Waitohu Stream Study

Flood hazard assessment

River characteristics and sedimentation

Gary Williams
G & E Williams consultants Ltd
Otaki
April 2004

Waitohu Stream

River Characteristics and Sedimentation

and

Channel Management

Preface

Gary Williams of G & E Williams Consultants Ltd was commissioned to undertake a study of the morphology and sedimentation processes of the Waitohu Stream. In particular he was to consider the sediment supply budget of the stream and to recommend appropriate channel widths for ongoing management. An analysis of the stream morphology and sedimentation was carried out with the aid of aerial photography taken since 1948 and repeat surveys of channel cross sections, and a report was completed in 2004. Following a meeting between Flood Protection staff of Greater Wellington and Gary Williams to discuss the report and its implications for stream management, a brief report on stream channel management was also prepared. These two reports, along with maps of the suggested design alignments are bound together in this document.

WAITOHU STREAM – FLOOD HAZARD ASSESSMENT

RIVER CHARACTERISTICS & SEDIMENTATION

1 INTRODUCTION

The Flood Protection Group of the Wellington Regional Council is carrying out a series of investigations for its Flood Hazard Assessment of the Waitohu Stream. This investigation concerns the nature of the stream channel, covering the geo-morphology (or formative influences) of the stream and its sedimentation processes.

The stream conditions along the study reach of the Waitohu Stream change markedly, and an assessment of the way in which the form and behaviour of the stream changes is especially important for an appropriate management of the stream. The catchment and study length are shown on Figure 1.

The Waitohu Stream drains relatively steep and rugged foothill land of the Tararua Range, and has a catchment area of 54 km^2. From the start of the study reach, the stream flows across one side of a relatively steep plain of old alluvial deposits, and the stream has a defined channel area within a terrace system. This terrace entrenchment peters out upstream of the State Highway bridge, and from here to downstream of the Railway bridge there is a natural deposition area. Most of the gravel bed material carried down by the stream is deposited in this reach, due to the flattening of the grade of the stream, and without intervention a depositional fan would form in this area.

Below the Railway bridge the stream flows across a much flatter alluvial plain, within the landward limit of the coastal sand dune formations. The stream has a single well defined and meandering channel, with regular flood overflows across the alluvial plain, while still retaining a gravel bed with minor beaches. The existing channel follows an artificial diversion, which has been altered by slow processes of bank erosion and deposition, to give a meandering channel along the original straight alignments.

Downstream of the Old Coach Road bridge the stream channel becomes even flatter and more meandering, as it crosses what would have been a large area of swamp land. Along this reach tree vegetation along the banks is generally more intrusive and constricting.

The reach within the terrace system, between the Ringawhati Road and State Highway bridges, is very active, with the low flow channel and overall channel form changing from flood to flood. The channel has the overall form of a single low flow channel within an extensive gravel area, but this low flow channel is continually moving and splitting around gravel islands, as the channel migrates through the erosion and deposition processes of flood events.

In the past there has been a significant amount of extraction of gravel from the stream where there is the major change of grade, from the State Highway to below the Railway bridge. Increasingly stringent standards for road aggregate has reduced the usefulness of the Waitohu Stream gravel, and extraction has been more restricted over about the last decade. Bed material is extracted from around the Railway bridge on occasions and dumped beside the rail track. Below this bridge there is an on-going operation of dozing the deposited gravels from the channel to stockpiles on each side of the stream.

2 RIVER CHARACTERISTICS

2.1 GENERAL

The nature of a river, the type of channel form it has and the dynamics of its flows and sediment transport processes, depends on the characteristics of its catchment. The physical form and processes of a river are then primarily determined by the climatic regime over the river catchment and the physical setting of the catchment in terms of topography, geology, vegetative cover etc.

The characteristics of the Waitohu Stream, downstream of the Waterworks bridge, have then been assessed from a general study of catchment conditions, and an investigation of channel form and river conditions. This investigation has been based on aerial photography taken since 1948, repeat surveys of channel cross sections and empirically derived relationships between channel form and measurable stream parameters.

2.2 AERIAL PHOTOGRAPHY & CHANNEL SURVEYS

The earliest vertical aerial photography of the Waitohu Stream was taken in April 1948, and since then such aerial photography has been repeated as part of aerial survey runs at irregular intervals. Since 1990 approximate (non-rectified) aerial photography has been taken at intervals, providing colour photography. Accurate aerial photographic plans have been produced from the latest run of March 2002.

A selection of the available aerial photography has been obtained, as given in Table 1 below.

Aerial Photography Table 1

DATE	SURVEY
Apr-48	NZAM 198
Apr-66	NZAM 1847
Mar-83	NZAM 8171
Apr-90	Colour Prints
Sep-96	Colour Prints
Mar-99	Colour Prints
Mar-01	Lawrie Cairns
Mar-02	Lawrie Cairns

2.2.1 1948 Stream Channel

The 1948 photography showed an incised stream channel within complex terracing, of recent cut faces and older wider terraced flats, after leaving the hills. There was no tree vegetation along the stream course, and in general a single main channel followed a very winding and in some places very distorted course. This channel would have been migrating rapidly within the wider terraced land, with minimal channel splitting. A higher terrace face along the southern true left side fixed the extent of channel movement on this side.

Below the Waitohu Valley Road bridge the stream flows across a wide depositional plain, and its course across this sloping plain is unconstrained. In 1948 the stream approximately followed the present course. However other channel courses are clearly apparent in the photography, and over time the stream would have followed distinctly different courses.

The channel process would have been one of channel build up – over this reach where there is a marked reduction in grade – and then break out, with the stream following a completely different course for a long distance. An early survey plan, of 1875, shows the main channel across this plain coming from a confluence with the Ngatotara Stream to cross the Railway line where the Greenwood Stream presently crosses the line.

At the bottom of this plain the Waitohu Stream and its tributaries flowed through a swampy area beside the sand hills of an extensive complex sand dune formation, and then passed through the formation to the Old Coach Road. The stream then followed a very windy meandering course across a low-lying swampy inter-dunal area, to pass through another extensive sand dune formation to the sea.

In 1948 the stream flowed around a wide sandy spit to its mouth at the north end of the spit.

2.2.2 1966 Stream Channel

The lower reaches of the Waitohu Stream were included in a 'River Control and Drainage Scheme' for the Otaki area, which commenced in 1950. The 1966 aerial photography shows a significantly different channel form between the Ringawhati Road bridge and the State Highway. The channel upstream of the Waitohu Valley Road bridge was straighter, with a low flow channel meandering within wider bare gravel areas, and with some channel splitting. Downstream of Waitohu Valley Road there was less change, but the channel is somewhat more split, and has been straightened over a short reach below the bridge.

Downstream of the State Highway there had been very little change in the channel, except at the area of major deposition, where there had been some channel movement, and a channel loop had been cut off.

The swampy area by the sand hills had been drained, and a channel dug through the area. The Ngatotara Stream diversion had been constructed. Upstream and downstream of the Old Coach Road short diversions had also been cut through some of the very twisty meanders.

There was still virtually no tree vegetation along the stream.

The stream mouth was at the southern end of the sandy spit, with a large meander loop just upstream within the spit area.

2.2.3 1983 Stream Channel

There was no significant change in the channel form between 1966 and 1983. There was some scattered tree vegetation along the stream by 1983, and in the reach around the Waitohu Valley Road the position of the active (bare gravel) channel was different, due to the channel migration typical of the channel form.

2.2.4 Stream Channel in the 1990's

There is a periodicity in flood flows, between quiescent and more stormy periods, and streams become more active (in terms of erosion and deposition processes) during periods with a greater than average number of significant (> 2 year return period) and intense storms events. There is only a very short record of flood flows in the Waitohu Stream (less than 10 years), but a large flood event occurred in March 1990, with another significant event having occurred in January 1990. These floods seem to have marked a change to a period of more floods, with significant events in 1991, 1996, 1998 and 2000.

The flood activity of the 1990 flood events resulted in an enlargement of the bare gravel areas along the stream above the State Highway. A tight channel loop upstream of the Ringawhati Road bridge was cut through by the stream, and this new course was then established as the stream channel. Channel re-shaping work with the re-alignment of the low flow channel was carried out, and partly because of this the low flow channel was much straighter than it would be naturally.

Over the 1990's vegetation buffers were established along both sides of the stream upstream of the Railway bridge, with the stream being contained within a relatively straight fairway area. This intervention altered the channel form, with the low flow channel having a much longer meander, and a general alternating of beaches from one side to the other, as shown on the 1996 photography.

The 1999 photography showed a general increase in tree vegetation along the lower reaches up to the Railway bridge. Upstream of this bridge, vegetation buffers had become established over most of the length of the stream up to the Waterworks bridge. Large areas between the buffers – in the fairway area – had been naturally re-vegetated, and in places the stream was being confined and deflected by these re-vegetated areas. At the same time, where stream meanders had cut into and migrated up to the buffer vegetation, large embayments with a tight curvature had formed and the main channel had been sharply deflected.

The stream in 2001 was very similar to the 1999 conditions. The buffer zones had become more established, while in places the vegetation within the fairway had become denser and with more tree establishment. The low flow channel along the fairway reach of the stream was also somewhat more split up and distorted.

The 2002 photography shows an increase in the vegetation within the fairway, with a rapid colonisation of the gravel beaches taking place. The main channel has also developed a more definite and well-defined oscillating meander around the vegetating beaches.

The stream is then re-developing a more incised meandering channel, but now within the area defined by the fairway and its edge buffer zones. Thus where the stream is eroding into the buffer trees the bank is relatively high, and the stream can undercut below the root zone of willows.

2.2.5 Channel Cross Sections

Cross sections of the stream channel were surveyed from the mouth to the Waitohu Valley Road bridge in 1978. A repeat survey was carried out in 1992, with the section survey extended up to the Waterworks bridge. A further repeat survey was carried out in 2003. The survey lines for the later two surveys were not always the same as for the 1978 survey.

No analysis has been undertaken of the cross section data, in terms of mean bed level calculations or changes in bed levels and bank accretion or erosion. The repeat surveys have, though, been plotted at the same scale, and overlaid as far as possible. A visual assessment has been carried out using these multi-plots.

The section surveys indicate little change in either the bed level or section area over the lower reaches of the stream. There was some tendency towards bed degradation and bank accretion between the 1978 and 1992 surveys, with an opposite tendency between the 1992 and 2003 surveys. Above the State Highway bridge the stream has a steep grade, and bed levels do not alter significantly. The shifting of the main channel shows up in the section surveys, with some entrenchment of this channel in the 2003 survey.

2.3 CHANNEL MEANDERS

The type of channel and the nature of the waterway environment varies down the length of rivers and streams, as well as from catchment to catchment. There may be a rugged stepped form in the steep headwaters, and then a semi-braided form with a main channel but islands and flood overflow channels, or a fully braided form of multiple channels. Further down the form may change to a channel with alternating beaches from bend to bend, and then become a more sharply incised and highly meandering channel.

The Waitohu Stream has a relatively small catchment, and falls rapidly from steep range land across a tilted outwash plain to a geologically recent flat coastal plain of swamp land and sand dunes. The channel form and the natural river environment thus change greatly, in concert with the landform changes.

The natural meander form of the stream, and the way it varies down its length, has been assessed using empirically derived formulae for channel widths, and simple wave form relationships between width, radius of curvature and wavelength of the meander. The formulae use different combinations of the main channel forming characteristics of flow, slope and bed material size.

The formulae have been derived from measurements on different types of rivers, and relate to channel form under different regime conditions. The formulae do not define the plan configuration of the channel, and the type of channel has to be assumed from the general nature of the stream when applying the results of the regime formulae.

The type of channel along any reach depends on the relative erodibility of the bank material compared to the transportability of the bed material, as well as the relative power of the flood flows in moving and transporting these materials. Where the relative power is low, for instance in the upper catchment where flood flows are small and baserocks are exposed, or where there is a large input and throughput of gravel bed material, the channel formation is associated with bed material movement. Here the channel form relates to the threshold of motion regime conditions. Where flood flows can fully mobilise the bed material, these flows are dominant in the channel formation processes, and the channel form reflects the form of the flood flows. The different channel types the formulae relate to are outlined in Table 2.

The characteristic flood flow is taken as the 2 year return period peak flow which is representative of the channel forming energy of the flood flow. The available energy for a given flow depends on the slope, and this has been determined from a profile plot of the stream channel, using the minimum bed level of the active channel at each of the surveyed cross sections (see Figure 2). The channel slope, in terms of flood levels, has also been determined from the output of the hydraulic modelling of the stream.

The size of the bed material of the stream channel determines the resistance to the flow, and a medium size for the surface armouring layer has been determined from samples taken from beach deposits. The samples were selected to be representative of the bed material, and a 0.5 m^2 area of surface material to the underside of the exposed stones was collected, and then dried and sieved to give a size grading curve. The sample sites are shown on the Design Channel plans. The resulting grading curves are shown on Figure 3.

The widths of the natural channel meanders, as estimated by different formulae, are then as given in Table 3. These formulae relate to different natural meander forms, covering both threshold of motion conditions where the bed material has a high resistance to the imposed forces of flood flows, and flow dominant live bed conditions where the flood flows fully mobilise the bed material.

Because of the large size of the bed material and the roughness of the bed, the channel form of the Waitohu Stream would generally be dictated by the narrow meander of the threshold of motion conditions.

Actual stream conditions, as they exist, and as they have varied over time, as shown by the repeat aerial photography, indicate that a threshold of motion regime applies throughout the study length of the Waitohu Stream. Despite the change in channel slope – from a steep slope of around 1½ metres per 100 metres above the Waitohu Valley Road bridge, to a very flat slope of about 1 metre per 1000 metres around the Mangapouri Stream confluence – the main channel retains a similar threshold of motion width and form. From Wakapua Farm downstream this main channel has a single incised channel form, with flood waters spilling over a wide flood plain area. Upstream, under present conditions, this main channel forms within a defined stream corridor, with partly active and partly re-vegetating gravel beaches.

2.4 DESIGN CHANNEL

The stream channel along the steep reach of the Waitohu Stream above the State Highway is naturally a narrow tightly meandering channel, which is highly mobile. The stream could not be managed by trying to fix the position of this narrow channel, and space has to be provided for meander migration. However, because the channel form relates to threshold of motion conditions and not live bed flow dominant conditions, a wider fairway approach is not really appropriate either. Flood flows are not sufficiently powerful to mobilise all of the fairway area and maintain an active channel over the fairway. This is demonstrated by the re-vegetation of the fairway that is occurring at present.

A stream corridor approach has, therefore, been applied, with the width of this corridor based on the live bed fairway width. However, the management of this defined area would be different. The rapid re-vegetation trend has to be managed, and the buffer zones are more a tree border zone than an edge protection measure for an actively worked fairway. The buffer zone does not, then, have to consist of edge protection willow trees, but can be more diverse. The aim is to provide a defined border to the stream activity area, but one that has a flexible edge, and can thus be maintained over time through vegetation management.

A design channel and buffer areas have then been drawn up on this basis, as shown on the Design Channel plans. This design channel has been drawn up from the Waterworks bridge to the deposition area at Wakapua Farm. Along the uppermost and lower reaches, the wider threshold of motion meander, that takes account of the actual slope of the stream, has been used. This gives a 20 metre wide design channel. Otherwise the live bed fairway width of 35 metres has been used. Minimum buffer zone width would be 10 and 20 metres respectively. However, the suggested buffer zones also relate to existing tree vegetation and the topography of terraces etc along the reach.

No design channel – based on natural meanders – can be drawn up for the very tight bend downstream of the Ringawhati Road bridge. If the existing stream alignment is retained, then strong bank protection measures should be used around the bend, to provide an artificial control at this point. Alternatively, a short diversion would allow a natural meander bend to be formed between the upstream and downstream bend, as shown on the plans.

There are no other practical design channels, based on the natural meander form and trends of the stream. There could be different levels of management of the design fairway and buffer zones, but the only other general alternative is a 'do nothing' or very minimal approach to management of the stream.

2.5 STREAM MOUTH

The sand dunes along the coast are naturally unstable features, which are easily eroded by wind blow, wave action and water flows. At the stream mouth there is an extensive lower area of a sandy spit within the fore dunes. The stream naturally migrates within this area, depending on the timing and intensity of the stream flood flows, and the effects of coastline re-working. The stream can erode away the spit and foredune land, but there is a natural balance between the stream flow energy of this very flat graded stream and the beach building processes of the sea. At times of high flood levels the stream can naturally flow over and breach the spit, but generally the stream forms a northward loop to enter the surf zone in a slightly southerly direction.

The coastal beach deposits are then moved by wind and waves, with movement both on and off shore and along the coast as longshore drift. Wave directions and intensities continually vary as weather systems move across New Zealand and this gives rise to a physically mobile and dynamically changing environment. Most of the movement takes place within the sea covered area of the beach, but the higher beach and the spit area of the stream mouth are affected by storm generated larger waves and high seas.

Since the 1950s, when works on the Waitohu Stream were included in the Otaki River Scheme, the stream mouth has been periodically moved by forming diversion cuts through the sand spit. The aim of this intervention was to shorten the stream and improve flood water outflows, while maintaining the mouth away from the houses of the Otaki Beach settlement on the south side and the vegetated foredune and farm land on the north side. There has been a progressive northward development of the beach settlement, and since the 1950s the housing area has extended about four blocks, from Koromiko Street to past Konini Street.

Present mouth management is guided by the Regional Coastal Plan provisions, which allow the cutting of a mouth diversion "when the channel outlet within the coastal marine area migrates either north or south of the area defined by the projected lines 250 metres north and 1000 metres north of Konini Street or the channel outlet creates a vertical scarp in the sand dunes which exceeds 2 metres in height."

Bare foredune areas around the present mouth are being planted in pingao and other suitable dune plants. There is also an intention to remove marram from the dunes over time. Some form of stabilisation of the present mouth position has been suggested as well.

The earliest aerial photography of 1948 shows the stream mouth prior to any intervention, and at that time the stream followed a long northward loop and entered the sea at the northern end of the bare sandy spit area. The photography shows severe wind blow areas on both the foredune and back dunes in the vicinity of the mouth. The 1966 photography shows a looped stream channel at the south end of the spit, no doubt due to mouth diversions. This demonstrates how artificial cuts near the south end can give rise to an erosion threat to the foredune area where there are Otaki Beach houses. The 1983 photography shows the mouth about mid way along the spit, at about the most desirable location.

The present mouth and spit configuration is also relatively complicated due to management interventions, with a back channel behind a partly vegetated area of the spit. Attempts have been made in the past (see the 1966 photography) and are being made now to vegetate this area of the spit, around about where the Old Coach Road ends (as a legal road), to assist in stabilising the mouth position.

The bare area of the spit has not changed significantly since the 1948 photography. However, there has been some northward shift, with vegetation extending further north at the south (settlement) end, and the low sand area extending about 150 metres into the higher vegetated foredune at the north end. The cadastral survey of the stream (that defines its legal boundary) is taken from the earliest survey of about 1875. This shows a mouth at about the legal road end of the Old Coach Road, and a relatively small ‘gap’ area in the foredune. What area was bare spit and what was vegetated at the time can not, however, be determined from the survey plan. The plan does, though, show an “old mouth” at about Konini Street, which would have been an old flood breach channel.

The position of the stream mouth and extent of the re-worked spit area as shown on vertical aerial photographs is indicated by overlays on the latest photography in Figure 4. Legal boundaries are also shown, which for the stream is taken from the earliest survey.

There is a complex inter-play of physical forces at the stream mouth, and in such an environment management interventions can easily give rise to unexpected results. Training or protection measures are only too often outflanked and/or made redundant in these environments. Partly re-vegetated areas on the spit are also easily outflanked and/or eroded away as the stream channel migrates and conditions change.

The best policy is to allow the stream to move naturally within its general area of movement, with the minimum of intervention. There are natural limits to the movement of the stream and changes in the beach formations along the coast. While management at the more extreme limits can be effective and worth the cost, there should be sufficient buffer zones to minimise the need for intervention.

Thus it would be better to focus planting efforts along the edges of the existing vegetated foredunes, along the edge of the higher sand country behind the spit and at each end of the spit. The stream should be allowed to migrate within the bare spit area without restriction and with as few diversion cuts as possible. When diversions are constructed, the best position for them would be around the legal road end of the Old Coach Road. It should also be cut as a curve, first heading northward and then curving around for a southwest entrance to the sea.

Areas within the spit should not be planted, as this only disrupts and complicates the mouth channel and spit formation. Any efforts to stabilise a particular stream mouth position, by either planting or more structural measures would in all likelihood be ineffective and not worth the time and cost.

3 SEDIMENTATION PROCESSES

3.1 GENERAL

The Waitohu catchment gives rise to a mixed river sediment load, of fine wash-off materials, sands and gravels. This sediment load is transported in different ways. The fine silty materials are transported as suspended load within the flowing water. The coarse gravel materials are transported along the bed of the river in a rolling and jumping manner by a friction drag process. Sand materials can be partly entrained into the water flow as a semi-suspended load, while partly streaming along within or above the bed of the river.

The transport of these materials takes place during flood events, with the rate of transport increasing as the flood flow increases. However, the transportability of the materials varies in different ways for materials of different size. Fine silty materials are transported at relatively small flows, while the concentration of these materials in flood water increases greatly as flows increase. The amount of material transported depends mainly on the supply of fine materials from the catchment runoff water, and varies greatly from catchment to catchment.

The gravel material on the bed of a river forms a interlocking matrix, and generally remains in place up to some threshold of movement, when the flood flows have sufficient power to break open the matrix and initiate movement. A generalised movement of gravel bed material normally only takes place during significant flood flows, when flows are above what occurs about every 2 years. There is then an increase in bed load transport as flood flows increase, but at a much lesser rate than for the suspended load.

3.2 SEDIMENT TRANSPORT

Given information on channel and flood flow conditions, empirically derived formulae can be used to estimate bed material transport rates. These formulae use flow depths and velocities, the energy slope down the channel, bed material size and a proportion of the channel resistance.

The transporting power of the stream, from the magnitude of the flow and its downhill slope, is expended on moving the bed material, given other frictional losses from obstructions and the changing form of the channel. The proportion of the stream power expended on bed material transport can then be determined from a proportioning of the channel resistance, between the grain resistance of the bed material and the form resistance of the channel.

Sediment transport rates were calculated at each cross section, using flow levels, velocities, energy slopes and channel resistances at the sections, as given by the hydraulic modelling of the stream. Flow depths were determined using average bed levels, as estimated from the cross section plots, for the main channel where transport activity takes place. For some cross sections a single average bed level (essentially the mean bed level of the channel) could be used, but for the wider and less entrenched channel sections, the active width was divided into two parts.

The grain resistance of bed material can be estimated from the size of the material. For a gravel-bearing stream like the Waitohu Stream, most of the channel roughness arises from the grain resistance, and the active channel resistance for bed material transport was taken as a large proportion of the total resistance.

The average bed material size along the stream was determined from the grading curves derived from the surface armouring layer samples. There are approximate relationships between the armour layer grading and that of the bed material as a whole. The effective bed material size was taken as the medium size of the bed material, which is approximately given by the d_{25} of the armouring layer.

Three empirical formulae were used to calculate the sediment transport rates, being the Meyer-Peter & Muller, Engelund & Hansen, and Einstein & Brown formulae. The results were calculated on a spreadsheet, and the input data and results for each section are given on Tables 4 to 7, for flood flows of the estimated 2, 10, 20 and 50 year return period peak flow. These section by section transport rates will vary, but together they do give an indication of reach rates and general changes in transport capacity along the stream.

There is a clear reduction in transport rates as the stream grade flattens out. Below the State Highway bridge there is a marked reduction in transport capacity, and below the Wakapua Farm bridge there is very little transport capacity, even in large flood events. The stream becomes too flat graded to carry gravel material, and flood flows spill out of the main channel.

3.3 SEDIMENT VOLUMES

Average sediment transport rates were determined for the upper reach of the Waitohu Stream, above the State Highway bridge, for the range of flood flows of the calculations. A relationship between flood flow and sediment transport was then derived for the Meyer-Peter & Muller formula results, and another for the Einstein & Brown results.

A threshold of motion was estimated using the Shield's relationship of flow depth or stress to bed material size. For the threshold depth of about 0.5 metre, the flow at the recorder site was estimated from the site stage-flow rating curve. This suggested a threshold of motion at around 10 to 20 m3/s.

Flow to sediment transport rating curves were then drawn up for both formulae, taking a fixed threshold of motion flow of 20 m3/s, and a power relationship derived (see Figure 5). For this stream the relationships were virtually linear above a threshold of motion transition.

These rating curves were applied to continuous flow data generated at the recorder site from the hydrological record. Average monthly and yearly transport volumes were then determined from the continuous data. Where there were small gaps in the data these gaps were ignored, and averages calculated from the remaining data. Large gaps in the record were, though, treated as missing data periods.

Monthly and yearly volumes obtained in this way are shown for the two formulae in Tables 8 and 9.

The variability of sediment transport and its dependence on flood flows is demonstrated in these tables. Over long periods of time there is no significant movement of bed material along the stream, and then there is a burst of activity. The transport of the gravel bed material, and hence accumulation of gravel at the major change in grade of the stream, closely follows the pattern of flood events.

The two formulae give quite similar results, particularly given the variations that can arise in calculated results. The indicated transport volumes can then be summarised as follows:

Annual Transport – Gravel Bed Material

(m^3)

	AVERAGE	RANGE
Meyer-Peter & Muller	1700	0 - 3500
Einstein & Brown	1100	0 - 2000

The hydrological records do not include large flood events, with the highest peaks being around a 10 year return period frequency of recurrence. There was though a relatively high level of flood activity over the 1990's. The estimates of transport volumes should, therefore, probably be taken as indications of volumes over periods of significant flood activity, but without any of the large inputs and activity that can occur in more extreme events. The Meyer-Peter & Muller formula is generally more appropriate for steep gravel-bearing rivers, but for a stream such as the Waitohu Stream, with a tendency towards a narrow well-defined channel, a transport rate somewhere between the two formula results may apply. A reasonable estimate of the average supply rate to the deposition reach at the major change of grade would then be, say, 1500 m3/year.

4 CONCLUSIONS

The Waitohu Stream changes in character and form over its lower reaches, from the Waterworks bridge to the sea, with a major change of grade around the Railway bridge.

Along the upper part of this reach the stream is contained within a terrace system, and is naturally degrading. Its natural channel form is that of a relatively well-defined channel, which is slightly entrenched within a narrow floodplain, and which migrates across this floodplain. It has a relatively coarse gravel bed material, and despite its steep grade, extensive mobilisation of the channel is a very short term and infrequent phenomenon during medium to large flood events.

Along the lower reaches of the stream, below the Railway bridge, where there is a progressive reduction in grade, the stream has a well-formed meandering channel, and flood waters overflow onto a wider alluvial plain, which is constrained and defined by a complex sand dune system.

The natural channel form and character of the stream has been assessed through a study of its catchment setting, the changes shown on repeat aerial photography and by repeat cross section surveys, and by applying empirically derived relationships about channel widths and form. Based on this assessment, a design channel has been drawn up from the

Waterworks bridge to just downstream of the Railway bridge. This design channel can guide river management, and by providing a consistent channel to a natural form reduce on-going management effort.

The design channel is a guide to management along the reach, and if implemented, it has to be formed and managed over the reach and over the long term. There is no other practical design channel based on the natural meander forms of the stream, and if a comprehensive management of the stream is not going to be carried out, then management effort should be restricted to localised works as and when they are worth doing.

There is a relatively large bare area of a low sandy spit at the stream mouth, and periodically an artificial cut is formed through this spit. This stream mouth area is a physically very mobile and dynamically changing environment, but its condition and extent reflects an overall balance. The natural processes that take places, with the movement of the stream and spit, should, as far as possible, be unrestrained, with any assets kept beyond the area of natural activity. Efforts to alter or fix the position of the stream channel and spit are likely to be ineffective and not worth the time and cost. When diversion cuts are formed they are best located around the middle of the spit, with the cut being curved like a natural channel.

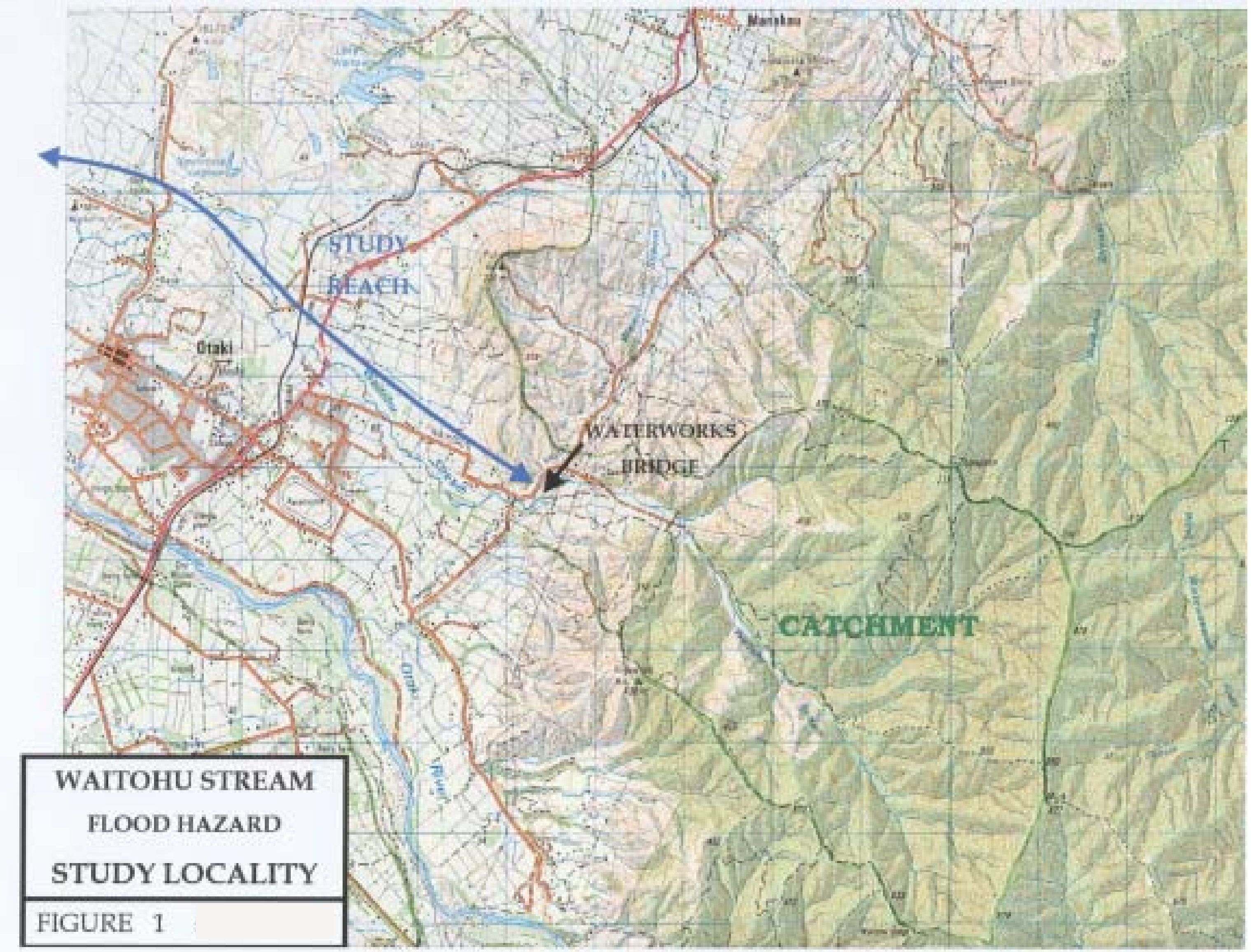
The information obtained from the channel surveys and the hydraulic modelling carried out of the stream, has been used to estimate the amount of gravel bed material being transported down the lower reaches, to the natural deposition area around the Railway bridge. Sediment transport rates were calculated for a range of flood flows using empirically derived formulae, and a flow-transport rating curve drawn up. By applying this rating to continuous flow data generated from the hydrological records, the likely range and average volume of gravel moved down the stream was estimated.

The relatively low estimated supply rate of around 1500 m3/year on average is considered reasonable for the Waitohu Stream, given the nature of the stream.

April 2004

G J Williams
Water & Soil Engineer

G & E Williams Consultants Ltd
R D 1,
OTAKI (06) 3626684



WAITOHU STREAM

FLOOD HAZARD

STUDY LOCALITY

FIGURE 1

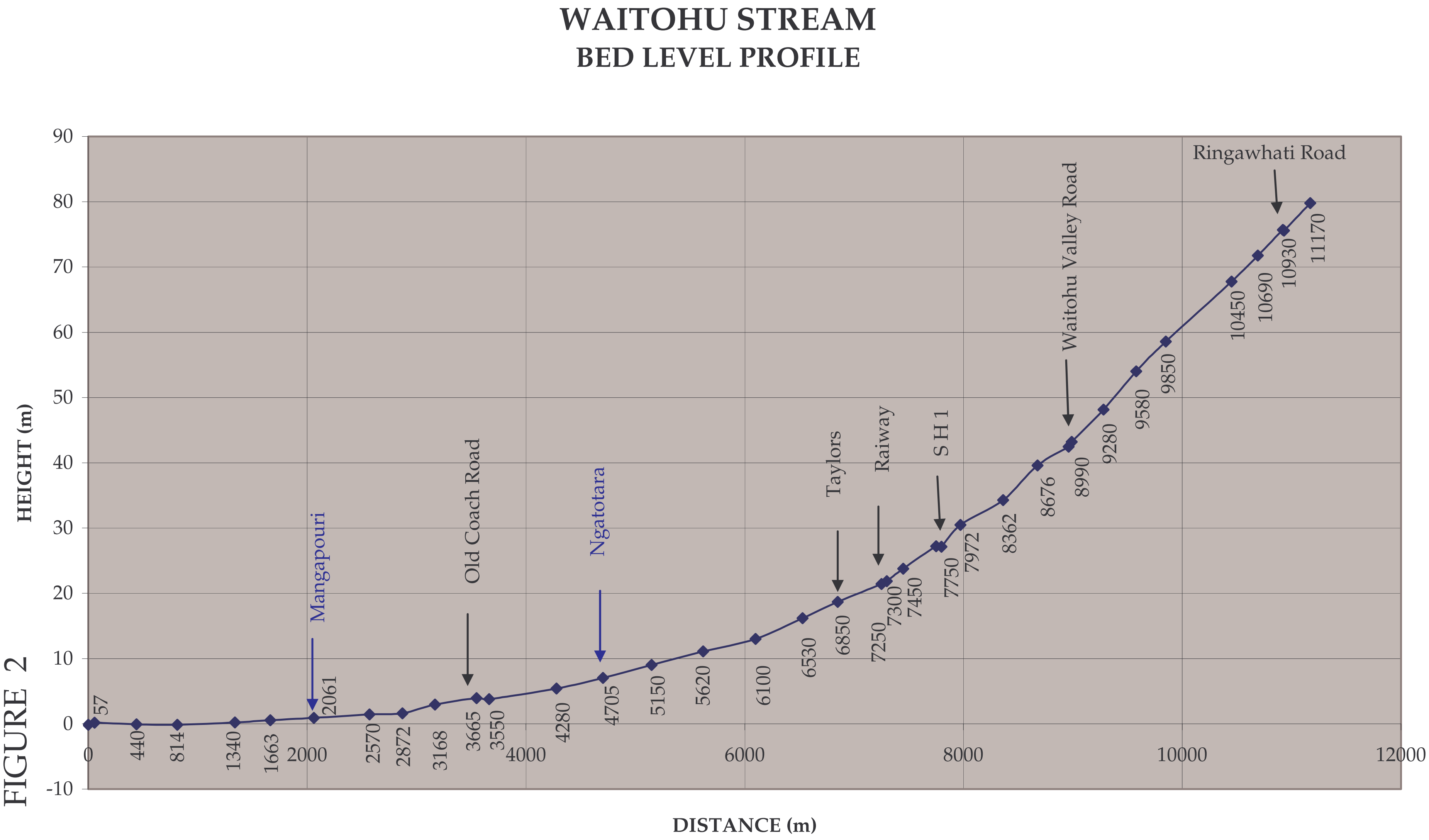

WAITOHU STREAM
BED LEVEL PROFILE
HEIGHT (m)
DISTANCE (m)
90
80
70
60
50
40
30
20
10
0
-10
0
2000
4000
6000
8000
10000
12000
57
440
814
1340
1663
2061
2570
2872
3168
3665
3550
4280
4705
5150
5620
6100
6530
6850
7250
7300
7450
7750
7972
8362
8676
8990
9280
9580
9850
10450
10690
10930
11170
Mangapouri
Old Coach Road
Ngatotara
Taylors
Raiway
S H 1
Waitohu Valley Road
Ringawhati Road

FIGURE 2

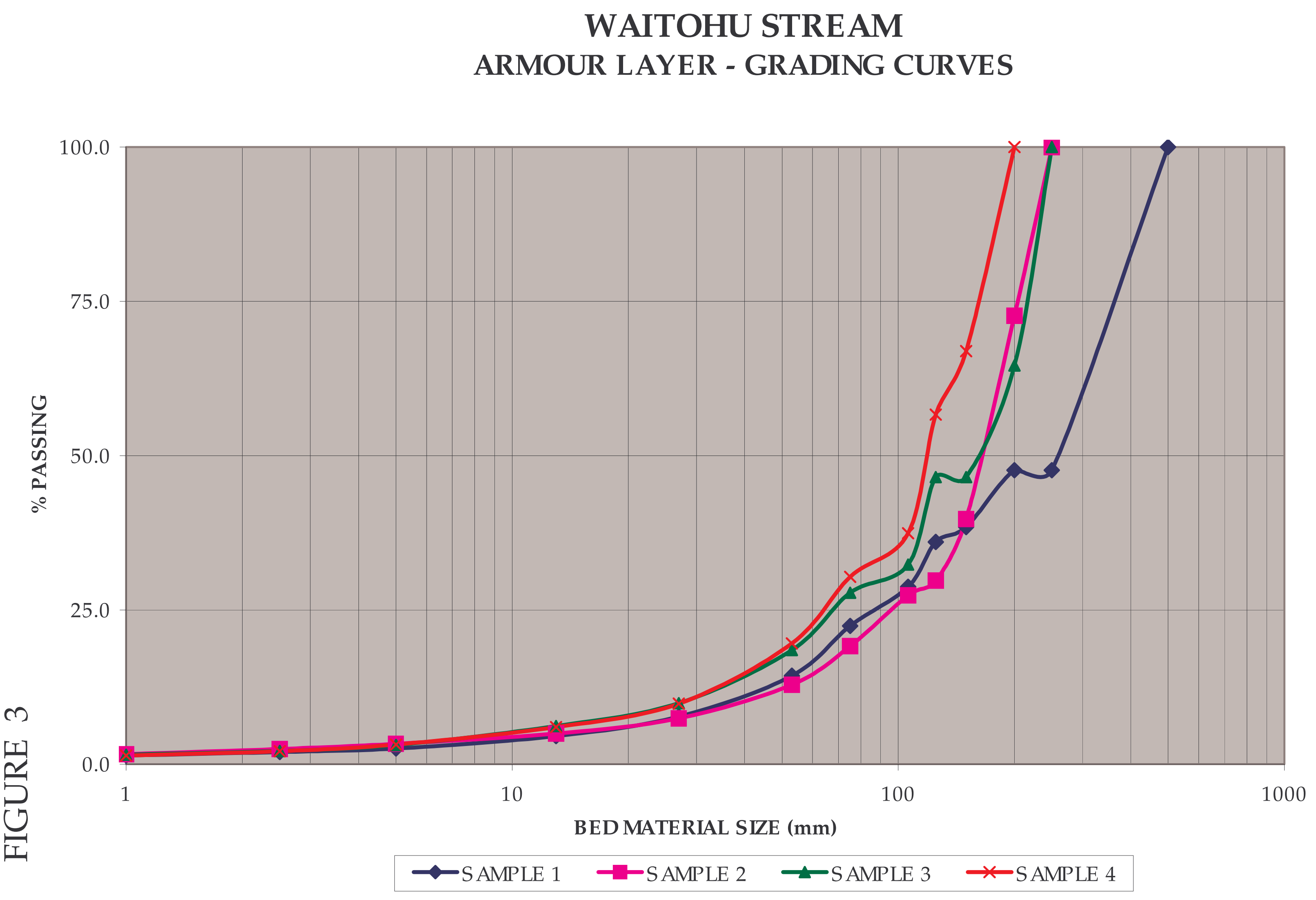

WAITOHU STREAM
ARMOUR LAYER - GRADING CURVES
% PASSING
100.0
75.0
50.0
25.0
0.0
1
10
100
1000
BED MATERIAL SIZE (mm)
SAMPLE 1
SAMPLE 2
SAMPLE 3
SAMPLE 4

FIGURE 3

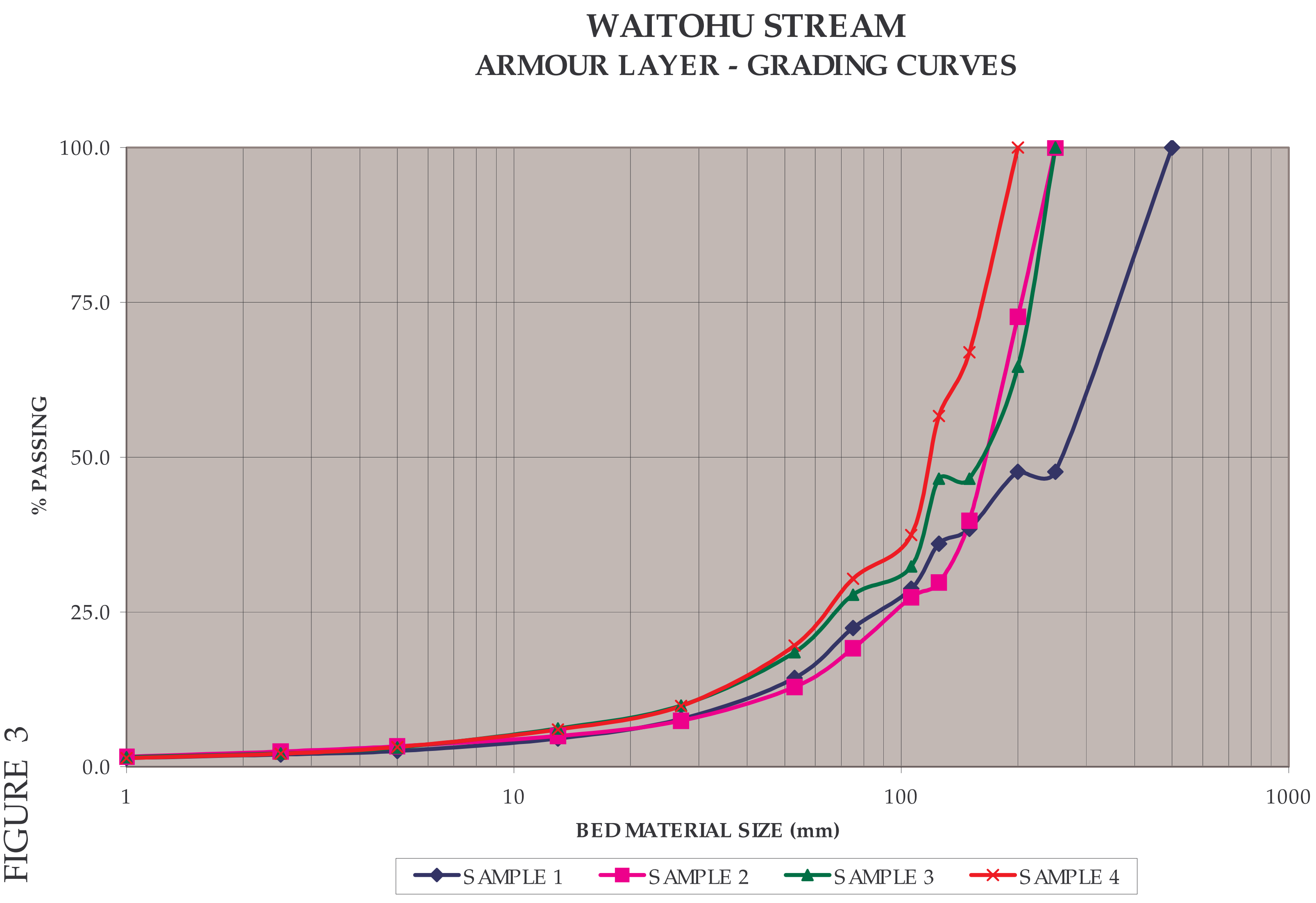
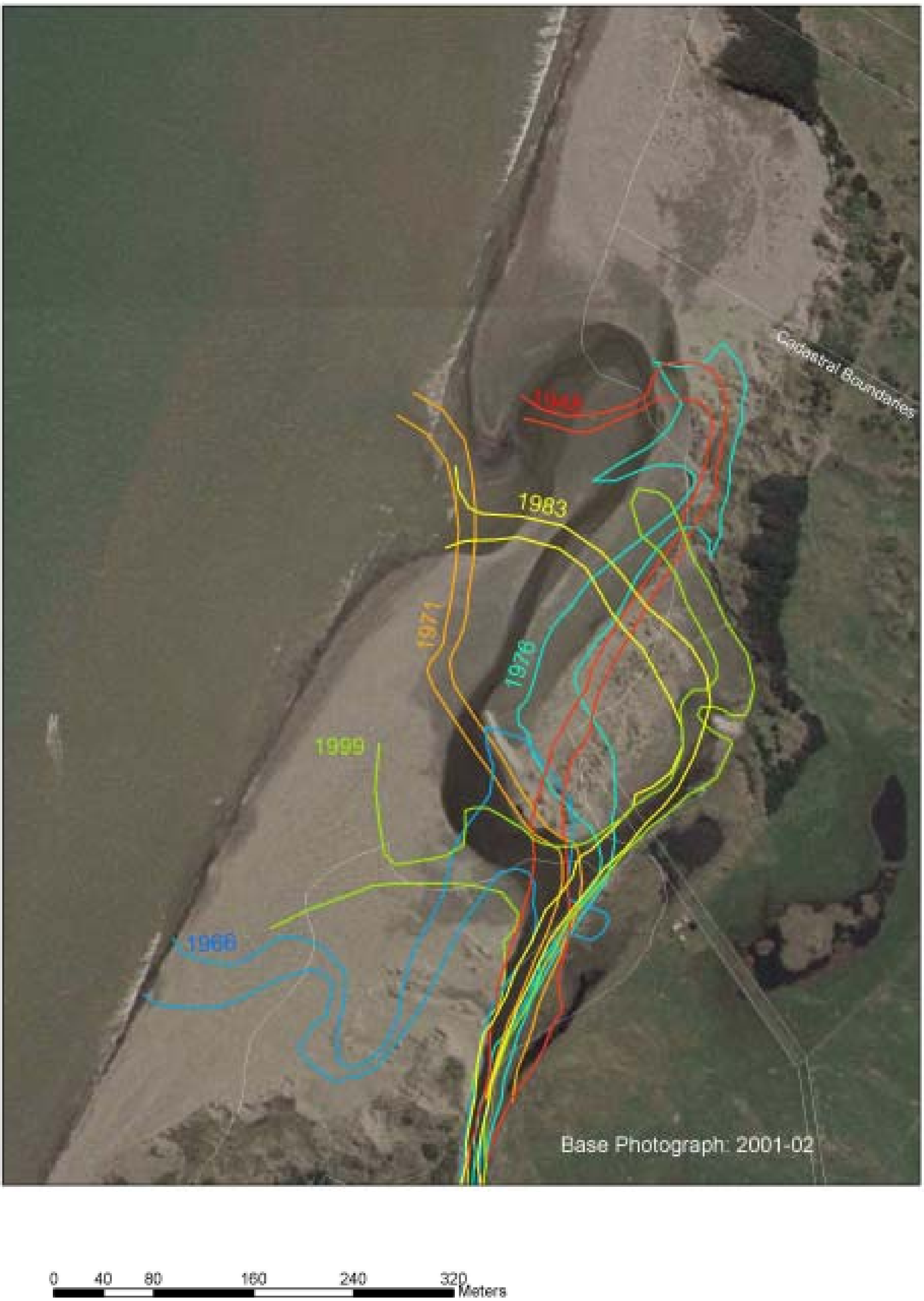

WAITOHU STREAM
ARMOUR LAYER - GRADING CURVES
100.0
75.0
50.0
25.0
0.0
% PASSING
1
10
100
1000
BED MATERIAL SIZE (mm)
SAMPLE 1
SAMPLE 2
SAMPLE 3
SAMPLE 4

FIGURE 3


Cadastral Boundaries
1983
1971
1976
1999
1966
Base Photograph: 2001-02
0 40 80 160 240 320
Meters

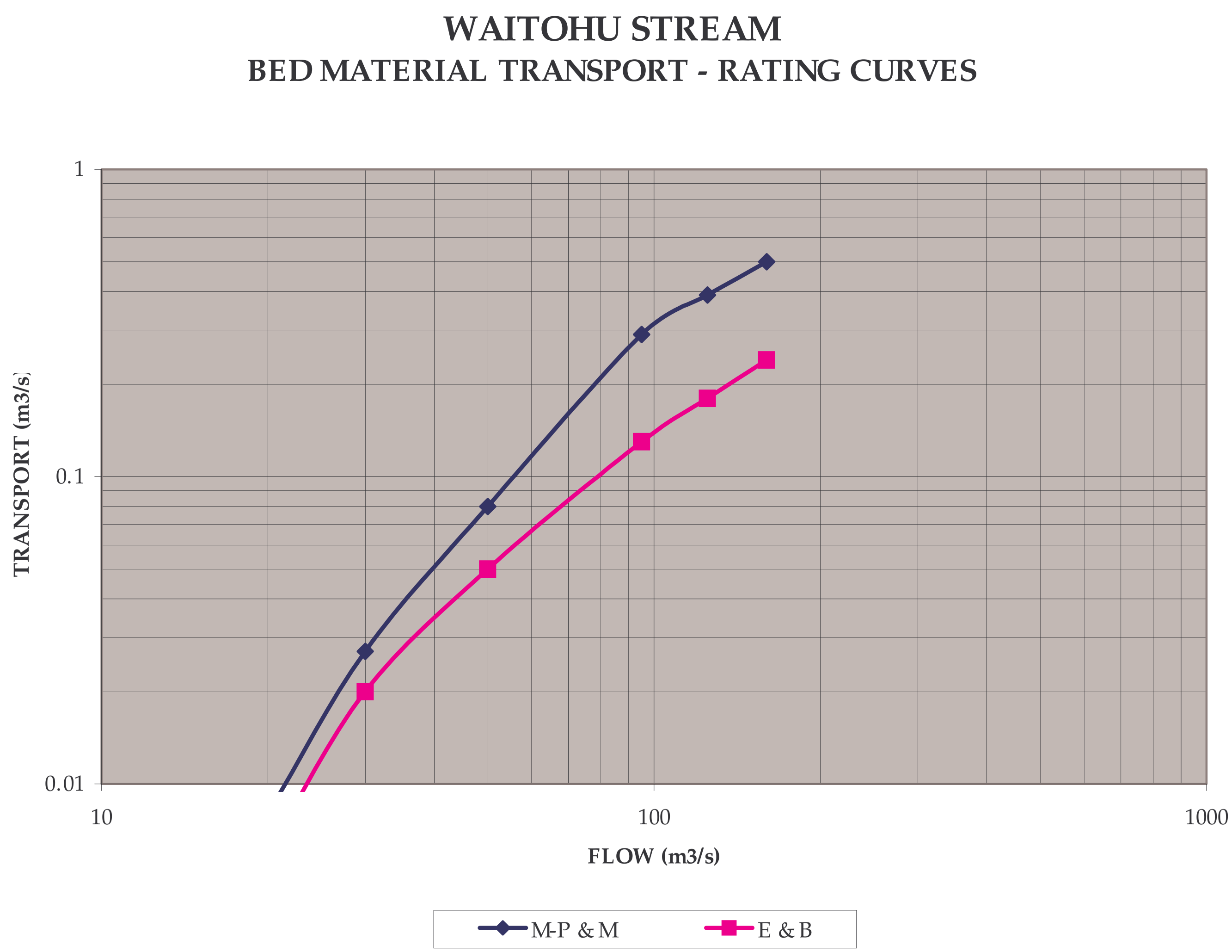

WAITOHU STREAM
BED MATERIAL TRANSPORT - RATING CURVES
TRANSPORT (m3/s)
1
0.1
0.01
10
100
1000
FLOW (m3/s)
M-P & M
E & B

FIGURE 5

RIVER CHANNEL MEANDERS

NATURAL MEANDER FORMS & DESIGN CHANNELS

TABLE 2

FORMULA	PARAMETERS			NATURAL CHANNEL TYPE	DESIGN CHANNELS	DESIGN & MANAGEMENT COMMENTS
	Q_2	s	d_{50}			
LACEY	X			Relatively uniform single entrenched channel. Mobile bed of sand material. Flow dominant in channel formation. Sufficient power to transport bed material.	WIDE FAIRWAY (1.7 x Flow Dominant Width)	Permits migration of the flow dominant meander form. Channel width wide enough for this meandering, while minimising over-extension and channel splitting. Moveable channel edge, with wide vegetation buffer zone (of major threshold width) to manage erosion embayments.
RUSSIAN	X	X		Relatively uniform channel, but wider and including gravel bearing rivers. Flow dominant and sufficient power to transport bed material.	NARROW FAIRWAY (Flow Dominant Meander Width)	Fixes the active channel of the flow dominant meander, but permits migration of the threshold meanders associated with bed material movement. Channel edge generally requires strengthening, with vegetation buffer (of minor threshold width).
THRESHOLD - REGIME - SLOPE	 X X	 X	 X X	Shallow channels within wide gravel carrying rivers. Channel formation associated with the movement of the bed material, with channels formed on flood recessions at the threshold of motion. Sediment transport restricted, and depends on mobilisation.	MINIMUM CHANNEL (Major Threshold Meander Width)	Fixes the minimum channel meanders associated with bed material movement. Single more entrenched channel with a radius of curvature between 4 and 6 times the (major) meander width. Strong channel banks required to maintain fixed position, with distortions from the restraining of the meander movement.

TABLE 3

WAITOHU STREAM

CHANNEL WIDTHS

(m)

FLOW Q2 (m3/s)	MATERIAL d50 (m)	SLOPE s	THRESHOLD OF MOTION WIDTH			FLOW DOMINANT WIDTH			DESIGN FAIRWAY WIDTH	
			at REGIME	at ACTUAL SLOPE		LACEY	RUSSIAN		NARROW	WIDE
				Henderson	Chang		I	II		
65	0.040	0.0009	14	5	26	39	48	57	39	65
57	0.040	0.0009	13	4	25	37	45	54	37	61
57	0.060	0.0025	12	7	22	37	36	44	37	61
50	0.080	0.0040	11	7	20	34	31	38	34	57
50	0.120	0.0075	10	8	20	34	27	33	34	57
50	0.150	0.0125	10	11	20	34	25	30	34	57
50	0.160	0.0170	10	14	20	34	23	28	34	57
50	0.225	0.0170	9	8	20	34	23	28	34	57

WAITOHU STREAM - BED MATERIAL TRANSPORT

2 YEAR FLOOD FLOW

TABLE 4

CROSS SECTION	BED MATERIAL d50 (m)	SLOPE	CHANNEL WIDTH (m)	CHANNEL WIDTH (m)	BED LEVEL (m)	BED LEVEL (m)	FLOOD LEVEL (m)	FLOW VELOCITY (m/s)	CHANNEL RESISTANCE Total	CHANNEL RESISTANCE Active	SEDIMENT TRANSPORT (m3/s) M-P&M	SEDIMENT TRANSPORT (m3/s) E-H	SEDIMENT TRANSPORT (m3/s) E-B
30	0.012	0.0005	8		0.0		2.52	0.75	0.0300	0.0200	0.00	0.00	0.00
50	0.015	0.0010	6		0.4		2.81	1.30	0.0350	0.0200	0.00	0.00	0.00
90	0.025	0.0015	6		2.0		5.07	1.65	0.0400	0.0200	0.00	0.00	0.00
120	0.025	0.0025	6		4.0		6.78	1.85	0.0370	0.0220	0.01	0.00	0.00
140	0.035	0.0025	6		7.1		9.02	3.00	0.0370	0.0250	0.00	0.00	0.00
170	0.065	0.0040	7	20	13.1	13.9	14.59	1.80	0.0370	0.0270	0.00	0.00	0.00
200	0.065	0.0075	11		18.8		20.00	2.30	0.0370	0.0300	0.01	0.00	0.01
220	0.070	0.0075	26		22.2		23.30	1.55	0.0370	0.0300	0.01	0.00	0.02
230	0.070	0.0130	14		24.2		24.95	2.05	0.0400	0.0350	0.04	0.01	0.02
240	0.070	0.0130	8.5	5.5	27.4	28.1	28.73	2.70	0.0400	0.0350	0.18	0.02	0.07
260	0.070	0.0130	8	12	30.7	31.0	31.80	2.50	0.0400	0.0350	0.16	0.02	0.06
270	0.080	0.0150	14	26	34.7	35.1	35.47	2.55	0.0400	0.0350	0.00	0.02	0.03
280	0.080	0.0170	8		39.7		40.58	3.05	0.0400	0.0350	0.09	0.01	0.03
320	0.090	0.0175	12	36	54.1	54.6	54.84	2.15	0.0400	0.0350	0.00	0.01	0.03
340	0.090	0.0175	20		64.7		65.24	3.05	0.0400	0.0350	0.02	0.02	0.02
350	0.090	0.0175	12	11.5	68.0	68.6	69.00	2.65	0.0400	0.0350	0.00	0.02	0.07
390	0.090	0.0175	10		80.2		81.40	4.05	0.0370	0.0350	0.34	0.05	0.13

TABLE 5

WAITOHU STREAM - BED MATERIAL TRANSPORT
10 YEAR FLOOD FLOW

CROSS SECTION	BED MATERIAL d50 (m)	SLOPE	CHANNEL WIDTH (m)	(m)	BED LEVEL (m)	(m)	FLOOD LEVEL (m)	FLOW VELOCITY (m/s)	CHANNEL RESISTANCE Total	Active	SEDIMENT TRANSPORT (m3/s) M-P&M	E-H	E-B
30	0.012	0.0005	8		0.0		2.52	0.95	0.0300	0.0200	0.00	0.00	0.00
50	0.015	0.0010	6		0.4		2.96	1.50	0.0350	0.0200	0.00	0.00	0.00
90	0.025	0.0015	6		2.0		5.27	1.85	0.0400	0.0200	0.00	0.00	0.00
120	0.025	0.0025	6		4.0		7.07	2.10	0.0370	0.0220	0.01	0.00	0.00
140	0.035	0.0025	6		7.1		9.13	3.25	0.0370	0.0250	0.00	0.00	0.00
170	0.065	0.0040	7	20	13.1	13.9	14.72	1.95	0.0370	0.0270	0.00	0.00	0.00
200	0.065	0.0075	11		18.8		20.41	2.95	0.0370	0.0300	0.06	0.01	0.02
220	0.070	0.0075	26		22.2		23.86	1.95	0.0370	0.0300	0.15	0.01	0.06
230	0.070	0.0130	14		24.2		25.19	2.20	0.0400	0.0350	0.12	0.01	0.04
240	0.070	0.0130	8.5	5.5	27.4	28.1	29.05	3.40	0.0400	0.0350	0.32	0.04	0.14
260	0.070	0.0130	8	12	30.7	31.0	32.18	3.35	0.0400	0.0350	0.40	0.06	0.16
270	0.080	0.0150	14	26	34.7	35.1	35.73	3.05	0.0400	0.0350	0.21	0.04	0.09
280	0.080	0.0170	8		39.7		40.83	3.50	0.0400	0.0350	0.18	0.02	0.07
320	0.090	0.0175	12	36	54.1	54.6	55.02	2.60	0.0400	0.0350	0.00	0.03	0.07
340	0.090	0.0175	20		64.7		65.53	3.95	0.0400	0.0350	0.20	0.05	0.07
350	0.090	0.0175	12	11.5	68.0	68.6	69.48	3.10	0.0400	0.0350	0.62	0.06	0.25
390	0.090	0.0175	10		80.2		81.98	5.20	0.0370	0.0350	0.79	0.15	0.44

TABLE 6

WAITOHU STREAM - BED MATERIAL TRANSPORT
20 YEAR FLOOD FLOW

CROSS SECTION	BED MATERIAL d50 (m)	SLOPE	CHANNEL WIDTH (m)	(m)	BED LEVEL (m)	(m)	FLOOD LEVEL (m)	FLOW VELOCITY (m/s)	CHANNEL RESISTANCE Total	Active	SEDIMENT TRANSPORT (m3/s) M-P&M	E-H	E-B
30	0.012	0.0005	8		0.0		2.53	1.00	0.0300	0.0200	0.00	0.00	0.00
50	0.015	0.0010	6		0.4		3.00	1.55	0.0350	0.0200	0.00	0.00	0.00
90	0.025	0.0015	6		2.0		5.32	1.85	0.0400	0.0200	0.00	0.00	0.00
120	0.025	0.0025	6		4.0		7.12	2.25	0.0370	0.0220	0.01	0.00	0.00
140	0.035	0.0025	6		7.1		9.15	3.30	0.0370	0.0250	0.00	0.00	0.00
170	0.065	0.0040	7	20	13.1	13.9	14.75	2.00	0.0370	0.0270	0.00	0.00	0.00
200	0.065	0.0075	11		18.8		20.59	3.25	0.0370	0.0300	0.09	0.02	0.03
220	0.070	0.0075	26		22.2		24.11	2.10	0.0370	0.0300	0.24	0.02	0.09
230	0.070	0.0130	14		24.2		25.28	2.25	0.0400	0.0350	0.16	0.01	0.06
240	0.070	0.0130	8.5	5.5	27.4	28.1	29.15	3.70	0.0400	0.0350	0.38	0.06	0.17
260	0.070	0.0130	8	12	30.7	31.0	32.32	3.70	0.0400	0.0350	0.51	0.08	0.21
270	0.080	0.0150	14	26	34.7	35.1	35.84	3.20	0.0400	0.0350	0.33	0.06	0.13
280	0.080	0.0170	8		39.7		40.95	3.70	0.0400	0.0350	0.23	0.03	0.09
320	0.090	0.0175	12	36	54.1	54.6	55.11	2.80	0.0400	0.0350	0.21	0.04	0.10
340	0.090	0.0175	20		64.7		65.66	3.90	0.0400	0.0350	0.32	0.06	0.11
350	0.090	0.0175	12	11.5	68.0	68.6	69.48	3.35	0.0400	0.0350	0.62	0.07	0.25
390	0.090	0.0175	10		80.2		82.25	5.45	0.0370	0.0350	1.04	0.20	0.67

TABLE 7

WAITOHU STREAM - BED MATERIAL TRANSPORT

50 YEAR FLOOD FLOW

CROSS SECTION	BED MATERIAL d50 (m)	SLOPE	CHANNEL WIDTH (m)	CHANNEL WIDTH (m)	BED LEVEL (m)	BED LEVEL (m)	FLOOD LEVEL (m)	FLOW VELOCITY (m/s)	CHANNEL RESISTANCE Total	CHANNEL RESISTANCE Active	SEDIMENT TRANSPORT (m3/s) M-P&M	SEDIMENT TRANSPORT (m3/s) E-H	SEDIMENT TRANSPORT (m3/s) E-B
30	0.012	0.0005	8		0.0		2.53	1.15	0.0300	0.0200	0.00	0.00	0.00
50	0.015	0.0010	6		0.4		3.11	1.65	0.0350	0.0200	0.00	0.00	0.00
90	0.025	0.0015	6		2.0		5.39	1.90	0.0400	0.0200	0.00	0.00	0.00
120	0.025	0.0025	6		4.0		7.18	2.45	0.0370	0.0220	0.01	0.00	0.00
140	0.035	0.0025	6		7.1		9.18	3.30	0.0370	0.0250	0.00	0.00	0.00
170	0.065	0.0040	7	20	13.1	13.9	14.78	2.00	0.0370	0.0270	0.00	0.00	0.00
200	0.065	0.0075	11		18.8		20.71	3.50	0.0370	0.0300	0.11	0.02	0.04
220	0.070	0.0075	26		22.2		24.32	2.15	0.0370	0.0300	0.33	0.02	0.12
230	0.070	0.0130	14		24.2		25.35	2.25	0.0400	0.0350	0.19	0.01	0.07
240	0.070	0.0130	8.5	5.5	27.4	28.1	29.23	3.95	0.0400	0.0350	0.42	0.07	0.20
260	0.070	0.0130	8	12	30.7	31.0	32.46	4.15	0.0400	0.0350	0.62	0.11	0.28
270	0.080	0.0150	14	26	34.7	35.1	35.95	3.40	0.0400	0.0350	0.47	0.08	0.18
280	0.080	0.0170	8		39.7		41.06	3.90	0.0400	0.0350	0.28	0.04	0.12
320	0.090	0.0175	12	36	54.1	54.6	55.20	3.05	0.0400	0.0350	0.33	0.06	0.14
340	0.090	0.0175	20		64.7		65.79	4.15	0.0400	0.0350	0.44	0.08	0.16
350	0.090	0.0175	12	11.5	68.0	68.6	69.64	3.65	0.0400	0.0350	0.83	0.10	0.36
390	0.090	0.0175	10		80.2		82.55	5.85	0.0370	0.0350	1.35	0.28	1.00

TABLE 8

WAITOHU STREAM - SEDIMENT TRANSPORT

MEYER-PETER & MULLER

(m^3)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1995	0	0	54	547	0	47	3	0	0	5	200	21	876
1996	0	1185	#VALUE!	#VALUE!	11	130	0	0	0	279	130	729	#VALUE!
1997	0	24	217	18	0	0	0	0	10	324	544	386	1524
1998	54	27	0	39	3	26	579	27	492	1607	0	43	2895
1999	0	0	0	0	664	0	0	865	0	11	41	1462	3044
2000	27	0	0	0	0	0	0	0	78	3214	0	35	3353
2001	0	0	161	0	0	0	0	0	0	0	91	54	305
2002	0	0	3	#VALUE!	#VALUE!	#VALUE!	#VALUE!	0	8	21	0	134	#VALUE!
2003	0	0	0	0	0	10	8	0	54	169	31	5	278
Minimum	0	0	0	0	0	0	0	0	0	0	0	5	5
Mean	11	7	54	10	111	6	98	127	92	764	101	303	**1684**
Maximum	54	27	217	39	664	26	579	865	492	3214	544	1462	8183
										MEAN - excluding 1996 & 2002			**1754**

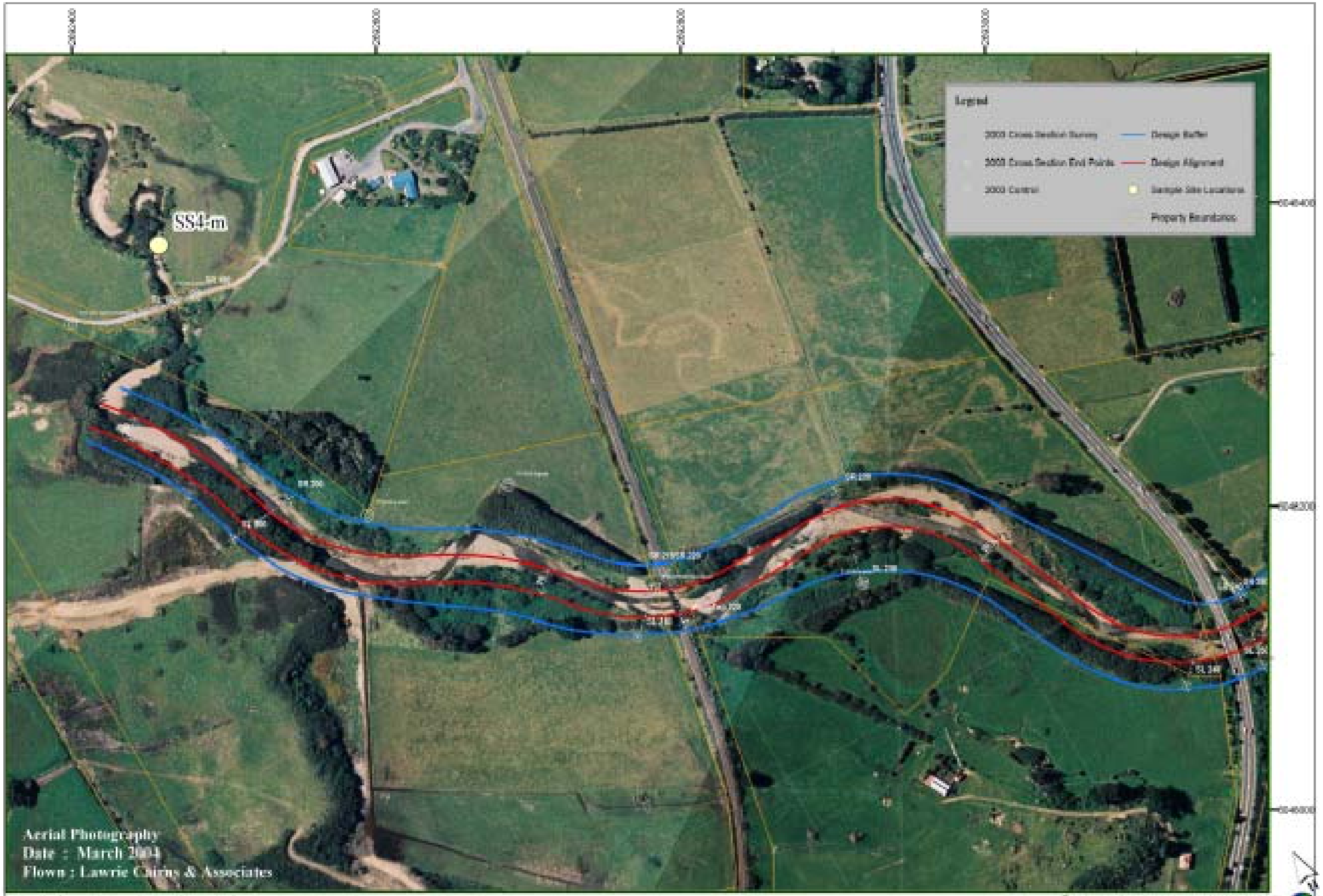
TABLE 9

WAITOHU STREAM - SEDIMENT TRANSPORT

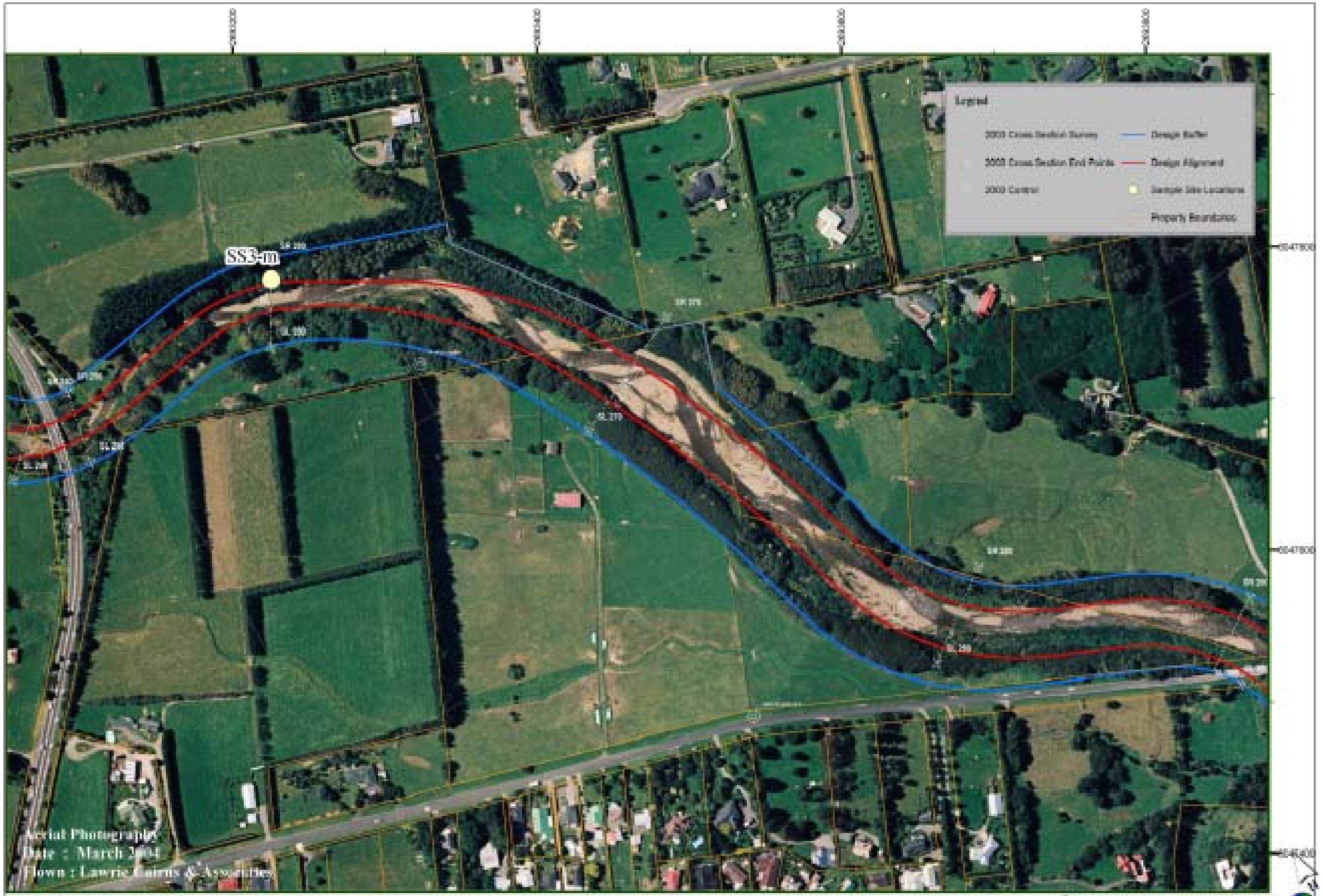
EINSTEIN & BROWN

(m^3)

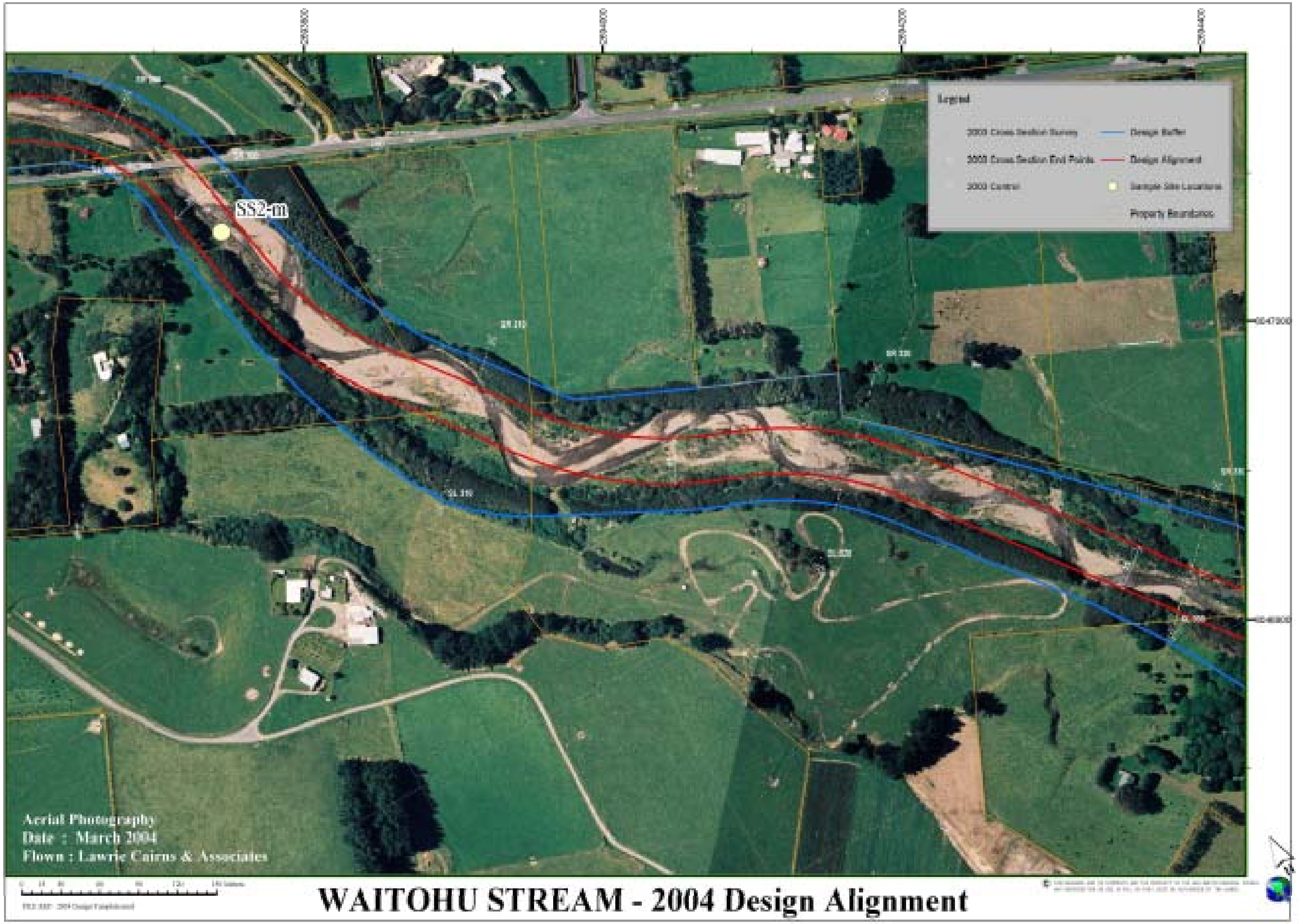
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1995	0	0	37	389	0	36	3	0	0	5	148	16	634
1996	0	677	#VALUE!	#VALUE!	0	101	0	0	0	206	93	541	#VALUE!
1997	0	24	163	13	0	0	0	0	8	241	363	279	1091
1998	40	19	0	29	3	18	421	13	337	1071	0	32	1983
1999	0	0	0	0	453	0	0	611	0	8	31	951	2053
2000	27	0	0	0	0	0	0	0	52	1982	0	27	2087
2001	0	0	123	0	0	0	0	0	0	0	67	40	231
2002	0	0	3	0	#VALUE!	#VALUE!	#VALUE!	0	5	16	0	99	#VALUE!
2003	0	0	0	0	0	8	5	0	41	123	23	3	204
Minimum	0	0	0	0	0	0	0	0	0	0	0	3	3
Mean	7	80	41	54	57	20	54	69	49	406	81	221	**1139**
Maximum	40	677	163	389	453	101	421	611	337	1982	363	951	6487
												MEAN - excluding 1996 & 2002	**1183**

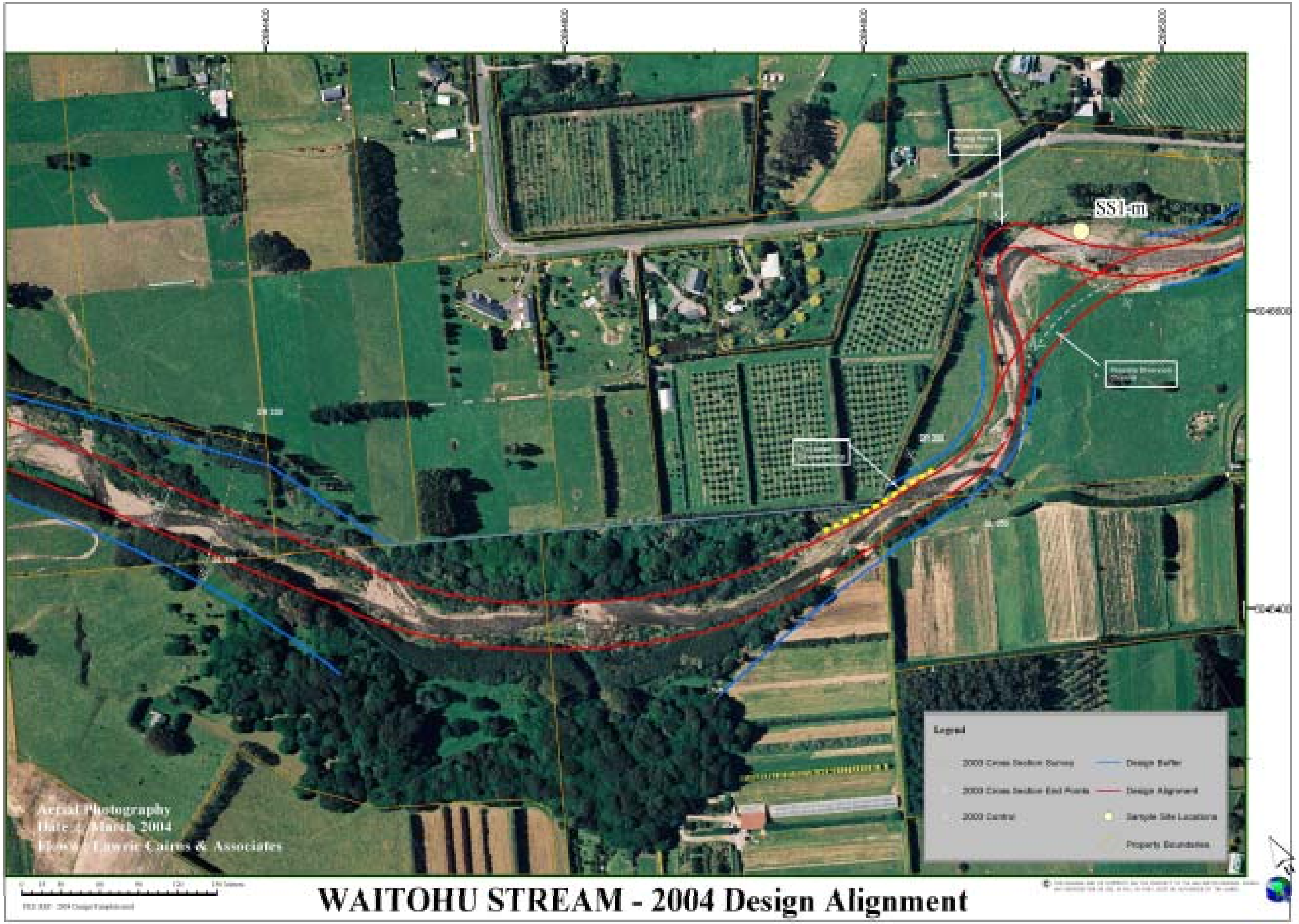


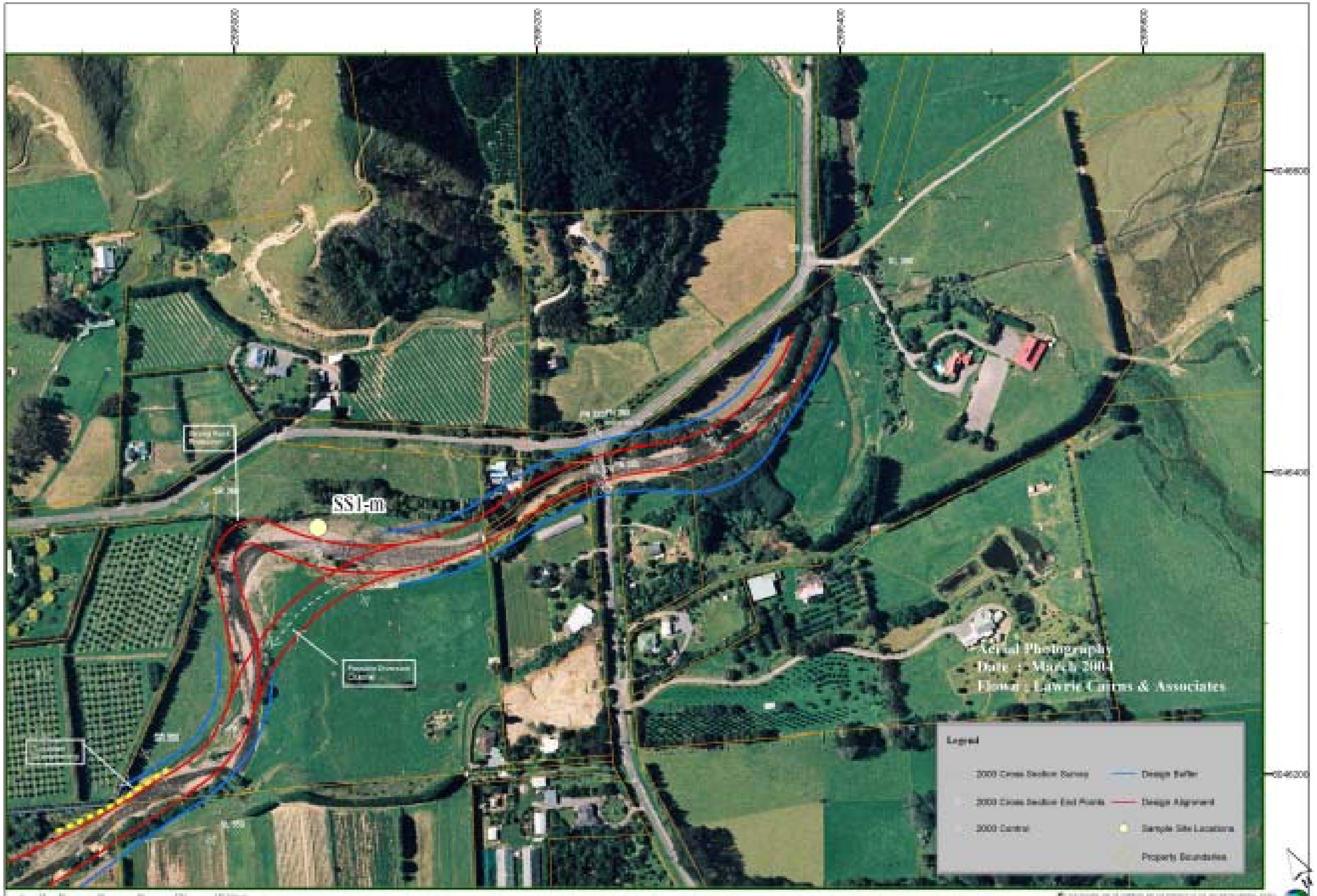
WAITOHU STREAM - 2004 Design Alignment



WAITOHU STREAM - 2004 Design Alignment


Legend
2003 Cross Section Survey
2003 Cross Section End Points
2003 Control
Design Buffer
Design Alignment
Sample Site Locations
Property Boundaries
SS2-m
Aerial Photography
Date : March 2004
Flown : Lawrie Cairns & Associates
WAITOHU STREAM - 2004 Design Alignment


SS1-m
Legend
2003 Cross Section Survey
2003 Cross Section End Points
2003 Control
Design Buffer
Design Alignment
Sample Site Locations
Property Boundaries
Aerial Photography
Date : March 2004
Flown : Lawrie Cairns & Associates
WAITOHU STREAM - 2004 Design Alignment



WAITOHU STREAM - 2004 Design Alignment

WAITOHU STREAM – FLOOD HAZARD ASSESSMENT

CHANNEL MANAGEMENT

1 Introduction

The ‘River Characteristics & Sedimentation’ report provides information on the nature of the Waitohu Stream and its catchment, including the geomorphology of the stream, its channel meandering and sedimentation processes, and outlines the basis of a design channel for management purposes. Discussions were held on river management options based on the information contained in this report.

There is only a limited degree of choice in the way the Waitohu Stream is managed, with options really revolving around the amount of effort or resources put into channel management. This short report provides some comment on the channel management options discussed, and the impacts of a greater of lesser effort in managing the stream channel.

2 Upper Reach – Upstream of State Highway Bridge

The stream is entrenched in a terrace system along this reach, and has an on-going degradation trend. The stream has a steep grade and a coarse gravel bed material, and naturally forms a narrow twisting channel that migrates within the small floodplain area between the lower terraces. The objective of past management has been the development of a clear channel fairway, with willow vegetation buffer zones on each side, to contain channel migration within this river corridor area.

A design fairway and buffer zones have been drawn up based on a natural ‘flow-dominant’ meander form. This fairway is wide enough to allow a migration of the tightly twisting channels of the actively worked gravel bed, which move during significant flood events and become fixed on flood recessions. However, the flood flows are generally not powerful enough to mobilise all the fairway during flood events, and much of the fairway becomes vegetated as the higher areas of the gravel bed are colonised by weedy vegetation and willow snags.

Maintaining a clear fairway is then difficult, with periodic herbicide spraying, machine clearing or beach ripping being necessary. The buffer zone willows are also undermined by the relatively high banks of the narrow main channels, and when they collapse into the stream bed they can obstruct much of the channel width.

Fixing the stream into a narrow tightly meandering channel, which fits the smallest natural meander form of the ‘threshold of motion’ conditions, would be very expensive, and this is not a practical option.

There is then no practical management approach that fits a natural meander form of the stream, and a compromise approach has to be used. The realistic options then relate to the effort and resources put into managing the channel itself on the one hand and the edge vegetation on the other.

Three representative levels of management can be identified for the buffer zones and the channel fairway, as follows:

Fairway –

- Do nothing
- Occasional minor in-channel works – where more severe distortions develop
- Regular maintenance – ripping of bed/islands, clearing of higher beaches, etc

Buffer Zone –

- Do nothing
- Occasional bank repairs, replanting etc as needed to re-establish buffer zones, especially when breaks out through the buffer zone occur
- Intensive management, with erosion embayments being reclaimed over time to maintain effective buffer zones

These levels of management are part of a continuum, with higher levels of management reducing the risks of channel break outs, but not eliminating them. The 'Do nothing' option means there would be no programme of stream management along the stream, but the major assets of the bridges can still be protected by on-site works, on an 'as and when required' basis by the responsible authority.

There is a narrow area of benefit from stream management, as stream break outs would be contained by the confining terraces. The effort put into a management containment should then relate to the extent and value of the land at risk out to the natural containment.

The stream edge vegetation, either as a buffer zone or to a more restricted extent, does not have to consist of willow edge protection trees. Willows are not particularly effective along this stream reach, and have adverse impacts through obstructive blockages and snag colonisation of the active channel area. The aim is to retard the rate of bank erosion as channel migration occurs, through a constant renewal of the edge vegetation, and thereby contain the stream movement within a defined area. Given a programme of stream management, a stream corridor should be defined by a retirement fence, and vegetation used within the corridor area to contain the stream movement. Along this reach of the stream a greater diversity of vegetation would be more effective, and tall grasses such as flax and toetoe could be used along the channel edges. When the channel banks collapse from undermining, these grasses hold together relatively large chunks of bank along the toe of the bank, and are relatively effective in deflecting flood flows in small streams

3 State Highway Bridge to Wakapua Farm Bridge

The stream grade reduces below the State Highway Bridge and the gravel bed load of the stream is deposited along an aggradational fan reach of the stream. The stream naturally builds up and then breaks out into a new course along this reach. The terraces of the upstream degradational reach peter out, and break outs along this reach can give rise to long stream diversions and re-alignments.

Narrow willow buffer zones have been developed alongside a single main channel by past management, from upstream of the State Highway Bridge, and a design channel, based on a fixed 'threshold of motion' meander, has been drawn up, with narrower buffer zones. The lesser stream grade means that the channel meanders move less rapidly, and a fixed channel is more easily managed. However, the natural aggradation trend in this area gives rise to a specific management issue.

In the past, gravel has been extracted from the stream bed for commercial use or stockpiled alongside the Railway embankment. In recent years there has been no commercial extraction (apart from local use for farm tracks etc) and the deposited gravel material has been pushed to the sides of the channel.

The management options for this reach are similar to the upper reach. However, the stream is less powerful and the channel migrates more slowly, while there is a natural on-going aggradation of the stream channel and hence high risk of break outs, which would give rise to long course changes. The estimated average annual rate of supply of the gravel bed material to this aggradational sink is around 1,500 m3. The actual supply would vary greatly, depending on flood intensities, and range from virtually nothing to over twice the average amount.

If the deposition of the gravel bed load is not managed then the stream will break out over the downstream farm land and form new courses across this land, down to at least Convent Road. The stream is confined by high sand dunes around the Convent Road crossing, and downstream of here the stream becomes very flat graded.

The State Highway Bridge, but more especially the Railway Bridge, is affected by the stream aggradation. These bridges are short and there is little height between the stream bed and the bridge superstructure. The bridge abutments or approaches have been damaged in the past, with rock and other structural works being used to protect the bridges. If stream bed aggradation is not managed in some way, then these main transport routes (S H 1 and the Main Trunk Line) would be cut during future flood events by stream erosion, regardless of the protection measures in place.

3 Wakapua Farm to Convent Road:

The stream has a much lesser grade, and has a single channel, of the threshold of motion meander form, which moves quite slowly. There is still some gravel in the stream bed, and the outer side banks at bends are vulnerable to erosion. A straight diversion was cut through in the past, and over time the stream has slowly developed a meandering curvature along the diversion, while the Ngatotara Stream was diverted to a lower confluence to increase the drainage grade along this waterway.

The main management issue along this reach is the amount of effort put into preventing erosion at the bends and consequentially the channel movement that arises from this erosion and associated deposition on the opposite bank. Preventing erosion at one bend, by strengthening the outer bank, will have an effect on the channel form as channel migration continues elsewhere, and this can give rise to alignment distortions that increase erosion pressures at the bend and elsewhere. While willow and other vegetation can be quite effective in preventing erosion along this reach, if it is well placed and managed, the longer term consequences because of meander migration should be considered when undertaking such measures. Denser and stronger rooting vegetation should be restricted to outer banks at bends, and even here there should still be some accommodation of meander migration in the layout and extent of the vegetation.

A stream corridor could be developed by fencing off around the outside of the meandering channel, from outside of bend to outside of bend down the reach. The channel could then slowly migrate within this corridor area, in a relatively unhindered way. In this case, a wider diversity of tall grasses, shrubs and trees could be planted along the stream margins, and in a way that reflected local variations in stream character, of inner and outer bank etc.

4 Downstream of Convent Road

The stream is very flat graded downstream of Convent Road, where the stream flows through what was once swamp land. Here the stream channel is very windy, and there is little erosion pressure at bends. Willows spread along the stream banks here as elsewhere, but along this reach they can greatly reduced the flood capacity of the flat-graded channel. The main works carried out along the Waitohu Stream under the original scheme was willow clearing and bend cut-offs along this reach of the stream.

The main management issue along this reach is then channel capacity, not bank erosion or change of course threats. Again, though, it is a question of degree. Here about how much effort should be put into removing willows and other large trees from the stream banks. Where there are easily eroded materials, such as sand, in the stream banks, then some vegetation cover is needed to prevent erosion, and in these areas willows should be removed progressively, and replaced by tall grasses and shrub vegetation.

5 Mouth

The coastal and estuarine reach of the stream is affected by a complex interplay of sea and stream forces and processes, and it is naturally a place of continual change with a high degree of variation and movement of the stream channel. There are, though, natural limits to this variability, and the best approach is to provide sufficient space for the stream to alter and move naturally without constraint. Diversion cuts have, though, been formed through the beach formation periodically over many years, and this mouth management is presently guided by limits on the outlet position and erosion against the landward side sand dunes.

The main management issues are erosion of the sand dune land around the mouth and the nature and extent of vegetation on these sand dunes. The variability of the mouth area and the difficulties of predicting responses to either structural or vegetative measures means that management interventions should be undertaken only when essential and then with carefully consideration of the possible consequences. All too often there are unexpected outcomes, especially when more extreme conditions (of sea storms or stream floods) occur.

Climate change is also likely to give rise to more intense storms more often, as well as rising sea levels. This will affect both the natural variability at the mouth, and hence the extent of the natural re-working processes at the mouth, and the difficulties of any management intervention.

If diversions are cut through the beach formation they should be formed to a natural curve and positioned around about where the legal road of the Old Coach Road ends. The relief gained, in terms of reduced erosion pressures at one place or another, is necessarily temporary, and there is always a trade-off in the relief gained around the mouth area. This type of intervention, therefore, has to be continued indefinitely and with a continual balancing of relief or erosion pressure.

Structural measures to hold the outlet in one place are not, though, recommended, because of their design problems, implementation difficulties and expense, both of construction and/or repairs and maintenance.

Any planting of the sand dunes should be concentrated around the margins of the actively worked mouth area, reinforcing existing vegetation, rather than extending onto the (longer term) area of active re-working by the stream or the sea. Where planting is undertaken for species conversion, this should be done in a progressive manner, maintaining a vegetation cover as far as practical throughout the conversion process.

September 2004 G J Williams
Water & Soil Engineer

G & E Williams Consultants Ltd
R D 1,
OTAKI (06) 3626684