AN EARTHQUAKE AND RECOVERY OF A STORMWATER SYSTEM

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ABSTRACT

The Canterbury Earthquakes in September 2010, February 2011 and June 2011, caused substantial damage to the infrastructure in the greater Christchurch region. Within the Waimakariri district, the urban areas of Kaiapoi, The Pines Beach and Kairaki, which are prone to liquefaction and lateral spread, suffered the most damage. The Council's stormwater system was particularly affected by siltation of pipes and waterways, damage to pipes, pump stations and stormwater basins and land movement which has altered localised flooding in the area. The immediate response focused on identifying damage and undertaking temporary repairs to key infrastructure to provide a functioning system, albeit at a lower level of service.

This paper looks at subsequent recovery stage for stormwater, including the detailed condition assessment, development of a stormwater strategy for these areas and subsequent revision of the strategy based of the classification of large portions as red zones. The focus of this paper is on the Council's approach and the key lessons learnt.

KEYWORDS

Lateral Spread – the finite, lateral displacement of gently sloping ground as a result of pore pressure build up or liquefaction in a shallow underlying deposit during an earthquake.

Liquefaction – describes the phenomenon whereby a saturated soil substantially loses strength and stiffness in response to an applied stress, usually earthquake shaking or other sudden change in stress condition, causing it to behave like a liquid.

Red Zone – describes the residential area as defined by the Christchurch Earthquake Recovery Authority (CERA), where remediation would be prolonged and may be uneconomic. The includes land that has suffered damage, most buildings are uneconomic to repair, there is a high risk of further damage to land and buildings from low-levels of shaking, the infrastructure needs to be completely rebuilt and land repair solutions would be difficult to implement, prolonged and disruptive for landowners.

PRESENTER PROFILE

Kalley is a civil engineer with 14 years experience in water engineering and has a particular interest in stormwater engineering. He started with the Waimakariri District Council following the September 2010 earthquake, looking after the stormwater recovery programme of works. Currently he is working as the 3 Waters Manager for the Waimakariri District Council.

1 INTRODUCTION

The township of Kaiapoi and seaside settlements of The Pines Beach and Kairaki are located in the east of the Waimakariri district immediately north of the Waimakariri River, north of Christchurch. Kaiapoi is situated on the banks of the Kaiapoi River, which is an historical flow route of the Waimakariri River North Branch, and The Pines Beach and Kairaki are located further east between Saltwater Creek and the coast.

These residential areas experienced liquefaction during the September 2010, February 2011 and June 2011 earthquakes, with the majority of damage to infrastructure occurring during the September 2010 quake. The area is located approximately 50 kilometres from the epicentre of the September 2010 Darfield (Canterbury) Earthquake and approximately 20 kilometres from the epicentre of the February 2011 and June 2011 aftershock earthquakes in Christchurch.

The existing stormwater systems sustained moderate to major damage in parts of Kaiapoi, The Pines Beach and Kairaki, as a result of the earthquakes and subsequent aftershocks. The damaged predominantly occurred in areas prone to liquefaction and lateral spread, though some damage occurred in other areas due to shaking. The Council's stormwater system was particularly affected by siltation of pipes and waterways, damage to pipes, pump stations and stormwater basins and land movement which has altered localised flooding in the area.

This paper gives an overview of the damage that occurred and the condition assessment process, the stormwater strategy adopted to assess issues and develop options for these areas, and subsequent revision of the strategy based of the classification of large portions as red zones. Information is also given on the key lessons learnt through this process to date.

Council is currently finalising its revised strategy with a focus of implementing recovery works in the green zones as the repair and rebuild progresses in these area.

2 THE DAMAGE

The damage to the stormwater infrastructure was predominantly caused by liquefaction and lateral spread, although some shaking damage occurred to concrete structures. Some of this damage was observable from above ground (e.g.: manhole levels, pump station condition), however most of the infrastructure required CCTV inspection to confirm the extent of damage. Additionally, some damage was not evident until detailed condition surveys had been undertaken (e.g.: loss of storage capacity in stormwater basins and open drains).

2.1 LIQUEFACTION

Liquefaction was widespread in some areas (refer Photographs 1 & 2) and resulted in siltation of pipes, open drains and basins. Some sections of pipework were so heavily silted that the material had effectively set in the pipework, with one 300 metre section of 450mm pipe in particular taking approximately 4 days to remove the silt using high pressure jetting.

Photographs 1 & 2– Liquefaction in Kaiapoi west (left) and Kaiapoi east (right)

Sections of open drains had to be excavated to remove silt and restore the flow capacity. Some sections required excavation on numerous occasions following aftershocks and also weeks or months later once the silt in the upstream system had worked its way into the lower reaches of the system.

Photographs 2 & 3– Hilton Street Culvert (downstream view), pre-earthquake (left) water level approximately 1100mm below soffit and post-earthquake (right) water level approximately 600mm below soffit

2.2 LATERAL SPREAD

There was a high degree of correlation between the areas of lateral spread and damaged stormwater infrastructure. Figure 1 below shows the area of ground movement, which was derived from comparing pre-earthquake 2005 LiDAR data to post earthquake LiDAR data flown immediately after the September earthquake. In the figure the Kaiapoi River can be seen, the purple corridor through the middle of the figure, and two distinct horse shoe type curves where lateral spread had occurred. These areas may be old alignments of watercourses.

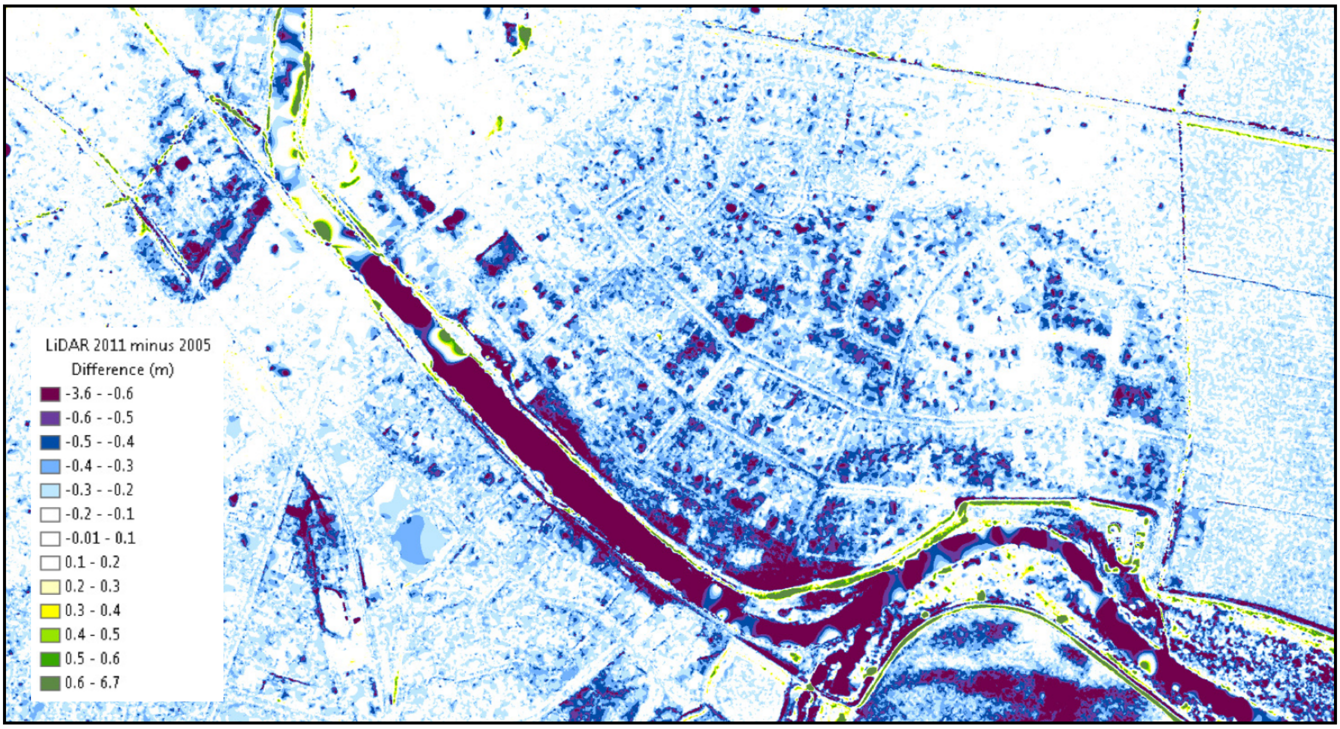
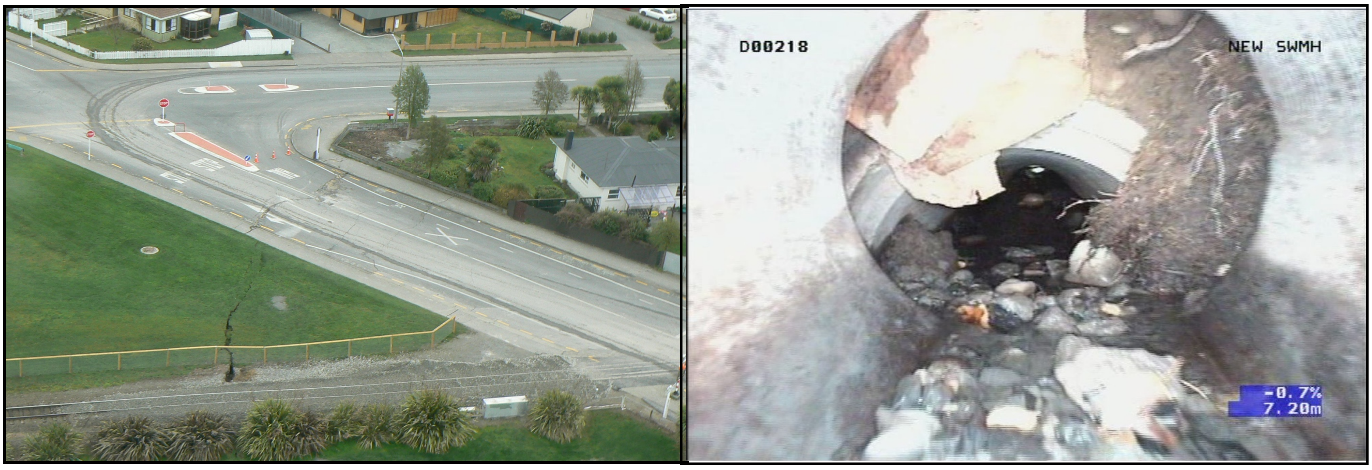


Figure 1: Comparison of pre and post earthquake LiDAR data.

The damage at the interface of land movement was evident in several locations. An example, shown in Photographs 4 & 5 below at the extent of the lateral spread in Kaiapoi west. A section of 450mm diameter pipe had been pulled apart and displaced downwards by approximately 300mm.



Photographs 4 & 5: Damage at extent of lateral spread on Peraki Street. Cracking in road and reserve is evident next to stormwater manhole (left). Damage to 450mm pipe.

Initial inspection of pump stations located in the stop bank of the Kaiapoi River suggested that the pump stations had popped under buoyancy forces during the earthquake. However further investigation and comparison to pre-earthquake levels indicated that most of the movement was due to lateral spread and settlement of the surrounding land.

Photographs 6 & 7: Laterals spread of stop bank adjacent Dudley Pump Station.

2.2.1 CONDITION ASSESSMENT

The following work was completed to assess the extent of damage to the stormwater system in the recovery areas:

- Jetting and CCTV inspection of all pipework.
- Walkover inspection of open drains.
- Manhole survey of all manholes.
- Inspections of all pump stations and detailed inspection of moderate / major damaged pump stations by structural and geotechnical engineers.
- Detailed inspection of stormwater basins by a civil and geotechnical engineers.

The extent of damage, together with the asset age and condition was used to establish the extent of replacement / repair work.

Outside of the recovery areas a district wide condition assessment was undertaken to ensure no other damage had occurred due to shaking. Given the number of stormwater assets in the district, it would not have been economically feasible to assess the condition of each asset. Therefore the following criteria was proposed to select a sample of assets that should be checked for earthquake damage:

- Critical assets – based on the Drainage Reticulation Critically Ranking undertaken in 2008.
- Assets within areas susceptible to liquefaction – based on the Beca 2000 study and Geotech 2008 study.
- Assets of types (e.g.: material and or size) that are known to have performed poorly – based on information collected to date from the earthquake recovery areas.

A review of the data collected from the recovery areas (refer Table 1 below) identified that although concrete had the longest length of damaged pipe the percentage of concrete pipe damaged was the lowest. Steel and cast insitu pipes appear to have performed badly in the earthquake. The steel pipes were corrugated steel type pipes and the cast insitu pipes unreinforced concrete all off Parnham Lane near the Old Kaiapoi Cemetery. AC, Earthernware and PVC all performed moderately and had a similar percentage of damage by pipe length.

Table 1: Pipe damage data from condition assessment in recovery areas

Material Type	Length Damaged	% Damaged of Total Damage	Length Inspected	% Damaged of Length Inspected

Concrete	613	54%	8970	7%
PVC	275	24%	1303	21%
Earthernware	27	2%	85	32%
AC	52	5%	227	23%
Steel	135	12%	135	100%
Cast Insitu	40	4%	61	66%

3 ORIGINAL STRATEGY

3.1 OVERVIEW

The original strategy, prior to the red zoning of large areas of Kaiapoi, The Pines Beach and Kairaki, was focused on the repair and replacement of damaged stormwater infrastructure. The stormwater system was split into four geographical areas where moderate to major infrastructure and property damage had occurred from the earthquakes:

- Kaiapoi East – Including the Central North, Beswick and Feldwick catchments
- Kaiapoi West – Including the Dudley and Central South catchment
- Kaiapoi South – Including the Bowler, Courtenay and Kaikanui catchments
- Pines Kairaki – Including the Pines and Kairaki catchments

The issues that were considered, in assessing and developing the recovery options for stormwater infrastructure, included not only earthquake damage but also existing and future deficiencies, other recovery works and other constraints as listed below:

- Existing network deficiencies / compliance with the Council's Engineering Code of Practice (ECOP) (e.g.: existing flooding, excessive kerb runs, pipes on private property, discharge during high river levels, secondary flow paths)
- Future network deficiencies (e.g.: climate change (higher rainfall, sea level rise), development (land use change or infill development), requirement to treat stormwater)
- Earthquake damage (e.g.: damaged sumps, pipework, manholes and pump stations, future liquefaction risk / damage (particularly for key assets – pump stations))
- Integration with other works (e.g.: land improvement works, streetscape and road recovery works, future planned works (LTCCP), social support)
- Consenting requirements
- Funding constraints

Generally the following four principal replacement options were assessed:

1. Replace existing system (like for like)
2. Replace existing system to ECOP level
3. Construct new system to comply with ECOP
4. Construct new system to comply with ECOP and provide stormwater treatment

This formed the over arching strategy for the development of Issues and Options reports for all stormwater infrastructure recovery work.

3.2 ASSESSMENT OF ISSUES

3.2.1 EXISTING DEFICIENCIES

FLOODING

Kaiapoi, The Pines Beach and Kairaki are low lying urban areas that sit in behind the flood stop banks of the Waimakariri River. The areas have experienced historical flooding due to flat topography, location within the tidal and flood plain area of the Kaiapoi and Waimakariri rivers and undersized stormwater infrastructure.

The Council had previously prepared several stormwater reports covering existing or predicted flooding in Kaiapoi and has an existing hydraulic model (DHI Mike Urban) for the Kaiapoi stormwater system. Limited flooding information was available for the beach communities of The Pines Beach and Kairaki.

The land movement that occurred as a result of the earthquakes has altered the secondary overland flow paths, flood storage and habitable floor levels. It is estimated that the land has dropped by up to 400mm in some areas to below the high tide and flood level. Consequently the flood risk to habitable buildings in these areas has changed.

The flood models were updated to assess the 2%AEP flood levels within the recovery areas to assist in setting minimum floor levels for rebuilding. The models were also used to evaluate the various options investigated within the Issues and Options reports. A separate model was also developed to assess the 2%AEP flood level for Kairaki. Additionally the Mike Flood, 2D Rapid Flood Hazard Models (RFHM), for the rural areas were rerun for the areas surrounding Kaiapoi.

The flood modelling work determined the effect of the land movement on flood risk and the required minimum floor level for any habitable building being rebuilt in the recovery areas. The work suggested that the minimum floor levels for some habitable buildings needed to be raised by up to 330mm, to provide a minimum 300mm freeboard above the modelled flood level. Note that this accounts for localised flooding in the 2% AEP event only and does not account for breakout flooding from the Waimakariri or Ashley rivers in more extreme events.

LEVEL OF SERVICE

The stormwater infrastructure in Kaiapoi, The Pines Beach and Kairaki was constructed over many years in an ad-hoc manner as development has occurred. Parts of the system, particularly in the older parts, do not meet the current Level of Service (LOS) as set out in the ECOP. While there is no strict requirement to meet the ECOP, it was an objective that where funding was available, the stormwater recovery works should generally comply with the guidelines in the ECOP.

This will involve seeking to meet the following key guidelines:

- All pipelines designed to convey a 20% AEP storm event
- Provision within the road carriageways to convey the 2% AEP storm event
- Spacings between manholes and sumps not to exceed 100m
- Kerb and channel runs not to exceed 100m
- Pump stations designed to convey the 20% AEP storm event
- Double sumps to be used in valley positions in the kerb and channel
- Rainfall data will be HIRDS Version 3 data with a 16% contingency for climate change

Additionally consideration was been given to integrating any bubble up sump arrangements into the reticulated piped systems.

PIPES ON PRIVATE PROPERTY

The earthquake gave the opportunity to consider realigning pipes out of private property. While the Council has right, either via an easement or power under Local Government Act 2002, to undertake works on private property, it is difficult and expensive to maintain, repair and replace infrastructure located on private property. Additionally the secondary flow path may be through private properties that are not protected by an easement. Therefore consideration was given to assessing whether pipes on property can be relocated into Council owned land (e.g.: road reserves or park reserve) or where it was necessary to cross private property, to establish appropriate easements for future works.

DISCHARGE DURING HIGH RIVER LEVELS

All stormwater infrastructure in the affected areas of Kaiapoi, The Pines Beach and Kairaki is located in areas where gravity discharge is not possible during high tide or flood conditions in the receiving waters (e.g.: Kaiapoi River or Waimakariri River). Most catchments discharge to a pump station (i.e.: stormwater lift station), to permit discharge during these conditions. However, some smaller catchments do not connect to a pump station and are at risk of flooding when high tide or flooding in the receiving waters prevent gravity discharge. Consideration has been given to connecting these smaller catchments to an existing pump station (or new pump station) either via a permanent diversion or high level overflow pipe.

SECONDARY FLOW PATHS

Kaiapoi, The Pines Beach and Kairaki are all located on flat land where the secondary overland flow path is not well defined. The ECOP recommends that roads (except strategic and arterial roads) and if necessary accessways, parks and reserves are used as secondary flow paths. Where this is not possible, private land may be used if the route is protected by an easement, though this is not a desirable option. Proposed reconstruction of the road in some areas gave the opportunity for defined secondary flow paths to be formed.

3.2.2 FUTURE DEFICIENCIES

CLIMATE CHANGE

The effect of climate change, both in terms of higher rainfall intensities and sea level rise, was considered in accordance with the following Ministry for the Environment documents, as set out in the ECOP:

- Climate Change Effects and Impacts Assessment – A Guidance Manual for Local Government in New Zealand (2nd Edition) May 2008.
- Coastal Hazards and Climate Change – A Guidance Manual for Local Government in New Zealand (2nd Edition) July 2008.

Although based on latest information from the NZ Coastal Policy Statement and other work in New Zealand and Australia, consideration has also been given to the impact of the see level rise of 1.0m. Any upgrades to address flooding issues have incorporated or considered the impacts of climate change on the flood hazard / risk.

FUTURE DEVELOPMENT

The assessment of the stormwater system and any proposed upgrades considered the development within the catchment over 30 year growth planning horizon defined in the District Plan and Change 1 to the Regional Policy Statement.

STORMWATER TREATMENT

It is desirable to employ stormwater treatment measures in the construction of modern stormwater systems. These could potentially achieve protection of the downstream environment (the Kaiapoi River and Waimakariri River) from contaminants normally associated with residential and commercial land use. While currently not mandatory for existing systems, it is possible that Environment Canterbury may seek a higher standard of discharge in the future. Retrofitting stormwater treatment in the future is likely to be more expensive than constructing them in conjunction with proposed network upgrades.

Consideration was given to the following treatment devices:

- Sumps and silt traps
- Oil and Grease Interceptors
- Sump Filter Baskets
- Gross Pollutant Traps
- Vegetated Swales
- Rain Gardens
- Soakage Systems (either Swales, Chambers or Basins)
- First Flush Treatment Basins (either wet or dry)
- Constructed Wetland
- Sand Filters
- Watercourse enhancement

Where a potential treatment device could be readily retrofitted in the future or constructed independent of the proposed works, it was not included with the immediate recovery works, however if the device was an integral part of the works that could not be easily added in the future it was included in the proposed recovery works. Consideration was also given to making provisions for future treatment devices (e.g.: connections to manholes and pump stations).

Treatment devices are considered as part of the overall treatment train in removal of expected contaminants from the runoff.

3.2.3 EARTHQUAKE DAMAGE

NETWORK DAMAGE

The earthquakes and aftershocks have resulted in damage to:

- Pipework – siltation, displaced joints, broken / collapsed pipes, differential settlement (sag in pipes).
- Open Drains – siltation, collapse banks / retaining walls
- Sumps – broken / cracked concrete, displaced inlet/outlet pipe, differential settlement (no longer at low point in kerb).
- Manholes – broken / cracked concrete, displaced inlet/outlet pipes, differential settlement (higher / lower than surrounding ground and/or pipework).
- Inlet/Outlet and Outfall Structures – broken / cracked concrete, displaced inlet/outlet pipes, differential settlement, lateral spread into watercourse.
- Pump stations – damage to building structure, broken / cracked concrete, displaced inlet/outlet pipes, differential settlement (higher / lower than surrounding ground and/or pipework).
- Basins – siltation, side slump / collapse, ground movement (change to storage/treatment volume).

Some of this damage is observable from above ground (e.g.: manhole levels, pump station condition), however most of the infrastructure required CCTV inspection to confirm the extent of damage. The following work was completed to assess the extent of damage to the stormwater system in the recovery areas:

- Jetting and CCTV inspection of all pipework.
- Walkover inspection of open drains.
- Manhole survey of all manholes.

- Inspections of all pump stations and detailed inspection of moderate / major damaged pump stations by structural and geotechnical engineers.
- Detailed inspection of stormwater basins by a civil and geotechnical engineers.

The extent of damage, together with the asset age and condition has been considered to establish the extent of replacement / repair work.

LAND / BUILDING MOVEMENT

The earthquake caused substantial land movement, both vertically and laterally, that has resulted in the formation (or exacerbation) of numerous localised low points (not readily picked up by LiDAR surveys). An assessment of post earthquake levels was undertaken to identify localised low points in the road reserve and on private property. It was intended that in the road reserve road regarding works and kerb replacement works would be undertaken to direct stormwater runoff to sumps and in private property land with rebuilding will be regraded to provide a slope to the roadway, as per the ECOP.

RESILIENCE TO FUTURE EVENTS

To design new infrastructure to avoid future damage from an earthquake, consideration was given to the following possible measures that could be employed for critical infrastructure (e.g.: pump stations) or if the marginal cost increase was minimal:

- Location of asset (i.e.: relocation of assets to be replaced in area less likely to be damaged from liquefaction or lateral spread)
- Proximity to proposed land improvement works (i.e.: integrating ground treatment works in with repair or replacement work to infrastructure to make it more resilient)
- Material type (i.e.: PE joint-less pipe as opposed to concrete or PVC pipe with joints)
- Structure foundations / bedding (i.e.: modifications to the foundation and / or bedding to make the structure less likely to be subject to damage during a future earthquake.

3.2.4 INTEGRATION WITH OTHER WORKS

CONSTRUCTION WORKS

The proposed works shall be integrated with the following other construction works:

- Roading and Streetscape
- Water / Sewer
- Community and Recreation
- Land Rehabilitation
- Stopbanks (ECan)
- Social Support Initiatives

It was planned that most of the stormwater physical works will be undertaken as part of the roading packages, however, some individual packages may be released for pump station and basin repair work.

FUTURE PLANNED WORKS

Any future planned works as set out in the AMP or LTCCP in the area of repairs or replacement works were identified. Consideration was given to bringing these works forward instead of undertaking repair work.

The following proposed and possible future works were considered:

- Peraki Street / Ohoka Road stormwater upgrading – unaffected by earthquake or recovery works
- Beswick Street Pump Station – planned for upgrading originally during the 2010/11 financial year but this has been deferred due to the earthquake.

- McIntosh Stormwater Treatment System – proposed future system to be funded partly by developers and partly by Council – considered in evaluating options for Feldwick Catchment recovery works
- Kairaki Stormwater Systems (Waimakariri Outfall and Featherstone Drain) – in discussions with ECan regarding future planned works for stopbank upgrading and possible opportunities to improve stormwater system

3.2.5 CONSENTING REQUIREMENTS

CONSTRUCTION ACTIVITIES

Resource consents were obtained for the following construction activities:

- CRC110883 – Works within the beds and margins of waterways.
- CRC110884 – Diversion of surface water.
- CRC110885 – Discharge of stormwater containing contaminants to surface water during the construction phase.

An Environmental Management Plan was prepared that the contractors will be required to implement to ensure compliance with the consent conditions.

PERMANENT WORKS

It was proposed that the permanent works would come under the existing consent or existing use right of the existing infrastructure. Therefore like for like replacement will be covered by the existing discharge rights. If the system was significantly modified or a new discharge outlet is proposed, the consenting requirements would need to be confirmed with ECan.

Repair and replacement of existing as well as new infrastructure within 20m of any flood defence structure will require consultation and approval from ECan River Engineers. Replacement and repair of the outfall pipes to the Kaiapoi River fall into this category.

3.2.6 OPTIONS

The assessment of the earthquake damage and development of options was planned to be undertaken in the following process for assessment reporting:

- Scoping Report
- Issues and Options Report
- Design Report, including Construction Drawings and Specification
- Completion Report

In the issues and options report phase the following options following principal replacement options were considered for stormwater network:

- Replace existing system
- Replace existing system to ECOP level
- Construct new system to comply with ECOP
- Construct new system to comply with ECOP and provide stormwater treatment

Additionally the following replacement options were considered for stormwater facilities (e.g.: pump stations, basins):

- Do nothing
- Do minimum - maintain and monitor
- Repair
- Replace

Issues and Options reports and some Design Reports were prepared prior to the red zoning of large areas of Kaiapoi, The Pine Beach and Kairaki, however the main physical works had not commenced. Consequently the recovery strategy for stormwater works was revised.

4 REVISED STRATEGY

Following the announcement of the red zoning of large areas of Kaiapoi, The Pines Beach and Kairaki, it was necessary to revise the strategy and develop a new stormwater strategy document. The revised strategy which is currently being developed has been based on the previous relevant Issues and Options reports, as in most cases the options developed under the original strategy still applies to areas in the green zones and some areas boarding the red zones. However, in the red zones the previous options are unlikely to be still relevant depending on the ultimate use of this land.

The red zoning does provide potential opportunities for improvement of the stormwater network, mainly in terms of stormwater management areas that may be possible in the red-zoned areas. While it is not possible to determine whether or not they will be feasible and affordable at this stage, the revised strategy has considered the following two options:

- Option A assumes that red-zoned land not currently owned by the Council will not be available for stormwater purposes
- Option B assumes that it will be possible for Council to acquire red-zoned land for stormwater management use.

The underlying assumption is that the red zones will be fully retreated, however there is no certainty as the future form or use of this land. It is planned that these options will enable Council to be in an informed position, once CERA has turned its attention to the future use of the red zone areas.

5 LESSONS LEARNT

Through this process to date Council has learnt the following key lessons with regard to asset management:

- **Good asset data** – The recovery work highlighted need to have good asset data both in terms of quantity and quality of the data. It was found that numerous stormwater pipes that were damaged were not included in Council's GIS system and consequently not specifically itemised in the valuation report or covered by the Local Authority Protection Programme (LAPP) Fund. Prior to the earthquake the cost of data collection was seen to be expensive, however after the earthquake the true value of this information was clearly evident.

  Additionally the need to improve the quality of the data set was evident. For example while good information was available on a pump stations mechanical and electrical equipment, limited information was available on levels of platforms and surrounding ground to establish the amount the pump station structure had moved. Similarly open drains were recorded with average dimensions and did not detail variation in cross section along the length or locations of retaining walls and other structures. This made it difficult to determine changes to the drain and also meant that the replacement value of the retaining wall was not covered in the valuation report.

- **Revaluation Approach** – The replacement costs included in the Council most recent valuation report were found to be insufficient to cover the actual replacement cost follow a major disaster. The cost of civil construction work increased by approximately 30% in the District immediately after the earthquake, although the current market is still volatile. Council has therefore separated its revaluation work to cover replacement cost for the purposes of depreciation funding and replacement cost for the purposes of insurance funding.

- **Future Resilience** – The main changes made to the decision process when considering future resilience are location of the asset in relation to areas of potential liquefaction and lateral spread, depth of pipework to allow efficient repair following an earthquake (i.e.: the repair of deep pipework was restricted by the high groundwater level and unstable soils after an earthquake) and installation of geofabric wrap on the joints of PVC pipes to prevent silt entering pipes during or after an earthquake event.

6 CONCLUSION

The areas of Kaiapoi, The Pines Beach and Kairaki suffered the damage predominantly in areas prone to liquefaction and lateral spread. The damage to the stormwater infrastructure was predominantly caused by liquefaction and lateral spread, although some shaking damage occurred to concrete structures. Some of this damage was observable from above ground however most of the infrastructure required CCTV inspection or more detailed condition surveys to confirm the extent of damage.

The strategy developed for the stormwater recovery works was comprehensive as it considered not only earthquake damage, but also existing and future deficiencies, integration with other works, including social support initiatives and consenting requirements and funding requirements. The strategy ensured the most appropriate recovery options were proposed for the stormwater system, albeit that these works will now need to be revised based on the red zoning. The stormwater strategy is currently being revised to enable Council to be in an informed position once the future use of the red zone is announced. In the interim Council is proceeding with recovery works in the surrounding green zones.

ACKNOWLEDGEMENTS

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REFERENCES

Ministry for Environment (MfE) Climate Change Effects and Impacts Assessment – A Guidance Manual for Local Government in New Zealand (2nd Edition) May 2008.

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