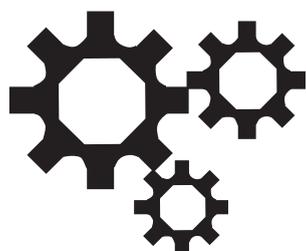


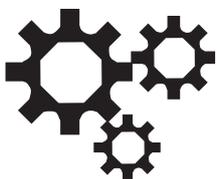
Dunedin City Lifelines Project Report



— DUNEDIN CITY LIFELINES PROJECT —

DUNEDIN CITY LIFELINES PROJECT REPORT

December 1998



==== *DUNEDIN CITY LIFELINES PROJECT* ====

DISCLAIMER

The purpose of the Dunedin City Lifelines Project and its published documents is to assess the general risk to lifeline services and to identify areas where further investigations or remedial engineering actions on lifeline services are indicated.

Whilst the information has been produced using the best advice available, it is not intended for any other application than the limited purposes of this Project.

No liability will be accepted by any of the parties to the Dunedin City Lifelines Project for any wider interpretation of or reliance which may be placed upon its published documents or upon any other findings of the Dunedin City Lifelines Project.

Any person or organisation having a concern with any issue raised by the Project should consult their professional advisers before taking any action.

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**“Civilisation exists by geological consent,
subject to change without notice.”**

Philosopher/Historian, Will Durant (1885/1981)

FOREWORD

Dunedin is wonderfully endowed with a variety of landforms, coastline and weather conditions.

It is this variety that makes Dunedin such an attractive place to residents and visitors alike. It is also this variety that presents a challenge to those who have responsibility for the vital lifeline services upon which our population and industry depend.

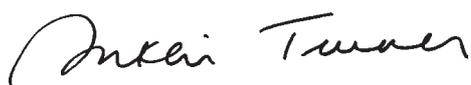
If Dunedin is to retain its healthy population and environment with continued opportunity for businesses to develop and grow, we must assure in so far as we possibly can, continuation of these vital services to the community.

For this reason it gives me great pleasure to introduce this report covering the extensive work carried out for the Dunedin City Lifelines Project. This project has involved many people and organisations in seeking to increase the resilience of our community and its vital services to all manner of hazards.

While nobody living in or visiting Dunedin should feel unsafe, we will never be immune to the impacts of hazards, including the recently recognised increased probability of major movement of the Alpine Fault. It would have been imprudent of the community not to address these risks and this is why Council initiated and helped to sponsor the Dunedin City Lifelines Project.

In the interests of promoting wider community emergency awareness and planning, I commend this publication to citizens, businesses and organisations, who should carry out their own analysis of vulnerability based on the extensive information presented here.

I wish to express gratitude on behalf of the people of Dunedin to all of those who, under the guidance of the Lifelines Co-ordinator, have worked so willingly and diligently on this project. I am sure that the mitigation strategies arising from their work will lead to development of a more secure base for the economic and social future of Dunedin.



Sukhi Turner
Mayor of Dunedin

ACKNOWLEDGEMENTS

The Dunedin City Lifelines Project wishes to acknowledge with gratitude the involvement of the large number of people and organisations who have actively helped with the work of critically examining the city's lifelines. This acknowledgement recognises the assistance and unstinted co-operation of all project personnel, associates and staff members who have given their time, support and encouragement to the project.

The majority of the work has been undertaken without any charge to the project and represents a valued contribution to community resilience, confirming the strong social conscience of our lifelines management.

Special thanks are due to members of the academic, scientific and engineering team who addressed the question of hazard definition and thereby established the basis for assessment of vulnerability.

The staff at City Consultants made a vital contribution by preparing GIS mapping which has been and will continue to be invaluable in progressing the objectives of the Dunedin City Lifelines Project. Their enthusiasm, patience and professionalism have been sincerely appreciated.

The provision by the Dunedin City Council Civil Defence & Rural Fires Department of project administration and accommodation for the Project Co-ordinator and the many meetings held is gratefully acknowledged.

The project further acknowledges the financial support given by the following organisations:

Principal Sponsor Dunedin City Council Civil Defence

Major Sponsors Otago Regional Council
 Ministry of Civil Defence
 Earthquake Commission (EQC)

Sponsors (alphabetically) Dunedin Airport Limited
 Dunedin City Council Building Control
 Dunedin City Council City Consultants
 Dunedin City Council Contracts & Asset Management
 Dunedin City Council Environmental Health
 Dunedin City Council Waste Services
 Dunedin City Council Water Department
 Dunedin Electricity Limited
 Otago Power Limited
 Port Otago Limited
 Telecom New Zealand Limited
 Transit New Zealand
 Transpower New Zealand
 Tranz Rail New Zealand Limited

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Ms Laura Nicol	GIS Analyst, City Consultants, Dunedin City Council

CHAPTER 1. EXECUTIVE SUMMARY

The primary function of the work undertaken in the Dunedin City Lifelines Project is to identify potential weaknesses in the services which provide for our community welfare and employment and wherever possible to make a positive physical improvement in the survivability of the service asset.

The in depth and critical examination of vulnerability to hazard events by the engineers and managers who operate the various services has been thorough and, at times, revealing.

In reporting upon their various service assets the operators have collectively answered the four questions asked of them:

- What assets do we have?
- How vulnerable are these to natural hazard?
- What are the most critical components of our at-risk systems?
- What can we do to help them survive?

The results of their work is contained in this report but there has been, and will continue to be, a benefit from the study by association and understanding developed between engineers, managers, scientists and academic personnel who have been involved in three years of input to the project.

Today's economic climate does not make delivery of physical improvements to our many service assets easy, particularly where earlier commitments made by our forebears as to the location and quality of some service assets makes mitigatory strategy costly. There are a number of areas within the city which we would now avoid building upon.

There are, nevertheless a number of less expensive strategies which may be undertaken which will have markedly beneficial effect upon our community welfare and early recovery following hazard events. In recognising these the project has aroused the awareness of the management and public alike to the serious possibility of hazard events and forms of preventative action which may be taken.

The three seminars initiated through the Lifelines Project were all well attended, with over ninety contributors present on average, and there can have been no doubt about the sincerity of their commitment to understanding the possibility of serious damage to our economic future if steps are not taken now to manage potential disaster.

Included in the report are details of how "assessment of vulnerability" was undertaken, adopting a scoring method which was used to avoid too much variation in assessment criteria by the task groups and which highlighted the proportionate importance of the various hazard effects in a standard manner.

It is considered significant that recent research on the Alpine Fault forecasts probable seismic events within the next 50 years at a level higher than previously expected and points out that such events are likely to mean that Dunedin may not be the recipient of help from further north, but will rather be in the position of having to help itself to recover and may be faced with the need to assist Central Otago towns with their recovery at the same time.

This report commends preparedness and the establishment of an ongoing lifelines review on an annual basis. It also recommends preventative action in mitigation of hazard damage to the critical components identified for each lifeline service over the next 10 to 20 years.

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PROJECT OUTLINE

Introduction

Modern society is more than ever dependant upon the efficient and continued functioning of basic utility services, information technology and transportation.

Not only the community physical welfare, but the ability of industry to perform efficiently and economically in a world of increasingly high competition is intimately connected to the survival and early reinstatement of these basic service assets when disasters occur.

These service lifelines - for that is what they represent - are often taken for granted, and their importance under appreciated. Many are underground and most are never seen by the public.

Widespread or local damage due to a number of different natural and technological hazards can affect the lives and livelihood of thousands of people and when taken to extremes may cause economic damage which is irrecoverable.

In the last half of the 20th century, immense progress has been made in material improvement and design, resulting in more flexible structures and buildings. An older city like Dunedin has many examples of aging technology on display and many of our Lifeline assets have a potential towards failure in extreme hazard circumstances.

The greater Dunedin City area is fortunate in many respects that the history of seismic activity has not placed it among the most serious areas of such influence as in the case of Wellington and the east coast of the North Island.

Nevertheless, there has been in recent years local seismic activity of moderate magnitude and the nature of this hazard and other natural hazards are worthy of our understanding and study, with a view to reducing damage occurrence by mitigation strategies which may be adopted.

The study of lifelines has become an essential element of effective planning and economic development.

The United States of America, disturbed by continued seismic impact, commissioned a nation wide assessment of lifeline vulnerability in 1988. This formed the basis for establishing many other localised assessments which were generally based upon seismic reviews only. The USA work was completed in September 1991 and was regarded as a useful model by many cities working along similar lines - some extending the hazard range beyond seismic affects to cover particular local hazards.

In New Zealand, the Centre of Advanced Engineering at the University of Canterbury undertook a seismic assessment of lifelines in the capital city of Wellington and published their "Wellington Case Study" in August 1991. This was the first lifelines study to be undertaken and greatly benefited from the academic and engineering support of the University.

Since then, a number of major cities and some smaller towns in New Zealand have commenced lifeline assessments; Christchurch in 1993/4 and Dunedin in 1995/6. In the latter cases, the hazard base has been extended beyond pure seismic vulnerability to cover hazards such as flooding and landslip and this has involved a wider range of contributors and increased awareness of the hazard problems which may be encountered.

Objectives

The objective of the "Dunedin City Lifelines Project" is to study the effect of natural hazards upon the existing services which are essential to sustain community welfare and employment, and to determine what action may be taken to improve survivability in the event of disaster.

The examination of lifelines was undertaken in stages.

Identification of Hazards

Academic and scientific reporting was undertaken by people engaged in environmental study of hazards which might impact upon the region. Mapping to define areas of influence was prepared with the assistance of City Consultants.

Description of Service

The project sought to identify, describe and record all major elements of lifelines in order to assess the vulnerability of discrete elements and complete systems to damage from a number of natural and technological hazards.

Assessment of Vulnerability

Each element and complete system was examined by asset managers to determine the exposure of the lifeline to the hazards and to "rate" its vulnerability.

Mitigation Strategies

The final objective was to establish and develop practical engineering work strategies designed to increase survivability.

Methods of mitigation, questions of reinstatement periods, cost and availability of skills and materials came under review as peripheral issues arising from the asset vulnerability assessment. The importance of interdependence of services was also considered.

Hazards will almost always cause damage in some form or another and the availability of capital may limit the resources which may be directed towards mitigation. The project sought to give direction as to where money should be directed as it becomes available, and draw attention to future design considerations and planning initiatives.

Programme

Though partially modelled on the lifelines studies earlier carried out in the U.S.A. by the Federal Emergency Management Agency (FEMA/224/September 1991), and more specifically upon the work carried out by the Centre for Advanced Engineering (CAE) - University of Canterbury in their Wellington Case Study (August 1991), it was decided that the Dunedin City Lifelines Project needed to investigate a slightly wider range of hazards than that in the Wellington study and to be less "broad brush" than the U.S. study.

Accordingly, an initial programme covering a 32 month period was prepared, including three seminars to increase awareness of contributors and associated asset managers.

In the event, this programme and the estimate of progress during assembly of the data by the various groups within the study proved reasonably accurate, though the time required for publication of the results was underestimated, and the overall period to publication extended to become 36 months.

Administration

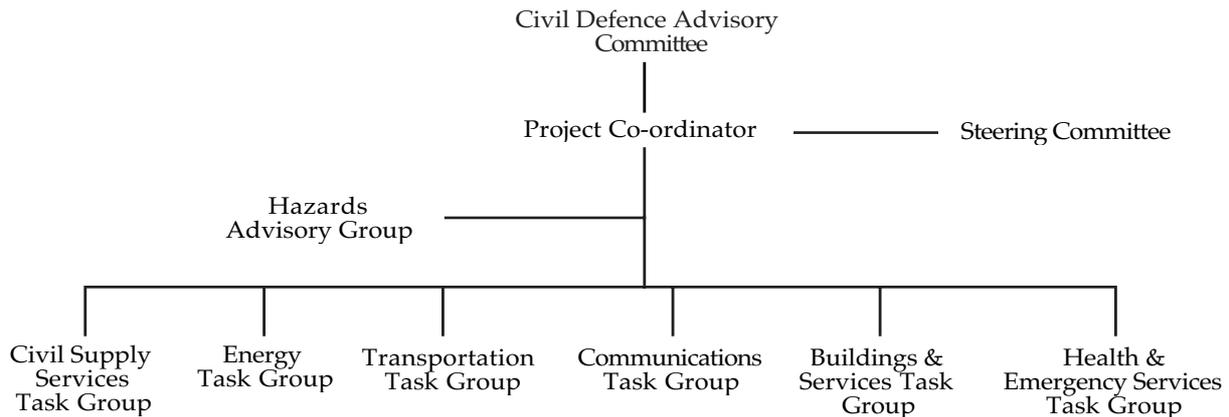
The project administration was undertaken in combination with the Civil Defence and Rural Fires Department of Dunedin City Council, by an appointed part time Co-ordinator. The appointment was made by the Civil Defence Advisory Committee.

The Co-ordinator was a retired consulting civil engineer with a wide number of contacts among engineering, management and academic personnel within the City of Dunedin and with a knowledge of various city services.

Guided by the order of work undertaken in the Wellington study, teams of engineering, academic and management people were assembled into task groups as follows:

- Civil Supply Systems
- Energy/Fuels
- Transportation/Harbour
- Communications/Information
- Buildings/Services
- Health and Emergency Services
- Hazard Analysis Group

A Steering Committee consisting of senior management, task group leaders and members of the Civil Defence Advisory Committee was appointed to maintain an overview of project progress. Control of finance was undertaken independently by Dunedin City Council on behalf of the Steering Committee.



Definition of Lifelines

Identification of lifelines and recording of asset detail was undertaken in the “Description of Service” part of the project.

The study involved all major lifelines in the greater Dunedin City area. While greater emphasis is placed upon urban locations with their substantially greater population, areas of primary production and tourism were not neglected.

Lifelines assets cover the supply of water, power, fuel, the treatment and disposal of waste waters, transport by road, rail and sea, communications and broadcasting.

Because of the essential service performed in the carriage of personnel and distribution of goods within the Dunedin City area, road transport equipment and maintenance facilities were considered as lifelines.

Major buildings including essential administration and commercial facilities, together with power generation, harbour, hospital, police, fire and ambulance services were examined against a background of survivability under hazard impact.

Advice upon their dependence on lifelines was sought from Health and Emergency Services groups and consideration given to the economic and planning aspects of all lifelines in their recovery from disaster.

Definition of Hazards

The project identified a range of hazards which may impact upon the lifelines either singly or collectively. The degree of severity of impact has been widely discussed between lifelines managers and interpretation sought from academic, scientific and engineering sources on the various hazards.

Hazards which are considered to offer a potential for damage of a significant nature to lifelines are:

- Earthquake
 - Shaking
 - Faulting
 - Liquefaction
- Tsunami
 - Near & far field events
- Flooding
 - Nominated locations
- Weather
 - Snow, wind, rain
- Landslide
 - Earthquake or natural instability
- Technological
 - Fire, explosion etc

These hazards have been defined by the Hazard Group and are set out in detail in Chapter 3 Hazards.

Methodology

Introduction

Hazard identification and mapping of areas of influence was prepared by a separate academic and scientific team and was made available to task groups.

The various stages of procedure adopted were undertaken by task groups concerned with the asset management of the particular service involved. Task groups were asked to prepare drawings of asset routes and other significant service locations and overlay maps were made available for subsequent review in assessing vulnerability.

Mapping, was prepared by City Consultants and has been retained on the Council's GIS system.

Description of Service

Description of Service involves the description and mapping of lifelines assets by the system operators and management. Asset managers were asked to describe the service purpose, location, quality of material etc. in a logical order to present a good word picture of the extent of the asset. From these statements the next stage of the study proceeded.

During this period the Hazard Analysis Group was involved in preparing data and mapping the hazards.

Assessment of Vulnerability

The Dunedin City Lifelines Project involved assessment of the vulnerability of lifeline services to various hazards. An understandable method of determining relative vulnerability was developed and applied in a common way to all lifeline services.

The basis of the methodology for assessing lifeline services' vulnerability to hazards is described below and takes into account a range of factors other than simple exposure to a hazard, incorporating quality, condition and location.

Terms used in hazard analysis are sometimes used in different ways in different methods. To avoid confusion, terms used in this project are defined below:

- *Hazard* is defined as a physical event with the potential to cause damage or loss.
- *Risk* is a measure of the level of exposure to a particular hazard in a defined location and is often described by the simple formula $Risk = Probability \times Magnitude$. While giving a measure of the likely impact of the hazard, risk does not take into account the physical nature of assets affected and their relative importance to the community.
- *Vulnerability* is a measure of the consequences of identified hazards affecting a particular network (or its component parts). Factors taken into account by this method include the probability and magnitude of the sum of the hazards it is exposed to (total risk); its relative importance to the network (significance); the degree to which it is prone to damage (fragility); the likely delay before it can be re-instated (time); and the economic impact of the expected level of damage (cost).

For the purpose of assessment, vulnerability was broken down into three separate elements within the vulnerability analysis worksheets:

- Physical Vulnerability = Total Risk x Fragility
- Network Vulnerability = Total Risk x Fragility x Redundancy x Time
- Community Vulnerability = Total Risk x Fragility x Redundancy x Time x Cost

Computerised ranking of these elements enabled an assessment to be made of the order of importance of various parts of the lifelines and to identify where the highest risks lay.

Values for Calculating Vulnerability

For this calculation to produce a meaningful ranking of vulnerabilities of a range of assets, suitable weightings were established for the numerical values given to the risk for different hazards and the modifying factors for the assets, and a Vulnerability Calculation Chart was prepared (see appendix to this chapter).

Among criteria for the weighting of these numeric values were:

Total Risk

Values for each hazard established based upon:

- The level of magnitude (as defined in the hazard mapping).
- The probability of occurrence of that magnitude of event.
- The level of disruption to services likely to be caused.

The numeric values established had to bear relativity to each other so that a high probability event with little disruption potential did not outweigh a lower probability event with high disruption potential. Risk values for hazards to which any asset or part of an asset was exposed were added so that exposure to a number of events increased the weighting of the risk factor in the equation.

Redundancy

This factor is based on the relative impact of the loss of the asset (or component of the asset) to the network of which it is a part, taking into account the degree of redundancy provided for that element of the network. The more redundancies there are, the less vulnerable the network as a whole should be.

Fragility

This indicates a measure of the degree of protection from or resilience to damage of the asset. Considerations include:

- Age (in relation to its assessed economic life).
- Standard of construction, including any hazard resistance designed in.
- Type of construction.
- Current condition.

Time

Included in this factor are values based on the total time the asset is likely to be out of service or until an alternative is brought into use following the most disruptive event to which it is susceptible. The weighting of this factor is influenced by the availability of:

- Replacement componentry.
- Skilled personnel.
- Specialist equipment from outside sources.
- Outside contractors (for whom there may be competing requirements).

Cost

Determining the value of this factor (based on the most disruptive event to which it is susceptible) included:

- The cost of repairing or replacing the asset.
- Cost of temporary alternatives used to resume service.
- Whether there is insurance cover or other financial support for repairs or replacement.

The end result of this process was to produce a comparative vulnerability ranking for assets in a network rather than an absolute value.

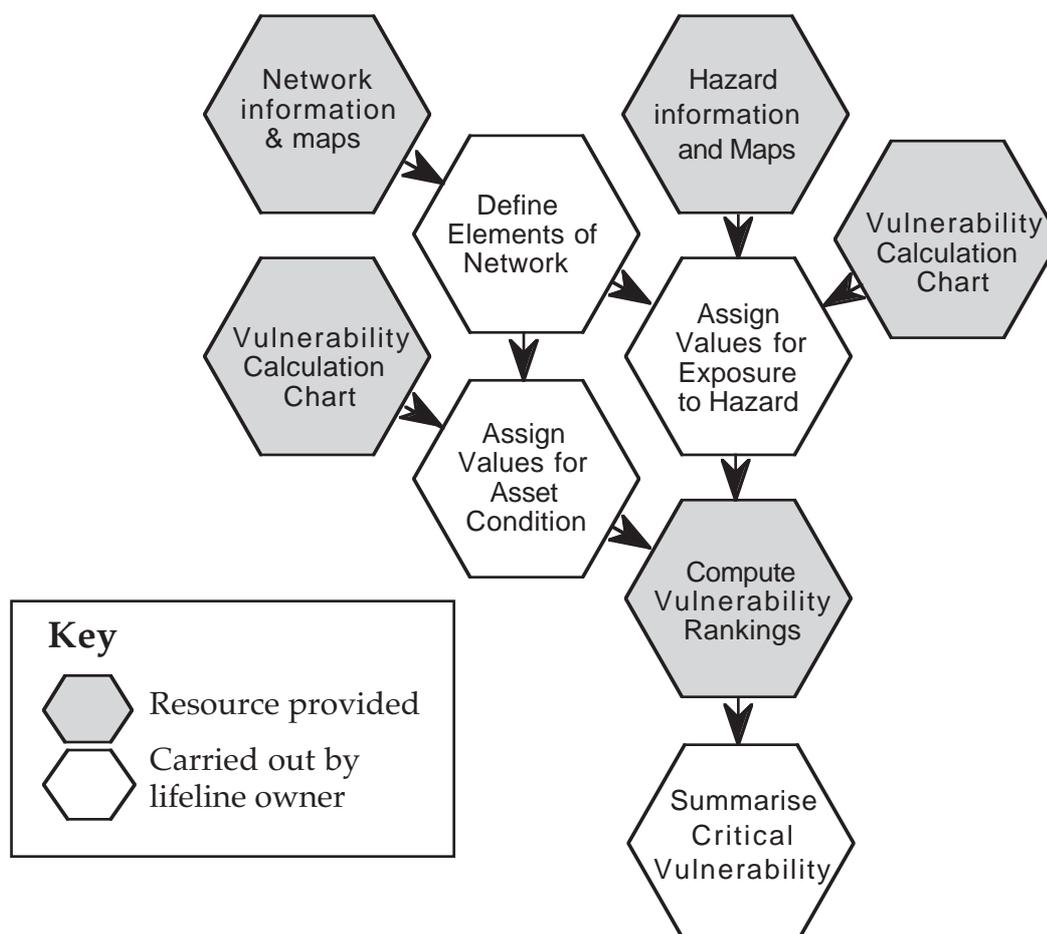
Methodology for Lifelines Vulnerability Analysis

The process applied to the assessment of vulnerability was to:

- Use network maps appropriate to the lifeline group service.
- Divide the network into discrete elements and enter the description in the Lifeline Vulnerability Analysis Worksheet (see appendix for an example). This requires knowledge of the elements and their physical location.
- Overlay the network maps with the hazard boundary maps, or refer to the hazard definition papers presented by the academic and scientific group in their publication set out in Chapter 3.
- Determine exposure of each component to each hazard using the Vulnerability Calculation Chart to establish hazard values. Enter these onto the Lifeline Vulnerability Analysis Worksheet. These are factors which relate solely to the asset locality.

- Establish values for fragility, redundancy, time and cost to reinstate from the Vulnerability Calculation Chart, and enter these onto the Lifeline Vulnerability Analysis Worksheet. These are modifying factors and this element of the work required a good deal of engineering judgement and some imagination. Familiarity with the lifeline and knowledge of inherent weaknesses, whether due to age or location, was necessary to complete the assessment effectively.
- Submit Lifeline Vulnerability Analysis Worksheet for computer input. The computer programme calculated the three vulnerability categories of each element and sorted them into order. These worksheets have been retained for reference.
- Based on the calculated vulnerabilities, produce a written description of the anticipated type and extent of damage to each element of the network by exposure to hazard. This part of the work was important and required critical examination and full description of the vulnerability of the elements of the network. This work formed the basis for consideration of mitigation strategies.

Vulnerability Assessment



As some of the calculations had an element of commercial sensitivity, working documents remain confidential to the lifeline owner. Reporting on general intentions for mitigation strategies was the only outcome needed for inclusion in this report.

Mitigation Strategies

Background

Task groups were asked to formally report upon mitigation strategies designed to prevent damage and increase overall survivability of the critical assets identified in the summaries of vulnerability. To assist this process a Mitigation Strategy Record Worksheet was developed (see appendix) for task groups to complete and retain in-house for future reference.

A written statement on the prepared mitigation strategies, including conclusions and recommendations, was produced by each group.

VULNERABILITY CALCULATION CHART

EARTHQUAKE

Choose highest values applicable
Enter values on vulnerability analysis chart

Shaking	5	-	5	Liquefaction	Active	2	3	1	0	Non-active
Background	10				Within 50m of a fault line					
Enhanced										

TSUNAMI

Choose highest value applicable
Enter value on vulnerability analysis chart

Within 1 km of coast or estuary	0	1	2
Above 5m contour			
Between 2 & 5m			
Below 2m contour			

WEATHER

Choose and add highest values applicable
Enter total on vulnerability analysis chart

Disruption	0	0
Some	0.5	0.5
Much	1	1
Severe		

Windstorm	0	0
Snowstorm	0.5	0.5
	1	1

FLOODING

Choose and add highest values applicable
Enter totals on vulnerability analysis chart

Exposed	3	2	2	1	1	1
Yes	0	0	0	0	0	0
No						

LANDSLIDE

Choose highest value applicable
Enter value on vulnerability analysis chart

Exposure	0	1	2
None			
Infrequent			
Significant			

TECHNOLOGY

Choose highest value applicable
Enter value on vulnerability analysis chart

Exposure	0	1
Not exposed		
Exposed		

FRAGILITY

Choose highest value applicable
Enter value on vulnerability analysis chart

Economic Age	1	2	3	4
First third	1	2	3	4
Second third	1	2	3	4
Last third	2	3	4	4
Hazard resistant				
Meets current std				
Meets older std				
Inadequate std				

REDUNDANCY

Choose highest value applicable
Enter value on vulnerability analysis chart

Impact of loss	1	1	2
Low	1	1	2
Medium	1	2	3
High	1	3	4
Full redundancy			
Some redundancy			
No alternative			

TIME

Choose highest value applicable
Enter value on vulnerability analysis chart

Reinstatement time	1	2	3	4
Within 1 week				
1-4 weeks				
1-3 months				
More than 3 months				

COST

Choose highest value applicable
Enter value on vulnerability analysis chart

Reinstatement cost	1	2	3	4
Low impact*				
Moderate impact*				
Major impact*				
Uneconomic*				

* Definition of financial impact on the owner of the asset

Low impact means cost can be funded from within normal annual operating costs.

Moderate impact means cost can be funded by some re-prioritising of existing capital works and maintenance.

Major impact means cost need to be funded from external sources and/or considerable restructuring of financial plans.

Uneconomic means the cost is such that the asset is unlikely to be re-instated.

Appendix - Mitigation Strategy Record Worksheet

Example

**Dunedin City Lifelines Project.
Stage 3 Mitigation Strategy.
Record Worksheet.**

TASK GROUP NO: 1
UTILITY: Water Supply
INDEX HEADING: Supply System

Unique I/D: 1/DS/PL
Date: April 1998

Description of vulnerable element (Include detail of location for identification):

1 Deep Stream and Deep Creek pipelines Taieri River Bridge 2km to the west of Taioa Road.

Nature of vulnerability (Exposure & consequences):

Earthquake, Land movement & Technology.

The predominant risks of failure of the 3 - pinned riveted truss lattice are:

- 1 landslide at the western abutment by either rapid movement or creep resulting in compression of the bridge and ultimate failure of the pipelines.
- 2 Rockfall from the steep bluffs above the true left abutment.
- 3 Distortion of the bridge or damage by rockfall induced by seismic activity.
- 4 There is also some risk of the bridge being badly damaged by a low flying aircraft such as helicopter.

Identify mitigation options (With estimated order of cost):

The following mitigation measures should be considered.

Protection of the bridge or stabilisation of the steep schist slopes on the true left bank. (Estimated Cost \$500,000 ??)

The bridge should also be repainted in a more visible colour to make it easier to see from a helicopter. (Estimated Cost \$200,000)

Recommended mitigation strategy (With reasons):

- 1 Establish survey levelling points on the bridge and compare camber of bridge span with design drawings on a yearly basis.
- 2 Set up a ground movement survey network on the Pipe Bridge and Mt Hyde slide complexes and survey yearly.
- 3 Consider relocating one or both of the pipeline river crossings upstream to the ridge on which the power transmission lines are located.
- 4 Repaint bridge.

Other design considerations:

The above mentioned upstream pipe route and crossing are flanked by landslides, however there does not appear to any other viable options.

Serious consideration needs to be given to buried pipe crossing of the river as opposed to a bridge option.

Works already planned/programmed (Where applicable):

Replacement or duplication of the bridge would only take place after 2007 when the Deep Creek pipeline is replaced. This is identified in the Water Upgrade plan but no funding provision has been made at this stage.

Interim contingency planning measures (until mitigation proposals are in place)

- 1 Regular walk over inspections of the bridge and pipelines to continue.
- 2 Consider regular level surveys.

General comments on mitigation strategies:

Consider alternative pipeline routes and crossing site and obtain consents to deviate one or both of the pipelines.

