GREATER WELLINGTON REGIONAL COUNCIL

WESTERN RIVER SCHEMES

NATURAL CHARACTER

REPORT ON
THE NATURAL CHARACTER OF THE RIVERS AND AN ASSESSMENT OF NATURAL CHARACTER FOR SCHEME MONITORING

Report prepared by

Gary Williams

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G & E WILLIAMS CONSULTANTS Otaki

WESTERN RIVER SCHEMES — NATURAL CHARACTER

ASSESSMENT OF NATURAL CHARACTER
FOR SCHEME MONITORING

1 INTRODUCTION

Investigations into the natural character of the scheme reaches of the Otaki, Waikanae and Hutt rivers has been undertaken as part of the Assessment of Effects for consents for river management measures and works along the scheme reaches. This has been part of coordinated investigations into the effects of river management, carried out through a consultation science group.

This report provides background on river character and what gives rise to the natural character of a river reach. It outlines the climatic and landscape setting that determines the character of rivers, and the dynamic variations and changing influences that impact on the flow, sediment transport and channel forming processes of rivers. A general description of the river reaches and their formative context is given with reference to previous studies of river characteristics and sedimentation processes.

Approaches used for the assessment of natural character are briefly described, along with the assessment based on some physical features that has been used in this study. A general natural character index [NCI] has been determined using available aerial photography to measure the physical features, and comparing conditions in early photography with that of the current (2010) aerial photography.

This NCI provides an indication of changes in the physical conditions of the river reaches, and hence general trends in environmental health. It can, therefore, be used as a monitoring tool for consent conditions.

2 RIVER CHARACTER

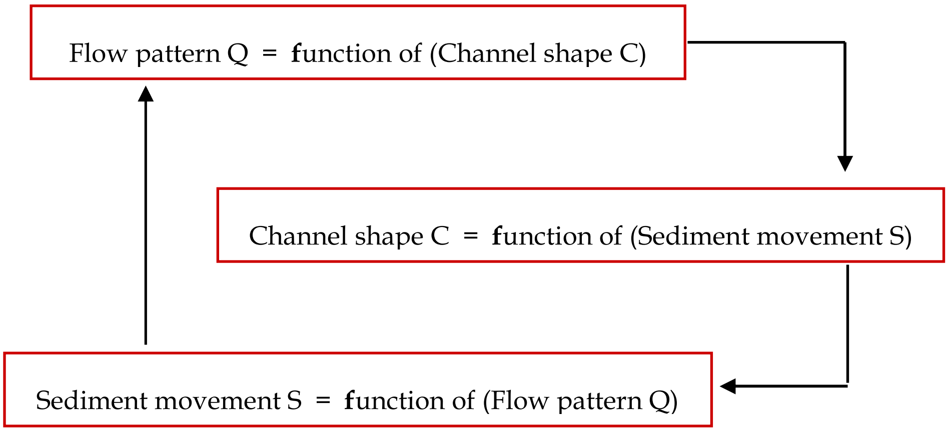
2.1 GENERAL

A river reach has a natural character that depends on the overall setting, of climatic regime and catchment conditions, and the local physical and ecological conditions along the reach. This character is not fixed, but varies over time and along river reaches. It is a dynamic expression of the processes at work and the variations over time and space of the influencing forces. It is more a matter of the processes at work than a specific state or channel condition.

The natural character of a river, thus, changes along the river, from the headwaters to the sea, and when characterising a river this is done by reaches. It is a given reach that can be characterised, not a river. The nature, character and responses of a river change from reach to reach, as the forces and processes at work change, and a given character can only be defined for a reach where there is a similarity of river processes along it.

From steep forested headwaters to wide flat marshy alluvial plains, rivers change their form, and over time they change with climatic variations and changes in the intensity of floods. These changes alter the ecology of the river, which in turn feeds back and alters the physical processes and form of the river.

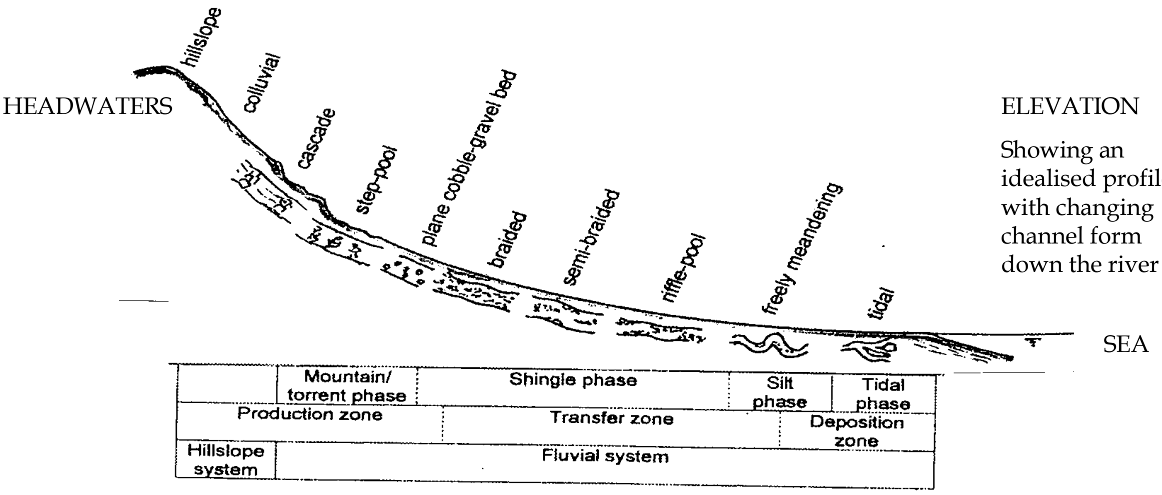
The natural character of a river reach, in its physical expression, arises from a complex interplay of the flow forces, the rate of supply and nature of the river sediments, and the channel form and resistance to erosion of the river bed and banks. The self-similarity of river channels, that form and re-form to a characteristic pattern from flood to flood, arises from an interconnection or feedback loop between flow pattern, sediment transport and channel shape. Flow pattern is a function of channel shape. Channel shape is a function of the erosion and deposition processes of sediment transport. Sediment movement is a function of the flow pattern. Thus, while the river channel moves, its meander form stays the same, through a feedback loop connecting all these aspects of the physical behaviour of the river.



River management that alters channel shape thus has direct effects on flow patterns and sediment transport. Conversely, channel shape is very important in river management.

The diagram below is an example of the characterisation of changes in channel form down a river.

RIVER TYPES — Down a River



ELEVATION

Showing an
idealised profile,
with changing
channel form
down the river

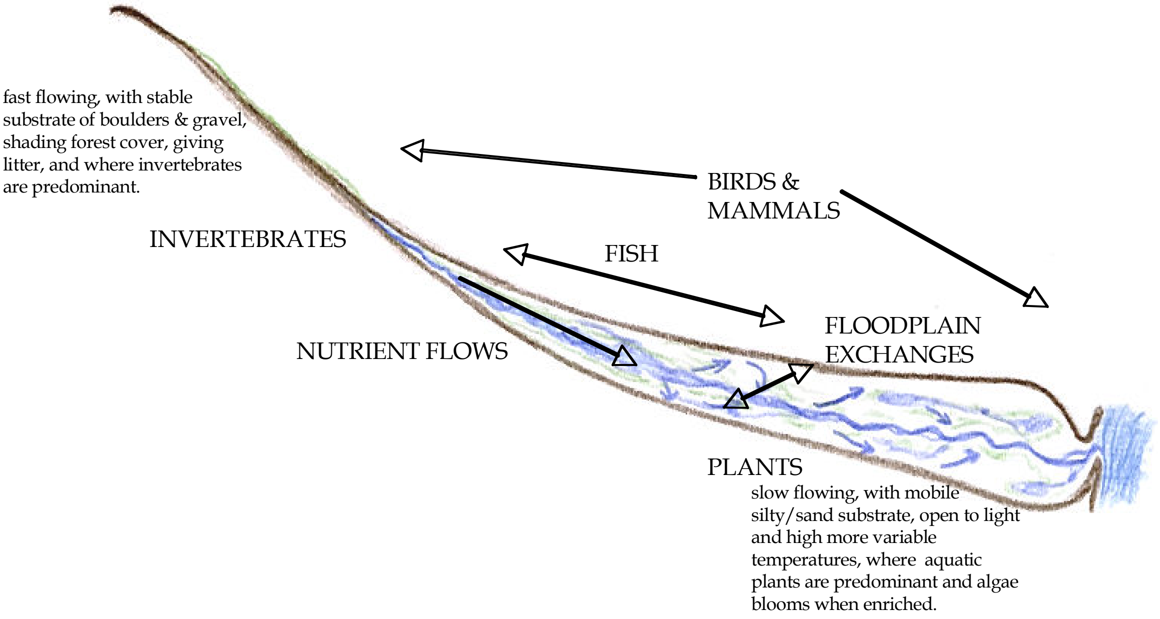
CREDITS: "Gravel Bed Rivers", by Paul Mosley & Stanley Schumm

Rivers and their margins have an especially diverse ecology, given the availability of water, edge effects, and the dynamic interactions between surface and ground water, and channels and floodplains. The ecological systems are highly linked and inter-dependent. There are complex interactions between the biology of flora and fauna along waterways and the physical nature of the waterways. The physical processes and ecological relationships of aquatic and terrestrial habitats form an inter-dependent and inter-connected system. Most noticeable are the interactive effects of vegetation in rivers, with river margins providing diverse vegetative habitats, and vegetation affecting the channel form through island colonisation and channel splitting. The deposition of logs and snagging of vegetative matter also encourages the growth and spread of vegetation within the channel.

The primary biological energy input to a forest stream is the leaf litter, while the primary energy input to an open river channel is from in-stream algae and macrophytes. This gives rise to very different eco-systems, which in turn impact on the channel form.

ECOLOGICAL PROFILE — Along a River

Biological activity adds layer on layer of interconnected processes, which give rise to very complex and dynamic river systems of inter-dependent ecosystems and physical exchange systems.



fast flowing, with stable substrate of boulders & gravel, shading forest cover, giving litter, and where invertebrates are predominant.

slow flowing, with mobile silty/sand substrate, open to light and high more variable temperatures, where aquatic plants are predominant and algae blooms when enriched.

A characterisation of waterways would then extend beyond a determination in terms of the physical features of river reaches. Along with physical form, it would include the hydrological regime (of flow variations over time), the riparian (and floodplain) vegetation or habitats, and the aquatic life (of invertebrates and fish). An assessment of the natural character of a river reach can then be undertaken in terms of a number of broad categories, with each aspect or influence determined or characterised in a way appropriate to its form, pattern, speciation or behavioural type.

2.2 RIVER MANAGEMENT

The natural character of a river reach can be used to guide river management along that reach, to make use of, and work in with the natural forms and patterns of the river.

Studies of river characteristics and the processes of sediment transport and channel formation can be used to determine the natural channel form of a river reach, and its variability over time and climatic cycles. From this, appropriate active channel areas and overall river corridors, comprising an active channel and margin vegetation buffers, can be determined. River management can then be directed at the maintenance of clear fairways for the active working of the river bed material, and of dense vegetation margins to buffer and absorb the channel migration and splitting or braiding that occurs as part of this activity. The natural form of the channel along the reach can also guide in-channel works and alterations to the active channel, while the wider river corridors define the overall space sufficient for the river to change and move according to its natural dynamic.

Allowances have to be made for the changes in channel form and increase in width during periods of high flood intensity, as compared to more quiescent periods. The buffer zones absorb the erosion and deposition processes of the river, without an encroachment onto productive land or threat to valuable assets. They also provide sufficient reserve to allow a slow re-establishment of lost vegetation over time, as the river naturally moves on and attacks other areas of the buffer. Remedial action can, therefore, be less intensive, with greater reliance on the re-establishment of vegetation over time.

The river corridor, therefore, defines a suitable area for the river, and the outer boundary beyond which productive uses can be made of the land alongside the river reach.

The character of a river reach, in terms of its channel form, can be determined at a more detailed level, as a way of representing channel conditions. Channel parameters, such as: - the ratio of the active bed width to the flood effected width; the substrate material and woody debris present; the degree of braiding or channel splitting, and the sinuosity of low flow channels or braids; the type of channel features of beaches, bars and islands; and low flow channel forms, in particular pools, riffles and runs - can be used to define the reach conditions, and then repeat determinations over time can be used as a monitoring mechanism. These physical parameters can be taken as indicators of the naturalness and health of the river reach, with changes being indicative of enhancement or degradation of river health.

In this way a Natural Character Index [NCI] can be developed and used as a measure of the state of the river reach, through its physical form. Changes over time would provide an indication of the environmental effects arising from the natural dynamic of the river and artificial interventions in the river channel. The index would not differentiate between naturally influenced changes and river management effects, and would include the indirect impacts from catchment or climatic changes, as well as direct impacts from local river system changes affecting river reaches.

Effective river management depends on an understanding of the larger hydrological system and the ecosystems of the landscape or watershed, and in particular the interactive and dynamic variability of these systems. Characterising river reaches and determining their natural character in terms of formative influences and the system processes of rivers, provides an appropriate basis for the definition of river management zones, and at the same time gives an indication of the overall environmental condition of the river reaches. A more detailed characterisation can be useful in determining whether the natural character of a reach is being maintained, enhanced or degraded.

A formal determination of the natural character of rivers and their margins, in a manner understood by all parties, can provide a useful environmental indicator, while assisting river management to be more comprehensive and effective.

2.3 LANDSCAPE SETTING

The natural character of river reaches in the western Wellington region depends on the catchment conditions and climatic regime of the lower North Island of New Zealand. The primary catchment influences are geology, topography and vegetation, and how this impacts on erosion and sediment movement processes along the river system. The climatic regime depends on the nature of the weather systems, their varying intensities, and the influence of climatic circulations and oscillations on the local weather.

New Zealand is made up of large islands on the tectonic boundary of the Pacific “ring of fire”, where a small area of continental crust has been pushed and shoved, raised and sunk, over long periods of geological time. It has a mountainous backbone along the line of this boundary, with rapidly uplifted and shattered base rocks, and steep gravel-bearing rivers that have a short run from the mountains to the sea. It has a southern mid-latitude oceanic location, where the mountain ranges cut across the westerly circulation of anti-cyclones and depressions, giving rise to high intensity rainfalls.

Flood flows are generated very rapidly, and give rise to sudden but brief flooding of floodplains, under natural conditions. The relatively high flood flows and steep grade of rivers in New Zealand give rise to powerful highly turbulent flows that move large amounts of sediments and debris, and the river channels are highly mobile and change rapidly even over human time spans. However, the short time span of these floods suddenly truncates sediment transport and channel movement, and this can leave sharp hook embayments and other channel distortions in the river bed following flood events. The steep landscape of weak fault-broken base rocks gives rise to high catchment input of sediments even with the natural forest cover of New Zealand.

The oceanic climate is highly variable, with an unstable seasonal pattern, and longer term variations from the oscillations of large global circulations, of the southern oceans circulation (around Antarctica) and circulations around the South Pacific. The back and forth movement of a convergence zone of these two large circulations gives rise to a decades long variation in the New Zealand climate. The diverse landscape and climatic regions of New Zealand are affected at different times and in different ways through this pulsating dynamic of the Interdecadal Pacific Oscillation [IPO]. Thus in a given region there are periods of high flood intensity followed by a generally quiescent period, before a return to more and larger floods. The river system responses to these changes, and this is reflected in changes in channel form and vegetation extent.

Over the last 2 million years, of the Pleistocene geological era, the major slip-strike faults of the Wellington region developed with mountain uplift and block faulting. This has given rise to a set of tilted blocks, split by the main (presently active) faults, with periodic uplift and horizontal displacement. The rivers of the region generally follow the fault lines, with a step-wise pattern around fault formed blocks. Block buckling has also occurred, especially along the Wellington Fault, where there is a series of infilled basins along the Hutt Valley and in the Wainuiomata and Whiteman's valleys.

Over this same time period, there has been marked swings in climate, from cold glacial periods, with large ice caps at the poles, to relatively warm interglacial periods, as at present. The mid-latitude position of New Zealand makes the climatic changes particularly pronounced, with the vegetation in the Wellington region shifting from cold tundra-like grasslands to the very dense multi-species rain-forests of the present native forests.

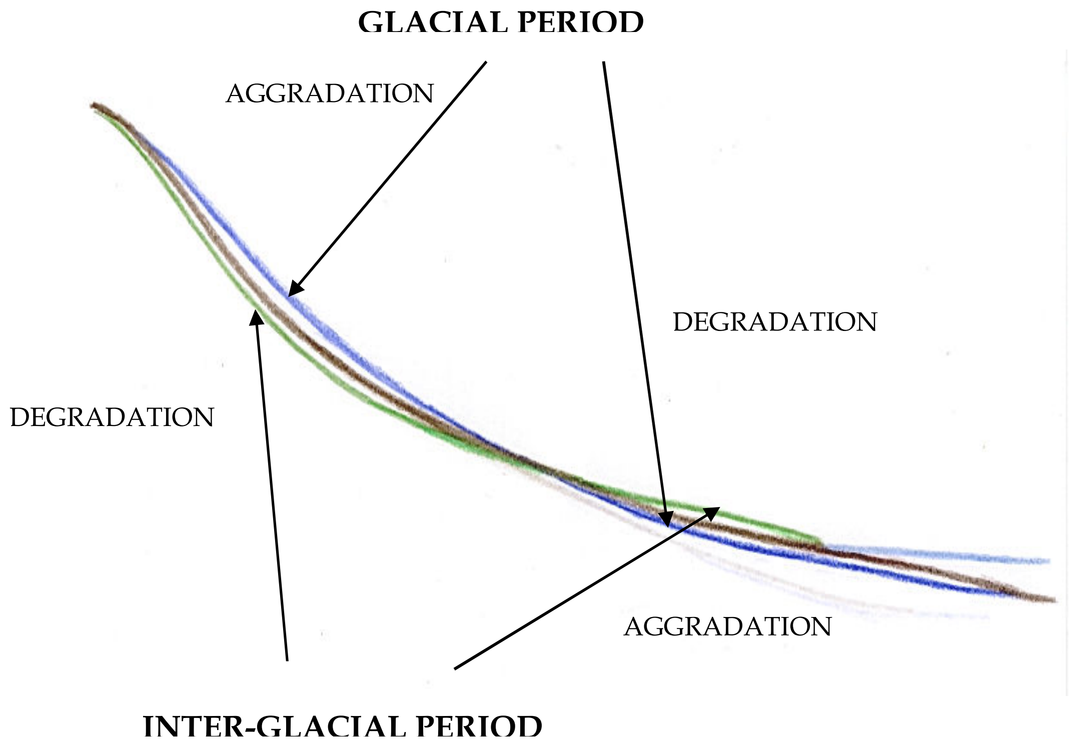
At the same time, sea levels have gone up and down, with ice accumulations at the poles lowering sea levels by over 100 m compared to interglacial periods.

These climatic changes have given rise to alternating periods of aggradation and degradation. In glacial periods there is a high sediment supply from the steep catchment land with valley infilling, but channel entrenchment on the plains down to a lower and further out coastline. In the shorter interglacial times the forest cover reduces catchment erosion, but more intense rainstorms degrade the rivers into the valley fill. At the same time, the higher sea level gives rise to aggradation and plains building at the coast, with coastline aggradation or wave attack retreat, as a new coastline forms.

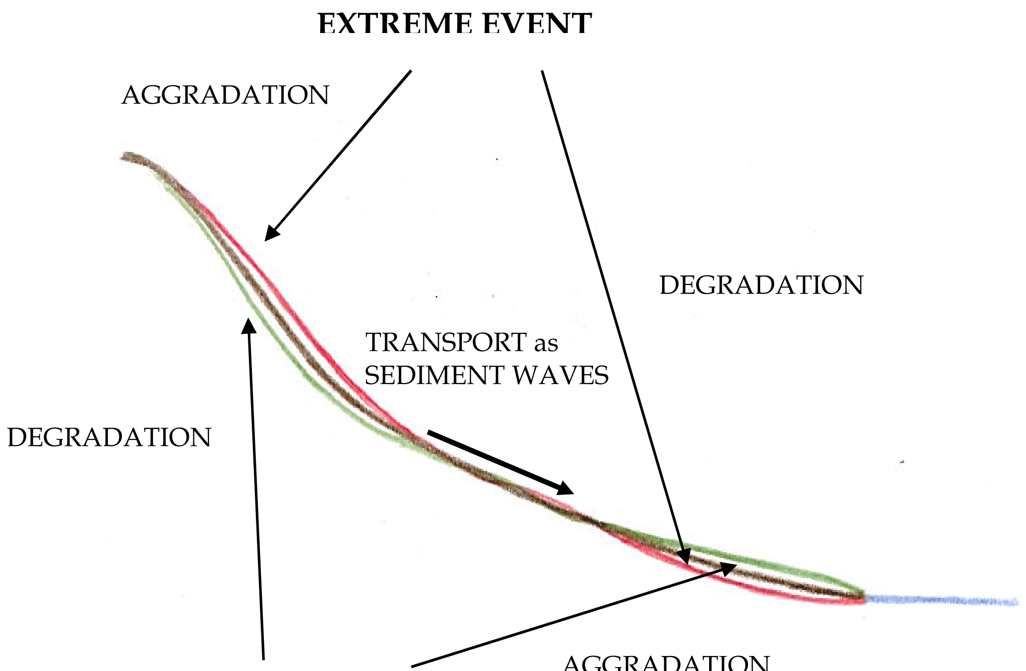
There is a similar effect from floods under present conditions, with the variations in catchment erosion and sediment movement between common and more extreme flood events giving rise to a down river pulse of sediment. In large storm events there is a high sediment input from the steeper upper catchment, and a flushing out of the lower reaches by the large flood flows. In more common flood events the upper catchment input is re-worked down the system and the lower reaches re-built.

RIVER PROFILES — Flood Intensity & Climate Change

Sediment transport and channel effects from Glacial to Interglacial periods



Sediment transport and channel effects between Common and Extreme floods



Particularly severe storms can destabilise catchments, giving rise to large erosion scars and greatly increase sediment input from the event itself and for many years afterwards. There was widespread erosion and wind damage to vegetation in the Tararua Range in the severe storms of 1936 and the 1950s, and these storms resulted in a large input of material to the river system, which continued over a period of many years. This material is transported down the waterways by lesser events, and over a period of time the large slip and infill deposits are eroded away and re-worked down the river system.

This pulse input of materials gives rise to a wave-like movement of the bed material gravels down the lower reaches of the river, as the storm deposits are re-worked and transported downstream. Bed levels at any given point will, then, vary due to the migration of channel meanders and the throughput of these gravel waves.

At present, there are relatively few active erosion scars in the Tarauras, with many of the old scars vegetated over. The main erosion activity is along the waterways themselves, with a re-working of the gravel sediments in the river systems.

2.4 WESTERN RIVERS

The Otaki, Waikanae and Hutt rivers are located on the south-western end of the North Island, and flow from headwaters in the Tararua Range mountains. The Otaki River flows from the Tararua Range divide westward to the Tasman Sea. Its watershed is mostly very steep forested land with very high rainfall intensities during storm events. It crosses a narrow coastal plain, initially within a terrace system, and supplies large quantities of gravel to the coastline.

The Waikanae River flows from lower but rugged rangeland of the Tararua Range. Its watershed is mostly a complex and broken up basin that is partly forested. It then passes through coastal hills to a coastal plain, where it has widened out due to the effects of Kapiti Island on coastal aggradation. The gravel bed load of the river is all deposited on this coastal plain.

The Hutt River flows from the high peaks at the southern end of the Tararua Range, southward to the basins along the Wellington Fault. Its upper catchment is mostly steep forested land, with tributaries draining the western side of the Rimutaka Range. The remaining catchment is basin and hill land, with remnant terraces. The river flows along the fault line in the Hutt Valley, and then across a short aggradation reach to the enclosed harbour of Port Nicholson. The gravel bed load of the river is partly deposited along its lower reaches and partly in the harbour at the river mouth.

WESTERN RIVER CATCHMENTS

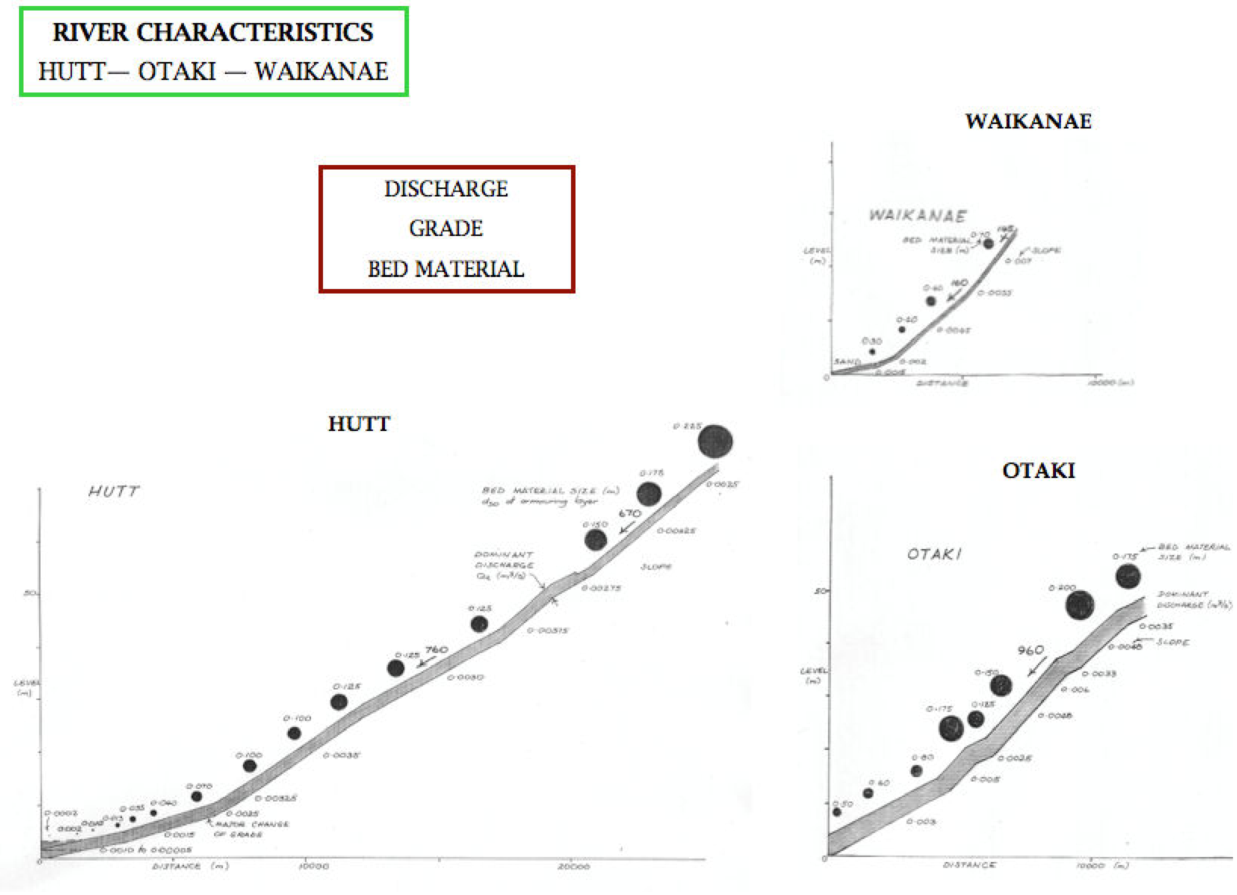
Catchment boundaries and major active faults shown

The type and form of river reaches along the three main rivers of the western region have been determined from the general characteristics of the reach and empirical relationships based on the determining factors of flow energy, gradient and bed material size. There is a basic relationship of the power of a river, derived from the flow mass and slope, being expended on the transport of bed (or bank) sediments, with the amount being moved dependent on the size and grading of the bed material. Given the interrelationships of flow, sediment transport and channel form, natural meander widths can be determined from formulae using the dominant flood flow (or 2 year return period flow), the slope and the medium size of the armouring bed material. The radius of curvature and wavelength of a channel meander can then be derived from its width using general wave relationships. In general, the radius of curvature of the meander is taken as 4 to 6 times the width, and the wavelength 10 to 12 times the width.

These three main characterising parameters are shown diagrammatically below, with the river characteristics plotted to the same scale.

RIVER CHARACTERISTICS

Representation of river grade, bed material size and dominant discharge



2.5 OTAKI RIVER

The river management scheme on the Otaki River extends from the river mouth to the lower gorge, over some 10 kilometres of river length. The river is tightly confined within a channel entrenched in base rock upstream of the scheme. Below this gorge the river has a narrow floodplain defined by high terraces, where the river has degraded into older (glacial period) plain deposits over the current interglacial period. The terraces become lower downstream and the river alignment is affected by fault movements along an active fault (at Chrystalls Bend). Below a low marine cut terrace parallel to the coast, the floodplain consists of an indistinct series of sand dunes and wind blown material, as well as alluvial deposits, and naturally the river was unconfined with widely separated channels.

The earliest plan records (of the 1870s) show the Otaki River having multiple channels, which could be widely separated, especially near the river mouth, and within the area of high terraces, upstream of Chrystalls Bend. The channels were highly mobile, with channel splitting and break outs during flood events.

The gravel bed material is relatively coarse, with the medium size for the whole of the bed material of around 50 to 80 mm, and varying from 50 to 200 mm for the surface armouring layer. There is a significant reduction in the armour layer size below the bridges, which may be due to a combination of river confinement and gravel extraction from the river bed, as well as the lesser grade of the river down to the sea. The river transports around 50,000 to 100,000 m3 a year. A substantial proportion of this sediment load can be transported to the sea, and feeds the coastline south of the river.

The river has been confined and managed by gravel extraction, in-channel reshaping and realignment works, edge vegetation establishment and reinstatement, pile and cable fences and a range of solid bank linings, mostly of rock in recent decades, and some rock groynes. Below the bridges, a straight channel was cut to the sea in the late 1940s, with the gravel bed material used to construct large bunds as stopbanks alongside the formed channel. Upstream of the bridges, the river channel was also tightly confined by river management over a period of time up to the 1990s. Since then a wider and more consistent channel has been developed, with more extensive and continuous vegetation buffers along the river channel. A major realignment at Chrystalls Bend was part of this development, with the old channel being formed into a wide vegetation and wetland buffer area.

There are now extensive lengths of rock lining along the river banks from Chrystalls Bend to the river mouth. Gravel extraction and channel reshaping is undertaken along much of the scheme length, as well as vegetation enhancement and reinstatement works.

Aerial photography of the scheme length of the river is available as follows:

DATE	SURVEY	DATE	SURVEY
Oct - 39	135	May - 91	8827
Apr - 48	198	Jul - 91	9168
Apr - 66	1847	Feb - 92	CPs
Oct - 68	3022	Apr - 92	8850
Dec - 72	CPs	98	
Feb - 74	CPs	Mar - 98	CPs
Nov - 75	6377	Mar - 99	CPs
Mar - 76	C 2963	Apr - 00	CPs
Nov - 78	5309	Mar - 01	LC
Mar - 83	8171	02	

DATE	SURVEY	DATE	SURVEY
Nov - 85	11208	Feb - 05	LC
Mar - 86	8628	Feb - 07	LC
Mar - 88	CPs	Feb - 09	LC
Apr - 90	CPs	Feb - 10	
Feb - 91	11776		

A fuller description of the Otaki River catchment and river channel is give in the 1992 report of the Floodplain Management Plan investigations, on River Characteristics and Sedimentation (see Reference 1).

2.6 WAIKANAE RIVER

The river management scheme on the Waikanae River extends from the river mouth to the Water Treatment plant, upstream of the bridges, over some 5 kilometres of river length. The river passes through the coastal hills in a well defined and entrenched channel, and is then bounded by low terraces before crossing a depositional fan. The river then flows around sand hills to a relatively large estuary area with a sandy base. The coastal sand hills were large shifting dunes until they were mostly stabilised by the planting of marram grass. There is naturally a significant coastal spit at the mouth, with a southern set.

The earliest plan records (of 1890) show the Waikanae River with two separate branches below the bridges, with one branch generally following the present river channel, and the other the present course of the Waimaha Stream. The river channels would have been relatively shallow, within a wetland and forest swamp environment.

The gravel bed material is relatively fine, with the medium size for the whole of the bed material of around 25 mm, and varying from 25 to 60 mm for the surface armouring layer. The bed material transport capacity decreases with the lessening of the river grade below the bridges, and the surface bed material becomes finer, with a sand bottom in the estuary. The gravel bed material, thus, naturally deposits on the coastal plain, and adds to the general coastline accretion from longshore drift. The river transport capacity along the lower reaches is small, at around 5,000 m3 a year.

A river management scheme commenced in the 1950s, following a series of large flood events. As well as flood mitigation stopbanks, this scheme included channel clearing and diversions, willow bank protection works and some rock linings. Over time a relatively well defined meandering channel was developed, with margin vegetation. Substantial amounts of gravel were extracted up to 1975, when extraction was closed down due to a lack of material. From 2000 substantial river works have been undertaken, along with riparian planting and recreational developments. The river works include rock linings, groynes and a weir, with the river channel developed to a design width and meander pattern.

Aerial photography of the scheme length of the river is available as follows:

DATE	SURVEY	DATE	SURVEY
Nov - 49	Oblique	Apr - 86	8640
Apr - 52	198	Feb - 91	9145
Apr - 57	1005		
Apr - 66	1847		
Apr - 68	3022		
Oct - 73	3686		
Nov - 85	11208		

A fuller description of the Waikanae River catchment and river channel is give in the 1992 report of the Floodplain Management Plan investigations, on River Characteristics and Sedimentation (see Reference 2).

2.7 HUTT RIVER

The river management scheme on the Hutt River extends from the river mouth to above Upper Hutt, over more than 25 km of river length. The river enters the infilled basins along the Wellington fault at Te Marua, where it is generally confined by both high and low terraces. The river is then entrenched in base rock, around Emerald Hill and past the Akatarawa River confluence, until it crosses the fault and flows within the Upper Hutt basin. Below the Taita gorge the river flows across the Lower Hutt basin, generally along the line of the fault on the western side, before turning away from the fault and losing grade, as the river adjusts to the sea level control at its mouth.

The present condition of the Hutt River within the two large basins of the valley is very different to what it was prior to European settlement. Early surveys of 1852 and 1867 show large meandering loops and split channels in the basins, and a substantial estuary at the river mouth, with three main channels entering the estuary. These channels would have been relatively shallow and mobile, with floodwaters spreading out over the lower basin and into the tree contributory channels of the estuary.

The Hutt Valley had been uplifted by a large earthquake around 1420, and the lower end of the valley would have been prograding through deltaic deposition. Another major earthquake in 1855 raised the valley by about another 2 metres, and the river would have degraded into the estuary materials and become more entrenched. Over time the river channel has been progressively straightened and confined, with the extraction of the gravel bed material being used to define and confine the river. The river channel has, thus, become substantially entrenched into the alluvial materials of the basins. The river straightening and entrenchment occurred later in the upper basin, starting in the 1950s.

The gravel bed material is relatively coarse, particularly above the Taita gorge, with the medium size for the whole of the bed material generally reducing downstream, from around 100 mm at the top end of the upper basin, to around 50 mm at the top end of the lower basin, and around 20 mm at the major change in grade. There is a similar reduction in the armour layer size from over 200 mm down to 30 to 40 mm at the major grade change, and then finer along the flat graded reach to the river mouth. The extraction of bed material and the entrenchment of the river into the underlying alluvial materials has probably given rise to a coarsening of the bed material. The river transport capacity is around 75,000 m3 a year, based on repeat channel surveys and extraction records. Somewhat over half of this supply is deposited in the natural deposition area above the major grade change, with the rest mostly deposited at the river mouth.

Timber and concrete block groynes were constructed along the river, over a long period of time, with edge vegetation being established and maintained as buffer zones. Rock linings were extensively used along the upper basin when the river channel was defined as part of the state highway development along the western side of the basin. Since the 1990s rock linings and groynes have been used in many places along the river, to a defined channel width and alignment, with more consistent vegetation buffer zones being established along the margins.

In-channel reshaping and beach raking works are undertaken along the river for channel management and in association with bank works. The river bed is being lowered along the natural deposition reach upstream of the major change in grade to maintain flood capacity. This is being done by pushing material from the low flow channel onto the gravel beach, and then removing this material from the beach over time. The in-channel work is undertaken one beach (or half meander) at a time, and the excavation is being undertaken to the natural meander pattern of the river reach and with pools and riffles being maintained.

Aerial photography of the scheme length of the river is available as follows:

DATE	SURVEY	DATE	SURVEY
1936	AF 20	1977	5146
1939	128 & 129	1978	5200
1941-43	163	1980	5497
1949	613	1983	8254
1950	718	1985	8457
1951	570	1988	8909
1957	1005		
1958	1093		
1959	1256		
1965	2001		

DATE	SURVEY	DATE	SURVEY
1966	1407	Feb - 05	LC
1969	3185	Feb - 07	LC
1973-74	3672		
1974	3783		

A fuller description of the Hutt River catchment and river channel is give in the 1991/1994 report of the Floodplain Management Plan investigations, on River Characteristics and Sedimentation (see Reference 3).

2.7 HUTT RIVER TRIBUTARIES

The Hutt River scheme includes some management along short reaches of tributary streams from their confluences with the Hutt River.

2.7.1 TE MOME STREAM

The Te Mome Stream takes storm water from the Petone stormwater system to the mouth of the Hutt River. It is an old tidal channel of the Hutt River, on one side of what was Gear Island. The channel has been cut off, and is now a narrow remnant channel, connected by road culverts to the Hutt River. The stream has a flat channel, and there are floodgates at the outlet to the river. However, inflows of tidal water and seepage gives rise to some tidal fluctuation, and hence to bare banks within the tidal range. The main management activity is the removal of rubbish and debris, and some channel clearing.

2.7.2 SPEEDY’S STREAM

A short reach at the lower end of Speedy’s Stream is with the Hutt River scheme. The stream enters the Hutt River on the downstream side of the Kennedy-Good Bridge, after flowing through large culverts under S H 2 and around Belmont School. The stream catchment covers an area of relatively steep land on the western side of the Hutt River valley, up to the loess-covered terraces and upland of the Belmont hills. The waterways are well entrenched into the greywacke base rock, and confined at the bottom of steep sided valleys. The scheme reach has been modified and enclosed by the long road culverts, but upstream of S H 2, the stream retains its natural character, with dense regenerating native forest along the main waterway reaches of the stream and its tributaries. The only real management activity is the removal of debris from a coarse debris collector upstream of the culverts.

2.7.3 STOKES VALLEY STREAM

The Stokes Valley Stream is the main waterway of a small basin, between the lower and upper Hutt basins, formed by buckling on the down thrust side of the Wellington Fault. The stream has been highly modified along its lower reaches, as part of the urban subdivision of the valley. It has been straightened, lined and enclosed by culverts. The lower 1.6 km of the stream is maintained by the Hutt scheme. This includes an outlet channel parallel to the Hutt River, where a separation bund takes the stream mouth about

300 m downstream. The scheme reach is very artificial, as a uniformly shaped straight channel with sharp bends, and with culverts, weir and stilling basin, and concrete lined banks along the upper part. The main management activity is the removal of rubbish and debris, with some structural repairs as required.

2.7.4 AKATARAWA RIVER

The Akatarawa River is one of the larger tributary rivers that flow in the Hutt River along the upper basin reach. Only a very short reach at the river confluence is within the scheme, and the only management measures are at the confluence itself.

3 ASSESSMENT OF NATURAL CHARACTER

3.1 METHOD

The characterisation of river reaches has been undertaken in different ways and for different purposes. A 'river styles' approach has been undertaken in Australia, with the most comprehensive application being the Tasmanian River Condition Index [TRCI] for the State of Tasmania (see Reference 4).

The TRCI has been developed as a framework for assessing the condition of Tasmanian river systems, and it does this by evaluating the condition of four key aspects of waterways: Aquatic Life, Hydrology, Physical Form and the Streamside Zone. These sub-indices of the TRCI can be used separately, or combined into an overall index.

The TRCI is designed as a practical tool to establish the existing condition and monitor changes from this baseline into the future. It is a referential approach whereby the current condition of sites is compared with a pre-European reference condition.

The TRCI can provide:

- a baseline assessment of condition from which changes can be monitored over time;
- an assessment of the effectiveness of natural resource management;
- monitoring of the impacts of human activity in catchments on river systems (such as water extraction and regulation, vegetation clearance, and in-stream structures); and
- data for relevant information systems.

A similar characterisation was undertaken, in a general way, for the plains (and scheme) reach of the Waingawa River in the Wairarapa. In this case the categories used were: Hydrological Regime, Channel Form, Riparian Vegetation and Aquatic Life. A more detailed inventory of the physical form of the river channel was also carried out based on channel features and pools, riffles and runs (see Reference 5).

However, there have not been any well defined and documented assessments of natural character for waterways in New Zealand, as a means of reach characterisation. There have been studies of river types and the characteristics of different types of rivers, which is directly applicable to New Zealand rivers. The natural meander pattern of rivers has also been assessed for many different types of rivers and reaches in New Zealand, to assist in river management, and to determine appropriate management corridors. The specific channel condition for a given reach was assessed from the general characteristics of the reach, based on repeat aerial photography and channel cross section surveys, and empirical relationships based on the determining factors of flow energy, gradient and bed material size.

As part of the investigations for the Scheme Consents, a basic assessment of natural character has been undertaken, based on a few physical features of river channels. This physical condition assessment should be understood in relation to the other investigations, in particular of aquatic life and river vegetation and bird habitat. The previous studies of river character should also be referred to, with the information they contain on channel conditions and hydrological data. This includes assessments of the natural form and responses of the river channels and their variability over time, the nature and size of bed material, and sediment transport rates for the hydrological regime and flood pattern of the rivers.

3.2 ASSESSMENT OF PHYSICAL CHARACTER

A NCI has been determined using some basic physical features of the channel for the scheme reaches of the Otaki, Waikanae and Hutt rivers, to give a high level index of natural character. These features are:

- the active (clear) bed of the channel, the bankfull width and the permitted floodplain width;
- channel sinuosity from flow length and direct valley length;
- and pool-run-riffle sequences.

A braiding index could be used as well, but the river reaches do not naturally have much braiding. Prior to catchment modification and alteration of the river channels through management measures, the river reaches had some channel splitting tendency, with separated channels and flood carrying back channels. The active channel areas, though, generally consisted of a single low flow channel with wide gravel beaches and some gravel islands. These active areas were surrounded by floodplain vegetation, and there was generally a dense forest cover where there had been no modification from fire or mechanical clearing.

The scheme length of the three rivers has been divided into generally consistent reaches, which are also used for management purposes. Indices have been determined for each of these reaches, as a unit, from measurements of the physical features. The NCI is, then, a combined index obtained from the average of the values obtained for each of the physical features.

The reference condition for the indices was taken from the earliest available aerial photography for the scheme reach of the three rivers. The date of this photography was different for each river, and the degree of modification of the river reach by that time also varied. The reference standard was not, therefore, an unmodified state, prior to any human intervention. The indices provide a measure of the changes in physical conditions over a defined period of time, and hence a basis for assessing further changes over time. They are not a measure of change from some “natural state”, in whatever way that may be defined or determined.

The physical features as shown on the earliest aerial photography have been compared with those same features (as measured) on the latest (2010) photography, and the index value obtained by dividing the current measured value by the earlier one, to give a condition ratio. The determination has been done from aerial photography and contour information produced from Lidar imagery surveying.

This NCI is based on physical features, and a comparison over a defined period of time, but if the same methodology is used in future determinations, then consistent and comparable assessments can be obtained and used to track trends in river conditions.

4 NATURAL CHARACTER INDEX

The physical features that provide the parameter values for a general index of natural character have been measured from aerial photography. This assessment has been undertaken as a Massey University project, and the methodology is explained in the university report on this project (Reference 6). The assessment of the pool-riffle sequences was undertaken separately, and added to the Massey project.

The determination of the indices that make up the overall NCI is briefly summarised below.

Bed width ratios —

> Three indices have been obtained from measurements of channel widths. These indices are ratios of the actively worked channel width, the bankfull width before overflows to the floodplain, and the width of floodplain available to flood water (or the permitted floodplain width) compared to the natural (unrestricted) floodplain width. For each of the scheme reaches along the three rivers, which are the unit reaches for each river, a series of width measurements were taken along the reach, and an average value obtained for the four required widths. Thus, the active width was measured over a set of cross sections along the reach, the bankfull width was measured for a similar set of cross sections, and the permitted flood extent width and the natural floodplain width similarly determined from sets of cross sections.

Channel sinuosity —

> An index of sinuosity has been obtained by measuring the flow length (or length along the thalweg line of maximum flow depth) along each unit reach, and dividing this by the direct length from the top to the bottom of the reach.

Pool-riffle sequence —

> An assessment of the number and sequences of pools and riffles was undertaken through a determination of the significant pools present along the unit reaches from the aerial photography. Only those pools that were clearly deep water pools were included. This is a simplified measurement, and the pool number was expressed as pools per kilometre, given the different lengths of the unit reaches.

The consistent reaches used in the NCI determination are given in Table 1. This defines the reaches in terms of river survey cross sections, and gives river distances. This table also gives the results of the pool count, with the position of the pools defined by cross section number.

The results of the NCI determination are given in Table 2 for the three rivers. The values are the ratios of the present to historic measurements, where 1 means no change over the assessment time period. The lower the ratio value the greater the change. The overall index is an average of the indices included in it. The table gives an overall index for the three bed width ratios, as determined using the Lidar topographical information overlaid on the aerial photography, and for the sinuosity and pool count values. The indices can, though, be used separately or in combinations, and when future re-assessments are undertaken, trends can be seen in each of the contributing indices (and hence the relevant physical feature) as well as through overall index changes.

The determination of the indices has been set up so that lower ratio values indicate a decline in the natural character of the river reach. Thus the lower the ratio the less the reach condition expresses its natural character, while a higher ratio indicates an improvement or enhancement of the natural character of the reach. Index values of greater than 1 mean that present conditions are an improvement on those at the time of the reference earlier aerial photography.

The Otaki River was relatively unmodified at the time of the earliest reference photography (of 1939), although recent severe storms in the Tararua Ranges had destabilised the river catchment and there was a high gravel bed load supply to the river at the time. Apart from the sinuosity parameter, there has been a substantial decline in the physical condition of the river, and hence in its natural character, as indicated by this NCI assessment.

The reference photography for the Waikanae River is more recent (at 1952), and there has been relatively little overall modification of the river channel, although river management has given rise to a more defined and consistent channel. The assessed NCI is, thus, close to 1.0, with some improvement in the width consistency and channel condition generally.

For the Hutt River there had been substantial modification of the lower basin reaches by the time of the reference photography (of 1941-43), but little river management intervention along the upper basin reaches. There has been some reduction in the active widths of the river, especially in the confinement of flood waters. While there has been a general decline in pool count, there has been some improvement along the lower reaches, which were been extensively reworked at the time of the earlier photography.

5 SCHEME MONITORING

5.1 MONITORING AIMS

The NCI has been produced, along with other baseline data and studies, to provide a basis for monitoring the condition of the scheme reaches of the three rivers and as a guide to river management. The index is a proxy for the environmental condition and health of the waterways, with its repeatability allowing trend monitoring and an indication of changes in condition. Significant changes in the index would then trigger investigations into what has given rise to the changes.

This NCI is based on readily determined physical features using an easily repeated data base, of aerial photography and Lidar imagery surveying.

Repeat river surveys have been set up along the scheme reaches of the rivers, and past surveys have allowed trends in channel shape and bed levels to be monitored. These surveys are carried out after significant flood events or at around 5 yearly intervals.

5.2 CONSENT MONITORING

The consent conditions are based on an adaptive management approach, and the NCI, as determined in this study, can be used as a general indicator of the overall impact of river management, and other influences, on the river. The index values are specific to each river and its reference conditions, but changes in the values over time do provide an indication of general changes in the natural character of the scheme reaches.

The periodic aerial photography and Lidar aerial surveying that is carried out as part of the management of the schemes should therefore be used to update the NCI, and this will provide a trend indicator to guide and assess the impacts with an adaptive management approach.

6 CONCLUSIONS

The scheme reaches of the Otaki, Waikanae and Hutt rivers have been substantially modified by river management and flood mitigation works, and on going management is required to maintain design standards of protection. These rivers are naturally highly mobile gravel bed rivers, with changing channels and very dynamic sediment transport processes. The natural character of the scheme reaches has, therefore, been affected by containment of the rivers and management aimed at protecting people and economic or social assets from flood damage.

An assessment of natural character has been undertaken to provide information on the present condition of the scheme reaches, and to set up a general index of natural character to provide a monitoring tool that will give an indication of changes in the condition and environmental health of the river.

The index is quite general and is based on changes from a given point in time, which was taken as the earliest available aerial photography (giving complete coverage). It is a relative measure, and can be re-assessed in the future to provide an update of river conditions, as indicated by the physical features that make up the index.

The NCI assessment gives an indication of changes from the reference time, which is different for the three rivers. Thus, the NCI values cannot be directly comparable from one river to another. They are a relative measure of changes over time, specific to each river and its reference conditions.

The NCI provides a monitoring tool, with the measurement of the physical features that make up the index been repeatable from the aerial photography and Lidar surveying that is obtained as part of scheme management. As aerial photography is updated, the NCI can be re-assessed, and changes in the index, and its constituent parts, determined. This can then provide an overall indication of natural character, and whether there have been improvements or not.

February 2013 G J Williams
Water & Soil Engineer

G & E Williams Consultants Ltd,
R D 3,
OTAKI. (06) 3626684

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6.

TABLES

OTAKI RIVER

TABLE 1 - A

REACH	DISTANCE	POOLS	POOL COUNT	POOLS	POOL COUNT	POSITION 2010	POSITION 1939
Cross sections	(km)	2010	/km	1939	/km	Pool position by XS	Pool position by XS
XS 990 – XS 870	1.56	2	1.3	3	1.9	990 960	980 960 880
XS 860 – XS 780	1.05	0	0.0	1	1.0		800
XS 770 – XS 610	2.02	0	0.0	4	2.0		720 700 680 660
XS 600 – XS 490	1.33	3	2.3	3	2.3	590 521 490	590 545 501
XS 480 – XS 370	1.11	0	0.0	1	0.9		470
XS 360 – XS 220	1.57	1	0.6	3	1.9	240	300 250 230
XS 210 – XS 80	1.65	1	0.6	4	2.4	130	190 165 120 100
TOTAL	10.29	7	0.7	19	1.8		

WAIKANAE RIVER

REACH	DISTANCE	POOLS	POOL COUNT	POOLS	POOL COUNT	POSITION 2010	POSITION 1952
Cross sections	(km)	2010	/km	1952	/km	Pool position by XS	Pool position by XS
XS 550 – XS 430	1.22	7	5.7	7	5.7	540 515 505 490 470 440 425	520 500 490 460 455 435 430
XS 420 – XS 350	1.04	5	4.8	6	5.8	410 405 385 360 355	420 410 400 385 380 370
XS 345 – XS 310	0.73	3	4.1	2	2.7	345 345 315	340 330
XS 300 – XS 240	0.81	0	0.0	4	4.9		300 295 290 275
XS 230 – XS 175	0.92	1	1.1	4	4.3	160	235 220 190 185
XS 155 – XS 80	0.59	5	8.5	6	10.2	135 125 120 105 90	160 155 140 130 120 105
TOTAL	5.31	21	4.0	29	5.5		

HUTT RIVER

TABLE 1 - B

REACH	DISTANCE	POOLS	POOL COUNT	POOLS	POOL COUNT	POSITION 2010	POSITION 1941-43
Cross sections	(km)	2010	/km	1941-43	/km	Pool position by XS	Pool position by XS
XS 2780 – XS 2560	1.55	6	3.9	–		2770 2750 2735 2720 2700 2650	
XS 2540 – XS 2410	2.64	3	1.1	–		2510 2500 2430	
XS 2400 – XS 2270	1.19	1	0.8	1	0.8	2270	2270
XS 2260 – XS 1920	3.73	2	0.5	6	1.6	2010 1990	2190 2170 2110 2090 2060 2040
XS 1910 – XS 1780	1.57	3	1.9	4	2.5	1910 1900 1840	1910 1900 1860 1810
XS 1770 – XS 1350	4.65	3	0.6	7	1.5	1650 1590 1520	1710 1670 1610 1530 1470 1430 1370
XS 1340 – XS 1090	2.69	0	0.0	3	1.1		1300 1260 1200
XS 1080 – XS 850	2.78	4	1.4	5	1.8	1080 1030 1010 920	1080 1060 1010 980 950
XS 840 – XS 510	3.56	5	1.4	5	1.4	770 720 640 620 530	770 740 660 620 580
XS 500 – XS 370	1.50	3	2.0	0	0.0	440 410 390	
XS 360 – XS 210	1.61	1	0.6	1	0.6	360	360
XS 200 – XS 100	1.21	2	1.7	1	0.8	170 130	170
TOTAL	24.49	24	1.0	33	1.3		

TABLE 2

OTAKI RIVER

REACH	SINUOSITY	POOLS	NATURAL FLOODPLAIN WIDTH to			**OVERALL**
Cross sections			ACTIVE	BANKFULL	PERMITTED	**INDEX**
XS 990 – XS 870	0.97	0.67	0.62	0.71	0.82	**0.76**
XS 860 – XS 780	1.21	0.00	0.94	0.57	0.36	**0.62**
XS 770 – XS 610	0.86	0.00	0.68	0.25	0.84	**0.53**
XS 600 – XS 490	0.83	1.00	0.75	0.62	0.34	**0.71**
XS 480 – XS 370	0.99	0.00	1.01	0.34	0.24	**0.52**
XS 360 – XS 220	0.91	0.33	1.13	0.26	0.11	**0.55**
XS 210 – XS 80	0.92	0.25	0.48	0.25	0.10	**0.40**
AVERAGE	0.96	0.32	0.80	0.43	0.40	**0.58**

WAIKANAE RIVER

REACH	SINUOSITY	POOLS	NATURAL FLOODPLAIN WIDTH to			**OVERALL**
Cross sections			ACTIVE	BANKFULL	PERMITTED	**INDEX**
XS 550 – XS 430	0.96	1.00	1.10	1.00	1.22	**1.06**
XS 420 – XS 350	0.97	0.83	1.28	1.17	1.13	**1.08**
XS 345 – XS 310	0.79	1.52	1.22	0.99	0.73	**1.05**
XS 300 – XS 240	0.98	0.00	0.79	1.00	0.41	**0.64**
XS 230 – XS 175	0.98	0.26	0.76	0.99	0.52	**0.70**
XS 155 – XS 80	0.74	0.83	1.03	1.00	0.82	**0.88**
AVERAGE	0.90	0.74	1.03	1.03	0.81	**0.90**

HUTT RIVER

REACH	SINUOSITY	POOLS	NATURAL FLOODPLAIN WIDTH to			**OVERALL**
Cross sections			ACTIVE	BANKFULL	PERMITTED	**INDEX**
XS 2780 – XS 2560	1.00		0.98	0.73	0.22	**0.73**
XS 2540 – XS 2410	1.00		1.13	1.03	1.00	**1.04**
XS 2400 – XS 2270	0.87	1.00	0.78	0.50	0.98	**0.83**
XS 2260 – XS 1920	0.98	0.33	0.64	0.47	0.28	**0.54**
XS 1910 – XS 1780	1.00	0.75	0.65	0.56	0.59	**0.71**
XS 1770 – XS 1350	0.99	0.43	0.79	0.73	0.54	**0.70**
XS 1340 – XS 1090	0.98	0.00	0.89	0.59	0.28	**0.55**
XS 1080 – XS 850	0.98	0.80	0.72	0.81	0.09	**0.68**
XS 840 – XS 510	0.89	1.00	0.95	0.57	0.17	**0.72**
XS 500 – XS 370	0.99	2.00	1.21	1.06	0.44	**1.14**
XS 360 – XS 210	1.00	1.00	0.95	0.91	0.98	**0.97**
XS 200 – XS 100	0.95	2.00	0.71	0.90	0.98	**1.11**
AVERAGE	0.97	0.93	0.87	0.74	0.55	**0.81**