flood hazard modelling work for the right berm is intended to be covered in a future study.

Note that the extent of flooding relates not only to the peak flow of a particular event but also its duration. Hydrographs for the 1970 and 1979 events (see Appendix C) show that although the maximum flow associated with the 1979 event was smaller than the 1970 event, the duration at which the river was above a flow of 6,000 m³/s was not significantly less for the 1979 event. Therefore the effects of the 1979 event were greater than the maximum flow would suggest.

Conclusions that can be reached for this first phase of the study are:

- Ignoring chainages 9.7 mile and 9.3 mile, which are located in the gorge, overbank flow along the right bank between chainage 9 mile and 7.5 mile begins to occur at peak discharge for the 1970 event, making the threshold a 40 year Return Period event;
- At 2,200 m³/s flow begins to move through the back channel at Organ's Island;
- The threshold for flow into the Overflow is estimated to be 3,000 m³/s, less than the estimated mean annual flood (4,894 m³/s);
- At peak discharge for the 1970 event (8,500m³/s) 18% of the total flow runs through the back channel at Organs Island, with just over half of this running out through the Overflow;
- Organs Island begins to be inundated in a 2 year Return Period event, becoming entirely flooded in events greater than 4 years;
- Flow overtops the right bank of the Organs Island channel above the Overflow confluence, re-entering the channel a few hundred metres above the Overflow confluence – this is estimated to have a threshold roughly equal to the mean annual flood;
- Section widths reduce and channel grades increase around chainage 6.5 mile, causing channel velocities to increase and water levels to drop (identifiable on the longsections);
- Between chainage 6 mile and 5 mile maximum overbank flow depths vary between 100mm and 1.0m. A series of old channels are visible on aerial photographs, linking chainage 6.51 mile in Organs Island with chainage 5 mile on the main channel. The threshold for this mechanism to occur is estimated to be slightly less than the mean annual event (no cross-section data exists to be able to model this mechanism);
- Between chainage 4.5 mile and 4 mile the right berm steps up onto a higher terrace (evident when driving along Nine Mile Road), higher than maximum water levels generated during the 1970 event and almost certainly higher than the predicted 100 year maximum levels;
- Right berm levels begin to decrease at chainage 3.5 mile (close to the computed top water level for the 1970 event) and at 3 mile the berm is inundated to a depth of 1.4m (at maximum flow for the 1970 event and incorporating losses associated with the old bridge). This low level section of berm extends approximately 1km upstream and is almost certainly the path by which floodwaters enter western parts of Westport (the higher terrace between chainage 4.5 mile and 4 mile blocks overland flow from entering Westport from the south);
- Flow also bypasses the bridge over the left berm, flooding State Highway 67 and Cape Foulwind Road. With the data available it would appear that the threshold for this to occur is a 10 year Return Period event (using the losses associated with the new bridge).

In addition to the brief we have run a synthetic 100 year Return Period hydrograph through the model, and the longsection showing water level profile along the main channel is presented in Appendix D. Note that the hydrograph was based on the shape of the main peak in the 1970 event, extrapolated out using the statistical estimate of the maximum flow for the 100 year Return Period event (supplied by WCRC). The computed levels are preliminary for discussion and should not been used for floodplain delineation and/ or building control.

Preliminary indications are that in a 100 year event debris may begin catching on the soffit of the highway bridge. Although pier losses associated with the new bridge are less than those generated by the old bridge, the soffit of the new bridge is 0.35m lower than the old bridge, giving a clearance of

0.45m between bridge soffit and computed top water level, less than the current minimum requirement given in Transit New Zealand's Bridge Manual (1.2m). In the event that debris does begin stacking up against the side of the bridge deck noticeable backwater effects could be expected, potentially increasing the extent and severity of flooding through Westport.

5. Recommendations

i. With regard to Section 3.4 - Sediment Sources, the presence of angular rock on beaches downstream of the former tunnel site was intended to confirm the effect that the tunnel daylighting work has had on bed levels, but this was prevented by high river levels. The Regional Council may wish to confirm the presence of angular material on beaches downstream of the gorge when weather conditions are more favourable.

ii. From Section 3 - Cross Section Profile Changes and Sediment Issues, we recommend that the Regional Council take the following actions:
   - Continue to regularly monitor river bed level profiles downstream of the gorge;
   - Direct Contractors to locations where aggradation has been identified and is having adverse impacts, using a series of incentives (forming or improving access tracks, discounting administration/ supervision costs etc);
   - Consider 'ripping' armoured/ vegetated beaches in aggrading sections, especially if the trend toward aggradation in the upper section and degradation in the lower section continues;
   - Continue encouraging dredging at the port. Westport benefits from dredging at the port – river levels would almost certainly be greater without this, lowering the threshold at which Westport becomes inundated;
   - Work with the Buller District Council in developing a joint control program to manage willow growth in the Orowaiti Overflow.

iii. From Section 4.1 - Model Construction, essentially all of the tidal data recorded in the harbour is in an unprocessed state. Access to this information would enable a greater degree of confidence in estimating downstream boundary conditions. We strongly recommend that the Regional Council have Land Information New Zealand process this data so that it can be used in any future analyses (this will be of critical importance in accurately predicting flood levels through Westport).

iv. In reference to Section 4.3 - Modelling Results and Conclusions, even crude assessments of the direction and scale of flow across the floodplain outside areas covered by cross-sections proved impossible with so little information available. We strongly recommend that aerial photogrammetry of the floodplain be undertaken to enable a Digital Terrain Model (DTM) to be constructed.

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- Land Information New Zealand,
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