AN INNOVATIVE APPROACH TO CONDITION AND DAMAGE ASSESSMENT OF LAND DRAINAGE ASSETS

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ABSTRACT

Land drainage and stormwater assets are often not prioritised when balancing the many challenges that confront councils' budget restrictions for managing extensive asset portfolios. However, these assets have a large potential to cause issues to the communities surrounding them.

This paper seeks to share the lessons learnt from several condition and damage assessments carried out by Christchurch City Council (CCC) on open channel assets following the Canterbury Earthquake sequence. The paper shows how valuable information and knowledge can be gathered from innovative approaches. The paper shares lessons on criticality assessments, condition and damage inspection, and tools to help share and visualise the outputs. The paper also identifies a recommended approach for undertaking these studies across a range of assets in public and private ownership in New Zealand.

The paper focuses on a condition assessment project carried out by Opus International Consultants that covered 20km of concrete lined drains in Christchurch City. The project ultimately sought to inform a renewals strategy for the assets based on an integrated solution involving criticality, and condition and damage assessment. The project also involved innovations such as a geo-referenced video survey that were developed to enhance the final output of the project.

KEYWORDS

Open channels, land drainage, asset management, condition assessment, damage assessment, data collection, criticality.

1 INTRODUCTION

Land drainage and stormwater networks in cities are vital assets that, when functioning properly, ensure adequate drainage is achieved and flooding is prevented. Following the Canterbury Earthquakes, damage to the Christchurch City land drainage and stormwater assets, combined with widespread land-subsidence, resulted in several flooding events. Christchurch City Council (CCC) recognised that the stormwater network needed to be repaired to its pre-earthquake condition, and potentially enhanced further to address new issues caused by the earthquakes.

A project was initiated to undertake a condition assessment of 20km of open channel concrete lined drains around the city. This would encompass around half of the total concrete lined drains network. The project would collect asset attribute and damage data in order to establish the post-earthquake condition of the drains. The damage assessment, combined with a criticality assessment, would help inform a repair and renewal strategy for the assets.

The project, which was undertaken by Opus, involved a number of innovations such as field-based data collection on a tablet and a geo-referenced video survey. These innovations are presented in this report alongside the background to the project and how the project methodology was developed. The report also presents the final outputs of the project that focused on combining extensive amounts of data in a useful and integrated way.

2 BACKGROUND

2.1 THE NEED

Asset management (AM) has become an increasingly important topic in the last few decades due to growing global concerns about the declining state of infrastructure networks across the world (NAMS Group, 2011). Asset providers, such as local authorities and councils, manage extensive portfolios of assets, and complete and updated records of asset data are not always available. Throw a natural disaster into the mix - earthquake, flood or tsunami, and things start to get even more complicated. And it is particularly in the aftermath of such events that complete knowledge of one's assets becomes vital. Which assets are the most critical? How do we prioritise which assets to attend to first? Are the assets capable of providing the required level of service? Solid AM practices can help provide answers to these types of questions.

In New Zealand, the Local Government Act (LGA) 2002 makes local authorities responsible for providing communities with infrastructure services that are efficient, effective, and able to meet current and future demands. This highlights how important *knowledge* of one's system is in order to meet these obligations. The Wisdom Hierarchy triangle (Figure 1) shows us that in order to attain knowledge, and ultimately wisdom, we first need a solid foundation built from data and information.

Figure 1: Wisdom Hierarchy Triangle (Wood, 2010).

Logan (2012) has the following definitions of the terms presented in the Wisdom Hierarchy triangle:

- **Data** are the pure and simple facts without any particular structure or organization, the basic atoms of information.
- **Information** is structured data, which adds more meaning to the data and gives them greater context and significance.
- **Knowledge** is the ability to use information strategically to achieve one's objectives.
- **Wisdom** is the capacity to choose objectives consistent with one's values and within a larger social context.

From these definitions we can see that collecting relevant data, and then organising them in a useful manner, is necessary in order to attain the knowledge and wisdom required to make informed decisions.

2.2 THE PROJECT

Following the Canterbury Earthquakes in 2010 and 2011, CCC recognised that information records on their land drainage and stormwater assets were incomplete or absent. Inspections of the network revealed damage that included bed heave, settlement, liquefaction, and lateral spreading causing structural damage. Some reactive repairs were carried out to restore hydraulic capacity in the worst-hit areas, however it became apparent that an extensive repair programme was needed.

CCC identified that in order to plan a repair programme they needed to establish the current condition of the network, and assess the physical damage due to the earthquakes. To do this, they first needed to collect asset attribute and damage data. A project was initiated to achieve this goal and the first instance, which would cover just over half of the concrete lined drain network, included:

- a desktop criticality study,
- a field asset attribute and damage data collection,
- a geo-referenced video survey.

The data collected would then be developed into useful information through software tools such as Excel and InfoNet. This information, combined with identification of repair options, would provide the underlying knowledge to develop a sound renewals programme for the drain network.

3 PROJECT AND PROCESS DEVELOPMENT

Opus were chosen as the consultant to carry out the assessment. Opus had presented innovative approaches to condition assessment on similar projects carried out for CCC, and had also demonstrated their expertise in GIS support and data management.

A collaborative approach between Opus and CCC was used to progress the condition assessment process further. From the experience that had been gained on previous projects it was recognised that there was room for improvement on the data collection system. Section 3.1 below briefly describes the earlier system that was used. Section 3.2 describes the innovations that were developed; the asset attribute data collection process was streamlined through a joint collaborative approach. Another innovation was also introduced that involved capturing geo-referenced video surveys of the drains. These advances ultimately improved the data and information that were captured, thus producing more valuable project outputs.

3.1 PREVIOUS SYSTEM FOR ASSET ATTRIBUTE DATA COLLECTION

3.1.1 DESKTOP CRITICALITY ASSESSMENT

Criticality, which relates to the consequence of a drain failing, was assessed by desktop analysis. Council GIS data was used to highlight elements of significance in the vicinity of the drains. Elements of significance included heritage areas, recreational facilities, underground infrastructure such as water and waste water pipes, and other Council-owned assets.

The criticality assessment, which was based on a modified version of CCC's existing criticality assessment matrix, focused on six main impact areas:

- Financial impact of failure to Council
- Public health and safety
- Effect on Level of Service (LoS)
- Effect on business customers
- Effect on heritage value
- Effect on value of asset.

Each impact area also included a number of subsets. The subsets had defined parameters that determined the corresponding criticality rating. The predefined criticality parameters for each subset ensured that the assessment was objective and repeatable. The criticality of each subset was scored on a scale from 1 to 5, with 1 being not critical and 5 being highly critical. The overall criticality for each drain section was then taken as the maximum of all the subset scores to capture the worst-case scenario.

The criticality assessment was considered to be working well for the purpose of asset condition assessments. CCC also advised that criticality would be addressed further in a city-wide modelling project. Due to these reasons, the criticality assessment was not developed any further for the concrete lined drains project.

3.1.2 ASSET DATA COLLECTION

Asset data collection was carried out through a field assessment. The data that was collected included attribute data, associated structures, and faults. The fieldwork process used previously was relatively cumbersome, and involved using several separate items of equipment:

- Sheets of paper, called Standardised Assessment Record Sheets (SARS), to note asset and damage information.
- A digital camera to take photos.
- A GPS to produce location coordinates for the start and end of each drain section. The GPS coordinates were recorded by hand on the SARS.
- Paper plans/maps of the drain locations.

After being collected, the field data was manually entered into spreadsheets. This double-handling of the data increased the amount of time required to complete the work, and provided additional opportunity for errors to be made. The resulting data collection process was thus fairly inefficient.

Opus proposed that this data collection system, while adequate, could be improved upon. The goals of this would be to:

- Reduce the amount of equipment required.
- Automate the data collection system to avoid double-handling and reduce errors.
- Enhance the information delivered to CCC.

An improved methodology was subsequently developed, as described in Section 3.2 below.

3.2 IMPROVED METHODOLOGY FOR ASSET ATTRIBUTE DATA COLLECTION

3.2.1 ASSET DATA COLLECTION ON A TABLET

Asset data collection on a tablet was proposed in order to streamline the field data collection process. The expectation was that the tablet would effectively incorporate all the previously required pieces of equipment into one device. There were several other benefits with the proposal:

- All the data collected in the field could be downloaded directly onto a computer, thus eliminating the previous need to manually enter the data, as well as any subsequent errors.
- The potential for error from hand-recording GPS coordinates would be eliminated.
- The data would be normalised through the use of dropdown lists. This made post-processing and filtering of the data easier, which allowed for more powerful analyses.
- The tablet could be carried in a waterproof case and attached to a neck lanyard to protect it, eliminating the previous risk of sheets of paper getting wet or lost.

The limitations that were identified with using a tablet in the field included battery life, screen visibility in bright sunlight, and protection from damage. These limitations were not considered to be major hindrances as they could be avoided or minimised. The GPS accuracy of the tablet was also raised as a potential issue. The GPS accuracy of modern tablets is as good as other general-purpose handheld receivers in open terrain (typically within a few metres), and this was considered to be sufficient for the application.

In order to make the tablet format a viable option, Opus went through a process of research and development to select appropriate equipment. A tablet was selected which could support an offline-capable GIS application. The application had to be offline-capable to allow work to be carried out in locations of limited or nil mobile network coverage. The application was set up to include the appropriate GIS data and functions for adding condition assessment information.

Condition assessment data points could be added in the field in exact locations on the GIS plot of the drain. Adding a new point would trigger a popup window with a template that was then filled out with the required data. Points were added to unique layers depending on their type: attribute, associated structure or fault. The separate layers made post-processing simpler and more efficient as the different types of points could be automatically sorted and separated on download.

A screenshot of the tablet GIS application can be seen in Figure 2. The image shows the prepopulated GIS information (roads, stormwater pipes and drains), and condition assessment data points (attributes, associated structures and faults) that have been added in the field.

Figure 2: Screenshot of tablet map application showing GIS data and data points captured in the field.

The popup template for new data points collected all the required data in one place; timestamp, GPS location, measurements, additional notes and photographs. As mentioned above, certain items in the template were normalised by using dropdown lists to ensure consistency of the data. This was particularly beneficial as different people conducted the condition assessment, and people may have different ways of recording the same data.

The items in the dropdown lists, such as drain construction methods and fault types, were developed during a pilot study to ensure that all the relevant items were captured. Each dropdown list also included ‘OTHER’ or ‘NOT APPLICABLE’ options and allowed notes to be added to detail these selections further. New items could also be added to the dropdown lists in the field if necessary.

Two people were required to do the field collection, for health and safety reasons, and to make the data collection more efficient. One person would operate the tablet and the other person would focus on measurements and identifying attributes, structures and faults to be collected. Photograph 1 shows field staff capturing asset condition data on the tablet.

Photograph 1: Field staff collecting condition assessment data on a tablet.

3.2.2 GEO-REFERENCED VIDEO SURVEY

With experience Opus had gained from similar projects undertaken previously, it was recognised that video footage of the drains would supplement the field data that was collected. This would be analogous to CCTV records collected from buried pipes, which has become a standard data collection technique. The expected benefits of the video footage included:

- The footage could provide a visual record of the condition of the drain. This information can then be recaptured at regular time intervals to examine deterioration over time.
- The video records could be easily accessed and shared by anyone that needed a complete visual overview of the drains, or nearby associated items, in a similar way that Google Streetview is used. This can potentially save time and costs by not having to conduct future site visits.
- The footage could provide a ‘full-picture’ view of the drains from upstream to downstream. This can be more useful than individual photographs that do not necessarily give enough representation of the immediate surroundings.
- Ultimately, the footage could be used to complete condition assessments through desktop studies, similar to that of CCTV. This could further streamline the data collection process.

As with the tablet for the asset data collection, a process of research and development was undertaken to select the appropriate equipment for the video survey. Using drones to capture the footage was considered, however this was discounted due to the difficulty of capturing sufficiently detailed shots, as well as the risk of low flying amongst multiple crash hazards (such as trees). Drones could also potentially generate complaints regarding privacy when flown near private properties. A trial which involved walking along a drain with a handheld camera was conducted. After the trial, it was determined that walking in or along the drain was the most effective method of capturing the video. However, the movement created while walking resulted in the picture being too unstable. As a solution, the camera was mounted on a handheld gimbal to stabilise the footage. The setup of the camera on the gimbal is shown in Photograph 2.

Photograph 2: Setup of geo-referenced video camera on handheld stabilising gimbal.

The requirements for the camera included GPS tracking, long battery life, excellent video quality and the capability to support video-capture applications. The latter was particularly important as this allowed capture of the camera position and direction during the recording process along with the video. This information could then be used to calculate other information such as walking pace and distance covered.

The videos were captured either by walking down the centre of the drain or alongside the shoulder, depending on the drain type and available access. Faults, associated structures or other interesting points were emphasised by stopping and focusing on the point of interest for a few seconds.

A screenshot from a video of a concrete lined drain can be seen in Figure 3. The data field on the bottom of the screen was added during post-processing of the videos. The field details relevant information such as drain ID and name, time into video (s), distance from upstream point (m), speed (km/h), GPS location, approximate elevation above sea level (MAMSL), and direction.

Figure 3: Geo-referenced video screenshot. The field on the bottom identifies data in the video such as distance from the upstream point, speed, GPS location, elevation (estimate), and direction.

Two people were required for conducting the video survey. This was again for health and safety purposes, and so that one person could capture the videos while the other person provided audio comments. The comments focused on providing information about the general drain condition, as well as insight into maintenance and repair strategies that would be practical and appropriate for the drain. In order to ensure sound information was provided in the audio comments, a person from CCC's operational staff (City Care) was designated for this task.

Both the asset data collected on the tablet and the geo-referenced videos provided valuable outputs to the project. Conducting field assessments on the tablet had streamlined the data collection process significantly and reduced the number of errors in the data. The video files were found to be a very valuable tool both for internal use within the Opus project team, and as an output to CCC. The videos were particularly useful for 'revisiting' particular drain sections and allowing the project team and client to appreciate the overall condition of the drain network without having to conduct site visits.

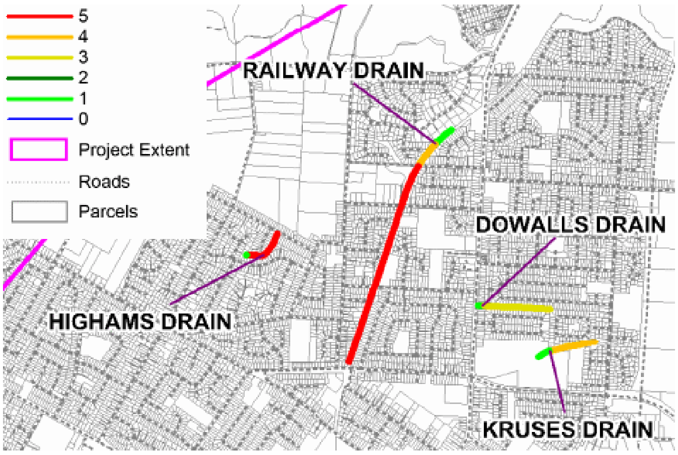
4 OUTPUTS FROM DATA COLLECTION

Once all the criticality, asset condition and video data had been collected, the focus was shifted to how it could be presented in the most useful and integrated way. Data is turned into information when it is organised in a structure that gives it meaning. Subsequently, information can only be used to gain knowledge and wisdom when it is combined with other relevant information and strategies. As such, the following sections describe how the criticality, condition assessment and video survey data were developed into useful information. The information output would ultimately help CCC inform a prioritisation programme and renewals strategy, and examples of these outputs are also presented.

4.1 DATA INTO INFORMATION

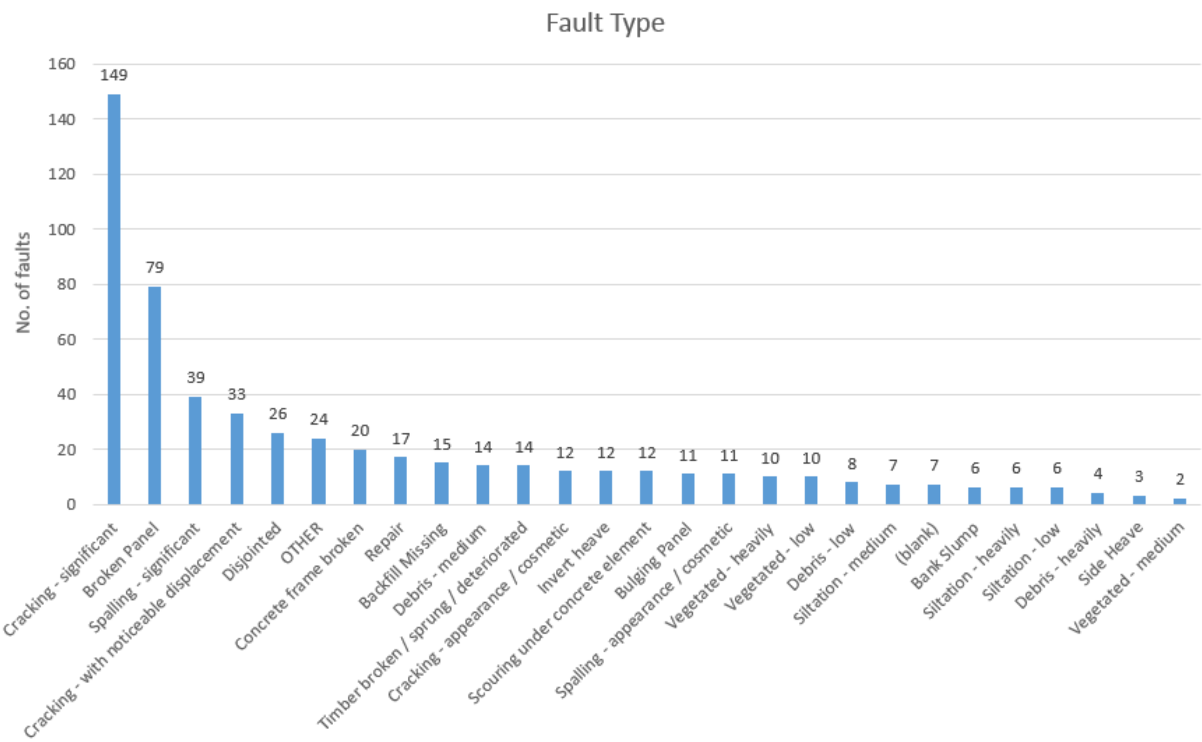
The complete criticality data, including all the subsets and corresponding scores, were stored in a spreadsheet matrix that was delivered to CCC for further use. The overall criticality scores were presented visually on a map, with different colours portraying the different drain sections' criticalities, such as the example shown in Figure 4.

Figure 4: Map excerpt showing criticality rating of individual drain sections.



The asset condition data captured in the field were collected into a spreadsheet where attribute data, associated structures and faults were automatically separated into different tabs. The spreadsheet organised all the information in one place and analyses could then be made depending on what output was needed. For example, pivot tables could be generated to examine the most prevalent faults, as shown in Figure 5.

Figure 5: Pivot table result of fault types logged in condition assessment.



4.2 INFORMATION INTO KNOWLEDGE

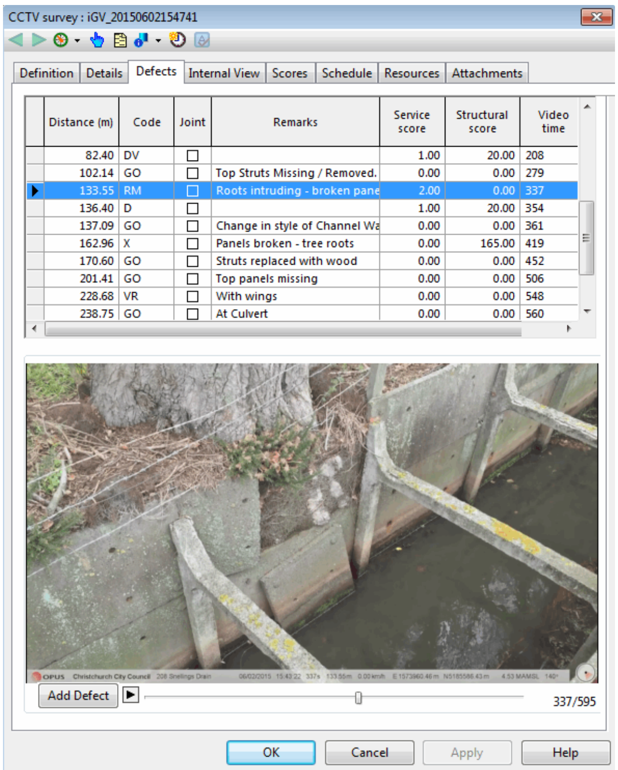
In order for end-users to be able to use and analyse these large datasets effectively, it can often be helpful if they are presented in a visual and intuitive way. A suitable platform was needed that could combine the criticality, asset condition and videos in one place.

Opus created an example in InfoNet to show the potential for this type of data visualisation. The software allows all the asset information to be overlayed onto an aerial image or a map, and then viewed and arranged in a way that suits the user. Figure 6 shows an example of what the visual layout could look like; the geo-referenced video trail and associated asset attributes and faults have been laid on top of the GIS plot of the drain.

Figure 6: Example of InfoNet overview of drain with geo-referenced video survey trail and faults added at appropriate points along the way.

Fault and asset information can be stored and presented on the software platform as well. The information can be stored in individual points in appropriate locations along the drain and can be individually selected to bring up detailed information. An example of what this could look like in InfoNet is shown in Figure 7 which depicts an information window that includes detail on individual faults along a drain section.

Figure 7: Example of individual fault information screen in InfoNet.



Standardised methods of presentation can also be beneficial for effective use of large amounts of data. For example, CCTV surveys use standardised scoring systems in order to assess the structural and serviceable condition of pipes. This means that the results of CCTV surveys can be reliably interpreted by various persons without the need to see the raw data.

Similarly, there is potential for developing a standardised scoring system for open drains with the geo-referenced video surveys. Essentially, the videos could replace the need for field-based condition assessments. The videos could also work in conjunction with CCTV surveys in cases where drains are a combination of open and piped sections.

4.3 KNOWLEDGE INTO WISDOM

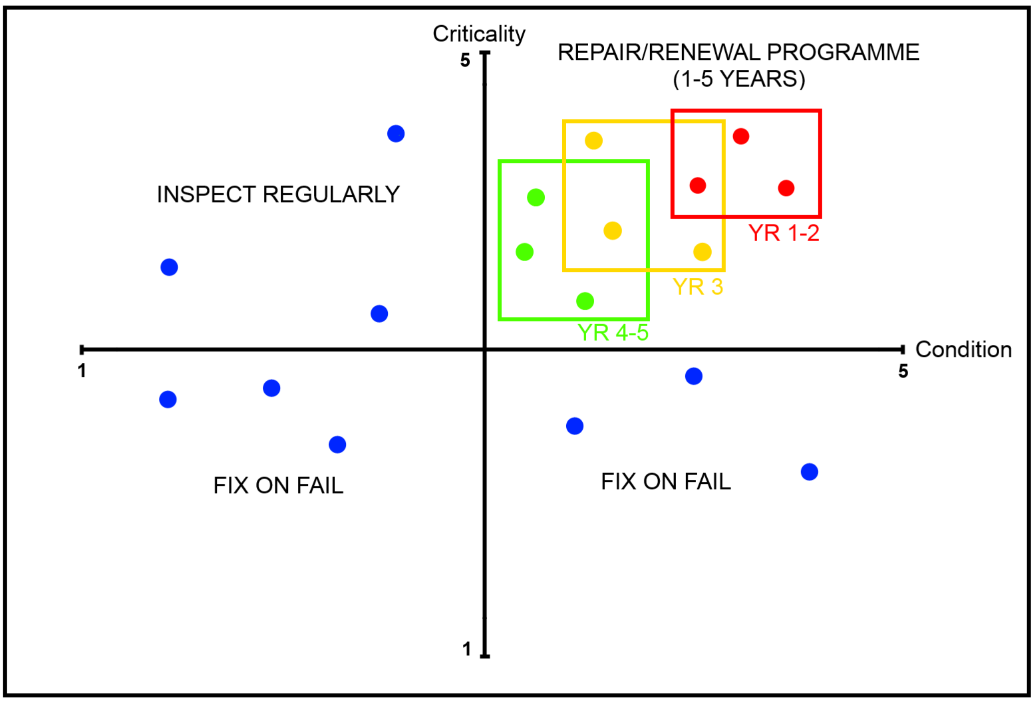
At the time of writing, the final project stage involving the development of a prioritisation programme and renewals strategy for the 20km of concrete lined drains had not yet been completed. Consequently, the following section outlines examples of how these deliverables can be presented and utilised.

The ultimate aim of the project was to underpin a renewals strategy for the drains that had been assessed. The project required that repair strategies, costing estimates and a prioritisation programme be developed. Repair strategies and costing estimates would be presented based on the knowledge of the faults that existed in the network. The criticality and condition assessment would then be combined to give the knowledge required to develop the prioritisation programme on a sound basis.

The prioritisation of renewals would be based on the product of the criticality score and the average condition score. Both elements were scored from 1 to 5, with 1 being not critical/good condition, and 5 being highly critical/very poor condition (ie a prioritisation score of 25 signifies a highly critical and very poor condition drain section).

A high-level representation of how the prioritisation can be structured is shown in Figure 8. The figure shows an example of how the prioritisation scores can be divided into different strategy-quadrants. For example, assets that are critical and in poor condition can be arranged into a renewal and repair programme over a set number of years. Regular inspections can be implemented for assets that are critical but in good condition, and assets that are not critical and in good condition can be dealt with at failure or as part of more extensive upgrade programmes.

Figure 8: Example of repair prioritisation programme based on asset criticality and condition scores.



The physical and digital outputs from the project will be presented to CCC at a handover workshop. The workshop will ensure that a clear and comprehensive understanding of the delivered information is achieved. Opus believes the outputs from the project will provide CCC with valuable information about the condition of their stormwater assets. The information can be used to tie in with other asset condition assessments and surveys across the city. This will hopefully help CCC make informed decisions regarding the overall repair and renewal strategies for the wider stormwater network.

5 LESSONS LEARNT AND CONCLUSIONS

As is often the case with first-time developments, a number of lessons were learnt throughout this project. In particular, the process of balancing efficiency with capturing sufficient information in the field is a case of ongoing development. Even after streamlining the data collection process with a tablet, the amount of information collected in the surveys made the job relatively time-consuming. On average, between 1 - 1.5km of drain could be assessed during a full day in the field, including driving time. Consequently, it is important to undertake a thorough process to determine what information is required and relevant before starting the project. Targeted data collection will ensure that the fieldwork is efficient and that the data can be applied to pre-determined purposes.

Including audio comments from someone with wide-ranging knowledge of the drains was found to greatly enhance the information captured in the videos. On-the-ground knowledge, such as general operation of the drains and practical maintenance/repair strategies, is normally held in the heads of operational staff that deal with the drains on a regular basis. Capturing this type of knowledge and experience through the audio comments, and then making it widely available, can help fill knowledge gaps in the organisation and thereby improve decision-making.

The scope of this project was to collect asset data for half of the concrete lined stormwater drain network in Christchurch City. The outputs of the project would help provide valuable information for the overall aim of developing and implementing a repair programme following the Canterbury Earthquakes. The deliverables from the project included:

- a criticality assessment,
- asset attribute and damage data,
- geo-referenced video footage,
- a prioritisation overview based on the information from the criticality and condition assessments.

The information capturing system that was developed in this project provided detailed and valuable information on the condition of asset networks. The process is flexible, and can be applied to a wide range of open channel assets. Targeted information can be captured efficiently, and the system also allows a wider range of attribute data to be collected. The data that is collected ultimately helps asset owners build a solid foundation to use in strategic and sound decision-making.

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