1 Introduction

1.1 BACKGROUND TO THE WELA PROJECT

The Wairarapa Engineering Lifelines Association (WELA) was formed at a public meeting held in Masterton on 21 June 1996. At that meeting were representatives from the three local authorities in the Wairarapa area, Wairarapa Electricity (now Powerco), Transit New Zealand, the New Zealand Fire Service, Masterton Hospital, the Wairarapa Ambulance Service, the Wairarapa Automobile Association, the Wellington Earthquake Lifelines Group, consulting engineers, and the Wellington Regional Council (WRC). The meeting discussed the risks to engineering lifelines from natural hazards, the likely impact on the local community, what was being achieved by study groups elsewhere in New Zealand, and lessons gained from recent earthquakes at Northridge and Kobe.

It was agreed that WELA would:

- Study the Wairarapa's engineering lifelines in order to assess levels of risk to identified natural hazards and to suggest measures which could reduce these risks; and
- Support existing lifeline providers by updating and refining information on hazards and mitigation measures, and by participating in research on engineering lifelines.

WELA's activities are voluntary and their costs are borne by the organisation involved – apart from contracts for specific research studies. WRC's Wairarapa office provides administrative, secretarial, and GIS support. Participants in the WELA project include the three district councils, the WRC, and providers of engineering lifelines: Transit, Tranzrail, Transpower, Powerco, Telecom, Telstra-Clear and Vodaphone.

From the outset of the project it was known that information about natural hazards in the Wairarapa area was limited. It consisted of a 1982 climate study, and studies carried out for WRC on liquefaction and earthquake risk assessment, centred on the townships on the Wairarapa valley floor. In addition, the GIS services were only just being developed. Rather than delaying the project until more definitive hazard information was available, it was decided to undertake the WELA work in parallel with other studies.

1.2 SUMMARY OF THE WAIRARAPA AREA

The area covered by the WELA project extends north from Palliser Bay to include the South Wairarapa, Carterton and Masterton districts (**Figure 1.1**). The population of these three districts was 38,208 in the 2001 census. This was made up of 22,617 from the Masterton district, 6,849 from the Carterton district and 8,742 from the South Wairarapa district. Most of this population resides within the five main Wairarapa towns of Masterton, Carterton, Greytown, Featherston and Martinborough.

The Wairarapa is predominantly rural in character and extends about 130 kilometres from north to south, 75 kilometres from east to west, and has an area of 6,010 square kilometres. This represents almost three-quarters of the Wellington region's land area, but only nine per cent of the region's population (423,765).

The Wairarapa is within a very active tectonic region, located close to the boundary of the Pacific and Indo-Australian plates. This setting has produced three distinct landscapes which strongly influence the climate and land uses of the region. These landscapes include the Tararua and Rimutaka mountains in the west of the district, the central plains on which all the five main towns are located, and the eastern hills.

Most of the Wairarapa's infrastructure and productive land is located on the central plains. However, there are still significant risks to infrastructure, including roads, civil services and electrical services, from natural hazards in the mountains and in the eastern hills.

1.3 METHODOLOGY

The project concentrated on natural hazards, though technological and other hazards will be considered in future studies. Hazards identified were earthquake (including ground shaking, liquefaction, fault displacement, ground settlement, tsunami), landslide,

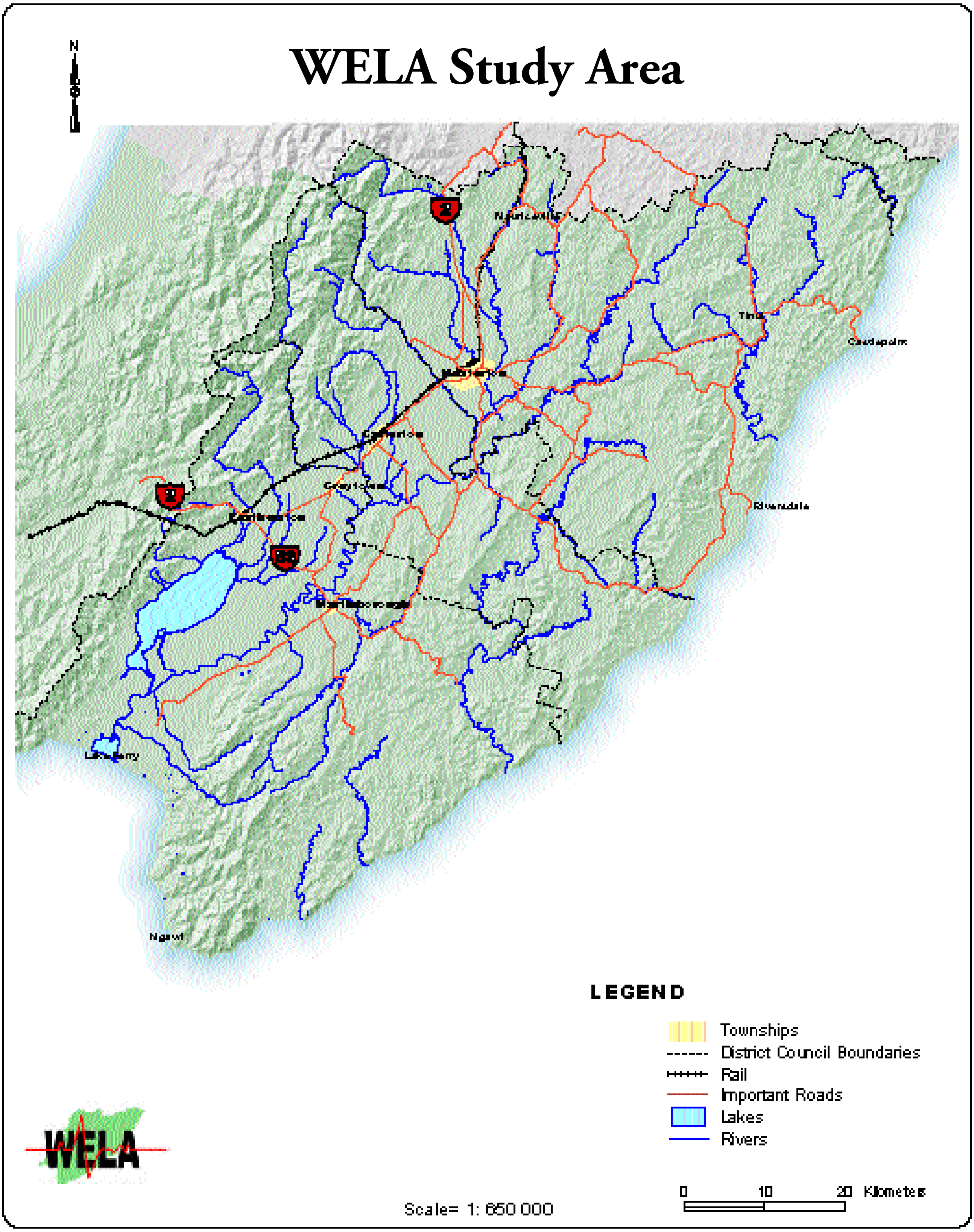

Figure 1.1. Major towns, roads and geographical features of the Wairarapa. The three district council boundaries are shown.

flood, windstorm, local wind effects, severe storm, wild fire and volcanic ash.

To begin the study, five task groups were formed, each with a convenor. They were:

- **Task group 1** – Hazard identification and assessment
- **Task group 2** – Civil services (water supply, sewage, drainage, flood protection)
- **Task group 3** – Transportation (including fuel supplies)
- **Task group 4** – Electrical, communications, and broadcasting
- **Task group 5** – Critical facilities

Project briefs prepared for each task group were supplemented as necessary with 'WELA Notes', which clarified issues encountered by task groups and provided additional information. Early in the study the lack of published hazard information was overcome by the use of provisional information which allowed the vulnerability and impact of damage assessments to proceed. These were also published as WELA Notes. An example of this was using the 1855 Wairarapa earthquake as a more realistic basis for MMI (Modified Mercalli Intensity) and PGA (peak ground acceleration) than the Wellington fault scenario which had been used in previous WRC Wairarapa studies.

In general, the project studies followed the well-proven methods and procedures adopted in the CAE Lifelines in Earthquake Wellington study. Significant changes however were necessary to accommodate a multi-hazard approach and these are reflected in the format of the vulnerability charts.

Information used in the project include:

- Topographic maps of the Wairarapa area held on the WRC GIS.
- Probabilistic ground shaking hazard data with return periods of one in 142 and one in 475 years.
- Fault data including likely displacements and return periods.
- Probabilistic rainfall and wind data, with return periods of one in 142 and one in 475 years.
- Flood data for return periods of 20 years and 100 years.
- Areas subject to mass movement – from minor scarps and cliffs, to landslides greater than 10^5 m^3.
- Areas where there is a potential for liquefaction.
- Return periods for volcanic ash falls.
- Areas likely to be subject to tsunami.
- Components and network segments of engineering lifelines, based, wherever possible, on asset registers held by utility providers.
- Results from the hazard screening of critical facilities.
- Civil services, including stopbanks, drainage schemes and pump stations.

Where possible, data was digitised and GIS layers produced to enable the printing of hazard maps. These are reproduced throughout the report.

Guidelines and standards followed included:

- Risk Management AS/NZS 4360:1999 (modified as necessary for use in an engineering lifeline project).
- Guidelines for managing risk in the Australian and New Zealand public sector SAA/NZS HB143:1999.
- Transit New Zealand Bridge Screening Manual, second draft.

Qualitative assessments were made of vulnerabilities to given hazards, and the consequences of damage. The assessments estimated the level of risk, using a modified matrix from the Risk Management Standard AS/NZS 4360. The standard's risk descriptions were not entirely suitable in the context of engineering lifeline studies for natural hazard events. However, the descriptions were retained and made more definitive, by adding occurrence time intervals as well as descriptions of likelihood levels.

WELA also needed to modify the AS/NZS 4360 'level of risk' matrix, which gave a higher proportion of high and extreme risk results than considered reasonable in practical terms. Methods followed in the WELA project are discussed further in WELA Note 5, which is attached in Appendix 2.

Vulnerability assessments were only carried out on roads designated as important routes. Bridges on these routes were subject to seismic screening in accordance with a Transit New Zealand seismic prioritisation grading system. Bridges subject to the highest seismic risk were identified.

Practical mitigation measures were identified for most network components and critical facilities identified by utilities providers. Where information was available or practicable, costs of mitigation measures were estimated on an 'order of magnitude' basis (+/- 30 percent). Critical facilities were assessed against a checklist. The structural scores and detailed check recommendations used in the earthquake vulnerability assessments of buildings reported in Chapter 6, Critical Facilities, were derived using the "Rapid Evaluation Procedure for Building Earthquake Vulnerability". This procedure is published in Chapter 4 of *The Assessment and Improvement of the Structural Performance of Earthquake Risk Buildings* prepared for the Building Industry Authority by the New Zealand National Society for Earthquake Engineering, 4 June 1996. Unreinforced masonry is set a default score of 100.

1.4 STATISTICAL THRESHOLDS USED FOR EVENTS/FLOODS

Earthquake and meteorological hazards

We know that devastating hazardous events such as the Masterton earthquake and Cyclone Bola do occur, but we don't appreciate the risk of such events. How likely are we to experience such events in our lifetime? What are the appropriate statistical thresholds?

Two different return periods have been used by WELA to describe, in a statistical sense, likelihoods of earthquake and meteorological hazards occurring in the Wairarapa. The same standards are used in other New Zealand studies and they underpin our building standards.

These are the one in 142 year and one in 475 year events. These events have return periods (R) of 142 and 475 years, and are the average number of years within which a given event will be equalled or exceeded. The risk (R) of these 142 and 475 year events occurring is calculated as:

$$R = 1 - p^n$$

where n is the period in time over which the event may occur and p is the event probability, which is equal to:

$$1 - \frac{1}{R}$$

Therefore, the one in 142 year event has a 10 per cent chance of being equalled or exceeded in any 15 year period, and a 30 per cent chance of being equalled or exceeded in any 50 year period. The one in 475 year event has a three per cent chance of being equalled or exceeded in any 15 year period and a ten per cent chance of being equalled or exceeded in any 50 year period.

To put this in a more human context, the one in 142 year event has a 44 per cent chance of being equalled or exceeded during the average person's life span. The one in 475 year event has a 15 per cent chance of being equalled or exceeded during the average person's life span. These return periods have been applied to earthquake and meteorological hazards in this study. **Table 1.1** summarises the meaning of the return periods.

Different return periods have been used when describing flood events, because flood protection structures are built to withstand predetermined flood heights which equate to certain return periods. These are discussed below.

WELA statistical thresholds (used for earthquake, rainfall and wind)		
Return period	1 in 142 Year (Operating Basis Event)	1 in 475 Year (Design Level Event - standard applied to engineered building in New Zealand)
Likely effects in the Wairarapa (earthquake)	MM VIII shaking *PGA 0.33 – 0.35 g. Damage to modern structures minimal Moderate damage to masonry. Loss of life and lifelines unlikely	MM IX to MM X shaking *PGA 0.5 – 0.7 g. Minor to moderate damage to modern buildings Permanent damage to masonry. Loss of life and lifelines likely
Likelihood of occurrence	10% chance of exceedence in any 15 year period, or a 30% chance of exceedence in any 50 year period.	10% chance of exceedence in any 50 year period, or a 3% chance of exceedence in any 15 year period.
Human context	44% chance of occurring during the average person's life.	15% chance of occurring during the average person's life.

*Results from Berryman *et al* (1998)

Table 1.1. WELA statistical thresholds used for Earthquake, rainfall and wind events.

Flood hazards

Floods occur relatively frequently. This study uses a slightly different statistical approach to define flood risk than for severe earthquakes and meteorological events. The standard approach to quantifying flood events is to describe their probability of exceedence in any given year. What is commonly called a 20 year flood is a flood that has one chance in 20 of occurring in any single year. **Table 1.2** below summarises the characteristics of the annual flood, the five year flood, the 20 year flood and the 100 year flood.

Flood statistics				
Return period	Annual Flood (2.33 year)	5 Year Flood	20 Year Flood	100Year Flood
Likelihood of exceedence in any single year	43%	20%	5%	1%
Human context	Frequently expected	Common	Occurs occasionally	Occurs rarely
Likely effects in the Wairarapa	Refer to Section 2.5			

Table 1.2. Annual, 5 year, 20 year and 100 year flood statistics.

1.5 REPORT STRUCTURE

Chapters 2, 3, 4, 5 and 6 present the results of the five lifeline task groups in the following way:

Chapter 2: Task group1
– Hazard identification and assessment.

Chapter 3: Task group 2
– Civil services.

Chapter 4: Task group 3
– Transportation (including fuel supplies).

Chapter 5: Task group 4
– Electrical, communications, and broadcasting.

Chapter 6: Task group 5
– Critical facilities.

Chapter 2 provides information on the natural hazards in the Wairarapa region and focuses on processes that threaten engineering lifelines. It presents the results of the first task group, which looked at hazard identification and assessment. Much of the information in this chapter came from work commissioned by WELA specifically for this project. Historical local examples of hazardous events and their effects are provided where possible.

Chapters 3 to 6 were produced using the methodology described above and use the following structure where possible:

- Network description
- Vulnerability assessment
- Mitigation measures

Appendix 1 presents the vulnerability charts used in the assessments of vulnerability and level of risk.Some vulnerability charts have not been included for commercial reasons. WELA Note 5 in Appendix 2 helps explain some of the methodology described above.