Rain Rain Go Away, and Don't Come Back Some Other Day: Rebuilding Earthquake Damaged Stormwater Infrastructure in Christchurch

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Keywords: Stormwater, Christchurch, earthquake, rebuild, resilience, level of service

SUMMARY

The SCIRT alliance is responsible for the rebuild of Christchurch's horizontal infrastructure following the 2010 and 2011 earthquakes. Its stormwater objective is "to return the Land Drainage network to a condition that will facilitate the provision of levels of service that were provided prior to the 4 September 2010 earthquake."

SCIRT's rebuild approach has moved from an initial intervention point approach whereby all defects above a damage threshold were repaired, to a Level of Service approach. This requires SCIRT designers to understand pre- and post-earthquake drainage performance, and to evaluate how the network's level of service can be improved through their designs. This paper examines the processes SCIRT employs.

Damage to stormwater assets is evaluated through information collated from various spatial databases, pipe condition assessments, and sources such as pre-earthquake asset records and observed post-earthquake flooding; with all this information stored in shared software systems. Based on local site conditions, design standards that are being continually improved and refined, and the underlying drive for best-value solutions, SCIRT designers are producing resilient solutions that return Christchurch's stormwater system to pre-earthquake levels of service. Where appropriate, this may include deferring non-critical repairs while, on the other hand, out-of-scope works may be incorporated.

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1. INTRODUCTION

1.1 Christchurch's Stormwater Network

Christchurch's stormwater network is made up of a primary system of kerb and channel, sumps, pipes, swales, open channels and some pump stations, along with a secondary system of overland flow paths through roads and reserves. Christchurch City Council's (CCC) GIS records indicate the network comprises some 1000km of stormwater pipes, although it is estimated that a further 200km of pipes are not recorded in the database.

Stormwater catchments predominantly drain under the influence of gravity. Most drain to the Avon and Heathcote rivers or the Estuary, into which both rivers flow, see Figure 1. Gravity systems are complex in Christchurch due to our low-lying and relatively flat ground. Ground levels range from a reduced level (RL) (to Christchurch Drainage Datum) of around RL 15m at the head of the Avon River in the west, to below RL 10m in the lower reaches to the east. For comparison, the mean sea level is RL 9.3m, and a 5-year high tide is RL 10.8m.

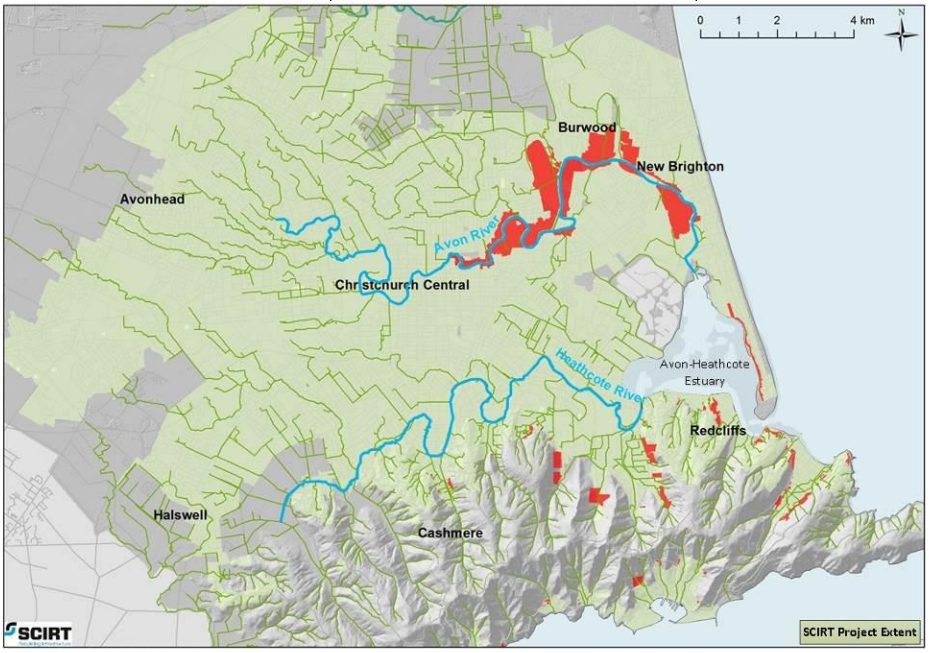


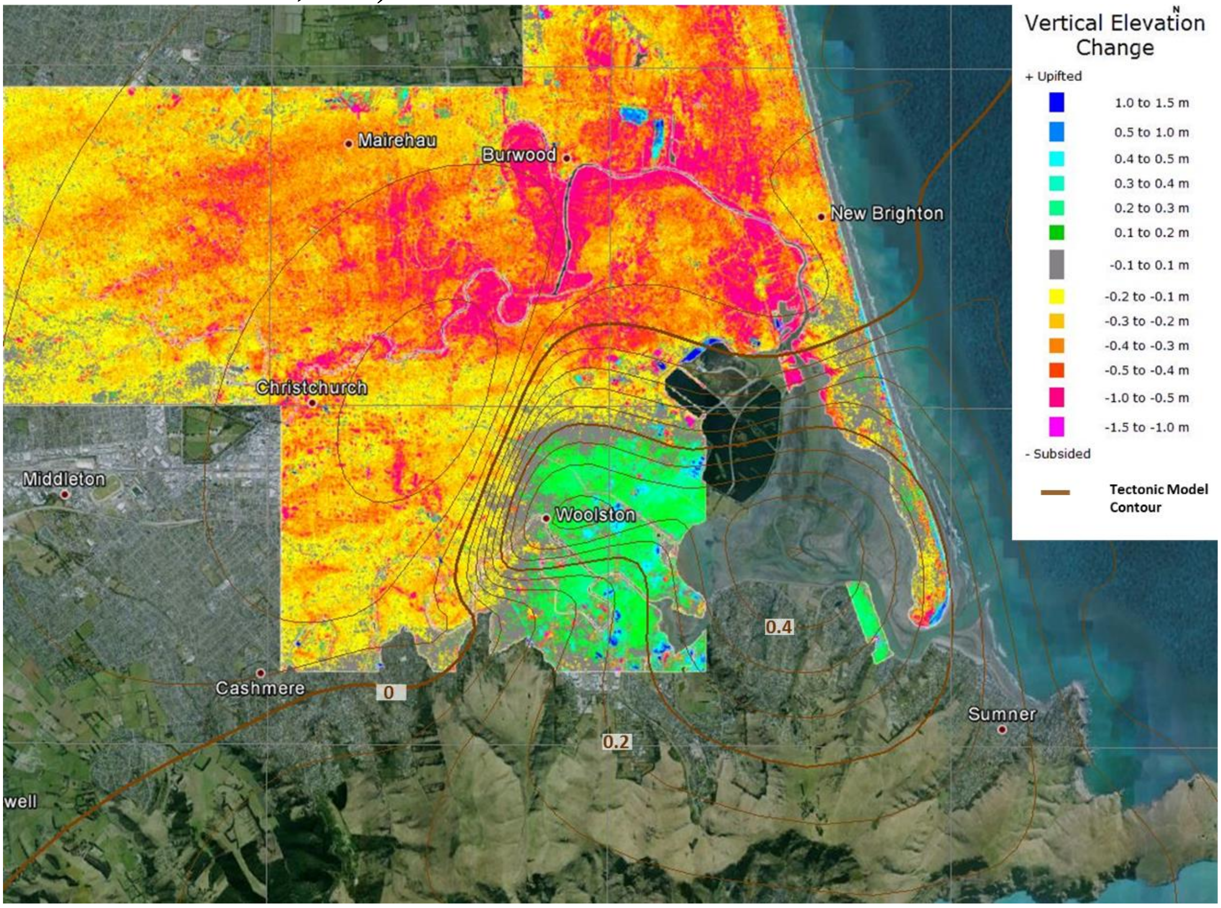
Figure 1: Map of Christchurch’s watercourses, overlain with the geographical extent of the SCIRT project (the green-shaded area- see Section 2) and the CERA Red Zones (red-shaded areas – see Section 5.2.3)

The recorded stormwater gravity pipes in Christchurch range in size from subsoil drains of less than 150mm diameter to pipes of 2.1m diameter. 60% of the pipework is between DN (nominal diameter) 225 and DN375, with 25% between DN450 to DN900. Approximately 70% of the pipework is reinforced concrete rubber ring jointed pipe (RCRRJ). Other pipe materials, in order of prevalence, include polyvinyl chloride unplasticised (PVC-U), asbestos-cement, unreinforced concrete pipe, earthenware, and a small amount of polyethylene (PE) and brick barrel.

1.2 The Impact of the 2010 and 2011 Earthquakes

The earthquakes of 2010 and 2011 caused severe damage to the city’s horizontal infrastructure (i.e. the water, wastewater and stormwater systems, along with the roading network). The cost of the SCIRT infrastructure rebuild is expected to be $1.8 billion; the damage to gravity pipe systems is approximately 50% of this cost, and this damage is focused in the eastern suburbs. Besides physical damage to the assets themselves, vertical ground movement was widespread; caused by both tectonic movement and differential settlement. Areas of the Port Hills have experienced up to 0.5m tectonic uplift, whilst areas near the Avon River have experienced 1.0m subsidence, refer to Figure 2. This degree of movement has had significant implications for gravity drainage in both the wastewater and stormwater systems.

Figure 2: Vertical ground movement from 2010 and 2011 earthquake events (Canterbury Geotechnical Database, 2013)



Challenges faced by the stormwater systems after the earthquakes include:

- Damaged pipes, blocked pipes and outlets, missing or broken flap valves
- Silt ingress into pipes and sumps, causing blockages and a reduction in pipe capacity
- Road drainage being impeded, changes to secondary flow paths, and sumps no longer being positioned at low points
- Properties no longer being able to drain to the road
- Land settlement reducing the capacity of stormwater reticulation
- Land settlement affecting the ability of land drainage at extreme high tides

See Photograph 1 for an illustration of the impact of this damage.

Photograph 1: Post-earthquake flooding on Beresford Street, New Brighton, in January 2013. Flooding was during a low intensity storm and high tide event, in a catchment that had experienced land settlement of up to 1.0m and severe damage to the stormwater reticulation

1.3 This Paper

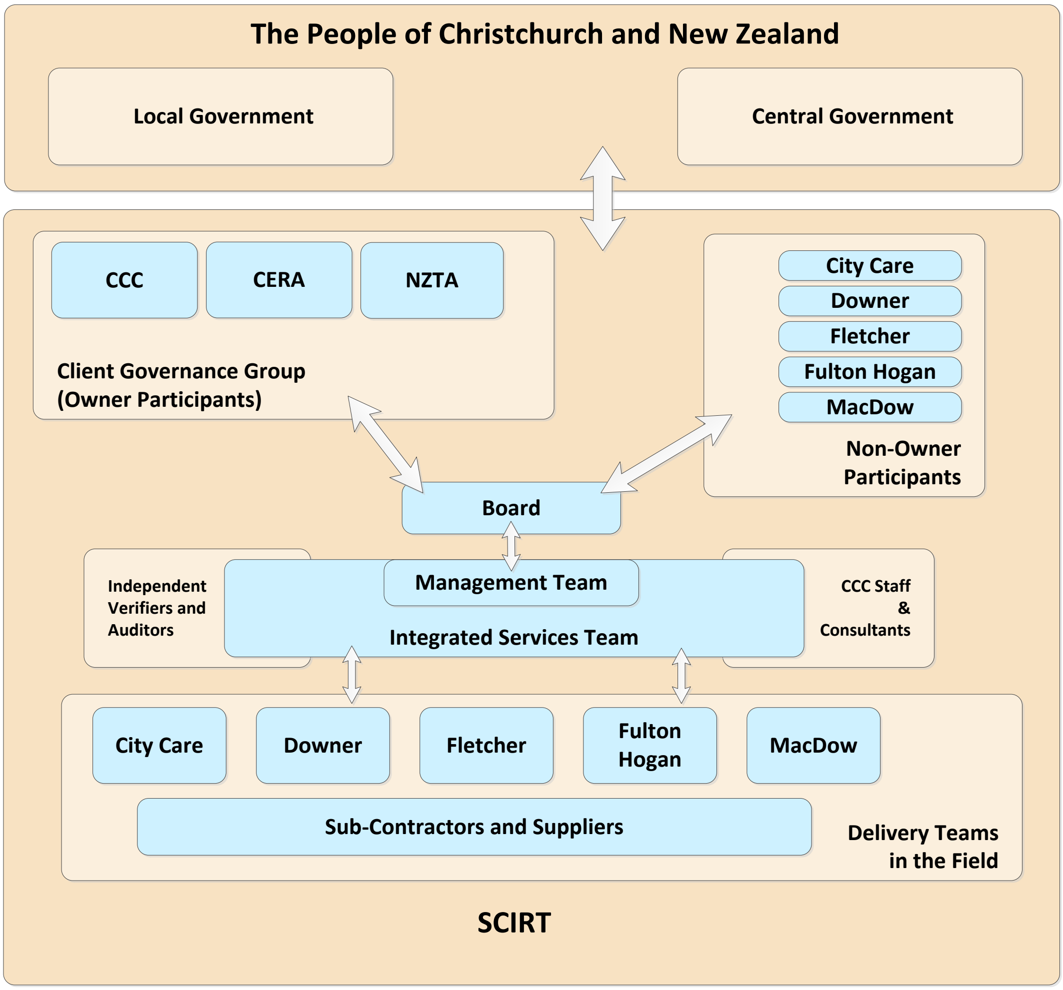
This paper examines the processes through which the stormwater system is being repaired and rebuilt, along with some of the decision-making involved, the on-going evolution of standards, and the solutions that have been adopted. It will use examples from a range of SCIRT projects to illustrate how best-value resilience has been incorporated into stormwater design.

2. STRONGER CHRISTCHURCH INFRASTRUCTURE REBUILD TEAM

2.1 Organisational Structure and Purpose

The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) alliance was created in September 2011. It consists of three *Asset Owners* – CCC, the Canterbury Earthquake Recovery Authority (CERA) and the New Zealand Transport Authority (NZTA); along with five *Non-Owner Participants* (the Delivery Team Contractors) – City Care, Fletcher Construction, Fulton Hogan, McConnell Dowell, and Downer. In addition, staff from engineering design consultancies (as well as CCC staff) service the alliance. All of the approximately 250 personnel work together as the Integrated Services Team (IST), housed in a single purpose-built building in the west of the city. The organisational structure is shown in Figure 3. The IST aims to operate as a high performing team; and its structure, processes, and culture are based around this concept.

Figure 3: SCIRT Organisational Structure



SCIRT's stated purpose is "creating resilient infrastructure that gives people security and confidence in the future of Christchurch". This statement is the cornerstone for any work in SCIRT and is regarded as its underpinning goal. With a limited taxpayer-funded budget, all SCIRT design decisions need to include careful consideration of what value they are adding to Christchurch. The intention is that SCIRT's values, mindsets and behaviours create a work environment that challenges business-as-usual in order to achieve SCIRT's purpose in a best-value manner.

SCIRT's geographical range for the rebuild is shown shaded in green in Figure 1, largely reflecting the CCC city boundaries, and it is envisaged that SCIRT's work will be complete in 2016, with the rebuilt assets handed over to the asset owners.

2.2 In-house Sharing of Best Practice

SCIRT has several organisational processes in place to assist designers. These include technical groups, asset owner representatives, technical advisors, asset champions, and Delivery Team early contractor involvement (ECI).

Various **technical groups**, such as the stormwater land drainage technical group**,** are technical forums to utilise the shared knowledge of the SCIRT design teams. The groups share lessons learnt, investigate innovations, prepare standard details and resolve technical issues. The groups integrate the knowledge of the wider SCIRT team, and support designers. The groups are expected to be output-driven; a solution to all topics must be found and communicated to the wider team.

The **asset owner representatives** liaise between SCIRT and CCC and provide guidance on scoping and concept design. The **technical advisors** are representatives of CCC; their role is to guide and mentor SCIRT designers. They check compliance with minimum design standards and provide comments on design. The **asset champions** drive achievement of the SCIRT level of service design approach. They have information on level of service indicators and an understanding of the network level of service performance. They coordinate CCC operation and maintenance interviews, and challenge workshops to support designers in achieving the best value design solution for projects.

Early contractor involvement is required at SCIRT for concept and detailed designs; the purpose being to provide construction input into the design process to ensure constructability opportunities, issues and risks are identified and taken into consideration. The process shares ideas across all delivery teams, and facilitates collaboration between designers and contractors to deliver the best value solution.

2.3 SCIRT Stormwater Objective

Within SCIRT's overall purpose, the stormwater objective is "to return the Land Drainage network to a condition that will facilitate the provision of levels of service that were provided prior to the 4 September 2010 earthquake." This includes assessing the damage, understanding the effect of the damage on the stormwater systems' level of service, and designing the repair or renewal of the pipe system, inlet and outlet structures, and pump stations. It also requires the re-establishment of flood protection and maintenance activity to pre-earthquake levels, and the mitigation of increased flood risks caused by the earthquakes.

This requires consideration of current design standards, multi-value based stormwater management, coordination with other rebuild works, opportunities where appropriate for deferral of repairs, opportunities for cost efficient betterment of systems, and infrastructure resilience to future changes.

Performance of the stormwater network under normal conditions, and service during and following extreme events is considered. Resilience is considered for not only future earthquake events, but also other natural disasters and hazards, climate change, future land use changes, and operational and maintenance requirements.

The cost of the stormwater system rebuild is expected to be approximately $200 million. To date, the design of around half of this work has been completed.

3. THE STORMWATER SYSTEM REBUILD

3.1 Emergency Works

Immediately after the earthquakes, the focus of the infrastructure recovery was on public health: re-establishment of water supply service and then wastewater conveyance, to the extent that, in some instances, the stormwater system was used to provide wastewater overflow points. The extent of damage to the stormwater network was only made clear after storm and high tide events; particularly when these occurred concurrently. Although no severe storm events have been experienced post-earthquake, storms of 1-year and 2-year return periods have resulted in severe flooding causing road closures, and ingress into private properties.

As an initial response, emergency works to restore some drainage service and reduce the effect of the damage to the network included:

– Installation of flap gates or steel plates on outlets to prevent tidal inflow during high tide events (see example in Photograph 2)

– Concrete infilling of pits near waterways to stop tidal inflow during high tide events

– Temporary pumping to manage severe ponding

– Emergency stopbanking activities to inhibit tidal inundation of low-lying land

Photograph 2: Steel plate positioned to block a stormwater outlet within the tidal reach of Avon River, New Brighton, to prevent tidal inflow

3.2 Initial 'Intervention Point' Approach

Following the establishment of SCIRT, CCC developed the Infrastructure Recovery Technical Standards and Guidelines (IRTS&G) to "inform and guide the technical assessment of damage, the design and construction of the repair and renewal of Christchurch City Council-owned infrastructure as well as hand over back to Council." This document outlines SCIRT's scope, objectives, condition assessment tools, and design philosophy.

The IRTS&G defines *intervention points* (damage thresholds) that describe what defects and damage to the stormwater system should be repaired, and the standards to which the work should be designed. Through condition assessment tools, defects were identified and all those exceeding defined damage thresholds were scheduled for repair. Pipes that required renewals under the IRTS&G were renewed to restore pre-earthquake capacity and drainage service to their contributing runoff catchment. For the most part, this approach has resulted in like-for-like replacement of severely damaged pipes.

3.3 Current 'Level of Service' Approach

From 2013, SCIRT's rebuild approach has moved from the 'condition based' intervention point approach to a Level of Service approach across the city (assessed at a network level). Targeted repair work or alternative solutions for projects are evaluated, based on their effect on the network.

In so doing, this approach more closely aligns with SCIRT's level of service-based stormwater objective (as described in Section 2.3).

The advantages of this approach are: design work is able to be assessed based on its effects on the network; through targeted works there is a potential reduction in the overall rebuild cost to ratepayers/taxpayers; it encourages a better understanding of the levels of service that are being achieved throughout the city; and remaining asset life is being utilised where practical. It does however mean that some damaged assets, which are not affecting the overall network level of service, will remain unrepaired once SCIRT's work is completed.

The level of service approach is based on the following indicators:

– Capacity (20% annual exceedance probability (AEP) storm kept within kerbs, 10% AEP storm kept within back of footpaths, 2% AEP storm kept out of house platforms)

– Breaks and blockages

– Average remaining asset life

– Maintenance impact

– Renewals impact

These indicators are evaluated for each project and compared to the levels of service achieved prior to the earthquakes. Essentially, SCIRT designers must not only understand the current drainage system (and its deficiencies) and understand what has changed due to earthquake events (and therefore understand pre-earthquake conditions), they must also understand the implications of any proposed works.

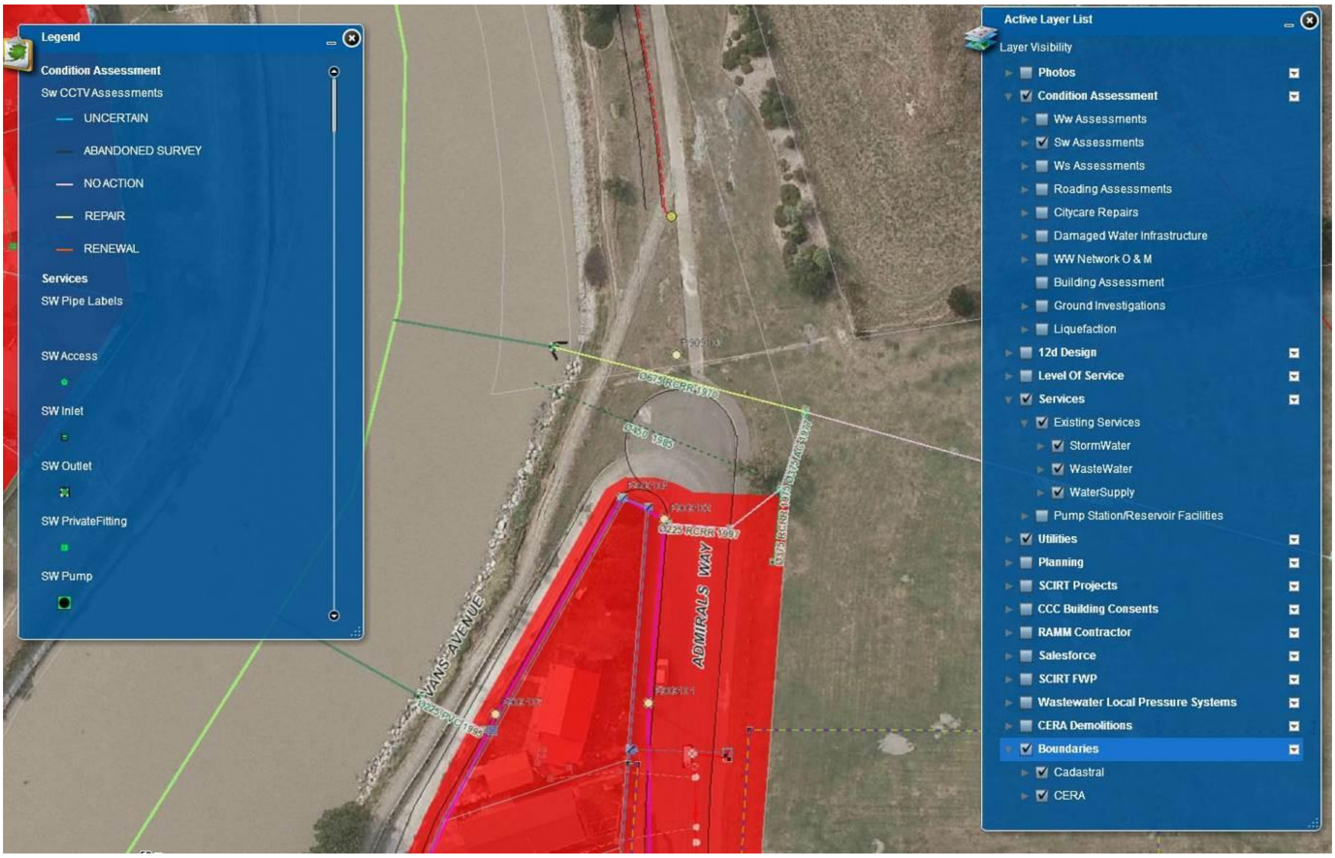
The level of service approach makes provision for adding resilience and assessing out-of-scope works. Any proposed designs that would involve out-of-scope work or incorporate elements of resilience and betterment to the pre-earthquake network are passed to the asset owners for consideration. The asset owners may then approve the designs where an integrated solution would provide a better value solution. For all design work, the IRTS&G objective of "where reasonably possible and economically viable, build greater resilience into the infrastructure networks" still applies.

4. ASSET DAMAGE ASSESSMENT

4.1 General Asset Information

SCIRT designers obtain asset information from a range of sources. CCC, CERA, City Care, The Earthquake Commission (EQC), Environment Canterbury, GNS Science, Land Information New Zealand (LINZ), Port Hills Geotech Group, and several other organisations provide information and data to SCIRT. Once obtained, SCIRT's GIS viewer is used to spatially represent this data in an accessible and informative way (see Figure 4).

Figure 4: Example aerial plan seen in SCIRT's GIS Viewer interface. Layers shown include stormwater, wastewater and water supply assets, utilities, CERA Red Zones, and stormwater CCTV condition assessment



Other important sources of information include site visits, site-specific geotechnical investigations, roading asset condition data (including Road Assessment and Maintenance Management, RAMM), flood complaints, existing design drawings from CCC archive, details of the emergency works undertaken, post-earthquake repair works by City Care, and the personal knowledge of CCC design, operation, and maintenance staff.

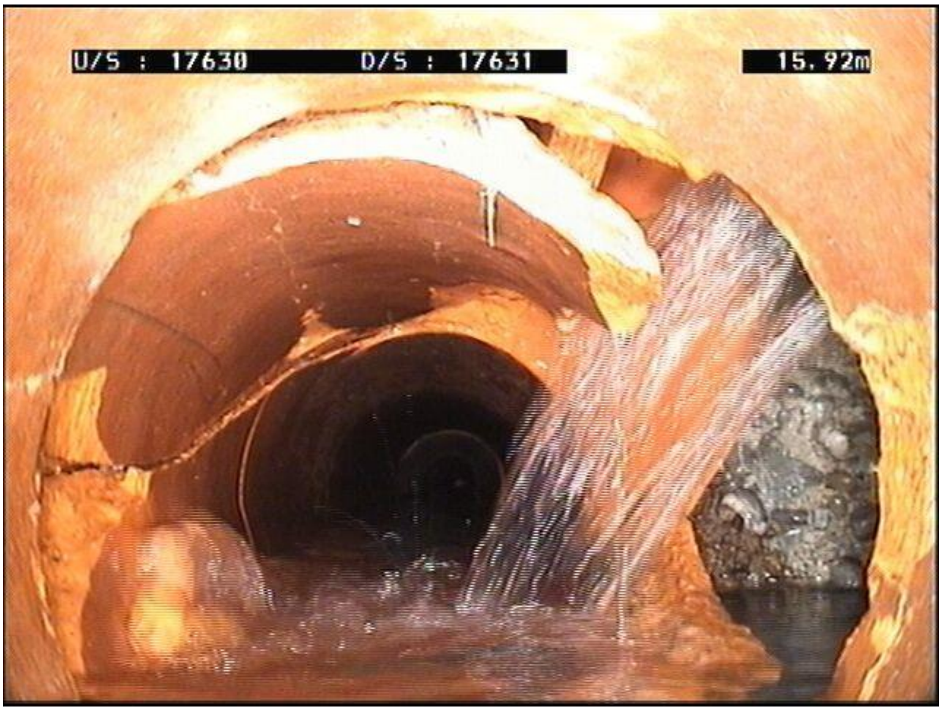
4.2 Pipe Condition Assessment

The SCIRT assessment team collects information to allow functional and structural assessment of pipes. For stormwater assets this includes primarily: CCTV (closed circuit television), Pole Camera, manhole level survey, and the Pipe Damage Assessment Tool (PDAT) as described in the following paragraphs.

CCTV

CCTV has been used extensively to investigate the structural condition of pipes. CCTV footage standards and assessment criteria are based on the New Zealand Pipe Inspection Manual (NZPIM). To date, some 450km of stormwater gravity pipework have been examined by CCTV (see Photograph 3 for an example). CCTV operations also provide the additional benefit of cleaning the pipe in situations where liquefied silt and debris have been deposited, causing blockages and a reduction in pipe capacity.

Photograph 3: CCTV footage identifying a significant defect in a DN150 earthenware pipe



Pole Camera

Pole Camera (a camera mounted on a pole) is used on short stormwater pipes to ascertain whether significant defects are either clearly evident or absent. After insertion into a manhole, the camera is zoomed along the pipe length, to obtain images. The method is also used above-ground to pan above the pipe and the manholes, providing the designer with more asset condition and site attribute information. It is significantly (approximately 75%) cheaper than CCTV survey.

Manhole Level Survey

Manhole level surveys are used to determine pipe inverts and pit lid levels, which can be used for grade assessment and hydraulic modelling. Whilst in the field, the surveyors can also verify the location and alignment of pipes, pipe diameter and pipe materials, as well as identifying assets not previously recorded in CCC's GIS database. At the completion of SCIRT works, CCC will have been issued with a comprehensive asset database.

Pipe Damage Assessment Tool (PDAT)

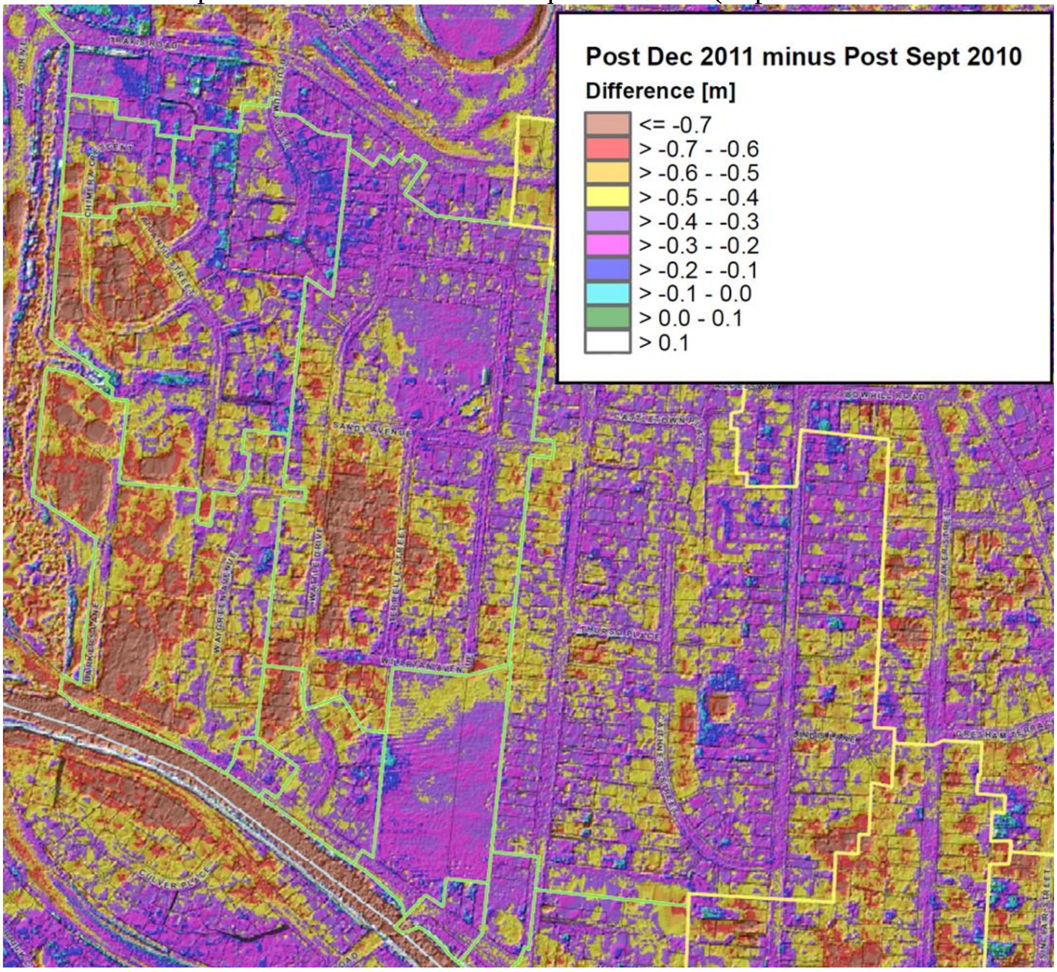
The PDAT (a multi-criteria analysis tool) is an innovative methodology developed by the SCIRT team to predict the structural condition of pipe assets based on previously completed CCTV surveys in similar situations, in combination with other damage predictors such as pipe depth, material, diameter, direction, local RAMM data, LRI, proximity to waterways, and subcatchment area. The fundamental benefit of PDAT is that it reduces the reliance on costly and time-consuming CCTV surveys; a good example of the best-value approach being developed by the SCIRT team.

4.3 Ground Level Assessment

LiDAR (Light Detection and Ranging remote measurement technology) ground level information is used to show land topology (current and historic), and to analyse ground movement. LiDAR datasets are available for most of Christchurch for several pre- and post-earthquake dates, enabling comparative ground movement between events to be established. Where more detailed level information is required, topographic surveys are undertaken by the SCIRT Asset Assessment Team.

This topographic information is used to identify drainage paths and subcatchment boundaries, identify low-lying areas of land, and for stormwater hydraulic modelling. Critically, the comparative data identifies how drainage patterns have changed as a result of the earthquake events. As clearly illustrated in the example image shown in Figure 5, differential settlement of up to 700mm has occurred, significantly altering drainage paths and the ability of the land to drain.

Figure 5: LiDAR comparison map, overlain with subcatchment boundaries, showing ground movement of up to 700mm between earthquake events (September 2010 – December 2011)



5. DESIGN OF STORMWATER SYSTEMS

5.1 Design Standards

A number of documents define the stormwater design standard for SCIRT. The documents include (in order of precedence):

– *Infrastructure Recovery Technical Standards and Guidelines* (IRTS&G) (current version 3.1 December 2012)

– *CCC Waterways, Wetlands and Drainage Guide* (WWDG), (2003, revised December 2011) – describes CCC's waterways, wetlands and drainage philosophy

- *CCC Infrastructure Design Standards* (IDS) (January 2013) – standards applying to the design of infrastructure assets in Christchurch

- *CCC Construction Standard Specifications* (CSS) (including earthquake amendments February 2012) – set out CCC's technical requirements for construction works

- *CCC Approved Materials List* (current May 2013) – details the current materials approved for use in CCC infrastructure assets

- *CCC Surface Water Strategy (2009) – CCC's goals and objectives for surface water management in Christchurch*

It can be seen that most of these documents have either been developed in response to the earthquake events (e.g. the IRTS&G), or have been revised and re-issued in the light of the events. This revision process is on-going; for example, the IRTS&G is being updated and re-issued on a six-monthly basis, and still has some standards, intervention points and guidance yet to be completed.

Any deviations from these standards require a Scoping and Standards paper to be submitted for approval by the SCIRT Asset Owners. These papers often address areas where the IRTS&G and the CCC standards are incomplete, and approved papers are considered for incorporation into them. In this way, the design standards are continually being improved through a collaborative process of refinement and enhancement.

5.2 Design Coordination

5.2.1 Site-Specific Attributes

To determine the most appropriate and best-value solutions, SCIRT designers consider site-specific attributes. Important aspects to consider include the asset's environment, pipe-specific information, and land use:

Asset Environment – soil type, groundwater level, groundwater corrosivity.

Pipe Specifics – pipe depth, pipe position in stormwater system (e.g. is pipe serving only a single sump, at the upstream end of the stormwater system, functioning as a bubble-up system, or is the pipe critical?), pipe function (e.g. infiltration and exfiltration may be a component of the pipe's function), other dependent pipes (e.g. laterals or downstream pipes), location of surrounding services and utilities.

Land Use – contributing runoff catchment, land zoning, traffic loading, roading hierarchy (e.g. is the pipe serving a major road or lifeline?), future land use and land drainage changes.

The consequences of asset failure and the performance of the system during extreme events need to be taken into account. SCIRT designers need to ascertain what really matters to the stormwater system in their project. Questions SCIRT designers ask are:

– What will happen during extreme events? Where will this ponding occur (in private land, the road network, or public reserve)? What will be the depth and extent of flooding?

– Will asset failure result in nuisance or dangerous ponding? Where will this ponding occur (in private land, the road network, or public reserve)? What will the depth and extent of flooding be?

– Will asset failure cause damage to other assets? For example stopbanks, road carriageways, or private property.

5.2.2 Integrated Design

Integration of stormwater land drainage design with roading design is critical. Because roads provide a drainage path, changes to roading alignment, grades and falls can significantly affect the requirements for piped stormwater assets. Coordination of works (completing all the rebuild works for an area in one pass) to reduce the overall disruption and rebuild cost is also important. If, because of differential land settlement, overland flow path characteristics have been detrimentally affected in the vicinity of a damaged pipe, there may be a benefit in installing a larger new pipe, or additional pipes and inlet sumps.

The level of service approach requires SCIRT designers to evaluate the effect an integrated design solution will have on the network. The best value solution (that which provides the greatest improvement to the network level of service) may not be to repair or install new piped reticulation. For example, a combined pumping and storage option has been designed in South New Brighton to provide reinstatement of the system's capacity (a level of service indicator). Another example is the incorporation of out-of-scope assets in Shirley where works to watercourses and culverts provide a more cost effective means to provide adequate system capacity than solely works to the stormwater reticulation.

Rationalisation of assets may also provide the best value solution; for example, where there are undersized assets adjacent to the piping system under consideration, or where there are multiple neighbouring outfalls. The risk of future damage and repair costs of these assets will be reduced by having fewer, but upgraded assets, while the required on-going maintenance effort will also be reduced. In both Mt Pleasant and Beachville suburbs, SCIRT projects have reduced the number of outfalls through new seawalls to provide these benefits.

Maintenance requirements of the existing network and any proposed designs are considered by SCIRT designers for normal conditions as well as those required during extreme events.

Opportunities for improvement include situations where access pits are positioned in undesirable locations (e.g. on private land or within the road carriageway), pipes in private land, root intrusion, and silt deposition points. Improvements may be achieved through relocation of assets, reduction in the number of assets (pipes, outlets, flap gates), and the elimination of silt deposition points through pipe grade and pit realignment.

5.2.3 CERA Red Zone land

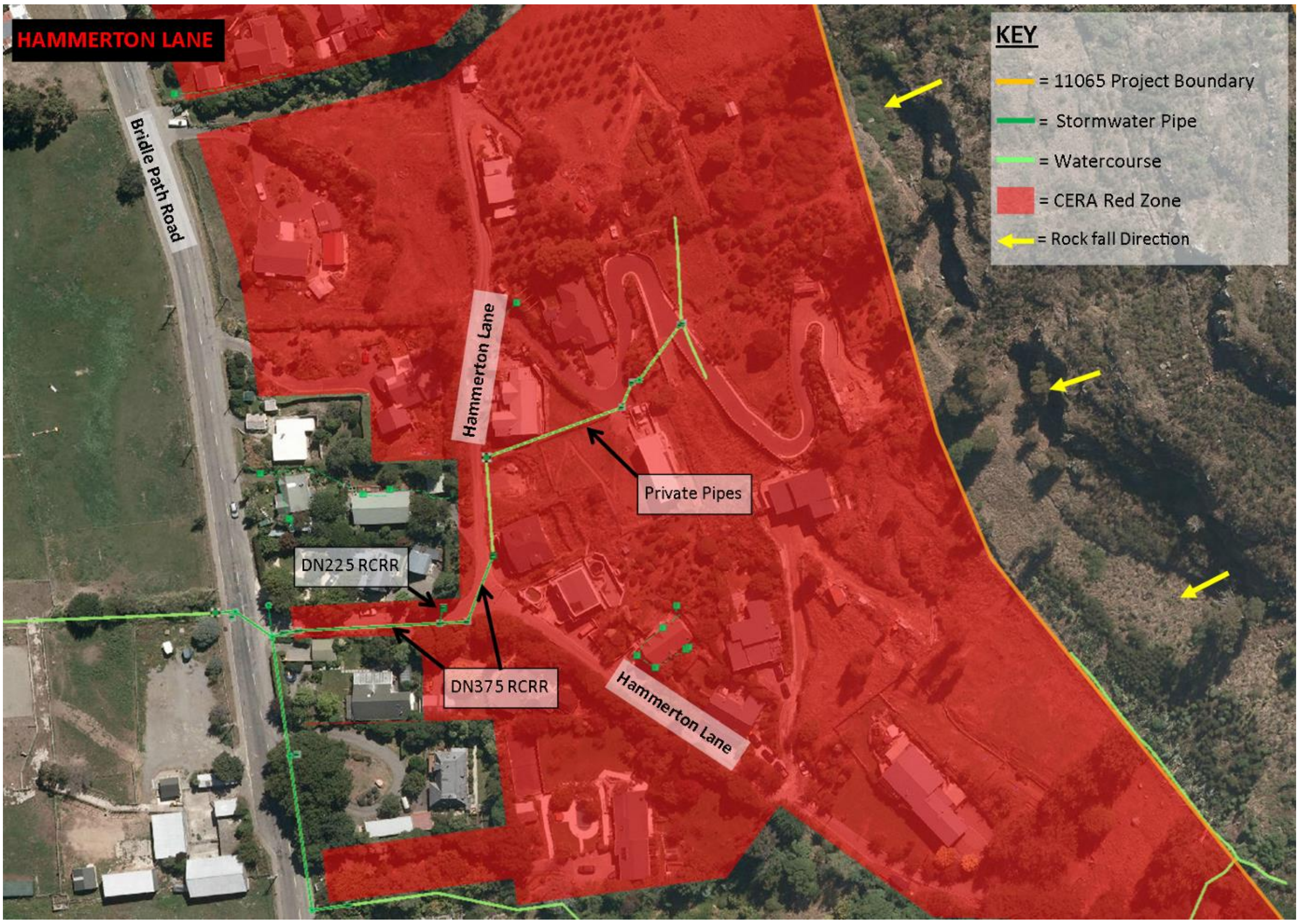
A significant factor affecting the entire SCIRT project is the CERA Red Zones; i.e. the land areas designated by the Crown as being unsuitable for rebuild (as shown in Figure 1). The bulk of this designation occurs in the eastern suburbs, in the vicinity of the Avon River or near the Estuary, where land settlement and lateral spread has been significant. Smaller pockets occur in the hill suburbs where rock fall or cliff instability is an issue.

In the case of stormwater assets within these zones, repairs are only justified if they are conveying drainage from Green Zone properties (i.e. areas where land is designated as being suitable for construction), while unnecessary pipework with Red Zones is abandoned. If drainage systems through a Red Zone are required, it may be appropriate to re-route pipework out of the zone to more stable land. Design work needs to consider the potential for negative impacts on downstream Green Zone land or stormwater systems. As shown in Figure 6, coordination may be required with other organisations in order to protect Green Zone land.

The potential future use of Red Zones needs to be considered: *residential* use would require land remediation techniques that would cause damage to piped assets (if not already damaged); while use as a *recreational reserve* is likely to see any pipeline substituted with a swale or open drain.

SCIRT designers also consider substitution of pipelines with a swale or open drain. These provide flood storage volume (increasing the system's resilience to storm events), and have ecological, recreational, and water quality benefits. In addition, they are more resilient to future events: being unaffected by the common pipes defects of cracking and displaced joints. However the lateral spread risk in a seismic event should be considered; an open channel may put adjacent land at risk. Factors that increase this risk include shallow foundation dwellings, liquefiable sands, and a high groundwater table.

Figure 6: Aerial plan of a Red Zone drainage catchment with adjoining down-gradient Green Zone properties. If pipes and watercourses within the Red Zone are abandoned, runoff will instead discharge through Green Zone properties. Thus a design solution to protect the Green Zone land is required



5.3 SCIRT Design

5.3.1 SCIRT-Developed Standards

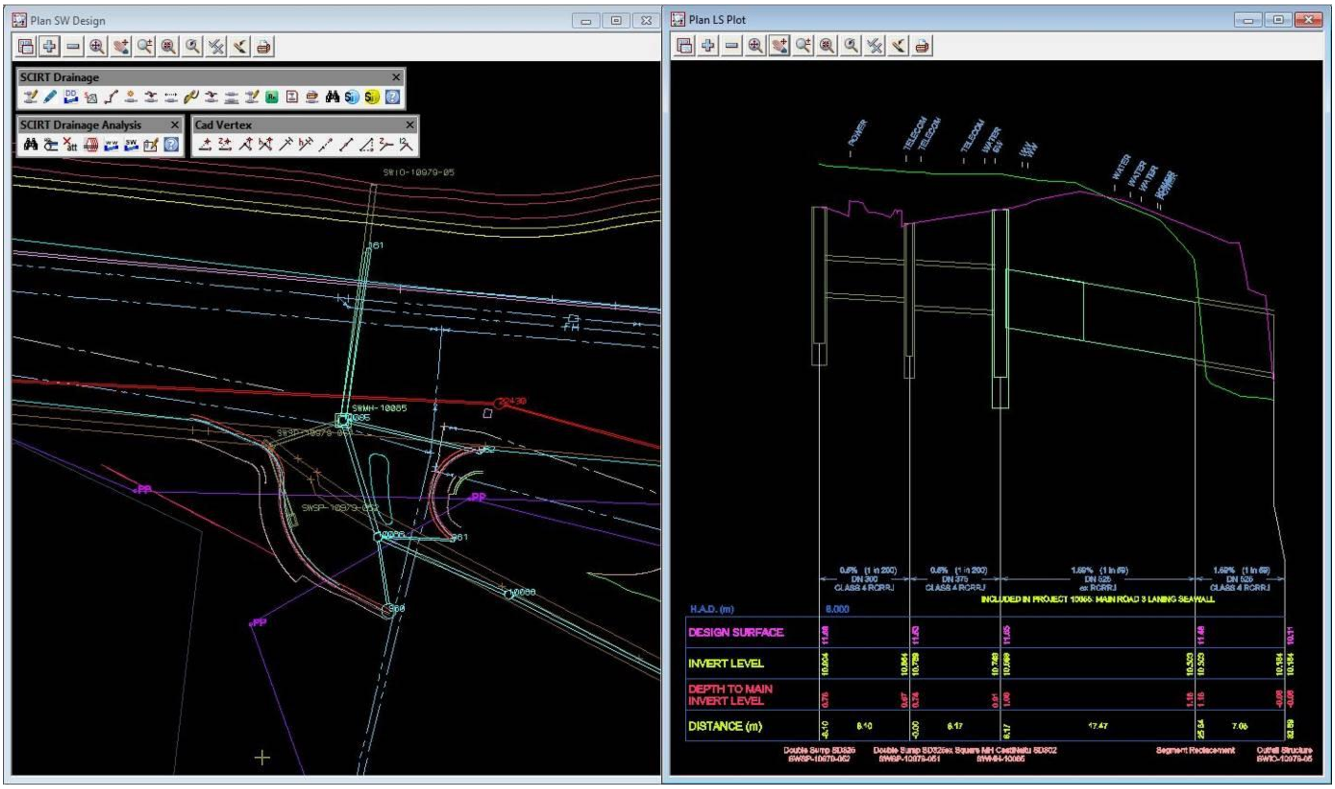
Besides the defined design standard documents, SCIRT has developed several of its own design standards.

Software

Design throughout the IST is carried out with selected software, to facilitate consistency in design process and outputs. Asset data and pipe condition assessments are stored in the SCIRT GIS viewer and in Infonet (CCC pipe condition software). Survey and existing GIS information is available in 12d (SCIRT's chosen terrain modelling, surveying and civil engineering software). Design work is completed in 12d, as illustrated in the example shown in Figure 7. 12d will eventually encompass all survey, design and as-built information, and this information will be handed over to CCC.

A SCIRT *Asset Assessment Spreadsheet* has been developed as a one-stop link to all these various asset datasets.

Figure 7: Example stormwater design using 12d software



Hydraulic Modelling

For complex projects or catchments, hydraulic modelling may be warranted. This work is contracted to external consultants. Modelling of the 20% AEP and 2% AEP events informs SCIRT designers of the issues in the stormwater reticulation and overland flow paths, the current stormwater level of service, and the change in level of service from pre- to post-earthquake. This information will be passed on to CCC for city-wide integration in the future. As such, a modelling specification has been created to ensure all SCIRT modelling meets CCC requirements.

Pipework System

As noted in Section 1.1, the majority of the stormwater network is laid in RCRRJ pipe. Due to its cost efficiency and comparatively good seismic performance in most areas, this is still the pipe material used most often for SCIRT pipe renewals and new pipes. Other less common pipe materials such as asbestos-cement, earthenware, and unreinforced concrete have not performed well in the earthquake events, sustaining considerable damage and are not being specified for rebuild works. In areas at risk of lateral spread, bank instability, or where root intrusion is a high risk, plastic pipe materials are considered for their durability and flexibility. For smaller diameter pipes (less than DN300), PVC-U may be appropriate, while for larger diameter pipes PE is considered. The additional cost of these materials is considered to be worthwhile if the risk of further damage in future earthquakes is diminished, or the risk of damage to other assets is reduced (for example, SCIRT has used PE for pipe outlets through stop banks).

For the most part, larger pipes and structures have performed better than small diameter pipes. The majority of pipes requiring renewal are less than DN300. The SCIRT standard is that all new pipes within the carriageway will have a minimum size of DN225 (as per the CCC IDS). In some situations, it may be good value to use a DN300 pipe which, with minimal additional cost, provides twice the pipe capacity.

As a SCIRT standard, double sumps are used for all new sump installations in place of single sumps (unless there is inadequate space). Double sumps, at a minimal additional cost, provide greater design flexibility and inlet capacity for larger storm events, as well as reducing the risk of blockage. Due to the additional capacity, less maintenance (and associated cost) will be required. A wavy-type grate and frame is specified for all sumps; having greater strength and capacity than standard slotted grates. In addition, they have also tested favourably for cycle safety. To ensure good value, the delivery teams are required to recover sound sump grates and frames for reuse.

Low-lying land is at risk of tidal inundation during high tide events, and low level outlets are at risk of silt deposition and migration within the piped system, causing capacity and blockage issues. To prevent this, SCIRT is installing non-return valves on all low level outlets or those with low-lying sumps in their reticulation system. Many outlets have existing flap gates but, where a new valve is required, inline check valves are specified. Issues with classic flap gates include theft, breakage, and the gates being prevented from closing by debris. Inline check valves are less prone to theft due to their position inside the pipeline and are thus also less aesthetically obstructive. They also have flushing qualities, and a longer asset life.

Pipe Repair Methods

Where more cost efficient, repairs to pipework are undertaken rather than full pipe renewal. A standard SCIRT pipe repair specification and corresponding guidelines have been developed, covering:

– Cured in Place Pipe (CIPP) lining, which is cured by ambient cure, by circulating hot water, or by introducing controlled steam within the tube

– Lining with spiral-wound profile strip, with or without grouting

– Folded PVC lining

– No Dig Spot Repair (NDSR) patching using CIPP

– Lateral Junction Repair (LJR) patches

Pipe repairs are designed to re-establish a minimum of 50 years asset life. Other guidelines have been developed for pipes that are not circular, including brick barrel assessment and rehabilitation. For stormwater, in situations where infiltration and exfiltration are not a concern, other repair methods may be considered more cost effective and appropriate. For example, SCIRT designs have detailed repairs methods such as: epoxy crack repair, installation of concrete saddles and steel plates, a concrete surround of the existing pipe, and relaying the existing pipe.

Drawings

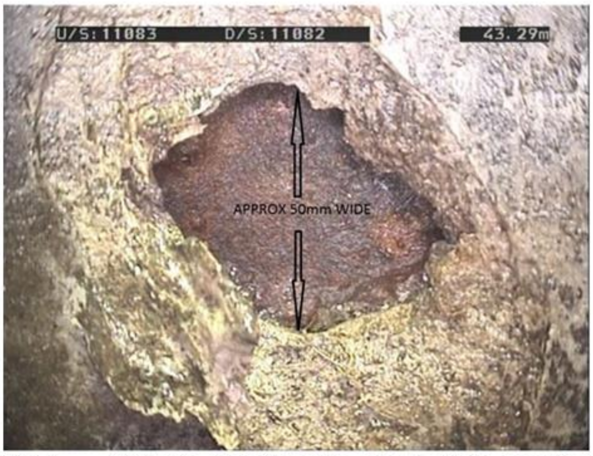
SCIRT standard drawings have been developed for stormwater repair plans and schedules, a combined stormwater and roading plan, and stormwater long sections. Specific standard details for common design features have also been prepared; these include river outfall structures, corbels for PVC-U pipes, PE pipe connections to concrete chambers, pipe bursting, shared utilities trenches, pipe embedment, large diameter manholes, and subsoil drains. These details are developed through consultation with relevant persons at SCIRT and the asset owner organisations, and approved through Scoping & Standards papers (as per the process described in Section 5.1). The standards are then available for use by all designers, and will be passed to CCC for adoption into their standards if desired.

5.3.2 Deferrals

SCIRT allows for the deferral of stormwater pipe repairs that have minor or insignificant damage; where the damage is unlikely to reduce functionality, remaining asset life or resilience of the asset. Deferral is considered if the pipe is considered as being capable of conveying storm flows for at least 15 years without problems or causing damage to other assets (for example road carriageways). Factors considered include; if a road is being restored or rebuilt as part of the rebuild, the criticality of the pipe, the effect of infiltration and exfiltration, the possibility of groundwater contamination or aggressive groundwater, pipe depth and traffic loading, and the maintenance implications of root intrusion. Examples of defects being deferred are shown in Photograph 4.

Photograph 4: Examples of deferred repairs

JF-L due to minor concrete damage at joint. IRTS&G requires repair to DN1800 pipe.



PH-L – historic repair with steel plate sealing hole prior to backfill.

Rubber ring moved but not protruding. Resulting infiltration possibly beneficial in this particular area.

Autogeneous healing possibly occurring

Deferring repairs of non-critical defects will achieve the best value outcome from the rebuild, smooth future renewal programmes, minimise boom and bust in the contracting environment and reduce the cost of finance.

Evidence for deferrals is compiled by designers and submitted through a Scoping and Standards paper for approval. Details of deferred assets are recorded into CCC systems for future works and maintenance.

5.3.3 Out-of-Scope Work

SCIRT designers, through asset investigation and design may consider options that involve work beyond SCIRT's scope (SCIRT's scope excludes private laterals beyond the street, drains, rivers, stopbanks, waterways, detention basins and treatment facilities, waterway structures, and hydrometric assets). These options will improve the network stormwater level of service, but require an extension of scope. Design solutions are presented to the relevant asset owner, usually through a Scoping and Standards paper and, if accepted, the work can either be added to SCIRT's scope, or undertaken by the asset owner.

Examples of projects that have incorporated out-of-scope works include:

- A catchment with multiple pipelines discharging to a central open drain. An option was produced that returns the flood depth and extents to pre-earthquake levels by making improvements to both the open drains (out-of-scope) and the pipe network where necessary

- A catchment assessment of the stormwater network in accordance with the IRTS&G demonstrates that the majority of the stormwater assets are beyond economic repair and complete replacement is recommended. A like-for-like replacement of the stormwater network would not meet the current CCC IDS Guideline; and therefore it is recommended that the opportunity be taken to increase some pipe sizes (betterment)

- Opportunities (beyond SCIRT's scope) for CCC to incorporate water quality improvement, and opportunities for a solution adding value to landscape, recreational, ecological, historic and cultural amenities (betterment)

- Opportunities to address known pre-earthquake capacity and flooding issues, or stormwater system enhancement to address future urban design strategy growth or land drainage changes (betterment)

6. CONCLUSIONS

The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) alliance is responsible for the rebuild of the horizontal infrastructure in Christchurch, including stormwater and land drainage infrastructure.

SCIRT's stormwater objective is "to return the Land Drainage network to a condition that will facilitate the provision of levels of service that were provided prior to the 4 September 2010 earthquake."

SCIRT's design approach is now based on a 'level of service' methodology. Targeted repair work or alternative solutions for projects are evaluated based on their effect on the city's network.

Design solutions are based on design standards, primarily:

- Infrastructure Recovery Technical Standards and Guidelines (IRTS&G)
- CCC Infrastructure Design Standards (IDS)
- CCC Waterways, Wetlands and Drainage Guide (WWDG), 2003 (revised December 2011): Describes CCC's waterways, wetlands and drainage philosophy

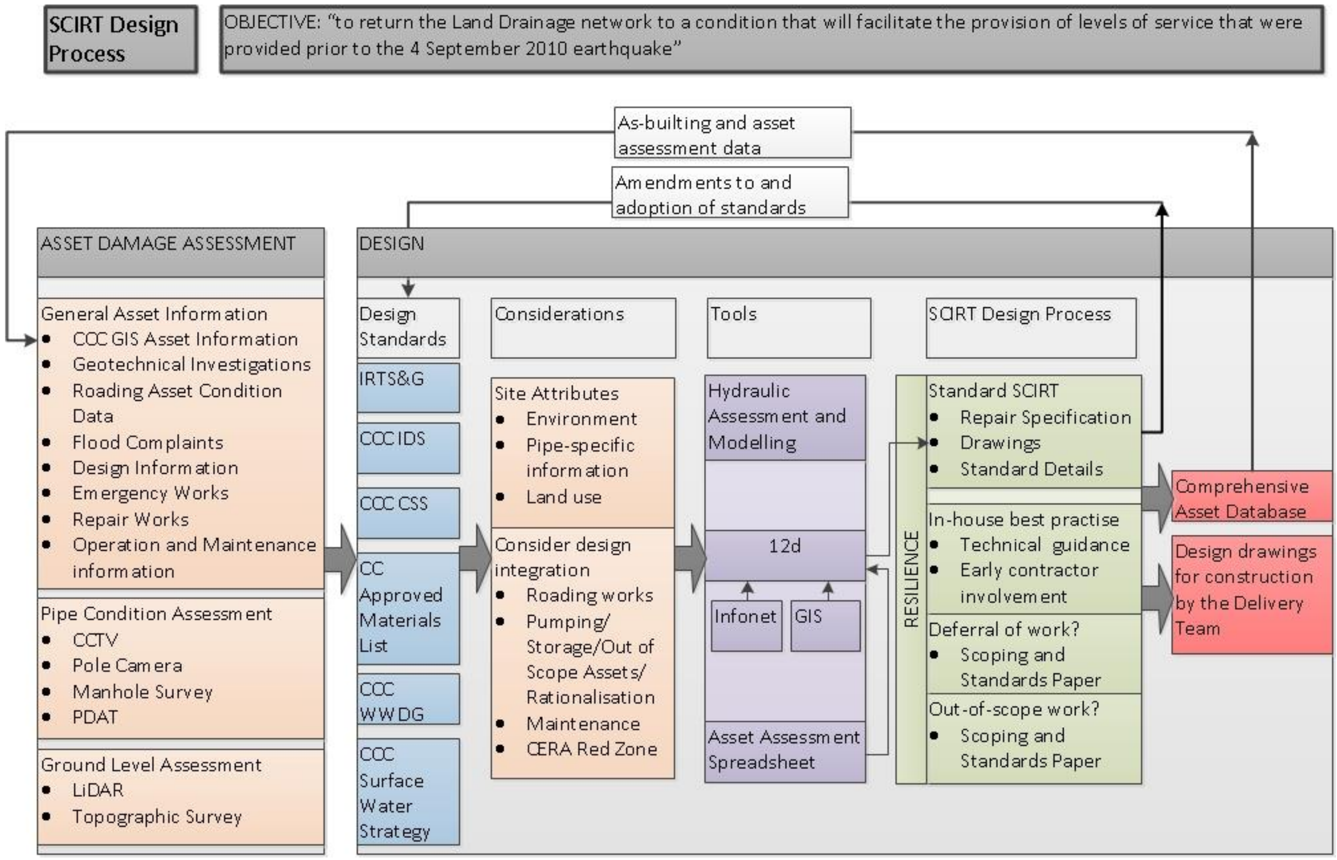
Though efficient asset assessment investigations, SCIRT designers are able to design appropriate solutions. Deferral of non-critical defect repair is undertaken in appropriate situations.

In addition, SCIRT has developed its own standard details and guidance to support designers, achieve the best value for the rebuild, and produce resilient design solutions. SCIRT standards incorporate the knowledge and lessons learnt throughout the SCIRT alliance; the IST, the delivery teams and the asset owners.

Integration with other rebuild works (especially roading), consideration of maintenance implications, and identifying opportunities for incorporating out of scope work to achieve the best value design solutions are all an important part of SCIRT rebuild work. Out-of-scope assets play a significant role in providing the overall network level of service. SCIRT needs to take into account what could happen with out-of-scope assets and produce integrated solutions.

The process for SCIRT stormwater design is summarised in the flowchart in Figure 8.

Figure 8: SCIRT stormwater design flow chart



7. ACKNOWLEDGEMENTS

The SCIRT team for working hard to rebuild earthquake damaged stormwater infrastructure, 'create resilient infrastructure', and sharing their knowledge.
Beca for their support and guidance.

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