DUDLEY CREEK FLOOD REMEDIATION FROM A PROJECT MANAGER'S PERSPECTIVE

MW Smith; CPEng; CIWEM; IPENZ; Christchurch

ABSTRACT

Following the recent Canterbury earthquakes the flood risk to large parts of Christchurch increased due to land damage, ground levels going down greater than 500mm in some places and lateral spread along the creeks draining large parts of the city.

The Dudley Creek catchment was particularly badly affected by the earthquakes and is an area that was already at a high risk of flooding prior to the earthquakes.

Three separate flood events in the autumn of 2014 led the Council to put in place a plan to fast track a land drainage scheme to return the Dudley Creek catchment to a pre-earthquake level of flood risk. Approximately 600 properties were at increased risk of flooding following the Canterbury earthquake sequence in this part of Christchurch alone.

The successful delivery of this $48M project relied upon a collaborative approach between Christchurch City Council, the Designer and the contractor as well as a high level of co-operation by the public and property owners who live alongside the creek.

Following the appointment of a Designer the first phase involved a high level of public consultation by Council to identify an option that not only met the criteria set to reduce flood risk but also had public 'buy-in' due to the impact that the works would have on their local environment.

The second phase was to appoint a Contractor under an Early Contractor Involvement Contract (ECI) to work alongside the Designer and Council to ensure delivery of a design that could be delivered to programme, within budget and meet the Council's objectives of reducing the flood risk. Council have set an ambitious time frame of reducing the flood risk by the winter of 2017.

KEYWORDS

Flood risk, project management, delivery, public consultation

PRESENTER PROFILE

Martin Smith is a Principal Water Engineer with GHD in Christchurch and has over 35 years' experience in the water industry in the UK, Thailand and New Zealand. Having worked in SCIRT as a Team Leader on the earthquake horizontal infrastructure rebuild in Christchurch he is now seconded to Christchurch City Council as a Project Manager on their Land Drainage Recovery Programme.

1 INTRODUCTION

"Those of us who have never experienced the devastation of flood waters entering our homes would find it hard to imagine what it is like.

Over the last 12 months I have met you in school and church halls. I have sat around the kitchen table in your flooded homes and heard your stories, your frustration and your anger. I have watched, helpless as you evacuated your homes, carrying your children to the car in the middle of the night."

These are the words of the Mayoral Flood Task Force Leader Mike Gillooly as the foreword to his report on the floods which have devastated parts of Christchurch post-earthquake in 2014.

This paper describes the consultation and design process, the construction and delivery of the Dudley Creek Flood Remediation Project. The designer is Beca /Opus with support from EOS. The main contractor is Downer NZ Ltd and the Client is Christchurch City Council. The initial conceptual design was undertaken by Jacobs in 2014.

A flood task force was set up by the Mayor of Christchurch in April 2014 to fast track schemes that had been already identified to combat flooding of properties. The flood risk of low lying parts of Christchurch was exacerbated as a result of the Canterbury Earthquakes in 2010 and 2011 which caused land settlement in excess of 500mm in some areas.

The earthquakes caused damage to creeks due to liquefaction, loss of grade and lateral spread resulting in an increased risk of flooding to low lying areas already at high risk of flooding. Nearly 600 properties in the Dudley Creek catchment were at an increased risk of flooding during high rainfall events. Heavy rainfall, of varying intensity across Christchurch, caused flooding three times in just a few weeks in the autumn of 2014: Information taken from the Mayoral Flood Task Force Report (2014)

Photograph 1: Aerial photograph of flooding: Mayoral Flood Task Force Report (2014)

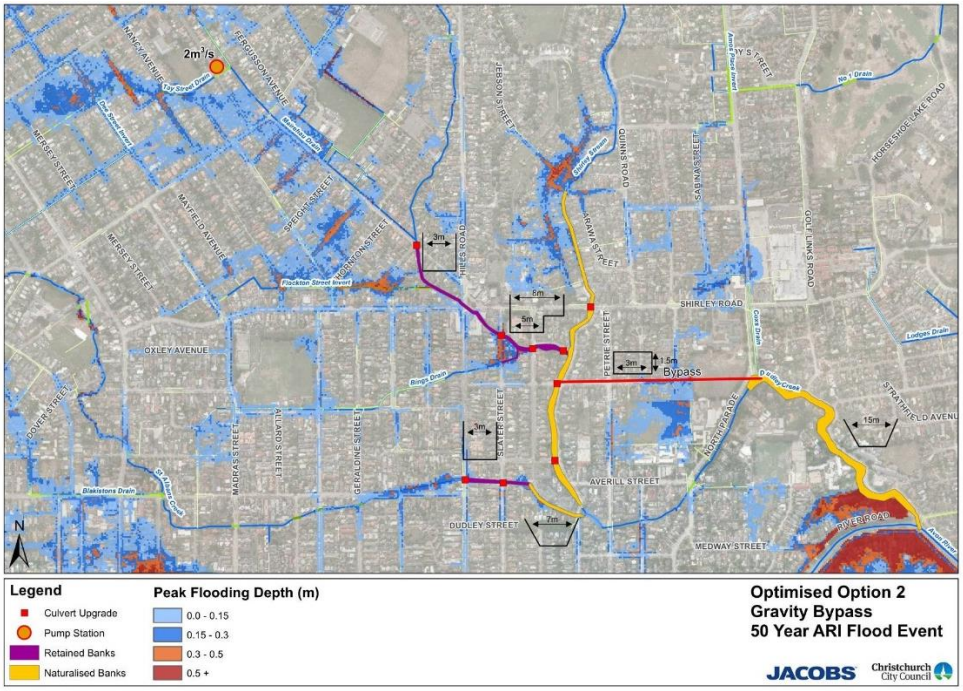
The Council's Land Drainage Recovery Programme, LDRP, was established in 2012 to identify critical projects to reduce the long term flood risk to pre-earthquake levels of risk. See figures 4 and 5 below showing the pre and post-earthquake flood risk. One of the highest risk areas was the Dudley Creek catchment and increasing the capacity of Dudley Creek was identified as a high priority project. The catchment is to the north of Christchurch and is mainly residential with over two thousand properties over an area of about three square kilometers. It had a history of flooding pre-earthquake. During their

investigations the flood task force determined that 28 homes experienced flooding above the ground floor level, 260 homes experienced flooding below the floor and 281 experienced flooding preventing access to their homes in two or more flooding events post-earthquake. In the March 2014 rainfall event over 80 homes were flooded above the ground floor level. Information taken from the Mayoral Flood Task Force Report (2014)

A Consultation Paper was produced by the Council Land Drainage Team which identified various options to reduce the flood risk for the residents in the Dudley Creek catchment. The options all had improvements to the capacity of the creek and a large capacity by-pass pipe to take flows greater than 2.2m^3/sec up to a maximum flow of 9.3m^3/sec, discharging stormwater by gravity into the Avon River downstream: Jacobs (2014) .Consultation took place with residents affected by the floods over the next couple of months and a paper was submitted to Council for approval in November 2014

It's important at this point to understand the impact of the flooding on a community that had been faced with the challenge of engaging with authorities and insurance companies for earthquake repairs and rebuilds for the past three years. Feelings were running very high and the Council officers carrying out the consultation had to be sympathetic to many people's concerns, treading a delicate line between producing a solution that achieved an acceptable level of flood risk whilst not unnecessarily disrupting people's lives. Many of the residents had suffered significant hardship and stress.

Figure 1: Preferred Option for By-pass and creek improvements: Jacobs (2014)



There was strong opposition to the preferred option from some residents affected by the works and therefore when the final report was issued to the Council for approval Councilors would only approve the works upstream of the proposed by-pass and asked officers to give further consideration to the downstream works. This was in November 2014 and further modelling and design was required to come up with an acceptable solution.

Because of the seriousness of the situation and the fact that feelings were running very high amongst the affected residents an undertaking was given to Councilors by the LDRP team that works to reduce the flood risk to at least pre-earthquake levels in the Dudley

Creek catchment would be completed by winter 2017. Only a little over three years after the Mayoral Flood Task Force was set up.

It was against this backdrop that a design contract was awarded for developing alternative options in March 2015 and three options were presented in a second round of consultation carried out in June and July 2015.

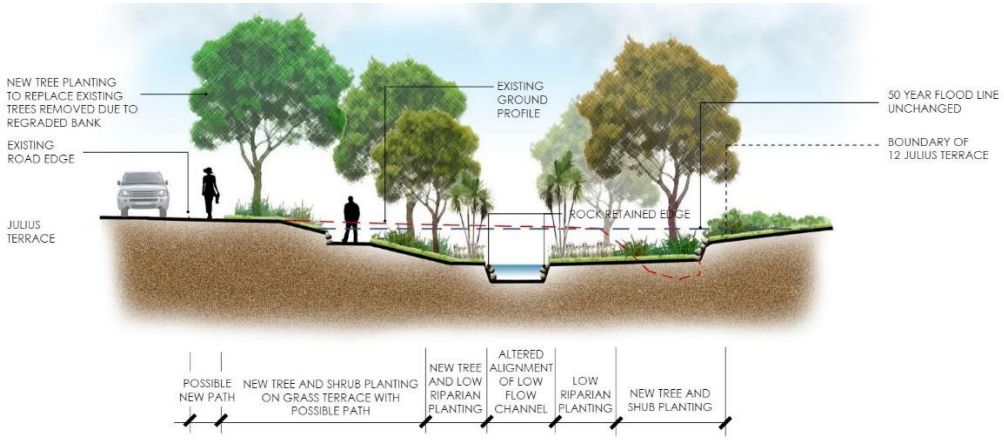
2 CONSULTATION

2.1 THE CONSULTATION PROCESS

The first part of the consultation process was informing the public of the three options. Plans were drawn up for each option, along with typical landscaping details where the capacity of the creek was to be improved.

It was important the residents were fully informed of the impact the creek widening and piped by-pass would have in the local area. The route of the by-pass would have a major impact on the residents during the construction period and on the environment that the residents enjoyed. Where the creek was to be widened it was essential to identify the trees to be removed and the properties most likely to be affected by the construction works. See figure 2. It was important during this consultation period that no one option was identified by the Council as a preferred option to ensure that there was no influence on the decision making process and whichever option was presented to Councilors for approval it was considered to be the best option. Consequently, it had to be also demonstrated to local residents that each option would work, the risk identified, had been costed and could be delivered within the timeframe set by Councilors. This allowed residents to make informed comments on which option they favoured.

Figure 2: Typical Cross-Section through widened section of creek: Beca/Opus (2015)



Several public meetings were held at various venues throughout the area with displays to help the public identify with the three options and help to gauge public opinion. Question and answer sessions were held between residents and Council officers and key members of the design team. Several useful suggestions were made by residents who had good local knowledge and concerns were raised about various issues, mostly the public perception that the flood risk was just going to be moved downstream. A website was set up to allow members of the public to ask questions, score the importance to them of various key aspects such as ecological

and environmental improvements, look at the cost of each option and also voice any other concerns they may have.

As well as consultation with local residents it was also necessary to consult with the local Iwi, Ngai Tahu. Christchurch City Council have a Six Values approach to Land Drainage, this covers the essential areas to be taken into consideration as part of the design process: Christchurch City Council Infrastructure Design Standard Part 5 (2013). The six values are, Ecology, Drainage, Culture, Heritage, Landscape and Recreation. These values are embraced by the local Iwi and therefore getting their input to the solution was essential.

Because some of the options required access through the newly created Residential Red Zone, RRZ, discussions with the Canterbury Earthquake Recovery Agency, CERA, also took place. Access through the RRZ proved to be problematic as a decision on the use of the RRZ was a long way off and CERA would have to get Cabinet approval from the Government to use the land for an infrastructure project with a long asset life. This would have taken several months if not longer to achieve and so this option was considered to be high risk.

Discussions with other key third parties was also essential. Local schools affected by the by-pass crossing their land and Housing New Zealand who owned properties along the route of the by-pass were also consulted.

Whilst the third parties understood the need for the project there were also a lot of implications that had to be assessed. Potential future use of the land, if the by-pass was laid across their property, or, the value of land earmarked for future development, had to be taken into consideration making these options a higher risk.

Discussions with Ngai Tahu were held. Their spiritual and cultural bonds with water and the environment meant that their interest in the creek was associated with the improvements to the ecology of the creek that the works would bring about and meeting the Council's Six Values as well as the impact the flooding has had on the community. There was a balance that had to be met between meeting the project objective to reduce the flood risk and improving the water quality and the ecology of the creek. A site visit with the local Iwi was arranged to enable the work to be discussed in more detail. The environmental and ecological improvements and a lot of the benefits were discussed. The Resource Consent application included the input received from Ngai Tahu as part of the submission.

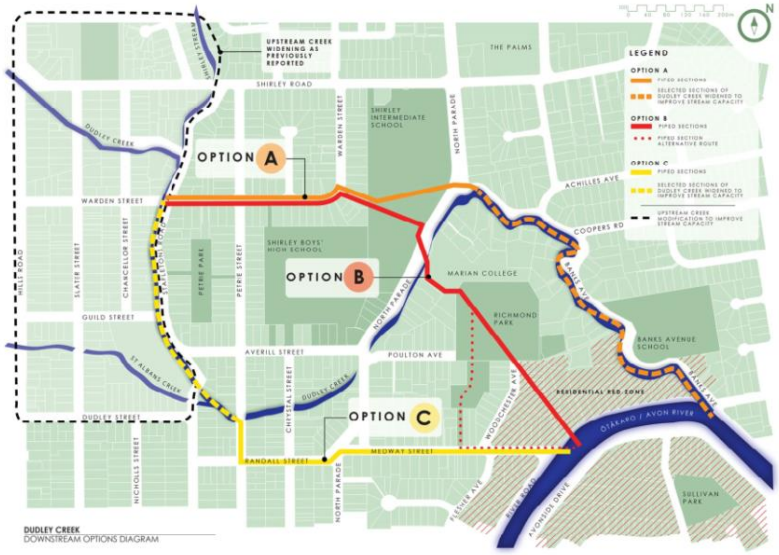
2.2 CONSULTATION PLANS

2.2.1 THE THREE OPTIONS:

The three options identified in the initial design phase and presented for consultation are summarized below:

- **Option A:** Improvements to Creek upstream and by-pass pipe discharging to top of Banks Avenue with improvements to downstream capacity before discharging to the Avon River
- **Option B:** Improvements to Creek upstream and a longer by-pass pipe crossing the Residential Red Zone land and discharging direct to the Avon River
- **Option C:** Improvements to Creek upstream with by-pass pipe along Medway Street and discharging direct to the Avon River

Figure 3: The Three Options: Beca/Opus (2015)



2.3 PROJECT OVERVIEW

2.3.1 CHOOSING THE PREFERRED OPTION

A Multi Criteria Analysis, MCA, was carried out to determine the preferred option following the conclusion of the consultation process. Scores for each option were determined by the key members of the project team against factors such as Capital Cost, Whole Life Cost, Risk, Deliverability, Programme, Ecological and Environmental benefits, taking the Six Values into consideration.

Option C was the option with the highest score following the MCA process. When the results of the public consultation were factored in it was clear that this option be recommended to Councilors for approval, comprising widening of the creek for a length of 600m, replacement of private bridges and culverts and an overflow to a 750 long by-pass pipe to the Avon River.

One of the major factors to be taken into consideration during the MCA process was resilience. Whilst possible damage by an earthquake could not be ruled out with the ever present risk of future earthquakes it was necessary to produce a solution where the by-pass could be quickly repaired and brought into use if needed. Damage to the creek such as lateral spread was also a key consideration.

Resilience against climate change, resulting in higher rainfall events, and sea level rise was also an important consideration. The catchment was already 500mm lower post-earthquake in some areas: Mayoral Flood Task Force (2014).

A separate MCA was used to assess if a gravity by-pass and outfall was the best solution as opposed to a pumped by-pass. Based on the capital and operational costs and the factors such as the location of the pump station it was determined that a gravity by-pass was the better solution. Future capacity increases could be provided by improving the creek downstream of the by-pass overflow and if necessary a lift station on the by-pass could be provided at the outfall to the river or a pump station at the inlet.

Based on all of these factors a report was submitted to Council for approval to proceed with Option C for the downstream solution in August 2015.

Hydraulic modelling of flows identified increasing capacity of Dudley Creek upstream of the by-pass to 9.5m^3/sec and a resultant reduction in head of approximately 800mm to return the catchment to at least pre-earthquake levels of flood risk: Beca/Opus Downstream Options Report (2015).

The flood risk was measured by the number of 'at risk' properties pre and post-earthquake. The hydraulic model was verified by checking against recorded levels during the recent floods. See figures 4 and 5 below.

Figure 4: Pre Earthquake Flood Risk: Jacobs (2014)

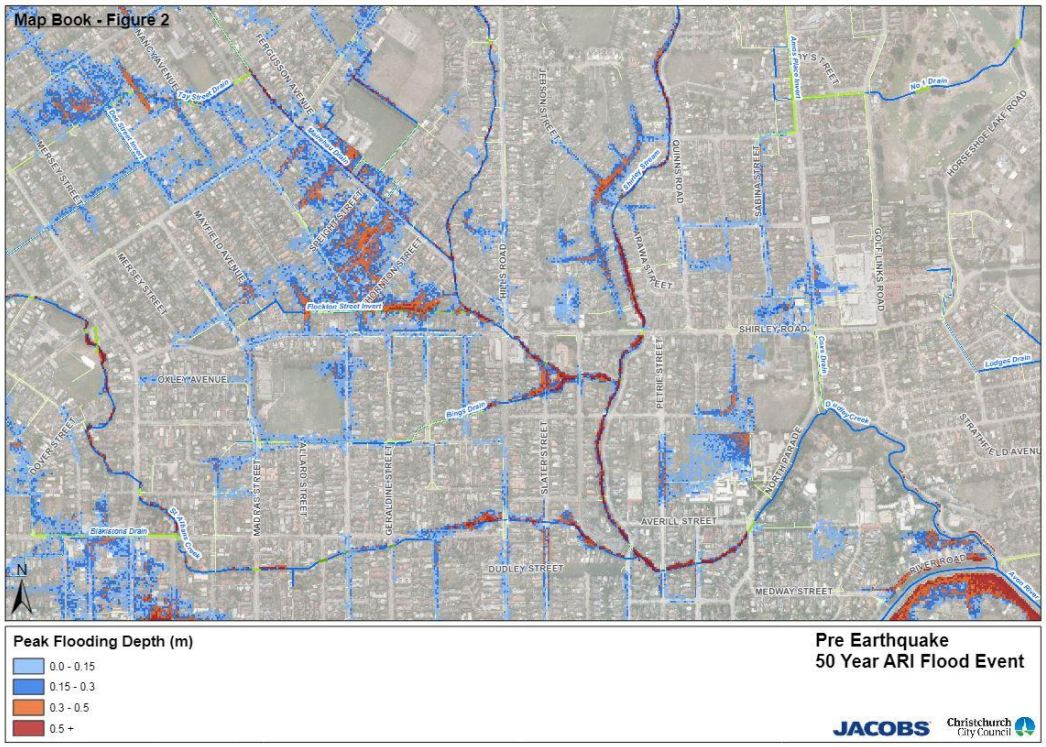
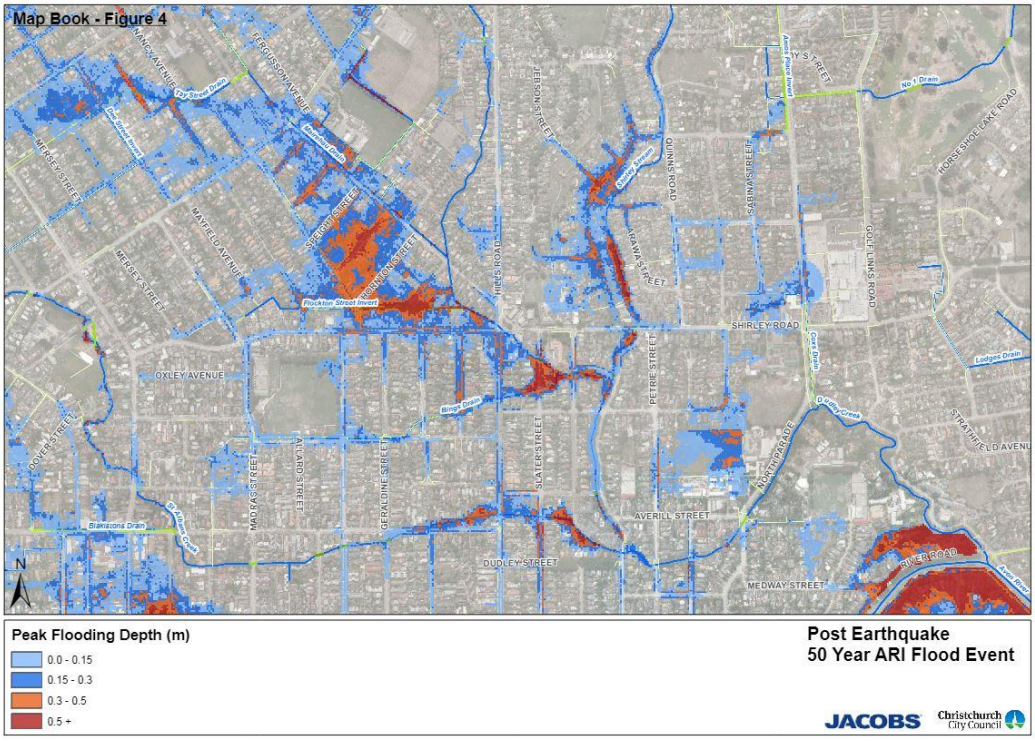


Figure 5: Post Earthquake Flood Risk: Jacobs (2014)



2.3.2 PROGRAMME

Meeting the programme was going to be difficult from the start. A Designer was appointed in March 2015 after competitive bids were submitted by local consultants. Initially it was intended to go with a design and construct contract, however, after some discussion about the best way to deliver the contract it was

decided to go with an ECI contract, Early Contractor Involvement. At this stage a downstream solution had not been recommended to Council and also a Contractor had not been appointed. The clock was ticking and the promise given to Council to have a solution in place by winter 2017 was looking very high risk.

The first two activities after appointment of the Designer were to put a tender document together to appoint a Contractor and at the same time develop three options to go to out to consultation. By the middle of July 2015 the consultation process was complete and the preferred option was known. This meant that by the time a Contractor was appointed in August 2015 the design for the upstream works had started and the downstream option had been selected. This meant there was just under two years to finalise the design, carry out all the client reviews, price individual work packages and construct the works.

Construction started on the first work package in early October 2015. This was part of the upstream improvements agreed in November 2014. The first work package was a 250m stretch of creek wholly in the Council's ownership and therefore the Contractor could make a start on site quickly without having to negotiate access with private property owners.

All the creek widening work and construction of the by-pass had to be complete by July 2017. To meet this target it was essential to have an overall Project Programme for the design and construction of the works to ensure delivery of the project on time and within the budget. The ECI Contract allowed for a flexible approach to the construction contracts to be adopted. Construction on site could proceed at the same time as the Designer was designing future work packages. Each work package was to have its own contract duration with a separate construction programme. The value of each work package was priced separately by the Contractor. The pricing mechanism being described later in the paper.

2.3.3 BUDGET AND RISK

Early on in the project a budget of $48M was established for all the upstream and downstream works: Report to Council, Dudley Creek Flood Remediation, (November 2014). This was re-evaluated once the downstream works and by-pass route were known. Identifying the project priorities was essential at this early stage of the project to ensure the estimated cost captured all the various elements that had to be delivered, reduced flood risk, an improved creek environment and ecology, meeting the Council's Six Values and construction of the by-pass.

A big part of ensuring delivery to budget and time was identifying what the main risks were. A risk workshop was held as part of the project cost estimating process. Not only construction risks but programme risks were identified. These included delays due to service diversions, negotiations with property owners and key stakeholders, technical design reviews and procurement of long lead items.

On completion of this stage the project team had the confidence that was required to deliver the project to time and budget. This was absolutely essential if the Council's commitment to the residents to reduce the flood risk to pre-earthquake levels of risk by winter 2017 was going to be met.

2.3.4 CONTRACT APPROACH

After it was decided to have the project delivered using an ECI Contract a Request for Pricing, RFP, document, was issued by Council for contractors to express an interest in bidding for the work and a select list was drawn up, based on capability. Each contractor submitted a proposal with a schedule of prices for the typical works and after evaluation a contractor was appointed under a NZS3910:2013, ECI Contract, to deliver the construction packages. This process took about three months during which time the design for the upstream catchment was proceeding.

The construction contract for the first upstream work package was incorporated into the ECI Contract and was awarded as a separate contract following submission of a tender document which included a price, construction programme and construction methodology.

2.3.5 BENEFITS OF ECI

One of the benefits of the ECI Contract is the ability to tap into the contractor's knowledge and resources enabling a degree of flexibility essential to reduce the risk of delays to delivery of the project.

Key risks identified which could potentially delay delivery were service diversions, property negotiations, procurement of key construction elements, communications with local residents during the construction of the works and traffic management. One of the requirements put into the ECI Contract was for the Contractor to provide an experienced Communications Team to help build good relations with the public.

The location of services along the creek and the by-pass route was carried out by the Contractor as part of the ECI Contract. Adopting this approach meant the Contractor could start to quickly build up the information required by the Designer to identify which services needed to be diverted early. An NZS3910 Advance Works contract was drawn up and awarded to the Contractor to enable services such as the wastewater, water and stormwater pipes to be diverted in advance of the by-pass construction. This contract also included setting up of a large site compound in the RRZ, essential for storage of the materials for the by-pass.

Property negotiations were also identified as a big risk to delivery of the project. A member of the Council's Property Management team was appointed and a list of potential properties where work was required was drawn up very early in the project. The Property Manager, Designer and Contractor's Communications Lead worked closely together to identify potential problem areas. A spreadsheet was produced to keep track of what stage each of the property negotiations was at. This was updated regularly by the project team recording agreements with individual property owners.

Once draft plans were drawn up for each work package a meeting was arranged with the owner of a property and the Designer, Property Manager and Communications Lead met with the owner to discuss the works, take note of any specific requirements the owner may have and adapt the plans to suit. Many of the owners had earthquake repairs and house rebuilds planned whilst the creek works were ongoing. The Contractor had to take these into consideration as part of the construction programme for each work package. There was a degree of flexibility required to accommodate the needs of the property owners in some cases.

An example of this was the replacement of a private bridge identified as being a restriction in the flow of water in the creek. The owner of the property was expecting his house rebuild to start in September 2016 and he would be out of the country for two months during June and July 2016. A design was quickly produced for the replacement bridge deck and abutments and a variation to an existing contract, which had already started on site, was issued by the Engineer's Representative to enable procurement of the pre-cast bridge deck and construction of the bridge. A price was agreed and work was able to commence in a few weeks. The flexibility of the ECI contract enabled the construction of the bridge to be fast-tracked and ensure the property owner was not delayed in his house rebuild by the creek improvement works.

To reduce the risk of delays due to the procurement of construction materials with long lead in times, such as the pre-cast concrete by-pass units, pre-cast bridge

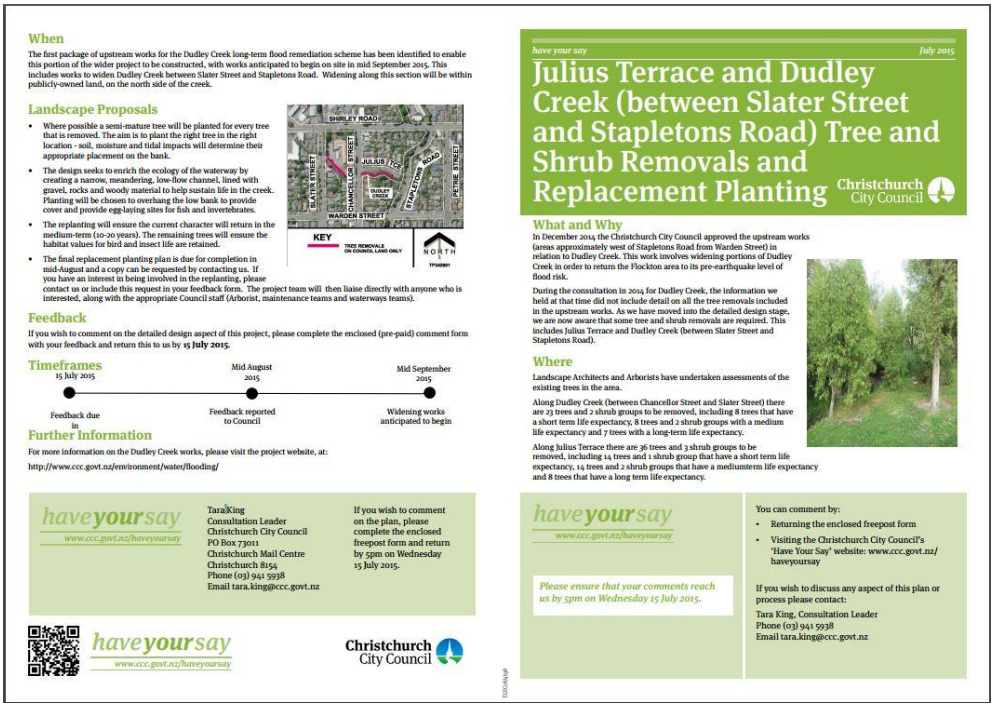
decks and culvert units and steel sheet piles, a variation under one of the individual work package contracts already in place was issued instructing the Contractor to place orders early, reducing the risk of delay and enabling a quicker start on site.

Regular project meetings with the Designer and the Contractor were invaluable in keeping the design on track, getting problems sorted and raising important design or construction issues. A traditional contract, with the design having to be completed prior to going out to tender, would likely have extended delivery of the project programme.

As well as communication with the project team another essential area of communication was between the project team and the residents affected by the works. See figures 6 and 7 below with an example of a typical notice sent to residents. Early contact with residents was of great benefit to the Contractor in determining what would be required during the construction of the works. In many areas tree removal was a big concern. In order to avoid this causing a delay to the start of construction meetings were held with local people and the need to remove the trees was explained. Generally once residents could see the benefits of removing the trees and the plans for re-planting new trees were explained there was little opposition. With seven separate work packages involving widening of the creek over a total length of 1,200m, construction of nearly 750m of by-pass and the removal of over 100 trees, it was important that the public were on our side. It could easily have gone the other way if the communication had not been effective and the start on site delayed as a result. The Contractor's Communications team along with the Designer and Council officers worked together to get the message across to residents. As many of the residents had been affected by the floods they were generally accepting of the works as planned. All trees removed as part of the works were replaced with either native trees close to the creek edges or exotic trees further back from the creek.

The greatest challenge to the Contractor's Communications team was the construction of the by-pass. Nearly 750m in length with an internal cross-section 4m wide by 2m deep, all in a road through a residential area. Access to properties had to be maintained where road closures were required. Notices were posted to local residents directly affected by the works and the Contractor's team played a big part in developing good relationships with residents to ensure that the disruption was minimised.

Figures 6 and 7: Typical Communications Leaflets: Christchurch City Council Communications Team (2015)



When

The first package of upstream works for the Dudley Creek long-term flood remediation scheme has been identified to enable this portion of the wider project to be constructed, with works anticipated to begin on site in mid September 2015. This includes works to widen Dudley Creek between Slater Street and Stapletons Road. Widening along this section will be within publicly-owned land, on the north side of the creek.

Landscape Proposals

- Where possible a semi-mature tree will be planted for every tree that is removed. The aim is to plant the right tree in the right location - soil, moisture and tidal impacts will determine their appropriate placement on the bank.
- The design seeks to enrich the ecology of the waterway by creating a narrow, meandering, low-flow channel, lined with gravel, rocks and woody material to help sustain life in the creek. Planting will be chosen to overhang the low bank to provide cover and provide egg-laying sites for fish and invertebrates.
- The replanting will ensure the current character will return in the medium-term (10-20 years). The remaining trees will ensure the habitat values for bird and insect life are retained.
- The final replacement planting plan is due for completion in mid-August and a copy can be requested by contacting us. If you have an interest in being involved in the replanting, please contact us or include this request in your feedback form. The project team will then liaise directly with anyone who is interested, along with the appropriate Council staff (Arborist, maintenance teams and waterways teams).

SHIRLEY ROAD, CHANCELLOR STREET, JULIUS TCE, STAPLETON ROAD, PETRE STREET, DUDLEY CRESC, WARDEN STREET, KEY, TREE REMOVALS ON COUNCIL LAND ONLY, NORTH

Feedback

If you wish to comment on the detailed design aspect of this project, please complete the enclosed (pre-paid) comment form with your feedback and return this to us by **15 July 2015**.

Timeframes

15 July 2015 — Feedback due in
Mid August 2015 — Feedback reported to Council
Mid September 2015 — Widening works anticipated to begin

Further Information

For more information on the Dudley Creek works, please visit the project website, at:
http://www.ccc.govt.nz/environment/water/flooding/

haveyoursay
www.ccc.govt.nz/haveyoursay

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Phone (03) 941 5938
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If you wish to comment on the plan, please complete the enclosed freepost form and return by 5pm on Wednesday 15 July 2015.

haveyoursay
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Christchurch City Council

have your say — July 2015

Julius Terrace and Dudley Creek (between Slater Street and Stapletons Road) Tree and Shrub Removals and Replacement Planting

Christchurch City Council

What and Why

In December 2014 the Christchurch City Council approved the upstream works (areas approximately west of Stapletons Road from Warden Street) in relation to Dudley Creek. This work involves widening portions of Dudley Creek in order to return the Flockton area to its pre-earthquake level of flood risk.

During the consultation in 2014 for Dudley Creek, the information we held at that time did not include detail on all the tree removals included in the upstream works. As we have moved into the detailed design stage, we are now aware that some tree and shrub removals are required. This includes Julius Terrace and Dudley Creek (between Slater Street and Stapletons Road).

Where

Landscape Architects and Arborists have undertaken assessments of the existing trees in the area.

Along Dudley Creek (between Chancellor Street and Slater Street) there are 23 trees and 2 shrub groups to be removed, including 8 trees that have a short term life expectancy, 8 trees and 2 shrub groups with a medium life expectancy and 7 trees with a long-term life expectancy.

Along Julius Terrace there are 36 trees and 3 shrub groups to be removed, including 14 trees and 1 shrub group that have a short term life expectancy, 14 trees and 2 shrub groups that have a mediumterm life expectancy and 8 trees that have a long term life expectancy.

haveyoursay
www.ccc.govt.nz/haveyoursay

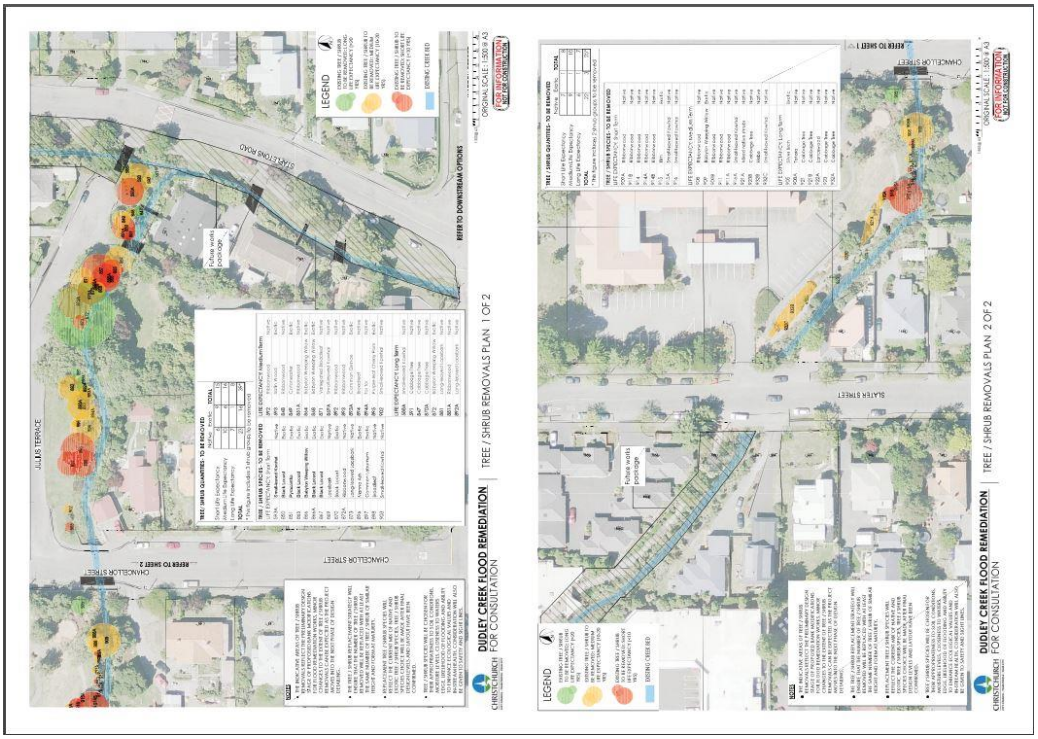
Please ensure that your comments reach us by 5pm on Wednesday 15 July 2015.

You can comment by:

- Returning the enclosed freepost form
- Visiting the Christchurch City Council's 'Have Your Say' website: www.ccc.govt.nz/haveyoursay

If you wish to discuss any aspect of this plan or process please contact:

Tara King, Consultation Leader
Phone (03) 941 5938
Email tara.king@ccc.govt.nz



The ECI Contractor also played a big part in developing safe methods of working as part of the construction methodology and this influenced the approach of the design team when developing solutions. Designing for safety and construction safety was a major aspect of the design process and Safety in Design reviews were held with the Designer and Contractor. HAZOP and Risk identification meetings with the Council's Operation Manager and Maintenance teams were also held.

2.3.6 DIFFICULTIES IN ACHIEVING DELIVERY TO PROJECT PROGRAMME

Keeping the project programme and construction programme up to date was very important to keep track of any potential risks to delivery. A programme review meeting was held every two weeks with the Designer, Contractor and Engineer's

Representative. An Early Warning notification system was introduced to identify potential delays or cost increases. The early warnings can be generated by either the Designer, Contractor or Engineer's Representative and these were reviewed at the programme meetings and the risk to delivery evaluated.

One of the greatest risks to the project programme, and delivery of the project, was getting the agreement to work on private property.

Firstly, early agreement had to be reached with the property owners where it was essential to carry out creek widening works. This meant setting up meetings with property owners and discussing the need to carry out the works, provide an outline of the works, discuss their concerns and take into consideration any factors which either prevented works going ahead or which might influence the design. For example trees may have been planted as a memorial to a loved one or just be a good tree specimen that it would be difficult to justify cutting down.

The hardest discussions were where the owners were resistant to any work being carried out on their property. This could be for various reasons, not wanting trees or shrubs to be removed from the creek edge, outstanding issues with insurance companies or EQC or just an objection to the work altogether. A large degree of empathy by the project team was required when dealing with owners going through extensive repairs and rebuilds. A lot of the resident's homes had not only endured significant earthquake damage but also flooding as well. Dealing with people who were essentially exhausted by what had happened in their lives over the past few years was critical. It is important to note at this point that several of the project team had also gone through an exhausting time dealing with their own repair and rebuild issues at the same time as dealing with residents affected by the same issues. It is to the Project team's credit that they managed this process with a great deal of patience and resolution to successfully deliver the project, knowing that there was a lot of benefit to the residents with the work they were doing. Even though it may not have seemed so obvious at the time.

Generally the design could be amended to fit in with owners wishes but occasionally the Council had to resort to issuing a notice under powers vested in Council by the Land Drainage Act, 1908, to go on to property to carry out essential works. This really was used as a last resort when all negotiations and options had been exhausted. Out of approximately 100 private properties where work was required there have been only two occasions where the Council have resorted to issuing a Section 28 Notice, under the Land Drainage Act. This is a reflection of the effort put in by the project team into getting the right solution by agreement with owners but also a desire by a lot of residents to reduce the flood risk in the area. The Contractor's Communication team arranged the meetings with owners and the Contractor was able to explain the impact the construction would have on a particular property well in advance of a contract being awarded. The Communications team were invaluable in getting residents on board at the earliest opportunity and obtaining agreements to carrying out the works.

Some discussions were protracted and took a great deal of time and effort to get agreement with owners. This was understandable in some cases where owners were rebuilding their properties or still waiting to reach agreement with their insurance companies to make a decision on repairs or rebuild.

Easements for future maintenance were required in some areas and there were also several properties along the creek that the Council purchased where there was an opportunity to carry out widening works. Altogether Council purchased five properties in strategic locations where the maximum benefit could be gained from the widening works. One of these areas was the location of the screened inlet structure for the by-pass pipe. See photographs 2 and 3 below.

Photograph 2 & 3: By-pass inlet site prior to start on site and following creek widening

2.3.7 DESIGN ACCEPTANCE

The time taken to get acceptance of the design by the Council could not be underestimated. Obtaining acceptance for the design by the Council's Lead Technical Engineers was always going to be a critical activity on the Project Programme. Any delays to acceptance of the design by the Council would have a direct effect on the construction programme. It was essential to get the right members of the Council's team to gain acceptance of the design at the right time.

Structural, geotechnical and hydraulic peer reviews were undertaken for the main elements of the creek widening and by-pass and the technical aspects were reviewed by the Council's Lead Technical Engineers.

To reduce the time taken to gain obtain acceptance of the design for the individual work packages it was agreed with the Designer and Contractor that the design reviews would take place at the same time as the construction works was being priced. This introduced an element of risk into the pricing process but with the co-operation of the Contractor it was agreed that some aspects of the works which were possibly a little uncertain still would be covered by Provisional Sums and a price agreed after the contract was awarded.

The biggest element of the design was the by-pass pipe. This had to be designed to provide the maximum overflow capacity of 9.3m^3/sec. A high degree of resilience to ensure it could be quickly brought back into use following an earthquake and provide the flexibility to possibly take pumped flows to increase the future capacity or to combat future sea level rise. The outfall to the Avon River is tidal and the surrounding land has already been subject to ground levels dropping as a result of the recent earthquakes.

During the development of the design for the by-pass pipe review meetings were held with the Council's Operations and Maintenance Managers and it was initially determined that twin concrete pipes would make up the by-pass. Future operation and maintenance were factors in going with concrete pipes as well as providing the resilience needed as the joints could take a certain degree of movement in an earthquake, the pipes could be easily repaired or replaced if damaged and also they could be pressurised to provide additional capacity and head against future sea level rise if it was needed.

When the design had been developed sufficiently to carry out a review with the Council's Lead Technical Engineers they were not sure it was the best solution and would not accept the design. Earlier designs had come up with a solution utilising pre-cast box-section culverts but this was not developed further because it was considered not as resilient as the concrete pipe solution.

So when the Lead Technical Engineer asked the Designer to review the design the box-section culvert design was revisited and a new design was produced.

A structural design for a bespoke box-section, pre-cast, unit was developed with resilience against earthquake damage being provided by tying four units together with post tensioning cables tensioned up sufficiently to be able to bridge any

ground settlement. Flexible joints were supported on a pre-cast laying block to reduce the risk of vertical displacement. See figure 8 below.

The joints between the units are grouted, as are the post tensioning tendons, and then wrapped to prevent ingress of fines and backfill in the event of any movement due to ground settlement.

Figure 8: Typical Section through box-section culvert: Beca/Opus (2016)

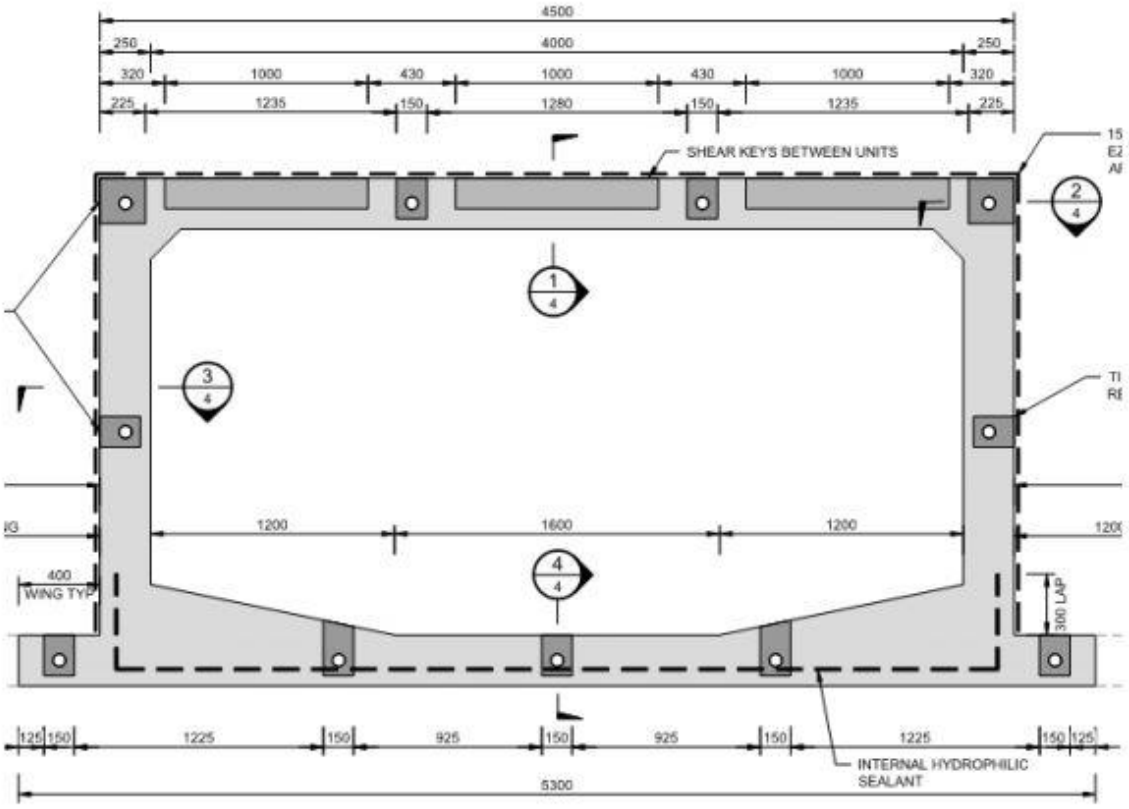


Figure 4- Bypass Pipeline Typical Cross-section

The design was developed in conjunction with the Contractor and a specialist pre-cast sub-contractor and the design was accepted by the Council in April 2016. The construction was originally programmed to commence in April therefore to avoid any further delay to the programme it was agreed that the contract for the by-pass be awarded with a fixed price for the supply of the pre-cast units, which could then be made in advance of a start on site, whilst the Contractor was pricing up the construction of the works. A Provisional Sum was agreed for the installation of the by-pass, outfall and inlet structures to enable the contract to be awarded. The Contractor obtained 3 competitive sub-contract prices for the installation and there was also a parallel pricing exercise to check the prices were competitive.

Work commenced on site with the installation in July 2016, with a 12 month construction period to meet the Council's undertaking that the flood risk would be reduced by winter 2017.

As well as the by-pass and creek widening works in the area there was still a great deal of horizontal infrastructure rebuild work ongoing. This posed a few problems with traffic management, several road closures were already in place when the by-pass contract started on site, but with good liaison between the various contractors, the Christchurch Transport Operations Centre, CTOC, and a degree of flexibility the Contractor's programme has not been significantly affected.

2.3.8 PRICE RECONCILIATION MECHANISM

Each Work Package had its own contract and price schedule. The Contractor priced up the work based on the drawings and a pricing schedule along with a parallel price from a Quantity Surveyor. This parallel pricing exercise has been used to verify the Contractor's price as well as check that the Council is getting the work priced at market rates.

Whilst this is not a guarantee that the prices obtained are the lowest that could be set if all the work packages were competitively priced the Contractor was expected to obtain sub-contract prices competitively by obtaining at least three alternative prices from sub-contractors.

This price reconciliation process has worked very well and generally the time taken to obtain a price for each work package has taken less than three weeks in total. This not only speeds up the time taken for the contracts to be awarded but it reduces the time taken carrying out tender evaluations and pricing evaluations.

The price reconciliation process involves both the Contractor and the consultant pricing the same work package and then sending a copy of the prices to each other for review. A Price Reconciliation meeting is held and the rates and lump sums compared and common ground reached on the final contract value for the individual work packages.

Risks were generally priced by the Contractor separately and these were agreed by the Pricing Consultant, Engineer and Project Manager.

P&G costs for individual work packages were also agreed during the price reconciliation.

To save time and avoid lengthy discussions around the value of the P&G costs it was agreed with the Contractor that a lump sum for the main by-pass contract be agreed and this was spread out over the length of the contract and paid as a monthly lump sum. There are several benefits in adopting this approach:

- The value of the P&G costs was known right from the very start of the work package.
- The monthly claim could be agreed a lot quicker. Speeding up the payment process.
- Any additional P&G costs for other work packages could be quickly and easily agreed.

2.3.9 SUCCESSFUL PROJECT DELIVERY

2.3.10 PROJECT OBJECTIVES

The ultimate measure of how successful the project has been will be whether the Council's objectives have been met. The Six Values approach to land drainage are a good guide to measure success against and the project has gone a long way to meeting all of these values.

- Ecology: A great deal of work has been put into improving the ecology of the creek. Silt and liquefied material has been removed from the creek bed and replaced with gravels and boulders to provide habitats for fish and invertebrates, see photograph 4. Eel hotels have been created, see photograph 5 below. These are 150 mm diameter pipes set into the bank, to provide a habitat for eels to rest and mate. Rock edges have been put in place to protect the banks and provide shade for smaller fish and invertebrates.

Photograph 4:70 Year old eel caught in creek by electric fishing: EOS (2016)

Photograph 5: Eel Hotels in Creek Edge: Downer (2015)

- Drainage: The main driver is obviously to reduce the flood risk in the Dudley Creek catchment. The project has successfully delivered on this objective by increasing the capacity of the creek and lowering the hydraulic grade line by 800 mm to take away the flood risk to a large number of properties. This is already evident during high rainfall events. See photograph 6.

Photograph 6: Creek during recent high rainfall

- Culture and Heritage: The project team have worked closely with local schools and community groups to maintain a cultural link with the creek. This included members of the local Iwi. Where large flax have been removed the plants were given to a local community group to use for weaving baskets and mats. See figure 9. Schools have been involved in tree planting and helped move fish from areas where work has taken place.
- There has also been work in the classroom to encourage children to respect the creek and the environment and help raise an awareness of how important the creek is not only to the well-being of the creatures that depend on the creek to survive but also for their own well-being.
- Landscape: A great deal of time and effort has been put into improving the landscape of the creek whilst improving the capacity. See photograph 7. Hard landscaping has been avoided where possible and where unavoidable low timber walls have been used to reduce the visual impact.

Figure 9: Poster created by Contractor showing community involvement: Downer (2016)

Photograph 7: New retained bank with fresh plain

- Exotic trees have been removed from the creek margins to reduce leaf fall and shade and replaced with native trees to provide a habitat for birds to thrive. See photograph 8. Over 120 trees have been removed and replaced with a mix of exotic and native trees, more than 300 trees have been replanted. See photograph 9. Wood from the trees that were cut down was made available for local residents, for wood carving and as firewood. Realignment of the creek, see photograph 10, was necessary in places to improve the flow characteristics but the creation of a fresh plain with rock edging and planting along the margins has reduced the visual impact of these stretches.

Photograph 8: Several old exotic trees were removed from the creek edge

Photograph 9: Native trees were planted along the creek edge

Photograph 10: Realignment of the creek to improve flow

- Recreation: A new footpath has been laid along the full length of the creek where it has been improved and access provided to allow residents to see the creek close up and observe the fish and eels. Interpretation sign boards have been produced which will be erected at strategic locations along the length of the creek and at the outfall to the Avon River. These will inform people of the work that has taken place to reduce the flood risk and the ecological and environmental benefits of the works. An area previously used by local residents as an informal reserve has been enhanced to allow the space to be utilised by the local community. Fruit trees are to be planted in this area as part of the Council's Living Gardens initiative to grow fruit and vegetables in communal areas.

3 CONCLUSIONS

It's important to understand that successful delivery of a project of this size and complexity requires all of the members of the Project Team working closely together. This requires working collaboratively on problem solving, meeting tight delivery timeframes, and innovative thinking and a great deal of trust between the Designer, Contractor and Engineer's Representative and good management of the relationship between the various members of the Project Team.

A great deal of flexibility is required to overcome problems on site that have arisen. To the credit of the Contractor very few of the problems on site have resulted in significant variations or price increases. Potential delays have been

resolved by working closely with the Contractor to ensure that the effect of the delays and impact on the overall project delivery are minimised.

There has also been a strong desire by the members of the team to deliver the project on time and to budget and make the project a success. This has been demonstrated by the site team who have been dealing with the local residents affected by the works on a daily basis. Difficulties gaining access have been resolved amicably, whether it is for earthquake repairs and rebuilds or just problems that individual residents may have.

Very few complaints have been received which is always a good measure and there have been lots of complimentary emails from residents praising the site team.

Altogether the success of this project has been reliant upon each of the members of the team working closely together to ensure successful delivery and I would like to thank everyone from the design team, the planning team who dealt with the resource consents, the hydraulic modellers, the communications team, the construction team and the technical leads who carried out the design reviews in what were sometimes very short time frames and provided valuable advice to both the Designer and the Contractor.

Whether the project has been a success will not be known until the time comes when the by-pass is operating in anger. When that will be cannot be predicted but successful delivery of the project has already been achieved on time and within budget. The by-pass will be complete by winter 2017 and the benefits of the creek improvements are already obvious with local residents complimenting the project team on what a great job they are doing.

Just to be able to be part of a project where the flood risk to over 600 family homes has been reduced to a level where they can sleep soundly in their beds at night without having to worry about the risk of their property being flooded is a tremendous achievement and all of the Project Team can be proud of this.

ACKNOWLEDGEMENTS

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Thanks to all the members of the design team from Beca, Opus, EOS, the Contractor, Downer, and the sub-contractors, for their passion and determination to achieve successful delivery of the design and support during construction and their willingness to try alternative approaches.

In particular thanks to the site teams for their role in keeping the public sweet and ironing out the problems that could so easily have escalated into major issues on site.