ASSET ASSESSMENT USING GIS AND INFONET

David Heiler, Data Assessment Lead, Stronger Christchurch Infrastructure Rebuild Team (Technical Director – Water Infrastructure, CH2M Beca Ltd)
John Moore, Asset Assessment Manager, Stronger Christchurch Infrastructure Rebuild Team (Team Leader, Project Delivery – Water and Waste, Christchruch City Council)
Andy Gibson, Associate Director, AECOM New Zealand Ltd

ABSTRACT

Throughout the past 23 months, Christchurch City has encountered four significant earthquakes (EQ) of magnitude 6 and above. The earthquake of 22 February 2011 centred 2km West of Lyttelton and 10km southeast of the centre of Christchurch, w hich follow ed five months after a magnitude 7.1 earthquake in September 2010, tragically took 185 lives. It caused w idespread damage across the central city and neighbouring eastern suburbs, exacerbated by buildings and infrastructure already weakened from the September 2010 event and subsequent aftershocks. It is estimated that the total cost to insurers of rebuilding the city w ill be approximately NZ$15 – 16 billion.

Follow ing the February quake, significant liquefaction affected the eastern suburbs, producing some 400,000 tonnes of silt which mixed with wastewater to become a significant health risk. Wastew ater and sewerage systems were severely damaged with households having to establish emergency latrines. More than 20,000 chemical toilets w ere distributed around Christchurch together w ill some 2,000 portable toilets. A significant portion of the ground level in the eastern suburbs has dropped, resulting in varying levels of flood risks during w et w eather. This, coupled w ith severely damaged stormw ater infrastructure, has added to the issues in the eastern suburbs.

This paper explores how Christchurch is embarking on rebuilding the w astewater and stormw ater infrastructure, and the integral role that thorough data assessment, using GIS and InfoNet is playing in this strategy to ensure that multiple data sources are reviewed, risk profiled and then prioritised to meet the requirements of the Stronger Christchurch Infrastructure Rebuild Team, insurance companies and the future asset management processes of Christchurch City Council.

KEYWORDS

Christchurch, Earthquake, Wastew ater, Stormw ater, Pipes, GIS, Infonet, CCTV

1 INTRODUCTION

1.1 OVERVIEW

Gravity pipe assessment is the largest and arguably the most important component of the asset assessment process being undertaken by the Stronger Christchurch Infrastructure Rebuild Team (SCIRT). The rebuild of gravity w astewater (WW) and stormw ater (SW) pipelines makes up over 50% of the estimated cost of the rebuild and typically needs to be undertaken in advance of other rebuild w orks due to its depth. Gravity pipelines therefore need to be assessed before other infrastructure can be rebuilt as they typically are the deepest asset and are grade critical, so are not able to be readily diverted to facilitate w ork on other assets.

1.2 SCIRT

The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) has been formed to undertake the damage investigation, planning, design and construction of rebuild w orks on horizontal infrastructure assets ow ned by Christchurch City Council (CCC). Horizontal infrastructure assets include all Council owned water supply, wastewater collection and conveyance, stormwater, and roading infrastructure, including bridges and retaining walls.

SCIRT is a design and construct alliance consisting of Owner Participants (the Asset Owners) - CCC, CERA, NZTA; and Non-owner Participants (the Contractors) – Fulton Hogan, City Care, McConnell Dowell, Downer, and Fletcher Construction. Specialist resources, including design engineers, are contracted to SCIRT to assist in the rebuild.

1.2.1 ASSET ASSESSMENT AT SCIRT

The creation of SCIRT in September 2011 brought together all asset assessment functions under the direct control of SCIRT. Prior to the formation of SCIRT, asset damage investigations were being managed by individual Design and Construct Contractors engaged directly to CCC. The individual Contractor groups had been contracted by CCC after the September 2010 EQ and were operating in distinct geographical areas, known as Pods. These Contractors were responsible for undertaking their own damage investigations and asset assessments to support the design of rebuild works within their specific Pod areas. The February 2011 EQ resulted in significantly greater and more widespread damage across the city, which ultimately led to the formation of SCIRT.

In parallel to the investigations being undertaken by the Contractor groups, CCC's 3-waters network maintenance contractor (City Care Ltd) were involved in assessing the condition of wastewater and stormwater pipe assets in order to restore and maintain service. The different Contractors working for CCC and the City Care Maintenance Team were each using different systems to store data and using different assessment criteria for assessing the condition of assets.

SCIRT was immediately faced with the following challenges:

1. Deciding, in collaboration with CCC, what criteria would be used to assess the condition of assets using condition data collected in the field,
2. Deciding what field investigations tools were required to collect asset condition data, and
3. Deciding how investigation data would be stored, analysed, and made available to designers and asset owners.

This paper outlines how SCIRT is responding to these challenges and how GIS and databases (namely InfoNet) are key tools in the rebuild of gravity wastewater and stormwater networks.

2 CHRISTCHRUCH GRAVITY WASTEWATER AND STORMWATER NETWORKS

2.1 WASTEWATER NETWORK

The Christchurch wastewater network consists of around 1600km of Council owned gravity pipelines (greater than 100mm diameter). The network has grown from the early 1880's to present and consists of various different pipe materials and sizes. A breakdown of pipe sizes and materials is provided in Tables 1 and 2.

Table 1: Gravity Wastewater Pipe Network by Diameter

Diameter[1]	***<150mm***	***150-199mm***	***200-299mm***	***300-399mm***	***>400mm***	***Total***
Length	*32km*	*1020km*	*353km*	*89km*	*116km*	*1610km*

% of Total	2%	63%	22%	6%	7%	100%

Table 2: Gravity Wastewater Pipe Network by Material

Material	EW	Conc	RCRR	PVC	AC	Other[1]	Total
Length	380km	115km	615km	345km	115km	40km	1610km
% of Total	24%	7%	38%	21%	7%	3%	100%

Notes
1. Other contains all other less common pipe materials (PE, CI, etc) and where no material is defined in GIS

2.2 STORMWATER NETWORK

The Christchurch stormw ater netw ork consists of around 900km of Council ow ned gravity pipelines (greater than 100mm diameter). The SW pipe netw ork is an integral part of the overall land and surface drainage system that includes 2 major rivers (Avon River and Heathcote River), open channels, road drainage channels and subsoil drains. The pipe network generally discharges to open channels but is also used to convey surface water between road drainage channels on either side of the road using 'bubble up' pipelines and sumps. A breakdow n of pipe sizes and materials is provided in Tables 3 and 4.

Table 3: Gravity Stormwater Pipe Network by Diameter

Diameter[1]	<150mm	150-199mm	200-299mm	300-399mm	>400mm	Total[2]
Length	10km	57km	250km	235km	328km	880km
% of Total	1%	6%	29%	27%	37%	100%

Table 4: Gravity Stormwater Pipe Network by Material

Material	EW	Conc	RCRR	PVC	AC	Other[1]	Total[2]
Length	33km	47km	604km	107km	63km	26km	880km
% of Total	4%	5%	69%	12%	7%	3%	100%

Notes
1. Other contains all other less common pipe materials (PE, CI, etc) and where no material is defined in GIS
2. This total based on GIS. This total will increase as unknown SW assets are added to GIS by SCIRT. The combined total length of WW and SW pipe shown in Figure 5 has been increased to account for new assets we expect to identify during the rebuild.

3 GRAVITY PIPE ASSET ASSESSMENT CRITERIA

3.1 ASSET INVESTIGATION AND ASSESSMENT FOCUS

The focus of gravity pipe asset damage investigation and assessment undertaken by SCIRT is to identify and repair pipe defects that will aide in returning the WW and SW networks to a condition that meets the levels of service provided prior to the 4 September 2010 earthquake.

The key tasks that SCIRT is undertaking to achieve this are:

1. Undertaking a pipe investigation programme to collect pipe condition data that allows for functional and structural assessments to be made of all pipes against agreed assessment guidelines, and

2. Maintaining an up-to-date database of pipe investigation data and having systems that make this raw data and assessments available to various groups within SCIRT.

There is also a requirement for SCIRT to transfer asset condition information across to CCC. This requires alignment between SCIRT and CCC systems.

3.2 ASSESSMENT GUIDELINES

CCC have the 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'.

The IRTS&G requires the city wide assessment of pipe defects using the *New Zealand Pipe Inspection Manual* (NZPIM) and stipulates what types of defects need to be repaired as part of the rebuild. Since the guidelines were first issued in October 2011, SCIRT and CCC have agreed a number of refinements to these guidelines, including departures from the NZPIM. The refinements have included:

- Changing damage thresholds (generally resulting in a relaxation of requirements) to target specific defects and defects severities that affect the ability of the pipe to provide the required level of service.

- Modifications to NZPIM CCTV requirements to suit post EQ conditions. This has included accepting camera footage taken under less than ideal conditions.

- Modifications to NZPIM coding to separate construction and service defects from earthquake related structural defects.

These refinements have required changes to field operations and to the assessment of data at SCIRT.

3.3 DEFFERING REPAIRS TO MAXIMISE ASSET LIFE

The next refinement in the assessment of pipe defects being investigated by SCIRT is to identify damaged pipes that have at least 15 years of remaining life through no or limited immediate repairs. This is to maximize the remaining life of existing damaged yet functional assets where road reconstruction is not programmed to occur within 15 years.

The advantages of this approach are:

- It maximises remaining asset life

- Allows defect repairs to be deferred, resulting in a smoothing of expenditure and reduced borrowing

- It smooth's the future renewal programme

- It reduces disruption to community in the short term

- It reduces boom and bust in the industry

- It reduces the risk that new assets will be damaged in further seismic events, which are expected to continue for possibly 20 years.

The disadvantages are that:

- Community expectation that work completed in 5 years not realized as repairs will continue beyond the SCIRT timeframe
- Operational costs will reduce at a slower rate
- It requires a modified funding model.

A process for applying this approach on a citywide basis is still being developed in conjunction with CCC.

4 FIELD INVESTIGATION AND ASSESSMENT TOOLS

SCIRT has embarked on a pipe investigation programme to collect the information required to allow functional and structural assessments to be made of each gravity pipe asset. The following field investigation programmes are currently underway:

1. Manhole level survey (functional assessment)
2. CCTV (structural condition assessment)
3. Pole Camera (structural condition assessment)
4. Pipe Profile (functional assessment)

In addition to the above field investigation programmes, a Pipe Damage Assessment Tool (PDAT) has been developed within SCIRT to predict the structural condition of pipes that have not been surveyed by CCTV.

4.1 MANHOLE LEVEL SURVEY

A manhole (MH) level survey has been conducted across the city to collect invert and lid levels for all manholes in the SW and WW network. This has been undertaken by GPS survey, and detailed level survey using laser level is also undertaken where a greater accuracy is required.

MH level data has allowed a comparison of post-EQ grades against pre-EQ grades and minimum design grades (for solids movement). The MH level data is also used being used for network hydraulic modelling to undertake network capacity assessments.

4.2 CCTV

CCTV (closed circuit television) is the primary industry-wide method for investigating the structural condition of gravity pipes. It has been used extensively by both SCIRT (to show where repairs are required) and CCC network maintenance teams (to show where urgent repairs are required to restore and maintain service).

There are currently 20 combined camera, jetting, and suction crews operating across the SW and WW networks. City Care Ltd is managing this operation on behalf of SCIRT and have modified their own in-house, web-based job management system to allow for an online, real-time coding of defects to the NZPIM. The CCTV operation involves around 150 full time equivalent staff and equates to around half of the New Zealand's current CCTV field resource. The combined team is currently achieving around 50km/month of physical survey. Due to the large amount of cleaning involved this is costing around $55/m to collect and code to the NZPIM.

This level of CCTV activity can be compared to pre-EQ conditions where CCC was typically undertaking around 10km of CCTV a year (normally driven by street renewals) at a cost of less than $10/m. The increased cost is due to the large amount of cleaning required to remove liquefaction silt and debris from pipes before CCTV can occur. Around 80% of field CCTV costs relate to traffic management, pipe cleaning (using jetting units and suction trucks) and over-pumping.

Initial quality audits completed by SCIRT found significant variation in the quality of CCTV field w ork and defect coding across the CCTV teams. An extensive training programme w as implemented to up-skill all CCTV teams in undertaking surveys and coding defects to the NZPIM. This has led to a significant lift in the quality of CCTV w ork, resulting in a reduction in the number of non-conformances. Some typical pipe defects encountered through CCTV are show n in Figures 2 and 3 below .

Figure 1: Typical CCTV Operation with combined jetter/sucker truck and CCTV Van

Figure 2: Joint defect and displacement in RC pipe, resulting in exposure of reinforcing steel

Figure 3: Breaks in EW pipe resulting in Tomo

CCTV has some drawbacks when used as the only tool for assessing pipe condition. This has resulted in SCIRT investigating alternative methods for assessing pipe condition. Drawbacks with relying solely on CCTV include:

1. CCTV does not necessarily provide all the information needed to assess damage in pipes that have few structural defects. It needs to be used in conjunction with grade assessments (completed using MH level data) and pipe dip assessments (completed using pipe profile data).

2. A number of pipes cannot be practically CCTV'd due to high flows and access issues. This can apply to more than 10% of pipes in damaged areas.

3. CCTV is slow and expensive. The assembled CCTV resource cannot achieve the productivity needed to match the rebuild programme. In low damage areas CCTV costs can be higher than the rebuild CAPEX, making this a poor return on the investment in asset assessment.

Pole Camera, Pipe Profile and the Pipe Damage Assessment Tool were applied to overcome these deficiencies.

4.3 POLE CAMERA

Pole Cameras are being used to make fast structural condition assessments of short large diameter pipe lengths. Pole Cameras consist of a high resolution camera mounted on a pole. The pole is inserted into manholes or other pipeline structures and the camera used to provide an image along the pipes. The cameras have integral lighting and zooming which allows various views to be taken along the pipe, all from a stationary location.

Pole Cameras are currently being used on short (<15m long) SW pipes to assess whether significant defects are clearly evident (resulting in the need to repair or renew the pipe) or absent (resulting in no further action). CCTV is requested where the Pole Camera finds signs of damage or cannot view the full length of the pipe asset. This is because the NZPIM cannot be applied to pole camera results.

To date around 40% of pipes that have had Pole Camera surveys need to be CCTV'd. The 60% of pipes that have be assessed by Pole Camera present a significant asset investigation saving as Pole Camera surveys on average cost less than $15/m compared to CCTV surveys w hich can cost more than $55/m for the same assets.

4.4 PIPE PROFILE BY PROFILOMETER

Profilometers are used to determine the long section profile of gravity pipe invert between manholes. It makes use of profilometer technology developed for geotechnical settlement monitoring. Follow ing cleaning of the pipe, a level sond is pulled through the pipe and relative levels recorded at 1m intervals (0.25m intervals near MH connections).

The determination of the pipe profile allows for a quantitative assessment of dips, which is not possible w ith CCTV. Although CCTV can identify dips, there is inconsistency in the coding due to the CCTV often being undertaken directly behind the jetter head, w hich displaces w ater from the pipe, making dip identification more difficult.

The IRTS&G requires dips greater than 30% of the pipe diameter to be repaired. Investigations have found that in high liquefaction areas w ith relatively new PVC pipe (eg Parklands and Brookhaven), pipe dips have resulted in a higher number of pipe repairs and renewals than caused by structural defects alone. An example of a typical pipe profile plot is provided in Figure 4.

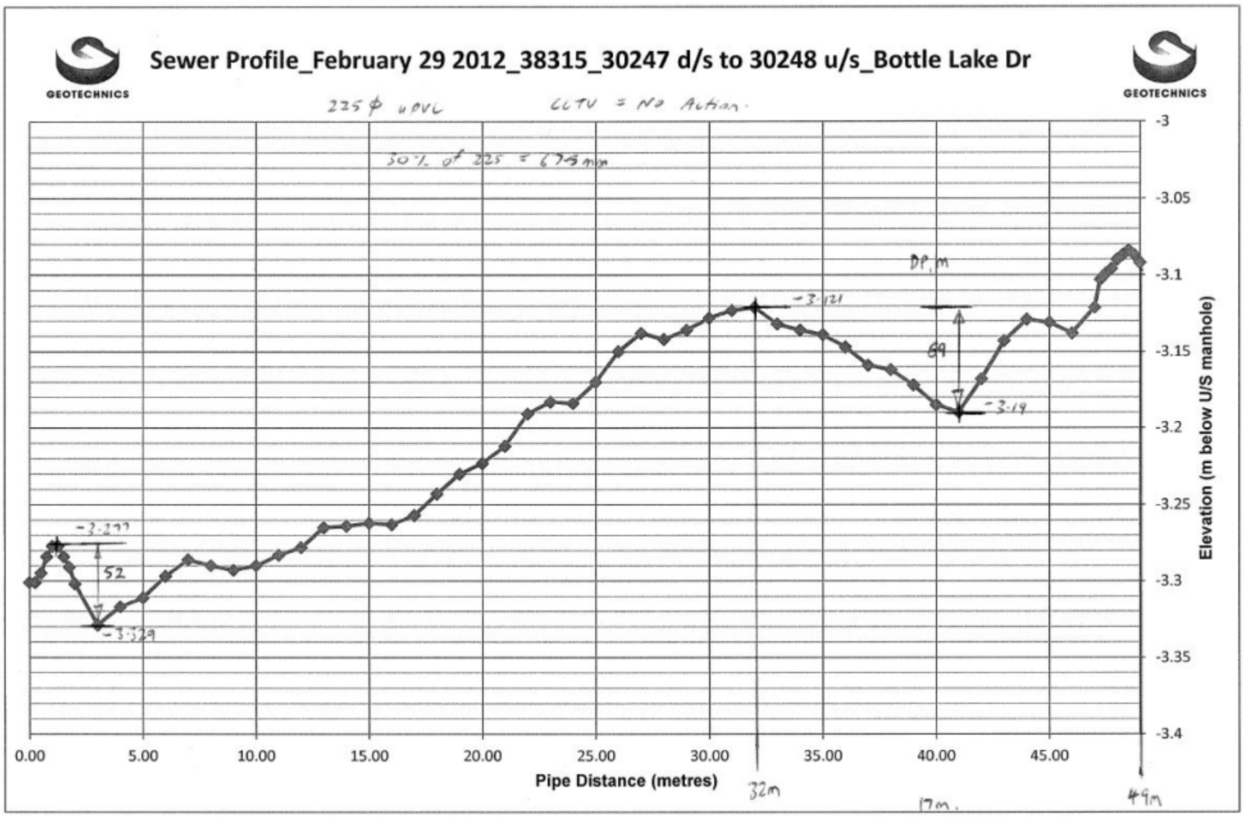

Figure 4: Pipe Profile between MHs recorded using Profilometer

4.5 PIPE DAMAGE ASSESSMENT TOOL

A pipe damage assessment tool (PDAT) has been developed by SCIRT to allow a risk based prediction to be made of pipe condition and so avoid the need to CCTV every pipe in the city.

The PDAT is a desktop based tool used to predict the structural condition of pipes that have not been CCTV'd, based on CCTV that has been completed to date, and looking and other key damage indicators such as:

- Pipe material type and age
- Land damage (from liquefaction index) and surface damage features (from RAMM)
- Geographic location and orientation.

The PDAT uses GIS to assign damage indicator attributes to individual pipe assets. The tool then identifies trends between the indicators and pipe condition (where known, imported from InfoNet) and matches the most likely condition to pipes that have w e no CCTV for. The development of the PDAT removes the need to CCTV every pipe in the city in order to assess or predict its condition.

The PDAT is being used by SCIRT for the follow ing:

- Key early step in the pipe assessment process to inform concept design and so save investigation costs
- To predict the condition of pipes that can't be practically CCTV
- To assess damage in low and high damage areas to reduce the amount of CCTV required
- To assist in assessing EQ related damage. CCTV cannot alw ays differentiate EQ damage from pre-EQ faults so other damage indicators are required.

The PDAT is an integral part of the pipe assessment strategy. Figure 5 shows how the PDAT is being used to predict the condition of pipes at various stages of the rebuild. At present SCIRT is collecting a sample of CCTV in low damage areas (where no damage investigations have been completed) to allow the PDAT to be used to estimate the total amount of damage across the city. Where an understanding of damage is available, the PDAT is used for targeting w here further CCTV is required to inform detailed design.

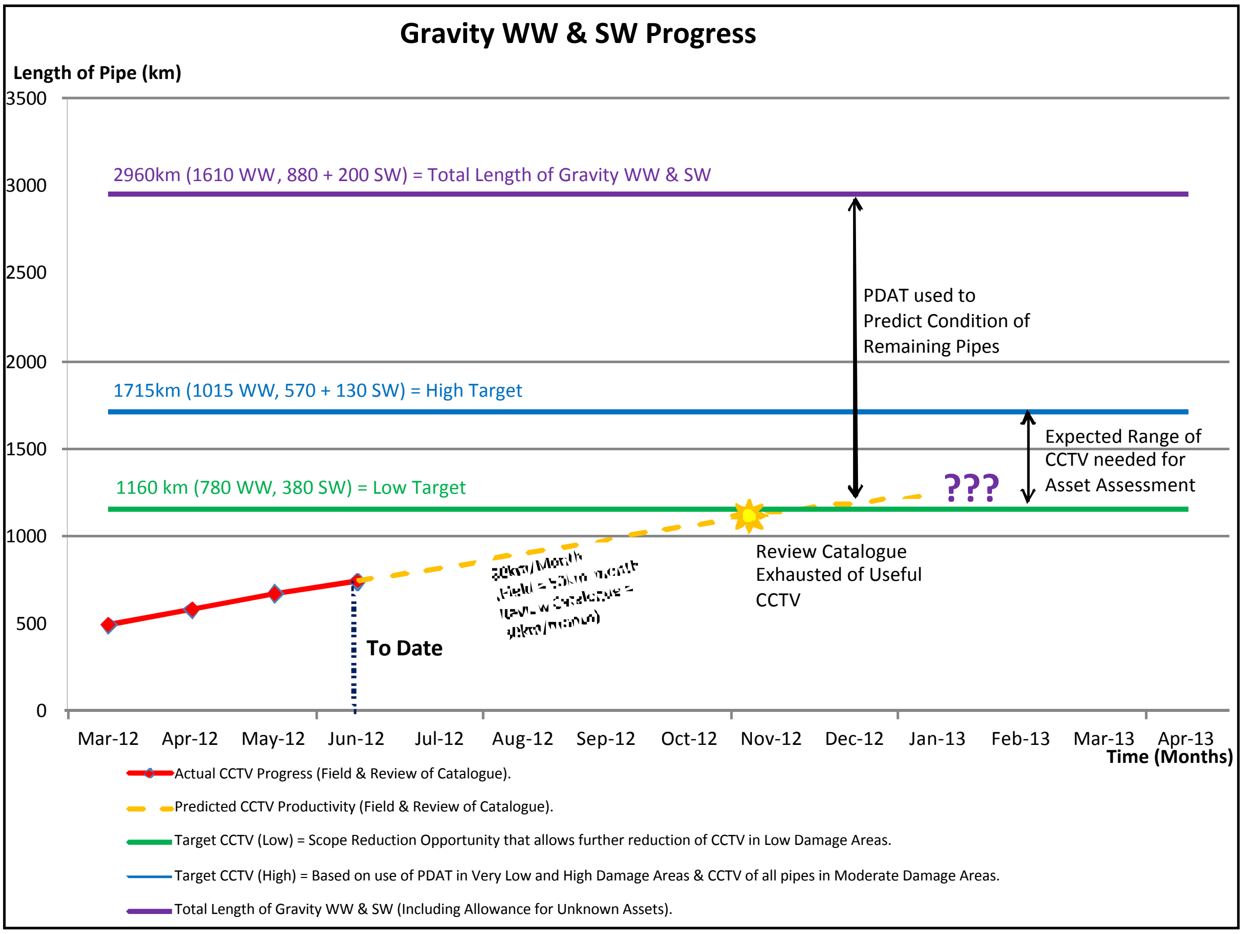

Figure 5: Gravity SW and WW CCTV for Condition Assessment and Application of the PDAT

The accuracy of the PDAT varies across the city. Where damage trends are strong, the tool is predicting the presence or absence of damage in individual pipes with more than 90% accuracy. In areas where damage appears to more random (eg RCRR pipe in badly damaged areas) the prediction accuracy reduces, requiring a greater level of CCTV to inform the rebuild. The High Target line on Figure 5 follows this approach.

There is an opportunity to further reduce the amount of CCTV requiredby not chasing down the location of defects in low damage areas. In these areas the return on investigation investment can be very low as the investigation costs can be similar to the value of the repairs made. The prerequisites for following this approach are that the area in question is not generating unsustainable levels of infiltration or incurring high maintenance costs. Where this is true, adopting this strategy effectively results in a deferral of repairs to the defects that are present. This has some funding issues that are still being reviewed with CCC. The Low Target line on Figure 5 follows this approach.

It is expected that the final amount of CCTV required for condition assessment will fall somewhere between the High and Low targets.

5 USE OF INFONET AND GIS IN ASSET ASSESSMENT

5.1 INFONET

InfoNet is a purpose built network based software tool used for gravity and pressure pipe network asset planning. It is a database with a geospatial interface that stores data against individual assets (with unique IDs).

InfoNet is being used by SCIRT to store all WW and SW pipe investigation surveys and assessments outlined above (MH levels, CCTV surveys, Pole Camera assessments, Pipe Profile assessments, PDAT assessments) and to undertake analysis of this data.

Prior to the creation of SCIRT, InfoNet was used by City Care/AECOM for storing CCTV data collected by City Care on behalf of main Contractors employed by CCC. With the creation of SCIRT the use of InfoNet has been expanded to including the following functions:

- To store all pipe investigation surveys and assessments. This includes both current surveys and historical surveys undertaken on the same asset.
- Make assessments against the damage thresholds provided in the IRTS&G. Assessments indicate whether the pipes require Renewal, Repair, or No Action.
- Undertake analysis of this data, including:
  - Assessing the impact changes to damage thresholds
  - Investigating damage trends for different materials and asset ages across the city
  - Comparing surveys taken at different times
  - Undertaking tractive force calculations to determine minimum design pipe grades
- Present data in a form that can be directly accessed by designers and exported for viewing on SCIRT GIS.

All pipe assessments are stored in InfoNet and exported to the PDAT for analysis. PDAT predictions are then imported back into InfoNet before being exported with other condition information to SCIRT GIS. The hierarchy of different surveys and assessments is managed in InfoNet so that the best condition information is available to designers. CCTV surveys are completed on all new pipes as part of SCIRT's as-built process and these surveys are handled in the same way as condition surveys. This effectively closes the loop for each damaged pipe asset and allows SCIRT to provide CCC with an up-to-date asset record.

Figures 6 and 7 provide examples of different queries written to assist designers in pulling useful information out of InfoNet.

For Figure 6 (InfoNet plot of dips in WW network based on Profilometer Survey), red dots are large (>50%) dips and orange dots are medium (25 to 50%) dips.

For Figure 7 (InfoNet plot of assessments in WW network based on CCTV, PDAT and MH Level Survey), purple lines are Renewals based on pipe condition or grade (MH level, CCTV or PDAT derived), orange lines are Repairs based on pipe condition (Pipe Profile, CCTV or PDAT), green lines are No Action based on pipe condition (Pipe Profile, CCTV or PDAT derived).

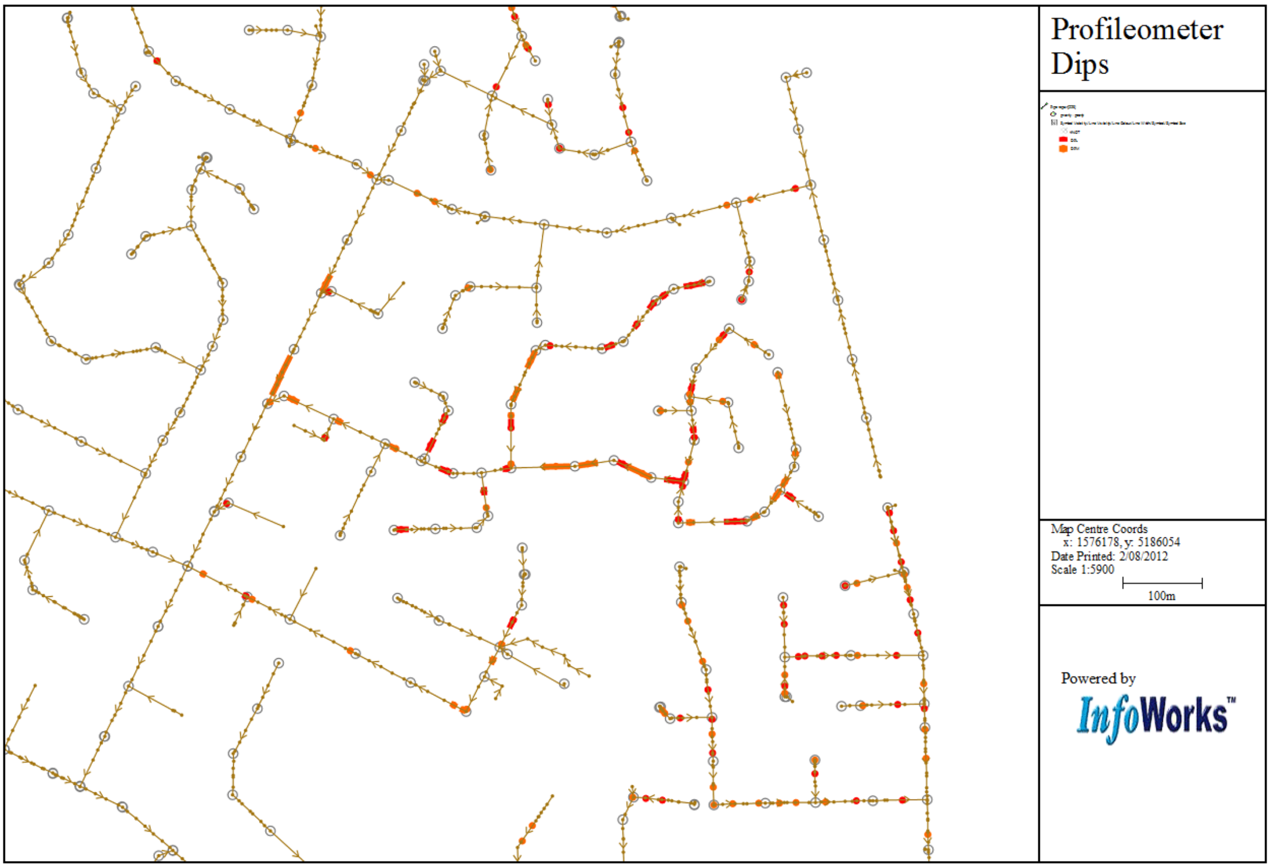

Figure 6: InfoNet plot of dips in WW network based on Profilometer Survey

SCIRT has worked with Innovyze (software developer) to tailor InfoNet to SCIRT's specific project needs and a SCIRT version (Version 12.51) was issued to incorporate these requirements. These changes have now been incorporated into Version 13 which is due to be issued in the coming month. The changes included the following:

1. A function to print to a NZPIM CCTV report format that met the needs of SCIRT designers.
2. Ability to associate CCTV surveys with the pipe asset IDs – making the matching of surveys to pipes much easier.
3. Improved map control such as server map services
4. Better caching of drawing performance.

Photos of defects recorded through CCTV are currently stored in InfoNet. SCIRT plans to migrate a copy of relevant video files across from City Care to SCIRT and have these linked to assets in InfoNet. This will improve the availability of information for designers and allow an easier migration of records across to CCC.

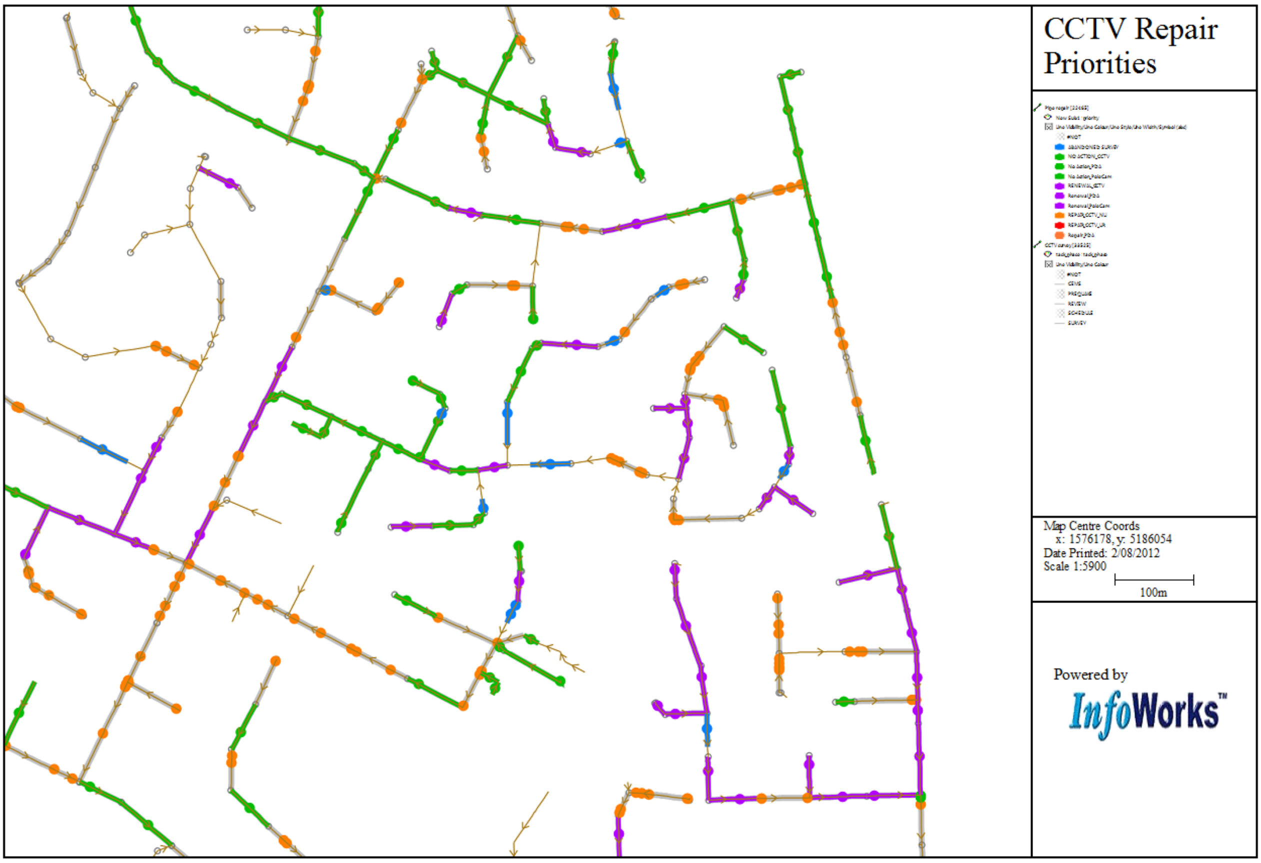

Figure 7: InfoNet plot of assessments in WW network based on CCTV, PDAT, Pipe Profile and MH Level Survey

5.2 SCIRT GIS VIEWER

SCIRT have developed an in-house web-based GIS system to manage all spatial data relating to the rebuild. The web-based viewer is currently being used by around 920 users from over 20 organisations. This includes in-house design and delivery teams, utility service providers, CCC, CERA, NZTA, ECan and the University of Canterbury.

The GIS system is used for various functions by SCIRT including:

- Storing asset information
- Storing condition information and the results of assessments
- Prioritising rebuild projects
- Identifying project areas and attributing project costs back to individual assets.

Asset assessments are imported to GIS from InfoNet on a weekly basis. Within GIS, designers can layer pipe condition information against other spatial information. Data can be exported to tables for manipulation and then taken back into GIS for presentation on maps.

Designers have developed their own spreadsheet based design tools that are automatically updated on a daily basis with asset data from GIS and pipe condition data from InfoNet. This ensures that designers are working with the best information in their designs of repairs to WW and SW systems.

Figure 8 provides an example of the asset condition information displayed on SCIRT GIS (with background aerial switched off).

Figure 8: SCIRT GIS plot of pipe condition assessments for the WW network

6 CONCLUSIONS

InfoNet and GIS are integral parts of the rebuild effort. The use of these systems has been tailored to meet the asset investigation and assessment needs of SCIRT. Further refinement is expected as SCIRT and CCC adapt the assessment processes to suit the changing needs of the rebuild.

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Chris Scott – MH level survey

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