The Canterbury Earthquake

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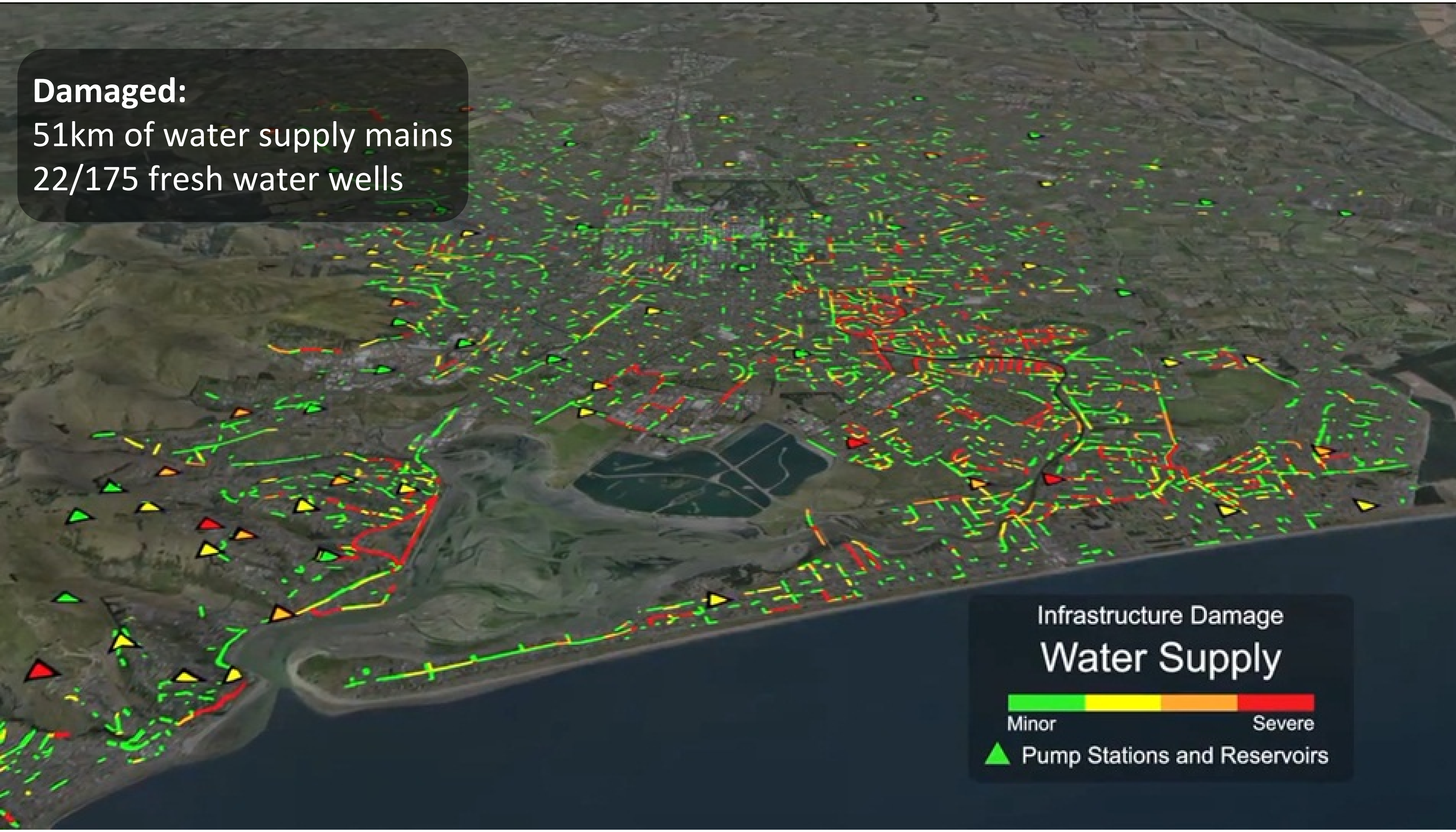
Building Resilient Infrastructure

8 November 2012

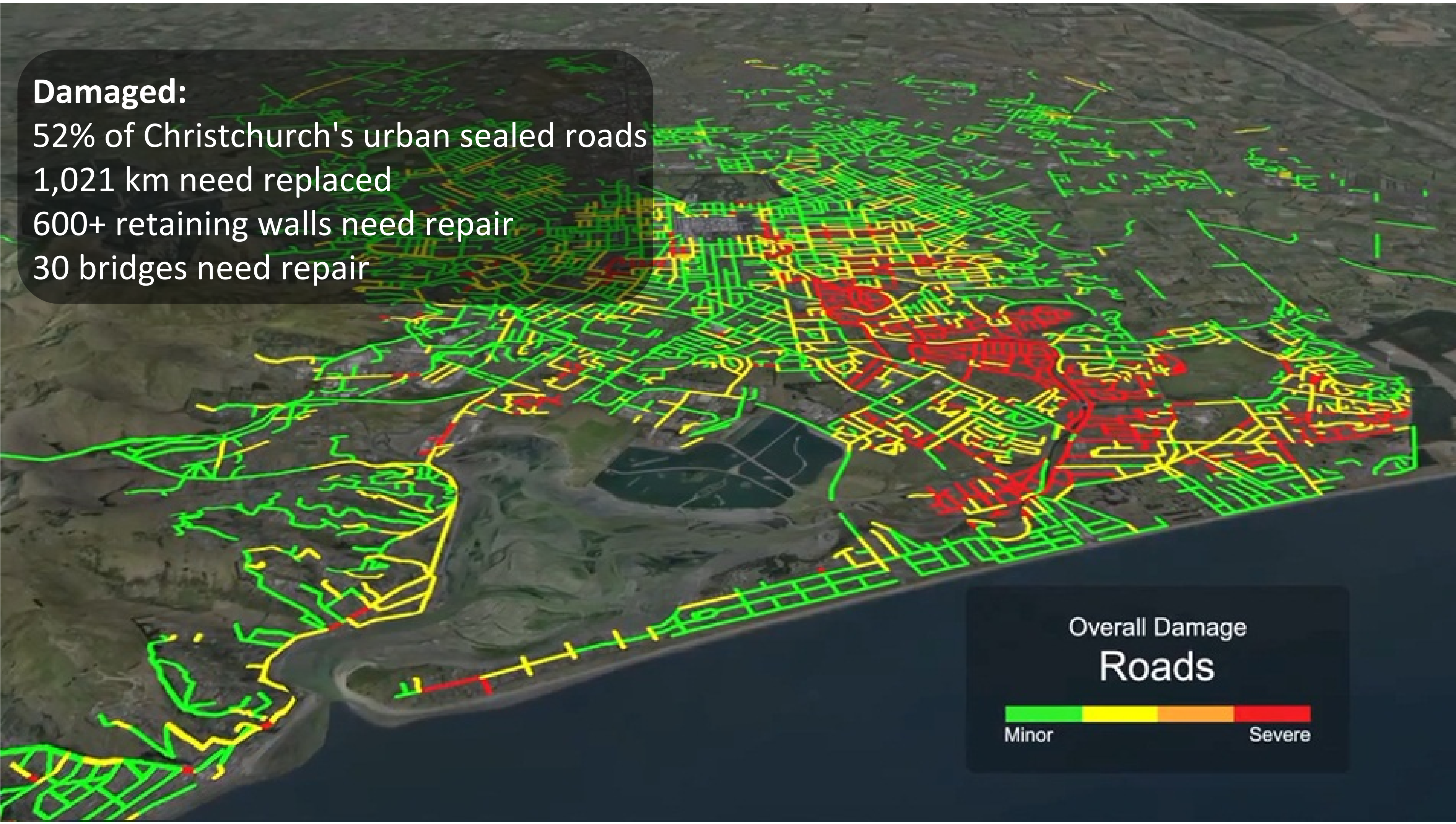
New Zealand National Lifelines Forum

Agenda

- Extent of Damage
- Reconstruction
- Infrastructure Resilience Overview
- Lifelines Utilities - Service Restoration
- Lifeline Lessons Learned Project
- Resilience Metrics


Damaged:
51km of water supply mains
22/175 fresh water wells
Infrastructure Damage
Water Supply
Minor
Severe
Pump Stations and Reservoirs


Damaged:
528 km of waste water network
Need to rebuild or replace 100+
sewer pumping stations
Infrastructure Damage
Wastewater
Minor
Severe
Pump Station

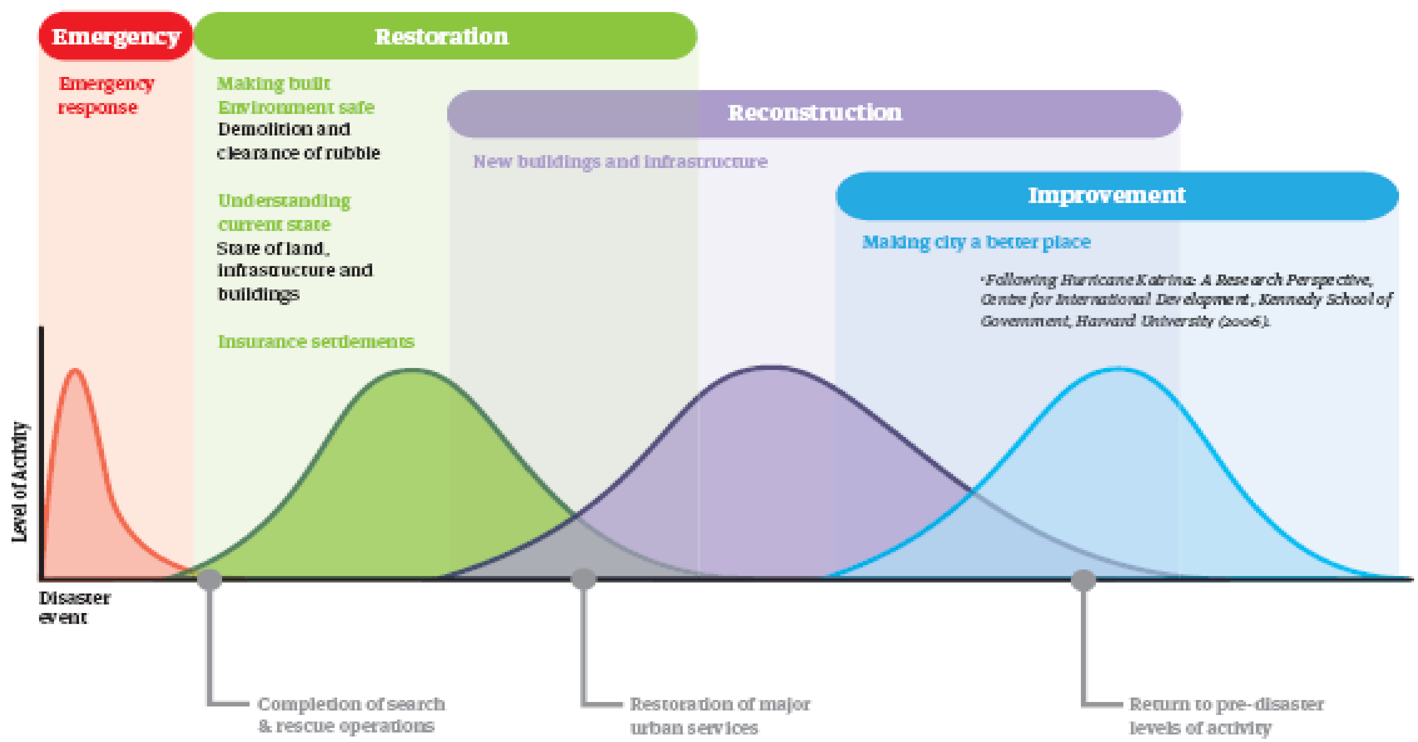

Damaged:
52% of Christchurch's urban sealed roads
1,021 km need replaced
600+ retaining walls need repair
30 bridges need repair
Overall Damage
Roads
Minor
Severe

Extent of Stormwater Damage

- In a largely in a functional state
- The stop bank network is approximately 12km
  - 14 severe/major stretches of damage were reported and a further 25 stretches of medium to minor damage.
  - This damage is compounded by evidence of settlement of the banks themselves (by up to 400mm in places) combined with decreases in channel capacity due to lateral spread and effective narrowing of the channels.
- Significant investigation programme in progress
  - River and tidal flood protection
  - Port Hills drainage
  - Land subsidence to below road levels

Where Do We Start?

- Indicators? What does success look like.
  - Design and construction standards
  - Organisational ability
  - Adaptability and redundancy
  - Cross-sectoral dependencies
- Identify Pinch Points
  - Constraints on service capacity
- Identify Hot Spots
  - Risk to multiple networks

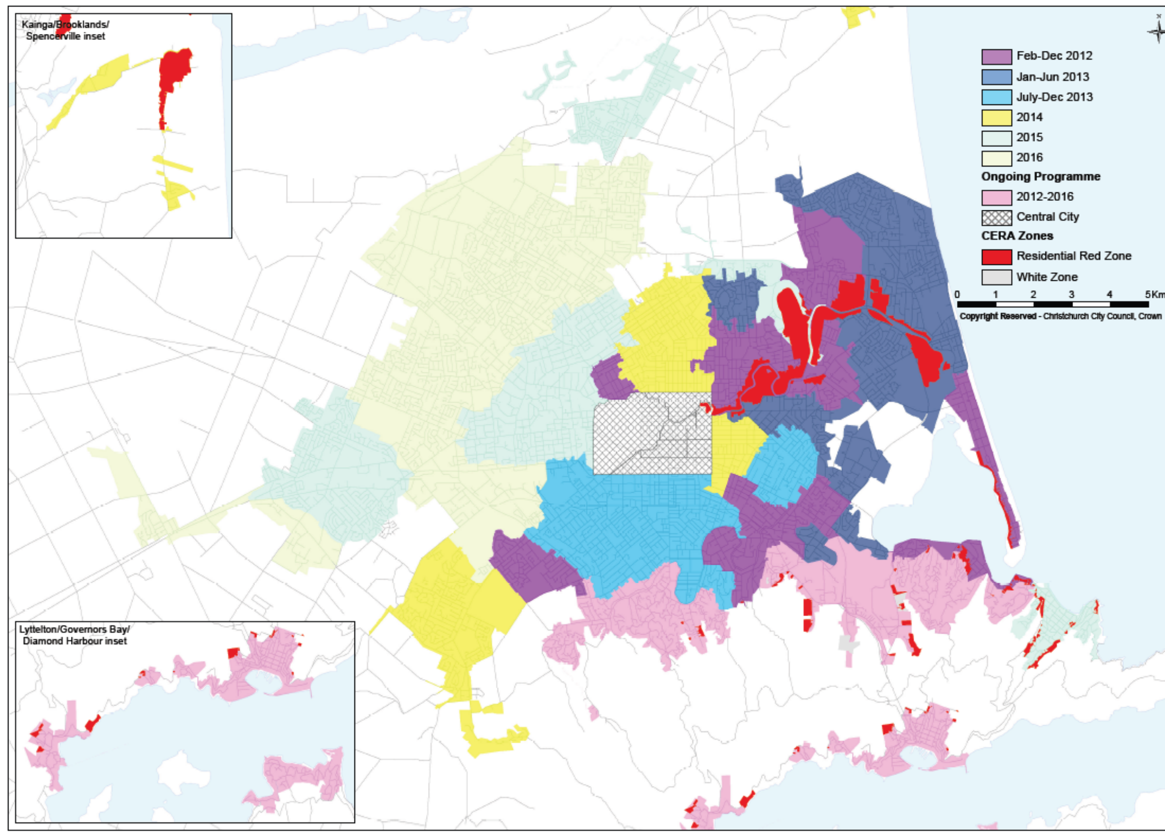


Challenges

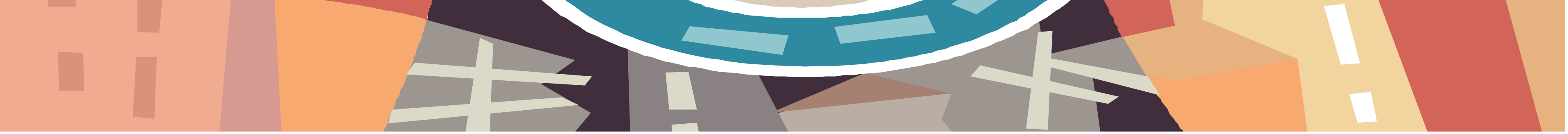
- Leadership & Integration
  - Consideration of different components of recovery
- Multiple stakeholders
  - Difference in responsibilities, vision and objectives
- Uncertainty
- Resilience
- Scope & standards for repair and/or reconstruction
- Funding allocations and/or limitations

Reconstruction

- Stronger Christchurch Infrastructure Rebuild Team
  - Alliance between 3 owner and 5 non-owner participants
  - Estimated $2B+
  - Generally includes:
    - Water
    - Wastewater
    - Stormwater
    - Roads
    - Bridges
    - Retaining Walls

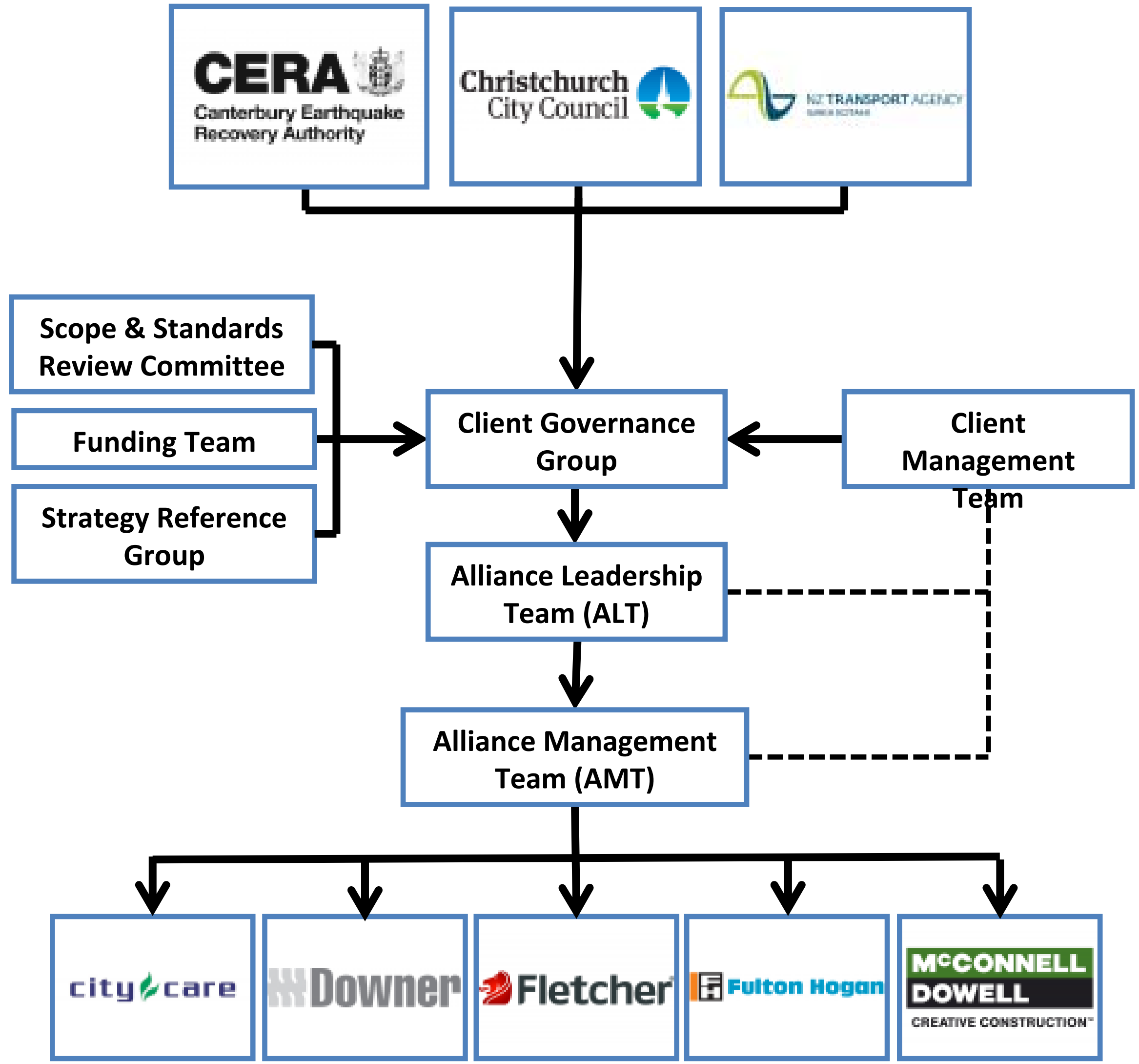


- Other
  - Council / District or other contract mechanisms



SCIRT
Rebuilding Infrastructure

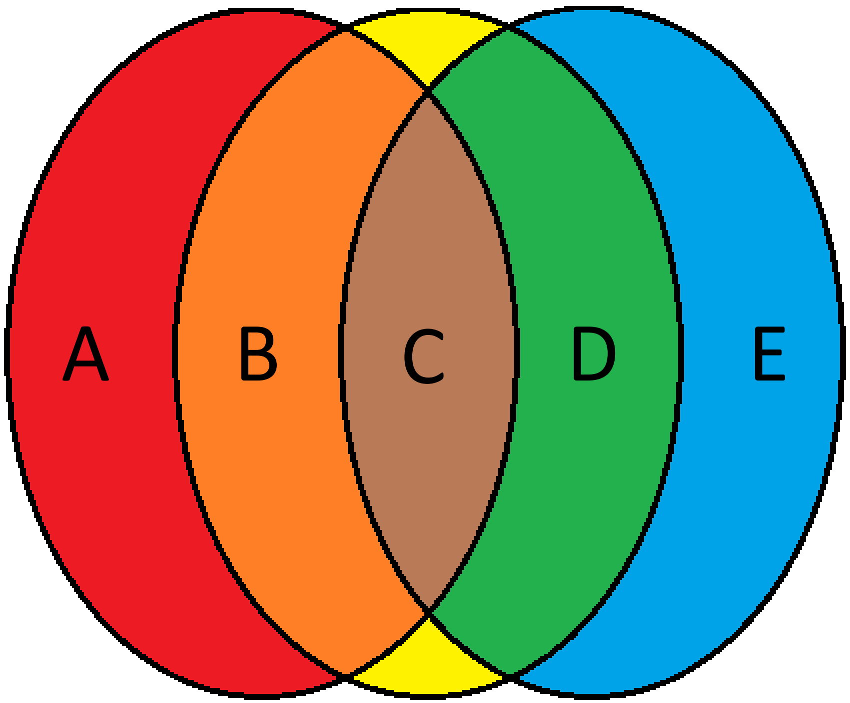
The Stronger Christchurch Infrastructure Rebuild Team



Infrastructure Resilience is…

- The ability of a system to withstand or quickly recover from significant disruption
  - Attributes:
    - Service Delivery (Levels of service)
    - Adaptation (Recognise and respond to changing conditions)
    - Community Preparedness (Readiness)
    - Responsibility (Voluntary and regulatory)
    - Interdependencies (Consideration of linkages)
    - Financial Strength (Affordability and capability)
    - Continuous (Vigilance and assurance)
    - Organisational Performance (Leadership and culture)

Concept of Infrastructure Resilience



Existing Methods & Materials

Modern Methods & Materials

Resilient Methods & Materials

A. Some existing methods & materials are obsolete
B. Some are not, but don't provide resilience
C. Some existing methods & are still used today, and are resilient
D. Some of the modern methods & materials provide resilience
E. Some new and/or additional methods & material exist (or are under develop) which provides more resilient infrastructure.

Infrastructure resilience is the ability of a system to withstand or quickly recover from significant disruption

Systems / Network Approach

- The sum of many components
- What are the high risk areas? *(make safe/connected)*
- What are the interdependencies? *(system of systems)*
- What are the catchments? *(geospatial considerations)*
- Where do they go? *(destinations and linkages)*
- What are the necessary connections *(prioritise)*
- ASCE principles:
  - Quantify, communicate and manage risk
  - Employ an integrated systems approach
  - Exercise sound leadership, management & stewardship in decision making
  - Adapt critical infrastructure in response to dynamic conditions

Hazard Identification

- Seismic Risk
- Flood Risk
- Tsunami Hazard
- Slope/Rock Fall Hazard
- Wind Hazard
- Snow Hazard
- Changing Seal Level (Sea Level Rise)
- Volcanic Hazard
- Drought Hazard
- Other Hazards (Natural or Man-made, instant or gradual)

Lifelines Utilities – Service Restoration

- Japan

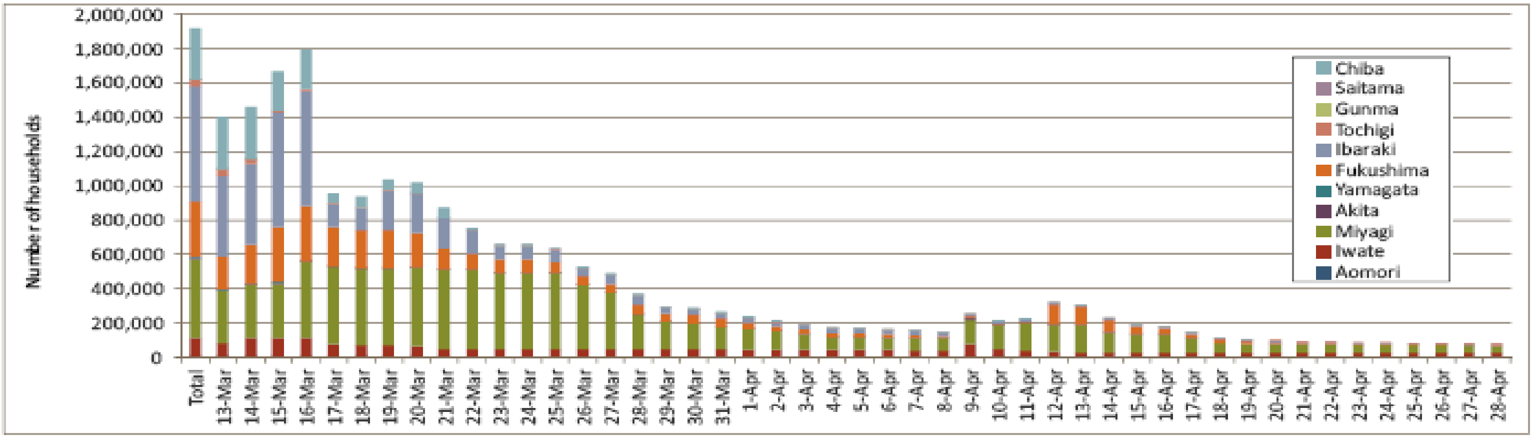


Fig. 4 Number of households without water supply

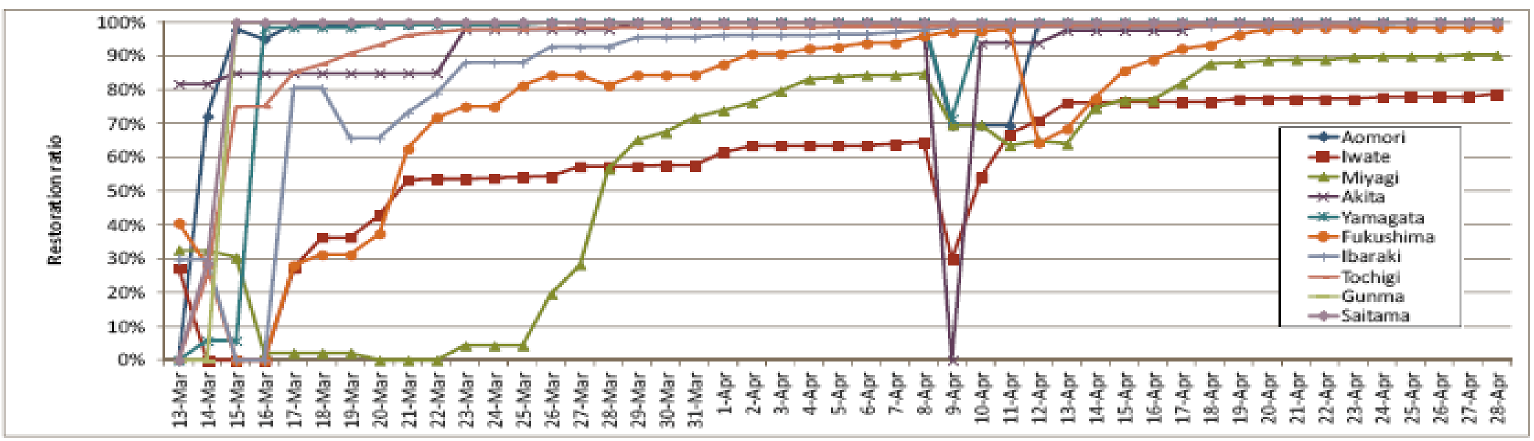


Fig. 5 Restoration curves of water supply function in affected prefectures

Lifelines Utilities – Service Restoration

- USA

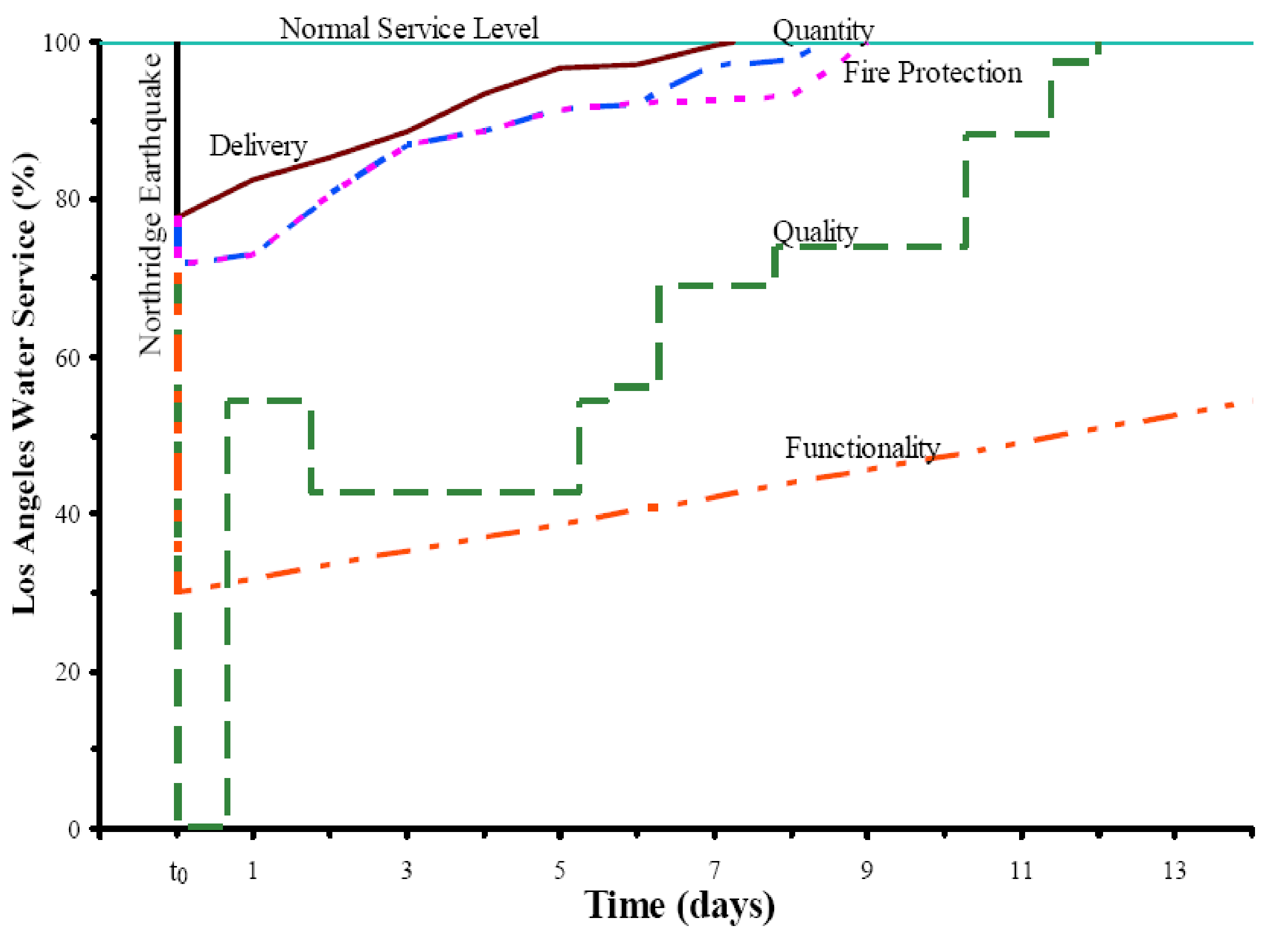


Figure 3. Los Angeles water system service restorations following the 1994 Northridge earthquake.

Lifelines Lessons Learned Project

Overview:

•Six month timeline

•Two years after the Sept. 2010 Earthquake

•Investigate and gather lessons from researchers, asset owners, commentators and Lifeline organisations

Deliverables *(In progress)*:

•Summaries of collected lessons

•Gap analysis and theme identification

•Analysis report outlining key findings

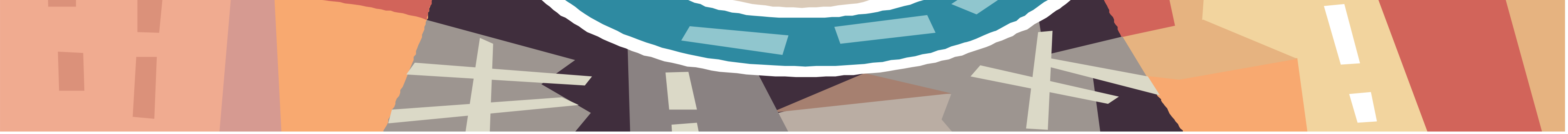
Lifelines Lessons Learned Findings

- Overall 120 documents are being analysed

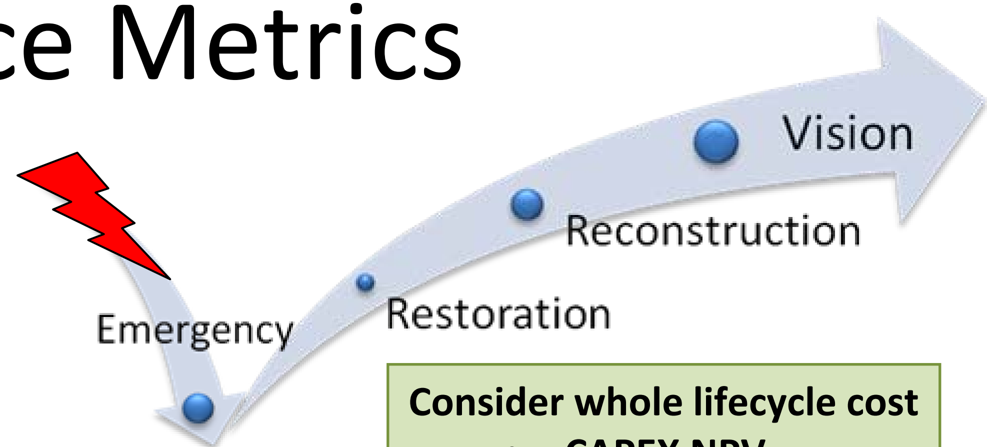
- The key themes found *(draft)*:
  - Decision making
  - Asset performance
  - Organisational performance
  - Outage consequences
  - Regulatory environment

Lifelines Issues for Consideration

- Integration of decision making
  - Economic analysis
  - Infrastructure resilience
  - Understanding outage consequences
- Reconnaissance coordination (between researchers and Lifelines)
- Coordination of hazard planning
- Translating the learnings into usable guidelines and updated standards

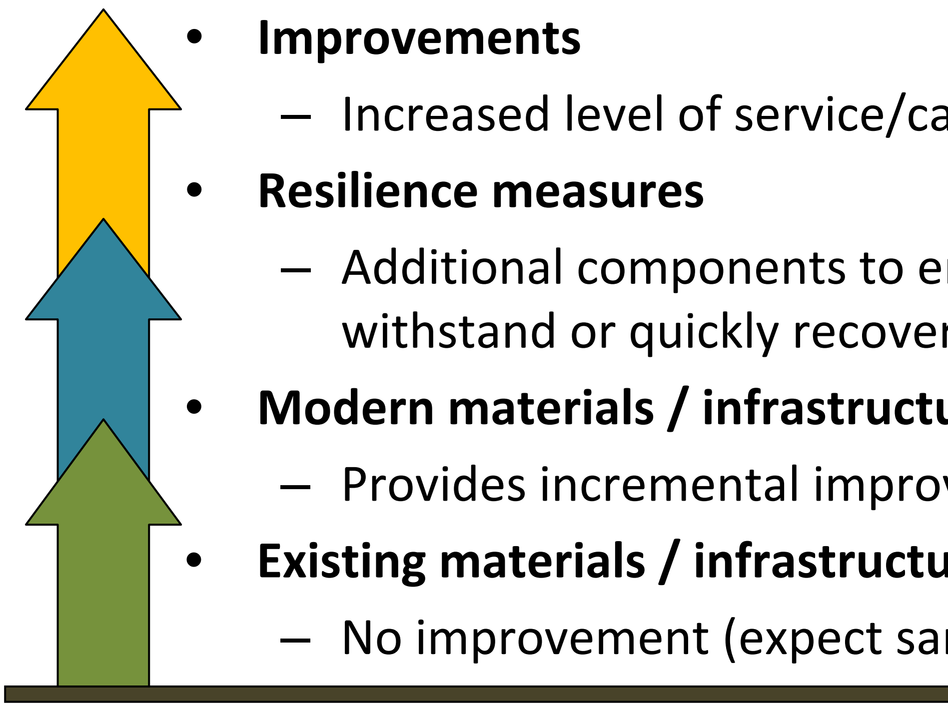


Resilience Metrics



- Inform decision making
- Method for measurement
- Categorisation / definitions:

Consider whole lifecycle cost
- **CAPEX NPV**
- **OPEX NPV**



- **Improvements**
  - Increased level of service/capacity (Betterment)
- **Resilience measures**
  - Additional components to ensure modern materials & methods can withstand or quickly recover from an event. Extra redundancy.
- **Modern materials / infrastructure**
  - Provides incremental improved resilience. No extra redundancy.
- **Existing materials / infrastructure**
  - No improvement (expect same results next time). May be obsolete.

Lifelines Utilities – Why Resilience?

- Objective of resilience is to minimise service outage

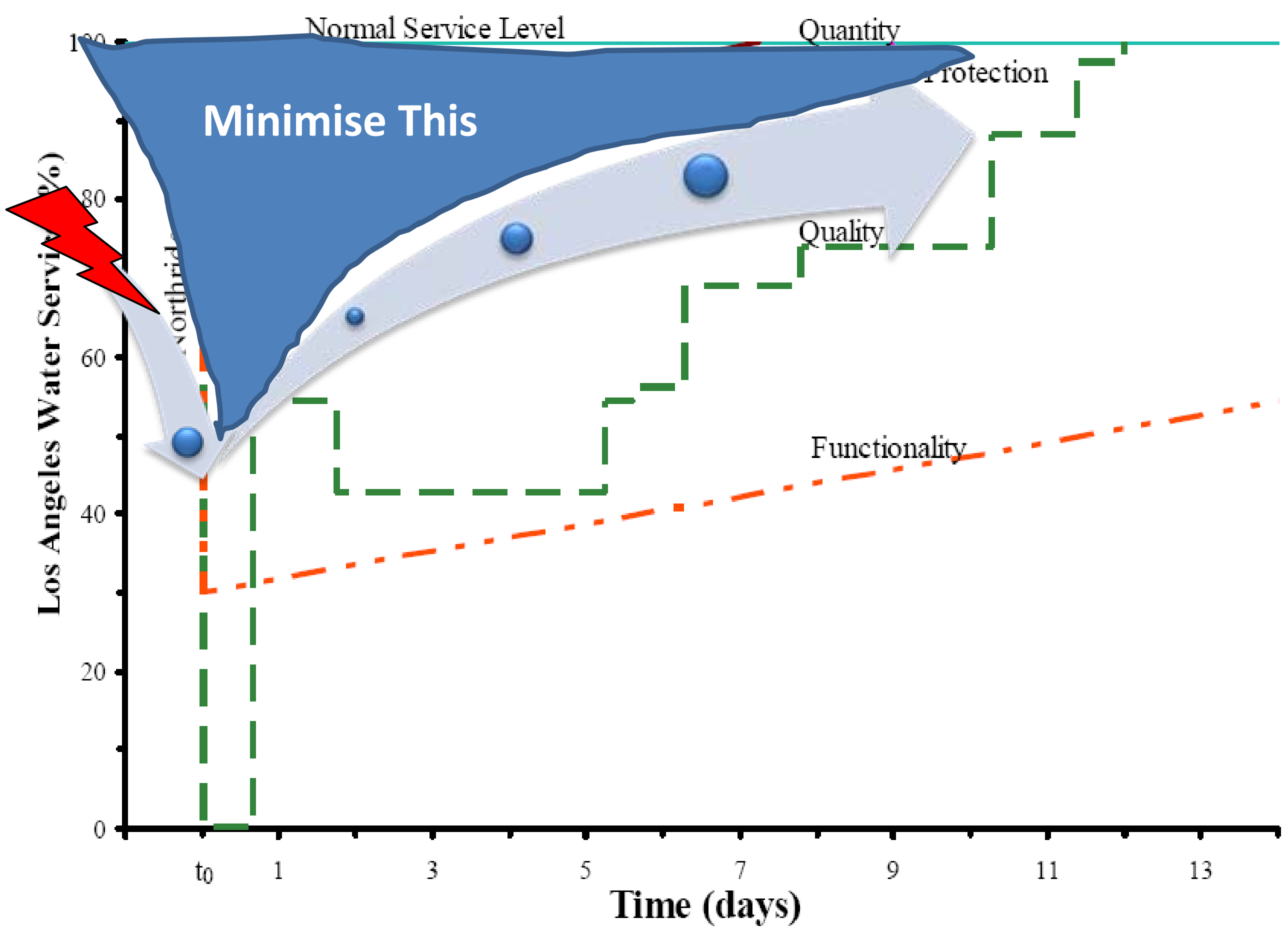


Figure 3. Los Angeles water system service restorations following the 1994 Northridge earthquake.

Resilience Metrics (v1) [Sample]

Water System

	Modern Materials / Infrastructure	
PW	1.1	Use PE pipe with bolted self-restraining pipe fittings.
PW	1.2	Use computer network models to select pipe routes that avoid areas with high risk of liquefaction or lateral spread.
PW	1.3	Design systems for easy access to common failure points.
PW	1.4	Design network to allow isolation of failure locations.
PW	1.5	Use computer network models to design network with adequately looped distribution (x-connections and bypass lines).
	Resilience Measures	
PW	2.1	Install anchor blocks at connection from existing less flexible networks to new networks (prevents failure of sliding rubber pipe ring at connection).
PW	2.2	Design network to allow large scale isolation of failure locations, and large scale interconnection between zones.
PW	2.3	Operate all distribution zones at the same pressure to allow greater cross-connection and flow diversion as required.
PW	2.4	Provide flow diversion methods for routing water to/from adjacent districts.
PW	2.5	Provide cycled emergency water storage within each distribution zone.
PW	2.6	Prepare emergency treatment systems for use as required, and periodically test their installation and operation.
PW	2.7	Outer well casings made of heavy duty Oil and Gas drilling pipe to resist bending forces from “slippery” subterranean clays.
PW	2.8	Avoid sinking wells in liquefiable land or ground subject to lateral spreading. This protects production capacity by keeping wells in good ground, then route easier to repair pipes into poorer ground for local distribution to houses.
PW	2.9	Use specific geotechnical designs for pump station foundations.
PW	2.10	Fill voids between inner and outer well casings with bendonite to isolate well pipes from wellhead protection chambers.
PW	2.11	Alter flexible coupling connection to wellhead protection chambers to improve vertical and horizontal movement.
	System Improvements	
PW	3.1	Increase pipe sizes for additional capacity or future proofing.
PW	3.2	Replacing components nearing the end of service life while the opportunity is available (e.g. replacing pipe which doesn’t meet the threshold for replacement while the area is closed for other repairs).
PW	3.3	Introduction of volumetric charging to residents (Current CCC policy does not charge for water). Metering is already installed on most residential properties and all new properties are metered. Commercial and industrial users are currently charged for water.
PW	3.4	Maintain up to date and calibrated computer network models.

Wastewater System

	Modern Materials / Infrastructure	
WW	1.1	Use PVC for gravity pipe, with longer pipe lengths (fewer joints).
WW	1.2	Use steeper grades as designated by tractive force design methodology for gravity sewer pipe.
WW	1.3	Use HDPE or PE for sewer pressure pipe (welded joints).
WW	1.4	Use computer network models to select pipe routes that avoid areas with high risk of liquefaction or lateral spread where possible.
WW	1.5	Design systems for easy access to common failure points.
WW	1.6	Design below ground structures to withstand buoyancy (Includes manholes, pump stations, and any storage tanks).
WW	1.7	Use specific geotechnical designs for pump station foundations.
	Resilience Measures	
WW	2.1	Limit pipe depth to <3.5m to avoid deep repairs (laterals limited to <2.5m).
WW	2.2	Wrap PVC pipe joints with geotextile to protect against siltation if the joints open up.
WW	2.3	Use geotextile wrapped haunching in areas with a high risk of liquefaction or lateral spread.
WW	2.4	Use pressure or vacuum systems in areas with a high risk of liquefaction or lateral spread.
WW	2.5	Over excavate liquefiable material surrounding below ground structures, and replace with suitable backfill.
WW	2.6	Use gibaults and flange adapters for pipe connections to pump stations (joints sliding off are preferable to shear failure at penetration).
WW	2.7	Provide bypass overflow connections at lift stations and pump stations to allow emergency bypass in case of power failure.
WW	2.8	Integrate valves into lift station or pump station structures to avoid differential settlement, shear failure, or restricted flow.
WW	2.9	Provide increased flow and load buffering within the primary wastewater treatment plant to accommodate significant hazards, disruption, or surges.
WW	2.10	Provide oversized sand/grit removal capability to enable plant to better handle future liquefaction events.
WW	2.11	Provide flow diversion methods for routing wastewater into adjacent districts for treatment and disposal.
WW	2.12	Provide emergency storage within each catchment basin where this provides overall network benefits.
WW	2.13	Analyse entire catchment basins when evaluating design solutions on a large scale (consider economy of scale and full lifecycle factors).
WW	2.14	Avoid heavy chambers adjacent to main pump station structures to minimise excessive shear and bending forces on connecting pipes.
	System Improvements	
WW	3.1	Increase pipe sizes for additional capacity or future proofing.
WW	3.2	Develop satellite treatment plants in line with the growth strategy, and restrict further growth at the primary treatment site.

Issues that may need further investigation

- Ensure hazards and risks are well understood within each city, council and district
- Identify most critical and vulnerable infrastructure, and invest in resilient asset replacement as soon as practical *(target < 5 years)*
- Establish long term plans for asset renewal, to incorporate resilience into system networks *(target by priority into 10 year, 30 year, and 50 year programmes)*
- Update standards to include resilience into modern methods and materials *(part of on-going updates)*

Questions?

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