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Application of Room for the River for NZ Rivers & Streams

NZ River Managers Guidelines

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Limitations

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1 Introduction

Christensen Consulting Limited has been commissioned by the Regional Council River Managers Special Interest Group (RMSIG) to research current and evolving practices for managing flooding and erosion risks through giving “Room for the River”. The “Room for the River” concept has been talked about a great deal over the past 5 years although this has largely focussed on erosion management rather than holistic flood risk management.

Other countries have successfully applied the “Room for the River” concept for managing erosion particularly in rural areas (France & Canada) and others have used it for managing flood risk (Netherlands & UK). Within the New Zealand context I believe it is particularly useful for managing both flood and erosion risk and should be seen as a key strategic tool for working with iwi partners to integrate Te Mana o te Wai in flood and erosion management. This is particularly the case when developing long term management plans for responding to climate change in a way that is effective, sustainable and affordable for communities.

Figure 1-1 Erodible buffers being established on Te Awa Kairangi (Hutt River)

The purpose of this guideline is to provide Regional Council officers, consultants and others with the tools to enable them to work with Iwi, stakeholders and communities to develop “Room for the River” concepts that are fit for purpose for their particular river system. There will be a range of barriers to implementing these schemes and it would only be through support from landowners, iwi, communities, and Councils and Government that “Room for the River” options could practically be implemented.

Notwithstanding the above, the adoption of the “Room for the River” mindset and the development of strategic plans that have the appropriate trajectory towards this outcome are an essential first step for creating momentum for more widespread adoption.

There is also a significant opportunity to formally incorporate “Room for the River” concepts within the new legislation being developed in the coming years, especially the proposed Natural and Built Environments Act and the Climate Adaptation Act. The Engineering NZ/Water NZ Rivers Group have specifically identified these pieces of legislation as being an essential driver towards implementing “Room for the River” and will be making a submission with the assistance of Resource Management lawyers and planners and input from key stakeholders.

It is hoped that the information in this guideline provides a useful starting point so everyone is aware of the work and methods that are already in use and we can work together towards improving our understanding of effective methods of implementation including overarching legislation and funding sources.

Figure 1-2 River Waal in the Netherlands with newly constructed overflow channel on the right as part of “Making Room for the River” programme

2 Background

Application of the "Room for the River" concept has been an ever increasing topic of interest for river practitioners across New Zealand over the past decade and was the focus of the 2022 Water NZ/Engineering New Zealand Rivers Group conference - "Making Room for Rivers". Depending on how you define and interpret "Room for the River" it could be suggested that a number of regional councils across the country have been applying this philosophy since the early to mid 1990's.

This is within the context of managing planform variability and the application of the empirical methods developed by Gary Williams to determine design river channel fairways (typical channel location & buffers). The design river channel fairways (river management envelopes) have then been integrated into wider river corridors that include the fast flowing (high risk) portion of the design flood extent (See Figure 2-1). The design river corridor being defined as the minimum area necessary to manage a major flood, including lateral erosion that may occur during the event, and let flood waters safely pass to the sea[1].

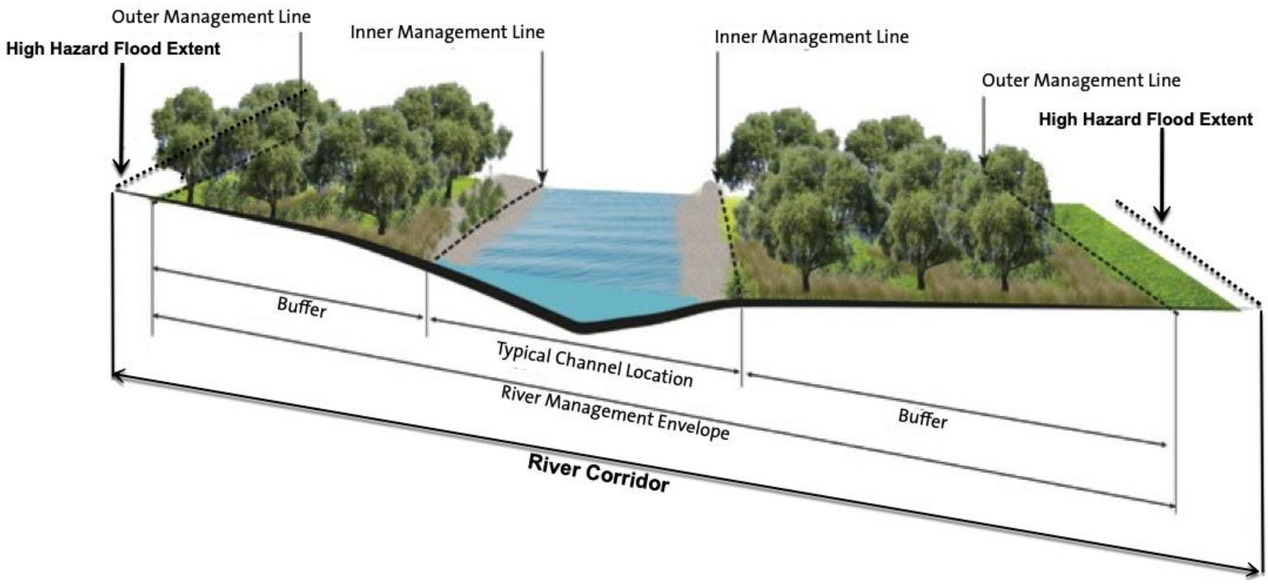

Figure 2-1 River Zone Definitions (adapted from Te Kāuru Floodplain Management Plan)

In Canada, work by Biron et al (2014)[2] provided a similar framework for river channel management with the area between the inner management lines being defined as the M_{50} mobility space, the outer management lines the $M_{floodplain}$ mobility space and then the river corridor being named the 'flooding space'. Similarly in France, the same concepts are applied but with different names encompassed by the 'space of freedom' being defined as "the floodplain in which the active channel can naturally move in order to maintain coarse sediment supply and optimal terrestrial and aquatic ecosystem functioning"[3]. In Italy, the erodible corridor encompassing lateral buffers is built up from consideration

[1] Greater Wellington Regional Council (1997). Waikanae Floodplain Management Plan
[2] Biron, P.M. (2014). Freedom Space for Rivers: A sustainable Management Approach to Enhance River Resilience. *Journal of Environmental Management 54: 1056-1073*
[3] Malavoi J.R., Bravard J.P., Piegay H., Herouin E., Ramez P. (1998). Determination de l'espace de liberte´ des cours deau. Guide technique no. 2, SDAGE RMC, 39 pp.

of maximum past extents of the alluvial floodplain (EMAX), more recent observed changes (functional mobility zone) and the locally negotiated minimum extent (EMIN)[4].

All of these concepts, including the ones already in-use in New Zealand are guiding us towards giving rivers more room to enable a safe and sustainable future for the communities that live within the floodplain as well as a healthy and well-functioning river systems that provide ecological, cultural and recreational value.

The previous application of the “Room for the River Philosophy” can also be extended to the management of the vertical variability of river bed levels with the use of target mean bed levels or bed level envelopes which has also been reasonably standard practice for many decades across New Zealand.

Although the above design line and bed envelope concepts have been around for a reasonably long time the operational implementation has most typically been towards managing to the inner set of design lines with the expectation from landowners that once the river was eroding into a buffer then it would be “put back” to where it previously flowed.

The above management practices evolved following the mid-20th century practices[5] of controlling and confining rivers, particularly gravel bed rivers with aggradation issues. The thinking at the time being that confinement would sufficiently increase the sediment transport capacity so that gravel would be flushed out to sea. It became apparent that this wasn’t usually the case and that in some instances the confinement amplified aggradation (e.g North Ashburton, Lower Waimakariri & Waiho Rivers) and in many cases created significant bank erosion issues.

The current discussion around “Room for the River” is more focussed on allowing lateral erosion to occur rather than intervening with river bank reinstatement and bank protection works.

There are many potential benefits to this approach including –

- Improved aquatic habitat;
- Improved terrestrial habitat;
- Improved interface between terrestrial and aquatic environments;
- More cost effective;
- Allows rivers to behave more naturally;
- Improves overall river health and mauri.

These benefits are well articulated in more general terms in the Principles of River Management described in the Greater Wellington Regional Council Code of Practice for River Management Activities[6]–

1. Rivers are dynamic: They are constantly changing and at any time are a physical expression of a combination of their physical, climatic and human processes (both past and present) at the catchment and reach level.
2. Work with rivers and not against them: Healthy rivers are diverse rivers. Diverse rivers have greater natural character, which provides for a greater expression of mauri and

[4] Malavoi et al
[5] Significantly influenced by Nevins, T.H.F. (1969). River Training – The Single Thread Channel. *New Zealand Engineering Journal*
[6] Greater Wellington Regional Council (2019). Code of Practice for river management activities. Te Awa Kairangi/Wainuiomata Rivers consent version

their inherent aquatic and riparian habitats, which in turn support greater species diversity.

3. Rivers need room to move: Rivers naturally meander, and the meander pattern will tend to migrate downstream over time. Central to this process is erosion and deposition of bed and bank material and the re-location of riparian margins.

Allowing the river more space to express its natural character in a more dynamic way reduces long-term management interventions, while allowing a greater expression of mauri which is beneficial culturally, economically and environmentally.

Within this context of allowing erosion to occur the key question that arises is –

How much lateral erosion should be allowed before an intervention is required?

To answer this question requires consideration of the following –

- What state is the channel and catchment in?
- What would the natural limits of erosion be?
- Is there a risk to life?
- What assets are at risk?
- How much erosion is expected from a large flood or sequence of smaller floods,
- What is the agreed intervention protocol?
- How quickly can we respond when we need to?
- What is acceptable to landowners?

In some instances, particularly rural areas with no stopbanks, erosion is the key hazard being managed and the “Room for the River” concept is focused on developing and agreeing erodible corridors that the river can occupy. However, once flood risk management becomes an issue and where there are stopbanks involved this becomes more complex. To allow “Room for the River” in terms of lateral erosion might require stopbanks to be retreated so that they are not at risk of eroding and failing during a flood event. By retreating the stopbanks we are not only providing more room for lateral erosion to occur, but also a wider river corridor to convey floodwaters that will generally result in lowering flood depths and velocities, reducing risks to assets and life and allowing a less intensive management regime.

This concept certainly provides a goal but the potential cost of implementation could be a limiting factor. A current example of this concept in action is the RiverLink project on the Te Awa Kairangi through the Lower Hutt Central Business District. In the lower reaches of the project significant property purchase is required to make sufficient room to safely convey flood flows. The new stopbanks are being constructed higher and slightly further away from the river than the current stopbanks. However, even with this slight stopbank retreat there is not sufficient space to allow the river freedom to laterally erode. For this reason, extensive rock revetments are included throughout this reach to ensure the integrity of the new stopbanks under design flood conditions.

This is in contrast to the upper reach of the project where stopbanks constructed during a previous phase were retreated up to 250 m away from the river. In this reach a degree of lateral freedom is provided with softer vegetated river bank edges allowing natural erosion to occur.

This philosophy of retreating stopbanks as far as it is cost effective and practical to do so to provide more room for floodwaters, and then applying a risk management approach to how much room for lateral erosion is acceptable is considered a useful high level framework for thinking about “Room for the River”. It also integrates with bed level management through the mechanism of the further stopbanks are retreated the less sensitive the overall conveyance capacity will be to changes in river bed level, up to the point where avulsion becomes an issue.

This wider view and interpretation of “Room for the River” which encompasses giving floodwaters more room by retreating stopbanks or creating offline storage areas, including wetlands, as well as allowing more room for lateral erosion makes the concept extremely valuable as part of the toolkit for managing future increases in flood and erosion risk.

It is this wider view of giving floodwaters more room which was the focus of the Making Room for the River programme in the Netherlands,[7] as well as the recently released Ciria Guidelines – The Natural Flood Management Manual[8] and the International Guidelines on Natural and Nature-Based Features for Flood Risk Management[9].

Due to the much wider application and greater utility once room for floodwaters is integrated into the “Room for the River” philosophy this has been specifically included within these guidelines. However, the application in terms of hydraulics is fundamentally driven by hydraulic design (typically numerical modelling) so the information provided here is towards highlighting key concepts and referencing key international guidelines (as noted above) rather than providing specific details on hydrological and hydraulic analysis.

The analysis associated with understanding lateral variability and a method for developing design lines is discussed in far more detail in subsequent chapters of this document as this information is more specific in terms of how it has been applied to NZ rivers in the past and how it might be used in the future.

Before providing discussion on the technical aspects of applying the “Room for the River” philosophy an overview of how it fits within the key strategic legislation and associated Council planning and asset management documents is provided in the next chapter.

[7] https://www.dutchwatersector.com/news/room-for-the-river-programme
[8] Ciria (2022). The Natural Flood Management Manual. CIRIA C802
[9] Bridges, T. S., J. K. King, J. D. Simm, M. W. Beck, G. Collins, Q. Lodder, and R. K. Mohan, eds. 2021. International Guidelines on Natural and Nature-Based Features for Flood Risk Management. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

3 Strategic Overview

This section provides a strategic overview of how “Room for the River” fits within the context of NZ River Management legislation and practices.

3.1 Te Mana o te Wai

The meaning and application of Te Mana o te Wai has been strengthened and clarified in the most recent (2020) revision of the National Policy Statement for Freshwater Management. The key obligation of Te Mana o te Wai is prioritising the health and well-being of rivers above the health, social, economic and cultural well-being of people and communities[10]. Although people and communities are lower down the hierarchy the idea is that if the river is looked after and in good health then the surrounding people and community will also be in good health.

It is useful to reference the six principles of Te Mana o te Wai -

- Mana whakahaere: the power, authority, and obligations of tangata whenua to make decisions that maintain, protect, and sustain the health and well-being of, and their relationship with, freshwater;
- Kaitiakitanga: the obligation of tangata whenua to preserve, restore, enhance, and sustainably use freshwater for the benefit of present and future generations;
- Manaakitanga: the process by which tangata whenua show respect, generosity, and care for freshwater and for others;
- Governance: the responsibility of those with authority for making decisions about freshwater to do so in a way that prioritises the health and well-being of freshwater now and into the future;
- Stewardship: the obligation of all New Zealanders to manage freshwater in a way that ensures it sustains present and future generations;
- Care and respect: the responsibility of all New Zealanders to care for freshwater in providing for the health of the nation.

These six principles are applied under a hierarchy of obligations[11] that prioritises -

1. First, the health and well-being of water bodies and freshwater ecosystems;
2. Second, the health needs of people (such as drinking water);
3. Third, the ability of people and communities to provide for their social, economic, and cultural well-being, now and in the future.

It is acknowledged that by its very nature Te Mana o te Wai is focused on the water within our awa but that a more holistic view incorporating the beds, banks and floodplain will often be needed to truly provide a healthy well-functioning river system[12].

[10] Ministry for the Environment (2020) Te Mana o te Wai factsheet, Pub No:Info 968.
[11] Section (5) National Poilicy Statement For Freshwater Management 2020.
[12] Ian Fuller pers comm 6 April 2023.

It is up to Regional and District councils to work with Iwi partners to interpret and apply the above principles and hierarchy to Infrastructure Strategies[13], Regional Policy Statements, Regional Plans and District Plans respectively. Specifically, for regional councils they must give effect to Te Mana o te Wai by applying the five requirements shown overleaf in Figure 3-1.

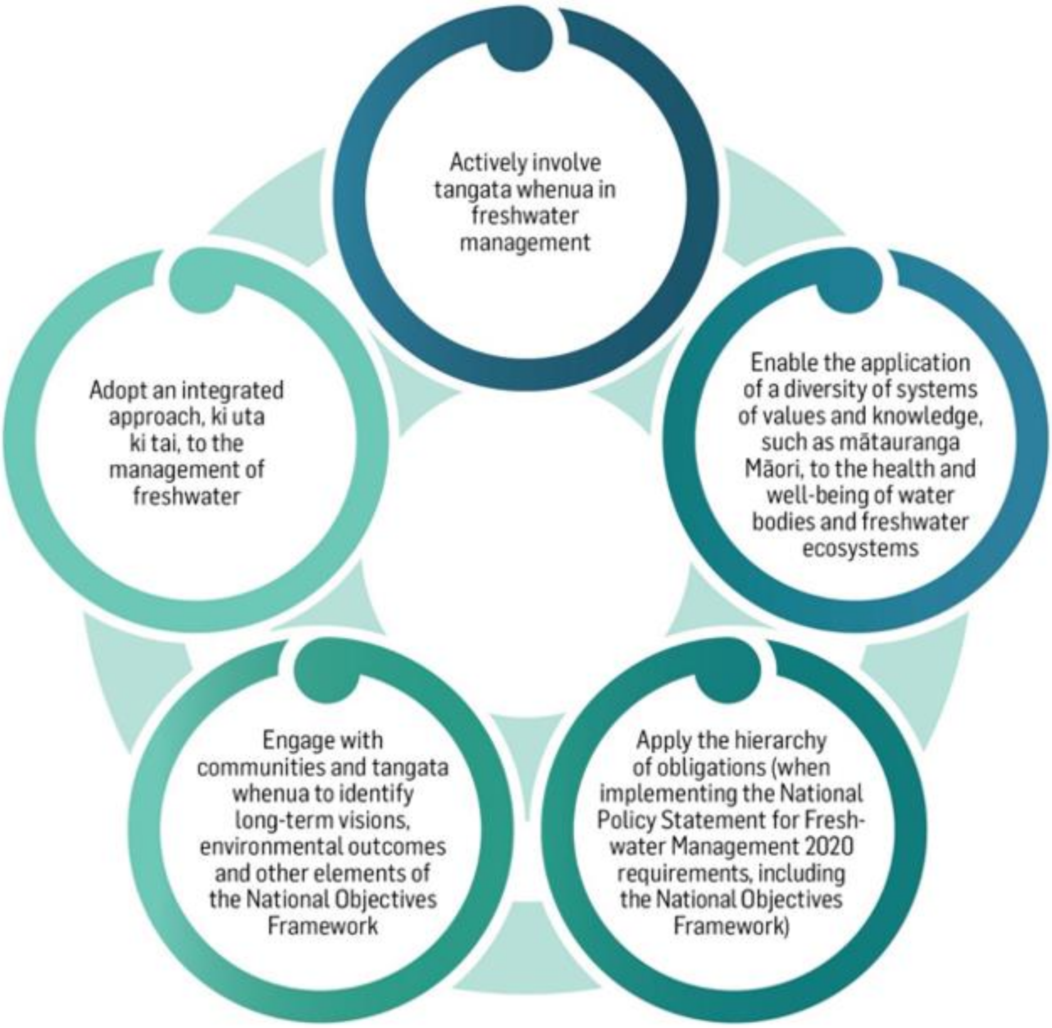

Figure 3-1 Requirements for regional councils to give effect to Te Mana o te Wai[14]

As noted above, the key obligation of Te Mana o te Wai is prioritising the health and well-being of rivers. It is considered that the "Room for the River" philosophy is aligned with this and provides a solid basis for working together with iwi partners communities and stakeholders to develop sustainable solutions to flood and erosion risk management problems.

[13] 101B Infrastructure Strategy Local Government Act 2002
[14] Ministry for the Environment (2020) Te Mana o te Wai factsheet, Pub No:Info 968.

3.2 Strategic Management

Key elements of the legislative framework are highlighted in the following section, which provide important basis and context for developing and implementing "Room for the River".

Common Law

The Common law applies to the management of watercourses in New Zealand, except to the extent that is modified by legislation[15]. Common law suggests that in general property owners are responsible for managing flooding and erosion risks on their property[16]. Any physical works that they wish to undertake require authorisation through the Resource Management Act 1991 by means of a Resource Consent or Permitted Activity provisions within a Regional Plan. The management of flooding and erosion risks also extends to the maintenance of the watercourses to keep them free of obstructions so that flood waters are not impeded.

For larger river systems as well as urban streams with a large number of property owners it can be too complex and inefficient for property owners to independently manage flooding and erosion risks so the responsibility can be taken on by either Regional or District (or Unitary) Councils. As with the property owners the Regional or District Councils would require prior authorisation through the Resource Management Act 1991 for building and maintaining physical works. In addition to this Regional or District Councils would also need agreement from the community on the scope and funding of physical works as well as control over access to the land through easements, or acquisition through the Public Works Act 1981.

There is no statutory requirement or obligation for Regional or District Councils to take on physical works upgrades and maintenance of watercourses but there is a requirement under the Local Government Act 2002 to identify flood and erosion protection works that they are responsible for and describe how they will manage those assets in the long term, as well as identifying areas where new assets may be required. It is highlighted that any proposed new assets are discretionary based on the requirements described above.

Common law claims for damages in tort can be made against councils for failing to perform a statutory duty or negligently performing that duty[17]. However, as noted above there are no non-discretionary statutory duties to provide flood and erosion mitigation works within the New Zealand legal context[18] and there is no liability[19] (without negligence) as a result of any accidental overflowing or breaching of flood or erosion mitigation works.

In terms of "Room for the River" and the Common law it is important to highlight the discretionary basis for flood and erosion mitigation works within the New Zealand legal context as well as there be no liability for the breaching or accidental overflowing of these works without negligence.

Soil Conservation and Rivers Control Act 1941

Although somewhat historic in nature and heavily amended by the Resource Management Act 1991 (RMA) the Soil Conservation and Rives Control Act 1941 (SC & RCA) still sets out the general discretionary[20] functions and powers of Regional Councils who have taken on the responsibilities of Catchment Boards. Of note is S126 which sets out the general powers -

[15] Marshall, J.R. & Page E.F. (1942). The Law of Watercourses and a Handbook for Catchment Boards.
[16] Forlong, R. (2004). Responsibilities for flood and erosion protection. GWRC Councillors Bulletin.
[17] Todd, S. (2017). A Framework for Public Liability in Negligence, Liability of Local Authorities.
[18] Gary William Pers Comm 15 June 2023.
[19] S148(1) Soil Conservation and Rivers Control Act 1941
[20] Requires consent or permitted activity status through RMA instruments.

Section 126 General Powers of Catchment Boards

(1) It shall be a function of every Catchment Board to minimise and prevent damage within its district by floods and erosion.

The strict interpretation and implementation of past river control schemes to prevent erosion is one of the barriers to implementing the “Room for the River” approach. The idea that erosion is seen as damage and is therefore bad as opposed to being part of the healthy natural functioning of a normal river system is the root of the problem. It is also highlighted that this legislation governs soil conservation where generally hillside erosion will in fact result in negative downstream outcomes and remedy should be part of the active catchment management interventions.

The expectations of river side landowners are based on past interventions and management regimes where erosion was seen as a problem which needed to be immediately “fixed”. The basis of allowing “Room for the River” is that erosion is allowed to occur within defined buffers alongside the river channel and when erosion occurs within these buffers there is no need to immediately “fix it” and mechanically shift the river back to where it was prior to a flood.

There could of course be a more nuanced interpretation of S126 with regard to what constitutes “damage” and that erosion of land immediately adjacent to active river beds is not in fact damage but is just natural erosion that should be allowed to occur for the health of the river and for the long-term economic viability of river management activities and use of the land beyond the river management corridor. Changing the approach will require significant effort and education for landowners, key stakeholders and Council staff to enable a collaborative approach in achieving successful outcomes.

The forthcoming Climate Adaptation Act, also provides an opportunity to refine the interpretation of S126 of the SC & RCA and also further specify requirements for enabling a “Room for the River” approach.

Local Government Act 2002

The Local Government Act 2002 (LGA) sets out very broad purposes for both District and Regional Councils, being to meet the current and future needs of communities for good-quality local infrastructure, local public services, and performance of regulatory functions in a way that is most cost-effective for households and businesses. The avoidance or mitigation of natural hazards including erosion and flooding are core services that Councils must pay particular regard to.[21]

This responsibility includes identifying flood and erosion protection works that they are responsible for and how they will manage those assets in the long term, as well as identifying areas where new assets are required. These obligations are discharged through key documents including the Long-Term Plan (LTP),[22] Annual Plans, and Asset Management Plans (AMP). Included within the requirements of the LTP is a 30-year Infrastructure Strategy which for Regional Councils in particular, would be the place where a strategic shift to a “Room for the River” approach would be documented and consulted on with the community. This would then be reflected in Annual Plans and AMPs with specific details provided for all major watercourses within each region or district.

The “Room for the River” approach is not a short-term outcome, so the development and consultation through the key long term strategic processes to inform the Infrastructure Strategy, LTP, Annual Plans and AMPs is considered essential for successful implementation. Alongside this is the issue of regional vs national funding and the likely need for co-investment to allow this concept to work in less populated areas. It is foreseeable that property purchase and retreating to allow “Room for the River” to be applied could be the preferred long-term outcome but that this could be constrained by the

[21] Section 11A

[22] The LTP must include a separate infrastructure strategy for a period of at least 30 consecutive financial years.

affordability of locally sourced funding. The upcoming Climate Adaptation Act provides the opportunity for clear direction on the funding of these types of scenarios.

Resource Management Act 1991

The Resource Management Act 1991 (RMA) is in the process of being repealed and replaced with the Natural & Built Environment Act (NBA), Spatial Planning Act (SPA) and the Climate Adaptation Act (CAA). The stated objectives of the new laws are -

- To protect and, where necessary, restore the environment and its capacity to provide for the wellbeing of present and future generations;
- To better enable development within natural environmental limits including a significant improvement in housing supply, affordability and choice, and timely provision of appropriate infrastructure including social infrastructure;
- To give proper recognition to the principles of Te Tiriti o Waitangi and provide greater recognition of Te ao Māori including mātauranga Māori;
- To better prepare for adapting to climate change and risks from natural hazards and better mitigate the emissions.
- To improve system efficiency and effectiveness and reduce complexity while ensuring local input and involvement[23].

The NBA has recently been open for consultation for which the Rivers Group provided a submission seeking clarity on definitions of river beds, which will set the scene for more comprehensive coverage in the Climate Adaptation Act (CAA). The goal from the Rivers Group and River Managers SIG perspective for the CAA should be the inclusion of requirements for assessing "Room for the River" options in terms of allowing erosion and allowing flood waters to spread over wider areas when considering climate change responses, as well as nationally equitable and consistent funding arrangements where regional funding sources are inadequate.

Floodplain Management Planning

There is no legislated process for managing flood risk, but there is a New Zealand Standard NZS 9401:2008 – Managing Flood Risk that provides a best practice approach.

The overall process is divided into three key phases which encompass –

- Understanding and quantifying the values within the natural, social and cultural systems within the catchment;
- Quantifying the risk and identifying options to manage risk;
- Implementing solutions.

Alongside these activities there is ongoing communication and consultation, in parallel with monitoring, reviewing and adaptation. It is highlighted that the NZA9401:2008 is not a detailed technical guideline and it is only describing the process for managing flood risk. In terms of where "Room for the River" fits in with the process needs further explanation with reference to the key tools for managing flood risk.

[23] MfE webpage - https://environment.govt.nz/what-government-is-doing/areas-of-work/rma/resource-management-system-reform/key-components-of-our-future-resource-management-system/#natural-and-built-environment-act

The four key categories of tools for managing flood risk along with examples of each are summarised in Table 1 below. These have been abridged from the New South Wales Government's *Floodplain Development Manual* (2005) and the Greater Wellington Regional Council's *Guidelines for Floodplain Management Planning* (2015).

Table 1: Tools for Managing Flood Risk[24]

River Management & Maintenance	Room for the River Application
Gravel extraction, sand/silt dredging; River bed and beach recontouring (with bulldozers or large excavators); Hard river bank protection (groynes, rock revetments); Planted willow buffer zones and other riparian planting; Wetlands.	Retreating flood defences reduces the sensitivity to changes in main channel bed levels and potentially reduces the requirements for active bed management. Allowing erosion to occur reduces the need for hard river bank protection which is expensive to build and to maintain. Planted buffers work well in combination with allowing erosion to occur. Will still be a need for maintaining a relatively clear main channel including recovery of trees eroded from buffers.
Structural Works	
Stopbanks; Flood diversion channels; Detention dams; Floodplain storage compartments;	Retreating stopbanks can provide significant increases in conveyance and allow more flexibility for erosion to occur. Flood diversion channels, offline spill compartments, wetlands and detention dams all fit with the context of giving more room for flood waters.
Planning & Land Use Controls	
Designations; Catchment land-use; Flood hazard maps or zones (often included in District Plan); Restrictions on subdivision or building; Voluntary or compulsory property purchase.	Formalising areas that are identified as erodible corridors for the river through designations or zones in the district plan is essential for clearly communicating the intention for those areas. This is particularly useful in managing existing assets in these zones as well as preventing further development in inappropriate areas.
Emergency Management	
Flood risk awareness and education; Community readiness;	Allowing floodwaters to spill over wider areas and for rivers to erode will increase the requirements for effective emergency

[24] **Adapted from New South Wales Government, 2005; Greater Wellington Regional Council, 2015**

Flood forecasting and warning; Evacuation triggers and procedures; Inspection of key structures (e.g. floodgates, stopbanks); Planned emergency works (e.g. deployment of sand bags, installation of temporary flood barriers); Insurance.	management. In particular ensuring safe and effective evacuation of floodable areas and excluding the public from areas that will be prone to erosion.

It is clear from the above that adopting a “Room for the River” design mindset opens up many options when considering river management and structural flood risk management tools, which have flow on effects for planning controls and emergency management. An integrated approach which considers the full spectrum of flood events and includes all of the different categories of tools will provide the most effective pathway towards successful floodplain management using a “Room for the River” approach.

4 Room for the River – Hydraulics

Providing more room for floodwaters can be an effective method for managing increasing flood sizes and frequency as we consider options for living with the effects of climate change. By providing more room for floodwaters the velocity and depth will typically be reduced, which will reduce the hazard (depth x velocity) we are managing. Providing more room for floodwaters also enables opportunities for allowing more room for lateral erosion with less dependence on heavy structural options (typically rock revetments). This chapter specifically deals with the concept of making room for floodwaters whereas the next chapter deals with the concepts and tools for understanding making room for lateral erosion.

4.1 Making Room for Floodwaters

The "Room for the River" concept can be applied in many different forms when considering floodwaters including –

- Reconnecting floodplains, paleochannels, oxbows and back water complexes;
- Removing or retreating stopbanks;
- Creation of offline storage areas including wetlands.

An example from the Hawkes Bay region is shown in Figure 4-1 where a stopbank was removed to reconnect the stream to the floodplain and reduce erosion in the stream.

Figure 4-1 Kahikanui Stream stopbank removal (earthworks complete – planting to come)

These types of activities which allow water to spread out are covered under the categories of channel restoration and floodplain reconnection described in Ciria C802 and the NNBF and were the basis for the “Making Room for the River” programme in the Netherlands.

The “Making Room for the River” programme provides an interesting example of a significant ($2.3 B euro) project implemented to reduce flood risk by allowing water to spread out. The suite of tools used in the Netherlands is summarised in Figure 4-2 below.

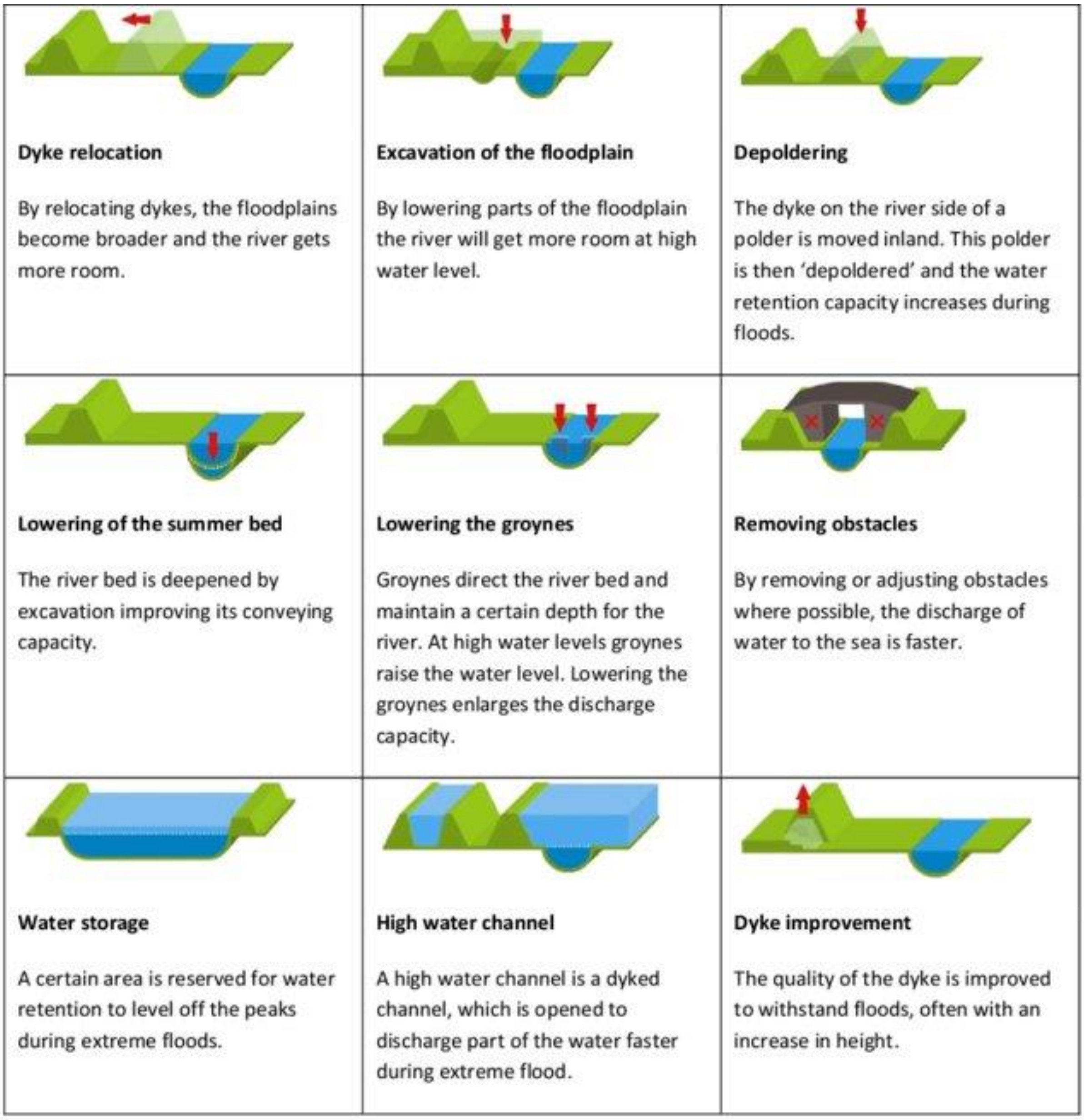

Figure 4-2 Measures used in the Room for the River programme in the Netherlands

It is clear that all of these measures provide either an increase in conveyance capacity or a decrease in flood peak through enhanced storage. It is highlighted that this project was specifically focused on making room for the floodwaters and not for the river channel, with traditional rock armour and other forms of protection used to fix the channel in place. Also of note was the centralised funding model which was reasonably prescriptive on project requirements with local authorities then responsible for delivery.

All of these methods provide hydraulic benefits in terms of either increasing conveyance capacity or decreasing peak discharge through storage and will generally require hydraulic analysis through 1-D or 2-D modelling as part of the design process. The hydraulic benefits can also include lowered flood levels and velocities which will generally reduce the risk.

The Bay of Plenty Regional Council have been working on a River Scheme Sustainability (RSS) project for a number of years, particularly for the Rangitāiki and Whakatane Rivers. The scope of the investigations has included[25] –

- Upstream retention and detention areas;
- Ponding and spill compartments in lower reaches;
- Flow diversions
- Widening
- Converting pasture to wetlands.

All of these options are providing more room for floodwaters and fit within the "Room for the River" philosophy.

[25] River Scheme Update – Presentation to Rangitaiki Information Day 2018

5 Room for the River – Morphology

The width that the main channel is to be managed to and the overall erodible corridor that it occupies are the fundamental parameters to be determined through a "Room for the River" investigation where allowing lateral erosion is the objective. Equally important is the set of management protocols that go alongside them that sets out what the thresholds for intervention will be and the scope of those interventions once the river has eroded beyond the agreed corridor.

Economic efficiency and effectiveness dictated by the Local Government Act 2002[26] requires a balance to be met whereby a solution is found that recognises the excessive costs of managing a river corridor that is too narrow, but equally the cost limitations of a very wide corridor where assets (private or public) are put at risk, significant land acquisition or compensation is required and the cost of maintaining the very wide corridors is prohibitive.

In terms of the overall methodology for determining the erodible corridor it is worth referencing definitions from the literature and how these relate to determining some practically implementable solutions. The definitions (EMAX, EFONC & EMIN) and associated methods from Malavoi et al. (1998)[27] are particularly relevant and useful for application within a New Zealand River management context and are discussed below.

5.1 The Erodible Floodplain (EMAX)

Defining the complete extent of the erodible floodplain from geological and geomorphic mapping using LiDAR derived digital elevation models is an important starting point for understanding the trajectory and limits of a river channel's behaviour. Malavoi et al (1998) calls this EMAX and defines it as " the whole alluvial plain of erodible materials (Holocene and late Pleistocene deposits)". In the Canterbury Region this has been mapped for the main rivers and is referred to as the contemporary (or topographic) braidplain[28].

It is certainly useful to have this data for identifying distinctive changes in geomorphology that affect current channel behaviour and to also understand the broad trajectory of river behaviour over the past 1000 to 3000 year time frames. There may also be bedrock gorges, outcrops or less erodible features identified from the geological mapping that are affecting river morphology that are useful to identify and include in decision making.

Care must be taken with putting too much emphasis on this data, particularly where the river trajectory is degradation into early Holocene/late Pleistocene deposits where terrace features could be many thousands of years old. In this situation the current river channel could be at a level and location which makes it highly unlikely, if not physically impossible, to reach these perched features within the context of a reasonable future planning horizon (circa 100 years). However, these terraces could still be subject to lateral erosion from the river which should be considered in decision making around buffers or setbacks from terrace edges.

Having a geological map which identifies changes in the erodibility of the underlying material (especially bedrock features) and geomorphological map identifying the extent of important features including Holocene terraces is considered important base data to have for a "Room for the River" investigation.

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[26] 14 (g) a local authority should ensure prudent stewardship and the efficient and effective use of its resources in the interests of its district or region, including by planning effectively for the future management of its assets
[27] Malavoi J.R., Bravard J.P., Piegay H., Herouin E., Ramez P. (1998). Determination de l'espace de liberte´ des cours deau. Guide technique no. 2, SDAGE RMC, 39 pp.
[28] NIWA (2018). Braidplain Delineation Methodology. Report to Environment Canterbury

5.2 Recent Channel Behaviour (EFONC)

Probably the most reliable and readily available information about a rivers recent (<100 years) behaviour is from analysis of aerial photographs over the longest historic period available. Digitising the movements of the main channel over time provides the most useful data in terms of understanding the width and mobility of the channel. Old survey plans of early European settlement can also provide useful information to extend the historic record of the channel width and location. However, the further back in time one travels the greater care must be taken in considering the changing catchment and floodplain conditions and how they have influenced the hydrology and sediment flux that determine the form and location of the channel.

The more recent channel behaviour over past decades and comparison with older information provides the best basis for understanding the current behaviour within the context of a trajectory of change and the bounds of past behaviour. It must be highlighted that the past behaviour and channel extents represent a minimum corridor when considering the likely future behaviour with climate change increasing flood frequency and in most cases sediment flux.

Malavoi et al. (1998) describes this as the functional mobility zone and it is defined "as a corridor marking the extent of the lateral channel movements within the last 5 to 10 decades". In the Canterbury Region this has been mapped for the main rivers and is referred to as the historical braidplain.

5.3 River Management Envelope (EMIN)

The design River Management Envelope (EMIN) is the final and most important corridor to define and is "effectively a locally negotiated minimum mobility corridor"[29]. Whereas the whole erodible floodplain (EMAX) and the functional mobility zone (EFONC) are relatively easy to define based on physical attributes, the design river management envelope requires reach specific consideration of channel dynamics and trajectories while also balancing costs and benefits to achieve long term sustainable outcomes.

In terms of an illustrative example, consider the inefficient use of capital in abandoning productive use of an entire erodible floodplain or managing the river within an over-narrowed rock lined channel. Neither of these options offer a sustainable and cost effective future management regime. The alternative option of developing a design river management envelope (EMIN) that allows an agreed amount of lateral erosion before interventions occur provides a balanced approach. Such an option is more likely to be successfully negotiated with stakeholders and is cost effective in providing long term sustainable solutions. The methods for defining the design river management envelope are described in the following section.

5.4 Definition

The design river management envelope is typically made up of inner and outer management lines that are used to define the typical channel location bounded by buffers within an overall river management envelope (See Figure 5-1). The inner management lines indicate the typical location of the active river channel and are defined on a reach by reach basis where each reach has some reasonably consistent physical characteristics.

[29] Pg 770 para 1 Piegay, H. et al. A review of techniques available for delimiting the erodible river corridor: A sustaianble approach to managing bank erosion.

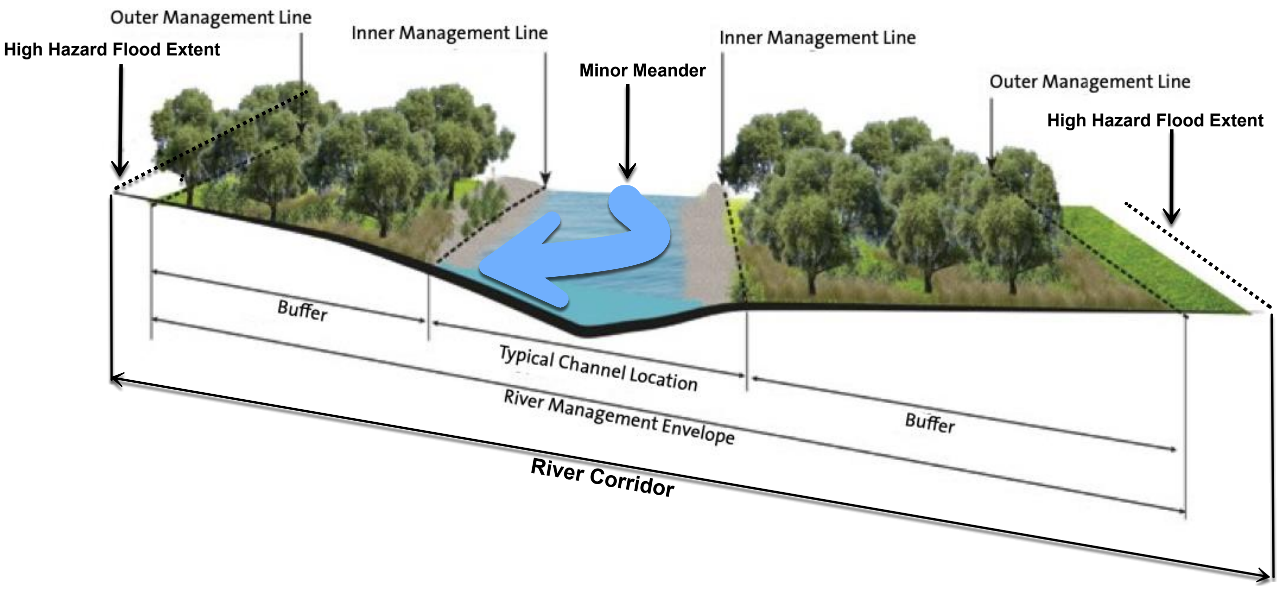

Figure 5-1 Design Line Schematic[30]

The outer management lines provide the outermost limit to which the river will be managed with the area between the inner management line defined as a buffer. The buffer provides additional space for the river to move laterally, particularly during periods of higher flood activity and or higher sediment loads. For the buffer to function most effectively it is desirable to have it planted with a mixture of willows on the front line interspaced with natives.

The front line of rapidly growing and resilient willows enables the slower growing natives to develop and become a more erosion-resisting feature. It has been noted[31] in the unmodified sections of several rivers the apparent effectiveness of podocarp-broadleaf beech forests in reducing bank erosion.

The river is generally completely free to move within the typical channel location bounded by the inner management lines and can also erode and occupy parts of the buffer subject to agreed interventions around critical assets or areas identified as having particular significance. Once a significant portion of the buffer has eroded or the outer management lines are threatened or exceeded then an agreed intervention will take place.

In the Wellington Region, as part of the Te Kāuru Floodplain Management Plan (TKFMP), the buffers are managed with a Hierarchy of Intervention presented in Table 5-1.

[30] Adapted from Te Kāuru Upper Ruamāhanga Floodplain Management Plan (2019).
[31] Peter Blackwood Pers Comm 11 April 2023

Table 5-1 Hierarchy of Intervention

SITUATION	INTERVENTION TYPE	ACTIVITIES	TIMEFRAME FOR COMPLETION
LOW RISK Land in buffer is at risk of erosion	Limited intervention/monitoring of risk by staff	Only activities that will result in a low risk of adverse impacts (these will have the effect of limiting work in the wetted channel and in high-value riparian areas)	Scheduled regular maintenance (annual work programmes)
MEDIUM RISK The outer management line is at risk of erosion	Moderate-priority intervention	Only activities that will result in low and/or medium risk of adverse impacts, or a limited amount of high-impact activities	Incorporated in annual work programmes
HIGH RISK Risk to life Risk of damage to key infrastructure Erosion has occurred beyond the outer management line	Immediate intervention	All activities available – with low, medium and high adverse impacts	Urgent – to be completed ahead of programmed work that can be practically deferred to allow for the completion of priority, reactive work

The *Hierarchy of Intervention* process provides a risk based approach on how much room the river can move into buffers before river management interventions can be undertaken to return the river to be within the inner management lines and for the buffers to be re-established. The level of risk determines the urgency of the intervention and the range of tools available. For most areas if there is some erosion within the buffer there would be very limited management intervention.

When the outer management line is considered to be at risk of erosion then a greater range of intervention tools are available for use and the works would be incorporated into annual work programmes. This is where there is a balance between providing room for the river whilst also managing erosion risk to property beyond the outer management lines to meet the agreed level of service. This medium risk situation still provides the opportunity for the river to move but once it has moved to occupy most of the buffer and is looking to continue moving laterally beyond the outer management line then a programmed intervention is required.

Once erosion has occurred beyond the outer management line or in the situation where there is a high value asset in the buffer the risk level escalates to HIGH and an immediate intervention using all of the available tools in the river management tool kit is applied. Once the risk is in the HIGH category the balance has shifted towards maintaining the river within the inner management lines, especially when there are assets in the buffer, and the opportunities for providing room for the river are far more limited than in other situations where there are no assets in the buffer.

This method of implementation provides some flexibility in managing areas where there are assets in the buffer and also provides the opportunity for asset owners and stakeholders to consider the feasibility of retreating or relocating assets to achieve long term sustainable outcomes.

Within the Canterbury Region, Environment Canterbury are developing a similar concept which includes sub-zones in the buffers where different management interventions would apply (See Figure 5-2).

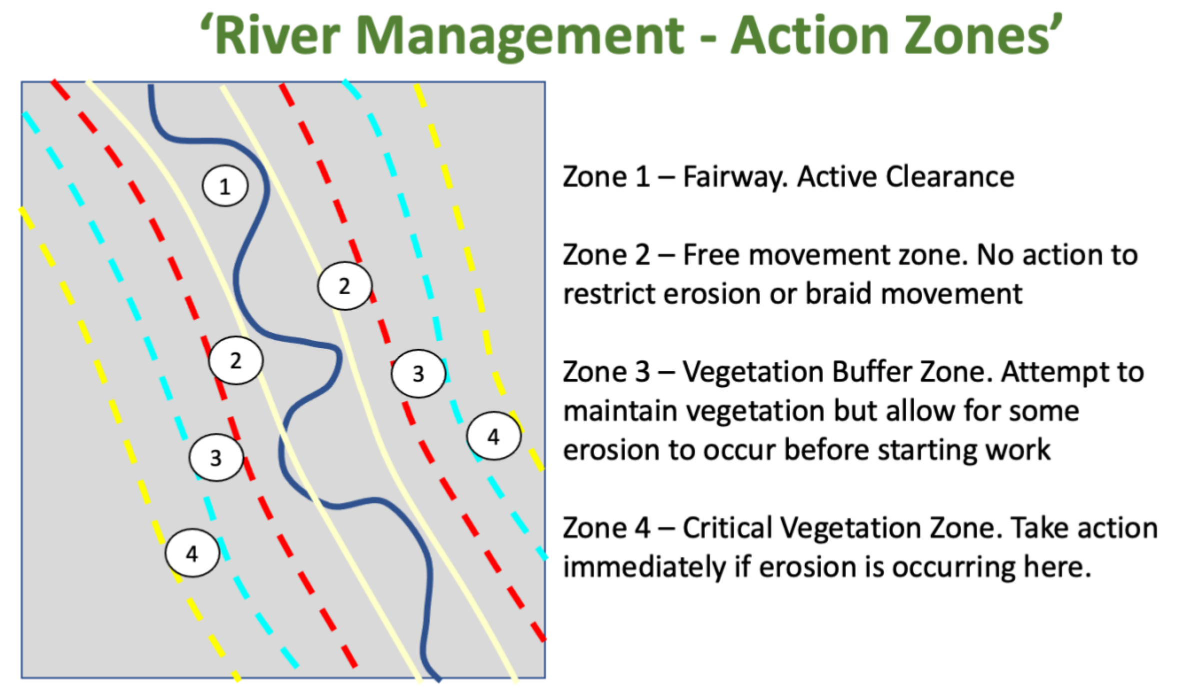

Figure 5-2 River Management Action Zones[32]

The use of sub-zones with the ECAN framework effectively achieves the same outcomes as the hierarchy of intervention within the GWRC framework. Both provide for a design river channel bounded by buffers where there are agreed actions for intervening when critical thresholds are exceeded. This definition, including the concept of an agreed set of actions for managing erosion within the buffers, is essential for moving towards the locally negotiated design river management envelope described in the next chapter.

It is highlighted that in the identification and delineation of these zones that the fundamental channel processes and trajectory of the rivers future behaviour are given due consideration that reflect the hierarchy of Te Mana o te Wai that the health and well-being of water bodies and freshwater ecosystems comes first[33].

[32] Shaun McCracken presentation at 2022 Rivers Group Conference
[33] Ian Fuller pers comm 6 April 2023

6 Methodology - Design River Management Envelope

This section provides a description of the methods available and those typically used across New Zealand to define the Design River Management Envelope.

6.1 Determining the Design River Management Envelope

There are many options available for determining the design river management envelope, often based on analysis of past channel widths and positions from historic aerial photographs. A thorough review and commentary on these techniques is provided in Piegay et al (2005)[34]. The general premise is that average rates of lateral erosion are calculated from past channel positions and then applied to a future time horizon extending from either the current bank edges[35] or from the maximum observed past extent of the river[36].

Another method that has been used in New Zealand is the Natural Character Index (NCI)[37] which calculates changes to geomorphic characteristics including active channel width, thalweg length, braiding index and vegetated area from a historic baseline. The general concept being that the historic baseline provides a reference for strategically applying restoration techniques.

These are certainly valid techniques and could be applied to some river reaches within a New Zealand context. However, the analysis becomes difficult if there has been an overall narrowing of a river reach due to reductions in sediment supply or past engineering interventions, and it doesn't explicitly account for any agreed future management interventions within the buffer zones.

Other possibilities include detailed numerical morphological modelling that includes bank erosion mechanisms. This would require specialist modelling input and there would still be a degree of uncertainty around the accuracy of outputs, particularly with regard to lateral migration which accounts for vegetated buffers and management interventions. This certainly could be considered as an option on some rivers and floodplains but is unlikely to be something that is practical or cost effective to universally apply.

The methodology that is described below builds on the methodology that has been applied by Gary Williams, Peter Blackwood, Ian Heslop and others over the past three decades and has been used by GWRC over the past five years to update and develop Design River Corridors for a number of rivers across the region. The methodology is accessible for Regional Council Officers and consultants to use and doesn't require specialist modelling capability other than basic GIS experience.

6.2 Methodology

The overall methodology is based on integrating a range of data sources including -

- Geomorphic mapping of terraces and other landscape features;
- Geological mapping of changes of underlying erodibility (especially rock);
- Catchment/landuse changes, tectonic setting, long-term hydrological cycles;
- Catalogue of past river management activities;

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[34] Piegay H., Darby S.E., Mosselman E., Surian N. (2005). A Review of the Techniques Available for Delimiting the Erodible Corridor: A Sustainable Approach to Managing Bank Erosion. *River Research & Applications 21: 773-789*
[35] Defining possible erosion zones within a future timeframe.
[36] Defining a wider erodible corridor.
[37] Fuller I.C. et al (2021). An idex to assess the extent and success of river and floodplain restoration: Recognising dynamic response trajectories and applying a process-based approach to managing river recovery. *Rivers Res Applic 2021:37 163-175*

- Topographical features;
- Digitising river width and planform extent from historic aerial photographs; and
- Empirical river regime equations;

These data sources are all taken into account to assess a relatively stable width and planform location for the main channel as defined by the inner management lines on a reach by reach basis. The sub-reaches are identified based on the extent of relatively homogenous hydromorphic conditions with a constant width for the main channel determined for each reach being based on the average of the assessed parameters throughout the reach.

The buffer width to the outer management line is determined by considering the range of historic variability of the channel location along with the outputs from the empirical equations and the lateral erodibility of the particular reach of river under consideration. As with the inner management lines, the buffer widths defining the outer management lines are assessed on a reach by reach basis.

The approach provides a blend of data spanning different time spans where in some instances the underlying geology will determine the design widths whereas in other more dynamic reaches it may be the more recent geomorphic mapping. The use of the empirical relationships also provides some consistency in the widths that are determined within homogeneous sub-reaches which is considered useful in terms of fairness and equity if landowner negotiations are required.

Understanding longer term changes in sediment flux as a result of land-use changes, tectonics, extreme rainfall and longer term hydrological macro-cycles are also important for interpreting changes in river morphology and likely trajectories of future behaviour. Similarly, understanding past river management interventions in terms of structural works and operational activities is also important in understanding past river behaviour and also anticipating changes if a less interventionist approach is applied in the future.

6.3 Mapping of Geomorphology and Geological Features

Understanding the geological and geomorphological context of the floodplain is fundamentally important for assessing the geomorphic variability and relative stability of the modern river channel. Mapping the interface of different geological layers and identifying older (Pleistocene) terrace features is useful for determining the full width of the Erodible Floodplain (EMAX). Using a combination of geological maps and LiDAR (discussed further below) provides the best basis for identifying key features including rock constrained reaches and the ages of terrace formations on the floodplain.

An example for the Waitohu catchment in the Wellington Region is provided in Figure 6-1. The GNS webmap https://data.gns.cri.nz/geology/ is a particularly useful resource for understanding and mapping the underlying geology.

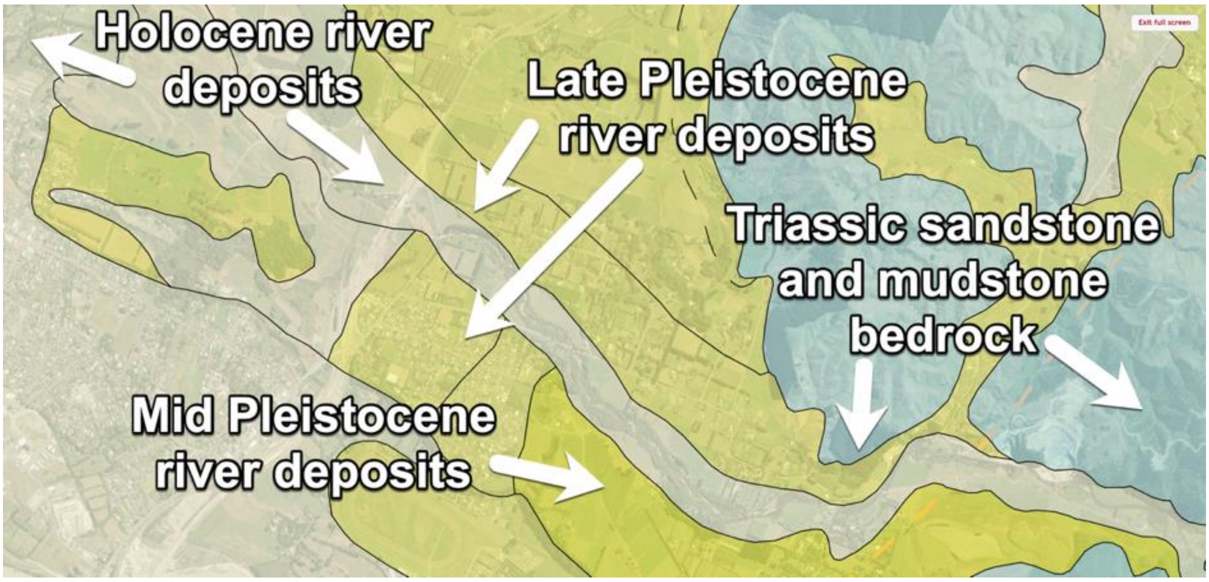

Figure 6-1 Upper/Mid Waitohu Geological Mapping[38]

6.4 Landuse Changes, Tectonic Setting, Long-term Hydrological Cycles

It is important to consider past land-use changes within the catchment in conjunction with notable tectonic activity. Significant changes in land-use e.g. post European settlement deforestation, clear-fell forestry operations and native regeneration programs can all have significant effects of sediment flux within the catchment and the resulting downstream river morphology. Combined with tectonic and or extreme rainfall induced landslides the changes in longer term sediment supply are important to broadly understand to provide context around observed changes in the behaviour of river systems across downstream floodplains.

One common typology is significant native regeneration and a lack of significant recent tectonic activity resulting in reduced sediment inputs and a narrowing or entrenching of downstream river channels. This typology is common within the Wellington Region. On the opposite end of the spectrum is significant tectonic activity, widespread forestry operations and or extreme rainfall induced landslides. This typology generally results in increased sediment supplies with downstream widening and instability of river channels. This typology is common within the north-Canterbury (especially Kaikoura) region and Hawkes Bay/Gisborne regions.

Along with understanding the changes in longer term sediment supply it is important to understand the hydrological macro-cycles providing the energy to transport, deposit and shape the river morphology. A large landslide with no flood flows to move it is just a landslide. The most important hydrological macro-cycle to consider is the interdecadal Pacific Oscillation (IPO). Understanding the effects of the IPO on the local catchment is important particularly when considering giving more weighting to recent behaviour if this has been in a particular IPO phase which has markedly higher or lower flood intensity and sediment flux. IPO data is available from the Ministry for the Environment database[39].

Understanding past river behaviour in terms of sediment flux and flood frequency is important in guiding future predictions of behaviour, especially when considering recent behaviour and whether that represents relatively quiescent flood and sediment inflow conditions or higher flood intensity with accompanying higher sediment fluxes. In terms of future predictions of river behaviour, allowing for

[38] https://data.gns.cri.nz/geology/
[39] https://data.mfe.govt.nz/data/category/environmental-reporting/atmosphere-climate/climate-oscillations/

higher sediment loads and wider river channels as a result of increased flood size and frequency is considered to be a reasonably universal assumption to apply across all NZ rivers.

Therefore, in terms of interpretation of past data this will generally represent the minimum width and range of variability when considering projecting out to future scenarios with larger floods, greater sediment throughput and most likely with reduced structural or operational interventions.

6.5 Catalogue of Past River Management Activities

Understanding past river management activities in terms of structural works and operational maintenance is also important in providing context to observed changes in morphology. In many cases it will be difficult to get accurate information on historic works but information from recent decades should generally be reasonably available from Council records and databases. As a minimum, the current physical assets (especially rock lines, groynes and stopbanks) should be mapped and the current operational practices should be documented.

This provides context for observed changes or stability within particular reaches or over past time periods under specific management regimes. It is highlighted that it is often difficult to distinguish between anthropogenic and natural changes in river behaviour and morphology. However, having at least a high level understanding of these practices over time provides both important context for understanding past behaviour as well as being helpful in for predicting future behaviour under a less interventionist philosophy.

Minimum data requirements for understanding river management activities would be current assets from Asset Management Plans, preferably already mapped into GIS format along with current and historic Operational Management Plans.

6.6 Historic Channel Movement from Aerial Photography

The mapping of historic channel movement is considered to be the most useful dataset in determining a design river management envelope. This data accurately reflects the behaviour of the river over typically 70 – 80 years and provides a great insight into assessing trends and the overall position and extent of the river channel and how a design river channel might fit. See Figure 6-2 for an example of river channel digitisation for Waitohu Stream within the Wellington Region. As previously highlighted it may be possible in some instances to determine average rates of erosion and apply a strictly analytical approach using this data. However, it is considered that a less rigid approach which blends this data with the other sources provides greater flexibility in determining an appropriate design river channel.

The Retrolens database https://retrolens.co.nz/ is the key data source for historic (pre 2000) imagery and most Regional and District Councils will have post 2000 georeferenced aerial imagery for use. Note that the data from Retrolens needs to be georeferenced before being used. The digitisation is typically done in GIS with the main channel being identified with left and right bank lines. There can be some degree of interpretation as to where the main channel edges are, but taking the most obvious clear channel extent is a good starting point, while interpolation where it is obscured or missing is sometimes necessary.

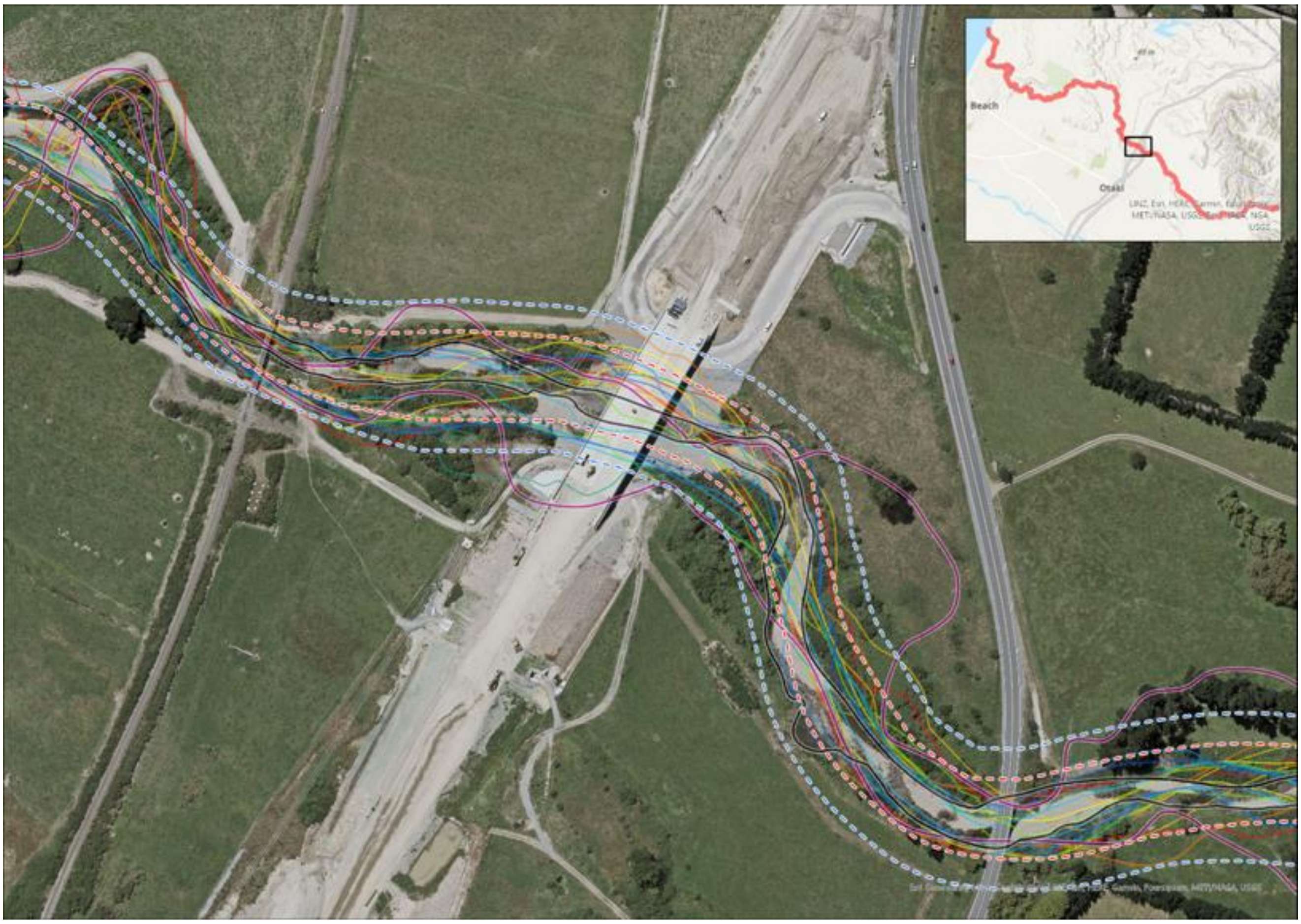

Figure 6-2 Historic bank edge digitisation at new Peka Peka to Otaki Bridge

6.7 Surface Elevation Data (from LiDAR)

As with the geological data, detailed surface elevation data, typically from LiDAR, provides further information to inform decision making for the outer management lines, particularly where there is evidence of recent channel cut-offs and terraces in close proximity to the current active channel. An example of the underlying LiDAR surface is provided in Figure 6-3 below. LiDAR will generally be available for major river systems and where it is not available it should be a priority of the relevant authority to gather this data.

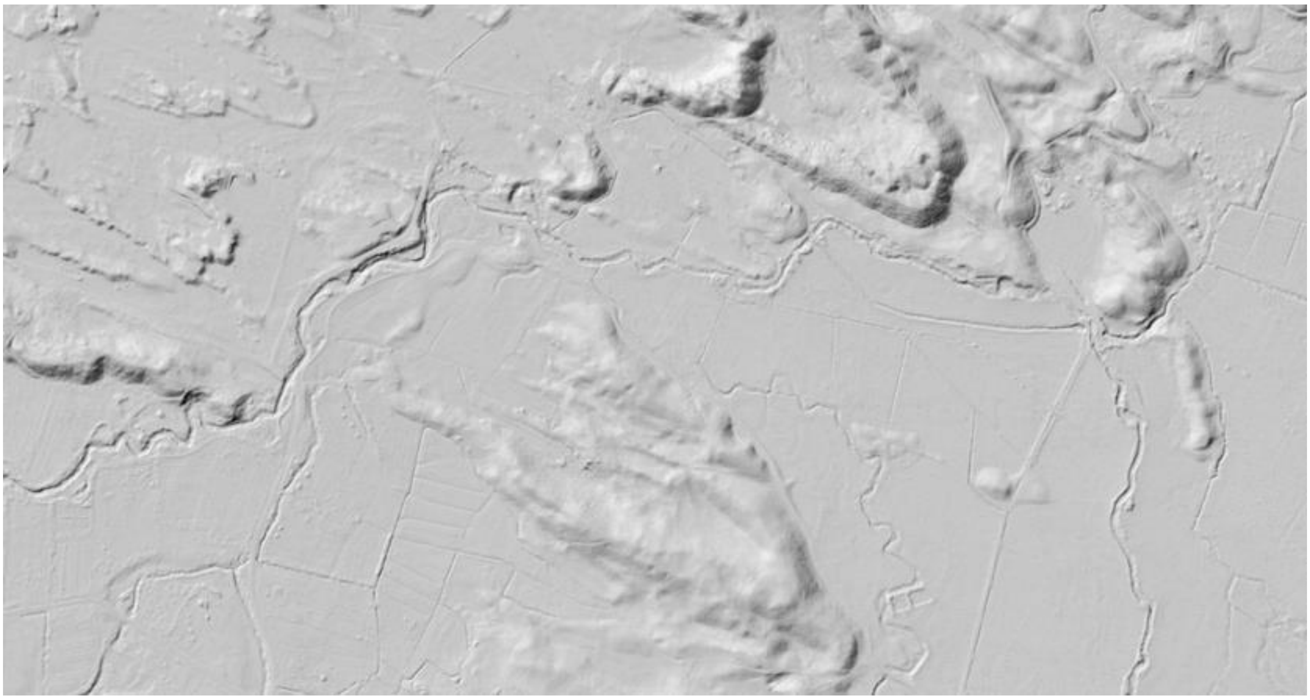

Figure 6-3 Waitohu Stream LiDAR 1 m DEM (2013)

6.8 Empirical Analysis

The use of regime channel equations and "Catchment Board Rules of Thumb" have seen widespread use across New Zealand, particularly across the North Island by respected Rivers Engineers Gary Williams, Peter Blackwood, Ian Heslop and others. All of the large gravel bed rivers within the Wellington and Canterbury regions have been analysed with "regime widths" and "buffer widths" determined.

The overall method utilises a selection of empirical and physically based theoretical models to determine a range of river widths that are likely to encompass the range of natural variability within a river system. In this context the natural variability is based on some degree of relative stability where there is less likelihood of excessive river bed or bank erosion or aggradation and the river should be able to pass through the incoming sediment and water load during floods. This is of course within the context of the general characteristics of a particular reach, which may in some cases be in a long term phase of entrenchment (degradation) into past alluvial deposits. It is highlighted that these simplified representations do not account for channel avulsions and major changes in channel planform location that may be the fundamental processes dictating channel extents in some situations.

The selection of theoretical models (equations) for both a wider dominant flow meander as well as smaller threshold of motion meanders are provided overleaf. Extensive use of these equations has shown that they reasonably approximate the range of widths evident in natural and more heavily managed river systems across New Zealand. It must be highlighted that these equations provide a range of widths ranging from relatively narrow for the threshold of motion meander channels through to much wider channels for the dominant flow meanders. The observed river widths from analysis of past aerial photographs and geomorphic markers can generally be matched to the outputs of one of the equations with the appropriate multiplier (See Table 6-1) to determine the average reach based characteristics.

The input parameters into these empirical equations include typical sediment size characteristics of the river bed, flood discharge and slope (hydraulic grade line).

Typical Sediment Size Characteristics

Approximate grain size distribution curves can be developed using the data published on the NIWA NZ River Maps website - https://shiny.niwa.co.nz/nzrivermaps/. By selecting the Bed Sediment Cover[40] tab on the "Select Variable Type" from the dropdown menu you can get an estimate of the percentage cover for the full range of sediment sizes from < 0.06 mm up to 512 mm.

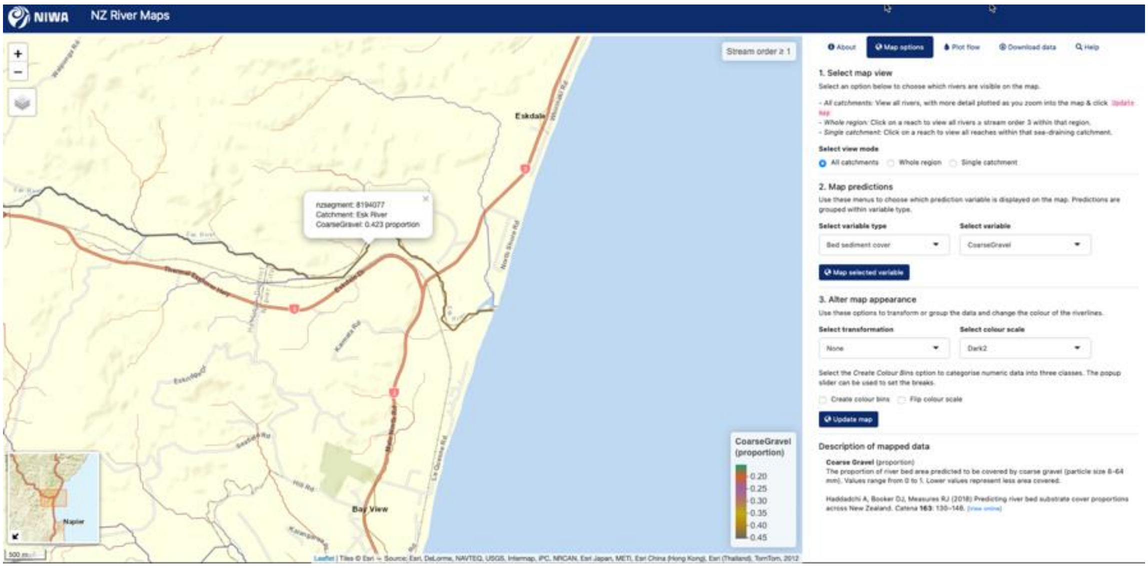

Figure 6-4 Approximate river bed substrate data for NZ (Source NIWA)

Alternatively site specific analysis could be undertaken using the Wolman Pebble Count[41] for coarse sediment or taking bulk samples to a testing laboratory. If the Wolman Pebble Count is used it is useful to use a gravelometer[42] which makes greatly speeds up the data collection.

Once the raw data is obtained from either the published source or field collection, analysis is required to determine the characteristic sediment size (D_{50}). An easy to use EXCEL tool[43] is freely available within the Gary Parker E-Book[44] where the data can be entered into to calculate the D_{50}. Both the Bed Sediment Cover data and the Wolman Pebble Count provide an approximation of the surface cover which, for the purposes of use in the Empirical equations is considered to represent the armour layer.

Flood Discharge

If catchment specific flood hydrology is not available then the recommended source of data is the NIWA New Zealand River Flood Statistics webpage[45] noting that this provides current flood hydrology which would need to be adjusted to account for climate change. Alternatively, specific flood frequency analysis could be completed on appropriate surrounding flow recording sites and transposed to the location of interest. This more detailed method of analysis could also be used to include historic floods prior to the continuously recorded dataset that has been used as the basis for the NIWA flood statistics.

[40] Haddadchi A, Booker DJ, Measures RJ (2018) Predicting river bed substrate cover proportions across New Zealand. Catena 163: 130–146

[41] https://andrewsforest.oregonstate.edu/sites/default/files/lter/data/studies/gs002/Wolman_Pebble_Count.pdf
[42] https://www.envco.co.nz/catalog/soil/soil-classification/soil-size/gravelometer-field-sieve
[43] RTe-bookGSDCalculator.xls
[44] http://hydrolab.illinois.edu/people/parkerg/morphodynamics_e-book.htm
[45] https://www.arcgis.com/apps/webappviewer/index.html?id=933e8f24fe9140f99dfb57173087f27d

Slope (Hydraulic Grade)

The most accurate source of information for the slope would be from a hydraulic model of the mean annual flood, appropriately adjusted to account for climate change. The next best option would be to use slope derived from surveyed cross sections of the reach under consideration, and finally if no other information is available then a published topographic map or contours could be used.

With the above data the following formula can be used to determine a range of base empirical design channel characteristics.

Dominant Flow Meander

- $W = 4.85 \times Q_{2.33}^{0.5}$ (Lacey, 1929)[46] Low gradient sand canals
- $W = 1.45 \times Q_{2.33}^{0.5}/S^{0.2}$ (Altunin, 1962)[47] Lowland sand rivers in Russia actual slope
- $W = 1.45 \times Q_{2.33}^{0.5}/Sc^{0.2}$ (Altunin, 1962) Lowland sand rivers in Russia critical slope

Where $Sc = 0.33\ d_{50}^{1.15}/Q_{2.33}^{0.46}$ (Henderson, 1966).[48] The theoretical critical slope for Type B channels. Lesser slopes would not cause erosion, while steeper slopes would cause erosion

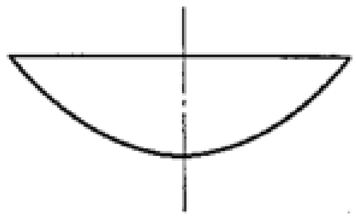

Figure 6-5 Type B Channel (Henderson, 1966)

Threshold of Motion Meander

$W = 1.22 \times Q_{2.33}^{0.46}/S^{0.15}$ (Henderson, 1966) Type B Channel at Critical Slope

$W = 2.065 \times Q_{2.33}^{0.46}S^{1.167}/d_{50}^{1.5}$ (Henderson, 1966) Type A Channel at Actual Slope

$W = [3.1 + 0.405 (\ln (0.672 \times d_{50}^{1.15}/S \times Q_{2.33}^{0.42})^2)] \times Q_{2.33}^{0.47}$ (Chang, 1988)[49]

Where –

W = width (m)

$Q_{2.33}$ = Mean average flood (adjusted for climate change) (m^3/s)

S = channel slope (m/m)

d_{50} = Median sediment size in (m)

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[46] Lacey, G. (1929). Stable channel in alluvium. Min. Inst. CivilEngrs., London 229, 259–285
[47] Altunin S.T. (1962). Regulirowanie rusel. (in Russian). River Training. Moscow SLJP
[48] F.M. Henderson (1996). Open Channel Flow.
[49] H.H Chang (1988). Fluvial Processes in River Engineering

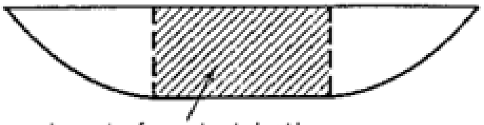

Figure 6-6 Type A Channel (Henderson, 1966)

Following the calculation of these base widths the "Rules of Thumb" presented in **Error! Reference source not found.** can be applied to calculate a range of design widths to fit the Wide, Narrow or Extreme Narrow channel typologies for single thread channels as well as semi-braided and braided river systems.

Table 6-1 Catchment Board "Rules of Thumb" Fairway Types, Channel & Buffer Widths

Fairway	Channel	Buffer	Remarks
Braided	3.5 – 5.5 x Dominant Flow Meander (Lacey, Altunin or Altunin at Henderson critical slope for Type B)	1-1.5 x Dominant Flow Meander	Permits migration of main braids. Vegetation can be used to contain bank erosion.
Semi Braided	1.7 – 2.5 x Dominant Flow Meander (Lacey, Altunin or Altunin at Henderson critical slope for Type B)	1.5 x Major Meander	Permits migration of main braids. Vegetation can be used to contain bank erosion.
Wide (Single thread)	1.7 x Dominant Flow Meander (Lacey, Altunin or Altunin at Henderson critical slope for Type B)	2 x Minor Meander (Henderson Type B Channel at critical slope)	Permits migration of dominant flow meanders. Vegetation can be used to contain bank erosion.
Narrow (Single thread)	Dominant Flow Meander	Minor Meander	Permits migration of small meanders. Channel banks generally need strengthening/armouring
Extreme Narrow (Single thread)	Major Meander Width (Henderson Type A at actual slope or Chang)	½ x Minor Meander	Strong channel banks required.

It is interesting to note that the minimum space for the channel (M_{50} Mobility Space) determined by the methods described in Biron et al (2014) was 1.7 times the channel width as per the wide (single thread) typology referenced above. However, it must also be noted that this minimum space corresponds to a highly variable width, which Biron et al. (2014) emphasises must be determined from a thorough assessment of hydrogeomorphology and cannot be predicted using a representative average. Furthermore, it must be noted that the empirical Dominant Flow meander design formulae were developed for low energy sand rivers and meandering channels, while most New Zealand rivers are much steeper and coarser grained, and many do not conform to classic meandering patterns[50]. Caution is advised in their application, particularly for the Narrow and Extreme Narrow channel typologies in steep gravel rivers for which they were not developed for.

6.9 Other Methods

In addition to the above relatively simple methods more complex numerical modelling methods could also be considered. One or two dimensional morphological modelling which includes flexible boundaries to represent both lateral mobility (bank erosion) and bed level change could be applied to further understand possible future trajectories in river behaviour. Applying this type of method would require specialist modelling skills and software as well as significant effort in terms of data collection and model calibration to provide meaningful results. Utilising this approach could probably be justified on larger river systems where there are significant areas of land/floodplain at stake but in most cases utilising the simpler methods will provide sufficient data to form the basis for consultation and development of design river management envelopes.

6.10 Overall Approach

The overall approach is a synthesis of the data described above to estimate the natural bounds of the typical main channel location (inner management lines) with an allowance for the predicted variability (outer management lines). Using this overall approach, it typically emerges that there are relatively homogeneous reaches which is what would be expected when the underlying geomorphology is being used as a key data source.

Although all data sources are evaluated, the greatest weighting is generally given to the observed recent geomorphic data, namely the river bank edge delineation from the past 50+ years. This data gives a very accurate picture of the trends in channel width and the natural tendencies of the river in terms of lateral migration and changes in width. The underlying geological and geomorphological data also provides a useful reference for considering longer term trends for channel width and location.

The empirical regime equations provide a useful reference particularly for providing a buffer width that reflects the relative erosion potential for the various reaches within each river system and also provides a degree of consistency which can be helpful in landowner negotiations.

It is also important to consider past landscape and landuse evolution and how this has interacted with macro cycles within the historical flood record as well as significant flood events. Considering the past flux of sediment and flood flows and projecting these out into the future requires judgement but one thing that is certain that floods will be getting larger and more frequent and that for sediment grain sizes that are not supply limited then the accompanying sediment flux will also increase. This combination of increased flood flows and increased sediment flux will generally result in increasing widths and instability of downstream channels.

Equally important is considering past river management practices and how these may have affected river behaviour in certain reaches under consideration. Where there has been significant intervention including constraint with rock lines and on-going gravel extraction it will be more difficult to determine what the “natural” behaviour of that particular reach will be. In this situation, looking for reaches upstream or downstream with less interventions can be useful as can giving more weighting to the empirical equations which effectively provide averages from observed behaviour across a great number of rivers as well as theoretical derivations based on energy balance.

[50] Ian Fuller pers comm 9 June 2023.

6.11 Management Interventions

The other essential aspect that goes alongside the design river management envelope is the agreed management interventions that will occur once the river exceeds certain trigger points within the buffers. The degree to which these are defined will depend on the particular situation and the negotiation with affected parties. In some instances a very analytical approach could be applied where a specific width or % of the overall buffer could be used as a trigger for intervention. At the other end of the scale a more qualitative risk based approach could be applied where judgement is used as to whether the erosion is likely to cease as a meander profile moves downstream or whether erosion of a sharp bend is going to continue. Either approach can be made to work as long as there is clarity on how it will be implemented.

The other key aspect of agreeing the management interventions is identifying where there will be exceptions or departures from the standard operating procedures. This will most commonly be where there are critical community assets/infrastructure, sites of cultural significance, ecologically sensitive areas or private dwellings located within the buffer. It is important that the full design corridors are what is used when formalising these areas (see following section) so that there are adequate planning constraints around further development within these areas, as well as highlighting the need to consider retreating community assets/infrastructure where appropriate to do so.

As well as management interventions within the buffer it is also important to consider operational management within the active channel itself, particularly with regard to gravel extraction and vegetation clearance. Gravel extraction in terms of bed level management is discussed in the next chapter and the underlying assumption with regard to vegetation is that the main active channel would be kept clear.

6.12 Formalising the Design River Corridors

Typically the design river management envelope will be integrated into a wider design river corridor that accounts for high flood hazard as well as the erosion hazard implied by the river management envelope. The method used to formalise the design river management envelope and or the design river corridor needs careful consideration. Within the current guidelines and legislation the typical options could include –

1. Mapping within Floodplain Management Plan (no legally binding commitments);
2. Mapping within Asset Management Plans (levels of service agreed and bound by LGA 2002);
3. Zoning within District Plans (legal control of landuse through RMA 1991);
4. Designation through an RMA process (legal control of land use and potential obligation to purchase through RMA 1991);
5. Negotiated purchase.

As can be seen by the above list there is an escalating level of control through these mechanisms, with the Designation coming with the highest degree of control but also with the obligation to purchase the land if the owner wishes to sell.

A logical approach, where flooding and erosion are an issue, would be to follow the Flood Risk Management Process (NZS 9401:2008) to develop a floodplain management plan that includes design lines for the rivers within the catchment that are integrated with a suite of “Room for the River” tools for allowing more space for floodwaters and lateral erosion management. The floodplain management plan would then be incorporated into Asset Management Plans which would formalise the requirements regarding levels of service and agreed management interventions. Alongside this, the erodible corridors within the design lines as well as the flood risk information would be appropriately zoned within the District Plan (or equivalent provided by new legislation). Where significant capital works are included within the floodplain management plan, then Designations could be a more appropriate tool for implementation.

In situations where it is specifically erosion that is being managed then an Asset Management Plan may provide an adequate process for working with iwi, the community and stakeholders to develop and agree erodible corridors and design lines. These could then also be formalised through the District Plan if necessary.

Within the Wellington Region, Kapiti Coast District Council has a “River Corridor” zone in the district plan (See Figure 6-7) which is extremely restrictive with regard to the type of land use that will be consented. This “River Corridor” zone encompasses the design river channel (See Figure 6-8) which was developed within the Otaki Floodplain Management Plan but also generally includes a wider extent which recognises risk around stopbank failures and areas of high hazard in terms of water depth and velocity. The “River Corridor” is considered to be the minimum necessary extent to safely convey a major flood to the sea and encompasses lateral erosion risk as well as the high hazard (d x v >1) portion of the design flood extent. It is highlighted in this situation that the “River Corridor” zone restricts the land use within the District Plan rules, but the details of the river management are provided for in the Floodplain Management Plan which is periodically reviewed and updated.

In conjunction with formalising the river corridor, the flood hazard extent including areas where constructed spillways, storage areas and diversions are provided to give more room for floodwaters, must also be included in District Plans so that the land use can be managed appropriately.

Figure 6-7 River Corridor Otaki River (Kapiti Coast District Council District Plan)

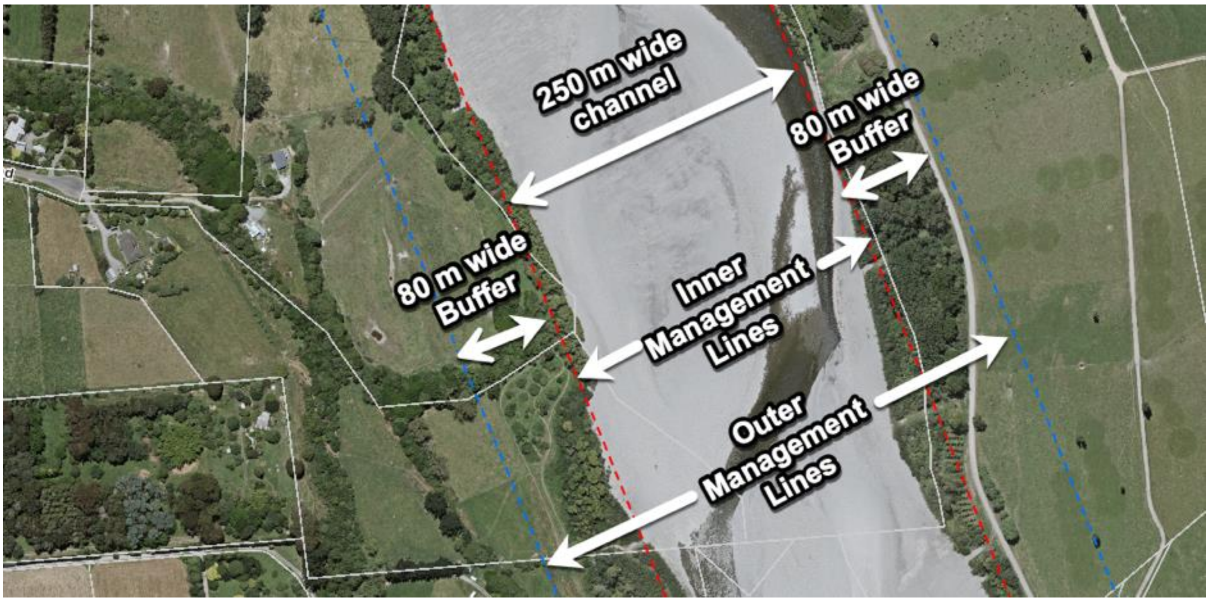

Figure 6-8 Design River Management Envelope Otaki Floodplain Management Plan

7 Bed Level Management

Managing river bed levels through gravel extraction or underwater dredging of finer sediment is an on-going issue in many rivers across New Zealand. There is also the potential for the extent of this issue to increase with climate change related impacts, particularly increasing sea level which will reduce the hydraulic grade at the downstream end of river systems and likely increase the rate and extent of sediment deposition. This could also be exacerbated through increased sediment supply due to the increased size and frequency of flood events and the corresponding increase in sediment transport capacity from upstream reaches.

Equally important is considering bed level management in reaches where there is long-term degradation of the bed as this can also has adverse effects, particularly on structures and surrounding groundwater levels. The careful management of gravel extraction and considering river widening opportunities are key tools for managing degrading reaches.

7.1 Managing Degradation

Many river reaches have the issue of persistent bed degradation. Although this can provide an increase in flood capacity it has many possible adverse effects including –

- Undermining foundations of structures e.g. bridges and rip-rap;
- Lowering water levels which affects surrounding groundwater levels including spring fed streams and water takes from wells;
- More difficult recreational access into entrenched channels.

The reasons for long-term bed degradation can be a mixture of natural and anthropogenic with long-term reductions in sediment supply combining with large volumes of gravel extraction and the residual effects of mid-20th century narrowing of river channels to create the worst case conditions for on-going bed degradation.

In terms of managing long-term degradation the options are fairly limited but the most obvious one is restricting or stopping gravel extraction completely from degrading reaches. This can be challenging, particularly if the extraction industry has well established infrastructure, existing long-term consents and there is a strong local demand for the processed aggregate. Strong regulatory control based on robust evidence of bed level changes and the associated effects is needed to ensure gravel extraction is appropriately managed.

The other option to consider, and in keeping with the “Room for the River” philosophy, is to widen degrading reaches either naturally or mechanically or by removing constraining rock lines. These widening techniques should reduce the energy within the reach and to therefore reduce the sediment transport capacity so that there is the potential for the rate of degradation to reduce. This option is most likely to be effective in reaches that have been significantly narrowed by past interventions.

7.2 Managing Aggradation

In some instances where gravel deposition is an issue there is sufficient local demand for the extracted gravel and it can be removed through a cost neutral arrangement. However, where the material is not desirable due to size, quality, contamination or location there can be significant ongoing costs if it is actively managed.

The standard method for analysing river bed levels across New Zealand is very well established and typically involves 5-yearly monitoring of cross sections in the major rivers. This cross section data is then analysed to determine changes in mean bed levels and the change in bed volume (See Figure 7-1 for an example).

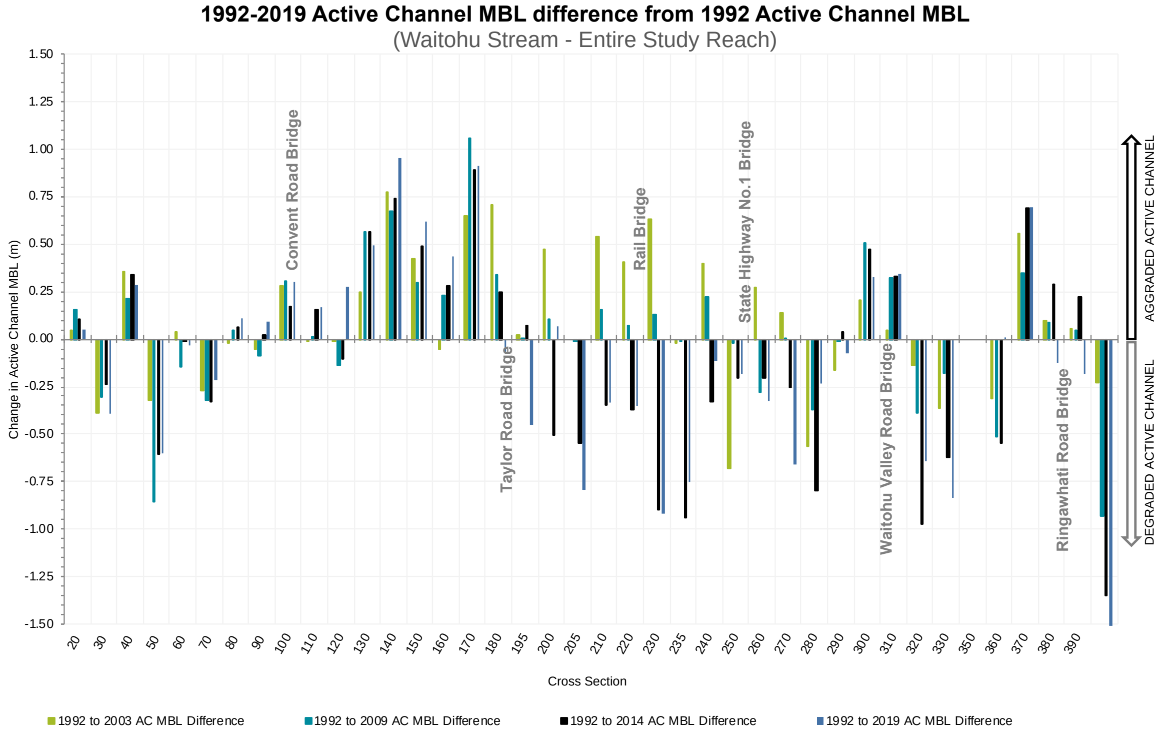

Figure 7-1 Mean Bed Level Graph Waitohu Stream[51]

Often as part of this assessment a gravel budget will be developed which provides an estimate of the natural supply of sediment accounting for past measured changes in bed levels and reported gravel extraction.

A management plan is then typically developed that aims to extract down to within a bed level envelope or to a referenced past survey level. The bed level envelope (See Figure 7-2 for an example) is typically developed with the upper bound governed by the maximum allowable level to achieve safe conveyance of the design flood and the lower bound governed by the sensitivity of structural foundations, particularly bridges and rock works, as well as water level requirements for intake structures.

[51] Greater Wellington Regional Council (2020). Waitohu Stream Gravel Bed Analysis

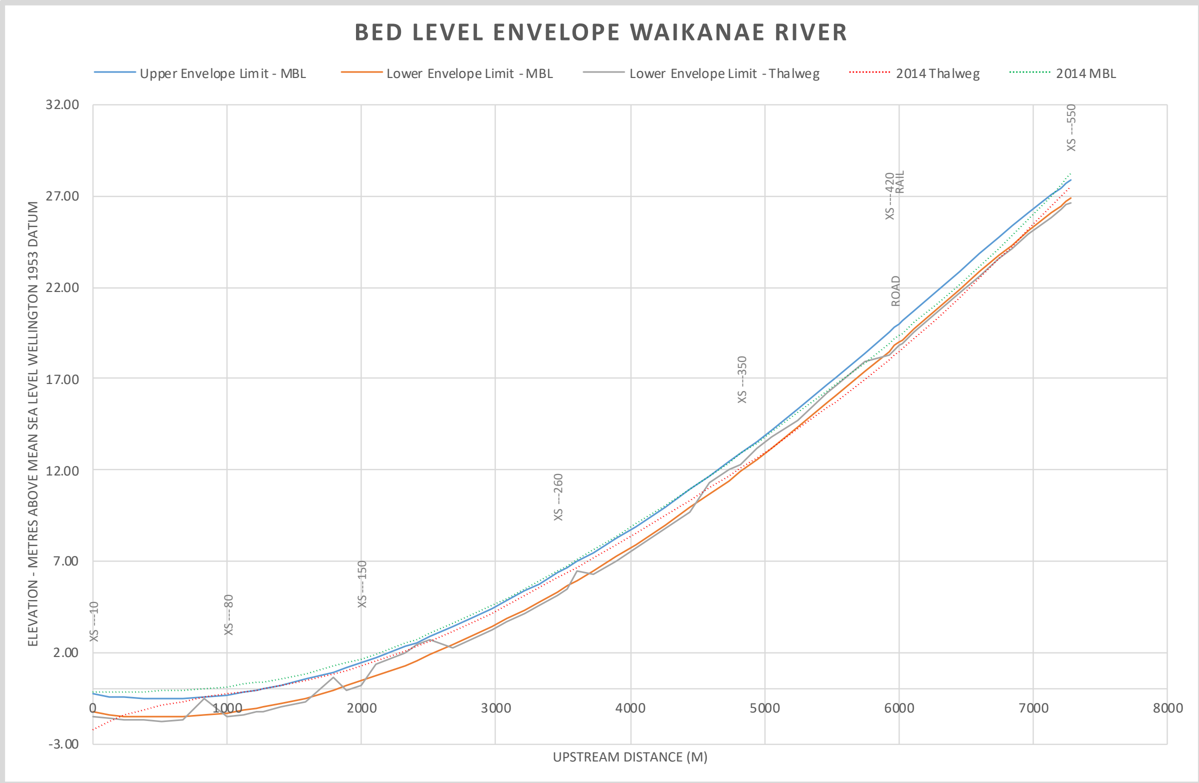

Figure 7-2 Waikanae River Bed Level Envelope[52]

In some instances where there has been limited extraction there would be the requirement to extract volumes significantly greater than the long term natural supply to bring levels down to within the accepted envelope. Equally there will be situations where the bed is degrading below the lower bound of the envelope and extraction activities would generally be ceased and shifted elsewhere.

From discussions with Regional Councils across the country the two main trends emerging in the gravel/sediment management space are –

- the move towards increasing the accuracy of river bed sediment budgets with detailed full surface surveys;
- increasing challenges in consenting gravel management activities due to ecological and cultural effects as well as land ownership.

Both of these are discussed below in further detail as they relate to “Room for the River”.

7.3 Increased Accuracy

The increasing accuracy and availability of bathymetric LiDAR as well as drone based photogrammetry applying structure from motion techniques is making full surface analysis a more viable option for analysing changes to river beds. These techniques are particularly useful for wide river beds with limited vegetation where manual survey techniques are time consuming and limited by the fact that they are only picking up a sample of river bed behaviour at intervals along the channel, which at times might be as infrequent as cross sections at 800 m centres.

The far greater detail available when analysing differences in complete surfaces between surveys (See Figure 7-3) has the potential to provide the basis for improved decision making around river bed

[52] Greater Wellington Regional Council

level management. However, the historic cross section data set will typically provide the longest record of river behaviour and will likely still need to be referenced when developing bed level envelopes and estimating average long term sediment transport rates.

The additional complexity in the gathering, processing and analysis of data should also not be underestimated and these methods should be applied strategically where a greater degree of accuracy is required. The Geomorphic Change Detection Software (GCD)[53] tool has been used successfully by some regional councils. The GCD tool simplifies and streamlines the processing and analysis of LiDAR surfaces and accounts for uncertainty and tolerances when presenting the information for a river reach[54].

It was noted that some Councils are planning to continue with the traditional approach of repeated cross sections surveys and managing the bed to a past reference survey date. This approach is equally valid and highlights the balance between effort and accuracy when considering the variability and degree of accuracy achievable especially when managing large gravel bed river systems.

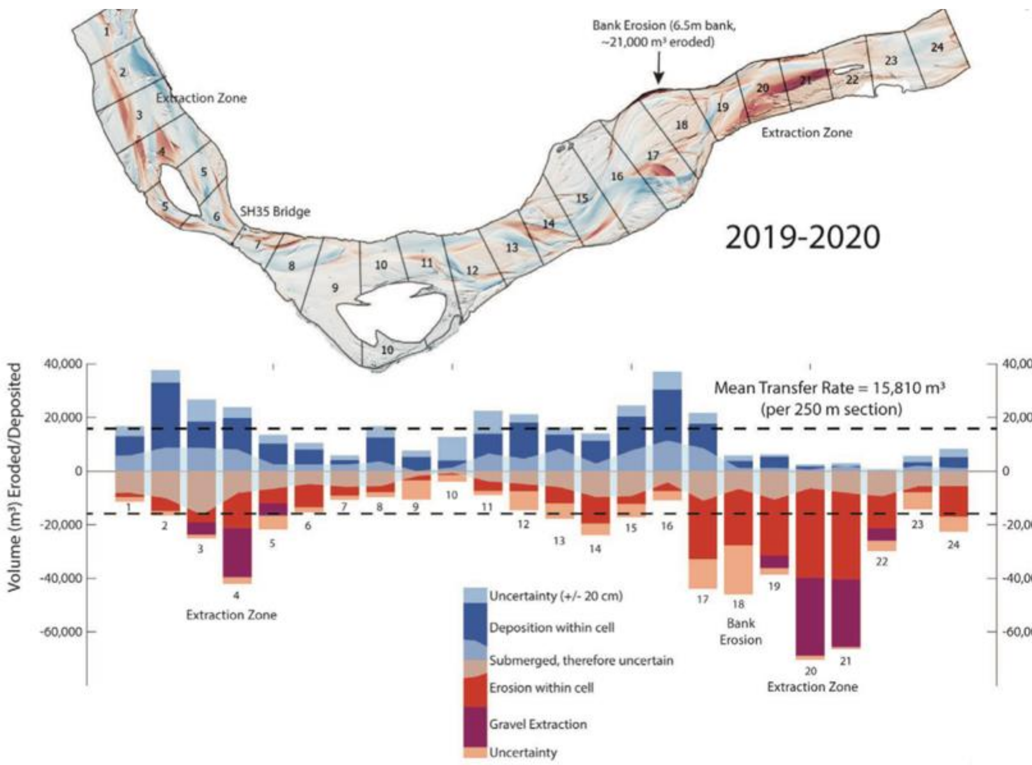

Figure 7-3 Digital Elevation Model of Difference for Waiapu River[55]

In terms of "Room for the River" the availability of higher resolution survey data can be utilised in numerical morphological models (e.g. Delft3D) discussed earlier to assist with understanding possible future trajectories and boundaries for a river's behaviour. This type of analysis can be in terms of possible aggradation or degradation risks as well as lateral mobility including avulsion. This is likely to be useful when managing larger river systems where there are significant areas of private property or high value community assets at risk.

[53] https://gcd.riverscapes.net
[54] Matt Surman pers comm 13 April 2023
[55] Tunnicliffe, J.F. & Baucke, D. (2021). Bedload Transport and Gravel Supply in the Waiapu Catchment. Technical Report for Gisborne District Council

7.4 Consenting Challenges

A common theme when discussing sediment extraction across the country was the increasing challenges in undertaking the works in a way that is acceptable to iwi partners and key stakeholders such as Fish & Game and Forest & Bird. This is particularly the case where extraction is proposed in the wetted part of the channel and in larger rivers where fish exclusion/relocation protocols are unable to be applied.

The standard approach often requires working within a restricted time of year based on seasonal sensitivities for particular species or activities and actively managing effects on aquatic life with rescue and relocation protocols as well as post works mitigation.

The “Room for the River” concept does provide further opportunities for reducing the reliance on on-going extraction, especially in the situation where stopbank retreat or berm enlargement are viable options. The need for extraction most often arises in the lower reaches of river systems which are confined between stopbanks and where aggradation reduces channel capacity. Considering stopbank retreats and berm enlargement to provide increased capacity to manage climate impacts as well as allowing for ongoing aggradation could be a viable alternative to ongoing extraction.

This scenario is limited by cases where the channel completely fills up with sediment and avulsion to another course occurs. In most instances this will be extremely difficult to accommodate and some level of on-going extraction will be required. Likewise, allowing vegetation to spread and establish within the active channel increases the risk of avulsion as well as concentrated lateral erosion that is unable to be effectively managed within buffer areas.

Another application of “Room for the River” in terms of gravel management is being used in the RiverLink project in Lower Hutt. The upper reach of the river within the project is being widened to reduce sediment transport capacity and encourage sediment deposition. The concept being that increased deposition with accompanying extraction in this reach will reduce the throughput of sediment to downstream reaches where gravel extraction is more difficult and more ecologically sensitive. This strategic widening and extraction of quasi sediment traps is another possible application of the "Room for the River” concept.

8 Summary

- The “Room for the River” philosophy opens up a valuable toolkit for river management practitioners to work with Iwi partners, communities and stakeholders in developing effective and sustainable flood and erosion risk management solutions.
- Following the successful path, led by the Netherlands amongst others, of providing more room for floodwaters through stopbank retreats, diversion channels and storage compartments, would provide a pathway for managing increasing flood sizes and frequency as we seek to upgrade our flood management infrastructure so it is fit for purpose for the future.
- Integrating erosion risk management with flood risk management and adopting the same “Room for River” philosophy will also provide opportunities for more cost effective long-term management that is less reliant on rock works and other structural measures, while enhancing the ecological functioning of river systems.
- Upcoming changes to legislation, particularly the Climate Adaptation Act provide an opportunity for enabling “Room for the River”, especially through requirements for specifically assessing these types of solutions as well as nationally subsidised funding models for situations where the most appropriate outcome is unaffordable for the local community.
- It is considered that the “Room for the River” philosophy works in harmony with Te Mana o te Wai by making the river the central focus and providing space for it to operate more naturally to enhance mauri and mana.
- Incorporating “Room for the River” in key strategic plans such as the LTP Infrastructure Strategy, and then working through options for specific catchments with iwi partners using good practice Flood Risk Management processes (NZS 9401:2008), or engaging with communities through Asset Management Plan processes, provides an effective framework for developing plans for the future.
- Exploring options within these planning processes for making more room for floodwaters using the numerous tools described in the Natural Flood Management Manual and the Natural and Nature Based Solutions as well as defining and providing for erodible corridors that allow natural functioning, will be essential in achieving successful outcomes.
- Integrating river bed level management within the overall flood and erosion management scheme with a focus on minimising on-going maintenance requirements can also work in harmony with “Room for the River” concepts, particularly through focussed extraction along over-widened reaches and stopbank retreat that reduces the reliance on main channel capacity.
- Finally, formalising the outcomes from these processes in District Planning provisions or Designations provides security and surety around future implementation.
- “Room for the River” will become the foundation of best practice erosion and flood risk management in New Zealand and hopefully these guidelines providing a useful starting point on our journey.