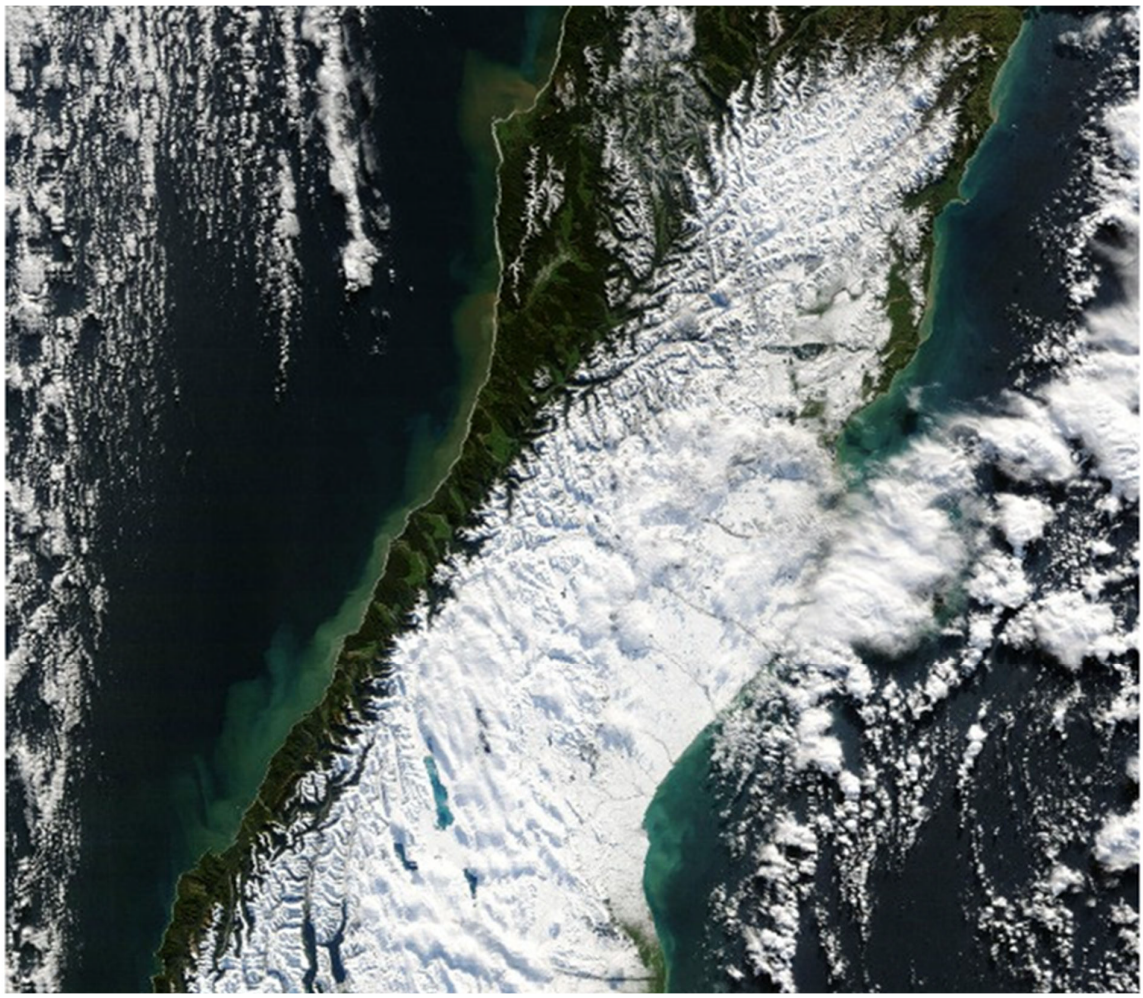
Risks and Resilience

Advancing the Maturity of Infrastructure Vulnerability and Resilience Investment Business Case Assessments

Final Report

Canterbury Civil Defence Emergency Management Group



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			Name/Position	Signature
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1.0 Introduction

1.1 Project Description

Risks & Resilience: Using a new GIS portal, MERIT tool and existing body of knowledge base to standardise and advance the maturity of vulnerability assessments and resilience-focussed investment business cases.

This project sought to "connect the dots" in relation to data, tools, resources, knowledge, and practice, with the aim of facilitating informed, up-to-date, and efficient vulnerability and resilience assessments using a lifelines GIS portal. A maturity-based approach has been developed and was tested along with a recommended data schema that can be nationally applied.

Engagement has to date largely focussed on the lifelines sector, universities, and research agencies. Drawing on research programmes and tools, an "intermediate" level approach that lies between the current methodology for vulnerability assessments and the more comprehensive "Wellington Regional Lifelines programme business case" approach[1] has been developed.

It is anticipated that this work will be valuable to the wider lifelines sector in improving resilience outcomes elsewhere.

1.2 Background

Canterbury Lifelines is completing a vulnerability assessment of the region's infrastructure networks and the hazards that could disrupt these networks. This is Phase 1 of the "Risks & Resilience" project and has been fully funded by the Canterbury CDEM Group.

In parallel, Environment Canterbury has developed a GIS-based lifelines portal that can be used either in resilience planning or in response. It displays feeds from a range of open sources, including some lifeline utilities, social and demographic data, hazard data, etc. Further work is necessary in closing data gaps and securing missing data from some lifeline utilities.

A key national issue is the lack of a common data schema for lifeline utilities. This makes it less efficient in responding to calls for data from the regions. There is also a significant gap between traditional "core" vulnerability assessment practice and the "advanced" business case work completed by Wellington lifelines.

The project was designed to advance this previous resilience work, close the data gaps, and produce a methodology and resources that can be used at local, regional or national level for resilience planning.

1.3 Report Structure

This report is structured in the following way:

- Firstly, sections that provide a summary of each of the five project phases including reference to approach and outcomes.
- Secondly, sections that address other requirements, including:
  - Successes and challenges
  - Management approach
  - Funding arrangements
  - Lessons identified
  - Communicating outcomes and accessing content
  - Future direction

[1] Refer to https://www.wremo.nz/assets/Uploads/191111-Wellington-Lifelines-PBC-MAIN-20191009.pdf

2.0 Milestone 1 - Scanning Stocktake

2.1 Tasks Summary

Table 2-1 Task Summary – Milestone 1

Task	Description	Status Summary
1	Scanning stocktake of approaches in use or planned throughout the country in relation to vulnerability assessments and business cases for investment similar to that recently completed by the Wellington Lifelines Group.	Report includes summary of relevant vulnerability assessments and business cases.
2	Scanning stocktake of economic, social and cultural stakeholders to identify what locations and facilities should be considered in impacts analysis within Canterbury. Includes key "community sites" such as emergency services, hospitals, marae, industry, commercial, rural advisory groups, etc.	Report includes summary of stakeholders and nominates facility types for inclusion in modelling work.
3	Scanning stocktake of relevant tools, resources and knowledge used in lifelines risk reduction planning – what they are, how they are being used, who owns them, what are the barriers, how they could be used. Engage with science community and universities.	A summary of available risk reduction tools and resources is included in the report. Knowledge gained was utilised during the modelling approach.
4	Milestone 1 | Produce report on the scanning process and findings from tasks 1-3 above.	Milestone 1 report delivered in January 2022.

2.2 Regional Lifeline Vulnerability & Resilience Assessment Projects

Over the last 25 years, lifelines projects have been carried out in many regions in New Zealand. The typically stated purpose of 'vulnerability assessments' is to:

Identify the potential impacts from major natural hazard events on critical infrastructure in the region and potential measures to improve resilience to hazards.

The term vulnerability, in the context of lifelines projects, is used to refer to the susceptibility of lifelines networks to service outages when events occur and the inability to recover quickly. Vulnerability and resilience can be regarded as opposite ends of a continuum. Some lifelines vulnerability projects are titled 'Regional Infrastructure Resilience Project' or similar, the latter term is now encouraged.

Most regional lifelines vulnerability assessment projects in the last decade have broadly followed a similar methodology, illustrated in Figure 2-1.

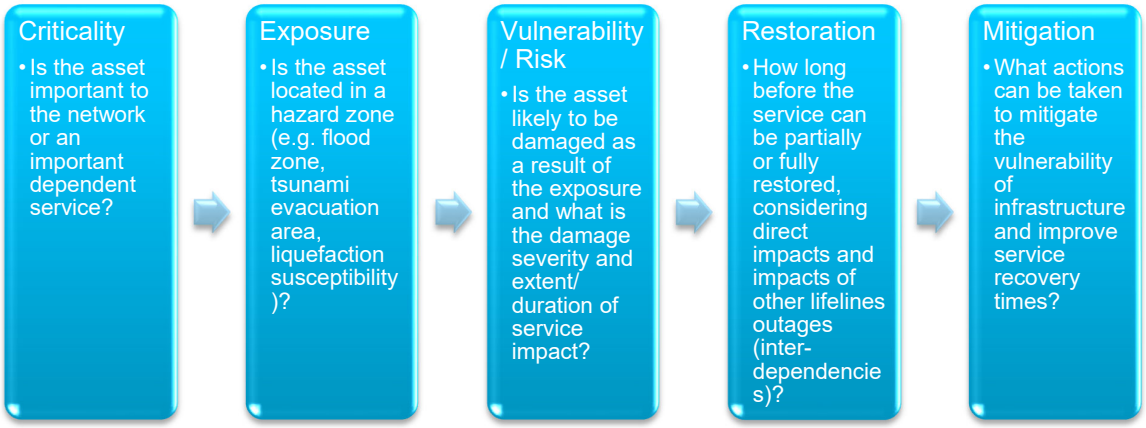


Figure 2-1 Overview of Lifelines Vulnerability Assessment Process

2.2.1 Identifying Critical Assets and Critical Customer Sites

Lifelines projects usually start with identifying critical infrastructure in the region and focussing on assets that are likely to have the highest consequences of failure for communities. This is for the purpose of managing the scale of the assessment and prioritising efforts in the area of highest impact.

2.2.2 Identifying Hazards for Assessment

The scope of hazards covered in Lifelines projects typically include:

- A multi-hazard assessment covering the major natural hazard risks (commonly earthquake, tsunami, volcano and severe weather).
- A multi-hazard assessment covering all the hazards in the region, for example, as listed in the regional CDEM Group Plan. This might include hazards such as pandemic, cyber-attack and technological failure.
- A single-hazard assessment.

2.2.3 Exposure and Vulnerability Assessment

The extent to which quantitative risk scoring systems are used in regional lifelines projects varies; some earlier studies used detailed asset lists, spreadsheets and multi-criteria analysis to rank asset risks based on criticality and exposure to hazards. More recent projects have undertaken a higher-level lifelines project approach which provides a more strategic, sector-based view of the potential infrastructure impacts from natural hazards rather than an asset-by-asset assessment.

Most recent vulnerability assessment projects have provided information in the form of GIS asset and hazard overlays to support vulnerability assessments by lifeline utility subject matter experts (SMEs).

2.2.4 Dependencies and Interdependencies

Understanding lifeline utility interdependencies is an important feature of vulnerability assessments. Firstly, this is considered in the criticality assessment, where an asset becomes more critical if it services another lifelines asset that requires the service to function. Secondly, when considering service impacts and recovery times, consideration is given to the impact from other lifelines failures, e.g. road access, telecommunication disruptions.

2.2.5 Wellington Business Case

This project is the most comprehensive of its type carried out in the New Zealand lifelines sector and is regarded as “advanced” practice, providing a step-change improvement to the Wellington region’s resilience. It assessed the impacts of a major earthquake on the region’s infrastructure and communities and the economic benefits of investment in a range of mitigation strategies.

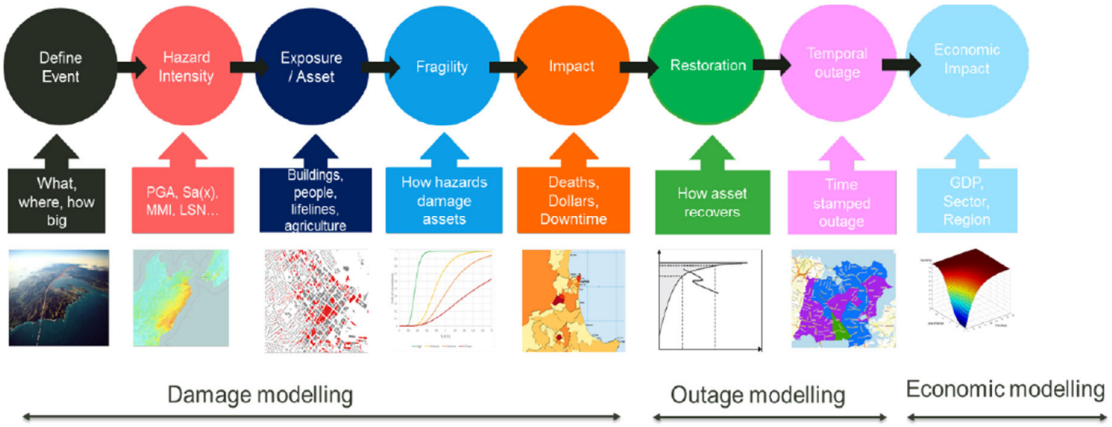


Figure 2-2 Modelling Workflow for Wellington Lifelines Projects

2.3 Tools & Resources for Lifelines Risk Reduction Planning

Historically, the use of spreadsheets has been widespread in lifelines vulnerability assessments and other work such as priority routes, with GIS applications now becoming much more prevalent.

In addition to GIS tools, the most significant software applications used in New Zealand for infrastructure resilience assessments are RiskScape and MERIT. Both are relevant for application in the Canterbury lifelines project.

A substantial body of scientific and research work has been carried out in recent years, or being progressed, through programmes such as the National Science Challenges, QuakeCoRE and MBIE Endeavour Fund programmes. Typically, these involve collaboration between universities and science agencies. The following figure provides an overview of the national landscape of programme areas and research agencies.

Figure 2-3 Disaster Resilience Research Landscape

Table 2-2 lists the key tools and resources considered for application in this project.

Table 2-2 Available Tools and Resources

Tools and Resources	Overview	Relevance / Applicability
GIS Applications	• GIS tools are increasingly being used across lifelines and CDEM functions • NZGIS4EM and LINZ are working to improve coordination and collaboration in the use of GIS	• GIS is a key element of the Canterbury project • The portal needs to leverage off national work
MERIT	• Suite of 'Integrated Spatial Decision Support Systems' used to evaluate the socio-economic impacts of both infrastructure investment and disruption • Wellington addressed economic impacts relating to recovery times and interdependencies, freight impacts as well as people and business relocation	• Advanced modelling tool • MERIT requires detailed outage and duration data • Linked to application for Deep South AF8 funding • Canterbury configured application of MERIT exists • GIS layers to MERIT directly from the Canterbury GIS portal.
Urban and Community Resilience	• Urban Intelligence conducts a range of resilience research, GIS analysis and data science	• Significant future potential – ready development of useful GIS based tools • Brings social dimensions into the impacts analysis using GIS tools, perhaps an additional layer in the Lifelines GIS portal
RiskScape	• Provides framework for multi-hazard impact modelling and physical loss modelling • Can be used to quantitatively evaluate the benefits of implementing planning and mitigation options • Fragility models – probability of a certain damage state as a function of a hazard metric • Vulnerability models - % of damage or % cost of replacement of an asset as a function of a hazard metric • Consequences are described spatially • Forward programme of research work is contributing to ongoing model development in RiskScape 2.0	• Risk modelling tool that integrates datasets together in an efficient way to do analyses • Requires risk data, exposure data, and vulnerability models • Provides an opportunity to demonstrate a "proof of concept" application in disaster modelling and resilience work

2.4 Stakeholders Stocktake

Both "critical customers" and stakeholder and iwi groups were considered. All of these groups are likely to be impacted in some way when disruption to lifelines occurs due to significant natural hazard events. In a wider sense the needs and expectations of communities need to be recognised when assessing the economic, social and cultural impacts of hazard events.

The following terms are defined:

- **Lifeline utility "critical customers"** – those agencies responsible for the health, safety and welfare of the community and, in an emergency, CDEM response and recovery activities. Typically, this includes emergency services agencies such as health, police, fire, and others, but also those lifeline utilities that depend on another lifeline utility – such as fuel.
- **Stakeholder and iwi groups** – this encompasses a wider representation of community groups and sectors, both people and businesses. It includes representative entities as well as individual sectors.

These groups are summarised in the figure and table below.

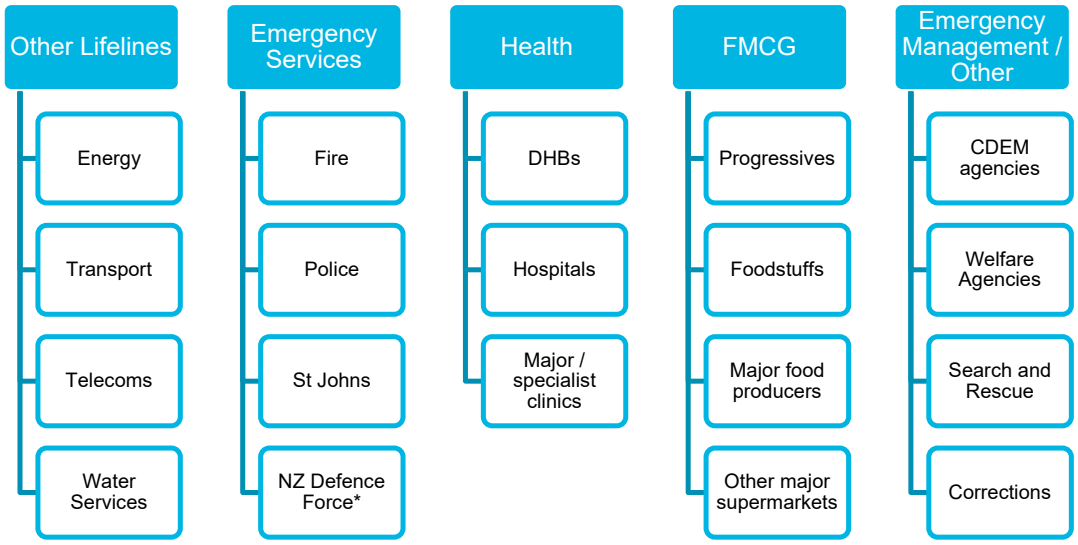


Figure 2-4 Critical Customers / Stakeholders

Table 2-3 Stakeholder Groups

Stakeholder Groups	
Age Care	Banking
Businesses	Central Government Agencies
Community Groups	Community Service
Construction Supplies	Contractors
Education	Emergency Services
Freight Providers	Food Production
Insurance	Funeral / Crematoria
Military	Industry
Tourism	Iwi
Welfare	Rural
Vineyards	

3.0 Milestone 2 - Maturity Pathway

3.1 Tasks Summary

Table 3-1 Task Summary – Milestone 2

Task	Description	Status Summary
5	Describe the features and approaches of a "maturity-based" pathway from "core" vulnerability assessment work through "intermediate" to "advanced" practice incorporating tools such as MERIT and RiskScape. Describe how the above resources would be connected with the ECan Lifelines GIS portal and how they could be used by practitioners at different maturity levels and what to expect out of them.	Maturity pathway approach developed and detailed in key steps and overall schematic to allow practitioners to select maturity practice level appropriate to their organisation.
6	Milestone 2 | Produce report describing the "Integrated Approach" and recommendations for application at different maturity levels.	Milestone 2 report delivered in March 2022. Explains what is meant by integrated approach.

3.2 Maturity Approach

The following figure provides an overview highlighting the modelling / analytic tools that support the pathway from “core” towards “advanced” maturity – the Urban Intelligence (UI) Resilience Explorer, MERIT, and RiskScape. Underpinning the use of these tools is the Lifelines GIS Portal, hazards and infrastructure data, and the outputs of research.

In the bottom left corner is the qualitative approach typically adopted for describing infrastructure networks and potential vulnerabilities to natural hazards. The arrow moves practice towards a highly quantitative approach embodying fragility relationships or thresholds in vulnerability analysis, service level disruption and outage, loss modelling and economic modelling in determining and evaluating potential mitigation investment strategies.

The Wellington Programme Business Case to the right side of this diagram currently represents “best practice” in the NZ lifelines context, taking economic evaluation into the assessment of alternative investment scenarios for improved resilience.

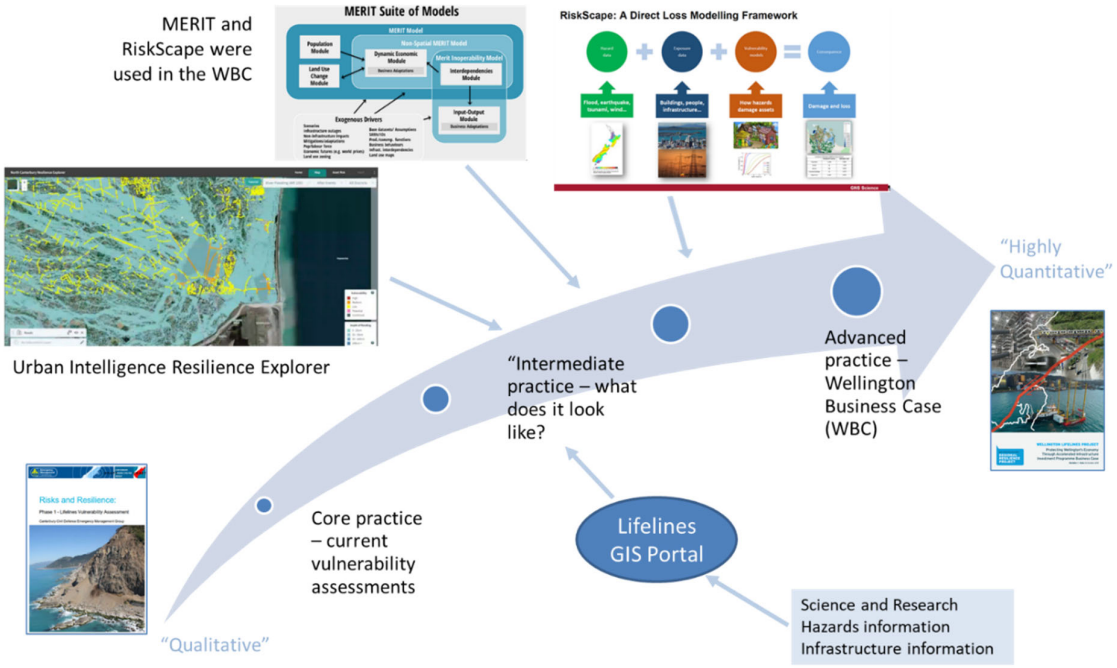


Figure 3-1 Maturity Pathway

3.3 Maturity Pathway Features

In developing the maturity pathway, a number of tools and resources were identified in the scanning stocktake. The diagram below shows a vertical sequence, highlighting maturity progressively increasing towards advanced. The steps can be adopted by any region or Lifelines group in New Zealand. What is important is to be able to develop maturity at each step progressing towards alignment with the pathway at a level appropriate to the region and the resources that are available.

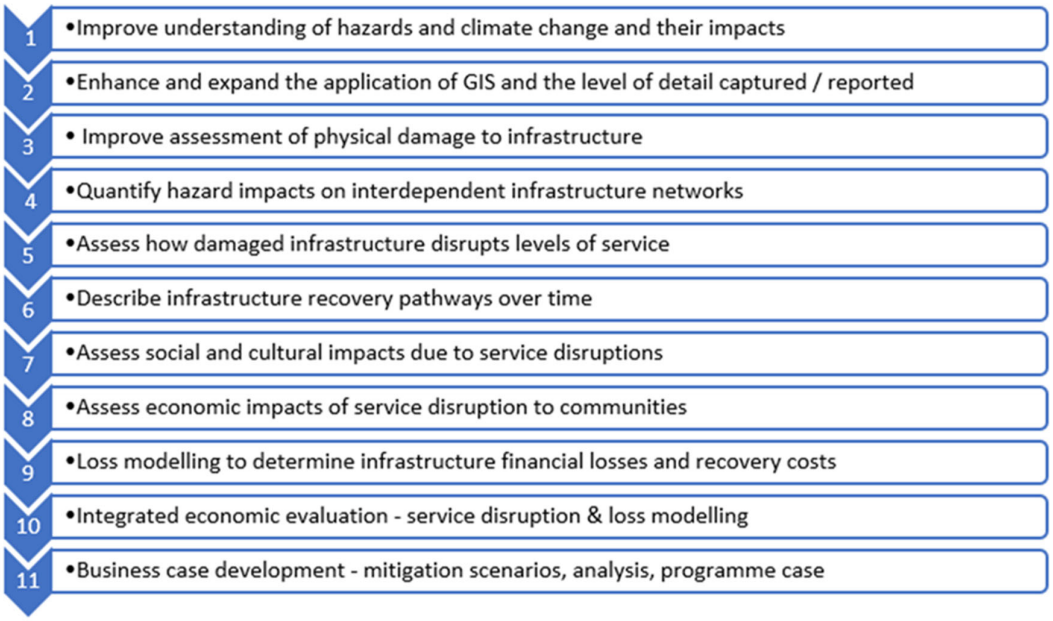


Figure 3-2 Features of the Maturity Pathway

4.0 Milestone 3 - Pilot Approach & Data Needs

4.1 Task Summary

Table 4-1 Task Summary – Milestone 3

Task	Description	Status Summary
7	Scope up a pilot for Canterbury – agree selection of hazard event types (e.g., AF8 earthquake, tsunami, flood), select LLUs in key sectors and engage with them (including power, fuel, telecommunications, transport, water, wastewater). This could be a sub-regional area within Canterbury. The pilot will be used to test the "intermediate" approach using MERIT and extend on Canterbury's Risks & Resilience Phase 1 to develop broad-brush indication of potential economic impacts.	North Canterbury has been selected as the pilot area – comprising the Kaikoura, Hurunui and Waimakairiri Districts. The key hazards for vulnerability assessment are flooding and tsunami. Engaged with LLUs in key sectors to begin to source network data.
8	Define the data attributes / data schema for each lifelines sector and by hazard event type needed to conduct an "intermediate" level analysis. Describe also the future data needs for "advanced" practice using RiskScape 2.0. Data schema will be tested, modified and recommended for national adoption as an outcome of this project.	Data schemas developed for all lifeline sectors for core and intermediate. Additional attributes to support loss modelling and economic analysis are defined. Urban Intelligence platform selected for the pilot for vulnerability modelling and GIS visualisation.
9	Approach documented. Agreed participation in the pilot "intermediate" level analysis, defined scope of this analysis, agreed data schema and required data attributes for the pilot.	Modelling approach described and participants identified. Milestone 3 report completed in August 2022.

4.2 Project Approach

The focus was on scoping and defining process steps using a GIS-based platform leading into economic modelling, noting that there are a number of tools that can be deployed. The intent was to demonstrate a “proof of concept”, identifying information needs and showing integration between different steps in the process. It is expected that different tools, new and emerging, could be used in future applications of this process.

4.2.1 Lifelines GIS Portal

A GIS portal was developed to capture and display both lifelines infrastructural asset data and natural hazards data from a variety of sources. Some of these are live feeds while for others, shape files or static feeds are recorded. These layers were then accessed by the Urban Intelligence platform for the vulnerability assessment process.

4.2.2 Urban Intelligence Platform

The Urban Intelligence platform links readily to the Lifelines GIS portal and the available impact (fragility) models drawn from international research, supplemented by local knowledge and assumptions where necessary.

4.2.3 MERIT

The MERIT tool is a suite of ‘Integrated Spatial Decision Support Systems’ that estimate the economic consequences associated with disruption events across time. MERIT was configured for North Canterbury, and required disruption and recovery timeframes for each lifelines sector on a Statistical Area (SA) basis to perform a modelling run.

4.2.4 Pilot Area

The selected pilot area covered North Canterbury comprising three Territorial Authority areas: Kaikoura, Hurunui, and Waimakariri District Councils.

In addition to the above Councils, the following lifeline sectors were invited to participate:

- Electricity
- Telecommunications
- Transport
- Flood Protection
- Solid Waste

4.2.5 Hazards

The following hazards were selected for the vulnerability assessment:

- Tsunami affecting coastal areas
- Flooding from a range of river catchments in North Canterbury (100-to-500-year return periods)

4.3 Data Attributes / Schema

4.3.1 Data Input Formats

GIS data can come in various proprietary and open-source formats. The preferred method for gathering and using data is for online services published from the asset owners' corporate systems. Rather than building a single data store of analysis data, loosely coupled services drive the system architecture. The key benefit of using this method is that repeated approaches to keep data current are no longer necessary, as the latest available data is being used for modelling.

4.3.2 Asset Class Library

An asset class library was developed from a review of existing Lifelines data capture work carried out for Canterbury Lifelines and other regional Lifelines groups. The work involved comparing and harmonising the sector and asset types into a standardised list with common naming conventions. See example below for the telecoms sector.

Asset Class	GIS	Fragility Ref	Attributes – draft
Broadcasting Towers	Point		
Cables	Linear		Type
Cell Sites	Point	Mobile Towers	Tower material, tower height
Comms Systems	Network		
Control Centres	Point	Buildings*	Material, foundation height, number of storeys
Exchanges	Point		Size

Table 4-2 Telecommunications Sector Asset Classes (Example)

The draft asset class library was designed to adapt and grow via feedback / testing from the Lifelines community. This library is intended to provide a useful starting point by reflecting the work to date and proposing a standards-based model for more consistent capture of lifelines information.

4.3.3 Common Attributes

A list of proposed common attributes was also developed based on a combination of previous lifelines work and knowledge of data handling within asset management and GIS environments.

Theme	Attribute Name	Maturity	Notes
Identification	Asset Owner	Core	Name of organisation
	Asset ID	Core	Unique owner ID
	Asset Name	Core	Asset / site name
	Asset Type	Core	Level 2 type description
Profile	Criticality	Intermediate	Internal criticality rating
	Install Date	Core	Installation date for the asset
	Renewal Value	Core	Current asset replacement cost
Location	Street Address	Intermediate	AIMS/LINZ
	Object ID	Core	GIS host ID
Dependencies	Electricity Required	Core	For site to function
	Electricity Backup	Core	Generator, plugs, battery
	Fuel Stored Onsite	Intermediate	Days running for generator
Metadata	Date Supplied	Core	Date of data supplied
	Data Source	Core	Format of source data

Table 4-3 Common Attributes

5.0 Milestone 4 - Data Acquisition & Setup

5.1 Task Summary

Table 5-1 Task Summary – Milestone 4

Task	Description	Status Summary
10	Populate the qualitative information from Canterbury's Risks & Resilience Phase 1 vulnerability stocktake into the GIS portal – this being current textual knowledge about each LLU's network assets and likely vulnerabilities.	This has not been progressed as the level of work involved has not been scoped, resources were not available, and also because the qualitative information involved needs to be reviewed and updated by lifeline utilities.
11	Obtain data as per schema and populate / update the data model in the Lifelines GIS portal for the pilot LLUs – this is expected to be a mix of "live" open source data feeds and subscribed feeds and include infrastructure, hazards and "community sites" data. Include climate change induced effects such as more intense rainfall, sea level rise, etc.	Workshop with lifeline utilities followed by a process of data acquisition as per the sector schemas. Flood and tsunami hazard layers obtained. North Canterbury Resilience Pilot GIS Portal created.
12	Set up the "Integrated Approach" with connections via the GIS portal to relevant tools and knowledge including MERIT and other resources as determined in the scanning stocktake.	Modelling approach confirmed. Urban Intelligence Platform configured and linked to the GIS Portal. Format of data required for MERIT analysis confirmed.
13	GIS portal ready to be used, data compiled, produce report on implementing the "Integrated Approach".	This report summarises achievements under Milestone 4.

5.2 Data Acquisition

5.2.1 Lifelines Sectors

A project workshop to introduce and explain the project to the following invited North Canterbury lifeline utilities was conducted in August 2022.

- Electricity Sector:
  - Transpower
  - MainPower
- Telecommunications Sector:
  - Enable
  - Vodafone
  - Chorus
- Three Waters Sector
  - Waimakariri District Council
  - Hurunui District Council
  - Kaikoura District Council
- Transport Sector
  - Waka Kotahi
  - KiwiRail
  - Waimakariri District Council
  - Hurunui District Council
  - Kaikoura District Council

5.2.2 Lifelines Utility Infrastructure Layers

Each of the lifeline utilities above were individually contacted following the August 2022 workshop and asked to provide data in accordance with the data schema for each sector.

Onsite meetings were held with lifeline utilities to highlight the project objectives and outline data requirements. The visits provided a good opportunity to collectively review available asset data and discuss any related disaster resilience and risk reduction initiatives.

The meetings were used to explain how the data would be handled and kept secure during the project to provide asset owners with some comfort around data risk management.

Good representation of asset data was received across the five sectors with only two utilities not able to provide data within the project timeframe. This reflected the strong support observed from North Canterbury utilities for this project and recognition of the insights it can collectively offer to the region.

5.2.3 Hazard Layers

Geospatial data was obtained from Environment Canterbury (ECan) for the following hazard types:

- River breakout flooding scenarios for a range of storm return periods across North Canterbury. This includes modelled water depth and flow velocity information for a range of return period events, 100, 200 and 500 years, some of these models included provision for climate change rainfall (e.g., RCP8.5 for 2081-2100).
- Tsunami Evacuation Zones and a tsunami scenario based on a possible Hikurangi Trench earthquake event.

5.3 GIS Portal

The GIS Portal was configured with the available hazard and infrastructure data layers provided by the lifeline utilities. An example snapshot is provided below.

It should be noted that keeping the GIS Portal up to date with research outputs will need to be an ongoing task as research is completed and the results translated into a GIS-consumable format. Research outputs could include new understanding in relation to the nature and scale of hazards, the ways in which infrastructural assets can be damaged or affected by such hazards, through to the social and cultural implications to communities.

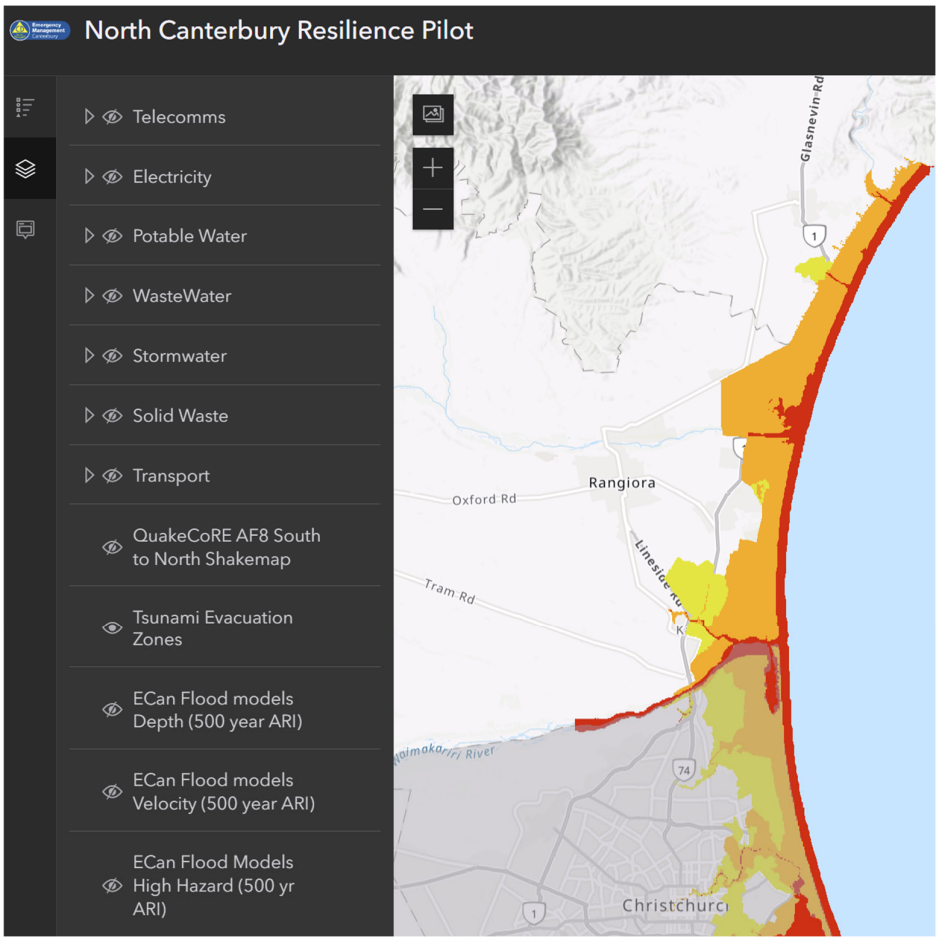


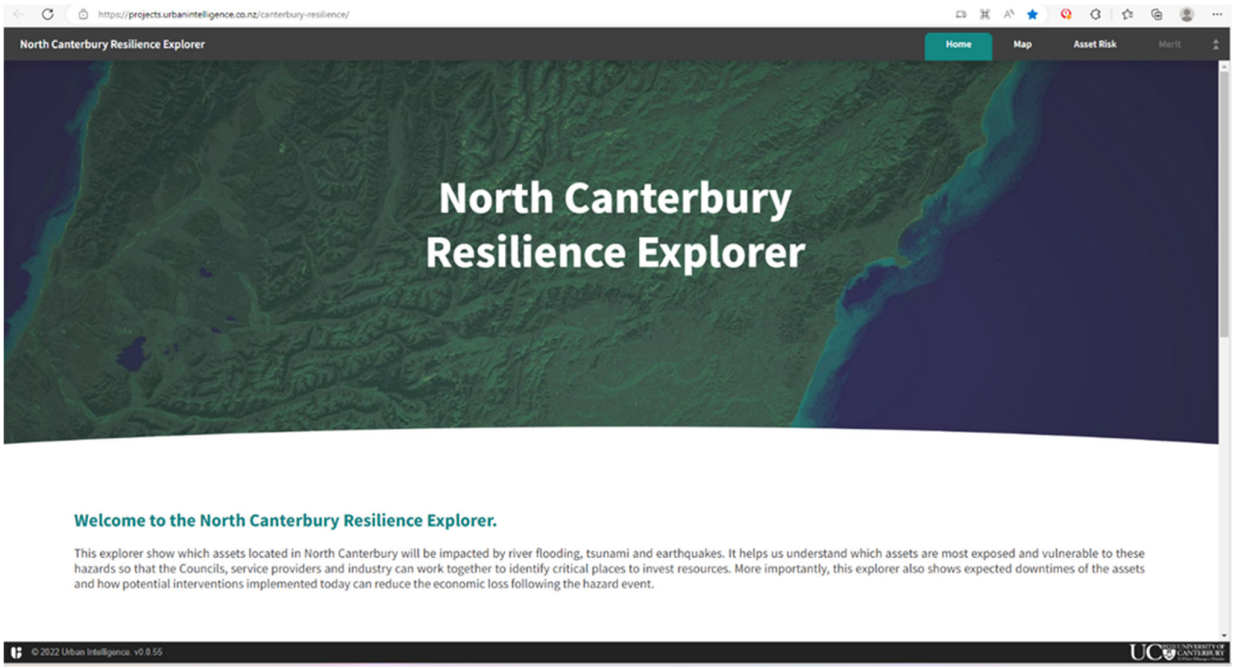
Figure 5-1 North Canterbury Resilience Pilot – GIS Portal

5.4 Urban Intelligence (UI) Platform

This project has leveraged the advanced capabilities of ArcGIS Online by providing a diverse set of analysis-ready data to Urban Intelligence's third-party application. This means that the Urban Intelligence platform holds no data, instead it accesses relevant data from The Portal and performs analytics on the fly as the user demands. An example snapshot is provided below.

The UI application was configured to demonstrate the following functionality:

- Mapping and selection of hazard events
- Selection of lifelines asset layers using a menu
- Vulnerability assessment utilising fragility relationships or nominated threshold levels



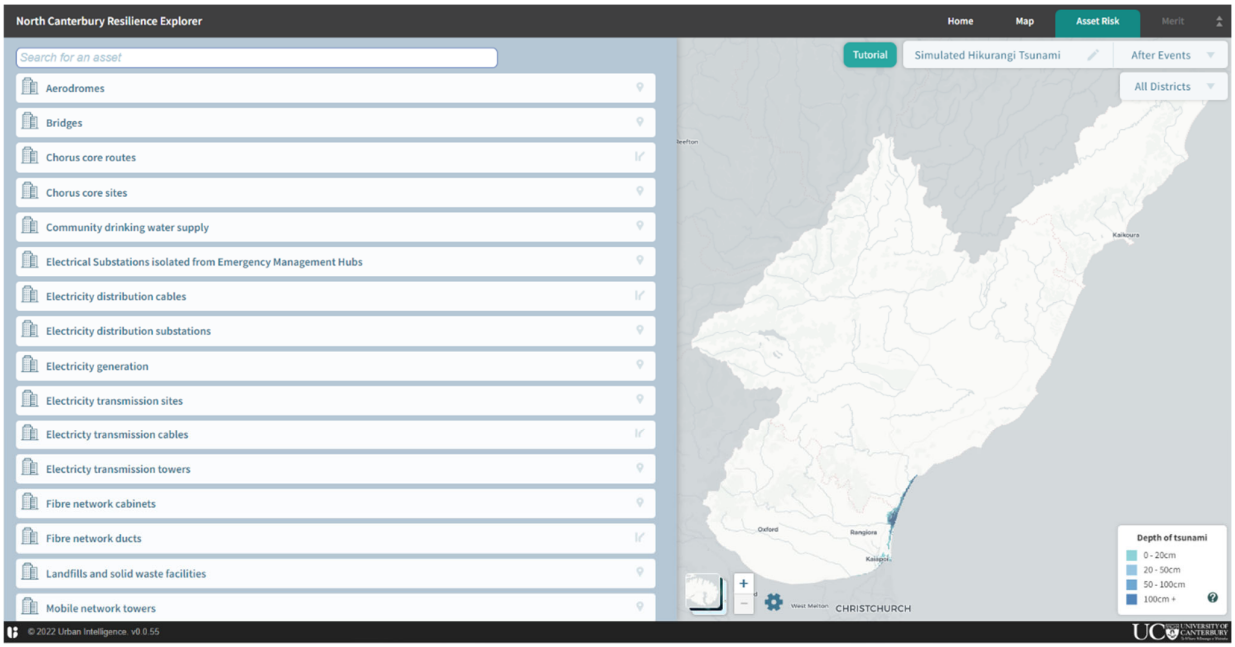


Figure 5-2 North Canterbury Resilience Pilot – UI Platform

6.0 Milestone 5 - Vulnerability Modelling & Merit Analysis

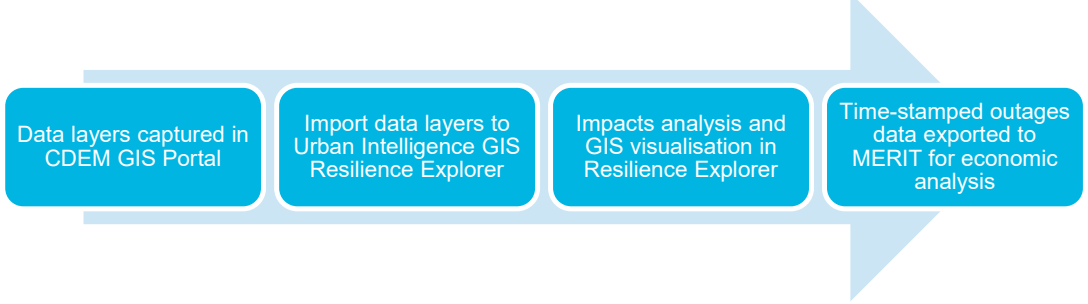
6.1 Task Summary

Table 6-1 Task Summary – Milestone 5

Task	Description	Status Summary
14	Test the use of the GIS portal through workshop with pilot LLUs to assess hazard impact areas for each hazard event, likely damage and disruption effects and outages, interdependencies and cascade effects, affecting stakeholders identified in the scanning stocktake.	A project workshop with North Canterbury lifeline utilities was held in January 2023 – this presented the work to data and provided attendees with hands-on experience in using The GIS Portal and UI Resilience Explorer. Expected lifelines outage times were agreed for incorporation in the pilot output to MERIT. Feedback from lifeline utilities was positive.
15	Test the use of MERIT and other tools as determined above in assessing the social, cultural and economic impacts of the hazard events. As a worked example, "reverse-analyse" the May 2021 Canterbury flood event.	Following the above workshop, the project team compiled the information needed for the MERIT modelling, the spatial layers and the availability matrix by sector and Statistical Area. MERIT models were configured and run for the North Canterbury pilot area for a 500 year return period flood event – covering economic impacts only. The May 2021 event was not considered.
16	Second workshop with pilot LLUs to identify potential risk reduction mitigation strategies and use the GIS portal to assess the expected reduction in disruptive impacts – e.g., through new infrastructure, increased diversity, strengthen existing, renewal programmes etc.	This step was included in the workshop above, where a range of potential interventions were identified and discussed. These have not been further developed, and would in practice form part of a scenario based mitigation investment planning process as input to business case development.
17	Rerun the MERIT assessment based on selected mitigation strategies.	Due to time and budget constraints this step was not carried out. Comprehensive flood modelling work would have been required to test the impact on up-stream river protection investments prior to rerunning vulnerability assessment and MERIT. There were no real additional benefits to the project in doing so.
18	Prepare report on the pilot analysis and recommendations for further development and use of the tools.	This report provides a description of the vulnerability assessment process, MERIT modelling, and recommendations for application and further improvement.

6.2 Modelling Steps

The modelling process selected is summarised in the diagram below. All input layers (hazards and infrastructure) were captured in The GIS Portal and extracted by the UI Resilience Explorer.



6.3 Hazard Scenarios

6.3.1 Flooding

Flooding is most widespread in the Waimakariri District with exposure due to various river systems, including the Ashley, Okuku and Eyre Rivers and their tributaries. Kaiapoi township and rural areas to the north are the most significantly affected. Modelling allows for RCP 8.5 rainfall for the 2081-2100 period.

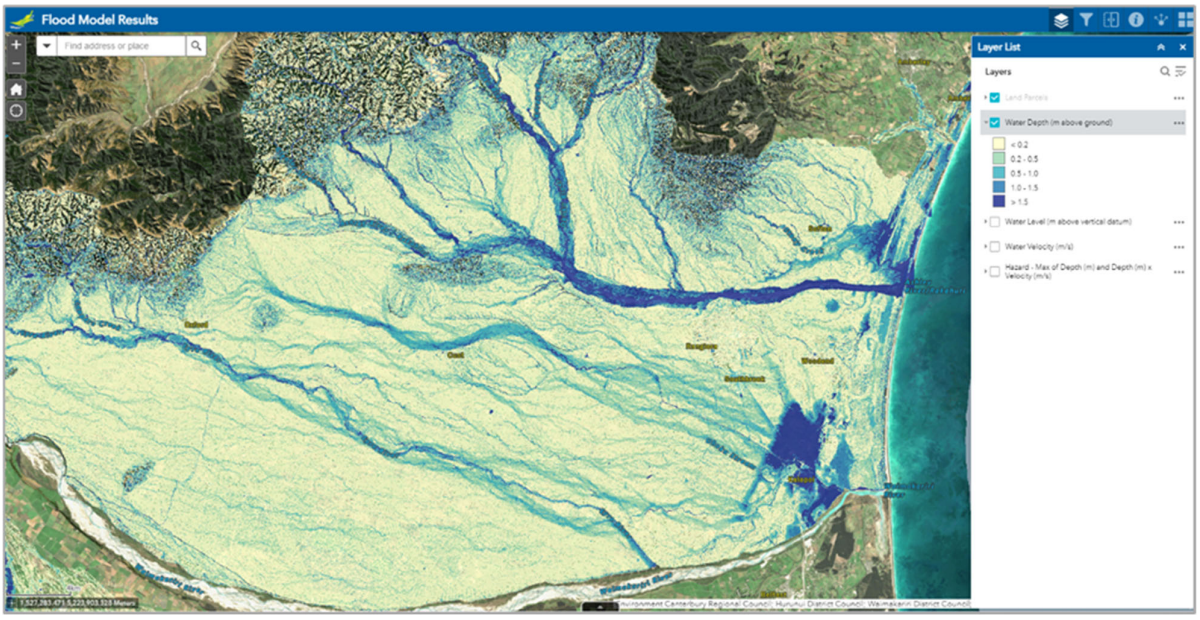


Figure 6-1 Ashley/Okuku/Eyre Rivers and their tributaries – breakouts affecting the Waimakariri District

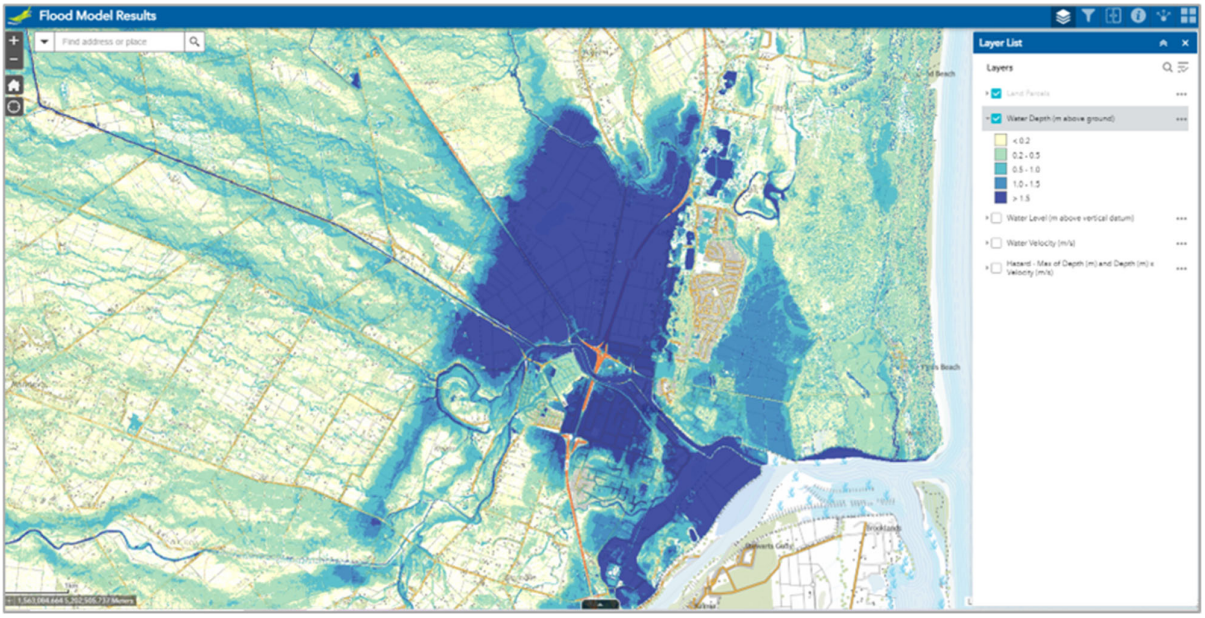
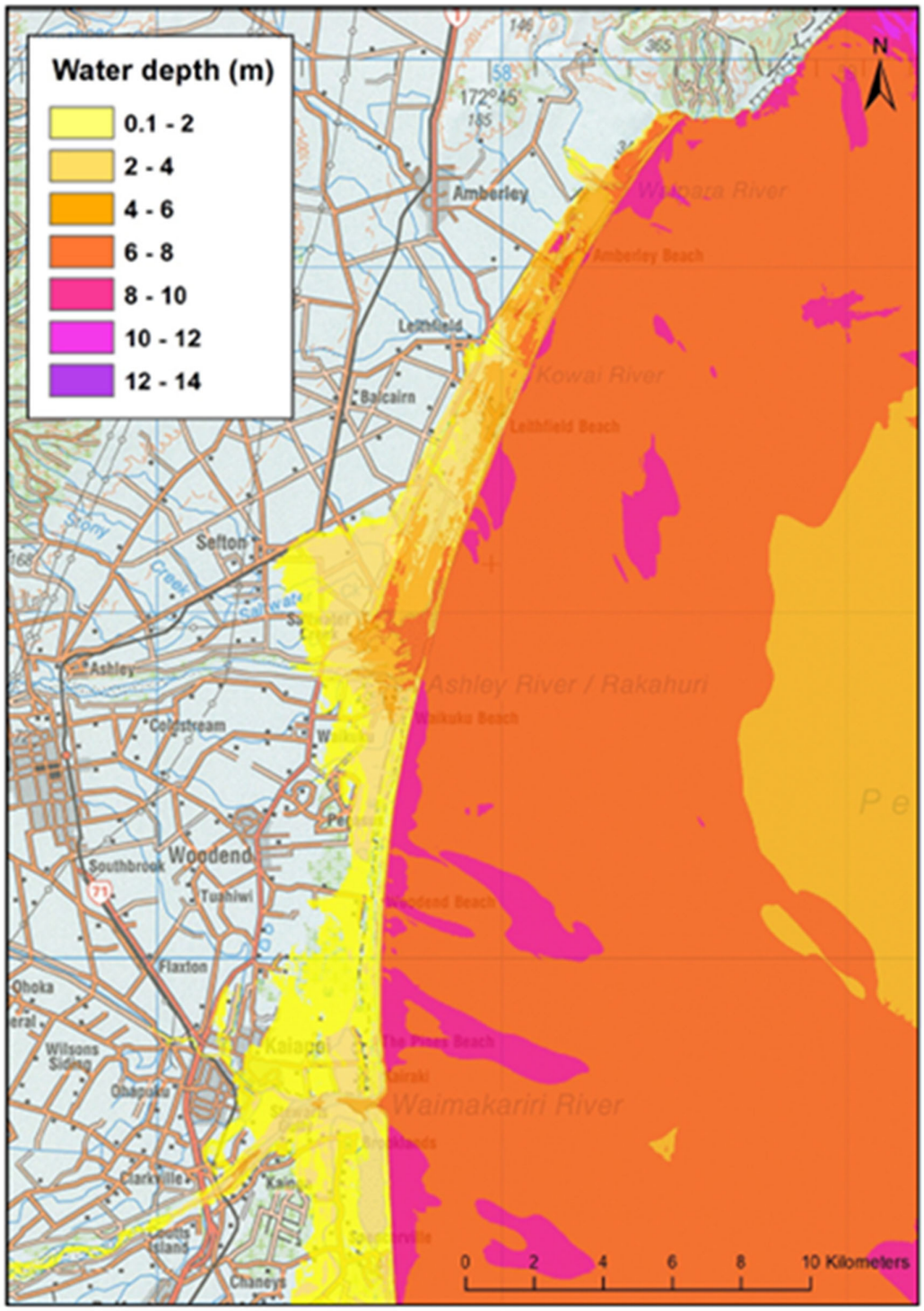


Figure 6-2 Kaiapoi township and environs flooding

6.3.2 Tsunami

The tsunami scenario illustrated below is from a major Hikurangi trench earthquake event (M9.0). Mapping was carried out as part of a review of the tsunami evacuation zones for the Waimakariri District and the southern portion of Hurunui District.



Maximum modelled inundation water depths for thirty M9.0 southern Hikurangi subduction zone earthquake tsunami scenarios (ECan report R21/08)

Figure 6-3 Tsunami risk – Hurunui and Waimakariri Districts

6.4 Impacts to Lifelines

While there is an international body of knowledge around the relative vulnerability of some physical assets to hazard events, this is incomplete in relation to the assets that form part of this study. Expanding this knowledge base and embedding in future modelling is an improvement need.

Fragility relationships were defined only for electricity substations and roads and mapped in the UI Resilience Explorer for demonstration purposes. Categories are linked to the likelihood of failure or damage, defined as follows:

Table 6-2 Defined Fragility Relationships

Asset Type	Low	Medium	High
Electricity Substations	Probability of failure < 10% (Sanchez-Munos 2020)	Probability of failure 10% to 50% (Sanchez-Munos 2020)	Probability of failure >50% (Sanchez-Munos 2020)
Roads	Expected damage < 10% (Espinet et al 2010)	Expected damage 10% to 50% (Espinet et al 2010)	Expected damage > 50% (Espinet et al 2010)

Example snapshots for these asset types are shown below. For all other asset types considered in the analysis, mapping and overlay against the hazards has been incorporated. As new fragility relationships become available these can easily be added to the platform.

In determining outage periods, simplifying assumptions were made in order to develop and test the "proof of concept" process through to economic analysis, allowing for the application of the vulnerability (above) together with an elicited view of lifelines damage or functionality and timeframe to restoration. Outages in relation to the 500 year flooding scenario were discussed and agreed at the January 2023 workshop with lifeline agencies.

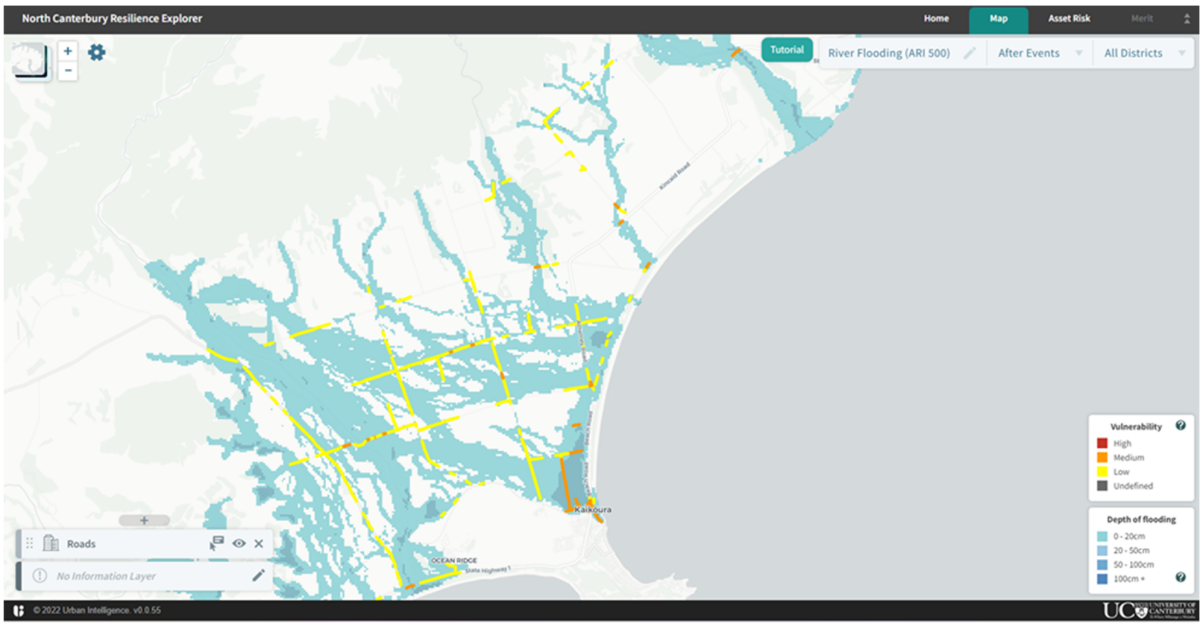


Figure 6-4 Vulnerability of Road Network to Flooding – Kaikoura and Environs

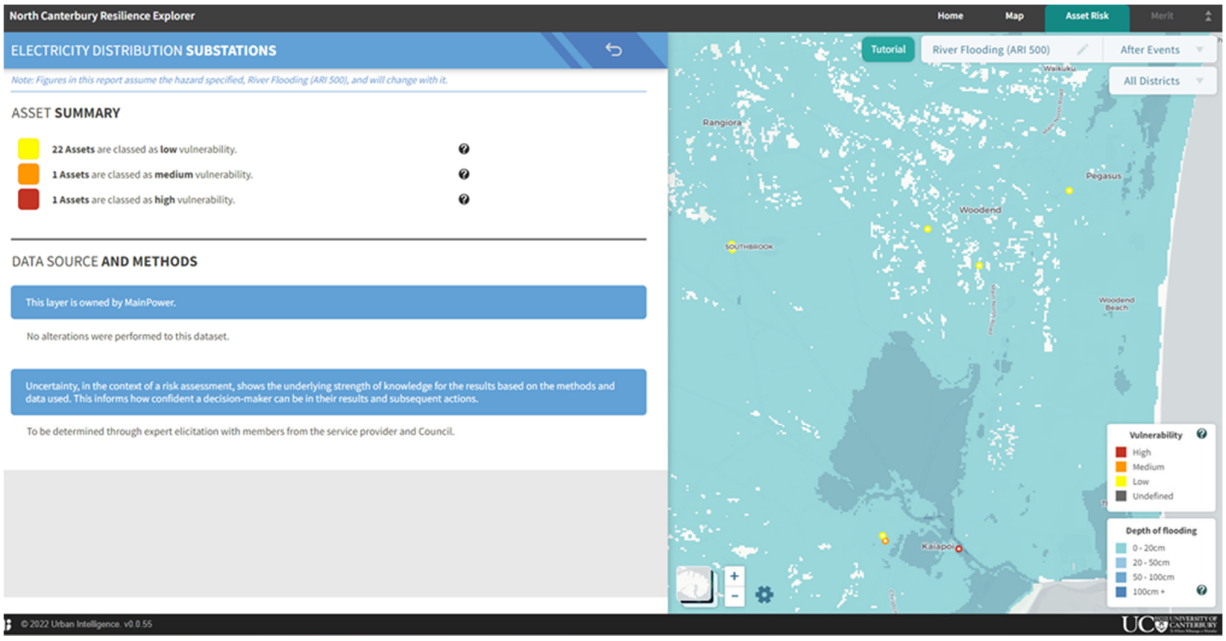


Figure 6-5 Vulnerability of Electricity Substations to Flooding – Kaiapoi and Environs

Using the analysis and modelling results above along with the outage assumptions, the availability matrix output for MERIT was created. Individual outages were aggregated to the Statistical Area 1 (SA1) level, such that any outage within an SA1 area resulted in MERIT modelling the entire SA1 as having a loss of service for the given utility.

6.5 MERIT Modelling

MERIT is a modelling pipeline with a range of components shown below. Not all of these were used in the North Canterbury pilot, with those shown in yellow modelled. The focus was on Business Behaviours Modelling and Freight Margin / Travel Cost Analysis.

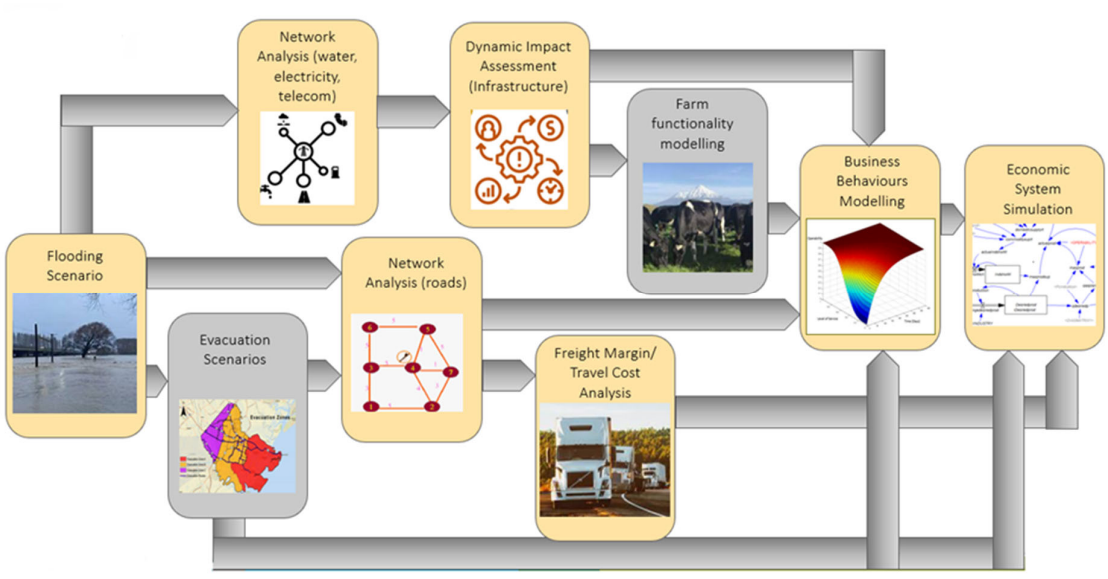


Figure 6-6 MERIT Modelling Pipeline

MERIT modelling was carried out in two phases:

- Calculation of initial direct economic impacts using the Business Behaviours Module (BBM) – this estimates the ability of industries to continue operating from initial disruption back to full production. Operability curves are shown for the manufacturing sector in Figure 6-7. Similar sets of curves were produced for other sectors, including farming, services, accommodation, etc.
- Assessment of wider flow-on impacts in the Dynamic Economic Model (DEM) – this combines all the inputs and simulates how the economy responds over time, providing a dynamic picture of the disruptive economy. GDP impacts are illustrated in Figure 6-8, showing a "dip" at both national and regional levels.

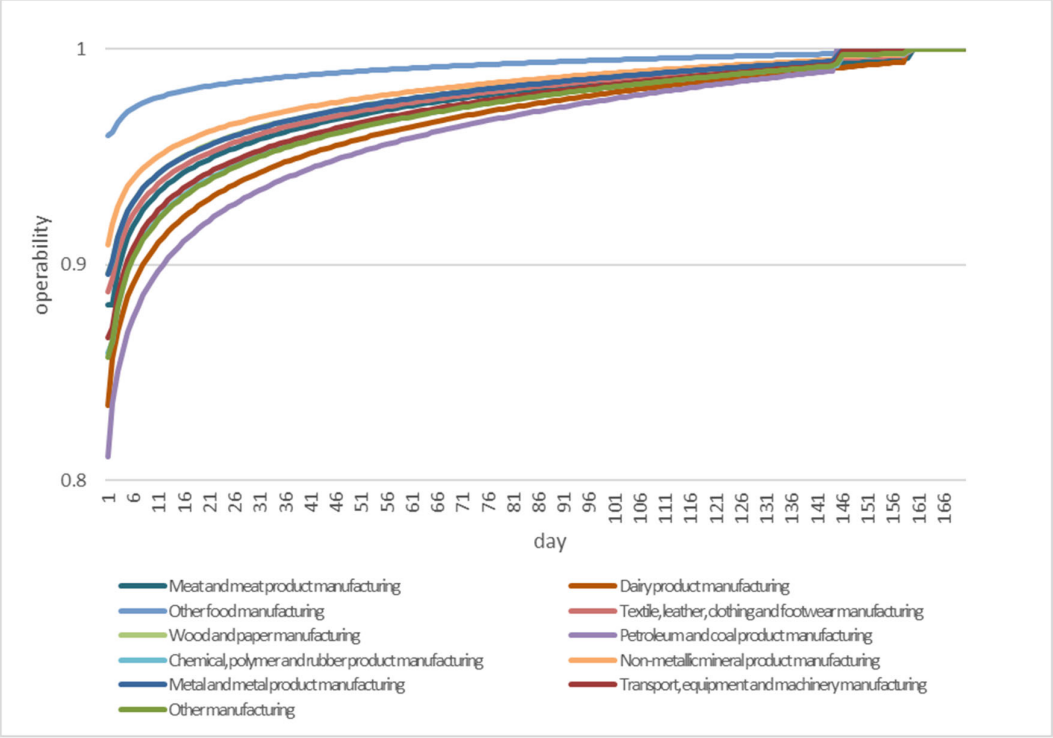


Figure 6-7 Operability Curves for Manufacturing Industries

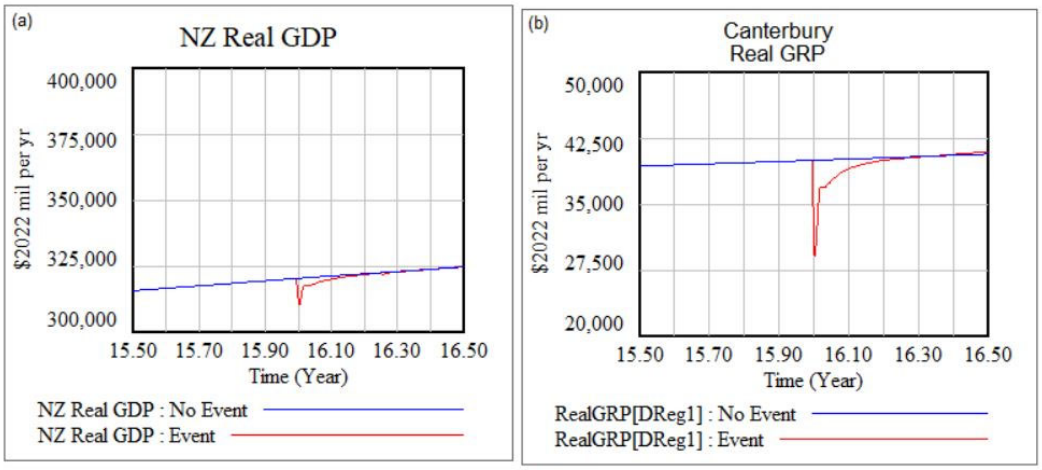


Figure 6-8 GDP Impacts – MERIT Dynamic Economic Model

Ultimately, the cumulative loss of value added across all industries over the first six months of the event was estimated to be ~$NZ_{2022}$$390m, noting the exclusion of

- Loss of capital assets" (financial loss modelling) – e.g., damage to infrastructure, buildings and property.
- "Loss of farm production" – direct losses by farmers are not currently modelled in MERIT.
- "Impacts on natural capital affecting economics service benefit delivery".

6.6 Economic Analysis of Investment Options

While the pilot did not identify and examine the effectiveness of potential mitigation options, this is the natural next step in developing cross-sector scenarios that consider:

- The benefit of mitigation in terms of reducing the impacts of the hazard.
- Remodelling the hazard following intervention.
- "Before and after" vulnerability assessment, impacts analysis, economic modelling and financial loss modelling.

This then informs business case development, asset management planning, and cross-sectoral investment strategies.

7.0 Successes & Challenges

7.1 Project Achievements

The purpose and broad approach proposed for this project is described in the table below. Alongside these paragraphs is a summary of how the project addressed the original intent.

Table 7-1 Project Purpose and Approach

Funding Submission – Intent	Project Achievements
This project is intended to "connect the dots" in relation to tools, resources, knowledge, and practice in use throughout NZ, with the aim of facilitating informed, up-to-date, efficient vulnerability and resilience assessments using a lifelines GIS portal. *A standardised maturity-based approach will be developed along with a data schema for lifeline utilities that can be applied across the country.*	The Scanning Stocktake report provides a comprehensive summary of the "state of play" with the Maturity Pathway report describing the step-by-step process for moving from "Core" to "Intermediate" and "Advanced" practice, drawing from the outputs of the research sector and utilising available tools. A standardised data schema was developed and is documented in the Pilot Approach and Data Needs report. This is available for other lifelines groups to use. Maturity levels were defined and are described in the Maturity Pathway report.
It will include engagement with the lifelines sector, universities, research agencies as well as a wide range of stakeholders and Iwi, drawing on research outputs such as Resilience to Natures Challenges and tools such as MERIT and, in the future, RiskScape. *It will develop an "intermediate" approach that lies between the current methodology for vulnerability assessments and the more advanced "Wellington business case" approach.*	Contact was made with a range of stakeholders as part of the Scanning Stocktake, identifying "social and cultural" sites for use in vulnerability and other lifelines planning work. This data was not in GIS format and has not been used in this project – this is an improvement action. Lifeline utilities in North Canterbury were closely involved, providing asset data and contributing to development of assumptions to support the modelling process. Specific challenges around asset data are further discussed below. In the "intermediate" approach, the research sector was engaged through the University of Canterbury and Urban Intelligence to develop a simplified analytical approach relative to Wellington, while still achieving the economic impacts analysis objectives.
From a Canterbury perspective, this "intermediate" approach will make tangible progress on Phase 2 of the Risks & Resilience project, utilising the GIS portal and information documented in Phase 1 (Vulnerability Assessment). *The intent is to identify and evaluate potential social, economic and cultural impacts arising from both hazard events and climate change, including the use of MERIT.*	Development of The GIS Portal has been a core output of this project. It allows both hazard and infrastructure data layers to be collated and used in a qualitative way to understand where assets are exposed to hazards. Other sites (such as emergency services, community sites, etc.) can be readily imported using suitable geospatial data. The "end-to-end" process developed allows the data in this layer to be connected to the UI Resilience Explorer, enabling models to be developed and applied that link lifelines exposure to hazards with the outage and duration inputs needed for economic analysis in MERIT.
It is anticipated that this work will be valuable to the wider lifelines sector in improving resilience outcomes elsewhere.	All of the technical reports are readily available to the lifelines community and the approach can be replicated. The GIS Portal could be further developed and managed at a national level for the benefit of all regions. The UI Resilience Explorer and MERIT are commercial products that can be used for similar purposes in other regions, providing the base GIS data layers are available.

7.2 Challenges

Specific challenges addressed by the project included data acquisition and hazard impact modelling. These topics are further discussed below.

7.2.1 Lifeline Utility Data Acquisition

Engagement with the lifeline utilities in North Canterbury was positive overall, and they recognised the benefits that this project could deliver for their own future resilience planning work. There was recognition of the insights that such a project can collectively offer to the region. Having visibility of other utility asset locations with interdependent relationships also helps close a gap in current knowledge.

Good asset data was received across five participating sectors with only two utilities not able to provide data within the project timeframe. Asset data layers from national and regional level utility owners often extended beyond the project area of North Canterbury. These wider data sets offer a great platform to scale reach beyond North Canterbury during future work.

However, there are several data issues that should be considered as part of future work:

1. Openly or publicly sourced data sets were used for supplementary asset location data for the telecommunications, three waters and transport sectors. Feedback suggests that this information is available from utilities directly if more time was provided to process the request.
2. Spark New Zealand asked that all data requests be made through the national lifelines group to improve regional coordination and avoid duplication of effort. This is a valid point and should be followed up at a national lifelines level to agree engagement protocols.
3. Several larger utilities publish data layers at a high level for selected asset types and locations. These data sets while being easy to access can hold limited specific attribute information making it more time consuming to obtain the data needed.
4. Provision of attributes was varied and usually centred on name, type and internal technical codes. This was a deviation from the data schemas and possibly reflected the limited time given for utilities to process the data request. Another potential factor is the level of trust necessary before asset owners are comfortable sharing more sensitive data.
5. The One Network Road Classification (ONRC) dataset maintained by Waka Kotahi does not currently hold bridge and tunnel location information. A supplementary data set has been utilised from LINZ for the project as an interim measure. This knowledge gap should be resolved with Waka Kotahi as part of future work.

7.2.2 Hazard Impact Modelling

While there is an international body of knowledge around the relative vulnerability of some physical assets to hazard events, this is incomplete in relation to the asset types that were part of this study.

Vulnerabilities were assessed in the UI Resilience Explorer using the available fragility relationships for Electricity Substations and Roads. While most asset types were not able to be categorised in this way in the pilot, assets exposed to the hazard are mapped in the UI Resilience Explorer and the depth of floodwater or tsunami can be easily identified.

The project therefore made assumptions about the relationship between water depth and operability for other asset types, and associated interdependencies, in order to develop outage and duration information for MERIT economic modelling.

The robustness of this process can be improved through expert elicitation, a potentially time consuming process across a large region, or through refinement of fragility relationships in the New Zealand context. The project team is aware of work being done in this area, for example in RiskScape2.0, and this offers the potential for more comprehensive analysis in the future. It is important to note that the more sophisticated the approach, the more resource and funding is required.

8.0 Management Approach

8.1 Project Team

Key personnel involved in delivering the project are listed Table 8-1 below. Expertise was drawn from a mix of suppliers, including:

- IAM Consulting (M Gordon) Ltd – led the project, having long-term experience with Canterbury lifelines and asset management.
- Urban Intelligence – specialist software and modelling analytics, with support from the University of Canterbury.
- Resilient Organisations – involvement in workshops, ongoing review, support and advice.
- Market Economics – economic analysis using the MERIT tool.
- Infrastructure Decisions Ltd – contribution to the Scanning Stocktake report, provided national lifelines context.

There was close collaboration with Environment Canterbury, in particular around GIS and hazards data acquisition, as well as the University of Canterbury.

Project management activities included the following:

- Regular progress meetings with the project delivery team on a weekly or as required basis.
- Management and coordination of activities and providing direction for the project team.
- Review of Milestone reports and approval for finalization.
- Tracking of physical and financial progress against the original (and subsequently updated) programmes.
- Monthly invoicing to Environment Canterbury CDEM.
- Quarterly reporting to NEMA.

Table 8-1 Project Team

People	Organisation	Main Involvement
Mark Gordon	IAM Consulting | Canterbury Lifelines Programme Manager	Project Manager, Technical Lead
Steve Ferris	Environment Canterbury	GIS Portal
Martyn Wooster	IAM Consulting	Data Needs, Data Acquisition, Technical Review and Support
Tom Logan	Urban Intelligence | University of Canterbury	UI Resilience Explorer
Sam Archie	Urban Intelligence	UI Resilience Explorer
Charlotte Brown	Resilient Organisations	Scanning Stocktake report, Workshops, MERIT Support, Technical Support
Tracy Hatton	Resilient Organisations	Workshops, MERIT Support
Garry McDonald	Market Economics	MERIT Analysis
Lisa Roberts	Infrastructure Decisions | National Lifelines	Scanning Stocktake report
Liam Wotherspoon	University of Auckland	Scanning Stocktake report

9.0 Funding Arrangements

9.1 Project Revenue

The original budget for this project was $240,000 with funding proposed from four different sources. Actual funding was $220,000 as shown below, although final costs are yet to be processed. The amount approved through the NEMA Resilience Fund ($175,000) has been fully invoiced to NEMA, with the balance of the required funding being managed through Environment Canterbury CDEM.

The University of Canterbury allocation was an amount from an earlier grant provided by Canterbury CDEM to the University and applied to undergrad studentships for data processing purposes.

The final potential funding source (Resilience to Natures Challenges) was not progressed, although technical review was provided on the Milestone 1 Scanning Stocktake report by the University of Auckland, in ensuring that the content on research programmes completed, underway or proposed was appropriate. Essentially, this meant that some potential project activities were not carried out, for example, utilisation of RiskScape or development of potential mitigation scenarios. This did not however detract from the end result in terms of defining the maturity pathway and testing an end-to-end process for vulnerability assessment incorporating economic analysis.

Table 9-1 Funding Sources

Funding Source	Details	Amount	Secured
CDEM resilience fund contribution	Successful project funding application.	$175,000	Yes
Local authority / organisation contribution	Canterbury CDEM contribution plus CDEM personnel and lifeline utilities “time in kind”.	~$30,000	Yes
University of Canterbury	Research grant	~$15,000	Yes
Resilience to Natures Challenges	Co-funding / co-involvement from the Resilience to Natures Challenges programme not progressed.	$20,000	No
Total Submission Budget		$240,000	
Total Funding Available		$220,000	

9.2 Project Expenditure

Project tasks were structured as a sequence of Milestones, with a report being produced for each. The table below compares the original budget submission split with the actual or current costs for each. Some final costs have yet to be accounted for as noted below.

Table 9-2 Expenditure Details

Item	Tasks	Budget	Cost (Actual)
Project Management	0	$8,000	$7,000 est[1]
Milestone 1 – Scanning Stocktake	1-4	$36,000	$29,260
Milestone 2 – Maturity Pathway	5-6	$28,000	$16,625
Milestone 3 – Pilot Approach & Data Needs	7-9	$38,000	$31,085
Milestone 4 – Data Acquisition & Setup	10-13	$50,000	$52,563[2]
Milestone 5 – Vulnerability Modelling	14-18	$80,000	$80,281[3]
	Total	$240,000	$215,271

Notes:

1. To be confirmed following completion of all PM tasks, project closure and invoicing.
2. Assumes nominal $15,000 for University of Canterbury task – exact amount to be confirmed.
3. To be confirmed following final project invoicing.

10.0 Lessons Identified

10.1 Lessons by Theme

Observations can be made in a number of areas categorized below by theme.

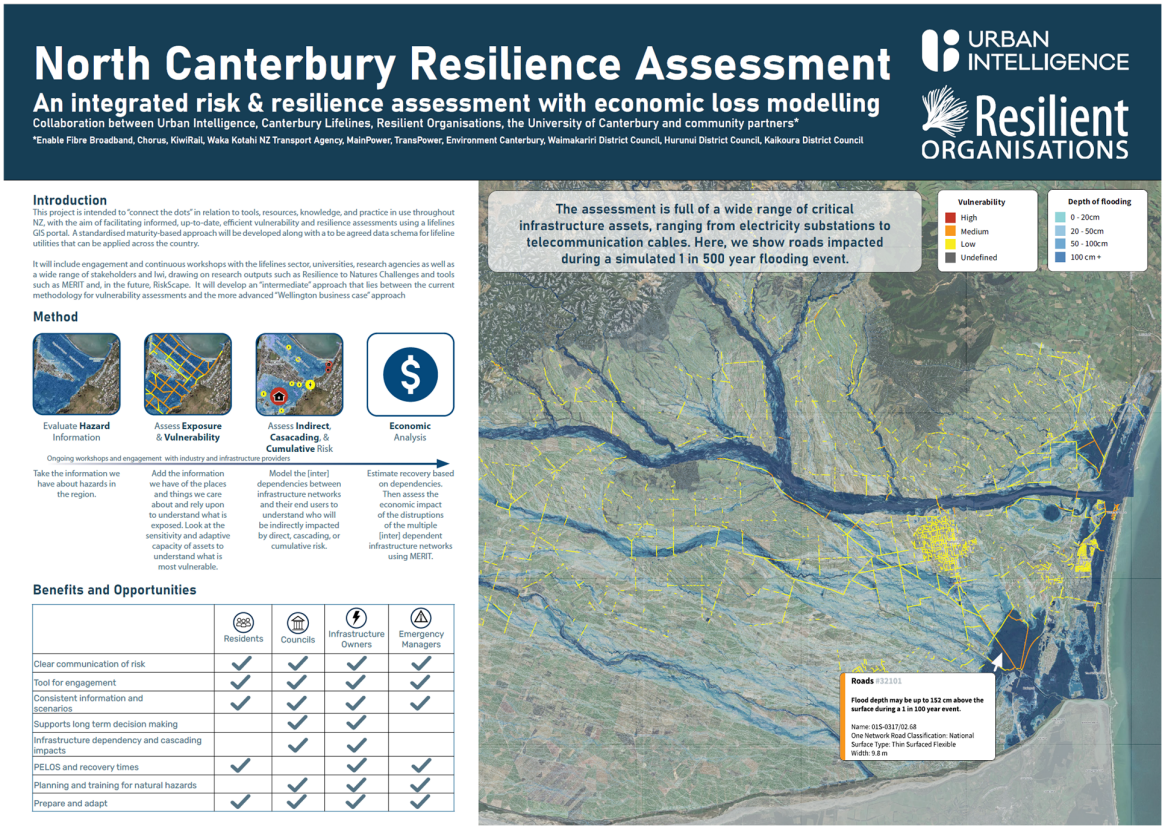
Table 10-1 Lessons Identified by Theme

Theme	Lesson	Takeaway
Research and Knowledge	There is a substantial body of research work available that needs to be continually monitored and used where it adds value to the approaches used by lifelines to understand vulnerability and improve resilience.	This includes improved understanding of hazards and the effects of hazards on infrastructure, as well as social and cultural implications.
Community Sites	There are numerous stakeholder groups each with a range of sites that depend on lifelines operability.	They need to be part of vulnerability assessments and resilience planning.
Asset Data	Supply of the correct level of attribute data is essential if the impacts are to be accurately modelled and risk of failure better understood.	Common factors preventing the supply of core attribute data need to be further explored with utilities in future work.
Asset Data	Local authority roading asset data is stored on the Think Project (formerly RAMM) asset management system and can be externally accessed with Council permission.	This could be an easy way in the future to efficiently capture local roading data across Canterbury and other regions using a single login.
Asset Data	Developing a comprehensive fit for purpose data set is going to be an iterative process.	Maintain momentum by sharing data and insights within the GIS and risk assessment platforms.
Fragility	Asset fragility relationships for different hazard events are not sufficiently documented to cover the core asset types of interest.	This may improve over time as more natural hazard events occur and are studied by the international research community.
Fragility	Practitioner workshops should be used to develop a framework of asset damage / service impacts with varying levels of event severity.	A generalised approach to estimating vulnerability levels for the main asset and hazard types is an effective way to bridge the gap in fragility information.
Platform	A common risk assessment platform can deliver benefits to individual utilities that outweigh perceived risks around data sharing.	Continue to promote the benefits of a shared risk platform with lifeline utilities.
Platform	The aspiration to develop a live asset data feed on a digital platform that facilitates agile analysis and updates is appropriate.	Persevere with the platform in future work and expand into Canterbury and beyond.
Resilience Mitigations	The level of effort in justifying infrastructure options for improving resilience in a business case approach should consider the financial, economic, social and cultural benefits and be appropriate to the scale of the potential impacts.	A business case approach can be carried out at different levels – e.g., high level with assumptions to test potential impacts, to more detailed and comprehensive approaches where the impacts are significant and interdependencies need to be recognised.

11.0 Communicating Outcomes

11.1 Poster Symposium

The following project poster was presented at the 2023 Resilience Symposium held at Te Pae on 21 March 2023. The symposium was attended by people involved with community and urban resilience.



11.2 Dissemination

In addition to the above, the outputs of this pilot proof-of-concept project will also be disseminated as follows:

- Development of a slide pack for communication purposes.
- Presentation to National Lifelines Forum later in 2023. An initial presentation was provided to the 2022 Forum.
- Provision of links to demonstration tools (subject to current data confidentiality agreements relating to the project).

This project potentially has wider South Island appeal, and neighbouring groups will be invited to participate in workshops as appropriate to improve their awareness and understanding of the work.

12.0 Accessing Content

12.1 Project Outputs

The five milestone reports submitted for this project will be able to be accessed via the CDEM Resilience Fund website. They are also available from Environment Canterbury's CDEM office or the Canterbury Lifelines Group Programme Manager, Mark Gordon.

The GIS Lifelines Portal and Urban Intelligence Platform contain asset data layers supplied by a selection of North Canterbury lifeline utilities on the basis that access would be limited to the project team for confidentiality reasons. Please refer to the contact details below to request a demonstration or restricted access to the respective platforms.

It is anticipated that concerns around data security can be explored further with lifeline utilities during the next phase of this work with the aim of establishing data sharing agreements and enabling access to a wider CDEM and lifelines community audience.

Table 12-1 Where to find Project Outputs

Output	Format	Date	Access
Scanning Stocktake Report	Document	January 2022	Download a copy from the CDEM Resilience Fund website: https://www.civildefence.govt.nz/cdem-sector/cdem-resilience-fund/
Maturity Pathway Report	Document	March 2022	
Pilot Approach & Data Needs Report	Document	August 2022	
Data Acquisition & Setup Report	Document	February 2023	
Vulnerability Modelling & Merit Analysis Report	Document	June 2023	
GIS Lifelines Portal	CDEM GIS Platform	June 2023	Contact Steve Ferris at Canterbury Civil Defence Emergency Management to request access: Steve.Ferriss@cdemcanterbury.govt.nz www.cdemcanterbury.govt.nz
UI Resilience Explorer	Urban Intelligence Platform	June 2023	Contact Sam Archie or Tom Logan at Urban Intelligence Limited to request access: sam.archie@urbanintelligence.co.nz tom.logan@urbanintelligence.co.nz www.urbanintelligence.co.nz

13.0 Future Direction

The project has already been discussed in various forums across the lifelines community, and there is interest in making further improvements to enhance vulnerability assessments. In particular, it would be desirable to:

- Expand coverage to the wider Canterbury region and beyond, and encompass additional lifelines sectors, in particular Ports, Airports, Fuel, and Fast Moving Consumer Goods.
- Improve the capture of infrastructure data and other data such as community sites – seek ways to create a common GIS platform that all regions can readily access. In addition, introduce "criticality" considerations to help inform prioritisation.
- Leverage off research and gradually improve the quality and currency of hazards data and our understanding of the fragility of different asset types to hazard events.
- Enhance the modelling approach to improve interdependency and cascade failure impacts analysis across multiple well-beings, the use of fragility curves, outage estimation, recovery capacity, etc.
- Broaden the impacts analysis to include financial loss analysis, as well as social, cultural and environmental impacts, thus implementing more of the maturity pathway. This could involve both MERIT and other tools such as RiskScape 2.0 and the UI Resilience Explorer. Note that these applications are commercial in nature.
- Work with the CDEM community across response and recovery functions to identify ways in which these approaches and tools could be better understood and further developed for the benefit of all stakeholders.

An application was submitted to the CDEM resilience fund in January 2023 to request additional support to expand the GIS-based impacts modelling across Canterbury lifelines in pursuit of the above. The application also noted the following features:

- Leverage off University of Canterbury PhD research and provide a natural link to "emergency levels of service". As with the current project, infrastructure asset data and hazard layers (likely to be selected from flooding, tsunami, AF8 / earthquake) will be brought together in the GIS-based portal.
- Broaden the impacts analysis beyond economic to include asset value loss analysis, social, and cultural, thus implementing more of the maturity pathway.

Co-funding is currently also being sought from the lifelines community and, potentially, other CDEM groups in the South Island. This will enable further progress to be made, and also ensure collaboration with other initiatives such as the AF8 Programme.