Lessons learned from one of New Zealand's most challenging civil engineering projects: rebuilding the earthquake damaged pipes, roads, bridges and retaining walls in the city of Christchurch 2011 - 2016.

Asset Investigation Management Plan

Story: SCIRT Management Plans

Theme: The SCIRT Model

A plan which outlines how SCIRT is to carry out condition investigations and analysis.

Programme funded by

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SCIRT
Rebuilding Infrastructure

Asset Investigation Management Plan

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ACRONYMS, ABBREVIATIONS AND DEFINITIONS

Term	Definition
AA	Alliance Agreement
AOC	Actual Outturn Cost
CCC	Christchurch City Council
CSS	(CCC) Construction Standard Specifications
CERA	Canterbury Earthquake Recovery Authority
DMP	Design Management Plan
DTL	Delivery Team Leader
EMP	Environmental Management Plan
EOC	Estimated Out-turn Cost
FMP	Financial Management Plan
FOC	Forecast Out-turn Cost
GM	General Manager
IAT	Integrated Alliance Team
IDS	(CCC) Infrastructure Design Standards
IRMO	Infrastructure Rebuild Management Office
IRTSG	Infrastructure Recovery Technical Standards and Guidelines
ITP	Inspection and Test Plan
IWMS	Integrated Work Method Statements
JDE	JD Edwards Accounting System
KPI	Key Performance Indicator
KRA	Key Result Area
NZTA	New Zealand Transport Agency
NOP	Non Owner Participant
PMP	Programme Management Plan
PMS	Programme Master Schedule
QMP	Quality Management Plan
SCIRT	Stronger Christchurch Infrastructure Rebuild Team
TOC	Target Out-turn Cost

ACRONYMS, ABBREVIATIONS AND DEFINITIONS

Abbreviation	Definition
Like for like (modern equivalent)	Is the replacement of the infrastructure that returns the Levels of Service back to what existed prior to the failure or damage occurring. It should be designed and constructed to conform to the accepted modern standards and include the use of the natural advances in materials, design, and construction techniques, and technology that have occurred. By utilising these “natural advances”, any incremental change in service, efficiency, resilience etc. that results is not considered to be betterment. It does not need to be a precise replica of what existed prior. For example “Like for like” could include the use of newer technologies (e.g. pressure systems in lieu of gravity) providing there are sound logical reasons for doing so, and levels of service increases are incidental, minor and not the main driver for the change.
Betterment (Improvement)	Is the improvement that is provided as a result of an intentional decision to provide a step change in level of service, capacity, efficiency etc. Examples include increasing pipe size to accommodate future (or existing under) capacity; changing from a water supply rural restricted supply to an Urban on demand supply; or consciously paying extra for a step change in energy efficiency. Such betterments are identified, costed, and reported on in design reports. Provision of increased capacity to meet changing network requirements, or flows as a result of the earthquakes is not considered betterment.
SalesForce	Software used by CCC to initially manage the storage of asset defect information and to group defects into work packages for IRMO contractors. This has subsequently been replaced by systems at SCIRT.

1 INTRODUCTION

1.1 PURPOSE

The purpose of this Management Plan is to outline how the SCIRT is carrying out condition investigations and analysis of Christchurch's Road, Wastewater, Water and Land Drainage and Stormwater networks to determine the extent of earthquake related damage.

This plan is one of a suite of management plans forming the Stronger Christchurch Infrastructure Rebuild Team's Programme Management Plan, the delivery mechanism by which the SCIRT will manage the rebuild of Christchurch's infrastructure.

The SCIRT task was originally *"To return, within a 5-year period, the Road, Wastewater, Water and Land drainage and stormwater networks to a condition that will facilitate the provision of more resilient levels of service than those prior to the 4 September 2010 earthquake."*

Since the middle of 2014, the SCIRT task is to carry out rebuild works in accordance with Network Guidelines (DG36A (roading), DG43B (stormwater and wastewater), and DG60 (water supply)), and to include the option of rebuild in accordance with DG43A-1 (stormwater and wastewater).

This Management Plan addresses how asset assessment is undertaken in order to meet the expectations of stakeholders.

1.2 BACKGROUND

Due to the earthquakes, considerable damage was inflicted on all of Christchurch City's Road, Wastewater, Water supply and Land Drainage and Stormwater networks.

1.3 INFRASTRUCTURE DAMAGE

1.3.1 Road Network

With regard to the Road and Transportation network, damage was caused by slumping, liquefaction and ground movement opening fissures across the network. Road closures were triggered by destabilised geological features, many buildings were damaged and flooding was caused by burst and broken water mains. There was also been significant damage to a number of bridges, culverts and retaining walls. Additional road infrastructure assets that sustained damage include; footpaths, Kerb and Channels, street lighting, cycle-ways, traffic lights, parking infrastructure, amenity areas and road landscaping.

The types of damage observed include;

- Depressions or humps due to liquefaction
- Collapsed trenches or pipe failures
- Raised manholes due to differential settlement and/or manholes becoming buoyant

- Cracking due to lateral spread or stress cracking
- Surface damage due to cracking, liquefaction or falling masonry
- Infiltration of liquefaction sands and silts into pavement layers
- Full width large scale settlement and subsidence

1.3.2 Wastewater Network

Considerable damage was inflicted on the Wastewater network, with approximately 30% of all premises initially not being able to use the network.

<u>Damage Sustained</u>

Several failure modes have been observed. These include;

- Ingress of silt and liquefaction
- Breaks and damage with Joints, fittings, and pipes
- Changes in grade from as-built grades
- Pipe profile change (e.g. ovality)
- Dips and sags in pipelines
- Manholes and structures uplifted or tilted
- Pump stations uplifted and/or tilted
- Structures cracked and/or split
- Excessive wear occurring to pumps due to excessive pumping of sand/silt

1.3.3 Water Supply Network

Considerable damage was inflicted on the Water supply network, with approximately 60% of all premises initially not having a water supply.

Following significant emergency repair work, the water supply network is presently operating and supplying service to all its customers, but parts are in a fragile state and require work over the next few years to return it to the condition it was prior to the earthquakes. The water supply assets comprise reservoirs, water bores, pump stations, and water mains.

<u>Damage Sustained</u>

Several failure modes have been observed. These include:

- Breaks and damage with joints, fittings, and pipes
- Pump stations uplifted and/or tilted
- Reservoir structurally damaged
- Structures cracked and/or split
- Wells casings bent in the ground
- Well screens filled with fine silt etc. and requiring redevelopment

- Well heads cracked/damaged and causing concern re contamination from surface water ingress
- Excessive wear occurring to pumps due to excessive pumping of sand/silt from wells

1.3.4 Land Drainage and Stormwater Network

Considerable damage was inflicted on the Land Drainage network. Work to date has restored service to much of the city and reduced the risk of flooding.

Damage Sustained

Several failure modes have been observed. These include:

- Ingress of silt and liquefaction
- Breaks and damage with joints, fittings, and pipes
- Changes in grade from As-Built pipe grades
- Pipe profile change (e.g. ovality)
- Dips and sags in pipelines, Manholes and structures uplifted or tilted
- Pump stations uplifted and/or tilted
- Structures cracked and/or split
- Excessive wear occurring to pumps due to excessive pumping of sand / silt
- Loss of service due to land settlement

2 SCIRT SCOPE

The Infrastructure Recovery Technical Standards and Guidelines (IRTSG) has been produced by Asset Owners (CCC, NZTA, CERA) to identify the scope, objectives, intervention levels and standards for the rebuild of horizontal infrastructure. The IRTSG is reviewed and updated on a regular basis.

Since the middle of 2014, aspects of the IRTSG have been superseded by Client instruction to carry out rebuild works in accordance with Network Guidelines (DG36A (roading), DG43B (stormwater and wastewater), and DG60 (water supply)), and to include the option of rebuild in accordance with DG43A-1 (stormwater and wastewater).

3 OBJECTIVES AND TARGETS

The objectives and targets of asset investigation are to define assessment methodologies to be carried out on each asset class to:

1. Determine the degree of damage that has been sustained by the assets resulting from the September 2010 earthquake and all subsequent earthquakes and aftershocks.
2. Provide sufficient information to Designers to allow the determination of the type of repair or renewal that is best suited to meet the objectives of the rebuild.
3. Provide sufficient information to allow Project Definition work for concept design and costing of repairs/renewal to determine whole of life costs. Designs should also take account of the criticality of each asset within the network, the need to achieve resilience against future seismic events, and provide capacity for future growth if appropriate (as Improvement).
4. Provide a framework for a methodology of assessment to meet 1 to 3 above taking account of available resources on an asset class basis.

4 REQUIREMENTS

4.1 CLIENT AND OTHER REQUIREMENTS

Works on the programme shall be undertaken in accordance with the requirements of the following:

- IRTSG and Network Guidelines
- CSS
- IDS
- The SCIRT Agreement (AA)
- Requirements and Minimum Standards defined in Schedule 5 of the AA

4.2 LEGISLATIVE REQUIREMENTS

Legislative Requirements relevant to Asset Investigation are:

- Statutes
- Regulations
- Approvals
- Licences
- Consents
- Permits

These requirements may dictate the commencement and progress of certain facets of the work.

Specific statutory requirements that have been identified as applying to elements of the Programme have been referenced in the applicable Management Plan within this Programme Management Plan set.

5 INTERFACES WITH OTHER MANAGEMENT PLANS

The list of management plans to be produced for the Programme is included in the Programme Management Plan Map.

This management plan primarily interacts with the row of management plans across the top of the Programme Management Plan map which are the plans that are generally more relevant to the activities of the NOPs Delivery Teams.

6 ASSESSMENT METHODOLOGY

A diverse range of methodologies has been employed to determine the extent of earthquake related asset damage.

Sufficiently detailed network condition information has been required to adequately rate the section/sub-catchment of each asset type to determine the most appropriate (and economic) repair and/or replacement solution. To this end the information gathered and assessments carried out need to provide a clear picture of the assets condition and be robust enough to demonstrate that the correct choice (repair and/or renew) has been made.

Each asset group has required a specific 'tailored' investigation to provide this information.

A significant quantum of infrastructure condition survey information was collected as part of the first response phase where the focus was on restoring a minimum level of service for customers. This information has been collated and used for condition assessment.

The methodology of condition assessment is of necessity specific to each asset category. Surface structures such as roads, bridges and retaining walls are able to be viewed, damage severity assessed and condition rated without sophisticated tools. By comparison wastewater and stormwater pipelines require measurement of level and gradient to determine hydraulic integrity and cleaning and CCTV inspection to determine structural condition.

6.1 ROAD NETWORK

6.1.1 Information Required

Carriageways, Footpaths, Cycleways

Two levels of information are required for the roading network:

- Surface Damage
- Sub Surface Damage to the structural layers

Surface damage has already been collected with a complete data set for Carriageways, Footpaths, Cycleways and Kerb and Channels utilising RAMM Contractor post-earthquake events. However, significant 'Make Safe' work has been undertaken to prove safe passage for vehicles by removing liquefaction, removing humps (where liquefaction has lifted the surface layer), filling voids and rip and remake repair work. As such, much of the surface damage is not apparent and therefore the of sub surface damage data may be required. The requirement for this is assessed at the Concept Design Stage.

Road Drainage (land Drainage)

Significant damage has occurred to the Kerb, Channel, Sumps and catchment pipework through the earthquake events. Post EQ damage to the Kerb and Channel has been fully assessed and given a condition grade similar to that above. Damage to sumps, catchment pipe work and outfall pipes, is assessed during the design stages.

Where either restoration or rebuild of the pavement is identified at Concept Stage, a full level survey and pipework assessment is likely to be required during Detailed Design to finalise damage and repair requirements. Where pavement patch repair is recommended, isolated repairs will also be identified to the road drainage assets under the Detailed Design process.

Bridges & Structures

Bridges and retaining walls were inspected and ranked with a condition grade following the Earthquake events to give initial priority ranking. A full structural assessment is undertaken for assets with moderate or major earthquake damage during the Concept Design phase.

6.1.2 Assessment Tools

A full network survey was undertaken post September 2010, post February 2011 and post June 2011 events to identify the type and volume of damage. This information was collected through RAMM Software using specific defect codes collected with GPS Coordinates and respective Route Position and Route Station (RAMM) data.

The Defects were quantified and the section of road given an overall condition grade to assist with prioritisation. Similar information has been collected for Footpaths, Cycleways and Kerb and Channels.

Carriageways, Footpaths, Cycleways, Road Drainage

A further condition inspection is undertaken during the Concept Design phase to identify the current condition of the pavement. This information is collected utilising RAMM and forms the base of the Repair, Restore or Rebuild option development, based on the Network Guideline requirements. Where Restore or Rebuild is recommended, further sub base testing may be required dependant on the site specific conditions, visible defects and proposed option development.

PoleCam or CCTV surveys may also be necessary for road drainage pipework or road culvert assessments along with topographical surveys for pavement shape and K&C levels and alignment.

The Design Team is responsible for the collection of this data.

Bridges

All Bridges have an initial visual assessment of structural condition to allow prioritisation.

Full structural analysis and geotechnical investigations is undertaken for all bridges that are found to have moderate or major earthquake damage or on a case by case basis dependant on type of damage to the structure. These assessments will determine whether the damaged structures meet building code standards and form the basis of the repair option development.

The Design Team is responsible for the structural analysis and geotechnical investigation process as part of the design process.

Retaining Structures

All retaining walls have visual assessment of structural condition to allow prioritisation. The necessity to undertake geotechnical investigation and full structural assessment is made on a case by case basis, based on the level and type of damage to ensure Building Code standards are met.

The Design Team is responsible for all structural analysis and geotechnical investigation to support the design process.

6.2 WASTEWATER NETWORK

6.2.1 Information Required

Gravity Pipeline Network (including manholes):

Investigations into network condition require assessments of:

1. Hydraulic performance – this is the ability of gravity pipes to convey their design flow and solids along pipelines. This is affected by differential settlement, changes in pipeline gradient and the presence of local dips.

2. Pipe Condition – this is the structural condition of the pipeline.

Information required to undertake the above assessments includes:

1. Network plans, age of pipelines and material types (available from GIS and as-built plans)
2. Original manhole lid and invert levels (available from GIS and as-built plans)
3. Post-earthquake manhole and invert levels (collected by MH invert level survey)
4. Ground settlement (and heave) at "say" 100 mm contours in each area as derived from survey benchmark levels and pre/post-earthquake LiDAR
5. Plans of ground shearing/cracking and liquefaction areas (presented on Observed Liquefaction Maps and Liquefaction Resistance Index (LRI) Map)
6. Internal manhole inspection to ascertain, pipeline displacement at manhole, pipeline damage immediately adjacent to manhole and gradient of pipelines at intervals away from manhole at "say" 1 to 5 metres from manhole (collected through MH condition inspections (completed by surveyors undertaking MH invert level survey) and by profilometer survey)
7. CCTV inspection assessment – latest available (collected through the CCTV programme and Pole Cam programme)
8. Damage/repair history – earthquake specific (and last 5 years) (available from City Care and published to SCIRT GIS)
9. Pipeline long section profile to establish dips (collected through the profilometer survey programme)
10. Desktop based prediction of pipe structural condition using the Pipe Damage Assessment Tool (PDAT) – a risk based pipe condition predictor that associates pipe condition with various damage indicators to predict the structural condition of the pipe.

Pipe condition surveys (CCTV, Pole Cam, Profilometer, PDAT) are stored in the InfoNet database. InfoNet is an asset management software tool used to store the surveys, analyse damage against damage thresholds given in the IRTSG, and present the raw survey information through to Designers, network modellers and Project Definition staff. This is competed by publishing assessment outputs to SCIRT's GIS system and through direct upload of data by Designers.

<u>Siphons</u>

Condition assessment was undertaken by City Care Ltd under the direction of CCC (as part of the first response phase). Records of siphon condition are contained on the siphon register (held by CCC, Chris Mance).

<u>Rising Mains</u>

Rising mains were inspected by various Head Contractors under the direction of IRMO (as part of the first response phase). Renewal decisions were made at this stage on the basis of:

1. Plans, age of pipelines and material types
2. Leaks and observations and performance issues.

Laterals in the public street

CCTV inspection/assessment by SCIRT Delivery Teams as part of the main sewer line renewal works.

Pump Stations and Equipment - Inspections were completed and defects loaded to Salesforce under the direction of IRMO. Work packages were subsequently issued to SCIRT.

Inspections were arranged by CCC after each after-shock and comprised;

1. Thermal imaging of electrical equipment
2. Vibration analysis on major rotating equipment
3. Visual inspection of pump stations and ancillary equipment (e.g. hoists)
4. Visual inspection of pump station surrounds (paths, landscape, fences etc.)
5. Inspection to ensure Health and Safety standards are being complied with.

No further asset assessment is planned by the Asset Assessment Team. Designers will refer to earlier inspection records and update themselves of any changes in condition through detailed inspection and discussion with CCC Network Operations (on a project by project basis).

Odour Control Facilities (in the collection system)

No programmed asset assessment is occurring. Designers shall review the performance of odour control facilities with CCC Network Operations. This review shall consider:

1. Whether the medium has been contaminated.
2. Whether air pipes are fully functioning and whether the back pressure on the odour fan(s) is within acceptable levels.
3. Whether irrigation and drainage systems functioning.

Ancillary Structures

Designers shall assess ancillary structures for structural damage and develop inspection process specific to the asset.

6.2.2 Assessment Tools

The SCIRT priority is to determine the hydraulic integrity of the catchment, sub-catchment or line prior to considering pipeline structural condition i.e. prove the pipeline is fit for purpose before assessing structural damage.

Any network investigation must start with the assessment of the trunk sewer, progressing up the catchment and sub-catchments.

The sequence of gravity pipe assessment for each new Project Definition Area is as follows:

Information Gap Analysis

Information gap analysis using information in InfoNet to identify what we know:

1. Coarse grade assessment (all gravity pipes) to identify pipes that are now flatter than Pre-EQ and Pre-IDS grades.
2. Pipe condition assessment using available CCTV data (only covers a sample of pipes).
3. Pipe dips using pipe profile (only covers a sample of pipes)
4. Asset age where road reconstruction is proposed.

Desktop Assessment of Pipe Damage

Undertake desktop assessment of all gravity pipelines in the project definition area. Identify un-assessed lines that we can predict the condition of with a high degree of confidence.

Design Engineer Input

Has a catchment strategy been developed or capacity analysis completed that would allow the identification of redundant pipelines (if any), which do not require assessment? Is so, identify lines not requiring assessment.

Request field assessments

Request field assessments for pipes requiring investigation and whose condition cannot be predicted by the above steps.

- CCTV
- Pipe profile

Stage 1 of the investigation is to analyse the invert level information collected (at the manhole) compared to earlier (pre-earthquake) invert levels (and cross referenced to ground level settlement from bench mark surveys and LiDAR data) may indicate whether settlement and/or manhole floatation has occurred. This desk top study may be sufficient of its self to determine whether the catchment or sub-catchment being considered, or parts thereof, has changed hydraulically and hence may not meet the original design criteria, and will indicate further investigation is required.

Stage 2, in those sections failing to meet the design criteria, is to investigate the gradient of the pipelines immediately adjacent to the manhole, specifically, by inspecting inside each manhole to determine pipe displacements relative to the manhole and pipe gradient at "say" 1 m intervals away from the manhole (out 5 m) using profile meter, level sonde or gradient measure. This investigation is expected to be able to be carried out while the pipes are in operation (flowing less than full).

Defects observed are to be added to the GIS.

In the event that there are obvious pipe displacements or changes in grade in the vicinity of the manhole, recalculate the gradient of the pipeline (excluding the local influence of manhole level changes).

If the sub-catchment or section of pipeline falls outside of the minimum design criteria, that section can be considered to require replacement. Alternatively, if it is demonstrated that the pipeline has maintained its hydraulic integrity and the manhole level is required to be 'adjusted' this will also be recorded in GIS. Note: the decision to re-level the manhole will only be made following Stage 3 and 4 investigations below.

Stage 3 is to profile each section of pipeline meeting the hydraulic design criteria using either a profile meter or level sonde. The device will be mounted in a guide frame to centralise it in the pipe and pushed through on fibreglass rods. In the event that a blockage or significant displacement is encountered the device can be inserted from the next manhole back to the obstruction. This investigation may be able to be carried out while the pipes are in operation (flowing less than full).

Analysis of the profile will determine whether the sag thresholds have been exceeded (and the section of pipeline is to be replaced). The profile will also identify significant vertical displacements and possible areas of damage. The number of displacements can be entered into the GIS. Note: if at any time the total number of defects recorded exceed the replacement threshold criteria, the investigation for the affected section of pipeline will have been completed as set out in Appendix A.

Modelling of the catchment or sub-catchment will be required to ensure that the capacity of the network (once repaired) will meet the original.

Stage 4 is to clean and carry out a CCTV inspection of all lines and sections of pipeline calculated to be hydraulically sound and not considered up for replacement due to the number of breaks and repairs recorded to date.

<u>Manholes</u>

Internal manhole inspection will be carried out to ascertain and quantify:

1. Any damage to the risers, horizontal displacement of risers lid etc.
2. Separation between risers, base and lid
3. Lid level relative to existing (and likely) surrounding ground

<u>Siphons</u>

1. CCTV in conjunction with jetting and sucking to identify pipeline integrity
2. Pressure sond profile to determine that pipeline remains on grade
3. Consider pressure test if CCTV cannot be achieved due to bends in pipe

<u>Rising Mains</u>

1. No of breaks over length of pipeline in accordance with replacement strategy to meet threshold
2. Leak detection survey
3. Pressure test

<u>Laterals in the public street</u>

1. CCTV from boundary where street sewer being replaced and there is no other identifiers that replacement is required.

<u>Pump Stations and Equipment</u>

1. Undertake a full structural inspection and assessment including wet wells, pipe work, valve and pump foundations etc.
2. Confirm design life and design capacity

Odour Control Facilities (in the collection system)

1. Check if biofilter medium is contaminated with ejecta
2. Check air pipes are fully functioning
3. Check back pressure is in accordance with operations manual

6.3 WATER SUPPLY NETWORK

6.3.1 Information Required

Pressure Mains and Sub-mains

Information is required on the piped network to ascertain whether individual repairs or sectional replacement (between street intersections) is required.

The aspects that determine the networks functionality are:

- Pipe condition i.e. breaks, joint separation, thrust block displacements – exacerbated by 'fragility' of pipeline and jointing materials and age of asset
- Undetected (significant) leaks – 'short circuiting' to adjacent damaged wastewater or stormwater systems
- Minor leaks

Information required:

1. Network plans, age of pipelines and material types
2. Inspections of above ground pipelines, pipe bridges etc.
3. Zone water flows (minimum night flow rates) compared with pre-earthquake minimum flows
4. Leak reports (surface) and damage/repair history – earthquake specific (and last 5 years)
5. Leak detection results – 'Three pass' survey to find significant below ground leaks
6. Undertake zone leak detection where night flow rates are returned to pre September 2010 night flow rates

Reservoirs

Inspections were completed as a result of the earthquakes up to June 2011 to determine:

1. Structural integrity
2. Watertightness

3. Health and Safety standards are being met

Pump Station Buildings and Equipment

Inspections carried out are as per those described for Wastewater pump stations above.

Suction Tanks

Inspections were similar to those carried out on reservoirs as described above.

6.3.2 Assessment Tools

The current CCC practice is to assess the overall condition as follows;

- **Pipeline** in street intersection to intersection sections – The pipeline criticality, and the number and nature of the damage within this nominal length will generally determine whether that length is to be repaired, replaced or remain in its present state. Mains and sub main condition tends to be considered separately to each other but often renewal of a main triggers renewal of the sub main in the same street section.
- **Pump Stations** and other structures – Assessed individually and treated on a case by case basis.
- **Pumping Equipment,** Pumps, Standby (diesel) equipment, electrics etc. – treated as individual assets but clearly are interrelated.

Mains and Sub-mains

SCIRT Proposal

The SCIRT proposal is to continue with the current practice of assessing the pipeline condition by:

1. Reference to the number of recorded breaks and/or repairs recorded in GIS.
2. Carrying out a 'coarse' leak detection survey to identify larger 'unseen' leaks (short circuiting to damaged wastewater or storm water systems) and adding this into the DRI database
3. Check network requirements taking account of retirement areas to maintain network requirements. Undertake any condition assessments required to achieve the appropriate LOS's resulting from retirement areas

Wells

Assessed individually and treated on a case by case basis, but combined required capacity at a facility taken into account.

Reservoirs

All reservoirs have visual assessment of structural condition to allow prioritisation. The necessity to undertake geotechnical investigation and full structural assessment will be made on a case by case basis, based on the level and type of damage to ensure Building Code standards are met.

The Design Team is responsible for all structural analysis and geotechnical investigation to support the design process.

Pump Station Buildings

All pump stations have visual assessment of structural condition to allow prioritisation. The necessity to undertake geotechnical investigation and full structural assessment will be made on a case by case basis, based on the level and type of damage to ensure Building Code standards are met.

The Design Team is responsible for all structural analysis and geotechnical investigation to support the design process.

Suction Tanks

Assessments of Pump stations, reservoirs and suction tanks have been undertaken post each significant EQ and aftershock. Further assessment of condition will be undertaken during the design phase on a case by case basis.

6.4 LAND DRAINAGE AND STORMWATER NETWORK

6.4.1 Information Required

Gravity Pipeline Network

As per the Wastewater network requirements, information is required on the piped catchments to ascertain whether individual repairs, sectional replacement (between manholes) or catchment redesign and/or possibly pumping regimes are required.

There are four aspects that combined determine the networks functionality;

- Hydraulic performance – as affected by ground settlement, differential settlement, changes in gradient due to displacement resulting in sags, hogging etc.
- Pipe condition i.e. breaks, joint separation – exacerbated by 'fragility' of pipeline and jointing materials and age of asset
- Manhole and invert levels – affected by manhole flotation, displacement etc.
- Outfall controls – affected by general ground settlement (relative higher sea level), settlement of stop banks, open drain functionality etc.

Information required is as per the Wastewater network, with the addition of items highlighted below;

Information required:

1. Network plans, age of pipelines and material types
2. Original manhole lid and invert levels (although this can be difficult and not always possible to obtain)
3. Post-earthquake manhole and invert levels

4. Original outfall levels and outfall level constraints, be they open drain levels, flood levels and tidal constraints
5. Post-earthquake outfall levels and outfall level constraints as in item 4 above
6. Ground settlement (and heave) "say" at 100 mm contours in each area as derived from survey benchmark levels and pre/post-earthquake LiDAR
7. Plans of ground shearing/cracking and liquefaction areas
8. Internal manhole inspection to ascertain manhole condition, pipeline displacement at manhole, pipeline damage immediately adjacent to manhole and gradient of pipelines at intervals away from manhole at "say" 1 to 5 metres from manhole – all manholes
9. Inspection of outfall structure, non-return gates and pipeline displacements at/through stop banks including pipeline profile – profile meter or similar
10. CCTV inspection assessment – latest available
11. Damage/repair history – earthquake specific (and last 5 years)
12. Pipeline profile – profile meter or similar
13. CCTV inspection/assessment – if all of the above indicate the pipeline is likely to be serviceable

<u>Rising Mains</u>

1. Number of breaks over length of pipeline in accordance with replacement strategy to meet threshold
2. Leak detection survey
3. Pressure test

<u>Laterals in the public street up to the property Boundary</u>

1. CCTV from boundary where street sewer being replaced

<u>Manholes, Sumps, Inlet and Outlet Structures</u>

Information required in addition to that detailed in pipeline above:

1. Internal manhole inspection to identify damage to the risers, horizontal displacement of risers lid etc.
2. Separation between risers, base and lid
3. Lid level relative to existing (and likely or proposed) surrounding ground

<u>Pump Stations and Pumping Equipment</u>

Inspections have been completed and defects loaded to Salesforce and work packages issued to Delivery Teams. Inspections comprised:

1. Thermal imaging of electrical equipment

2. Vibration analysis on major rotating equipment
3. Visual inspection of pump stations and ancillary equipment (e.g. hoists)
4. Visual inspection of pump station surrounds (paths, landscape, fences etc.)
5. Inspection to ensure Health and Safety standards are being complied with

Ancillary Structures

1. Assess for structural damage and develop inspection process specific to the asset

6.4.2 Assessment Tools

The SCIRT priority is to continue to determine the hydraulic integrity of the catchment, sub-catchment or line prior to considering pipeline condition i.e. prove the pipeline is fit for purpose before considering repair.

Stage 1 of the investigation is to determine whether changed ground levels, outlet controls and relative river and/or tidal levels have impacted on the capacity and effectiveness of the network. Investigations comprise of level surveys of outlets, profile of outlet through stop banks etc. and assessment of integrity of any flap gate/backflow prevention. This investigation is expected to be able to be carried out while the pipes are in operation (flowing less than full).

In the event of demonstrable loss of capacity or effectiveness, sufficient further investigation will be carried out to determine if the outlet control is capable of being modified to enable return to the pre-earthquake condition/levels. Note: a decision on acceptance of reduced level of service, outlet improvement, provision of additional storage or pumping options is desirable before proceeding with subsequent upstream investigation.

Stage 2 is to compare invert level information collected (at the manhole) to earlier (pre-earthquake) invert levels (and cross referenced to ground level settlement from bench mark surveys and pre/post-earthquake LiDAR). This will indicate whether settlement and/or manhole floatation has occurred. This desk top study may be sufficient of its self to determine whether the catchment or sub-catchment being considered, or parts thereof, is hydraulically capable of meeting the design criteria.

Stage 3, in those sections failing to meet the design criteria, is to investigate the gradient of the pipelines immediately adjacent to the manhole, specifically, by inspecting inside each manhole to determine pipe displacements relative to the manhole and pipe gradient at “say” 1 m intervals away from the manhole (out 5 m) using profile meter, level sonde or gradient measure.

In the event that there are obvious pipe displacements or changes in grade in the vicinity of the manhole, recalculate the gradient of the pipeline (excluding the local influence of manhole level changes).

If the sub-catchment or section of pipeline falls outside of the minimum design criteria, that section can be considered to require replacement. Alternatively, if it is demonstrated that the pipeline has maintained its hydraulic integrity and the manhole level is required to be 'adjusted' this will also be recorded in the DRI database. Note: the decision to re-level the manhole will only be made following Stage 4 and 5 investigations below.

Stage 4 is to profile each section of pipeline meeting the hydraulic design criteria using either a profile meter or level sonde. The device will be mounted in a guide frame to centralise it in the pipe and pushed through on fibreglass rods. In the event that a blockage or significant displacement is encountered the device can be inserted from the next manhole back to the obstruction. This investigation may be able to be carried out while the pipes are in operation (flowing less than full).

Analysis of the profile will determine whether the sag thresholds have been exceeded (and the section of pipeline is to be replaced. The profile will also identify significant vertical displacements and possible areas of damage. The number of displacements can be entered into the DRI database. Note: if at any time the total number of defects recorded exceed the replacement threshold criteria, the investigation for the affected section of pipeline will have been completed.

Modelling of the catchment or sub-contract will be required to ensure that the capacity of the network (once repaired) will meet the original.

<u>Manholes, Sumps, Inlet & Outlet Structures</u>

In addition to the level information collected above, undertake an internal inspection of the manhole to ascertain and quantify:

1. Any damage to the risers, horizontal displacement of risers lid etc.
2. Separation between risers, base and lid
3. Lid level relative to existing (and likely) surrounding ground

<u>Rising Mains</u>

1. No of breaks over length of pipeline in accordance with replacement strategy to meet threshold
2. Leak detection survey
3. Pressure test

<u>Laterals in the public street up to the property Boundary</u>

1. CCTV from boundary where street sewer being replaced

<u>Pump Stations and Equipment</u>

1. Undertake a full structural inspection and assessment including wet wells, pipe work, valve and pump foundations etc.
2. Confirm design life and design capacity

6.4.3 Information Storage

All damage information is stored in the GIS.

7 MONITORING AND MEASUREMENT

Conformity with the processes and procedure in the management plan set will be monitored and the results measured against the objectives and targets of the programme.

The quality of the products and services produced by the programme will also be measured to assess the effectiveness of the management plans and may initiate a review and revision of the management plan utilising the process described under 10.4 Management Plan Review and Revision.

7.1 MONITORING AND MEASUREMENT

Systematic monitoring and measuring processes involving inspection and testing fulfil a two-fold purpose to:

- Ensure product conformity to contractual and statutory requirements
- Provide an ongoing risk management process and early warnings of hazards

The monitoring and measuring process to be utilised comprises monitoring by management and structured inspections and audits as detailed in:

- SCIRT Quality Management Plan
- SCIRT Health and Safety Management Plan
- SCIRT Environmental Management Plan.

8 MANAGEMENT PLAN CONTROL

8.1 AUTHORISATION

Authorisation is in accordance with the AA, Section 6.1.1.

8.2 DISTRIBUTION

The Plan is a controlled document and shall be distributed and revised in accordance with the SCIRT Quality Management Plan. Hardcopies are Un-Controlled copies. The Controlled copies are maintained in Project Centre.

8.3 AUDITING

Systematic internal audits will be undertaken to monitor the Plan for suitability, relevance and effectiveness. The auditor will be a suitably qualified person who is independent of the activity being audited.

Various audits are undertaken, including but not limited to:

- Internal Audits (System)
- Site Process Audits

- External Audits
- Subcontractor audits (site, office and desktop)

Refer to Audit Plan.

8.4 MANAGEMENT PLAN REVIEW AND REVISION

The process for monitoring and review or its implementation and operation are detailed within the SCIRT Quality Plan.

Implementation of resolutions from reviews will contribute to continuous Improvement.

Revisions to any management plan will always involve the Quality Manager who will take responsibility for ensuring the management plan set remains co-ordinated when revisions occur.

The document may be revised and updated in response to areas identified for improvement, such as;

- Changes in the Requirements and Minimum Standards defined in Schedule 5 of the AA
- Substantial changes in design or scope, construction sequence, staging, methodology, process or resource
- Requests by any Statutory Authority
- Internal and external audits
- Suggestions and comments from personnel
- Preventative action following a non-conformance
- Necessity for corrective action
- Senior management review
- Recommendations of the Independent Design Verifier, Independent Estimator or Strategic Review Panel

9 RECORDS AND REPORTING

9.1 REPORTING INVESTIGATION PROGRESS

- Informal internal reporting
- Monthly reports will be compiled and issued as part of the Operations Report

10 ROLES AND RESPONSIBILITIES

The responsibility for meeting the key requirements of this plan are assigned primarily to the roles identified in the table below:

Responsibility	**Role**
Plan Issue/Revision authorisation	SCIRT Manager
Plan Evaluation and Review	Quality Manager and SCIRT Manager

11 QUALITY ASSURANCE SYSTEMS

11.1 DRAINAGE SURVEY

Drainage survey includes wastewater, stormwater networks and some land drainage networks.

Various systematic checks and controls are built into the workflow to ensure quality control of the survey data received.

1. A survey specification was developed at the commencement of SCIRT through consultation with stakeholders in the data. This provides the technical detail and performance standards for 3rd party survey consultants.
2. Work is allocated on a performance basis to an available survey firm who has a highest level of relevant competency for a certain task.
3. Quality checks are carried out on the work at various stages of the process including:
    - Initially before the 3rd party surveyor submits to SCIRT by internal survey firm QA system
    - By the Survey coordinator for completeness,
    - By the 12d Technician, for general technical correctness
    - By the Designer and delivered via informal and formal feedback, for suitability, fit for purpose and general improvement.

The system is set up to generate competitiveness, high performance and continual improvement.

APPENDIX A

LIST OF ASSET ASSESSMENT DOCUMENTATION AVAILABLE TO SCIRT

The following is a list of asset condition assessment documentation collected subsequent to the earthquakes that is available for use by the SCIRT Project.

Asset Network	Type	Responsibility	Asset Inventory	Data Collection	Other Information	Survey Information	Data Format	Data Structure	Software Used
Wastewater Network	Gravity pipe work	CityCare	CCC Asset Inventory, SCIRT GIS	By City Care	City Care programme office (also hold historic recovery info	CCTV	Video, (Infonet compatible)Spreadsheet, database and picture	Pipe asset ID, Node ID's, Street Address	Infonet (Cam / Cem) transferred to Cleanflow at the end of the CCTV process
	Manholes	SCIRT IST	GIS / 12D	SCIRT contractors	N/A	GPS / Total station	12Da/ Spreadsheets/ photo's	Asset ID	12D
	Laterals in the public street	Delivery Teams When replacing main lines							
	Pump Stations	SCIRT IST	GIS	SCIRT	Renewal project files	Inspection	Excel spreadsheet	Name, SAP	Excel, RAMM
	Odour control facilities	Designers							
	Catchment 15	Opus (during IRMO)	CCC Asset Inventory, GIS	By Downers and collated by Opus	No	Manhole Lid and Invert surveys on Wastewater and Stormwater	Manhole Inventory Sheets, Spreadsheet summaries and Survey Database	CCC Asset ID	12D, AutoCAD, ACAD Civil 3D and MapInfo GIS
Road Network	Pavement (carriageways)	SCIRT IST	GIS, RAMM	SCIRT	Renewal Project Files	Full visual RAMM Survey, Damage cost per road, damage rating 1-5	RAMM	RAMM RP/RS	RAMM
	Bridges	SCIRT IST	GIS, RAMM	SCIRT	Construction / Renewal project files	Inspection undertaken and prioritised.	Excel Spreadsheet	Asset ID, Road Name, dimensions, description, rating	Excel,
	Footpaths	SCIRT IST	GIS	SCIRT	Renewal Project Files	Full visual RAMM Survey, Damage cost per road, damage rating 1-5	RAMM	RAMM RP/RS	RAMM
	Kerb & Channel	SCIRT IST	GIS	SCIRT	Renewal Project Files	Full visual RAMM Survey, Damage cost per road, damage rating 1-5	RAMM	RAMM RP/RS	RAMM
	Retaining Walls	SCIRT IST	GIS	SCIRT	Construction / Renewal project files	Inspection	Excel spreadsheet and RAMM	RAMM RP/RS, Road Name, type, material, dimensions	Excel, RAMM
Water Supply Network	Mains and sub-mains	CCC	CCC GIS inventory	CCC, Detection Services, Aqua Environmental	Leakage Assessment by Detection Services and Aqua	Minimum Night flow testing. Leak reporting	Excel, Cam/Cem	Asset ID's, addresses, WLZ's, leakage rates & types	Excel, Cam/ Cem, SCIRT GIS, infonet
	Connections including meters and stop cocks	CCC	CCC GIS inventory	CCC, Detection Services, Aqua Environmental	Leakage Assessment by Detection Services and Aqua	Minimum Night flow testing. Leak reporting	Excel, Cam/Cem	Asset ID's, addresses, WLZ's, leakage rates & types	Excel, Cam/ Cem, SCIRT GIS, infonet
	Reservoirs	SCIRT IST	GIS	SCIRT	Renewal project files	Inspection	Excel spreadsheet	Name, SAP	Excel, RAMM
	Pump Station buildings	SCIRT IST	GIS	SCIRT	Renewal project files	Inspection	Excel spreadsheet	Name, SAP	Excel, RAMM

Asset Network	Type	Responsibility	Asset Inventory	Data Collection	Other Information	Survey Information	Data Format	Data Structure	Software Used
Land Drainage and Stormwater Network	Gravity pipe work	CityCare	CCC Asset Inventory (SCIRT GIS inventory updated by assessment team)	CityCare	City Care programme office (also hold historic recovery info)	CCTV, Level survey of MH's and Inverts, Profilometer	Video, (Infonet compatible)Spreadsheet, database and picture	CCC Asset ID, Node ID's Street address	Cam/ Cem (Infonet)
	Manholes, sumps, inlet & outlet structures	SCIRT IST	Spreadsheet	Hydrotech	N/A	Pole Camera / comments	Video / spreadsheet	Asset ID	N/A
	Laterals in the public street	Delivery Teams during relay							
	Storm water Structures (River stop banks)	CCC	CCC Asset Inventory (Mostly complete). Missing River retaining structures	CCC Stormwater Asset Manager	No	Structural Assessments, Geotech assessments, level surveys and long sections	Spreadsheet and reports	GPS Coords	GIS, Excel
	Pumping Stations	CCC	CCC Asset Inventory	Chris Mance	No	Inspections only	Electronic database	Location, name, type, components, capacity, dimensions	Unknown