RESTORATION AND BETTERMENT OF A UNIQUE CHRISTCHURCH WATERWAY CATCHMENT POST-EARTHQUAKE

Byron Munro and Richard Brunton (Pattle Delamore Partners Ltd)

ABSTRACT

The Christchurch earthquake series caused widespread land damage across Christchurch City, including damage to the city's waterways. Impacts on the city's waterways included bed heave, settlement, liquefaction and lateral spread of banks. Pattle Delamore Partners Ltd were engaged by Christchurch City Council to undertake a series of investigations to determine the extent of earthquake damage and its effects on the "six-values" (capacity, ecology, landscape, recreation, heritage and culture) in the Wairarapa Stream and Wai-iti Stream. The ultimate purpose of this project was to identify options to remediate these unique and valuable waterways to pre-earthquake condition, and identify opportunities for longer-term improvements.

In conjunction with site visits and stream surveys, a hydraulic capacity model of the streams was built using the MIKE modelling software. The purpose of the model was to identify and compare areas where post-earthquake capacity no longer meets the pre-earthquake capacity. This paper examines how the site visits, stream surveys and hydraulic model were used to develop options for longer-term betterment which would enhance all six values.

KEYWORDS

Earthquake Recovery, Waterways, 6-values, Modelling

PRESENTER PROFILE

As a graduate engineer at Pattle Delamore Partners Ltd, Byron has been working in the field of environmental engineering for 2 years. As part of PDP graduate program Byron has completed work in a number of fields including stormwater, water resources, irrigation, contaminated sites and environmental management.

1 INTRODUCTION

The Christchurch earthquake series caused widespread land damage across Christchurch City, including damage to the city's waterways. Impacts on the city's waterways included bed heave, settlement, liquefaction and lateral spread of banks. As a result, a series of investigations was instigated by Christchurch City Council to determine the extent of earthquake damage to waterways and its effects on their drainage, ecology and landscape, along with their recreational, heritage and cultural values ("six values"). Pattle Delamore Partners Ltd (PDP) were contracted to undertake this investigation for the Wairarapa and Wai-iti Streams.

This project was completed in two stages. Firstly, Stage 1 aimed to identify issues associated with earthquake-related damage and investigate options to repair the Wairarapa and Wai-iti streams to pre-earthquake condition. Stage 2 developed the preferred repair options into a concept design.

1.1 WAIRARAPA AND WAI-ITI STREAMS

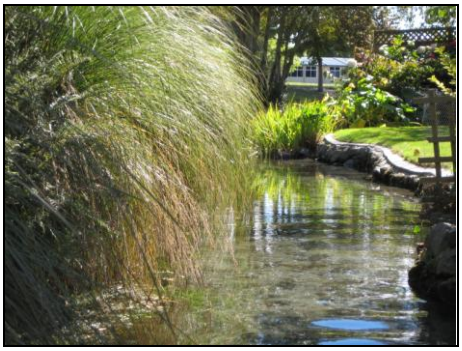
The Wairarapa and Wai-iti streams are tributaries of Avon River/Ōtakaro, which is one of the three major river systems that meander through Christchurch City. The Avon River/Ōtakaro and its tributaries, including the Wairarapa and Wai-iti streams, are all groundwater fed streams, whose source waters originate in the north-western part of the city. The Wairarapa Stream has significant cultural importance, flowing through the historic property of Mona Vale, a popular garden park in Fendalton. Both streams also have a strong connection to the adjacent residential properties, with many using the streams as landscape features or for kayaking/boating.

Figure 1: Wairarapa Stream in Mona Vale Gardens

1.2 SIX VALUES APPROACH

The Christchurch City Council has developed a framework for integrating a set of six key values into its approach to assessing and managing the city's waterways. This "six values" approach advances the previous primary focus of waterways as drainage networks to integrate drainage values with ecological, cultural, recreational, heritage and landscape values (CCC, 2003). This is a unique response to managing urban waterways and provides for more holistic and community minded solutions.

To determine the extent of earthquake damage and its effects on the "six-values" in the Wairarapa and Wai-iti streams, the streams were divided into fine scale reaches to allow detailed examination of stream condition. For reporting simplicity, the stream reaches were separated into 5 sections of broadly similar characteristics, these are reported in Table 1 and shown in Figure 2.

Table 1: Description of the Stream Sections for the Wairarapa and Wai-iti stream project		
Section ID	**Section Description**	**Example Photo**
1	Tributary of Wairarapa Stream, large extent of ephemeral channel. Bounded by private property.	
2	Upper reaches are ephemeral, flows begin as the stream passes through Jellie Park. The stream also passes through Cobham School, otherwise it is bounded by private property	
3	Meandering stream bounded by private property, small reach passes through Waiwetu Reserve. Area of highest ecological value.	
4	Stream starts to widen, accumulation of silts on stream bed is noticable. Bounded by private property. Greater private recreational use (boating)	
5	Wide, shallow reach of river, heavily silted. Area of road reserve along Wairarapa Terrace, and significant open space in Mona Vale.	

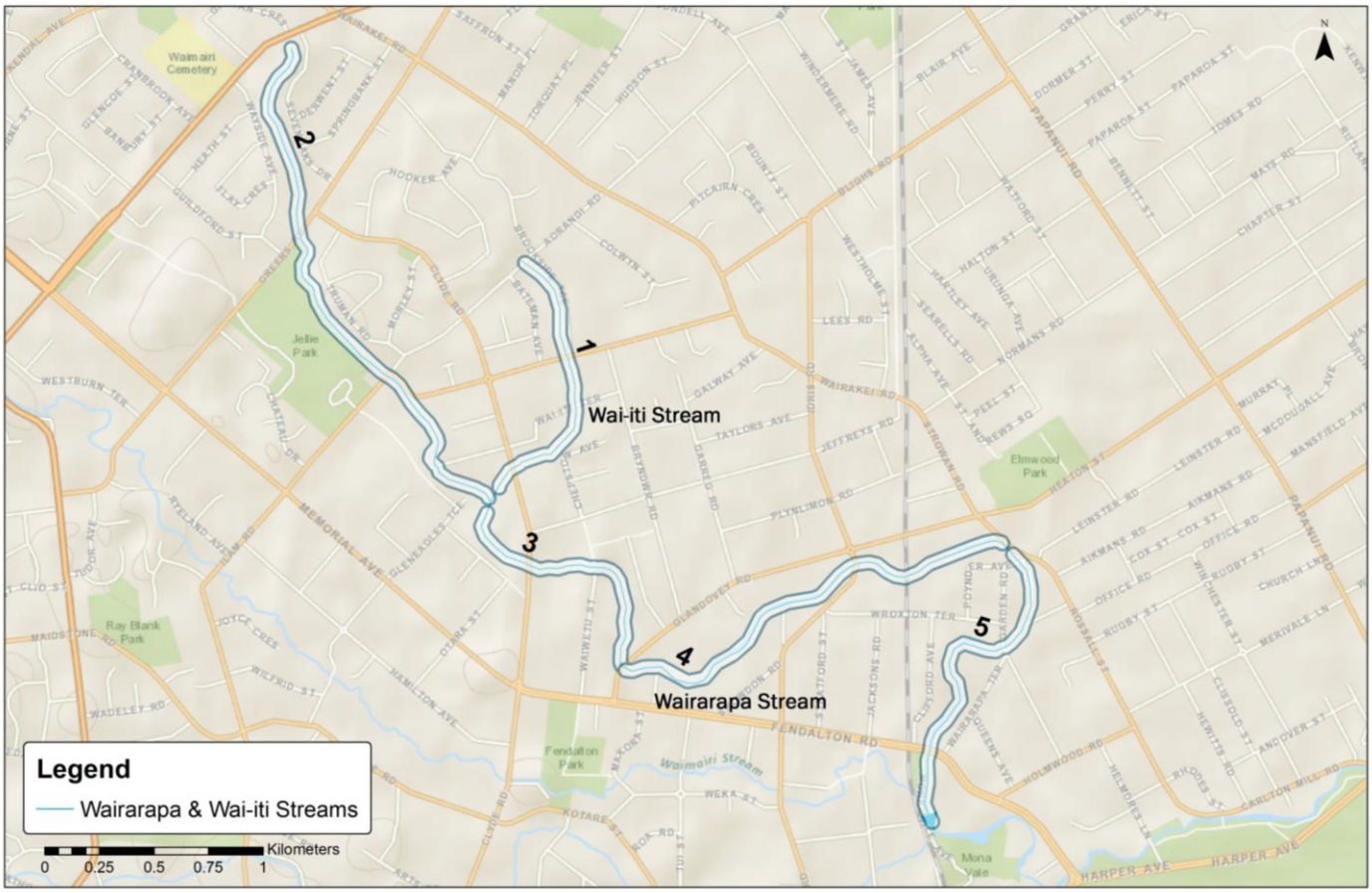


Figure 2: Stream Sections for the Wairarapa and Wai-iti Stream Project Reaches

1.3 RELEVANT STRATEGIES AND REGULATIONS

In the development of options for repair and betterment, relevant strategy and policy documents were reviewed. These documents can be broadly separated into those that provide guidance on community aspirations and outcomes sought, and those that have a regulatory aspect.

The guidance documents include the Canterbury Regional Policy Statement, Mahaanui Iwi Management Plan 2013, Christchurch City Council Biodiversity Strategy and Jellie Park Management Plan (2010). The Regulatory documents include the Christchurch City Plan and Environment Canterbury Regional Plans, including the Natural Resources Regional Plan (2011) and the proposed Canterbury Land and Water Regional Plan (2012). Some remediation activities may be covered by existing global resource consents held by Christchurch City Council, or they may require further specific resource consents.

2 SIX VALUES INVESTIGATION (STAGE 1)

2.1 DRAINAGE ASSESMEMENT

For the drainage assessment, the in-bank hydraulic capacity was established for three different scenarios using the MIKE 11 modelling software. The first scenario is the "pre-

earthquake" condition, with capacity assessed based on a stream cross section survey that was undertaken in 1982-4.

The second scenario was the "post-earthquake" condition. This was based on a cross section survey carried out in January 2013 by the Christchurch City Council survey team. This resulted in an updated (or "post-earthquake") set of cross sections that were used to generate an updated version of the "pre-earthquake" model. The 2013 survey included many more structures (weirs, culverts and bridges) than were present in the 1982-4 survey.

Because of the differences between the "pre-earthquake" and "post-earthquake" model versions (cross sections), it was necessary to separate out the differences that were due to construction and development in the period between 1984 and 2013 (i.e. constructed weirs, culverts and bridges), from those that could be directly attributed to earthquake activity. For this reason, a third scenario was modelled, this only included the same structures as were present in the 1982-4 version of the model. By comparing the results from this model scenario with those from the "pre-earthquake" version, the differences due to earthquake activity are better able to be defined.

Comparisons of these scenarios revealed that the upstream reaches of the Wairarapa Stream (Stream Section 2) and Wai-iti Stream (Stream Section 1) both have current capacity's greater than the "pre-earthquake" condition. Therefore, no remedial works are required to bring hydraulic capacity back to pre-earthquake condition.

The same cannot be said for downstream reaches of Wairarapa Stream (Stream Sections 3, 4 and 5), where current hydraulic capacity is notably lower than it was for the "pre-earthquake" condition. Some of these differences are attributable to the recent assessment being inclusive of many more structures that limit capacity (i.e. constructed weirs, culverts and bridges constructed between 1982-4 and January 2014. However, even when the structures used in the comparative assessment are kept constant (Scenario 3), there is a notable loss of hydraulic capacity in these lower reaches. Earthquake damage (bank slumping and lateral spread) are apparent in parts of these reaches and are likely contributors to loss of hydraulic capacity. Because of this remedial works to restore the stream "drainage" value to pre-earthquake conditions were recommended.

2.2 ECOLOGICAL ASSESSMENT

2.2.1 ECOCLOGICAL SURVEY

Ecological surveys of the Wairarapa and Wai-iti streams were undertaken by Aquatic Ecology Limited in December 2012. The ecological survey focussed on three sites where pre-earthquake data existed (fish and macroinvertebrates). These sites were all on the Wairarapa Stream. In addition, surveys of trout spawning habitat in the Wairarapa Stream had been undertaken previously during the winters of 2002 (Taylor & Burrell 2002), 2008 (Taylor & Bray 2008) and 2011 (Taylor *et al.* 2012). These sites were resurveyed in January 2013.

The highest surveyed site in the catchment exhibited a finer substrate composition compared to previous surveys. At least some of this was due to seismic activity, and some probably due to gradual sedimentation since the pre-earthquake survey in 1992. Subsequently, the numbers of juvenile trout and native bully have decreased at this site, which was considered to be attributable to the decrease in suitable substrate cover at this site. The habitats at the remaining two sites were noted as having little change since previous surveys. However, the fish population has changed and is now dominated

by juvenile trout, which is likely due to a release of juvenile trout by the North Canterbury Fish and Game Council.

The 2012 trout redd survey indicated that a significant amount of trout spawning habitat had been lost in the period between 2008 and 2012. Most of the reduction was in the upper portion of the catchment, between Wai-iti Terrace downstream to about Clyde Road.

2.2.2 CREAS SURVEY

The Christchurch River Environment Assessment Survey (CREAS) is a GIS-based assessment tool developed to assist the Christchurch City Council with the integrated management of the city's waterways (McMurtrie & Suren 2008). CREAS is a broad-scale habitat mapping programme that assesses the physical condition of waterways at regular intervals (50 m) in order to provide quantitative data on natural asset condition of the waterways.

CREAS was undertaken in December 2005 at 50 m intervals along the Wairarapa Stream downstream of Grahams Road to the confluence with Waimairi Stream and along Wai-iti Stream from Aorangi Road to the confluence with the Wairarapa Stream. This survey provides a pre-earthquake baseline habitat dataset for the Wairarapa and Wai-iti streams. PDP repeated the CREAS survey in February 2013 at the same locations as those in the 2005 survey to determine post-earthquake habitat condition. The 2013 survey focussed on earthquake-related attributes and, therefore, excluded riparian vegetation assessment as this was unlikely to be altered by earthquake damage.

Differences in substrate composition are apparent between the two surveys. Some of this difference may be attributable to variability due to observers interpreting substrate type slightly differently. However, given the large differences observed for some reaches, this is more likely to be from physical changes in the bed substrate than observer variability. A key change in substrate composition between the two surveys appears to be a shift in composition of fine sediment in the lower reaches (stream reaches 4 and 5) from predominately mud/silt/clay to sand. This finding is consistent with liquefaction material entering the stream, which is predominately sands and silts, possibly displacing or obscuring finer-grained muds and clays. In addition, areas where substrate was recorded as comprising cobbles and gravel in 2005, recorded lower proportion of cobbles and greater proportion of sands in 2013. These changes occurred in the reaches between Jellie Park and Glandovey Road, and match areas identified as having reduced trout spawning habitat.

Another notable difference is the increase in depth of total fine sediments, again particularly in the two lower reaches. In stream reach 4 the average depth of fine sediment has increased from 0.22 m to 0.31 m, and in Stream Section 5 the average depth of fine sediment doubled from 0.18 m to 0.36 m. While some increase in sedimentation may be the result of gradual increases over the past 5 years, prior to the earthquakes, it is likely that at least some of the increases are as a result of liquefaction silts and sands entering the stream.

2.3 LANDSCAPE, CULTURAL, RECREATIONAL AND HERITAGE ASSESSMENT

A landscape, cultural, recreational and heritage values assessment was undertaken by Graham Densem Landscape Architects in February 2013. A team of two people walked the full length of the Wairarapa Stream from Grahams Road to Mona Vale, and Wai-iti Stream from Aorangi Road to its confluence with the Wairarapa Stream.

Obvious earthquake effects were seen, but appear to have been mostly at a site-specific scale and have had little effect on the wider landscape, cultural, recreational and heritage values of the Wairarapa and Wai-iti streams. The typical observed earthquake effects were stream bank damage, such as shown in Figure 3. The current state of these four values identified in this assessment, should therefore be used as a baseline to either be retained or improved on when carrying out remediation works. None were triggers of necessary remedial work in themselves.

Figure 3: Earthquake related stream bank damage – Lateral Spread

2.4 TANGATA WHENUA VALUES

Tangata whenua values and expectations are described in the recently released Mahaanui Iwi Management Plan (IMP) (Jolly et al 2013). The IMP identifies issues and establishes objectives and policies at a regional level, and also distinguishes specific objectives and policies for a number of catchments including Ihutai.

The IMP describes the cultural health of the Ihutai catchment based on a cultural health assessment that was undertaken in 2007 at 30 sites across the catchment. One site on the Wairarapa Stream was assessed (Wairarapa Stream at Jellie Park) while the Wai-iti Stream was not assessed (Pauling et al 2007). The overall monitoring results found the catchment to be in a state of poor or very poor cultural health. However some sites were seen as having positive cultural attributes and these provided ideas for how future management may be able to improve the cultural health of the Ihutai catchment. This included the Jellie Park site which was valued because of the presences of springs and also valued because of the presence of native vegetation.

These findings indicate the potential for providing for tangata whenua values in the Wairarapa Stream, and in particular that there is opportunity to enhance the cultural health and cultural utilisation of Jellie Park, (although that is not in relation to any earthquake related effects).

2.5 INTEGRATION OF SIX VALUES AND RECOMMENDATIONS

The lasting effects of the Christchurch earthquakes on the Wairarapa and Wai-iti streams are primarily of reduced flow capacity below the Wairarapa/Wai-iti confluence and loss of trout spawning habitat (gravel stream bed) by earthquake-related silt and sand deposition through the middle reaches of the Wairarapa Stream. There was limited earthquake related effects on landscape, cultural, recreation or heritage values, only site specific localised effects, relating mostly to stream bank damage.

Options for remedial work focussed on restoring stream capacity in a manner sympathetic with other values. The main remedial works identified, to restore Wairarapa and Wai-iti streams to pre-earthquake condition, are excavation of stream bed sediments and changes to stream cross section profiles. Also, the removal of fine sediments and reinstatement of riffle/run sequences are the main options for restoring trout spawning areas. These remedial works, and their desired location, are shown in Figure 3.

Options for longer-term betterment could also be completed to enhance all six values above the "pre earthquake" state.

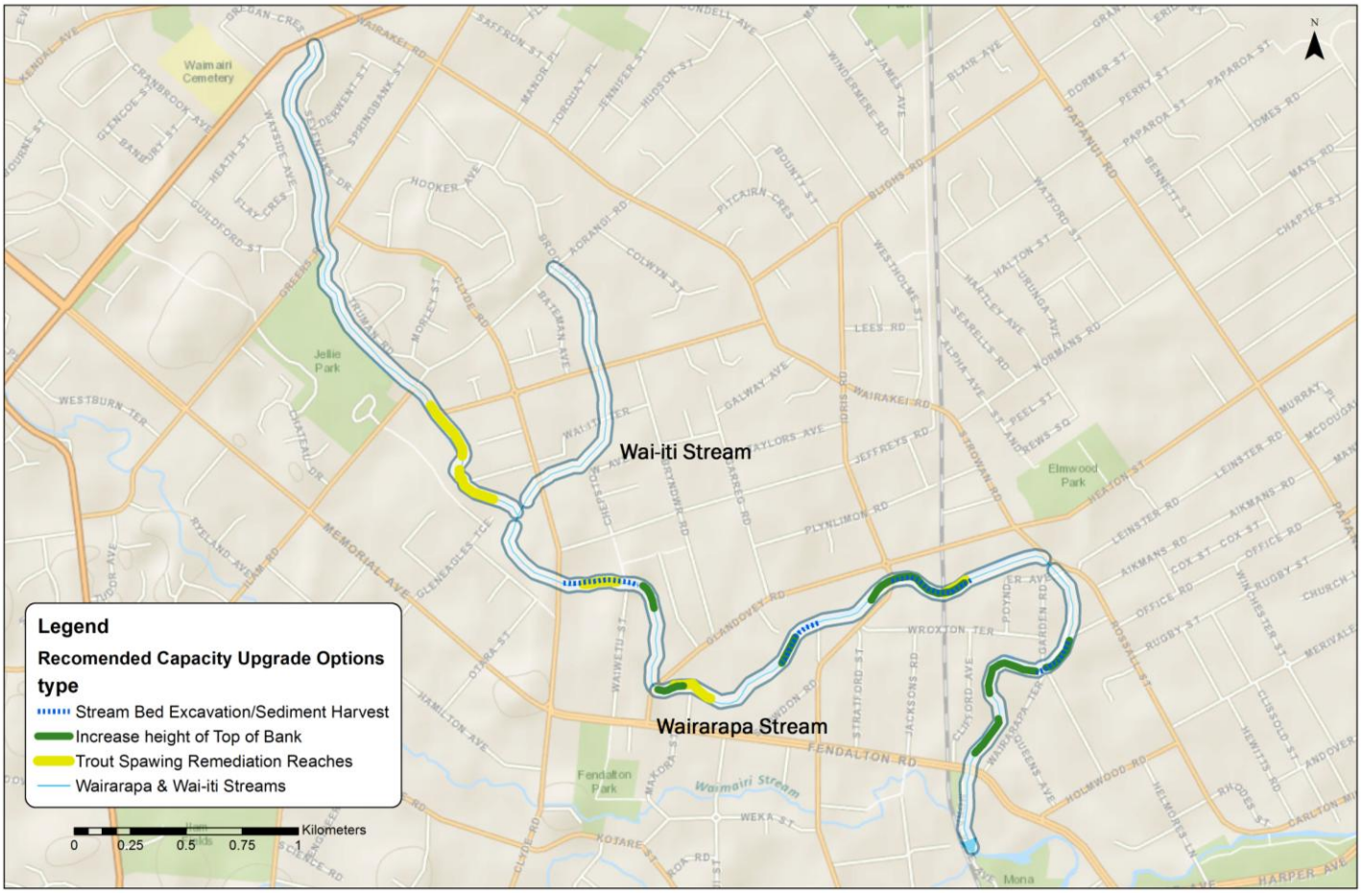


Figure 3: Location of earthquake related remediation options within each Stream Section

3 CONCEPTUAL DESIGN FOR POST-EARTHQUAKE REMEDIATION AND BETTERMENT OPTIONS (STAGE 2)

The conceptual design approach focused on areas and issues relating to the restoration of flow capacity below the Wairarapa/Wai-iti confluence, and the restoration of trout spawning habitat. These were identified as the key impacts of the earthquake series on the Wairarapa and Wai-iti streams in Stage 1, and are outlined below in Section 3.1. Significant impacts on landscape, cultural, heritage and recreational values were not found, and any impacts that were observed were restricted to localised areas of bank damage. Options to enhance the "six values" above the "pre earthquake" state were also incorporated into the conceptual design developed in this stage and are described below in Section 3.2.

The conceptual design for remedial works has been developed to incorporate the following elements:

- Increase hydraulic stream capacity to pre-earthquake condition,
- Restore trout spawning habitat in priority reaches,
- Create ecologically beneficial low flow channels,
- Improve stream bank ecological value,
- Improve stream bank cultural, landscape and recreational value.

In developing the conceptual design, PDP considered potential constraints such as ease of access into the stream, setback distances of houses or other buildings that might require greater bank support, and the current condition of stream banks and any instability issues that may exist.

3.1 KEY DESIGN FACTORS – RESTORATION TO PRE-EARTHQUAKE CONDITION

3.1.1 STREAM PROFILE

A key design factor, for restoring ecological and cultural values, is to create a low flow habitat suitable for fish and invertebrates. Generally this can be done by narrowing the low flow channel to increase water depth and velocity. Any narrowing of the low flow channel must not affect stream capacity in higher flows. Where narrowing of a low flow channel is carried out, additional capacity should be added above the low flow channel. This can be done by creating a terraced cross section, with a narrow lower terrace and a wider upper terrace. It is recommended that, where capacity is to be maintained, the cross sectional area of the channel should be increased by between 10 – 20% of the existing cross sectional area. This increase is to take into account changes in stream roughness and wetted perimeter. An example of the post-earthquake cross-section compared to the recommended cross-section is shown in Figure 4.

The Wairarapa Stream has suffered flow loss over the past decade or more, and consequently the low flow channel is now wider in many places than desirable at current base flows. Creating a narrower low flow channel with terraced high flow capacity is the preferred option whenever bank or channel remediation works are undertaken.

3.1.2 STREAM BANK TREATMENTS

The Christchurch City Council has recently completed a guideline for bank treatment options for stream remediation works (Shadbolt et al, 2013). This guideline contains a

variety of bank stability details which can be used for different applications. PDP evaluated these bank treatment options in the context of their appropriateness for remedial works in the Wairarapa and Wai-iti streams. Aquatic Ecology Ltd also evaluated each treatment option in the context of their potential for providing instream ecological benefits in the Wairarapa and Wai-iti streams. Each treatment was considered in the context of access requirements, bank stability, and house/building setback

The preferred bank treatment options were identified for each stream section where raising the bank height is identified as remediation option. The preferred option for each reach is identified as Option 1 in the conceptual designs, a suitable alternative option (Option 2) was also provided, for use in situations where Option 1 does not provide for specific needs or land owner preferences. An example of the preferred bank treatment options for a stream section can be seen in Figure 4.

3.1.3 TROUT SPAWNING HABITAT REMEDIATION

Trout in the Avon River spawn at the downstream boundary of laminar-flow runs, immediately upstream of shallow, more turbulent riffles. In this zone, there is a downwelling of oxygenated surface water through the gravels before the crest of the riffle, and this water flow facilitates trout egg respiration. In remediating trout spawning reaches, alternating reaches of riffles and runs is required, creating water slope 'inflections' or boundaries over a restored gravel bed.

Where bed excavations are required to increase hydraulic capacity, and where these coincide with trout spawning reaches, it is important that the water slopes be maintained, or restored. As well as maintaining water slopes, an undisturbed layer of gravel substrate of 250 mm would be required to provide adequate depth of gravels for trout spawning habitat (Mark Taylor, pers comm.).

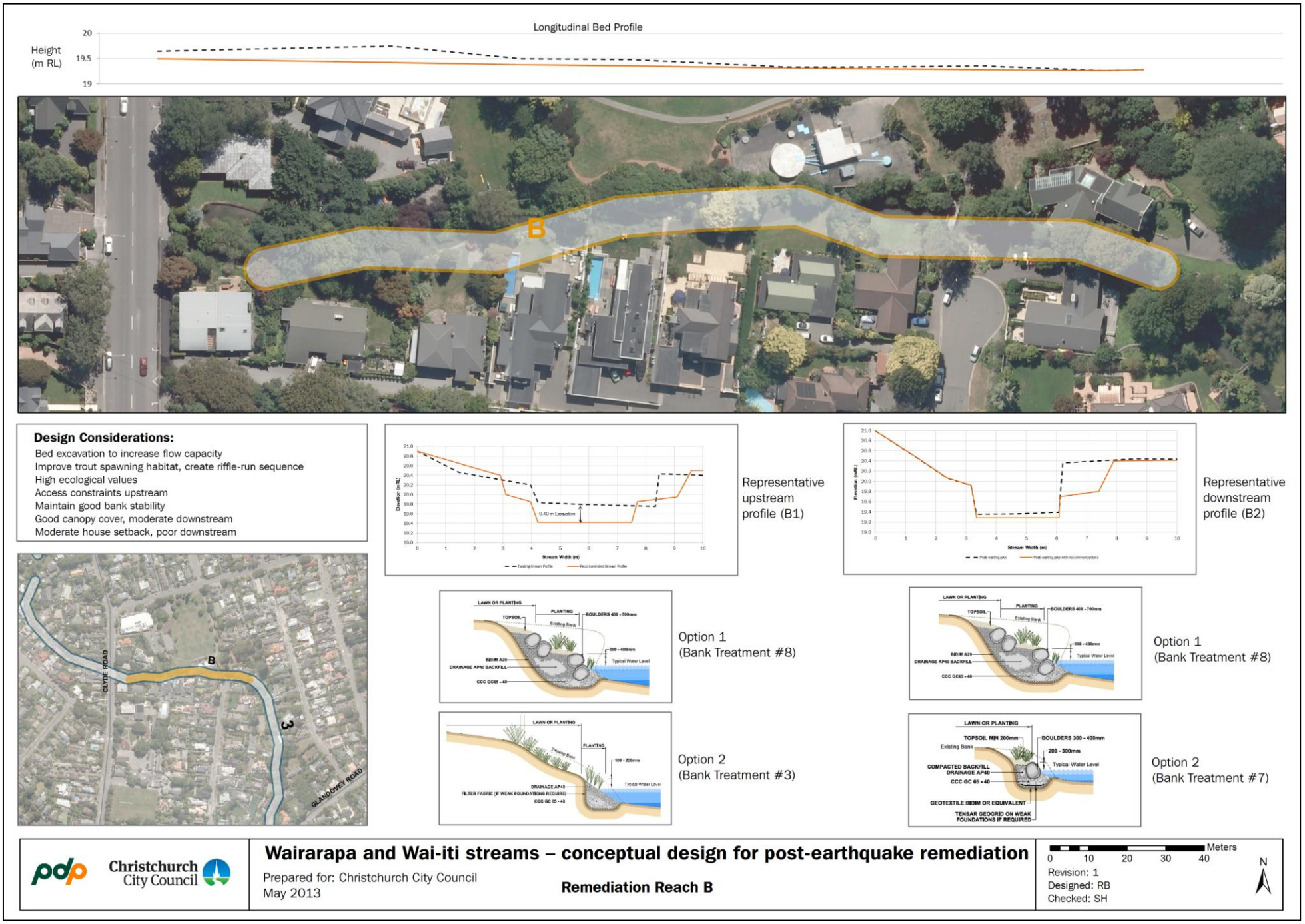


Figure 4: Example of Post-earthquake remediation

3.2 OPPORTUNITIES FOR BETTERMENT TO PRE-EARTHQUAKE CONDITION

3.2.1 INSTREAM SEDIMENTATION TRAPS

Liquefaction as a result of the earthquakes has resulted in the deposition of silts throughout the Wairarapa Stream. In addition, gradual accumulation of fine sediments will have also occurred in the river over decades of urbanisation. Extensive accumulation of silt was known to occur in the lower reaches of Wairarapa Stream prior to the earthquakes, and siltation of the gravel stream bed in the middle to upper reaches appears to have occurred incrementally over the past decade or more. In some reaches, this has caused deterioration of instream habitat for native fish and invertebrate species, and encourages the development of excessive aquatic plants. Liquefaction silts and sands have exacerbated this situation.

In order to capture the fines and silts over time, the use of a sediment trap was recommended. Further design work would be required to determine the exact size requirements of the trap. A sediment trap operates by decreasing the stream velocity, whereby sediment "drops out" (deposited), a larger (greater volume) sediment trap results in lower velocities. When determining the size of the sediment trap, the desired frequency of sediment removal also needs to be considered. The design also needs to prevent entrainment of sediment that has already been deposited. For the Wairarapa Stream, the sedimentation trap could be constructed using an excavator to shape and realign the bank channel. Further investigation and design work would be required to investigate this option.

3.2.2 ENHANCEMENT OF ECOLOGICAL, CULTURAL AND LANDSCAPE VALUES

The bulk of the Wairarapa and Wai-iti stream are bounded by private properties. There is very little public access to the streams with the main public areas being Jellie Park and Mona Vale. Therefore, opportunities for betterment of Wairarapa and Wai-iti streams (particularly for cultural, heritage, ecological and landscape and recreational values) are quite dependent on how private property owners manage their stream boundaries. The development of a 'Riverside Property Guideline' for the Wairarapa and Wai-iti streams would provide an opportunity to inform and guide property owners on their obligations and options when undertaking remedial or maintenance/enhancement works on their property/stream boundary. Such guidelines could include:

- The 'story' of Wairarapa and Wai-iti streams including information on the six values,
- Details of landowner obligations and constraints on landscaping and building along the riverside (e.g. setback distances, any consenting requirements),
- Details of Christchurch City Council obligations and commitments,
- Description of options for landscaping that could enhance keys aspects of the six values.

4 IMPLEMENTATION PLAN

The following components were identified as necessary steps for implementation of any remedial works. However, it is important to note that further analysis of actual flooding risks (determine overflow paths using a 2-dimensional model analysis) was recommended to assist with final prioritisation of remedial works.

- Communication/consultation plan with property owners,
- Prioritisation of works,
- Timing of works to avoid sensitive times for instream values (e.g., avoid trout spawning during May to July),
- Identify opportunities to access waterway via vacant properties,
- Site visit to establish details of remediation works,
- Finalise costings for works,
- Agreements for any cost sharing arrangements with property owners.

5 CONCLUSION

Overall this project identified the effects of the Christchurch earthquake series on the CCC "six values" of the Wairarapa and Wai-iti streams, and outlined an approach to return these values to the 'pre-earthquake' condition, and where applicable increase these values above their pre-existing levels. The underlying approach of this project was where one value was required to be remediated, it was to be done in a manner which was sympathetic to the other values i.e. the overall solution must have a net gain in all of the "six values". An example of this is creating ecologically beneficial low flow channels while increasing the hydraulic stream capacity to pre-earthquake condition.

An important factor in developing the remediation and betterment options for the Wairarapa and Wai-iti streams was community participation and support. Especially given that both streams have strong connections to the adjacent residential properties, with many using the streams as landscape features, or for recreation. These streams are considered an asset to their communities. Therefore it is essential to promote a catchment wide approach to the betterment of the stream, which the proposed development of a 'Riverside Property Guideline' should achieve.

This project offered a unique perspective on the enhancement of an urban waterway. Where traditional enhancement projects would focus on a singular value, be it drainage capacity, ecological or recreational, this project had to balance CCC's "six values" and develop a solution which provided a net gain for all of the values.

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