FINAL REPORT — STAGE 1

Auckland Engineering Lifelines Project

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EXECUTIVE SUMMARY

The Auckland Engineering Lifelines Project

Three years work by voluntary task groups from lifeline utilities

Modelled on the Wellington and Christchurch projects

This report summarises the results of three year's work by several largely voluntary task groups into the risks posed by selected natural hazards to critical utility networks in the Auckland region. The work was part of the Auckland Engineering Lifelines Project (AELP), which was modelled on the success of similar projects in Wellington and Christchurch. Its objective was to reduce the impact of hazards on lifeline infrastructure — that is, key utility services such as transport, communication, energy, water supply and wastewater disposal.

What's in the report

This report:

- examines the effects of direct damage by major natural hazards to lifeline services
- assesses the vulnerability of lifeline services to damage from natural hazards which would directly affect more than one utility at a time
- identifies interdependencies between the lifeline services
- identifies practical strategies for reducing risk
- helps project participants identify and implement mitigation and respon strategies for their own networks and co-ordinate these with the plans other lifelines

Aims of the report

The report aims to:

Hindsight and future work needs

- collate and record the methodologies used in the Auckland Engineering Lifelines Project and their results
- help other organisations undertaking similar projects by outlining what worked well and what would be done differently with the benefit of hindsight
- act as a resource document for planning and implementing recommended actions
- form a basis for future work on the indirect effects of loss infrastructure, for example on people and other services such hospitals

Hazards

The major natural hazards selected were:

- earthquake
- volcano
- cyclone
- tsunami

Lifelines

The critical lifeline utilities examined were:

Bringing hazards and critical lifeline utilities together

- communications: land and cellular
- energy: electricity, petroleum fuels and gas supply and reticulation
- transport: road and rail networks and port and airport facilities
- civil: water supply, reticulation and treatment, wastewater collection and treatment and stormwater drainage

Scenarios

Credible events were developed that would test the Auckland region's infrastructure, in order to assess vulnerability, response and recovery

In order to define the various hazard scenarios, credible events were developed that would test the region's infrastructure should they occur. The hazard analysis was done in two ways:

- a uniform hazard analysis, which analysed the vulnerability of each utility to the hazards based on known information
- a scenario hazard exemplifying the most likely worst case for each hazard

The vulnerability of the lifeline utilities to these hazards and the expected response and recovery requirements were examined.

Only major natural hazard events (earthquake, volcanic eruption, cyclone and tsunami) were considered, to focus on hazards that were likely to cause direct damage to more than one lifeline at the same time

Several different hazards were initially considered, including natural, technological and biological hazards that could have a significant impact on the region's engineering lifelines. After the initial investigations, it was decided to restrict the focus of the vulnerability analysis to only major natural hazard events (earthquake, volcanic eruption, cyclone and tsunami). This was done to keep the focus of the project on hazards that were likely to cause direct damage to more than one lifeline at the same time.

The hazards considered and the exceedance probabilities for specific scenarios are summarised overleaf.

	% probability of exceedance	
Hazard	**In 1 year**	**In 50 years**
Earthquake	0.05	2.5
Local volcanic eruption	0.1	5
Distant volcanic eruption	0.3 - 2.0	15 - 63
Tropical cyclone	1.0	39
Tsunami	1.3	49

Recovery

Recovery profiles were used to help assess their capacity at different stages after the event and their time to full recovery

The concept of a 'Recovery Profile' was developed to describe how a hazard event would affect a lifeline utility's ability to function at different stages after the event by asking:

- **Day 1:** What percentage of service is available immediately after the event?
- **Week 1:** What percentage of service is available one week after the event?
- **Time to Full Recovery:** How many days, weeks or months are required to get back to full service? This includes temporary fixes which restore 100% service

These recovery profiles were initially assessed assuming unlimited resources and unlimited access. Subsequent review of the more limited resources actually likely to be available once other lifelines' recovery abilities were understood extended the recovery periods.

Effects

The effects of a major natural hazard event on some of Auckland's lifeline utilities are potentially severe

The effects of some of these events on some of Auckland's lifeline utilities are potentially severe. Auckland is New Zealand's largest urban area and its ports and airport are the country's main gateway for goods and people. Home to 30% of the country's population — over a million people — its long, thin shape means most transport movement is north - south. Immediately after a hazard event, all normal traffic would cease, only to be quickly followed by mass congestion as people tried to travel on a damaged network to check on family and property.

Land transport and energy supply are key points of vulnerability

Energy imports are similarly constrained to a narrow corridor: up to 95% of the region's electricity is transferred from the south by national grid, while natural gas is transferred from Taranaki region by pipeline and oils are piped from Marsden Point to the Wiri Oil Services Terminal.

Land transport and energy supply are thus key points of vulnerability.

Overload by users is the most serious overall threat to telecommunications networks after a hazard event in the Auckland region

Overload by users is the most serious overall threat to telecommunications networks after a hazard event in the Auckland region. The redundancy available in key networks means that in most cases, some degree of service can still be provided after loss of nodes or network segments, while given reasonable access, restoration after damage is also prompt. However, damaged systems operating at lower than normal capacity would be still more vulnerable to overload than undamaged ones.

All services are vulnerable to failure of bridges carrying them across the region's many streams and estuarine inlets

All services are vulnerable to failure of bridges carrying them across the region's many streams and estuarine inlets.

A volcanic eruption at a key location (for example, the port and CBD or the airport and Wiri Oil Terminal) was found by most lifelines to be the most potentially destructive hazard event. The worst case would require total abandonment of services and re-routing of supply around the area of destruction.

Interdependency amongst the lifelines

Lifeline utilities' interdependencies with other lifelines must be understood

To enable effective and efficient recovery of lifelines from an event that disrupts their service, their interdependencies with other lifelines must be understood.

Operational and recovery interdependencies were both analysed

The Auckland Engineering Lifelines Project enabled each of the lifelines to assess its own reliance on and interdependence with other lifeline utilities by examining their ordinary operational needs as well as their recovery needs in the event of the scenario hazards devised. Interdependence matrices were used to demonstrate the relative reliance of each lifeline network with each of the others.

Telecommunications and access for repairs were identified as crucial interdependencies for all the lifeline utilities

Telecommunications and access for repairs were identified as crucial interdependencies for all the lifeline utilities, along with other needs such as energy for emergency generators and water supply for cleaning up.

Water as a support for other lifelines versus its community importance

Water supply was often ranked quite low, but this does not prioritise hazard response, when potable water supply would clearly have a very high priority

Water supply was often ranked reasonably low in the interdependency analysis. This was because the project focused on the recovery needs of the lifelines themselves on the assumption that knowing their own recovery priorities gives them more information on which to plan for wider recovery needs for the rest of the community.

Loss of potable water supply poses a significant public health risk, while in an emergency, water is also essential for fire fighting. However, these interdependency rankings are not intended to prioritise response to a hazard event, when clearly community health and safety needs would give potable water supply a very high priority.

Wider civil defence and health and safety needs were not addressed as part of this project, and there is considerable support for progressing such work in the future

Wider civil defence and health and safety needs were not addressed as part of this project, and there is considerable support for progressing such work in the future.

As part of the project, a workshop on response and recovery planning was held. The workshop aimed to:

- convey an understanding of the principles and implementation of response planning
- demonstrate contingency preparedness requirements using the example of Y2K response planning
- provide a methodology for participating lifelines to use for their own response planning

A practical workshop using Y2K as an example was very helpful

In reviewing the project methodology and process participants recognised the advantage of undertaking the lifelines vulnerabilities before the end of 1999, as it provided familiarisation with Y2K analysis. The iterative analysis of the hazards, one after the other, meant the hazard analyses improved as the project progressed.

What worked well

Benefits from taking part in the Project

Benefits identified from undertaking the project included:

- the relative frankness and free exchange of information on the vulnerabilities of individual lifelines and services underlining the providers concern for the serious consequences of the scenarios examined
- emphasising the need for lifeline service providers to continue and enhance risk management procedures
- enabling lifelines operators to recognise their interdependencies
- identifying actions that can be taken to improve regional co-ordination following a hazard event

What worked less well

Difficulties encountered mainly arose from lack of time and resources as well as turnover of representation of utilities on task groups

Difficulties identified in undertaking the project included:

- lack of staff time and resources to fully support the project
- lack of participation by some key players
- the high turnover of participants, hampering efforts to produce consistently reliable results
- difficulty in dealing with Emergency Management and Civil Defence during their restructuring

What would be done better next time

There are several ways in which the project could be improved if it were being done again

Ways in which similar projects could be improved included:

- improving the induction process of the participants
- using electronic data to accelerate vulnerability identification
- providing an overview of all the hazards in order to select the most appropriate to initiate the analyses
- improved recovery profile assessments
- commitment to representation on task groups by participants

Further work

A great deal of further work remains to be done, by:

- **individual utilities or utility sectors**
- **the utilities collectively**
- **the hazards team**

Participants also identified a large amount of further work that was considered to be outside the scope of Stage 1, but which is worthy of recording because it could decrease vulnerability and improve response and recovery of the lifeline utilities either individually or collectively.

Most participants identified two categories:

- further work the lifelines identified as needing to do themselves, either individually or as sectors, such as more detailed damage assessments for critical network components and undertaking specific investigation to progress mitigation measures like the identification of a safe transport routes network
- further work from which there would be benefits in undertaking collectively, such as developing a volcanic building code, facilitating communications between the lifeline organisations and establishing region-wide strategies to share resources and concentrate on reinstalling critical regional services

A lifelines group for Auckland?

There is support for establishing an Auckland Engineering Lifelines Group to continue this work

As a result of the Auckland Engineering Lifelines Project, there is strong support for the establishment of an Auckland Engineering Lifelines Group, and the report concludes with some suggestions for how such a group could be established and some of its initial tasks.

HOW TO USE THIS REPORT

Readers will be approaching this report from different backgrounds and perspectives, so the information has been presented in a format that allows it to be used in the most efficient and effective manner.

The following chapter descriptions outline the content of each chapter in order to allow easy navigation around the document:

Chapter 2 outlines the project background and methodology. It explains the project structure, the tasks the participants carried out in order to analyse the networks and their vulnerabilities to the hazards examined and the way in which the tasks were undertaken.

Chapter 3 outlines the hazards and potential damage used to assess vulnerability and recovery for each of the lifeline utilities. It also describes the way in which the hazard information was created and collated.

Chapter 4 identifies the lifeline utility networks examined in the project and their typical function and structure.

Chapters 5 and 6 report on the outcomes of the assessment of lifelines' vulnerabilities to and recovery from the various hazards examined.

Readers whose interest focuses on the hazards should go to Chapter 5.

Readers whose interest focuses on the utilities should go to Chapter 6.

Chapter 5 outlines the assessed vulnerabilities of each lifeline network from the hazard under examination. All lifeline utilities are considered against the same hazard allowing similarities between utilities and the effects on service to be compared. It replicates the information in Chapter 6, but from the point of view of the hazards.

Chapter 6 looks at the vulnerability of each separate lifeline network to the hazards identified. It replicates the information in Chapter 5, but from the point of view of the utilities. Discussing the responses of each utility to the hazards allows each utility to assess common vulnerabilities to a range of hazards. The effects on service are summarised.

Chapter 7 examines the interdependencies amongst the lifeline utilities.

Chapter 8 outlines typical response and recovery requirements and uses an example of Y2K preparedness to demonstrate these.

Chapter 9 critiques the Auckland Engineering Lifelines Project, methodology and outcomes so that other similar projects can gain the benefit of what was done well, what could have been improved and more importantly how it could be improved.

Chapter 10 identifies further work considered to be outside the scope of Stage 1 of the project but worthy of recording because it could improve response and recovery of the lifelines individually, by sector or as a whole.

Chapter 11 looks at possible future developments for hazard analysis and response and recovery planning for Auckland's engineering lifelines.

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DISCLAIMERS

This report by its nature is general in its application and subjective in its recommendations and is intended as an initial guide only. While every effort has been made to ensure the accuracy of the report, no liability whatsoever can be accepted for any error or misprint.

HAZARD INFORMATION

The hazard information in this report has been prepared for the purposes of the Auckland Engineering Lifelines Project. Its use for any other purpose may be limited. The hazard maps have been prepared at a regional scale and do not replace any requirement for detailed site specific geological, geotechnical or other investigation. Readers of the report are advised to consult with the Auckland Regional Council as to the suitability of information in this report for other applications.

NODE AND NETWORK INFORMATION

Ongoing programmes as well as special projects initiated in response to the Auckland Engineering Lifelines Project have resulted or will result in changes to the assets and systems described in this report. Information in this report should not, therefore, be taken to indicate the current state of hazard vulnerability or preparedness of the lifeline utilities described.

VULNERABILITY INFORMATION

It is important to note that the vulnerabilities in this report were identified by the utilities themselves and the Auckland Engineering Lifelines Project is not responsible for the disclosures made or withheld. The decision as to which vulnerabilities to identify and disclose was the responsibility of each individual utility.

PREFACE

As I write this I contemplate the megacyclone which recently almost hit the United States East Coast, the major earthquakes in Turkey and Taiwan and the series of infrastructure failures in New Zealand and Australia over recent years.

I review the history of natural hazards in New Zealand and speculate on how much longer we might have the good fortune to avoid a disaster of major proportions - a situation we have not had to address in almost 70 years.

Add to the equation the substantial organisational changes in New Zealand over the past 15 years and the increased complexity, interdependence and vulnerability of infrastructure utilities in communities. The value of a co-ordinated assessment of risk and options for managing risk in these utilities becomes obvious.

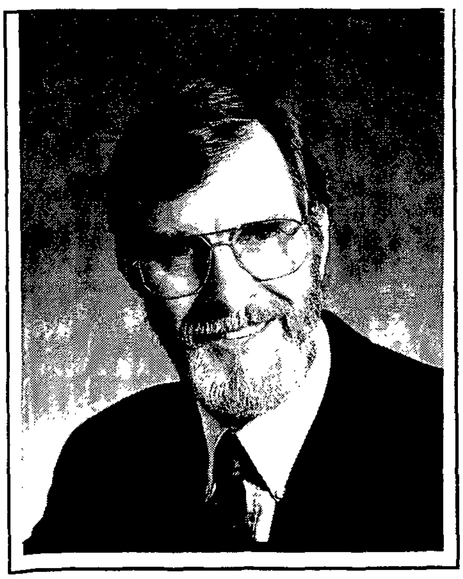
I am delighted to be introducing a report that does just that for the Auckland region. It has been over three years in the making and already the benefits are clear to those participating.

It is an enormous task of commitment and co-operation to bring such a study together and make it happen. The Auckland Engineering Lifelines Project, and the organisations and individuals who have contributed to it are to be congratulated. They have created the potential to significantly reduce risks in their communities and the social and economic costs of disasters.

The challenge for Auckland organisations over the next decade is to convert the potential to reality through the deliberate and systematic application of planning, mitigation and management measures.

Resilient systems are created through the co-ordinated application of asset management, risk management and emergency management disciplines to remove risk and better manage those which remain. Community and individual trauma following disasters can be significantly reduced by such measures and communities and businesses are better off as a result.

The work of the Auckland Engineering Lifelines Project is consistent with the new directions for emergency management in New Zealand. It is now important that Boards and Councils commit resources to give effect to their recommendations.



John Norton
Director, Ministry for Emergency Management

TEAM PARTICIPANTS

Auckland Engineering Lifelines Project Participants

Steering Committee

* denotes current Steering Committee member

John Morris (Chair February 1996 – July 1996)	Auckland City Council
Warwick Moulton (Chair August 1996 - January 1999)	Auckland Engineering Lifelines Project – Steering Committee
Michele Daly * (current Chair)	Auckland Regional Council
John Leuchars	Association of Consulting Engineers
Joseph Flanagan *	Auckland City Council
John McShane *	Auckland International Airport Ltd
Michael Barnett	Auckland Regional Chamber of Commerce
Chris Freke	Manukau City Council
Daniel Newcombe *	Manukau City Council
Fred Henare	Ministry for Emergency Management
John Titmus *	Ministry for Emergency Management
Rob Lorden *	North Shore City Council
Peter Thorley	Orion Ltd
Lou Clements	Ports of Auckland Ltd
Jim Harknett *	Ports of Auckland Ltd
Geoff Broadhead *	Richard Oliver Ltd
Stephen Franklin	Telecom New Zealand Ltd
Stuart Broome	Telecom New Zealand Ltd (Auckland)
Brian Potter *	Telecom New Zealand Ltd (Auckland)
Philip Sutton *	Transit New Zealand
Mike Taylor	Transpower New Zealand Ltd
John Clark *	UnitedNetworks Ltd
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Robert Burley *	VECTOR Ltd

Project Managers

Tony Nicklin	Carson Group (Auckland) Ltd
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David Wilkie *	Carson Group (Auckland) Ltd

Task Groups

Transportation

Daniel Newcombe (Chair)	Manukau City Council
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Mike Mueller	Auckland Regional Council
Steven Cable	North Shore City Council
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Eddie Dearham	Rodney District Council
Murray Parker	Serco
Terry Boyle	Transit New Zealand
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Alan Tresadern	Waitakere City Council
Roger Ward	Waitakere City Council

Civil

Rob Lorden (Chair)	North Shore City Council
Catherine Bayley	Manukau Water
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Eddie Dearham	Rodney District Council
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Ranjit Ranatunga	Waitakere City Council
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Alistair Shanks	Watercare Services Ltd

Communication

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Jeff Hodson	BCL
David Tapp	CLEAR Communications Ltd
Stuart Broome	Telecom New Zealand Ltd
David Crozier	Telecom New Zealand Ltd
Ron Bush	Vodafone New Zealand Ltd

Energy

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Graeme Smith	Mobil New Zealand Ltd
Ian Ward	Mobil New Zealand Ltd
John Payne	Natural Gas Corporation
Rob Howell	Orion Ltd
Peter Thorley	Orion Ltd
Brent Mortensen	Richard Oliver Ltd
Mike Taylor	Transpower New Zealand Ltd
Russell Stewart	Transpower New Zealand Ltd
John Clark	UnitedNetworks Ltd
Robert Burley	VECTOR Ltd
Gary Jefferies	Wiri Oil Services Ltd

Hazard Task Group

Michele Daly (Chair)	Auckland Regional Council
Dr Lester Calder	Auckland Healthcare
Graham Ferguson	Auckland Healthcare
Dr Virginia Hope	Auckland Healthcare
Royd Cumming	Auckland Regional Council
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Dr Ian Billings	Beca Carter Hollings & Ferner Ltd
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Graeme Levy	Beca Carter Hollings & Ferner Ltd
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Dr Kelvin Berryman	Institute of Geological & Nuclear Sciences Ltd
Dr Graham Hancox	Institute of Geological & Nuclear Sciences Ltd
Dr David Johnston	Institute of Geological & Nuclear Sciences Ltd
Dr Graeme McVerry	Institute of Geological & Nuclear Sciences Ltd
Dr Alan Hull	Ministry of Research, Science and Technology
Tony Haggerty	New Zealand Fire Service
Insp B England	New Zealand Police
Supt Don McConnell	New Zealand Police
A S Porteous	NIWA
J Renwick	NIWA
Dr Jim Salinger	NIWA
Dr Philip Shoemack	Public Health - Tauranga
Trevor Robertson	Sinclair Knight Merz Ltd
Dr Tam Larkin	University of Auckland
Dr Bruce Melville	University of Auckland
Dr Warwick Pebble	University of Auckland
Dr Ian Smith	University of Auckland
Dr Willem de Lange	University of Waikato

Plate 1: The Auckland Engineering Lifelines Project Steering Committee

Front row (left to right): Daniel Newcombe (Manukau City Council), Brian Potter (Telecom), Geoff Broadhead (Richard Oliver Ltd), Philip Sutton (Transit), Joseph Flanagan (Auckland City Council)

Back row (left to right): Dr Tam Larkin (Auckland University), Bryce Solomon (Carson Group), Michele Daly (Auckland Regional Council)

A complete list and full contact details of Steering Committee members can be found in Appendix A.

ACKNOWLEDGEMENTS

The completion of Stage 1 of the Auckland Engineering Lifelines Project (AELP) would not have been possible without the help of many people and organisations. The co-operation and commitment of all participants and organisations involved in the project has been willingly given and gratefully received. Special mention is made of:

- the members of the Task Groups who participated in various meetings, workshops, and report reviews. This work was often done in the participants' own time in addition to their normal work. A special mention must be made of the Task Group Chairs and members who kept things going, often in circumstances where company restructurings put pressure on their time and sometimes resulted in changes to Task Group membership
- Mr John Lamb, Project Manager of the Christchurch Engineering Lifelines Project, who provided inspiration, support and guidance to the Steering Committee, particularly during the early part of the project
- Mr David Brunsdon, Project Manager of the Wellington Earthquake Lifelines Group, was also instrumental in helping to get the Auckland Engineering Lifelines Project off the ground. David's advice during the course of the project, assistance at various workshops and commitment to promoting Lifeline studies throughout New Zealand has greatly contributed to the Auckland Engineering Lifelines Project's success
- Mr David Hopkins, Deputy Chairman of the Steering Committee of the Lifelines in Earthquakes, Wellington Case Study, who helped in providing advice during the initial stages of the project, particularly during the first public workshop in December 1995
- Sir Barry Curtis, Mayor of Manukau City, who provided support and patronage for the project in its early stages
- the regional, city and district councils of the Auckland region who have collectively supported the project over the past few years. The Auckland Regional Council has provided financial control and rooms for workshops and Steering Committee meetings

The following organisations have provided financial support for the project:

- Auckland City Council
- Auckland International Airport Ltd
- Auckland Regional Council
- EQC
- Manukau City Council
- Ministry for Emergency Management (formerly Civil Defence)
- North Shore City Council
- Orion Ltd
- Rodney District Council
- Telecom NZ Ltd
- Transit NZ
- Transpower Ltd
- United Water
- UnitedNetworks Ltd
- Vector Ltd
- Vodafone New Zealand Ltd
- Waitakere City Council
- Watercare Services Ltd

Full contact details of all project participants are in Appendix A.

Introduction

1. INTRODUCTION

What is the Auckland Engineering Lifelines Project?

The Auckland Engineering Lifelines Project (AELP) is modelled on the success of similar projects in Wellington and Christchurch. Its objective is to reduce the impact of hazards on lifeline infrastructure — that is, key utility services such as transport, communication, energy, water supply and wastewater disposal.

What does this report aim to do?

This report examines the effects of direct damage by known major natural hazards to lifeline services. It:

- assesses the vulnerability of lifeline services to damage from hazards
- identifies interdependencies amongst the lifeline services
- identifies practical strategies for reducing risk
- helps project participants identify and implement mitigation and response strategies for their own networks and co-ordinate these with the plans of other lifelines

This report aims to:

- collate and record the methodologies and results of the work done
- help other organisations undertaking similar risk reduction strategies by outlining what worked well and what would be done differently with the benefit of hindsight
- act as a resource document for planning and implementing recommended actions
- form a basis for Stage 2 of the process, which will examine and plan for the indirect effects of loss of infrastructure, for example on people and other services such as hospitals and emergency response organisations

Who is this report for?

Key audiences for this report include:

- infrastructure providers
- emergency management/civil defence interests
- other lifelines groups
- public and private organisations

Infrastructure providers can use the report to:

- help identify risk and implement mitigation and response strategies for their networks
- help co-ordinate these strategies with those of other lifeline operators and other emergency response agencies

Emergency management/civil defence interests (regional, city and district councils, emergency response organisations and other groups with interests or roles in emergency management) can use the report to:

- plan for co-ordinated emergency response
- carry out their own strategic planning for hazard management

Other lifelines groups can use the report to:

- find out what elements of the process used by the Auckland Engineering Lifelines Group worked well, what elements didn't and why
- undertake or modify similar risk reduction strategies

Public and private organisations can use the report to:

- help with their own risk management planning

Where does the report fit into the Lifelines process as a whole?

This brief summary of key dates below shows where this report fits in to the Lifelines process as a whole.

November 1995:	Lifelines Forum: Support for project gained from key stakeholders
February 1996:	Steering Committee established
February 1996 - July 1996:	Project terms of reference, funding secured
July 1996:	Project Manager appointed
July 1996 - July 1997:	Project structure definition, hazard and damage analyses, methodology development, lifeline mapping
July 1997:	*AELP Report - Parts 1 and 2 (hazard and network utility information)*
July 1997:	Hazard Presentation: Overview of hazards to project participants and key stakeholders, and report on project progress
July 1997:	Vulnerability Workshop: Interactive workshop for project participants and other stakeholders which marked the initiation of the vulnerability assessment phase
July 1997 - February 1998:	Methodology refinement and additional hazard and damage analyses
February 1998:	Auckland power crisis
February 1998 - May 1998:	Earthquake vulnerability analysis
May 1998:	Earthquake hazard vulnerability, interdependence and recovery workshop: Interactive workshop for project participants to bring together the results of the earthquake vulnerability analysis and to explore interdependence and recovery issues
June 1998 - November 1998:	Volcanic hazard vulnerability analysis
October 1998:	Risk Management: Looking Forward from the Auckland Power Crisis: Seminar for project participants and other stakeholders on the Auckland power crisis and lessons learned
November 1998:	Volcanic hazard vulnerability, interdependence and recovery workshop: Interactive workshop for project participants to bring together the results of the volcanic hazard vulnerability analysis and to explore interdependence and recovery issues
December 1998 - March 1999:	Cyclone/Tsunami hazard vulnerability analysis
January 1999:	*AELP Report - Part 3. Risk Management: Looking Forward from the Auckland Power Crisis*

April 1999:	Cyclone/Tsunami hazard vulnerability, interdependence and recovery workshop: Interactive workshop for project participants to bring together the results of the cyclone and tsunami hazard vulnerability analysis and to explore interdependence and recovery issues
April 1999:	Response and Recovery Workshop: Interactive workshop for project participants focusing on response and recovery issues around the hazards previously considered and co-ordination of utility response at a regional level using Y2K contingency planning as an example
May 1999 - November 1999:	Final Stage 1 report compilation
August 1999:	Steering Committee support for the formation of an Auckland Engineering Lifelines Group
November 1999:	*Auckland Engineering Lifelines Project Stage 1 — Final Report*

Methodology

2. METHODOLOGY OF THE AUCKLAND ENGINEERING LIFELINES PROJECT

This chapter describes the methodology of the Auckland Engineering Lifelines Project, including:

- its background, development and use
- its benefits and limitations

2.1 Background

The AELP follows the Wellington and Christchurch approaches, but does not consider community lifelines like ambulance, fire and similar services

The Auckland Engineering Lifelines Project methodology is based on the general approach developed by the Wellington and Christchurch projects. It has departed somewhat from those approaches in an attempt to enable the vulnerability analysis to examine the interdependence of utilities as well as effects on the individual utilities themselves.

In a further departure from the Christchurch approach, the community lifeline services (ambulance, fire, hospitals, emergency management/civil defence and the like) were excluded from the hazard impact analysis, with the focus placed on utility impact and response. This was done in order to make the task manageable, and was also based on the assumption that rapid and efficient network restoration by the utilities would also benefit community recovery.

Vulnerability analyses led to improved response and recovery planning

The initial objective of the methodology was to enable the utilities to assess their vulnerability to hazards that would affect more than one utility at the same time, and to identify mitigation measures. Once the Task Groups got into their work, however, the focus shifted more towards improving their response and recovery abilities, and this was considered to add considerably to the value of the project.

Analysis of the hazards and their impacts was broken into the series of tasks shown in Figure 1.

A multi - hazard approach focused on damage most likely to represent the impacts of any one or more of four major natural hazards

In line with the Christchurch project, the Auckland Engineering Lifelines Project took a multi - hazard approach. The time and cost of fully analysing the impact of all hazards would have been prohibitive, so a group of major natural hazards was selected that would affect more than one utility and encompass most of the impacts that needed to be planned for. These were:

- earthquake
- volcanic eruption
- tropical cyclone
- tsunami

Analysing the impacts of and developing mitigation strategies for these major natural hazards would also enable the effects of lesser hazards to be addressed.

2.2 Project structure

Key Auckland lifeline utilities were identified on which to undertake hazard analysis

The following lifeline utilities were identified as being important enough to the Auckland Region to be included in the hazard analyses:

- electricity supply and reticulation
- gas supply and reticulation
- water supply treatment and reticulation
- wastewater collection and treatment
- telecommunications (land and cellular)
- petroleum supply
- stormwater drainage
- road and rail transportation
- port facilities
- airport facilities

Facilities such as hospitals, public health, emergency management/civil defence headquarters, Police, Ambulance, Fire and so on, while of critical importance in the event of a hazard, rely on the services supplied by the lifeline utilities to operate. As such they are considered to be part of an analysis of priority service restoration which will follow on from this first stage of the project.

With the focus on utility lifelines, task groups were established to facilitate and communicate the objectives of the project

In order to facilitate and communicate effectively to the different participating organisations during the project, task groups were established which had commonality or similarity of purpose.

A hazard task group was created to establish and define the actual hazard information and impacts to the utilities, and the utility representatives were divided into four main task groups based on their sector type:

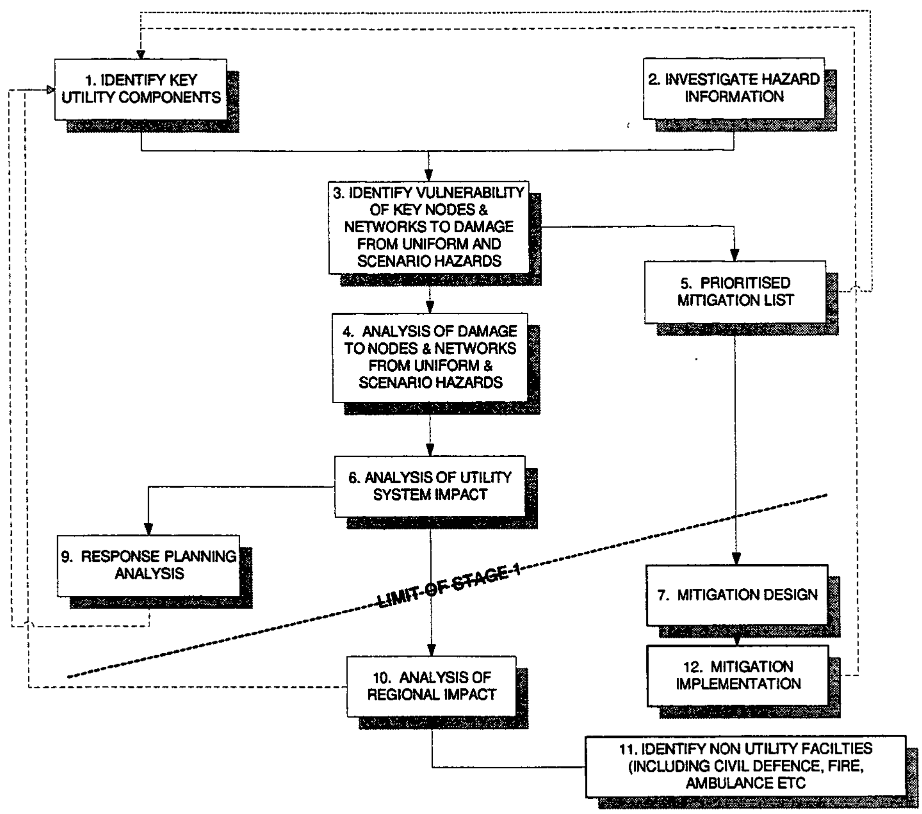
- communications
- transport
- energy
- civil (water, sewerage, stormwater)

Each of the task group participants analysed the impacts of the selected hazards on their own utility and provided insight into the performance of their task group sector as a whole.

Disclosure is determined by the utilities

It is important to note that the vulnerabilities in this report were identified by the lifeline utilities themselves and the Auckland Engineering Lifelines Project is not responsible for the disclosures made or withheld. The decision as to which vulnerabilities to identify and disclose was the responsibility of each individual utility.

Figure 1: Methodology of the Auckland Engineering Lifelines Project



2.3 Definitions

The definitions below were used to promote consistent use of language in the Auckland Engineering Lifelines Project.

Damage — Physical harm impairing the operation of a system, network or node caused by an event.

Event — The hypothetical occurrence of any of the natural disasters considered. An incident or situation which occurs in a particular place during a particular time interval (Australian/New Zealand Risk Management Standard 4360:1999).

Hazard — The future occurrence or risk of occurrence of any of the natural disasters considered. The source of potential harm or a situation with a potential to cause loss.

In this report, the term 'hazard' is used to refer to, while the term 'event' is used to refer to

Impact — The time - related effect of damage, comprising:

- node impact - the reduction in operational performance and function of a damaged node

- network impact - the time and spatial reduction in function of the utility network caused by the cumulative node impacts
- system impact - the reduction in function of the combined network impacts on the whole utility system
- regional impact - the cumulative effect of the system impact and other non utility effects on the region

Regional system	The integrated and interrelated social, commercial, cultural, political, legal and natural environment of the region.
Scenario analysis	Defining a particular scenario enables the impact of a specific event on the entire utility system to be assessed.
Uniform hazard analysis	Defining a given hazard enables mitigation measures for the each utility to be rapidly identified.
Utility network	An interconnected set of utility components and links for providing a utility service.
Utility node	A discrete constituent of the utility network.
Utility system	The combined utility networks, their interdependencies and interrelations for providing infrastructure services.
Vulnerability	The extent to which a system, network or node is sensitive to damage from an event.

2.4 Tasks

The Auckland Engineering Lifelines Project methodology comprised three main tasks:

- Task 1: identifying core — lifeline — services for each utility
- Task 2: collating known hazard information
- Task 3: identifying the vulnerabilities of their networks and critical facilities to selected hazards

Task 1 involved identifying key lifeline components, including network and distribution systems as well as facilities in order to give a snapshot of all the utility networks.

Defining the lifeline elements to give a snapshot of the lifelines network

Each utility was asked to identify what it believed to be its core lifeline services. This has resulted in some inconsistency, for example different water providers may have defined core lifelines pipes as anything from 150mm to 300mm diameter.

The information was produced in the form of utility network and key facility maps. These maps were produced at two scales: 1:100,000 and 1:250,000. The 1:250,000 maps allowed wider analysis of the outer lying districts of Rodney and Papakura.

Selecting the most likely hazards to work with and gathering information about them

Task 2 was to collate known information on hazards into the Auckland Engineering Lifelines Project's first report on Hazard and Utility Information. This report identified the following significant hazards as posing significant threats to Auckland's lifeline utility networks:

- earthquake
- volcanic eruption
- tropical cyclone and/or tsunami
- fire
- drought
- terrorism and/or vandalism

Of these, earthquake, volcano, cyclone and tsunami were used.

Bringing the utility and the hazard information together to highlight vulnerabilities

Task 3 identified the vulnerabilities or sensitivities of each utility's distribution networks and critical facilities ('networks' and 'nodes') to the hazards using the information from Tasks 1 and 2.

The Task 3 analysis was split into:

- a uniform hazard analysis, which analysed the vulnerability of each utility to the hazards based on known information
- a scenario hazard, which analysed the vulnerability of all utilities to a clearly defined hypothetical event exemplifying the most likely worst case for each hazard

Expected response and recovery requirements were discussed and examined for the scenario impacts.

Chapter 3 outlines the hazards in more detail, with the next sections of this chapter giving a broad overview.

The uniform hazard analysis presented known information about actual hazards and risks

The uniform hazard analysis examined information known about each of the four hazards across the entire region in order to highlight to each utility specific areas where its networks and nodes might be vulnerable to the impacts of a hazard event.

Workbooks for this analysis are in Appendices B, C and D.

Earthquake analysis and map overlays of networks

The earthquake hazard analysis overlaid utility network maps onto hazard maps to identify network sections or nodes with a high, moderate or low probability of damage, as shown in the example in Figure 2.

The volcanic hazard information related to eruptions from:

The volcanic analysis looked at the effects of an eruption in the Auckland volcanic field as well as eruptions elsewhere in the North Island, as these could have major effects on the region

- the Auckland volcanic field, within which a volcanic eruption could occur anywhere
- outside the Auckland region

A local eruption of the magnitude used for the Auckland Engineering Lifelines Project would totally destroy above ground services within a 3km radius. Below ground services would be affected within a 1km radius. In order to ensure full service redundancy, a 6km separation (or 2km separation for services below ground) would be needed between the utility elements. The lifeline utilities examined their own vulnerabilities on this basis.

However, because the main effects of the distant eruptions were from ash fall, most of the vulnerability assessments focused on the effects of ash fall rather than complete localised destruction of utilities.

The scenario analysis helped with detailed risk assessment and response by presenting a specific event

In order to examine likely impacts, scenario events were developed for each hazard. The utilities were then asked to examine specific vulnerabilities resulting from these scenarios and to identify response and recovery profiles for identified network and node elements.

Recovery profiles helped utilities work out how long it would take to restore partial and full service

The concept of a 'Recovery Profile' was developed to describe how a hazard event would affect a utility's ability to function at different stages after the event by asking:

Day 1: What percentage of service is available immediately after the event?

Week 1: What percentage of service is available one week after the event?

Time to Full Recovery: How many days, weeks or months are required to get back to full service? This includes temporary fixes that restore 100% service

Each profile included consideration of the resources such as labour, resources, plant and other utility services that would be needed to initiate and maintain recovery.

The recovery profiles of all lifelines were discussed and reviewed, then the individual utilities reassessed their profiles on the basis of a more realistic assessment of access, competition for resources and interdependency of services

An iterative process was used, initially assuming unlimited resources and unrestricted access. The recovery profiles of all lifelines were discussed and reviewed, then the individual utilities reassessed their profiles on the basis of a more realistic assessment of access, competition for resources and interdependency of services. Subsequent discussions with other Lifeline utilities typically had the effect of making recovery profiles longer.

The methodology initially proposed to map the recovery profiles to show impacted zones; areas where service was unavailable one day and one week after the event, and where full recovery took a long time. In practice this proved too difficult, as there were upstream and downstream service effects which also needed consideration. For example, the loss of a key water supply pumping station would not be confined just to the pumping station itself: it would have significant downstream impact. As a result, the exercise was amended to focus on areas or elements of significant service loss in each utility and how that affected the rest of that network.

Workshopping to identify interdependencies

A workshop was then held at the conclusion of each hazard vulnerability assessment to allow each lifeline utility to:

- outline its network's lifeline capabilities for servicing the other utilities
- hold individual discussions with each of the other lifeline groups to identify and understand each others' dependencies and interdependencies

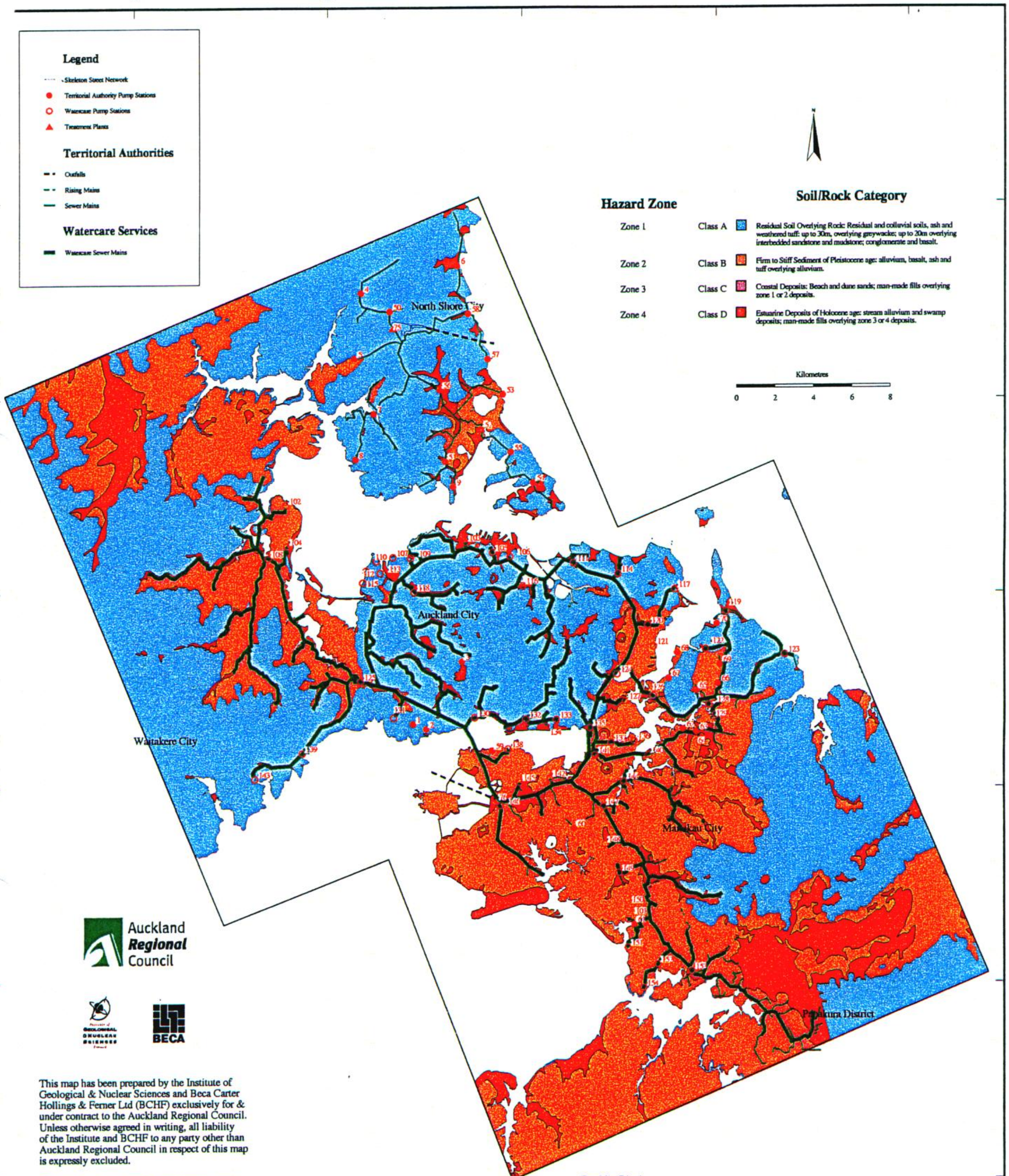
Matrices were developed which demonstrated these interdependencies and the priority which each utility had on the others for operation and recovery. Examples of these interdependence matrices are in Chapter 7.

Combined cyclone and tsunami analyses

Cyclone and tsunami hazards were examined together because they have similar impacts, especially in coastal areas.

Auckland Wastewater Network and Ground Shaking Hazard

Region A



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This map has been compiled at a regional scale. It is not suitable as a site investigation database and should not replace any requirement for a detailed site specific geological or geotechnical investigations.

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Figure 2

Auckland Engineering Life Lines

This map was prepared as part of the Auckland Engineering Lifelines Project
It accompanies and should be read in conjunction with the
Auckland Engineering Lifelines Project, Stage 1 Report, July 1997.

Plate 2: One of the Auckland Engineering Lifelines Project workshops

Failure or disruption of one utility can affect others, so the interdependencies between utilities must be fully understood in order to produce and implement effective response plans after a hazard event

In order to reduce vulnerability, produce effective and efficient response and continuity plans and use them after a hazard event, interdependencies between the utility lifeline providers must be fully understood.

Utilities continually upgrade and develop their networks to improve service delivery, performance and efficiency through the use of more modern techniques, equipment and materials. Growing use of telemetry, complex communications systems and highly specialised equipment has created high levels of interdependence between individual utility networks. For example, a telecommunications network relies on the continuous provision of electricity in order to deliver its services to its customers, while the power company delivering the electricity would struggle to maintain its service for long without telecommunications services.

Failure or disruption of any one or more of the lifeline utilities would affect the others, as shown in the 1998 Auckland power crisis where the localised loss of power to the CBD (central business district) affected other major utilities (AELP, January 1999).

Analyses were based on 'snapshots' of the lifelines at the time, so these do not reflect ongoing improvement and development of lifeline networks

Over the period that the project ran, changes to the initial utility information provided was expected as a result of modernisation and improvement of existing systems.

It was agreed at the outset that in order to manage the large amount of information, the analyses would be based on a 'snapshot' of the lifelines at the time the information was provided. The outcomes from the analyses, while specific for the scenarios developed, would enable general principles and frameworks to be established.

However, ongoing programmes as well as special projects initiated in response to the Auckland Engineering Lifelines Project have resulted or will result in improvements to the assets or response strategies described in this report. Information in this report should not, therefore, be taken to indicate the current hazard vulnerability or preparedness of these lifeline utilities.

A confidentiality agreement was signed by all participants, who approved publication of the information before release

As concerns were initially expressed about commercial and strategic sensitivity of some of the information provided for the project, each participant signed a confidentiality agreement. Participants then approved publication of information before release.

Hazards

3. THE HAZARDS AND DAMAGE ASSESSMENT

In order to assess risk to Auckland's lifeline services, this chapter outlines:

- the hazards considered by the Auckland Engineering Lifelines Project
- the rationale for selecting scenario events
- the likely damage to lifelines from the selected scenarios

3.1 The hazards assessed

The AELP focused on hazards that were likely to cause:

- ***direct* damage**
- **to *more than one* lifeline**
- **at the *same time***

The Auckland Engineering Lifelines Project initially considered several natural, technological and biological hazards that could have a significant impact on the region's engineering lifelines, including earthquakes, volcanic eruptions, tropical cyclones, tsunami, algal blooms, disease outbreaks, fire, hazardous substance spills, vandalism and terrorism.

These hazards are discussed in detail in the earlier Auckland Engineering Lifelines Project report listed in the references, so only a summary of the hazards is presented here. However, some hazard information was revised and updated since the earlier report, and wherever possible this new information has been included in the discussion below. The Task Group Hazard Analysis Workbooks (Appendices B, C and D) contain more detailed information.

Dealing with only four major natural hazards kept the project to a manageable size, but more work may need to be done on other hazards

After the initial hazard investigations, it was decided to restrict the focus of the lifelines vulnerability analysis to major natural hazards only, mainly to keep the focus of the project on hazards that were likely to cause direct damage to more than one lifeline at the same time. Hazards such as disease outbreak and algal blooms in the water supply, while having the potential to cause significant effects, tended to cause minimal direct damage to the lifelines themselves, which were the project's key focus.

However, as another reason for considering fewer hazards was to keep the project to a manageable size, it may be worthwhile to consider other hazards in a future stage.

The hazards the Auckland Engineering Lifelines Project used in its vulnerability and interdependence analysis are:

- earthquake: ground shaking; liquefaction; earthquake induced instability
- volcanic eruption: local Auckland volcanic field eruption; eruptions elsewhere in the North Island
- tropical cyclone: flooding; high winds; rain-induced instability; storm surge
- tsunami: coastal inundation; scour

In this report, the term 'hazard' is used to refer to the source of potential harm or a situation with a potential to cause loss. The term 'event' is used to refer to an incident or situation which occurs in a particular place during a particular time interval (Australian/New Zealand Risk Management Standard 4360:1999).

The uniform hazard analysis presented known information on the four hazards to give the utilities a real impression of the vulnerability of each network and to highlight susceptible areas irrespective of the location of specific hazard events. The application of a uniform hazard analysis across a utility's network also enables comparison of the vulnerability of the different networks. However, it would have taken too long for each utility to analyse all of this information in detail. To make the task of identifying vulnerabilities and response to each hazard more manageable and to give a realistic impression of the likely damage, a series of scenario events was therefore developed.

The advantage of using scenario events was that they made it easier to identify specific impacts

The scenario hazards analysed the vulnerability of all utilities to a given event, making it more straightforward for the utilities to rapidly identify impacts and response and mitigation measures for the individual networks. They also made it easier to assess impacts on the lifeline network as a whole.

As a result, most of the work presented in this report was based on the scenario events, because they helped the task groups focus on practical implications and also identified some key response requirements.

Hazards such as earthquake- and rain- induced instability can be mapped over the region based on a triggering scenario event. For hazards such as tsunami, where the effects are more localised along the coast, only scenarios were used to illustrate effects, because although vulnerable stretches of coastline have been identified, they have not been mapped in any detail.

Scenario hazards were particularly helpful where there was no detailed hazard-specific information

Where a geographic approach has been used, data was analysed using GIS (geographical information systems) at two scales:

- Region A (areas of medium to high population and services density): 1:100 000
- Region B (areas of low population and services density): 1:250 000

For ease of presentation and reproduction, maps accompanying this and the other Auckland Engineering Lifelines Project reports are produced at smaller scales.

3.2 Risk and exceedance probabilities

Credible scenario events were developed that would test the region's infrastructure should they occur. This approach has produced scenarios with different return periods

In order to define the various hazard scenarios, credible events were developed that would test the region's infrastructure should they occur. This approach has produced scenarios with different return periods.

The exceedance probability is the likelihood of any hazard being equalled or exceeded in a given time period. It allows the likelihood of future occurrence to be related to a specific time frame, and also allows direct comparison of the likely recurrence intervals of a range of events with different return periods.

The return periods and exceedance probabilities for one, fifty and one hundred years are summarised in Table 1.

Risk = consequences x likelihood

The risk to the community from hazard events is measured in terms of the consequences of the event (for example damage, loss or community disruption) and the likelihood of the event occurring. The magnitude of the consequences depends on the vulnerability of what is potentially under threat.

Risk assessment enables identification of mitigation measures which if implemented could reduce the vulnerability of lifelines and consequently the risk

Assessing the risk to the community is a large task of which the Auckland Engineering Lifelines Project is only one component. The focus of the project is on assessing the vulnerability of infrastructure to direct physical damage to hazard events. The project also enables identification of mitigation measures which if implemented could reduce the vulnerability of lifelines and consequently the risk.

The decision to implement mitigation measures depends on the level of risk that is acceptable. Generally the higher the risk the utility or community is willing to accept, the less need there is for mitigation.

Risk assessment is subjective, so a decision – making framework was used

The decision about what is an acceptable level of risk can be a difficult one and is often subjective. The Auckland Engineering Lifelines Project aimed to help in this decision - making process by providing utilities with additional information about hazards and a framework within which decisions about how to manage risk can be better informed.

3.3 Earthquake

Auckland is one of the regions of New Zealand that has been least seismically active over the last 150 years. This is partly because it is some 300km from the major north-east/south-west—oriented seismically active zone underlying the east coast of the North Island that marks the boundary between the Australian and Pacific tectonic plates. However, lack of knowledge about some of the potentially active faults in the region, the potential soil and rock response and the fact that a third of the country's population lives in the region means the earthquake hazard cannot be underestimated.

Historical earthquakes and their effects together with known potentially active faults are described in the Auckland Regional Council's Technical Publication No. 57, April 1995.

An earthquake scenario was developed which equates to an earthquake with a return period of 2,000 years

The Auckland Engineering Lifelines Project assessed the region's geology in terms of its ground - shaking and liquefaction potential. An earthquake scenario was then developed by selecting earthquake motions about or slightly more than earthquake code standards. Based on the current level of understanding of the earthquake hazard in Auckland, this equates to an earthquake with a return period of 2,000 years.

Table 1: ***Return periods and exceedance probabilities for one, fifty and one hundred years for selected hazards in the Auckland region***

Source: Auckland Engineering Lifelines Project Stage 1 Report - Part 1: Hazard Information, July 1997

Hazard	Return period (years)	Probability of exceedance (%)		
		1 year	50 years	100 years
Ground shaking (peak horizontal ground accelerations, or PGAs)	2000 (≤ 0.3g) 500 (≤ 0.2g)	0.05 0.2	2.5 9.5	4.9 18
Liquefaction susceptibility	2000	0.05	2.5	4.9
Earthquake induced slope instability	2000	0.05	2.5	4.9
Volcanic eruption: • **Distant andesitic** • **Distant rhyolitic** • **Local basaltic**	 50 - 300 1000 - 2000 1000[1]	 0.33 -2.0 0.05 -0.1 0.1	 15 - 63 2.5 - 4.9 4.9	 28 - 86 4.9 - 9.5 9.5
Tropical cyclone	100	1.0	39	63
Rain induced slope instability	100	1.0	39	63
Tsunami: • **2.5m wave (local)** • **1m wave** • **1m - 4m wave (far field)**	 7000 1000 75	 0.014 0.05 1.3	 0.71 2.5 49	 1.4 4.9 74
Storm surge: • **Centre crosses Auckland** • **Centre near Auckland**	 100 6 - 7[2]	 1.0 13 - 15	 39 99	 63 99

Notes:

[1]- Return period based on 20 events in the last 20,000 years.

[2] - Storm conditions occur more frequently than when tropical cyclone centres cross Auckland.

These return periods are for specific scenarios developed as part of the AELP, and should only be used with reference to the event to which they relate.

Hazard maps were then produced showing:

- ground shaking (peak horizontal ground accelerations (PGA), using modified Mercalli intensity (MM)
- earthquake - induced instability and liquefaction for the scenario earthquake
- uniform hazard maps for a 2,000 year return period event for earthquake - induced instability and liquefaction

Examples of some of the maps produced are in Figures 3 and 4.

Applied uniformly to the whole of the Auckland Region, the uniform hazard model allows an assessment of the earthquake - induced slope instability hazard and liquefaction susceptibility within 20km of a potential earthquake epicentre anywhere in the Region

A uniform hazard model developed for several engineering studies in Auckland was used to estimate the ground motions expected in central Auckland from a 2,000 year return period earthquake event. The model uses two seismic source regions around the greater Auckland area:

- New Zealand - based PGA and MM intensity attenuation functions and inclusion of large earthquakes from the Kerepehi Fault
- an estimated PGA of 0.17g to 0.27g (depending on the soil type) for the central Auckland area

When applied uniformly to the whole of the Auckland Region, this model allows an assessment of the earthquake - induced slope instability hazard and liquefaction susceptibility within 20km of a potential earthquake epicentre anywhere in the Region.

It was considered useful for the Auckland Engineering Lifelines Project to simulate one realistic earthquake which generates the highest levels of PGA at the selected epicentre, reducing with distance from it. In the past, earthquake scenarios for engineering and emergency management projects in the Auckland area have modelled ground shaking derived from an earthquake along the Kerepehi fault, a known active fault to the east of Auckland. From investigations of fault length and single event displacements, the fault is believed to be capable of generating earthquakes of about magnitude 7. Shaking from these earthquakes would generate a PGA of 0.15g in Auckland City. However, given this fault's distance from downtown Auckland, more frequent, smaller magnitude events closer to the city could possibly produce more severe ground motions than the Kerepehi fault in areas of medium to high population density.

The Auckland Engineering Lifelines Project's scenario earthquake is not associated with the Kerepehi fault, because it would not produce ground shaking as severe as a 2,000 year return period earthquake

Accordingly, the project selected as its scenario earthquake one that generated the expected higher level of PGA derived from the uniform hazard model, rather than an earthquake associated with the Kerepehi fault, which does not produce ground shaking as severe as a 2,000 year return period earthquake would.

The scenario adopted is a point source magnitude 6.0 earthquake at 10km depth with an epicentre 20km east of central Auckland, as shown in Figure 5. This location was selected so that:

- the higher PGA values calculated from the uniform hazard model for a 2,000 year earthquake cover the central Auckland area
- PGA values higher than expected for a 2,000 year event (that is, PGAs indicating a longer average return period) occur in offshore areas that are less critical for engineering lifelines, and that would not affect the central part of Auckland City

Because the scenario earthquake is arbitrarily selected, its epicentre could equally be at any other location within the Auckland Region, resulting in a different distribution of ground motions.

Figure 5 illustrates the scenario earthquake.

An earthquake-induced damage and damage type matrix combines the findings of the earthquake - induced slope instability hazard assessment and the liquefaction susceptibility assessment for a 2,000 year return period with the anticipated effect on lifelines services and structures in the Auckland Region

A matrix of earthquake - induced damage to structures was developed. Shown in Table 2, it combines the findings of the earthquake - induced slope instability hazard assessment and the liquefaction susceptibility assessment for a 2,000 year return period event with the anticipated effect on lifelines services and structures in the Auckland Region. The matrix addresses earthquake - induced damage in broad terms based on:

- the likely design factors of safety for each type of structure
- earthquake hazard models developed for recent engineering projects in Auckland City
- observed performance of similar structures in other recent earthquakes
- the Modified Mercalli Intensity scale as presented by the Study Group of the New Zealand Society for Earthquake Engineering 1992 in the Bulletin of the New Zealand National Society for Earthquake Engineering 25: 345 - 357

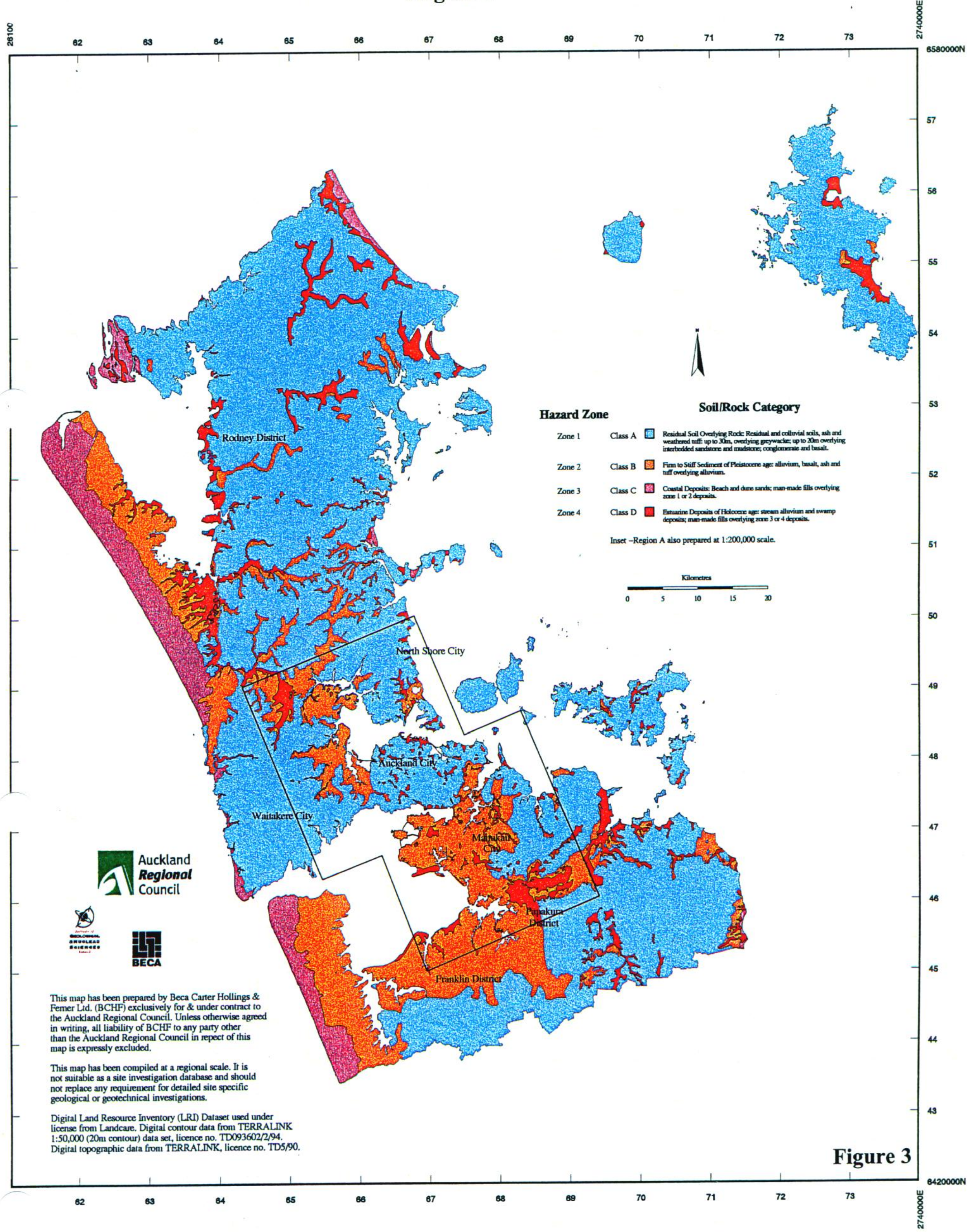
The probability ratings anticipated for each structure type for the nominated ranges of PGA (Table 2) can be used in conjunction with the earthquake - induced damage type matrix (Table 3) to provide an assessment of the likely type of damage which might be expected in each case.

These matrices formed the basis of the vulnerability analysis.

Differences in the number and type of matrices for each hazard reflect variations between the hazards and their effects.

Ground Shaking Hazard and Soil/Rock Mass Distribution

Region B

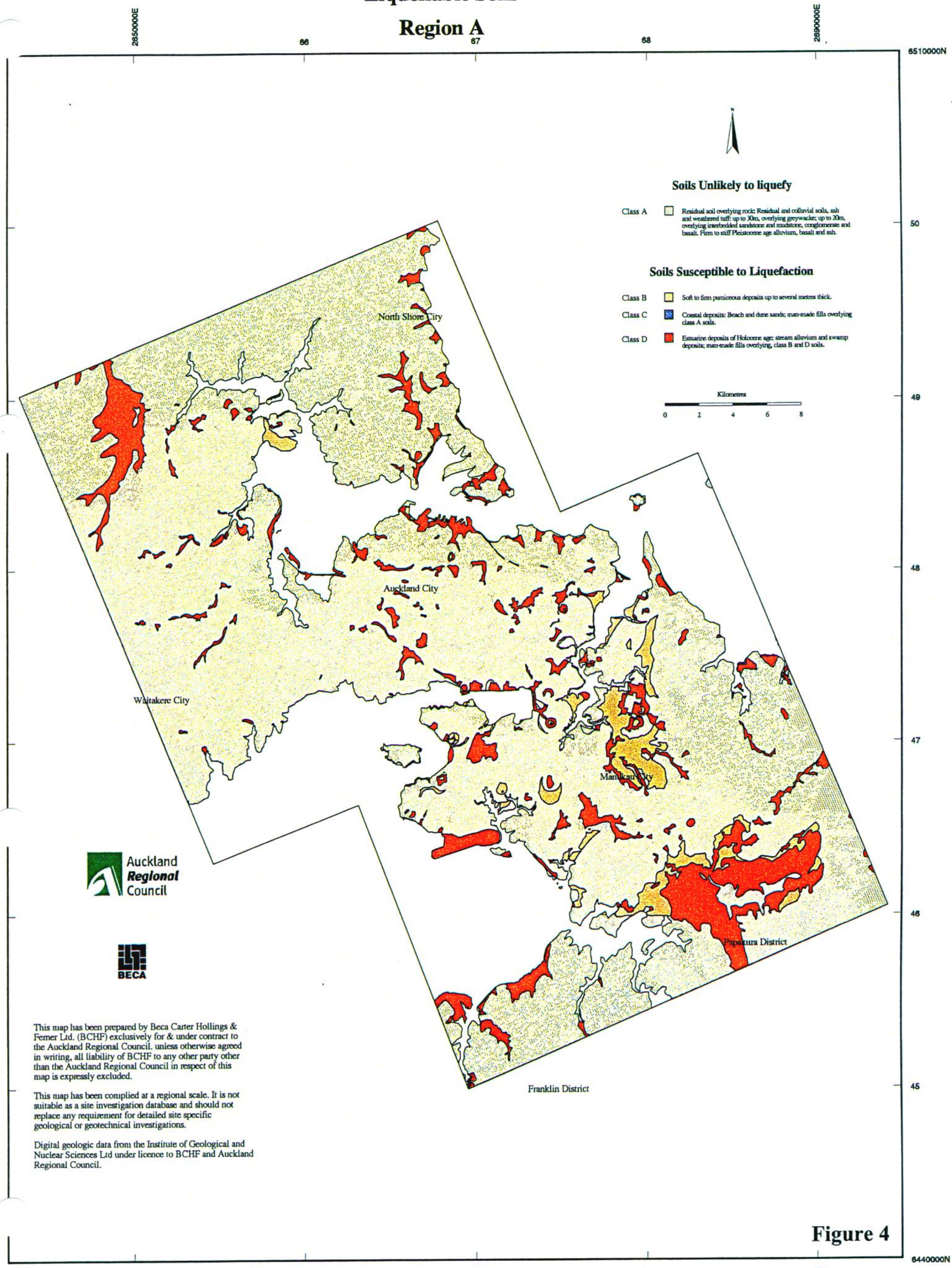


Auckland Engineering Life Lines

This map was prepared as part of the Auckland Engineering Lifelines Project
It accompanies and should be read in conjunction with the
Auckland Engineering Lifelines Project, Stage 1 Report, July 1997.

Liquefiable Soils

Region A



Auckland Regional Council

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Figure 4

Auckland Engineering Life Lines

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Peak Ground Accelerations : 2000 Year Earthquake Scenario

Region A and B

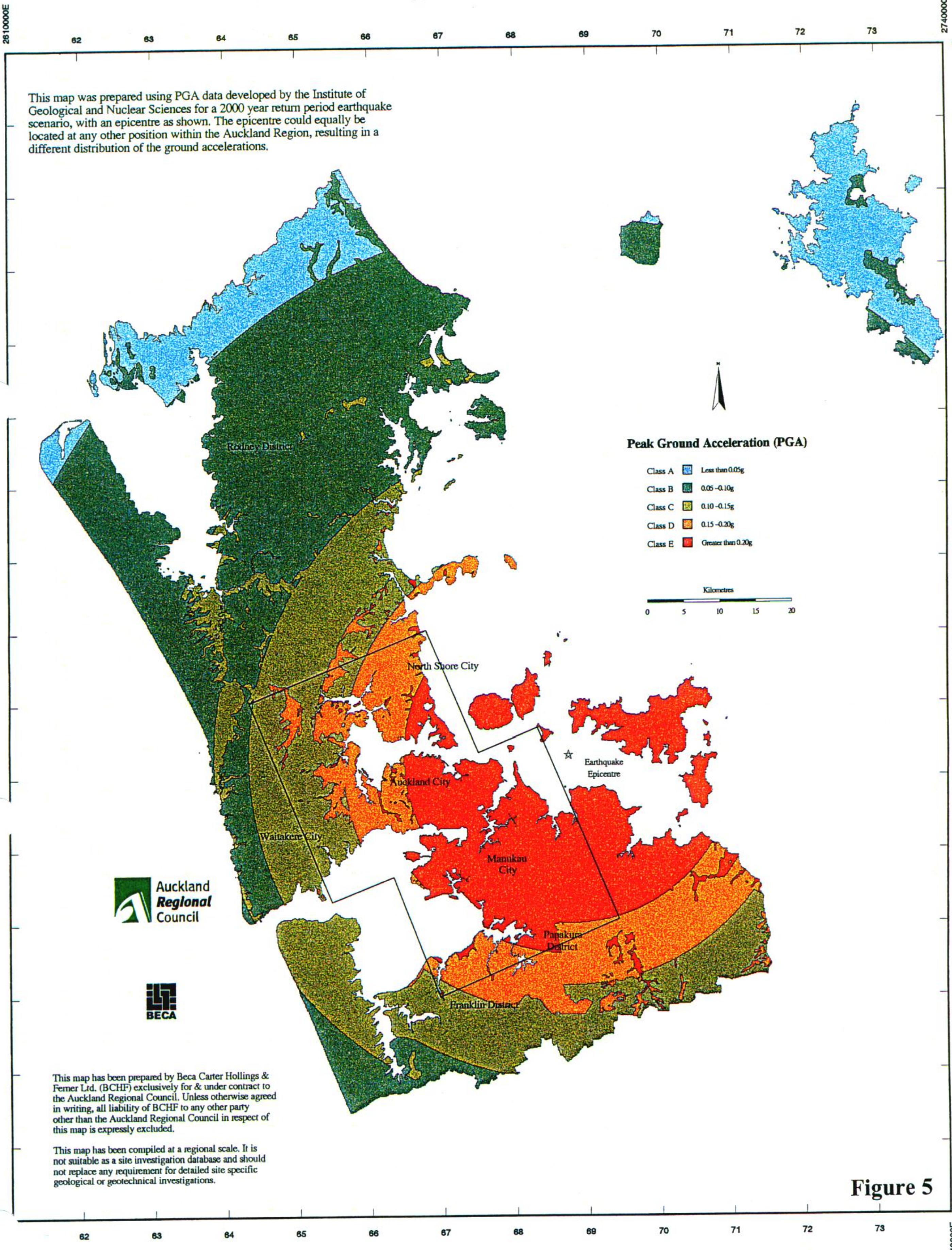


Figure 5

Auckland Engineering Life Lines

This map was prepared as part of the Auckland Engineering Lifelines Project
It accompanies and should be read in conjunction with the
Auckland Engineering Lifelines Project, Stage 1 Report, July 1997.

Table 2: ***Earthquake - induced damage to structures matrix***

Source: *Updated from the Auckland Engineering Lifelines Project Stage 1 Report - Part 1: Hazard Information, July 1997*

STRUCTURE	Range of Ground Acceleration (PGA) and Modified Mercalli Felt Earthquake Intensities (MMI)							
	MMI ≤ VI 0.05 - 0.10g	MMI VI - VII 0.1 - 0.15g		MMI VII - VIII 0.15 - 0.20g		MMI > VIII > 0.2g		
	No risk of Liquefaction	Minor Risk of Liquefaction		Some Risk of Liquefaction		Non-Liquefiable Soils		Liquefiable Soils
		Slopes A/B	Slopes C/D	Slopes A/B	Slopes C/D	Slopes A/B	Slopes C/D	
PIPEWORK								
Moderately Ductile Pipes	negligible	negligible	low probability	negligible	moderate probability	negligible	moderate probability	high probability
Low Strength or Low Ductility Pipes (includes Underground Services Duct)	negligible	negligible	low probability	low probability	high probability	low probability	high probability	high probability
Non-Ductile Pipes	low probability	low probability	moderate probability	low probability	high probability	moderate probability	high probability	high probability
CONNECTIONS & FITTINGS								
Seismically Designed (eg HDPE; steel pipe with expansion loops)	negligible	negligible	negligible	low probability	low probability	moderate probability	moderate probability	high probability
Rubber Joints (modern spun concrete or plastic pipes laid in ground)	negligible	negligible	negligible	low probability	moderate probability	moderate probability	high probability	high probability
Cement Joints (old; very common)	negligible	low probability	moderate probability	high probability	high probability	high probability	high probability	high probability
BUILDING STRUCTURES								
Modern Multistorey	negligible	negligible		low probability		low to moderate probability		moderate probability
Older Multi-level Brick/Masonry	negligible	moderate probability		high probability		very high probability		very high probability
Residential	negligible (timber frame) to low probability (brick)	negligible (timber frame) to moderate probability (brick); old brick chimneys break off		low (timber frame) to high probability (brick); old brick chimneys break off		low (timber frame) to very high probability (brick); old brick chimneys break off		high to very high probability
SERVICES								
Power Lines, Lamp Posts	negligible	negligible		low probability		moderate probability		high probability
Pipe Bridges	negligible	low probability		moderate probability		high probability		high probability

CIVIL STRUCTURES								
Roads, Rail	negligible	negligible	low probability	negligible	moderate probability	low probability	high probability	high probability
Embankments	negligible	low probability	moderate probability	low to moderate probability depending on embankment height	moderate to high probability	moderate probability	high probability	high probability
Earth Dams	negligible	low probability	moderate probability	moderate probability	*not applicable*	moderate to high probability	not applicable	not applicable
Concrete Dams	negligible	negligible	low probability	low probability	low probability	moderate probability	moderate probability	not applicable
Steel Tanks	negligible	negligible	not applicable	low probability	not applicable	moderate probability	not applicable	*moderate* probability
Concrete Tanks and Reservoirs	low probability	*moderate* probability	not applicable	*moderate* probability	not applicable	high probability	not applicable	high probability
BRIDGES								
Modern	negligible	negligible	negligible	low probability	low probability	low to moderate probability	low to *moderate* probability	moderate to high probability
Old	low probability	low to moderate probability	low to moderate probability	moderate probability	moderate to high probability	high probability	high probability	high probability
SPECIFIC INFRASTRUCTURE								
Auckland International Airport	negligible	negligible		low probability Short shut-down period for repairs.		low to moderate probability Shut-down for repairs.		moderate probability; shut-down for repairs.
Auckland Ports	negligible (modern) to low probability (old)	low (modern) to moderate probability (old)		moderate (modern) to high probability (old)		high probability		*very high* probability
Water Supply Dams, Waitakere and Hunua	negligible	low to moderate probability		moderate probability Low risk of dambreak: severe impact potential.		moderate to high probability Moderate risk of dambreak: severe impact potential.		not applicable

Slope Classes:
Class A slopes 0 - 7°
Class B slopes 8 - 15°
Class C slopes 16 - 20°
Class D slopes > 20°

Not applicable:
Dams are unlikely to be constructed on liquefiable soils.
Earth dams, tanks and reservoirs are unlikely to be constructed on steep slopes.

Table 3: Earthquake - induced damage type matrix

Source: Updated from the Auckland Engineering Lifelines Project Stage 1 Report - Part 1: Hazard Information, July 1997

STRUCTURE	Negligible	Low Probability	Moderate Probability	High Probability	
				Non-Liquefiable Soils	Liquefiable Soils
PIPEWORK					
Moderately Ductile Pipes	alignment may be disturbed	some pipes stretched to yield point	necking damage or tear (require replacement): leakage	not applicable	rupture or loss of anchorage
Low Strength or Low Ductility Pipes (Includes Underground Services Duct)	alignment may be disturbed	some cracked joints; minor leakage	some joints ruptured; major leakage	displaced joints; major leakage	displaced joints; major leakage or loss of anchorage
Non-Ductile Pipes	not applicable	cracked pipes; minor leakage	some ruptured pipes; major leakage	displaced pipes; major leakage	
CONNECTIONS & FITTINGS					
Seismically Designed (eg HDPE; steel pipe with expansion loops)	minor movement	minor yielding;	yielding and distortion of joints: minor leakage	tear or rupture of joints: leakage	
Rubber Joints (modern spun concrete or plastic pipes laid in ground)	minor movement	movement, particularly where sited within sloping or settlement prone ground	joint leakage	joint separated or sheared: major leakage	
Cement Joints (old; very common)	minor cracking	cracking; minor leakage	cracking; major leakage	joint displaced; major leakage	
BUILDING STRUCTURES					
Modern Multistorey	suspended ceilings damaged; large windows broken	minor cracking; minor spalling of beams	some spalling and cracking; repair required; architectural ornaments fall	moderate damage or permanent distortion	serious damage and/or permanent distortion
Older Multi-level Brick/Masonry	as above; cracking of plaster	not applicable	spalling of finish; cracking and damage to walls; damage to brick veneers and plaster or cement based linings	serious damage: falling debris; panel collapse; possible floor collapse	serious damage/ total loss
Residential	cracked finish (timber frame)	some damage to chimneys; cracked finish; roofing tiles dislodged	loss of chimney; cracked plaster; loss of panels; some windows crack; structural damage where founded on partially liquefiable soils	falling debris; panel collapse; possible floor collapse; houses not secured to foundations shifted off brick veneers fall and expose frames	total loss (brick or timber)
SERVICES					
Power Lines, Lamp Posts	minor loss of verticality	some movement	loss of support and yielding of wires; some twisted or brought down	power line breaks; posts brought down	

Pipe Bridges	minor yielding of abutments	yielding of abutments; pipe moves out of alignment	yielding of abutment; support bolt sheared	loss of pipe support	
CIVIL STRUCTURES **Roads, Rail and Embankments**	minor distortion (rail only)	movement in a downhill direction; visible distortion or cracking	distortion to rails and cracking or scarp displacement of roads	buckling of rails or loss of support; impassable scarps in roads	loss of support
Earth Dams	minor distortion	measurable distortion (situation to be reviewed)	visible scarps/cracks (urgent action required to prevent failure)	large scarps or cracks resulting in leakage (Civil Defence alerted)	not applicable
Concrete Dams	not detectable	increased seepage (situation to be reviewed)	some spalling/ cracking; increase in seepage (urgent action required to prevent failure)	*(extensive cracking and leakage @ PGA ≥ 0.3g)*	not applicable
Steel Tanks (Industrial)	not detectable	signs of yielding at pipe joints	yielding at joints; distortion of base plates	cracking of joints, elephants foot yielding at tank base	tilting of tank
Concrete Tanks and Reservoirs	not detectable	increased weeping at joints; minor cracking and spalling	leakage of joints (pre-cast tanks); cracking and leakage	wide cracks formed; leakage; rupture of older tanks	substantial settlements
BRIDGES: **Modern**	minor cracking	minor cracking	spalling, abutment damage	lateral movement; loss of alignment	loss of span; loss of approach ramp; foundation damage; rotation
Old	minor spalling	spalling, loss of support	spalling; loss of span	damage; loss of span; collapse	collapse
SPECIFIC INFRASTRUCTURE **Auckland International Airport**	*Pipework, connections and fittings, buildings, services and civil structures as above.* Not detectable	some opening or closing of joints on concrete slabs	spalling at pavement joints; settlement of pavement (temporary closure)	*(buckling of concrete pavement @ PGA ≥ 0.3g; closure of airport)*	
Auckland Ports	*Pipework, connections and fittings, buildings, services and civil structures as above.* Minor movement of seawalls.	movement of seawalls	settlement at edge of reclamation	spreading and subsidence of reclamation; crane rails distorted	
Water Supply Dams, Waitakere and Hunua	*Pipework, connections and fittings, buildings, services and civil structures as above.* Not detectable	*see earth and concrete dams*	*see earth and concrete dams*	*see earth and concrete dams*	

Not applicable: Dams are unlikely to be constructed on liquefiable soils.

3.4 Volcanic eruption

Not only is Auckland situated on a potentially active volcanic field, it also faces an additional volcanic threat from several large central North Island volcanic centres.

Situated on a potentially active volcanic field, Auckland also faces an additional volcanic threat from several large central North Island volcanic centres

Two volcanic scenarios and their effects on lifelines are discussed in this report:

- an eruption from the Auckland volcanic field
- two eruptions elsewhere in the North Island, at Egmont volcano (Mt Taranaki) and the Okataina volcanic centre

For the Auckland volcanic field, meaningful probabilities of eruption occurrence in any century cannot be calculated. However, for the purposes of the Auckland Engineering Lifelines Project, a return period of 1:1,000 years has been assumed. Return periods for Mt Taranaki and Okataina are taken as 1:300 and 1:2,000 respectively.

Auckland is a monogenetic volcanic field covering an area of 360km^2 in which activity has occurred from scattered vents during the past 140,000 years. There are 49 identified vents, although there is evidence that some adjacent vents may have been active in the same episode. By definition, monogenetic volcanoes erupt only in a single episode, after which the magma conduit is blocked by solidification. Subsequent eruptions are from new pathways to the surface and from different and unpredictable vent locations.

For the Auckland Engineering Lifelines Project, a scenario eruption in downtown Auckland on the waterfront was chosen. This particular location was selected because it encompasses both phreatomagmatic (explosive) and magmatic (effusive) eruption styles and because it affects the central business district (CBD), rail and port services and residential areas.

A scenario eruption in downtown Auckland on the waterfront was chosen because it encompasses both phreatomagmatic (explosive) and magmatic (effusive) eruption styles and because it affects the central business district (CBD), rail, port, and residential areas

The parameters used in the scenario are based on evidence from the geological record of the Auckland volcanic field and observed eruptions at similar volcanoes overseas. However, a future Auckland eruption will not necessarily be similar to the scenario event, in sequence, size, duration or vent location.

A full discussion of the scenario can be found in the Auckland Regional Council's Technical Report Number 79, April 1997.

Figure 6 shows the location of the scenario eruption and the areas likely to be impacted. Lava flows, ballistic block impacts, pyroclastic surges and lightning strikes from ash clouds present a high risk to life and destroy near vent structures, but in a typical Auckland eruption the extent of these hazards is mostly limited to within a few kilometres of the vent. Severe near vent ground shaking accompanying volcanic earthquakes will also damage buildings, possibly including in areas not greatly damaged by eruption products. Apart from evacuating people and removing transportable assets (if possible) few mitigation options except service redundancy are available to counteract any of these near vent hazards.

The local scenario eruption was assumed to totally destroy above ground services within a 3km radius from the vent, with below ground services similarly affected within a 1km radius

Further away from the vent, volcanic ash poses the greatest risk to engineering lifelines. The deposition of only a few millimetres to centimetres of ash is enough to disrupt transport, electricity, water, sewerage and stormwater systems. Most systems, if affected only by thin tephra fall of less than 50mm, can be restored within a few days to weeks after an eruption has ended.

For the purposes of the vulnerability assessment, total destruction of above ground services within a 3km radius from the vent was assumed, with below ground services similarly affected within a 1km radius.

Figure 7 illustrates the uniform hazard for a volcanic eruption from the Auckland volcanic field. Mitigation of near vent destruction by providing full service redundancy would require a 6km separation between above ground services and a 2km separation between below ground services within the high hazard zone shown.

A moderate eruption from Mt Taranaki could deposit 1mm of ash over greater Auckland. A typical eruption from the Okataina volcanic centre could deposit up to 10cm of ash

Auckland is also at risk from volcanic eruptions elsewhere in the North Island. Scenarios have been developed to consider eruptions from both a large andesitic cone volcano (Mt Taranaki) and a rhyolitic caldera complex (the Okataina volcanic centre).

The impact of a distant eruption will be uniformly widespread across the entire Auckland Region and contrasts with the relatively localised impact of hazards generated from an eruption within the Auckland volcanic field. Ash falls and aerosols are types of hazards potentially affecting Auckland following a distant eruption.

The differences between the two distant eruption scenarios relate to the size of the eruption and the thickness of ash likely to be deposited. A moderate eruption from Mt Taranaki could deposit 1mm of ash over greater Auckland. A typical eruption from the Okataina volcanic centre could deposit up to 10cm of ash.

Those regions will suffer more damage than Auckland. Substantial resources may be more urgently needed there, which may delay lifelines recovery in Auckland

Regions closer to the source area of distant eruptions will suffer more damage than Auckland. Substantial resources such as heavy equipment needed for clean up operations may be more urgently needed in more seriously affected areas, which may delay lifelines recovery in Auckland.

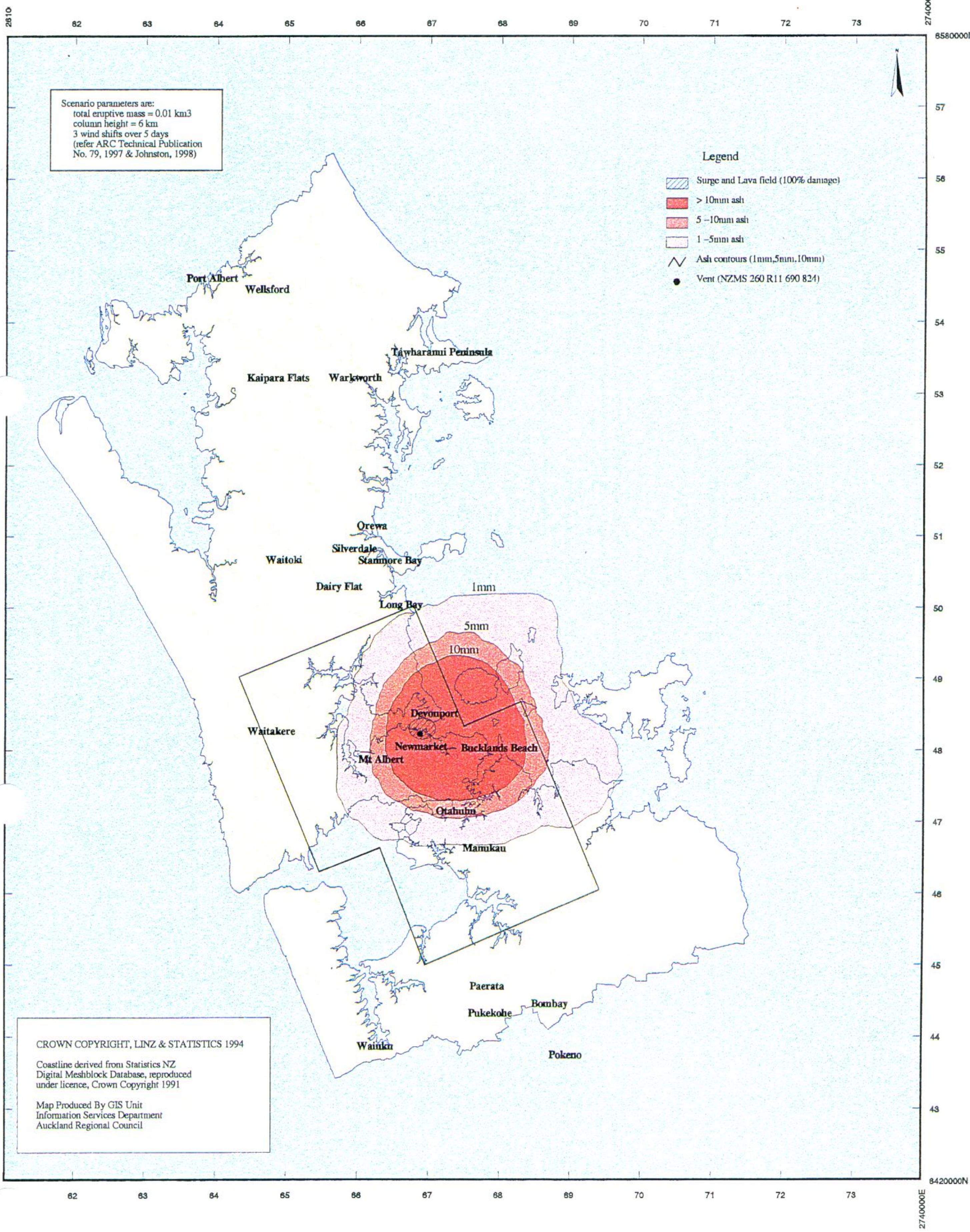
Matrices looked at the likelihood of damage to various lifeline structures for different ash thicknesses, the type of damage that could be expected and what mitigation measures might be appropriate to reduce the risk of damage

Apart from service redundancy, few mitigation measures can be identified for the near vent destruction likely in a volcanic eruption from the Auckland volcanic field. For this reason, and also because of the higher probability that Auckland would be impacted by ash from distant eruptions (as summarised in Table 1), the vulnerability assessment focused on damage from ash.

Three matrices were developed to assist with the vulnerability assessment. The first (Table 4) summarises the likelihood of damage to various lifeline structures for different thicknesses of ash. The second (Table 5) summarises the type of damage that could be expected, and the third (Table 6) summarises what mitigation measures might be appropriate to reduce the risk of damage.

Auckland Volcanic Field: Scenario

Region B



Auckland Engineering Lifelines

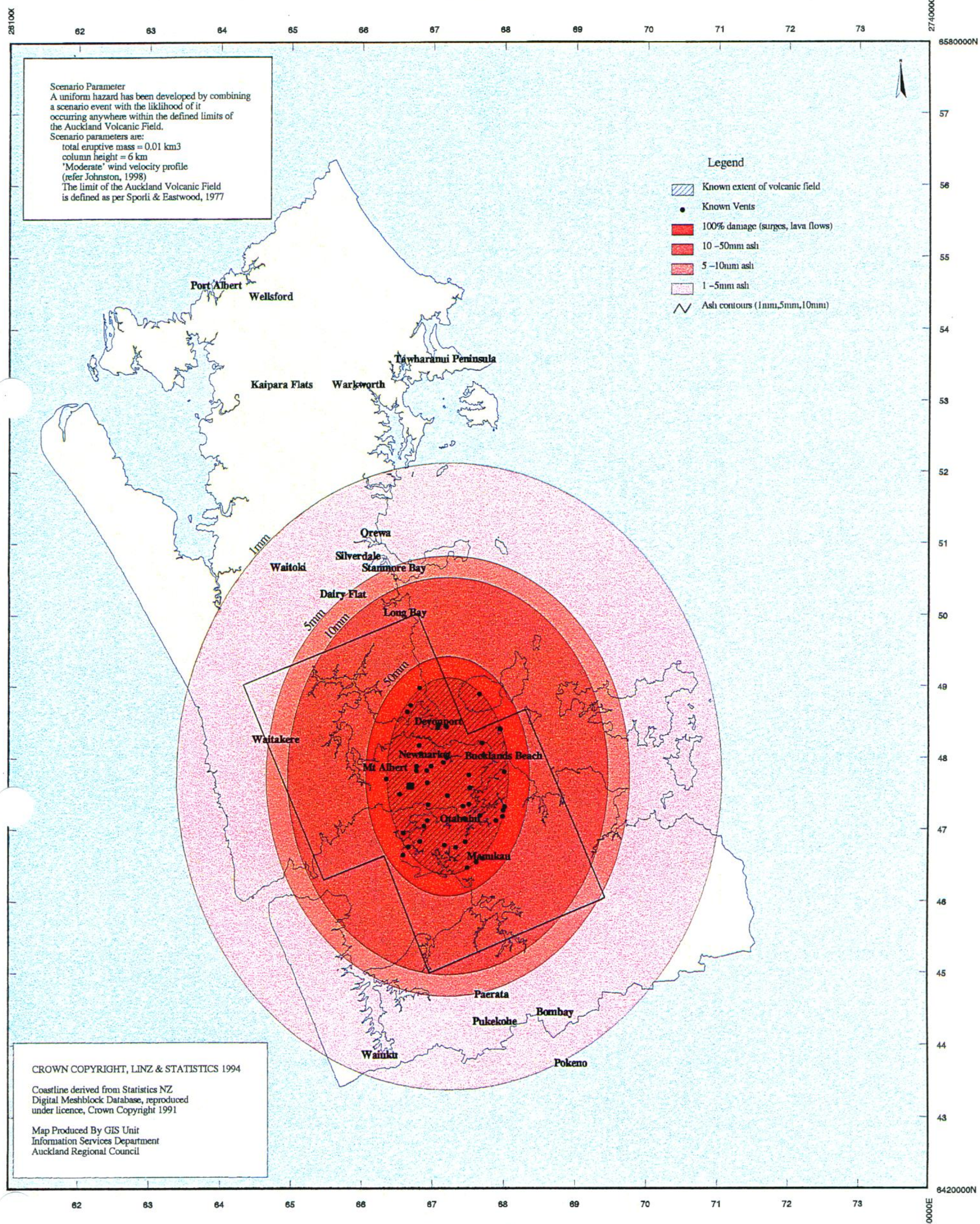
Kilometres
0 5 10 15 20

Figure 6

Auckland Regional Council

Auckland Volcanic Field: Uniform Hazard (Moderate Wind Profile)

Region B



Auckland Engineering Life Lines

Figure 7

Auckland Regional Council

Table 4: Volcanic ash - induced damage to structures matrix

STRUCTURE	Ash thickness < 1 mm	Ash thickness 1 - 5 mm	Ash thickness 5 - 100 mm	Ash thickness >100 mm
PIPEWORK				
open systems (i.e. stormwater)	low probability	high probability	high probability	high probability
closed systems	negligible	negligible	negligible	negligible
BUILDING STRUCTURES				
flat-roofs	low probability	moderate probability	high probability	high probability
pitched-roofs (>20°)	low probability	moderate probability	high probability	high probability
BUILDING SERVICES				
air-conditioning	low probability	moderate probability	high probability	high probability
gutters	low probability	moderate probability	high probability	high probability
ELECTRICITY SERVICES				
power lines	negligible	low probability	moderate probability	high probability
power line insulators				
-low voltage	negligible	moderate probability	high probability	high probability
- high voltage	negligible	low probability	moderate probability	high probability
substations	negligible	moderate probability	high probability	high probability
CIVIL STRUCTURES				
roads,	low probability	high probability	high probability	high probability
rail	negligible	moderate probability	high probability	high probability
WASTEWATER				
sewage pumps	low probability	high probability	high probability	high probability
sewage treatment plant	low probability	moderate probability	high probability	high probability
WATER SUPPLY SYSTEM				
river/ stream	low probability	high probability	high probability	high probability
uncovered reservoir	low probability	moderate probability	high probability	high probability
cover reservoir/ground water	negligible	negligible	negligible	negligible
roof-fed tank	low probability	high probability	high probability	high probability
TELECOMMUNICATIONS				
exchange equipment				
- external air-conditioning	low probability	high probability	high probability	high probability
- internal air-conditioning	negligible	low probability	low probability	low probability
lines	negligible	low probability	moderate probability	high probability
microwave towers	low probability	moderate probability	moderate probability	high probability
SPECIFIC INFRASTRUCTURE				
ports	low probability	high probability	high probability	high probability
airports - air transport	moderate probability	high probability	high probability	high probability

Table 5: Volcanic ash - induced damage type matrix

STRUCTURE	Ash thickness < 1 mm	Ash thickness 1 - 5 mm	Ash thickness 5 - 100 mm	Ash thickness >100 mm
PIPEWORK Open systems	blockage depending on water (or sewage) turbidity	blockage depending on water (or sewage) turbidity	blockage depending on water (or sewage) turbidity	blockage depending on water (or sewage) turbidity
closed systems	n/a	n/a	n/a	n/a
BUILDING STRUCTURES flat roofs	corrosion damage to metal roofs, especially if freshly painted	corrosion damage to metal roofs, *especially if freshly painted*	corrosion damage to metal roofs, especially if freshly painted	corrosion damage to metal roofs; loading damage potential for flat roofed structures, moderate if dry (high over 300mm), high if wet
pitched roofs	corrosion damage to metal roofs, especially if freshly painted	corrosion damage to metal roofs, especially if freshly painted	corrosion damage to metal roofs, especially if freshly painted	corrosion damage to metal roofs, low to moderate risk of load damage depending of roof pitch
BUILDING SERVICES air-conditioning	abrasion damage to moving parts	abrasion damage to moving parts	blockage, abrasion damage to moving parts	blockage, abrasion damage to moving parts
gutters	blockage from reworked ash	blockage from reworked ash, load damage	blockage from reworked ash, load damage	blockage from reworked ash, load damage
ELECTRICITY SERVICES lines	n/a	loading, tree breakage onto lines	loading, tree breakage onto lines	loading, tree breakage onto lines
line insulators	n/a	short-circuiting (flashover), low potential if ash is dry, high if ash is wet	short-circuiting (flashover), low potential if ash is dry, high is ash is wet	short-circuiting (flashover), low potential if ash is dry, high is ash is wet
substations	n/a	short-circuiting (flashover), low potential if ash is dry, high is ash is wet, abrasion damage to moving parts	short-circuiting (flashover), low potential if ash is dry, high if ash is wet, abrasion damage to moving parts	short-circuiting (flashover), low potential if ash is dry, high if ash is wet, abrasion damage to moving parts
CIVIL STRUCTURES roads,	n/a	blockage, reduced traction and visibility	blockage, reduced traction, and visibility	blockage, reduced traction, and visibility
rail	n/a	reduced traction and visibility, short-circuiting of electric signals if ash is wet	reduced traction and visibility, short-circuiting of electric signals if ash is wet	blockage, reduced traction and visibility, short-circuiting of electric signals if ash is wet

STRUCTURE	Ash thickness < 1 mm	Ash thickness 1 - 5 mm	Ash thickness 5 - 100 mm	Ash thickness >100 mm
WASTEWATER				
sewage pumps	abrasion damage to moving parts (depends on turbidity of sewage)	abrasion damage to moving parts (depends on turbidity of sewage)	abrasion damage to moving parts (depends on turbidity of sewage)	abrasion damage to moving parts (depends on turbidity of sewage)
sewage treatment plant	abrasion damage to moving parts (depends on turbidity of sewage)	abrasion damage to moving parts (depends on turbidity of sewage), damage to pond oxidation process	abrasion damage to moving parts (depends on turbidity of sewage), damage to pond oxidation process	abrasion damage to moving parts (depends on turbidity of sewage), damage to pond oxidation process
WATER SUPPLY SYSTEM				
river/ stream	pH and turbidity contamination	pH and turbidity contamination	pH and turbidity contamination	pH and turbidity contamination
uncovered reservoir	turbidity contamination	pH and turbidity contamination	pH and turbidity contamination	pH and turbidity contamination
cover reservoir/ground water	n/a	n/a	n/a	n/a
roof-fed tank	chemical , pH and turbidity contamination	chemical , pH and turbidity contamination	chemical , pH and turbidity contamination	chemical , pH and turbidity contamination
TELECOMMUNICATIONS				
exchange equipment - external air-conditioning	short-circuiting (flashover) of equipment, abrasion damage to moving parts	short-circuiting (flashover) of equipment, abrasion damage to moving parts	short-circuiting (flashover) of equipment, abrasion damage to moving parts	short-circuiting (flashover) of equipment, abrasion damage to moving parts
- internal air-conditioning	n/a	n/a	n/a	n/a
lines	n/a	loading, tree breakage onto lines	loading, tree breakage onto lines	loading, tree breakage onto lines
microwave towers	n/a	corrosion of metal surfaces	corrosion of metal surfaces	corrosion of metal surfaces, possible load damage
SPECIFIC INFRASTRUCTURE				
ports	potential corrosion and abrasion damage to port facilities	potential corrosion and abrasion damage to port facilities	potential corrosion and abrasion damage to port facilities	potential corrosion and abrasion damage to port facilities
airports - air transport	potential corrosion and abrasion damage to aircraft and airport (communications) installations	potential corrosion and abrasion damage to aircraft and airport (communications) installations	potential corrosion and abrasion damage to aircraft and airport (communications) installations	potential corrosion and abrasion damage to aircraft and airport (communications) installations, loading damage potential for flat roofed structures, moderate if dry (high over 300mm), high if wet

Table 6: Volcanic ash effects mitigation matrix

STRUCTURE	Before the event	During ash fall event	After the event
PIPEWORK			
open systems	increase awareness of potential problems, develop contingency plans	monitor turbidity levels, where possible limit ash entering systems	monitor turbity levels, where possible limit ash entering systems, remove ash from pipes.
closed systems	n/a		
BUILDING STRUCTURES	increase awareness of potential problems, develop contingency plans	close windows, doors and other openings	initiate ash remove procedure immediately, prioritize efforts
BUILDING SERVICES	increase awareness of potential problems, develop contingency plans		
air-conditioning	"	shut down and cover air-intakes, if still in use monitor filters and clean or replace when necessary	initiate ash remove procedures immediately, prioritize efforts
gutters	"	n/a	remove ash to prevent loading damage
ELECTRICITY SERVICES	increase awareness of potential problems, develop contingency plans		
line and substation insulators	"	monitor the situation carefully	initiate ash remove procedures immediately, prioritize efforts
lines	cut back tree branches from above lines	"	
CIVIL STRUCTURES roads, rail	increase awareness of potential problems, develop contingency plans	monitor the situation carefully, limit vechicle use	initiate ash remove procedures immediately, prioritize efforts, enhance vehicle maintainence
WASTEWATER	increase awareness of potential problems, develop contingency plans	warn public against disposing of ash in the stormwater system	warn public against disposing of ash in the stormwater system
sewage pumps	"	monitor turbidity levels in the sewage and shut down if levels are high	monitor turbidity levels in the sewage and shut down if levels are high
sewage treatment plant	"	"	"
WATER SUPPLY SYSTEM	increase awareness of potential problems, develop contingency plans	cover reservoir ventilators, disconnect roof fed supplies, monitor water quality	initiate water supply management procedures, monitor water quality
TELECOMMUNICATIONS	increase awareness of potential problems, develop contingency plans		
exchange equipment - external air-conditioning	fit internal air-conditioning units	seal exchanges where possible, shut down if required, monitor the situation carefully	initiate ash remove procedures immediately, prioritize efforts
microwave towers, other equipment	n/a	monitor the situation carefully	"
SPECIFIC INFRASTRUCTURE	increase awareness of potential problems, develop contingency plans		
ports	"	shut down vulnerability equipment, monitor the situation carefully	initiate ash remove procedures immediately, prioritize efforts
airports - air transport	"	close airspace, shut down airports	initiate ash remove procedures immediately, prioritize efforts

3.5 Tropical cyclone

Tropical cyclones that intrude into the New Zealand area move south and east, their path slowed by blocking anticyclones. In crossing New Zealand they get caught up in the westerly circulation of the mid-latitudes and move rapidly south-east.

The 1:100 year return period scenario cyclone is based on events which were 'near misses' for Auckland, such as Cyclone Bola, and on 1:100 year return period gust and rainfall information for the Auckland region

An extreme cyclone scenario has been developed for the Auckland Engineering Lifelines Project with a 1:100 year return period. It is based on a number of events which were 'near misses' for Auckland, such as Cyclone Bola, and also 1:100 year return period gust and rainfall information for the Auckland region. The cyclone has been tracked such that its highest impact is on the Auckland metropolitan area.

With central pressures of 970hPa (mb) from Day 1 to Day 3, it moves south-east to lie just north-east of Northland on Day 3, before moving across Auckland and then south-east of Wairarapa by Day 4.

The cyclone initially produces wind gusts as high as 74km/hr from the north-east, then winds veer to the east and strengthen to over 140km/hr. By Day 3 the winds have veered south-east, with gusts up to 120km/hr. However the strongest winds occur on Day 4 from the south-west with gusts as high as 170km/hr.

Rainfall rates vary. Maximum hourly amounts occur in the easterlies, with rates as high as 85mm/hr. The accumulated rainfall totals for the duration of the cyclone vary from 415mm at Warkworth in the north to 230mm at Pukekohe in the south.

Effects include winds up to 170km/hr, rainfall up to 85mm/hr causing widespread flooding and a storm surge up to 0.9m above mean sea level

Wind and rainfall profiles were used to prepare a rain - induced instability hazard map. A uniform flood hazard map (Figure 8) was used to give an indication of areas likely to be inundated during a significant (1:100) rainfall event.

Barometric pressure associated with the cyclone was used to develop a storm surge scenario. During the two days when the cyclone is closest to Auckland, the storm surge is estimated to be up to a maximum of 0.9m above mean sea level (msl) on the east coast. This surge, in combination with tide, seasonal variations and wave setup effects in exposed locations, is estimated to produce a maximum still water level of 3.0m above msl.

Climatic change (global warming) is likely to lead to an increase in frequency over time of the scenarios used in the Auckland Engineering Lifelines Project

In addition to inundation, wave runup will also cause damage. In exposed coastal areas wave runup levels are estimated as up to 8m above msl in the Hauraki Gulf. The effects of the wave runup are influenced and dissipated by structures located in its path and for this reason a zone of 100m from the coast is considered suitable to assess damage from wave runup.

The likelihood of the 100 year cyclone scenario coinciding with the highest astronomical tide to produce the storm surge effects used for the Auckland Engineering Lifelines Project is an extreme case with a return period of over 100 years. However, that storm conditions that occur more frequently can also produce a storm surge similar in size to the one the project used.

Climatic change (global warming) is likely to lead to an increase in frequency over time of the scenarios used n the Auckland Engineering Lifelines Project.

Cyclone - induced damage matrix

The damage to lifelines from wind, rain, flooding, slope failure, surges and wave action for the cyclone and storm surge scenarios has been qualitatively assessed and is presented as a matrix in Table 7.

3.6 Tsunami

The most likely damaging tsunami event for Auckland is a teletsunami originating from South America. A scenario has been developed based on a tsunami caused by a Magnitude 9 earthquake off northern Chile. This has an estimated return period of 75 years and produces wave heights of up to 5m in some locations

The most likely damaging tsunami event for Auckland is a teletsunami originating from South America. A scenario has been developed based on a tsunami caused by a Magnitude 9 earthquake off northern Chile. This has an estimated return period of 75 years and produces wave heights of up to 5m in some locations. Using data from historical tsunami impacts and a simple hydrodynamic model, a hypothetical sequence of events was developed which formed the basis of the vulnerability assessment.

Two other scenarios were developed for the Auckland Engineering Lifelines Project based on local sources: an earthquake on the Kerepehi Fault (4,500 to 9,000 year return period), and a local volcanic eruption in the inner Hauraki Gulf (1,000 year return period). The effects of these are unlikely to be greater than the teletsunami, and consequently only the teletsunami scenario was used in the vulnerability assessment.

The behaviour of tsunami can vary considerably along a coast, making it difficult to assess the risk for specific locations. In general terms, areas along the coast and alongside rivers may be susceptible to:

- inundation due to increased water levels
- scour due to much higher current velocities generated in response to varying water levels

Semi - enclosed basins such as estuaries and harbours can amplify tsunami, while opposing currents in the lower reaches of streams and rivers can lead to over-steepening of the waves and increased turbulence.

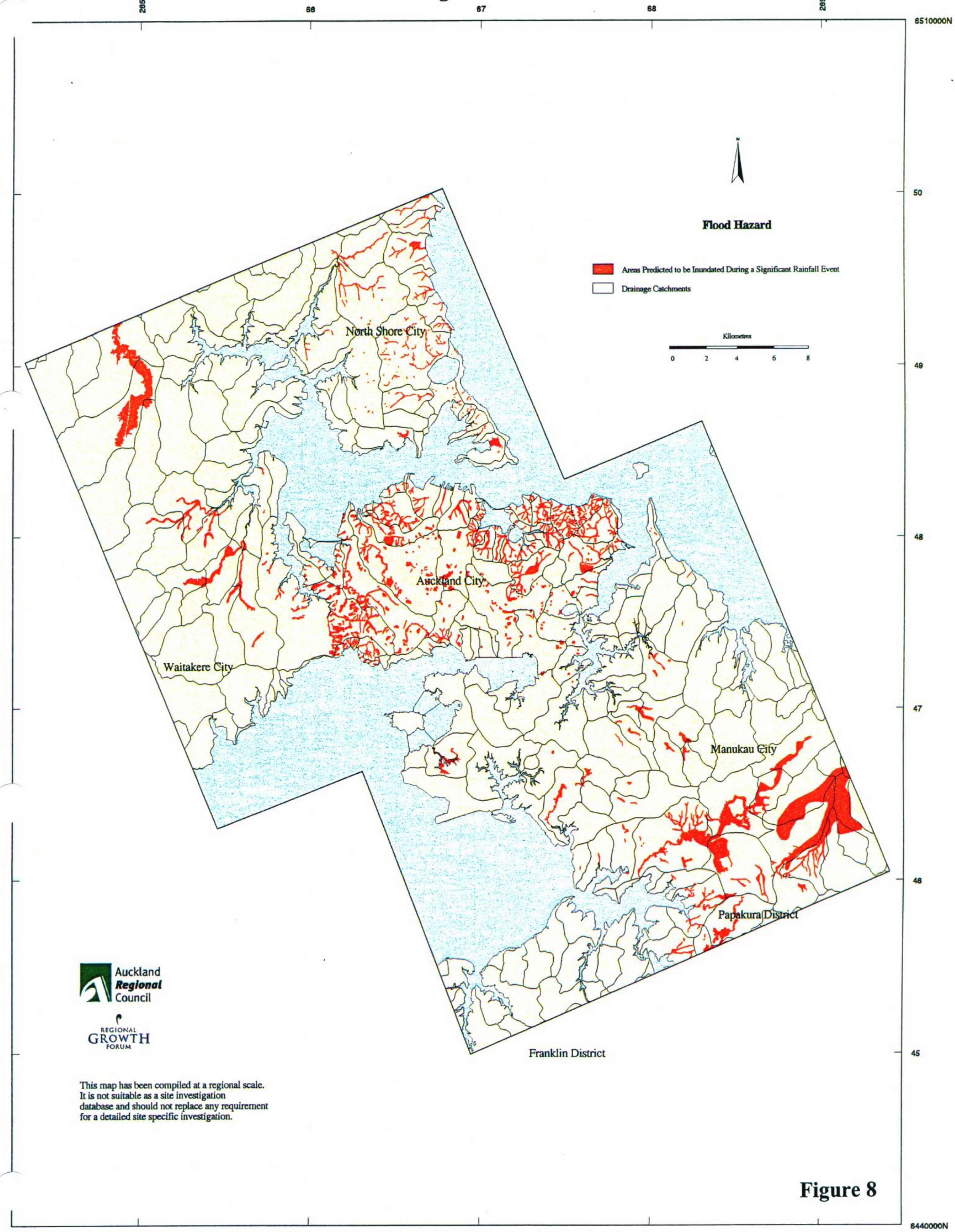
A matrix analysis was again used to identify likely damage to lifeline structures

For the purposes of the vulnerability assessment, node and network elements in coastal regions (within 100m of the coast) or in the immediate vicinity of the mouth of a river or stream were considered potentially vulnerable to the effects of the scenario tsunami. Maximum tsunami heights above msl and estimated current velocities were calculated for locations noted in the Cyclone/Tsunami workbook in Appendix D to further help refine vulnerability estimates.

Likely damage to structures was based on the storm surge component of the cyclone - induced damage to structures matrix in Table 7.

Flood Hazard

Region A



This map has been compiled at a regional scale. It is not suitable as a site investigation database and should not replace any requirement for a detailed site specific investigation.

Figure 8

Auckland Engineering Life Lines

This map was prepared as part of the Regional Growth Forum Study and has been included in the Auckland Engineering Lifelines Project. It accompanies and should be read in conjunction with the Auckland Engineering Lifelines Project, Stage 1A Report, July 1999

Table 7: **Cyclone - induced damage to structures matrix**

Source: *Updated from the Auckland Engineering Lifelines Project Stage 1 - Part 1: Hazard Information, July 1997*

		Wind	Rain	Flooding	Slope Failure	Surge & Waves
Pipes	**pressure**	Negligible effect	Negligible effect	Scour of backfill	Small (non-engineered) lines will be vulnerable	Pipelines in wave erosion zone and outfalls
	non-pressure	Negligible effect	Negligible effect	Scour of backfill	Small (non-engineered) lines will be vulnerable	Pipelines in wave erosion zone and outfalls
Building Structures	**residential**	Roof and cladding damage to non-complying houses	Flooding of damaged and flat roofs	Evacuation of limited low-lying areas	Slight vulnerability in recently established hilly areas	Inundation and wave erosion in low-lying coastal areas
	non-residential	Non-structural damage only	Flooding of damaged and flat roofs	Evacuation of limited low-lying areas	Low vulnerability	Generally lower risk
	bridges	No structural damage, but may become unserviceable	Negligible effect	Low risk due to small catchments or estuarine location	Similar risk to adjacent bank erosion	Inundation at some motorway locations
Services	**lampposts**	Decayed hardwood poles will be vulnerable	Negligible effect	Negligible effect	Low risk	Negligible effect
	cranes	Will be shut-down	Negligible effect	Negligible effect	Negligible effect	Negligible effect
	power lines	Shorting, falling debris	Negligible effect	Negligible effect	Low risk	Negligible effect
	pipe bridges	Negligible effect	Negligible effect	Generally comprise steel pipe	Low risk	Pipes strapped to wharves
Civil Structures	**roads**	No structural damage, but may become unserviceable	un-driveable in downpours, potential for collisions	Flooding, scour where culverts overtop, slips	Motorways engineered for this risk, other roads susceptible	Low-lying motorways closed, scour on exposed coasts
	rail	No structural damage, but may become unserviceable	Negligible effect	Risk to rail bridges from debris in flooded rivers	Cuttings susceptible	Some potential for embankment scour and inundation
	rivers/floodways	Negligible effect	Negligible effect	Scour, bank slumping and reduced capacity	Slumping of banks - not a lifeline hazard	Backwater effects will accentuate flooding
	embankments	Small (farm) dams only affected by wave chop	Negligible effect	Older stormwater detention dams may overtop	Dams are usually engineered for this risk	Foreshore erosion
Specific Infrastructure	**masts**	Engineered masts (eg: Telecom) will not be damaged, but may be unserviceable	Negligible effect	Negligible effect	Low risk	Negligible effect
	airports	Some flights re-directed	Visibility effects will not disrupt	AIAL runway will not be flooded, some loss of friction	Negligible effect	Low risk
	ports	Container cranes shut down	Negligible effect	Negligible effect	Negligible effect	Flooding by wave overtopping, containers moved around
	wastewater treatment plants	Negligible effect	Negligible effect	High inflows would be bypassed	Negligible effect	Inundation of Mangere ponds, overflows
	water treatment plants	Negligible effect	Negligible effect	Negligible effect	Negligible effect	Negligible effect
	electrical	Negligible effect	Negligible effect	Low-lying infrastructure flooded	Low risk	Low risk
Other	**Large trees**	Moderate impact	Negligible effect	Negligible effect	Not a lifeline hazard	Loss of trees which protect coastline

Lifelines

4. THE LIFELINES

This chapter outlines the networks comprising Auckland's engineering lifeline utilities.

The lifeline utilities considered are:

- communications: land and cellular
- transport: road, rail, air and sea
- energy: electricity, petroleum fuels and gas
- water networks: water supply, wastewater and stormwater

Most of the utility networks (except stormwater) are depicted in maps in the Auckland Engineering Lifelines Project's Stage 1 report.

The various utilities are colour coded for ease of reference in the following discussion.

4.1 Communications lifelines

Land line telecommunication services in the greater Auckland region are provided by:

- Telecom New Zealand Ltd (Telecom)
- CLEAR Communications Ltd (CLEAR)

Cellular telecommunication services in the greater Auckland region are provided by:

- Telecom
- Vodafone New Zealand Ltd (Vodafone)

Figure 9 at the end of this chapter shows the key communications networks.

Land lines

Telecom

Telecom's telecommunications network is 100% digitally switched, with built in redundancies, network rings and overlays

Telecom's telecommunications network is 100% digitally switched, with built in redundancies, network rings and overlays. The overall network is relatively tolerant of path failures.

Telecom's public switched telephone network comprises:

- remote line units
- local exchanges
- secondary exchanges
- international gateway exchanges

Nodes

A remote line unit is a decentralised switching unit physically remote from a parent exchange. Nearly all Telecom's remote line units have several path diverse links back to their host parent exchange.

Local exchanges may have direct access to Intelligent Network databases (such as 0800 services) or may pass the call to secondary exchanges. Likewise, calls to other local exchanges may be routed directly or via secondary exchanges. Calls to customers on the same local exchange can be connected entirely within that local exchange.

Secondary exchanges are trunk exchanges providing the high level of network interconnectivity required to ensure that every call is capable of being completed. If an attempted call from a local exchange to another local exchange finds a direct route is congested, the call is passed to the secondary exchange for completion.

Telecom's overall network is relatively tolerant of path failures

There are two secondary exchanges in the Auckland area. Failure of one would see the traffic taken by the other. Every local exchange has access to at least two secondary exchanges and some local exchanges may have additional routes to secondary exchanges outside the local region.

New Zealand's two international gateway exchanges are both located in Auckland

International gateway exchanges act as an interface for communication between the Telecom network and the rest of the world. Telecom's two international gateways are both located in Auckland. Failure of one gateway would see the traffic taken by the other.

Networks

(inter exchange connections)

Telecom's inter - exchange connections are provided by fibre-optic transmission systems. The higher capacity of fibre-optic cables has lead to the development of network rings with in-built redundancy (some instantaneous). Major Telecom nodes in the Auckland region are connected by a series of interconnecting fibre-optic transmission rings.

Digital microwave radio complements the fibre – optic and switching systems

To supplement the fibre-optic transmission network, the central Auckland area is overlaid with a digital microwave radio network. The antenna sites north and south of Auckland allow some calls originating outside the Auckland region to cross the isthmus without passing through the ground based fibre-optic transmission system or central Auckland's switching network.

Emergency power is available for up to three weeks at all major Telecom sites but fuel must be replenished within several days to maintain major nodes

All major Telecom sites have emergency power - generating equipment and back - up batteries. The batteries have capacity for up to 1.5 hours and supporting diesel-powered emergency generating capacity ranges from two days to three weeks.

Larger nodes have higher power consumption and larger generation capacity, but have fuel reserves in the order of days rather than weeks.

It is imperative for maintaining communications that fuel reserves are replenished within several days of a hazard event affecting major network nodes.

Management

Disasters put unprecedented pressure on communication services

Any major disaster means more customers need to talk to one another. This creates unprecedented demand for communication services to ask for emergency help, co-ordinate recovery, gather or update information or talk to friends and family. Whatever the motivation for calls, demand can soon far exceed node and network capacity. To maintain network stability and to promote efficient use of available resources, network management is essential.

Managing emergency demand on phone services by automatic means and human intervention

24 - hour monitoring and network management of all Telecom nodes and links is provided from the National Control Centre in Hamilton, from which plans for managing identified events anywhere in the whole network may be implemented. This may include discarding some calls to a particular area or opening alternative routes for phone traffic.

As well as manual intervention and network management controls, most digital exchanges also have an automatic process to control overloads. When calling demand reaches a threshold, dial tone access is progressively removed from customers in a predetermined sequence until the processing load becomes manageable.

CLEAR

CLEAR can provide diverse network connectivity between

CLEAR entered the market as a toll bypass operator, providing diverse long distance routes between main centres in New Zealand and overseas. CLEAR's own customers (those with direct access into its network) are served by fibre optic rings.

main centres

Digital Microwave Radio is used by CLEAR to serve certain customers, and is used in some instances to provide diversity in the Auckland network.

Self – healing fibre optinc rings in CLEAR's network

CLEAR employs fibre optics to optimise flexibility and scalability of services ranging from voice and ISDN to very high speed data services.

Fibre optic rings offer protection against single point failure, since traffic is automatically redirected around the ring in the event of a break in the fibre or equipment breakdown.

Interconnection with Telecom's network

There are numerous points of interconnection between the CLEAR and Telecom networks. In the Auckland area these are at Papatoetoe and central Auckland.

Management

24 hour management of CLEAR's network is provided at Takapuna, from where network restoration and switch loading can be controlled.

CLEAR's call centre in Christchurch provides backup for the Auckland call centre.

CLEAR's Auckland exchange and International gateway switch are co-located in the CBD

CLEAR's traffic in the Auckland region is switched at its principal exchange site in central Auckland. In the event of this building being unserviceable, traffic could be routed to CLEAR's other main switches in Wellington and Christchurch.

Access to national and international terminal fibre optic cables is possible at a nearby city building.

Co-located at the principal exchange site is CLEAR's International gateway switch, which is linked to overseas cable terminals and the Auckland Satellite Earth Station by a fibre optic ring. This offers diverse routes over the Harbour bridge and via west Auckland.

The Internet may become a useful information medium

The Internet, supported by CLEAR's own ISP (Internet Service Provider), could provide an appropriate medium for disseminating information to selected groups in event of a civil emergency.

Cellular telephone

Telecom

Telecom's cellular network coverage area is divided into a series of overlapping zones, or cells, each projected from a cellular antenna site and controlled by a parent mobile switching centre

Telecom's cellular telephone service uses a cellular radio network that allows mobile telephones to call each other and phones in the public switched telephone network. The cellular network coverage area is divided into a series of overlapping zones, or cells, each projected from a cellular antenna site. Each cell is under the control of a parent mobile switching centre. At switch-on, a mobile is allocated to the cell of best signal strength and as the mobile moves into another cell of better strength, the call is automatically transferred ('handed off') to that new cell by the mobile switching centre. Users are unaware of this constant hand off as they travel.

There is some redundancy in the cellular network, but one of the problems with cellular service is the way it handles dramatic increases in demand. The overall efficiency of channel allocation may decrease

Two mobile switching centres provide Auckland's Telecom cellular coverage. Both analogue and digital services are offered from the same network and switching platforms.

The connections between cellular sites (antennae) and their parent switches are provided by the fibre-optic transmission system and where necessary, by dedicated digital microwave radio links. Generally, links to major multiple antenna sites have redundancy, while links to minor cell sites do not. The various types of antenna sites also have differing levels of redundancy.

The cellular transmitting and receiving site antennae are rated to withstand winds in three ranges from 160 to 240km/hr.

As cellular usage grows, more cell sites are added into the network, with a corresponding reduction in coverage area for the surrounding sites. If a cell fails, adjacent cell sites extend their range into the neighbouring zone. While this may maintain service coverage, capacity will decline with fewer service channels available.

Overseas experience shows that within 15 to 30 minutes of an emergency, the mobile network can be seriously overloaded even when free channels may still be available

One of the problems with cellular service is the way it handles dramatic increases in demand. Because reception of a coherent bidding message is required before any individual mobile phone is allocated a service channel, it can become difficult to identify an individual customer from any other bidders for service. As the rate of bidding for service increases, the overall efficiency of channel allocation may decrease.

Overseas experience has shown that within 15 to 30 minutes of an emergency, the mobile network can become seriously overloaded even when free channels may still be available.

Vodafone

The nature of Vodafone's cellular services in the Auckland region means that in most areas, there is significant overlapping coverage. Loss of a few sites would thus have little impact on coverage, but capacity to carry calls could be temporarily reduced

The Vodafone GSM Cellular Network structure comprises an extensive network of individual cell sites linked to controllers and then to switches which in turn are connected to other operators for termination of non - Vodafone traffic.

The nature of cellular services in the Auckland region means that in most areas, there is significant overlapping coverage. Loss of a few sites would thus have little impact on coverage, but capacity to carry calls could be temporarily reduced.

Connection to and from landlines, Telecom 025 and international networks is via other telecommunication operators.

All major Vodafone sites have route and carrier diversity, along with diesel generation systems. All cell sites are designed for extreme conditions and have battery backup that can maintain services from two to twelve hours (depending on location and the size or importance of the site). They also all have connections for external generators, and Vodafone holds a number of generators for emergency power supply.

The Auckland CBD power crisis showed the effectiveness of the Vodafone response methodology in that no sites were lost from operation and in a number of cases the capacity was able to be increased to meet customers' needs.

Mobile radio

Telecom also provides a trunk mobile radio network with access to the public switched telephone network. This system uses either vehicle - mounted units or hand - helds to access a national network of repeater stations.

4.2 Transport lifelines

A smoothly operating transport network in Auckland is vital for the regional and national economy. Auckland is New Zealand's largest urban area and its ports and airport are the country's main gateway for goods and people. Home to 30% of the country's population — over a million people — Auckland has a relatively low population density compared with overseas cities, with a dispersed population and employment distribution. It has a high and growing level of car ownership and the road network has expanded to cater for this.

The Auckland region's long, thin shape means most transport movement is north - south, making it vulnerable to disruption

The region's undulating topography, with the city built on 50 - odd volcanic cones, makes the region vulnerable to slips, flooding and volcanic activity. Its long, thin shape means most transport movement is north - south.

Auckland's transport network is made up of four modes, all providing major transport connections vital to the national economy and the needs of Auckland residents:

- road
- rail
- sea
- air

Figure 10 at the end of this chapter shows the region's key transport networks.

Roads

Auckland's road network has three components:

- strategic arterial roads
- non - strategic arterial roads
- local roads

Strategic arterial roads

Strategic arterial roads consist of roads generally carrying over 20,000 vehicles per day and include:

The small number of strategically important roads are built to a very high standard

- all motorways and state highways in the motorway network; north - south via State Highway 1 and west via SH16 and SH20
- some regional arterial routes, including all other non - motorway state highways

Strategic arterial roads are designed to provide access to ports and airports, industrial areas and tourist centres and to serve major urban areas. Some of these roads carry less traffic than certain non-strategic roads but have strategic importance in Auckland's road network, for example by providing links to the airport or port.

There is no redundancy in the strategic road network

These routes provide for very high traffic volumes and are thus designed and maintained to a very high standard. The largest volume is on the Southern Motorway at Gillies Ave, which carries about 100,000 north - bound and 95,000 south - bound vehicles a day.

The construction of these large multi - lane roads usually includes large scale earthworks, with grade separation (such as bridges and viaducts) often used to avoid interaction with other roads. In order to minimise the number of potential delays and impediments along a route, intersections are generally avoided or designed with a large capacity. There is generally no redundancy of strategic arterial routes: each section is vitally important to the operation of the entire network.

Transit New Zealand manages motorways and state highways, while territorial authorities manage all other roads.

Non - strategic arterial roads

A larger number of important road links to strategic routes are built to a high standard

Non-strategic arterial roads link the motorway system and local roads. They comprise the remaining major non-motorway arterial connections in Auckland's transport network, and generally carry 5,000 to 20,000 vehicles a day. They include:

- some regional arterial roads
- all district arterial roads
- some high-volume collector routes

There is little redundancy in the non – strategic road network

Most of Auckland's non-strategic arterial roads operate around the motorway network, either linking to outlying areas or providing a parallel route. Although mainly designed for 50km/hr speeds, they usually consist of multi - lane roads with large signalised intersections catering for high volumes of vehicles. There is generally very little immediate redundancy and in the event of a major blockage, surrounding local roads would become extremely congested. Most are lined by low rise buildings, and generally carry moderate volumes of heavy traffic. Capacity is often limited more by intersection operation than by the number of lanes available.

Arterial roads are designed and maintained to a higher standard than local roads, to provide the optimum capacity for the high vehicle volumes with the minimum of potential disruptions.

Local roads

Most Auckland roads are local roads, built to a lower standard and thus more vulnerable to damage

Local roads make up all other roads in the region, comprising the bulk of Auckland's road network. They range from small single lane roads in rural areas to much larger multi - lane roads serving densely populated urban areas and generally carry up to 5,000 vehicles a day.

The many alternative routes in the local road network can fill up if nearby arterial roads are blocked

Local roads feed vehicles onto arterial roads and motorways. Their key role is to provide access to residential, rural or commercial areas. There is usually a large degree of redundancy within the network, but congestion can easily occur if an adjacent arterial road is blocked and high volumes of traffic seek alternative routes.

Local roads generally have a limited capacity, with non - signalised intersections, high numbers of intersections, vehicle crossings (property entrances) and carriageway obstacles (such as parked vehicles). Most roads are designed for 50km/hr speeds (although some rural roads allow for 100km/hr) but are built and maintained to a lower standard than motorways and arterial roads. They are thus more vulnerable to slips, earthquakes or damage from high traffic volumes.

Rail

No redundancy in the rail network, with vulnerabilities at overbridges and underpasses

Auckland's rail network consists of a single north - south main trunk line, with minor branches connecting to the CBD and the Port of Onehunga. In many instances, the line consists of two or three tracks, but their close proximity means they can be considered as one because if one track is damaged, the other will usually also be damaged. Except for a small section in central Auckland, there is no redundancy in the network: any rail blockage would prevent not only Auckland rail traffic but all North Island rail traffic from passing that point.

Although a small and growing passenger service carries some commuters into the central area, most rail journeys in Auckland carry freight. The rail network provides an extremely important connection to the port for freight distribution, but does not connect to the airport. The rail network generally runs parallel to Auckland's motorway network and avoids almost all road crossings by means of overbridges and underpasses. Many of the network's vulnerabilities are at these points.

Tranzrail is the sole operator and manager of rail within Auckland.

Ports

Both ports are built on reclaimed land and rely heavily on road and rail networks for inward and outward cargo movement

Ports of Auckland's activities are mainly based at the container terminals and associated wharves on the Waitemata Harbour near the CBD, although another smaller port operates at Onehunga. These ports operate all year round, providing 5,000 metres of berthage and handling over 12 million tonnes of cargo a year (more than any other New Zealand port), including over 500,000 containers. Businesses dependent on the ports account for 13% of national economic activity, 30% of the Auckland Region's and 209,000 full time equivalent jobs. The port company concentrates on high value exports and imports with a combined value of $18 billion per annum.

At mean low water, the depth in the various Waitemata Harbour wharves ranges from 3 - 12 metres and in the Onehunga port between 3 and 5 metres. The Onehunga entrance is restricted by a shifting bar in the main channel.

Both ports are constructed on reclaimed land. The main fuel depot for the Waitemata port is on Wynyard Wharf.

Both ports rely heavily on road and rail networks to distribute cargo, so a disruption to either of these modes can affect the ports' operation.

Airport

The airport is a vital component of the Auckland and the national economy

Auckland International Airport is New Zealand's major international air link, the gateway for around 80% of overseas visitors. It is the country's busiest airport, with approximately 7.5 million passengers (3 million domestic and 4.5 million international) passing through the airport every year, on around 140,000 flights.

Several smaller airfields operating in Auckland, for example Hobsonville, Whenuapai, Ardmore, Dairy Flat and others on the Gulf Islands, but this study focused on the International Airport

The airport handles 200,000 tonnes of freight a year to an annual value of nearly $8 billion and employs around 7,500 people. The original concrete runway is now past its design life, but has been carefully maintained. The existing 350mm concrete slabs are systematically being replaced with 500mm slabs in stages over five years.

Several smaller airfields operating in Auckland, for example Hobsonville, Whenuapai, Ardmore, Dairy Flat and others on the Gulf Islands, but this study focused on the International Airport.

4.3 Energy lifelines

Up to 95% of the region's electricity is currently imported from the south

Virtually all of the Auckland region's energy supplies originate from outside the region. There is only very limited electricity generation in the region relative to total demand and no gas or oil deposits. The only power currently generated from within the region is from the Southdown Power Station (120MW). The Otahuhu Power Station will be commissioned soon but most electricity will still be imported: up to 95% of the region's electricity is currently transferred from the south by national grid. Natural gas is transferred from Taranaki by pipeline and oils are piped from Marsden Point to the Wiri Oil Services Terminal (the Wiri oil terminal).

Distant hazard events have the potential to be far more disruptive than those within the region

Energy supplies to the Auckland region may be affected not only by hazard events occurring within the region, but also by events occurring outside it. Indeed, distant events have the potential to be at least as disruptive as events occurring within the region.

This section of the report discusses:

- electricity
- petroleum fuels
- gas

For each energy source, the following is outlined:

- network description and critical nodes
- risks to supply from within the Auckland region
- risks to supply from outside the Auckland region

Figure 11 at the end of this chapter shows the region's key energy networks.

Electricity

Network description and critical nodes

Most electricity consumed in the Auckland region and north of Auckland is generated much further south, mainly by:

- thermal generation from Huntly Power Station
- hydro generation from along the Waikato River
- hydro generation from the Tongariro Power Scheme
- geothermal generation from Wairakei and Ohaaki Stations

The Southdown and Otahuhu gas fired power stations will produce about 30% of Auckland's electricity demand

The Southdown gas fired power station is the only significant electricity generator in the region. Once commissioned, the Otahuhu Power Station will also provide local electricity, but like Southdown, it will also rely on natural gas for fuel supply. The total generation from Southdown and Otahuhu (once commissioned) will produce around 500MW, about 30% of Auckland region's 1500 - 1600MW demand.

Elements of Auckland's electricity network comprise:

- the national grid, owned and operated by Transpower
- two local sub - transmission and distribution systems operated by VECTOR and UnitedNetworks

Transpower

Transpower's Auckland network

Up to 95% of the main power supplies to Northland and Auckland regions is delivered to the region by a high voltage transmission system which forms part of Transpower's national grid. This transmission system comprises six separate high voltage overhead transmission lines. All of these traverse potentially liquefiable areas in the southern part of the region around Takanini.

Up to 95% of Auckland's electricity enters the region through six separate high voltage overhead transmission lines, all of which traverse potentially liquefiable areas in the southern part of the region

The six high voltage transmission lines are:

- 1 x 110kV single circuit line, Arapuni switchyard to Pakuranga substation
- 2 x 220kV single circuit lines, Whakamaru to Otahuhu
- 1 x 220kV double circuit lines, Whakamaru to Otahuhu via Huntly
- 1 x 220kV double circuit lines, Whakamaru to Otahuhu
- 1 x 110kV double circuit lines, Hamilton - Bombay - Wiri - Otahuhu

Failure of an individual tower is possible under extreme circumstances, but the large distances between the six separate high voltage transmission lines should ensure that only one is affected by earthquake liquefaction, except in the case of the Whakamaru - Otahuhu lines, which are very close together.

Main supply lines converge on substations, so these are potential problem areas should significant damage occur there.

The area north of Otahuhu is especially vulnerable where transmission lines between the Otahuhu switchyard and Penrose traverse liquefiable soils in an area where the narrow isthmus squeezes them together in the Otahuhu - Penrose and Southdown area.

80% of Auckland's power passes through the Otahuhu Switchyard, which is primarily a switching station. It also houses several 220/110kV auto transformers on which the Penrose substation and the CBD are virtually totally dependant

80% of Auckland's power passes through the Otahuhu Switchyard. It is primarily a switching station and a 220/110kV inter connection station, and is not a significant point of supply. Loss of the 220/110kV inter connecting transformers means that virtually all supply to Mangere and Mt Roskill substations would be lost. Loss of the 110kV from Otahuhu to Penrose would mean some of the CBD load, supplied off the Penrose 110kV substation, could not be met. The main alternative CBD supply is from Mt Roskill and this is also supplied from Otahuhu. There is a limited alternative 110kV supply to Mt Roskill and Mangere through the 220/110kV interconnecting transformer at Henderson.

Transpower takes generation from power station switchyards and conveys the energy to VECTOR and UnitedNetworks, the two lines companies which own the local sub - transmission and distribution systems. The interconnection points between Transpower's national grid and the line companies are known as points of supply or grid exit points.

The national grid voltage is 110kV/220kV. The lines companies' voltage ranges from 110kV to 11kV and less. VECTOR supplies the CBD substations using 110kV underground cables, and by 22kV or 33kV underground cables to their 45 other zone substations.

VECTOR

VECTOR's local sub - transmission and distribution system

VECTOR's power is received at eight points of supply by twin radial transmission lines. This 100% redundancy means that loss of either line at any point will not cause an outage. Output from the points of supply is at 110, 33 or 22kV to 45 zone substations, where voltage is converted to 6.6kV or 11kV.

The links to the 11kV substations are not duplicated, so a fault with the 11kV distribution system will cause an outage to customers.

The CBD is supplied from three substations, mainly Quay and Liverpool, with backup from Kingsland. Supply to each of these substations is by underground 110kV lines.

VECTOR will shortly commission a new tunnel from the Penrose substation to the Liverpool and Hobson substations. This tunnel will be critical for maintaining the CBD's power supply. The Hobson substation is currently supplied from the Quay substation, but once the tunnel is completed, it will receive high voltage supply directly.

VECTOR'S main vulnerabilities are at:

- **points of supply**
- **zone substations**
- **the control centre**

The network is controlled from the control centre in Newmarket, without which all switching would have to be done manually.

The effects on customers of outage in VECTOR's area are:

- loss of a single substation: approximately 6000 customers (there is redundancy at zone substations)
- loss of an 11kV transmission line: approximately 600 customers (repair times are typically under two hours)

VECTOR's main areas of vulnerability are at:

- points of supply
- zone substations
- the control centre

UnitedNetworks

UnitedNetworks' local sub - transmission and distribution system

Supplied, like VECTOR, with power from the south, UnitedNetworks has only three points of supply in the Auckland region, at Henderson, Hepburn Road and Albany. These supply all the North Shore. The Henderson substation receives power from the national grid on two circuits carried on a common set of towers and supplies both the Hepburn Road and Albany points of supply.

If the Henderson substation were damaged, there would be no power on or north of the North Shore. Transmission lines to the Henderson substation are two 110kV double circuit lines from the Roskill point of supply and one 220kV double circuit line from the Southdown power station.

UnitedNetworks' main vulnerabilities are at:

- **point of supply**
- **substations**
- **the control centre**

UnitedNetworks' main North Shore substation is at Wairau. It is supplied from Albany by a 110kV double circuit line and a 110kV single circuit line.

The Silverdale substation is supplied by a 220kV double circuit line that currently operates at 33kV. Large blocks of load are also supplied at 33kV from the grid exit points at Henderson, Albany and Hepburn Road.

UnitedNetworks' main areas of vulnerability are at:

- the points of supply
- the zone substations
- the Wairau substation
- the Takapuna Control Centre
- the 220kV double circuit single tower line which crosses the isthmus

Events, nodes and networks

The closer an event to the source of supply, the wider the area of potential disruption

The closer an event to the source of supply, the wider the area of potential disruption. As a result, the only sections of local lines companies' reticulation considered in this study are the points of supply to substation (sub - transmission) systems. The distribution network downstream of the line companies' zone substations is below the threshold of this study. (A zone substation has less than 6000 customers, with 11kV lines from substations supplying less than 600 customers each.)

The Auckland Engineering Lifelines Project focused on the following critical nodes in the regional network:

- the high voltage supply into the region from the south via the 110/220kV national grid
- power supplies generated within the region
- the points of supply to local lines companies
- lines company sub-transmission systems, from points of supply to substations
- lines company substations
- lines company control centres

Events outside the region affect generation or high voltage transmission, while events in the region affect points of supply

Threats to electricity supplies in the region fall into two categories:

- events occurring outside the region, affecting generation or high voltage transmission
- events within the region, where the points of supply and key high voltage transmission lines are the most critical nodes

Table 8 summarises these critical nodes.

Natural hazards in other parts of New Zealand can affect the region's power supplies via the Transpower network, even if the region itself is not directly affected by the event :

- damage to high voltage direct current link or converter stations would make it impossible for the South Island to export power to the North Island, or vice versa
- damage to critical switchyards, such as Whakamaru, would affect up to 50% of supplies to the Auckland region
- a volcanic eruption disrupting North Island hydrogeneration or damaging critical high voltage transmission lines between Bunnythorpe and Wairakei/Whakamaru
- Huntly being unable to generate for whatever reason

Table 8: Critical electricity supply nodes in the Auckland region

Critical Node	VECTOR	United Network	Others
Transpower's high voltage transmission lines from south			6
Otahuhu switchyard (Transpower)			1
Power stations			2
Points of supply	8	4	
Lines company sub - transmission systems			
Lines company control centres	1	1	

While strictly outside the scope of Auckland Engineering Lifelines Project, these scenarios are among the issues that must be considered because of Auckland's extreme dependence on generation from outside the region.

The extent of the impact, if any, generally depends on the extent of generation available in the top half of the North Island. Examples which could affect the Auckland region are:

Auckland's extreme dependence on power imported from outside the region means energy lifelines must consider the impact of events outside the region

- extensive damage to critical switchyards would affect up to 50% of supplies to the Auckland region
- a volcanic eruption affecting the area north of Whakamaru could disrupt hydro generation and Huntly generation and also adversely affect transmission lines supplying Auckland
- a volcanic eruption damaging critical high voltage transmission lines in the bottom half of the North Island, especially if it coincided with low generation availability from Huntly and the Waikato hydro generators arising from low water levels in Lake Taupo and the Waikato River

Petroleum fuels

Network description and critical nodes

The main storage facilities in the region for petrol, diesel and aviation fuels are:

- the Wiri oil terminal at Manukau City
- various petroleum company bulk storage at Freemans Bay
- the Navy's storage at Devonport

Wiri Oil Services Ltd terminal

The Wiri oil terminal assets are owned by the New Zealand Refining Company and managed by Wiri Oil Services Limited. They contain at least two tanks and at least two pumps for each product grade. Bulk storage tank fuel stocks at the Wiri terminal are:

- 2 x 8Mℓ tanks: Floating roof – premium motor spirit
- 2 x 20 Mℓ tanks: Floating roof – regular motor spirit
- 2 x 12 Mℓ tanks: Fixed roof – diesel
- 3 x 12 Mℓ tanks: Fixed roof – Jet A1

Typical stock levels would be able to meet short term demand.

The Wiri oil terminal is totally dependent on the common multi - fuel pipeline from Marsden Point

The terminal is totally dependent upon the common, multi - fuel pipeline between Wiri and Marsden Point refinery for stock replenishment. The pipeline is owned and operated by the New Zealand Refining Company and transfers petrol, diesel and jet fuel. Both the New Zealand Refining Company and the Auckland region are very reliant upon the pipework availability: the Wiri oil terminal handles 35% of the national volume of petrol and diesel and 70% of its Jet A1 fuel. Jet A1 fuel represents 36 - 42% of the fuel volume the terminal handles.

Without electricity, the terminal has only 10% of its normal capability

Without electricity, the terminal has only very limited operational capability: less than 15% of supplies could be accessed by relying solely on site backup facilities and tank head pressures — a very slow process.

The Wiri oil terminal supplies Auckland International Airport with jet fuel via the jet pipeline to the Airport terminal. Jet fuel supplies could not be fully maintained without electricity for the main pump. Fuel stocks at the airport are limited.

Freemans Bay no longer stores gasoline or bulk petrol

Products currently stored at Freemans Bay are mainly lubricating oils, diesel oils, industrial solvents, bitumen and Avgas delivered by tankers berthing at Wynyard Wharf. There is no petrol bulk storage at Freemans Bay. Avgas may be relocated from Freemans Bay to Mt Maunganui from 2000; one of the two Avgas storage tanks at Freemans Bay has already been emptied. Before that relocation is complete, the nearest alternative Avgas fuel supply will be in Wellington.

Alternative diesel supplies at Freemans Bay can not necessarily be relied upon in an emergency because they may just have been emptied to meet normal demand

Alternative diesel supplies at Freemans Bay can not necessarily be relied upon in an emergency affecting the Wiri terminal. The 10 million litres of diesel stored at Freemans Bay is generally used for bunkers of vessels and demand can vary greatly, with a single order being up to 3.5 million litres.

This diesel is not generally intended for inland use but may be available to mitigate the worst effects of an emergency,.

Auckland's supplies of petroleum fuels are now more vulnerable because fewer oil companies store diesel or motor spirit at Freemans Bay.

Generally, Auckland's supplies of petroleum fuels are more vulnerable than in the past, since there is reduced storage at Freemans Bay and Caltex no longer stores any diesel or motor spirit there. Shell is now the only supplier of bunker oil from Freemans Bay.

Avgas stocks may not be available in an emergency

Avgas stocks at Freemans Bay can be low prior to replenishment, so supplies for emergency use for fixed wing aircraft and helicopters may be limited.

New Zealand Navy

For security reasons, the Navy does not release information.

The New Zealand Refining Company Marsden Point to Wiri pipeline is a key petroleum fuel lifeline into the Auckland region. There are four separate facilities at Marsden Point:

There are four separate facilities at Marsden Point

- the refinery
- a ships loading gantry for coastal tankers
- the Wiri Oil Services Ltd Marsden Point terminal (outside the refinery fence line), controlled from Wiri and supplied direct from the refinery by a short pipeline
- the pipeline to Auckland

The ships loading gantry is used for fuelling coastal tankers (petrol, diesel, bitumen) for destinations around the country.

The New Zealand Refining Company Marsden Point to Wiri pipeline is a key petroleum fuel lifeline into the Auckland region

The New Zealand Refining Company pipeline from Marsden Point to Wiri is spiral - welded steel. Management precautions are similar to those for the Natural Gas Corporation gas pipeline for monitoring, valving and leak detection. Leaks can be traced to within 5km of source via the pipeline company's SCADA system. (SCADA is an acronym for Supervisory Control And Data Acquisition systems, which are control systems that maintain contact with the various elements of a network and enable control and status monitoring.) Expertise from the Natural Gas Corporation pipeline is contracted for general pipeline maintenance.

Key characteristics of the pipeline are:

- 169km long
- 273mm diameter
- fitted with 18 isolating block valves:
  - 8 remote hydraulic block valves operated from the Marsden Point Refinery
  - 1 oil operated valve at the Refinery
  - 9 local, manually operated valves
- 6 non return valves:
  - 4 remote hydraulically operated valves in the region, at Taupaki, Henderson Valley, Hillsborough and Wiri
  - 2 local manual valves at Links Road in Titirangi and Ambury Park in Mangere
  - 1 non - return valve at Waitakere Road

Flow rates vary according to the product being pumped:

- petrol: 345 m^3/hr
- diesel: 280 m^3/hr
- jet A1: 300 m^3/hr

The pipeline is operational 24 hours a day except for two scheduled annual maintenance shutdowns of only 8 - 24 hours

The line operates at high pressure (85 bar) at the Refinery and low pressure at Wiri (2.5 bar), creating a reducing pressure profile over the length of the pipeline. The flow rate is controlled by the pressure at Wiri: to slow the flow, pressure is increased, and to increase the flow the pressure is reduced. Maximum flow rates are achieved by activating the recently installed Intermediate Pumping Station north of Warkworth.

There have been no unplanned releases of products from the pipeline to date. Careful monitoring enables any shortfall in product to be quickly identified and problem areas located.

The pipeline is operational 24 hours a day except for two scheduled annual maintenance shutdowns of only 8 – 24 hours. The line is 'pigged' every six months, that is, cleaned by running a solid object through it.

Risks from outside the region

Fuel availability in the region would be affected in the short term by:

- damage to the New Zealand Refining Company's Marsden Point refinery
- damage to the pipeline itself
- disrupted fuel transfer from the refinery to Wiri

If all three pumping stations at the refinery were out of operation, all three export facilities (the Wiri Oil Services Ltd Terminal, ships loading gantry and the pipeline) would also be unable to operate.

The Wiri terminal (tank farm) holds 1½ days supply and is replenished daily from the Marsden Point refinery. As well as serving the Auckland region, the oil companies draw from it to serve Warkworth and areas further north.

Loss of electricity from the Bombay hills north would put fuel supplies for both Auckland and Northland at risk.

As a consequence of the oil companies' withdrawal from Freemans Bay, there is now no alternative to the Marsden Point - Wiri pipeline for supplying petrol direct to Auckland.

Risks within the region

The pipeline's operating communications rely on the following provisions at valve stations:

- a leased Telecom UHF microwave link
- a satellite link
- land line backup

Failure of the communications system would result in the pipeline valves closing.

The Wiri oil terminal is the region's most significant petroleum fuel node

The most significant nodes are the Wiri oil terminal and, to a lesser extent, the Freemans Bay terminal, which stands on reclaimed land.

There are no other critical nodes associated with the pipeline within the region. The pipeline control room is at the Marsden Point refinery and there is one pumping station along the pipeline. The pipeline can operate to 80% capacity without the intermediate pumping station.

Backup fuel reserves

Backup fuel for the region could be sourced from:

- petrol: Marsden Point and Mt Maunganui
- diesel: Freemans Bay

The alternative supplies at Mt Maunganui equate to ten days stock for contingencies in the event that stocks at the Wiri terminal could not be replenished through the pipeline from Marsden Point. However the logistic difficulties of supplying fuel from outside the region would limit the amount of product able to be delivered to Auckland.

Gas

Network description and critical nodes

Natural gas supplies into the region are all sourced from the south. All the country's gas supplies currently come from Taranaki, about 80% from the Maui gas field. The balance is from a number of privately owned onshore gas fields such as:

- Kapuni gas
- McKee gas
- TAWN gas (Tariki, Ahuroa, Waihapa, Ngaere) and others
- Karamiro gas

Rationing of gas supplies throughout the North Island would be inevitable in the event of loss of Maui gas. Loss of other gas fields would have no effect, as Maui can meet 100% of gas demand.

All of Auckland's gas comes from Taranaki, 80% of it from the Maui gas field

Auckland gas supplies are now reliant solely on Maui gas:

- offshore separation on Maui Platform A
- onshore treatment at Oaonui

Since the commissioning of the Te Rapa cogeneration plant at the New Zealand Dairy Group factory early in 1999, treated gas from the Kapuni - Rotowaro line no longer supplies gas to Auckland. Under normal circumstances treated Kapuni gas can not now reach Auckland. However, in the event of a serious loss of Maui gas, non - Maui gas (including some treated Kapuni gas) could be injected into the Maui pipeline for transport to Rotowaro and thence into the Natural Gas Corporation system to Auckland. Alternatively, the Kapuni - Rotowaro pipeline could be temporarily reconfigured to take Maui gas again.

The natural gas transmission pipeline network is owned and operated by the Natural Gas Corporation. Its control centre is based in Bell Block, New Plymouth.

Two major gate stations are the points of supply of 90% of Auckland's gas into the region, one of them meeting 60% of total demand

The Natural Gas Corporation's transmission network incorporates a number of compressor stations to maintain gas pressures over the long transmission distances involved.

Rotowaro compressor station, near Huntly, is the only Natural Gas Corporation compressor station normally used in supplying the Auckland region (the only Natural Gas Corporation compressor station in the Auckland region is at Henderson, but this is not normally used).

Two principal gate stations (Westfield and Papakura) act as points of supply into the region, where gas is reduced in pressure and metered before entering the local distribution network. From here, Orion's network (formerly Enerco) conveys the gas mainly to gas retailers. Orion is a lines company — it does not own the gas at any stage.

Most of the local network though Auckland is owned and operated by Orion, but competition is beginning to emerge in some areas.

The Natural Gas Corporation transmission pipeline continues via Henderson north of Auckland to Whangarei.

Orion's Auckland gas distribution system pipes gas from the Natural Gas Corporation gate station to end users. 60% of this gas is received at the Westfield gate station and 30% at the Papakura gate station, with the balance from 11 smaller gate stations in the region.

Gas pipeline

Major damage to a compressor station could affect gas supplies for up to a month until installation of a replacement unit

The gas supply is transported to Auckland's two main gate stations in buried ductile steel pipelines. The pipeline is typically 1.0m below ground. It is not subject to internal corrosion, as the gas is dry and non - corrosive. Protection against external corrosion is by means of the pipe coating and an impressed - current cathodic protection system.

Gas supplies along the pipeline are shut down automatically at valve stations if the supply is ruptured.

Valve stations automatically shut down the pipeline if gas supply stops or if pressure falls too low. The control centre can also manually shut down valves

There are two high pressure gas trunk mains into the Auckland region: 200mm (8") and 355mm (14"). Should the 355mm pipeline need to be taken out of service temporarily, the Natural Gas Corporation, with the co-operation of Orion, can transfer a substantial proportion if not all of the Westfield load onto the Papakura gate.

The 200mm pipeline supplies the Glenbrook steel mill and the Papakura gate station. The 355mm pipeline supplies Westfield gate station and the Southdown and Otahuhu B power stations. The 200mm pipeline is rated at 86 bar g operating pressure and the 355mm pipeline at 86 bar g as far as Papakura East where the pressure is cut to 66 bar g. The region's gas distribution system downstream of the gate stations operates at less than 20 bar g except for Papakura gas, which is delivered to Orion at 26 bar g.

In the event of abnormally low pressures being observed from a leak or rupture in the gas pipeline, the New Plymouth control centre would shut the appropriate main line valves. Without any intervention from the control centre, pressures would continue to fall until the valves (typically 5 – 8km apart in the Auckland area) closed automatically

Major damage to a compressor station could affect gas supplies until installation of a replacement unit. The Natural Gas Corporation has some spare units that could be relocated in an emergency. New units take 6 - 12 months to put into operation. If a gate station were damaged, replacement would be relatively quick — only a few days.

There is spare capacity within the Natural Gas Corporation system. For example, at Rotowaro, there are two gas turbine compressor units — one duty, one stand by, plus two reciprocating units, one duty, one standby.

The Natural Gas Corporation pipeline is continually monitored from the control centre in New Plymouth. If abnormally low pressures were observed from a leak or rupture in the pipeline, the control centre would shut the appropriate main line valves. Without any intervention from the control centre, pressures would continue to fall until the valves (typically 5 – 8km apart in the Auckland area) closed automatically.

The valves cannot be opened remotely.

Purging between main line control valves on the Natural Gas Corporation pipeline takes only a few hours.

Risks to gas supply from outside the region are more serious than those within it

All natural gas supplies currently come from Taranaki. All gas currently used in Auckland is first transported from Oaonui to Rotowaro in the Maui pipeline owned by Maui Development Ltd before entering the Natural Gas Corporation's two pipelines between Rotowaro and Auckland. In the event of a failure of the Maui pipeline, gas rationing would be inevitable.

The further south the breakdown in gas supply, the greater the potential impact on the Auckland region

A substantial volume of gas is stored in the pipelines. This would be used in conjunction with local shedding and possible redirection of the Kapuni - Rotowaro pipeline to maintain minimum supplies until repairs could be effected. Local shedding would be the responsibility of energy traders or owners and local distribution network operators.

Loss of Maui gas or the main high pressure gas pipeline would cause and extended period of gas rationing

Loss of Maui gas supply for an extended period is not inconceivable, for example from damage to either Maui Platform A or to Oaonui gas compressor plant. An extended period of gas rationing would result, utilising the 20% or so of current supply available from onshore gas fields. Output from the onshore fields could be increased but could not currently replace loss of Maui gas.

Other critical natural gas supply nodes outside the region are:

- Natural Gas Corporation control centre, Bell Block, New Plymouth
- Natural Gas Corporation compressor stations, although there is some redundancy in the system (only the Rotowaro compressor station affects Auckland)

Loss of or damage to the Bell Block control centre would not automatically affect supplies to Auckland, because Rotowaro and the Mokau compressor station on the Maui pipeline could be staffed and controlled locally.

Risks within the region

Westfield and Papakura gate stations are the interconnection points, or points of supply, between the Natural Gas Corporation and local suppliers. The Natural Gas Corporation supplies pass through Auckland to Marsden Point via Hillsborough, Blockhouse Bay, Glen Eden and Waitakere City. Between Marsden Point and Hillsborough the Natural Gas Corporation pipeline is in the same trench as the Petroleum Products pipeline owned by the New Zealand Refining Company Ltd (the Marsden Point - Wiri Oil Services pipeline).

The two gate stations are the region's critical gas nodes, but replacement times in the event of damage are relatively brief

A new connection into the region off the Natural Gas Corporation pipeline brings natural gas eastwards to Albany and East Coast Bays. This effectively 'rings' the gas reticulation to Auckland's North Shore, whereas original gas supplies previously relied on a gas pipe along the Harbour Bridge.

Critical nodes within the region are the two gate stations, but replacement times in the event of damage are relatively brief.

4.4 Water lifelines

The Auckland region has over a million people living in a small area, and without a potable water supply, the community's public health is at significant risk

Because of the extreme risk to the region in the event of loss of the bulk water system, the operations of Watercare are given prominence in this discussion

This discussion focuses on water supply and wastewater services, with stormwater considered for some scenarios.

In any urban area water supply and wastewater disposal are essential, though in an emergency, water supply is more important for protecting public health and for fire fighting, especially after earthquakes.

The Auckland region has over a million people living in a small area, and without a potable water supply, the community's public health is at significant risk.

The Auckland region's entire urban area has piped services and may be vulnerable in certain areas identified by the Auckland Engineering Lifelines Project to date. Assets not individually included in this report will need closer examination by the individual local network operators.

Most of the region relies for its water supply and wastewater services on Watercare Services Ltd (Watercare), a wholesaler. This report therefore outlines separately the issues associated with Watercare assets and the assets of the six local network operators (the retailers).

This discussion relates to Watercare and the following local network operators:

- Eco Water (Waitakere City)
- Manukau Water (Manukau City)
- Metro Water (Auckland City)
- North Shore Water Services (North Shore City)
- Rodney District Water Services (Rodney District)
- United Water (Papakura District)

North Shore City and Rodney District supply their own wastewater treatment. Franklin District is not included in this discussion because it is not supplied by Watercare.

Figures 12 and 13 of this chapter show the region's key water supply and wastewater networks.

Local network operators are generally expected to take care of their own networks in an emergency, but will need to establish prior relationships with the other lifeline organisations on whom they depend as part of their own emergency preparedness planning. Details of the six individual local network operators' networks have not been included in this report.

Because of the extreme risk to the region in the event of loss of the bulk water system, the operations of Watercare are given prominence in this discussion.

Watercare Services Limited is a Local Authority Trading Enterprise established in 1992 from departments of the Auckland Regional Council. In October 1992 the ownership was transferred to the Auckland Regional Services Trust. When the Trust was disbanded in October 1998, ownership of Watercare was transferred to six of the Auckland region's seven territorial authorities.

Watercare has four key business units:

- bulk water supply
- wastewater collection and disposal
- design services
- laboratory services

Auckland Healthcare and the Auckland Regional Council also have an interest in this report, though these interests are not covered by Stage 1 of the Auckland Engineering Lifelines Project:

- Auckland Healthcare has a strong public health interest in the continuing supply of potable water to the people of the region and the possible impact on public health of uncontrolled sewage discharges. It will need to be involved in the drafting of Emergency Response Plans
- the Auckland Regional Council has an interest in the environmental issues that could arise if significant amounts of sewage were spilled. It will also need to be involved in the drafting of Emergency Response Plans

Water supply

Watercare's bulk water system

Watercare's Water Business Unit collects and treats fresh water from the Hunua and Waitakere Ranges and from groundwater sources at Onehunga and Papatoetoe. Through the local network operators, this water supplies about a million end consumers who, along with commercial and industrial businesses, use an annual average of 320,000 cubic metres of water per day.

Residential users account for 80% or 270km^2 of the 340km^2 urban area supplied by Watercare

An urban area of approximately 340 square kilometres (km^2) of the Auckland Region is reticulated for water supply. Residential zones account for 80% or 270km^2 and there are 50km^2 of industrial zoned land and 20km^2 of commercial zoned land.

Most of the area supplied with treated water lies between the two main water catchment areas, the Hunua and the Waitakere Ranges. Rugged and heavily bush clad, they attract about 70% more rainfall than the lower lying settled areas of the region.

Water is stored in lakes behind five dams in the Waitakere Ranges, four dams in the Hunua Ranges and the Hays Creek Dam in the Hunua Gorge. The groundwater source at Onehunga and two local emergency sources complete the tally of Watercare's water sources.

Source and filter stations are:

- Hunua Ranges, which can provide around 70% of Auckland's daily water demand:
  - Ardmore Filter Station treats water from the four lakes behind dams in the Hunua Ranges
- Waitakere Ranges, which can provide around 30% of Auckland's daily water demand:
  - Waitakere Filter Station treats water from the lake behind the Waitakere Dam
  - Huia Filter Station treats water from the lakes behind the other four dams in the Waitakere Ranges
- Papakura Filter Station treats water from the lake behind the Hays Creek Dam

(At these filter stations, treatment consists of the addition of coagulants, clarification, filtration and the addition of chlorine for disinfection. Fluoride is currently not added to the water at the Papakura Filter Station.)

- Onehunga Filter Station receives water from the bores at the local Onehunga wells and treatment is similar to that at the other filter stations, except that fluoride is not added for local supply
- a groundwater source at Papatoetoe and a river abstraction source on the Wairoa River are retained for emergency supply purposes
- Metrowater – Three Kings

About 80% of raw water is gravity fed to filter stations in the Waitakeres and the Hunuas

About 80% of the raw water is supplied to the filter stations by gravity feed, through pipelines, tunnels, and aqueducts. (The lake levels behind two dams in the Waitakere Ranges are below the elevation of the Huia Filter Station, so water must be pumped out of these lakes.)

Water from the underground sources is pumped to the bulk water distribution system at Onehunga and is then conveyed by gravity. Supplies from the other filter stations to service reservoirs and supply points throughout the Auckland region and gravity fed with booster pumping to supply elevated areas.

About 15% of Watercare water consumers rely in pumped local distribution systems

About 15% of Watercare's water consumers depend on pumped systems. In the event of a power failure, water supply to most of these elevated areas would continue, but at reduced pressures.

Water is supplied to the local network operators at agreed supply points which are metered for billing, operational and planning purposes.

The water supply system is capital intensive: the total replacement value of the water assets — dams, filter stations, water mains, pumping stations and reservoirs — is $1,039 million.

Local network operators' water systems

The area supplied by local network operators is generally urban. Most local water systems are supplied from Watercare bulk supply points directly off Watercare trunk mains and reservoirs. The main exception is those parts of Rodney District which have their own supply systems independent of Watercare.

Local network operators distribute this water to their customers via their own reticulation networks. In some instances, pumping is required either by Watercare or the local network operator, depending on the areas served and their elevation. The local systems include many distinct pressure zones for reasons of operational efficiency.

Wastewater

Watercare's bulk sewerage system

Watercare's Wastewater Unit is responsible for wastewater collection, treatment and disposal, including trade wastes. Wastewater usually flows by gravity from private properties into sewers operated by local network operators, the territorial local authorities or their agents. These sewers transport the wastewater to Watercare sewers, except on the North Shore, Rodney and in parts of Papakura and Franklin Districts. Gravity and pumping are used to transport the wastewater to the Wastewater Treatment Plant at Mangere.

Watercare has 50 wastewater pumping stations and approximately 290km of pipeline.

The largest pump station can pump 3,600 litres per second and the largest pipe can carry approximately 13,000 litres per second. The average flow to the treatment plant in 1998 was 269,000m^3 per day.

Local network operators' sewerage systems

Watercare provides a bulk wastewater service to most of the metropolitan region except for North Shore City and Rodney District. North Shore City and Rodney District provide their own wastewater treatment independently of Watercare. The local network operators collect sewage from their area and take it by conventional piped and pumped systems to points of discharge into Watercare bulk sewers.

These systems are subject to inundation and overloading by stormwater during heavy rainfall, resulting in overflows throughout the region. Because the wastewater flows downhill to a place where it needs to be pumped into the next catchment, many of the larger stations and trunk sewers are near the coast.

Four main types of wastewater network components are at risk from a hazard event:

- pipe bridges
- buried pipelines
- pump stations
- wastewater treatment plants

Stormwater

Most of the metropolitan area is serviced by a reticulated stormwater system discharging runoff from outfalls into streams and estuaries and onto beaches. There are several outfalls into Lake Pupuke. Some of the Auckland isthmus area underlain by volcanic basalt aquifers has minimal stormwater reticulation, with stormwater being disposed of by groundwater recharge.

Communication
Region A

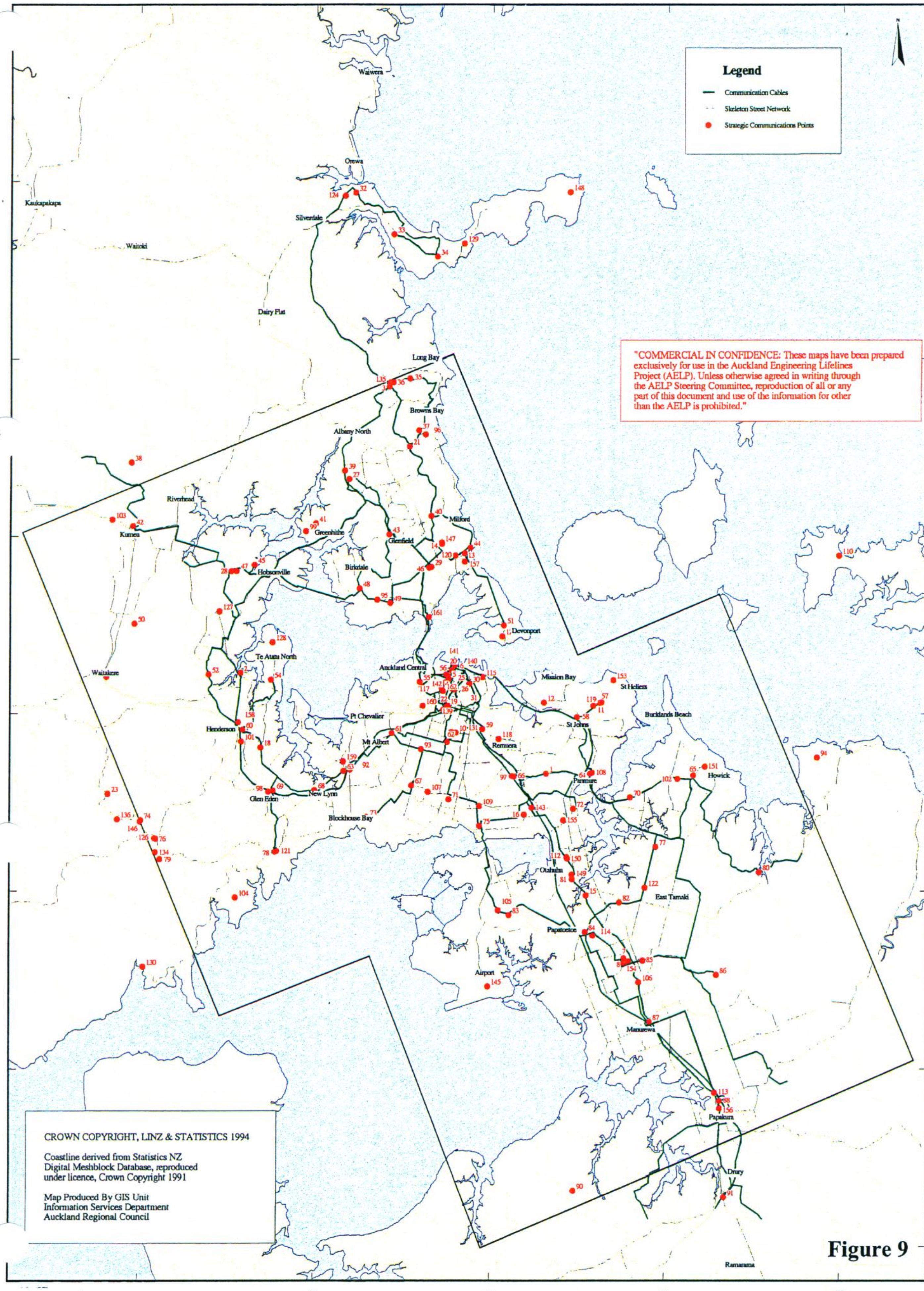
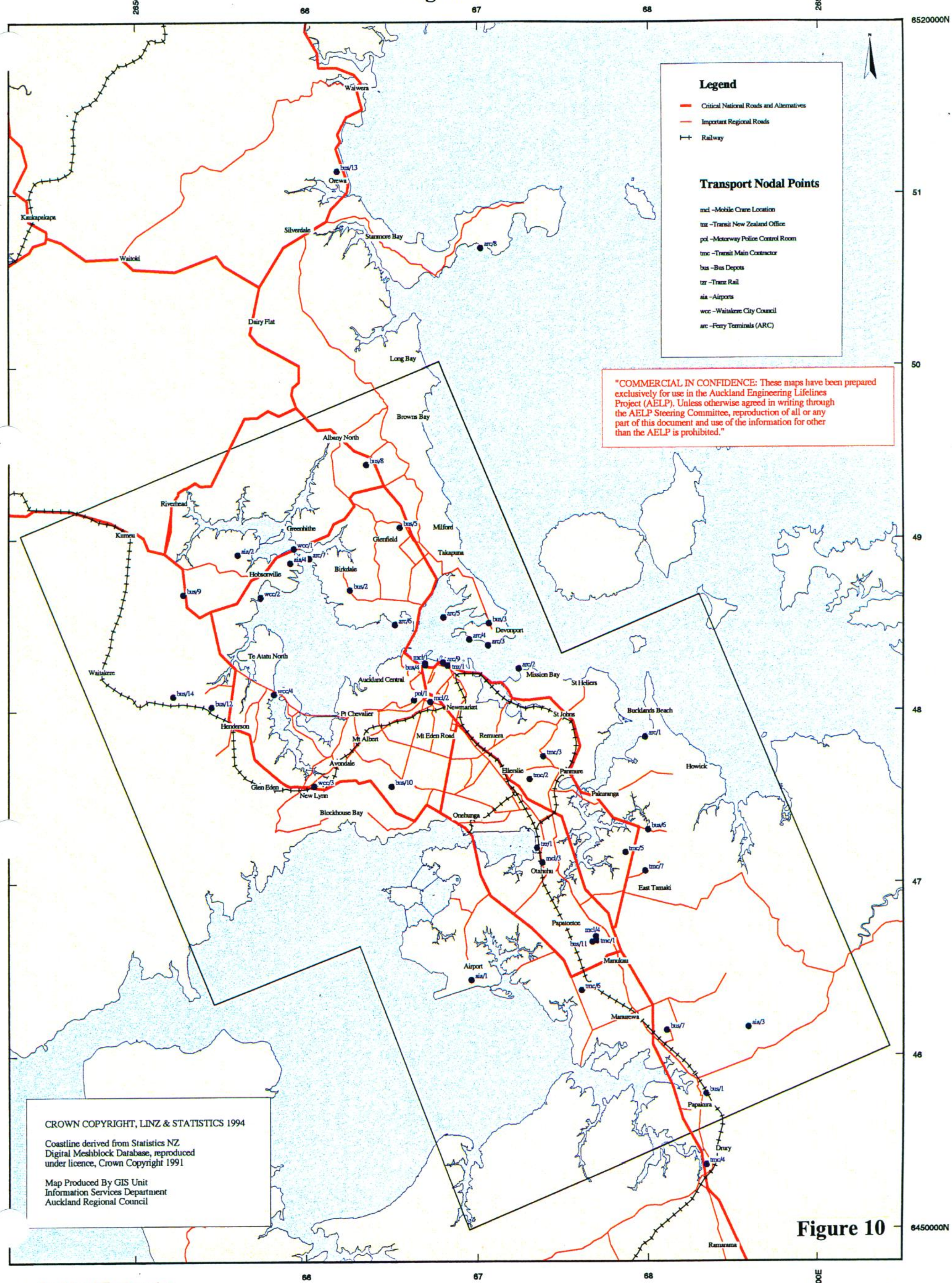


Figure 9

Auckland Engineering Life Lines

Auckland Regional Council

Transportation
Region A



Kilometres
0 2 4 6 8

Auckland Engineering
Life Lines

Auckland
Regional
Council

Energy
Region A

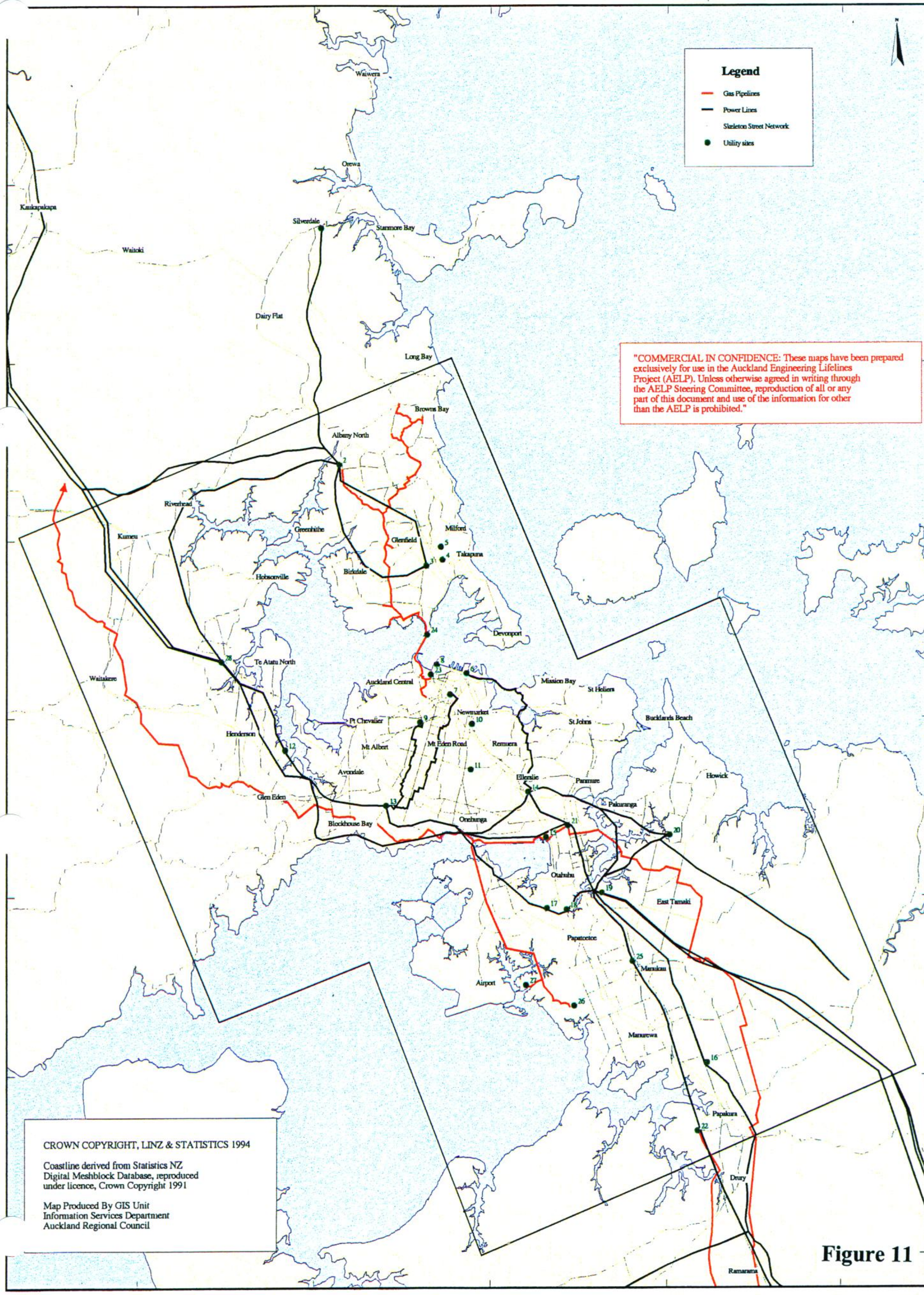


Figure 11

66 67 68 2690000E

Kilometres
0 2 4 6 8

Auckland Engineering Life Lines

Auckland Regional Council

Water Supply
Region A

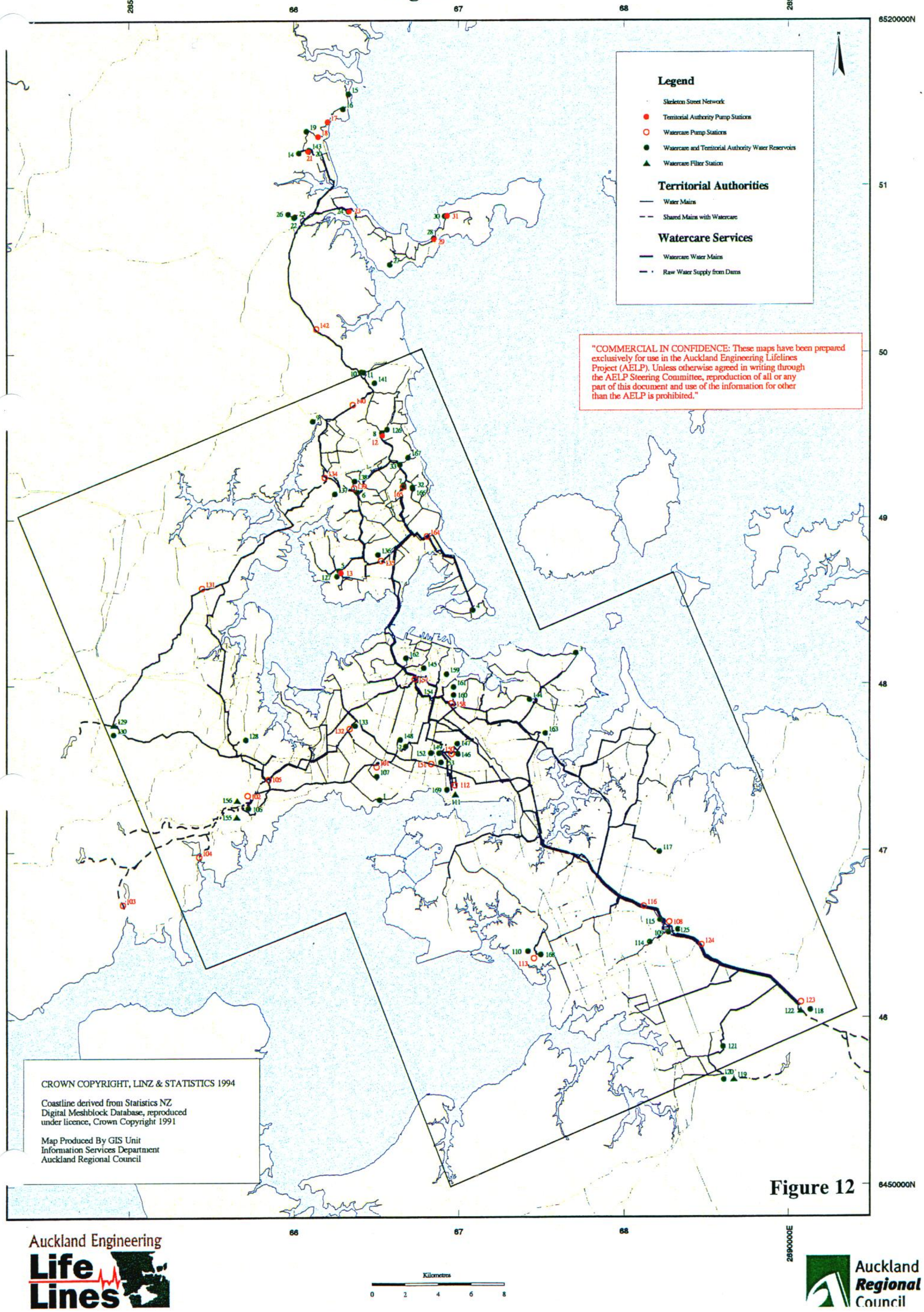


Figure 12

Auckland Engineering Life Lines

Auckland Regional Council

Sewage
Region A

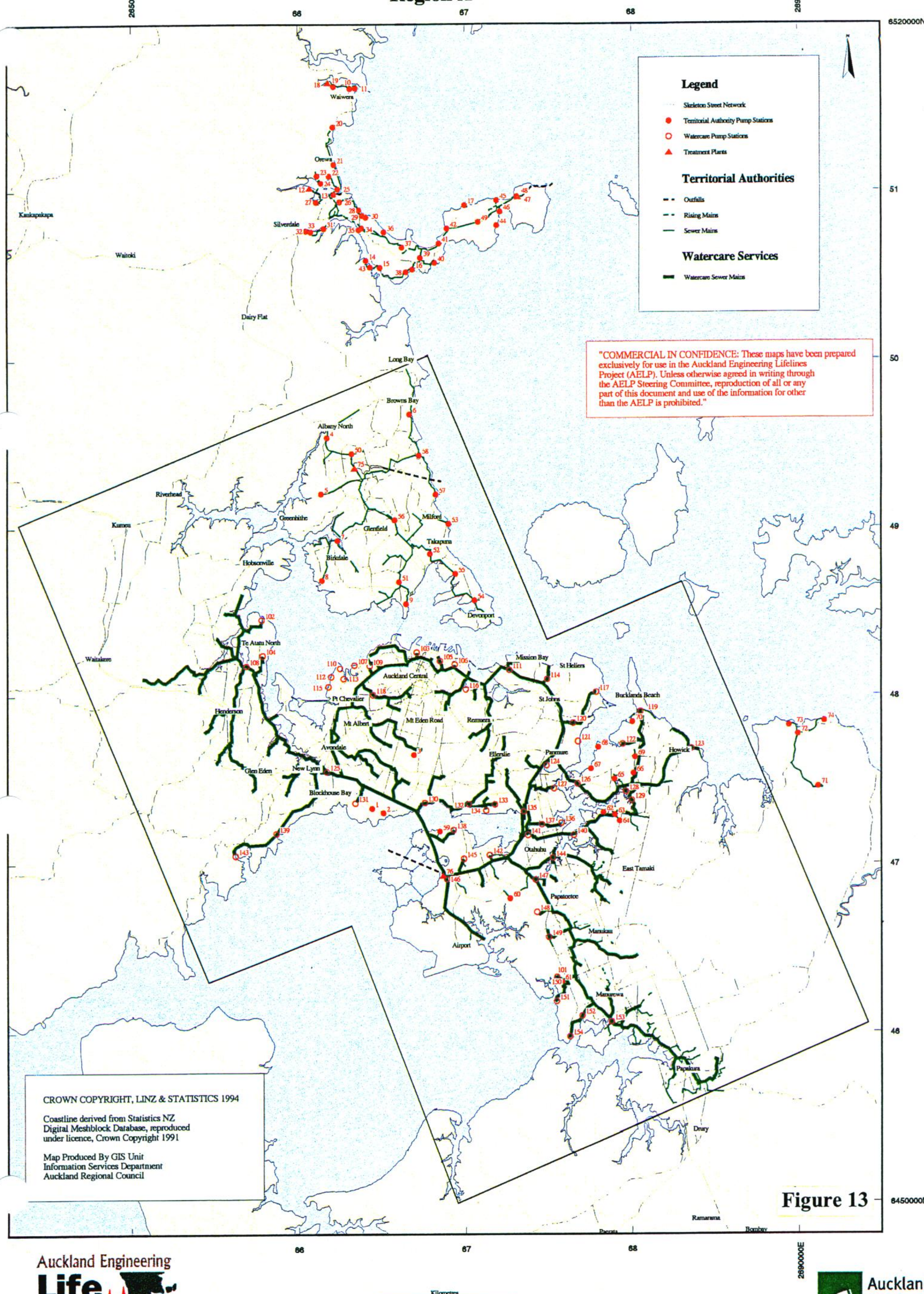


Figure 13

Auckland Engineering Life Lines

Kilometres 0 2 4 6 8

Auckland Regional Council

Hazard Impact

5. HAZARD IMPACT: EFFECTS OF EACH HAZARD ON THE LIFELINES

This chapter outlines the results of the Auckland Engineering Lifelines Project analysis by hazard, outlining:

- the effect of each scenario hazard on the lifelines
- recovery profiles for lifelines after each scenario hazard

This chapter duplicates Chapter 6, but groups the information by hazard, while Chapter 6 groups the information by lifeline.

This chapter is thus event - based rather than consequence - based.

Tables summarising effects and recovery profiles are included.

The structure of this chapter is:

5.1 Earthquake

The key effects of earthquake on utilities are caused by:

- ground shaking
- liquefaction of soils
- surface rupture

In general, bridges are a vulnerability in an earthquake for three of the four utility sectors; communications, transport and water services, as all three cross bridges. Some key communications and energy links also traverse ground with a high risk of liquefaction.

Recovery times for full restoration of services range from one to two days for communications networks to six months for large bridges. Most transport networks would, however, be at 10 - 50% capacity after one week, with energy supplies fully restored and essential water supplies in place pending full restoration in about three months.

5.1.1 Communications lifelines

Telecom

Loss of the three southern fibre optic transmission systems carried through the isthmus on bridges would result in a severe loss of capacity and considerable congestion of communications crossing the isthmus

Telecom's land line communication backbones are generally ring - configured with route redundancy, and rupture of multiple paths would be needed before service was affected. Some areas of the network still rely on single path access and will be susceptible to isolation in the event of duct route damage, but over time, as redundancy grows throughout the network, the number of nodes at risk will decrease. The loss of any one route may not have a serious effect on the network overall, but will lead to increased congestion in some places.

The most serious direct threat to network capacity is loss of one or more duct lines in ground at risk of liquefaction or displacement. Loss of any of these major routes would cause:

- full or partial outage in the Devonport, Whitford, Te Atatu North and Glendowie areas
- increased user congestion due to reduced network capacity

However, these areas have alternative routes or redundant capacity through which some service could be maintained.

Older bridges carrying network ducts are vulnerable parts of the communications network. Limited bridge movement could be tolerated, but collapse would take the duct lines out of service

All three southern fibre-optic transmission routes are carried over separate bridges through the narrow point of the Auckland isthmus, and two overlay digital microwave radio networks also cover this risk area. One network carries the national digital microwave radio backbone. The other, which is for local Auckland access, has three diverse connection points.

Loss of the three southern fibre optic transmission systems carried over separate bridges through the narrow point of the Auckland isthmus would result in a severe reduction in capacity. Public switched telephone network service could still be maintained but there would be considerable congestion of communications.

Where fibre-optic rings are damaged in only one place, there should be no effect on service or capacity

Where network duct lines cross natural features such as harbours, rivers and estuaries, they are attached to road or rail bridge structures with a risk of damage at connections across the bridge abutments or at the structure - to - ground interface. Some of the bridges carrying high capacity fibre-optic routes are of modern design which is assessed as being sound, such as Mangere Harbour Bridge. Other bridges are considerably older, such as the Otahuhu Bridge on Great South Road and the Orakei Estuary bridge at Pakuranga, though flexible duct design is estimated to allow for some movement at the more vulnerable points. Limited bridge movement could be tolerated, but a collapse would take the duct lines out of service.

Where the capacity carried is part of a fibre-optic ring and the damage is limited to only one location, there should be no effect on service or capacity.

Rain water damage to electrical systems is a higher risk than structural weakness of buildings

The communications node buildings that are most susceptible to earthquake damage are brick and concrete built before 1976. These buildings were conservatively designed by the Ministry of Works for much higher internal equipment loading than they carry today, so no major structural or foundation problems are expected. The worse case damage expected in buildings includes wall fractures and roof support failures, especially where there is a high component of glass. Resulting damage from rainwater poses a serious risk, so site access for damage assessment and repair work would be urgently required after such an event. The risk of fire immediately after an earthquake, though acknowledged, was not analysed.

Equipment miniaturisation helps distance it from the effects of building damage

The progressive miniaturisation of modern switching hardware has reduced the space formerly occupied in exchanges. It is often placed well away from glass and walls and is therefore less vulnerable if the surrounding structure is damaged. Roof failures, however, would be a major concern, requiring urgent repair to avoid or minimise water damage.

The risk of earthquake damage to storage batteries has been considerably reduced with the move to localised end – cabinet storage, with sealed (valved) storage devices or 'gel cells'.

Digital microwave radio links are relatively immune from earthquake damage: there is a reasonable amount of tolerance in beam alignment before total link failure. While there may be temporary link loss while the radio mast is swaying, the mast is unlikely to be completely felled. Any misalignment can be readjusted relatively easily after movement ceases.

The loss of any one of Telecom's land line routes may not have a serious effect on the network overall, but will lead to increased congestion in some places

Power for microwave terminal equipment is important and existing emergency generation plant at these sites should be able to provide this.

The loss of any one of Telecom's land line routes may not have a serious effect on the network overall, but will lead to increased congestion in some places.

Recovery profile

The recovery profile for network service was assessed to be 1 to 7 days (refer to the recovery profile assumptions in Chapter 2).

CLEAR

Both the uniform and scenario earthquake hazard analyses identified that the CLEAR network was only vulnerable if both sides of the fibre-optic rings were damaged, or if the core network node were damaged.

Areas where breakage of fibre optic rings could be expected are:

- Orakei Basin
- Harbour Bridge
- Upper Harbour Bridge
- rail bridges

Outage at any single one of these points would not cause a loss of service.

Recovery profile

The recovery profiles for the temporary repair to any damaged CLEAR fibre optic cables is expected to be under 2 days.

Vodafone

Vodafone's main communication backbone in Auckland, Waikato and the Bay of Plenty is by route diversity microwave system with spurs off to additional cell sites. Interconnection to land line and other major cities is via route and carrier diversity systems with other telecommunications operators. Vodafone depends on Telecom for connection to and from land line calls.

After an earthquake the use of mobile phones would be significant, with considerable congestion initially expected

While individual cell sites may suffer loss of service, the network has significant overlapping coverage. This will still deliver service, although capacity may be reduced.

While individual cell sites may suffer loss of service, the network has significant overlapping coverage which will still deliver service, although capacity may be reduced

Digital microwave radio links are relatively immune from earthquake damage. There is a reasonable amount of tolerance in beam alignment before total link failure. While there may be temporary link loss while the radio mast is swaying, the mast is unlikely to be completely felled. Any misalignment can be readjusted relatively easily after movement ceases.

The main communications node buildings that are most susceptible to earthquake damage are expected to suffer damage from glass and rainwater due to glass failure on external walls, urgently necessitating site access for damage assessment and repair work. The risk of fire immediately after an earthquake, though acknowledged, was not analysed.

Digital microwave radio links are relatively immune from earthquake damage. There is a reasonable amount of tolerance in beam alignment before total link failure

Batteries in all sites are sealed and housed in seismic rated cabinets.

After an earthquake the use of mobile phones would be significant, with considerable congestion initially expected.

All major network nodes are backed up with diesel generation systems, and each cell site is capable of being powered by small generators if necessary. Vodafone holds a number of generators for emergency power generation.

Recovery profile

Recovery time of the Vodafone network is expected to be short (0 - 2 days depending on severity), but is largely dependent on other telecommunications operators for delivery of services to landlines and international (when assessing recovery profiles, refer to Chapter 2).

Summary: Communications

Overload by users is the most serious overall threat to communications networks after an earthquake in the Auckland region.

The redundancy available in both land line and cellular networks means that in most cases, some degree of service can still be provided after loss of nodes or network segments, while given reasonable access, restoration after damage is also prompt.

Table 9 summarises the effects of the scenario earthquake on communications lifelines in the Auckland region.

Table 9: Summary of likely effects of the scenario earthquake on communications lifelines

	Land lines	Cellular system
Telecom	• some duct lines in ground at high risk of liquefaction or displacement. Serious threat: loss of major routes would impact on service in the Devonport, Whitford, Te Atatu North and Glendowie areas, with either full or partial outage, reduced network capacity and increased congestion. NB: alternative routes or redundant capacity can maintain service. No effect if fibre-optic rings are damaged at only 1 point • duct lines across older bridges at risk: limited movement tolerated but collapse would take duct lines out of service resulting in severe loss of capacity. Public switched services still maintained, but congestion of communications • pre-1976 brick and concrete node buildings at risk,, with rainwater damage a serious risk. Fire a possibility though not assessed • less risk to digital microwave radio links; possible temporary loss while radio mast sways is easily readjusted. Loss of mast unlikely	• the connections between cellular sites (antennae) and their parent switches may be compromised by damage to the public switched telephone network fibre-optic transmission system, although dedicated digital microwave radio links may be less affected. Links to minor cell sites more at risk • overseas experience has shown that within 15 to 30 minutes of an emergency, the mobile network can become seriously overloaded even when free channels may still be available

CLEAR	• The CLEAR network is only vulnerable and services would only be affected if both sides of the fibre optic rings were damaged or if a core network node were damaged. Areas where breakage could be expected are:
	  • Orakei Basin
	  • Harbour Bridge
	  • Upper Harbour Bridge
	  • rail bridges
	• outage at any single one of these points would not cause a loss of service	

Vodafone		• service possibly at risk from damage to networks of other telecommunications operators • individual cell sites may suffer loss of service, but network has overlapping coverage which will still deliver service, though capacity may be reduced • digital microwave radio links are relatively immune from earthquake damage • vulnerable communications node buildings may suffer damage from glass and rainwater. Site access for damage assessment and repair work would be urgently needed. Fire a possibility but not assessed • post-event use of mobile phones will be significant and considerable congestion is initially expected

5.1.2 Transport lifelines

Roads

Bridges and reclamations are risk points

Typical recovery profiles show 10 - 50% capacity a week after an earthquake

Restoring road access may not mean they can operate at full capacity: metal surfaces, speed restrictions and the presence of heavy plant may cause reduced flow and congestion. Roads may thus be temporarily restored to a functional state but may not be fully operational for some time

Many key roads will not be available after the scenario earthquake, while others will have reduced capacity. Bridges and their abutments are generally the most vulnerable points on the road network because of their vulnerability to ground movement. Their failure reduces capacity at only a few key points, but blocks the entire route.

Large unsecured pipelines may also cause damage if during an earthquake, they thrash about and damage the structure as well as other services on the bridge. A review of the seismic restraint of services may be desirable for risk mitigation.

Roads on liquefiable or unstable soils are the other main weakness in the network, with routes built on reclaimed land particularly at risk.

However, restoring road access may not necessarily mean they can operate at full capacity: metal surfaces, speed restrictions and the presence of heavy plant may cause reduced flow and congestion. Roads may thus be temporarily restored to a functional state, though they may not be fully operational for some time.

A typical recovery profile of a vulnerable section of road following an earthquake scenario would be closure immediately after the event and recovery to 10 - 50% capacity in the week after the event. Such is the variation in vulnerabilities that some roads could close but some could be completely unaffected. Most roads would be back to near full capacity within a month, although some with larger bridge structures could take up to six months to recover to full capacity. (When assessing recovery profiles, refer to Chapter 2, which outlines the assumptions made).

Strategic arterial roads would be greatly affected by the earthquake scenario. Older multi - span bridges and abutments along motorways and state highways such as around Spaghetti Junction would be most vulnerable to damage from ground liquefaction. Other strategic arterial routes are generally built on reasonably stable ground or to a standard able to withstand an earthquake with only superficial damage.

Some bridges along the region's most strategic arterial roads - the motorways - were identified as vulnerable points

Transit New Zealand's seismic investigation work has identified some key bridges are at risk, including:

- Khyber Pass
- Newmarket Viaduct
- Victoria Park Viaduct

Intact structures will need safety inspections

Structures left standing will need to be temporarily closed for careful inspection, as they may have suffered internal structural damage and may need large scale repairs or demolition and rebuilding before being reopened. With traffic generally unable to use the motorway system, Great South Road and Great North Road would become the main north - south routes if they were intact.

The greatest impact on the capacity of these and other key non - strategic arterial roads from the scenario earthquake is likely to be:

- loss of bridges and similar structures
- damage to the carriageway around bridges and abutments or where roads are built on reclaimed land

The motorway could be 'patched' to give north - south access for emergency vehicles, as it is not yet known if alternative routes like Great South Road and Great North Road would remain intact

However, there is not enough information to identify whether similar structures along alternative routes like Great South Road and Great North Road would remain intact in the event of damage to the motorways. More work is thus needed to determine whether these alternative routes would be able to assume bigger roles within the network if the motorway becomes impassable (see Chapter 10).

Although the motorway system would generally be unusable, it could quickly be 'patched' for essential north - south use by emergency vehicles. The Harbour Bridge would withstand the event, but both the St Mary's Bay and Northcote approaches are likely to be impassable. The Upper Harbour Bridge would suffer similar problems. However, it may be possible for the Curran Street on ramp and Stafford Road off ramp to be quickly repaired to open the Harbour Bridge to emergency vehicles.

The collapse of adjacent buildings may block many non - strategic arterial roads

Many arterial routes are likely to be completely closed after the event, with adjoining buildings likely to collapse and block the road and earth movement creating gaps and uneven levels in the carriageway, especially in hilly areas. The non - strategic network should still have more passable sections than the motorway (which has more bridges), but any access will be at a much reduced capacity. This means long delays to traffic using operational sections of road and a complete loss of access to some areas.

Most local roads would be affected but there is good redundancy in the local roading network

The scenario earthquake is likely to have a widespread impact on local roads, with severe disruptions to capacity. Even minor embankments are likely to collapse, either blocking or undermining adjacent roads. Movement of liquefiable soils is likely to have more extreme effects than on arterial roads because of lower construction standards. Local roads in hilly areas and those built on reclaimed land are likely to be worst affected by soil instability, but many other roads will be unaffected and will provide alternative routes. Areas with good redundancy in the local road network are least likely to lose access.

Rail

The rail network is the most vulnerable of all transport modes to ground movement and has the least redundancy

The rail network is probably the most vulnerable of all modes to earthquakes because the tracks are so sensitive to ground movement. Even minor earth movements can misalign tracks, totally impeding capacity because there is no opportunity for detour. Engines would be trapped wherever they were when the quake occurred, and may not be able to get back to a station.

Several sections of the rail network were identified as being at high risk of slope failure, which would completely destroy sections of the track. Repairs would involve major land stabilisation and earthworks. Vulnerable sections of the rail network include those built on reclaimed land, such as across the Orakei Basin; or in hilly areas like the Waitakere Ranges.

Recovery profiles range from weeks to months

A typical recovery profile of a vulnerable section of rail network following the scenario earthquake would be zero capacity immediately after the event, and zero to 50% capacity after a week, depending on the length of track affected. If the track is affected in multiple sections along a route, it could take six months to restore full capacity. Track misalignment is a lesser problem than track loss, enabling full capacity to be restored within a few weeks or months (refer to the recovery profile assumptions in Chapter 2).

Although rail plays such an important freight function in the Auckland region, loss of services would not be significant given the likely economic effects of a hazard event on the region, especially in its immediate aftermath.

However, rail can play a major role in carrying essential supplies both for recovery and humanitarian purposes, especially if ports and airports are damaged. Loss of rail services could therefore be significant in the recovery phase.

Ports

Ports are built on reclaimed land at risk of ground movement

Both the Waitemata and Onehunga ports are built on reclaimed land, placing them at higher risk from earthquakes. Reclaimed land is generally more susceptible to ground shaking and damage could be severe enough to require an alternative port facility, with existing piles and wharves misaligned and thus unusable as docking facilities. Port operations may also be indirectly affected by impacts on rail and road connections. As a number of bridges and roads near both ports are also built on reclaimed land, they are likely to lose capacity and reduce the ports' ability to distribute cargo.

Recovery profile

A typical recovery profile of the ports following the scenario earthquake is 10% after the first day, rising to 50% within one week, as wharves are stabilised and operations can resume. However, it may be up to three months before all wharves are completely repaired and normal operations can continue (refer to the recovery profile assumptions in Chapter 2).

In the long term, loss of port functions could have a very serious effect on the region's recovery. It would take years to rebuild another port on the Waitemata Harbour following total destruction

As with rail, loss of the economic aspect of port function, especially immediately after the event, would probably not be a primary consideration. Again, however, especially if road and air access to the region were lost, any remaining port function would be extremely important for recovery (including restoration of other lifeline services) and humanitarian purposes.

However, in the long term, loss of port functions could have a very serious effect on the region's recovery. It would take years to rebuild another port on the Waitemata Harbour following total destruction. Diversion to other ports such as Whangarei, Tauranga and Wellington could mitigate some of the adverse effects on the national, and to some extent, the Auckland economy.

Airport

Some of Auckland International Airport Ltd's facilities are located on ground that might be subjected to lower intensity shaking than others because they are on stiffer soils. Previous work done for the airport (Kingston Morrison and Engineering Geology, 1993) used scenarios which encompass the 2,000 year return period scenario earthquake developed for the Auckland Engineering Lifelines Project. The information below is based on that assessment, which examined effects of earthquakes of the following average return periods:

- 150 years
- 450 years
- maximum credible earthquake, estimated at 5,000 - 20,000 years

Effects were assessed on:

- aircraft pavements (runways, taxiways and aprons)
- roads and parking areas used to service the airport

The 150 and 450 year earthquakes might cause some inconvenience to airport users by causing delays of perhaps 1 - 2 days while runways and taxiways are inspected and minor repairs carried out

The severity of effects depends on several factors including variations in soil type and whether the pavement is asphalt or concrete.

Findings were that the 150 and 450 year events might cause some inconvenience to users by causing delays of perhaps 1 - 2 days while runways and taxiways are inspected and minor repairs carried out. Damage would probably consist of minor spalling, separation or differential vertical displacement as well as extrusion of sealant from between paving slabs. As commercial landing gear is designed to operate with vertical steps in the runway of 40 to 50mm, this was not expected to significantly affect operations. Access to the airport would probably be affected, but restricted access to most facilities could probably be maintained.

The following discussion therefore focuses on the more serious effects of the 2,000 year return period Auckland Engineering Lifelines Project scenario earthquake based on findings on the 5,000 - 20,000 maximum credible earthquake.

In the scenario 2,000 year earthquake, the runway at the international airport is likely to displace but it may be partially useable

Minor damage to runway and taxiways from the Auckland Engineering Lifelines Project scenario earthquake is expected at several joint locations because of ground surface movements. Minor uplift and/or differential settlement of up to 300mm of parts of the runway and taxiway may result from underlying liquefaction and varying depths of shallow cohesive material. Any resulting changes in grade and level along the runway and taxiways are expected to be relatively gradual and the pavements should remain structurally sound. It may be necessary to restrict operations, for example to a reduced runway length, until repairs are made.

Roads and car parks may be affected by fractured seal, footpaths and kerbs and broken stormwater services. Secondary damage may arise from damaged buried services such as burst water mains.

Road access to the airport may be affected and damage to airport buildings and equipment may also affect operations

Road access may be affected by closure of one or more traffic lanes, but it is unlikely that any road will be completely impassable. Parts of some car parks may need to be closed off immediately after the event. Reopening of all roads and parking areas would depend on access and resources needed to repair damaged underground services.

Damage to buildings and equipment is also likely to disrupt airport operations.

Recovery profile

A recovery profile for the airport following the scenario earthquake sees the airport at around 10% capacity after the first day, with only light aircraft able to operate. This rises to around 100% after 1 - 2 days as quick repairs are completed (refer to the recovery profile assumptions in Chapter 2).

Whenuapai Airbase is likely to be the least vulnerable of Auckland's airports, but does not have the capacity of the international airport

More extensive damage is unlikely from the scenario earthquake, though extended loss of airport services would affect the regional and national economies. Diversion to other airports could, however, mitigate some of the adverse effects on the national, and to some extent, the Auckland economy.

Whenuapai Airbase is likely to be the least vulnerable of Auckland's airports and may cater for some transferred air traffic, but it does not have the capacity of the international airport.

Summary: Transport

Disaster would alter traffic patterns

Immediately after a hazard event, all normal traffic would cease, only to be quickly followed by mass congestion as people tried to travel to check on family and property.

The most important task is to provide basic routes for emergency services

After a hazard event, the most important task would be to establish strategic routes for basic north - south and east - west road access, even if only for emergency vehicles. These strategic routes would preferentially use surviving motorways or state highways, but surviving lengths of smaller roads may also need to be used.

However, restoring road access may not necessarily mean they can operate at full capacity: metal surfaces, speed restrictions and the presence of heavy plant may cause reduced flow and congestion. Roads may thus be temporarily restored to a functional state, though they may not be fully operational for some time.

Non – strategic arterial roads are likely to be blocked by debris from collapse of buildings along them

Non - strategic arterial roads are built to a slightly lesser standard than strategic ones, and most are likely to suffer a loss of capacity from any of the hazard scenarios. Further loss of capacity on these roads is likely because businesses often line arterial roads with low rise buildings because of their good access and public profile, something that does not occur to the same extent on local roads or motorways. This increases the chance that the road would be blocked by falling debris.

Bridge approaches may be difficult to access due to flooding from burst pipes, which are often buried within bridge embankments. This may also hamper access immediately after an event for repair of other lifeline services such as gas pipelines.

Because smaller traffic volumes on local roads mean they are generally designed and maintained to a lower standard than arterial roads, most local roads are vulnerable to suffering a loss of capacity. However, the generally good redundancy in the local network means that alternative routes will usually be available.

Table 10 summarises the effects of the scenario earthquake on transport lifelines in the Auckland region.

Bridges are the weakest points in both the road and rail networks in an earthquake, with rail most sensitive to ground movement. Building collapse and land movement would cause widespread disruption to both networks. With both ports on reclaimed land, damage is likely, while displacement of the runway would make the international airport unusable by all except small aircraft and helicopters.

Table 10: Summary of likely effects of the scenario earthquake on transport lifelines

Road	Strategic arterials	Non - strategic arterials	Local roads
	• bridges along motorways are the weakest points, especially older multi-span bridges and abutments eg Spaghetti Junction area and some on the Southern motorway • roads on liquefiable and unstable land, especially reclaimed land, also at risk • Harbour Bridge likely to be unaffected but some northern on ramps likely to be impassable • possible flooding and physical damage from ruptured and unsecured pipes	• many likely to be closed by collapsed buildings • earth movement creating gaps and uneven levels in the carriageway, especially in hilly areas • should still have more passable sections than the motorway (which has more bridges), but any access will be at a much reduced capacity, meaning long delays to traffic using operational sections of road and a complete loss of access to some areas	• widespread impact and severe disruptions to capacity • even minor embankments are likely to collapse, blocking or undermining roads • movement of liquefiable soils likely to have more extreme effects than on arterial roads due to lower construction standards. Hilly areas and reclaimed land likely to be worst affected, but many alternative routes likely in areas with good redundancy
Rail	• rail is probably the most vulnerable of all modes to earthquakes because tracks are sensitive even to minor ground movement. Misaligned tracks totally impede capacity because of no detours • engines may not be able to get back to a station • high risk of slope failure completely destroying vulnerable sections on reclaimed land such as by Orakei Basin or in hilly areas like the Waitakeres • serious damage could affect regional recovery by loss of bulk rail transport of supplies		
Ports	• both the Waitemata and Onehunga ports are built on reclaimed land, placing them at higher risk from earthquakes. Reclaimed land is generally more susceptible to ground shaking and damage could be severe enough to require an alternative port facility, as existing piles and wharves become misaligned and thus unusable as docking facilities • port operations may also be indirectly affected by impacts on rail and road connections. As a number of bridges and roads near both ports are also built on reclaimed land, they are likely to lose capacity and reduce the ports' ability to distribute cargo. However, in the long term, loss of port functions could have a very serious effect on the region's recovery • it would take years to rebuild another port on the Waitemata Harbour following total destruction. Diversion to other ports such as Whangarei, Tauranga and Wellington could mitigate some of the adverse effects on the national, and to some extent, the Auckland economy		
Airport	• minor displacement of the runway would not significantly affect operations, although runway length may be reduced until repaired • damage to buildings and equipment may also affect operations • access to the airport may be reduced because of damage to roads and roadside services • Whenuapai Airbase is likely to be the least vulnerable of Auckland's airports and may cater for some transferred air traffic, but it does not have the capacity of the International Airport		

5.1.3 Energy lifelines

Modern design standards and system reliability requirements mean that energy supplies are only seriously threatened by earthquakes where there are abnormal ground conditions, that is, in areas where either nodes or network segments are on liquefiable soils

Modern design standards and system reliability requirements mean that energy supplies are only seriously threatened by earthquakes where there are abnormal ground conditions, that is, in areas where either nodes or network segments are on liquefiable soils.

The methodology used identified anything on liquefiable soils as having a high risk. While ground shaking was examined for all energy nodes and networks, no high risk areas were identified, as most of the sites and network sections have been designed for seismic loadings.

The following discussion thus focuses only on liquefiable soils.

Nodes and network segments for all three energy sources which, based on the uniform and scenario hazards, are at risk from liquefiable soils are summarised in Table 11.

Electricity

Uniform hazard nodes at risk

Nodes at high risk from liquefaction in the uniform hazard event are the Silverdale, Quay Street, Takanini and Pakuranga substations (Subs).

The uniform hazard also threatens power supplies to the CBD by amplifying earthquake intensity in liquefied soils. While most CBD properties would be expected to be undamaged by the event (only a small part of the CBD is on liquefiable or reclaimed land), power supplies from Quay Street Sub may be affected by liquefaction on reclaimed land

A large number of critical energy nodes are located on areas where the risk of earthquake - induced slope instability exceeds 20%. These are collectively regarded as potentially high risks pending more specific site information. Electricity nodes located in such areas are:

- Control centres:
  - Newmarket
  - Takapuna
- Points of supply/zone substations:
  - Liverpool St
  - Quay Street
  - Roskill (may or may not be in the area affected by soil liquefaction)
  - Penrose
  - Takanini
  - Mangere
  - Papakura
  - Wiri
  - Silverdale
  - Hepburn Road

- Power stations:
  - Southdown
  - Otahuhu B

- Transpower switchyard:
  - Otahuhu

Earthquake damage to substations and other nodes overseas is typically repaired within seven days

Recovery of electricity nodes from the uniform hazard earthquake is expected to be relatively quick. Earthquake damage to substations and other nodes overseas is typically repaired quite quickly — often within seven days.

Uniform hazard networks at risk include some of the high voltage transmission lines into the region

23 sections of electricity network are exposed to above average risk of damage due to liquefiable soils, as shown in Table 11:

- 17 sections of Transpower's high voltage transmission network
- 6 sections of VECTOR's sub - transmission network

Six high voltage transmission lines currently convey up to 95% of Auckland's power to the region, but loss would almost certainly be confined to one or two, rather than all six. There is no general liquefaction threat in the bottleneck through Otahuhu, where these critical high voltage transmission lines are concentrated (only the lines to Pakuranga substation avoid this area). There are just one or two pockets of susceptible ground so any damage or disruption is likely to be confined to relatively small sections of supply. Transpower would probably repair these very quickly.

Scenario earthquake nodes at risk are again in areas where abnormal amplification occurs

Some power outages or shortages may result from damage at nodes, but restoration of power to meet demand is not expected to take very long. Nodes at risk from the scenario earthquake are:

- Quay Street
- Takanini
- Pakuranga

The earthquake intensities involved are well within the design capabilities of high voltage transmission and sub - transmission systems, so damage is only expected where abnormal amplification occurs.

Scenario earthquake networks at risk

As with the uniform hazard, electricity networks are exposed to greater potential earthquake intensities in some areas where liquefiable ground is near the scenario epicentre. However, attenuation of effects from the epicentre reduces the number of sections of network at risk compared with the uniform hazard.

Ten sections of network were at risk from liquefaction or poor ground conditions:

- eight sections of Transpower's high voltage transmission lines
- two sections of sub - transmission systems

Petroleum fuels

Uniform hazard nodes at risk

The Freemans Bay / Wynyard Wharf area is vulnerable to liquefaction during an earthquake, as it is reclaimed land, but loss of or damage to Freemans Bay would not constitute a major problem. Some damage to tanks from ground movement is possible because the Freemans Bay facility stands on reclaimed land, but no petrol is held there. The probability of damage is relatively high in such an event, but the impact is relatively low.

Loss or damage could however affect availability of Avgas fuels for light aircraft and helicopters, the latter possibly being needed to help other lifelines restore their services.

The risk of earthquake - induced slope instability exceeds 20% in the uniform hazard event for:

- Wynyard Wharf / Freemans Bay
- Wiri Oil Services Terminal
- the fuel line to Auckland International Airport

Uniform hazard networks at risk

The same risks facing gas pipelines also face petroleum pipelines, though petroleum spare parts are not at risk. Four sections of petroleum fuel line were identified as being at risk in the uniform hazard analysis.

Scenario earthquake nodes and networks at risk

Petroleum nodes are not affected by the scenario earthquake except for the Freemans Bay/Wynyard Wharf area, which is closer to the epicentre and on reclaimed land. However, the consequences are not serious, as discussed above.

Two at risk sections of petroleum pipework were identified in the scenario earthquake analysis.

Gas

Uniform hazard nodes at risk

Orion's spare parts store and possibly Westfield Gate Station are vulnerable to liquefaction of soils during an earthquake in the uniform hazard event.

Uniform hazard networks at risk

Gas nodes located in areas where earthquake induced slope instabiltiy is estimated to exceed 20% include:

- Westfield Gate Station
- Papakura Gate Station
- Beaumont Street Site
- Auckland Harbour Bridge

Gas supplies over the Harbour bridge are expected to fail in a major earthquake because of bridge abutment displacement.

The main gas transmission pipeline passes through liquefiable soils in the area of Takanini, but repairs to damaged pipeline would be relatively quick.

At risk sections of network were identified as:

- one section of Natural Gas Corporation pipeline
- 11 sections of Orion gas pipeline

In the 1987 Edgecumbe earthquake the 100mm high pressure gas transmission pipe withstood 1.2m of movement

Pipeline damage cannot be assumed even where the pipeline crosses poor ground conditions. A Natural Gas Corporation pipeline crosses the faultline that moved during the March 1987 Edgecumbe earthquake. The pipeline was subjected to a 1.2m vertical displacement, but did not fail and there were no gas leaks. The pipe flexed adequately to absorb the land movement and the original pipeline remains in service today.

This performance suggests that damage to the gas pipeline from earthquake is not a serious threat in the Auckland region.

Scenario earthquake nodes at risk

The Westfield Gate Station, which supplies 60% of Auckland's gas, is next to liquefiable land and may suffer some damage. Damage to the spare parts store in Beaumont St may delay any gas recovery should Westfield be damaged. Damage is not foreseen at the other major gate station at Papakura.

Scenario earthquake networks at risk

Eight sections of Natural Gas Corporation and Orion gas pipeline were identified as being at risk.

It is difficult to estimate recovery profiles, as restoration of service depends on the type of failure. The minimum disruption from a pipeline leak or rupture is likely to be 24 hours. All gas pipelines repair welds require testing before commissioning, necessitating X-ray inspection of welds (refer to the recovery profile assumptions in Chapter 2).

Summary: Energy

Table 12 summarises the effects of the scenario earthquake on energy lifelines in the Auckland region.

The CBD is vulnerable if all three substations supplying it are affected and there may be damage elsewhere in the network, but recovery is expected to be relatively prompt — within a week.

Neither the petroleum pipeline from Marsden Point nor the gas pipeline from New Plymouth is considered at major risk, although Orion's spares store is at risk because it is on reclaimed land. The Westfield gate station is also next to liquefiable soils and may also be at risk.

Table 11: Summary of energy node and network earthquake vulnerabilities

HAZARD	ELECTRICITY	PETROLEUM	GAS
Uniform hazard: nodes at risk from liquefied soils			
	Transpower: • Pakuranga substation • Takanini substation **VECTOR:** • Quay, substation **UnitedNetworks:** • Wairau Substation # • Silverdale Substation	**Petroleum Industry:** • Freemans Bay terminal/Wynyard Whard	**Orion:** • Beaumont St (spares) • Westfield Gate Station #
Uniform hazard: network segments at risk from liquefied soils			
	Transpower: • 17 sections of high voltage transmission network **VECTOR:** • 6 sections of sub transmission network	**Petroleum Industry:** • 4 sections of fuel line	**Natural Gas Corp:** • 1 section of high pressure gas pipeline **Orion:** • 11 sections of medium pressure gas pipeline
Scenario hazard: nodes at risk from liquefied soils			
	• Quay substation (reclaimed land) • Takanini substation • Wairau substation # • Pakuranga substation #	**Petroleum Industry:** • Freemans Bay/Wynyard Wharf (reclaimed land)	• Westfield Gate Station # • Beaumont St spare parts store
Scenario hazard: network segments at risk from liquefied soils			
	Transpower: • 8 sections of high voltage transmission lines **Local network operators:** • 2 sections of sub - transmission systems	**Petroleum Industry:** • 2 sections of petroleum pipework	**Natural Gas Corporation/Orion:** • 8 sections of gas pipeline

Note: # indicates nodes that are on the edge of liquefaction zones – they may be just in or just out of the zone. A site evaluation would be needed to determine this.

Table 12: ***Effects of the scenario earthquake on the Auckland region's energy supplies***

NB: The methodology used identified anything on liquefiable soils as having a high risk. While ground shaking was examined for all energy nodes and networks, no high risk areas were identified, as most of the sites and network sections have been designed for seismic loadings. The following summary thus focuses only on liquefiable soils.

ELECTRICITY	PETROLEUM	GAS
• power supplies to CBD may be threatened since Quay Street Substation is on reclaimed land which is vulnerable to liquefaction • Other nodes at risk due to possible liquefaction are Takanini, Pakuranga and possibly Wairau Substations. • one or two of the six high voltage transmission lines currently conveying up to 95% of Auckland's power could be lost: there are just one or two pockets of susceptible ground so any damage or disruption is likely to be confined to relatively small sections of supply. These would probably would be repaired very quickly by Transpower • some power outages or shortages may result from damage at nodes, but restoration of power to meet demand is not expected to take very long. The earthquake intensities involved are well within the design capabilities of high voltage transmission and sub - transmission systems, so damage is only expected where abnormal amplification occurs	• loss of or damage to Freemans Bay would not constitute a major problem. Some damage to tanks from ground movement is possible because the facility stands on reclaimed land, but no motor spirit is held there • loss of or damage to Freemans Bay could affect availability of Avgas fuels for light aircraft and helicopters, the latter possibly being needed to help other lifelines organisations restore their services • some possible damage to the petroleum pipeline, but spares are not at risk	• Orion's Beaumont Street gas spares store was the gas node most at risk from the uniform hazard, because the store, on reclaimed land, is likely to experience liquefaction • the main gas transmission pipeline passes through liquefiable soils in the area of Takanini, but repairs to damaged pipeline would be relatively quick • the Edgecumbe experience indicates that pipeline damage cannot be assumed, even where the pipeline crosses poor ground conditions • the Westfield Gate Station, which supplies 60% of Auckland's gas, is next to liquefiable land and may suffer some damage. Damage to the spare parts store in Beaumont St may delay any gas recovery should Westfield be damaged. Damage is not foreseen at the other major gate station, at Pakuranga

5.1.4 Water lifelines

Water supply

Watercare's water networks have some redundancy in the urban supply areas. This means that some degree of pipe damage can be sustained and, with some reconfiguration of the network, the bulk of the urban supply would continue after an earthquake.

There is some redundancy in urban bulk water distribution networks, but less in the bulk supply pipes to them from the dams

However Watercare's supply mains from the Huia and Hunua dams to the treatment stations do not have the same degree of redundancy, and there is an element of risk that one or more of the pipelines from the dams to the treatment plants might fail during an earthquake.

The mains from Ardmore Filter Station were assessed as being vulnerable between Ardmore and East Tamaki, where they pass through peat soils that may amplify ground movement.

If the Ardmore supply were completely shut down, then the Huia filter station would be able to supply areas at least as far south as Mangere, provided water use restrictions were in place.

Similarly, if the western supply failed, then parts of the Waitakere supply area would be without water from the mains.

Local water supply networks are more vulnerable, with considerable disruption of service: in the worst case, repairs may take some time and tankered water supplies may be needed

Between two-thirds and 70% of Auckland's water comes from the Ardmore Filter Station, so the region is very dependent on the Ardmore system and the piped network between Ardmore and Manukau City. The vulnerability of the water supply from the Hunuas will be reduced with the commissioning of the Waikato water supply in early 2002, but there is still some vulnerability from the Redoubt Road reservoir site. However, a new main under construction from Flatbush to the East Tamaki reservoir will reduce the vulnerability of supplies beyond Redoubt Road by providing two divergent bulk supply main routes.

A new Nihotupu reservoir and a Titirangi pump station are part of a programme under way at present to reduce the vulnerability of the Waitakere supplies to a local supply failure.

The local water supply network is more vulnerable to earthquakes and loss of service is likely: even if Watercare's bulk supply remained operational, there would be significant local problems with burst mains and possible loss of reservoir storage.

Most local water supply networks have more ability to be reconfigured to ensure continuity of supply.

Local water networks

Local networks are likely to suffer major effects from the scenario earthquake, with damaged pipework likely to cause considerable disruption of service. In the worst case, repairs may take considerable time, and tankers or other methods of distributing water would be needed.

Key effects of the scenario earthquake on water supply systems were identified as:

- ground displacement causing topographic and gradient changes, resulting in breakages of pipelines and damage to water pump stations
- structural concerns about reservoirs that may not have been constructed for seismic loadings
- liquefaction of alluvial deposits in coastal regions causing structural damage to buildings, water pump stations and some pipes
- ground accelerations and differential settlement causing minor damage to water pump station buildings, pipe bridges and other structures
- differential settlement and possible displacement due to landslides causing extensive breakages throughout water pipeline networks where pipe connections are damaged because of their inflexibility
- minor damage to pumping equipment
- low risk to electrical componentry and SCADA systems, although both rely on power and telecommunications in order to provide continued service

Recovery profile

Possible basic scenarios for recovery of water networks after an earthquake are outlined below (refer to Chapter 2 which outlines the assumptions made when assessing recovery profiles):

- 1 day: 100% of all problem areas identified, with all burst mains isolated. If bulk supply is still available and roading is intact, all areas would have essential water supply services except areas affected by breakages.
- 1 week: essential water supply services would be in place, although minor structural integrity issues would not have been identified. Nonessential water supply would be provided by tanker until repairs were complete
- time to full recovery: 3 months, assuming unlimited resources. In reality, the recovery period would be substantially increased because of lack of labour resources, piping supplies and so on

Wastewater

The regional wastewater network is vulnerable to earthquake, with ruptures causing discharges and consequent health and environmental risk

Watercare has many wastewater pipe bridge crossings over creeks or tidal areas. In a very severe earthquake these could settle, move or collapse, discharging raw sewage into the environment.

Buried pipelines could be ruptured in the event of major slippage or ground liquefaction. Most at risk are those under the sea bed in the coastal marine area which act as inverted siphons to convey the wastewater under marine inlets. Ruptures would result in discharge into the environment, or blockage causing a discharge further upstream.

Overflows from broken pipes and loss of power to pump stations would be widespread

In most of the scenario hazards, failed sewage pumping stations are likely to be a source of wastewater overflows, although (other things being equal) response can be prompt because the locations are known. Restoration of service would depend on the nature of fault. Failure of the wastewater network would cause raw sewage to discharge into the environment, posing a public health risk although not an immediate threat to life. In some cases, significant environment degradation would also result, depending on the flow rate, location and duration of the overflow. Overflows from blocked or broken sewers would be harder to locate. Both would need to be addressed quickly, with the immediate health hazard minimised by appropriate signage.

Generally, however, failure of the wastewater system is considered less significant, as long as sewage overflows can be directed to waterways and away from people and property. This would be the first priority before attempting to restore the wastewater service

Wastewater flows by gravity into pump stations where it is lifted to a higher level so it can flow again by gravity. If the pumps stop pumping, the wastewater continues to flow by gravity into the station and overflows into the environment through purpose - made outlets. In a major hazard event, pump stations could cease to function because of failure of power supply, damage to critical electrical or mechanical fittings or pipes or damage to telecommunication control equipment.

Because wastewater flows by gravity into the Manukau Wastewater Treatment Plant, if all the power sources fail, the flow can gravitate through the oxidation ponds and then into the sea. Discharge by gravity to the sea will still be possible after the plant is upgraded.

Generally, however, failure of the wastewater system is considered less significant than failure of the water supply system, as long as sewage overflows can be directed to waterways and away from people and property. This would be the first priority before attempting to restore the wastewater service.

Key effects of the scenario earthquake on wastewater systems were identified as:

- ground displacement causing topographic and gradient changes, resulting in breakages of sewer lines and rising mains and damaging pump stations
- liquefaction of alluvial deposits in coastal regions causing structural damage to buildings, wastewater pump stations, rising mains and some gravity mains
- ground accelerations and differential settlement causing minor damage to pump station buildings, pipe bridges and other structures
- differential settlement and possible displacement due to landslides causing extensive breakages throughout wastewater networks where pipe connections are damaged because of their inflexibility
- minor damage to pumping equipment
- low risk to electrical componentry and SCADA systems, although both rely on power and telecommunications in order to provide continued service
- coastal pumping stations may be inundated by an earthquake - induced tsunami
- the Manukau Wastewater Treatment Plant may experience possible failure of clay liners and concrete wave barriers, breakage of ultraviolet tubes and other treatment equipment and minor damage to site buildings

Recovery profile

Possible simple scenarios for recovery of wastewater networks after an earthquake are:

- 1 day: loss of power will result in sewer overflows to the environment. Widespread breakages in pipelines may result in loss of service to both small and large catchments. No immediate effects would be visible in people's homes Overflows would be diverted away from critical areas
- 1 week: 50% of major problem areas would be identified, maintenance crews would be repairing essential sites, major pump stations and trunk mains. All overflows channelled to waterways or stormwater systems
- time to full recovery: 3 months, assuming unlimited resources. In reality, the recovery period would be substantially increased because of lack of labour resources, piping supplies and so on

Stormwater

Recovery periods for stormwater would be substantially longer because of the higher priority given to restoring for water and wastewater services

Loss of stormwater services generally has less serious effects than loss of water or wastewater services.

Key impacts of the scenario earthquake on stormwater networks were identified as:

- liquefaction of alluvial deposits in coastal regions and ground displacement, ground acceleration and differential settlement elsewhere causing breakages and changes in pipe gradients
- pipe breakages from possible displacement by landslides
- damage to pipe connections because of their inflexibility
- localised flooding problems from rainfall after the event
- possible floods from landslides displacing existing waterways

Recovery profile

Recovery profiles for stormwater services would be (refer to the assumptions in Chapter 2):

- 1 day: 3 most serious problem areas being actioned
- 1 week: most serious problem areas identified
- time to full recovery: 3 months, assuming unlimited resources. In reality, however, the recovery period would be substantially increased because of lack of labour resources, piping supplies and the higher priority given to restoring for water and wastewater services, especially if weather remains dry so that flooding problems are avoided

Summary: Water, wastewater and stormwater

Table 13 summarises the effects of the scenario earthquake on water lifelines in the Auckland region. Essentially, all three piped networks are sensitive to rupture by ground movement, with repair of water networks the top priority.

Table 14 summarises the recovery profiles of all the lifeline utilities after the scenario earthquake in the Auckland region.

Table 13: Summary of likely effects of the scenario earthquake on wastewater, water and stormwater services

SERVICE	WATER SUPPLY	WASTEWATER	STORMWATER
Bulk networks	• loss of bulk supplies from possible failure of the Hunua and/or Huia dams • there may be structural concerns about some reservoirs under extreme seismic loadings • if Watercare's bulk supply remained operational, there would be significant local problems with burst mains and possible loss of reservoir storage	• extensive breakages throughout wastewater networks resulting from differential settlement and possible displacement due to landslides, with pipe connections being damaged due to inflexibility • minor damage to pumping equipment	

Local networks	• similar problems to those expected with the wastewater pipe work would be expected in the local water supply pipework
	• the effect of the loss of some supply following an earthquake will be amplified by:
	  • increased demand from water loss through damaged pipes
	  • people initially trying to store water
	  • a probably high fire fighting demand
		• ground displacement causing to topography and changes in gradients hence breakages of sewer lines, rising mains, pump stations
		• liquefaction of alluvial deposits in coastal regions resulting in structural damage to buildings, wastewater pump stations, rising mains and some gravity mains
		• minor damage to pump station buildings, pipe bridges and other structures due to ground accelerations and differential settlement.
		• low risk to electrical componentry and SCADA systems, both reliant on power and telecommunications networks providing continued service. Coastal pumping stations may be inundated due to post - quake tsunami risk
		• treatment plant: possible failure of the clay liners and concrete wave barriers, breakage of UV tubes and other treatment equipment and minor damage to site buildings
			• liquefaction of alluvial deposits in coastal regions and ground displacement, ground acceleration and differential settlement elsewhere causing breakages and changes in pipe gradients
			• pipe breakages from possible displacement due to landslides
			• damage to pipe connections being damaged because of their inflexibility.
			• flooding from landslide displacement of streams

Table 14: Summary of recovery profiles after the scenario earthquake

	Day 1	Week 1	Full recovery
Communications lifelines			
Land lines	Severe loss of capacity	100%	1 - 7 days
Cellular networks	Loss of some capacity	100%	1 - 2 days
Transport lifelines			
Road	Complete closure of some key roads; some local redundancy	10 - 50% capacity	1 month (roads) 6 months (big bridges)
Rail	Zero capacity	0 - 50% capacity	6 months
Ports	10% capacity	50% capacity	3 months
Airport	10% capacity	100% capacity	1 - 2 days
Energy lifelines			
Electricity	Some power outages or shortages may result from damage at nodes or to networks, but any restoration of power to meet demand is not expected to take long	Pylons replaced, substations and other nodes operational	7 days (longer for CBD)
Petroleum fuels	Little damage expected to Wiri Oil Services from the scenario event - pipeline also expected to be undamaged. Freemans Bay is on the edge of the destruction zone. Possible loss of region's Avgas fuels	100%	24 hours or longer
Gas	Gas volumes available after the event may be reduced, but so too would demand. The region's main gas spare parts store may be destroyed	100%	24 hours or longer
Water lifelines			
Water supply	All problem areas identified and burst mains isolated	Essential supplies in place	3 months
Wastewater	Sewer overflows to critical sites diverted	Overflows channelled to waterways or stormwater systems	3 months
Stormwater	Most serious problems identified	Most serious problems being rectified	3 months

Note: All recovery profiles assume unlimited resources and unrestricted access, as outlined in Chapter 2

5.2 Volcano

The effects of two volcanic scenarios on lifeline services were considered:

- a localised event in downtown Auckland with major local effects and widespread ash effects
- two distant events, causing a light dusting (1mm) of ash from Mt Taranaki or a heavy dusting of ash (100mm) from Okataina, near Rotorua

In general, the worst effects arose from:

- total destruction of utilities in the area of a local vent in the Auckland volcanic field with ash fall and disruption of services elsewhere in the region
- total loss of key services imported from outside the region, especially energy, combined with the effects of heavy ash fall on the region

Recovery times for full restoration of services range from two to seven days for communications and transport to several weeks to four months for energy and water lifelines. Apart from facilities destroyed by an eruption, most utilities would be fully repaired or have temporary alternative supplies in place after one week.

5.2.1 Communications Lifelines

Telecom

The scenario eruption indicated a vulnerability of the CBD fibre-optic ring, which relies on some locally powered equipment at the nodes that access the ring. Local power failures could isolate the service the ring provides, although the fibre cable itself was assessed as being far enough away from the eruptive centre to remain intact.

Ash fall is the most serious issue outside the zone of destruction

Outside the zone of immediate destruction, volcanic ash fall would have a serious impact. Emergency generation and air conditioning plant were assessed as being the network components most vulnerable to the abrasive dust generated by volcanic activity. The control of air intakes is a high priority, with the construction of temporary pre - filters an important task. These filters would need to be fitted to air intakes for telecommunications plant and emergency generators, with plant air conditioning set to recirculate air. These countermeasures may mean temporary suspension of customer service during maintenance checks and plant servicing. Although these would generally be done after normal business hours, service may be interrupted at any time if more urgent repair or service were needed.

Air conditioning systems are at risk and may need to be shutdown until the environment is cool enough to bring it back into service

Air conditioning systems also rely upon air transfer or water tower cooling systems to remain operational, and there is a risk of insufficient cooling if these systems lose efficiency. Shutdowns may be needed until the equipment's environment can be cooled down enough to bring it back into service. The duration would be affected by ambient temperature, that is, hotter weather would cause longer shutdown periods.

Failure of electricity supplies would necessitate increased maintenance, lubricant changes and filter cleans or changes of on site emergency generation plant.

Ash fall could overload flat roofs at equipment sites and damage air conditioners and generators

While volcanic ash fall was assessed as having a low impact on towers and antennae for digital microwave and related radio systems, including cell sites, their supporting air conditioning and emergency generating equipment was identified as vulnerable.

The flat roofs of a number of Telecom equipment sites indicate a need for ash clearing measures to prevent roof collapse.

Advance warning of an eruption would help with planning of temporary repairs and alternative services

The links to Devonport, Waiheke Island and Glendowie were identified as vulnerable to volcanic activity and these network nodes could become isolated. This would limit telephone service to local calling only within these areas until alternative bearer capacity was provided. It is possible for some extended range cellular coverage to provide service into these areas, but congestion is very likely. An alternative bearer to Waiheke is available, but this would take several days to arrange.

Temporary repairs by aerial laying of fibre-optic cables would restore service to Devonport and Glendowie, but again this could take several days to complete.

The cellular network is less vulnerable to the scenario eruption than land lines

Cellular network nodes are evenly distributed over the Auckland area and hence the network as a whole is likely to be less seriously damaged than the ground - based public switched telephone network. However, links to the cell sites in the more vulnerable areas are also likely to be affected. Neighbouring cell sites would extend their range into such affected areas as the terrain would allow, but there may be an increase in black spots or shadow areas of no service. There may also be cellular congestion problems as fewer operational cell sites try to cope with dramatically increased traffic in these areas.

Recovery profile

Service to affected nodes could be restored in 2 - 7 days (refer to the recovery profile assumptions in Chapter 2).

CLEAR

The volcanic hazard analysis identified the CLEAR network was only vulnerable if both sides of the fibre optic rings were damaged

The volcanic hazard analysis identified that the CLEAR network was only vulnerable if both sides of the fibre-optic rings were damaged, or if the core network node were damaged.

The scenario eruption indicated a possibility that a small segment of the network or a single node could be destroyed in the near vent region.

Recovery profile

The recovery profile back to full service following a volcanic ash fall is estimated to be 1 to 2 days unless the network node were to suffer severe damage.

Vodafone

Air conditioning plant and direct air access to plant were assessed as being most vulnerable to the dust and gases generated by volcano activity. The control of air intakes and addition of extra filters will be an important task, while maintaining these filters could be time consuming

Air conditioning plant and direct air access to plant were assessed as being most vulnerable to the dust and gases generated by volcano activity. The control of air intakes and addition of extra filters will be an important task, while maintaining these filters could be time consuming.

The major nodes have flat roofs, so clearing ash away would also be a high priority.

Depending on the depth of ash fall, the use of vehicles may be limited because of air filter clogging.

Microwave linking is not expected to suffer from ash fallout.

The cellular network nodes are more evenly distributed over the Auckland area and hence are less likely to be as seriously damaged. While individual cell sites may suffer loss of service, the network has significant overlapping coverage, which will still deliver service. However, capacity may be reduced, causing congestion as fewer operational cell sites try to cope with dramatically increased traffic in these areas.

Cell sites themselves were assessed as having a low vulnerability to volcanic ash fall.

Recovery profile

Recovery time within the Vodafone network is expected to be within a short time (0 - 2 days depending on severity), but will be largely dependent on other telecommunications operators for delivery of Vodafone services to land and international lines.

Summary: Communications

Table 15 summarises the effects of the scenario eruption on communications lifelines in the Auckland region. It shows that damage is likely to be limited, apart from effects of ash on air conditioning systems and a possible vulnerability of the CBD fibre-optic ring to a local vent.

Table 15: Summary of likely effects of the scenario eruption on communications lifelines

	Land lines	Cellular system
Telecom	• emergency generation and air conditioning plant vulnerable to abrasive dust, so there may be some suspension of customer service during maintenance checks and servicing, generally after normal business hours but service may be interrupted at any time if urgent repair or service is needed • shutdowns may be needed until the equipment's environment can be cooled to bring it back into service. Hotter weather would cause longer shutdown periods • ash fall would have a low impact on towers and antennae for digital microwave and related radio systems, but air conditioning and emergency generating equipment is vulnerable • links to Devonport, Waiheke Island and Glendowie could become isolated, limiting service to local calling only within these areas until alternative bearer capacity was provided. Some extended range cellular coverage could provide service, but congestion is very likely. An alternative bearer to Waiheke would take several days to arrange • the CBD fibre-optic ring is vulnerable. Local power failures could isolate the service the ring provides, although the fibre cable itself was assessed as being far enough away from the scenario eruption to remain intact • recovery profiles are affected by the ability of maintenance staff to travel to affected sites	• cellular network nodes are more evenly distributed over the Auckland area and hence are less likely to be as seriously damaged as the ground - based public switched telephone network • however, links to the cell sites in the more vulnerable areas are also likely to be affected. Neighbouring cell sites would extend their range into such affected areas as the terrain would allow, but there may be an increase in black spots or shadow areas of no service • there may also be cellular congestion problems as fewer operational cell sites try to cope with dramatically increased traffic in these areas
CLEAR	• the CLEAR network is only vulnerable if both sides of the fibre optic rings were damaged of the core netwrok node were damaged	
Vodafone		• air conditioning plant and direct air access to plant is vulnerable to ash fall and gases • depending on the severity and quantity of ash fall, the use of vehicles maybe limited due to air filter clogging • microwave linking is not expected to suffer from ash fall • cellular network nodes are more evenly distributed over the Auckland area and hence are less likely to be seriously damaged. While individual cell sites may suffer loss of service, the network has significant overlapping coverage which will still deliver service • capacity may be reduced, causing congestion problems as fewer operational cell sites try to cope with dramatically increased traffic in these areas

5.2.2 Transport lifelines

Roads

Ash fall is likely to be the most serious threat to roads because of congestion caused by accidents and breakdowns

The major impact of the scenario volcano on the road network is from the indirect effect of ash on vehicles. Ash fall is unlikely to cause structural damage to the roading network, and only those routes in the immediate vicinity of the vent would suffer permanent damage. However, volcanic ash reduces visibility and traction, making vehicles more likely to have accidents, and clogs air filters, promoting breakdowns. Although ash fall itself will generally have minimal effect on the capacity of most roads, the congestion caused by multiple accidents and large numbers of broken down vehicles is likely to seriously disrupt access to and capacity of the road network.

Rain will clog drains with ash, so it must be removed as quickly as possible

If it rains on the ash, drains will quickly block and many lower lying roads will be flooded, including many with no history of flooding. It is therefore important to remove ash as quickly as possible. Arterial roads along ridge lines may be less vulnerable to volcanic effects and these routes should be highlighted and prioritised.

The recovery plans of all utility and transport operators depend on removing ash from roads and facilities, but dump sites have not been identified. If not determined prior to the event, ad hoc ash dumping would hamper network recovery and cause environmental damage (see Chapter 10, Further work).

Recovery profiles show roads back at 100% a week after an eruption

A typical recovery profile of a vulnerable section of road immediately following a volcanic scenario would see the road at between 30 - 100% capacity, depending on the amount of ash fall. The road should be at full capacity as soon as the ash is removed, most likely within one week (refer to the recovery profile assumptions in Chapter 2).

Strategic arterial roads away from the vent will be mostly unaffected

Transit New Zealand's office is in the volcanic scenario's destruction zone, but with enough warning could be relocated before the event (Transit manages Auckland's motorway and state highway networks). The scenario vent was not located by motorways or other strategic arterial roads, so little direct impact on them was expected. Roads that are destroyed provide access to the port and CBD, but these sites are also likely to be destroyed. However, should a vent appear in the narrow Otahuhu Isthmus (where there is very little roading redundancy) maintaining north - south routes would be very difficult. Regardless of where the eruption occurs, ash fall is likely to cause widespread congestion and delays on strategic arterial roads.

Non - strategic arterial roads away from the vent will be mostly unaffected

Several arterial roads near the vent would be completely destroyed, but there is enough redundancy in the network to provide alternative routes into the CBD. Again, ash fall will bring major disruption to vehicles and thus to the arterial road network. Lower lying roads or sections of road are likely to accumulate deeper ash which could block the road or worsen flooding.

Ash may block many local roads, especially in low lying areas, until more strategic routes are cleared

The high level of redundancy in the local roading network is likely to help recovery from a volcanic event. Though many local roads will be completely blocked by either ash fall or broken down vehicles, the number of alternative routes should minimise delays. Some local roads are likely to experience unprecedented flooding in the event of rainfall soon after an eruption due to blocked drains, and would not be attended by contractors until after more important arterial roads were cleared. Impacts are thus likely to be most prolonged on the local road network.

Rail

The rail network would probably not be greatly affected by the scenario volcano, although tracks and stations near the vent would be destroyed. While lines elsewhere are unlikely to be structurally affected, they may be blocked by ash fall, or engines may lose traction, hindering their operational capacity. The ash may also disrupt engine air intakes, immobilising them or delaying their use until the ash has been removed. As with the road network, lower lying rail lines may become blocked if rain falls on the ash.

Tracks would become slippery or be covered by ash

Recovery profile

A typical recovery profile of a vulnerable section of rail network would be between zero and 80% immediately after the scenario volcano, depending on wind direction and the amount of ash fall. Within a few days ash could be cleared to the side of the track, leaving only the effects of airborne ash on air filters to restrict capacity (refer to the recovery profile assumptions in Chapter 2).

Ports

An eruption in the vicinity is the worst case scenario for the Waitemata port, causing total loss, or at best, serious damage.

An eruption in the vicinity is the worst case scenario for the Waitemata port, causing total loss, or at best, serious damage

The scenario volcano would completely destroy the main port and radically alter much of the sea front. The port would have to relocate to an alternative site, provided equipment could be evacuated before the event. Onehunga would be able to take some of the redirected ships, as would other North Island ports such as Whangarei, Tauranga and Wellington. A vent further away than the scenario vent would not destroy the main port facility, but it would still be disrupted because of the effects of ash fall on engine operation.

Recovery profile

The recovery profile of the Waitemata port following the volcano scenario is zero, as the site would be completely destroyed. However, Onehunga would only be affected by ash fall, which is a temporary disruption (refer to the assumptions in Chapter 2).

Airport

Aircraft may operate around ash clouds with care

The worst case scenario for the airport is total loss or serious damage by an eruption in the vicinity.

Although the scenario eruption was not in the vicinity of the International Airport, the airport can be vulnerable to ash fall from a more distant event. Jet engines are highly susceptible to ash and must avoid contact with it, both in the air and on the ground. Following the scenario eruption, increased maintenance would be required while planes are on the ground, to keep ash out of aircraft engines and machinery. Aircraft operation should still be possible during daylight hours, when pilots can fly clear of visible ash clouds. Operation is unlikely to be possible at night or while ash is falling at the airport itself. Physical assets such as navigation equipment and aircraft hangers should not be affected by the ash fall, although the runway will probably need to be continually cleared of ash, because it reduces traction for aircraft.

Recovery profile

A recovery profile for the airport following the scenario eruption would see the airport at less than 50% capacity immediately after the event, while the ash clouds settle. Once prevailing winds and areas of ash cloud have been identified, the airport should be able to operate at near full capacity, although it may need to shut down if ash clouds come too close (refer to the recovery profile assumptions in Chapter 2).

Summary: Transport

Table 16 summarises the effects of the scenario eruption on transport lifelines in the Auckland region. It shows that apart from destruction of the Waitemata port by a local vent, the worst effects are likely to be felt on the roading network as a result of ash fall, though aircraft may also be affected by ash clouds.

Table 16: Summary of likely effects of the scenario eruption on transport lifelines

Road	**All roads**		
	• indirect effect of ash on vehicles is the major impact. Ash fall is unlikely to cause structural damage to the network, and only those routes in the immediate vicinity of the vent would suffer permanent damage, but volcanic ash reduces visibility and traction, making vehicles more likely to have accidents, and clogs air filters, promoting breakdowns • ash fall itself will generally have minimal effect on the capacity of most roads, but congestion caused by multiple accidents and large numbers of broken down vehicles is likely to seriously disrupt access to and capacity of the road network. • if it rains on the ash, drains will quickly block and many lower lying roads will be flooded, including many with no history of flooding		
	Strategic arterials	**Non - strategic arterials**	**Local roads**
	• little direct impact as port and CBD are destroyed as well as key routes to them • no north - south routes if a vent appears in the narrow Otahuhu isthmus	• several arterial roads near the vent would be completely destroyed, but there is enough redundancy to provide alternative routes into the CBD • major disruption by ash fall • lower lying areas may accumulate deeper ash which could block the road or worsen flooding	• many local roads will be completely blocked by either ash fall or broken down vehicles, but the many alternative routes should minimise delays • some local roads are likely to experience unprecedented flooding due to blocked drains, and would not be attended by contractors until after more important arterial roads were cleared • impacts are thus likely to be felt the longest on the local road network
Rail	• tracks and stations near the vent would be destroyed but the rest of the rail network would probably not be greatly affected, but may be blocked by ash fall • engines may lose traction, hindering their operational capacity and ash may also disrupt engine air intakes, immobilising them or delaying their use until the ash has been removed • lower lying rail lines may become blocked if rain falls on the ash		
Ports	• the Port of Onehunga would only be temporarily affected by ash fall, and would be able to take some of the ships redirected from the Waitemata port, as would other North Island ports such as Whangarei, Tauranga and Wellington • the Waitemata port would be completely destroyed and much of the sea front radically altered. It would have to relocate, provided equipment could be evacuated beforehand • a vent further away than the scenario vent would not destroy the main port facility, but it would still be disrupted by effects of ash fall on engine operation		
Airport	• the International Airport is vulnerable to ash fall from local and distant events. After the scenario eruption, increased maintenance would be needed to keep ash out of aircraft engines and machinery. Daylight operation should still be possible when pilots can fly clear of visible ash clouds unless ash is falling at the airport itself • physical assets such as navigation equipment and aircraft hangers should not be affected by the ash fall, although the runway will probably need to be continually cleared of ash, because it reduces traction for aircraft		

5.2.3 Energy lifelines

Electricity

The worst scenario

An eruption in the vicinity of Otahuhu would cause the maximum disruption to electricity supplies. This is the worst possible scenario: within the defined area of destruction (a 3km radius from the eruptive centre) the following would be destroyed:

- five out of six of Transpower's high voltage transmission lines into the region (only the Pakuranga substation high voltage transmission line is outside the zone of destruction)
- Otahuhu switchyard and Otahuhu power station (once commissioned)
- Southdown power station
- the Mangere substation point of supply

There would be only very limited electricity supply into the region, no generation within the region and only limited alternative energy supplies.

There are few risk mitigation options.

The scenario eruption would probably mean no power to the CBD

The scenario eruption would destroy the Quay substation, and the Liverpool substation may also be within the zone of destruction. There would therefore be no power to the CBD except that available from Kingsland substation. However, most of the CBD is in the destruction zone of the scenario eruption, so loss of electricity is of far less significance than it would otherwise be: even the port facilities would be destroyed.

VECTOR's Newmarket control centre is outside the zone of destruction, but ash falls likely to exceed 10mm would cause problems for the distribution systems. Supply outages due to insulator flashovers and line cleaning after the event are expected in areas beyond the destruction zone:

Insulation flashovers are possible from ash falls of over 10mm

- as far south as Otahuhu
- west as far as Mt Albert
- east as far as Bucklands Beach
- north (UnitedNetworks) as far as Takapuna and Milford

Several factors affect insulator flashovers, and overseas experience suggests that less than 5mm of ash fall will trigger them. Distribution systems are much more vulnerable to insulator flashover than high voltage transmission lines.

Critical nodes likely to be affected in this scenario are:

- UnitedNetworks:
    - Control centre, Takapuna
    - Wairau substation

- VECTOR:
    - Control centre, Newmarket
    - Kingsland substation
- Transpower:
    - Roskill substation
    - Penrose substation
    - Otahuhu Switchyard

(Transpower's high voltage transmission system is not expected to be affected, unless the insulators are wet or the ash is wet)

- Southdown power station
- Otahuhu power station

Effects of the distant eruptions are:

- Mt Taranaki would probably cause no problems in the Auckland region, though there may be some minimal outages to low voltage local distribution networks. However, gas supply from Taranaki may be halted by the eruption while gas demand in Auckland remains unaffected
- Okataina: insulation flashovers would be a problem, restricting electricity supply to the region. Recovery would depend on the availability of road access and water for cleaning

Networks

Electricity supply may be restricted throughout much of the region, and subject to disruption.

Electricity recovery profiles

Restoration of distribution networks would depend upon the availability of road access and water for cleaning. Without power, water may be in very short supply.

Electrical supply will recover more quickly than users' demand

Experience with natural hazards overseas suggests that electrical supplies will be restored more quickly than users' demand will recover. The period immediately after the event poses the most problems for restoring supply, and this will slow the restoration of other essential services (refer to the recovery profile assumptions in Chapter 2).

Petroleum fuels

The worst scenario

The worst scenario is total loss or serious damage to the Wiri oil terminal by an eruption in the vicinity.

The worst scenario is an eruption by Wiri and the airport destroying the Wiri oil terminal, the Joint User's Hydrant Installation at the airport and up to 2 km of pipework.

With the Wiri oil terminal out of action, the Marsden Point – Wiri pipeline, which normally replenishes petrol and diesel, would have to be shut down and bulk petrol supplies in Auckland would be very limited.

The closest fuel supplies are at Mt Maunganui. It is very unlikely that normal fuel demand could be maintained to the region from there. However, ash fall in the region would reduce demand for fuel because most motors would be at serious risk of damage resulting from blocked air filters. As supplies would also initially need to be restricted to emergency vehicles, loss of the Joint Users Hydrant Installation would probably not be too serious in the short term.

This would require shutdown of the Marsden Point – Wiri pipeline. Bulk petrol supplies would be very limited

Ash fall would also prevent planes from flying in the region, although once it was safe to fly again, airlines would be able to refuel at other airports before reaching Auckland.

The Wiri oil terminal is not expected to be damaged by the scenario event. The scenario event only poses a destruction threat to Freemans Bay and Wynyard Wharf, but these are not critical lifelines facilities. Loss of Avgas stocks may, however, hinder use of helicopters and light aircraft during lifelines recovery phases.

Effects of the local scenario eruption on petroleum fuels would be minor

The pipelines would be undamaged, so the main concern would be the effects of 1 - 5mm ash falls on the pipeline valve controls and SCADA system. SCADA systems would not fail because of volcanic ash, but could become inoperable from:

- computer shutdown and truck loading shutdown due to air conditioning problems
- failure of the communication control because of volcanic ash

Effects from the local scenario eruption are, therefore, expected to be relatively minor, mainly because the Wiri oil terminal is outside the ash fall zone.

A distant eruption (the Okataina scenario) would not damage local pipelines, and the pipeline SCADA surveillance system could probably operate in the predicted ash falls, but only if its communication systems were still operable. Sensors and control valves in the open may also be vulnerable to the heavy ash falls predicted. This would result in closure of the pipelines between Marsden Point and Wiri, and from the Wiri oil terminal to the terminal servicing Auckland International Airport.

Ash fall from a distant eruption could sink the floating roof on bulk petrol tanks, especially if the ash is wet. Hazardous vapour clouds could result

Once ash is removed, however, the pipeline should be restored to operation quite quickly. Increased wear and corrosion damage may result from the event, but this is not expected to have any impact on the petroleum fuels recovery profile (refer to the assumptions in Chapter 2).

The main concern from the Okataina scenario eruption arises from the effects of rain on the ash. Petrol is stored in tanks with floating roofs, and these could sink under the combined weight of water and ash. However, the different petrol grades are each held in two separate tanks and each tank has two separate pumps for filling road tankers, so it is unlikely that all the tanks would be inoperable.

Dry ash fall from the scenario event would not cause disruption to product availability, though ash would need to be cleared from the floating roofs within a short space of time. Again, as there are at least two tanks per product, the risk to supplies is low from dry ash.

The collapse of a floating roof without an appropriate emergency response could, however, create a very hazardous vapour cloud, with a risk of fire and/or explosion and subsequent damage to the terminal.

The Mt Taranaki eruption scenario poses no threat to petroleum supplies in the Auckland region.

Gas

The worst scenario

The worst scenario for gas supplies would be destruction of Westfield gate station, which supplies 60% of Auckland's natural gas, together with up to 2km of pipeline. This scenario assumes the event occurs within 3km of Westfield.

The underground gas pipe network is not at risk from the uniform eruption hazard unless it is within 1km of the vent.

The underground gas pipework is not at risk from the uniform eruption hazard

Effects of a localised event - the scenario eruption

In the scenario eruption, Westfield gate station would experience ash falls of 5 - 10mm and this might disrupt the volume of gas available. However, since demand would also be much reduced, the overall effect on the region's recovery is minor, provided gas flow monitoring equipment continues to function and enable the gas pipeline to remain in service. Gate stations in areas likely to be affected by ash fall would be encapsulated to minimise damage and corrosion risks, while gas supplies would be shut down before any eruption.

Loss of or damage to the region's main store of gas spare parts may affect the recovery time from damage to the pipeline or valves.

Eight sections of gas pipeline were identified as being at risk.

The Okataina scenario eruption would affect local gate stations with falls of up to 100mm

Both principal gate stations would be affected to some degree by predicted ash fall of up to 100mm from the Okataina event, but in such heavy ash falls it is difficult to envisage any major demand for natural gas. The effects of the corrosive and abrasive ash on the gate stations are difficult to estimate. They may be able to continue in service but increased wear and corrosion would be likely, and the effects would not be immediate.

Although the scenario Taranaki eruption would cause little direct damage in Auckland, it may remove gas supplies closer to their source

Volcanic events outside the Auckland region may disrupt gas supplies to a far greater extent than events within the region. Negligible direct damage would be expected in Auckland from the predicted 1mm of ash fall from the Mt Taranaki event, but could affect production in Taranaki and/or the Natural Gas Corporation operations at Bell Block. Gas supplies could be severely — possibly totally — lost for the duration of the eruption while demand in Auckland (comparatively unaffected by the eruption) may remain near normal.

The worst scenario is a local eruption destroying up to 2 km of pipeline and the Westfield gate station, which supplies 60% of the region's natural gas

The distant Taranaki eruption may severely restrict gas availability although the scenario presents no threat to regional gas facilities.

The distant Okataina eruption would affect both main gate stations and the smaller gate stations to some degree, with ash falls of up to 100mm but, again, it is difficult to envisage any major demand for natural gas immediately after such a major ash fall.

Summary: Energy

Volcanic eruption is considered to pose less of a threat than earthquake in terms of recovery times but could possibly knock out all gas supplies entirely, albeit for a much shorter period of time. Heavy ash fall could make it necessary for both Oaonui (Maui) and Kapuni gas treatment plants to shut down, although outage would be far briefer than the worst earthquake scenarios.

Worst case scenario for electricity

Maximum disruption to Auckland's electricity supplies would result from a volcanic eruption in the vicinity of Otahuhu destroying everything within a 3km radius, including five of the six high voltage power lines which bring in 90% of Auckland's power, along with 100% of local generating capacity. Only the Pakuranga high voltage transmission line is outside the destruction zone.

The result would be:

- very limited electricity supply into the region
- no power generation in the region
- only very limited alternative energy supplies

Nevertheless, given reasonable access to damaged sites to do repairs, supplies to much of the region could be restored in a matter of weeks — probably ahead of restoration needs, except for the first few days.

Worst case scenario for petroleum fuels

The worst case scenario for the region's petroleum fuel supplies is total loss of or serious damage to the fuel tank farm at the Wiri oil terminal, although it is not expected to suffer major harm from most lifeline scenarios considered. There is ten days contingency supply at Mt Maunganui and Marsden Point, but loss of the Wiri oil terminal would severely restrict fuel supplies to the region.

Inner city service stations hold short term petrol supplies and these would be supplemented by the stores at the Wiri terminal, assuming it were undamaged. However, panic buying is likely, and would quickly reduce the available stocks.

Worst case scenario for gas

The worst gas supply scenario is total destruction by an eruption of the Westfield gate station, which supplies 60% of the Auckland region's natural gas. Up to 2km of pipeline would also be destroyed, and possibly also Auckland's other main gate station at Papakura.

However, it is difficult to envisage any major demand for natural gas immediately after such a major event, so the recovery period would not cause major problems in comparison with the difficulties cause by loss of other lifeline services.

Note, however, that the three scenarios above are three separate worst cases: an eruption south of Otahuhu would badly damage electricity supplies but would not destroy the Wiri oil terminal or the Westfield gate station, being slightly outside the defined zone of destruction.

Table 17 summarises the effects of the scenario eruption on energy lifelines in the Auckland region.

Table 17: Effects of the scenario eruption on the Auckland region's energy supplies

ELECTRICITY	PETROLEUM	GAS
Local eruption		
• an eruption in the vicinity of Otahuhu would destroy 5/6 of the high voltage transmission lines into the region; the Otahuhu switchyard, the Mangere substation point of supply and the Otahuhu and Southdown power stations, resulting in very limited electricity supply into the region, no generation within the region and only limited alternative energy supplies • the scenario eruption would destroy the Quay substation and possibly the Liverpool substation, but most of the CBD is also in the destruction zone • VECTOR's Newmarket control centre is outside the zone of destruction, but ash falls would affect the sub - transmission and distribution systems, causing supply outages due to insulator flashovers and line cleaning after the event beyond the destruction zone between Otahuhu, Mt Albert, Bucklands Beach and Milford • supply may be restricted throughout much of the region, and subject to disruption	• the worst scenario is an eruption in the vicinity of Wiri and the airport, which would destroy the Wiri oil terminal, the Joint Users Hydrant Installation at the airport and up to 2km of pipework. The Marsden Point – Wiri pipeline would have to be shut down and bulk petrol supplies in Auckland would be very limited. The closest supplies at Mt Maunganui are unlikely to meet normal fuel demand (NB demand would be reduced to avoid ash damage to engines) • the scenario eruption would not damage the Wiri oil terminal, but could cause loss of Avgas, possibly hindering use of aircraft during recovery, though airlines could refuel elsewhere • Freemans Bay and Wynyard Wharf would be destroyed but are not critical facilities • pipelines would be undamaged, but ash falls could affect pipeline valve controls and SCADA systems • overall effects relatively minor if Wiri not damaged	• the worst scenario would be destruction of Westfield gate station, which supplies 60% of Auckland's natural gas, together with up to 2km of pipeline • underground gas pipework is not at risk unless it is within 1km of the vent • ash falls of 5 - 10mm might disrupt the volume of gas available via Westfield gate station. However, since demand would also be much reduced, the overall effect on the region's recovery is minor, provided gas flow monitoring equipment continues to function and enable the gas pipeline to remain in service • gate stations in areas likely to be affected by ash fall would be encapsulated to minimise damage and corrosion risks, while gas supplies would be shut down before any eruption • loss of or damage to the region's main gas spare parts store may affect the recovery time from damage to the pipeline or valves
Distant eruption		
• Mt Taranaki would probably cause no problems, though there may be some minimal outages to low voltage local distribution networks • Okataina: insulation flashovers would be a problem, restricting electricity supply to the region	• Mt Taranaki eruption scenario poses no threat • the Okataina scenario would not damage local pipelines. The SCADA system could probably operate if communication systems were operable. Sensors and control valves in the open may be vulnerable. Heavy ash fall could cause the floating roof on a petrol tank to sink, possibly creating a very hazardous vapour cloud, with a risk of a devastating explosion	• *negligible direct* damage expected in Auckland from the Mt Taranaki event, but could affect production in Taranaki and/or the Natural Gas Corporation operations at Bell Block. Gas supplies could be lost during the eruption while demand in Auckland remains near normal • both main gate stations affected to some degree by the Okataina event. Gate stations may be able to operate but with increased wear from ash

5.2.4 Water lifelines

A local volcanic event would cause a localised area of service failure that would be evacuated during the event. The water services networks around the area would be isolated, and water supply in particular would be disrupted as a result. Both the local and distant scenario would scatter ash across the region.

The effects of ash may require choosing between having non - potable water in the system or no water at all

Ash is unlikely to physically affect pipes but could cause structural failure of some roofs or abrasive failure of pumps and motors. There may be implications for water treatment, possibly requiring a choice between having non - potable water in the system or no water at all.

Ground deformation around a local volcano would have severe effects: services would need to be totally redesigned

Ground deformation around a local volcano would have severe effects: services would need to be totally redesigned. Although prompt restoration of services would not be needed (many properties would be destroyed, with the rest becoming unoccupied), there would be severe problems for sewers passing through the affected area. Stormwater flooding would probably affect some properties near the edge of the disturbed ground.

Conclusions from analysing the effects of the two scenario eruptions on the three piped water services (water supply, wastewater and stormwater) were that:

Heavy ash fall is a major problem for all three piped services

- a local volcano is a major localised problem for all piped services and a significant wastewater problem in the area affected by ash
- a thin layer of ash is a minor wastewater problem
- a thick layer of ash is a major problem for all three piped services

Water supply

Assuming Watercare could continue to supply water, most of the region not directly affected by a localised volcano in terms of water supply would receive service. The affected areas would be evacuated and water supplies valved off

Water supply networks are vulnerable to local volcanic activity, especially in the immediate area of the vent, where all services are likely to be inoperable. The extent of effects is heavily influenced by the exact location of the vent in relation to trunk facilities, especially water pumping stations.

Assuming Watercare could continue to supply water, most of the region not directly affected by a localised volcano would receive service. The affected areas would be evacuated and water supplies valved off.

The main problems for water supply relate to pipe work and concerns that the water supply may not be useable because of ash contamination. Major effects of the scenario eruption on water supply services were identified as:

- high turbidity in raw water disturbing the disinfection process and possibly impairing the filtration process
- disruption of water treatment plant biological processes by ash fall
- contamination with ash through any open system
- complete destruction of pipework and other facilities in the eruption's immediate zone, causing loss of service in that area and downstream

- ground displacement around that area causing changes to topography and changes in gradients, resulting in breakages of pipes, rising mains and pump stations
- increase in water demand for cleaning
- transport disruptions as vehicles become inoperable because of filter clogging
- possible loss of communications during very heavy ash falls

The local water supply network is likely to be able to supply most of its normal customers for most of the scenarios. Some at higher elevated areas will be without water or with reduced pressure for varying periods of time while services are restored, during which time water will generally be available from adjacent areas at lower elevations.

Ash fall is a major problem, clogging pipes and raising water demand as people try to wash it away

Water demand may increase as people attempt to wash ash away, although media advice will discourage this.

Ash fall may affect the operation of water treatment plants.

The effects of a local volcano are very localised and with evacuation of people from the worst affected area, the number affected is likely to be relatively small.

Recovery profile

A basic recovery profile for water supply services after the scenario volcano is (refer to the recovery profile assumptions in Chapter 2):

- 1 day: 100% of all problem areas identified, namely all burst mains isolated. Co-ordination of portable water supply would start, using water tankers and so on
- 1 week: essential water supply services would be in place, though not all minor structural integrity issues would yet be identified. Non essential water supply would be provided by tanker until key services were repaired
- time to full recovery: 4 months minimum, assuming unlimited resources. Temporary pump stations would be in place within 3 - 4 months, with catchments re-routed around the devastated area

Wastewater

Gradient changes and pipe breakage from mounding around the vent would affect pipes

Wastewater systems may be vulnerable to entry of ash and blockage or damage to pump impellers by abrasion, as well as to overflows as a result of ground distortion by a local volcano.

Major effects of the scenario eruption on wastewater services were identified as:

- ground displacement causing changes to topography and changes in gradients resulting in breakages of sewer lines, rising mains, pump stations
- complete destruction in the eruption's immediate zone, causing loss of service in that area and upstream perhaps if the bulk collection main is damaged or destroyed
- long term widespread blockages of sewer network by ash falls carried into the system by rainfall

- abrasion and corrosion of pumps by ash particles
- disruption of treatment plant biological processes by ash falls

If it rains and possibly also for some of the above reasons, ash is likely to enter sewage systems, especially Auckland City's combined system.

Recovery profile

A basic recovery profile for wastewater services after the scenario volcano is (refer to the recovery profile assumptions in Chapter 2):

- 1 day: localised complete destruction of the wastewater network with widespread leaks and breaks. Loss of power would result in sewer overflows to the environment. Widespread breakages in pipelines may result in loss of service to both small and large catchments, albeit with immediate effects
- 1 week: major problem areas would be identified, maintenance crews would be repairing essential sites, major pump stations and trunk mains, with plans for remediation starting to be made
- time to full recovery: 4 months minimum, assuming unlimited resources. Temporary pump stations would be in place within 3 - 4 months, with catchments re-routed around the devastated region

Stormwater

Key impacts of the scenario eruption on stormwater networks were identified as:

- complete destruction within the zone of influence of the volcano, resulting in loss of service in that area
- ground displacement outside the immediate zone of destruction causing changes in gradients and breakages of pipes and connections
- long term widespread blockages of the stormwater network by ash falls, causing relatively severe localised flooding

Stormwater is again a low priority for restoration compared with water and wastewater services

There is a real need to prevent ash from settling into stormwater pipes, because removing it is so difficult. This may necessitate identification of temporary stockpile sites to enable rapid response, especially if transport networks are disrupted.

Loss of stormwater services generally has less serious effects than loss of water or wastewater services. However, effects could be locally serious where flooding exacerbated other damage, especially if it rained after a heavy ash fall.

Recovery profile

Recovery profiles for stormwater services would be (refer to the recovery profile assumptions in Chapter 2): Recovery profiles for stormwater services would be (refer to the recovery profile assumptions in Chapter 2):

- 1 day: local disruption of stormwater network
- 1 week: most serious problem areas identified

- time to full recovery: 4 months, assuming unlimited resources. The recovery period would probably be much longer than this because of scarce labour and piping supplies and the higher priority for water and wastewater services to be restored, especially if weather remains dry

Summary: Water

Table 18 summarises the effects of the scenario eruption on water lifelines in the Auckland region. A local eruption would destroy networks in the affected area, requiring reconnection around it, while ash fall from local and distant eruptions causes widespread problems for all three piped networks.

Table 19 summarises the recovery profiles of all the lifeline utilities after the scenario eruption in the Auckland region.

Table 18: Summary of likely effects of the scenario eruption on wastewater, water and stormwater services

SCENARIO	WATER SUPPLY	WASTEWATER	STORMWATER
Local event	**Immediate area** • Watercare trunk water mains unaffected • Metrowater water mains severely damaged around CBD and area isolated - note area would be evacuated and the only water demand would be for fire fighting **Wider area** • ash prevented from entering water pumping stations by appropriate means	**Local area** • three trunk Watercare pumping stations and local catchment sewers severely damaged • overflow of the Orakei sewer (which takes 20% of the Mangere Wastewater Treatment Plant (MWTP) flow) • sewer gradients affected **Wider area** • ash from combined system causes flow and treatment problems - possible turning off of all sewage pumps • ash in sewers may cause problems if it rains • ash prevented from entering wastewater pumping stations by appropriate means • grit chambers quickly fill	**Local area** • severe drainage problems from reshaped topography • flooding from dammed 'valleys' **Wider area** • ash causes relatively minor flooding problems as pipes and channels block
1 - 2mm ash	• ash prevented from entering water pumping stations by appropriate means • possible problems for water storage dams if ash in suspension	• ash prevented from entering wastewater pumping stations by appropriate means	• minor problems
3 -100mm ash	• major problems for dams especially if ash in suspension • filter stations overloaded • filters will need covering • ash prevented from entering water pumping stations by appropriate means • reservoirs possibly subject to structural failure	• ash prevented from entering wastewater pumping stations by appropriate means • problems of sewage turning to "paste" more likely in combined area • pumping stations shut down to avoid abrasive damage • operational, maintenance and possible odour problems at MWTP. Sediment overload: processes bypassed to land or the harbour	• lots of blockages and localised flooding

Table 19: Summary of recovery profiles after the scenario eruption

	Day 1	Week 1	Full recovery
Communications lifelines			
Land lines	0 - 100%	100%	2 - 7 days
Cellular networks	0 - 100%	100%	2 - 7 days
Transport lifelines			
Road	30 - 100% capacity, depending on the amount of ash fall	Full capacity	Full capacity
Rail	Zero to 80% capacity immediately after the event, depending on wind direction and the amount of ash fall	Full capacity, depending on duration of ash fall (reduced capacity while ash may damage engines)	4 - 7 days, depending on duration of ash fall
Ports	Total destruction of Waitemata port; temporary disruption of Onehunga port	Zero for Waitemata port Full capacity Onehunga port, depending on duration of ash fall	Zero for Waitemata port. 1 week for Onehunga port, depending on duration of ash fall
Airport	Less than 50% capacity while ash clouds settle	Near full capacity once prevailing winds and clouds are identified	1 week, depending on duration of ash fall
Energy lifelines			
Electricity	Loss of affected services; disruption to adjoining services	Temporary repairs and alternative supplies in place	Several weeks, depending on extent of loss of services
Petroleum fuels	Loss of affected services; disruption to adjoining services	Temporary repairs and alternative supplies in place	Depends on extent of loss of services
Gas	Total loss for duration of a distant eruption	Temporary repairs and alternative supplies in place	Several weeks
Water lifelines			
Water supply	100% of all problem areas identified, namely all burst mains isolated. Co-ordination of portable water supply would start, using water tankers and so on	Essential water supply services would be in place, though not all minor structural integrity issues yet identified. Non essential water supply provided by tanker until key services repaired	4 months minimum, assuming unlimited resources. Temporary pump stations would be in place within 3 - 4 months, with catchments re-routed around the devastated area
Wastewater	Localised complete destruction of the wastewater network with widespread leaks and breaks. Sewer overflows. Widespread breakages result in loss of service	Major problem areas identified, maintenance crews repairing essential sites, major pump stations and trunk mains, with plans for remediation starting to be made	4 months minimum,. Temporary pump stations would be in place within 3 - 4 months, with catchments re-routed around the devastated region
Stormwater	Local disruption of stormwater network	Most serious problem areas identified	4 months, probably much longer because resources and the higher priority for water and wastewater services, especially if weather remains dry

Note: All recovery profiles assume unlimited resources and unrestricted access (see Chapter 2

5.3 Tropical cyclone

The main effects of a tropical cyclone in the Auckland region arise from:

- high winds
- heavy rainfall and flooding
- slope failure
- storm surge

In general, the worst effects from the scenario cyclone arose from:

- disruption to land transport from wind blown debris, flooding and slips
- worst case damage to key nodes or sections of water supply and wastewater networks

Communications and energy remained virtually unaffected.

Recovery times for full restoration of affected services range from 0 - 2 days for communications to 1 - 2 days for energy and up to six weeks for badly damaged water networks. Most lifeline utilities would be fully repaired or with temporary alternative supplies in place after one week.

5.3.1 Communications lifelines

Telecom

The scenario cyclone and tsunami were both assessed as having the lowest impact on Telecom's communications network, apart from the impact on individual customers. All Telecom communication equipment buildings were assessed.

Only 12% of Telecom's network nodes were identified as being vulnerable to a cyclone. These are generally smaller exchange buildings and the sites are well distributed over the network area. Road access for damage assessment and temporary repair is important. Impact should be minimal provided remedial action can be taken before serious water damage occurs. The impact would be limited to suburban customer lines.

Water damage and landslip are the main risk, with wind damage enabling water to get in to electrical equipment

While fibre optic cable is comparatively immune to water damage, there is a risk of damage if the cable is stretched or kinked by slips and washouts. The reliability of the network depends upon 'safe path' cable routes and redundancy. Landforms in some areas are less stable than others and there are limits to the availability of alternative duct lines or routes.

Some older buildings are vulnerable

Six nodes were identified as being vulnerable to high winds, five having fibre - cement roof cladding and one having clay tiles. Aged fibre - cement is acknowledged as a brittle roof covering and the strength of the fastenings is essential for retention. Tile roofs are assumed to have a louvre effect to release roof pressure in extreme conditions, but are normally fastened at every second row, so loose tiles can be a hazard. Equipment buildings with large glass walls were identified as vulnerable to flying debris, but the equipment in a number of these is centred remotely from this hazard.

All Telecom buildings undergo a five - yearly detailed inspection audit, which includes sampling the strength of the roof cladding fixings. This building audit feeds into the building maintenance programme that helps determine work contract priorities for replacement and repair.

Six cable crossings were identified as being prone to flooding or washout but the impact on the overall network was assessed as relatively minor.

One site in west Auckland has been known to be flooded in the past twenty years. This site has subsequently had a stop bank improvement, additional flood pumps and other mitigation work to limit the likelihood of recurrence.

Recovery profile

Service to affected network nodes could be restored in 1 - 4 days (refer to the recovery profile assumptions in Chapter 2).

CLEAR

Analysis indicated there would not be any significant damage to CLEAR's network, apart from possible loss of external building cladding resulting in water damage.

Vodafone

The scenario cyclone and tsunami were both assessed as having the lowest impact on Vodafone's communications network.

Very few Vodafone sites were considered to suffer any direct tsunami impact, with effects considered minor to nil.

The Vodafone network is expected to recover within a short time (0 - 2 days depending on severity), but recovery will be largely dependent on other telecommunications operators for delivery of Vodafone services to land and international lines

The roof of one major node was identified as being vulnerable to high winds and work is currently underway to minimise this risk. Another node has large glass walls and was identified as vulnerable to flying debris and rain penetration.

Individual cell sites have been designed to cope with severe conditions, and the buildings themselves are secure. However, flying debris such as roofing iron from other buildings is a potentially serious hazard.

The vulnerabilities of individual cell sites were identified as power and access to sites for installing generation equipment.

Recovery profile

The Vodafone network is expected to recover within a short time (0 - 2 days depending on severity), but recovery will be largely dependent on other telecommunications operators for delivery of Vodafone services to land and international lines.

Summary: Communications

Table 20 summarises the effects of the scenario cyclone on communications lifelines in the Auckland region, showing that landlines are somewhat more vulnerable than cellular systems.

Table 20: Summary of likely effects of the scenario cyclone on communications lifelines

	Land lines	Cellular system
Telecom	• the scenario cyclone has the lowest impact of the hazards assessed, with no impact on the overall network and only individual customers affected. 12% of Telecom's network nodes were identified as being vulnerable. These are generally smaller exchange buildings and the sites are well distributed over the network area. Impact should be minimal provided access for damage assessment and repair can be taken before serious water damage occurs. The impact would be limited to suburban customer lines • fibre-optic cable is comparatively immune to water damage, but could be damages by being stretched or kinked by slips and washouts in unstable areas • 6 nodes are vulnerable to high winds • 6 cable crossings are prone to flooding or washout	• the cellular transmitting and receiving site antennae are rated to withstand winds in three ranges from 160 to 240 kph • impact on the overall network assessed as relatively minor apart from the impact on individual affected customers
CLEAR	• there would not be any significant damage to CLEAR's network, apart from possible loss of external building cladding resulting in water damage	
Vodafone		• 1 major node has a roof vulnerable to high winds and another node with large glass walls is vulnerable to flying debris and rain penetration • damage is most likely from flying debris such as roofing iron from other buildings • provided there is access to individual cell sites to install generation equipment, effects should be minor

5.3.2 Transport lifelines

Roads

Flooding from heavy rain is likely to be the major impact of the scenario cyclone, although high winds could also cause disruption from fallen trees and poles. While the extent of flooding is reasonably predictable based on past events, the impact of fallen debris is not. Generally, all roads would have reduced capacity at times because of debris blockages, and delays would be expected.

The main problems are flooding, high winds, wind blown and flood borne debris and slips

High winds would not affect the road network itself, and exposed structures such as the Harbour Bridge may be able to remain open. However, the bridge may be closed to light traffic like motor cycles for safety reasons and the clip - on lanes may need to be closed, while in extremely high winds, the bridge itself may be closed for safety reasons.

Some problems from slips are also possible, and while overslips (which deposit material on the road) are relatively easily cleared, underslips (where part of the road is lost) may result in roads being closed for significant periods of time.

Strategic arterial roads are less likely to be affected by flooding and wind blown debris

The higher construction standard of strategic arterial roads makes them less vulnerable to cyclones, as potential risks tend to be removed from these roads. For example, it is standard practice for vulnerable trees adjacent to a State Highway to be removed before they are blown onto the carriageway, and similar safety standards apply to the proximity of buildings and signs. This means that strategic arterial roads are less likely to be affected by fallen debris from high winds, although it is inevitable that some disruption will occur.

SH16, Tamaki Drive and Great South Road are vulnerable, but flooding should not generally affect other strategic or non - strategic arterial roads

Very few strategic routes are sufficiently close to the coast to be affected by rougher cyclonic seas, with all routes but two likely to remain open (although some may have temporarily reduced capacity). The most vulnerable route is State Highway 16, which is likely to be inundated at the low lying Waterview causeway and near Helensville. However, a detour is available at Waterview.

Tamaki Drive is also vulnerable to the cyclone scenario, and is likely to be closed to avoid risk to vehicles from the cyclonic storm surge and cliff collapse from heavy rain.

Great South Road is likely to have reduced capacity in several areas where it crosses rivers likely to flood, although it should remain open.

Few non - strategic arterial roads at risk

Flooding should not generally affect other strategic or non - strategic arterial roads.

Local roads are more vulnerable to blockage by flooding and debris

Local roads are more vulnerable to the cyclone scenario than arterial roads because they are common in low lying areas and are built to a lesser standard. It is not possible to accurately predict the extent of flooding from the scenario, but areas that have flooded in the past provide a good basis for response planning. During the worst of the flooding there is likely to be very little traffic demand, as most people shelter indoors from the storm. Most roads closed by flooding would reopen shortly after the event, although some will be covered in debris and others will have suffered scouring. High winds are more likely to affect local than arterial roads because they have more roadside trees, signs and poles. Many roads not flooded are likely to be fully or partly blocked by fallen debris.

Rail

Flooding may cover low lying lines and some slips may damage tracks

The scenario cyclone is likely to block most sections of the rail network, with fallen debris on the tracks and flooding in low lying areas. Large sections of the Main Trunk Line through the Waitakere Ranges have been identified as vulnerable to slope failure in heavy rain. Similar slope problems are likely around the Orakei Basin, although an alternative route is available. Several areas of flooding are likely to the south and debris may be washed onto the track in places.

Recovery profile

A typical recovery profile of a vulnerable section of rail network following a cyclone would be zero capacity immediately after the event, because of the debris blown onto the track. Once this has been cleared, probably within a few days, network operation would depend on the extent of slope failure. If only isolated sections are affected, repairs could be completed within a few weeks, but for more widespread slope failure delays of several months are likely (refer to the recovery profile assumptions in Chapter 2).

Ports

Given enough warning, ports can avoid cyclone damage

Given enough warning, the ports can avoid serious damage to structures, equipment and vessels from the scenario cyclone. Ships can be put to sea and containers can be evacuated or strategically stacked to withstand wind gusts. Most port damage is likely to be from smaller vessels that have broken free from their moorings and are washed into the harbour area. If electronic equipment and power survives the scenario and road and rail access are maintained, the ports should be quickly back to full capacity after riding out the storm.

Recovery profile

A recovery profile following a cyclone has the ports closed down during the storm and back up to 50% immediately after the event. Depending on the amount of damage, full capacity should be restored within one or two days (refer to the recovery profile assumptions in Chapter 2).

Airport

The airport would close during the storm peak

Most problems for the international airport from the scenario cyclone arose from high wind speeds. Light aircraft are unable to operate in winds of more than 20 knots across the runway, though larger aircraft have a higher threshold and high winds parallel to the runway are less problematic to both. No flights are likely during the cyclone peak, but with enough warning the disruption can be minimised by re-routing flights. Rain is unlikely to affect operations or access to the airport, although visibility will be impaired.

Recovery profile

A recovery profile for the airport following the cyclone scenario sees the airport at close to zero capacity during the height of the storm, with full capacity quickly restored once winds drop. Most aircraft, equipment and buildings are sufficiently robust to withstand the cyclone without damage (refer to the recovery profile assumptions in Chapter 2).

Summary: Transport

Table 21 summarises the effects of the scenario cyclone on transport lifelines in the Auckland region, showing that roads are likely to be most vulnerable elements of the transport network, as well as some sections of the rail network.

Table 21: Summary of likely effects of the scenario cyclone on transport lifelines

<table>
<tr><td rowspan="4">Road</td><td colspan="3">All roads</td></tr>
<tr><td colspan="3">• flooding from heavy rain is likely to be the major impact, the extent being reasonably predictable based on past events
• all roads would have reduced capacity at times because of debris blockages from fallen trees and poles, and delays are to be expected
• some slips are also possible, overslips being relatively easily cleared, but underslips resulting in roads being closed for significant periods</td></tr>
<tr><td>Strategic arterials</td><td>Non - strategic arterials</td><td>Local roads</td></tr>
<tr><td>• exposed structures such as the Harbour Bridge may remain open, but the Bridge may be closed to light traffic, or the clip on lanes or the bridge itself may close
• some disruption of strategic roads by debris from high winds
• very few are close enough to the coast to be affected by cyclonic seas though some may have temporarily reduced capacity. The most vulnerable routes are State Highway 16, likely to be inundated at Waterview and near Helensville; and Tamaki Drive
• Tamaki Drive is also vulnerable to slips
• Great South Road may have reduced capacity where it crosses rivers but should remain open</td><td>• flooding should not generally affect other arterial roads, though debris and slips may be problems</td><td>• local roads are more vulnerable to flooding because they are common in low lying areas and are built to a lesser standard. During the worst of the flooding there is likely to be very little traffic demand, as most people shelter indoors from the storm. Most roads closed by flooding would reopen shortly after the event
• some coastal roads will suffer scouring.
• some roads will be covered in debris: high winds are more likely to affect local roads because they have more roadside trees, signs and poles. Many roads not flooded are likely to be fully or partly blocked by fallen debris</td></tr>
<tr><td>Rail</td><td colspan="3">• most sections of the rail network are likely to be blocked with fallen debris on the tracks and flooding in low lying areas
• large sections of the Main Trunk Line through the Waitakere Ranges have been identified as vulnerable to slope failure in heavy rain. Similar slope problems are likely around the Orakei Basin, although an alternative route is available
• several areas of flooding are likely to the south and debris may be washed onto the track in places</td></tr>
<tr><td>Ports</td><td colspan="3">• given enough warning, the port can avoid serious damage to structures, equipment and vessels from the scenario cyclone
• most port damage is likely to be from smaller vessels that have broken free from their moorings and are washed into the harbour area
• if electronic equipment, power and road and rail access are maintained, the ports should be quickly back to full capacity after riding out the storm</td></tr>
<tr><td>Airport</td><td colspan="3">• high wind speeds are likely to cause the airport most problems. Light aircraft are unable to operate in winds of more than 20 knots across the runway, though larger aircraft have a higher threshold. No flights during the cyclone peak
• rain is unlikely to affect operations or access, although visibility will be impaired</td></tr>
</table>

5.3.3 Energy lifelines

Electricity

High rainfall and flooding were not identified as affecting electricity supplies, although debris laden high winds might cause localised failure of overhead lines. Rain - induced slope failure may affect the occasional local network supply power pole, but the six high voltage transmission lines are not at risk. Basement flooding may cause local supply disruption, while a very high storm surge could affect the Quay substation.

Petroleum fuels

Neither flooding, slope failure nor storm surge was identified as a risk to petroleum nodes or network. Communications are critical for continued operation of the petroleum pipeline, but three systems are available (microwave, satellite and land line).

The main effect of torrential rain on the Wiri oil terminal would be (in a worst case scenario with rainfall of more than 250mm) to sink the floating roof on any of the petrol tanks if the stormwater roof drains were not opened. This is unlikely, however, as it is a routine wet weather operation, including out of normal business hours.

Gas

Neither wind, rainfall, flooding nor storm surge was identified as posing a risk to natural gas nodes or networks, unless access for inspection or repair were impeded.

Slips may cause some problems, but pipelines can tolerate some movement

Cyclone Bola caused some superficial slips, although all have since been stabilised and Auckland gas supplies were not disrupted. Some superficial damage to gas pipes from land movement cannot be ruled out, but it would not be a threat to supply. In the 1987 Edgecumbe earthquake the 100mm high pressure gas transmission pipe withstood 1.2m of movement.

In the event of disruption, restoration would typically take 2 - 7 days.

Summary: Energy

Table 22 summarises the effects of the scenario cyclone on energy lifelines in the Auckland region.

Table 22: Effects of the scenario cyclone on the Auckland region's energy supplies

RISK	ELECTRICITY	PETROLEUM	GAS
Wind	• localised failure of overhead <11kV lines because of debris. Repairable once wind abates. Substations and Transpower lines would not be affected • note that power can still be transferred without operational communication systems	• communications are critical for maintaining supply, but two systems (microwave and satellite) are available, with land line backup	• no threat
Rainfall	• no effect. No substation flooding anticipated, except perhaps at Wairau Road	• risk of floating roof collapse, but there are strict procedures for ensuring roof drainage valves are opened to prevent this happening	• no threat, unless access becomes impeded
Flooding	• no effect. It is assumed that the Penrose tunnel, in construction, would not be at risk – but detailed information is not available	• no problem except for ensuring appropriate emergency response to manually open/close out turn, bund and drain valves	• no threat, unless access becomes impeded
Slope failure	• the odd pole in the local supply network may be at risk, but the main towers carrying the six high voltage Transpower lines from the south are not at risk • in the worst case, only one of the six separate transmission lines would be affected • slope failure presents less of a threat than soil liquefaction	• comments under 'Gas' apply here too	• rupture of the gas main by slope failure is not expected except perhaps in some remote areas. The high pressure trunk pipelines from the south do not pass through unstable ground. Some superficial damage due to land movement cannot be ruled out but it would not be a threat to supply. In the 1987 Edgecumbe earthquake the 100 mm high pressure gas pipeline withstood 1.2m of movement
Storm surge	• VECTOR's Quay substation has a floor raised by 0.5 m, but water would only need to rise 0.3 m above that before the substation was affected. If water level exceeds 0.3m inside the substation CBD supplies may be disrupted • many CBD high rise buildings basements may be vulnerable to flooding in these conditions. Basement flood pumps are sometimes connected to emergency generator systems, the latter also sometimes being located in a low level basement where they may be most at risk when most needed	• Wynyard wharf is not at risk from a 3m storm surge • Avgas pumps are above ground. The chemical pump is not critical • at the Wiri terminal the site drainage outflow is 2.5m above mean sea levels, so no problems are foreseen	• no threat

5.3.4 Water lifelines

Table 23 at the end of this chapter summarises the effects of the scenario cyclone on all three piped water networks. It was assumed that the two Waitemata Harbour bridges and customer service would both remain largely unaffected.

Buildings related to water lifelines are thought to be able to withstand wind loads. Aerials for SCADA systems may need securing and these will need to be individually checked during and after the event.

Rainfall may be localised, short and intense as over Pukekohe in January 1999, or widespread and prolonged as region wide in July 1979. Buildings will need to be waterproofed, as leaks can cause problems for electrical circuitry.

Water supply

The pipe component of Watercare's bulk water supply system is not very vulnerable to the scenario cyclone: its main vulnerability is loss of power or communication to the system. However, as the system is mainly gravity fed, a power loss has minimal effect

The most serious effect of a power supply loss would be on the Khyber pump station, which maintains the supply to Mount Eden and thence to various hospitals

The pipe component of Watercare's bulk water supply system is not very vulnerable to the scenario cyclone: its main vulnerability is loss of power or communication to the system. However, as most of the source water is fed by gravity to the supply stations, and then on to consumers, a power loss has minimal effect.

In general, pipelines and other assets are located in relatively stable areas which should not be affected by cyclonic storms, although access to these assets may be hampered for a short period until roads are cleared of any slips.

Power loss could cause possible loss of communication and pumping capability. Although wind may topple power lines, loss of one local supply line is usually compensated for by switching to an alternative source. Customers in affected areas relying on pumped systems would have no water, and others may have reduced pressure. However, few customers will be without water.

The most serious effect of a power supply loss would be on the Khyber pump station, which maintains the supply to Mount Eden and thence to various hospitals. The filter stations have standby power capacity to maintain service in the event of a power supply loss for up to two days. Standby generators would be utilised to maintain critical water supply pumping stations, should power supply fail for an indefinite period. However, this depends on reinstating roads to ensure the supply of fuel to priority sites such as the Ardmore and Huia filter stations.

Local instability would affect access to some assets for a period, and may cause some local sections of cast iron main in potentially unstable landforms to fail. In almost all cases an alternative supply could be provided.

Local instability would affect access to some assets for a period, and may cause some local sections of cast iron main in potentially unstable landforms to fail. In almost all cases an alternative supply could be provided

Pipelines located on unstable hillsides might be affected by any slips.

A small part of the Waitakeres near Titirangi could be affected if a slip on Scenic Drive cut the cast iron main running along it. Procedures are already in place to provide an alternative supply, with a pump station located at the Titirangi reservoirs to feed back to the high level zone.

Water delivery systems are not at risk from storm surges because they last such a short time. Their effect on the Onehunga aquifer would, if any, be negligible.

Watercare's water supply dams are subjected to regular surveillance, monitoring and analysis. In addition, an independent dam safety assurance audit is undertaken on each facility every five years, to ensure that the structures meet public expectations, and international practice in dam safety assurance. None of the dams would be subjected to hazardous conditions in the scenario cyclone

Watercare's water supply dams are subjected to regular surveillance, monitoring and analysis. In addition, an independent dam safety assurance audit is undertaken on each facility every five years, to ensure that the structures meet public expectations, and international practice in dam safety assurance. None of the dams would be subjected to hazardous conditions in the scenario cyclone.

There would be direct and indirect effects upon the supply system from the winds associated with the cyclonic storm. Some of the SCADA aerials with higher than normal aerials in locations with poor reception may be lost, but the main repeaters are built to withstand significant storms without damage. In the event of aerial loss, service would continue with manual data input until the aerials were reinstated. The repeater stations are either fed by solar energy or have enough standby capacity to maintain service beyond the period of the scenario cyclone.

High winds would be likely to disrupt power supplies, especially in the headworks, where services are run through several kilometres of roads formed through steep bush clad slopes. In places without standby power, power loss would result in a continuation of whatever had been happening at the time until staff arrive to manually effect any necessary changes. In the event of extended power outage, facilities are available for linking in a portable three phase standby generator that can be taken in by helicopter, vehicle or foot.

Staff are located at critical dam sites, so even if vehicle access is not possible, they would be available to maintain the core services.

Local water networks would be unlikely to be significantly affected by cyclonic storms, provided Watercare could continue to supply water to maintain reservoir supplies. Localised problems such as slips may affect a relatively small number of customers

Local water networks would have similar vulnerabilities to Watercare's network: they would be unlikely to be significantly affected by cyclonic storms, provided Watercare could continue to supply water to maintain reservoir supplies. The networks may however be subject to localised problems such as slips, affecting a relatively small number of customers.

In the event of a regional power outage following a storm, most of the city would be able to receive gravity water from Watercare reservoirs for a few days. A small number of customers would be without water unless generators were used at local water boost stations.

In the event of a prolonged outage lasting several days, much of the region (31% of North Shore Water Services) would be without water unless emergency generators were used at Watercare's key water pumping stations.

In summary, the effects of the scenario cyclone on water supply are that:

- service to most customer would continue, as reservoirs generally have at least 48 hours storage. Small areas at higher elevations could have no water
- some local mains would be affected by scouring of water courses
- important buildings are likely to be unaffected, but minor leakage may affect electrical circuitry
- some local mains may be affected by slips, and repairing them may be a problem
- most but not all trunk mains are generally outside sensitive areas, but more investigation is needed
- Watercare raw water mains are generally in areas more prone to slippage. Access difficulties are expected but the dams are unlikely to be affected. Loss of a line would be compensated for by switching to another line
- dam water would probably be more turbid, needing more treatment
- bore supplies could possibly be contaminated
- effects of the storm surge are likely to be minor, but coastal scouring would be likely to affect local water mains. Shutoff valves will minimise the area affected

Recovery profile

The basic recovery profile for water supply services after the scenario cyclone is (refer to the recovery profile assumptions in Chapter 2):

- 1 day: very little damage would be reported, apart from possible structural failure of exposed pipelines and minor damage at reservoirs. There would be very little loss of service
- 1 week: maintenance well under way for exposed pipelines
- time to full recovery: 4 - 6 weeks, assuming unlimited resources. Temporary pump stations would be in place

Wastewater

Power loss could cause possible loss of communication and pumping capability, resulting in overflows. Although wind may topple power lines, loss of one local supply line is usually compensated for by switching to an alternative source

Power loss could cause possible loss of communication and pumping capability, resulting in overflows. Although wind may topple power lines, loss of one local supply line is usually compensated for by switching to an alternative source.

Effects of the scenario cyclone on wastewater networks were expected to be minor, with most customers still receiving service.

Key effects were identified as:

- important buildings are likely to be unaffected, but minor leakage may affect electrical circuitry and monitoring telemetry
- localised and regional flooding means the sewer system would become overloaded and overflow to the environment, as happens currently in major storms. The system would nevertheless remain functional
- some scouring from lifted manhole lids
- inundation of gully traps
- scouring of bridge piers and pipe bridges possibly affected
- some trunk and local sewers would at risk from slips
- sewers may be flooded by dammed creeks

- some local pump stations may be affected by slips
- storm surge erosion may occur at coastal pumping stations and foreshore sewers, especially along the east coast beaches
- pump station switchboard gear in about ten pump stations would be affected by saltwater intrusion from the storm surge, so without pumping, uncontrolled discharges would result
- some stations would be affected by leakage at high tide
- possible overtopping and or scouring of Mangere and Orewa ponds with possible odour incidents
- possible erosion of the Orewa ponds

Recovery profile

The basic recovery profile for wastewater services after the scenario cyclone is (refer to the recovery profile assumptions in Chapter 2):

- 1 day: complete inundation of coastal regions — Bucklands Beach, eastern beaches, East Coast Bays and Auckland beaches, Beachlands – Maraetai. Widespread uncontrolled discharges. At risk coastal pump stations and pipelines affected by structural failure would be identified
- 1 week: pump station maintenance crews would be at work, with initial repairs or temporary switchboards in place. Temporary repair to pipe bridges and coastal pipelines would have started
- time to full recovery: 4 - 6 weeks, assuming unlimited resources. Temporary pump stations would be in place

Stormwater

Key impacts of the scenario cyclone on stormwater networks were identified as:

- scouring of earth lined banks and some overland flow paths
- localised and regional flooding due to hydraulic overload of the stormwater system and blockage of cesspits, pipes, culverts and watercourses by debris
- loss of road access by flooding
- scouring of bridge piers possibly affecting pipe bridges
- some road and property damage
- slope failure causing breakages of stormwater pipelines

Recovery profile

Problems are likely to be localised. Recovery profiles for stormwater services would be (refer to the assumptions in Chapter 2):

- 1 day: serious local flooding
- 1 week: essential repairs would be under way
- time to full recovery: 4 - 6 weeks, assuming unlimited resources

Summary: Water

Table 23 summarises the effects of the scenario cyclone on water lifelines in the Auckland region, showing that effects are likely to be comparatively minor and able to be repaired in a reasonable time.

Table 24 summarises the recovery profiles of all the lifeline utilities after the scenario cyclone in the Auckland region.

Table 23: Summary of likely effects of the scenario cyclone on wastewater, water and stormwater services

EFFECT	WATER SUPPLY	WASTEWATER SYSTEM	STORMWATER
Wind	• nil, assuming power still available and roof aerials on pump stations secured	• nil, assuming power still available and roof aerials on pump stations secured	• negligible
Rainfall and Flooding	• minor: service to most customers continues • some local mains affected by scouring of water courses • important buildings are likely to be unaffected, but minor leakage may affect electrical circuitry • possible contamination of bore supplies	• minor: customer system still functions • important buildings are likely to be unaffected, but minor leakage may affect electrical circuitry • localised and regional flooding overloads sewers causing overflows to environment, as happens currently in major storms. System remains functional. Some scouring from lifted manhole lids. Gully traps inundated • bridge piers scoured, pipe bridges maybe affected • Orewa ponds may be affected by erosion	• scouring of earth lined banks and some overland flow paths • loss of road access by flooding: cesspits blocked • localised and regional flooding due to hydraulic overload of the stormwater system and blockage of pipes, culverts and watercourses by debris • scouring of bridge piers possibly affecting pipe bridges
Slope failure	• loss of some local mains in slips • most but not all trunk mains are generally outside sensitive areas, but more investigation is needed • Watercare raw water mains generally in areas more prone to slippage. Access difficulties expected but dams unlikely to be affected. • dam water likely to be more turbid and will need more treatment • Rodney District water supply: similar position	• customer system still functions • some trunk and local sewers at risk from slips • sewers flooded by dammed creeks • some local stations possibly affected by slips • treatment plants generally unaffected	• damming of creeks and waterways resulting in flooding • some road and property damage • slope failure causing breakages of stormwater pipelines
Storm surge	• minor • coastal scouring likely to affect local water mains. Shutoff valves will minimise area affected	• possible erosion at coastal pumping stations and foreshore sewers especially east coast beaches • some stations affected by leakage at high tide • possible overtopping and or scouring of Mangere and Orewa ponds with possible odour incidents • Mangere treatment plant may be affected	• flooding and scouring in coastal area

Table 24: Summary of recovery profiles after the scenario cyclone

	Day 1	Week 1	Full recovery
Communications lifelines			
Land lines	90%	100%	1 - 4 days
Cellular networks	90%	100%	1 - 4 days
Transport lifelines			
Road	Road closure or reduced capacity in some areas as a result of flooding, debris or slips	Full recovery except in areas of severe underslips	0 - 2 days except in areas of severe underslips
Rail	Zero capacity because of debris on tracks	2 - 7 days to full capacity if only isolated sections of track are affected	A few weeks to several months if there is widespread slope failure
Ports	Closure during storm, 50% capacity immediately after the event	Full capacity	1 - 2 days
Airport	Zero or near zero capacity during storm, full capacity once winds drop	Full capacity	As soon as winds drop to 20 knots
Energy lifelines			
Electricity	Local loss of power from debris laden high winds and local flooding or very high storm surge	Full capacity	1 - 2 days
Petroleum fuels	Full capacity	Full capacity	-
Gas	Possible loss of supply if pipeline ruptured by slips (very unlikely)	Full capacity	2 - 7 days
Water networks lifelines			
Water supply	Very little reported damage or loss of service, apart from possible structural failure of exposed pipelines and minor damage at reservoirs	Maintenance well under way for exposed pipelines	4 - 6 weeks. Temporary pump stations would be in place
Wastewater	Complete inundation of coastal regions. Widespread uncontrolled discharges. At risk coastal pump stations and pipelines affected by structural failure would be identified	Pump station maintenance crews at work, with initial repairs or temporary switchboards in place. Temporary repair to pipe bridges and coastal pipelines would have started	4 - 6 weeks. Temporary pump stations would be in place
Stormwater	Serious local flooding	Essential repairs under way	4 - 6 weeks

Note: All recovery profiles assume unlimited resources and unrestricted access (see Chapter 2)

5.4 Tsunami

The main effects of a teletsunami in the Auckland region arise from:

- inundation of coastal areas
- scour from incoming and receding debris laden water
- amplification in semi - enclosed harbours and estuaries
- increased turbulence and oversteepening of waves by opposing currents in the lower reaches of streams and rivers

In general, coastal roads and water lifelines were worst affected, with communications and energy remaining virtually unaffected.

Recovery times for full restoration of services range from 1 - 2 days for transport lifelines up to six weeks for badly damaged water networks. Most affected utilities would be fully repaired or with temporary alternative supplies in place after one week.

5.4.1 Communications lifelines

Telecom

The scenario tsunami, along with the scenario cyclone, was assessed as having the lowest impact on Telecom's communications network, apart from the impact on individual affected customers. There was no disruption to network service.

CLEAR

The tsunami hazard analysis identified there would not be any significant damage to the CLEAR network.

Vodafone

The scenario cyclone and tsunami were both assessed as having the lowest impact on Vodafone's communications network.

Very few sites were considered vulnerable to direct tsunami impact, with effects considered minor to nil.

The Vodafone network is expected to recover within a short time (0 - 2 days depending on severity), but recovery will be largely dependent on other telecommunications operators for delivery of Vodafone services to land and international lines.

Summary: Communications

Table 25 summarises the effects of the scenario tsunami on communications lifelines in the Auckland region.

Table 25: Summary of likely effects of the scenario tsunami on communications lifelines

	Land lines	Cellular system
Telecom	• the scenario tsunami was assessed as having the lowest impact on Telecom's land line network, along with the cyclone	• the scenario tsunami was assessed as having the lowest impact on Telecom's cellular network, along with the cyclone
CLEAR	• the scenario tsunami was assessed as having the lowest impact on CLEAR'S network, along with the cyclone	
Vodafone		• only a very small selection of sites were considered likely to experience to have any direct impact from tsunami, and the effects were considered minor to nil

5.4.2 Transport lifelines

Roads

Although several small coastal roads would be closed, these areas have enough redundancy for the road network to keep operating. Minimal scouring of bridge abutments and loss of services crossing bridges is expected

The scenario tsunami would have limited impact on the roading network. Although several small coastal roads would be closed by damage, most of these areas have enough redundancy to allow the network as a whole to keep operating. The possibility of scouring around bridge embankments was examined, as this affects both the structural safety of the bridge and the security of buried services that use the bridge as a crossing point. Generally only minimal scouring is expected, with services more likely to be affected by slips elsewhere in the road network. However, bridges over long narrow estuaries may be more susceptible.

A typical recovery profile of a vulnerable section of road following a cyclone or tsunami would see the road closed by water during and immediately after the event. Capacity should be quickly restored as the waters recede and, as long as there is no scouring, full capacity should be achieved within two days (refer to the recovery profile assumptions in Chapter 2).

Strategic arterial routes are generally unaffected

Strategic arterial routes are generally far enough from the coast to be unaffected by the tsunami scenario. However, several sections of SH1 to the north of the city are likely to be affected where the road crosses rivers at low topographical points (the new Albany - Puhoi section of SH1, ALPURT, will eliminate these problems).

The worst affected state highway is SH16, because the causeway at Waterview is only one metre above mean sea level. This section is expected to be inundated, although an alternative route is available for diverted traffic. Further towards Helensville the road is expected to be completely closed where the Kaipara River will flood, and in this case there is no suitable detour. The Harbour Bridge approaches are likely to have temporarily reduced capacity during the event due to inundation from sea water. Strategic routes tend to be built to a higher standard and are therefore less vulnerable to scouring or damage from the incoming or receding sea water.

Although three strategic road sections may be flooded, little damage is expected

Tamaki Drive is the strategic route most vulnerable to the scenario tsunami. The tsunami waters will damage vehicles and cliffs as well as damaging or undermining the carriageway by scouring. However, there are enough alternative routes to avoid a significant effect on the road network.

The greatest impact is on local roads near the coast

The scenario tsunami is likely to have a greater impact on local roads than any other transport mode, because local roads are common in low lying or coastal areas. Roads on eastern shores are the most vulnerable to damage from inundation and scouring, although most have alternative routes should they become impassable. Damage is likely on many of the local roads with culverts and bridges, as receding waters could cause scouring. This increases the delay in reopening the roads to full capacity.

Rail

Most rail lines are away from the coast

The only rail route likely to be at risk during the scenario tsunami is around the Mechanics Bay/Orakei Basin area, where water may cover the line temporarily. All other tracks are far enough from the coast or high enough above rivers to be probably unaffected. No rail bridges have been identified as vulnerable to scouring from receding waters.

Recovery profile

A typical recovery profile of a section of rail network following a tsunami is up to 100% after the first day, although the Mechanics Bay section may not be completely repaired for up to a month (refer to the recovery profile assumptions in Chapter 2).

Ports

With enough warning ports can prepare for and withstand tsunami

Given enough warning, the ports can prepare for the scenario tsunami and minimise damage. Ships can be put out to sea to ride the waves more safely and containers can be moved to positions that will be more robust when the water rises. Again, vessels that have broken free may cause the most damage, along with other debris that may be washed over the port by the water.

Recovery profile

Recovery should be swift as long as access and power are maintained. As with the scenario cyclone, the ports should be back to 100% operations within one or two days after shutting down during the event.

Airport

The airport is not affected by a tsunami

The airport is high enough above mean sea level not to be at risk of inundation by the scenario tsunami. The runway is at least 4 metres above mean sea level, and is higher in many areas. Any waters that do encroach on airport land are not likely to lead to scouring. Roads to the airport would remain open at all times.

Recovery profile

A recovery profile for the airport sees the airport at 100% for the tsunami's duration (refer to the assumptions in Chapter 2).

Summary: Transport

Table 26 summarises the effects of the scenario tsunami on transport lifelines in the Auckland region, illustrating the vulnerability of coastal road and rail networks.

Table 26: Summary of likely effects of the scenario tsunami on transport lifelines

<table>
<tr><th rowspan="4">Road</th><th colspan="2">All roads</th></tr>
<tr><td colspan="2">• limited impact on the road network overall
• several small coastal roads would be closed by damage, but most of these areas have enough redundancy to allow the network as a whole to keep operating
• generally only minimal scouring is expected around bridge embankments
• services that use bridges as a crossing point are more likely to be affected by slips elsewhere in the road network
• bridges over long narrow estuaries may be more susceptible</td></tr>
<tr><th>Strategic and non - strategic arterials</th><th>Local roads</th></tr>
<tr><td>• strategic arterial routes are generally far enough from the coast to be unaffected by the tsunami scenario. However, several sections of SH1 to the north of the city are likely to be affected where the road crosses rivers at low topographical points (the new ALPURT route will eliminate these problems)
• the worst affected state highway is SH16, with inundation at Waterview (detour available) and road closure by Helensville at the Kaipara River (no detour)
• Harbour Bridge approaches are likely to have temporarily reduced capacity during the event
• strategic routes tend to be built to a higher standard and are therefore less vulnerable to scouring or damage from the incoming or receding sea water
• Tamaki Drive is most vulnerable. The tsunami waters will damage vehicles and cliffs as well as damaging or undermining the carriageway by scouring. However, there are enough alternative routes to avoid a significant effect on the road network.
• the tsunami will not generally affect other arterial roads</td><td>The scenario tsunami is likely to have a greater impact on local roads than any other transport mode, because local roads are common in low lying or coastal areas. Roads on eastern shores are the most vulnerable to damage from inundation and scouring, although most have alternative routes should they become impassable. Damage is likely on many of the local roads with culverts and bridges, as receding waters could cause scouring. This increases the delay in reopening the roads to full capacity</td></tr>
<tr><th>Rail</th><td colspan="2">• the only rail route likely to be at risk during the scenario tsunami is around the Mechanics Bay/Orakei Basin area, where water may cover the line temporarily
• all other tracks are far enough from the coast or high enough above rivers to be probably unaffected
• no rail bridges were identified as vulnerable to scouring from receding waters</td></tr>
<tr><th>Ports</th><td colspan="2">• given enough warning, the ports can prepare for the scenario tsunami and minimise damage. Ships can be put out to sea to ride the waves more safely and containers can be moved to positions that will be more robust when the water rises
• vessels that have broken free may cause the most damage, along with other debris that may be washed over the port by the water</td></tr>
<tr><th>Airport</th><td colspan="2">• the airport is high enough above mean sea level not to be at risk of inundation by the scenario tsunami. The runway is at least 4 metres above mean sea level and is higher in many areas
• any waters that do encroach on airport land are not likely to lead to scouring. Roads to the airport would remain open at all times</td></tr>
</table>

5.4.3 Energy lifelines

Electricity

The Hepburn Road substation may be at risk from a tsunami, but it is assumed the Waitemata's narrow entry and wide harbour will attenuate this risk.

The Tamaki Estuary may also be vulnerable but Transpower and Contact Energy assets at Otahuhu are well designed, with damage not foreseen since the building platform is more than 2m above ground level.

Petroleum fuels

Freemans Bay could be vulnerable to the scenario tsunami, but the only critical fuel stored is Avgas. The industry could maintain supply if Freemans Bay were flooded, provided there was good road access within the region.

The Wiri oil terminal is not at risk from waves less than 2.5m high.

Gas

The scenario tsunami was not identified as posing a threat to Natural Gas Corporation assets or to the Westfield Gate Station

Summary: Energy

Table 27 summarises the effects of the scenario tsunami on energy lifelines in the Auckland region, generally indicating that effects would be minor.

Table 27: Effects of the scenario tsunami on the Auckland region's energy supplies

ELECTRICITY	PETROLEUM	GAS
• the Hepburn Road substation may be at risk from tsunami but it is assumed the Waitemata's narrow entry and wide harbour will attenuate this risk • the Tamaki estuary may also be vulnerable but Transpower and Contact Energy assets at Otahuhu are well designed, with damage not foreseen since the building platform is more than 2 m above ground level	• Freemans Bay could be vulnerable to the scenario tsunami, but the only critical fuel stored is Avgas. The oil companies could maintain supply if Freemans Bay were flooded, provided there was good road access within the region • the Wiri oil terminal is not at risk from waves of less than 2.5 m	• the scenario tsunami was not identified as posing a threat to Natural Gas Corporation assets or to the Westfield Gate Station

5.4.4 Water lifelines

Both the Waitemata Harbour bridges were identified as remaining largely unaffected by the scenario tsunami, as would the water services carried across them.

Effects of the scenario tsunami would similar to those of the cyclone storm surge but the greater wave height would cause more damage.

Water supply

Tsunami are not a risk to Watercare's regional water delivery systems

Tsunami are not a risk to Watercare's regional water delivery systems. Their duration will be short and they would have a negligible if any effect upon the underground aquifer in Onehunga.

Local instability could affect access to some assets for a period, and may cause some local sections of cast iron main in potentially unstable areas to fail. In almost all cases an alternative supply can be provided.

Local water networks are unlikely to be significantly affected provided Watercare can continue to maintain reservoir supplies, but may be affected by localised problems affecting a relatively small number of customers

Local water networks are unlikely to be seriously affected by a tsunami provided Watercare can continue to maintain reservoir supplies. Local networks may however be affected by localised problems such as coastal erosion, albeit affecting a relatively small number of customers.

Key effects of the scenario tsunami would be:

- coastal scouring likely to affect local water mains. Shutoff valves would minimise area affected
- bridges with water and other services on them would be at risk
- local instability may cause some local sections of cast iron main in potentially unstable areas to fail
- local instability could affect access to some assets for a period

Recovery profile

The basic recovery profile for water supply services after the scenario tsunami is (refer to the assumptions in Chapter 2):

- 1 day: very little damage reported. Possible structural failure of exposed pipelines and minor damage at reservoirs would be detected. There would be very little loss of service
- 1 week: maintenance of exposed pipelines would be well under way
- time to full recovery: 4 - 6 weeks, assuming unlimited resources. Temporary pump stations would be in place

Most of Watercare's wastewater system is not vulnerable

In a very severe tsunami, one or more of Watercare's many wastewater pipe bridge crossings over creeks or tidal areas could settle, move or collapse, discharging raw sewage into the environment. However, Watercare's sewerage system is not very vulnerable to the scenario tsunami, as almost all assets are above the area of influence. The few steel pipe bridges that may be affected by a tsunami are not expected to suffer damage.

Wastewater

Local wastewater networks throughout the region are vulnerable to flooding by stormwater. This happens moderately frequently, resulting in sewage overflows as systems' hydraulic capacity is exceeded. Overflows are likely

Local wastewater networks share the vulnerabilities of Watercare's networks. They are unlikely to be significantly affected by tsunami or cyclonic storms, provided Watercare can continue to supply water to maintain reservoir supplies. Localised problems such as slips may affect a relatively small number of their customers.

Local wastewater networks throughout the region are vulnerable to flooding by stormwater. This happens moderately frequently, resulting in sewage overflows as systems' hydraulic capacity is exceeded. Overflows are likely in a tsunami.

Key effects of the scenario tsunami were:

- scouring of bridge piers, pipe bridges possibly affected
- localised flooding
- sea water ingress into the wastewater system, resulting in increased wastewater overflows.
- erosion may occur at coastal pumping stations and foreshore sewers, especially at east coast beaches
- wastewater pumping stations in coastal areas would be inundated
- salt water intrusion would affect control boxes
- possible electrical failure from leakage into buildings, with power outages removing pumping capabilities and causing overflows, especially in those with montrose boxes
- some stations would be affected by leakage at high tide
- overtopping and/or scouring of the Mangere and Orewa ponds is possible, with odour incidents possibly resulting
- the Mangere wastewater treatment plant may be affected
- bridges carrying mains near the coast likely to be affected by coastal scouring.

Recovery profile

The basic recovery profile for wastewater services after the scenario tsunami is (refer to the assumptions in Chapter 2):

- 1 day: complete inundation of coastal regions — Bucklands Beach, eastern beaches, East Coast Bays and Auckland beaches, Beachlands - Maraetai. About 10 pump stations would be directly affected, resulting in overflows. Pump station switchboard gear would be affected by saltwater intrusion, with no pumping available. At risk coastal pipelines and possible structural failure in coastal environments, along with any uncontrolled discharges would be identified
- 1 week: pump station maintenance crews would be at work with initial repairs started or temporary switchboards in place. Temporary repair to pipe bridges and coastal pipelines would have started.
- time to full recovery: 4 - 6 weeks, assuming unlimited resources. Temporary pump stations would be in place

Stormwater

The scenario tsunami would cause greater flooding and scouring of stormwater networks than the scenario cyclone. Key impacts were identified as:

- localised and regional flooding causing stormwater ingress into the stormwater system
- scouring of bridge piers possibly affecting pipe bridges
- risk of slope failure causing breakages of stormwater pipelines
- blockages caused by debris in the system

Recovery profile

Problems are likely to be localised. Recovery profiles for stormwater services would be (refer to the assumptions in Chapter 2):

- 1 day: complete inundation of coastal regions, with possible structural failure in coastal environments affecting pipes
- 1 week: essential repairs would be under way
- time to full recovery: 4 - 6 weeks, assuming unlimited resources. Remediation of affected pipelines would be complete

Summary: Water

Table 28 summarises the effects of the scenario tsunami on water lifelines in the Auckland region, showing that generally, wastewater and stormwater networks are more vulnerable than water supply networks, especially bulk supplies.

Table 29 summarises the effects of the scenario tsunami on all the lifelines in the Auckland region.

Table 28: Summary of likely effects of the scenario tsunami on wastewater, water and stormwater services

WATER SUPPLY	WASTEWATER SYSTEM	STORMWATER
• minor effects • coastal scouring likely to affect local water mains. Shutoff valves will minimise area affected • bridges with water and other services on them at risk • local instability may cause some local sections of cast iron main in potentially unstable landforms to fail • local instability could affect access to some assets for a period	• as for cyclone storm surge but greater wave height and more damage • erosion may occur at coastal pumping stations and foreshore sewers especially at east coast beaches • wastewater pumping stations on coastal areas would be inundated • salt water intrusion would affect control boxes • power outages would remove pumping capabilities. • some stations affected by leakage at high tide • possible overtopping and or scouring of Mangere and Orewa ponds with possible odour incidents • Mangere wastewater treatment plant may be affected • bridges carrying mains near the coast likely to be affected by coastal scouring • possible electrical failure from leakage into buildings • local montrose box pumping stations at risk from electrical damage	• greater flooding and scouring than for the scenario cyclone • localised and regional flooding causing stormwater ingress into the stormwater system • scouring of bridge piers possibly affecting pipe bridges • risk of slope failure causing breakages of stormwater pipelines • blockages caused by debris in the system

Table 29: Summary of recovery profiles after the scenario tsunami

	Day 1	Week 1	Full recovery
Communications lifelines			
Land lines	100%	100%	0 days
Cellular networks	100%	100%	0 days
Transport lifelines			
Road	Coastal roads closed by flooding, small coastal roads closed by damage, but network as a whole keeps operating. Minimal scouring around bridge embankments but possible effects on bridges over long narrow estuaries	Full capacity	1 - 2 days
Rail	100% capacity, except for Mechanics Bay	100% capacity, except for Mechanics Bay	Up to 1 month for Mechanics Bay
Ports	Closure during the event	100% capacity	1 - 2 days
Airport	100%	100%	-
Energy lifelines			
Electricity	100%	100%	-
Petroleum fuels	Freemans Bay affected but Avgas is the only critical fuel stored. Supply maintained with good road access. Wiri oil terminal not affected by waves less than 2.5 m	100%, even with damage to Freemans Bay	1 - 2 days
Gas	100%	100%	-
Water lifelines			
Water supply	Little damage or loss of service. Possible structural failure of exposed pipelines and minor damage at reservoirs	Maintenance of exposed pipelines well under way	4 - 6 weeks. Temporary pump stations would be in place
Wastewater	Complete inundation of coastal regions. About 10 pump stations directly affected by saltwater intrusion, causing overflows. At risk areas and uncontrolled discharges identified	Pump station maintenance crews at work with initial repairs started or temporary switchboards in place. Temporary repair to pipe bridges and coastal pipelines started	4 - 6 weeks. Temporary pump stations would be in place
Stormwater	Complete inundation of coastal regions, with possible structural failure affecting pipes	Essential repairs under way	4 - 6 weeks. Remediation of affected pipelines would be complete

Note: All recovery profiles assume unlimited resources and unrestricted access (see Chapter 2)

Network Impact

6. NETWORK IMPACT: EFFECTS ON EACH LIFELINE OF THE SCENARIO HAZARDS

In order to enable the impact of a hazard event on the entire utility system to be assessed, this chapter examines the impact on each lifeline of the selected scenario events, outlining the vulnerabilities of each network in terms of:

- the effect of each scenario hazard on the lifelines
- recovery profiles for lifelines after each scenario hazard

This chapter duplicates Chapter 5, but groups the information by lifeline, while Chapter 5 groups the information by hazard.

This chapter is thus consequence - based rather than event - based.

Tables summarising effects and recovery profiles are included.

The structure of this chapter is:

Lifeline utilities are colour coded for ease of reference.

6.1 Communications lifelines

Overload by users is the most serious overall threat to communications networks after any hazard event in the Auckland region.

The redundancy available in both land lines and cellular networks means that in most cases some degree of service can still be provided after loss of nodes or network segments, while provided reasonable access is available, restoration after damage is also prompt.

Tables 30 - 33 summarise the effects of the scenario hazards on communications lifelines, while Table 34 summarises communications lifelines recovery profiles after all the scenario events.

In general, the longest recovery period for communications networks is after an eruption because of the effects of ash on air conditioning systems in key nodes: this is estimated to be a week in cool weather, but longer in hot weather as a result of higher ambient air temperatures.

Recovery from earthquake is estimated to take one to two days, while the scenario tsunami and scenario cyclone were assessed as having the lowest impact on communications networks, apart from the impact on individual affected customers.

6.1.1 Earthquake

Telecom

Loss of the three southern fibre optic transmission systems carried through the isthmus on bridges would result in a severe loss of capacity and considerable congestion of communications crossing the isthmus

Telecom's land line communication backbones are generally ring - configured with route redundancy, and rupture of multiple paths would be needed before service was affected. Some areas of the network still rely on single path access and will be susceptible to isolation in the event of duct route damage, but over time, as redundancy grows throughout the network, the number of nodes at risk will decrease. The loss of any one route may not have a serious effect on the network overall, but will lead to increased congestion in some places.

The most serious direct threat to network capacity is loss of one or more duct lines in ground at risk of liquefaction or displacement. Loss of any of these major routes would cause:

- full or partial outage in the Devonport, Whitford, Te Atatu North and Glendowie areas
- increased user congestion due to reduced network capacity

However, these areas have alternative routes or redundant capacity through which some service could be maintained.

Older bridges carrying network ducts are vulnerable parts of the communications network. Limited bridge movement could be tolerated, but collapse would take the duct lines out of service

All three southern fibre-optic transmission routes are carried over separate bridges through the narrow point of the Auckland isthmus, and two overlay digital microwave radio networks also cover this risk area. One network carries the national digital microwave radio backbone and the other, which is for local Auckland access, has three diverse connection points.

Loss of the three southern fibre optic transmission systems carried over separate bridges through the narrow point of the Auckland isthmus would result in a severe reduction in capacity. Public switched telephone network service could still be maintained but there would be considerable congestion of communications.

Where fibre-optic rings are damaged in only one place, there should be no effect on service or capacity

Where network duct lines cross natural features such as harbours, rivers and estuaries, they are attached to road or rail bridge structures with a risk of damage at connections across the bridge abutments or at the structure - to - ground interface. Some of the bridges carrying high capacity fibre-optic routes are of modern design which is assessed as being sound, such as Mangere Harbour Bridge. Other bridges are considerably older, such as the Otahuhu Bridge on Great South Road and the Orakei Estuary bridge at Pakuranga, though flexible duct design is estimated to allow for some movement at the more vulnerable points. Limited bridge movement could be tolerated, but a collapse would take the duct lines out of service.

Where the capacity carried is part of a fibre-optic ring and the damage is limited to only one location, there should be no effect on service or capacity.

Rain water damage to electrical systems is a higher risk than structural weakness of buildings

The communications node buildings that are most susceptible to earthquake damage are brick and concrete built before 1976. These buildings were conservatively designed by the Ministry of Works for far higher internal equipment loading than they carry today, so no major structural or foundation problems are expected. The worse case damage expected in buildings includes wall fractures and roof support failures, especially where there is a high component of glass. Resulting damage from rainwater poses a serious risk, so site access for damage assessment and repair work would be urgently required after such an event. The risk of fire immediately after an earthquake, though acknowledged, was not analysed.

Equipment miniaturisation helps distance it from the effects of building damage

The progressive miniaturisation of modern switching hardware has reduced the space formerly occupied in exchanges. It is thus often placed well away from glass and walls and is therefore less vulnerable if the surrounding structure is damaged. Roof failures, however, would be a major concern requiring urgent repair to avoid or minimise water damage.

The risk of earthquake damage to storage batteries has been considerably reduced with the move to localised end cabinet storage, with sealed (valved) storage devices or 'gel cells'.

Digital microwave radio links are relatively immune from earthquake damage. There is a reasonable amount of tolerance in beam alignment before total link failure. While there may be temporary link loss while the radio mast is swaying, the mast is unlikely to be completely felled. Any misalignment can be readjusted relatively easily after movement ceases.

Power for microwave terminal equipment is important and existing emergency generation plant at these sites should be able to provide this.

The loss of any one of Telecom's land line routes may not have a serious effect on the network overall, but will lead to increased congestion in some places.

Recovery profile

The recovery profile for network service was assessed to be 1 to 7 days (refer to the recovery profile assumptions in Chapter 2).

CLEAR

Both the uniform and scenario earthquake hazard analyses identified that the CLEAR network was only vulnerable if both sides of the fibre-optic rings were damaged, or if the core network node were damaged.

Areas where breakage of fibre optic rings could be expected are:

- Orakei Basin
- Harbour Bridge
- Upper Harbour Bridge
- rail bridges

Outage at any single one of these points would not cause a loss of service.

Recovery profile

The recovery profile for the temporary repair to any damaged CLEAR fibre optic cables is expected to be under 2 days.

Vodafone

Vodafone's main communication backbone in Auckland, Waikato and the Bay of Plenty is by route diversity microwave system with spurs off to additional cell sites. Interconnection to land line and other major cities is via route and carrier diversity systems with other telecommunications operators. Vodafone depends on Telecom for connection to and from land line calls.

After an earthquake the use of mobile phones would be significant, with considerable congestion initially expected

While individual cell sites may suffer loss of service, the network has significant overlapping coverage which will still deliver service, although capacity may be reduced.

Digital microwave radio links are relatively immune from earthquake damage. There is a reasonable amount of tolerance in beam alignment before total link failure. While there may be temporary link loss while the radio mast is swaying, the mast is unlikely to be completely felled. Any misalignment can be readjusted relatively easily after movement ceases.

While individual cell sites may suffer loss of service, the network has significant overlapping coverage which will still deliver service, although capacity may be reduced

The main communications node buildings that are most susceptible to earthquake damage are expected to suffer damage from glass and rainwater due to glass failure on external walls, urgently necessitating site access for damage assessment and repair work. The risk of fire immediately after an earthquake, though acknowledged, was not analysed.

Batteries in all sites are sealed and housed in seismic rated cabinets.

Digital microwave radio links are relatively immune from earthquake damage. There is a reasonable amount of tolerance in beam alignment before total link failure

After an earthquake the use of mobile phones would be significant, with considerable congestion initially expected.

All major network nodes are backed up with diesel generation systems, and each cell site has the capability to be powered by small generators as required. Vodafone holds a number of generators for emergency power generation.

Recovery profile

Recovery time within the Vodafone network is expected to be within a short time (0 - 2 days depending on severity), but is largely dependent on other telecommunications operators for delivery of services to landlines and international (when assessing recovery profiles, refer to Chapter 2 which outlines the assumptions made).

Table 30: Summary of likely effects of the scenario earthquake on communications lifelines

	Land lines	Cellular system
Telecom	• some duct lines in ground at high risk of liquefaction or displacement. Serious threat: loss of major routes would impact on service in the Devonport, Whitford, Te Atatu North and Glendowie areas, with either full or partial outage, reduced network capacity and increased congestion. NB: alternative routes or redundant capacity can maintain service. No effect if fibre-optic rings are damaged at only 1 point • duct lines across older bridges at risk: limited movement tolerated but collapse would take duct lines out of service resulting in severe loss of capacity. Public switched services still maintained, but congestion of communications • pre-1976 brick and concrete node buildings at risk,, with rainwater damage a serious risk. Fire a possibility though not assessed • less risk to digital microwave radio links; possible temporary loss while radio mast sways is easily readjusted. Loss of mast unlikely	• the connections between cellular sites (antennae) and their parent switches may be compromised by damage to the public switched telephone network fibre-optic transmission system, although dedicated digital microwave radio links may be less affected. Links to minor cell sites more at risk • overseas experience has shown that within 15 to 30 minutes of an emergency, the mobile network can become seriously overloaded even when free channels may still be available

CLEAR	• The CLEAR network is only vulnerable and services would only be affected if both sides of the fibre optic rings were damaged or a core network node were damaged. Areas where breakage could be expected are:
	  • Orakei Basin
	  • Harbour Bridge
	  • Upper Harbour Bridge
	  • rail bridges
	• outage at any single one of these points would not cause a loss of service	

Vodafone		• service possibly at risk from damage to networks of other telecommunications operators • individual cell sites may suffer loss of service, but network has overlapping coverage which will still deliver service, though capacity may be reduced • digital microwave radio links are relatively immune from earthquake damage • susceptible communications node buildings may suffer damage from glass and rainwater. Site access for damage assessment and repair work would be urgently needed. Fire a possibility but not assessed • post-event use of mobile phones will be significant and considerable congestion is initially expected

6.1.2 Volcanic eruption

Telecom

The scenario eruption indicated a vulnerability of the CBD fibre-optic ring, which relies on some locally powered equipment at the nodes that access the ring. Local power failures could isolate the service the ring provides, although the fibre cable itself was assessed as being far enough away from the eruptive centre to remain intact.

Outside the zone of immediate destruction, volcanic ash fall would have a serious impact. Emergency generation and air conditioning plant were assessed as being the network components most vulnerable to the abrasive dust generated by volcanic activity. The control of air intakes is a high priority, with the construction of temporary pre - filters an important task. These filters would need to be fitted to air intakes for telecommunications plant and emergency generators, with plant air conditioning set to recirculate air. These countermeasures may mean temporary suspension of customer service during maintenance checks and plant servicing. Although these would generally be done after normal business hours, service may be interrupted at any time if more urgent repair or service were needed.

Air conditioning systems are at risk and may need to be shutdown until the environment is cool enough to bring it back into service

Air conditioning systems also rely upon air transfer or water tower cooling systems to remain operational, and there is a risk of insufficient cooling if these systems lose efficiency. Shutdowns may be needed until the equipment's environment can be cooled down enough to bring it back into service. The duration would be affected by ambient temperature, that is, hotter weather would cause longer shutdown periods.

Ash fall is the most serious issue outside the zone of destruction

Failure of electricity supplies would necessitate increased maintenance, lubricant changes and filter cleans or changes of on site emergency generation plant.

While volcanic ash fall was assessed as having a low impact on towers and antennae for digital microwave and related radio systems, including cell sites, their supporting air conditioning and emergency generating equipment was identified as vulnerable.

Ash fall could overload flat roofs at equipment sites and damage air conditioners and generators

The flat roofs of a number of Telecom equipment sites indicate a need for ash clearing measures to prevent roof collapse.

The links to Devonport, Waiheke Island and Glendowie were identified as vulnerable to volcanic activity and these network nodes could become isolated. This would limit telephone service to local calling only within these areas until alternative bearer capacity was provided. It is possible for some extended range cellular coverage to provide service into these areas, but congestion is very likely. An alternative bearer to Waiheke is available, but this would take several days to arrange.

Advance warning of an eruption would help with planning of temporary repairs and alternative services

Temporary repairs by aerial laying of fibre-optic cables would restore service to Devonport and Glendowie, but again this could take several days to complete.

The cellular network is less vulnerable to the scenario eruption than land lines

Cellular network nodes are evenly distributed over the Auckland area and hence the network as a whole is likely to be less seriously damaged than the ground - based public switched telephone network. However, links to the cell sites in the more vulnerable areas are also likely to be affected. Neighbouring cell sites would extend their range into such affected areas as the terrain would allow, but there may be an increase in black spots or shadow areas of no service. There may also be cellular congestion problems as fewer operational cell sites try to cope with dramatically increased traffic in these areas.

Recovery profile

Service to affected nodes could be restored in 2 - 7 days (refer to the recovery profile assumptions in Chapter 2).

CLEAR

The volcanic hazard analysis identified the CLEAR network was only vulnerable if both sides of the fibre optic rings were damaged

The volcanic hazard analysis identified that the CLEAR network would only be vulnerable if both sides of the fibre optic rings were damaged or the core network node were damaged.

The scenario eruption indicated a possibility that a small segment of the network or a single node could be destroyed in the near vent region.

Recovery profile

The recovery profile back to full service following a volcanic ash fall is estimated to be 1 to 2 days unless the network node were to suffer severe damage.

Vodafone

Air conditioning plant and direct air access to plant were assessed as being most vulnerable to the dust and gases generated by volcano activity. The control of air intakes and addition of extra filters will be an important task, while maintaining these filters could be time consuming

Air conditioning plant and direct air access to plant were assessed as being most vulnerable to the dust and gases generated by volcano activity. The control of air intakes and addition of extra filters will be an important task, while maintaining these filters could be time consuming.

The major nodes have flat roofs, so clearing ash away would also be a high priority.

Depending on the depth of ash fall, the use of vehicles may be limited because of air filter clogging.

Microwave linking is not expected to suffer from ash fall.

The cellular network nodes are more evenly distributed over the Auckland area and hence are less likely to be as seriously damaged. While individual cell sites may suffer loss of service, the network has significant overlapping coverage, which will still deliver service. However, capacity may be reduced, causing congestion as fewer operational cell sites try to cope with dramatically increased traffic in these areas.

Cell sites themselves were assessed as having a low vulnerability to volcanic ash fall.

The Vodafone network is expected to recover within a short time (0 - 2 days depending on severity), but recovery will be largely dependent on other telecommunications operators for delivery of Vodafone services to land and international lines.

Table 31: ***Summary of likely effects of the scenario eruption on communications lifelines***

	Land lines	Cellular system
Telecom	• emergency generation and air conditioning plant vulnerable to abrasive dust, so there may be some suspension of customer service during maintenance checks and servicing, generally after normal business hours but service may be interrupted at any time if urgent repair or service is needed • shutdowns may be needed until the equipment's environment can be cooled to bring it back into service. Hotter weather would cause longer shutdown periods • ash fall would have a low impact on towers and antennae for digital microwave and related radio systems, but air conditioning and emergency generating equipment is vulnerable • links to Devonport, Waiheke Island and Glendowie could become isolated, limiting service to local calling only within these areas until alternative bearer capacity was provided. Some extended range cellular coverage could provide service, but congestion is very likely. An alternative bearer to Waiheke would take several days to arrange • the CBD fibre-optic ring is vulnerable. Local power failures could isolate the service the ring provides, although the fibre cable itself was assessed as being far enough away from the scenario eruption to remain intact • recovery profiles are affected by the ability of maintenance staff to travel to affected sites	• cellular network nodes are more evenly distributed over the Auckland area and hence are less likely to be as seriously damaged as the ground - based public switched telephone network • however, links to the cell sites in the more vulnerable areas are also likely to be affected. Neighbouring cell sites would extend their range into such affected areas as the terrain would allow, but there may be an increase in black spots or shadow areas of no service • there may also be cellular congestion problems as fewer operational cell sites try to cope with dramatically increased traffic in these areas
CLEAR	• the CLEAR network is only vulnerable if both sides of the fibre optic rings were damaged of the core netwrok node were damaged	
Vodafone		• air conditioning plant and direct air access to plant is vulnerable to ash fall and gases • depending on the severity and quantity of ash fall, the use of vehicles maybe limited due to air filter clogging • microwave linking is not expected to suffer from ash fall • cellular network nodes are more evenly distributed over the Auckland area and hence are less likely to be seriously damaged. While individual cell sites may suffer loss of service, the network has significant overlapping coverage which will still deliver service • capacity may be reduced, causing congestion problems as fewer operational cell sites try to cope with dramatically increased traffic in these areas

6.1.3 Tropical cyclone

Telecom

The scenario cyclone and tsunami were both assessed as having the lowest impact on Telecom's communications network, apart from the impact on individual customers. All Telecom communication equipment buildings were assessed.

Only 12% of Telecom's network nodes were identified as being vulnerable to a cyclone. These are generally smaller exchange buildings and the sites are well distributed over the network area. Road access for damage assessment and temporary repair is important. Impact should be minimal provided remedial action can be taken before serious water damage occurs. The impact would be limited to suburban customer lines.

Water damage and landslip are the main risk, with wind damage enabling water to get in to electrical equipment

While fibre optic cable is comparatively immune to water damage, there is a risk of damage if the cable is stretched or kinked by slips and washouts. The reliability of the network depends upon 'safe path' cable routes and redundancy. Landforms in some areas are less stable than others and there are limits to the availability of alternative duct lines or routes.

Six nodes were identified as being vulnerable to high winds, five having fibre - cement roof cladding and one having clay tiles. Aged fibre - cement is acknowledged as a brittle roof covering and the strength of the fastenings is essential for retention. Tile roofs are assumed to have a louvre effect to release roof pressure in extreme conditions, but are normally fastened at every second row, so loose tiles can be a hazard. Equipment buildings with large glass walls were identified as vulnerable to flying debris, but the equipment in a number of these is centred remotely from this hazard.

All Telecom buildings undergo a five - yearly detailed inspection audit, which includes sampling the strength of the roof cladding fixings. This building audit feeds into the building maintenance programme that helps determine work contract priorities for replacement and repair.

Six cable crossings were identified as being prone to flooding or washout but the impact on the overall network was assessed as relatively minor.

One site in west Auckland has been known to be flooded in the past twenty years. This site has subsequently had a stop bank improvement, additional flood pumps and other mitigation work to limit the likelihood of recurrence.

Recovery profile

Service to affected network nodes could be restored in 1 - 4 days (refer to the recovery profile assumptions in Chapter 2).

CLEAR

Analysis indicated there would not be any significant damage to CLEAR's network, apart from possible loss of external building cladding resulting in water damage.

Vodafone

The scenario cyclone and tsunami were both assessed as having the lowest impact on Vodafone's communications network.

Very few Vodafone sites were considered to suffer any direct tsunami impact, with effects considered minor to nil.

The Vodafone network is expected to recover within a short time (0 - 2 days depending on severity), but recovery will be largely dependent on other telecommunications operators for delivery of Vodafone services to land and international lines

The roof of one major node was identified as being vulnerable to high winds and work is currently underway to minimise this risk. Another node has large glass walls and was identified as vulnerable to flying debris and rain penetration.

Individual cell sites have been designed to cope with severe conditions, and the buildings themselves are secure. However, flying debris such as roofing iron from other buildings is a potentially serious hazard.

The vulnerabilities of individual cell sites were identified as power and access to sites for installing generation equipment.

Recovery profile

The Vodafone network is expected to recover within a short time (0 - 2 days depending on severity), but recovery will be largely dependent on other telecommunications operators for delivery of Vodafone services to land and international lines.

Table 32: Summary of likely effects of the scenario cyclone on communications lifelines

	Land lines	Cellular system
Telecom	• the scenario cyclone has the lowest impact of the hazards assessed, with no impact on the overall network and only individual customers affected. 12% of Telecom's network nodes were identified as being vulnerable. These are generally smaller exchange buildings and the sites are well distributed over the network area. Impact should be minimal provided access for damage assessment and repair can be taken before serious water damage occurs. The impact would be limited to suburban customer lines • fibre-optic cable is comparatively immune to water damage, but could be damages by being stretched or kinked by slips and washouts in unstable areas • 6 nodes are vulnerable to high winds • 6 cable crossings are prone to flooding or washout	• the cellular transmitting and receiving site antennae are rated to withstand winds in three ranges from 160 to 240 kph • impact on the overall network assessed as relatively minor apart from the impact on individual affected customers
CLEAR	• there would not be any significant damage to CLEAR's network, apart from possible loss of external building cladding resulting in water damage	
Vodafone		• 1 major node has a roof vulnerable to high winds and another node with large glass walls is vulnerable to flying debris and rain penetration • damage is most likely from flying debris • provided there is access to individual cell sites to install generation equipment, effects should be minor

6.1.4 Tsunami

Telecom

The scenario tsunami, along with the scenario cyclone, was assessed as having the lowest impact on Telecom's communications network, apart from the impact on individual affected customers. There was no disruption to network service.

CLEAR

The tsunami hazard analysis identified there would not be any significant damage to the CLEAR network.

Vodafone

The scenario cyclone and tsunami were both assessed as having the lowest impact on Vodafone's communications network.

Very few sites were considered vulnerable to direct tsunami impact, with effects considered minor to nil.

The Vodafone network is expected to recover within a short time (0 - 2 days depending on severity), but recovery will be largely dependent on other telecommunications operators for delivery of Vodafone services to land and international lines.

Table 33: Summary of likely effects of the scenario tsunami on communications lifelines

	Land lines	Cellular system
Telecom	• the scenario tsunami was assessed as having the lowest impact on Telecom's land line network, along with the cyclone	• the scenario tsunami was assessed as having the lowest impact on Telecom's cellular network, along with the cyclone
CLEAR	• the scenario tsunami was assessed as having the lowest impact on CLEAR'S network, along with the cyclone	
Vodafone		• only a very small selection of sites were considered likely to experience to have any direct impact from tsunami, and the effects were considered minor to nil

Table 34: Summary of communications lifelines recovery profiles after the scenario events

	Day 1	Week 1	Full recovery
Earthquake			
Land lines	Severe loss of capacity	100%	1 - 7 days
Cellular networks	Loss of some capacity	100%	1 - 7 days
Eruption			
Land lines	0 - 100%	100%	2 - 7 days
Cellular networks	0 - 100%	100%	2 - 7 days
Cyclone			
Land lines	90%	100%	1 - 4 days
Cellular networks	90%	100%	1 - 4 days
Tsunami			
Land lines	100%	100%	0 days
Cellular networks	100%	100%	0 days

Note: All recovery profiles assume unlimited resources and unrestricted access (see Chapter 2)

6.2 Transport lifelines

The most important task is to provide basic routes for emergency services

After a hazard event, the most important task would be to establish strategic routes for basic north - south and east - west road access, even if only for emergency vehicles. These strategic routes would preferentially use surviving motorways or state highways, but surviving lengths of smaller roads may also need to be used.

Capacity describes a road's ability to handle traffic; for example an accident that closes two of four motorway lanes is said to have reduced the route's capacity by 50%, though the road is still open. Capacity analyses have therefore been used to describe roading ability to accommodate vehicle traffic after a hazard event.

Disaster would alter traffic patterns

Immediately after a hazard event, all normal traffic would cease, only to be quickly followed by mass congestion as people tried to travel to check on family and property.

Tables 35 - 38 summarise the effects of the scenario hazards on transport lifelines, while Table 39 summarises transport lifelines recovery profiles after all the scenario events.

In general, the longest recovery period for transport networks is after an earthquake because of damage to bigger bridges. However, in some worst case scenarios, eruptions destroy the port or airport, and it could take months to years to replace them.

Recovery from cyclone and tsunami is estimated to take one to two days (apart from Mechanics Bay, which could be out of commission for up to a month after a tsunami), while the scenario eruption could also disrupt all modes of transport for up to a week.

6.2.1 Earthquake

Roads

Bridges and reclamations are risk points

Typical recovery profiles show 10 - 50% capacity a week after an earthquake

Restoring road access may not mean they can operate at full capacity: metal surfaces, speed restrictions and the presence of heavy plant may cause reduced flow and congestion. Roads may thus be temporarily restored to a functional state but may not be fully operational for some time

Many key roads will not be available after the scenario earthquake, while others will have reduced capacity. Bridges and their abutments are generally the most vulnerable points on the road network because of their vulnerability to ground movement. Their failure reduces capacity at only a few key points, but blocks the entire route.

Large unsecured pipelines may also cause damage if during an earthquake, they thrash about and damage the structure as well as other services on the bridge. A review of the seismic restraint of services may be desirable for risk mitigation.

Roads on liquefiable or unstable soils are the other main weakness in the network, with routes built on reclaimed land particularly at risk.

However, restoring road access may not necessarily mean they can operate at full capacity: metal surfaces, speed restrictions and the presence of heavy plant may cause reduced flow and congestion. Roads may thus be temporarily restored to a functional state, though they may not be fully operational for some time.

A typical recovery profile of a vulnerable section of road following an earthquake scenario would be closure immediately after the event and recovery to 10 - 50% capacity in the week after the event. Some roads could close but some could be unaffected. Most roads would be back to near full capacity within a month, although some with larger bridge structures could take up to six months (refer to the assumptions in Chapter 2).

Strategic arterial roads would be greatly affected by the earthquake scenario. Older multi - span bridges and abutments along motorways and state highways such as around Spaghetti Junction would be most vulnerable to damage from ground liquefaction. Other strategic arterial routes are generally built on reasonably stable ground or to a standard able to withstand an earthquake with only superficial damage.

Transit New Zealand's seismic investigation work has identified some key bridges are at risk, including:

- Khyber Pass
- Newmarket Viaduct
- Victoria Park Viaduct

Bridges along the region's most strategic arterial roads - the motorways - were identified as vulnerable points

Structures left standing will need to be temporarily closed for careful inspection, as they may have suffered internal structural damage and may need large scale repairs or demolition and rebuilding before being reopened. With traffic generally unable to use the motorway system, Great South Road and Great North Road would become the main north - south routes if they were intact.

Intact structures will need safety inspections

The greatest impact on the capacity of these and other key non - strategic arterial roads from the scenario earthquake is likely to be:

- loss of bridges and similar structures
- damage to the carriageway around bridges and abutments or where roads are built on reclaimed land

However, there is not enough information to identify whether similar structures along alternative routes like Great South Road and Great North Road would remain intact in the event of damage to the motorways. More work is thus needed to determine whether these alternative routes would be able to assume bigger roles within the network if the motorway becomes impassable.

The motorway could be 'patched' to give access for emergency vehicles, as it is not yet known if alternative routes like Great South Road and Great North Road would remain intact

Although the motorway system would generally be unusable, it could quickly be 'patched' for essential north - south use by emergency vehicles. The Harbour Bridge would withstand the event, but both the St Mary's Bay and Northcote approaches are likely to be impassable. The Upper Harbour Bridge would suffer similar problems. However, it may be possible for the Curran Street on ramp and Stafford Road off ramp to be quickly repaired to open the Harbour Bridge to emergency vehicles.

The collapse of adjacent buildings may block many non - strategic arterial roads

Many arterial routes are likely to be completely closed after the event, with adjoining buildings likely to collapse and block the road and earth movement creating gaps and uneven levels in the carriageway, especially in hilly areas. The non - strategic network should still have more passable sections than the motorway (which has more bridges), but any access will be at a much reduced capacity. This means long delays to traffic using operational sections of road and a complete loss of access to some areas.

Most local roads would be affected but there is good redundancy in the local roading network

The scenario earthquake is likely to have a widespread impact on local roads, with severe disruptions to capacity. Even minor embankments are likely to collapse, either blocking or undermining the road. Movement of liquefiable soils is likely to have more extreme effects than on arterial roads because of lower construction standards. Local roads in hilly areas and those built on reclaimed land are likely to be worst affected by soil instability, but many other roads will be unaffected and will provide alternative routes. Areas with good redundancy in the local road network are least likely to lose access.

Non - strategic arterial roads are built to a slightly lesser standard than strategic ones, and most are likely to suffer a loss of capacity from any of the hazard scenarios. Further loss of capacity on these roads is likely because businesses often line arterial roads with low rise buildings because of their good access and public profile, something that does not occur to the same extent on local roads or motorways. This increases the chance that the road would be blocked by falling debris.

Bridge approaches may be difficult to access due to flooding, Any ruptured pipes on bridge approaches would exacerbate the problem. This may also hamper access immediately after an event for repair of other lifeline services such as gas pipelines.

Because smaller traffic volumes on local roads mean they are generally designed and maintained to a lower standard than arterial roads, most local roads are vulnerable to suffering a loss of capacity. However, the generally good redundancy in the local network means that alternative routes will usually be available.

Rail

The rail network is the most vulnerable of all transport modes to ground movement and has the least redundancy

The rail network is probably the most vulnerable of all modes to earthquakes because the tracks are so sensitive to ground movement. Even minor earth movements can misalign tracks, totally impeding track capacity because there is no opportunity for detour. Engines would be trapped wherever they were when the quake occurred, and may not be able to get back to a station.

Several sections of the rail network were identified as being at high risk of slope failure, which would completely destroy sections of the track. Repairs would involve major land stabilisation and earthworks. Vulnerable sections of the rail network include those built on reclaimed land, such as across the Orakei Basin; or in hilly areas like the Waitakere Ranges.

Recovery profiles range from weeks to months

A typical recovery profile of a vulnerable section of rail network following the scenario earthquake would be zero capacity immediately after the event, and zero to 50% capacity after a week, depending on the length of track affected. If the track is affected in multiple sections along a route, it could take six months to restore full capacity. Track misalignment is a lesser problem than track loss, enabling full capacity to be restored within a few weeks or months (refer to the recovery profile assumptions in Chapter 2).

Earthquake poses the worst threat to rail services because the tracks are so sensitive to ground movement. Engines would be trapped wherever they were when the earthquake occurred and extensive repairs might be needed.

Although rail plays such an important freight function in the Auckland region, loss of services would not be significant given the likely economic effects of a hazard event on the region, especially in the immediate aftermath.

However, rail can play a major role in carrying essential supplies both for recovery and humanitarian purposes, especially if ports and airports are damaged. Loss of rail services could therefore be significant in the recovery phase.

Ports

Ports are built on reclaimed land at risk of ground movement

Both the Waitemata and Onehunga ports are built on reclaimed land, placing them at higher risk from earthquakes. Reclaimed land is generally more susceptible to ground shaking and damage could be severe enough to require an alternative port facility, with existing piles and wharves misaligned and thus unusable as docking facilities. Port operations may also be indirectly affected by impacts on rail and road connections. As a number of bridges and roads near both ports are also built on reclaimed land, they are likely to lose capacity and reduce the ports' ability to distribute cargo.

Recovery profile

A typical recovery profile of the ports following the scenario earthquake is 10% after the first day, rising to 50% within one week, as wharves are stabilised and operations can resume. However, it may be up to three months before all wharves are completely repaired and normal operations can continue (refer to the assumptions in Chapter 2).

As with rail, loss of the economic aspect of port function, especially immediately after the event, would probably not be a primary consideration. Again, however, especially if road and air access to the region were lost, any remaining port function would be extremely important for recovery (including restoration of other lifeline services) and humanitarian purposes.

However, in the long term, loss of port functions could have a very serious effect on the region's recovery. It would take months to years to rebuild another port on the Waitemata Harbour following total destruction. Diversion to other ports such as Whangarei, Tauranga and Wellington could mitigate some of the adverse effects on the national, and to some extent, the Auckland economy.

Airport

Some of Auckland International Airport Ltd's facilities are located on ground which might be subjected to a lower intensity of shaking than others because they are on stiffer soils. Previous work done for the airport (Kingston Morrison and Engineering Geology, 1993) used scenarios which encompass the 2,000 year return period scenario earthquake developed for the Auckland Engineering Lifelines Project. The information below is based on that assessment, which examined effects of earthquakes of the following average return periods:

The 150 and 450 year earthquakes might cause some inconvenience to airport users by causing delays of perhaps 1 - 2 days while runways and taxiways are inspected and minor repairs carried out

- 150 years
- 450 years
- maximum credible earthquake, estimated at 5,000 - 20,000 years

Effects were assessed on:

- aircraft pavements (runways, taxiways and aprons)
- roads and parking areas used to service the airport

The severity of effects depends on several factors including variations in soil type and whether the pavement is asphalt or concrete.

Findings were that the 150 and 450 year events might cause some inconvenience to users because of delays of perhaps 1 - 2 days while runways and taxiways are inspected and minor repairs carried out. Damage would probably consist of minor spalling, separation or differential vertical displacement as well as extrusion of sealant from between paving slabs. As commercial landing gear is designed to operate with vertical steps in the runway of 40 to 50mm, this was not expected to significantly affect operations. Access to the airport would probably be affected, but restricted access to most facilities could probably be maintained.

The following discussion therefore focuses on the more serious effects of the 2,000 year return period Auckland Engineering Lifelines Project scenario earthquake based on findings on the 5,000 - 20,000 maximum credible earthquake.

The runway is likely to displace but it may be partially useable

Minor damage to runway and taxiways from the Auckland Engineering Lifelines Project scenario earthquake is expected at several joint locations because of ground surface movements. Minor uplift and/or differential settlement of up to 300mm of parts of the runway and taxiway may result from underlying liquefaction and varying depths of shallow cohesive material. Any resulting changes in grade and level along the runway and taxiways are expected to be relatively gradual and the pavements should remain structurally sound. It may be necessary to restrict operations, for example to a reduced runway length, until repairs are made.

Roads and car parks may be affected by fractured seal, footpaths and kerbs and broken stormwater services. Secondary damage may arise from damaged buried services such as burst water mains.

Road access to the airport may be affected and damage to airport buildings and equipment may also affect operations

Road access may be affected by closure of one or more traffic lanes, but it is unlikely that any road will be completely impassable. Parts of some car parks may need to be closed off immediately after the event. Reopening of all roads and parking areas would depend on access and resources needed to repair damaged underground services.

Damage to buildings and equipment is also likely to disrupt airport operations.

Recovery profile

A recovery profile for the airport following the scenario earthquake sees the airport at around 10% capacity after the first day, with only light aircraft able to operate. This rises to around 100% after 1 - 2 days as quick repairs are completed (refer to the recovery profile assumptions in Chapter 2).

More extensive damage is unlikely from the scenario earthquake, though extended loss of airport services would affect the regional and national economies. Diversion to other airports could, however, mitigate some of the adverse effects on the national, and to some extent, the Auckland economy.

Whenuapai Airbase is likely to be the least vulnerable of Auckland's airports, but does not have the capacity of the international airport

Whenuapai Airbase is likely to be the least vulnerable of Auckland's airports and may cater for some transferred air traffic, but it does not have the capacity of the international airport.

Table 35: Summary of likely effects of the scenario earthquake on transport lifelines

Road	Strategic arterials	Non - strategic arterials	Local roads
	• bridges along motorways are the weakest points, especially older multi-span bridges and abutments eg Spaghetti Junction area and some on the Southern motorway • roads on liquefiable and unstable land, especially reclaimed land, also at risk • Harbour Bridge likely to be unaffected but some northern on ramps likely to be impassable • possible flooding and physical damage from ruptured and unsecured pipes	• many likely to be closed by collapsed buildings • earth movement creating gaps and uneven levels in the carriageway, especially in hilly areas • should still have more passable sections than the motorway (which has more bridges), but any access will be at a much reduced capacity, meaning long delays to traffic using operational sections of road and a complete loss of access to some areas	• widespread impact and severe disruptions to capacity • even minor embankments are likely to collapse, blocking or undermining roads • movement of liquefiable soils likely to have more extreme effects than on arterial roads due to lower construction standards. Hilly areas and reclaimed land likely to be worst affected, but many alternative routes likely in areas with good redundancy
Rail	• rail is probably the most vulnerable of all modes to earthquakes because tracks are sensitive even to minor ground movement. Misaligned tracks totally impede capacity because of no detours • engines may not be able to get back to a station • high risk of slope failure completely destroying vulnerable sections on reclaimed land such as by Orakei Basin or in hilly areas like the Waitakeres • serious damage could affect regional recovery by loss of bulk rail transport of supplies		
Ports	• both the Waitemata and Onehunga ports are built on reclaimed land, placing them at higher risk from earthquakes. Reclaimed land is generally more susceptible to ground shaking and damage could be severe enough to require an alternative port facility, as existing piles and wharves become misaligned and thus unusable as docking facilities • port operations may also be indirectly affected by impacts on rail and road connections. As a number of bridges and roads near both ports are also built on reclaimed land, they are likely to lose capacity and reduce the ports' ability to distribute cargo. However, in the long term, loss of port functions could have a very serious effect on the region's recovery • it would take years to rebuild another port on the Waitemata Harbour following total destruction. Diversion to other ports such as Whangarei, Tauranga and Wellington could mitigate some of the adverse effects on the national, and to some extent, the Auckland economy		
Airport	• minor displacement of the runway would not significantly affect operations, although runway length may be reduced until repaired • damage to buildings and equiopment may also affect operations • access to the airport may be reduced because of damage to roads and roadside services • Whenuapai Airbase is likely to be the least vulnerable of Auckland's airports and may cater for some transferred air traffic, but it does not have the capacity of the International Airport		

6.2.2 Volcanic eruption

Roads

Ash fall is likely to be the most serious threat to roads because of congestion caused by accidents and breakdowns

The major impact of the scenario volcano on the road network is from the indirect effect of ash on vehicles. Ash fall is unlikely to cause structural damage to the roading network, and only those routes in the immediate vicinity of the vent would suffer permanent damage. However, volcanic ash reduces visibility and traction, making vehicles more likely to have accidents, and clogs air filters, promoting breakdowns. Although ash fall itself will generally have minimal effect on the capacity of most roads, the congestion caused by multiple accidents and large numbers of broken down vehicles is likely to seriously disrupt access to and capacity of the road network.

Rain will clog drains with ash, so it must be removed as quickly as possible

If it rains on the ash, drains will quickly block and many lower lying roads will be flooded, including many with no history of flooding. It is therefore important to remove ash as quickly as possible, and temporary stockpile areas may need to be identified, especially if transport networks are disrupted. Arterial roads along ridge lines may be less vulnerable to volcanic effects and these routes should be highlighted and prioritised.

Recovery profiles show roads back at 100% a week after an eruption

The recovery plans of all utility and transport operators depend on removing ash from roads and facilities, but dump sites have not been identified. If not determined prior to the event, ad hoc ash dumping would hamper network recovery and cause environmental damage (see Chapter 10, Further work).

A typical recovery profile of a vulnerable section of road immediately following a volcanic scenario would see the road at between 30 - 100% capacity, depending on the amount of ash fall. The road should be at full capacity as soon as the ash is removed, most likely within one week (refer to the assumptions in Chapter 2).

Strategic arterial roads away from the vent will be mostly unaffected

Transit New Zealand's office is in the volcanic scenario's destruction zone, but with enough warning could be relocated before the event (Transit manages Auckland's motorway and state highway networks). The scenario vent was not located by motorways or other strategic arterial roads, so little direct impact on them was expected. Roads that are destroyed provide access to the port and CBD, but these sites are also likely to be destroyed. However, should a vent appear in the narrow Otahuhu Isthmus (where there is very little roading redundancy) maintaining north - south routes would be very difficult. Regardless of where the eruption occurs, ash fall is likely to cause widespread congestion and delays on strategic arterial roads.

Non - strategic arterial roads away from the vent will be mostly unaffected

Several arterial roads near the vent would be completely destroyed, but there is enough redundancy in the network to provide alternative routes into the CBD. Again, ash fall will bring major disruption to vehicles and thus to the arterial road network. Lower lying roads or sections of road are likely to accumulate deeper ash which could block the road or worsen flooding.

Ash may block many local roads, especially in low lying areas, until more strategic routes are cleared

The high level of redundancy in the local roading network is likely to help recovery from a volcanic event. Though many local roads will be completely blocked by either ash fall or broken down vehicles, the number of alternative routes should minimise delays. Some local roads are likely to experience unprecedented flooding in the event of rainfall soon after an eruption due to blocked drains, and would not be attended by contractors until after more important arterial roads were cleared. Impacts are thus likely to be most prolonged on the local road network.

Rail

Tracks would become slippery or be covered by ash

The rail network would probably not be greatly affected by the scenario volcano, although tracks and stations near the vent would be destroyed. While lines elsewhere are unlikely to be structurally affected, they may be blocked by ash fall, or engines may lose traction, hindering their operational capacity. The ash may also disrupt engine air intakes, immobilising them or delaying their use until the ash has been removed. As with the road network, lower lying rail lines may become blocked if rain falls on the ash.

Recovery profile

A typical recovery profile of a vulnerable section of rail network would be between zero and 80% immediately after the scenario volcano, depending on wind direction and the amount of ash fall. Within a few days ash could be cleared to the side of the track, leaving only the effects of airborne ash on air filters to restrict capacity (refer to the assumptions in Chapter 2).

Ports

An eruption in the vicinity is the worst case scenario for the Waitemata port, causing total loss, or at best, serious damage.

An eruption in the vicinity is the worst case scenario for the Waitemata port, causing total loss, or at best, serious damage

The scenario volcano would completely destroy the main port and radically alter much of the sea front. The port would have to relocate to an alternative site, provided equipment could be evacuated before the event. Onehunga would be able to take some of the redirected ships, as would other North Island ports such as Whangarei, Tauranga and Wellington. A vent further away than the scenario vent would not destroy the main port facility, but it would still be disrupted because of the effects of ash fall on engine operation.

Recovery profile

The recovery profile of the Waitemata port following the volcano scenario is zero, as the site would be completely destroyed. However, Onehunga would only be affected by ash fall, which is a temporary disruption (refer to the assumptions in Chapter 2).

Airport

The worst case scenario for the airport is total loss or serious damage by an eruption in the vicinity.

Aircraft may operate around ash clouds with care

Although the scenario eruption was not in the vicinity of the International Airport, the airport can be vulnerable to ash fall from a more distant event. Jet engines are highly susceptible to ash and must avoid contact with it, both in the air and on the ground. Following the scenario eruption, increased maintenance would be required while planes are on the ground, to keep ash out of aircraft engines and machinery. Aircraft operation should still be possible during daylight hours, when pilots can fly clear of visible ash clouds. Operation is unlikely to be possible at night or while ash is falling at the airport itself. Physical assets such as navigation equipment and aircraft hangers should not be affected by the ash fall, although the runway will probably need to be continually cleared of ash, because it reduces traction for aircraft.

Recovery profile

A recovery profile for the airport following the scenario eruption would see the airport at under 50% capacity immediately after the event, while the ash clouds settle. Once prevailing winds and areas of ash cloud have been identified, the airport should be able to operate at near full capacity, although it may need to shut down if ash clouds come too close (refer to the assumptions in Chapter 2).

Table 36: Summary of likely effects of the scenario eruption on transport lifelines

<table>
<tr><td rowspan="4">Road</td><td colspan="3">All roads</td></tr>
<tr><td colspan="3">• indirect effect of ash on vehicles is the major impact. Ash fall is unlikely to cause structural damage to the network, and only those routes in the immediate vicinity of the vent would suffer permanent damage, but volcanic ash reduces visibility and traction, making vehicles more likely to have accidents, and clogs air filters, promoting breakdowns
• ash fall itself will generally have minimal effect on the capacity of most roads, but congestion caused by multiple accidents and large numbers of broken down vehicles is likely to seriously disrupt access to and capacity of the road network.
• if it rains on the ash, drains will quickly block and many lower lying roads will be flooded, including many with no history of flooding</td></tr>
<tr><td>Strategic arterials</td><td>Non - strategic arterials</td><td>Local roads</td></tr>
<tr><td>• little direct impact as port and CBD are destroyed as well as key routes to them
• no north - south routes if a vent appears in the narrow Otahuhu isthmus</td><td>• several arterial roads near the vent would be completely destroyed, but there is enough redundancy to provide alternative routes into the CBD
• major disruption by ash fall
• lower lying areas may accumulate deeper ash which could block the road or worsen flooding</td><td>• many local roads will be completely blocked by either ash fall or broken down vehicles, but the many alternative routes should minimise delays
• some local roads are likely to experience unprecedented flooding due to blocked drains, and would not be attended by contractors until after more important arterial roads were cleared
• impacts are thus likely to be felt the longest on the local road network</td></tr>
<tr><td>Rail</td><td colspan="3">• tracks and stations near the vent would be destroyed but the rest of the rail network would probably not be greatly affected, but may be blocked by ash fall
• engines may lose traction, hindering their operational capacity and ash may also disrupt engine air intakes, immobilising them or delaying their use until the ash has been removed
• lower lying rail lines may become blocked if rain falls on the ash</td></tr>
<tr><td>Ports</td><td colspan="3">• the Port of Onehunga would only be temporarily affected by ash fall, and would be able to take some of the ships redirected from the Waitemata port, as would other North Island ports such as Whangarei, Tauranga and Wellington
• the Waitemata port would be completely destroyed and much of the sea front radically altered. It would have to relocate, provided equipment could be evacuated beforehand
• a vent further away than the scenario vent would not destroy the main port facility, but it would still be disrupted by effects of ash fall on engine operation</td></tr>
<tr><td>Airport</td><td colspan="3">• the International Airport is vulnerable to ash fall from local and distant events. After the scenario eruption, increased maintenance would be needed to keep ash out of aircraft engines and machinery. Daylight operation should still be possible when pilots can fly clear of visible ash clouds unless ash is falling at the airport itself
• physical assets such as navigation equipment and aircraft hangers should not be affected by the ash fall, although the runway will probably need to be continually cleared of ash, because it reduces traction for aircraft</td></tr>
</table>

6.2.3 Tropical cyclone

Roads

Flooding from heavy rain is likely to be the major impact of the scenario cyclone, although high winds could also cause disruption from fallen trees and poles. While the extent of flooding is reasonably predictable based on past events, the impact of fallen debris is not. Generally, all roads would have reduced capacity at times because of debris blockages, and delays would be expected.

The main problems are flooding, high winds, wind blown and flood borne debris and slips

High winds would not affect the road network itself, and exposed structures such as the Harbour Bridge may be able to remain open. However, the bridge may be closed to light traffic like motor cycles for safety reasons and the clip - on lanes may need to be closed, while in extremely high winds, the bridge itself may be closed for safety reasons.

Some problems from slips are also possible, and while overslips (which deposit material on the road) are relatively easily cleared, underslips (where part of the road is lost) may result in roads being closed for significant periods of time.

Strategic arterial roads are less likely to be affected by flooding and wind blown debris

The higher construction standard of strategic arterial roads makes them less vulnerable to cyclones, as potential risks tend to be removed from these roads. For example, it is standard practice for vulnerable trees adjacent to a State Highway to be removed before they are blown onto the carriageway, and similar safety standards apply to the proximity of buildings and signs. This means that strategic arterial roads are less likely to be affected by fallen debris from high winds, although it is inevitable that some disruption will occur.

SH16, Tamaki Drive and Great South Road are vulnerable, but flooding should not generally affect other strategic or non - strategic arterial roads

Very few strategic routes are sufficiently close to the coast to be affected by rougher cyclonic seas, with all routes but two likely to remain open (although some may have temporarily reduced capacity). The most vulnerable route is State Highway 16, which is likely to be inundated at the low lying Waterview causeway and near Helensville. However, a detour is available at Waterview.

Tamaki Drive is also vulnerable to the cyclone scenario, and is likely to be closed to avoid risk to vehicles from the cyclonic storm surge and cliff collapse from heavy rain.

Great South Road is likely to have reduced capacity in several areas where it crosses rivers likely to flood, although it should remain open.

Few non - strategic arterial roads at risk

Flooding should not generally affect other strategic or non - strategic arterial roads.

Local roads are more vulnerable to blockage by flooding and debris

Local roads are more vulnerable to the cyclone scenario than arterial roads because they are common in low - lying areas and are built to a lesser standard. It is not possible to accurately predict the extent of flooding from the scenario, but areas that have flooded in the past provide a good basis for response planning. During the worst of the flooding there is likely to be very little traffic demand, as most people shelter indoors from the storm. Most roads closed by flooding would reopen shortly after the event, although some will be covered in debris and others will have suffered scouring. High winds are more likely to affect local than arterial roads because they have more roadside trees, signs and poles. Many roads not flooded are likely to be fully or partly blocked by fallen debris.

Rail

Flooding may cover low lying lines and some slips may damage tracks

The scenario cyclone is likely to block most sections of the rail network, with fallen debris on the tracks and flooding in low lying areas. Large sections of the Main Trunk Line through the Waitakere Ranges have been identified as vulnerable to slope failure in heavy rain. Similar slope problems are likely around the Orakei Basin, although an alternative route is available. Several areas of flooding are likely to the south and debris may be washed onto the track in places.

Recovery profile

A typical recovery profile of a vulnerable section of rail network following a cyclone would be zero capacity immediately after the event, because of the debris blown onto the track. Once this has been cleared, probably within a few days, network operation would depend on the extent of slope failure. If only isolated sections are affected, repairs could be completed within a few weeks, but for more widespread slope failure delays of several months are likely (refer to the recovery profile assumptions in Chapter 2).

Ports

Ports can avoid damage with warning

Given enough warning, the port can avoid serious damage to structures, equipment and vessels from the scenario cyclone. Ships can be put to sea and containers can be evacuated or strategically stacked to withstand wind gusts. Most port damage is likely to be from smaller vessels that have broken free from their moorings and are washed into the harbour area. If electronic equipment and power survives the scenario and road and rail access are maintained, the ports should be quickly back to full capacity after riding out the storm.

Recovery profile

A recovery profile following a cyclone has the ports closed down during the storm and back up to 50% immediately after the event. Depending on the amount of damage, full capacity should be restored within one or two days (refer to the recovery profile assumptions in Chapter 2).

Airport

The airport would close during the storm peak

Most problems for the international airport from the scenario cyclone arose from high wind speeds. Light aircraft are unable to operate in winds of more than 20 knots across the runway, though larger aircraft have a higher threshold and high winds parallel to the runway are less problematic to both. No flights are likely during the cyclone peak, but with enough warning the disruption can be minimised by re-routing flights. Rain is unlikely to affect operations or access to the airport, although visibility will be impaired.

Recovery profile

A recovery profile for the airport following the cyclone scenario sees the airport at close to zero capacity during the height of the storm, with full capacity quickly restored once winds drop. Most aircraft, equipment and buildings are sufficiently robust to withstand the cyclone without damage (refer to the recovery profile assumptions in Chapter 2).

Table 37: Summary of likely effects of the scenario cyclone on transport lifelines

<table>
<tr><td rowspan="4">Road</td><td colspan="3">All roads</td></tr>
<tr><td colspan="3">• flooding from heavy rain is likely to be the major impact, the extent being reasonably predictable based on past events
• all roads would have reduced capacity at times because of debris blockages from fallen trees and poles, and delays are to be expected
• some slips are also possible, overslips being relatively easily cleared, but underslips resulting in roads being closed for significant periods</td></tr>
<tr><td>Strategic arterials</td><td>Non - strategic arterials</td><td>Local roads</td></tr>
<tr><td>• exposed structures such as the Harbour Bridge may remain open, but the Bridge may be closed to light traffic, or the clip on lanes or the bridge itself may close
• some disruption of strategic roads by debris from high winds
• very few are close enough to the coast to be affected by cyclonic seas though some may have temporarily reduced capacity. The most vulnerable routes are State Highway 16, likely to be inundated at Waterview and near Helensville; and Tamaki Drive
• Tamaki Drive is also vulnerable to slips
• Great South Road may have reduced capacity where it crosses rivers but should remain open</td><td>• flooding should not generally affect other arterial roads, though debris and slips may be problems</td><td>• local roads are more vulnerable to flooding because they are common in low lying areas and are built to a lesser standard. During the worst of the flooding there is likely to be very little traffic demand, as most people shelter indoors from the storm. Most roads closed by flooding would reopen shortly after the event
• some coastal roads will suffer scouring.
• some roads will be covered in debris: high winds are more likely to affect local roads because they have more roadside trees, signs and poles. Many roads not flooded are likely to be fully or partly blocked by fallen debris</td></tr>
<tr><td>Rail</td><td colspan="3">• most sections of the rail network are likely to be blocked with fallen debris on the tracks and flooding in low lying areas
• large sections of the Main Trunk Line through the Waitakere Ranges have been identified as vulnerable to slope failure in heavy rain. Similar slope problems are likely around the Orakei Basin, although an alternative route is available
• several areas of flooding are likely to the south and debris may be washed onto the track in places</td></tr>
<tr><td>Ports</td><td colspan="3">• given enough warning, the port can avoid serious damage to structures, equipment and vessels from the scenario cyclone
• most port damage is likely to be from smaller vessels that have broken free from their moorings and are washed into the harbour area
• if electronic equipment, power and road and rail access are maintained, the ports should be quickly back to full capacity after riding out the storm</td></tr>
<tr><td>Airport</td><td colspan="3">• high wind speeds are likely to cause the airport most problems. Light aircraft are unable to operate in winds of more than 20 knots across the runway, though larger aircraft have a higher threshold. No flights during the cyclone peak
• rain is unlikely to affect operations or access, although visibility will be impaired</td></tr>
</table>

6.2.4 Tsunami

Roads

Although several small coastal roads would be closed, these areas have enough redundancy for the road network to keep operating. Minimal scouring of bridge abutments and loss of services crossing bridges is expected

The scenario tsunami would have limited impact on the roading network. Although several small coastal roads would be closed by damage, most of these areas have enough redundancy to allow the network as a whole to keep operating. The possibility of scouring around bridge embankments was examined, as this affects both the structural safety of the bridge and the security of buried services that use the bridge as a crossing point. Generally only minimal scouring is expected, with services more likely to be affected by slips elsewhere in the road network. However, bridges over long narrow estuaries may be more susceptible.

A typical recovery profile of a vulnerable section of road following a cyclone or tsunami would see the road closed by water during and immediately after the event. Capacity should be quickly restored as the waters recede and, as long as there is no scouring, full capacity should be achieved within two days (refer to the recovery profile assumptions in Chapter 2).

Strategic arterial routes are generally unaffected

Strategic arterial routes are generally far enough from the coast to be unaffected by the tsunami scenario. However, several sections of SH1 to the north of the city are likely to be affected where the road crosses rivers at low topographical points (the new Albany - Puhoi section of SH1, ALPURT, will eliminate these problems).

Although three strategic road sections may be flooded, little damage is expected

The worst affected state highway is SH16, because the causeway at Waterview is only one metre above mean sea level. This section is expected to be inundated, although an alternative route is available for diverted traffic. Further towards Helensville the road is expected to be completely closed where the Kaipara River will flood, and in this case there is no suitable detour. The Harbour Bridge approaches are likely to have reduced capacity during the event due to inundation from sea water, but this would be a temporary disruption. Strategic routes tend to be built to a higher standard and are therefore less vulnerable to scouring or damage from the incoming or receding sea water.

Tamaki Drive is the strategic route most vulnerable to the scenario tsunami. The tsunami waters will damage vehicles and cliffs as well as damaging or undermining the carriageway by scouring. However, there are enough alternative routes to avoid a significant effect on the road network.

The greatest impact is on local roads near the coast

The scenario tsunami is likely to have a greater impact on local roads than any other transport mode, because local roads are common in low lying or coastal areas. Roads on eastern shores are the most vulnerable to damage from inundation and scouring, although most have alternative routes should they become impassable. Damage is likely on many of the local roads with culverts and bridges, as receding waters could cause scouring. This increases the delay in reopening the roads to full capacity.

Rail

Most rail lines are away from the coast

The only rail route likely to be at risk during the scenario tsunami is around the Mechanics Bay/Orakei Basin area, where water may cover the line temporarily. All other tracks are far enough from the coast or high enough above rivers to be probably unaffected. No rail bridges have been identified as vulnerable to scouring from receding waters.

Recovery profile

A typical recovery profile of a section of rail network following a tsunami is up to 100% after the first day, although the Mechanics Bay section may not be completely repaired for up to a month (refer to the recovery profile assumptions in Chapter 2).

Ports

With enough warning ports can prepare for and withstand tsunami

Given enough warning, the ports can prepare for the scenario tsunami and minimise damage. Ships can be put out to sea to ride the waves more safely and containers can be moved to positions that will be more robust when the water rises. Again, vessels that have broken free may cause the most damage, along with other debris that may be washed over the port by the water.

Recovery profile

Recovery should be swift as long as access and power are maintained. As with the scenario cyclone, the ports should be back to 100% operations within one or two days after shutting down during the event.

Airport

The airport is not affected by a tsunami

The airport is high enough above mean sea level not to be at risk of inundation by the scenario tsunami. The runway is at least 4 metres above mean sea level, and is higher in many areas. Any waters that do encroach on airport land are not likely to lead to scouring. Roads to the airport would remain open at all times.

Recovery profile

A recovery profile for the airport sees the airport at 100% for the tsunami's duration (refer to the assumptions in Chapter 2).

Table 38: Summary of likely effects of the scenario tsunami on transport lifelines

<table>
<tr><td rowspan="4">Road</td><td colspan="2">All roads</td></tr>
<tr><td colspan="2">• limited impact on the road network overall
• several small coastal roads would be closed by damage, but most of these areas have enough redundancy to allow the network as a whole to keep operating
• generally only minimal scouring is expected around bridge embankments
• services that use bridges as a crossing point are more likely to be affected by slips elsewhere in the road network
• bridges over long narrow estuaries may be more susceptible</td></tr>
<tr><td>Strategic and non - strategic arterials</td><td>Local roads</td></tr>
<tr><td>• strategic arterial routes are generally far enough from the coast to be unaffected by the tsunami scenario. However, several sections of SH1 to the north of the city are likely to be affected where the road crosses rivers at low topographical points (the new ALPURT route will eliminate these problems)
• the worst affected state highway is SH16, with inundation at Waterview (detour available) and road closure by Helensville at the Kaipara River (no detour)
• Harbour Bridge approaches are likely to have temporarily reduced capacity during the event
• strategic routes tend to be built to a higher standard and are therefore less vulnerable to scouring or damage from the incoming or receding sea water
• Tamaki Drive is most vulnerable. The tsunami waters will damage vehicles and cliffs as well as damaging or undermining the carriageway by scouring. However, there are enough alternative routes to avoid a significant effect on the road network.
• the tsunami will not generally affect other arterial roads</td><td>The scenario tsunami is likely to have a greater impact on local roads than any other transport mode, because local roads are common in low lying or coastal areas. Roads on eastern shores are the most vulnerable to damage from inundation and scouring, although most have alternative routes should they become impassable. Damage is likely on many of the local roads with culverts and bridges, as receding waters could cause scouring. This increases the delay in reopening the roads to full capacity</td></tr>
<tr><td>Rail</td><td colspan="2">• the only rail route likely to be at risk during the scenario tsunami is around the Mechanics Bay/Orakei Basin area, where water may cover the line temporarily
• all other tracks are far enough from the coast or high enough above rivers to be probably unaffected
• no rail bridges were identified as vulnerable to scouring from receding waters</td></tr>
<tr><td>Ports</td><td colspan="2">• given enough warning, the ports can prepare for the scenario tsunami and minimise damage. Ships can be put out to sea to ride the waves more safely and containers can be moved to positions that will be more robust when the water rises
• vessels that have broken free may cause the most damage, along with other debris that may be washed over the port by the water</td></tr>
<tr><td>Airport</td><td colspan="2">• the airport is high enough above mean sea level not to be at risk of inundation by the scenario tsunami. The runway is at least 4 metres above mean sea level and is higher in many areas
• any waters that do encroach on airport land are not likely to lead to scouring. Roads to the airport would remain open at all times</td></tr>
</table>

Table 39: Summary of transport lifelines recovery profiles after the scenario events

	Day 1	Week 1	Full recovery
Earthquake			
Road	Complete closure of some key roads; some local redundancy	10 - 50% capacity	1 month (roads) 6 months (big bridges)
Rail	Zero capacity	0 - 50% capacity	6 months
Ports	10% capacity	50% capacity	3 months
Airport	10% capacity	100% capacity	1 - 2 days
Eruption			
Road	30 - 100% capacity, depending on ash depth	Full capacity	Full capacity
Rail	Zero to 80% capacity, depending on wind direction and ash depth	Full capacity, depending on duration of ash fall (ash may harm engines)	4 - 7 days, depending on duration of ash fall
Ports	Total destruction of Waitemata port; temporary disruption of Onehunga port	Zero for Waitemata port Full capacity Onehunga port, depending on duration of ash fall	Zero for Waitemata port. 1 week for Onehunga port, depending on duration of ash fall
Airport	Less than 50% capacity while ash clouds settle	Near full capacity once prevailing winds and clouds are identified	1 week, depending on duration of ash fall
Cyclone			
Road	Road closure or reduced capacity in some areas as by flooding, debris, slips	Full recovery except in areas of severe underslips	0 - 2 days except in areas of severe underslips
Rail	Zero capacity because of debris on tracks	2 - 7 days to full capacity if only isolated sections of track are affected	A few weeks to several months if there is widespread slope failure
Ports	Closure during storm, 50% capacity	Full capacity	1 - 2 days
Airport	Zero or near zero capacity during storm, full capacity once winds drop	Full capacity	As soon as winds drop to 20 knots
Tsunami			
Road	Coastal roads closed by flooding, small coastal roads closed by damage, but network as a whole keeps operating. Minimal scouring around bridge embankments but possible effects on bridges over long narrow estuaries	Full capacity	1 - 2 days
Rail	100% capacity, except for Mechanics Bay	100% capacity, except for Mechanics Bay	Up to 1 month for Mechanics Bay
Ports	Closure during the event	100% capacity	1 - 2 days
Airport	100%	100%	-

Note: All recovery profiles assume unlimited resources and unrestricted access (see Chapter 2)

6.3 Energy lifelines

Maximum disruption to Auckland's electricity supplies would result from a volcanic eruption in Otahuhu destroying five of the six high voltage power lines which currently bring in up to 95% of Auckland's power, along with 100% of local generating capacity.

The result would be:
- very limited electricity supply into the region
- no power generation in the region
- only very limited alternative energy supplies

Nevertheless, given reasonable access to damaged sites to do repairs, supplies could be restored to much of the region in a matter of weeks — probably ahead of demand.

However, energy supplies to the Auckland region may be affected not only by hazard events occurring within the Auckland region, but also by events occurring outside the region. Indeed, distant events have the potential to be at least as disruptive as events occurring within the region.

The worst case scenario for the region's petroleum fuel supplies is total loss of or serious damage to the fuel tank farm at the Wiri oil terminal, although it is not expected to suffer major harm from most lifeline scenarios considered. There is ten days contingency supply at Mt Maunganui and Marsden Point, but loss of the Wiri oil terminal would severely restrict fuel supplies to the region.

Inner city service stations hold short term petrol supplies and these would be supplemented by the stores at Wiri, assuming the terminal were undamaged. However, panic buying is likely, and would quickly reduce the available stocks.

The worst gas supply scenario is total destruction by an eruption of the Westfield gate station, which supplies 60% of the Auckland region's natural gas. Up to 2km of pipeline would also be destroyed, and possibly also Auckland's other main gate station at Papakura.

However, it is difficult to envisage any major demand for natural gas immediately after such a major event, so the recovery period would not cause major problems in comparison with the difficulties cause by loss of other lifeline services.

Tables 40 – 44 summarise vulnerabilities and the effects of the scenario hazards on energy lifelines, while Table 45 summarises energy lifelines recovery profiles after all the scenario events.

In general, the longest recovery period for energy networks is several weeks after either a local eruption which destroys key nodes and networks within the region, or after a distant eruption which cuts off energy supplies by affecting distant sources of energy.

Recovery from earthquake is estimated to take up to seven days, while the cyclone and tsunami were assessed as having the lowest impact on energy networks, apart from the impact on individual affected customers, with power restored within one or two days.

6.3.1 Earthquake

Modern design standards and system reliability requirements mean that energy supplies are only seriously threatened by earthquakes where there are abnormal ground conditions, that is, in areas where either nodes or network segments are on liquefiable soils

Modern design standards and system reliability requirements mean that energy supplies are only seriously threatened by earthquakes where there are abnormal ground conditions, that is, in areas where either nodes or network segments are on liquefiable soils.

The methodology used identified anything on liquefiable soils as having a high risk. While ground shaking was examined for all energy nodes and networks, no high risk areas were identified, as most of the sites and network sections have been designed for seismic loadings.

The following discussion thus focuses only on liquefiable soils.

Nodes and network segments for all three energy sources which, based on the uniform and scenario hazards, are at risk from liquefiable soils are summarised in Table 40, which repeats Table 11 from Chapter 5.

Electricity

Uniform hazard nodes at risk

Nodes at high risk from liquefaction in the uniform hazard "event" are the Silverdale, Quay Street, Takanini and Pakuranga substations (Subs).

The uniform hazard also threatens power supplies to the CBD by amplifying earthquake intensity in liquefied soils. While most CBD properties would be expected to be undamaged by the event (only a small part of the CBD is on liquefiable or reclaimed land), power supplies from Quay Street Sub may be affected by liquefaction on reclaimed land

A large number of critical energy nodes are located on areas where the risk of earthquake - induced slope instability exceeds 20%. These are collectively regarded as potentially high risks pending more specific site information. Electricity nodes located in such areas are:

- Control centres
  - Newmarket
  - Takapuna
- Points of supply/zone substations:
  - Liverpool St
  - Quay Street
  - Roskill (may or may not be in the area affected by soil liquefaction)
  - Penrose
  - Takanini
  - Mangere
  - Papakura
  - Wiri
  - Silverdale
  - Hepburn Road

- Power stations
  - Southdown
  - Otahuhu B

- Transpower switchyard:
  - Otahuhu

Earthquake damage to substations and other nodes overseas is typically repaired within seven days

Recovery of electricity nodes from the uniform hazard earthquake is expected to be relatively quick. Earthquake damage to substations and other nodes overseas is typically repaired quite quickly — often within seven days.

23 sections of electricity network are exposed to above average risk of damage due to liquefiable soils, as shown in Table 40:

Uniform hazard networks at risk include some of the high voltage transmission lines into the region

- 17 sections of Transpower's high voltage transmission network
- 6 sections of VECTOR's sub - transmission network

Six high voltage transmission lines currently convey up to 95% of Auckland's power to the region, but loss would almost certainly be confined to one or two, rather than all six. There is no general liquefaction threat in the bottleneck through Otahuhu, where these critical high voltage transmission lines are concentrated (only the lines to Pakuranga substation avoid this area). There are just one or two pockets of susceptible ground so any damage or disruption is likely to be confined to relatively small sections of supply. Transpower would probably repair these very quickly.

Scenario earthquake nodes at risk are again in areas where abnormal amplification occurs

Some power outages or shortages may result from damage at nodes, but restoration of power to meet demand is not expected to take very long. Nodes at risk from the scenario earthquake are:

- Quay Street
- Takanini
- Pakuranga

The earthquake intensities involved are well within the design capabilities of high voltage transmission and sub - transmission systems, so damage is only expected where abnormal amplification occurs.

Scenario earthquake networks at risk

As with the uniform hazard, electricity networks are exposed to greater potential earthquake intensities in some areas where liquefiable ground is near the scenario epicentre. However, attenuation of effects from the epicentre reduces the number of sections of network at risk compared with the uniform hazard.

Ten sections of network were at risk from liquefaction or poor ground conditions:

- eight sections of Transpower's high voltage transmission lines
- two sections of sub - transmission systems

Petroleum fuels

Uniform hazard nodes at risk

The Freemans Bay / Wynyard Wharf area is vulnerable to liquefaction during an earthquake, as it is reclaimed land, but loss of or damage to Freemans Bay would not constitute a major problem. Some damage to tanks from ground movement is possible because the Freemans Bay facility stands on reclaimed land, but no petrol is held there. The probability of damage is relatively high in such an event, but the impact is relatively low.

Loss or damage could however affect availability of Avgas fuels for light aircraft and helicopters, the latter possibly being needed to help other lifelines restore their services.

The risk of earthquake - induced slope instability exceeds 20% in the uniform hazard event for:

- Wynyard Wharf / Freemans Bay
- Wiri Oil Services Terminal
- the fuel line to Auckland International Airport

Uniform hazard networks at risk

The same risks facing gas pipelines also face petroleum pipelines, though petroleum spare parts are not at risk. Four sections of petroleum fuel line were identified as being at risk in the uniform hazard analysis.

Scenario earthquake nodes and networks at risk

Petroleum nodes are not affected by the scenario earthquake except for the Freemans Bay/Wynyard Wharf area, which is closer to the epicentre and on reclaimed land. However, the consequences are not serious, as discussed above.

Two at risk sections of petroleum pipework were identified in the scenario earthquake analysis.

Gas

Uniform hazard nodes at risk

Orion's spare parts store and possibly Westfield Gate Station are vulnerable to liquefaction of soils during an earthquake in the uniform hazard event.

Gas nodes located in areas where earthquake induced slope instabiltiy is estimated to exceed 20% include:

- Westfield Gate Station
- Papakura Gate Station
- Beaumont Street Site
- Auckland Harbour Bridge

Uniform hazard networks at risk

Gas supplies over the Harbour bridge are expected to fail in a major earthquake because of bridge abutment displacement.

The main gas transmission pipeline passes through liquefiable soils in the area of Takanini, but repairs to damaged pipeline would be relatively quick.

Table 40: Summary of energy node and network earthquake vulnerabilities

(This table duplicates Table 11 in Chapter 5)

HAZARD	ELECTRICITY	PETROLEUM	GAS
Uniform hazard: nodes at risk from liquefied soils			
	Transpower: • Pakuranga substation ∘ Takanini substation **VECTOR:** ∘ Quay, substation **UnitedNetworks:** • Wairau Substation # ∘ Silverdale Substation	**Petroleum Industry:** • Freemans Bay terminal/Wynyard Whard	**Orion:** • Beaumont St (spares) ∘ Westfield Gate Station #
Uniform hazard: network segments at risk from liquefied soils			
	Transpower: • 17 sections of high voltage transmission network **VECTOR:** • 6 sections of sub transmission network	**Petroleum Industry:** • 4 sections of fuel line	**Natural Gas Corp:** • 1 section of high pressure gas pipeline **Orion:** • 11 sections of medium pressure gas pipeline
Scenario hazard: nodes at risk from liquefied soils			
	• Quay substation (reclaimed land) ∘ Takanini substation ∘ Wairau substation # ∘ Pakuranga substation #	**Petroleum Industry:** ∘ Freemans Bay/Wynyard Wharf (reclaimed land)	∘ Westfield Gate Station # ∘ Beaumont St spare parts store
Scenario hazard: network segments at risk from liquefied soils			
	Transpower: ∘ 8 sections of high voltage transmission lines **Local network operators:** ∘ 2 sections of sub - transmission systems	**Petroleum Industry:** • 2 sections of petroleum pipework	**Natural Gas Corporation/Orion:** ∘ 8 sections of gas pipeline

Note: # indicates nodes that are on the edge of liquefaction zones – they may be just in or just out of the zone. A site evaluation would be needed to determine this.

At risk sections of network were identified as:

In the 1987 Edgecumbe earthquake the 100mm high pressure gas transmission pipe withstood 1.2m of movement

- one section of Natural Gas Corporation pipeline
- 11 sections of Orion gas pipeline

Pipeline damage cannot be assumed even where the pipeline crosses poor ground conditions. A Natural Gas Corporation pipeline crosses the faultline which moved during the March 1987 Edgecumbe earthquake. The pipeline was subjected to a 1.2m vertical displacement, but did not fail and there were no gas leaks. The pipe flexed adequately to absorb the land movement and the original pipeline remains in service today.

This performance suggests that damage to the gas pipeline from earthquake is not a serious threat in the Auckland region.

Scenario earthquake nodes at risk

The Westfield Gate Station, which supplies 60% of Auckland's gas, is next to liquefiable land and may suffer some damage. Damage to the spare parts store in Beaumont St may delay any gas recovery should Westfield be damaged. Damage is not foreseen at the other major gate station at Papakura.

Scenario earthquake networks at risk

Eight sections of Natural Gas Corporation and Orion gas pipeline were identified as being at risk.

It is difficult to estimate recovery profiles, as restoration of service depends on the type of failure. The minimum disruption from a pipeline leak or rupture is likely to be 24 hours. All gas pipelines repair welds require testing before commissioning, necessitating X-ray inspection of welds (refer to the recovery profile assumptions in Chapter 2).

Table 41: *Effects of the scenario earthquake on the Auckland region's energy supplies*

NB: The methodology used identified anything on liquefiable soils as having a high risk. While ground shaking was examined for all energy nodes and networks, no high risk areas were identified, as most of the sites and network sections have been designed for seismic loadings. The following summary thus focuses only on liquefiable soils.

ELECTRICITY	PETROLEUM	GAS
• power supplies to CBD may be threatened since Quay Street Substation is on reclaimed land which is vulnerable to liquefaction • Other nodes at risk due to possible liquefaction are Takanini, Pakuranga and possibly Wairau Substations. • one or two of the six high voltage transmission lines currently conveying up to 95% of Auckland's power could be lost: there are just one or two pockets of susceptible ground so any damage or disruption is likely to be confined to relatively small sections of supply. These would probably would be repaired very quickly by Transpower • some power outages or shortages may result from damage at nodes, but restoration of power to meet demand is not expected to take very long. The earthquake intensities involved are well within the design capabilities of high voltage transmission and sub - transmission systems, so damage is only expected where abnormal amplification occurs	• loss of or damage to Freemans Bay would not constitute a major problem. Some damage to tanks from ground movement is possible because the facility stands on reclaimed land, but no motor spirit is held there • loss of or damage to Freemans Bay could affect availability of Avgas fuels for light aircraft and helicopters, the latter possibly being needed to help other lifelines organisations restore their services • some possible damage to the petroleum pipeline, but spares are not at risk	• Orion's Beaumont Street gas spares store was the gas node most at risk from the uniform hazard, because the store, on reclaimed land, is likely to experience liquefaction • the main gas transmission pipeline passes through liquefiable soils in the area of Takanini, but repairs to damaged pipeline would be relatively quick • the Edgecumbe experience indicates that pipeline damage cannot be assumed, even where the pipeline crosses poor ground conditions • the Westfield Gate Station, which supplies 60% of Auckland's gas, is next to liquefiable land and may suffer some damage. Damage to the spare parts *store in* Beaumont St may delay any gas recovery should Westfield be damaged. Damage is not foreseen at the other major gate station, at Pakuranga

6.3.2 Volcanic eruption

Electricity

The worst scenario

An eruption in the vicinity of Otahuhu would cause the maximum disruption to electricity supplies. This is the worst possible scenario: within the defined area of destruction (a 3km radius from the eruptive centre) the following would be destroyed:

- five out of six of Transpower's high voltage transmission lines into the region (only the Pakuranga substation high voltage transmission line is outside the zone of destruction)
- Otahuhu switchyard and Otahuhu power station (once commissioned)
- Southdown power station
- the Mangere substation point of supply

There would be only very limited electricity supply into the region, no generation within the region and only limited alternative energy supplies.

There are few risk mitigation options.

Electricity and the worst case scenario

A local eruption would destroy the Quay substation, and the Liverpool substation may also be within the zone of destruction. There would therefore be no power to the CBD except that available from Kingsland substation. However, given that most of the CBD is in the destruction zone of the scenario eruption, loss of electricity is of far less significance than it would otherwise be: even the port facilities would be destroyed.

VECTOR's Newmarket control centre is outside the zone of destruction, but ash falls likely to exceed 10mm would cause problems for the sub - transmission and distribution systems. Supply outages due to insulator flashovers and line cleaning after the event are expected in areas beyond the destruction zone:

- as far south as Otahuhu
- west as far as Mt Albert
- east as far as Bucklands Beach
- north (UnitedNetworks) as far as Takapuna and Milford

Several factors affect insulator flashovers, and overseas experience suggests that less than 5mm of ash fall will trigger them. Distribution systems are much more vulnerable to insulator flashover than high voltage transmission lines.

Critical nodes likely to be affected in this scenario are:

- UnitedNetworks:
    - Control centre, Takapuna
    - Wairau substation
- VECTOR:
    - Control centre, Newmarket
    - Kingsland substation

The scenario eruption would probably mean no power to the CBD

Insulation flashovers are possible from ash falls of over 10mm

- Transpower:
  - Roskill substation
  - Penrose substation
  - Otahuhu Switchyard

(Transpower's high voltage transmission system is not expected to be affected, unless the insulators are wet or the ash fall is wet)

- generation:
  - Southdown power station
  - Otahuhu power station

Effects of the distant eruptions are:

- Mt Taranaki would probably cause no direct problems in the Auckland region, though there may be some minimal outages to low voltage local distribution networks. However, gas supply from Taranaki may be halted by the eruption while gas demand in Auckland remains unaffected
- Okataina: insulation flashovers would be a problem, restricting electricity supply to the region. Recovery would depend on the availability of road access and water for cleaning

Networks

Electricity supply may be restricted throughout much of the region, and subject to disruption.

Electricity recovery profiles

Restoration of distribution networks would depend upon the availability of road access and water for cleaning. Without power, water may be in very short supply.

Electrical supply will recover more quickly than users' demand

Experience with natural hazards overseas suggests that electrical supplies will be restored more quickly than users' demand will recover. The period immediately after the event poses the most problems for restoring supply, and this will slow the restoration of other essential services (refer to the recovery profile assumptions in Chapter 2).

Petroleum fuels

The worst scenario

The worst scenario is total loss or serious damage to the Wiri oil terminal by an eruption in the vicinity.

The worst scenario is an eruption by Wiri and the airport destroying the Wiri oil terminal, the Joint Users Hydrant Installation at the airport and up to 2 km of pipework. This would require shutdown of the Marsden Point – Wiri pipeline. Bulk petrol supplies would be very limited

With the Wiri oil terminal out of action, the Marsden Point – Wiri pipeline, which normally replenishes petrol and diesel, would have to be shut down and bulk petrol supplies in Auckland would be very limited.

The closest fuel supplies are at Mt Maunganui. It is very unlikely that normal fuel demand could be maintained to the region from there. However, ash fall in the region would reduce demand for fuel because most motors would be at serious risk of damage resulting from blocked air filters. As supplies would also initially need to be restricted to emergency vehicles, loss of the Joint Users Hydrant Installation would probably not be too serious in the short term.

Ash fall would also prevent planes from flying in the region, although once it was safe to fly again, airlines would be able to refuel at other airports before reaching Auckland.

The Wiri oil terminal is not expected to be damaged by the scenario event. The scenario event only poses a destruction threat to Freemans Bay and Wynyard Wharf, but these are not critical lifelines facilities. Loss of Avgas stocks may, however, hinder use of helicopters and light aircraft during lifelines recovery phases.

Effects of the local scenario eruption on petroleum fuels would be minor

The pipelines would be undamaged, so the main concern would be the effects of 1 - 5mm ash falls on the pipeline valve controls and SCADA system. SCADA systems would not fail because of volcanic ash, but could become inoperable from:

- computer shutdown and truck loading shutdown due to air conditioning problems
- failure of the communication control because of volcanic ash

Effects from the local scenario eruption are, therefore, expected to be relatively minor, mainly because the Wiri oil terminal is outside the ash fall zone.

A distant eruption (the Okataina scenario) would not damage local pipelines, and the pipeline SCADA surveillance system could probably operate in the predicted ash falls, but only if its communication systems were still operable. Sensors and control valves in the open may also be vulnerable to the heavy ash falls predicted. This would result in closure of the pipelines between Marsden Point and Wiri, and from the Wiri oil terminal to the terminal servicing Auckland International Airport.

Ash fall from a distant eruption could sink the floating roof on bulk petrol tanks, especially if the ash is wet. Hazardous vapour clouds could result

Once ash is removed, however, the pipeline should be restored to operation quite quickly. Increased wear and corrosion damage may result from the event, but this is not expected to have any impact on the petroleum fuels recovery profile (refer to the assumptions in Chapter 2).

The main concern from the Okataina scenario eruption arises from the effects of rain on the ash. Petrol is stored in tanks with floating roofs, and these could sink under the combined weight of water and ash. However, the different petrol grades are each held in two separate tanks and each tank has two separate pumps for filling road tankers, so it is unlikely that all the tanks would be inoperable.

Dry ash fall from the scenario event would not cause disruption to product availability, though ash would need to be cleared from the floating roofs within a short space of time. Again, as there are at least two tanks per product, the risk to supplies is low from dry ash.

The collapse of a floating roof without an appropriate emergency response could, however, create a very hazardous vapour cloud, with a risk of fire and/or explosion and subsequent damage to the terminal.

The Mt Taranaki eruption scenario poses no threat to petroleum supplies in the Auckland region.

Gas

The worst scenario

The worst scenario for gas supplies would be destruction of Westfield gate station, which supplies 60% of Auckland's natural gas, together with up to 2km of pipeline. This scenario assumes the event occurs within 3km of Westfield.

The underground gas pipe network is not at risk from the uniform eruption hazard unless it is within 1km of the vent.

The underground gas pipework is not at risk from the uniform eruption hazard

Effects of a localised event - the scenario eruption

In the scenario eruption, Westfield gate station would experience ash falls of 5 - 10mm and this might disrupt the volume of gas available. However, since demand would also be much reduced, the overall effect on the region's recovery is minor, provided gas flow monitoring equipment continues to function and enable the gas pipeline to remain in service. Gate stations in areas likely to be affected by ash fall would be encapsulated to minimise damage and corrosion risks, while gas supplies would be shut down before any eruption.

Loss of or damage to the region's main store of gas spare parts may affect the recovery time from damage to the pipeline or valves.

Eight sections of gas pipeline were identified as being at risk.

The Okataina scenario eruption would affect local gate stations with falls of up to 100mm

Both principal gate stations would be affected to some degree by predicted ash fall of up to 100mm from the Okataina event, but in such heavy ash falls it is difficult to envisage any major demand for natural gas. The effects of the corrosive and abrasive ash on the gate stations are difficult to estimate. They may be able to continue in service but increased wear and corrosion would be likely, and the effects would not be immediate.

Although the scenario Taranaki eruption would cause little direct damage in Auckland, it may remove gas supplies closer to their source

Volcanic events outside the Auckland region may disrupt gas supplies to a far greater extent than events within the region. Negligible direct damage would be expected in Auckland from the predicted 1mm of ash fall from the Mt Taranaki event, but could affect production in Taranaki and/or the Natural Gas Corporation operations at Bell Block. Gas supplies could be severely — possibly totally — lost for the duration of the eruption while demand in Auckland (comparatively unaffected by the eruption) may remain near normal.

The worst scenario is a local eruption destroying up to 2 km of pipeline and the Westfield gate station, which supplies 60% of the region's natural gas

The distant Taranaki eruption may severely restrict gas availability although the scenario presents no threat to regional gas facilities.

The distant Okataina eruption would affect both main gate stations and the smaller gate stations to some degree, with ash falls of up to 100mm but, again, it is difficult to envisage any major demand for natural gas immediately after such a major ash fall.

Summary: Energy

Volcanic eruption is considered to pose less of a threat than earthquake in terms of recovery times but could possibly knock out all gas supplies entirely, albeit for a much shorter period of time. Heavy ash fall could make it necessary for both Oaonui (Maui) and Kapuni gas treatment plants to shut down, although outage would be far briefer than the worst earthquake scenarios.

Maximum disruption to Auckland's electricity supplies would result from a volcanic eruption in the vicinity of Otahuhu destroying everything within a 3km radius, including five of the six high voltage power lines which bring in 90% of Auckland's power, along with 100% of local generating capacity. Only the Pakuranga high voltage transmission line is outside the destruction zone.

Worst case scenario for electricity

The result would be:

- very limited electricity supply into the region
- no power generation in the region
- only very limited alternative energy supplies

Nevertheless, given reasonable access to damaged sites to do repairs, supplies to much of the region could be restored in a matter of weeks — probably ahead of restoration needs, except for the first few days.

Worst case scenario for petroleum fuels

The worst case scenario for the region's petroleum fuel supplies is total loss of or serious damage to the fuel tank farm at the Wiri oil terminal, although it is not expected to suffer major harm from most lifeline scenarios considered. There is ten days contingency supply at Mt Maunganui and Marsden Point, but loss of the Wiri oil terminal would severely restrict fuel supplies to the region.

Inner city service stations hold short term petrol supplies and these would be supplemented by the stores at the Wiri terminal, assuming it were undamaged. However, panic buying is likely, and would quickly reduce the available stocks.

Worst case scenario for gas

The worst gas supply scenario is total destruction by an eruption of the Westfield gate station, which supplies 60% of the Auckland region's natural gas. Up to 2km of pipeline would also be destroyed, and possibly also Auckland's other main gate station at Papakura.

However, it is difficult to envisage any major demand for natural gas immediately after such a major event, so the recovery period would not cause major problems in comparison with the difficulties cause by loss of other lifeline services.

Note, however, that the three scenarios above are three separate worst cases: an eruption south of Otahuhu would badly damage electricity supplies but would not destroy the Wiri oil terminal or the Westfield gate station, being slightly outside the defined zone of destruction.

Table 42: Effects of the scenario eruption on the Auckland region's energy supplies

ELECTRICITY	PETROLEUM	GAS
	Local eruption	
• an eruption in the vicinity of Otahuhu would destroy 5/6 of the high voltage transmission lines into the region; the Otahuhu switchyard, the Mangere substation point of supply and the Otahuhu and Southdown power stations, resulting in very limited electricity supply into the region, no generation within the region and only limited alternative energy supplies • the scenario eruption would destroy the Quay substation and possibly the Liverpool substation, but most of the CBD is also in the destruction zone • VECTOR's Newmarket control centre is outside the zone of destruction, but ash falls would affect the sub - transmission and distribution systems, causing supply outages due to insulator flashovers and line cleaning after the event beyond the destruction zone between Otahuhu, Mt Albert, Bucklands Beach and Milford • supply may be restricted throughout much of the region, and subject to disruption	• the worst scenario is an eruption in the vicinity of Wiri and the airport, which would destroy the Wiri oil terminal, the Joint Users Hydrant Installation at the airport and up to 2km of pipework. The Marsden Point – Wiri pipeline would have to be shut down and bulk petrol supplies in Auckland would be very limited. The closest supplies at Mt Maunganui are unlikely to meet normal fuel demand (NB demand would be reduced to avoid ash damage to engines) • the scenario eruption would not damage the Wiri oil terminal, but could cause loss of Avgas, possibly hindering use of aircraft during recovery, though airlines could refuel elsewhere • Freemans Bay and Wynyard Wharf would be destroyed but are not critical facilities • pipelines would be undamaged, but ash falls could affect pipeline valve controls and SCADA systems • overall effects relatively minor if Wiri not damaged	• the worst scenario would be destruction of Westfield gate station, which supplies 60% of Auckland's natural gas, together with up to 2km of pipeline • underground gas pipework is not at risk unless it is within 1km of the vent • ash falls of 5 - 10mm might disrupt the volume of gas available via Westfield gate station. However, since demand would also be much reduced, the overall effect on the region's recovery is minor, provided gas flow monitoring equipment continues to function and enable the gas pipeline to remain in service • gate stations in areas likely to be affected by ash fall would be encapsulated to minimise damage and corrosion risks, while gas supplies would be shut down before any eruption • loss of or damage to the region's main gas spare parts store may affect the recovery time from damage to the pipeline or valves
	Distant eruption	
• Mt Taranaki would probably cause no problems, though there may be some minimal outages to low voltage local distribution networks • Okataina: insulation flashovers would be a problem, restricting electricity supply to the region	• Mt Taranaki eruption scenario poses no threat • the Okataina scenario would not damage local pipelines. The SCADA system could probably operate if communication systems were operable. Sensors and control valves in the open may be vulnerable. Heavy ash fall could cause the floating roof on a petrol tank to sink, possibly creating a very hazardous vapour cloud, with a risk of a devastating explosion	• negligible direct damage expected in Auckland from the Mt Taranaki event, but could affect production in Taranaki and/or the Natural Gas Corporation operations at Bell Block. Gas supplies could be lost during the eruption while demand in Auckland remains near normal • both main gate stations affected to some degree by the Okataina event. Gate stations may be able to operate but with increased wear from ash

6.3.3 Tropical cyclone

Electricity

High rainfall and flooding were not identified as affecting electricity supplies, although debris laden high winds might cause localised failure of overhead lines. Rain - induced slope failure may affect the occasional local network supply power pole, but the six high voltage transmission lines are not at risk. Basement flooding may cause local supply disruption, while a very high storm surge could affect the Quay substation.

Petroleum fuels

Neither flooding, slope failure nor storm surge was identified as a risk to petroleum nodes or network. Communications are critical for continued operation of the petroleum pipeline, but three systems are available (microwave, satellite and land line).

The main effect of torrential rain on the Wiri oil terminal would be (in a worst case scenario with rainfall of more than 250mm) to sink the floating roof on any of the petrol tanks if the stormwater roof drains were not opened. This is unlikely, however, as it is a routine wet weather operation, including out of normal business hours.

Gas

Neither wind, rainfall, flooding nor storm surge was identified as posing a risk to natural gas nodes or networks, unless access for inspection or repair were impeded.

Slips may cause some problems, but pipelines can tolerate some movement

Cyclone Bola caused some superficial slips, although all have since been stabilised and Auckland gas supplies were not disrupted. Some superficial damage to gas pipes from land movement cannot be ruled out, but it would not be a threat to supply. In the 1987 Edgecumbe earthquake the 100mm high pressure gas transmission pipe withstood 1.2m of movement.

In the event of disruption, restoration would typically take 2 - 7 days.

Table 43: Effects of the scenario cyclone on the Auckland region's energy supplies

RISK	ELECTRICITY	PETROLEUM	GAS
Wind	• localised failure of overhead <11kV lines because of debris. Repairable once wind abates. Substations and Transpower lines would not be affected • note that power can still be transferred without operational communication systems	• communications are critical for maintaining supply, but two systems (microwave and satellite) are available, with land line backup	• no threat
Rainfall	• no effect. No substation flooding anticipated, except perhaps at Wairau Road	• risk of floating roof collapse, but there are strict procedures for ensuring roof drainage valves are opened to prevent this happening	• no threat, unless access becomes impeded
Flooding	• no effect. It is assumed that the Penrose tunnel, in construction, would not be at risk – but detailed information is not available	• no problem except for ensuring appropriate emergency response to manually open/close out turn, bund and drain valves	• no threat, unless access becomes impeded
Slope failure	• the odd pole in the local supply network may be at risk, but the main towers carrying the six high voltage Transpower lines from the south are not at risk • in the worst case, only one of the six separate transmission lines would be affected • slope failure presents less of a threat than soil liquefaction	• comments under 'Gas' apply here too	• rupture of the gas main by slope failure is not expected except perhaps in some remote areas. The high pressure trunk pipelines from the south do not pass through unstable ground. Some superficial damage due to land movement cannot be ruled out but it would not be a threat to supply. In the 1987 Edgecumbe earthquake the 100 mm high pressure gas pipeline withstood 1.2m of movement
Storm surge	• VECTOR's Quay substation has a floor raised by 0.5 m, but water would only need to rise 0.3 m above that before the substation was affected. If water level exceeds 0.3m inside the substation CBD supplies may be disrupted • many CBD high rise buildings basements may be vulnerable to flooding in these conditions. Basement flood pumps are sometimes connected to emergency generator systems, the latter also sometimes being located in a low level basement where they may be most at risk when most needed	• Wynyard wharf is not at risk from a 3m storm surge • Avgas pumps are above ground. The chemical pump is not critical • at the Wiri terminal the site drainage outflow is 2.5m above mean sea levels, so no problems are foreseen	• no threat

6.3.4 Tsunami

Electricity

The Hepburn Road substation may be at risk from a tsunami, but it is assumed the Waitemata's narrow entry and wide harbour will attenuate this risk.

The Tamaki Estuary may also be vulnerable but Transpower and Contact Energy assets at Otahuhu are well designed, with damage not foreseen since the building platform is more than 2m above ground level.

Petroleum fuels

Freemans Bay could be vulnerable to the scenario tsunami, but the only critical fuel stored is Avgas. The oil companies could maintain supply if Freemans Bay were flooded, provided there was good road access within the region.

The Wiri oil terminal is not at risk from waves less than 2.5m high.

Gas

The scenario tsunami was not identified as posing a threat to Natural Gas Corporation assets or to the Westfield Gate Station.

Table 44: Effects of the scenario tsunami on the Auckland region's energy supplies

ELECTRICITY	PETROLEUM	GAS
• the Hepburn Road substation may be at risk from tsunami but it is assumed the Waitemata's narrow entry and wide harbour will attenuate this risk • the Tamaki estuary may also be vulnerable but Transpower and Contact Energy assets at Otahuhu are well designed, with damage not foreseen since the building platform is more than 2 m above ground level	• Freemans Bay could be vulnerable to the scenario tsunami, but the only critical fuel stored is Avgas. The oil companies could maintain supply if Freemans Bay were flooded, provided there was good road access within the region • the Wiri oil terminal is not at risk from waves of less than 2.5 m	• the scenario tsunami was not identified as posing a threat to Natural Gas Corporation assets or to the Westfield Gate Station

Table 45: Summary of energy lifelines recovery profiles after the scenario events

	Day 1	Week 1	Full recovery
Earthquake			
Electricity	Some power outages or shortages if nodes or networks damaged	Pylons replaced, substations and other nodes operational	7 days (longer for CBD)
Petroleum fuels	Little damage to Wiri Oil Services. Pipeline undamaged. Loss of Avgas at Freemans Bay	100%	24 hours or longer
Gas	Reduced volumes available, but lower demand. Main gas spare parts store may be destroyed	100%	24 hours or longer
Eruption			
Electricity	Loss of affected services; disruption to adjoining services	Temporary repairs and alternative supplies in place	Several weeks, depending on extent of loss of services
Petroleum fuels	Loss of affected services; disruption to adjoining services	"	Depends on extent of loss of services
Gas	Total loss during distant eruption	"	Several weeks
Cyclone			
Electricity	Local loss of power from debris-laden high winds and local flooding or very high storm surge	Full capacity	1 - 2 days
Petroleum fuels	Full capacity	Full capacity	-
Gas	Possible loss of supply if pipeline ruptured by slips (very unlikely)	Full capacity	2 - 7 days
Tsunami			
Electricity	100%	100%	-
Petroleum fuels	Loss of Avgas at Freemans Bay. Supply okay if roads clear. Wiri unaffected if waves <2.5 m	100%, even with damage to Freemans Bay	1 - 2 days
Gas	100%	100%	-

Note: All recovery profiles assume unlimited resources and unrestricted access (see Chapter 2)

6.4 Water lifelines

General comments

The effect of widespread water supply failure cannot be overstated — water is one of the most fundamental of human needs. While drinking water can be expected to be tankered in to meet basic drinking needs, severe public health issues arise from loss of the urban water supply. The wastewater network cannot operate without available water supply, adding to these public health issues.

The worst case scenario for the region's bulk water supply is loss of supply from the Hunua dams, which supply about 70% of the region's water. Such an event could also affect the Hays Creek dam and the two emergency sources, leaving the smaller supply from the Waitakere dams and the Onehunga bores to meet demand. Water loss through damaged pipes in those networks would further reduce supplies.

In the event of total failure of the Hunua supplies, up to 70% of the overall bulk water supply could be lost. The area south of and including Manukau City would have no reticulated supply. The failure of the Huia supplies would result in loss of reticulated water to areas west of New Lynn.

Pressure on remaining supplies would be amplified by increased demand as people try to store water, as well as a high probable demand for fire fighting.

Piped systems are particularly vulnerable to rupture or tilting from earthquake movement, so earthquake poses the worst risk to local water networks, causing considerable service disruption from damaged pipework and reservoirs. In the worst case scenario, this could take considerable time to fix, with tankers and other means of distributing water being needed.

Local networks are likely to suffer major effects from the scenario earthquake, with considerable disruption of service likely as a result of damaged pipework. In the worst case, repairs may take considerable time, and tankers or other methods of distributing water would be needed.

However, the local water supply network is probably able to supply most of its customers in most other scenarios. Some areas at higher elevation will be without water for varying periods of time while services are restored, although water would be made available nearby.

Tables 46 - 49 summarise the effects of the scenario hazards on water lifelines, while Table 50 summarises water lifelines recovery profiles after all the scenario events.

In general, the longest recovery period for water networks is at least four months after an eruption destroying key node and network elements.

Recovery from earthquake is estimated to take up to three months, while extensive damage from a cyclone or tsunami could take 4 - 6 weeks to fully repair, though temporary solutions could be very promptly put in place.

6.4.1 Earthquake

Water supply

There is some redundancy in urban bulk water distribution networks, but less in the bulk supply pipes to them from the dams

Watercare's water networks have some redundancy in the urban supply areas. This means that some degree of pipe damage can be sustained and, with some reconfiguration of the network, the bulk of the urban supply would continue after an earthquake.

However Watercare's supply lines from the Huia and Hunua dams do not have the same degree of redundancy, and there is an element of risk that one or more of the pipelines from the dams and treatment plants might fail during an earthquake. The main piped supply from the Hunua dams was assessed as being vulnerable between Ardmore and East Tamaki.

The mains from Ardmore Filter Station were assessed as being vulnerable between Ardmore and East Tamaki, where they pass through peat soils that may amplify ground movement.

If the Ardmore supply were completely shut down, then the Huia filter station would be able to supply areas at least as far south as Mangere, provided water use restrictions were in place.

Local water supply networks are more vulnerable, with considerable disruption of service: in the worst case, repairs may take some time and tankered water supplies may be needed

Similarly, if the western supply were to fail, then parts of the Waitakere supply area would be without water from the supply mains.

Between two-thirds and 70% of Auckland's water comes from the Ardmore Filter Station, so the region is very dependent on the Ardmore system and the piped network between Ardmore and Manukau City. The vulnerability of the water supply from the Hunuas will be reduced with the commissioning of the Waikato water supply in early 2002, but there is still some vulnerability from the Redoubt Road reservoir site. However, a new main under construction from Flatbush to the East Tamaki reservoir will reduce the vulnerability of supplies beyond Redoubt Road by providing two divergent bulk supply main routes.

A new Nihotupu reservoir and a Titirangi pump station are part of a programme under way at present to reduce the vulnerability of the Waitakere supplies to a local supply failure.

The local water supply network is more vulnerable to earthquakes and loss of service is likely: even if Watercare's bulk supply remained operational, there would be significant local problems with burst mains and possible loss of reservoir storage.

Most local water supply networks have more ability to be reconfigured to ensure continuity of supply.

Local water networks

Local networks are likely to suffer major effects from the scenario earthquake, with damaged pipework likely to cause considerable disruption of service. In the worst case, repairs may take considerable time, and tankers or other methods of distributing water would be needed.

Key effects of the scenario earthquake on water supply systems were identified as:

- ground displacement causing topographic and gradient changes, resulting in breakages of pipelines and damage to water pump stations
- structural concerns about reservoirs that may not have been constructed for seismic loadings
- liquefaction of alluvial deposits in coastal regions causing structural damage to buildings, water pump stations and some pipes
- ground accelerations and differential settlement causing minor damage to water pump station buildings, pipe bridges and other structures
- differential settlement and possible displacement due to landslides causing extensive breakages throughout water pipeline networks where pipe connections are damaged because of their inflexibility
- minor damage to pumping equipment
- low risk to electrical componentry and SCADA systems, although both rely on power and telecommunications in order to provide continued service

Recovery profile

Possible basic scenarios for recovery of water networks after an earthquake are outlined below.

- 1 day: 100% of all problem areas identified, with all burst mains isolated. If bulk supply is still available and roading is intact, all areas would have essential water supply services except those affected by breakages
- 1 week: essential water supply services would be in place, although minor structural integrity issues would not have been identified. Nonessential water supply would be provided by tanker until repairs were complete
- time to full recovery: 3 months, assuming unlimited resources. In reality, the recovery period would be substantially increased because of lack of labour resources, piping supplies and so on

Wastewater

The regional wastewater network is vulnerable to earthquake, with ruptures causing discharges and consequent health and environmental risk

Watercare has many wastewater pipe bridge crossings over creeks or tidal areas. In a very severe earthquake these could settle, move or collapse, discharging raw sewage into the environment.

Buried pipelines could be ruptured in the event of major slippage or ground liquefaction. Most at risk are those under the sea bed in the coastal marine area which act as inverted siphons to convey the wastewater under marine inlets. Ruptures would result in discharge into the environment, or blockage causing a discharge further upstream.

Overflows from broken pipes and loss of power to pump stations would be widespread

In most of the scenario hazards, failed sewage pumping stations are likely to be a source of wastewater overflows, although (other things being equal) response can be prompt because the locations are known. Restoration of service would depend on the nature of fault. Failure of the wastewater network would cause raw sewage to discharge into the environment, posing a public health risk although not an immediate threat to life. In some cases, significant environment degradation would also result, depending on the flow rate, location and duration of the overflow. Overflows from blocked or broken sewers would be harder to locate. Both would need to be addressed quickly, with the immediate health hazard minimised by appropriate signage.

Wastewater flows by gravity into pump stations where it is lifted to a higher level so it can flow again by gravity. If the pumps stop pumping, the wastewater continues to flow by gravity into the station and overflows into the environment through purpose - made outlets. In a major hazard event, pump stations could cease to function because of failure of power supply, damage to critical electrical or mechanical fittings or pipes or damage to telecommunication control equipment.

Generally, however, failure of the wastewater system is considered less significant, as long as sewage overflows can be directed to waterways and away from people and property. This would be the first priority before attempting to restore the wastewater service

Because wastewater flows by gravity into the Manukau Wastewater Treatment Plant, if all the power sources fail, the flow can gravitate through the oxidation ponds and then into the sea. Discharge by gravity to the sea will still be possible after the plant is upgraded.

Generally, however, failure of the wastewater system is considered less significant than failure of the water supply system, as long as sewage overflows can be directed to waterways and away from people and property. This would be the first priority before attempting to restore the wastewater service.

Key effects of the scenario earthquake on wastewater systems were identified as:

- ground displacement causing topographic and gradient changes, resulting in breakages of sewer lines and rising mains and damaging pump stations
- liquefaction of alluvial deposits in coastal regions causing structural damage to buildings, wastewater pump stations, rising mains and some gravity mains
- ground accelerations and differential settlement causing minor damage to pump station buildings, pipe bridges and other structures
- differential settlement and possible displacement due to landslides causing extensive breakages throughout wastewater networks where pipe connections are damaged because of their inflexibility
- minor damage to pumping equipment
- low risk to electrical componentry and SCADA systems, although both rely on power and telecommunications in order to provide continued service
- coastal pumping stations may be inundated by an earthquake - induced tsunami
- the Manukau Wastewater Treatment Plant may experience possible failure of clay liners and concrete wave barriers, breakage of ultraviolet tubes and other treatment equipment and minor damage to site buildings

Recovery profile

Possible simple scenarios for recovery of wastewater networks after an earthquake are:

- 1 day: loss of power will result in sewer overflows to the environment. Widespread breakages in pipelines may result in loss of service to both small and large catchments. No immediate effects would be visible in people's homes Overflows would be diverted away from critical areas
- 1 week: 50% of major problem areas would be identified, maintenance crews would be repairing essential sites, major pump stations and trunk mains. All overflows channelled to waterways or stormwater systems
- time to full recovery: 3 months, assuming unlimited resources. In reality, the recovery period would be substantially increased because of lack of labour resources, piping supplies and so on

Stormwater

Loss of stormwater services generally has less serious effects than loss of water or wastewater services.

Recovery periods for stormwater would be substantially longer because of the higher priority given to restoring for water and wastewater services

Key impacts of the scenario earthquake on stormwater networks were identified as:

- liquefaction of alluvial deposits in coastal regions and ground displacement, ground acceleration and differential settlement elsewhere causing breakages and changes in pipe gradients
- pipe breakages from possible displacement due to landslides
- damage to pipe connections being damaged because of their inflexibility
- rainfall after the event would cause localised flooding problems.
- possible floods from landslide displacement of existing waterways

Recovery profile

Recovery profiles for stormwater services would be (refer to the assumptions in Chapter 2):

- 1 day: 3 most serious problem areas being actioned
- 1 week: most serious problem areas identified
- time to full recovery: 3 months, assuming unlimited resources. In reality, however, the recovery period would be substantially increased because of lack of labour resources, piping supplies and the higher priority given to restoring for water and wastewater services, especially if weather remains dry so that flooding problems are avoided

Table 46: Summary of likely effects of the scenario earthquake on wastewater, water and stormwater services

SERVICE	WATER SUPPLY	WASTEWATER	STORMWATER
Bulk networks	• loss of bulk supplies from possible failure of the Hunua and/or Huia dams • there may be structural concerns about some reservoirs under extreme seismic loadings • if Watercare's bulk supply remained operational, there would be significant local problems with burst mains and possible loss of reservoir storage	• extensive breakages throughout wastewater networks resulting from differential settlement and possible displacement due to landslides, with pipe connections being damaged due to inflexibility • minor damage to pumping equipment	

Local networks	• similar problems to those expected with the wastewater pipe work would be expected in the local water supply pipework
	• the effect of the loss of some supply following an earthquake will be amplified by:
	  • increased demand from water loss through damaged pipes
	  • people initially trying to store water
	  • a probably high fire fighting demand
		• ground displacement causing to topography and changes in gradients hence breakages of sewer lines, rising mains, pump stations
		• liquefaction of alluvial deposits in coastal regions resulting in structural damage to buildings, wastewater pump stations, rising mains and some gravity mains
		• minor damage to pump station buildings, pipe bridges and other structures due to ground accelerations and differential settlement.
		• low risk to electrical componentry and SCADA systems, both reliant on power and telecommunications networks providing continued service. Coastal pumping stations may be inundated due to post - quake tsunami risk
		• treatment plant: possible failure of the clay liners and concrete wave barriers, breakage of UV tubes and other treatment equipment and minor damage to site buildings
			• liquefaction of alluvial deposits in coastal regions and ground displacement, ground acceleration and differential settlement elsewhere causing breakages and changes in pipe gradients
			• pipe breakages from possible displacement due to landslides
			• damage to pipe connections being damaged because of their inflexibility.
			• flooding from landslide displacement of streams

6.4.2 Volcanic eruption

A local volcanic event would cause a localised area of service failure that would be evacuated during the event. The water services networks around the area would be isolated, and water supply in particular would be disrupted as a result. Both the local and distant scenario would scatter ash across the region.

The effects of ash may require choosing between having non - potable water in the system or no water at all

Ash is unlikely to physically affect pipes but could cause structural failure of some roofs or abrasive failure of pumps and motors. There may be implications for water treatment, possibly requiring a choice between having non - potable water in the system or no water at all.

Ground deformation around a local volcano would have severe effects: services would need to be totally redesigned

Ground deformation around a local volcano would have severe effects: services would need to be totally redesigned. Although prompt restoration of services would not be needed (many properties would be destroyed, with the rest becoming unoccupied), there would be severe problems for sewers passing through the affected area. Stormwater flooding would probably affect some properties near the edge of the disturbed ground.

Conclusions from analysing the effects of the two scenario eruptions on the three piped water services (water supply, wastewater and stormwater) were that:

Heavy ash fall is a major problem for all three piped services

- a local volcano is a major localised problem for all piped services and a significant wastewater problem in the area affected by ash
- a thin layer of ash is a minor wastewater problem
- a thick layer of ash is a major problem for all three piped services

Water supply

Water supply networks are vulnerable to local volcanic activity, especially in the immediate area of the vent, where all services are likely to be inoperable. The extent of effects is heavily influenced by the exact location of the vent in relation to trunk facilities, especially water pumping stations.

Assuming Watercare could continue to supply water, most of the region not directly affected by a localised volcano in terms of water supply would receive service. The affected areas would be evacuated and water supplies valved off

Assuming Watercare were able to continue to supply water, most of the region not directly affected by a localised volcano would receive service. The affected areas would be evacuated and water supplies valved off.

The main problems for water supply relate to pipe work and concerns that the water supply may not be useable because of ash contamination. Major effects of the scenario eruption on water supply services were identified as:

- high turbidity in raw water disturbing the disinfection process and possibly impairing the filtration process
- disruption of water treatment plant biological processes by ash fall
- contamination with ash through any open system

- complete destruction of pipework and other facilities in the eruption's immediate zone, causing loss of service in that area and downstream
- ground displacement around that area causing changes to topography and changes in gradients, resulting in breakages of pipes, rising mains and pump stations
- increase in water demand for cleaning
- transport disruptions as vehicles become inoperable because of filter clogging
- possible loss of communications during very heavy ash falls

Ash fall is a major problem, clogging pipes and raising water demand as people try to wash it away

The local water supply network is likely to be able to supply most of its normal customers for most of the scenarios. Some at higher elevated areas will be without water or with reduced pressure for varying periods of time while services are restored, during which time water will generally be available from adjacent areas at lower elevations.

Water demand may increase as people attempt to wash ash away, although media advice will discourage this.

Ash fall may affect the operation of water treatment plants.

The effects of a local volcano are very localised and with evacuation of people from the worst affected area, the number affected is likely to be relatively small.

Recovery profile

A basic recovery profile for water supply services after the scenario volcano is (refer to the assumptions in Chapter 2):

- 1 day: 100% of all problem areas identified, namely all burst mains isolated. Co-ordination of portable water supply would start, using water tankers and so on
- 1 week: essential water supply services would be in place, though not all minor structural integrity issues would yet be identified. Non essential water supply would be provided by tanker until key services were repaired
- time to full recovery: 4 months minimum, assuming unlimited resources. Temporary pump stations would be in place within 3 - 4 months, with catchments re-routed around the devastated area

Wastewater

Wastewater systems may be vulnerable to entry of ash and blockage or damage to pump impellers by abrasion, as well as to overflows as a result of ground distortion by a local volcano.

Gradient changes and pipe breakage from mounding around the vent would affect pipes

Major effects of the scenario eruption on wastewater services were identified as:

- ground displacement causing changes to topography and changes in gradients resulting in breakages of sewer lines, rising mains, pump stations
- complete destruction in the eruption's immediate zone, causing loss of service in that area and upstream perhaps if the bulk collection main is damaged or destroyed
- long term widespread blockages of sewer network by ash falls carried into the system by rainfall

- abrasion and corrosion of pumps by ash particles
- disruption of treatment plant biological processes by ash falls

If it rains and possibly also for some of the above reasons, ash is likely to enter sewage systems, especially Auckland City's combined system.

Recovery profile

A basic recovery profile for wastewater services after the scenario volcano is (refer to the assumptions in Chapter 2):

- 1 day: localised complete destruction of the wastewater network with widespread leaks and breaks. Loss of power would result in sewer overflows to the environment. Widespread breakages in pipelines may result in loss of service to both small and large catchments, albeit with immediate effects
- 1 week: major problem areas would be identified, maintenance crews would be repairing essential sites, major pump stations and trunk mains, with plans for remediation starting to be made
- time to full recovery: 4 months minimum, assuming unlimited resources. Temporary pump stations would be in place within 3 - 4 months, with catchments re-routed around the devastated region

Stormwater

Key impacts of the scenario eruption on stormwater networks were identified as:

- complete destruction within the zone of influence of the volcano, resulting in loss of service in that area
- ground displacement outside the immediate zone of destruction causing changes in gradients and breakages of pipes and connections
- long term widespread blockages of the stormwater network by ash falls, causing relatively severe localised flooding

Stormwater again a low priority for restoration compared with water and wastewater services

There is a real need to prevent ash from settling into stormwater pipes, because removing it is so difficult. This may necessitate identification of temporary stockpile sites to enable rapid response, especially if transport networks are disrupted.

Loss of stormwater services generally has less serious effects than loss of water or wastewater services. However, effects could be locally serious where flooding exacerbated other damage, especially if it rained after a heavy ash fall.

Recovery profiles for stormwater services would be (refer to the assumptions in Chapter 2):

Recovery profile

- 1 day: local disruption of stormwater network
- 1 week: most serious problem areas identified
- time to full recovery: 4 months, assuming unlimited resources. The recovery period would probably be much longer than this because of scarce labour and piping supplies and the higher priority for water and wastewater services to be restored, especially if weather remains dry

Table 47: ***Summary of likely effects of the scenario eruption on wastewater, water and stormwater services***

SCENARIO	WATER SUPPLY	WASTEWATER	STORMWATER
Local event	**Immediate area** • Watercare trunk water mains unaffected • Metrowater water mains severely damaged around CBD and area isolated: note that the area would be evacuated and the only water demand would be for fire fighting **Wider area** • ash prevented from entering water pumping stations by appropriate means	**Local area** • three trunk Watercare pumping stations and local catchment sewers severely damaged • overflow of the Orakei sewer (which takes 20% of the Mangere Wastewater Treatment Plant (MWTP) flow) • sewer gradients affected **Wider area** • ash from combined system causes flow and treatment problems - possible turning off of all sewage pumps • ash in sewers may cause problems if it rains • ash prevented from entering wastewater pumping stations by appropriate means • grit chambers quickly fill	**Local area** • severe drainage problems from reshaped topography • flooding from dammed 'valleys' **Wider area** • ash causes relatively minor flooding problems as pipes and channels block
1 - 2mm ash	• ash prevented from entering water pumping stations by appropriate means • possible problems for water storage dams if ash in suspension	• ash prevented from entering wastewater pumping stations by appropriate means	• minor problems
3 -100mm ash	• major problems for dams especially if ash in suspension • filter stations overloaded • filters will need covering • ash prevented from entering water pumping stations by appropriate means • reservoirs possibly subject to structural failure	• ash prevented from entering wastewater pumping stations by appropriate means • problems of sewage turning to "paste" more likely in combined area • pumping stations shut down to avoid abrasive damage • operational, maintenance and possible odour problems at MWTP. Sediment overload: processes bypassed to land or the harbour	• lots of blockages and localised flooding

6.4.3 Tropical cyclone

Table 48 summarises the effects of the scenario cyclone on all three piped water networks. It was assumed that the two Waitemata Harbour bridges and customer service would both remain largely unaffected.

Buildings related to water lifelines are thought to be able to withstand wind loads. Aerials for SCADA systems may need securing and these will need to be individually checked during and after the event.

Rainfall may be localised, short and intense as over Pukekohe in January 1999, or widespread and prolonged as region wide in July 1979. Buildings will need to be waterproofed, as leaks can cause problems for electrical circuitry.

Water supply

The pipe component of Watercare's bulk water supply system is not very vulnerable to the scenario cyclone: its main vulnerability is loss of power or communication to the system. However, as the system is mainly gravity fed, a power loss has minimal effect

The pipe component of Watercare's bulk water supply system is not very vulnerable to the scenario cyclone: its main vulnerability is loss of power or communication to the system. However, as most of the source water is fed by gravity to the supply stations, and then on to consumers, a power loss has minimal effect.

In general, pipelines and other assets are located in relatively stable areas which should not be affected by cyclonic storms, although access to these assets may be hampered for a short period until roads are cleared of any slips.

Power loss could cause possible loss of communication and pumping capability. Although wind may topple power lines, loss of one local supply line is usually compensated for by switching to an alternative source. Customers in affected areas relying on pumped systems would have no water, and others may have reduced pressure. However, few customers will be without water.

The most serious effect of a power supply loss would be on the Khyber pump station, which maintains the supply to Mount Eden and thence to various hospitals

The most serious effect of a power supply loss would be on the Khyber pump station, which maintains the supply to Mount Eden and thence to various hospitals. The filter stations have standby power capacity to maintain service in the event of a power supply loss for up to two days. Standby generators would be utilised to maintain critical water supply pumping stations, should power supply fail for an indefinite period. However, this depends on reinstating roads to ensure the supply of fuel to priority sites such as the Ardmore and Huia filter stations.

Local instability would affect access to some assets for a period, and may cause some local sections of cast iron main in potentially unstable landforms to fail.

Local instability would affect access to some assets for a period, and may cause some local sections of cast iron main in potentially unstable landforms to fail. In almost all cases an alternative supply could be provided.

Pipelines located in on unstable hillsides might be affected by any slips.

In almost all cases an alternative supply could be provided

A small part of the Waitakeres near Titirangi could be affected if a slip on Scenic Drive cut the cast iron main running along it. Procedures are already in place to provide an alternative supply, with a pump station located at the Titirangi reservoirs to feed back to the high level zone.

Water delivery systems are not at risk from storm surges because they last such a short time. Their effect on the Onehunga aquifer would, if any, be negligible.

Watercare's water supply dams are subjected to regular surveillance, monitoring and analysis. In addition, an independent dam safety assurance audit is undertaken on each facility every five years, to ensure that the structures meet public expectations, and international practice in dam safety assurance. None of the dams would be subjected to hazardous conditions in the scenario cyclone

Watercare's water supply dams are subjected to regular surveillance, monitoring and analysis. In addition, an independent dam safety assurance audit is undertaken on each facility every five years, to ensure that the structures meet public expectations, and international practice in dam safety assurance. None of the dams would be subjected to hazardous conditions in the scenario cyclone.

There would be direct and indirect effects upon the supply system from the winds associated with the cyclonic storm. Some of the SCADA aerials with higher than normal aerials in locations with poor reception may be lost, but the main repeaters are built to withstand significant storms without damage. In the event of aerial loss, service would continue with manual data input until the aerials were reinstated. The repeater stations are either fed by solar energy or have enough standby capacity to maintain service beyond the period of the scenario cyclone.

High winds would be likely to disrupt power supplies, especially in the headworks, where services are run through several kilometres of roads formed through steep bush clad slopes. In places without standby power, power loss would result in a continuation of whatever had been happening at the time until staff arrive to manually effect any necessary changes. In the event of extended power outage, facilities are available for linking in a portable three phase standby generator that can be taken in by helicopter, vehicle or foot.

Staff are located at critical dam sites, so even if vehicle access is not possible, they would be available to maintain the core services.

Local water networks would be unlikely to be significantly affected by cyclonic storms, provided Watercare could continue to supply water to maintain reservoir supplies. Localised problems such as slips may affect a relatively small number of customers

Local water networks would have similar vulnerabilities to Watercare's network: they would be unlikely to be significantly affected by cyclonic storms, provided Watercare could continue to supply water to maintain reservoir supplies. The networks may however be subject to localised problems such as slips, affecting a relatively small number of customers.

In the event of a regional power outage following a storm, most of the city would be able to receive gravity water from Watercare reservoirs for a few days. A small number of customers would be without water unless generators were used at local water boost stations.

In the event of a prolonged outage lasting several days, much of the region (31% of North Shore Water Services) would be without water unless emergency generators were used at Watercare's key water pumping stations.

In summary, the key effects of the scenario cyclone on water supply are that:

- service to most customer would continue, as reservoirs generally have at least 48 hours storage. Small areas at higher elevations could have no water
- some local mains would be affected by scouring of water courses
- important buildings are likely to be unaffected, but minor leakage may affect electrical circuitry
- some local mains may be affected by slips, and repairing them may be a problem
- most but not all trunk mains are generally outside sensitive areas, but more investigation is needed
- Watercare raw water mains are generally in areas more prone to slippage. Access difficulties are expected but the dams are unlikely to be affected. Loss of a line would be compensated for by switching to another line
- dam water would probably be more turbid, needing more treatment
- bore supplies could possibly be contaminated
- effects of the storm surge are likely to be minor, but coastal scouring would be likely to affect local water mains. Shutoff valves will minimise area affected

Recovery profile

The basic recovery profile for water supply services after the scenario cyclone is (refer to the assumptions in Chapter 2):

- 1 day: very little damage would be reported, apart from possible structural failure of exposed pipelines and minor damage at reservoirs. There would be very little loss of service
- 1 week: maintenance well under way for exposed pipelines
- time to full recovery: 4 - 6 weeks, assuming unlimited resources. Temporary pump stations would be in place

Wastewater

Power loss could cause possible loss of communication and pumping capability, resulting in overflows. Although wind may topple power lines, loss of one local supply line is usually compensated for by switching to an alternative source

Power loss could cause possible loss of communication and pumping capability, resulting in overflows. Although wind may topple power lines, loss of one local supply line is usually compensated for by switching to an alternative source.

Effects of the scenario cyclone on wastewater networks were expected to be minor, with most customers still receiving service.

Key effects were identified as:

- important buildings are likely to be unaffected, but minor leakage may affect electrical circuitry and monitoring telemetry
- localised and regional flooding means the sewer system would become overloaded and overflow to the environment, as happens currently in major storms. The system would nevertheless remain functional
- some scouring from lifted manhole lids
- inundation of gully traps
- scouring of bridge piers and pipe bridges possibly affected
- some trunk and local sewers would at risk from slips

- sewers may be flooded by dammed creeks
- some local pump stations may be affected by slips
- storm surge erosion may occur at coastal pumping stations and foreshore sewers, especially along the east coast beaches
- pump station switchboard gear in about ten pump stations would be affected by saltwater intrusion from the storm surge, so without pumping, uncontrolled discharges would result
- some stations would be affected by leakage at high tide
- possible overtopping and or scouring of Mangere and Orewa ponds with possible odour incidents
- possible erosion of the Orewa ponds

Recovery profile

The basic recovery profile for wastewater services after the scenario cyclone is (refer to the assumptions in Chapter 2):

- 1 day: complete inundation of coastal regions — Bucklands Beach, eastern beaches, East Coast Bays and Auckland beaches, Beachlands - Maraetai. Widespread uncontrolled discharges. At risk coastal pump stations and pipelines affected by structural failure would be identified
- 1 week: pump station maintenance crews would be at work, with initial repairs or temporary switchboards in place. Temporary repair to pipe bridges and coastal pipelines would have started
- time to full recovery: 4 - 6 weeks, assuming unlimited resources. Temporary pump stations would be in place

Stormwater

Key impacts of the scenario cyclone on stormwater networks were identified as:

- scouring of earth lined banks and some overland flow paths
- localised and regional flooding due to hydraulic overload of the stormwater system and blockage of cesspits, pipes, culverts and watercourses by debris
- loss of road access by flooding
- scouring of bridge piers possibly affecting pipe bridges
- some road and property damage
- slope failure causing breakages of stormwater pipelines

Recovery profile

Problems are likely to be localised. Recovery profiles for stormwater services would be (refer to the assumptions in Chapter 2):

- 1 day: serious local flooding
- 1 week: essential repairs would be under way
- time to full recovery: 4 - 6 weeks, assuming unlimited resources

Table 48: ***Summary of likely effects of the scenario cyclone on wastewater, water and stormwater services***

EFFECT	WATER SUPPLY	WASTEWATER SYSTEM	STORMWATER
Wind	• nil, assuming power still available and roof aerials on pump stations secured	• nil, assuming power still available and roof aerials on pump stations secured	• negligible
Rainfall and Flooding	• minor: service to most customers continues • some local mains affected by scouring of water courses • important buildings are likely to be unaffected, but minor leakage may affect electrical circuitry • possible contamination of bore supplies	• minor: customer system still functions • important buildings are likely to be unaffected, but minor leakage may affect electrical circuitry • localised and regional flooding overloads sewers causing overflows to environment, as happens currently in major storms. System remains functional. Some scouring from lifted manhole lids. Gully traps inundated • bridge piers scoured, pipe bridges maybe affected • Orewa ponds may be affected by erosion	• scouring of earth lined banks and some overland flow paths • loss of road access by flooding: cesspits blocked • localised and regional flooding due to hydraulic overload of the stormwater system and blockage of pipes, culverts and watercourses by debris • scouring of bridge piers possibly affecting pipe bridges
Slope failure	• loss of some local mains in slips • most but not all trunk mains are generally outside sensitive areas, but more investigation is needed • Watercare raw water mains generally in areas more prone to slippage. Access difficulties expected but dams unlikely to be affected. • dam water likely to be more turbid and will need more treatment • Rodney District water supply: similar position	• customer system still functions • some trunk and local sewers at risk from slips • sewers flooded by dammed creeks • some local stations possibly affected by slips • treatment plants generally unaffected	• damming of creeks and waterways resulting in flooding • some road and property damage • slope failure causing breakages of stormwater pipelines
Storm surge	• minor • coastal scouring likely to affect local water mains. Shutoff valves will minimise area affected	• possible erosion at coastal pumping stations and foreshore sewers especially east coast beaches • some stations affected by leakage at high tide • possible overtopping and or scouring of Mangere and Orewa ponds with possible odour incidents • Mangere treatment plant may be affected	• flooding and scouring in coastal area

6.4.4 Tsunami

Table 49 summarises the likely effects of the scenario tsunami on wastewater, water and stormwater services. Both the Waitemata Harbour bridges were identified as remaining largely unaffected by the scenario tsunami, as would the water services carried across them.

Effects of the scenario tsunami would similar to those of the cyclone storm surge but the greater wave height would cause more damage.

Water supply

Tsunami are not a risk to Watercare's regional water delivery systems

Tsunami are not a risk to Watercare's regional water delivery systems. Their duration will be short and they would have a negligible if any effect upon the underground aquifer in Onehunga.

Local instability could affect access to some assets for a period, and may cause some local sections of cast iron main in potentially unstable areas to fail. In almost all cases an alternative supply can be provided.

Local water networks are unlikely to be significantly affected provided Watercare can continue to maintain reservoir supplies, but may be affected by localised problems such as coastal erosion, albeit affecting a relatively small number of customers

Local water networks will be subject to similar vulnerabilities as Watercare's: they are unlikely to be seriously affected by a tsunami provided Watercare can continue to maintain reservoir supplies. Local networks may however be affected by localised problems such as coastal erosion, albeit affecting a relatively small number of customers.

Key effects of the scenario tsunami would be:

- coastal scouring likely to affect local water mains. Shutoff valves would minimise area affected
- bridges with water and other services on them would be at risk
- local instability may cause some local sections of cast iron main in potentially unstable areas to fail
- local instability could affect access to some assets for a period

Recovery profile

The basic recovery profile for water supply services after the scenario tsunami is (refer to the assumptions in Chapter 2):

- 1 day: very little damage reported. Possible structural failure of exposed pipelines and minor damage at reservoirs would be detected. There would be very little loss of service
- 1 week: maintenance of exposed pipelines would be well under way
- time to full recovery: 4 - 6 weeks, assuming unlimited resources. Temporary pump stations would be in place

Wastewater

Most of Watercare's wastewater system is not vulnerable

In a very severe tsunami, one or more of Watercare's many wastewater pipe bridge crossings over creeks or tidal areas could settle, move or collapse, discharging raw sewage into the environment. However, Watercare's sewerage system is not very vulnerable to the scenario tsunami, as almost all assets are above the area of influence. The few steel pipe bridges that may be affected by a tsunami are not expected to suffer damage.

Local wastewater networks throughout the region are vulnerable to flooding by stormwater. This happens moderately frequently, resulting in sewage overflows as systems' hydraulic capacity is exceeded. Overflows are likely

Local wastewater networks share the vulnerabilities of Watercare's networks. They are unlikely to be significantly affected by tsunami or cyclonic storms, provided Watercare can continue to supply water to maintain reservoir supplies. Localised problems such as slips may affect a relatively small number of their customers.

Local wastewater networks throughout the region are vulnerable to flooding by stormwater. This happens moderately frequently, resulting in sewage overflows as the systems' hydraulic capacity is exceeded. Overflows are likely in a cyclone or tsunami.

Key effects of the scenario tsunami were:

- scouring of bridge piers, pipe bridges possibly affected
- localised flooding
- sea water ingress into the wastewater system, resulting in increased wastewater overflows.
- erosion may occur at coastal pumping stations and foreshore sewers, especially at east coast beaches
- wastewater pumping stations in coastal areas would be inundated
- salt water intrusion would affect control boxes
- possible electrical failure from leakage into buildings, with power outages removing pumping capabilities and causing overflows, especially in those with montrose boxes
- some stations would be affected by leakage at high tide
- overtopping and/or scouring of the Mangere and Orewa ponds is possible, with odour incidents possibly resulting
- the Mangere wastewater treatment plant may be affected
- bridges carrying mains near the coast likely to be affected by coastal scouring.

Recovery profile

The basic recovery profile for wastewater services after the scenario tsunami (refer to the assumptions in Chapter 2) is:

- 1 day: complete inundation of coastal regions — Bucklands Beach, eastern beaches, East Coast Bays and Auckland beaches, Beachlands - Maraetai. About 10 pump stations would be directly affected, resulting in overflows. Pump station switchboard gear would be affected by saltwater intrusion, with no pumping available. At risk coastal pipelines and possible structural failure in coastal environments, along with any uncontrolled discharges would be identified
- 1 week: pump station maintenance crews would be at work with initial repairs started or temporary switchboards in place. Temporary repair to pipe bridges and coastal pipelines would have started.
- time to full recovery: 4 - 6 weeks, assuming unlimited resources. Temporary pump stations would be in place

Stormwater

The scenario tsunami would cause greater flooding and scouring of stormwater networks than the scenario cyclone. Key impacts were identified as:

- localised and regional flooding causing stormwater ingress into the stormwater system
- scouring of bridge piers possibly affecting pipe bridges
- risk of slope failure causing breakages of stormwater pipelines
- blockages caused by debris in the system

Problems are likely to be localised. Recovery profiles for stormwater services would be (refer to the assumptions in Chapter 2):

Recovery profile

Problems are likely to be localised. Recovery profiles for stormwater services would be (refer to the assumptions in Chapter 2):

- 1 day: complete inundation of coastal regions, with possible structural failure in coastal environments affecting pipes
- 1 week: essential repairs would be under way
- time to full recovery: 4 - 6 weeks, assuming unlimited resources. Remediation of affected pipelines would be complete

Table 49: Summary of likely effects of the scenario tsunami on wastewater, water and stormwater services

WATER SUPPLY	WASTEWATER SYSTEM	STORMWATER
• minor effects • coastal scouring likely to affect local water mains. Shutoff valves will minimise area affected • bridges with water and other services on them at risk • local instability may cause some local sections of cast iron main in potentially unstable landforms to fail • local instability could affect access to some assets for a period	• as for cyclone storm surge but greater wave height and more damage • erosion may occur at coastal pumping stations and foreshore sewers especially at east coast beaches • wastewater pumping stations on coastal areas would be inundated • salt water intrusion would affect control boxes • power outages would remove pumping capabilities. • some stations affected by leakage at high tide • possible overtopping and or scouring of Mangere and Orewa ponds with possible odour incidents • Mangere wastewater treatment plant may be affected • bridges carrying mains near the coast likely to be affected by coastal scouring • possible electrical failure from leakage into buildings • local montrose box pumping stations at risk from electrical damage	• greater flooding and scouring than for the scenario cyclone • localised and regional flooding causing stormwater ingress into the stormwater system • scouring of bridge piers possibly affecting pipe bridges • risk of slope failure causing breakages of stormwater pipelines • blockages caused by debris in the system

Table 50: Summary of water lifelines recovery profiles after the scenario events

	Day 1	Week 1	Full recovery
Earthquake			
Water supply	Problem areas identified and burst mains isolated	Essential supplies in place	3 months
Wastewater	Sewer overflows to critical sites diverted	Overflows channelled to waterways or stormwater systems	3 months
Stormwater	Most serious problems identified	Most serious problems being rectified	3 months
Eruption			
Water supply	100% of all problem areas identified, namely all burst mains isolated. Co-ordination of portable water supply would start, using water tankers and so on	Essential water supply services would be in place, though not all minor structural integrity issues yet identified. Non essential water supply provided by tanker until key services repaired	4 months minimum, assuming unlimited resources. Temporary pump stations would be in place within 3 - 4 months, with catchments re-routed around the devastated area
Wastewater	Localised complete destruction of the wastewater network, widespread leaks and breaks. Sewer overflows. Widespread breakages, loss of service	Major problem areas identified, maintenance crews repairing essential sites, major pump stations and trunk mains, remediation plans starting to be made	4 months minimum,. Temporary pump stations would be in place within 3 - 4 months, with catchments re-routed around the devastated region
Stormwater	Local disruption of stormwater network	Most serious problem areas identified	4 months, probably much longer because resources and the higher priority for water and wastewater services, esp. if weather remains dry
Cyclone			
Water supply	Very little reported damage or loss of service, apart from possible structural failure of exposed pipelines and minor damage at reservoirs	Maintenance well under way for exposed pipelines	4 - 6 weeks. Temporary pump stations would be in place
Wastewater	Complete inundation of coastal regions. Widespread uncontrolled discharges. At risk coastal pump stations and pipelines affected by structural failure would be identified	Pump station maintenance crews at work, with initial repairs or temporary switchboards in place. Temporary repair to pipe bridges and coastal pipelines would have started	4 - 6 weeks. Temporary pump stations would be in place
Stormwater	Serious local flooding	Essential repairs under way	4 - 6 weeks
Tsunami			
Water supply	Little damage or service loss. Possible failure of exposed pipelines, minor damage at reservoirs	Maintenance of exposed pipelines well under way	4 - 6 weeks. Temporary pump stations would be in place
Wastewater	Complete inundation of coastal regions. About 10 pump stations directly affected by saltwater intrusion, causing overflows. At risk areas and uncontrolled discharges identified	Pump station maintenance crews at work with initial repairs started or temporary switchboards in place. Temporary repair to pipe bridges and coastal pipelines started	4 - 6 weeks. Temporary pump stations would be in place
Stormwater	Complete inundation of coastal regions, with possible structural failure affecting pipes	Essential repairs under way	4 - 6 weeks. Remediation of affected pipelines would be complete

Note: All recovery profiles assume unlimited resources and unrestricted access (see Chapter 2)

Interdependencies

7. INTERDEPENDENCIES AMONG THE LIFELINE UTILITIES

All the lifeline utilities rely on each others' services to run or repair their own. This chapter:

- summarises these interdependencies
- portrays interdependencies in a visual form

To enable effective and efficient recovery of lifelines from an event which disrupts their service, dependencies on other lifelines must be understood.

Lifeline utilities rely heavily on energy and communications in particular for their continued operation. In the event of failure, however, access is also necessary to visit a site and provide power for recovery, as well as, in the event of a hazard event, requiring clean up water for restoration of service.

The Auckland Engineering Lifelines Project enabled each of the lifelines to assess its own reliance on and interdependence with other lifelines by examining their operational needs as well as their recovery needs in the event of the scenario hazards devised.

The results were summarised in the form of the interdependence matrices developed in the Wellington and Christchurch lifeline projects. These are shown at the end of this chapter.

7.1 Communications lifelines

Telecom

Communication is essential for all lifeline utilities

Telecom focused on the problem of maintaining reliable and convenient communication services for other utilities and their contractors and its needs in order to do this.

Communications for all lifelines is essential, be this the 'plain old telephone service', mobile phones, radio or data — but all communication nodes need:

- power
- failing that, road access and diesel fuel to replenish emergency generators
- alternative locations from which to run key services
- contracting staff
- spare parts
- a water supply for some cooling systems

The major central city nodes with inherently higher power consumption have fuel capacity on site for only a couple of days emergency power generation. If power supplies to the city fail, fuel delivery to these nodes is of paramount importance for continued communications.

In most cases, though with considerable effort, staff can be relocated to alternative accommodation equipped to allow them to continue essential tasks. Alternatively, calls to affected customers could be diverted to alternative centres outside the affected zone, as was done on a small scale during the Auckland power outage. The viability of this option would depend on the nature of the event, but while not ideal, it could maintain lifeline utilities' essential communication services.

Maintenance contracts and spare parts are held by local and regional firms whose workload is likely to be highest when the utilities' requirements are greatest. Rationing of high demand stock is likely

Plant maintenance contracts and spare parts are held by local and regional firms whose workload is likely to be highest when the utilities' requirements are greatest. Rationing of high demand stock is likely. 'Just in time' management of stocks and external service level agreements may make hazard response more difficult.

Several products could be enhanced to promote the maintenance of reliable and convenient communication services for other utilities and their contractors, but the cost of development make this an area for additional study.

CLEAR

The recovery time for CLEAR services depend on a number of resources, including:

- the road network, to assess and restore the CLEAR network, transport people, equipment and diesel
- electricity, to operate the CLEAR network
- diesel fuel, to operate emergency generators and vehicles
- water, to wash away ash and clean air filters
- contractors, to restore the CLEAR network
- fibre-optic cable, to restore any breaks in the fibre-optic network
- air filters, to protect air conditioning units and generators volcanic ash

Vodafone

Recovery from any event will depend on the ability to maintain:

- power (including access for generator supply)
- fuel supply (and the transport thereof)
- the interconnection to other telecommunication operators.

7.2 Transport lifelines

Transport's need for other utilities

The road network has the highest priority for all utility operators, because so many of their activities revolve around it — moving staff and goods and getting to key nodes and networks. Alternative transport modes such as sea and air can also substitute for damage to land transport.

Transport modes provide alternative access for utility operators

However, to keep these transport networks operational or to restore capacity after a hazard event, transport operators likewise rely on other utilities: recovery of transport can be seriously disrupted or delayed by problems with other utility networks.

Key utility needs for transport operators to maintain their services include:

- cellular communication, to co-ordinate response
- diesel for earth moving equipment
- prompt response by water and gas utilities to shut off valves on broken pipes to protect the integrity of available roads and prevent further damage for example by washout of bridge approach embankments from broken water mains
- land lines to maintain traffic light systems (a lower priority)

These are briefly summarised below.

Transport's need for communications

Contractors rely on cell phones

Managers and contractors repairing transport networks rely heavily on cellular communication to co-ordinate response. If this network is not working, transport recovery is hindered, as it takes longer to identify damaged sites, notify contractors or give orders. Traffic lights rely on telephone land lines to operate, although initially this is not a priority. Although traffic signals use telephone land lines to operate as a system, they can operate independently as long as they have power. Port and rail operators use both cellular and land lines to operate, although some radio communications are in use.

Access to both the road network and cellular communications may need to be prioritised in order to reduce the congestion caused by the general public overwhelming both networks after a hazard event. Emergency vehicles and contractors' plant also need priority to help with response. Although emergency management would be involved in this prioritisation, intended procedures should be explained to road contractors before any event.

Transport's energy needs

In a power failure, fuel, particularly diesel, is a vital substitute for electricity, so diesel would be in great demand for running emergency generators and other machinery. Road contractors would require large amounts of diesel for their earth moving equipment. If normal supplies are disrupted or inadequate, tanker supplies would be needed.

Fuel distribution would be a problem, and demand would need some sort of prioritising to ensure utility operators have enough fuel to restore services quickly.

An alternative to the Wiri oil terminal would be needed for fuel distribution if the terminal suffered access or damage problems.

Coping with fuel shortages and distribution problems

Street and traffic lights would not be important enough to warrant providing emergency generators.

The stormwater system needs to be operational so as to minimise flooding and maintain road and rail access

Impaired operation of stormwater systems could affect recovery times and access after an eruption or cyclone: blocked or overflowing stormwater systems can quickly harm road and rail networks, and although flooding may only be temporary, the effects of scouring or debris can hinder the restoration of capacity. For these reasons, the stormwater network needs to be robust so it can remain operational during and after an event.

Gas and water utilities need to respond promptly to shut off flow from ruptured pipes

Road operators rely on water suppliers to quickly turn off valves where pipes under roads have broken to minimise scouring and washouts. This is especially important around older bridges, which often carry water pipes where embankments can quickly be washed out.

Similarly, gas leaks from broken pipes can make roads dangerous and unusable even if there is no structural damage to the carriageway, so gas valves also need to be shut off quickly.

It is therefore important for the road network that other utilities are able to respond quickly in such a situation.

There are also interdependencies amongst the different transport modes. For example, rail is important to the ports, which use it to move a large amount of cargo. It also provides an alternative mode for shipping heavy plant from elsewhere in the country if the state highway network is congested or blocked.

The different transport modes are also interdependent

The ports can play a similar role, bringing large quantities of cargo in shipments from both elsewhere in New Zealand and overseas to aid recovery.

The airports play an important role in quickly transporting people between regions and countries, although weight restrictions mean they play a lesser role for bringing in spare equipment.

Substitution among and between these modes may help overcome damage to any of them.

Transport recovery profiles assumed unlimited access and resources, but since power and communications are also likely to be disrupted, actual responses will take longer.

Other utilities' need for transport

Access is vital for all utilities

Transport is always vital to the recovery of other utilities. Whether access is needed to check or repair their network, to provide fuel to emergency generators or simply to allow staff to key sites, all of Auckland's transport networks are of great importance to all lifeline utilities.

All utility operators rely on access — mainly by road, but also via rail, air or sea — to maintain or repair their networks. Even if a utility itself were unaffected by a hazard event, service could be disrupted by a lack of access to key operational sites. These and other vulnerabilities in the transport network must be identified and taken into account during hazard event response planning.

Other utility operators' hazard event response plans should assume major delays on all roads that are still open, even if they are not damaged, because of the congestion resulting from limited availability of alternative routes.

Reduced capacity means alternative routes will be needed, but utilities should assume major delays and fuel shortages

Fuel supplies are a vulnerability, because recovery relies on fuel being available for plant repairing the road network. Fuel depots may be sufficiently robust to survive the scenario events, but if access to them is disrupted, it may be difficult or impossible to distribute the fuel. Energy utility operators rely heavily on access to their sites for distribution or to enable repairs and maintenance, yet road managers may not be able to guarantee access to these sites without adequate fuel supplies for their own plant. Moreover, demand for fuel will dramatically increase if mains electricity fails and facilities start using diesel powered emergency generators.

Fuel supplies are critical

Although traffic signals use telephone landlines to operate as a system, they can operate independently as long as they have power.

The recovery plans of all utility and transport operators depend on removing ash from roads and facilities, but dump sites have not been identified. If not determined prior to the event, ad hoc ash dumping would hamper network recovery and cause environmental damage.

7.3 Energy lifelines

Electricity

Key lifeline services that electricity utilities need include:

- communications, to organise and co-ordinate response and repair
- transport, to access damaged nodes and networks
- fuel for emergency generators and vehicles
- water for some cooling purposes, as well as cleaning

Petroleum fuels

If the power-dependent communication systems fail, valves may fail-safe: that is, close

The Wiri oil terminal is extremely reliant on both electricity and water: without electricity the terminal would operate at 15% capacity.

Water must be available at all times that fuel storage terminals are operating for fire fighting purposes

If the power - dependent communication systems fail, valves may fail-safe: that is, close. There is redundancy in the Marsden Point - Wiri oil pipeline's communication system, though road access limitations could affect any pipeline repairs and the ability to distribute products, except to the airport.

Water must be available at all times that fuel storage terminals are operating for fire fighting purposes, and both the Wiri terminal and the Freemans Bay depot would have to close down if water supplies could not be maintained. However, water to Wiri is gravity supplied from the Hunua catchments, so as long as pipelines were intact, water could be provided. At Freemans Bay, pumps on tugs could be connected to the fire system mains if these were operating, or else water could be pumped straight from the sea by cannon.

Gas

Without electricity, the Natural Gas Corporation could still maintain 50% of its gas supply to the region.

7.4 Water lifelines

The focus of this project on the utilities themselves meant that water supply for needs such as fire fighting and public health were not addressed. These will be examined in future stages of the project.

Water and wastewater services' need for other utilities

Telecommunications are essential for communication between network operators and maintenance crews and for operating pump station alarms. Sourcing products, liaising with other local network operators and providing public information also relies on telecommunications

Water networks' key resource needs from other utilities include:

- energy, to:
  - supply booster pumps in selected areas in order to maintain water supply
  - run water and wastewater treatment plants
- fuel for:
  - generators if power fails
  - vehicles doing repairs
- roading access:
  - for site inspections and maintaining normal operation
  - to nodes or networks needing replacement, major repair or temporary works, though this may be difficult where burst water mains cause erosion
- backup equipment, including portable and in situ generators and portable pumps
- spare parts and pipeline
- electricians and other skilled personnel
- communication systems and telemetry are desirable but not essential

Energy — both electricity and diesel — is essential for ongoing business operations, pump station operation and use of maintenance equipment

A widespread loss of communications would seriously hamper co-ordination of the response and recovery process, delaying the restoration of water services: fault reports would not be received and teams would have to report back periodically for instructions.

Telecommunications are essential for communication between network operators and maintenance crews and for operating pump station alarms. Sourcing products, liaising with other local network operators and providing public information also relies on telecommunications.

Energy — both electricity and diesel — is essential for ongoing business operations, pump station operation and use of maintenance equipment. Standby generators could provide power supply at water supply treatment plants and pump stations.

In a widespread power outage, which could potentially happen in any of the hazard scenarios, the water supply is expected to suffer some loss of service to elevated areas dependant on pumping. Wastewater overflows from pumping station emergency overflow structures could occur in areas without power supply.

Damaged water networks and equipment could be replaced, subject to fuel and access needs from other Lifeline services, but there may not be enough spare pipes, fittings and replacement equipment immediately available

Watercare has enough plant and equipment in house to maintain its network. Wheeled loaders may be needed in the headworks to effect vehicle access to some dams, but this would not affect the supply of water to the filter stations: the supplies are generally in underground concrete – lined steel pipes, or in tunnels though slip - prone areas.

Damaged pipelines and equipment could be replaced, subject to fuel and access needs from other lifeline services. However, there may not be enough spare pipes, fittings and replacement equipment immediately available.

Local water supply and wastewater systems are heavily reliant on the continued provision of service by Watercare.

For continued wastewater network operation at the usual level of service, wastewater operators need:

- roading networks, for site inspections and access to areas requiring major repair, replacement or temporary works
- electricity for pump stations, maintenance equipment and management services
- fuel supplies for vehicles or emergency generators
- telecommunications to operate pump station alarms, enable contact with maintenance crews, source products and supplies, maintain liaison with other local network operators and meet requests for public information

Other utilities' need for water and wastewater services

Other utilities need water supplies because:

- communication systems need cooling water at key sites
- energy providers need water for cooling, cleanup operations and fire fighting

Loss of wastewater services does not reduce the level of service other utility operators are able to provide. They have very little reliance on wastewater, although public health considerations will start to emerge if service cannot be restored for some time.

7.5 Hazard event - based interdependence matrices

Each lifeline utility assessed its need for all of the others by ranking them on a scale of 0 to 5, or a zero to high requirement for recovery and operation.

Figures 14 to 16 illustrate the results of this analysis for the scenario earthquake and eruption, showing interdependencies both for normal operation and for recovery of lifeline utilities after the scenario earthquake and eruption.

Recovery interdependence matrices were not prepared for the scenario cyclone and tsunami, as no significant outages were expected and interdependencies for recovery from any service losses would reflect the patterns expressed in the earthquake and eruption matrices.

The operational interdependencies shown in Figure 14 indicated that the priority lifelines under normal circumstances are:

- electricity
- roading
- telecommunications land lines
- cellular communications

Telecommunications and fuel and access for repairs were crucial for all the lifeline utilities

Water supply was often ranked reasonably low, because the project focused on the recovery needs of the utilities themselves, on the assumption that if they know what their recovery priorities are, this gives them more information on which to plan for wider recovery needs for the rest of the community

However, for recovery after the scenario earthquake, analysis of interdependencies indicated that the highest priority lifelines were:

- fuel
- cellular communications
- electricity
- roading

Interdependencies for recovery after the scenario eruption indicated that the priority lifelines were:

- roading
- cellular communications
- fuel

The actual scores obtained from these comparisons are not numerically significant: they are only intended to indicate the levels of interdependence that each lifeline has on the others and which lifelines are critical for operation and recovery.

Telecommunications and fuel and roading access for repairs were identified as the key recovery needs – the crucial interdependencies – for all the lifetime utilities, along with other needs such as fuel for emergency generators and water supply for cleaning up.

Electricity has a higher priority for operations than recovery

Water supply was often ranked reasonably low in the interdependency analysis. This was because the project focused on the recovery needs of the lifelines themselves on the assumption that knowing their own recovery priorities gives them more information on which to plan for wider recovery needs for the rest of the community.

Rankings are not intended to prioritise response after a hazard event, when community health and safety needs make potable water supply a very high priority

These interdependency rankings are not intended to prioritise response after a hazard event, when clearly community health and safety needs would give potable water supply a very high priority.

These wider community response and recovery needs will be examined in later stages of the Auckland Engineering Lifelines Project.

Figure 14: Interdependence operational matrix for Auckland's lifeline utilities

Dependence for Operation

Base Lifeline	Electricity	Gas	Fuel	Land Comms	Cell Comms	Broadcasting	Water	Sewage	Road	Rail	Ports	Airports
Electricity		5	2	2	2	0	3	0	4	0	0	0
Gas	1		0	2	2	0	0	0	4	0	0	0
Fuel	4	0		2	2	0	0	0	4	0	0	0
Land Comms	5	1	3		4	0	3	3	3	0	0	
Cell Comms	5	0	3	5		0	2	2	3	0	0	
Broadcasting	5	0	3	4	2		3	3	3	0	0	
Water	4	1	1	3	5	1		1	3	1	1	1
Sewage	5	1	1	3	5	1	1		3	1	1	1
Road	5	4	5	4	4	3	4	3		3	3	3
Rail	5	2	5	5	4	2	3	2	4		5	3
Port	5	3	5	5	4	2	3	2	5	4		3
Airports	5	2	5	5	4	3	4	4	5	1	3	
TOTAL	**49**	19	33	**40**	**38**	12	26	20	**41**	10	13	11

○ High priority lifelines for operation

Interdependence assessed against each lifeline item on a scale from 1-5 (low - high requirement for operation)

Figure 15: Interdependence recovery matrix for Auckland's lifeline utilities after the scenario earthquake

Dependence for Recovery

Base Lifeline	Electricity	Gas	Fuel	Land Comms	Cell Comms	Broadcasting	Water	Sewage	Road	Rail	Ports	Airports
Electricity		0	4	3	3	0	3	0	5	0	5	3
Gas	2		4	3	3	0	0	0	5	0	0	0
Fuel	5	0		3	3	0	0	0	5	0	0	0
Land Comms	5	0	5		5	0	1	0	5	0	2	3
Cell Comms	5	0	5	5		0	0	0	4	0	2	3
Broadcasting	5	0	4	5	5		0	0	2	0	0	0
Water	4	1	5	4	5	5		1	5	1	2	2
Sewage	5	1	4	4	5	3	2		5	1	1	1
Road	3	4	5	3	5	4	5	3		3	5	2
Rail	5	4	5	5	5	2	4	2	5		4	3
Port	5	3	5	3	5	2	3	2	3	3		3
Airports												
TOTAL	44	13	46	38	44	16	18	8	44	8	21	20

○ High priority lifelines for recovery

Interdependence assessed against each lifeline item on a scale from 1-5 (low - high requirement for operation)

Figure 16: Interdependence recovery matrix for Auckland's lifeline utilities after the scenario eruption

Dependence for Recovery

Base Lifeline	ELECTRICITY	GAS	FUEL	LAND COMMS	CELL COMMS	BROADCASTING	WATER	SEWAGE	STORMWATER	ROAD	RAIL	PORTS	AIRPORT
ELECTRICITY		3	5	4	5	5	5	1	1	5	2	2	2
GAS	1		5	4	5	5	1	1	1	5	2	2	2
FUEL	5	1		4	5	5	2	1	1	5	2	2	2
LAND COMMS	4	1	5		3	0	4	0	2	4	0	1	4
CELL COMMS	4	0	5	4		2	1	0	2	4	0	1	4
BROADCASTING	4	0	5	4	3		2	0	1	4	0	1	4
WATER	5	1	4	3	5	5		1	1	5	2	1	1
SEWAGE	5	1	3	3	5	4	3		1	5	1	1	1
STORMWATER	2	1	1	3	5	5	4	1		5	1	1	1
ROAD	2	1	5	4	5	5	4	1	5		1	3	3
RAIL	4	1	5	4	5	5	3	1	5	5		2	1
PORT	4	1	5	4	5	2	2	1	4	5	2		1
AIRPORT	4	1	5	4	5	5	5	1	2	5	1	2	
TOTAL	44	12	53	45	56	48	36	9	31	57	14	19	26

○ High Priority lifelines for recovery

Interdependence to be assessed against each lifeline item on a scale from 0 - 5 (nil - high requirement for recovery)

Response and Recovery

8. RESPONSE AND RECOVERY PLANNING

After the specific hazard analyses were completed, a Response and Recovery Workshop was convened on 28 April 1999 to review response and recovery planning needs for lifeline utilities.

The workshop was facilitated by David Brunsdon, the National Lifelines Co-ordinator, who had recently completed a Y2K contingency planning framework document for New Zealand Emergency Management and Civil Defence.

This chapter outlines:

- the workshop's objectives
- elements of response and recovery planning
- the structure of a utility response plan
- regional co-ordination of utility emergency responses
- a worked example of contingency planning using Y2K
- the results of an evaluation of each utility's response planning preparedness

Objectives of the response and recovery workshop

The workshop aimed to:

- convey an understanding of the principles and implementation of response planning
- demonstrate contingency preparedness requirements using the example of Y2K response planning
- provide a methodology for participating utilities to use for their own response planning

8.1 Principles and implementation of response and recovery planning

Context and scope of risk management for response planning

Response planning is closely aligned with risk management, with key tasks including:

- establish the risk context
- identify the risks
- analysis the risks
- evaluate the risks
- treat or accept the risks

This process identifies what risks can be mitigated and how the residual risk can be managed.

The status and organisational structure of many lifeline utilities has changed significantly in the last few years from being publicly owned and monopolistic to being privately owned and restructured into a series of separate asset ownership, management and operational units.

Ownership and organisational structure of utilities

As a result, many utilities have contracted out their operational or maintenance services. This fragmentation reduces their integrated emergency response capability by reducing direct, rapid access to considerable human and physical resources in an emergency.

As part of the restructuring, many utilities have also significantly downsized, which can result in:

- a loss of system knowledge
- nominal contingency capability

Emergency Response

The three phases of utility emergency response to a hazard event are:

- immediate response (1 - 2 days)
- recovery of partial service (up to 2 weeks)
- restoration of full service (6 months or more)

Immediate response focuses on:

- impact assessment on which to base strategic decisions
- establishing an Emergency Operations Centre from which response actions can be co-ordinated and communicated
- securing critical facilities to prevent further loss or damage

Recovery of partial service in the period following the immediate response utilises the impact assessments to restore full service as quickly as possible. Considerations include:

- identifying and prioritising initial 'band aid' repairs needed to re - establish service
- initiating repair and replacement strategies for short term and longer term requirements
- identifying resource requirements and allocation so repair works can be co-ordinated and appropriate resources sought and secured when needed without wasting time, effort and resources in storing or protecting resources which are not needed
- activating Mutual Aid Agreements, and ensuring that those receiving mutual aid assistance ensure donated resources are appropriately looked after and effectively and efficiently used

Restoration of full service may be influenced by considerations such as:

- accelerated and intensive capital works programmes have an obvious financial impact as well as resource implications
- the usual or regular procedures by which these works are normally undertaken need modification to fast track reconstruction programmes, such as funding approvals, procurement strategies and legislative requirements
- recovery programmes need to take account of the event's impact on the systems so that lessons are learnt and mitigation measures are incorporated where possible

Incident management systems

Response planning to date has tended to focus on major disasters which affect every person and every service. More recent realisation that plans need to accommodate a wider range of events has come about partly from the single utility failures experienced here and abroad during 1998 as well as year 2000 utility impacts. This has lead to a call for wider ranging Utility Incident Management Plans and systems.

Incident management systems provide for management of potential service risks from:

- within the organisation
- from other service providers
- from natural hazards

The process of incident management is shown below together with the appropriate levels of documentation required to facilitate immediate response requirements.

Response Process	Documentation
Detection	Activation and immediate notifications
Response Structures in place (Control Centre)	Control, command and co-ordination
Assess Impact	Impact assessment and response strategies
Specific Treatment Actions	Technical procedures

8.2 Structure of a Utility Response Plan

A Utility Response Plan may contain the following key elements:

- incident management systems
- specific procedures
- preparedness activities.

Incident management systems should include:

- activation triggers and procedures
- immediate notification requirements
- control, command and co-ordination structures
- impact assessment
- overall strategy for minimum service levels of recovered services
- contact lists
- communications management

Specific procedures should:

- be element - specific, avoiding generalities
- give details on the duration of response operations
- outline criteria and procedures for transition back to normal operations
- include accurate and detailed criteria for assessing impact on and damage to particular elements in order to enable appropriate response strategies to be formulated

- list specific ongoing actions, including notifications

Preparedness activities should be documented in categories such as:

- Initial:
  - resource availability confirmed
  - Emergency Operations Centre prepared
  - clear understanding of contract resource availability

- Ongoing:
  - maintaining response plan documentation (including contact list)
  - testing communications systems

Key features of a response plan are:

- the emergency contact list is the cornerstone
- exclusivity of access to key contract resources must be assured
- personnel need to be designated for 'on the day' response strategies
- manual operation modes and start up procedures must be documented and personnel familiarised with them

Implementation, training and exercising

An essential part of response planning is implementing the plans and training personnel. Suggestions include:

- introducing the plans and doing initial training using scenarios
- regular training exercises to refresh team members
- regular practice of communication processes

A maintenance regime needs to be established to ensure the plans are kept up to date and accurate, including regular updates of internal and external contact lists, with preparedness measures revisited at least annually. The response plan is a live document, and needs frequent attention.

Common shortcomings of response planning are:

- not enough specifics — who, what, where, when and how
- not enough emphasis on external interfaces — dependence on service providers (contractors or other utilities) needs to be examined and impacts of supply failure assessed
- the planning process is rushed through, with inadequate time for staff inputs or peer reviews
- no provision for systematic revisitation by way of annual review

A response plan is only a decision - making framework: key initial actions must be clearly defined and understood. Response plans must reflect the current organisational structure, with the emphasis on seeking an integrated response. Adopting a supply chain approach enables external dependencies to be understood, examined and incorporated in the planning process. Enough time needs to be allocated for thorough planning, training and review.

8.3 Regional co-ordination of utility emergency responses

The main functions of a Regional Lifelines Co-ordination Centre are to:

- receive status reports from local and regional utility organisations
- process the information into an overall picture
- conveys the picture up to regional controller or emergency response co-ordinator and down to the utilities
- help prioritise utility response and resource allocation

Key elements of a Lifelines Co-ordination Centre include:

- a base location
- an agreed universal communications system.
- designated and trained personnel, both Lifelines co-ordinators and support staff
- An operations manual that identifies:
  - the scope of activity
  - who manages and maintains the Lifelines Co-ordination Centre
  - its relationship with the Emergency Management Group
- commitment both financially and through a memorandum of understanding

8.4 A worked example of contingency planning using Y2K

To highlight practical aspects of response planning, a suggested methodology for Y2K contingency planning was examined. Y2K was chosen because most lifeline utility organisations are well advanced in planning for this scenario and the methodology could yield prompts that could help them in their own response planning.

The methodology described was produced for the New Zealand Office of Emergency Management and Civil Defence (1999) and defines four main steps in the response planning process:

- project initiation
- impact analysis
- response plan development
- testing and implementation

Project initiation comprises:

1. Project preparation:
   - establish project teams
   - set a timeline with deliverable dates

2. Define response objectives and scope:
   - define minimum service delivery level or standards to be achieved
   - identify core operational processes, along with key dependencies and the minimum service levels required to meet the response requirement
   - identify processes and sub elements which can be temporarily bypassed if faced with operational difficulties

3. Introduce Year 2000 failure scenarios (the office of Emergency Management and Civil Defence has compiled three high level scenarios).

4. Link to other plans:
   - establish the relationship of the Y2K contingency plan with existing contingency or response plans
   - define the Incident Management Systems to be used

Impact analysis comprises:

1. Identifying specific possible failure situations for each core operational process.

2. Identifying likely impacts:
   - estimate the duration of disruption and service implications
   - establish the areas affected and prioritise in order of significance of impacts

Response plan development comprises:

1. Formulating contingency measures and developing procedures:
   - identify and document general response requirements such as activation triggers, incident management structures, personnel requirements and responsibilities, communication systems, procedures and protocols
   - identify and document element specific needs such as internal monitoring, fix or 'work around' options, manual operation modes, response operation durations and procedures for transition back to normal operation

2. Identifying resource requirements:

   - establish both standby and activation needs
   - ensure contract personnel and resources are exclusively available

3. Producing response plans:
   - compile response plan
   - put in place a mechanism for issuing updates

Testing and Implementation comprises:

- Testing the plan:
  - use test exercises with interfacing organisations
  - run test exercises on relevant sub - systems
  - test the communications systems and contact lists
  - use the tests to identify strengths and weaknesses
- Implementing the plan:
  - update and circulate revised plans

- Training and preparation:
  - continue the process of exercises with plan activation

8.5 Evaluating each utility's response planning preparedness

Workshop delegates split into task groups to evaluate their own organisation's response planning preparedness and to identify gaps both in general response planning as well as Y2K readiness using a worksheet to assess and evaluate the adequacy of existing response plans.

The following comments summarise matters considered important in lifeline response and contingency planning.

General comments

General comments in response to the Workshop were:

- post - event communication systems are vital
- economic restrictions can affect contingency planning and response planning if cost considerations mean risks are accepted instead of being mitigated
- co-ordinated communication to the public is essential to ensure consistent information
- significant changes have occurred in all utilities, but especially the energy sector with deregulation and division of supply, network and retail elements, so contact lists will be in a state of flux until restructuring is complete
- information fed to co-ordination centres should identify 'what works' and 'what doesn't'
- knowledge of the response plans of other lifelines can help individual utilities formulate their own response plans
- minor event response plans or standing orders work well because they are regularly tested or utilised, but major event response planning is not as advanced and the same testing regime is not available

Y2K comments

Specific comments in response to the Workshop were:

- any Y2K impacts on Auckland lifelines will affect a larger population because of the America's Cup and other millennium activities
- companies will need policies on staff leave, transportation and communication
- Y2K will have a world - wide impact which may cause a rolling wave effect, for example the key time for aviation is 1300 hours on 1 January 2000
- confirmation of Y2K readiness from external dependencies should be well advanced
- internal functions such as finance, environmental and internal communications need to be assessed, minimum levels of service established and response plans developed

Review

9. REVIEW OF THE AUCKLAND ENGINEERING LIFELINES PROCESS

This chapter looks at the lessons learned from the process and methodology used by the Auckland Engineering Lifelines Project. It looks at:

- the project methodology
- benefits of the project
- difficulties encountered
- what would be done differently if the project started afresh

9.1 The project methodology

Participants found the presentations well organised and thorough, with project information presented very well. The analysis process also worked well.

The workshop process was agreed to be a good format, with the issues of individual utilities being identified first, and then their interdependence with other utilities based on an understanding of their issues

The workshop process was agreed to be a good format, with the issues of individual utilities being identified first, and then their interdependence with other utilities based on an understanding of their issues.

There was an additional advantage in doing the Auckland Engineering Lifelines Project studies before the end of 1999 in that participants were more up - to - date and aware of the vulnerabilities in their facilities when performing Y2K analysis. They had a better understanding of their particular systems and perhaps some mitigation measures that may be directly applicable to Y2K scenarios and contingency planning.

Recovery profiles focused on areas or elements of significant service loss in each utility and how that affected the rest of that network

The methodology initially proposed to map the recovery profiles to show impacted zones; areas where service was unavailable at one day and one week and where full recovery took a long time. In practice this proved too difficult, as there were upstream and downstream service effects which also needed consideration. For example, the loss of a key water supply pumping station would not be confined just to the pumping station itself: it would have significant downstream impact. As a result, the exercise was amended to focus on areas or elements of significant service loss in each utility and how that affected the rest of that network.

There was some value in departing from the Christchurch and Wellington models, but perhaps not as much as anticipated

Recovery profiles were introduced into the methodology as a way of building on the interdependence analysis developed in the Christchurch and Wellington Lifelines Projects. However, it is questionable whether the Auckland Engineering Lifelines Project gained added value from departing from the Christchurch and Wellington approaches. Overall, it seems that there was some value in so doing, but not as much as had perhaps been anticipated.

Not all the information needed for the hazard analyses was available at the start of the project, so to maintain momentum and save time, the hazards were reviewed one after the other by preparing information for the next analysis while a prior one was being completed. As a result, the hazard analysis was done four times. Although this was repetitive, the methodology improved each time and the Task Groups' skills improved with each iteration.

Some inconsistency resulted from asking the utilities to identify their own core lifelines

However, because each utility was asked to identify what it believed to be its core lifeline services, some inconsistency resulted: for example different water providers may have defined core lifelines pipes as anything from 150mm to 300mm diameter.

9.2 Benefits of the project

Interdependencies and network redundancy

No single utility can consider itself immune from effects on any other and there is a social and financial responsibility to help each other where possible

The analysis underlined the utilities' dependence for survival on each others' services. No single utility can consider itself immune from effects on any other and there is a social and financial responsibility to help each other where possible.

The relative frankness about vulnerabilities underlined the utilities' concern for the serious consequences of the scenarios used

The relative frankness and free exchange of information on the vulnerabilities of individual utilities and services underlined their providers' concern for the serious consequences of the scenarios used.

While the risks and hazards identified in the studies were extreme scenarios, the concept of network redundancy and robustness are basic to the provision of reliable service.

The Auckland Engineering Lifelines Project studies have helped to focus network controllers and planners on the identified areas of potential risk and to plan for their mitigation.

Communications lifelines

Telecom has further developed its Business Continuity Plans and Item Recovery Plans. This work is ongoing in conjunction with Y2K preparation work.

The company has also achieved a better understanding of the natural hazards in the Auckland Region.

CLEAR has benefited from the Auckland Engineering Lifelines project by gaining:

- a high level of understanding of regional soil and rock types and slopes
- better knowledge of the natural hazards analysed

Vodafone noted the usefulness of the exercise in:

- identifying other utilities' needs from the communications group
- planning network growth and where not to place major nodes

Transport lifelines

The Auckland Engineering Lifelines Project has been of undoubted benefit, notably in:

- emphasising to Transit New Zealand the need to continue and enhance existing risk management processes
- encouraging the establishment of Transit New Zealand's Risk Management Group
- enabling utility operators to recognise their interdependence
- helping other parties to identify vulnerabilities and upgrade their existing response and recovery plans

Transit's involvement in this and other engineering lifelines projects has helped to advance risk management in areas such as:

- establishing regional risk management groups
- documenting hazard areas
- seismic investigation work, enabling a more comprehensive understanding of risk, making Transit's involvement in the Auckland Engineering Lifelines Project more effective
- helping to improve existing emergency plans
- identifying the need to investigate a national non - cellular emergency communication system
- identifying the need to ensure that services on bridges and under roads are more secure

The project has fostered greater awareness of how much other utility operators rely on the road network, and how changes can affect them

The project has fostered greater awareness of how heavily other utility operators rely on major roads such as state highways in order to supply and maintain their networks, and how changes can affect them. This reliance is two fold; utility services are buried in road berms and operators of other utilities also rely on vehicle access to their sites to repair or shut off their networks. After discussions on the vulnerability of services buried in road berms and bridge embankments, road network managers may change their service agreements with utility operators in order to minimise any risks to their services.

Other roading providers like local authorities were able to better identify areas of vulnerability in their networks as a result of the project. In many cases these vulnerabilities were already known, but the project was able to put them into a wider context and show how problems in other utility networks could hinder their recovery plans.

The project reinforced and improved existing response and recovery plans

The ports and airport have used the project to reinforce existing response and recovery plans, and have likewise gained important insights into other networks. For instance, the ports rely heavily on road and rail networks to distribute cargo, and it was valuable for Ports of Auckland Ltd to see how vulnerable those other networks were and how long it may take them to recover from a hazard event.

Water lifelines

The main benefit derived from the Auckland Engineering Lifelines Project analysis has been the contact with asset managers from the other local network operators and utility operators. As different organisations are at different stages with their risk management programmes, it was helpful to share ideas, gauge the progress of other groups and learn what processes they are undertaking now and plan to undertake in the future. Combining the risk management efforts of all service will enable more efficient responses to regional scale hazard events

Of great benefit to all parties involved has been a raised awareness of the regional interdependencies of the lifeline networks and the identification of actions that can be taken to improve the regional co-ordination following a hazard event.

In undertaking the internal risk assessment of Watercare's structures, definitions of 'normal', 'abnormal' and 'extreme' events have been assessed to test the susceptibility of the company's assets. It has been useful to benchmark the events the company uses against the scenarios used by the project, which are considered to represent a level of risk for which responsible planning should be done.

Local network operators too have experienced similar benefits from the Auckland Engineering Lifelines Project, and have identified several local areas of vulnerability for further analysis. Considerable benefits have been gained from jointly discussing these matters.

This dialogue is likely to continue and form the basis of regional water supply and wastewater emergency response plans for a number of scenarios.

The main benefit derived from the Auckland Engineering Lifelines Project analysis has been the contact with asset managers from the other local network operators and utility operators. As different organisations are at different stages with their risk management programmes, it was helpful to share ideas, gauge the progress of other groups and learn what processes they are undertaking now and plan to undertake in the future. Combining the risk management efforts of all service will enable more efficient responses to regional scale hazard events.

Using scenarios particular to Auckland conditions was very useful. Detailing their likely effects helped to reduce the time required for individual assessments.

Identifying interdependencies amongst the main service providers is vital. Having key customers advise on how loss of service will affect them helps ensure that all avenues are covered and highlights important aspects that may have been overlooked previously with an internal non - consultative approach.

9.3 Risk mitigation and management

Communications lifelines

A key outcome is the significance of the cellular network for utiity recovery

The project reinforced the importance of the cellular network in utility recovery.

Ongoing audit of customer priority settings in local exchanges aims to maintain a high priority to customers such as medical centres, utilities and emergency management/civil defence.

Vodafone will look at managing demand for contractors

Vodafone noted the benefit of the project in confirming its design and build process, noting also that the CBD power crisis showed the effectiveness of the company's response methodology.

Of particular concern for planning, response and mitigation was the contracting out of major services and the demand by utilities and contractors on cellular coverage in an emergency.

Transport Lifelines

As a result of the Auckland Engineering Lifelines Project, Transit New Zealand has created a Risk Management Group to deal with asset planning issues such as retrofitting existing structures.

Contractors can spread plant across Auckland to maximise access in the event that transport routes are disrupted

The different scenarios have both direct and indirect impacts upon transport networks, and also affect those responsible for recovery of other lifeline networks.

Some seismic retrofitting of bridges has already been completed and more is planned to address the remaining bridges In Transit's roading network.

For many of the scenario events there will be serious access restrictions, but these can be mitigated to some extent by ensuring transport contractors store their plant in strategic sites around Auckland, to maximise the potential access coverage.

Energy lifelines

There are few risk mitigation options for the worst case electricity scenario, loss of the high voltage lines into the region and local generation from an eruption in Otahuhu. Good planning for recovery, whether by repair or replacement, is the best possible mitigation.

There are few risk mitigation options for the worst case scenario, loss of the high voltage lines into the region and local generation from an eruption in Otahuhu. Good planning for recovery, whether by repair or replacement, is the best possible mitigation

However, other risks from within the region for which mitigation is needed are:

- the liquefaction threat to high voltage towers (pylons)
- the vulnerability of Transpower's switchyard at Otahuhu, through which 80 - 90% of Auckland's power passes

Risk mitigation measures address:

- tower foundations, spacing and angle minimisation
- seismic strengthening
- maintenance
- provision of spare parts
- restoration measures
- alternative supply routes

However, planning can mitigate other risks from within the region

Transpower was comparatively unaware of the liquefaction zones in South Auckland, so liquefaction risk was not specifically factored into tower design, although the foundations of each high voltage tower site had been core sampled and the foundation type determined.

Tower foundations, spacing and angle minimisation

Tower design considerations include wind, ice and conductor loadings. Towers located near estuaries, for example the Manukau Harbour, are on foundations specifically designed for the swampy site conditions.

Heavy angle towers are most at risk from liquefaction, which would cause the side of the tower under the greatest load to sink. Transpower minimises the use of heavy angle towers because they are more costly and because it is more economic under most conditions to keep high voltage lines as straight as possible. Typically there would not be more than one heavy angle tower in any 2km stretch of high voltage transmission line. Where angle towers are used, the angle is minimised as much as possible.

Seismic strengthening

Transpower has gone to considerable lengths to safeguard its high voltage reticulation network from seismic risk. The 1987 Edgecumbe earthquake's severity was very close to Transpower's seismic basis earthquake. In the Edgecumber earthquake, no Transpower towers were damaged, though some transformers were overturned and others were undamaged. The earthquake proved the effectiveness of these seismic strengthening designs, and they have since been applied throughout Transpower's network. In the Auckland region, all of Transpower's high voltage assets have had seismic inspections and all transformers are seismically secured.

Maintenance

Transpower contracts out the maintenance of its high voltage lines. There is a finite local contracting resource and these contractors also maintain electricity supply companies' reticulation. However, in the event of a regional hazard event, resources from outside the Auckland region would be available.

Provision of spare parts

Emergency spares for all high voltage transmission componentry are carried at three separate stores around New Zealand; Islington, Bunnythorpe and Otahuhu. Transpower has adopted a standard national design for all high voltage equipment, so these are able to be used anywhere in the country. Emergency stocks include concrete poles, hardwood poles, emergency towers, insulators, high voltage cable and so on. In addition to concrete poles, a stock of 52' (15.85m) hardwood poles is held at both Otahuhu and in Hamilton. Emergency towers are also available to use in difficult terrain. Other recovery requirements may include helicopters (which need Avgas) and additional high voltage cable.

Restoration measures

Restoration of damaged assets is subject to standard plans, for example, use of temporary concrete poles enable a collapsed high voltage tower to be replaced within 48 hours. Six temporary pole structures are needed for each failed high voltage tower.

The Otahuhu Switchyard (through which 80 - 90% of all Auckland's power passes) could be bridged out within two days if it were badly damaged, with high voltage supplies reconfigured directly to the Penrose and Henderson substations.

Alternative supply routes

The Otahuhu switchyard also has several 220/110kV auto transformers. Supply to Mangere and Mt Roskill is almost totally dependent on these transformers. Part of the load is also dependent on them. There is only a limited alternative 110kV supply to Mt Roskill and Mangere through the 220/110kV interconnecting transformer at Henderson.

Risk mitigation plans are therefore needed for this area.

Risk mitigation for petroleum fuels focuses on the Wiri oil terminal

Risk mitigation measures proposed by the Energy task group for petroleum fuels include:

- prioritising recovery for the Wiri oil terminal
- further developing emergency response plans

There is no standby power generation at the Wiri oil terminal, except for limited lighting and computer systems. In light of the seriousness of loss of supply from the terminal, a request will be made for it to be given the same priority as Emergency Services for emergency generator power in the event of major power outage. This will enable response agencies and other lifeline utilities to maintain fuel supplies following a hazard event.

Risk mitigation for gas nodes and networks includes:

- maintenance and repair standards
- provision of spares
- provision for restoration of services

Maintenance and spares are the focus for risk mitigation of gas supplies

All welds are inspected by X-ray before repaired pipe is commissioned.

Orion's spares in the Auckland region are vulnerable, being held in a building in an area likely to experience liquefaction.

The Natural Gas Corporation stores spare pipe at Whangarei, but all its emergency spares are held in New Plymouth. In the event of a hazard event in the Auckland region, emergency pipe, spares and other equipment would be transported by the most practical mode, including helicopters if needed. Earth moving equipment would be sourced from closer to the region in order to restore services as promptly as possible.

Water lifelines

Watercare has in place three main categories of measures to reduce risk, some of which have been enhanced as a result of the Auckland Engineering Lifelines Project:

- asset management
- works over procedure
- risk management plans

Asset management

Watercare's Asset Management Plan is reviewed annually, comprising risk assessment, maintenance planning and forward planning for all assets. The company aims to review 20% of all assets every year.

Approval procedure

Watercare maintains an approval procedure for all works undertaken by others within ten metres of its pipelines. These procedures reduce the risk of damage by others to Watercare's pipelines and keep pipeline records up - to - date.

Emergency preparedness plan

Watercare maintains an emergency preparedness plan in case of serious emergencies, as well as site specific risk management plans for items considered to be of significant risk, such as pipe bridges, siphons and water and wastewater treatment plant. Some emergency plans have been tested to evaluate the effectiveness of the procedures.

Node inspections

Aerials for SCADA systems may need securing and these will need to be individually checked.

Buildings will need to be waterproofed because leaks can cause problems for electrical circuitry.

Joint emergency response planning

Local network operators are working separately and together as well as with Watercare to produce or improve Emergency Response Plans for their networks. The Y2K scenario is the first of the regional response plans.

Many of the local network operators already have Emergency Response plans, some of which include the Auckland Engineering Lifelines Project Scenarios.

9.4 Difficulties

The main difficulties encountered during the Auckland Engineering Lifelines Project were:

- lack of staff time and resources to fully support the project
- lack of participation by some key players
- the high turnover of participants, hampering efforts to produce consistently reliable results
- the difficulty of dealing with Emergency Management and Civil Defence because of their restructuring

The overwhelming difficulty encountered by all participating organisations was the lack of resources — especially staff time — made available for the investigations the project required

The overwhelming difficulty encountered by all participating organisations was the lack of resources — especially staff time — made available for the investigations the project required. This was partly because the project was not given high priority by some organisations and partly because it was conducted largely on a voluntary basis. Both contributed to delayed results and production of results of doubtful validity where experienced input was not available.

Lack of participation from some key stakeholders meant that other participants had to use their general knowledge to assess other networks, and this also compromised the quality of some of the results.

The project also required utilities to acquire knowledge in new areas, such as earthquake damage assessment, soil classification, liquefaction and so on, and it took some of them some time to come to terms with this.

Some utilities did not have enough specific knowledge of their network vulnerabilities, and it took time for them to collate this information

Some utilities did not have enough specific knowledge of their network vulnerabilities, and again, it took time for them to collate this information.

Determining if sites were within the influence of the storm surge or the tsunami took time, but was not difficult.

Relating specific locations to the instability hazard map took some assessment, and was best done by using an overlay.

Vodafone noted that the only difficulty encountered in the project was making enough time available to commit to the project at a time of major work activity.

9.5 What would be done differently if the Auckland Engineering Lifelines Project started afresh

Key matters raised about how to improve the project related to:

- improved induction of participants into the scenario process
- more realistic assumptions for recovery profiles
- assessing interdependencies
- the varying level of detail required from investigations
- use of electronic data and map overlays to speed up work
- addressing confidentiality issues earlier in the process
- deciding on the format for final reporting at an earlier stage

An initial overview of the three scenarios would have been desirable. It would have helped firm up some of the internal processes and data keeping, perhaps with a more natural progression to the other scenarios, although the initial impact of the task may have been more challenging.

An initial overview of the three scenarios would have been desirable. Working through the scenarios in reverse order, that is, tsunami, cyclone, volcano, then earthquake would also have been preferable, starting with the tsunami, as it was possibly the simplest scenario

Working through the scenarios in reverse order, that is, tsunami, cyclone, volcano, then earthquake would have been preferable. Starting with the tsunami would have added more realism to the study given the recent event in Papua New Guinea. Moreover, as it was possibly the simplest scenario, it may have enabled participants to more readily appreciate the scope of the project and their expected contribution to it. The earthquake scenario was the most difficult to evaluate and could perhaps better have been studied last in order to utilise the experience and processes built up from the previous two scenarios.

It may also have been helpful to consider in more detail the effects of the tsunami entering harbours before issuing the scenario to participants, so that their assessment of the effect of entrance constriction was more consistent.

The risk of fire after an earthquake is high but did not form part of the hazard event scenario. While fire is a normal day to day risk, the result of fire during or after a hazard event is more devastating. This additional scenario could have added more realism to the study, though it could perhaps complicate the study further. Planning could possibly consider a random 5 - 10% of sites as devastated by fire after an earthquake.

Interdependencies could perhaps have been better assessed by the following analysis:

- identifying work the utilities need to do themselves as individual utilities
- identifying work the utilities need to do themselves as a sector
- identifying work from which there would be benefits in undertaking collectively
- identifying work in the area of hazards research which would collectively support all the utilities' work, individually and collectively

Preparing recovery profiles on the initial assumption of unlimited resources for recovery was impractical. Post - disaster constraints on utilities' recovery needed to be defined more realistically in order to enable better response planning.

The level of detail required from investigations fluctuated during the project, so some time was wasted investigating inconsequential matters, while other important matters (for example, the role of bridges in the road network) were initially almost completely overlooked.

The use of paper maps and see - through overlays slowed the project. Using an electronic medium such as a GIS package could have produced more accurate results in less time, making it easier to identify vulnerable nodes and networks

The use of paper maps and see - through overlays slowed the project. Using an electronic medium such as a GIS package could have produced more accurate results in less time, making it easier to identify vulnerable nodes and networks.

Participants would have been perhaps more inclined to add the various details directly onto electronic maps than onto paper copies, even in free hand if matching overlays were not of identical scales. This could have generated a more user – friendly 'universal' reference for the various groups, though it would have required participants to use compatible software.

The electronic maps could also allow control for a less precise indication of network nodes (to allow for some commercial security) but still give an overall concept of the networks, nodes and risk areas.

A light overlay of the major roads on the slope instability map would have been useful if it could have been done without clouding key information, for example by showing roads in light grey rather than black. This would have sped up the identification of the location of specific assets.

Some organisations were reluctant to release information either electronically or on paper, and it would have saved project time to obtain agreement beforehand on what could be expected to be made available.

If the process was started over again, participants should commit as far as possible to continuity of representation

If the process was started over again, participants should commit as far as possible to continuity of representation. Organisations which did not dedicate a representative to attend the Auckland Engineering Lifelines Project workshops found this lack of continuity meant they were not represented at all of the workshops and thus did not benefit immediately from the work done in them.

The process did not provide the opportunity for organisations to update their network information with either corrections or additions, a drawback to the accuracy of the final product. Moreover, the networks that were analysed were only a subset of the respective networks and therefore did not produce a complete view of the potential impacts.

Early indications of the layout of the final document would have helped individuals presenting information to align it more easily to the format of the final presentation.

Further Work

10. FURTHER WORK

This section outlines further work which was considered to be outside the scope of Stage 1 of the Auckland Engineering Lifelines Project, but which is worthy of recording because it could decrease vulnerability and improve response and recovery of the lifeline utilities either individually or collectively.

Most participants identified three overlapping categories:

- further work the utilities identified as needing to do themselves, either as individual utilities or as a sector
- further work from which there would be benefits in undertaking collectively
- further work in the area of hazards research which would help all the utilities' work, both individually and collectively

10.1 Work to do individually

Communications lifelines

Telecom

Further work Telecom identified as being desirable included a review of emergency communications systems, including investigating improved products.

Several products could be enhanced to promote the maintenance of reliable and convenient communication services for other utilities and their contractors, but the costs associated with their development make this an area for additional study.

CLEAR

CLEAR identified a need for detailed development of response plans for the scenario hazards; a near vent volcanic hazard, a volcanic ash fall hazard, an earthquake hazard, a storm surge and a tsunami.

Transport lifelines

The main needs related to the roading network and small regional airfields

Most of the Transportation task group's recommendations for additional work focused on roading, especially:

- completing several small investigations
- investigate computer - based information about actual and potential hazards to the road network

- carry out staff training in emergency response
- regularly review new information and network needs

These are briefly discussed below.

Roads

Several other small investigations identified during the Auckland Engineering Lifelines Project should be completed to progress development of a mitigation and response strategy for transport lifelines. Some are suitable for a Masters or Ph.D. engineering or planning thesis, including:

Complete several small investigations

- ridge line roads identification
- compiling a Safe Routes network
- identifying potential volcanic ash dump sites

The ridge line roads project involves examining arterial roads around the Auckland region to identify those whose topography makes them less vulnerable to disruption from volcanic ash fall. This will affect lower lying areas more seriously, so a higher priority needs to be assigned to keeping ridge line roads open and diverting traffic onto them.

Ridgeline roads need to be identified, as they will be relatively ash free

A Safe Routes network would comprise those routes identified as being the most robust (or least vulnerable) to ground shaking, structural failure or climatic events, including north - south alternatives to the motorway. They would have a minimum of bridges or other structures that could potentially collapse and block the road and would be suitable for large volumes of traffic in the event that the usual arterial routes are not available. A similar network has already been identified for overweight vehicles, but this has generally been developed on an informal basis by individual authorities. A comprehensive regional Safe Routes map needs to be developed for optimum management of Auckland's road network. This work should include examining the seismic susceptibility of bridges on roads other than Transit's state highways in order to identify alternative routes to the motorways. For example, there is not enough information at present to identify whether similar structures along alternative routes like Great South Road and Great North Road would remain intact in the event of damage to the motorways. More work is thus needed to determine whether these alternative routes would be able to assume bigger roles within the network if the motorway becomes impassable. Findings would need to be discussed with other utilities to analyse issues arising from them, and possible outcomes could include new standards or route protection in transport plans.

A network of safe routes will identify roads that avoid vulnerable points such as bridges

There is a need to identify dump sites for the huge volumes of volcanic ash that are expected to fall after an eruption in or beyond the region. Knowing the location of these sites will help operators better plan their recovery processes. Temporary local sites may also be needed to enable rapid response for road and drain clearance, especially if access to regional dump sites is not possible because of damage to transport networks.

Long term and temporary local ash dump sites are needed

Contractors will need computer – based information about actual and potential road damage

More use should be made of advanced communications and computer - based systems to give road contractors and utility operators more accurate and up-to-date information about actual and potential hazards to the road network. This could be useful for avoiding vulnerable areas when planning the layout of utility networks, or in designing more appropriate and robust structures.

Staff training in risk assessment and emergency response

All roading infrastructure managers need more training and expertise to assess the risks facing their assets and to deal with the consequences of a hazard event.

A mechanism is needed whereby roading asset managers can regularly review new information and network needs for improved response planning and mitigation.

Airports

The vulnerability and potential role of other airports in the region need investigation

Several smaller airfields operate in Auckland, for example Hobsonville, Whenuapai, Ardmore, Dairy Flat and others on the Gulf Islands, but this study focused on the International Airport. It would be beneficial in future stages of the Auckland Engineering Lifelines Project to investigate the vulnerabilities and possible role of other regional airports in a hazard event.

Energy lifelines

Liquefaction, the main risk, has been investigated

Members of the Energy task group did not identify any particular research needs, as Transpower has already completed site investigations into the main threat identified, namely that liquefaction could affect most of the six main high voltage transmission lines bringing power into the region. However, Tables 11 and 40 show some other nodes are on the edge of liquefaction zones, and some further site - specific investigations would be needed to identify if they are at risk.

The main need for further work by energy lifeline utilities is for more co-ordinated risk assessment and response planning.

Water lifelines

Most of the needs which the Civil task group identified for further work were sector wide, with work by individual water lifelines focusing on applying new information to operators' own networks, for example by:

- asset and risk management planning
- more detailed network planning and prioritising
- emergency response planning, especially for ash fall

Most of these would be progressed jointly and are discussed in section 10.2, but many involve the various water companies in detailed investigations and management of their own networks.

10.2 Work to do collectively

Communications sector

Further work the communications task group identified as being desirable included:

- regular asset updates
- review of emergency communications procedures
- investigating effects of volcanic ash fall on communications equipment
- development of detailed response plans and mitigation measures

These are briefly discussed below.

Continual network evolution means information updating is an ongoing process

Regular, perhaps annual, updating of asset records is required to ensure that information about network development, site facilities and vulnerabilities is up-to-date, because the continual evolution of networks, nodes and site facilities makes for constant change.

A prioritised communications system may be needed to enable emergency discussions to take place

Emergency communications procedures may need to be reviewed, because at present cell phone systems are likely to become congested if land - linked systems fail. Even emergency discussions may lead to congestion, with utilities having to discuss procedures with suppliers, consultants, contractors, other utilities and emergency organisations as well as their own staff. The communications task group identified that the utilities may therefore need to investigate providing a prioritised communications system for other utilities to use in emergencies.

University research projects could help in assessing effects

A sponsored engineering or physics thesis could usefully investigate the attenuation effects of volcanic ash, steam and airborne debris on digital microwave and cellular radio frequencies.

Response and mitigation includes system design and maintenance

A need was identified for detailed development of response plans for the scenario hazards as well as mitigation measures such as strengthening system design and maintenance.

Ongoing commitment is essential

Regular review is needed to ensure the communications sector continues to support lifelines work in order to meet its community, emergency management and civil defence obligations, even though this could be expensive in time and resources.

Transport sector

The Transportation task group identified several areas where further collective work was needed, especially to:

- communicate with emergency management operators about prioritising use of transport and communications networks after a hazard event
- establish clear lines of communication between roading and emergency management staff
- consider a requirement for relevant organisations to participate in response planning
- maintain ongoing networking with other utility operators for efficient response

Communicate with emergency management operators about prioritising use of transport and communications networks

Effective communication is needed between roading personnel and emergency management operators about prioritising use of transport and communications networks after a hazard event. In order for that to happen, representatives of roading utilities need to work together to determine road availability and how to prioritise road refurbishment to ensure that essential services can be restored in the necessary order. This means identifying the vulnerabilities of:

- key nodes and network elements of other lifelines
- the transport routes to these

Access to both the road network and cellular communications may need to be prioritised, in order to reduce the congestion caused by the general public overloading both networks after a hazard event. Emergency vehicles and contractors' plant also need priority treatment so they can better respond to the situation. Emergency management would be involved in this prioritisation, but intended procedures should be explained to road contractors before any event.

Emergency services would need priority over all other vehicles on the road. In order to prevent unnecessary congestion and delays where limited access is available, the general public may need to be advised not to travel.

Clear communication between roading and emergency management staff

Technology could play a bigger role in emergency response, when good communication is vital. Significant delays can occur if the general population overloads the cellular system, especially if the network is already operating below full capacity because of damage. Prioritising cellular phone calls between road contractors and managers would significantly reduce emergency response time.

Clear lines of communication must be established between road managers and emergency management/civil defence officers, so that public messages can be quickly broadcast to avoid unnecessary congestion.

Should it be a mandatory obligation for roading managers to take part in Auckland Engineering Lifelines work?

The Transportation task group discussed the possibility of a mandatory requirement for road network managers to be involved in the Auckland Engineering Lifelines Project or a similar emergency response project and contribute where necessary. The Auckland Engineering Lifelines Project's voluntary nature may mean some organisations overlook the importance of its work, but the network vulnerabilities and actions identified are often of such importance that some kind of legal framework may be required to ensure that recommendations are followed up. It may be appropriate for local authorities to include such provisions in their roading maintenance contracts.

Energy sector

More co-ordination is desirable

The main further work the Energy task group identified is for more co-ordinated risk assessment and response planning.

Water sector

More work is needed to identify additional areas of vulnerability and appropriate mitigation measures

The Civil task group identified that more work is needed to identify additional areas of vulnerability and appropriate mitigation measures in both Watercare and local networks, including:

- the effects of ash fall
- keeping ash out of stormwater systems
- risk and effects of pipe breakage
- resources likely to be available to respond to a hazard event in the region
- complete several other investigations
- further response initiatives which Watercare and other local network operators could jointly progress, especially:
  - more detailed network planning and prioritising
  - asset and risk management planing
  - emergency response planning

These are briefly discussed below.

Little is known about the range of adverse effects of volcanic ash on water networks

The effect of ash fall needs further investigation. Different types of ash have different physical properties and could possibly:

- solidify in pipes
- turn to paste and not flow
- corrode certain pipe materials
- create excessive wear on mechanical plant such as pumps
- have adverse biological, chemical or physical effects on wastewater and water treatment processes
- produce gas such as hydrogen sulphide (H_2S), resulting in hazardous working conditions
- fill wet wells and grit chambers

Knowing more about these effects would help determine appropriate responses.

More work needs to be done on developing procedures for keeping ash out of piped networks. Stormwater systems pose particular problems because they allow easy ingress of ash via gutters and grates, though water supply lakes and filter systems are also vulnerable. Wastewater systems are generally less vulnerable to ash ingress except for the combined sewers in Auckland City.

Risk of pipe breakage and need for seismic restraint of unsecured services on bridges need investigation

More work needs to be done on the risk and effects of pipe breakage: large unsecured pipelines may cause damage as well as disrupting service if during an earthquake, they thrash around and damage the structure as well as other services on the bridge. A review of the seismic restraint of services may be desirable for risk mitigation.

Lack of resources is likely to be the main hold up to remediation: registers of critical services and resources may help locate additional suppliers

Lack of resources is likely to be the main hold-up to remediation after a major region wide hazard event. Skilled labour, spares and supplies (pipes, switchboards, pumps, generators and so on) as well as maintenance and cleanup equipment would be in short supply. A register of critical services and resources available both from within and beyond the region is desirable. There would also need to be some pre – event agreement to allow for the division of labour and physical resources. This would help to prioritise critical supply lines such as Watercare trunk mains and critical services such as hospitals in the interests of the Auckland region as a whole.

There could also be a register of external contractors and suppliers that could be engaged should local resources be inadequate.

Several investigations would benefit both individual networks and the water sector as a whole

Further investigations and initiatives which Watercare and local network operators should progress as a result of the Auckland Engineering Lifelines Project include:

- prioritising areas for water supply repairs, for example hospitals and oil terminals
- improving communications with external agencies and contractors
- identifying potential hazards that could exacerbate transport problems
- getting better information on levels of coastal pump stations, the Manukau wastewater treatment plant, the Orewa ponds and various foreshore sewers
- collecting more information on operators' own systems
- addressing the safety of service personnel
- carrying out more work on the effects of localised coastal scouring and erosion where key services are carried over bridges near the coastline

Membership of a regional emergency / lifelines response group for water supply and wastewater

Task group members thought it very important to formalise a Regional Emergency/Lifelines Response Group for water supply and wastewater involving the local network operators, Auckland Healthcare and the Auckland Regional Council to continue the work currently being done for Auckland Healthcare. This group would link to any Auckland Engineering Lifelines Group that may be established (see Chapter 11).

It is envisaged that the information gathered throughout the Auckland Engineering Lifelines Project will be reviewed. Initiatives outlined in the workshops would then be incorporated in principle into the Regional Management Strategy to be prepared by the local water network operators. The findings from the project will be utilised as a stepping stone in this process.

All lifeline sectors

Analysing hazard impacts highlighted areas where more work was needed, some to be done now by each utility and some to be done in the future

A major hazard event will create an immediate need to prioritise utility recovery in order to provide service to essential community services such as hospitals so they can start up the recovery process for the rest of the community.

The priorities of the lifelines services may be affected by the needs or priorities of the essential community services, and how to best meet their recovery needs as they start the wider community recovery process.

It is anticipated that the interface between engineering lifelines priorities and community services priorities will be addressed as part of Stage 2 of the Auckland Engineering Lifelines Project.

Combined efforts on work that is beneficial to all utilities could be progressed through further workshops or projects

Several proposals for further work have been identified, and these should be investigated. Combined efforts on work that is beneficial to all utilities could be progressed through further workshops or projects, including:

- examining hazard events that have occurred elsewhere to identify what preparations need to be made and what mistakes have been identified
- more specific identification of vulnerabilities and incorporation of these into asset management plans, for example when reviewing renewals, maintenance, standards and so on
- possible development of a volcanic building code, for example allowing ventilation systems to be designed to enable them to shut off or otherwise deal with ash
- incorporating external interfaces into asset management and response and recovery plans
- developing more specific contractual agreements with external resource providers to allow for continuity of support during extreme events, including region wide strategies for sharing resources and focusing effort on reinstating critical region wide services
- peer review of emergency response procedures

It was also seen as important for the Auckland Emergency Management Group to continue the work currently jointly being done for the regional Y2K response plan.

Some of the comments in response to the Response and Recovery Workshop described in Chapter 8 indicate there may be a need for further work related to:

- post - event communication systems
- the effect of economic restrictions on contingency planning and response planning if cost considerations mean risks are accepted instead of being mitigated
- the need for co-ordinated communication to the public to ensure consistent information
- the need for up - to - date contact lists as soon as current restructuring of various lifelines utilities is complete, and development of methods for maintaining their accuracy

- ongoing analysis of 'what works' and 'what doesn't' and forwarding of this information to co-ordination centres
- sharing of response plans with other lifelines to help them formulate their own
- development of major event response plans and their regular testing or use
- development of policies on staff leave, transportation and communication
- assessment of internal functions such as finance, environmental and internal communications, establishment of minimum levels of service and development of response plans

More guidelines and recommendations can be derived from the Auckland Engineering Lifelines Project in terms of both asset management and emergency response planning.

Much work can be done as part of prudent asset management planning

Recommendations for asset management include:

- establishing an acceptable level of risk to be adopted by the individual utilities
- determining priority sites in individual utilities' asset management plans for upgrading, refurbishment or replacement based on vulnerability, reliability and flexibility
- considering environmental as well as mechanical and structural conditions when assessing the viability of assets
- when evaluating extending the life of older assets, for those that would need continued maintenance and refurbishment in order to maintain routine operation, carefully considering their ability to provide routine service during moderate to extreme events
- changing the service agreements that road network managers and other utility operators have with each other in order to minimise any risks to their services from works and repairs
- accepting a level of redundancy within a system that will cope with extreme events to an acceptable level of risk
- setting priority sites for upgrading based on criticality of supply to that point, for example the Mercy Hospital and the Wiri oil terminal
- more specifically identifying vulnerabilities, such as the need for seismic restraint of large unsecured pipe services on bridges, and incorporating them into asset management plans when setting performance standards and planning renewals and maintenance

Emergency response planning involves all utilities working together

Recommendations for emergency response planning include:

- setting priority sites for reinstatement
- setting priority entitlement to the use of available resources
- determining the effect of the scenarios on existing node and network flexibility and redundancy
- setting up communications with other utilities to maximise the use of information and resources in the event of a hazard event, for example one utility unable to access one of their own sites may be able to provide resources to be put into another utility's site
- training staff in preparedness for an extreme event
- putting more emphasis on incorporating external interfaces
- making more specific contractual agreements with external resources to allow for continuity of support during extreme events
- establishing region wide strategies to share resources and concentrate on reinstating critical regional services

- utility and contracting personnel will need life support — food, water, breathing masks and so on — and provision for this should be made in risk planning
- risk planning should also consider the possibility that resources such as heavy equipment may need to be diverted to regions in greater need than Auckland, for example if another North Island volcano erupts, making key response resources locally scarce

Ongoing collaboration and review are beneficial

As well as taking on board the need to carry out more work individually and within their separate sectors, all the utilities involved in the Auckland Engineering Lifelines project agreed that ongoing collaborative work would be beneficial, and some recommended that annual review of recommendations and progress was needed.

Better liaison between all utilities

Better liaison between the utility operators would enable networks to be maintained in a more robust manner before and after a hazard event in the region.

Regular review of new information and network needs

The Auckland Engineering Lifelines Project should be periodically reviewed as network and other information changes. For example, the road network is continually developing, with new sections being added and changes to the hierarchy of existing roads, while new information such as a completed ridge lines study can alter the way the network should be managed in order to respond the most effectively.

Maintain ongoing networking with other utility operators

Infrastructure managers of the various utilities should meet with each other at a regular forum. Although they interact on an ad hoc basis when necessary, a more formalised process would be of greater value in the long term for developing their expertise in hazard planning and response.

Tasks, groups and time frames for task completion

The respective Lifelines task groups should manage the implementation of agreed programmes. These should be restated in measurable terms, with an agreed timing for completion.

As well as facilitating further work, a new Engineering Lifelines Group could facilitate:

Links to Chapter 11: an Auckland Engineering Lifelines Group?

- raising awareness by individual groups of their own vulnerability, responsibilities, and capabilities
- the preparation of an emergency preparedness plan for the region for which the individual utilities feel ownership
- the preparation of an emergency action plan for the region, again for which the individual utilities feel ownership
- obtaining 'buy in' by the public of the acceptability of the plans produced

10.3 Hazards research in support of individual and collective work

The Hazards Task Group identified that the following areas need more work:

Better understanding of hazards will help lifeline utilities to analyse their networks and plan their response

- all hazard information needs periodic review and updating, especially for those hazards about which knowledge is currently limited, for example localities affected by storm surge and tsunami, as well as the impacts of earthquake and volcanic eruption
- damage information needs further development, perhaps through sponsored research, especially for those events about which knowledge is currently limited, such as volcanic ash fall
- different scenarios need to be developed, for example earthquakes and eruptions in different locations
- response and recovery exercises need to be run, based around the scenario hazards
- more detailed hazard assessments are needed for critical network nodes and elements (this needs to be done by the individual lifeline utilities themselves)
- a wider range of hazards needs to be assessed, for example fire after an earthquake, technological hazards, algal blooms, disease outbreaks, hazardous substance spills, vandalism or terrorism
- hazards information needs to be easier to use, for example by putting it on a CD-ROM or making it digitally available

Most of this work is collective or supports lifeline utilities in doing their own planning.

10.4 Overview

Further work can only be progressed if the various lifeline utilities maintain a commitment to the Auckland Engineering Lifelines Project

Many participants noted that the recommendations made could only be progressed if the various lifeline utilities maintain a commitment to the Auckland Engineering Lifelines Project.

Participating organisations need to retain the relationships built up with their counterparts in other services as a result of this Project.

Priorities need to be determined on the basis of the needs of individual utilities, all utilities considered together and the needs of the wider community as a whole, then fed into the asset management plans of the respective utilities.

How these recommendations relate to the next stage of the Auckland Engineering Lifelines Project is outlined next.

Where to from here

11. WHERE TO FROM HERE?

This chapter summarises the needs identified by the Auckland Engineering Lifelines Project participants for an ongoing forum to continue the work done to date. It looks at:

- the need to form an Auckland Engineering Lifelines Group
- some of the matters such a group could address

11.1 Doing further work

The Auckland Engineering Lifelines Project Steering Committee supports continuing the project's work by establishing an Auckland Engineering Lifelines Group

An important outcome of the hazard impact and interdependence analyses was identifying needs for further work, for example identifying safe transport routes and investigating how to prioritise communication. While considered outside the scope of this Auckland Engineering Lifelines Project, these further work items were deemed important enough to be progressed by each utility itself with support from a forum such as an Auckland Engineering Lifelines Group.

A strong need was identified to continue the achievements of the project so far, especially for:

- development of a co-ordinated approach for further stages of the project
- facilitation of sessions relating to the further work summarised in Chapter 10

One way of continuing on with the work the project has initiated is by forming an Engineering Lifelines Group.

At its meeting of 31 August 1999, the Auckland Engineering Lifelines Project Steering Committee supported continuing the project's work by establishing an Auckland Engineering Lifelines Group.

While objectives and terms of reference would need to be formally established, the Group is intended to:

- complement utilities' existing in house risk management processes
- provide a best practice risk management forum
- provide a more global view of utility risk management in the Auckland region
- provide annual reports on project deliverables and risk management work undertaken by the member utilities

The Steering Committee has agreed to continue as the interim Lifelines Group Steering Committee while support for the concept is being canvassed among project participants and interested parties and to facilitate developing terms of reference.

11.2 Lifeline projects and groups and the risk management process

Lifelines Groups tend to address a different part of the risk management continuum, providing a collective risk management function for participating utilities

Lifelines Projects and Groups are part of the same risk management continuum. While the distinction between the two may be artificial, Lifelines Groups tend to address a different part of the risk management continuum than Lifelines Projects, and are more focused on monitoring progress on the earlier project recommendations, reviewing project outcomes and risk communication. Lifelines Groups essentially provide the collective risk management function for utility organisations.

One way of illustrating the relationship between Lifelines Projects and Groups is shown in Figure 17 overleaf. The diagram also differentiates between the role of Projects, Groups and the responsibility of individual utilities.

There are clear advantages for lifelines utilities in participating in a Lifelines Group

The advantages of being in a Lifelines Group are similar to the advantages of participating in a Lifelines Project, namely:

- making potential cost savings through the sharing of resources and expertise
- having access to and influence on the development of hazard and damage assessment information
- improving asset management and business continuity planning through increased understanding of interdependencies and access to best practice information
- improving business continuity and contingency planning through enhanced communication between other service providers and responding agencies
- giving customers and the community confidence that minimising disruption to Lifelines is an organisational priority
- enabling access to forums for regular contact and interaction with counterpart lifeline organisations for the exchange of views and information

It is also likely that involvement in Lifeline Groups will prove a cost effective way for utilities to meet some of their obligations under proposed new emergency management legislation.

Engineering Lifeline Groups around the country have evolved from Lifeline projects

Lifeline Groups have evolved at the completion of both the Wellington and Christchurch Lifelines Projects. In Wellington, the Wellington Lifelines Group was established to provide support for the mitigation work of member organisations. It was formally established at the conclusion of the project phase and is supported by the Wellington Regional Council.

In Christchurch, after the completion of the final report *Risk and Realities*, the project steering committee decided to continue with the lifelines process and became the Christchurch Engineering Lifelines Group. To date this group operates in a similar fashion to the original project, with the same steering committee and project manager.

Much of the following discussion on how a Group could function in Auckland is based on the structure of the Wellington Lifelines Group.

Figure 17: ***The risk management and lifelines processes***

Source: *David Brunsdon, Wellington Lifelines Group, August 1999*

Risk Management Elements	Lifelines Task	Principal Responsibility			
		Individual Utility	Lifelines Project *(initial 2 to 3 years)*	Lifelines Groups *(ongoing)*	Lifelines Co-ordination Centres
Risk Context	Project Initiation				
Risk Identification	Hazard identification & system inventory				
Risk Assessment	Vulnerability and potential consequences assessment				
Risk Evaluation	Establish criteria, compare against & prioritise				
Risk Treatment	Identify mitigation options				
	Produce Report				
	Undertake mitigation				
	Planning to respond				
	Co-ordination of response				
Monitoring Progress	Annual review				
Ongoing Risk Communication	*External* - general publicity				
	Internal - development of best practice guidelines				

11.3 An Auckland Engineering Lifelines Group

Auckland Engineering Lifelines Group (AELG)

The Auckland Engineering Lifelines Group would essentially continue the work of the Auckland Engineering Lifelines Project by promoting Lifelines co-ordination and communication among member organisations.

Its possible mission statement and objectives could be:

Mission Statement:

Mission statement

To identify measures and co-ordinate efforts to reduce the vulnerability of Auckland's lifelines to hazard events so that our community is well prepared to function after a disaster.

Objectives:

Objectives of an Auckland Engineering Lifelines Group

1. To encourage and support the work of all those authorities and organisations including local authorities and network operators in identifying hazards and mitigating the effects of hazards on lifelines
2. To facilitate communication between all those authorities and organisations including local authorities and network operators involved in identifying hazards and mitigating the effects of hazards on lifelines, in order to increase awareness and understanding of interdependencies between organisations
3. To create and maintain awareness of the importance of lifelines to the various communities within the Auckland Region
4. To promote ongoing research and technology transfer aimed at protecting and preserving the lifelines of the Auckland Region
5. To review, update and further develop the approaches to mitigation and preparedness measures for lifelines in hazard events

Tasks and focus

The Group would act as a facilitator in promoting the mitigation and preparedness work to be carried out by its members. The emphasis would be on educating and motivating members by developing and providing best practice information.

Annual reports could be produced on project deliverables and risk management work undertaken by the member utilities.

The work of the Group would be focused on events or hazards that have consequences beyond the ability of individual organisations to respond to and control and which have regional impact.

Small events or 'business - as - usual' incidents should be the subject of risk management processes by the individual organisations themselves.

Possible activities

Examples of the sorts of activities in which the Auckland Engineering Lifelines Group could become involved include:

- considering the implications for lifelines of other hazards or updated hazard information
- promoting more detailed lifeline studies on smaller areas such as local authority areas
- monitoring progress made by member organisations on mitigation and contingency planning

- facilitating the interface between the emergency services and other responding agencies
- planning and co-ordinating the region's utility emergency response, for example, through a Lifelines Co-ordination Centre and response exercises
- reviewing lifeline issues after major overseas and domestic hazard events
- workshops and seminars on lifeline issues such as the one held on the Auckland power crisis
- other specific projects identified during Stage 1 of the project and summarised in Chapter 10

Suggested structure of an Auckland Engineering Lifelines Group

The Auckland Engineering Lifelines Group could be managed by a small Steering Committee including specific nominated representatives (typically those with responsibility for risk management) from Auckland's key lifelines organisations and local authorities, with input from other lifelines, consultants and researchers as required who are not members of the Steering Committee. Day to day input would be provided by a Project Manager, who would be engaged under contract. This would be similar to the way the Auckland Engineering Lifelines Project currently functions and is also how the Wellington Lifelines Group is managed.

Funding for the administration and management of the Group could be provided by these organisations in the form of a small annual grant.

Depending on objectives and priorities, the Group may decide to undertake one or more projects in any given year. Depending on the size and type of the project, financing of these projects would probably be in addition to the annual grant, and might include a mix of cash and in kind contributions.

This work would be less intensive than the project phase, so the Steering Committee would probably only need to meet two to three times a year.

The function and activities of the Auckland Engineering Lifelines Group need to be taken into account when considering its structure and linkages to other regional groups.

Relationship of the Auckland Engineering Lifelines Group to other groups

The Group could affiliate itself with or come under the auspices of an existing group such as the Auckland Utility Operators Group or the Auckland Emergency Management Group (EMG).

Until project terms of reference are established and emergency management legislation becomes operative, it is recommended that the Auckland Engineering Lifelines Group establish itself as a separate entity with close liaison with the EMG and the Auckland Utility Operators Group.

Auckland Engineering Lifelines Project - Stage 2

Much of the further work identified as needing to be done extends the focus of the project beyond lifeline utilities to include the emergency services and other community lifelines such as hospitals and other key buildings. This would enable a more complete picture of the regional impact of the scenarios used.

From the beginning of the Auckland Engineering Lifelines Project, this work was identified as needing to be done and was always referred to as Stage 2 of the Auckland Engineering Lifelines Project (refer also to Step 10 of Figure 1 in Chapter 2).

Participants in the Auckland Engineering Lifelines Project always recognised that it would probably need to progress to a further stage

In developing an Auckland Engineering Lifelines Group mainly to progress lifeline utility risk management issues, the need to consider the wider regional impact has not been overlooked.

Support for this part of the project and how it should be carried out will be sought from key stakeholders at the same time as support for an Auckland Engineering Lifelines Group is canvassed. Such a project may even become one of the further work items the Auckland Engineering Lifelines Group will pick up, with the group itself making recommendations as to how to further progress a regional impact study.

11.4 Summary

The formation of an Auckland Engineering Lifelines Group to continue the work of the Auckland Engineering Lifelines Project has advantages in that it:

- allows a more complete treatment of the risk management continuum
- adds value to participating lifeline organisations business objectives (business continuity, asset management, customer satisfaction and so on)
- is a possible way through which utility organisations can fulfil their obligations under proposed emergency management legislation

The structure and operation of the Group would need to be worked through in more detail once it was established (steering committee representation, objectives, project management and the like) but could be based on the Wellington Lifelines Group model.

Gaining support for structure, links and activities

In defining the most appropriate structure and linkages of a Lifelines Group, it is important to consider the Group's objectives and likely activities. At this stage it is recommended that the Auckland Engineering Lifelines Group establish itself as a separate entity with close links to the Auckland Utility Operators Group and the Auckland EMG.

Before setting up an Auckland Engineering Lifelines Group, support for the concept needs to be sought from both the Auckland Utility Operators Group, the Auckland Emergency Management Group as well as Auckland Engineering Lifeline Project members.

Support also needs to be sought for an expansion of the work of Stage 1 of the Auckland Engineering Lifelines Project to include an analysis of the regional impact of the hazard scenarios used.

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Appendices

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Auckland Engineering Lifelines Project

Appendix A

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November 1999

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FINAL REPORT — STAGE 1

Auckland Engineering Lifelines Project

Appendix B
Workbook for earthquake hazard and vulnerability analysis

November 1999

AUCKLAND REGIONAL COUNCIL

AUCKLAND ENGINEERING LIFELINES PROJECT

Auckland Engineering Lifelines Project - Hazard Analysis Workbook

January 1997

Rev 1

Contents

Earthquake Hazard Analysis Workbook

1.0 Preamble

It was apparent that the methodology trialed in the Vulnerability workshop was not complete and required more focus and modification before being used on the region's utilities. The features of the new methodology used in this work book have been designed to achieve the principal objective of the AELP.

"to reduce the impact on the lifeline services of the Auckland Metropolitan region from all known hazards".

In reviewing the methodology, a focus was maintained on key issues.

80/20 Focus

Rather than performing a full detailed analysis on the entire network it is essential to focus on those items / issues that will provide best value for time and money. Crudely, analysis on 20% of the area will identify 80% of the risk; the remaining 20% of the risk will be spread over the rest of the area.

Utility Focus

The risk analysis of the Lifelines System is complex with strong links to civil defence and regional recovery issues. In order that the AELP maintain momentum and value for its participants, it must focus, in stage 1 of the project, on the response of utility lifelines only. The integration of Civil Defence and regional recovery issues will be integrated in stage 2 of the project.

Mitigation Focus

In order to reduce the impact on lifelines services, the sensitivity of a utility to any event must first be lessened through the identification of mitigation measures that individual utility organisations can implement to reduce the impact of the various hazards on their service. The focus on mitigation must be maintained.

Impact Focus

To effect a reduction in the impact of a hazard event on the whole utility system, the implications and full extent of the impact must be understood. The identification of impact from an event is an iterative process.

Recovery Focus

Ultimately, the rapid and effective recovery of all lifelines is the purpose of the AELP. To this end the focus of the project on issues that will enhance recovery is paramount.

2.0 Revised Methodology

The revised methodology for completion of Stage I of AELP can be broken up into a number of tasks as shown in the flowchart *fig 1* and the task descriptions below:-

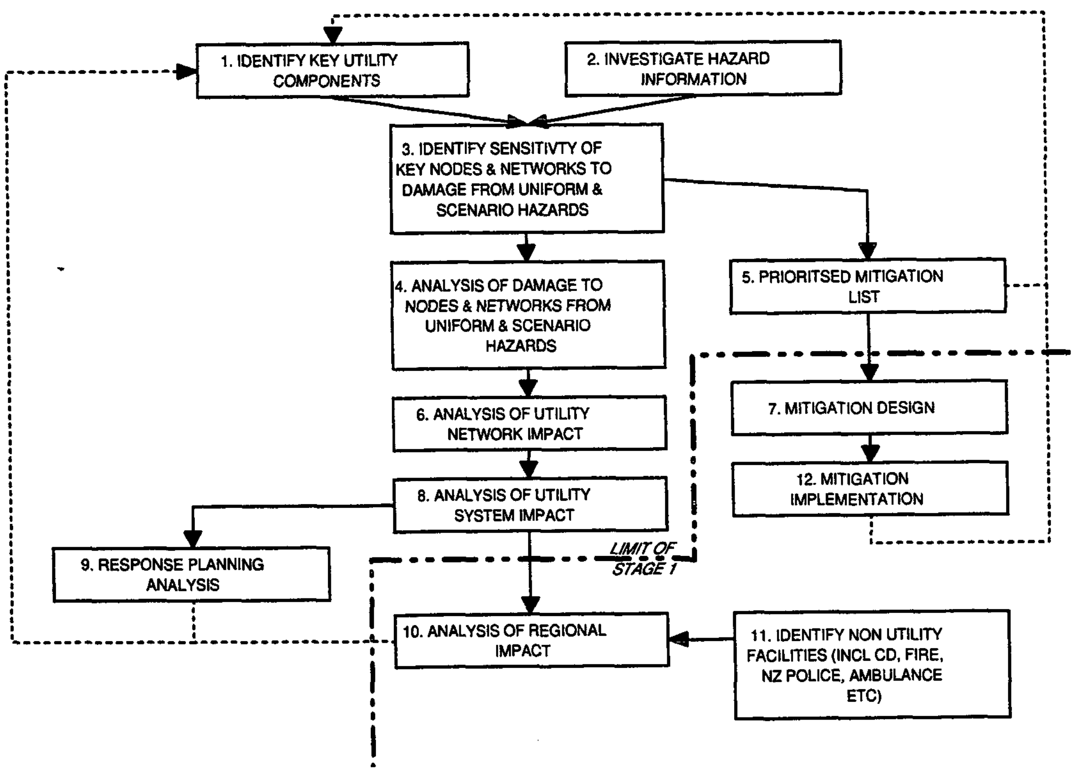


figure 1 Methodology

Task 1	Identify key utility components.
Task 2	Prepare Hazard Information.
Task 3	Identify sensitivity of Nodes and Networks to Damage from a Uniform Hazard.
Task 4	Identify sensitivity of Nodes and Networks to Damage from a Scenario Hazard.
Task 5	Establish a prioritised mitigation's list.

Task 1 & 2 are already complete. This work book details the methodology for completing tasks 3 & 4.

Task 3(A)	Damage Assessment of Nodes due to Uniform Hazard
Task 3(B)	Damage Assessment of Networks due to Uniform Hazard
Task 4(A)	Damage Assessment of Nodes due to Scenario Hazard
Task 4(B)	Damage Assessment of Networks due to Scenario Hazard

For each of these tasks, there is a work sheet to be filled in, and a series of steps to be followed. Reference is made to the Hazard Maps which are provided separately to this work book.

The work sheets should be photo copied before commencing analysis to provide sufficient for completion of the exercise.

Definitions

The following definitions seek to provide some uniformity to the use of language in the project.

Regional System	the integrated and interrelated social, commercial, cultural, political, legal and natural environment of the region.
Utility System	the combined utility networks, their interdependencies and interrelations for the provision of infrastructure services.
Utility Network	an interconnected set of utility components and links for the provision of a utility service.
Utility Node	a discrete constituent part of the utility network.
Vulnerability	the extent to which a system, network or node is sensitive to damage from an event.
Damage	Physical harm impairing the operation of a system, network or node caused by an event.
Impact	The time related effect of damage. *Node Impact* - is the reduction in operational performance / function of a node effected by damage. *Network Impact* - is the time and spatial reduction in function of the utility network caused by the cumulative node impacts. *System Impact* - is the reduction in function of the combined network impacts on the whole utility system. *Regional Impact* - the cumulative effect of the system impact and other non utility effects on the region.

3.0 EARTHQUAKE

3.1 Introduction

The following steps describe the method to produce a damage assessment profile on utilities due to uniform earthquake and scenario earthquake conditions.

3.2 Task 3(A): Damage Assessment of Nodes due to Uniform Earthquake

Materials Required

- Worksheet 3(A) Flowchart
- Task 3(A) Worksheet
- Table Ref A
- Utility Maps
- Maps Ref I, II, III, IV

Steps

To be carried out for each node. Enter information on Task 3(A) Worksheet at each step.

Site Assessment
(Use the Task 3(A) Worksheet).

1. Node - identify the node on the Utility Map provided and fill in the Node Type and ID No., eg. 'Reservoir 162'.

2. Soil Classification - Overlay the Utility Map onto Maps ref IA or IB (as appropriate) to ascertain soil class A B C or D.

3. PGA (Peak Ground Acceleration) - If soil is class A then PGA is between 0.15g and 0.2g. (Enter '0.15 - 0.2g'). If soil is class B, C or D then PGA is >0.2g.

4. Liquefaction - (Not required for soil class A) - Overlay Utility Map on to Map Ref II A & B to ascertain Liquefaction Susceptibility. (susceptibility is either A or E).

5. Slope Class -(Perform for all soil class types) - Overlay Utility Map onto Map Ref III A & B to ascertain Slope Class A, B, C or D.

6. Slope Instability - Overlay Utility Map onto Map Ref IV A & B to ascertain slope instability hazard. Class A, B, C or D. If slope is class D, then a detailed slope investigation is suggested. Enter yes or no accordingly in final box.

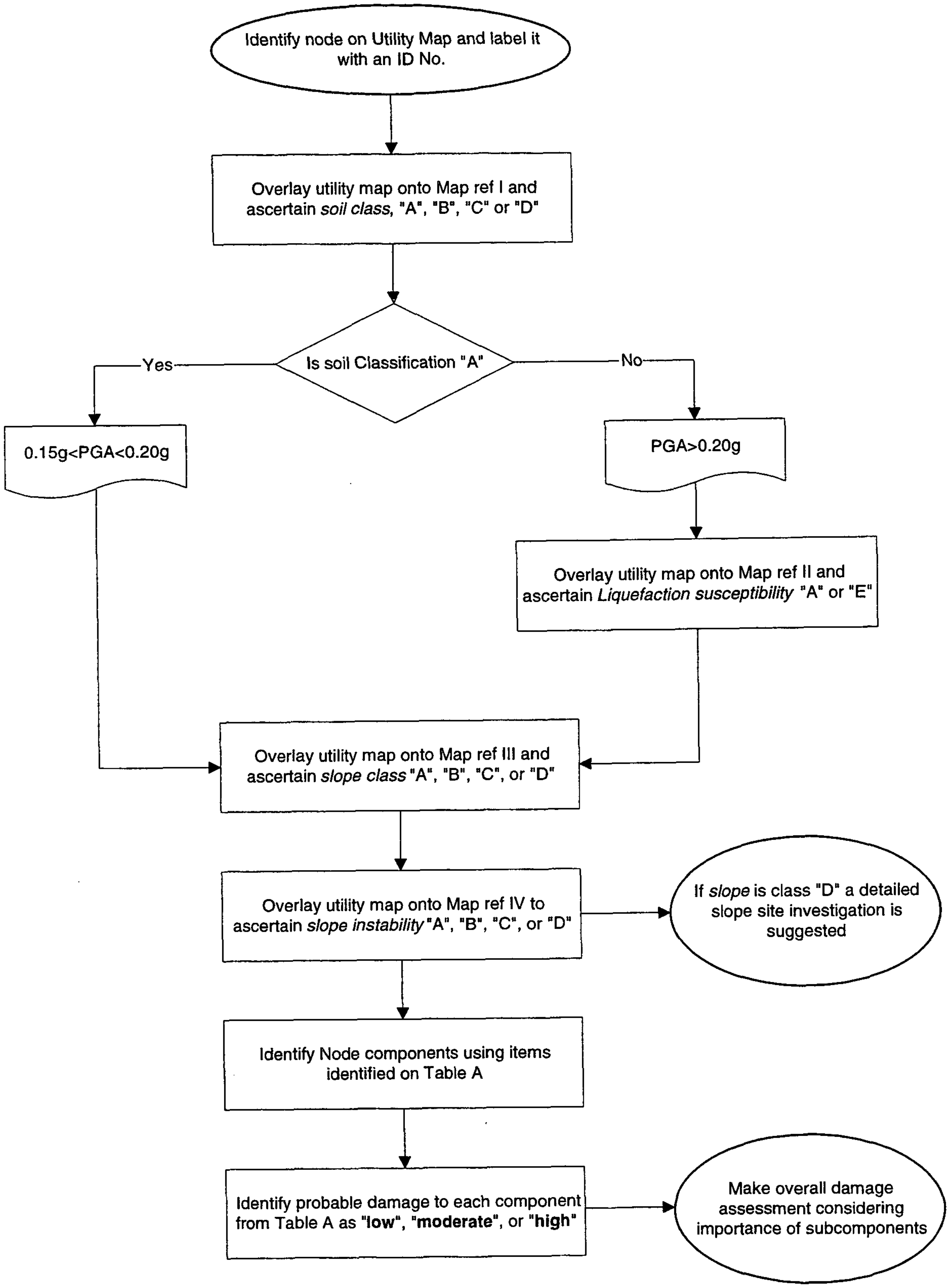
Damage Assessment
(Refer Table ref A)

7. Identify all components of the Node and list each on a separate line. Where possible describe the node components using the items identified on Table Ref A.

8. Identify probability of damage to each component from Table Ref A (LOW, MODERATE OR HIGH).

9. Make overall damage assessment by considering the importance of each sub component and its probable level of damage. *This is a subjective assessment based on your knowledge of the node, but generally can be taken as the worst damage description for the node components.*

Task 3(A) Worksheet Flow Diagram
Damage Assessment of <u>Nodes</u> due to a <u>Uniform Earthquake</u>



Task 3(A) Worksheet

DAMAGE ASSESSMENT OF **NODES** FROM **UNIFORM EARTHQUAKE**

UTILITY ______________________________

NODE TYPE AND ID NO.	SITE CHARACTERISTICS			DAMAGE ASSESSMENT (Ref Table A)			
	Site Characteristics	Reference		Node Components	Damage Description (High, Moderate, Low)	Overall Damage Assessment	Detailed Site investigation?
	Soil classification	Maps Ref I				(circle one)	(YES/NO)
	PGA	If soil class A, then 0.15-0.2g, otherwise >0.2g				HIGH	
	Liquefaction Class	Map Ref II				MODERATE	
	Slope Class	Map Ref III				LOW	
	Slope Instability	Map Ref IV	A B C (D)	ENTER YES WHERE SLOPE INSTABILITY IS CLASS "D"			
	Soil classification	Maps Ref I				(circle one)	(YES/NO)
	PGA	If soil class A, then 0.15-0.2g, otherwise >0.2g				HIGH	
	Liquefaction Class	Map Ref II				MODERATE	
	Slope Class	Map Ref III				LOW	
	Slope Instability	Map Ref IV	A B C (D)	ENTER YES WHERE SLOPE INSTABILITY IS CLASS "D"			
	Soil classification	Maps Ref I				(circle one)	(YES/NO)
	PGA	If soil class A, then 0.15-0.2g, otherwise >0.2g				HIGH	
	Liquefaction Class	Map Ref II				MODERATE	
	Slope Class	Map Ref III				LOW	
	Slope Instability	Map Ref IV	A B C (D)	ENTER YES WHERE SLOPE INSTABILITY IS CLASS "D"			
	Soil classification	Maps Ref I				(circle one)	(YES/NO)
	PGA	If soil class A, then 0.15-0.2g, otherwise >0.2g				HIGH	
	Liquefaction Class	Map Ref II				MODERATE	
	Slope Class	Map Ref III				LOW	
	Slope Instability	Map Ref IV	A B C (D)	ENTER YES WHERE SLOPE INSTABILITY IS CLASS "D"			

3.3 *Task 3(B): Damage Assessment of Networks due to* ***Uniform Earthquake***

Materials Required

- Worksheet 3(B) Flowchart
- Task 3(B) Worksheet
- Table Ref A
- Utility Maps
- Maps Ref: I, II, III

Steps

To be carried out for each type of network. Enter information on Worksheet 3(B) at each step.

Network Identification

1. Identify on the utility maps by highlighting in different colours each of the following types of network.

   (MD) Moderately Ductile Pipes - *steel, copper, PVC, HDPE*
   (LD) Low Strength or Low Ductility Pipes - *new cast iron, lead*
   (ND) Non-Ductile Pipes - *brick, ceramic, old cast iron*
   (PL) Power lines/telephone lines
   (RR) Roads/Rail

Damage Assessment

For all Network Types:

2. Overlay the highlighted network map onto the Liquefaction Map II (A or B appropriately)

   Identify and label uniquely all networks that cross liquefiable soils (mapped as red, class "E").
   Suggested labelling to include utility reference
   eg. **T/LD/EQU - 1**
   Telecom, Low Ductile, E/Q uniform, pipe location 1

   Transfer network reference to Worksheet (3B), note as "HIGH" and mark on the Utility map.

For Pipes only:

3. Overlay highlighted map on Slope Grade Map III. Identify & label uniquely as for step 2 all pipe networks that cross slope class "C" or "D".

   Where moderately ductile pipes (MD) are identified the probable damage is "MODERATE", for all other pipes the probable damage is "HIGH". Transfer this information to the Worksheet and mark on the Utility Map.

4. To identify areas of "MODERATE" probable damage to non ductile pipes, overlay the utility map onto Map I.
   Where non-ductile pipes cross soil classes "B", "C" or "D" the probable damage is "MODERATE". Transfer this information to the Worksheet and mark on the Utility map.
   All other pipes have probable damage "LOW".

For Powerlines, Lampposts only:

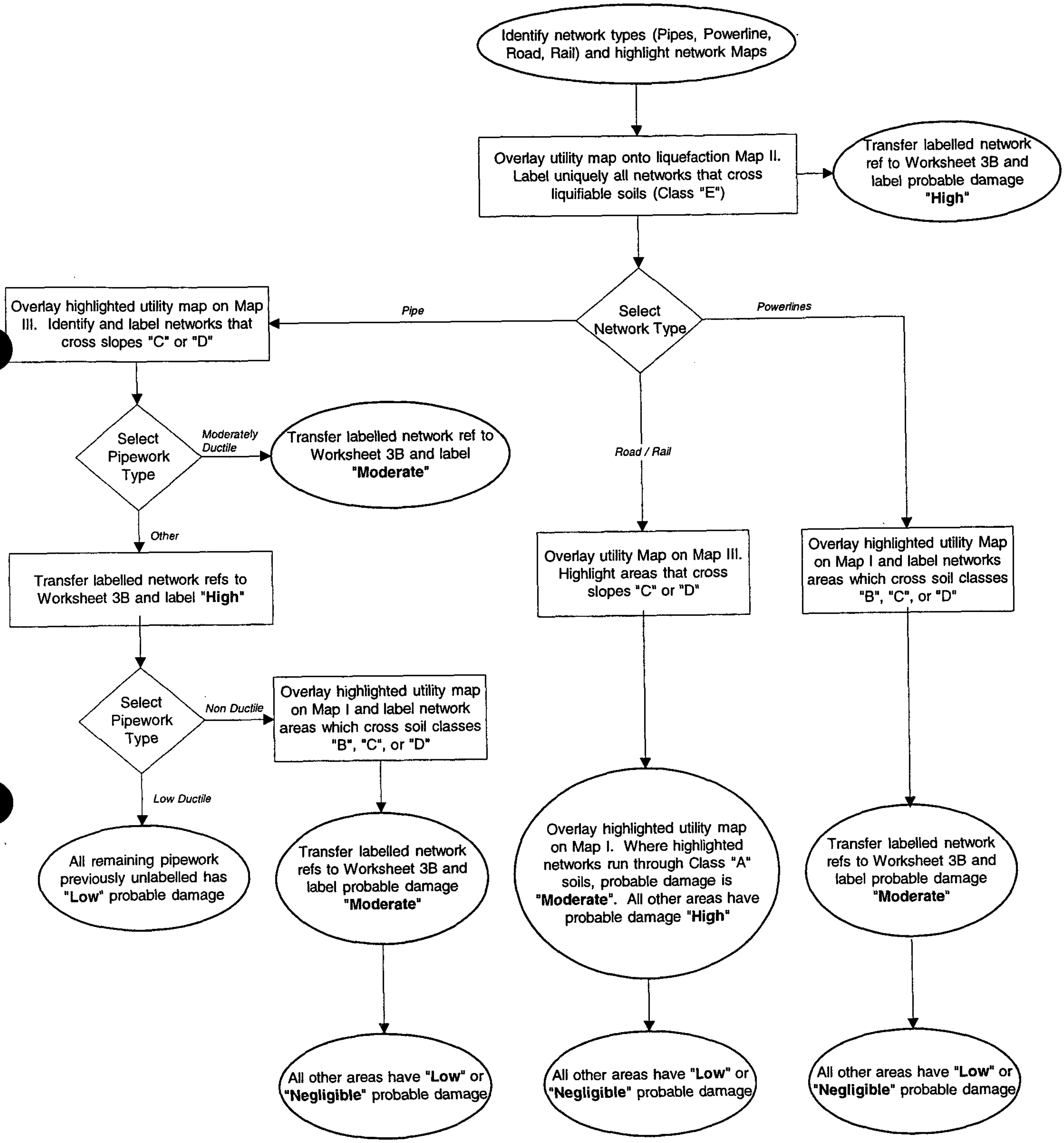
5. Overlay the utility map on Map I, identify and label uniquely as for step 2 where powerlines networks cross soil class "B", "C" or "D" the probable damage is "MODERATE". Transfer this information to the Worksheet and mark on the Utility Map. All other network sections have "LOW" probable damage.

For Road and Rail only:

6. Overlay the utility map on Map III identify and label uniquely as for step 2 and highlight where the road/rail networks cross slope class "C" & "D".

7. Overlay the network map onto Map I and where highlighted networks run through class A soils the probable damage is "MODERATE", all other areas the probable damage is "HIGH". Transfer this information to the Worksheet and mark on the Utility Map.
   All remaining road and rail network sections have "LOW" or "NEGLIGIBLE" probable damage.

Task 3(B) Worksheet Flow Diagram
Damage Assessment of <u>Networks</u> due to <u>Uniform Earthquake</u>



Task 3(B) Worksheet

DAMAGE ASSESSMENT OF **NETWORKS** FROM **UNIFORM EARTHQUAKE**

UTILITY: ____________________________

NETWORK TYPE & ID NO. eg T/LD/EQU-1	**DAMAGE ASSESSMENT CRITERIA** Circle one	**DAMAGE ASSESSMENT** Circle one
	LIQUIFACTION CLASS "E" →	**HIGH**
	SLOPE GRADE C/D	**MODERATE**
	SOIL CLASS B, C OR D	**LOW**
	LIQUIFACTION CLASS "E" →	**HIGH**
	SLOPE GRADE C/D	**MODERATE**
	SOIL CLASS B, C OR D	**LOW**
	LIQUIFACTION CLASS "E" →	**HIGH**
	SLOPE GRADE C/D	**MODERATE**
	SOIL CLASS B, C OR D	**LOW**
	LIQUIFACTION CLASS "E" →	**HIGH**
	SLOPE GRADE C/D	**MODERATE**
	SOIL CLASS B, C OR D	**LOW**
	LIQUIFACTION CLASS "E" →	**HIGH**
	SLOPE GRADE C/D	**MODERATE**
	SOIL CLASS B, C OR D	**LOW**
	LIQUIFACTION CLASS "E" →	**HIGH**
	SLOPE GRADE C/D	**MODERATE**
	SOIL CLASS B, C OR D	**LOW**
	LIQUIFACTION CLASS "E" →	**HIGH**
	SLOPE GRADE C/D	**MODERATE**
	SOIL CLASS B, C OR D	**LOW**

3.4 Task 4(A): Damage Assessment of Nodes due to Scenario Earthquake

Materials Required

- Worksheet 4(A) Flowchart
- Task 4(A) Worksheet
- Task 3(A) Worksheet *for reference*
- Table Ref A (see appendix)
- Table Ref B (see appendix)
- Utility Maps
- Maps Ref: VI, V

Steps

To be carried out for each Node. Enter information on Task 4(A) Worksheet at each step.

Site Assessment

1. Node - identify the node on the Utility Map and enter the Node Type and ID No. eg 'Reservoir 162'.

2. Uniform Earthquake Damage Assessment - circle probability of damage derived in Task 3(A).

3. Slope Class - circle Slope Class derived in Task 3(A).

4. PGA (Peak Ground Acceleration) - Overlay utility Map on to Map V to ascertain PGA. Circle PGA on Worksheet accordingly.

5. Liquefaction - (only required if PGA > 0.2g) - Overlay Utility Map on to Map VI to ascertain Liquefaction Susceptibility. Circle Worksheet accordingly.

Damage and Component Impact Assessment

6. Transfer components of the Node from Step 7. of task 3A Worksheet and enter each on Task 4(A) Worksheet .

7. Assess damage to each component in turn from Table Ref A and enter on Task 4(A) Worksheet - HIGH, MODERATE, LOW, NEGLIGIBLE.

8. Refer to Table Ref B (see Appendix) for the types of damage likely as a result of the event.

9. Estimate post-event performance for each component as a percentage of full capacity after 1 day and 1 week. Estimate the time for full recovery based on the assumption of unlimited resources and unrestricted access (as if this were the only damage sustained and needing to be repaired at the time).

10. Complete the estimated recovery profile at the top right corner of the Worksheet for the entire node.
The profile is a subjective assessment of the time taken to re-establish 100% performance of the node. Where temporary measures can be utilised to achieve 100% performance, this time profile should be used.

eg: The recovery profile to re establish a damaged concrete water reservoir may be 0/0/150, however by using a series of temporary plastic tanks to store water while the concrete tank is being repaired, a recovery profile of 0/20/15 may be achieved. This profile should be used and the use of temporary tanks noted.

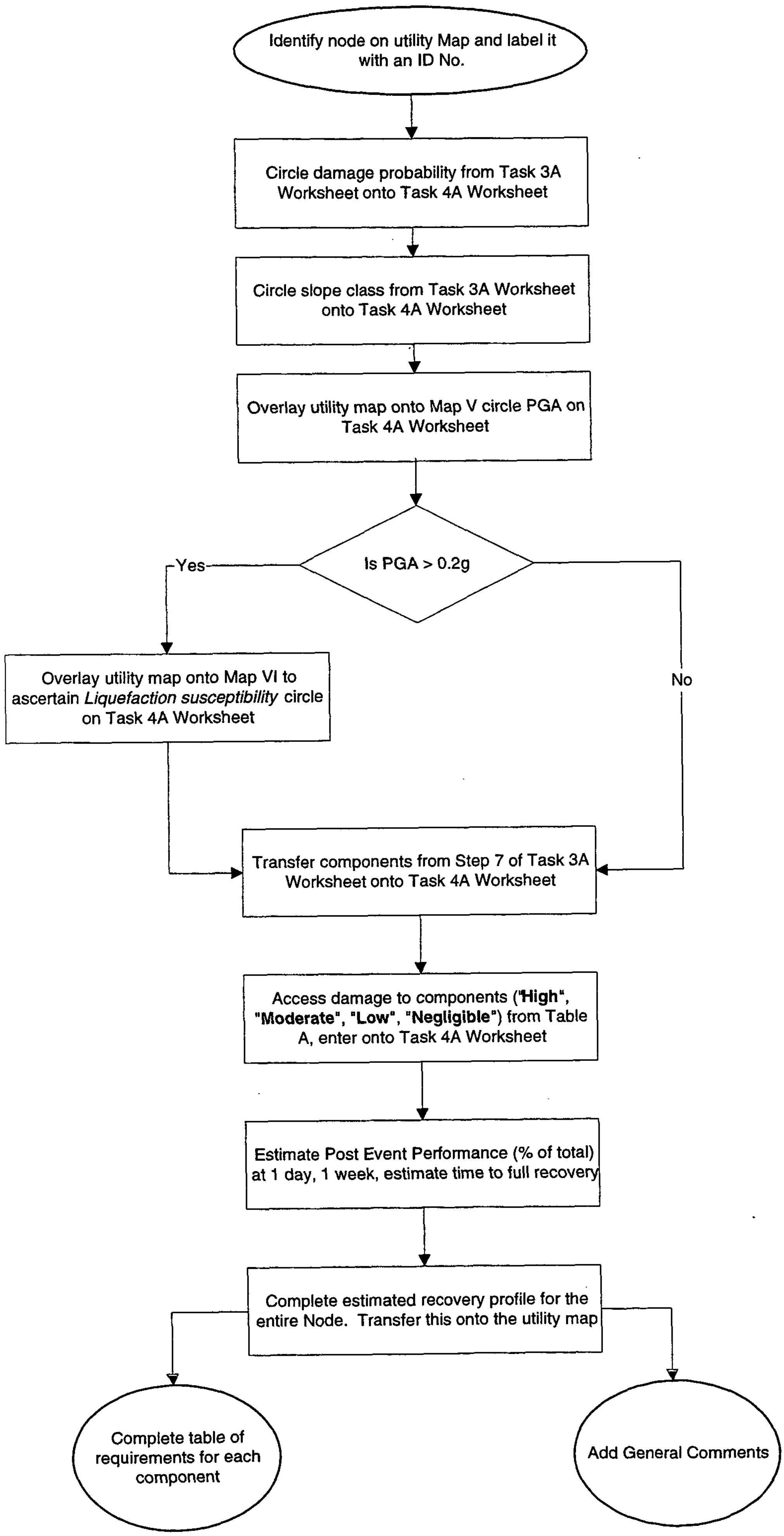
Recovery Requirements

11. Complete table of requirements for recovery of each component in turn.

12. Add any general comments eg. possible temporary measures for reducing recovery time.

13. Transfer the recovery profile to the Utilities Network Map.

Task 4(A) Worksheet Flow Diagram
Damage Assessment of <u>Nodes</u> due to <u>Scenario Earthquake</u>



Task 4(A) Worksheet

DAMAGE AND RECOVERY ASSESSMENT OF **NODES** FROM **SCENARIO EARTHQUAKE**

Node Num		
	1.	
% at day 1	% at 1 week	Days to full
Estimated Recovery		

UTILITY ____________________

COMPONENT NAME ____________________

UNIFORM E/Q DAMAGE ASSESSMI from Task 3(A) worksheet (circle one) HIGH MODERATE LOW

SITE CHARACTERISTICS

		A	B	C	D	
Slope Class (circle one)	From Worksheet 3(A), step 1	A	B	C	D	Liquefaction need only be conside
Scenario Earthquake PGA (circle one	**Map Ref V**	<0.05g	0.05-0.10g	010-0.15g	0.15-0.20g	>0.20g
Liquefaction Class	**Map Ref VI**	0%	0%-0.5%	0.5%-10%	10%-30%	30%-90%

DAMAGE AND COMPONENT IMPACT ASSESSMENT

Sub-components (from Worksheet 3A, step 7)				
Damage Assessment **(high,moderate,low, negligible) Table Ref A**				

POST EVENT PERFORMANCE ESTIMATE (Based on Unlimited Resources and Unrestricted Access)

Immediate (<1 day) (%)				
Intermediate (<1 week) (%)				
Time for full recovery (days)				

RECOVERY REQUIREMENTS

EQUIPMENT TO ESTABLISH AND MAINTAIN ACCESS				
MATERIALS				
SPARES				
OTHER LIFELINES				

COMMENTS

3.5 *Task 4(B): Damage Assessment of Networks due to a Scenario Earthquake*

Materials Required

- Task 4(B) Flow diagram
- Task 4(B) Worksheet
- Task 3(B) Worksheet *for reference*
- Table Ref A (see appendix)
- Table Ref B (see appendix)
- Utility Maps
- Maps Ref: III, IV, V

Steps

To be carried out for each type of Network. Enter information on Task 4(B) Worksheet at each step.

Network Identification

1. Use the network types and labelling established in Task 3(B) Worksheet.

ie (MD) Moderately Ductile Pipes
(LD) Low Strength or Low Ductility Pipes
(ND) Non-Ductile Pipes
(PL) Power lines/telephone lines
(RR) Roads/Rail.

Damage Assessment

For All Network Types:

2. Transfer the utility network sections identified in task 3(B) Worksheet *(step 2) with Liquefaction class"E"* into task 4(B) Worksheet changing the reference EQU to EQS.

eg WC/MD/EQU - 6 becomes — WC/MD/EQS - 6

Watercare, Moderately Ductile, E/Q Scenario, location 6.

3. The probable damage assessment of these network components in region A due to liquefaction is "HIGH". Note this on the task 4(B) Worksheet.

For Pipes Only:

4. Transfer pipe network references associated with slopes C & D of task 3(B) Worksheet *(step 3)* onto task 4(B) Worksheet again changing EQU/EQS references.

Overlay the "highlighted" utilities map onto Map ref V and using the PGA values coloured for each zone note the probable damage classification as "HIGH", "MODERATE" or "LOW" from Table A.

eg1) moderately ductile pipes on slopes C or D with PGA of 0.15-0.2g or >0.2g is "MODERATE"

eg2) non-ductile pipes on slopes C or D with PGA 0.1-0.15g is "MODERATE", with PGA 0.15-0.2g or >0.2g is "HIGH".

5. To identify sections of MODERATE probable damage for non ductile pipes elsewhere (ie slopes A or B) identify and uniquely label sections of non ductile pipework inside the PGA zone >0.2g ("red" zone). The probable damage classification is "MODERATE". Transfer this information onto the Worksheet.
   All other network areas have "LOW" or "NEGLIGIBLE" probable damage.

For Powerlines, Lampposts Only:

6. Overlay the utility map on Map ref V (PGA zones), where highlighted networks cross PGA >0.2 (red zone) the probable damage is "MODERATE". Transfer this information onto the Worksheet.
   All other network areas have "LOW" or "NEGLIGIBLE" probable damage.

For Road & Rail Only:

7. From step 6. of Worksheet 3B transfer the sections of network that cross slope class C & D onto task 4(B) Worksheet.

8. Overlay the utility map on Map Ref V (PGA zones), where labelled highlighted network sections cross zones of PGA > 2.0 probable damage is "HIGH".

9. Where network sections cross zones of PGA of 0.15-0.2g probable damage is "MODERATE". Transfer this information into the Worksheet. All other areas have "LOW" or "NEGLIGIBLE" probable damage.

Performance and Recovery Assessment

10. Against each utility network section identified in the above estimate the performance of the network as a percentage of the full capacity after 1 day and 1 week. Estimate the time for full recovery based on the assumption of unlimited resources and unrestricted access.

11. Complete the estimated recovery profile at the top right corner of the Worksheet.

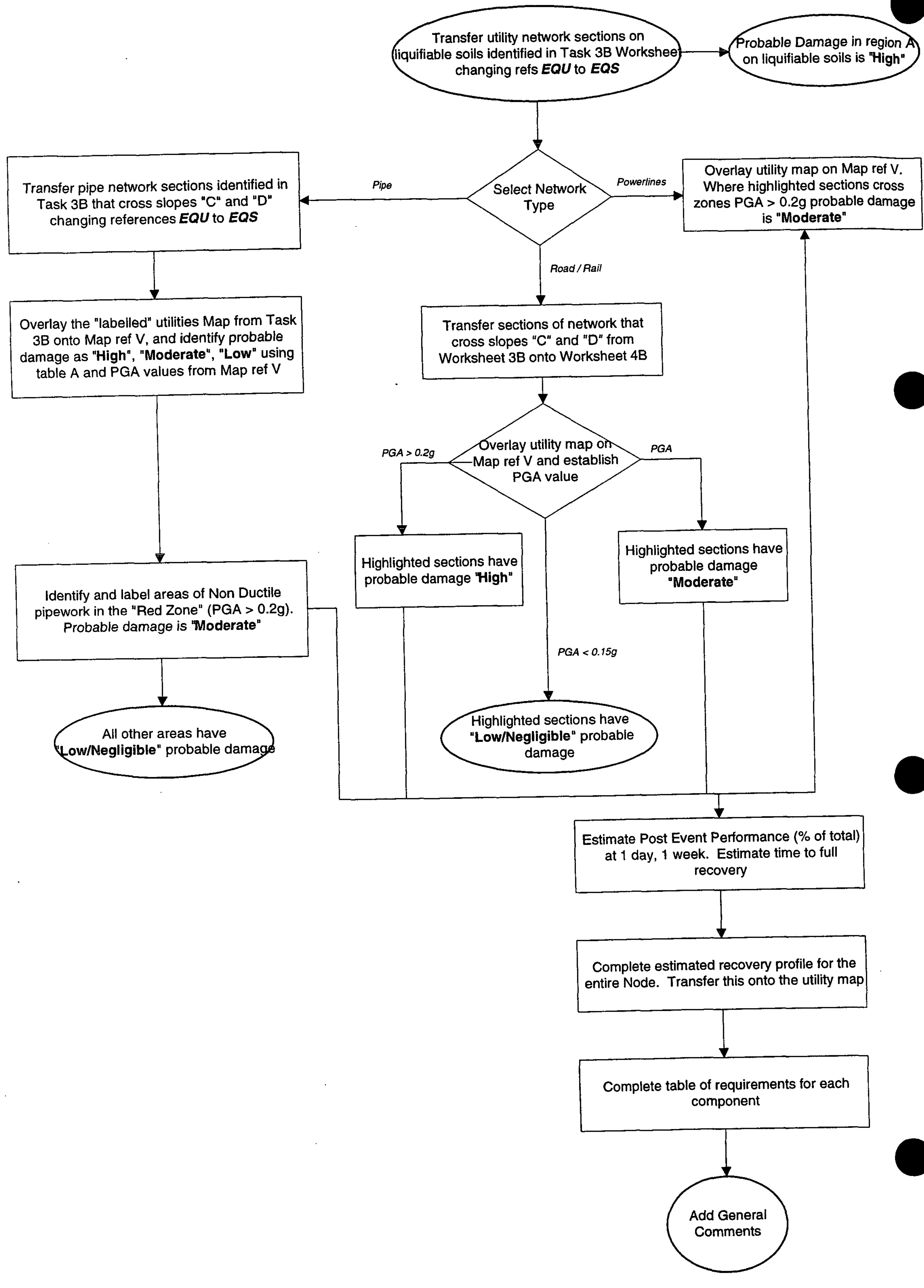
Recovery Requirements

12. Complete table of requirements for recovery of each network section in turn.

13. Add any general comments eg. possible temporary measures for reducing recovery time.

14. Transfer the recovery profile to the Utilities Network Map.

Task 4(B) Worksheet Flow Diagram
Damage Assessment of Networks due to Scenario Earthquake



Task 4(B) Worksheet

GE AND RECOVERY ASSESSMENT OF **NETWORKS** FROM **SCENARIO EARTHQUAKE**

UTILITY ______________________

NETWORK TYPE & ID NO.		
% at day 1	% at 1 week	Days to full
Estimated Recovery Profile		

UNIFORM E/Q DAMAGE ASSESSME   HIGH   MODERATE   LOW
from Task sheet 3(B) (circle one)

DAMAGE ASSESSMENT CRITERIA			
CIRCLE ONE	LIQUEFACTI ON CLASS D OR E	SLOPE GRADE C OR D	SOIL CLASS B, C OR D

DAMAGE ASSESSMENT (Table ref A)			
CIRCLE ONE	**LOW**	**MODERATE**	**HIGH**

POST EVENT PERFORMANCE ESTIMATE (Based on Unlimited Resources and Unrestricted Access)	
Immediate (<1 day) (%)	
Intermediate (<1 week) (%)	
Time for full recovery (days)	

RECOVERY REQUIREMENTS	
EQUIPMENT TO ESTABLISH AND MAINTAIN ACCESS	
MATERIALS	
SPARES	
OTHER LIFELINES	

Table A: **Earthquake - induced damage to structures matrix**

Source: *Updated from the Auckland Engineering Lifelines Project Stage 1 Report - Part 1: Hazard Information, July 1997*

STRUCTURE	Range of Ground Acceleration (PGA) and Modified Mercalli Felt Earthquake Intensities (MMI)							
	MMI ≤ VI 0.05 - 0.10g	MMI VI - VII 0.1 - 0.15g		MMI VII - VIII 0.15 - 0.20g		MMI > VIII > 0.2g		
	No risk of Liquefaction	Minor Risk of Liquefaction		Some Risk of Liquefaction		Non-Liquefiable Soils		Liquefiable Soils
		Slopes A/B	Slopes C/D	Slopes A/B	Slopes C/D	Slopes A/B	Slopes C/D	
PIPEWORK								
Moderately Ductile Pipes	negligible	negligible	low probability	negligible	moderate probability	negligible	moderate probability	high probability
Low Strength or Low Ductility Pipes (Includes Underground Services Duct)	negligible	negligible	low probability	low probability	high probability	low probability	high probability	high probability
Non-Ductile Pipes	low probability	low probability	moderate probability	low probability	high probability	moderate probability	high probability	high probability
CONNECTIONS & FITTINGS								
Seismically Designed (eg HDPE; steel pipe with expansion loops)	negligible	negligible	negligible	low probability	low probability	moderate probability	moderate probability	high probability
Rubber Joints (modern spun concrete or plastic pipes laid in ground)	negligible	negligible	negligible	low probability	moderate probability	moderate probability	high probability	high probability
Cement Joints (old; very common)	negligible	low probability	moderate probability	high probability	high probability	high probability	high probability	high probability
BUILDING STRUCTURES								
Modern Multistorey	negligible	negligible		low probability		low to moderate probability		moderate probability
Older Multi-level Brick/Masonry	negligible	moderate probability		high probability		very high probability		very high probability
Residential	negligible (timber frame) to low probability (brick)	negligible (timber frame) to moderate probability (brick); old brick chimneys break off		low (timber frame) to high probability (brick); old brick chimneys break off		low (timber frame) to very high probability (brick); old brick chimneys break off		high to very high probability
SERVICES								
Power Lines, Lamp Posts	negligible	negligible		low probability		moderate probability		high probability
Pipe Bridges	negligible	low probability		moderate probability		high probability		high probability

CIVIL STRUCTURES								
Roads, Rail	negligible	negligible	low probability	negligible	moderate probability	low probability	high probability	high probability
Embankments	negligible	low probability	moderate probability	low to moderate probability depending on embankment height	moderate to high probability	moderate probability	high probability	high probability
Earth Dams	negligible	low probability	moderate probability	moderate probability	not applicable	moderate to high probability	not applicable	not applicable
Concrete Dams	negligible	negligible	low probability	low probability	low probability	moderate probability	moderate probability	not applicable
Steel Tanks	negligible	negligible	not applicable	low probability	not applicable	moderate probability	not applicable	moderate probability
Concrete Tanks and Reservoirs	low probability	moderate probability	not applicable	moderate probability	not applicable	high probability	not applicable	high probability
BRIDGES								
Modern	negligible	negligible	negligible	low probability	low probability	low to moderate probability	low to moderate probability	moderate to high probability
Old	low probability	low to moderate probability	low to moderate probability	moderate probability	moderate to high probability	high probability	high probability	high probability
SPECIFIC INFRASTRUCTURE								
Auckland International Airport	negligible	negligible		low probability Short shut-down period for repairs.		low to moderate probability Shut-down for repairs.		moderate probability; shut-down for repairs.
Auckland Ports	negligible (modern) to low probability (old)	low (modern) to moderate probability (old)		moderate (modern) to high probability (old)		high probability		very high probability
Water Supply Dams, Waitakere and Hunua	negligible	low to moderate probability		moderate probability Low risk of dambreak: severe impact potential.		moderate to high probability Moderate risk of dambreak: severe impact potential.		not applicable

Slope Classes:
Class A slopes 0 - 7°
Class B slopes 8 - 15°
Class C slopes 16 - 20°
Class D slopes > 20°

Not applicable:
Dams are unlikely to be constructed on liquefiable soils.
Earth dams, tanks and reservoirs are unlikely to be constructed on steep slopes.

Table B: ***Earthquake - induced damage type matrix***

Source: Updated from the Auckland Engineering Lifelines Project Stage 1 Report - Part 1: Hazard Information, July 1997

STRUCTURE	Negligible	Low Probability	Moderate Probability	High Probability	
				Non-Liquefiable Soils	Liquefiable Soils
PIPEWORK					
Moderately Ductile Pipes	alignment may be disturbed	some pipes stretched to yield point	necking damage or tear (require replacement): leakage	not applicable	rupture or loss of anchorage
Low Strength or Low Ductility Pipes (Includes Underground Services Duct)	alignment may be disturbed	some cracked joints; minor leakage	some joints ruptured; major leakage	displaced joints; major leakage	displaced joints; major leakage or loss of anchorage
Non-Ductile Pipes	not applicable	cracked pipes; minor leakage	some ruptured pipes; major leakage	displaced pipes; major leakage	
CONNECTIONS & FITTINGS					
Seismically Designed (eg HDPE; steel pipe with expansion loops)	minor movement	minor yielding;	yielding and distortion of joints: minor leakage	tear or rupture of joints: leakage	
Rubber Joints (modern spun concrete or plastic pipes laid in ground)	minor movement	movement, particularly where sited within sloping or settlement prone ground	joint leakage	joint separated or sheared: major leakage	
Cement Joints (old; very common)	minor cracking	cracking; minor leakage	cracking; major leakage	joint displaced; major leakage	
BUILDING STRUCTURES					
Modern Multistorey	suspended ceilings damaged; large windows broken	minor cracking; minor spalling of beams	some spalling and cracking; repair required; architectural ornaments fall	moderate damage or permanent distortion	serious damage and/or permanent distortion
Older Multi-level Brick/Masonry	as above; cracking of plaster	not applicable	spalling of finish; cracking and damage to walls; damage to brick veneers and plaster or cement based linings	serious damage: falling debris; panel collapse; possible floor collapse	serious damage/ total loss
Residential	cracked finish (timber frame)	some damage to chimneys; cracked finish; roofing tiles dislodged	loss of chimney; cracked plaster; loss of panels; some windows crack; structural damage where founded on partially liquefiable soils	falling debris; panel collapse; possible floor collapse; houses not secured to foundations shifted off brick veneers fall and expose frames	total loss (brick or timber)
SERVICES					
Power Lines, Lamp Posts	minor loss of verticality	some movement	loss of support and yielding of wires; some twisted or brought down	power line breaks; posts brought down	

Pipe Bridges	minor yielding of abutments	yielding of abutments; pipe moves out of alignment	yielding of abutment; support bolt sheared	loss of pipe support	
CIVIL STRUCTURES **Roads, Rail and Embankments**	minor distortion (rail only)	movement in a downhill direction; visible distortion or cracking	distortion to rails and cracking or scarp displacement of roads	buckling of rails or loss of support; impassable scarps in roads	loss of support
Earth Dams	minor distortion	measurable distortion (situation to be reviewed)	visible scarps/cracks (urgent action required to prevent failure)	large scarps or cracks resulting in leakage (Civil Defence alerted)	not applicable
Concrete Dams	not detectable	increased seepage (situation to be reviewed)	some spalling/ cracking; increase in seepage (urgent action required to prevent failure)	*(extensive cracking and leakage @ PGA $\geq$ 0.3g)*	not applicable
Steel Tanks (Industrial)	not detectable	signs of yielding at pipe joints	yielding at joints; distortion of base plates	cracking of joints, elephants foot yielding at tank base	tilting of tank
Concrete Tanks and Reservoirs	not detectable	increased weeping at joints; minor cracking and spalling	leakage of joints (pre-cast tanks); cracking and leakage	wide cracks formed; leakage; rupture of older tanks	substantial settlements
BRIDGES: **Modern**	minor cracking	minor cracking	spalling, abutment damage	lateral movement; loss of alignment	loss of span; loss of approach ramp; foundation damage; rotation
Old	minor spalling	spalling, loss of support	spalling; loss of span	damage; loss of span; collapse	collapse
SPECIFIC INFRASTRUCTURE **Auckland International Airport**	*Pipework, connections and fittings, buildings, services and civil structures as above.* Not detectable	some opening or closing of joints on concrete slabs	spalling at pavement joints; settlement of pavement (temporary closure)	*(buckling of concrete pavement @ PGA $\geq$ 0.3g; closure of airport)*	
Auckland Ports	*Pipework, connections and fittings, buildings, services and civil structures as above.* Minor movement of seawalls.	movement of seawalls	settlement at edge of reclamation	spreading and subsidence of reclamation; crane rails distorted	
Water Supply Dams, Waitakere and Hunua	*Pipework, connections and fittings, buildings, services and civil structures as above.* Not detectable	*see earth and concrete dams*	*see earth and concrete dams*	*see earth and concrete dams*	

Not applicable: Dams are unlikely to be constructed on liquefiable soils.

FINAL REPORT — STAGE 1

Auckland Engineering Lifelines Project

Appendix C

Workbook for volcanic hazard and vulnerability analysis

November 1999

AUCKLAND REGIONAL COUNCIL

AUCKLAND ENGINEERING LIFELINES PROJECT

Auckland Engineering Lifelines Project - Hazard Analysis Workbook Part 2 - Volcanoes

August 1998

Rev 1

Contents

Section ***Page***

4.0 Volcanic Eruption

4.1 Introduction

The following steps describe the methodology to produce a damage assessment and recovery profile on utilities due to uniform and scenario volcanic eruption conditions.

The Volcanic conditions and impact assessment criteria have been previously established and reported in the AELP Report No.1 and Johnston, 1998 within which additional detail is available.

The focus of the Uniform Hazard is to identify the vulnerability of each utility's service network and nodes to an event, which could occur anywhere within the Auckland Volcanic Field.

The focus of the Scenario Events is not intended to identify vulnerable strategic assets but rather to show the interdependence between individual utilities by way of using a particular eruption scenario as an example.

3 scenario events are considered. One local to the Auckland region centred in the waterfront of the CBD and two distant eruptions of Mt Taranaki (Egmont) and at the Okataina Volcanic Centre.

Whereas the local eruption will have relatively localised impact within the Auckland region, the distant events will create impacts (typically ashfalls and aerosols) which are uniformly widespread.

4.2 *Task 5: Damage Assessment of Nodes & Networks due to Uniform Volcanic Activity*

Refer Map IA

The Auckland Volcanic Field is identified as a zone (shown on Map IA as the red hatched area). The zone is based on the known extent of the Auckland Volcanic Field (approximately 50 vents). The next eruption could occur anywhere within this zone and cause significant disruption.

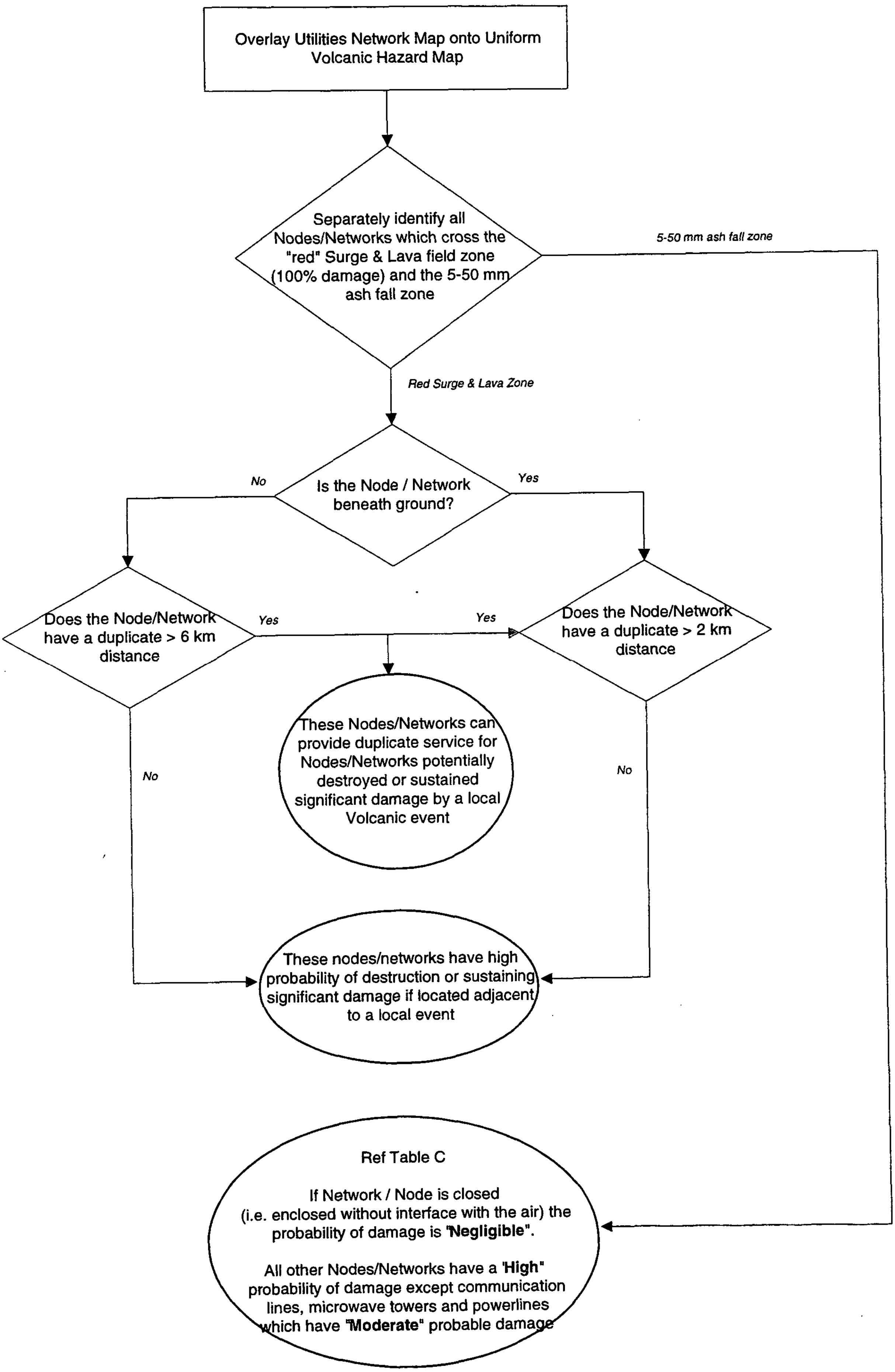
It is expected that above ground Nodes/Network sections within 3 km of the actual vent have the potential to be destroyed in a worst case scenario. Underground services (e.g. pipework) within 1 km of the actual vent would be destroyed or sustain significant damage. These distances are the maximum predicted, and dependent on the size of the eruption could be less than this.

To mitigate against this possibility, total redundancy of each node/network section within the hatched zone would be required, with the duplicate facility providing equivalent service and being at least 6km distant from its twin (2km in the case of underground pipework).

On the basis of this risk it is recommended that the individual utilities separately examine their own vulnerability through this zone.

Nodes and Networks outside of the "destruction" (red) zone and within the 5mm-50mm ash fall zone have a **high** probability of damage except powerlines, high voltage insulators, telecommunication lines and microwave towers which have **Moderate** probable damage, and closed pipework / reservoir systems which have **negligible** probable damage. (Refer Appendix 1 Table ref D for ash-induced damage type)

Task 5 Worksheet Flow Diagram
Damage Assessment of <u>Nodes/Networks</u> due to <u>Uniform Volcanic Hazard</u>



4.3 *Task 6(A): Damage Assessment of Nodes due to a local Scenario Volcanic Eruption*

The following brief description of the local volcanic scenario is taken from the AELP Stage one Report of July 1997 and Johnston, 1998. A copy of this more detailed outline of the scenario is included in Appendix 2 of this workbook. The 50 year exceedence probability for this scenario is 3%.

The local Volcanic scenario developed for use in the AELP is a waterfront eruption centred in the railyards which affects the CBD, port and residential areas. This particular scenario was selected because it encompasses both phreatomagmatic and magmatic eruption styles (descriptions from the Stage 1 report of these types of eruptions are included in Appendix 3).

Lava flows, ballistic rock impacts, pyroclastic surges and lightning strikes from ash clouds present a high risk to life, and destroy near vent structures, but the extent of these hazards is limited to within a few kilometres of the vent. Near-vent ground shaking accompanying volcanic earthquakes will also damage buildings. Apart from evacuation of people and removal of transportable assets there are few or no mitigation options available to counteract any of the near-vent hazards, which apply to all structures.

In this scenario the first instrumentally recorded activity has been set at 25 days prior to the start of eruptive activity with the 1st of 5 Scientific Alerts declared at day 9, 17 days prior to the eruption.

Volcanic activity continues for several months with sporadic eruptions occurring for more than a year after the 1st eruption.

Materials Required

- Flowchart 6A & B
- Task 6(A) Worksheet
- Table Ref C: Ash Induced Damage Matrix (refer appendix)
- Table Ref D: Ash Induced Damage Type Matrix (refer appendix)
- Table Ref E: Ash Induced Mitigation Matrix (refer appendix).
- Utility Maps
- Map Ref: IVA – Auckland Volcanic Field: Scenario Region A

Steps

To be carried out for each type of Node. Enter information on Worksheet 6 at each step.

Damage Assessment

1. Overlay the utilities map onto Map ref IVA. Identify and label each node that is located in the red hatched "destruction" zone.

2. Identify whether there is a duplicate node, which provides full redundancy of service outside of the hatched zone. Enter this information onto the worksheet.

3. Identify and label nodes that fall outside the "destruction" zone but within the 1mm-5mm and 5mm-100mm ashfall range. *Note: closed reservoirs have **Negligible** probability of damage.*

4. Break nodes down into sub-components and using Table ref C (Damage to Structures) identify the probability of damage **HIGH, MODERATE or LOW.** Enter this information onto the worksheet.

5. Using Table ref E (Mitigation Matrix), identify the mitigation measures that can be implemented before and during the event. Enter this information onto the worksheet. If other mitigation measures can be identified, include them on the worksheet.

6. Identify requirements for mitigation implementation before and during the event. i.e.) equipment, materials, other lifelines, spares. Enter this information onto the worksheet. Identify maintenance requirements due to expected corrosion in the longer term.

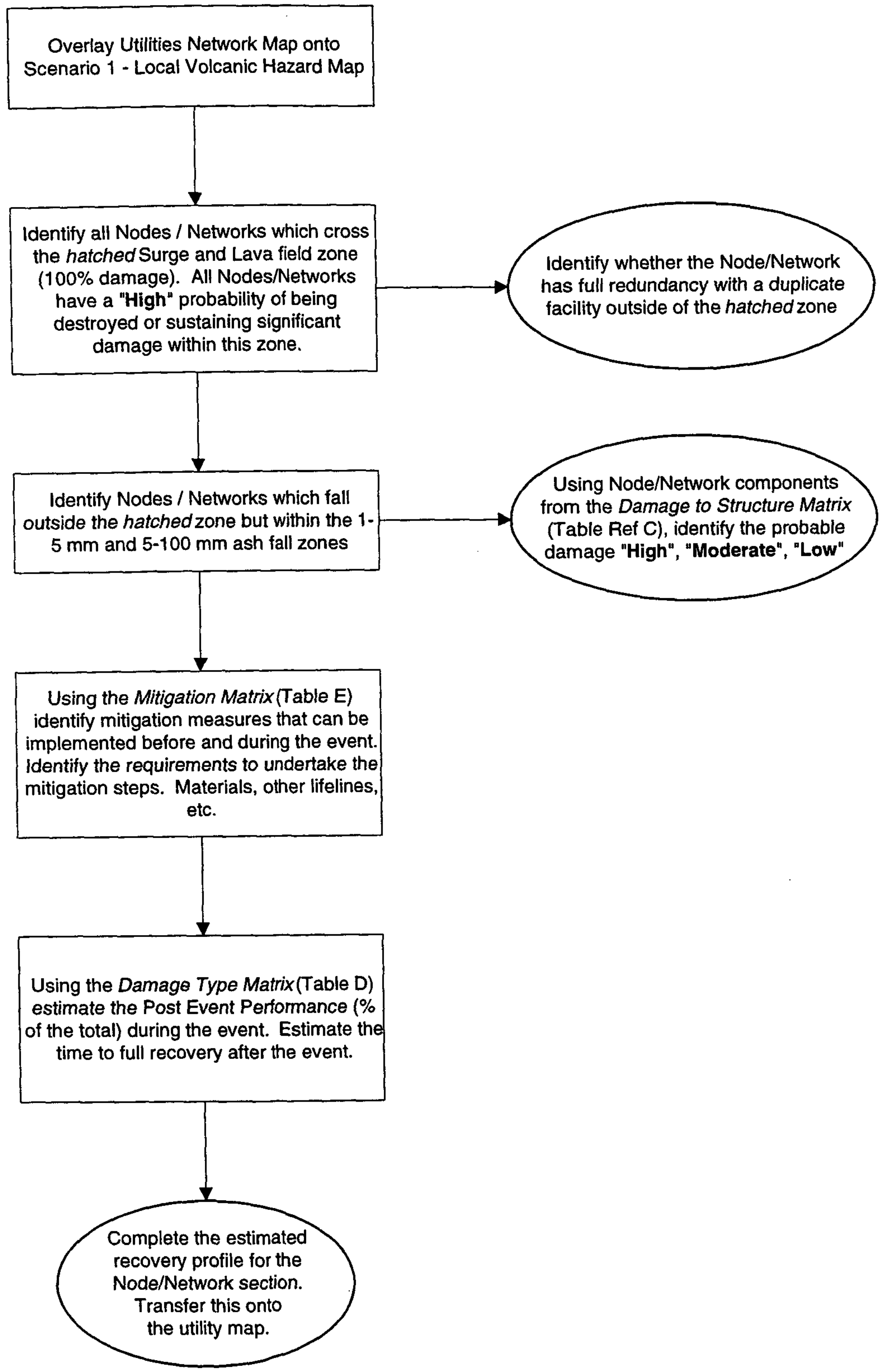
7. Using Table ref D (Damage type matrix) and considering the mitigation steps taken, assess the performance of the Node during the event as a % of full capacity. The assumption is made that subsequent eruptions are smaller and mitigation measures in place are adequate to deal with subsequent ash loads. Enter this information onto the worksheet.

8. Estimate the time required for full recovery after the event (in days) and enter this into the worksheet and complete the Estimated Recovery Profile at the top of the worksheet.

9. Add any general comments e.g.) other mitigation steps.

10. Transfer the Estimated Recovery Profile to the Utilities Map.

Task 6A and B Worksheet Flow Diagram
Damage Assessment of <u>Nodes/Networks</u> due to <u>Scenario 1 - Local Volcanic Hazard</u>



Task 6A Worksheet

DAMAGE AND RECOVERY ASSESSMENT OF **NODES** FROM **A LOCAL SCENARIO VOLCANIC HAZARD**

UTLITY ____________________

NODE TYPE & ID NO.	
% During	Days to full Recovery

Estimated Recovery Profile

IS THE NODE WITHIN THE TOTAL DESTUCTION ZONE? YES / NO (Circle one)

DOES THE NODE HAVE FULL REDUNANCY OUTSIDE THE DESTRUCTION ZONE? YES / NO (Circle one)

DAMAGE AND COMPONENT IMPACT ASSESSMENT OF NODES OUTSIDE OF TOTAL DESTRUCTION ZONE				
SUB-COMPONENTS				
DAMAGE ASSESSMENT *(HIGH, MODERATE, LOW, NEGLBLE) - USE TABLE 'C'*				

MITIGATION / RECOVERY MEASURES	
MITIGATION MEASURES BEFORE THE EVENT *- USE TABLE 'E'*	
EQUIPMENT TO UNDERTAKE MITIGATION MEASURES	
MATERIALS	
SPARES	
OTHER LIFELINES	
MITIGATION MEASURES DURING THE EVENT *- USE TABLE 'E'*	
EQUIPMENT TO MAINTAIN OPERATION	
MATERIALS	
SPARES	
OTHER LIFELINES	

PERFORMANCE ESTIMATE DURING THE EVENT (Consider mitigation measures taken before and during the event.)	
During (% of total operating capacity)	
Time for full recovery Post Event (days)	

COMMENTS

4.4 Task 6(B): Damage Assessment of Networks due to a local Scenario Volcanic Eruption

Materials Required

- Flowchart 6A & B
- Task 6(B) Worksheet
- Table Ref C: Ash Induced Damage to Structures Matrix
- Table Ref D: Ash Induced Damage Type Matrix
- Table Ref E: Ash Induced Mitigation Matrix
- Utility Maps
- Map Ref: IVA Auckland Volcanic Field: Scenario Region A

Steps

Damage Assessment

1. Overlay the utilities map onto Map ref IVA. Identify and label each network section that runs through the red hatched total destruction zone. Use labeling similar to that used on the earthquake analysis i.e.):

   e.g. **T/LD/VOS - 1**

   Telecom, Low Ductile pipe, Volcano Scenario, pipe location 1

2. Identify whether there is a duplicate network section, which provides full redundancy of service outside of the hatched zone. Enter this information onto the worksheet.

3. Identify network sections that fall outside the "destruction" zone but within the 5mm-100mm ashfall range. Use labeling similar to that noted above.

4. Using Table C identify the probability of damage **HIGH, MODERATE or LOW.** Enter this information onto the worksheet.

5. Using Table ref E (Mitigation Matrix) identify the mitigation measures that can be implemented before and during the event. Enter this information onto the worksheet. If other mitigation measures can be identified, include them on the worksheet.

6. Identify requirements for implementation before and during the event. i.e.) equipment, materials, other lifelines, spares. Enter this information onto the worksheet. Identify maintenance requirements due to corrosion in the longer term.

7. Using Table D (Damage type matrix) and considering the mitigation steps taken, assess the performance of the Network during the event as

a % of full capacity. The assumption is made that subsequent eruptions are smaller and mitigation measures in place are adequate to deal with subsequent ash loads. Enter this information onto the worksheet.

8. Estimate the time required for full recovery after the event (in days) and enter this into the worksheet and complete the Estimated Recovery Profile at the top of the worksheet.

9. Add any general comments e.g.) other mitigation steps.

10. Transfer the Estimated Recovery Profile to the Utilities Map

DAMAGE AND RECOVERY ASSESSMENT OF **NETWORKS** FROM A **LOCAL SCENARIO VOLCANIC HAZARD**

UTLITY ______________________

NETWORK TYPE & ID NO.	
% During	Days to full Recovery

Estimated Recovery Profile

IS THE NETWORK SECTION WITHIN THE TOTAL DESTUCTION ZONE? YES / NO (circle one)

DOES THE NETWORK SECTION HAVE FULL REDUNANCY OUTSIDE THE DESTRUCTION ZONE? YES / NO (circle one)

DAMAGE ASSESSMENT OF NETWORK SECTION OUTSIDE OF TOTAL DESTRUCTION ZONE	
DAMAGE ASSESSMENT *(HIGH, MODERATE, LOW, NEGLBLE)* *- USE TABLE 'C'*	

MITIGATION / RECOVERY MEASURES	
MITIGATION MEASURES BEFORE THE EVENT *- USE TABLE 'E'*	
EQUIPMENT TO UNDERTAKE MITIGATION MEASURES	
MATERIALS	
SPARES	
OTHER LIFELINES	
MITIGATION MEASURES DURING THE EVENT *- USE TABLE 'E'*	
EQUIPMENT TO MAINTAIN OPERATION	
MATERIALS	
SPARES	
OTHER LIFELINES	

PERFORMANCE ESTIMATE DURING THE EVENT (Consider mitigation measures taken before and during the event.)	
During (% of total operating capacity)	
Time for full recovery Post Event (days)	

COMMENTS

4.5 Tasks 6(C) & (D): Damage Assessment of Nodes & Networks due to distant Scenario Volcanic Eruptions

The following brief description of the distant volcanic scenarios is taken from the AELP Stage one Report of July 1997 and Johnston, 1998. A copy of this more detailed outline of the scenario is included in Appendix 2 of this workbook.

The distant Volcanic scenarios developed for use in the AELP consider eruptions from Mt Taranaki (Egmont) being a large andesitic cone volcano and the Okataina Volcanic Centre being a rhyolitic complex.

Activity at cone volcanoes are typically characterised by a succession of small to moderate eruptions occurring on average, every 50–300 years from approximately the same vent over a long period of time. Activity at caldera volcanoes, by contrast is characterised by far less frequent (on average every 1000-2000 years), moderate to exceptionally large sized eruptions. These eruptions are capable of generating large volumes of material that can be distributed over large areas many hundreds of kilometres downwind. The 50 year exceedance probability from Mt Taranaki is 65% for the 50 year return period event to 15% for the 300 year return period event. The 50 year exceedence probability from the Okataina Volcanic Centre is from 3 to 5 % for the 1000year and 2000 year return period events.

The impact of a distant eruption will be uniformly widespread across the Auckland region with the type of potential hazards being ash fall and aerosols.

Scenario 1 – Mt Taranaki (Egmont)

After several months of precursory activity an eruption occurs and southerly wind of 70km/hr disperse the volcanic ash and aerosols in a northerly direction towards Auckland. Ash begins to fall throughout the Auckland Region four hours later. By the following morning ash falls have ceased and a 1mm thick mantle of ash covers the region.

Materials Required

- Flowchart 6C & D
- Task 6(C) Worksheet
- Table Ref C: Ash Induced Damage to Structures Matrix
- Table Ref D: Ash Induced Damage Type Matrix
- Table Ref E: Ash Induced Mitigation Matrix
- Utility Maps

Steps

Damage / Recovery Assessment

1. Using Table C identify the probability of damage **HIGH, MODERATE or LOW** to Nodes and Networks. Enter the Node and Network elements that sustain **HIGH** or **MODERATE** damage onto the worksheet.

2. Using Table ref E (Mitigation Matrix) identify the mitigation measures that can be implemented before and during the event. Enter this information onto the worksheet. If other mitigation measures can be identified, include them on the worksheet.

3. Identify requirements for implementation before and during the event. i.e.) equipment, materials, other lifelines, spares. Enter this information onto the worksheet. Identify maintenance requirements due to corrosion in the longer term.

4. Using Table D (Damage type matrix) and considering the mitigation steps taken, assess the performance of the Network during the event and the cleanup period as a % of full capacity. Enter this information onto the worksheet.

5. Estimate the time required for full recovery after the event (in days) and enter this into the worksheet and complete the Estimated Recovery Profile at the top of the worksheet.

6. Add any general comments e.g.) other mitigation steps.

7. Transfer the Estimated Recovery Profile to the Utilities Map

Scenario 2 – Okataina Volcanic Centre)

After 12 months of precursory activity the climactic eruption begins with the development of a 40km high eruption column (based on Johnston & Nairn 1993). Southeasterly winds of 70km/hr begin to spread the ash and aerosol cloud in a northwest direction towards Auckland. Ash begins to fall throughout Auckland three hours later accumulating at a rate of 10mm/hr over the following ten hours. From the onset of the ashfall there is total darkness. By the following morning ash falls have ceased and the region is cover with a 100mm mantle of ash.

Materials Required

- Flowchart 6C & D
- Task 6(D) Worksheet
- Table Ref C: Ash Induced Damage to Structures Matrix
- Table Ref D: Ash Induced Damage Type Matrix
- Table Ref E: Ash Induced Mitigation Matrix
- Utility Maps

Steps

Damage / Recovery Assessment

1. Using Table C identify the probability of damage **HIGH, MODERATE or LOW** to Nodes and Networks. Enter the Node and Network elements that sustain **HIGH** or **MODERATE** damage onto the worksheet.

2. Using Table ref E (Mitigation Matrix) identify the mitigation measures that can be implemented before and during the event. Enter this

information onto the worksheet. If other mitigation measures can be identified, include them on the worksheet.

3. Identify requirements for implementation before and during the event. i.e.) equipment, materials, other lifelines, spares. Enter this information onto the worksheet. Identify maintenance requirements due to corrosion in the longer term.

4. Using Table D (Damage type matrix) and considering the mitigation steps taken, assess the performance of the Network during the event and the clean up period as a % of full capacity. Enter this information onto the worksheet.

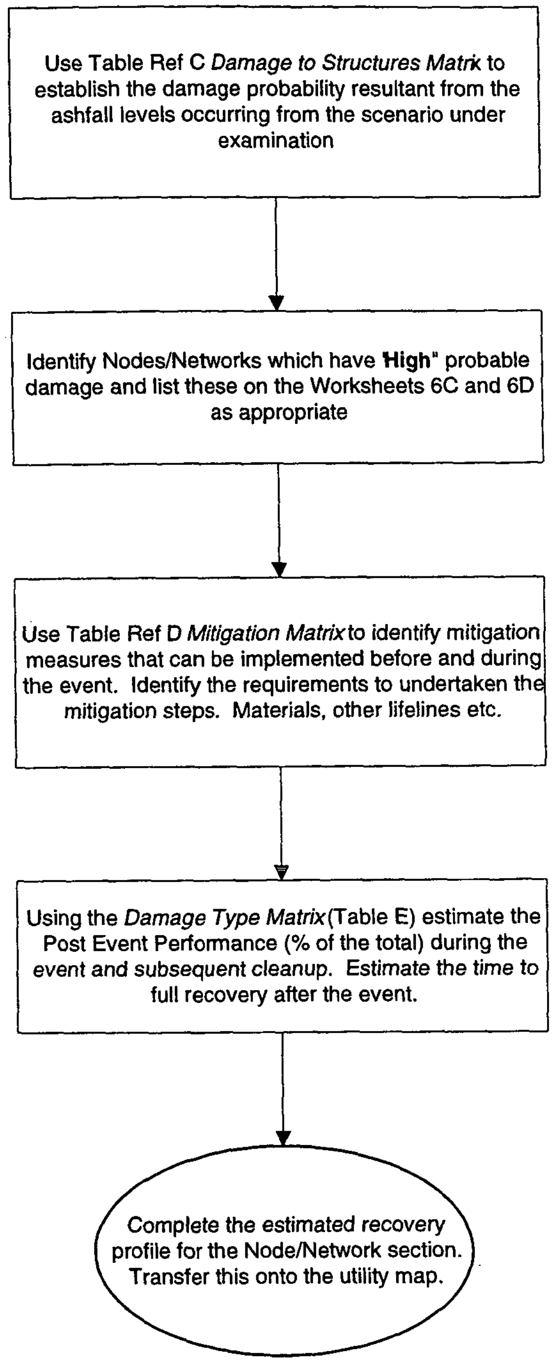
7. Estimate the time required for full recovery after the event (in days) and enter this into the worksheet and complete the Estimated Recovery Profile at the top of the worksheet.

8. Add any general comments e.g.) other mitigation steps.

7. Transfer the Estimated Recovery Profile to the Utilities Map

Task 6C and D Worksheet Flow Diagram

Damage Assessment of <u>Nodes/Networks</u> due to <u>Distant Volcanic Hazards - Scenario 1 and 2</u>



Task 6C Worksheet

DAMAGE AND RECOVERY ASSESSMENT OF **NODES & NETWORKS** FROM **SCENARIO 1 - DISTANT VOLCANIC HAZARD (Mt Taranaki) 1mm ashfall**

UTLITY ______________________

NODE TYPE & ID NO.

% During	Days to full Recovery

Estimated Recovery Profile

DAMAGE AND COMPONENT IMPACT ASSESSMENT OF NODES & NETWORKS DUE TO ASH FALL & AEROSOLS				
SUB-COMPONENTS				
DAMAGE ASSESSMENT *(HIGH, MODERATE, LOW, NEGLBLE) - USE TABLE 'C'*				

MITIGATION / RECOVERY MEASURES	
MITIGATION MEASURES BEFORE THE EVENT *- USE TABLE 'E'*	
EQUIPMENT TO UNDERTAKE MITIGATION MEASURES	
MATERIALS	
SPARES	
OTHER LIFELINES	
MITIGATION MEASURES DURING/AFTER THE EVENT *- USE TABLE 'E'*	
EQUIPMENT TO MAINTAIN OPERATION	
MATERIALS	
SPARES	
OTHER LIFELINES	

PERFORMANCE ESTIMATE DURING THE EVENT (Consider mitigation measures taken before and during the event.)	
During (% of total operating capacity)	
Time for full recovery Post Event (days)	

COMMENTS

DAMAGE AND RECOVERY ASSESSMENT OF **NODES & NETWORKS** FROM **SCENARIO 2 - DISTANT VOLCANIC HAZARD (Okataina) 100mm ashfall**

UTLITY ______________________________

NODE TYPE & ID NO.

% During	Days to full Recovery

Estimated Recovery Profile

DAMAGE AND COMPONENT IMPACT ASSESSMENT OF NODES & NETWORKS DUE TO ASH FALL & AEROSOLS				
SUB-COMPONENTS				
DAMAGE ASSESSMENT *(HIGH, MODERATE, LOW, NEGLBLE)* *- USE TABLE 'C'*				

MITIGATION / RECOVERY MEASURES	
MITIGATION MEASURES BEFORE THE EVENT *- USE TABLE 'E'*	
EQUIPMENT TO UNDERTAKE MITIGATION MEASURES	
MATERIALS	
SPARES	
OTHER LIFELINES	
MITIGATION MEASURES DURING/AFTER THE EVENT *- USE TABLE 'E'*	
EQUIPMENT TO MAINTAIN OPERATION	
MATERIALS	
SPARES	
OTHER LIFELINES	

PERFORMANCE ESTIMATE DURING THE EVENT (Consider mitigation measures taken before and during the event.)	
During (% of total operating capacity)	
Time for full recovery Post Event (days)	

COMMENTS

Appendix

TABLE REF C -VOLCANIC ASH-INDUCED DAMAGE TO STRUCTURES MATRIX				
STRUCTURE	Ash thickness < 1 mm	Ash thickness 1 - 5 mm	Ash thickness 5 - 100 mm	Ash thickness >100 mm
PIPEWORK				
open systems (i.e. stormwater)	low probability	high probability	high probability	high probability
closed systems	negligible	negligible	negligible	negligible
BUILDING STRUCTURES				
flat-roofs	low probability	moderate probability	high probability	high probability
pitched-roofs (>20°)	low probability	moderate probability	high probability	high probability
BUILDING SERVICES				
air-conditioning	low probability	moderate probability	high probability	high probability
gutters	low probability	moderate probability	high probability	high probability
ELECTRICITY SERVICES				
power lines	negligible	low probability	moderate probability	high probability
power line insulators				
-low voltage	negligible	moderate probability	high probability	high probability
- high voltage	negligible	low probability	moderate probability	high probability
substations	negligible	moderate probability	high probability	high probability
CIVIL STRUCTURES				
roads,	low probability	high probability	high probability	high probability
rail	negligible	moderate probability	high probability	high probability
WASTEWATER				
sewage pumps	low probability	high probability	high probability	high probability
sewage treatment plant	low probability	moderate probability	high probability	high probability
WATER SUPPLY SYSTEM				
river/ stream	low probability	high probability	high probability	high probability
uncovered reservoir	low probability	moderate probability	high probability	high probability
cover reservoir/ground water	negligible	negligible	negligible	negligible
roof-fed tank	low probability	high probability	high probability	high probability
TELECOMMUNICATIONS				
exchange equipment				
- external air-conditioning	low probability	high probability	high probability	high probability
- internal air-conditioning	negligible	low probability	low probability	low probability
lines	negligible	low probability	moderate probability	high probability
microwave towers	low probability	moderate probability	moderate probability	high probability
SPECIFIC INFRASTRUCTURE				
ports	low probability	high probability	high probability	high probability
airports				
- air transport	moderate probability	high probability	high probability	high probability

TABLE REF D -VOLCANIC ASH-INDUCED DAMAGE TYPE MATRIX

STRUCTURE	Ash thickness < 1 mm	Ash thickness 1 - 5 mm	Ash thickness 5 - 100 mm	Ash thickness >100 mm
PIPEWORK				
open systems	blockage depending on water (or sewage) turbidity	blockage depending on water (or sewage) turbidity	blockage depending on water (or sewage) turbidity	blockage depending on water (or sewage) turbidity
closed systems	n/a	n/a	n/a	n/a
BUILDING STRUCTURES				
flat roofs	corrosion damage to metal roofs, especially if freshly painted	corrosion damage to metal roofs, especially if freshly painted	corrosion damage to metal roofs, especially if freshly painted	corrosion damage to metal roofs; loading damage potential for flat roofed structures, moderate if dry (high over 300mm), high if wet
pitched roofs	corrosion damage to metal roofs, especially if freshly painted	corrosion damage to metal roofs, especially if freshly painted	corrosion damage to metal roofs, especially if freshly painted	corrosion damage to metal roofs, low to moderate risk of load damage depending of roof pitch
BUILDING SERVICES				
air-conditioning	abrasion damage to moving parts	abrasion damage to moving parts	blockage, abrasion damage to moving parts	blockage, abrasion damage to moving parts
gutters	blockage from reworked ash	blockage from reworked ash, load damage	blockage from reworked ash, load damage	blockage from reworked ash, load damage
ELECTRICITY SERVICES				
lines	n/a	loading, tree breakage onto lines	loading, tree breakage onto lines	loading, tree breakage onto lines
line insulators	n/a	short-circuiting (flashover), low potential if ash is dry, high if ash is wet	short-circuiting (flashover), low potential if ash is dry, high is ash is wet	short-circuiting (flashover), low potential if ash is dry, high is ash is wet
substations	n/a	short-circuiting (flashover), low potential if ash is dry, high is ash is wet, abrasion damage to moving parts	short-circuiting (flashover), low potential if ash is dry, high if ash is wet, abrasion damage to moving parts	short-circuiting (flashover), low potential if ash is dry, high if ash is wet, abrasion damage to moving parts
CIVIL STRUCTURES				
roads,	n/a	blockage, reduced traction and visibility	blockage, reduced traction, and visibility	blockage, reduced traction, and visibility
rail	n/a	reduced traction and visibility, short-circuiting of electric signals if ash is wet	reduced traction and visibility, short-circuiting of electric signals if ash is wet	blockage, reduced traction and visibility, short-circuiting of electric signals if ash is wet

TABLE REF D (contin.)

STRUCTURE	Ash thickness < 1 mm	Ash thickness 1 - 5 mm	Ash thickness 5 - 100 mm	Ash thickness >100 mm
WASTEWATER				
sewage pumps	abrasion damage to moving parts (depends on turbidity of sewage)	abrasion damage to moving parts (depends on turbidity of sewage)	abrasion damage to moving parts (depends on turbidity of sewage)	abrasion damage to moving parts (depends on turbidity of sewage)
sewage treatment plant	abrasion damage to moving parts (depends on turbidity of sewage)	abrasion damage to moving parts (depends on turbidity of sewage), damage to pond oxidation process	abrasion damage to moving parts (depends on turbidity of sewage), damage to pond oxidation process	abrasion damage to moving parts (depends on turbidity of sewage), damage to pond oxidation process
WATER SUPPLY SYSTEM				
river/ stream	pH and turbidity contamination	pH and turbidity contamination	pH and turbidity contamination	pH and turbidity contamination
uncovered reservoir	turbidity contamination	pH and turbidity contamination	pH and turbidity contamination	pH and turbidity contamination
cover reservoir/ground water	n/a	n/a	n/a	n/a
roof-fed tank	chemical , pH and turbidity contamination	chemical , pH and turbidity contamination	chemical , pH and turbidity contamination	chemical , pH and turbidity contamination
TELECOMMUNICATIONS				
exchange equipment - external air-conditioning	short-circuiting (flashover) of equipment, abrasion damage to moving parts	short-circuiting (flashover) of equipment, abrasion damage to moving parts	short-circuiting (flashover) of equipment, abrasion damage to moving parts	short-circuiting (flashover) of equipment, abrasion damage to moving parts
- internal air-conditioning	n/a	n/a	n/a	n/a
lines	n/a	loading, tree breakage onto lines	loading, tree breakage onto lines	loading, tree breakage onto lines
microwave towers	n/a	corrosion of metal surfaces	corrosion of metal surfaces	corrosion of metal surfaces, possible load damage
SPECIFIC INFRASTRUCTURE				
ports	potential corrosion and abrasion damage to port facilities	potential corrosion and abrasion damage to port facilities	potential corrosion and abrasion damage to port facilities	potential corrosion and abrasion damage to port facilities
airports - air transport	potential corrosion and abrasion damage to aircraft and airport (communications) installations	potential corrosion and abrasion damage to aircraft and airport (communications) installations	potential corrosion and abrasion damage to aircraft and airport (communications) installations	potential corrosion and abrasion damage to aircraft and airport (communications) installations, loading damage potential for flat roofed structures, moderate if dry (high over 300mm), high if wet

TABLE REF E- VOLCANIC ASH-INDUCED MITIGATION MATRIX

STRUCTURE	Before the event	During ash fall event	After the event
PIPEWORK open systems	increase awareness of potential problems, develop contingency plans	monitor turbidity levels, where possible limit ash entering systems	monitor turbity levels, where possible limit ash entering systems, remove ash from pipes.
closed systems	n/a		
BUILDING STRUCTURES	increase awareness of potential problems, develop contingency plans	close windows, doors and other openings	initiate ash remove procedure immediately, prioritize efforts
BUILDING SERVICES	increase awareness of potential problems, develop contingency plans		
air-conditioning	"	shut down and cover air-intakes, if still in use monitor filters and clean or replace when necessary	initiate ash remove procedures immediately, prioritize efforts
gutters	"	n/a	remove ash to prevent loading damage
ELECTRICITY SERVICES	increase awareness of potential problems, develop contingency plans		
line and substation insulators	"	monitor the situation carefully	initiate ash remove procedures immediately, prioritize efforts
lines	cut back tree branches from above lines	"	
CIVIL STRUCTURES roads, rail	increase awareness of potential problems, develop contingency plans	monitor the situation carefully, limit vechicle use	initiate ash remove procedures immediately, prioritize efforts, enhance vehicle maintainence
WASTEWATER	increase awareness of potential problems, develop contingency plans	warn public against disposing of ash in the stormwater system	warn public against disposing of ash in the stormwater system
sewage pumps	"	monitor turbidity levels in the sewage and shut down if levels are high	monitor turbidity levels in the sewage and shut down if levels are high
sewage treatment plant	"	"	"
WATER SUPPLY SYSTEM	increase awareness of potential problems, develop contingency plans	cover reservoir ventilators, disconnect roof fed supplies, monitor water quality	initiate water supply management procedures, monitor water quality
TELECOMMUNICATIONS	increase awareness of potential problems, develop contingency plans		
exchange equipment - external air-conditioning	fit internal air-conditioning units	seal exchanges where possible, shut down if required, monitor the situation carefully	initiate ash remove procedures immediately, prioritize efforts
microwave towers, other equipment	n/a	monitor the situation carefully	"
SPECIFIC INFRASTRUCTURE	increase awareness of potential problems, develop contingency plans		
ports	"	shut down vulnerability equipment, monitor the situation carefully	initiate ash remove procedures immediately, prioritize efforts
airports - air transport	"	close airspace, shut down airports	initiate ash remove procedures immediately, prioritize efforts

FINAL REPORT — STAGE 1

Auckland Engineering Lifelines Project

Appendix D

Workbook for cyclone/tsunami hazard and vulnerability analysis

November 1999

AUCKLAND REGIONAL COUNCIL

AUCKLAND ENGINEERING LIFELINES PROJECT

Auckland Regional Council
Auckland Engineering Lifelines Project
Hazard Analysis
Workbook Part 3 – Cyclone / Tsunami
Rev 2 – January 1999

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Part 3

Hazard Analysis Workbook

Part 3

5.0 *Cyclone / Tsunami Analysis*

5.1 Introduction

The hazards under examination in this workbook are different to the earthquake and volcanic hazards examined to date in that they would be expected to have more localised effects and of a lesser catastrophic nature.

Tropical cyclones typically produce characteristics of high winds, high rainfall intensities and storm surges to coastal areas.

Secondary effects include flooding and slope instability from heavy rainfall and inundation and coastal erosion from storm surges.

Tsunamis can have similar effects to cyclone storm surges such as inundation and erosion, however impacts can vary due to the different durations of the two events. Tsunami durations are usually measured in minutes to hours, storm surges have durations of hours to days.

Scenarios have been developed to assess impacts on the Auckland engineering lifelines for both tropical cyclone and tsunami events. As per the previous hazards, permutations of the scenarios and their effects are possible. The scenario effects described fall within an envelope range of which the most conservative have been used for impact assessment. It is recommended that should a lifeline facility be assessed as being significantly affected by the cyclone a specific site examination be done to confirm vulnerabilities using site specific information.

A 100-year return period cyclone (Cyclone "Grief") has been developed by the National Institute of Water and Atmospheric Research (NIWA) for the cyclone scenario. A storm surge event has been developed as part of the cyclone scenario.

Three tsunami events have been developed for use in the AELP, one teletsunami originating in Chile and two local events, one seismically and one volcanically generated. The most likely damaging tsunami is the teletsunami and this scenario only will be used for the impact assessment.

Indicative exceedence probabilities for the Cyclone, Storm surge and Tsunami scenarios developed for the AELP are shown in the following table.

HAZARD	PROBABILITY OF EXCEEDENCE		
	1 Year	50 years	100 years
Tropical Cyclone Scenario	1%	39%	63%
Storm Surge Scenario	1%	39%	63%
Tsunami (teletsunami scenario)	1.3%	49%	74%

Cyclone Scenario

5.2 *Description and Effects*

The AELP Stage 1 Hazard Report provides base parameters of a feasible major cyclone event with a 100-year return period (Cyclone Grief). This tropical cyclone has a similar strength to cyclone Bola but passes directly through the Auckland region in a southerly direction and has a duration of 4 days.

Extracts from the stage 1 hazard report are included in this methodology workbook to assist users to understand the scenario event and the effects on their lifelines.

The major cyclone effects are high winds, high intensity rainfall, flooding and storm surges.

(a) *Wind:*

Wind Scenario:

Wind gust speeds of up to 140 km/hr are predicted for metropolitan Auckland with gusts of up to 170 km/hr elsewhere in the region.

Wind Effects

The 140 km/hr gust speed corresponds approximately to the design wind speed of the Loadings Code. This indicates that wind damage to engineered structures is not likely, however buildings not complying with design codes will be vulnerable to a low degree. Widespread damage to structures, such as experienced in hurricane events on the US East and Gulf Coasts, is not expected. Damage will be largely non-structural and will include damage to roofs and cladding.

Lifelines will also be temporarily affected in other ways by the wind. Transport links may be temporarily inoperable and falling trees will damage power lines and buildings. It is likely that flights would be diverted from Auckland Airport at times during the storm. Typically large aircraft will prefer not to land if wind speed (sustained) across the runway is greater than 30 knots (55 km/hr) or 60 knots along the run-way (110 km/hr).

The Auckland Harbour Bridge will likely be closed by wind, if not by inundation of the northern approaches. Transit NZ have no trigger wind speed at which the bridge would be closed. Bridge closure was considered but not implemented for the 90-110 km/hr winds forecast for cyclone Drena. Gusts of 140 km/hr are predicted in the 100 year cyclone, and it is likely that the bridge would be closed to traffic.

The Port of Auckland will not be shut down as such, but container cranes will not operate in winds greater than 40 knots (75 km/hr). It is unlikely that any ships would leave port. The decision for a ship to leave port is up to the master and there has only been one recollected incidence of this. Extra storm lines would be used to secure ships. Empty containers are a hazard, but could be stacked in a pyramid shape to reduce windage effects.

Falling trees will threaten lifelines indirectly by falling on power lines and buildings, uprooting pipelines, and blocking bridges and culverts (possibly leading to washing away).

(b) <u>*Rainfall*</u>*:*

<u>Rainfall Scenario</u>:

The rainfall predicted for the cyclone event is shown below.

Table 1: Cyclone Rainfall:

Duration	***Rainfall (millimetres)***	
	Metropolitan Auckland	***Regional Range***
20 minutes*	40	-
1 hour	60	50-85
2 hours*	80	-
6 hours*	110	-
24 hours	125	80-170
4 days	320	230-415

* Derived from Regional values

<u>Rainfall Effects:</u>

The direct effects of rain (excluding flooding) will be limited to water damage to buildings with flat or wind-damaged roofs and visibility effects. Heavy rain squalls will make roads un-driveable due to a loss of visibility and collisions on the motorways are likely. Significant traffic blockage would occur in this situation depending on the time of day and location of collisions.

A lack of visibility due to heavy rain is unlikely to close the airport, although a squall may mean that a pilot aborts landing and goes around for another attempt. Generally larger aircraft have efficient windscreen wiping systems, and visibility has only to be good

enough for them to see the runway lights. Aircraft will be less affected than road vehicles.

(c) *Flooding:*

Flooding Scenario

The effects of flooding from the cyclone scenario will be site specific and will depend on such factors as:

- the size of catchment;
- the area variability of rainfall intensity;
- design capacity of drainage system;
- provision of overland flow paths;
- uprooting or breaking of vegetation which could block drainage system;
- land slips;
- the presence of slab on grade structures which have no freeboard in lower lying areas;
- planning controls and provision of engineering works within the catchment to alleviate flooding.

Within the last 30 years the worst storm to affect metropolitan Auckland was the July 1979 storm. The measured depths of rainfall over the Auckland area are listed in the following Table.

Compared to the rainfall depths associated with the cyclone scenario which have a return period of 100 years, the 1979 storm corresponded to between a 10 and 50 year event and its affects were worse on urbanised areas. It is also noted that the 1979 storm occurred during the middle of winter with wet antecedent conditions with a high potential for run-off. With a cyclonic event the antecedent conditions would be dry or normal and for storms occurring early in the cyclone, high infiltration could be expected. A feature of the cyclonic event is its persistence and after four days many of the catchment areas will be saturated and reporting direct run off. Another feature of the cyclonic event is the high wind conditions which will uproot and break off vegetation which will enter the drainage system and cause blockages. Similarly, slope failures and slumping of stream banks will entrain sediment into the drainage system to limit capacity over lower lying reaches.

Table 2 Scenario rainfall comparison with 1979 Storm

Duration	***Cyclone Scenario***	***1979 Storm***
30 minutes	45	24
60 minutes	60	40
2 hours	80	58
6 hours	110	100
12 hours	115	127
24 hours	125	148

Since the 1979 storm almost all the territorial local authorities (TLAs) have carried out engineering improvement works and have implemented planning controls to limit the degree of flooding. The flood standard for the Auckland region is the 100 year event and this is the level to which most TLAs are trying to avoid flood damage. A factor which would have increased the potential runoff, however, is the intensity of land development over metropolitan Auckland. Infilling of sections and office park type developments would have increased areas of imperviousness considerably above the 1979 levels. Overall it is considered that the effects of a cyclone scenario will be slightly worse than the effects reported for the 1979 storm. Damage could be amplified by a factor of 2.

<u>Flooding Effects:</u>

Using the 1979 storm as a basis, the effects / damage of the cyclone scenario is assessed as follows:

- Flooding could be expected in lower lying areas where the major drainage system has a relatively low capacity, or where development has limited the opportunity for overland flow. Examples of this would be in Blockhouse Bay, Avondale, St Heliers, several parts of East Coast Bays and the Wairau Valley in Takapuna.

- Open drains would potentially be blocked by upstream influx of vegetation or landslips. Examples of this could be the Takanini area in Manukau City, and Opanuku and Oratia streams in Waitakere City.

- Flooding of low lying areas relying solely on soakage or with poor drainage systems, and areas with low lying houses and no overland flowpaths. Examples include areas of Epsom, Mt Albert, Meola Creek and Newmarket.

- No major loss of vital services is envisaged although minor disruption to, for example, small pipelines and access to services could occur in some areas.

- Flooding of habitable houses will occur. In addition flooding of commercial and industrial buildings in low lying areas would occur, as would flooding of house basements and garages.

- Wide spread flooding of roads could be expected and could extend well over a day given the persistence of the cyclone scenario. In some areas this would severely restrict traffic, although there will generally be alternative routes available.

Rainfalls predicted in the 100-year cyclone scenario developed in the NIWA report are summarised below.

Table 3 Predicted rainfalls

100-year Cyclone Scenario				
Average 24 hour Rainfall (mm) [Range of 24 hour Rainfall]				***Accumulated Rainfall (mm)***
Day 1	Day 2	Day 3	Day 4	
74 [30-115]	124 [65-185]	93 [55-120]	24 [10-50]	325 [230-415]

The Auckland Regional Growth Forum has produced a flooding hazards map showing areas of land known to be or predicted to be inundated during a significant rainfall event. The information for areas predicted to be at risk from flooding hazard has been gained mainly from comprehensive flood management studies undertaken either to support applications for comprehensive stormwater discharge consents, or carry out in their own right.

The ARGF map does not give any indication as to the severity of the flooding hazard, that is the depth to which flood waters lie over the ground, or whether the area is subject to flood storage or flood flow conditions, only that the flooding hazard exists. The estimation of the extent of flood hazard areas within a catchment has been made under a number of assumptions about the hydraulic characteristics of the catchment such as the amount of impervious surfaces, infiltration capacities, and stream channel widths. Urbanisation of these catchments will significantly alter these catchment characteristics, consequently changing the nature and extent of the flooding hazard zones.

Not all catchments within the Auckland region have been studied, and therefore it should be recognised that there are areas likely to flood which are not presently shown on the flood hazards map.

Regional catchment management plans and draft plans have been produced which can be utilised to assess potential flood zones. Details of these plans are included in Appendix 3.

(d) Slope Failure:

Background
Conditions that Affect Instability:

Conditions that primarily influence the behaviour of slopes in response to rainfall include:

- Geology (interaction of the soil and rock mass, including defects), the degree of weathering of the rock mass, the depth of residual soil, and whether the slope has been subject to past instability or slope modification;

- Slope height and angle;

- Groundwater level and surface drainage.

Slope Failure Scenario

The rain-induced slope instability hazard maps designate areas of low, moderate, moderately high and high hazard, corresponding to expected percentages of all slopes within each hazard zone, likely to fail as a result of the proposed 100 year cyclone scenario.

Areas of Medium to High Population and Services Density (Region A):

Rain-induced Slope Instability Map 4A shows that for much of Region A, the 100-year cyclone scenario would result in only a low or moderate rain-induced slope instability hazard, that is, the rainfall is considered likely to cause in the order of 0.5% - 5% of slopes in the region to fail.

Some moderately high and high hazard zones are indicated, predominantly in higher rainfall areas where steeper slopes occur, such as in valley sides or coastal areas:

- In the south-eastern part of the map area (Waitemata Group slopes in the Whitford area and greywacke slopes in the Hunua area);

- In the western part of the map area (volcanic rich rocks in the Waitakere ranges); and

- In coastal slopes.

It is likely that the 100-year cyclone scenario proposed would generate failure of 5% to 20% of these slopes.

Areas of Lower Population and Services Density (Region B):

Rain-induced Slope Instability Map 4B indicates that the likelihood of rain-induced slope failure is higher in Region B than in Region A. In part, this is due to the very high rainfall (in excess of 400mm over 3 days) predicted for areas of steep slopes in the north-east, and relatively steep slopes in the west.

In particular, the 100-year cyclone scenario is likely to cause failure of 5% to 20% of slopes in the following key areas:

- North-east – Great Barrier and little Barrier Islands, the Wellsford to Cape Rodney area, and coastal areas of the Tawharanui Peninsula;
- North – Steeper slopes within the Rodney District, including the Kaipara South Peninsula area;
- West – The Waitakere Ranges;
- South-west – Elevated ground south of South Head; and
- South-east – Areas of Waiheke Island, Whitford east to Clevedon and north to Maraetai, and Ararimu east to the Hunua Ranges.

While most of these areas support few critical lifelines, it is noted that Auckland's water supply dams and pipelines occur within the moderately high rain-induced slope instability hazard class. In these areas specific design has been implemented to reduce this risk.

(e) <u>Storm Surge</u>:

Background

Storm surges are produced by the combination of two processes: adjustment of mean water level caused by changes in atmospheric pressure; and movement of water over the continental shelf due to stress exerted by winds. The response of mean sea level to pressure changes is relatively slow, taking about 2-12 hours. The response to wind stress is faster.

One of the hazards associated with storm surges is the flooding of low-lying coastal land. The other main hazards associated with storm surges are the increased penetration of storm waves, and increased shoreline erosion.

Due to the salinity of seawater, flooding by storm surges can be more damaging than a river flood. Historical storm surges in New Zealand have not produced extensive flooding, except for the Hauraki Plains. A storm surge in 1938 flooded about 35,000 ha, extending inland as far as Ngatea, 7.5 km from the coast. The total elevation including tide, storm surge and wave setup was 3.0 m above mean sea level. Following the 1938 storm surge, stop banks were constructed around the southern Firth of Thames coast.

The storms generating the surges often also produce heavy rainfall. A storm surge can impede the discharge of runoff from natural channels and drainage networks, thereby exacerbating the flood hazard inland. This effect is important in flat areas near the coast.

Another possible characteristic of storm surges is the formation of large wind-generated waves. These waves can approach more closely before breaking due to the increased water depth near to shore. Depending on the nature of the coast, it is possible for the wave to break inland of the mean sea level position.

Apart from the damage caused by the direct impact of the waves and the wetting of objects in the splash zone, the increased wave turbulence will erode loose sediments across a greater width of the beach than normal. Due to the increased water level at the shoreline, a near bed return flow is generated which transports any suspended sediment offshore. The strength of the return current is directly proportional to the increase in water elevation at the shore. Hence large storm surges will transport material offshore faster and further than small surges.

<u>Storm Surge Scenario</u>:

Dr W P de Lange has investigated tsunami and storm surge scenarios for the ARC (de Lange, 1997). During tropical cyclone *Grief*, the combination of low atmospheric pressure and wind stress on the ocean surface was assessed to produce a storm surge.

Hydrological data around coastal areas often refer to levels above "Chart Datum". This corresponds to a theoretical level below which sea level is not expected to fall. Lands and Survey levels refer to mean sea level (MSL) which has been taken as 1.8m above the Chart Datum in the Waitemata Harbour and 2.2 m above Chart Datum for the Manukau Harbour. Levels referred to in the subsequent text will be referred to MSL.

During the two days when the cyclone is closest to Auckland, the storm surge is estimated to be up to a maximum of 0.9m on the East Coast. This surge, in combination with tide, seasonal variations, and wave setup effects in exposed locations, is estimated to produce a maximum still water level of 3.0 m above Mean Sea Level.

The scenario of the 100 year storm coinciding with the highest astronomical tide (HAT) is acknowledge by de Lange (1997) as an extreme case with a return period in excess of 100 years.

However storm conditions do occur more frequently than when tropical cyclones cross Auckland and storm surges can occur more frequently than tropical cyclones

Storm Surge Effects and Wave Effects:

Damage will be experienced due to two effects; inundation by elevated sea levels and wave run-up.

Inundation: The peak of the storm surge will last for several hours and the maximum still water level will include storm surge and wave setup effects at high tide. Wave setup will only be significant on exposed shorelines, such as East Coast Bays and the Firth of Thames. These areas are assessed as having still water levels of 3.0 m above mean sea level.

Wave runup: Wave height in these exposed coastal areas has been assessed at up to 5 m giving a wave runup level up to 8m above mean sea level. The effects of the wave runup are influenced and dissipated by structures located in its path and for this reason a zone of 100m from the coast is considered suitable to assess damage from wave runup.

Where wave setup effects are lower, such as the Waitemata Harbour and Tamaki Estuary, the still water level is more likely to be about 2.5 m above MSL As the wave height is also expected to be lower in these areas the wave runup is more likely to be about 4.5 m above MSL. As with the exposed locations wave runup could be expected to affect areas within 100m of the coast dependent on dissipating structures.

The Manukau Harbour is assessed as having a still water level of 3.5 m above MSL with a wave runup of 6.0m above MSL. These levels have been calculated using storm surge data assessed for the scenario. A breakdown of these calculations is included in appendix 2.

Should the effects on lifelines facilities be assessed as being significant in these regions a specific site assessment is suggested.

On coastlines where the storm surge still water level does not inundate roads or berms, "green water" overtopping can be expected where the wave runup level extends beyond the crest of the seawall or berm. Elevations above the wave runup level will experience "white water" overtopping or heavy spray. For instance, green water over-topping is expected at the Port of Auckland and on the oxidation pond bunds at the Mangere Wastewater Treatment Plan, while heavy spray will affect Tamaki Drive.

In low-lying coastal regions, inundation will occur where the storm surge level is above the level of berms and roadways.

Storm surge and wave action effects experienced on low-elevation (inundated) shore areas can be described by the following categories.

1	Wave erosion zone
2	Zone of wave flooding
3	Still water flooding zone

The effects experienced in each zone are described as follows:

The wave erosion zone, the most hazardous location is the closest to the ocean and is the area that experiences erosion due to storm surge and waves.

The next zone, typically extending across the beach road and one or two blocks inland, is at risk from flooding with waves but not erosion. Conditions are dissipated from the wave erosion zone, but water levels and wave heights are still significant threats. Rather than eroding, this region is often buried by overwash deposits transported landward from the erosion zone. If the wave heights are high enough to deposit significant amounts of sand, the waves are usually large enough to cause significant damage to buildings.

Farther inland, most wave activity usually dissipates before the still water flooding zone is reached. Flooding by storm surge can extend inland over low topography and is similar to still water flooding typical of slow velocity riverine floods.

The wave erosion zone is likely to be limited to exposed shorelines and will affect shoreline roadways and properties with shore frontages. Lifeline services located on the coastline, such as pipelines, roads and rail will potentially be affected by erosion.

Inundation is likely to cause the closure of low-lying sections of motorways. Sections of the North-western motorway are at a level of 1 m above high water (2.2 m above MSL) and low points on the Northern Motorway just north of the harbour bridge are at 2.4 m above MSL. The storm surge scenario predicted for the Waitemata Harbour, with reduced wave setup effects, gives a still water level of 2.5 above MSL. During this event, these motorways would be inundated and are likely to be impassable.

Storm surge and storm waves on the Manukau Harbour would result in some perimeter flooding at Auckland International Airport and over-topping of oxidation pond bunds at the Mangere Wastewater Treatment Plant.

Task 7: Vulnerability and Damage Assessment of Nodes & Networks due to Tropical Cyclone "Grief" – Methodology:

Materials Required

- Task 7 Flow diagram
- Task 7 Worksheet
- Slope Instability Maps 4A & 4B
- Flooding Hazard Map
- Effects Matrix (refer Appendix 1)
- Utility Maps

Steps

Assess each element of the network for the following cyclone effects.

Damage Assessment

(a) Wind

- Services under ground will not be affected by wind or rainfall so proceed to *Flooding*.

- Nodes/Network sections with associated structures predating 1976, or those not complying with the wind provisions of the loadings code (NZS 4203) should be checked for structural integrity. Identify structures non-complying.

- Identify non structural elements such as light weight roofing and cladding which may be damaged.

- Identify services affected by wind, eg. Roads, bridges, masts, cranes, ports, airports and describe expected implications.

(b) Rainfall

- Identify structures affected by rainfall eg. with cladding damage and sensitive equipment or inadequate roofing/guttering etc.

- Identify service affected by rainfall intensity eg. Roads and describe expected implications.

(c) Flooding

- Note underground services would only be affected where entering or leaving underground locations or by ingress of water into underground services. Overhead services would not be expected to be affected. Support structures may be affected as may access.

- Using the flooding hazard map and previous flooding experience identify Nodes/Network sections in flood hazard zones.

- Describe service implications associated with flooding to the network element.

(d) Slope Failure

- Using maps 4A and 4B is the node/network section in a moderately high or high hazard zone? If so has it been designed for slope instability? If yes proceed to Storm surge effect.

(e) Storm Surge

- *Inundation:* Identify nodes/network sections in exposed coastal elevations at elevations lower than 3.0m above mean sea level on the East Coast Bays, 2.5m in the Waitemata Harbour or 3.5m in the Manukau Harbour. How is the element and service affected by inundation.

- *Wave runup: :* Identify nodes/network sections in exposed coastal elevations within 100m of the coast and at elevations lower than 8.0m above mean sea level on the East Coast Bays, 4.5m in the Waitemata Harbour or 6.0m in the Manukau Harbour. How is the element and service affected by wave runup.

- Identify nodes/network sections located in flood hazard zones near the coast. Describe service implications associated with the storm surge?

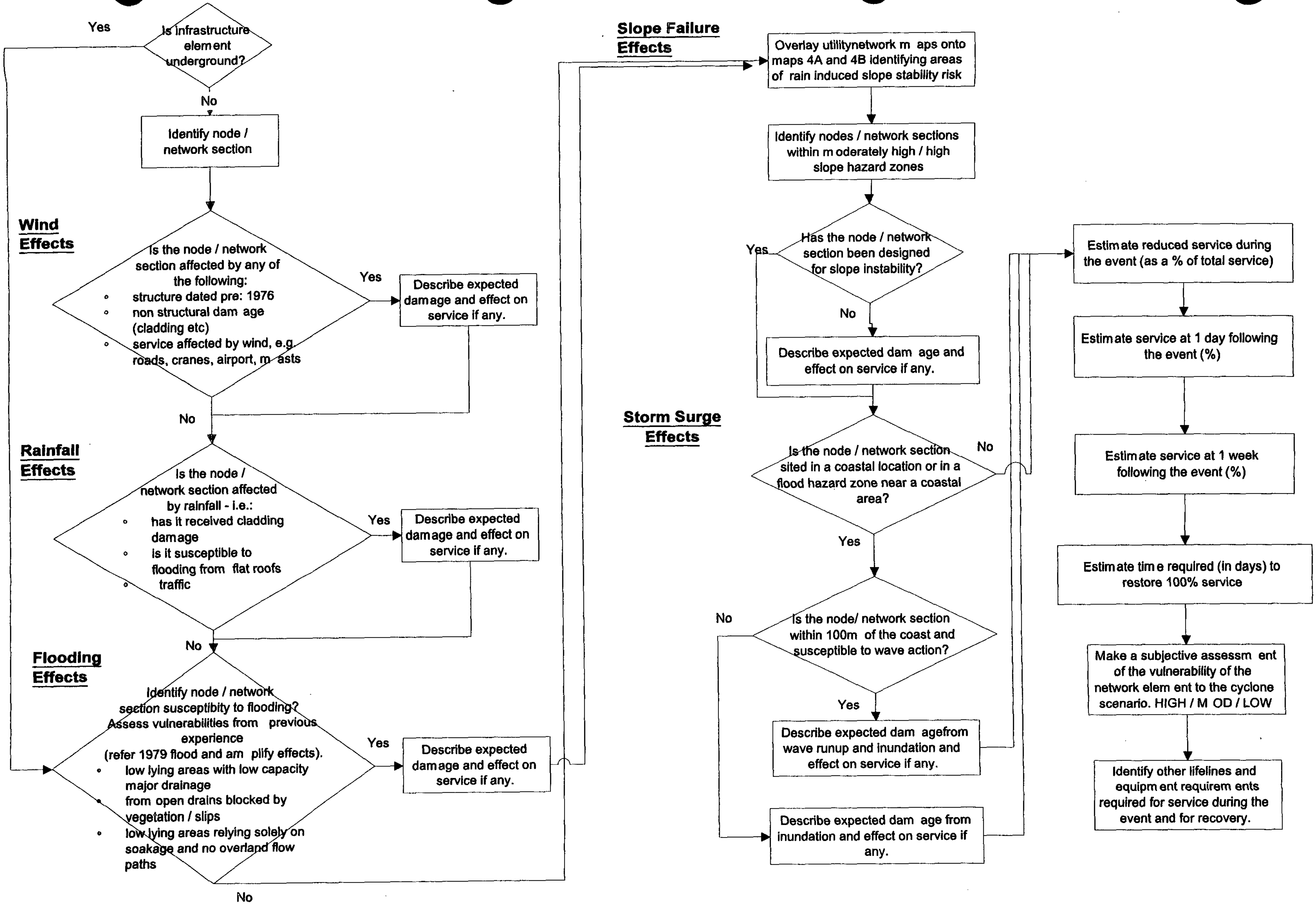
<u>Recovery Profile</u>

- Considering the above cyclone effects estimate the service available during the event; immediately following the event and 1 week after the event. Estimate the time to full recovery (in days).

- Give the Node/Network element under examination an overall subjective damage risk rating of **HIGH, MODERATE** or **LOW**.

- Identify additional lifelines required for operation and recovery.

Task 7 - [illegible]LONE FLOW DIAGRAM



Task 7 Worksheet

Overall Damage Risk Assessment:

DAMAGE AND RECOVERY ASSESSMENT OF NODES / NETWORK SECTIONS FROM A **SCENARIO CYCLONE "GRIEF"**

Utility: ____________________

Node / Network Section ID: ____________________

Estimated Recovery Profile

% during	% at 1 day	% at 1 week	days to full recovery

DAMAGE ASSESSMENT

Wind Effects

If the Node / Network section is beneath ground proceed to Flooding Effects.

circle appropiate : Structural damage, (pre 1976 and loadings code) | Non structural damage , (cladding etc.) | Service affected, (roads, cranes, masts) | N/A

Description of impact - refer Effects Matrix

....

....

Rainfall Effects

circle appropiate: Cladding damage sustained, | Flooding potential from inadequate roofing, | Service affected (roads) | N/A

Description of impact - refer Effects Matrix

....

....

Flooding Effects

circle appropiate: Low lying area susceptible to flooding, | Previous flooding problems, | Service affected (roads,) | N/A

Description of impact - refer Effects Matrix

....

....

Slope failure Effects *use slope instability maps*

circle appropiate: Moderate hazard zone, | High hazard zone, | N/A

If Mod or High zone is it designed for slope instability? **Y / N**

If Yes proceed to Storm Surge Effects

Description of impact - refer Effects Matrix

....

....

Storm Surge Effects

circle appropiate: Coastal area, | Sited in a flood hazard zone near coast, | Inundation, | Wave affected, | Service affected, | N/A

Description of impact - refer Effects Matrix

....

....

Service Performance Estimate

Estimate service availability for each network element for the above cyclone effects during and after the event assessing as a % of total service.

Estimated Recovery Profile

% during	% at 1 day	% at 1 week	days to full recovery

Overall Damage Risk Assessment: **HIGH** **MODERATE** **LOW**

→ more detailed site assessment recommended

Recovery Requirements

Materials/Spares: ....

Equipment: ....

Other Lifelines: ....

Tsunami Scenario

5.2 Description and Effects

Tsunamis are long period gravity waves generated by a sudden displacement of the water surface.

The cause of the sudden displacement is normally a submarine earthquake, but may also include volcanic eruptions, submarine landslides, diapiric extrusions and bolide impacts.

All of these source mechanisms produce an impulse that drives the tsunami.

Tsunamis are long period shallow water waves with typical periods ranging from 15 to 60 minutes.

As a tsunami enters shallow water it undergoes shoaling transformations. These can alter its characteristics considerably. For a region such as the inner Hauraki Gulf, the tsunami will tend to develop a narrow peaked crest and a broad shallow trough. This appears at the shore as a short rapid rise in water level followed by a long withdrawal. The tsunami is also refracted and reflected by the bathymetry causing zones of convergence and divergence.

Hence the behaviour of any given tsunami can vary considerably along the coast. The tsunami effects can also differ depending on the tsunami approach direction. This makes it difficult to define tsunami risk for a region.

As there is limited information available on the extent of inundation and tsunami effects along tributary lengths the analysis in this methodology is restricted to coastal regions.

Terminology

Tsunami Runup - this may be treated as either the vertical runup height, or the horizontal inland inundation distance. The horizontal inundation distance is a function of the vertical runup and the local topography therefore the vertical runup is more useful. For the purposes of this analysis we shall refer to vertical runup height. Tsunamis crossing a wide continental shelf decompose into a series of solitary waves. On reaching the shore the solitary[1] tsunami waves can behave as either a non-breaking or a breaking wave. Historically all tsunamis affecting the Auckland coast have behaved as a non-breaking wave. A non-breaking tsunami wave reaches a maximum vertical runup on natural beaches approximately equal to the maximum wave amplitude when the wave first reaches dry land. For this analysis we have assumed the runup is equal to the wave amplitude.

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[1]*Solitary wave = a non-periodic wave consisting of a single crest.*

Tsunami Bores – the most destructive tsunami waves are those that form a bore[2] due to the the transfer of momentum to the still water trapped in front of the bore. The momentum transfer results in high horizontal and vertical turbulence, and increases the wave height. The vertical turbulence is capable of entraining large objects. Within estuaries and the lower reaches of rivers and streams opposing currents may result in a greater steepness of the wave front and enhance bore formation.

Floating Debris – most fatalities associated with recent tsunamis were due to the impact of floating debris. Tsunamis may also spread liquid contaminants such as oil. The dispersal of contaminants by tsunami waves is of particular concern in port areas, especially regarding the availability of combustible contaminants such as fuel oils, diesel and lighter hydocarbons and the variety of chemical compounds present, that may cause reactions producing hazardous compounds.

Return flow and Currents – current velocities generated by receding tsunami waves can be high due to extreme variations in water level. Most drownings associated with tsunamis have been of persons swept into deep water by the return flow. The return flow may also carry floating debris with the same potential for injury and damage as an advancing tsunami bore. The high current velocities make tsunamis very erosive. The velocities are difficult to predict since erosion changes channel characteristics. In confined bays and regions with islands, the interation of refracted and reflected waves can produce very complex patterns of currents and waves.

Forced Oscilliations – tsunamis may force oscillations within semi-enclosed basins such as estuaries, harbours and the lower reaches of rivers. The forced oscillations may amplify the tsunami and can produce strong reversing currents and eddies within the basins.

Teletsunami - A teletsunami is a tsunami that travels more than 1000km from source before reaching the region of interest. The teletsunami scenario is based on historical tsunami impacts around Auckland from previous tsunami events.

---

[2]*Bore = solitary wave in a confined channel or advancing over dry land. It has a steep front face.*

Teletsunami Scenario

Tsunami Source region	Northern Chile
Earthquake Magnitude	$M_w = 9$
Tsunami Magnitude	4

Chronology

00.00hours An earthquake occurs near Arica in Northern Chile

00.30 hours Pacific Tsunami Warning Centre issues a Tsunami Alert based on Mw 9 earthquake.

00:45 hours Pacific Tsunami Waming Centre issues a Tsunami Waming following confirmation of a tsunami from Antafagasta, Chile and La Punta, Peru. National Civil Defence issues a warning with an estimated arrival time for Auckland of 17:30 hours. High tide is expected at 18:10 hours and to be 1.4 above MSL.

14:30 hours First tsunami wave reaches the east coast of tbe Chatham Islands. The estimated wave beight is 1.5 m.

15:10 hours Second tsunami wave reaches tbe east coast of the Chatham Islands. The estimated wave height is 2.0 m.

15: 50 hours First tsunami wave reaches East Cape. The height is difficult to assess due to large swells but thought to be at least 1 m. Third tsunami wave reaches the east coast of the Chatham Islands. The estimated wave height is 1.0 m.

16:00-17:00 Tsunami waves are reported from many eastern coastal regions between North Cape and Stewart Island. Wave heights vary from 0.5 m to 1.5 m.

16:45 hours Tsunami reported from Port Jackson, Coromandel Peninsula. Wave height is ~1.5 m

17:25 hours First tsunami wave reported from Auckland. The water level rises rapidly to above high water springs over a 10-15 minute period and remains at that level for several minutes before receding. Wave heights along the open coast of the metropolitan area are very similar (~0.75 m). The maximum wave heights occur in Omaha Bay (>2 m). Port Fitzroy on Great Barrier Island experiences a strong withdrawal of water. A number of tsunami effects are reported over the next 15 minutes:

- Tsunami bores are reported from several locations. The major ones occur on the Mahurangi River (Warkworth) and the Tamaki Estuary. Both are > 1 m in height. The Mahurangi River bore reaches the bridge on State Highway 1.

- Strong currents are generated in regions with restricted channels, including the entrances to the estuaries and river mouths (Whangateau Harbour, Puhoi Rivers, Waiwera River, Orewa River, Weiti River), marina entrances, and channels between islands in the Hauraki Gulf.

- Strong eddies and whirlpools form in harbour basins, marinas and several channels between islands. Moorings fail allowing small vessels and boats to drift with the currents.

- The currents associated with the withdrawal of water following the crest cause considerable scour around structures in estuaries and bridge foundations.

17:45 hours The trough of the tsunami arrives exposing estuary flats and numerous stranded fish.

18:05 hours The second and largest tsunami wave arrives.

- Areas exposed by the trough between the waves are rapidly flooded. In the Rangitoto channel the incoming wave is steepened by the receding waters of the first wave. Very strong reversing currents (>5 knots) and eddies form.

- Wave heights along the open coasts of the metropolitan areas are similar (~1.25m). However due to the interation between the first and second waves, higher wave heights are experienced in the upper Waitemata Harbour and the Firth of Thames (1.5-2.0m).

- Tsunami bores are reported on the Henderson and Lucas Creeks within the Waitemata Harbour. Further bores occur on theMahurangi River and Tamaki Estuary (~1.5m), and on the Waihou, Piako and Kauaeranga Rivers entering the Firth of Thames (1-2m), and the Wairoa and Weiti Rivers in the inner Hauraki Gulf (~1m).

- The maximum wave heights are experienced in Omaha Bay (>2.5 m). Large waves are also experienced on Pakiri Beach, the northern shores of Rangitoto, Motutapu and Waiheke Islands (Onetangi Bay), and between Howick and Maraetai (~2.5m).

- Large waves and very disturbed water occurs between Little Barrier and Great Barrier Islands (>5m) as the incoming second wave reflects around Great Barrier and collides with the reflected first wave.

18:25 hours Waters recede strongly with levels dropping by 1-2 m below expected tide level over most of the inner Hauraki Gulf. Some areas (Big Omaha Bay, Firth of Thames and Maraetai) experience 2-3 m drops. Strong flows occur in all tidal channels as a result.

A further 5 waves occur at 40 minute intervals. However the wave heights diminish rapidly and, combined with a falling tide, the shoreline impacts are minor. The waves do generate complex patterns of reversing currents and eddies that cause some problems for navigation. While this occurs on the east coast, the tsunami waves reach the west coast. The waves are considerably smaller. There is some evidence to suggest that the largest waves will be the result of reflection from the Great Barrier Reef. The maximum west coast waves are half the size of those observed in Auckland.

Task 8: Vulnerability and Damage Assessment of Nodes and Networks due to Tsunami scenarios.

Materials Required

- Effects Matrix
- Utility Maps

Steps

Assess each element of the network for the following tsunami effects.

Damage Assessment

Identify Nodes or network sections which are in coastal regions or in the immediate vicinity of the mouth of a tributary.

Those Nodes or network sections outside these areas will not be affected by the tsunami.

Is the element or its founding structure located at a level lower than the maximum height above MSL given in the table below?

If not the element should not be affected by the tsunami.

Describe the service implications associated with inundation and/or scour or erosion to the element. The damage effects matrix in Appendix 1 can be used for assistance.

Recovery Profile

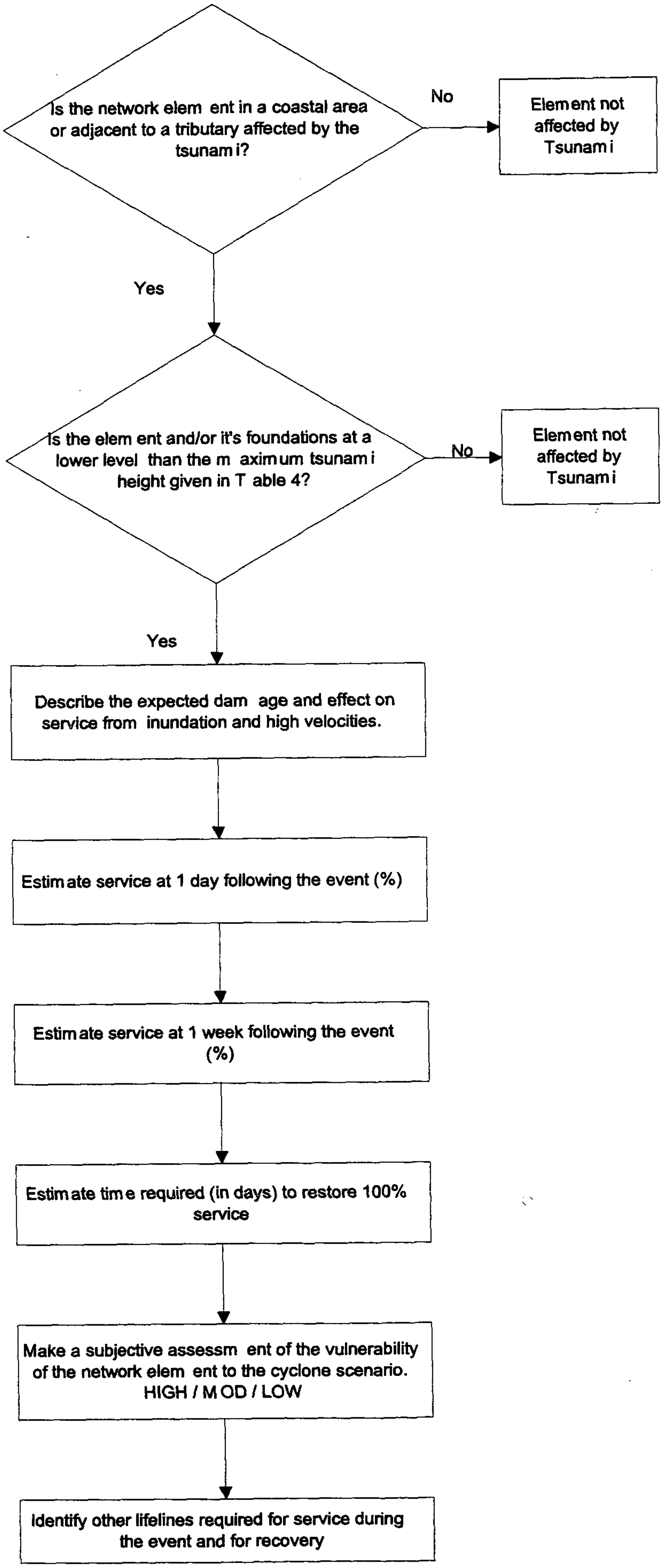
- Considering the above effects estimate the service available immediately following the event and 1 week after the event. Estimate the time to full recovery (in days).
- Give the Node/Network element under examination an overall subjective risk rating of **HIGH, MODERATE** or **LOW** to Tsunami effects.
- Identify additional lifelines required for operation and recovery.

Table 4 Maximum tsunami heights and expected current velocities.

Location	***Wave Runup Height***	***Max Tsunami ht above MSL***	***Velocities***
Confined rivers	2.0	3.4	5 – 10 knots
Open east coast*	1.25	2.65	4 times tidal flow
Waitemata Harbour	2.0	3.6	4 times tidal flow
West Coast	0.5	2.5	2 times tidal flow

*to Metropolitan areas

Task 8 - TSUNAMI FLOW DIAGRAM



DAMAGE AND RECOVERY ASSESSMENT OF NODES / NETWORK SECTIONS FROM A **SCENARIO TELETSUNAMI**

Overall Damage Risk Assessment: ....

Utility:.....................................

Node / Network Section ID:.............................

estimated recovery profile

% at 1 day	% at 1 week	days to full recovery

DAMAGE ASSESSMENT

Consider Nodes /Network Sections in coastal locations or tributaries affected by the tsunami.
Note: underground elements may be affected by scour and erosion.

Tsunami Effects

Is the element at a lower level than the maximum tsunami height given in Table 4? **Yes / No**

Does it have any supports foundation below this level? **Yes / No**

If "No" the element is not affected by the Tsunami.

Description of Impactdue to inundation and velocities (Effects matrix may be used for reference)

....

....

....

....

Service Performance Estimate

Estimate service availability for each network element for the above cyclone effects after the event assessing as a % of total service.

Estimated Recovery Profile

% at day 1	% at week 1	days to full recovery

Overall Damage Risk Assessment:

HIGH **MODERATE** **LOW**

→ more detailed site assessment recommended

Recovery Requirements

Materials/Spares: ....

Equipment: ....

Other Lifelines: ....

Appendix 1

Effects Matrix

Table 7: Cyclone - induced damage to structures matrix

Source: Updated from the Auckland Engineering Lifelines Project Stage 1 - Part 1: Hazard Information, July 1997

		Wind	Rain	Flooding	Slope Failure	Surge & Waves
Pipes	**pressure**	Negligible effect	Negligible effect	Scour of backfill	Small (non-engineered) lines will be vulnerable	Pipelines in wave erosion zone and outfalls
	non-pressure	Negligible effect	Negligible effect	Scour of backfill	Small (non-engineered) lines will be vulnerable	Pipelines in wave erosion zone and outfalls
Building Structures	**residential**	Roof and cladding damage to non-complying houses	Flooding of damaged and flat roofs	Evacuation of limited low-lying areas	Slight vulnerability in recently established hilly areas	Inundation and wave erosion in low-lying coastal areas
	non-residential	Non-structural damage only	Flooding of damaged and flat roofs	Evacuation of limited low-lying areas	Low vulnerability	Generally lower risk
	bridges	No structural damage, but may become unserviceable	Negligible effect	Low risk due to small catchments or estuarine location	Similar risk to adjacent bank erosion	Inundation at some motorway locations
Services	**lampposts**	Decayed hardwood poles will be vulnerable	Negligible effect	Negligible effect	Low risk	Negligible effect
	cranes	Will be shut-down	Negligible effect	Negligible effect	Negligible effect	Negligible effect
	power lines	Shorting, falling debris	Negligible effect	Negligible effect	Low risk	Negligible effect
	pipe bridges	Negligible effect	Negligible effect	Generally comprise steel pipe	Low risk	Pipes strapped to wharves
Civil Structures	**roads**	No structural damage, but may become unserviceable	un-driveable in downpours, potential for collisions	Flooding, scour where culverts overtop, slips	Motorways engineered for this risk, other roads susceptible	Low-lying motorways closed, scour on exposed coasts
	rail	No structural damage, but may become unserviceable	Negligible effect	Risk to rail bridges from debris in flooded rivers	Cuttings susceptible	Some potential for embankment scour and inundation
	rivers/floodways	Negligible effect	Negligible effect	Scour, bank slumping and reduced capacity	Slumping of banks - not a lifeline hazard	Backwater effects will accentuate flooding
	embankments	Small (farm) dams only affected by wave chop	Negligible effect	Older stormwater detention dams may overtop	Dams are usually engineered for this risk	Foreshore erosion
Specific Infrastructure	**masts**	Engineered masts (eg: Telecom) will not be damaged, but may be unserviceable	Negligible effect	Negligible effect	Low risk	Negligible effect
	airports	Some flights re-directed	Visibility effects will not disrupt	AIAL runway will not be flooded, some loss of friction	Negligible effect	Low risk
	ports	Container cranes shut down	Negligible effect	Negligible effect	Negligible effect	Flooding by wave overtopping, containers moved around
	wastewater treatment plants	Negligible effect	Negligible effect	High inflows would be bypassed	Negligible effect	Inundation of Mangere ponds, overflows
	water treatment plants	Negligible effect	Negligible effect	Negligible effect	Negligible effect	Negligible effect
	electrical	Negligible effect	Negligible effect	Low-lying infrastructure flooded	Low risk	Low risk
Other	**Large trees**	Moderate impact	Negligible effect	Negligible effect	Not a lifeline hazard	Loss of trees which protect *coastline*

Appendix 2

Storm Surge water level calculations

Storm Surge still water level and wave runup calculation (m)

LOCATION	Hauraki Gulf	Waitemata Harbour	Manukau Harbour
	Metres above mean sea level		
High Tide (HAT)	1.9	1.9	2.7
Seasonal Sea Level Variation	0.2	0.2	0.2
Barometric Surge	0.44	0.2	0.3
Wind Setup	0.46	0.2	0.3
Total Still Water level	3.0	2.5	3.5
Wave Height	5.0	2.0	2.5
Total Wave Runup	8.0	4.5	6.0