WHERE TO START? CHRISTCHURCH'S POST-QUAKE LAND DRAINAGE RECOVERY PROGRAMME

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ABSTRACT (300 WORDS MAXIMUM)

Where to start? Following a magnitude 7.1 earthquake how do you develop a programme of works to reinstate the pre-quake land drainage network of the city of Christchurch?

The Canterbury earthquakes increased flood risk in some parts of the city by changing the topography and damaging land drainage infrastructure. The scale of the increased flood risk is immense. Thousands of properties have been identified as potentially having increased flooding vulnerability due to the earthquakes, with many of those at increased risk of floor level flooding. In addition to the physical damage, the health and social impacts on communities have been severe. Reducing the post-earthquake flood risk is a necessary part of restoring restore community resiliency and wellbeing following the earthquakes.

The Land Drainage Recovery Programme (LDRP) was established, by Christchurch City Council in 2012, to understand the consequences of the earthquakes on the land drainage network within the city limits. In order to develop and prioritise the programme key questions needed to be answered: Where was the damage located? What areas were most at risk of increased flooding? What is the quickest way to analyse options? How is it possible to estimate the cost of unknown works? How to prioritise unknown works with unknown effects? As well as the technical considerations, the LDRP needs to manage expectations of families directly affected, wider residents' expectations, political drivers, fiscal restraints and the urgency of a remedy for the city in an uncertain long term planning environment.

This paper explores the LDRP from the programme management perspective of identifying information needs, developing stormwater quake damage projects, the process of prioritising and re-prioritising, creating a programme team who are set up for success, and delivering a programme worth hundreds of millions of dollars within a politically driven environment.

KEYWORDS

Programme management, disaster, recovery, resilience, flood, prioritisation, risk, community

PRESENTER PROFILE

Tom has been helping Christchurch City Council for the last 2-3 years on the Land Drainage Recovery Programme as Technical Manager. His focus has been on developing the programme from inception through to delivery. Tom relies on his experience in stormwater concept design and modelling from a range of different environments, here and overseas.

1 INTRODUCTION

The Canterbury earthquakes increased flood risk in some parts of the city by changing the topography and damaging land drainage infrastructure. The Land Drainage Recovery Programme (LDRP) was established by Christchurch City Council (Council) in 2012 to understand the consequences of the earthquakes on the land drainage network within the city limits. In addition to the immense physical damage, the health and social impacts on communities have been severe. Therefore, the LDRP will also help to restore community resiliency and wellbeing.

2 DRAINAGE IN CHRISTCHURCH

Christchurch has an extensive land drainage system consisting of rivers and tributaries, utility waterways (lined and unlined drains), and stormwater pipe networks (Table 1).

Table 1: Summary of Land Drainage Network

Feature	**Approximate Length**
Rivers	79 km
Tributaries	160 km
Utilities waterways (lined and unlined drains)	130 km
Stormwater pipe network	790 km

2.1 EXISTING FLOOD RISK

As a relatively flat and low-lying city, Christchurch has always been vulnerable to floods. Early on in the city's history the importance of the land drainage network was recognized, and a Drainage Board was established. The title of the history of the Drainage Board, *Swamp to City* (Wilson, 1989), points to the challenge involved in building a city on swampy low-lying land.

Most areas which have experienced flooding post-earthquakes were already vulnerable to flooding prior to the earthquakes. Photograph 1 below shows flooding in the Shirley area in 1945 which is also one of the worst affected areas post-earthquake. However, as described in the following section, flooding has been made worse by the earthquakes and heightened the problem.

Photograph 1: Flooding in Shirley (1945)

2.2 IMPACT OF THE EARTHQUAKES

The Canterbury earthquake sequence caused damage to the land drainage network and altered flood risk in Christchurch in the following ways:

- *Direct damage to waterways:* bed heave, bank slumping, subsidence, silting of bed and vegetation decline. (Photograph 2)

- *Direct damage to structures:* damaged bridges, retaining structure, concrete lined channel cracking, tilting of outfall structures, and wall failure of timber lined drains. Some of this damage is being addressed by the Stronger Christchurch Infrastructure Rebuild Team (SCIRT) work programme, but not all. (Photograph 3)

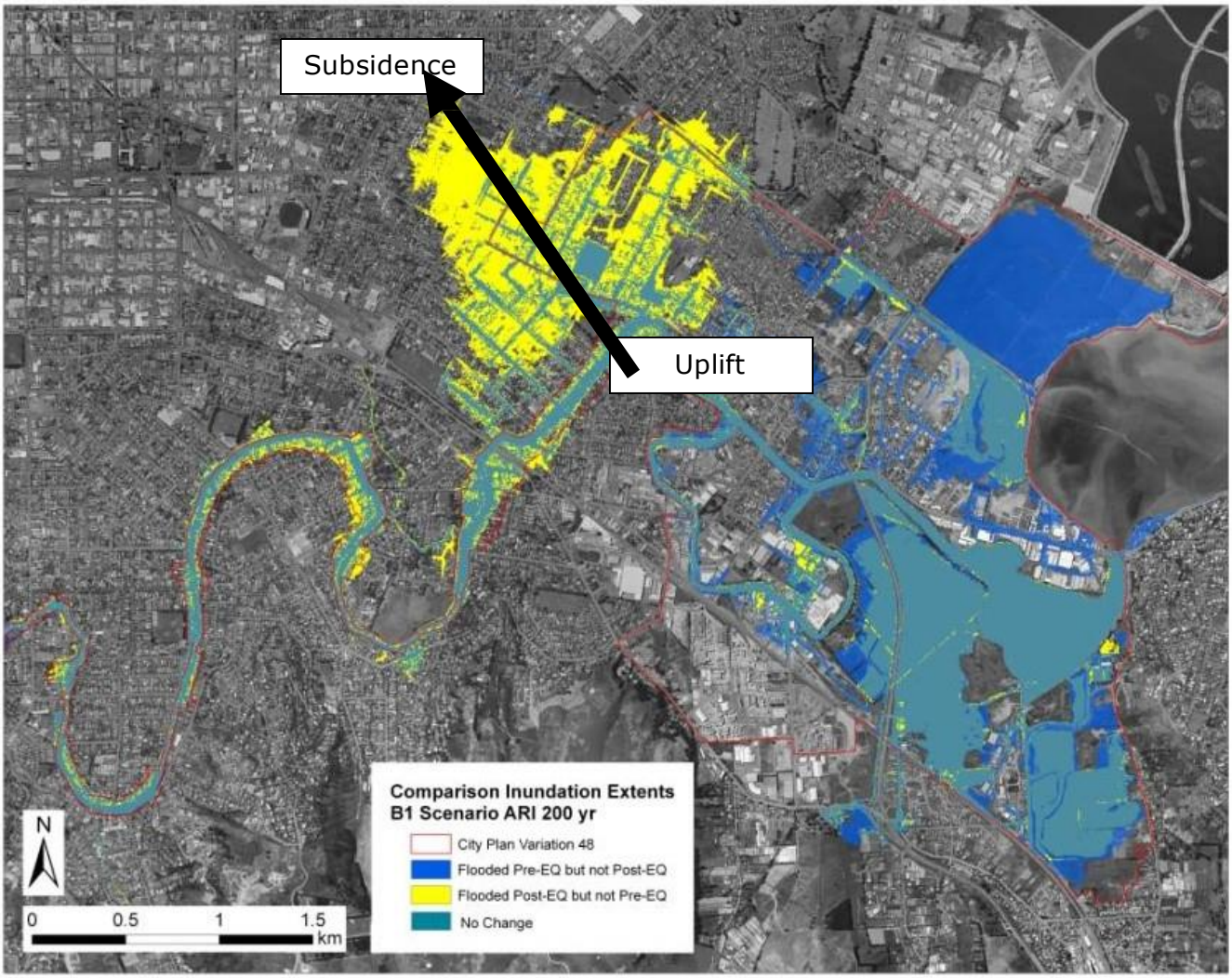
- *Change in flood risk:* land damage, tectonic shift and changing stream bed slopes have increased flood risk to properties and houses. Physical works to address change in flood risk include network capacity upgrades, which are typically far more expensive than direct damage repairs. (Figure 1)

Photograph 2: Example of Direct Damage to Waterways (Avonside Drive, Porritt Park Loop, October 2010)

Photograph 3: Example of Direct Damage to Structures (Gayhurst Road Bridge, October 2011)

Direct damage to waterways and structures presents some of the more visible effects of the earthquakes to the land drainage network, but the largest impact on the community is from the change in flood risk. This is driven by changes to the topography, both through land sinking (by up to one metre in places along the Avon River) and through a general tilting of the land. The impact of land tilting can be seen in Figure 1, where the land along the Heathcote River in the south-east experienced uplift, whereas to the north-west land subsided. This has resulting in a much wider extent of flooding in this sub-catchment, as shown by the yellow in the figure.

Figure 1: Impacts on Flooding Due to Earthquake Changes in Topography



3 DEVELOPMENT OF THE LDRP PROGRAMME

3.1 PROGRAMME DEVELOPMENT

The LDRP was established by Council to understand the consequences of the earthquakes on the land drainage network, and to undertake a capital programme to address the effects. The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) is largely responsible for the investigation and restoration of the piped network, whereas the LDRP is largely responsible for the open waterways.

The objectives of the LDRP are to:

- To implement a prioritised programme of investigations and physical works to repair damage and restore flood risk; and
- Use a benefit/cost analysis and risk based approach to determine an appropriate response being either: physical works, policy intervention (retreat), adaptation or adaptive management.

The LDRP is a large programme. In the current Long Term Plan 10-year horizon, approximately $315 million has been identified for investigations and physical works. To complete the full LDRP programme as initially estimated would require spend over greater than 30 years and total over $1.2 billion.

3.2 GUIDING PRINCIPLES

The LDRP developed a set of guiding principles to establish which response to flooding, if any, is appropriate. These principles are focused on:

- Demonstrating earthquake effect;
- Achieving significant social benefit;
- Adherence to long term planning ('no regrets') and Council's six values[1] approach; and
- Levels of service.

An engineering risk based approach is applied to the selection of which projects to proceed into the later stages of design and construction. Capital works will proceed prior to the completion of investigations across the entire city. Decisions on adaptive management and 'do nothing' need to be justified and relate to the guiding principles.

3.2.1 EARTHQUAKE EFFECT

An earthquake effect must be identified and proposed physical works must clearly demonstrate remediation of earthquake impacts. For example, in-stream works must be located in areas of direct damage or proposed increases in network capacity must be linked to restoration of pre-quake flood risk. Any direct enhancement must be clearly identified as funding of this may require re-prioritisation of other projects or a separate funding source. Indirect enhancement needs to be identified.

Photograph 4: Earthquake damage to a pump station and bridges in Christchurch

[1] The six values are: ecology, landscape, recreation, heritage, culture, and drainage. This approach ensures that wider cultural, community and environmental values are taken into account when making decisions about surface water drainage.

3.2.2 SOCIAL BENEFIT

Any proposed responses need to provide benefit. This could include social and economic benefit, such as: reducing the frequency or severity of flooding, preventing social decline or minimising damages. Any proposal with limited or no benefit should not be progressed.

3.2.3 'NO REGRETS'

Proposed responses need to be consistent with long term planning objectives and not compromise any responses to sea level rise (SLR). In general the works will not address SLR, but where they do (e.g. due to cost efficiencies in future-proofing the works) then this portion shall be clearly identified so that a funding path can be determined. The principle is that all projects should be consistent with proposed future works and investment should not impede long term strategies. Responses should also be consistent with Council's six values approach, ensuring that cultural, community and environmental values are taken into account.

3.2.4 LEVELS OF SERVICE

Existing levels of service were considered as targets for LDRP projects. However, as the programme has developed it has been identified that more definition around levels of service, particular in areas already developed, may be needed. For example, better definition may be required around above floor, below floor, property flooding, street flooding, residential versus commercial, return interval risk e.g. 1 in 50 years, 1 in 10 years, etc.

4 KEY QUESTIONS FOR PROGRAMME DEVELOPMENT

To develop the programme key questions that needed to be answered by the LDRP were:

- Where was the damage located?
- What areas were most at risk of increased flooding?
- What is the quickest way to analyse options?
- What information is required?
- How to estimate the cost of unknown works?
- How to prioritise unknown works with unknown effects?
- What is the business need?
- What are the risks and how are these to be managed?
- Who are the key stakeholders?
- How to set up a programme team to successfully deliver?
- How to measure a successful outcome to the programme?

The following sections describe how all of these questions were answered.

4.1 IDENTIFYING AT-RISK AREAS

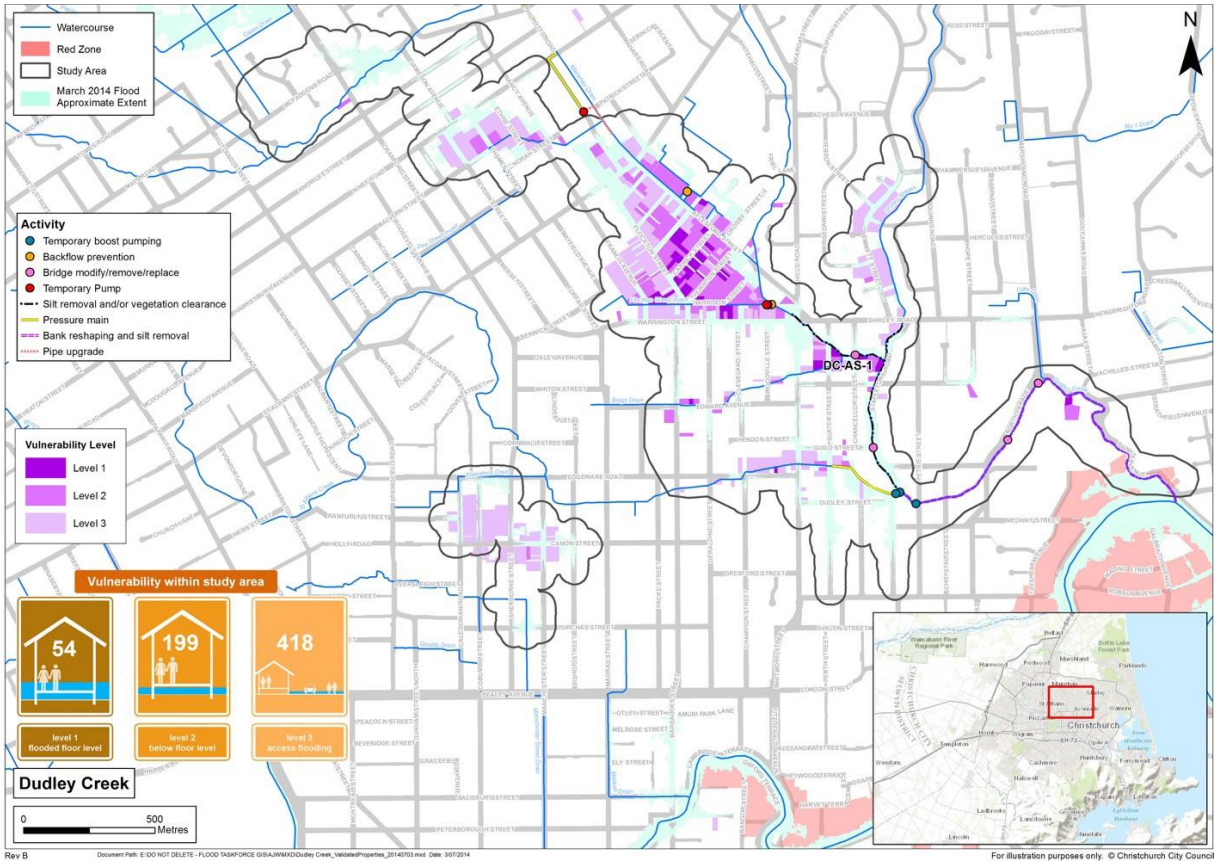
The initial programme of investigations was developed through consultation with operations and planning staff within Christchurch, and through modification of existing models to rapidly test the effects of changes to the topography. This allowed an initial list of priority investigation areas to be developed in order to get the programme started.

However, until the flood events of June 2013 and particularly March 2014, the change in flood risk was theoretical rather than real. Having a series of extreme rainfall events in the earthquake damaged catchments highlighted the severity of the changes in ways that modelling and reports never could.

After the March 2014 floods the Christchurch Mayoral Flood Taskforce was launched, and the data captured by the Taskforce enabled a much better understanding of the change in flood risk. For instance, as far as possible, all residents in houses where flooding occurred above floor were interviewed or surveyed to understand during which rainfall events flooding occurred and to what depth. This information has proved vital in the validation of flood models, and to better understand local effects on flooding. An example of the data collected by the Taskforce is shown in Figure 2.

The Earthquake Commission (EQC) was also developing a rain on grid TUFLOW model of post-earthquake flooding in order to assess properties with increased flooding vulnerability (IFV). The TUFLOW model results were provided to Council and were used to identify and/or validate areas with increased flood risk. Due to the level of resolution required for options assessment the TUFLOW model was not used for investigations, but it proved an effective tool for identifying areas potentially at risk and defining the extents of the investigations.

Figure 2: Mayoral Flood Taskforce Validated Flood Data (2014)



4.2 INFORMATION NEEDS AND ANALYSIS

The investigations programme is designed to inform the physical works programme. It provides the necessary information to allow for prioritisation and costing of high priority physical works.

A total of 107 investigation projects have been identified to date. Of the projects, 64% were completed or were underway in 2015. The remaining 36% are scheduled to initiate in 2016.

The investigation programme contains the key elements described below.

4.2.1 CONDITION ASSESSMENT

An important part of the LDRP is to assess the post-earthquake condition of the land drainage networks and to compare these against the pre-earthquake condition. This enables an understanding of the impact of the earthquakes which is important in the determination of repair, remediation and betterment options.

A high level assessment specification was developed for the six values Council recognises for waterways: drainage; culture; recreation; ecology; heritage; and landscape (CCC, 2016). The condition assessment involved a walkover of the full length of each waterway identified for assessment, and video assessment of some portions.

The condition assessment was designed to answer the following questions:

- What is the current condition of the assets?
- What is the effect of the earthquakes on the condition of the assets?
- What is the effect of the earthquakes on non-drainage values?
- Where is there damage, is it earthquake or non-earthquake related, and is there sufficient damage to require repair?

4.2.2 FLOOR LEVEL SURVEY

Floor level flooding is a major driver for LDRP engineering and policy responses. In order to identify the effects of flooding at a property level extensive floor level surveying has taken place in areas with known post-earthquake flood risk. This allows for easier prioritisation of areas based on the extent of floor level flooding.

4.2.3 CITY WIDE FLOOD MODEL

To date individual post-earthquake sub-catchment models have been developed to identify earthquake effects and to test mitigation measures. However, it is inefficient to develop multiple models and the flood models for all major city catchments are being updated to more accurately identify the effects of the earthquakes. In addition to updating the topography, extensive additional detail is being added to provide the resolution required to accurately identify earthquake effects at a property level, and to enable mitigation options to be tested.

The model is currently in development, and once completed will be an invaluable tool to identify earthquake effects. The development of this model is being separately reported on in another paper at the 2016 New Zealand Stormwater Conference.

4.2.4 INDIVIDUAL CATCHMENT STUDIES

Individual catchment studies are necessary to understand the effects of the earthquakes at a local level. A consultant and client project team are developed for each catchment area, and regular workshops are held to test the conceptualisation of the problems and solutions with Operations and Planning staff at Council.

This stage incorporates all of the data collected to date, and assesses whether the need is sufficient to proceed, or whether a solution is economical. Solutions developed to date have involved pump stations, detention basins, network upgrades, bypasses and active management of existing facilities. The aim of the LDRP is to move as rapidly as possible from investigations through to concept, detailed design and construction.

4.3 COST ESTIMATION

In order to inform decisions on the Long Term Plan, quantification of costs for the programme were needed. These costs were based on engineering intervention in the form of flood defence. However, these costs were needed to be developed ahead of the majority investigations work. Where investigations were yet to be developed the cost estimates were high level estimates based on the understanding of the likely intervention for each area and extrapolations from existing physical works projects.

One of the keys to enabling this methodology to succeed however, was to ensure that costs were reported primarily at a programme level rather than at the level of individual projects. This has resulted in funding being granted at the programme level. This means that while the estimates for individual projects may vary considerably, overall the programme estimate variance remains within acceptable limits. Over time, as the investigations are completed, more certainty about individual cost estimates will be gained, and so reporting at a project level will have greater confidence. For the purposes of transparency and public accountability reporting and Council decision making is required on each project prior to detailed design and as they require funding to be drawn down from the programme budget.

4.4 PRIORITISATION

Council and community expectations of the programme are high with a strong desire to see the most flood prone areas remediated as soon as possible (such as in Shirley, Photograph 5 below). As such considerable efforts are being expended to identify and prioritise projects, and to maximise savings and efficiencies at the project level to enable the greatest benefits in the shortest time.

An initial prioritised physical works package has been developed based upon an engineering intervention approach of defence. The budget estimate for the entire programme totals $1.227 billion (+/-40%). This does not consider affordability of the programme and if a lesser budget were to be available some projects would be left undelivered.

Photograph 5: Flooding in Shirley, Christchurch - June 2013

The prioritisation of the groups is based upon a range of weighted, qualitative and quantitative criteria:

- Flood risk and effects;
- Cost benefit;
- Alignment with long-term planning objectives, other programmes (SCIRT, CERA, LTP), projects etcetera; and
- Five values (non-drainage values i.e. ecology, landscape, recreation, heritage, culture).

There are a range of defence measures included in the programme, such as:

- Storage;
- Channel modifications, e.g. widening, regarding, bank trimming;
- Stopbanks;
- Pump stations; and
- Property level defences e.g. house raising.

Key to the future prioritisation of the programme are the following:

- The City Wide Stormwater Model, validated by floor level surveys etc., will better define the extent of flood risk and will inform long term sustainable decision making.

- The city wide Stormwater Infrastructure Economic Model will better define cost benefit assessments that do not easily consider differences between above and below floor flood risk, infrastructure versus policy responses (e.g. managed retreat), future climate change effects, etc.

- Levels of Service reviews.

- Project investigations considering the cost benefits of a number of options and identify cost by damage, remediation, and enhancement.

- Ongoing review of the LDRP programme priorities based on feedback from project investigations.

- Policy decisions regarding non-engineering interventions.

4.5 BUSINESS NEED

The LDRP needed to clearly articulate the business need for the investigations and any physical works. To do this, the LDRP focused on articulating two of the main impacts of flooding:

i. Social and health impacts; and

ii. Economic impacts.

4.5.1 SOCIAL AND HEALTH IMPACTS

The Mayoral Flood Taskforce in 2014 investigated the social and health impacts in the worst affected areas of Christchurch with the most vulnerable people and houses. The Taskforce identified a number of key social impacts from frequent flooding:

- People are concerned about living in damp, mouldy houses and consider that living in warm, dry, healthy homes is a priority for physical health and for personal wellbeing;

- There is a reported increase in stress, depression, feelings of hopelessness, frustration, anger and powerlessness. These feelings are partly because of a perceived lack of coordination between the agencies, and a perceived lack of urgency and communication from the agencies. These feelings are also because of uncertainty about the future, financial worries, and living in cold, damp, unhealthy homes;

- Wastewater contamination of floodwater can put public health at risk and potentially jeopardise untreated potable water supply especially where wells or pump stations are in flood prone areas. Stress on the wastewater network from flooding can result in uncontrolled overflows, contamination of people's homes and properties (directly from the wastewater network or from contaminated floodwater), risk of illness and disease associated with contact with wastewater and repeated clean-up costs;

- Financial concerns including increased insurance excess, reduced insurance cover, loss of equity in homes, insurance money running out, increased financial obligations such as having to service a mortgage and pay rent, increased electricity and heating costs, impacts on businesses (loss of revenue) and forced annual leave or leave without pay;

- People are concerned about the potential loss of community and/or fragmented communities and a loss of amenities;
- Uncertainty with timing of house repairs; and
- The time it may take to remedy or reduce flooding and uncertainty of what to do in the meantime.

In time if flooding issues, particularly regular flooding, are not addressed then social degradation may occur. Houses can lose value, abandonment can occur, crime can increase and this directly impacts on the fabric of the local community and the wider community.

Photograph 6: Polluted Flood Waters in Heathcote River, Christchurch (2014)

4.5.2 ECONOMIC IMPACTS

In addition to the social and health impacts it was identified that there are direct and indirect impacts from the increase in flooding resulting from the earthquakes:

- *Direct impacts (tangible):* damage to houses, business and infrastructure, clean-up costs and flood management activities; and
- *Indirect impacts (intangible):* reduced economic activity, inefficiency in transport network, increased insurance costs, stress on the public health system, delays in access for emergency response vehicles, social degradation from repeated flooding.

Historically land drainage infrastructure projects do not have 'positive' benefit cost ratios due to the intermittent nature of flooding. However they are often progressed based upon significant social impacts.

In order to better understand the economic drivers (both tangible and intangible), the LDRP has commissioned the development of a GIS-based economic model which will allow the testing of the economic impacts of different flood scenarios and mitigation measures in order to better understand the drivers for different projects.

4.6 RISK IDENTIFICATION AND MANAGEMENT

The programme needs to operate in part reactively due to the changing nature of the rebuild and recovery effort but in general has a structured approach as described above. The scope of the projects, programme and costs is reviewed regularly to adapt to this.

The scope of the projects and the budget cost estimates are based upon the latest understanding of the recovery effort (assessments based upon hydraulic modelling of the main river stems, pre-feasibility assessments and catchment investigations). The rapidly increasing knowledge of the post-earthquake flood situation means that the programme is very dynamic. This results in a range of confidence in the proposed physical works programme arising from:

- *Variation in investigations progress:* For example, the Dudley Creek investigations have progressed further than Bell's Creek;
- *Alternative responses:* The current physical works programme is based upon an engineering intervention approach (i.e. defend). The other responses (adapt, retreat) could give rise to changes in the proposed work or cost estimates. The policy and investigations work to support the optimal response strategy is ongoing; and
- *Ongoing review:* The proposed physical works programme is currently under review. Preliminary findings will be reported back in mid-2016. This may update the cost estimates and scope of the physical works packages.

Key stakeholders have been informed from an early stage that the programme is highly dynamic. A proactive approach to informing key stakeholders of this has ensured that changes are seen as expected rather than being seen to be surprises.

A programme risk register is the key management tool for programme-level risks. Risk identification covers all aspects of the programme throughout its lifecycle, including budget, procurement, programme administration, health and safety, and environmental.

Key risks to the programme include:

- *Power to implement:* Timeframes not being achievable, RMA processes cause increased time and cost or existing powers not available, political priorities shift.
- *Land requirement:* Unable to get agreement with land owners, land acquisitions not viable estimated cost not realistic. May need to forcibly acquire land.
- *Resource availability:* Lack of in-house resources, or loss of resources, results in slower than expected programme delivery.

4.7 KEY STAKEHOLDER MANAGEMENT

The LDRP interacts with a wide range of stakeholders, from central government representatives, runanga, internal Council staff, residents, and Councillors, to the wider community to those whose homes have actually been flooded. A proactive approach has been developed to ensure wide understanding of the programme, and to ensure that stakeholders are able to make decisions rapidly.

One example of stakeholder engagement was a bus tour along the Lower Heathcote River to provide a briefing on the issues and flood defence plans for the Heathcote River and Estuary. The tour comprised Councilors, representatives from Community Boards, the Zone Committee, and Environment Canterbury. This enabled discussion of the key issues in an open forum to enable all to gain an understanding of the issues involved.

Photograph 7: Heathcote River Land Drainage Recovery and Flood Defence Tour

Another example of this has been the establishment of a Working Group comprising three Councillors including the Chair of Infrastructure Transport and Environment Committee. This group is not a decision making body but is a forum to update on programme and projects, seek Councillor feedback and guidance, provide information and discussion on any land drainage or flood hazard issue from all parts of the business. The Working Group has helped guide and support work with Community Boards and resident and stakeholder engagement.

The Working Group's aspirations are to return the city to pre-quake levels of flood risk, with priorities given to the Eastern suburbs, and to consider opportunities for 'enhancement' where appropriate. The Working Group want to be well informed and to ensure that residents are also aware of the developing programme of works. They are increasingly aware of the complexities and inter-relationships in developing infrastructure and policy responses.

The Working Group has been very supportive of the programme and projects to date and has enabled the LDRP team to test the findings of the programme and possible physical works projects with Councillors as early as possible.

4.8 SETTING UP A PROGRAMME TEAM TO SUCCEED

It was crucial for the success of this programme that the right resources and personnel were selected. The "soft resources" (e.g. the programme memory, the people, the reason why we enjoy our work) were crucial to ensure the recipe was right. These people had to appreciate and thrive in a fast tracked dynamic environment. They required flexibility within their working style and planning skills and be un-phased by the volume of work and "curve balls". It was understood that this level of intensity of work was not short-term, so the right level of "pressure release" was allowed and welcomed. Within the recruitment and briefing of their workload, there was no sugar coating of what was ahead for them. Recruiting staff remained honest and open about the dynamics that they would strike. A focus on well-developed soft skills and team fit were critical for this recipe for ongoing programme success.

4.9 MEASURING SUCCESS

The LDRP needed to articulate what success for the programme would look like. This is expressed in the following statement:

> "The network will be recovered when all identified responses are in place and flood risk has been returned to pre-earthquake levels or a new level of risk accepted. Responses range from LDRP physical works (e.g. defence measures such as stopbanks) to non-LDRP policy change, (retreat or adaptation, e.g. modification to building stock or adaptive management practices)."

Ultimately, however, success will be measured by how the city functions when the next extreme storm event occurs. This is a key focus of the programme team and the Council.

Photograph 8: Success in action - early works undertaken on Dudley Creek, including laying pipes for eel habitat in constructed banks (Source: Downer)

5 CONCLUSIONS

The Canterbury Earthquake Sequence has significantly altered the performance of Christchurch's land drainage network. Direct damage to waterways and structures has combined with land damage to significantly alter flood risk across much of Christchurch. Many properties have been identified as having increased flooding vulnerability, with many of those at increased risk of floor level flooding.

Remediation of these impacts will be costly and will require an ongoing commitment to funding. The LDRP has developed a physical works remediation programme totaling $1.2 billion. The programme will continue to develop with time as further investigations are completed, reviews undertaken and policies developed on alternative responses.

The LDRP is an example of the development of a flexible solutions focused programme. This is necessary to enable investigations and projects to be developed as rapidly as possible to restore confidence in the community.

ACKNOWLEDGEMENTS

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