DATA SUMMARY REPORT

Land Drainage Recovery Programme

January 2017

OPUS

Prepared for Christchurch City Council

Prepared by: Jules Scott-Hansen
Environmental Engineer

Reviewed by: Liam Foster
Principal Environmental Consultant

Approved for release by: Liam Foster
Principal Environmental Consultant

Opus International Consultants
12 Moorhouse Avenue
PO Box 1482, Chch Mail Centre
Christchurch 8140
New Zealand

Tel: +64 3 365 5400
Fax: +64 3 365 7858

Date: 31 January 2017

Reference: 0814-3C1106.98-Chch-02-DataSummaryReport-FINAL

Status: FINAL

Version History:
Initial Draft - 9 December 2016
Final Draft - 23 December 2016
Final - 31 January 2017

OPUS

Christchurch City Council

00 EXECUTIVE SUMMARY

The Land Drainage Recovery Programme (LDRP) was initiated by Christchurch City Council in 2012. One of the Programme's main goals was to identify the effects of the Canterbury earthquakes (2010/2011) on the land drainage network of Christchurch and remediate it to a pre-earthquake level of service.

In order to inform strategic planning and asset management decisions under the LDRP, an extensive visual condition assessment and attribute data collection survey was undertaken. This focused on:

>> Open channel attributes and condition

>> Associated structures

>> Fault and damage assessment

>> Five Values (culture, ecology, heritage, landscape, recreation)

The data collection was undertaken through various projects and surveys, all guided by a visual survey specification to ensure consistency throughout the data. The final dataset was delivered to the Council in November 2016.

The final dataset covers:

>> 516 km of drains and waterways

>> 8294 associated structures

>> 9525 faults

>> Around 380 km of Five Values assessments

KEY FACTS

- 78% (402 km) of channels were average condition 3 (Average) or better
- 90% of structures were condition 3 (Average) or better
- 95% of faults were severity 3 (Moderate) or less
- 3% of faults were severity 5 (Catastrophic)
- 77% of faults were attributed to BAU causes
- 14% of faults were attributed to EQ causes
- 9% of faults were attributed to 'Other' causes, e.g. potential compliance issues

Key recommendations have been made following analysis and delivery of the final dataset. These are provided in full in Section 6 - Summary and Recommendations, and are summarised as follows:

1. Implement and share the dataset across the appropriate teams at the Council.

2. Utilise the dataset to derive a job management and feedback system to be shared with maintenance contractors to keep the data 'live'.

3. Identify issues where enforcement of the Drainage Act (1951) is necessary to eliminate potential hydraulic restrictions caused by compliance issues.

4. Derive a suitable and consistent reporting format for future maintenance contracts.

5. Create a rolling 10-year condition assessment programme to enable data updates and more sophisticated analysis of deterioration of assets.

6. Investigate the need for further CCTV surveys of critical assets and areas of known issues.

7. Review the waterway repair and renewal projects undertaken since the start of the visual field surveys (2015) to ensure these recent works are captured in the final dataset.

CONTENTS

OPUS

01 INTRODUCTION

The Land Drainage Recovery Programme (LDRP) was initiated by Christchurch City Council in 2012 to investigate the effects of the 2010/2011 earthquakes on the land drainage network in Christchurch city. In the initial years following the earthquakes, Christchurch experienced a number of unprecedented flooding events. It was assumed that damage to the stormwater network, combined with widespread land settlement, were major contributors to these events. However, without detailed information on areas of particular constriction and damage, it was hard for the Land Drainage team at the Council to make informed decisions on where efforts needed to be focused; it was apparent that a clearer picture of the post-earthquake condition of the stormwater network was required.

Throughout 2015 and 2016, extensive data collection on the waterways and drainage network was undertaken. The surveys gathered data on the stormwater network's attributes and drainage performance condition, as well as a high-level assessment of non-performance related values of culture, ecology, heritage, landscape and recreation (Five Values).

The data collection has been extensive; data has been collected over a number of years, under different projects, and by various consultants. A visual survey specification was developed to ensure consistency between the surveys.

Open Waterway Condition Assessment (LDRP98) was the final phase of the data collection process of the LDRP, undertaken by Opus International Consultants (Opus). This important final phase also involved amalgamating the data from the various LDRP projects into one complete dataset.

Despite all efforts to ensure consistency, the data collected through the various surveys varied somewhat. The inconsistencies created some challenges with regards to amalgamating the final dataset. A comprehensive standardisation process was undertaken wherever appropriate to fit data from earlier surveys to the most recent version of the survey specification.

The final dataset, which was delivered to the Council in November 2016, is a comprehensive database of information that will facilitate further works with issues and options and strategic budgeting and decision making.

This report provides an overall summary of the data collection process and presents the complete city-wide dataset for the first time since the inception of the LDRP. The report gives a brief overview of the background to the projects and the methodology used for data collection. As the report is mainly intended to give an overview of the data and findings from the field surveys, some of the background information and details have been excluded. A Technical Summary document has been prepared that provides further detail and should be referred to in conjunction with this report.

The timeline on the next page gives a summarised overview of the key events and milestones impacting the LDRP.

LDRP - PAST, PRESENT, FUTURE

22 FEBRUARY 2011
CHRISTCHURCH IS STRUCK BY A MAGNITUDE 6.3 EARTHQUAKE

...2012...
LAND DRAINAGE RECOVERY PROGRAMME (LDRP) IS INITIATED BY THE COUNCIL

EARLY 2014
CHRISTCHURCH HAS HEAVIEST SEQUENCE OF RAINFALL SINCE 1970s - FLOCKTON BASIN AND WIDER CHRISTCHURCH IS REPEATEDLY FLOODED DURING A SERIES OF EVENTS

APRIL 2014
MAYORAL FLOOD TASK FORCE IS STARTED TO FIND IMMEDIATE/SHORT TERM SOLUTIONS TO FLOODING PROBLEMS

MAY 2015
FIRST CONDITION ASSESSMENT SURVEYS ARE DONE ON CONCRETE LINED DRAINS

FEBRUARY 2016
LDRP 98 CONDITION ASSESSMENT SURVEYS BEGIN TO COLLECT DATA ON REMAINING 300 KM OF WATERWAYS

NOV/DEC 2016
FINAL AMALGAMATED LDRP DATASET AND SUMMARY REPORT ARE DELIVERED TO THE COUNCIL

...FURTHER ON...
LDRP DATASET SUPPORTS THE COUNCIL IN ASSET MANAGEMENT AND O&M DECISIONS --> ENABLING BETTER STRATEGIC DECISION-MAKING AND ULTIMATELY A BETTER OUTCOME FOR THE COMMUNITIES OF CHRISTCHURCH

02 DATA COLLECTION
SURVEY SPECIFICATION AND METHODOLOGY

OVERVIEW

The survey specification, which was developed as a joint effort between the Council and Opus, defined the requirements and set the methodology for the field assessments. The surveys were limited to visual assessments, and no physical investigations such as material strength testing or similar were undertaken.

The survey specification went through several iterations following feedback from pilot studies and in-field use. Undergoing several revisions created a robust survey specification that sets a solid framework for future data collection and analysis.

The waterways and channels included in the assessments were walked in their entirety. Data was collected on tablets that allowed automatic capture of GPS location, asset attributes, condition grading, and photographs.

Waterways were split into reaches based on Christchurch City Council asset IDs. Reaches could also be further broken down into sub-reaches at points of significant change in attributes or condition. Condition grading was on a 1 to 5 scale; from Very Good to Very Poor. More details and examples of grading guidelines are shown in the subsequent sections.

Post-processing of the field data was undertaken in GIS to enable integration into the Council's existing asset database. GIS also allows visual outputs to be created which supports analysis and interpretation of the data, as shown in the maps and graphical outputs in Section 4 - Data Overview.

The data that were captured focused on four main components, as shown below:

1 Channel attributes and condition

2 Associated structures attributes and condition

3 Faults and damage assessment

4 High-level assessment of Five Values

The data collection for the LDRP focused on a high-level visual assessment of the Six Values Christchurch City Council recognises for waterways:

CULTURE DRAINAGE ECOLOGY HERITAGE LANDSCAPE RECREATION

The assessments aim to answer:

What is the current condition of the assets?

What was the effect of the earthquakes on the condition and drainage value of the assets?

What was the effect of the earthquakes on non-drainage values?

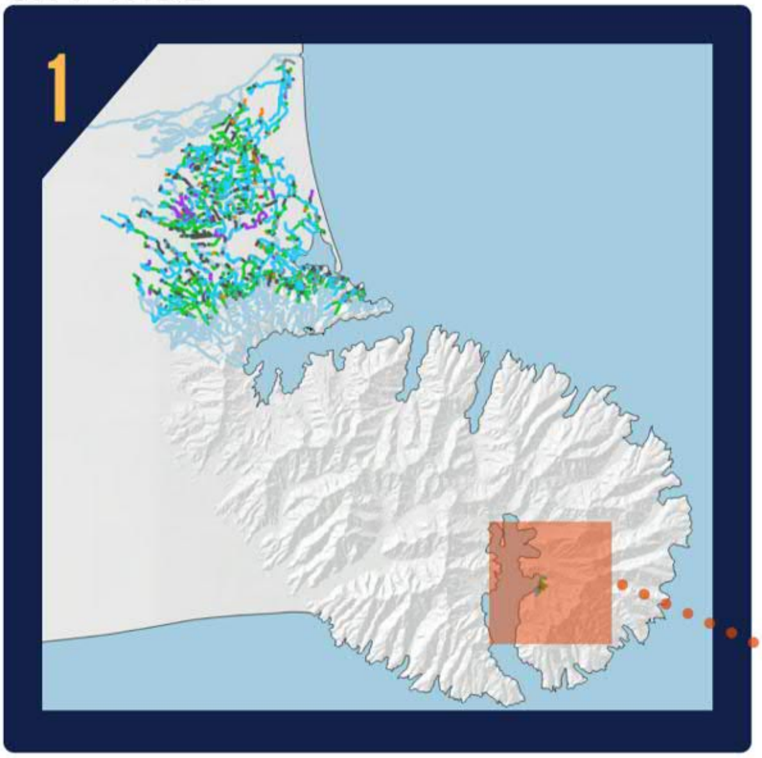
Where there is damage, is it earthquake or non-earthquake related, and is there sufficient damage to require repair?

DATA VISUALISATION

The dataset can be visualised and analysed in a variety of ways - both at the macro and micro scale. This page shows an example of how the data structure allows insights at various zoom levels; from the city-wide perspective through to the individual data points.

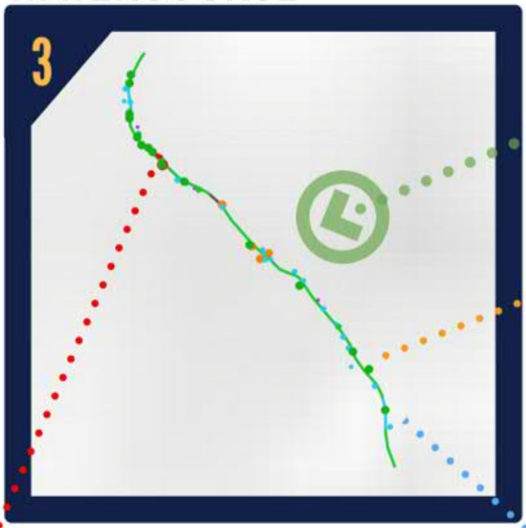
It is expected that the dataset will be used by Christchurch City Council, as well as their maintenance contractors, to prioritise future activity and manage maintenance works. This data visualisation example shows how GIS tools can facilitate this by providing accurate locations, asset information and condition grading, and surrounding assets. The data can also be kept 'live' by allowing updates to data points when capital or maintenance works have been completed.

CITY-WIDE



SUB-CATCHMENT

WATERCOURSE



STRUCTURE

FAULT

CHANNEL

GRADING ASSET CONDITION

Grading asset condition based on drainage capability was one of the key aspects of the LDRP data collection. The grading gives the Council a baseline of the current performance of the network and identifies where key areas of hydraulic constriction and performance issues exist.

Asset performance was visually assessed through three components; average asset condition (channels and structures), peak (worst) asset condition (channels only – referring to the poorest 5-10 m stretch of any reach), and fault severity/recommended response time. Examples and details of the grading scales are shown below.

AVERAGE AND PEAK CONDITION

1 - VERY GOOD

Assets with mainly cosmetic defects that will have no effect on performance. New or near new condition. No action required.

2 - GOOD

Assets with minor defects that will have no effect on performance. Monitor to see if anything changes.

3 - AVERAGE

Assets with defects that could affect performance. Asset is still functional but needs some attention. Repair or monitor depending on severity of defects.

4 - POOR

Assets with defects that reduce performance. Asset is performing below intended level of service. Repair or specialist assessment is required.

5 - VERY POOR

Assets with defects resulting in complete performance failure. Asset needs urgent repairs or replacement to uphold level of service.

FAULT SEVERITY

1 - INSIGNIFICANT
Cosmetic defects that will have no effect on performance in the foreseeable future.

2 - MARGINAL
Minor defects that will have no or minimal effect on performance.

3 - MODERATE
Defects that do not cause complete failure but could affect performance if not attended to.

4 - CRITICAL
Defects that reduce performance or have the potential to do so in the short-term.

5 - CATASTROPHIC
Defects that completely reduce asset performance, resulting in severe loss of service.


1 -2


3-4


5

RECOMMENDED FAULT RESPONSE TIME

URGENT

LESS URGENT (~ 3 MONTHS)

3+ MONTHS
No immediate risk to either safety or service levels and fault appears stable with no further degradation anticipated short-term.

WITHIN 3 MONTHS
No immediate risk to either safety or service levels in short term, but if not rectified will degrade further in short-term.

WITHIN 1 MONTH
No immediate safety risk, but service likely to be significantly impaired.

WITHIN 1 WEEK (URGENT)
Inaction could lead to safety or service failure and additional costs.

03 DATA AMALGAMATION

The LDRP data collection was undertaken through 14 individual surveys, carried out throughout 2015 and 2016. The data from all the surveys was amalgamated into one complete database, which was delivered to the Council in November 2016.

As mentioned previously, some variation existed between the different datasets, mainly due to the fact that they were collected under different versions of the visual survey specification. Inconsistencies in data inputs were standardised as much as possible in the process of compiling the final dataset. This involved mapping data entries to match the most recent version of the survey specification.

The Technical Summary document includes details on the methodology and data mapping process that was undertaken. The Technical Summary also outlines the consistency issues that were encountered and how these were resolved.

The key steps of the data amalgamation process are summarised below.

Input Processing

>> Fourteen datasets imported

>> Datasets from older versions of survey specification mapped to most recent version

>> Consistent data format created

>> ESRI Shapefiles of consistent format created for all datasets

Photo Processing

>> All images renamed to suit consistent naming convention of eight characters (XXXXXXXX.jpg)

>> All images resized to maximum 2.1 MP

>> All photos auto-rotated if possible

GIS Feature Clean-up

>> Overlapping geometry

>> Non-overlapping gaps in geometry

>> Partially overlapping geometry

>> Offset geometry

Attribute Clean-up and Normalisation

>> Additional clean-up and normalisation included:

>> Five Values ecology grade conversion

>> Option list normalisation (to fit most recent version of survey specification)

Asset Validation

>> Captured structures validated against existing CCC GIS within 10m buffer radius

>> 1145 (14%) validated automatically

>> 950 (11%) validated manually

>>1011 (12%) require spatial check

>> 1777 (21%) no suitable matches

>> 3411 (41%) excluded from validation due to structure type

Weighted Average Condition Scores

>> Weighted average condition score calculated for each reach (based on CCC ID)

>> Calculation based on average condition score of sub-reaches and length of sub-reach

>> Sub-reaches with non-numerical condition score (e.g. 'NA' / 'Not-Avl') ignored in calculation

04 DATA OVERVIEW
SUMMARY AND ANALYSIS

INTRODUCTION

The attribute and condition assessment data that was collected throughout the LDRP surveys creates a comprehensive database of asset and condition information for the waterways of Christchurch. The database, which will be integrated into the Council's existing information management systems, can serve multiple purposes across the Council's wide array of responsibilities. Examples include:

>> Creating a more comprehensive and up-to-date maintenance system, including opportunities for more involvement from maintenance contractor(s) around scheduling and updating information.

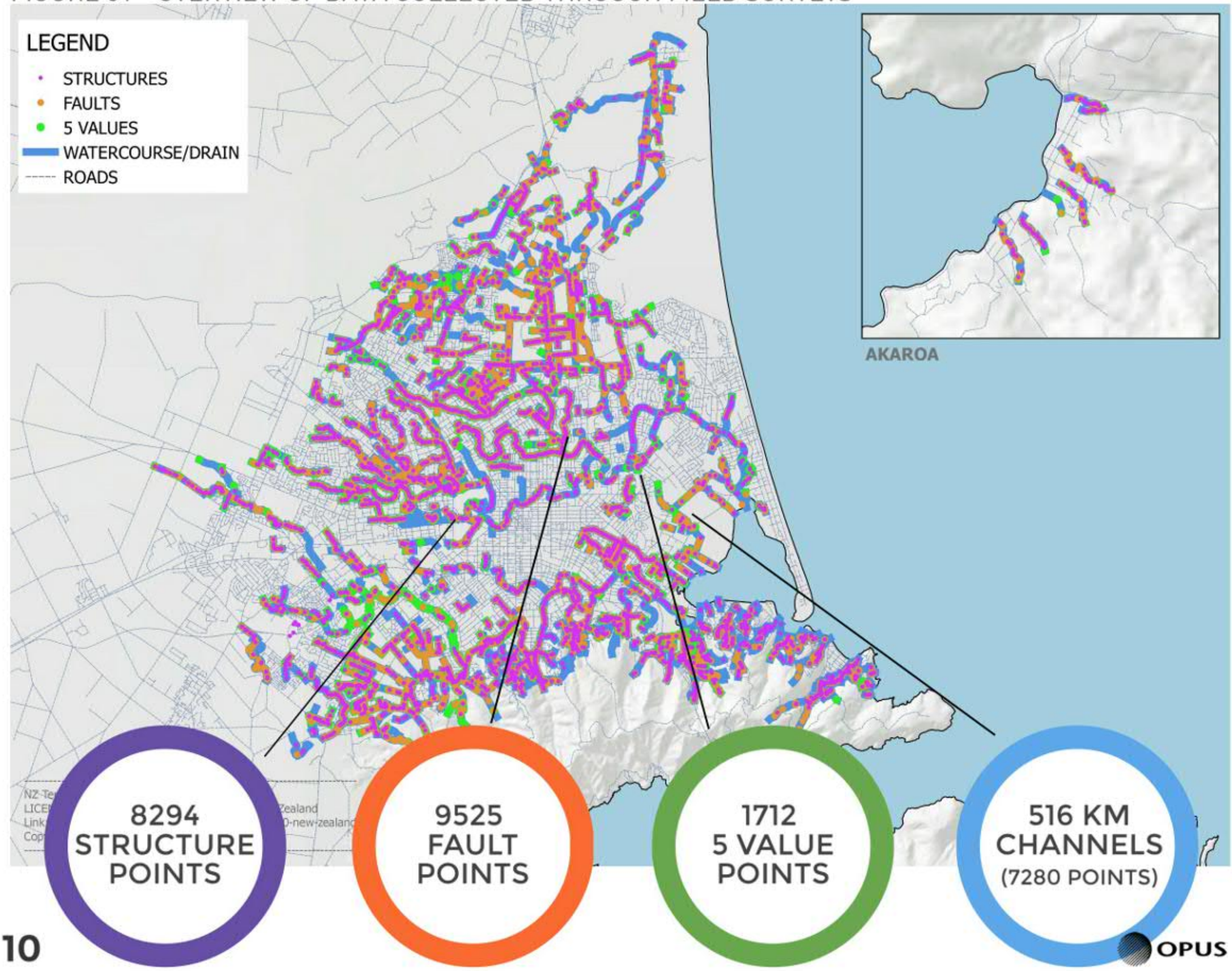
>> Updating the Council's existing asset database and GIS to create a more reliable picture of the assets that exist in the Council's stormwater portfolio.

>> Utilising the database for renewals planning of aging assets and enabling better informed decision-making around budgeting and wider stormwater strategy management.

One of the challenges with regards to managing the database will be how to keep the data 'live' and up to date. The data collected is essentially a snapshot of the condition of the assets at the time of survey, and as capital and maintenance works are carried out these improvements need to be captured.

A geographical overview of the data that were collected is shown in Figure 01. For the purposes of reporting the assessed waterways were split into sub-catchments, as shown in Figure 02.

FIGURE 01 - OVERVIEW OF DATA COLLECTED THROUGH FIELD SURVEYS



OPUS

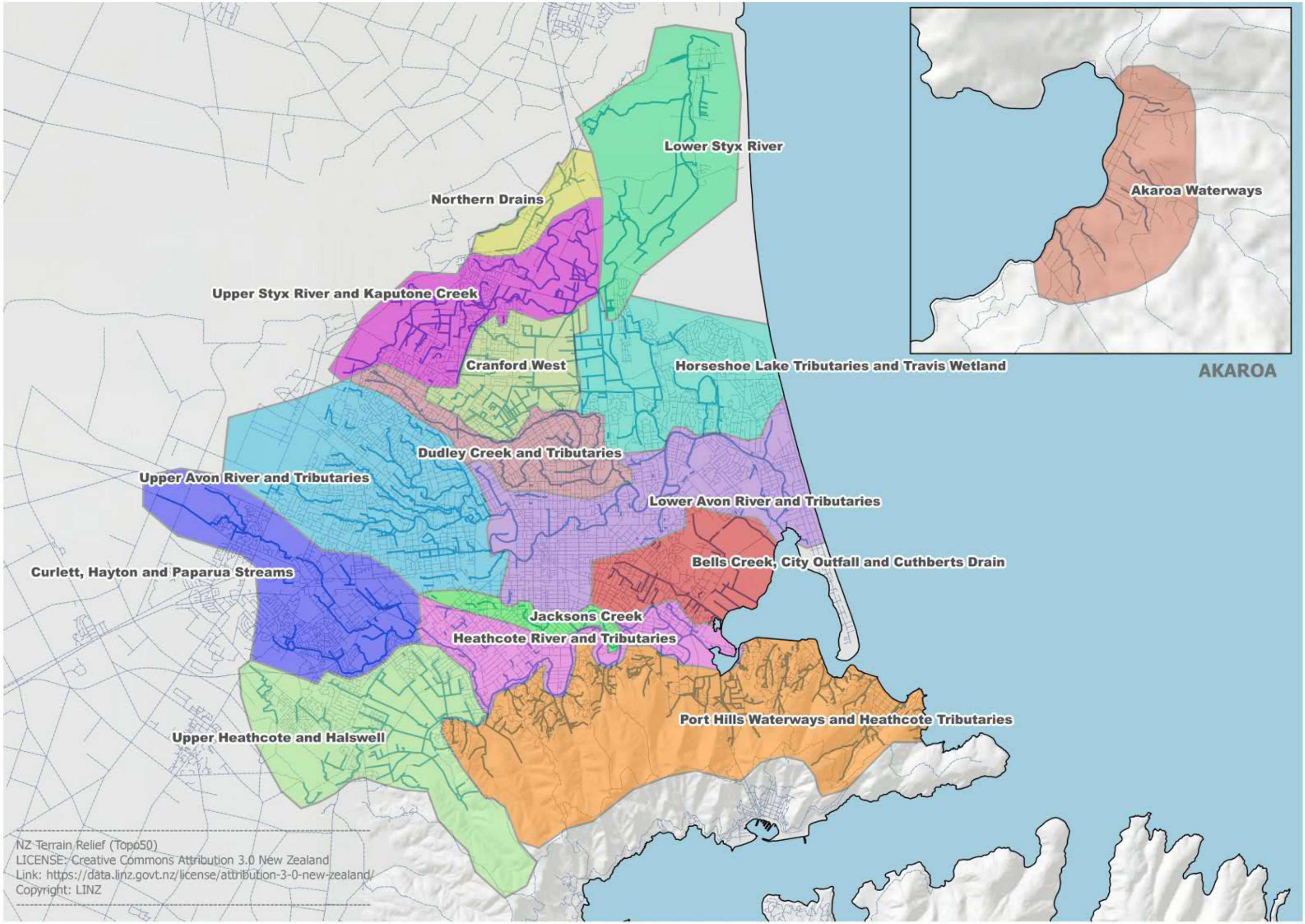


FIGURE 02 - OVERVIEW MAP OF SUB-CATCHMENTS OF WATERWAYS FOR DATA SUMMARY

CHANNELS

The channels that were inspected through the LDRP surveys involved a variety of waterway types; from minor grassed swales to major rivers, and from natural enhanced waterways to concrete- and timber-lined drains.

Three main rivers where included in the assessments; the Styx/Puharakekenui River in the North, the Avon/Ōtākaro River that runs through central Christchurch and the Heathcote/Ōpāwaho River that flows around the base of the Port Hills. The Styx discharges to the ocean at the Waimakariri River mouth whereas the Avon and Heathcote Rivers both flow into the Avon Heathcote Estuary.

Some of the smaller waterways have direct outflows to the ocean, however most of them contribute to these three main rivers. The waterways usually consist of a variety of channel types, generally influenced by their immediate surroundings. Waterways that flow through private residential properties are often shaped by the individual property owners - either enhanced and featured on the property or hidden away or fenced off for safety reasons. Waterways that are publicly accessible via parks and open spaces generally resemble natural channels whereas waterways through industrial areas are reflective of these environments by being boxed in and constructed with either concrete or timber panels.

Many waterways are also intermittently 'interrupted' by pipes and culverts where open channels are not practical, for example due to heavily trafficked roads or other constructed areas.

With regards to the average condition grading, the majority of channels (78%) were found to be in Very Good (1) to Average (3) condition. Only 14 km (3%) of channels were considered to be Poor (4) to Very Poor (5). The remaining 19% were either 'Not Applicable' or 'Not Available', generally referring to piped sections* or channels that could not be accessed at the time of the assessments.
A graphical summary of this is shown in Figure 03 and the geographical overview is shown in the map in Figure 05.

The peak condition grades, referring to the worst 5-10 m section of any channel reach, show that still the general majority (70%) of channels have peak grades of Average (3) or better. A total of 11% are grades Poor (4) or Very Poor (5), incorporating a total of 636 waterway reaches or sub-reaches. The distribution of peak condition grades is shown in Figure 04.

The distribution of average condition grades varies for the two major channel types; lined and unlined. Generally, the unlined waterways have a higher proportion of Good (2) grades and the lined channels have a higher proportion of Poor (4) grades. This trend agrees with the general findings of the field surveys where the assessments generally found more, and higher severity, faults on the lined drains.

>> KEY CHANNEL FACTS

Mixed 4%

Lined 25%

Unlined 71%

76% of channel average conditions were attributed to BAU effects (vs. 4% EQ effects)

Heathcote / Opawaho River was the longest watercourse assessed (27.3km)

97% of channels are average condition grade 3 or better (discounting NA / Not-Avl)

*Piped sections were not included in the condition assessment surveys, however attribute points were collected for pipes where they intersected an open channel that was assessed. Therefore, some pipe assets are included in the final dataset.

AVERAGE AND PEAK CONDITION GRADES

The distribution of average and peak condition grades, as shown in Figure 03 and Figure 04, indicates that the majority of channels were assessed as condition Good (2) or Average (3).

The relatively large proportion of reaches with 'NA' is due to pipes and culverts being included in the GIS-based survey scope. Data points were captured for these 'closed' reaches to create continuity in the waterway data, however they were not assigned an open channel condition score. Analysis of condition grades can be easily refined by discounting these non-numerical data entries.

Reaches with 'Not-Avl' were locations that could not be accessed for various reasons; construction sites, overgrown vegetation and potentially aggressive animals are some examples of scenarios that prevented access at the time of the assessments.

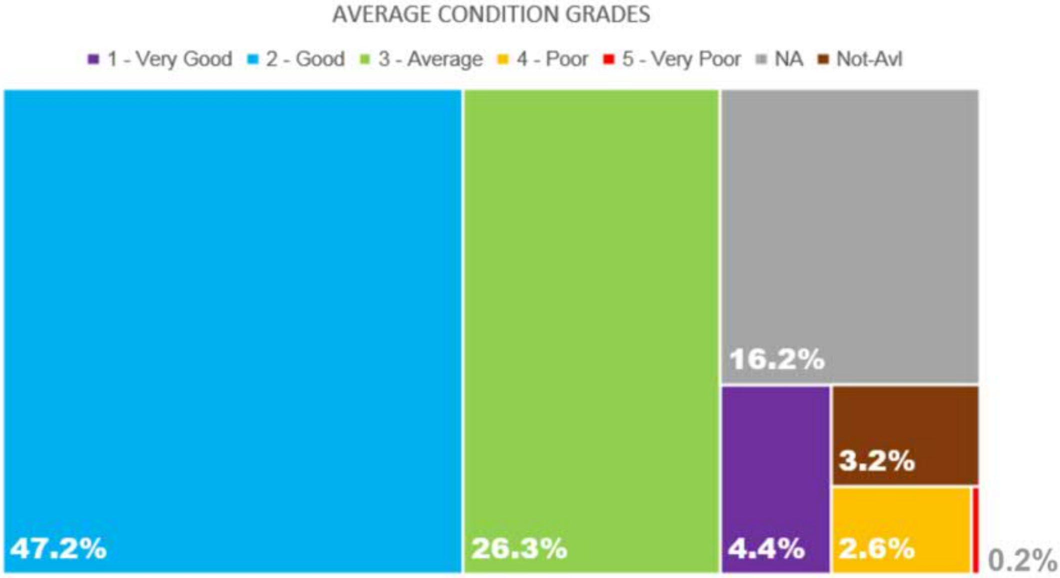


FIGURE 03 - AVERAGE CONDITION GRADE DISTRIBUTION FROM OPEN CHANNEL CONDITION ASSESSMENTS

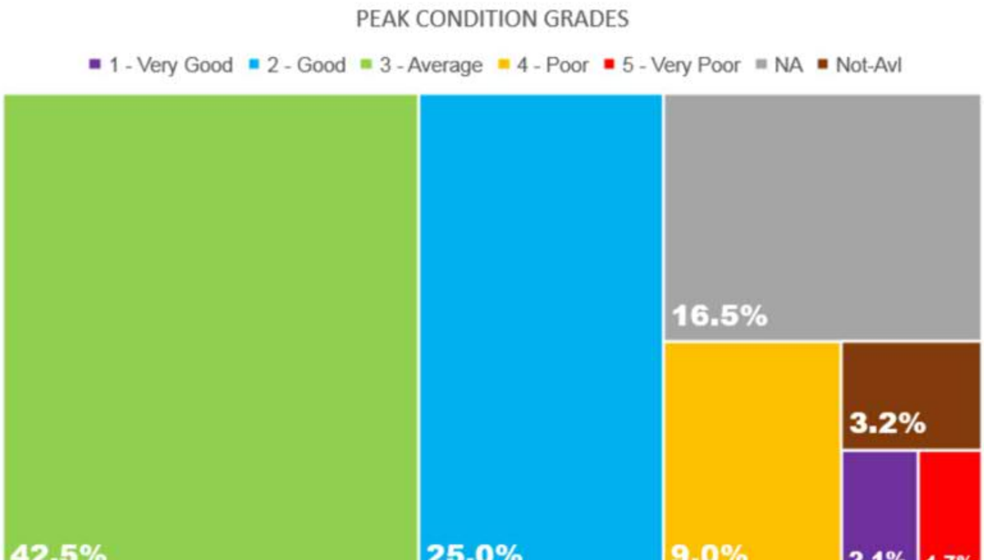


FIGURE 04 - PEAK CONDITION GRADE DISTRIBUTION FROM OPEN CHANNEL CONDITION ASSESSMENTS

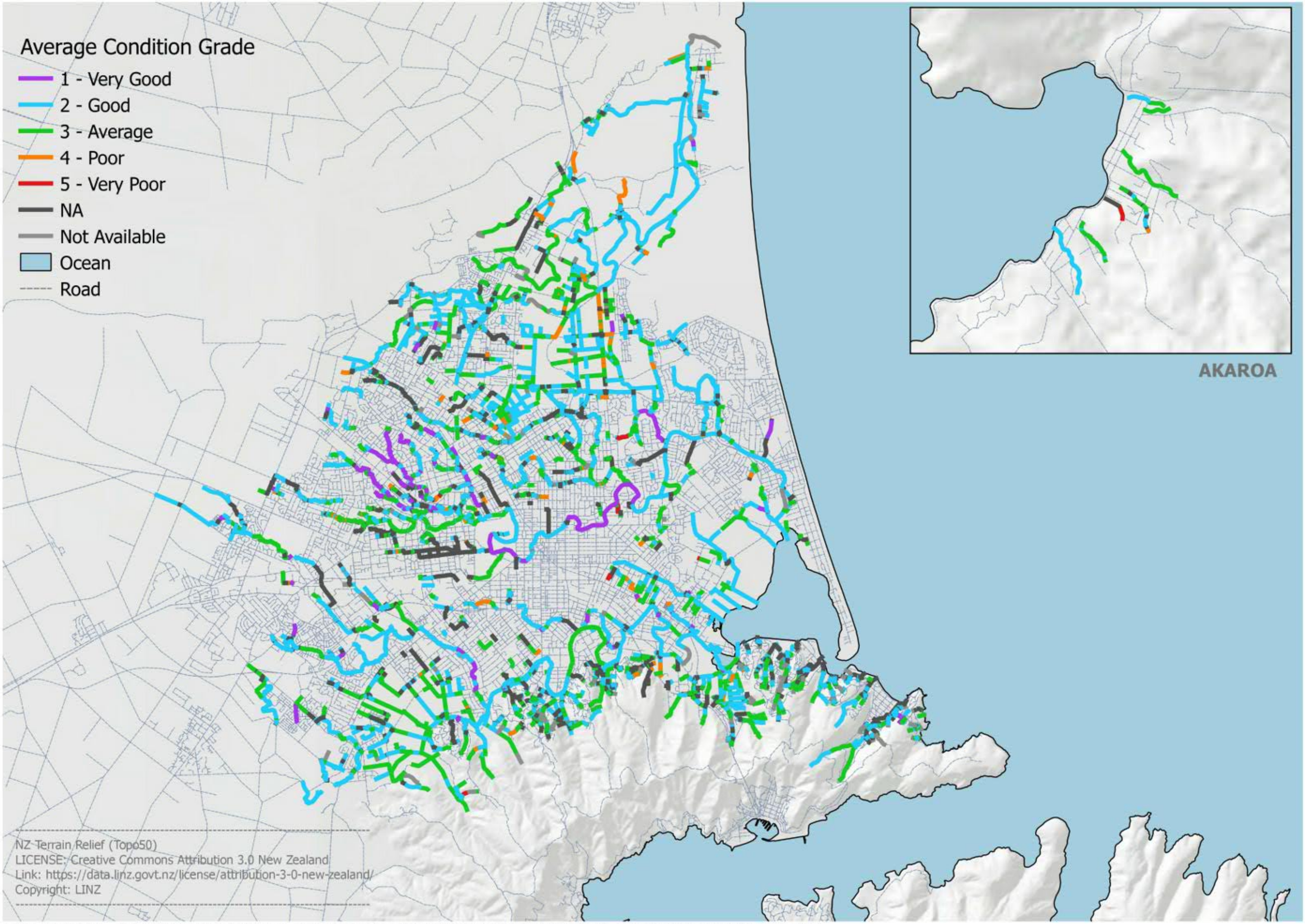


FIGURE 05 - OVERVIEW MAP OF AVERAGE CONDITION SCORES FOR SURVEYED CHANNELS

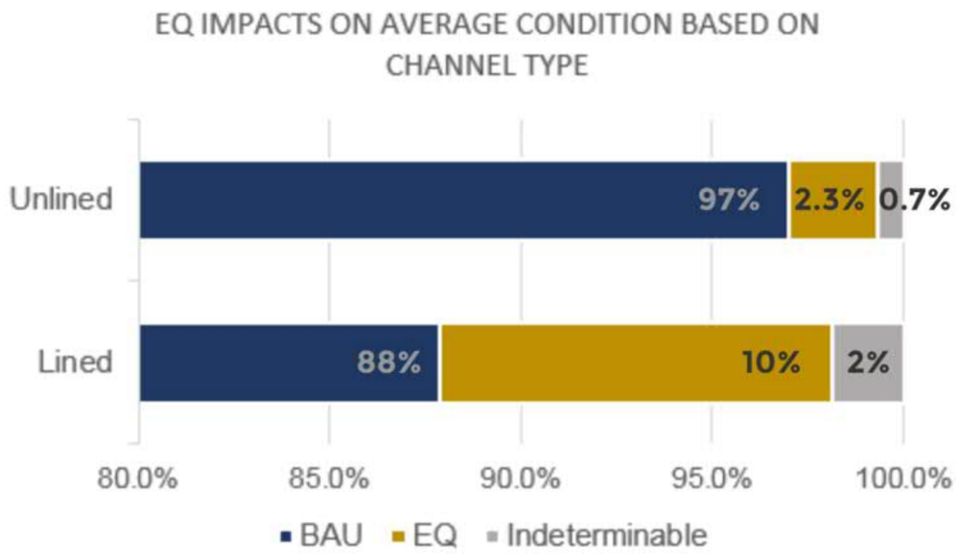
EQ VS. BAU

The open channel assessments involved an evaluation of whether the average condition of the channel reach was mainly influenced by earthquake (EQ) effects or Business-as-Usual (BAU).

It should be noted that the assessment of EQ vs. BAU as a general cause of deterioration is not straight-forward. Often a mix of both causes is evident, and the evaluation is a best-assessment based on the visual facts presented to the assessor. Several cases were encountered where channels that were in poor condition prior to the earthquakes experienced amplified damage during the earthquakes, thus resulting in a combination of BAU and EQ effects.

Analysis of the data reveals an apparent connection between channel type (unlined/lined) and the impacts of the earthquakes on the average condition.

A graphical summary, as shown in Figure 06, shows that lined channels are seemingly more influenced by earthquakes. One reason for this may be that earthquake damage is more apparent and easier to identify on lined channels, however it is not unexpected that earthquake damage is more prominent on constructed assets as opposed to natural ones. Another influencing factor may also be that these waterways are inherently unstable due to the surrounding ground conditions, which is why they were lined in the first place.

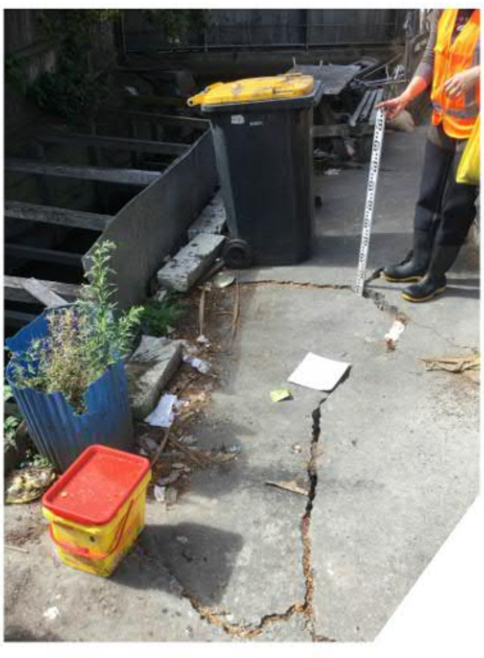


*Note scale is skewed

FIGURE 06 - GRAPHICAL SUMMARY SHOWING HOW EQ IMPACTS ARE MORE SIGNIFICANT ON LINED VS UNLINED CHANNELS

Typical earthquake effects on average channel condition included reaches where the majority of faults involved bank slumping or broken lining due to differential ground settlement or obvious lateral movement.

Some examples of characteristic earthquake effects are shown below.



STRUCTURES

There are a considerable number of structures associated with the waterways; a total of 8294 structures were assessed throughout the field surveys, equating to an average of 16 structures per km of waterway.

A total of 33 different structure types were identified throughout the surveys. The three most common structure types were culverts (21%), pedestrian bridges (17%) and pipe ends/outlets (13%).

The types of structures encountered varied greatly - from minor culverts to major vehicle bridges and small flow-regulating weirs to full tidal gates. An overview of the major structure types is provided in Figure 07 on the next page.

The assessments did not differentiate between private and Council-owned structures in the field. A validation exercise was run during post-processing of the data on certain types of structures to ascertain what proportion of the assessed structures exist in the Council's current asset database. A brief outline summary of this validation exercise is shown on page 18 and full details are provided in the Technical Summary document.

A significant number of pedestrian bridges and boundary fences were identified throughout the field surveys. It is not known what proportion of these structures are private, and have valid resource consents, and it is recommended that the Council investigate/review these structures and enforce their existing powers under the Land Drainage Act (1951) as required as the crossing objects could potentially cause hydraulic restrictions.

Condition scoring of structures was based on visually surveying structures and their performance based on their general purpose and assumed acceptable level of service. For assets where only part of the structure could be seen (e.g. culverts and pipe ends), only the visible part was assessed.

The majority of structures (90%) were considered to be condition Average (3) or better. Only 8% of structures were assigned grades Poor (4) and Very Poor (5). The remaining 2% involves structures where the condition could not be visually assessed, generally due to the asset being completely covered in vegetation or submerged.

The structure type with the highest proportion of condition Very Good (1) was pedestrian bridges. This is likely due to the fact that many of these structures are in regular use and maintained by private owners.

Conversely, culverts had the highest proportion of condition grade Very Poor (5). Many of these culverts were structurally fine, however, issues such as sediment or rubbish blocking them resulted in limited or no flow through the culverts, thus a poor condition grading was applied.

>> KEY STRUCTURE FACTS

AVERAGE CONDITION GRADE OVERVIEW:

Very Good: 8%
Good: 49%
Average: 34%
Poor: 7%
Very Poor: 2%

Pedestrian bridges had the highest proportion of condition grade 1 (24.2% of all grade 1s)

Culverts were most common, accounting for 1743 (21%) of all structures

90% of structures were considered to be average condition grade 3 or better

Figure 07 shows an overview of the types of structures encountered and the relative proportion of assets identified. Structure type 'Other' includes assets where less than 30 structures were identified, these were lumped together for visual purposes.

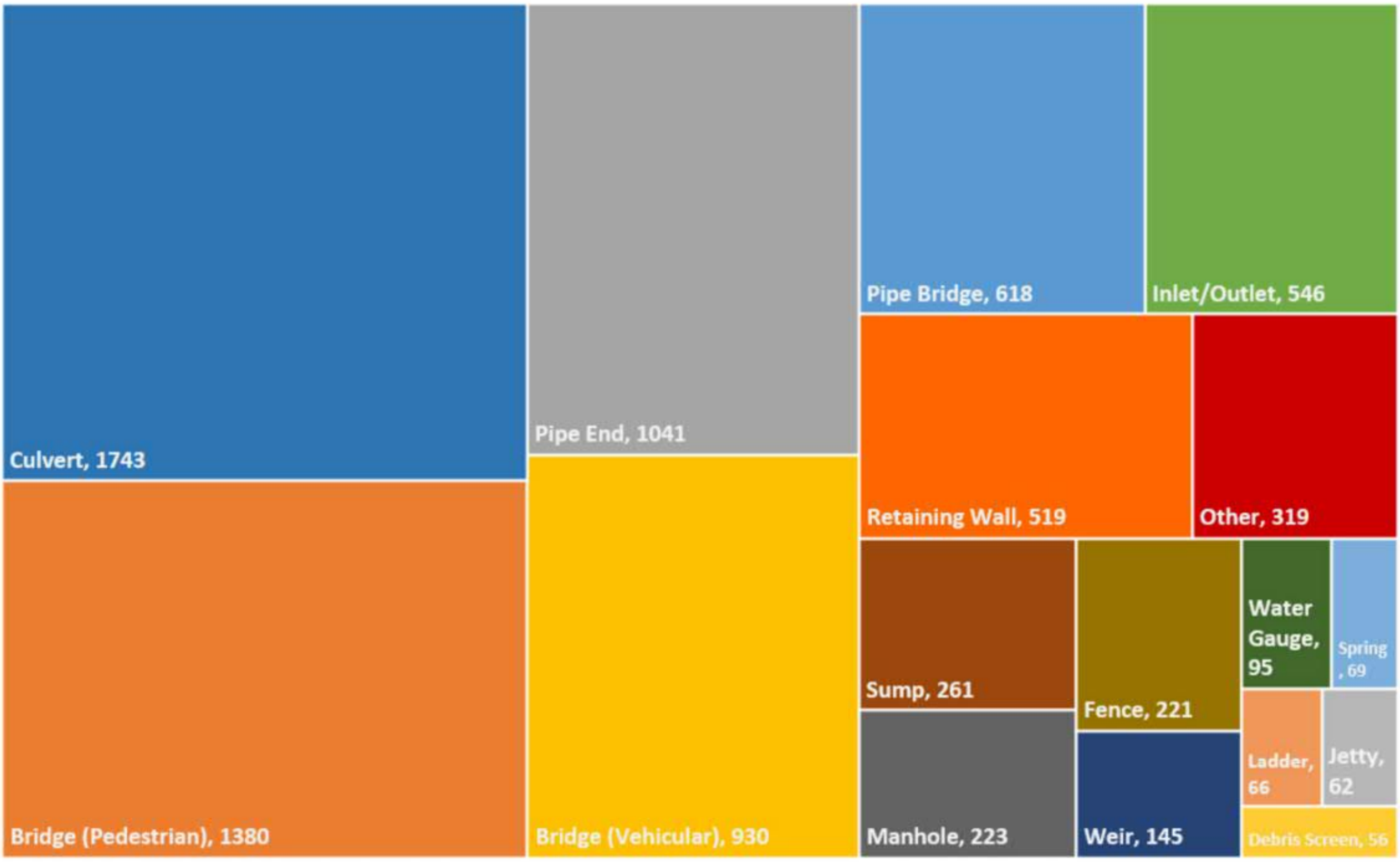


FIGURE 07 - OVERVIEW OF VARIOUS STRUCTURE TYPES AND NUMBER OF STRUCTURES IDENTIFIED

Examples of structures identified on the watercourses. Clockwise from top left: Pipe outlet with flap valve, culvert under road, pedestrian crossing in public space, pedestrian crossing on private property, culvert under vehicle driveway, fish ladder, flow dissipater, water level gauge on pipe outlet headwall.

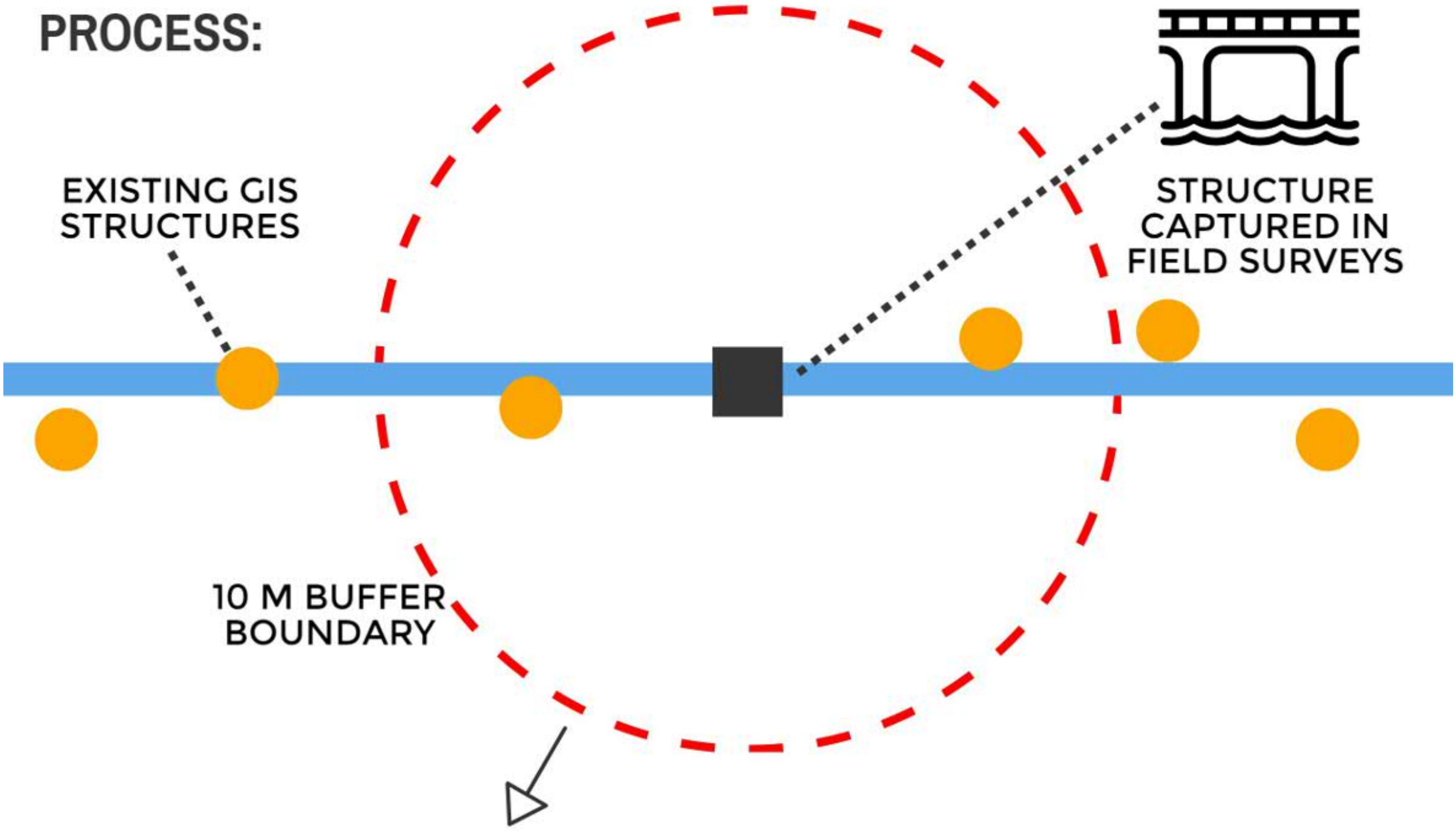
STRUCTURE VALIDATION

A validation process was undertaken to investigate what proportion of structures collected in the surveys exist in the Council's current GIS database.

The analysis was done as an automated GIS exercise where captured structures were verified against existing GIS structures within a 10 m radius, as explained in the diagram below. The analysis only included certain structure types, i.e. the ones that are well defined in the Council's GIS. Examples of structures that were included in the validation process include culverts, pipe ends and monitoring equipment. Structures that were excluded involved assets such as boat ramps, jetties, and fish ladders, that are not typically maintained by the Council.

Full details of the validation process and results are available in the Technical Summary document. The diagram below presents a brief outline of the validation process and results.

PROCESS:



STRUCTURE VALIDATION OUTPUTS:

>> AUTO VALIDATION
Only one existing GIS structure within boundary

>> NO SUITABLE MATCHES
No existing GIS structures within boundary

>> MANUAL VALIDATION
Multiple existing GIS structures within boundary

- **>> NO SUITABLE MATCHES** — No object type matches
- **>> MANUAL VALIDATION** — One object type match
- **>> SPATIAL CHECK REQUIRED** — Multiple object type matches

RESULTS:

Result Output	AUTO VALIDATION	MANUAL VALIDATION	NO SUITABLE MATCHES	SPATIAL CHECK REQUIRED
No. of Structures	1,145 (23%)	950 (20%)	1,777 (36%)	1,011 (21%)

OPUS

FAULTS

Specific locations of damage to the waterways and associated structures were identified during the field surveys; 9525 faults were identified in total, equating to around 23 faults per km of open channel (disregarding 'NA' or 'Not-Avl' reaches).

The faults identified throughout the field assessments covered 19 different fault types, from maintenance related faults such as overgrown vegetation, structural faults such as broken lining, and potential compliance issues such as structures across the waterways.

Alongside fault type, additional degrees of detail were captured in the form of fault severity, recommended response time and whether the fault was likely caused by EQ or BAU.

The most common fault type identified was broken lining, which accounted for 21% of the faults. The next most common fault types included undercutting/scouring (12%), overgrown vegetation/tree roots (11%) and cracks/structural damage (11%).

The majority (95%) of faults were evaluated as being severity Moderate (3) or less. The remaining 5% were considered to be either Critical (4) or Catastrophic (5).

As the requirement to specify a recommended response time was introduced in later versions of the survey specification, this detail was only available for 53% of the faults. The majority (80%) of these faults stated recommended response times of 3 months or longer, i.e. non-urgent. The remaining 20% was split evenly between within 1 week and 1 month urgency.

Combined analysis of fault severity and recommended response time shows that the less severe faults generally correspond to lower urgency, whereas the more severe faults have higher urgency. This is shown in Figure 09.

Overgrown/unmaintained vegetation issues contributed to many of the faults that were identified. Some of these were smaller issues that can be easily rectified by maintenance works. Some of the faults however were more major issues with large tree roots causing physical damage to the waterways, in particular concrete and timber linings. These faults are potentially also compliance issues as the trees may have been planted too close to the waterways. It is recommended that the Council investigate these and seek to enforce the rules set out in the Drainage Act (1951) as appropriate.

Another potential compliance issue that was commonly identified, in particular where waterways flowed through residential areas, was private boundary fences and bridges crossing the channels. Again, it is recommended that the Council investigate these and enforce the Drainage Act as appropriate as these structures could cause hydraulic restrictions.

>> KEY FAULT FACTS

FAULT SEVERITY OVERVIEW:

Insignificant: 33%
Minor: 21%
Moderate: 41%
Critical: 2%
Catastrophic: 3%

Broken lining accounted for the highest proportion (40%) of Catastrophic (5) severity faults

95% of faults were considered of Moderate (3) or less severity

56% of faults were identified on lined drains

FAULT SEVERITY

Fault severity is an important metric for classifying faults and prioritising repairs. Fault severity can be combined with other metrics such as recommended response time, fundamental fault cause (EQ or BAU), or criticality of the watercourse. Figure 08 shows an overview of the fault severities for each sub-catchment, as they were defined in Figure 02. The catchment colour highlights the proportion of high severity faults in the sub-catchment, by showing higher proportion of severity 5 (Catastrophic) as darker red.

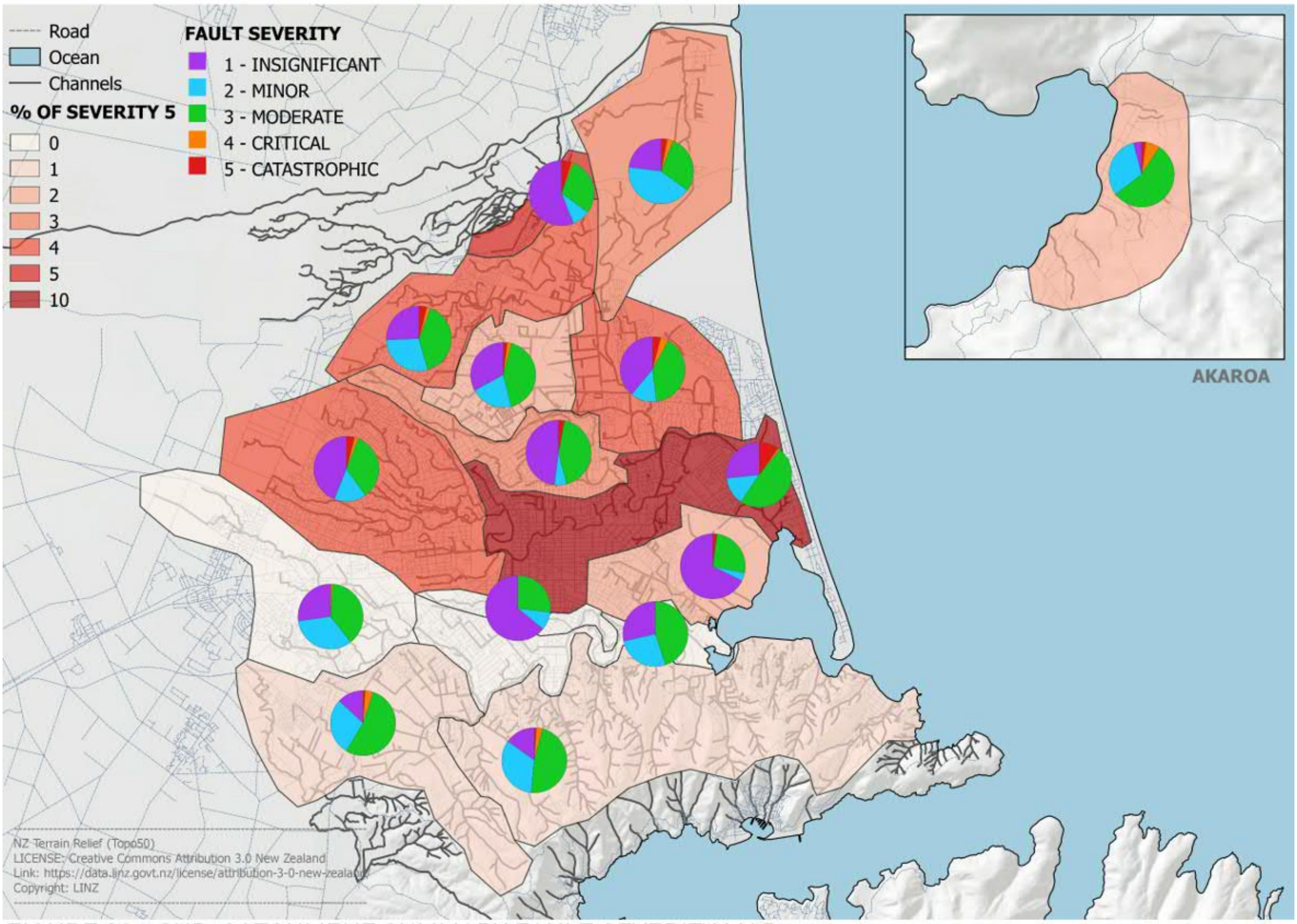


FIGURE 08 - SUB-CATCHMENT SUMMARY FAULT SEVERITY MAP

Figure 09 shows fault severity combined with recommended response time. It can be seen that faults that were considered to be urgent (Within 1 Week) generally also had higher severity. Correspondingly, less urgent faults have a higher proportion of lower severity faults.

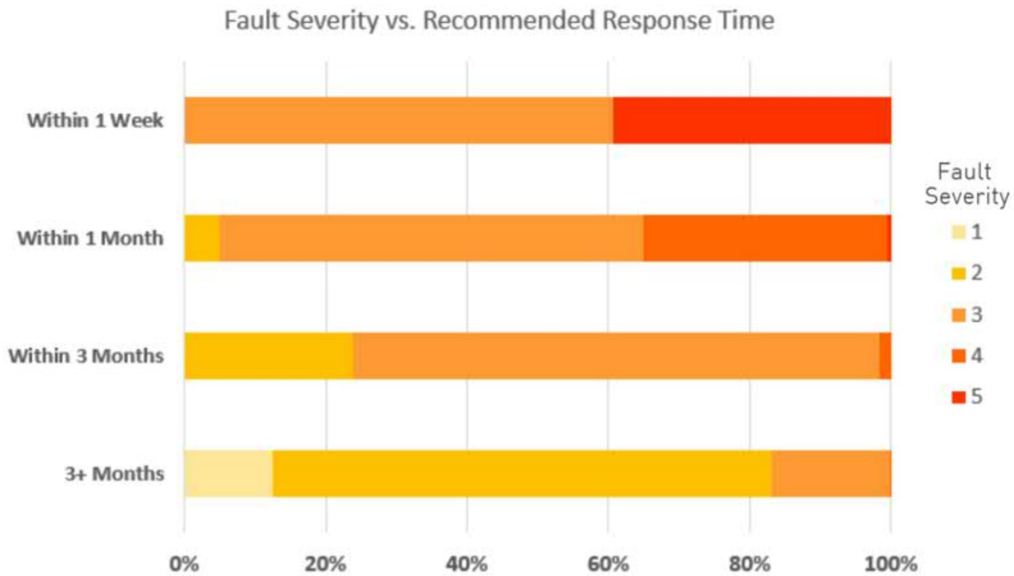


FIGURE 09 - FAULT SEVERITY AND RECOMMENDED RESPONSE TIME

OPUS

FAULT DENSITY

The relative density of faults is shown in Figure 10. The density of faults will be influenced by the number of waterways in the area, however the density map exhibits trends that correlate with general expectations. Firstly, faults are more common in areas of the city that were generally worse affected by the earthquakes, such as the north-eastern suburbs. In addition to this, the areas of higher fault density generally occur where there is a higher proportion of lined drains versus unlined channels. This is described further below.

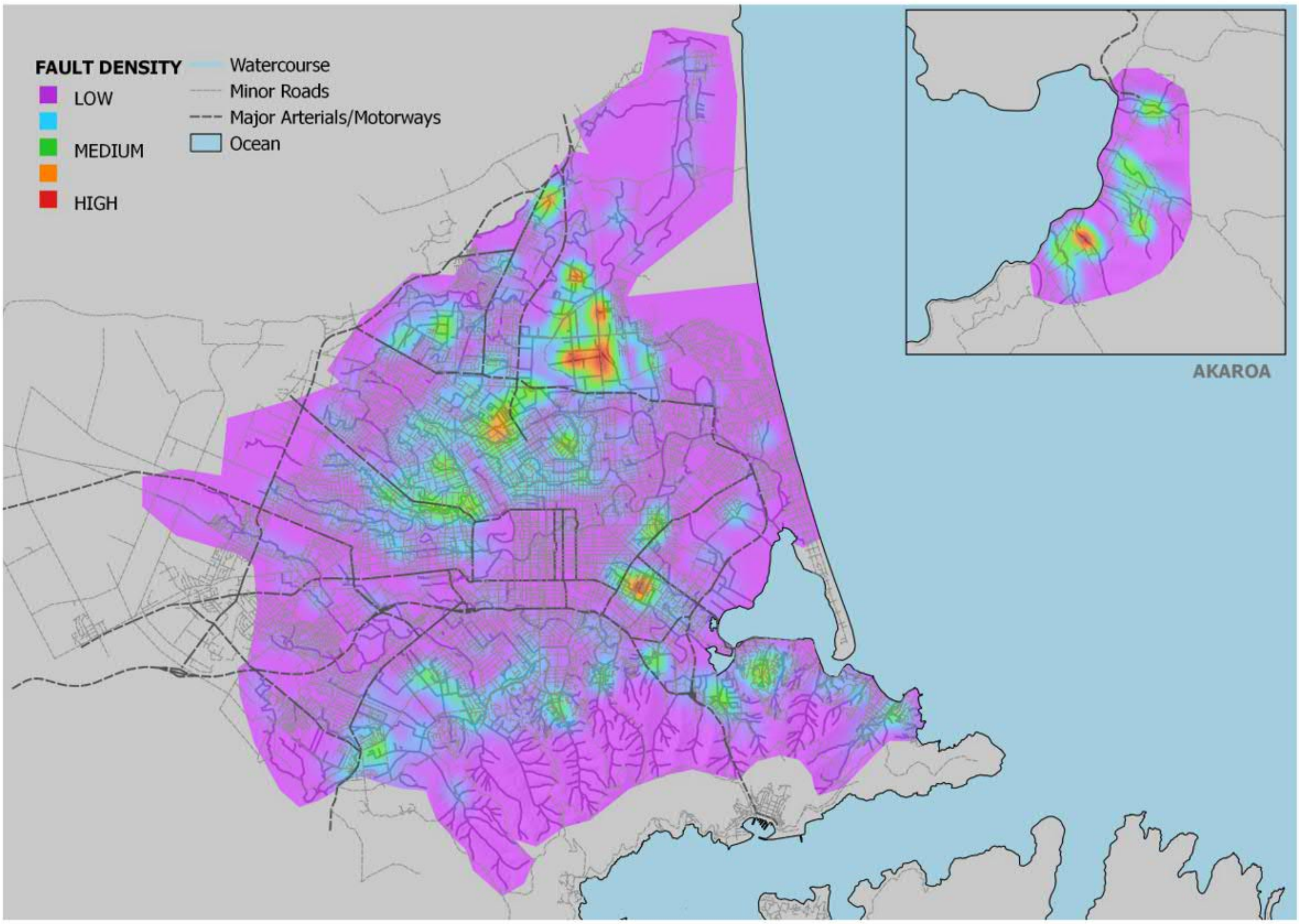


FIGURE 10 - DENSITY OF FAULTS IDENTIFIED ON WATERWAYS

The suggestion that the density of faults is higher on lined channels is supported by analysis of the data. The dataset shows that 56% of the faults were logged on the lined drains, however lined drains only account for 20% of the total length of waterways surveyed. This shows that proportionally a large number of faults exist on the timber and concrete lined waterways.

NUMBER OF FAULTS ON LINED DRAINS >> 5329 (56% OF TOTAL)
LENGTH OF LINED DRAINS >> 104 KM* (20% OF TOTAL)

~ 51 FAULTS PER KM

NUMBER OF FAULTS ON UNLINED WATERWAYS >> 3554 (37% OF TOTAL)
LENGTH OF UNLINED WATERWAYS >> 304 KM* (59% OF TOTAL)

~ 12 FAULTS PER KM

*These numbers are the total length of lined and unlined channels only. Excluded from this overview are channels of type 'Mixed' and reaches with 'NA' or 'Not-Avl' (i.e. piped or inaccessible).

FAULT CAUSE - EQ VS BAU

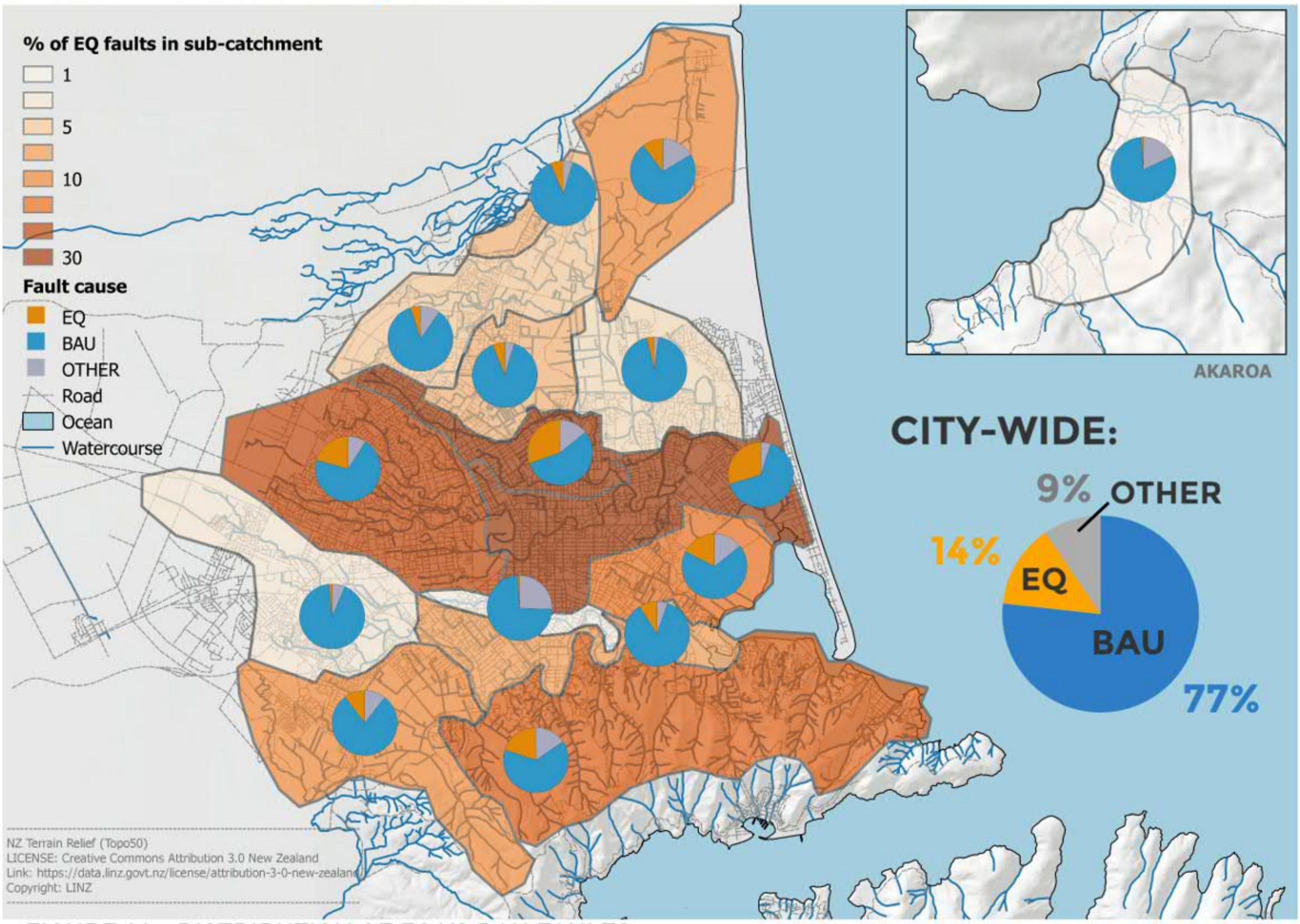


FIGURE 11 - DISTRIBUTION OF EQ VS BAU FAULTS

The assessment of faults included an evaluation of what the fundamental cause of the fault was; either earthquake (EQ) or Business-as-Usual (BAU). Fault cause 'Other' was used for scenarios where neither of the two other categories were applicable. This category related mostly to human interference with the waterways such as potential compliance issues including private fences crossing the channel and stock pugging the banks due to lack of fencing. Figure 11 shows an overview of EQ vs. BAU faults across the city.

As mentioned previously, the distinction between EQ and BAU causes was not straight-forward. Many faults may have been minor before the earthquakes however the significant forces applied from the ground movements would have exacerbated these and made them more severe. In these cases, assigning the category EQ or BAU relies on the judgement of the assessor. Vegetation cover also made the 'age' of faults harder to discern and given that several years passed between the earthquakes and the surveys it was difficult to distinguish between 'fresh' and older faults.

Regardless of the difficulties, the data gives some insight into the overall cause of faults on the waterways. Overall, the data shows the distribution as 77% BAU, 14% EQ and 9% 'Other'. This indicates that although the earthquakes have had an effect on the condition of the waterways, the majority of faults relate to genearl deterioration and highlights the need for continuous maintenance.

One interesting insight, as shown in Figure 12, is that the EQ-related faults often result in more severe damage. This applies in particular to category 5 (Catastrophic) faults where the split between BAU and EQ is close to 50/50 (versus average 85/15 for the lower severity ratings).

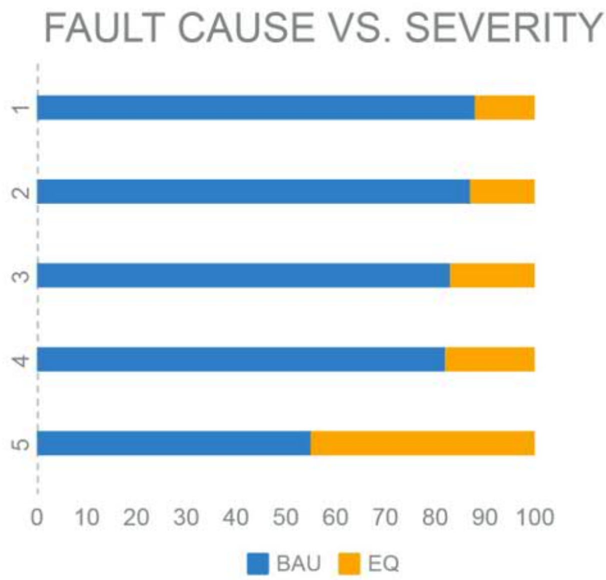


FIGURE 12 - EQ DAMAGE GENERALLY RESULTS IN HIGHER FAULT SEVERITY

OPUS

FIVE VALUES

The five non-performance related values recognised by Christchurch City Council for waterways include culture, ecology, heritage, landscape and recreation. The values were assessed at a high level during the field surveys; each value was graded on a 1-5 scale and comments and photographs were captured where applicable.

The Five Values assessments were not carried out across all the assessed waterways. Around 380 km, equating to 74% of the total length of surveyed waterways, had assessments on the Five Values completed.

Summarising the Five Values on a city-wide basis provides relatively limited insight. The data is more valuable for individual waterways or catchments where the Council are looking at restoring and enhancing the waterway to capture values beyond drainage.

As a quick overview, the condition grades for the five values have been summarised in the tables on the right. A spatial overview of waterway reaches with Good/Very Good and Poor/Very Poor condition grades for the individual values is shown in the maps (Figure 13 and Figure 14) on the next page.

CULTURE	
1 - Very Good	3%
2 - Good	10%
3 - Average	29%
4 - Poor	28%
5 - Very Poor	30%

ECOLOGY	
1 - Very Good	0%
2 - Good	13%
3 - Average	68%
4 - Poor	14%
5 - Very Poor	5%

HERITAGE	
1 - Very Good	6%
2 - Good	12%
3 - Average	11%
4 - Poor	28%
5 - Very Poor	43%

LANDSCAPE	
1 - Very Good	3%
2 - Good	20%
3 - Average	35%
4 - Poor	23%
5 - Very Poor	19%

RECREATION	
1 - Very Good	12%
2 - Good	14%
3 - Average	25%
4 - Poor	17%
5 - Very Poor	33%

Example of good values, plantings and recreational access via walkway and jetty.

Example of good heritage value, old railway bridge at Ferrymead Heritage Park.

Example of good recreation value, kayaking on the river.

OPUS

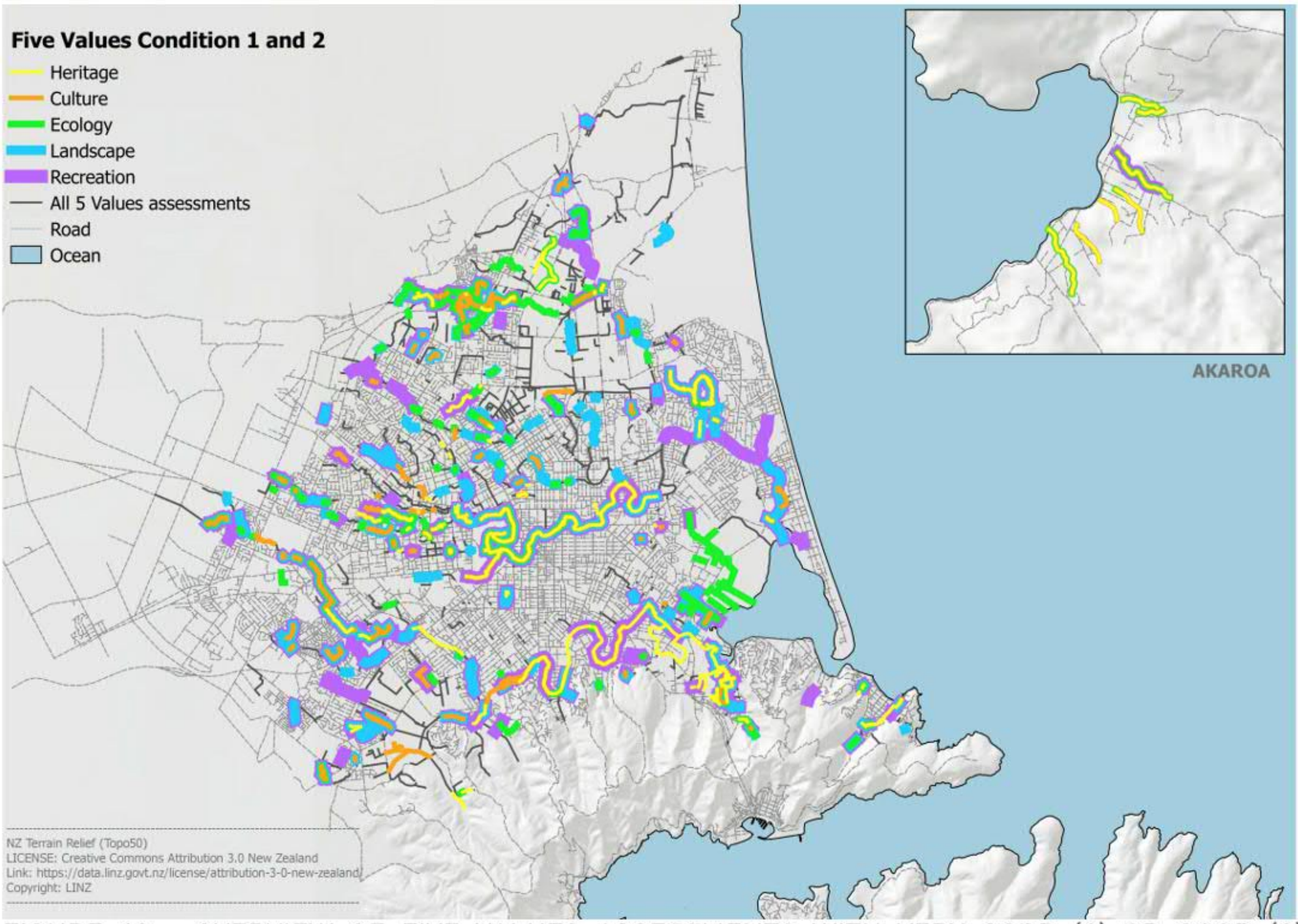


FIGURE 13 - OVERVIEW OF FIVE VALUES ASSESSMENTS WITH VERY GOOD (1) OR GOOD (2) CONDITION GRADES.

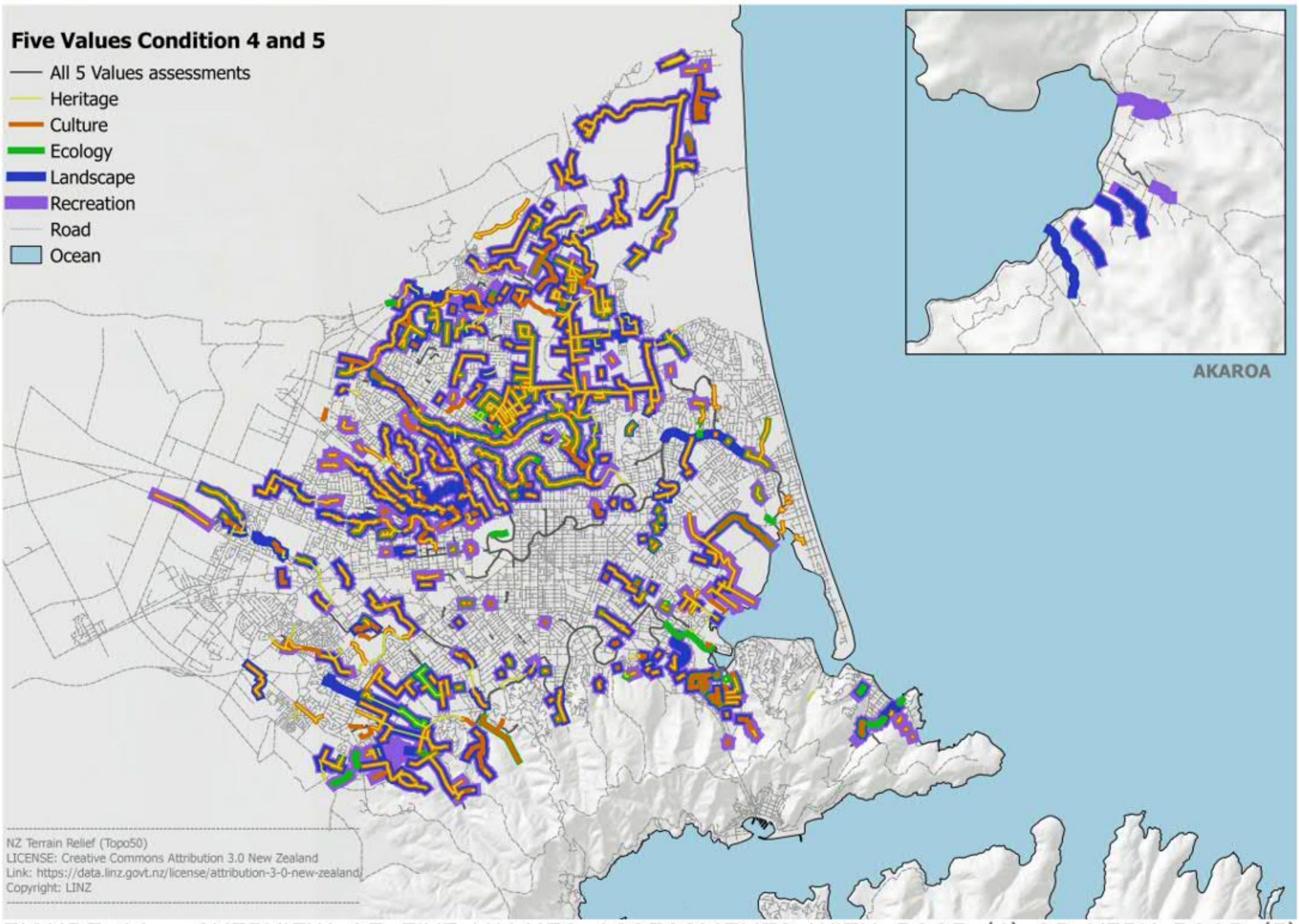


FIGURE 14 - OVERVIEW OF FIVE VALUES ASSESSMENTS WITH POOR (4) OR VERY POOR (5) CONDITION GRADES.

05 CCTV: OVERVIEW

Many of the watercourses and open drains in Christchurch are intermittently broken up by 'closed' channels such as pipes and culverts. Knowing the condition of the pipes and culverts in conjunction with the open channels is important as severe hydraulic restrictions may occur in the closed channels that are not as easy to detect or investigate as those on open channels.

Extensive CCTV surveys have been undertaken on the piped stormwater assets of Christchurch since 2011. The following overview gives a brief summary of the information available for the pipes and culverts that are in-line with the surveyed channels, based on data acquired from the Council in February 2016.

~1600 KM OF PIPE AND CULVERT STORMWATER ASSETS IN MAIN CHRISTCHURCH AREA

133 KM OF PIPES AND CULVERTS IN-LINE WITH SURVEYED CHANNELS

70 KM (53%) HAVE HAD CCTV SURVEYS ✓

63 KM (47%) NO CCTV SURVEYS UNDERTAKEN ✗

ASSETS WITH CCTV SURVEYS

Figure 15 and Figure 16 show a summary of mean and peak structural grades for the 70 km of pipes and culverts that have had CCTV surveys undertaken.

It should be noted that the data used for these assessments was extracted in February 2016 and therefore it is possible that the condition of some assets may have changed as capital and maintenance works may have been undertaken in the interim. Additional CCTV surveys may also have been undertaken which could be added to the analysis.

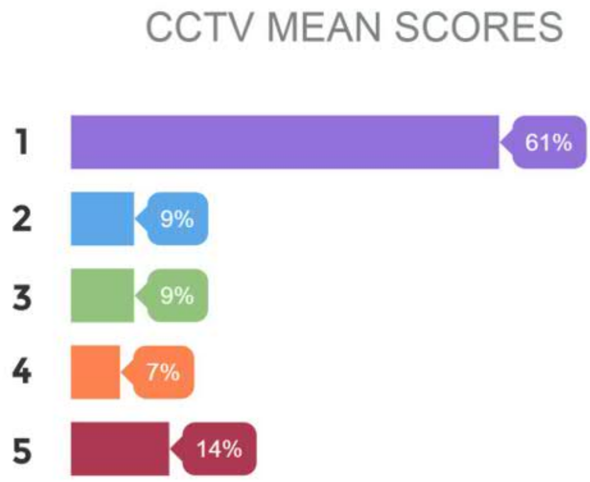


FIGURE 15 - CCTV MEAN SCORES FOR SURVEYED ASSETS

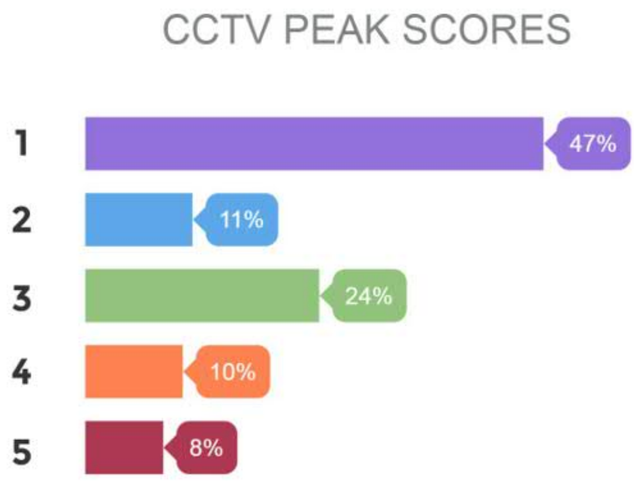


FIGURE 16 - CCTV PEAK SCORES FOR SURVEYED ASSETS

ACTION EVALUATION & RECOMMENDATIONS

For the surveyed assets an action evaluation process was developed by Opus for assessing CCTV data as part of the LDRP investigations. The evaluation is based on a matrix (Figure 17) that assesses the Mean vs. Peak structural scores and, based on this, outputs a suggested action.

The evaluation matrix is based on guidelines from the New Zealand Pipe Inspection Manual and was created by technical experts within Opus who have extensive experience with pipe condition assessments.

The results of running the analysis on the 70 km of surveyed pipes and culverts is shown in Figure 18.

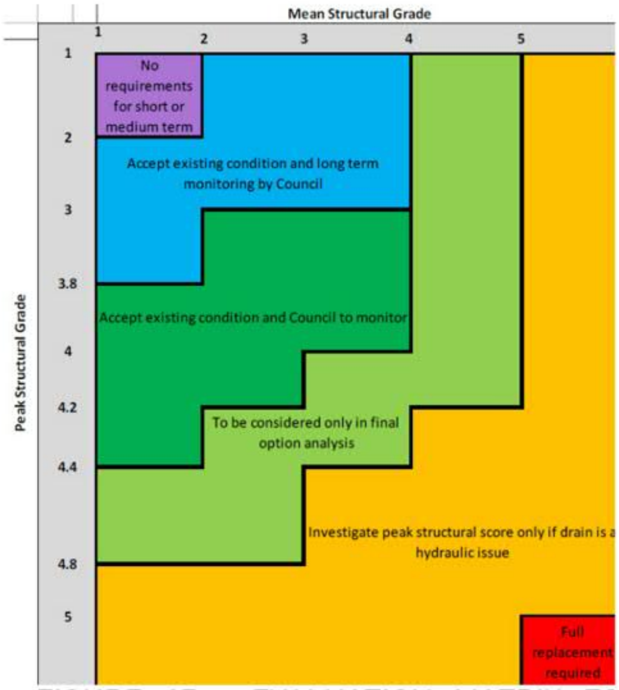


FIGURE 17 - EVALUATION MATRIX FOR RECOMMENDED ACTIONS BASED ON CCTV MEAN AND PEAK STRUCTURAL GRADES

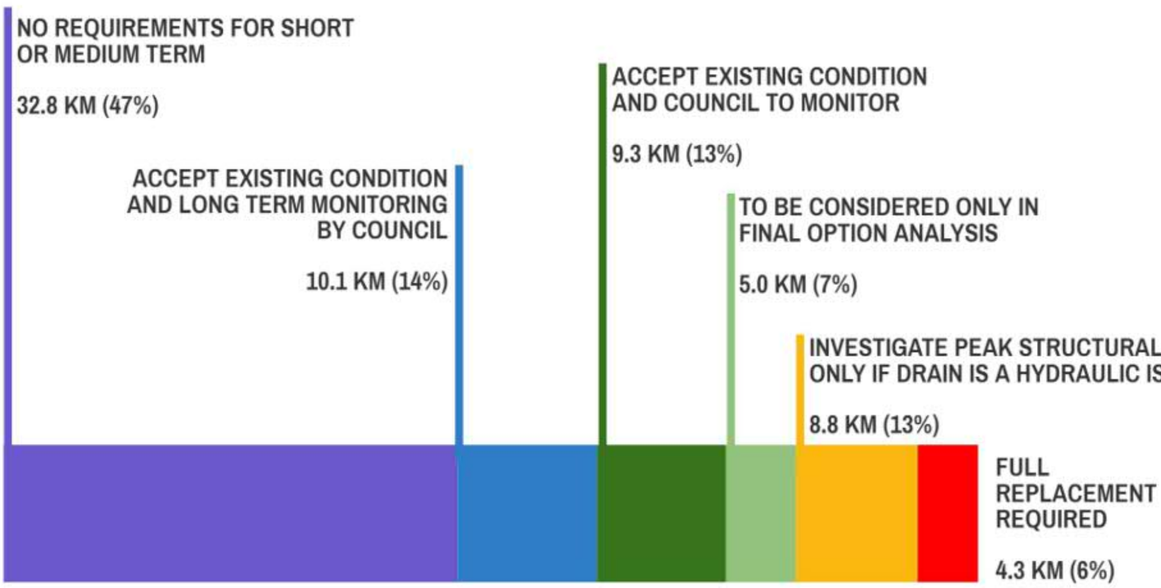


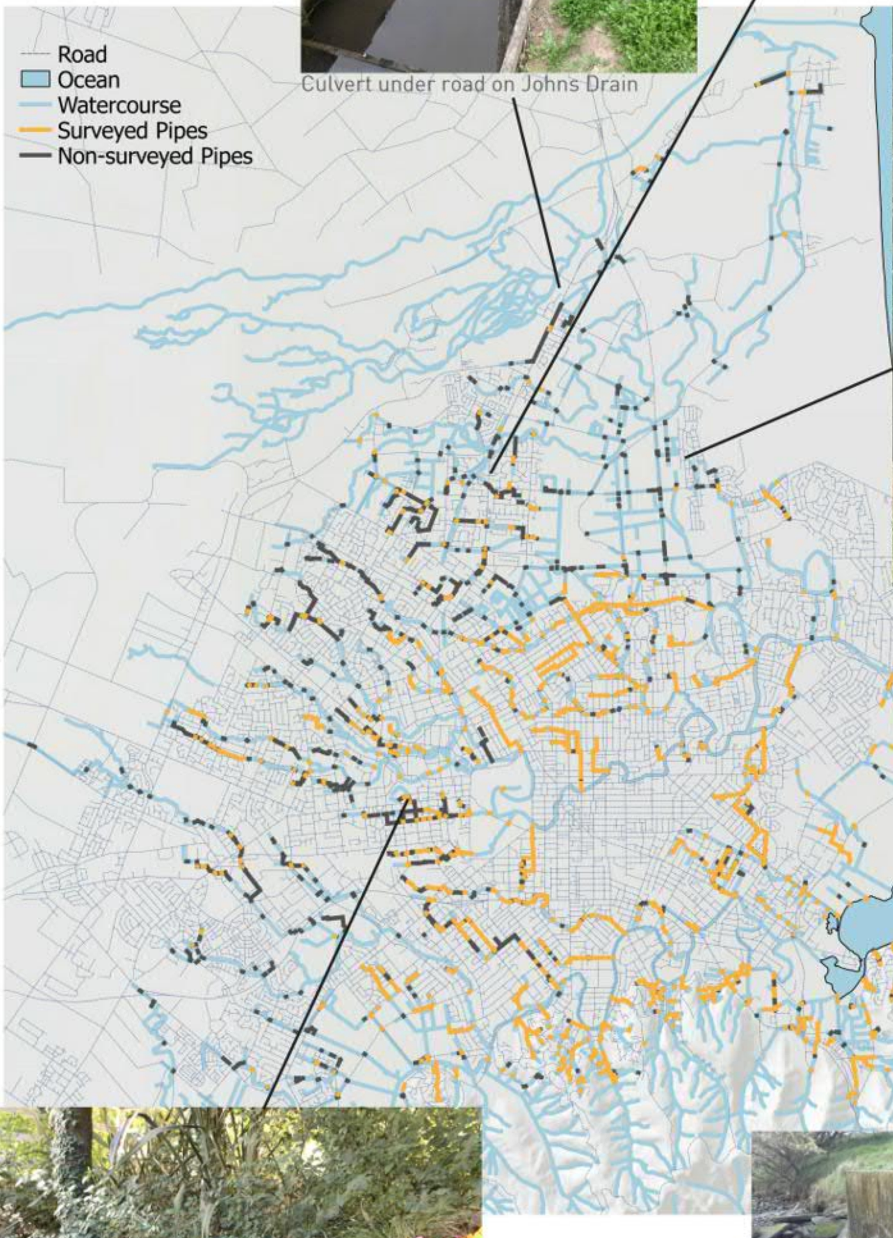
FIGURE 18 - RESULTS OF CCTV ACTION ANALYSIS

CCTV OVERVIEW AND ASSOCIATED FIELD DATA

The map below provides an overview of the surveyed and non-surveyed assets in-line with the open waterways included in the LDRP assessments. The photos are examples of locations where the open channel field surveys have collected information that can complement further evaluation of 'closed' assets.

Culvert under road on Johns Drain

Culvert under driveway on Kruses Drain



Stormwater outlet on Gibsons Drain

Multiple stormwater outlets on Avon River

Stormwater pipe outlet on Estuary Drain

UNSURVEYED ASSETS: PROXIMITY SCORING ANALYSIS

A total of 63 km (47%) of the culverts and pipes in-line with the surveyed watercourses have had no CCTV surveys undertaken according to the February 2016 dataset. In order to determine recommendations for which assets should be prioritised for CCTV surveys, Opus undertook a proximity analysis to infer grades from surrounding assets.

The analysis took the average mean structural scores of surveyed assets within a 250 m radius (Figure 19). If the average mean structural score of the assets within the proximity boundary was greater than or equal to 3, scoping CCTV surveys was recommended. Equally, if no surveyed assets exists within the 250 m radius, a scoping survey is recommended. Assets with inferred grades less than 3 are assumed to be in acceptable condition however, further analysis of this may be necessary in particular if an area is known to experience issues.

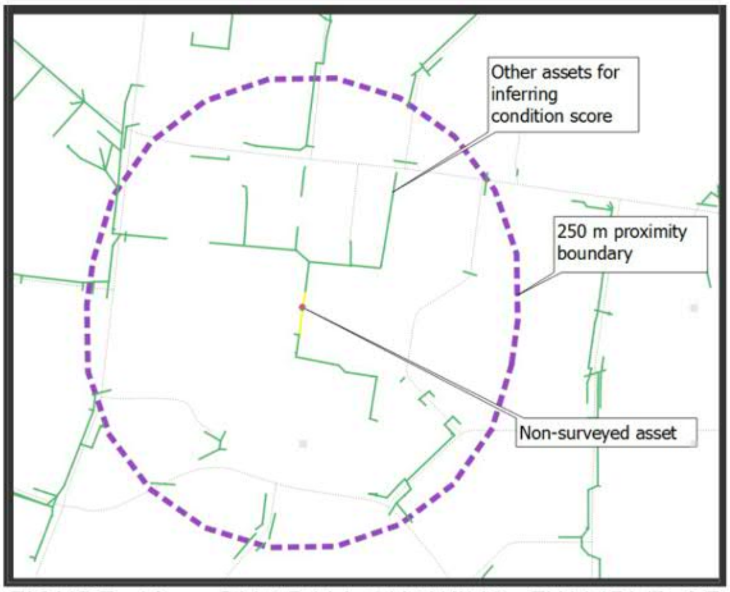
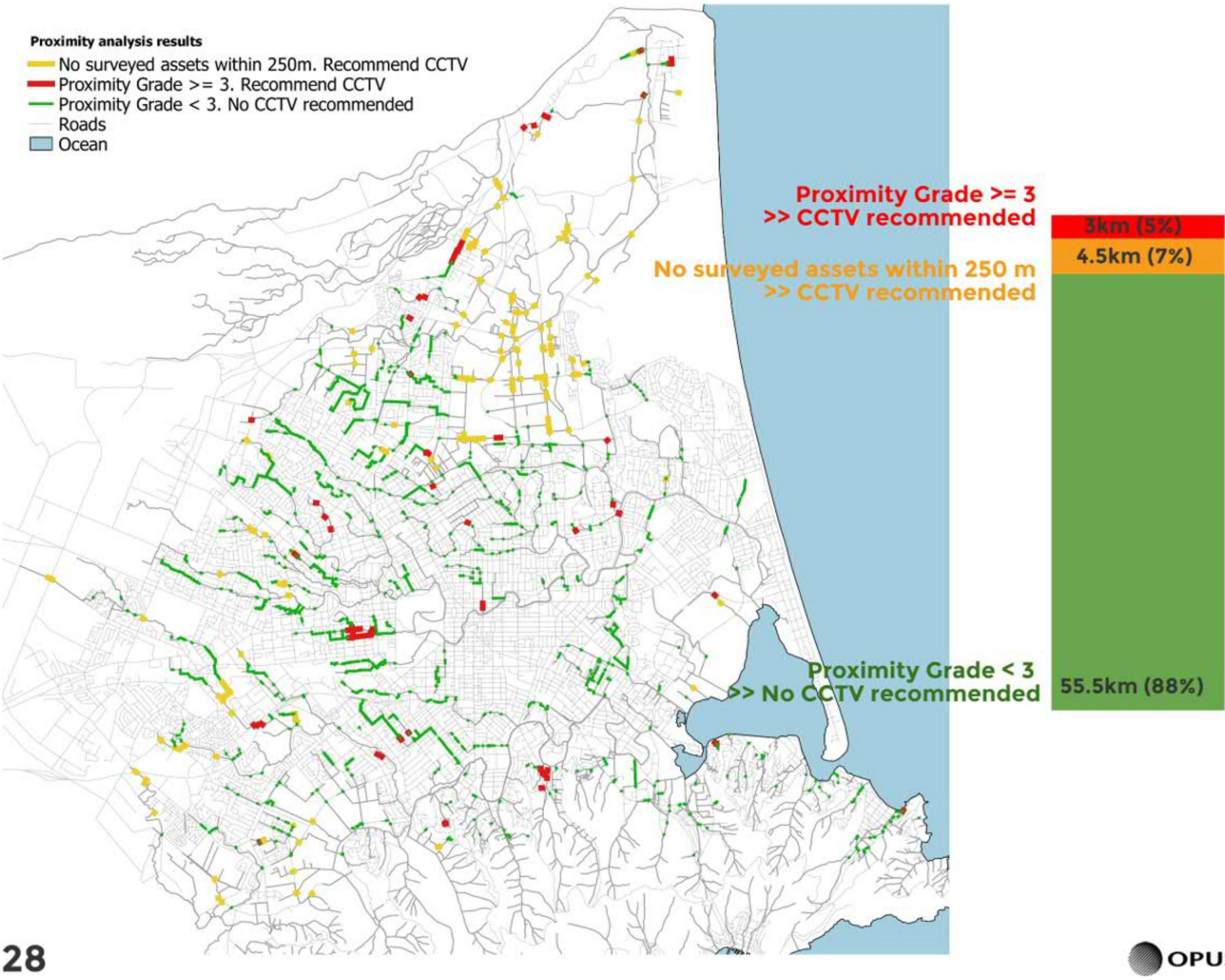


FIGURE 19 - DIAGRAM SHOWING EXAMPLE OF PROXIMITY SCORING ANALYSIS OF AN ASSET USING ASSET SCORES WITHIN 250 M RADIUS

The results of the proximity analysis are shown below. It can be seen that the large majority of unsurveyed assets (88%) are not recommended for CCTV scoping surveys as their inferred grade is less than 3. The remaining 12% of assets are recommended for CCTV scoping surveys, particularly if they are in an area experiencing regular performance issues or if the adjoining waterway is to be developed through further LDRP projects such as issues & options and concept design.



OPUS

06 SUMMARY & RECOMMENDATIONS

SUMMARY

The dataset that has been assembled from the LDRP field surveys is a comprehensive database of the open channels, and their associated structures, across Christchurch. The dataset exhibits a snapshot of the current condition of the land drainage network - providing a baseline for future assessments and deterioration evaluation. The dataset, which will be integrated into the Council's existing information system, will facilitate better decision-making around the waterways of Christchurch, ultimately helping create a stormwater network that is more resilient and reflects the values of the city and its communities. A summary of key points presented in this report is included below.

>> The dataset includes 516 km of watercourse reaches. A variety of channel types have been investigated; major rivers, enhanced waterways, roadside swales and concrete- and timber-lined drains to name a few.

>> 8294 structures that are associated with the waterways were assessed.

>> The damage assessments identified 9525 faults, involving various degrees of severity from Insignificant (1) to Catastrophic (5).

>> A high-level assessment of the non-performance related values of culture, ecology, heritage, landscape and recreation (Five Values) was undertaken on around 380 km of waterways. The assessments can help identify waterways of significant value to communities, thereby enabling and supporting enhancement opportunities.

>> The waterway visual condition assessments identified that the majority (78%) of open channels were in Very Good (1) to Average (3) condition, totaling roughly 402 km of open channels.

>> A small proportion (0.2%) of waterways were considered to be average condition Very Poor (5), representing 790 m of open channel.

>> The visual assessment of structures identified that the majority (90%) of structures are condition Average (3) or better.

>> The fault data shows that the majority (95%) of faults were considered to be severity Moderate (3) or less.

>> Analysis of the data showed that higher severity faults were more often related to earthquake damage than Business-as-Usual.

>> A rough costing estimate has shown that approximately $12-15 million would be required to rectify the severity 4 and 5 faults.

>> 7.5 km of scoping CCTV surveys for non-surveyed piped assets has been recommended based on a proximity analysis of surveyed assets within a 250 m radius.

RECOMMENDATIONS

1. Christchurch City Council should make the collected information accessible to teams across the Council, as well as maintenance contractors, so that the information can benefit work across all levels at the Council.

2. The Council and the selected waterway maintenance contractor should use the dataset to derive a job management system that allows a feedback function to keep the dataset 'live' and up to date.

3. The Council should consider enforcement of existing powers under the Drainage Act (1951) to rectify the potential compliance issues identified that could cause hydraulic restrictions.

4. The Council should derive a suitable reporting format for future maintenance contracts such that the data returned from the field is consistent with their data requirements.

5. The Council should consider a rolling 10-year Waterways Condition Assessment programme, covering 50 – 60 km annually, to assist Council functions such as operational programming, valuations, and determining the deterioration of assets over time with updated information.

6. The Council should consider the need to collate additional CCTV information of closed waterway assets to improve the current understanding of the main waterways.

7. A review of the waterways renewal and enhancement projects delivered since 2015 should be undertaken to ensure that the condition assessment status of the waterways reflects these recent works.

Opus International Consultants
12 Moorhouse Avenue
PO Box 1482, Chch Mail Centre
Christchurch 8140
New Zealand

Tel: +64 3 365 5400
Fax: +64 3 365 7858