The Edgecumbe Earthquake
A review of the 2 March 1987 Eastern Bay of Plenty Earthquake

George Butcher
Latham Andrews
& Graham Cleland

Centre for Advanced Engineering
University of Canterbury
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It is now more than a decade since the Edgecumbe earthquake (locally known as the Eastern Bay of Plenty earthquake) occurred on 2 March 1987. New Zealand is indeed fortunate that it has experienced no earthquakes causing substantial and widespread damage since then and I believe that it is still important to learn as much as possible from the experience of this particular earthquake event.

The idea for a review report on this earthquake first emerged during discussions which I had with Professor Ian Buckle, then Deputy Director of the National Centre for Earthquake Engineering Research at the State University of New York at Buffalo, USA and now Deputy Vice-Chancellor (Research) at the University of Auckland, while Professor Buckle was visiting New Zealand in March 1990. He suggested that the Centre for Advanced Engineering (CAE) might undertake such a project. However at that time there were still legal claims resulting from the earthquake damage to be resolved, which made it difficult to obtain some of the information required and it was decided to postpone further consideration of the project until this information was available.

The matter was further discussed when Professor Buckle returned to New Zealand in September 1990 as a Visiting Fellow for the three-day Project Workshop in Wellington on CAE’s first major project on Lifelines in Earthquakes: Wellington Case Study. It was discussed again during another visit which Professor Buckle made to New Zealand in November 1990, when he suggested that the emphasis in the report should perhaps be in the area of documenting recovery and reconstruction and the economic impact of the earthquake.

The Earthquake Commission advised me in April 1991 that court actions resulting from the earthquake had been settled and hence their information could now be made available for further study. This meant that the project could be considered in more detail and after further discussions held by CAE with various people, in May 1992 consulting engineers Mr George Butcher and Mr Latham Andrews were asked to undertake the study on behalf of CAE. A brief for the project was prepared and after some refinement of this brief, the project was approved to proceed by the Board of Directors of CAE in September 1992, subject to a detailed proposal being prepared that was acceptable to the Earthquake Commission. After several discussions held with the Commission on the nature and extent of the work involved, in August 1993 they agreed to partly fund the cost of the project. Shortly thereafter Messrs Butcher and Andrews commenced gathering information and undertaking preliminary studies on the project. Subsequently, economist Mr Graham Cleland was asked to join Messrs Butcher and Andrews as the third author of this publication.

The work actually required proved to be many times greater than originally envisaged because of the great difficulties experienced in bringing the necessary information together held by many organisations, as much of it had already been mislaid or lost even though only about seven years had then elapsed since the earthquake event occurred. Litigation which continued into 1996 delayed access to information from Farmers Mutual Group (FMG), insurers of Bay Milk Products and farmers in the region.

I wish to pay a tribute to the persistence and fortitude of the authors over a four year period from late 1993 in refusing to give up in the face of many obstacles in their path and ultimately after many hundreds of voluntary hours of work spent gathering information, bringing together this report in a form ready for final editing by CAE over the past few months.

I am sure that this report will be a useful reference work for all those who wish to study this particular
earthquake and its aftermath. In particular there are some lessons to be learned in regard to earthquake
preadiness in New Zealand so that as a nation we may be more able to cope with a future major earthquake
and the subsequent response and recovery periods. This will help to minimise the disruption to peoples’ lives
and the duration and cost of business interruption following such an earthquake.

The financial contribution of the Earthquake Commission towards the cost of undertaking this project is
gratefully acknowledged.

John P Blakeley

Executive Director
Centre for Advanced Engineering
University of Canterbury

July 1998
The earthquake of 2 March 1987 is known throughout the district it affected as the Eastern Bay of Plenty earthquake, and in scientific and engineering circles as the Edgecumbe earthquake. Although of modest magnitude, it generated more intensely felt shaking than has been experienced by any New Zealand community since the Inangahua earthquake in 1968. The decade since it shook the Rangitaiki Plains has seen some of its warnings heeded, some lessons learned and some lessons ignored. Communities and their assets are marginally safer and better prepared to combat an earthquake’s adverse effects than they were before this earthquake occurred, but more benefit could have been taken from analysis of the experience.

Stricken Edgecumbe, Te Teko and Kawerau are all comfortably close to, and were accessible from, Whakatane, the district’s principal town (which was almost unscathed), and a source of immediate aid after the earthquake. This fortunate circumstance is rare in New Zealand’s seismic experience; most areas devastated by our historically damaging earthquakes have been isolated by the events and have remained remote from effective help for lengthy periods.

The Edgecumbe earthquake was an ideal one for scientific study.

Monitoring the region before the main shock occurred was the national array of seismographs, and a group of strong motion accelerographs was at Matahina dam on the Rangitaiki River. At the time of the earthquake, the seismograph network was due for local augmentation by portable instruments, then in transit from Wellington, to gather improved information about the earthquake swarm occurring at the coast, retrospectively recognised as foreshock activity. The instruments were immediately deployed to record aftershocks. Thus the data needs of geophysicists and engineering seismologists were satisfied. Surface traces of earthquake fault movement were prominent — they traversed open uncluttered country, much of it pastureland, and were easily accessible for study, recording and measuring, by geologists, soil scientists, surveyors and photographers. Because New Zealand’s earthquake insurance scheme provided for cover by a single insurer, the Earthquake and War Damage Commission (now the Earthquake Commission), for almost all properties, a reasonably consistent record of property losses was compiled at one location. These data, although imperfect in some respects, are probably better for statistical evaluation of damage than have been collected after a comparable event anywhere else in the world.

But not all records are in a satisfactory state. Some err, others mislead, and many have been lost; observation seems occasionally to have been faulty, or the reporting of it incomplete. There are myths to dispel, among them some notable ones. In an authoritative 1990 paper to a World Bank sponsored colloquium, since cited in respected publications, the earthquake cost was overstated substantially, at more than twice its realistically estimated cost. In another account of post-earthquake effects, construction industry costs were said to have experienced a local, very large but apparently mythical (since no evidence of it survives), inflationary “Edgecumbe factor”. In another example, inexplicably, more than one team of experienced observers not only failed to investigate the earthquake’s effect upon an important lifeline, the natural gas supply and reticulation system, but were ignorant of the system’s existence. There are explicit denials in the record that the area was supplied with gas. An extensive gas supply and reticulation system did and does exist — it is not hidden and it was the only lifeline unharmed by the earthquake. This system should have been studied to identify features that contributed to its success, for gas system survival information is applicable to other lifeline maintenance and planning.

Before writing this report we assembled and examined records, eliminating inconsistencies by investigation where that was possible. The work was unexpectedly difficult and inordinately time consuming, principally because many records had vanished. The immediate post-earthquake period was one of economic restructuring and upheaval nationally, in which central government services and enterprises were reorganised, and
many organisations were transferred to private ownership. At least some records were made imperfectly in that time of uncertainty, and other records seem not to have been made at all, or not to have survived the transition from civil service control to private sector or state-owned enterprise control. Also, when we started our work, not all litigants on earthquake related matters had settled their differences, and access to potentially interesting material was denied us on that account. Occasionally we encountered a commercially inspired change from attitudes previously prevailing which hampered us. Whereas, formerly, information that was to be used in studies made for the public good was usually freely available, in the new commercial environment it sometimes came at a cost, even when the source was a publicly owned company. Nevertheless we were treated generously, even by those from whom we got unaffordable quotations for data supply. We are especially grateful to the many people, businesses and institutions who put themselves to much trouble to assist us. We did what we could to verify our record and to compensate for gaps in it.

This report is more than simply an account of the record we assembled of the scientific, engineering, administrative, economic, insurance and social consequences from a moderately intense earthquake in an area predominantly rural but containing several very large industries. Guidance and benefit should flow from the overview afforded by such a collection of reported fact and informed opinion. These are our primary purposes: to identify lessons, giving prominence to what has hitherto been overlooked, and to present a reliable picture of the earthquake, with misrepresentations eliminated, so that reliable conclusions can be drawn.

It is just as important to say what this study is not. It is not a scientific or an engineering investigation in the ordinary sense. We report technical matters from the work of other people, and we have compiled a fairly comprehensive list of reference documents (which is appended to help people pursuing detailed information), but we did not initiate or commission any technical account of the sort generally appropriate for a scientific or an engineering paper or monograph.

G.W.B, A.L.A and G.R.J.C.

Wellington, New Zealand, July 1998
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and from the following organisations:

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<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>acceleration response spectrum</td>
<td>for single-degree-of-freedom damped resonators subject to a given earthquake motion, a plot which displays peak acceleration response as a function of natural vibration period. It is calibrated from calculations made from an accelerogram (qv) and it is used for estimating acceleration responses in buildings and structures.</td>
</tr>
<tr>
<td>accelerogram</td>
<td>a record drawn by a strong motion accelerograph (qv) for one of three components of an earthquake’s motion (the components are in the vertical direction, or in either one of two orthogonal horizontal directions).</td>
</tr>
<tr>
<td>aftershock</td>
<td>an earthquake, one of a sequence of similar earthquakes, that follows a larger earthquake (the main shock, qv) and is related to it temporally (aftershocks usually occur within a year after the main shock) and tectonically.</td>
</tr>
<tr>
<td>dip</td>
<td>the acute angle that a fault plane makes with a horizontal plane.</td>
</tr>
<tr>
<td>dip-slip</td>
<td>displacement between two rock masses separated by a fault, in which one mass moves parallel to the fault, and downward or upward relative to the other.</td>
</tr>
<tr>
<td>epicentre</td>
<td>the point on ground surface that is vertically above the focus (qv) of an earthquake.</td>
</tr>
<tr>
<td>fault</td>
<td>a fracture, or a narrow zone of fractures, in rock; relative displacement between the two rock volumes, one on each side of a fault, is parallel to the fault that separates them.</td>
</tr>
<tr>
<td>focus</td>
<td>that point upon a fault where movement that generates an earthquake commences.</td>
</tr>
<tr>
<td>foreshock</td>
<td>a precursor to a main shock, to which it is related tectonically.</td>
</tr>
<tr>
<td>free field</td>
<td>places where earthquake ground motion is not modified by the behaviour of large-mass structures in proximity.</td>
</tr>
<tr>
<td>graben</td>
<td>a depression formed between normal faults (qv) having more or less parallel traces (qv) and dipping towards each other. As the faults are moved apart by tectonic forces, the graben deepens.</td>
</tr>
<tr>
<td>heave</td>
<td>the change (increase positive) in horizontal separation, measured normal to a fault trace, between surfaces on either side of the fault, that results from movement on it.</td>
</tr>
<tr>
<td>ignimbrite</td>
<td>rock formed of fine- to small-fragment glassy and other material ejected from volcanoes and hot enough when deposited to weld.</td>
</tr>
<tr>
<td>intensity</td>
<td>a subjective measure of the vigour of ground movement caused by an earthquake at a site. The scale most commonly used for measuring intensities in New Zealand is one of two national versions of the Modified Mercalli (MM) scale (one published after the Edgecumbe earthquake occurred), according to which intensities are rated from MM I to MM X,</td>
</tr>
</tbody>
</table>
or to MM XII, the upper limit depending upon the version. The versions, apart from upper limits, are almost identical.

**isoseismal**

A line on a map drawn through places that experienced identical shaking intensities in an earthquake.

**liquefaction**

A state lacking solidity that can occur in deposits of water-saturated fine-grained cohesionless sediments (mainly sand) when they are vigorously shaken. It is caused by increases in pore-water pressure.

**local magnitude**

The magnitude (qv) of an earthquake as determined from the amplitude response of a standard seismograph (qv) that is located at a standard distance from the origin of energy release.

**magnitude**

A measure of the energy released in an earthquake, according to which, approximately, the logarithm of energy released is a linear function of magnitude. There are several magnitudes defined, each with its own determination procedure and range of most effective applicability.

**main shock**

The largest of a sequence of related earthquakes.

**M<sub>L</sub>**

Local magnitude (qv)

**MM**

Modified Mercalli, a scale for measuring intensity (qv)

**normal fault**

A fault that dips in the direction of the downthrown side.

**right-lateral**

Strike-slip (qv) displacement between blocks of rock separated by a fault, in the sense that, when the fault is viewed from either side, the far block of rock is displaced to the right.

**seismograph**

An instrument for recording, as a function of time, motions generated by an earthquake at a site; the instrument is too sensitive to measure strong ground motion.

**seismoscope**

A simple instrument that records amplitudes and directions of ground accelerations in an earthquake. Records it makes have no time base, and resemble rosettes.

**strike**

Direction of the trace (qv) of an earthquake fault.

**strike-slip**

Relative horizontal displacement, parallel to a fault, between the two rock masses that are separated by a fault.

**strong motion accelerograph**

An instrument for recording strong ground acceleration as a function of time.

**swarm**

A great number, occasionally several thousands, of earthquakes of small magnitude, occurring in one locality in a relatively short space of time; no one member of the swarm is so predominantly stronger than the others as to merit main shock designation.

**throw**

The change in relative vertical distance between surfaces on either side of a fault following fault rupture displacement.

**trace**

The intersection of a fault with the ground surface.
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AC</td>
<td>asbestos cement</td>
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<tr>
<td>AEC</td>
<td>Adverse Events Committee</td>
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<tr>
<td>AREC</td>
<td>Amateur Radio Emergency Corp</td>
</tr>
<tr>
<td>AMF</td>
<td>anhydrous milk fat</td>
</tr>
<tr>
<td>API</td>
<td>American Petroleum Institute</td>
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<tr>
<td>BMP</td>
<td>Bay Milk Products</td>
</tr>
<tr>
<td>BSCTMP</td>
<td>Bleached Sulphonated Chemi-Thermo Mechanical Pulp Mill</td>
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<tr>
<td>CAE</td>
<td>Centre for Advanced Engineering</td>
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<tr>
<td>CD</td>
<td>Civil Defence</td>
</tr>
<tr>
<td>CP</td>
<td>Command Post</td>
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<tr>
<td>CST</td>
<td>Commissioner’s Support Team</td>
</tr>
<tr>
<td>DRC</td>
<td>Disaster Recovery Co-ordinator</td>
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<tr>
<td>DSIR</td>
<td>Department of Scientific and Industrial Research (now separated into individual entities)</td>
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<tr>
<td>ECNZ</td>
<td>Electricity Corporation of New Zealand</td>
</tr>
<tr>
<td>EQ&amp;WDC</td>
<td>Earthquake and War Damage Commission (now the Earthquake Commission)</td>
</tr>
<tr>
<td>EQC</td>
<td>Earthquake Commission (formerly Earthquake and War Damage Commission)</td>
</tr>
<tr>
<td>ERB</td>
<td>Earthquake Risk Building</td>
</tr>
<tr>
<td>ERIC</td>
<td>Edgecumbe Earthquake Recovery Information Centre</td>
</tr>
<tr>
<td>FMG</td>
<td>Farmers Mutual Group (insurers)</td>
</tr>
<tr>
<td>GEW</td>
<td>glazed earthenware</td>
</tr>
<tr>
<td>HERA</td>
<td>Heavy Engineering Research Association</td>
</tr>
<tr>
<td>MAF</td>
<td>Ministry of Agriculture and Fisheries (Ministry of Agriculture and Forestry from March 1998)</td>
</tr>
<tr>
<td>MDPE</td>
<td>medium density polyethylene/polythene</td>
</tr>
<tr>
<td>MED</td>
<td>Municipal Electricity Department</td>
</tr>
<tr>
<td>MG</td>
<td>machine ground (an MG cylinder is an item of plant found in a paper mill)</td>
</tr>
<tr>
<td>MM</td>
<td>Modified Mercalli</td>
</tr>
<tr>
<td>MWD</td>
<td>Ministry of Works and Development (now separated into individual entities including Works Consultancy Services; Opus International Consultants from March 1997)</td>
</tr>
<tr>
<td>NB</td>
<td>nominal bore</td>
</tr>
<tr>
<td>NGC</td>
<td>Natural Gas Corporation</td>
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<tr>
<td>Acronym</td>
<td>Definition</td>
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<tr>
<td>NRTF</td>
<td>Northern Region Task Force</td>
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<tr>
<td>NZPO</td>
<td>New Zealand Post Office (now separated into individual entities)</td>
</tr>
<tr>
<td>NZS</td>
<td>New Zealand Standard</td>
</tr>
<tr>
<td>OT</td>
<td>overhead travelling (crane)</td>
</tr>
<tr>
<td>PABX</td>
<td>Private Automatic Branch eXchange</td>
</tr>
<tr>
<td>PEP</td>
<td>Pre-employment Programme</td>
</tr>
<tr>
<td>PVC</td>
<td>polyvinyl chloride</td>
</tr>
<tr>
<td>RNZAF</td>
<td>Royal New Zealand Air Force</td>
</tr>
<tr>
<td>RNZN</td>
<td>Royal New Zealand Navy</td>
</tr>
<tr>
<td>SH</td>
<td>State Highway</td>
</tr>
<tr>
<td>TF</td>
<td>Territorial Force</td>
</tr>
<tr>
<td>TVZ</td>
<td>Taupo Volcanic Zone</td>
</tr>
</tbody>
</table>
Part 1
Crustal Events and Damage

Introduction

Early in the afternoon (at 1.42 pm) of Monday, 2 March, 1987, an earthquake of modest magnitude generated intense and destructive ground shaking at and near Edgecumbe in the Bay of Plenty (see Figure 1). It startled Rangitaiki Plains communities by the jolting violence of its motion and dismayed them by the damage it did to their properties, to industrial and rural developments in their midst, to road and rail links, to services and to communications. Shaking was more vigorous than had been felt for almost 20 years in any settled part of New Zealand. The country had been enjoying a period of unusual seismic quiescence.

This earthquake offered uncommon opportunities for study. It was larger than other New Zealand events historically associated with normal faulting. It had precursory small earthquake activity, unusual for a destructive New Zealand event, and it, together with each significant fore- and after-shock, was well recorded. High quality geophysical and geological evidence was available and there is reason for confidence in the results from the detailed and voluminous analyses that have been done.

Engineering observations included strong motion acceleration time-histories for the free field and for responses in a large embankment dam, and surveys of damage to the ground, to lifelines and to buildings. These data have also been studied carefully.

The setting

Faults trace like loosely braided fibres in a 250 km long by 20 km to 30 km wide strand between Mt Ruapehu and White Island (see Figure 2). They define the Taupo Volcanic Zone (TVZ), which contains active volcanoes and vigorous hydrothermal activity. Rock in the broader Central Volcanic Region is continuously and progressively strained in tension normal to the TVZ axis by tectonic forces, and episodically relieved of accumulated stress by fracture within the TVZ.

Crustal activity in the TVZ is most usually manifest in frequent swarms of small earthquakes which rarely generate devastating intensities of ground shaking. Typically swarm event magnitudes are small. All events occur in one compact sub-zone within the TVZ and no event is so outstandingly more energetic than others as to merit “main shock” designation. There are often many hundreds, even thousands, of events in a single swarm. Although swarms are characteristic of the TVZ, earthquakes of greater magnitude do occur there, sometimes associated with swarms and with sequences of swarms.

The North Island Shear Belt, from Cook Strait to the Bay of Plenty, consists of faults bearing generally 40 degrees or so east of north. Each fault is right-lateral and predominantly strike-slip, which means that land to the north-west of it shifts more or less horizontally and north-eastwards relative to land to the south-east during faulting. Some 60 km south of Whakatane the belt backs approximately 40 degrees, to head north and intersect the north-easterly striking system of TVZ faults in the Murupara-Whakatane region (see Figure 2), making the tectonic regime there more complex by contributing shear strains and fractures. Force systems at and near the intersection have been active in creating and deepening a depression, or graben, between the bounding faults of the TVZ (Nairn and Beanland, 1989).

Two rivers, the Rangitaiki and the Tarawera, traverse northward from the volcanic plateau across the Rangitaiki Plains, 35,000 ha of deep alluvial sediments. A third river, the Whakatane, joins from the east near the Bay of Plenty coast. The Rangitaiki Plains was a flood-prone region with an extensive swampy delta until reclaimed by confining its rivers and by draining work done early in this century. It is now a fertile and
Figure 1: Location map showing where major damage occurred in the Edgecumbe earthquake
(Scale 1:500,000)
Figure 2: Location of Whakatane Graben within the Taupo Volcanic Zone and North Island Shear Belt of New Zealand. Filled squares mark andesite/dacite arc volcanoes; outcropping greywacke is shown stippled. The star marks the location of the 1987 Edgecumbe earthquake main shock (Nairn & Beanland, 1989)
productive region given predominantly to dairy and orchard industries. Its susceptibility to flooding lessens as river containment developments and drainage improvements continue.

The Edgecumbe earthquake’s most vigorous effects were felt in the Rangitaiki Plains, and almost all the damage it did was done in that region and in its margins. The area supports a thriving population, rural and urban, with important towns being Whakatane, Kawerau and Edgecumbe. Whakatane, near the coast at the eastern extremity of the Plains, is the principal commercial and administrative centre. Kawerau, at the southern margin of the Plains, has two impressively large industrial plants producing paper and pulp from timber cut from the nearby Kaingaroa and Matahina exotic forests. At Edgecumbe, on the Rangitaiki River, dairy products are processed in a large plant and a distillery uses dairy plant by-products.

Other towns and settlements along the Rangitaiki River, downstream from Matahina dam (which is near the eastern margin of the Plains and is important for the generation of hydro electricity), are Te Mahoe, Te Teko and Thornton. Matata is a small coastal village west from the mouth of the Tarawera River, and Awakeri is a small inland town at the eastern edge of the Plains, 13 km by road from Whakatane.

Beneath the Rangitaiki Plains is a downthrown greywacke graben floor (see Figure 3), both bounded and intersected by normal faults of the TVZ system (a normal fault is one which dips in the direction of the downthrown side). Geological evidence has been interpreted to provide a measure for the rate of descent of the floor, which is estimated to have averaged 1 mm to 2 mm per year throughout the last 400,000 years of graben development. Although much of the movement would have been accompanied by seismic activity, with energy released in events comparable with the 1987 Edgecumbe Earthquake and also in swarms, land surveys disclose evidence for progressive and significant quiet aseismic displacement.

As the graben deepens, deposition of alluvial sediments transported by rivers from their catchments and of ignimbrites ejected by formerly very active neighbouring volcanoes, continuously restores ground surface elevation in the Rangitaiki Plains. Many earthquake generated scarps have been buried, obliterating superficial evidence for faulting within the graben. Sediments are abundantly available from the volcanic plateau which is drained by two of the Rangitaiki Plains rivers. The maximum depth of sediment fill beneath the Plains is now about two kilometres.

Contemporaneously with floor lowering between graben walls, margins have been elevated at average rates of between 0.5 mm per year and 1.9 mm per year throughout the past 400,000 years.

Figure 3: An interpretation of Whakatane Graben structures, shown on a section approximately normal to the TVZ axis (Nairn & Beanland, 1989)
The TVZ as a whole is widening at a geodetically determined rate of 12 mm per year. The Whakatane graben widened about 600 mm in the Edgecumbe earthquake.

The earthquake

The first of the two swarms of earthquakes that occurred in the Bay of Plenty region in early 1987 commenced at Maketu, on the coast and about 30 km west from Matata, on 22 February. The second, which culminated in the Edgecumbe earthquake, began five days later; epicentres of its earthquakes cluster about a line drawn parallel to the TVZ axis between Matata and Thornton. Together, the two swarms comprised some 135 earthquakes of M_L > 3, of which the last earthquake (M_L 5.2) occurred seven minutes before the Edgecumbe earthquake and had a closely adjacent focus. The second swarm is retrospectively recognisable as precursory to the Edgecumbe earthquake (M_L 6.3) which occurred at 1:42 pm New Zealand Standard Time on Monday, 2 March, 1987. The main shock epicentre was located a kilometre or two inland from the Bay of Plenty coast and about 4 km east of Matata. The focal depth was 8 ± 3 km. More than 400 aftershocks greater than M_L 3, the largest of which was M_L 5.7, followed the main shock.

Foreshocks and aftershocks were unusually well recorded and their data have been intensively studied (Smith and Wood, 1989).

Intensities of shaking

Assessed Modified Mercalli (MM) intensities are shown in Figure 4. Shaking in the epicentral region (which is also, for this event, the region of strongest shaking) was more vigorous than would have been predicted for an event of this moderate size by the prognostic procedures available in 1987 (when it occurred) probably due to unusually shallow energy release. Although not mapped by the isoseismals of Figure 4, intensity MM X was reported at locations in Edgecumbe. Anomally intense shaking might also have been felt in a residential area on the crest of the eastern hill in Whakatane, due perhaps to local topographic enhancement of earthquake motion. Elsewhere damage occasionally exceedd expectations for the shaking intensity an area experienced, this being due to causes other than shaking. For example, damage to several houses built on the Ohope Beach foredunes may have been associated more with differential settlement in the foundation.
sands than with the direct effects of the inertia forces generated by shaking in the framing, linings and cladding of the buildings.

**Strong motion records**

The strongest foreshock and the main shock were both recorded on all five strong motion accelerographs installed at the Matahina dam on the Rangitaiki River, 21 km from the epicentre, 15 km from the centroid of the zone of most intense ground shaking and 11 km from the nearest point of the ground surface trace of the Edgecumbe Fault (McVerry et al., 1989). Matahina is an embankment dam 85 m high with a weathered greywacke core and hard ignimbrite rock shoulders, commissioned for power generation in 1967. Although the site lies within MM intensity zone VIII (see Figure 4), the intensity reported for it was MM VII.

The strongest aftershock and some others which occurred in the first hour after the main shock were also recorded on three of the five instruments. Two instruments had exhausted their reserve of recording film and had shut down; the remaining three had ceased recording for the same reason by the end of the first post-earthquake hour.

One of the five instruments at the dam was located on ground below its downstream face. This instrument recorded the most vigorous strong motion free field accelerogram yet obtained in New Zealand (although larger accelerations have been measured by scratch plate seismoscopes). The record is remarkably similar to the 1940 El Centro, California, earthquake accelerogram, processed information from which has long been used in engineering structural design and structural resistance appraisals. This is shown in the comparison of their 5% damped acceleration response spectra in Figure 5. Records for Edgecumbe 1987 and for El Centro 1940 were made at sites similarly located with respect to sources of energy release, and the durations of strong shaking at the two recording sites were similar.

People who interpreted and processed the Edgecumbe record warn that this spectrum of strong motion responses should not be accepted uncritically as typical for New Zealand earthquakes. The TVZ, whence came the record, shares some geophysical characteristics with California, enough to make behaviours comparable, but it differs in important respects from the rest of seismic New Zealand. The other four Matahina instruments were located in the dam to measure its response. They recorded enhanced motion associated with the prime mode natural frequency of the structure, as expected.

![Figure 5: 5% damped acceleration response spectra, Edgecumbe earthquake (1987) at Matahina dam, and Imperial Valley earthquake (1940) at El Centro, California](McVerry Cousins and Hefford, 1989)
Ground damage

Normal faulting surface ruptures associated with the main shock occurred in at least eleven discrete places throughout a tract of country 8 km broad by 16 km long. The strike of these surface manifestations of crustal fracturing was north-east, parallel with the alignment of the TVZ axis (see Figure 6) (Beanland, Berryman and Blick, 1989). The most prominent and longest scarp is the surface trace of the Edgecumbe Fault, a pre-existing fault, but unrecognised before the 1987 earthquake, with a pre-existing metre-high scarp some 800 years old. The new scarp is 7 km long, 2.4 m high where the displacement is greatest and is downthrown to the north-west, as are most (but not all) other scarps of the 1987 Edgecumbe Earthquake.

Surface extensions occurred across the traces of faults and across those adjacent areas which are underlain by flexed soil strata. Corresponding compressions normal to the TVZ axis occurred between traces, perhaps as a result of relaxation of extension stresses in underlying rock. The earthquake also caused subsidence of up to 2 m, greatest in the vicinity of Edgecumbe, averaging 1 m in the Te Teko-Edgecumbe district, and elsewhere variable to about 0.4 m. These displacements were established by re-survey of Lands and Survey benchmarks. Further subsidence, of up to 0.2 m total, occurred at a progressively reducing rate over the first few months after the earthquake, some of it thought to be due to consolidation in disturbed near-surface soils.

Level ground liquefaction, indicated by boils of fine- to medium-grade sand, occurred in isolated locations throughout the Plains. There were dense concentrations of boils between the Whakatane-Matata road and foredunes east from the mouth of the Tarawera River, and also in a tract a few kilometres wide and about 10 km long from west of Edgecumbe to south-west of Te Teko, and at four sites near the river in Whakatane. Liquefaction also caused lateral spreading in berms adjacent to river channels, and thus promoted longitudinal splitting in riverside roads and stopbanks.

Minor slope failures occurred in road cuttings, usually in volcanic ash and poor quality ignimbrites. Shallow slope damage occurred along the route of the Matahina-Kawerau electricity transmission line, and two of the many towers sited on sharp ridge crests were slightly damaged as a consequence (Pender and Robertson, 1987).

There was an immediate increase in groundwater levels, shown by water levels in the drainage network, and

![Figure 6: Surface traces of Edgecumbe earthquake faults (Beanland, Berryman and Blick, 1989)](image-url)
there was some inundation of grazing pasture. Shallow bores discharged up to 3 m above ground briefly and groundwater levels remained high for some weeks.

**Damage to houses**

Residences within or close to zones where the felt intensity of shaking was reported to have been MM VIII or more numbered about 8000. Of these, only about 50 (0.6%) sustained substantial structural damage, principally to foundations and rarely to framing, according to the most authoritative and comprehensive of engineering survey reports dealing with housing performance in the earthquake (Pender and Robertson, 1987). Many more suffered substantial damage to chimneys or to roof and wall cladding, damage classified as non-structural in the survey. As always, whenever urban New Zealand has been shaken moderately energetically, there were large losses of house contents and expensive damage to services.

Almost everywhere timber framing survived well enough to maintain its reputation for reliability in earthquakes. Except when the supporting earth failed or was grossly displaced, damage was rare and always associated with the absence or serious inadequacy of bracing, or with split-level construction and other irregularities and discontinuities, horizontal and vertical, which are so often a feature of expensive housing. These critically impair strength and adversely affect performance. Framing in houses of simple rational design performed well in this moderate earthquake.

Foundation failures accounted for much of the serious structural damage. Perhaps none of those few failures that were caused by large deformation of the ground could have been prevented by any precaution feasible for residential construction. However, most foundation failures had another prime and preventable cause — where they occurred there was total lack of, or serious inadequacy in, bracing between floor level and ground. Many houses with no, or defective, below-floor bracing fell to the ground, or were seriously displaced, by the toppling or shifting of the piles and jack studs that supported them. This is a distressingly familiar failure mode for houses that have succumbed to moderately intense shaking in New Zealand’s recent seismic history.

Domestic buildings with concrete slabs on grade performed well, except in two cases of sliding displacement of the entire buildings together with their concrete slab floors. Each sliding building had a concrete perimeter foundation wall keyed to the ground. Above that, and separating the slab from it and from the ground surface inside (which had been levelled to the top of the wall) was laid a continuous plane of polythene vapour barrier. Everything above this polythene membrane slid as a unit. One of the tobogganing buildings was nominally dowelled to its perimeter foundation by bars through the membrane, but these were too few and too weak to prevent sliding.

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**Figure 7**: Two nearly identical houses, each on lightly braced jackstuds surmounting concrete piles. The house on the right has toppled; the one on the left is laterally displaced (R C Cooney)
Several masonry veneers to timber framed houses were demolished or damaged in the shaking. Failures were attributed to insufficient numbers of, and to inadequacies in, ties connecting these stiff veneers to relatively flexible timber framing, and also to poor fixings, especially to framing, for what ties there were. But it must be acknowledged that inherent difficulties are yet to be overcome to the complete satisfaction of engineering opinion in connecting stiff, brittle veneers to flexible support frames in such a way that neither veneers nor frames will be more than trivially damaged in moderately intense shaking. The problem has a rule-of-thumb solution given in the New Zealand Standard for light timber frame buildings not requiring specific design. This is less likely to be adequate when, as so often happens, a house with a masonry veneer also has a heavy concrete tiled or fired-clay tiled roof.

A survey reported some 2500 instances of damaged masonry chimneys, precast ordinary concrete, precast pumice concrete and brick constructions. Some were overthrown (and thus often the agent causing other damage) while others were cracked. Wherever chimneys were damaged, code-specified reinforcement required for them was absent, and few were properly tied to their supports. Investigation of the insurance record of chimney failures calls into question the reliability of damage classifications made by field inspectors and insurance assessors in the first few post-earthquake weeks. There is reason to believe that some chimney damage, perhaps a very significant proportion of all chimney damage, was due to thermal causes and was mistakenly ascribed by inspectors to the earthquake. For discussion see pages 37 and 38 in Part 2.

Almost universally, timber-framed houses built in New Zealand since World War II have internal linings of paper-faced gypsum plaster board, with applied plaster flushing finishes where sheets butt together and over nailed fixings. When nailed properly to studs and

Figure 8: A pole platform house of irregular shape (R C Cooney)

Figure 9: This broken pole once supported part of the house in Figure 8 (R C Cooney)
Figure 10: A collapsed panel of brick veneer (R C Cooney)

Figure 11: Half the upper floor of this house is on post and beam, and half on concrete block. Beam attachments to the blockwork failed (R C Cooney)

Figure 12: A displaced solid fuel stove (R C Cooney)
dwangs of the framing, plaster board is currently credited with conferring on the wall it lines considerable resistance to racking forces; but when a plaster board lined wall is subjected to racking loads, finishes are often marred by cracks through flushing plaster at sheet edges. These appear when shaking is moderately intense. Sheet margin plaster cracking was prevalent in housing which survived the Edgecumbe earthquake. There was, however, plenty of evidence that gypsum board linings did effectively counter racking forces generated in buildings by the shaking. Yet to be determined is the reliability of this resistance in buildings which are required to endure a greater earthquake with a longer duration of intense shaking and greater acceleration peaks than were experienced in the Edgecumbe earthquake.

Miscellaneous damage included the following:

- fractures at connections between toilet bowls and sewers, occasionally with cracking of the bowls;
- displacement of header tanks and hot water cylinders with consequent damage to plumbing, escape of water, and the damage caused by this;
- dislodgement of unsecured or inadequately secured heavy concrete roofing tiles, especially of gable and hip ridge capping tiles;
- failures in unreinforced and poorly reinforced concrete masonry house construction (instances at one house only were reported) and garden walls, some (but few) of which were overturned;
- bursting, collapse and toppling of water storage tanks for houses not served by an urban water reticulation system, and failures of the stands which had supported them;
- displacement of solid fuel space heating stoves and their unsecured hearths, with consequent damage to flues and other items; and
- damage to houses under construction, most notably to two-story houses having substantially more work completed upstairs, and thus more mass there, than downstairs, where bare framing had to support loads without stiffening and strengthening help from cladding and where temporary lateral support was lacking or inadequate.

**Damage to commercial buildings**

Commercial buildings (for this report these are retail stores, and office and administrative buildings that are not associated directly with industrial complexes) performed well. There were some exceptions, the most

![Figure 13: Overturning of bookshelves and filing cabinets and the spilling of books from shelves in the library of Edgecumbe College. Note the directional nature of the shaking is very evident (Whakatane Beacon)](image-url)
notable of which was a relatively new, large, mall-type retail building, called Riverslea Shopping Centre, in Edgecumbe. Also in Edgecumbe, shops with bearing walls of substantially unreinforced concrete masonry suffered damage. These were especially vulnerable because the arrangements of their wall elements for earthquake resistance were all poor. Commercial buildings elsewhere, most in the earthquake affected region’s MM VIII and MM VII intensity zones, were unscathed structurally, even although much of the building stock was in the construction category “Earthquake Risk Building” (ERB) as it was then defined.

Riverslea Shopping Centre, which was built in 1974, suffered critical damage. It was condemned by a decision taken sixteen days after the earthquake, and demolished two months later. Most of its 6,300 square metre retail floor space was in single storey construction. Support for its perimeter wall and its light roof was through a set of widely spaced multi-bay pitched-portal structural steel frames with trussed rafters and concrete encased rolled steel column legs. The floor was concrete on grade, the perimeter walls were precast reinforced concrete, and the roof was light-gauge profiled steel sheet.

The earthquake distorted the ground under Riverslea, so that the structure was strained and critically damaged. Chances of survival might have been improved had there been ties to control relative movement between
foundation units, but there were none. Ceiling tiles, supported before the earthquake in a metal track system which was not braced as rules now require (the rules were not in force when Riverslea was built), were displaced and fell. The lighting system was extensively damaged and retail stock fell from display stands, racks and shelves. There was structural distress but no collapse. To at least some of its tenant retailers, the Riverslea Shopping Centre appeared to be salvageable — they tidied their stocks, dusted off and attempted to resume business, their efforts being finally thwarted by the unfavourable result of structural investigations.

Also condemned and demolished after the earthquake for the damage suffered was the timber-framed two-storey Plains Hotel building which housed the only licensed liquor store and bar in Edgecumbe. Apparently this old building survived the earthquake with its framing more or less intact. However, the plumbing did not fare so well, especially under the ground floor, perhaps because there was no bracing between the ground floor and the ground to control displacements. This is a ubiquitous fault in old wooden houses and other buildings. Gross ground deformation apparently ruptured drains beneath the building. Documentation is not accessible, so identification of the shortcomings and of damage is conjecture.

In several Edgecumbe commercial premises unreinforced
concrete masonry bearing walls were damaged, primarily by effects of in-plane shear. There were also one or two minor flexural failures caused by face loading of low parapet extensions of party walls through roofs, and a few problems associated with permanent displacements of the ground in which walls were founded.

Energetic shaking, particularly in Edgecumbe, but also elsewhere in the earthquake affected region, emptied shelves and racks of their contents. There was damage to retail stock, which was spilled, and disarray of records, which were scattered, but no storage or display rack system is known to have failed in any commercial building.

Tiles were displaced from the ceilings in several commercial buildings, with most of the support installations for them having been completed before building controls requiring earthquake resistance capacity took effect. However, nowhere, other than at Riverslea (where, fortunately, the tiles were all light weight), were extensive ceiling areas involved in these failures.

Fixings to building services frequently proved inadequate for survival. At one building, connections for an entire fire compartment sprinkler system failed, allowing the assembly, with all its plumbing more or less intact, to drop from ceiling to floor of the fire compartment it had formerly been protecting.

Show windows that were subjected to energetic shaking behaved much as they have been observed to behave in every comparable New Zealand earthquake. Several silicone connected non-coplanar arrangements of vertical glass panes (angled show windows) shattered due to corner stress effects.

As has always been observed when moderately intense and stronger shaking has occurred in urban New Zealand, windows were broken wherever in-plane shear deformations of the walls containing them exceeded glass-protection movement allowances.

An inadequately secured lift motor was displaced at one Whakatane commercial building.

**Damage to Whakatane Hospital**

A six-storey flexibly-framed reinforced concrete Medical Services Block and, separated from it by a 100 mm seismic gap, a rigid shear-wall Tower Block of the same height above ground, were both built in the late 1960s. Each had a full basement and was founded on spread footings in fine oxidised sand which had been compacted to a depth of 5 m below ground level, approximately the level of the water table. Different compaction procedures were used. For the heavy Tower Block, compaction was by vibro-flotation, while for the lighter

![Figure 19: Displacement of equipment, lighting and medical supplies in a theatre of the medical services building. Note the anaesthetic trolley remained intact and appears to be undamaged (J Wink, 1996)](image_url)
Medical Services Block, the site was excavated to the level of the base of sand to be compacted, then backfilled to foundation level in individually densified layers.

Relative movement, which occurred between the buildings because they responded differently to the shaking, measured 75 mm at the seismic gap at roof level. Of this, 25 mm was permanent, probably the consequence of small foundation strain. The movement caused some superficial damage.

No structural damage was found anywhere, apart from minor cracking of the first floor beam-column joints in the frame of the Medical Services Block (Pender and Robertson, 1987).

In the Medical Services Block secondary damage was severe. The PVC piping to the hot and cold water reticulation systems ruptured in many places and PVC outlet pipes from unsecured water tanks in the plant room on the sixth floor fractured when the tanks moved and water flooded the stair towers, operating theatres, and floors below. Fittings, including power sockets, light fittings, and ceiling tiles were dislodged, lift counterweights jumped out of their guides, shelves were overturned, and medical supplies and instruments were spilt and became contaminated. This damage, together with the dislodgement of some fire protecting asbestos insulation from the light structural steel trussed beams and metal decking supporting the floor slabs was sufficient to make that building unservicable (Wink, 1996). It housed the following key departments and units: accident and emergency; operating theatres; sterile supplies; intensive care; coronary care; X-ray; laboratory; two wards; physiotherapy; occupational therapy; and administration, including computer facilities.

Damage to industrial facilities

**Tasman Pulp and Paper Company Ltd and Tasman Lumber Company Ltd**

The Tasman Pulp and Paper Mill, employing 1800 people, is situated on a 100 ha site at Kawerau, approximately 5 km from a new fault trace. The mill was constructed in the 1950s and in 1987 consisted of three paper making machines, two mechanical pulp mills, two chemical pulp mills, and a saw mill. The mill processes about 2 million cubic metres of wood per year, to produce up to 335,000 t of newsprint, 160,000 t of market Kraft pulp, and 180,000 cubic metres of sawn timber.

Annual exports total about 200,000 t newsprint, 155,000 t of Kraft pulp, and 90,000 cubic metres of sawn timber. Some Kraft pulp was supplied to the adjacent Caxton Mill.

Expansion and upgrading of the mill and its production capacity has been carried out in stages since 1955. In general, the mill structures reflect the advances in earthquake engineering that have occurred in the period, together with the changes in the loadings and structural materials codes of the New Zealand building bylaws. The mill layout in 1987 is shown in Part 2 (Figure 47, page 45).

The mill expansion in the 1960s included the No. 2 Paper Machine Room and the No. 2 Recovery Boiler. The 1970s expansion included the No. 2 Pulp Mill, Pulp Drying Building, Refiner Groundwood Mill, and No. 3 Paper Machine Room. The next major addition was the Chlorine Plant extension which was built to the requirements of NZS 4203:1976 and the related materials codes.

The major mill buildings were, for the most part, constructed in reinforced concrete with deep structural steel roof trusses, heights of about 20 m to 30 m and with a differing number of floors, part floors and mezzanine floors to suit the manufacturing process. Many of the earlier buildings had reinforced concrete frames with concrete masonry walls or unreinforced brick infill panels. Later buildings had ductile moment resisting frames. Other major buildings were in structural steel with horizontal loads resisted by concentric cross bracing or, in later designs, moment resisting frames. Some of the steel buildings were relatively tall; the top hung No. 2 Recovery Boiler for instance is supported by a 50 m high structure. Other buildings, such as administrative buildings, warehouses, and stores, were more conventional one and two storey buildings of various materials and ages.

A wide range of engineering services is required for the mill operation, including electricity and natural gas supply, treated and untreated water, geothermal steam, waste water treatment and disposal and stormwater disposal. Sewers, effluent clarifiers, aeration ponds, sludge ponds, pumping stations, drains, and three bridges across the Tarawera River are components of this infrastructure.
The mill uses steam produced from a combination of sources, geothermal steam by heat exchangers, four boilers using bark and wood waste or oil as a fuel, and two recovery boilers which burn black liquor from the chemical process. Three turbo-alternators, one of which operates on geothermal steam, produced 23 MW of electricity.

The subsurface materials at the mill site were found, during the extensive geothermal drilling in the area, to consist of 50 m to 100 m of alluvial pumiceous sands, silts, and clays, overlying numerous layers of volcanic material and greywacke bedrock at a depth of between 900 m and 1200 m.

The earthquake caused widespread damage and almost every building suffered. Damage to the mechanical and processing plant was not extensive. Most damage occurred to the No. 3 Paper Machine which, despite the foreshock, was operating at almost maximum design speed when the earthquake struck.

Damage to buildings, plant and services was as follows.

1950s reinforced concrete
Frames had inadequate confining steel in plastic hinges and in corbels. Where frame action between concrete columns and deep steel trusses had not been considered in the design, extensive damage occurred to the concrete at the roof truss supports and connections. Lower down, below operating floor levels where sufficient strength was provided, little damage was observed.

1950s structural steel
Cross-bracing was extensively damaged and in many cases failed at end connections, causing a change in building stiffness and a reduction in acceleration response but an increase in displacement response. One large masonry fire wall collapsed due to failure of attachments to a steel frame.

1960s structural steel
Moment resisting frames performed well but cross-bracing, although stronger than in earlier structures, suffered extensive damage and many bracing members failed at end connections.

1970s structures
Concrete structures performed well, but the large amount of spalled cover concrete falling from frames where
plastic hinges formed and from damage at corbels caused a hazard to workers during the earthquake and in the evacuation. The internal height of many of the buildings exacerbated the problem.

Steel structures were cross-braced in one direction and moment resisting in the other. The cross-bracing, usually much stronger than in the earlier structures, typically suffered some yielding but generally performed well. In some structures, holding-down bolts to columns of braced bays suffered heavy damage. In the case of the Refiner Mechanical Pulp Mill, the steel columns to the bracing bay in the south-west corner were held down by 36M bolts, four per column. After the earthquake, it was found that the threads of these bolts had been stripped or the bolts had fractured. There were indications that 60 mm to 70 mm of vertical movement of the column base plate had occurred relative to the concrete base.

Recent structures
Buildings constructed in the period immediately before the earthquake mostly performed well, except where adjacent buildings of differing structural types were interconnected.

Bridges
There were three bridges over the Tarawera River serving the mill at the time of the earthquake, and an overbridge was under construction with the superstructure almost complete. Detailing of the bridges generally followed the standard New Zealand Ministry of Works and Development details.

The road overbridge suffered no apparent damage, and the two continuous steel truss pipe bridges, carrying the 1.5 m waste water line and the geothermal steam line over the Tarawera river, were also undamaged apart from buckling of the transverse bracing at the ends of each of the bridges. The road bridge over the river, which consisted of prestressed concrete I beams on lead-rubber bearings and a continuous reinforced concrete deck, suffered damage only at the abutments where, even though an 85 mm expansion joint had been provided at each end of the bridge, both abutment seismic knock-off sections were dislodged.

Water supply
The raw water intake and pumping station, built during the original mill construction, was badly damaged due to ground movement which caused tilting and settlement of the pump and motor foundation slabs or rafts. Underground mains were damaged, particularly 200 mm and 300 mm diameter asbestos cement pipes, and leaks occurred at Gibault joints.

Sewers and effluent treatment
Ground damage caused breaks and opened up joints in the 1.25 m and 1.5 m effluent mains, and minor damage to the sewers within the mill site. The 600 mm fibreglass acidic effluent line from the bleach and chlorine plant collapsed. Differential settlement of the 83 m diameter effluent clarifier occurred in the form of a 70 mm tilt and a drainage pump station in the treatment area settled 1.5 m.

Paper machines
The mill has three paper machines that produce a 6.8 m wide sheet at the winder. The machines were installed in 1954, 1962 and 1975, but have been continually upgraded to improve product quality and efficiency of operation, and to maximise production. The three machines are each about 100 m long and about 14 m high.

Details of the paper machines are shown in Table 1.

The primary damage to all three machines was the fracturing of cast-iron components which supported rolls or formed part of the frame structure. Most of the damage occurred in the dryer section of the machines. Additional damage was caused by falling felt rolls. Damage was least in No. 1 machine, significantly worse in No. 2 machine, and greatest in No. 3 machine.

Steam plant
Apart from the two recovery boilers, damage to the steam plant was relatively light. Damage was limited to


<table>
<thead>
<tr>
<th>Machine</th>
<th>Production</th>
<th>Design Speed</th>
<th>Speed at time of main shock</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tonnes per annum</td>
<td>m/min</td>
<td>m/min</td>
<td></td>
</tr>
<tr>
<td>No. 1</td>
<td>80,000</td>
<td>615</td>
<td>600</td>
<td>Operating normally</td>
</tr>
<tr>
<td>No. 2</td>
<td>120,000</td>
<td>900</td>
<td>400</td>
<td>Running down, tripped by foreshock</td>
</tr>
<tr>
<td>No. 3</td>
<td>130,000</td>
<td>1000</td>
<td>950</td>
<td>Operating normally</td>
</tr>
</tbody>
</table>

**Table 1: Details of paper machines at the Tasman Pulp and Paper Mill Kawerau plant**

the displacement of steam lines from supports and spring collapse in some hangers. There was, however, some structural damage.

Recovery boilers burn cooking-process residues which contain dissolved organics derived from wood and caustic pulping chemicals. The resulting molten smelt reacts vigorously with water. Overseas experience is that most recovery boiler explosions occur when ruptured boiler tubes discharge water on to smelt. Fortunately, no explosion occurred in either recovery boiler.

**No. 1 Recovery boiler**
The No. 1 recovery boiler is the original unit on the site and was constructed about 1954. The boiler support structure is a cross-braced steel frame about 29 m high.

There was extensive failure of braces at connections and at sections reduced by corrosion or where the structure had been modified. Many braces buckled when the opposite diagonal failed in tension. It is estimated that 75% of the bracing in the structure failed and this led to large sway displacements. As a result, the brittle asbestos cement cladding was also extensively damaged. The progressive increase of flexibility of the total structure may have contributed to the survival of the various substructures. The refractory lining of the boiler and the reinforced concrete electrostatic precipitators were badly damaged. The main steel stack collapsed laterally at mid-height due to buckling and the formation of a hinge. Corrosion had reduced the wall thickness of the stack and contributed to the failure.

**No. 2 Recovery boiler**
The No. 2 recovery boiler manufactured in the 1960s and rebuilt about 1985, is a top-hung boiler supported by a cross-braced steel structure, 50 m high. Guides or “earthquake stops” are provided which allow unrestricted relative vertical movement and about 12 mm relative horizontal movement. The stops were designed to resist elastically a force equal to about 10% of the boiler’s weight.

Many of the stops collapsed in the earthquake but still achieved the design aim and prevented severe impact of the tubes on the boiler structure and the possibility of an explosion. Relative displacements of up to 150 mm occurred at the top of the boiler causing damage to ducts and other attachments. Some tubes and economiser baffles failed.

**Figure 21: Collapse of the Tasman Mill No. 1 recovery boiler chimney at mid-height. Corrosion contributed to the collapse (Whakatane Museum)**
The overall performance of the boiler and structure was regarded as satisfactory.

**Other plant and equipment and building services**

A leak in a pipeline of the chlorine dioxide manufacturing plant occurred as a result of the shaking, but the chlorine dioxide solution discharge was quickly isolated by the operators before it became a serious problem.

Damage to overhead travelling cranes was mainly to rail studs where cranes were parked.

Registered pressure vessels did not appear to have been damaged in any area of the mill. In a few cases, holding-down bolts to vessels yielded.

Spectacular and potentially hazardous failures of sprinkler systems occurred within several mill buildings. The principal causes of the failures were pipe mains not restrained against sway, pipe sections not designed to accommodate movement between building elements, and fixings inadequate for the imposed loads. Some of the pipes and fittings had corroded and this may have contributed to the extent of the damage.

Light fittings also fell to the floor as a result of the shaking. Some fittings weighing about 50 kg were particularly dangerous to people during the earthquake and in the evacuation. Many fittings fell as a result of suspension chains failing and, in the case of fluorescent fittings, hooks becoming detached from chains (Hodge, 1988; Jury and Sharpe, 1987).

**Caxton Paper Mills Ltd Kawerau (Now Carter Holt Harvey Tissue)**

The mill is situated on the right bank of the Tarawera River between the river and the Tasman Mill. The geological features of the site and distance from the earthquake epicentre are similar to the adjacent Tasman Mill.

The Caxton Mill employed 440 people and manufactured tissue of various types, and paper. Tasman supplied Caxton with Kraft pulp. The mill was commissioned in the mid-1950s and has been progressively expanded and upgraded since then to increase production. The layout of the mill in 1987 is shown in Part 2 (Figure 48, page 50).

The main elements of the plant were: a pulp mill, a pulper building, three paper machines, warehouse, finishing store, steam plant, workshop and roll store, main store, chemical store, storage tanks, underground services, water treatment plant and office buildings. Buildings for a Bleached Sulphonated Chemi-Thermo Mechanical Pulp Mill (BSCTMP) and Product Press were structurally complete at the time of the earthquake and plant was being installed. A geothermal steam line runs north to south through the mill site.

**Pulp mill building**

The building was built in 1966 and consists of single and two-story sections with structural steel moment frames and braced bays. The aspect ratio (height to span) is 0.46. Walls are concrete masonry to 1.2 m. A 10 t overhead travelling (OT) gantry crane operates in the two-storey section.

The main earthquake damage was to wall and roof bracing which yielded, buckled or fractured. There was also evidence of relative deformations of up to 100 mm between the Pulp Mill and the Product Press building. The gantry crane jumped off the rails but did not fall.

**BSCTMP building**

The single-storey building was built in 1986 and consists of precast reinforced concrete moment frames with steel angle cross-braced bays. The aspect ratio is 1.13. The walls are precast reinforced concrete panels to 2.0 m. A 25 t OT gantry crane is installed.

Damage was caused to bracing which yielded, precast panel fixings, wall and roof cladding, flashings, pipe supports and platform brackets.

**Product press building**

The single storey building was built in 1986 and is similar in construction to the BSCTMP building but with an aspect ratio of 0.73 and a 10 t OT gantry crane.
Damage was similar to that in the BSCTMP building.

High and low aspect ratio stainless steel tanks and vessels were empty at the time of the earthquake and were undamaged, but the holding-down bolts to the chip silos, which were not detailed for ductility, suffered damage.

Steam plant

The steam plant building is single storey, built in 1969 of structural steel columns and roof trusses, tension rod bracing in the south wall and reinforced concrete masonry shear walls to 8 m in the others. The aspect ratio is 0.8.

The earthquake caused substantial relative movement between the steam plant building and adjacent buildings as well as movement in the floor joints. Damage was caused to precast panel fixings, roofing, cladding, flashings, internal concrete masonry walls, pipe and equipment supports and brackets, and the bottom fixings of glazing mullions which allowed a number of glass panes to fall to the pavement below. The tension rod bracing yielded.

Paper machine No. 1

The building, which is single storey and the oldest building on site, was built in 1955. It consists of structural steel moment frames of columns and roof trusses and steel angle cross-braced bays. Five tonne monorail hoists operate throughout the building.

Paper machine No 1 is a small, low machine, of a pre-World War II design and is the oldest paper machine on site. The paper machine, MG cylinder and major plant items are supported on structural steel frames that resist seismic loads by frame action in one direction and cantilever action in the other.

Damage to the building and plant was minimal and consisted of local damage to walls, flashings, concrete plinths and ventilation ducting.

Paper machine No. 2

The single storey building was built in 1964 and three bays were added to the northern end in 1985. Structural steel moment frames with castellated beam rafters and steel angle cross-braced bays were used in the original building, and similar frames, but with solid beam rafters and precast reinforced concrete shear walls, in the addition. There is no seismic gap between the two sections of building. The aspect ratio is 0.9. Two 10 t OT gantry cranes are installed.

Paper machine No. 2 consists of the original MG cylinder with a new wet-end section constructed in 1980, and a new winder section constructed in 1986. The MG cylinder and adjacent plant are supported on structural steel frames which resist horizontal forces by frame action in one direction and cantilever action in the other. The wet-end section is supported on a similar structural steel frame but is braced in the other direction. The winder plant is supported on structural steel cantilever columns.

The seismic force resisting systems of both building and plant structures are difficult to model because of the many additions and modifications carried out over the years.

The damage sustained by the building was more extensive and more apparent than for any other building on site. Large deformations occurred at roof level which damaged the roof and wall claddings and flashings, and caused a permanent bow in the crane rail over the central portion of the original building and the addition. The bolted joints, rafter to column, at the eastern knee of the five central frames yielded, but the bolts did not. Residual displacements to the west at eaves level were between 40 mm to 50 mm. Many of the columns of the main frames rotated at their bases, causing holding-down bolts to yield and concrete column plinths to spall. Steel angle cross-bracing yielded in the walls and many of the connections between the precast reinforced concrete shear wall panels and the steel columns failed, particularly at the junction of the addition with the original building. A number of other connections to precast panels, supports and brackets failed or were cracked.

Plant damage consisted of the shear failure of all the bolts connecting the MG cylinder support frame to the mezzanine floor of the building.
Paper machine No. 3
The single storey building was built in 1973 and has structural steel moment frames and steel angle cross-braced bays. The aspect ratio is 0.8. Walls are of reinforced concrete masonry from floor to roof level between concrete encased columns. A 10 t OT gantry crane is installed and in addition a 5 t OT gantry is installed in the winder area.

The building is divided into two parts, the eastern section housing paper machine No. 3 and winder with about 70% of the floor area, and the remainder the built-in chests for stock preparation.

During the earthquake, the deformations of the building at roof level were high due to the amount and mass of plant at high levels on the mezzanine floors and the mass of the high masonry walls. Considerable damage was done to flashings and to the built-up roof system and reinforced concrete masonry walls which cracked and were no longer weatherproof. The bracing to the eastern end wall yielded.

Plant damage was similar to that to paper machine No. 2. All the bolts between the prop and the MG cylinder support frame suffered shear failures. Some holding down bolts to plant on the mezzanine floor yielded.

Building services were extensively damaged and pipe and equipment support brackets were damaged or collapsed; some roof-level fixings to light fittings failed and fittings fell to the operating floor below. In addition, some exhaust ductwork at roof level collapsed and fell to the floor. Sprinkler support brackets also failed allowing pipes to sag and fracture.

Warehouse and finishing store
These single storey buildings were built in three stages between the late 1950s and 1968 and consist of light steel angle constant depth trusses and structural steel columns forming alternate two- and three-column frames with steel cross-braced bays.

Damage to the building was extensive. Roof truss chord members buckled between points of lateral restraint provided by longitudinal ties. In some cases welded connections between trusses and columns failed. Tension rod cross bracing to walls and roof yielded or, in some cases, failed at connections or turnbuckles. Flashings pulled away from fixings, gutter linings split, and asbestos cement ridge and barge cappings cracked. At the joint in the walls between the north and centre buildings there was impact damage and the joint opened up. Joints in the floor slab also opened, extensive cracking was evident, and, where the bases of the steel columns rotated and moved, there was spalling. Sections of racking in the bulk store collapsed.

Other buildings and plant
Damage to the other buildings varied from slight (for instance to Lockwood timber offices and workshop/garage) to extensive in the case of the Export Store, which was considered unsafe and later demolished. Most damage involved flashings and claddings and the yielding or failure of wall and roof tension cross bracing systems.

Shelving and office fittings in the engineering offices collapsed, and in the Workshop-Roll Store block, air-conditioning ductwork and a unit were dislodged from support framework, roof level light fixings failed and some fittings fell to the floor, and a 10 t OT gantry crane jumped its rails on the west side.

The water treatment plant was undamaged (Kerslake and Partners, 1987a).

Bay Milk Products Limited
Bay Milk Products’ Edgecumbe plant is an integrated milk processing facility which, before the earthquake, could process about 2,000,000 litres of whole milk daily. Products then were milk powder, casein, caseinates, butter and whey products. At the time of the earthquake, the Company owned and operated other plants in Te Puke and Opotiki.

Buildings, all either single-storey or two-storey, housed production plant, storage for bagged products, coolstores, cold stores, administration services and an energy centre. Most were built either in reinforced concrete or in structural steel. Those built since 1970 had piled foundations, whereas those built earlier were founded on pad and strip footings. A new casein and caseinate factory was under construction at the time of the earthquake.
Ground at the site deformed in the earthquake. Surface vertical permanent displacements relative to deep-piled foundations averaged about 200 mm, with local maxima up to 500 mm. These are indicative of the contribution of consolidation and flow effects in upper strata to the total vertical displacements caused by the earthquake, which averaged 1.1 m in Edgecumbe. Lateral displacements were of the order of 300 mm. Minor additional permanent lateral displacement at Bay Milk’s site, west towards the Rangitaiki River, perhaps associated with lateral spreading, was suggested by the appearance of tension cracks near the river bank.

Every building on the site was damaged, some severely, by ground shaking and ground deformation, or by impact from collapsing plant items, racking systems and stacks of palletised stored product. Reinforced concrete piles were cracked at pile to pile-cap junctions under recently constructed buildings due to shear and flexure induced by the earthquake. In some cases, damage was exacerbated by defects from poor construction practices.

Figure 22: An aerial view with the Bay Milk Products plant at Edgecumbe in the foreground, Edgecumbe township in the background and the Rangitaiki River between. The New Zealand Distillery Company plant is located centre right, just above the long warehouse buildings. The large building in the centre-background of the photograph is the Riverslea Shopping Centre. The road and railway bridges over the Rangitaiki river are centre-left (Whakatane Museum)

Figure 23: Collapse of large silos at Bay Milk on to buildings and services bridge. The building on the left is the cool store (Whakatane Beacon)
Figure 24: Photograph of the same area shown in Figure 23 after removal of the collapsed silos showing damage to the buildings and the services bridge from silo collapse. To the rear is the butter factory and on the right is the separation unit (Brickell Moss Rankine and Hill).

Figure 25: General view of the collapsed services bridge to the New Zealand Distillery Company’s site from Bay Milk. In the distance is the distillation tower and on the right Bay Milk’s ultrafiltration plant (Whakatane Beacon).

Figure 26: View of the Bay Milk ultrafiltration plant and the surrounding area after some of the debris from the collapse of the services bridge had been removed. The distillery is at the bottom left hand corner of the photograph (Whakatane Museum).
Figure 27: Damage to the insulation envelope, structural frame and bracing caused by impact from a loaded pallet rack in the coldstore at Bay Milk Products (HERA)

Figure 28: Distortion and partial collapse of a loaded pallet racking system in the coldstore at Bay Milk Products. Note the seismic brace in place at the top of the racking (Brickell Moss Rankine and Hill)

Figure 29: View of the collapse of a portion of loaded pallet racking in the coldstore at Bay Milk Products (HERA)
Figure 30: General view of the chaos caused by the collapsing milk silos and the damage caused to standing silos, services and services bridge. The milk silo in the foreground appears to have suffered a cantilever collapse (Whakatane Beacon)

Process equipment and storage facilities suffered significant damage, particularly such items as full or partly full milk silos, chemical storage tanks, pallet racking systems (even though these were designed for earthquake loadings), overhead pipe gantries, driers, air conditioning ducting and refrigeration equipment. Of the 100 silos and storage tanks on the site, 95 collapsed or were substantially damaged.

Effects of permanent ground deformation were to distort pavements, separate joints, and destroy or alter drainage to sumps, so that ponding occurred in wet conditions (Davy, 1992; Pender and Robertson, 1987).

New Zealand Distillery Company Ltd

The distillery, built in 1982, produces alcohol from whey products (supplied via a dedicated elevated pipeline from the adjacent Bay Milk Products Edgecumbe plant) and from grain.

The site suffered similar ground damage to the Bay Milk site. Pile supported structures in the distillery complex settled about 0.95 m and the general ground surface dropped about 1.10 m. Concrete paths, kerbs, pavements and aprons were damaged and there were drainage changes caused by settlement.

The most severe damage occurred to fermenters and to the pipe-bridge structure. One of the four fermenters, each with a capacity of 190,000 l, survived; two were reduced to stainless steel scrap, and another was not worth repairing. Discharge pipework survived intact, but most high level pipework attached to vessels was destroyed. Collapse of the fermenter vessels was initiated by failure, in various modes, of holding down bolts. These included pull-out from anchorages, nut or bolt failure, and bolts pulling through tank fixings. Impact from collapsing fermenters damaged nearby pipework, steelwork, walkways and tanks.

The services pipe-bridge, connecting the Bay Milk plant to the distillery, carried a 65 nominal bore (NB) whey line, a 65 NB clean in place line, a 75 NB treated water line, a 150 NB high pressure steam line, a 200 NB untreated water line and a 250 NB effluent return, together with smaller pipelines and services. This bridge suffered sequential failure which was started by impact at the Bay Milk end from collapsing stainless steel milk silos. According to one observer, the predominant mode of failure of support columns at the distillery end was the excessive rotation of columns where they were connected to base plates by fillet welds. The rotations were caused by large longitudinal displacements of the pipe bridge (Christianson, 1997).

Some tanks collapsed, including a 120,000 l stainless steel finished product storage tank; others were damaged or moved, including caustic and nitric acid tanks. Acid tanks and small tanks with unbraced legs failed. Concrete masonry bunds around tanks were also damaged. A tank to API requirements and a corrugated steel grain silo survived without damage.

The distillation plant tower, although subjected to large distortions, suffered only minor damage, as did the
timber-framed office building. There was a substantial loss of glassware and chemicals in the laboratory, and some equipment was damaged beyond repair in the office and the laboratory (Connell Wagner Ltd, 1987; Christianson, 1997).

Subsequently, exploratory tunnelling under tanks and buildings revealed damage to piles where they join pile caps.

**Whakatane Board Mills**
The plant, on a 40 ha site on the west bank of the Whakatane River near Whakatane, is about 5 km from the fault. It produces packaging materials of various types, kraft paper and lining boards.

Liquefaction at the site, associated with lateral spreading of the ground towards the river, was probably the cause of cracking which occurred in reinforced masonry construction. Paper machines, which were on piled foundations, were unaffected. Suspended ceilings in the control room collapsed and light fittings throughout the plant fell to the floor.

Production machinery and control equipment survived the earthquake unimpaired, so the plant remained functional.

**Industrial plant equipment and services**
Plant, machinery and equipment was damaged at the Tasman Mill and at the Bay Milk Plant at Edgecumbe. By contrast, there was comparatively little damage to such items at the Caxton Mill and Whakatane Board Mill. At Bay Milk, and elsewhere, plant, machinery and equipment was removed from damaged buildings to store for safety or repair, or transported to suppliers workshops. Building services, racking, silos and storage tanks, particularly those storing liquids, performed badly and suffered extensive damage and collapse. The design and detailing of silos and storage tanks for liquids has received considerable study since the earthquake, as have holding down bolts and restraint details.

**Damage to farms and orchards**
Of immediate concern to the rural population after the earthquake was the loss of electricity supply and water supply to farms, orchards, and houses, and damage to drainage systems and to houses, all contributing to distress and discomfort, and all impeding production.

Milking sheds, yards, and plant on dairy farms were damaged, in some cases sufficiently to render them unusable.

![Figure 31: Collapsed strainer assemblies to support systems in a kiwifruit orchard (Whakatane Beacon)](image)
At the time of the earthquake, kiwifruit vines were heavily laden with fruit almost ready for harvesting. Structures used by orchardists to train and support fruiting vines were extensively damaged and some collapsed, leaving part of the crop on the ground or close to it. Packing sheds and facilities were being prepared for the harvest, and organisation of equipment, materials and staff was under way. There were losses of wooden pallets, trays and other packaging materials in overthrown stacks and amongst wreckage strewn about storage areas. Fortunately buildings and grading plant survived, and once the debris was cleared the harvest commenced on schedule.

Land settlement caused detrimental changes to the drainage system (see “Ground damage”, p 7). Effects were soon apparent, even under the dry weather conditions prevailing at the time. Water levels were higher relative to ground levels, and tides invaded the channel system, causing high-water back-flow into farmlands near the coast.

Water bores, sources of irrigation water, were also damaged. Worst affected were bores to depths greater than 300 m, which tapped high pressure aquifers in two districts, one at the western edge of the Plains, the other at the eastern edge. Steel casings to several bores were ruptured by ground movements, allowing pumice and sand to enter the flow and to block filters, irrigation lines, and sprinklers of orchard irrigation systems. There were adverse changes in the quality of water from some smaller bores; iron levels rose sharply, rendering supplies unsuitable for irrigation systems because iron minerals have potential for clogging filters, irrigation lines and sprinklers.

New springs appeared on some farms, and copious flows from them saturated previously dry paddocks. Most new springs disappeared soon after the earthquake, but persistent flow from a few larger ones had to be diverted into nearby watercourses (Kyle, 1989).

### Damage to lifelines

#### Water supply

The water intake, treatment plant, pumping stations, reservoirs and reticulation system in Whakatane all suffered some damage, most of it minor, but the supply to consumers was not interrupted.

Before the earthquake Edgecumbe, Te Teko, Kawerau and Matata each had its own high quality spring-water supply which needed no treatment. The quality and supply to Matata was not affected by the earthquake, but sources for Edgecumbe, Te Teko and Kawerau became contaminated.

Edgecumbe township and the surrounding rural district were supplied from the Braemar Springs at the base of the range.
of the Manawahe Hills, near the Tarawera River to the west. Water was pumped from this source through 11 km of 375 mm asbestos cement (AC) main to the township. The pumping station was undamaged, but a timber stave water storage tank of 250 cubic metre capacity failed completely. The main suffered compression failures at joints, shortening it by 6 m. Most mains in Edgecumbe were 100 mm AC, laid at a depth of 750 mm. Compressions at joints, commonly 100 mm, occasionally as much as 250 mm, caused failures by collar splitting. By contrast 100 mm PVC mains suffered little damage. Rider mains were either galvanised steel or 50 mm AC laid with a cover of 300 mm to 400 mm. These mains, particularly asbestos cement, performed very poorly. Service pipes were generally polyethylene; some of these were damaged at connections to mains.

At Kawerau the reticulation system was damaged in two places: a 150 mm pipe traversing a right-of-way failed
due to ground movement, and a 100 mm pipe, carried over the Tarawera River on a road bridge, failed where the pipe entered the ground from the span, because the arrangement there was too inflexible to accommodate earthquake generated movement of the bridge relative to the ground. In addition, some 20 to 30 toby valve connections needed repair where pipes failed on either side of them.

Gas supply
Two natural gas transmission pipelines traverse the earthquake affected zone: the main line from Kawerau to Gisborne, and a lateral from Kawerau through Edgecumbe to Whakatane. Neither line was damaged. The lateral intersects the main fault twice — obliquely in its Kawerau-Edgecumbe segment, and almost perpendicularly between Edgecumbe and Whakatane. It is a 114 mm nominal bore pipeline of API 5L Grade B steel with butt-welded joints, externally polyethylene coated, laid with cover between 1 m and 1.5 m, and it normally operates at a pressure of 8.6 mPa. A precautionary post-earthquake pressure reduction was maintained until unscathed survival was assured (Hammond, 1996). Both lines, main and lateral, have underground crossings of the Rangitaiki River, and thus avoid those rupture-threatening hazards to bridge supported service lines that result from differential earthquake response motion between bridges and approach fills, and from settlements in approach fills.

Reticulation at Kawerau, Edgecumbe, Te Teko and Whakatane is through a low pressure system, normally operating at between 350 kPa and 420 kPa. Figure 52 in Part 2 (page 63) is a map of regional gas distribution pipelines and of areas supplied with gas. The network is of steel and medium density polyethylene (MDPE) pipes, 50 mm, 80 mm and 100 mm diameter, laid at depths between 600 mm and 900 mm. Joints in steel are butt-welded to API 1104 and MDPE pipes 50 mm and larger are joined by butt fusion welding. Service connection joints are socket and spigot electrofusion welded. The distribution pipelines are carried across rivers on road bridges, in MDPE across the Tarawera River at Kawerau, and in steel across the Whakatane River at Whakatane. S-bends and flexibility in distribution lines at bridge abutments protect against effects of movements of bridge structures relative to approach fills.

At Edgecumbe the system suffered slight damage (Davy, 1992), and a metering shed was displaced by the force of water escaping from a ruptured neighbouring reservoir, but supply to consumers was not interrupted there or anywhere (Hammond, 1996), nor were there fires or explosions attributable to gas leaks.

Gas supply and reticulation systems survived the earthquake in fully operational order.

Sanitary drainage
Sewage treatment plants in Whakatane and Edgecumbe suffered minor damage. Septic tanks, many of which were damaged, were in use in Te Teko and in rural areas.

Sewers in central and western Edgecumbe were severely damaged, but in Whakatane and Kawerau damage was minor. Most sewers in Edgecumbe were 150 mm and 200 mm AC pipes with fixed collars and rubber ring joints. There were also some glazed earthenware pipes. AC pipes suffered compression failures at the collars due to shortening. Almost every pipe in several hundred metres of glazed earthenware sewer lines collapsed.

Ten pumping stations with submersible pumps at Edgecumbe were undamaged, but the inlet pipe to the pumping station which handled two-thirds of the sewage from Whakatane fractured. This allowed a large quantity of silt to enter the pump sump and the pipe under the Whakatane River (Pender and Robertson 1987; Davy, 1992; Lloyd, 1987).

Storm drainage
Urban stormwater systems in Edgecumbe and Te Teko were damaged. In Edgecumbe about one-third of grit sumps and their connections to stormwater pipes were damaged or put out of alignment and one-quarter of manholes were damaged. Kerb and channel suffered extensive damage by buckling and overriding due to compression and by fracture (Davy, 1987).

Mains electricity
All incoming 220 kV and 110 kV supply to the region was interrupted either by tripping of protection equipment or by damage to substations at Edgecumbe and Kawerau.
At the time of the earthquake, the Bay of Plenty Power Board station at Aniwhenua, comprising two generators and controls, was operating with one generator synchronised to the grid while the other was undergoing its annual maintenance overhaul. Protection equipment disconnected the working generator from the grid, but the station, undamaged, continued supplying the Murupara area. By midnight of 2 March, after accelerated reinstatement and testing, the second generator was ready for service, and the station was able to supply Whakatane. Thereafter it operated as an isolated power source until grid power was restored at approximately 6 am on 3 March (van Brink, 1988).

**Edgecumbe substation**

The substation comprises three switchyards (220 kV, 110 kV and 33 kV), with transformers, control and relay room, and workshop buildings. In the control and relay room three parallel rows of control panels collapsed in domino fashion towards the operator’s cubicle, which was struck by the row nearest to it. Fortunately damage to panels and instruments was slight and there was sufficient slack in the cables to accommodate rotations about panel bases.

Damaged were 110 kV and 220 kV current transformers, porcelain support columns of circuit breakers in the 220 kV switchyard, and banks of 210 kV transformers and spare 110 kV transformers, which overturned or
jumped off the rails. Transformer hold-down arrangements failed due to weakness of transformer undercarriage to rail fastenings and to weakness of transformer tank to undercarriage fastenings (Rutledge, 1988).

**Kawerau substation**

This substation, opposite the Tasman Mill, comprises two switchyards (220 kV and 110 kV), transformers and associated controls and buildings.

Three of sixteen control panels fell, but damage to the controls was slight.

Current transformers in the 220 kV switchyard were damaged and leaked oil due to stretching of the clamping bolts at the base of the porcelain. The support system for internal windings was also damaged. Circuit breakers in both switchyards were damaged, as were 220 kV busbars. Transformer hold down arrangements failed in a similar manner to those at Edgecumbe (Rutledge, 1988).
Figure 39: Slip on the hill section of SH30 near Lake Rotoma (Whakatane Museum)

Figure 40: Composite photograph showing slips west of Matata on SH2. Reports soon after the earthquake led to fears that cars and occupants had been engulfed (Whakatane Museum)

Electricity distribution system
The Power Board’s distribution and sub-transmission systems were damaged close to and on either side of the fault, and at Edgecumbe, Te Teko and Kawerau. Secondary causes, such as slips and slumping in volcanic ash soils, west from Kawerau, also damaged the system. Aerial structures were dislodged, poles cracked or split, and at least one reticulation transformer pole collapsed. Two damaged 11 kV underground cables to spur lines were temporarily replaced by aerial connections. About 10% of aerial service leads in the Edgecumbe-Te Teko area were pulled from buildings (van Brink, 1988).

Plains zone substation Edgecumbe
At the Bay of Plenty Power Board’s Edgecumbe 33/11 kV zone substation, supply transformers overturned
and impacted with overhead 11 kV busbars, and busbars, isolators and supports in the outdoor substation were extensively damaged (van Brink, 1988).

**Telephone system**

The Telecom network remained essentially intact during the earthquake, although stretching of underground cabling did cause insulation breakdown and sheath cracking. There was also some earth dislocation.

Damage to exchange equipment was small. Ten bent fingers on crossbar switches were found at both the Edgecumbe and Te Teko exchanges and a ringer rack at Edgecumbe toppled on its side but continued to operate. The worst damage occurred at the Tasman Mill where water entered the PABX room. The large PABXs at the Caxton Mill and at Bay Milk were also put out of order.

Power supply failure caused loss of service, particularly from exchanges at Edgecumbe, Te Teko, Waihau Bay, Te Kaha, Waiotahi, and Matata, where emergency generators were not installed. Circuit availability at Edgecumbe was reduced by 50%, and at Te Teko 25% of circuits (about 100 lines) were damaged. National and international networks were severely congested and traffic controls were imposed on calls into the Bay of Plenty region (Laytham, 1988).

**Roading**

The earthquake severed both direct road routes connecting eastern with western Bay of Plenty. SH2 from Tauranga was blocked west from Matata by slips which were erroneously reported to have engulfed cars and occupants. The inland route between Rotorua and Whakatane (SH30) was blocked by numerous slips on the Rotoma Hill section (Coup, 1987).
The main fault trace crossed and disrupted both the Edgecumbe-Awakeri road (McCracken Road) and the Edgecumbe-Te Teko road. Elsewhere damage to roads was associated with liquefaction and consequential lateral spreading, with compression, and with vertical and horizontal displacements (Pender and Robertson, 1987).

**Bridges**

Road and rail bridge structures sustained minor damage in the earthquake. A common feature at almost all bridges founded on piles, and one that prevented their immediate use after the earthquake, was settlement of pavements at abutments, due (perhaps principally) to consolidation in the upper 15 m or so of soils upon which approaches were constructed. In the same way, the earthquake generated level increments between pile-supported surfaces and ground surfaces at Bay Milk Products’ site and at New Zealand Distillery’s site (see page 21 et seq.). Settlement in approach fills due to abutment movement, lack of soil confinement and inadequate compaction might also have contributed.

Several bridge substructures were damaged. At the bridge over the Rangitaiki River at Te Teko, an inadequately retained laminated-rubber bearing was displaced, and at two rail bridges timber piers were misaligned or required repairs (Pender and Robertson, 1987; Holmes, 1994).

**Railways**

The earthquake caused extensive but relatively minor damage to about 60 km of track in the Awakaponga-Murupara-Taneatua area. Compression buckling of the track caused movements of up to 2 m horizontally and 1 m vertically. Several slips were reported on the Murupara Branch line. Settlements of up to 300 mm occurred at bridge approaches. The Edgecumbe railyards suffered extensive damage.

Four trains were stranded in the section — at Hauone, at Awakaponga, at Edgecumbe (where a locomotive was overturned), and at Awakeri.

Seven bridges suffered structural damage. Edgecumbe railway station was damaged and the Centralised Train Control panels at the station were overturned and damaged. Signalling was also damaged (Holmes, 1994).

**Damage to Matahina dam**

At Matahina, a narrow canyon has been eroded by the northward flowing Rangitaiki River through ignimbrite
of andesitic composition to underlying tertiary age sediments of weak conglomerate, sandstone and siltstone. Here, in the mid-1960s, an embankment dam was constructed, rising 85 m above foundation level, to impound water and to provide a head for generation of electric power. The lake behind the dam, 4.4 square kilometres in area, was filled in 1967 and annual power generation of 300 GWh commenced (Gillon and Newton, 1991).

The dam was strongly shaken in the earthquake. Power generation was interrupted when the one operating turbine (of the two in the power house) was shut down by a shock-activated protective relay. It was resumed about 12 hours later, after a damage survey had disclosed no cause for concern. The crest of the dam spread a little in the shaking. Minor cracking appeared in the road traversing the crest near each abutment, and downstream displacement, varying from zero at the abutments to 268 mm at the centre of the crest, was measured in a subsequent survey. Settlement in rockfill shoulders, initiated by the shaking, continued for some weeks, reaching maxima of 800 mm in the upstream shoulder and 102 mm in the downstream shoulder.

An earthquake generated landslide into Lake Matahina from road work in steep country at the lake margin, created a train of small (1 metre high approximately) waves in the lake. Several of these waves were reported to have overtopped the spillway gate (New Zealand Herald, 4 March 1987) but this was not a public safety or dam safety issue though it caused some alarm to observers.

Rangitaiki River flow downstream from Matahina dam increased significantly when, as a precaution and to facilitate inspection, spillway gates were opened and the lake level was drawn down 2.5 m. To those residents downstream who were unaware of the deliberate nature of this action, increased river flow raised apprehension, lending weight to rumours of critical damage at the dam. Fear of imminent catastrophic failure, and of an immense flood wave emptying Lake Matahina then sweeping villages out to sea, spread through Rangitaiki riverside districts. There was spontaneous evacuation from settlements at Te Mahoe and elsewhere, and from schools (Muller, 1987).

**Damage to flood protection structures**

Stopbank flood protection, designed for 100-year return period floods, had been developed for the Rangitaiki, Tarawera and Whakatane Rivers. Earthquake shaking did enough damage to some 26 km of stopbanks to make repairs necessary.

Bed materials of the Rangitaiki River consist of ash and pumice of volcanic origin, with silts and clays also present. A mixture of these materials was used to build stopbanks on foundations consisting of underlying...
permeable zones in some areas and deep peat near the coast. Major damage resulted from slumping of banks on narrow berm areas where foundations were known to be permeable, and where the main fault surface rupture crosses the river. Lesser damage, longitudinal and transverse cracking, occurred to stopbanks elsewhere along the river.

The Tarawera River has a bed of coarse pumice sand from the Tarawera eruption of 1886. For economic reasons, its stopbanks were constructed of this sand (and protected with a vegetation cover) on foundation which was, in many places, interbedded peat and pumice. Stopbank failures were believed to have been linked to development of wide longitudinal cracks in the foundation, promoted by liquefaction and spreading there. These were so extensive that cohesionless bank material collapsed into them.

The Whakatane River has bed material derived from greywacke rock. Stopbank construction material graded from clay to gravel and was well compacted. The earthquake generated predominantly longitudinal cracking, usually associated with liquefaction of the foundation materials (Pemberton, 1988).

### Damage to drainage works

Farm land between the Matata-Edgecumbe Road and the coast, approximately 8,200 ha, together with an area adjacent to the Tarawera River west of Otakiri, has been developed from peaty swamp since the turn of the century. Many community pumped drainage schemes now service this area, lifting water from land near to, or below sea level, into canals or rivers. Most of these large schemes were administered by the Rangitaiki Drainage Board (Kyle, 1989).

Of the 39 Drainage Board controlled pumping stations, six were seriously damaged in the earthquake and a further seven required repairs. In addition, several private pumping stations were damaged. Rigid connections between discharge pipelines and structures (pump sumps, headwalls and the like) proved to be fracture-prone weaknesses that were exposed by the earthquake. Pipelines also failed because rubber ring joints separated (Pemberton, 1988).
Houses

General
Approximately 4000 dwellings were damaged in the earthquake. Whakatane District inspectors identified 27 houses made uninhabitable, all but one of which were either in Edgecumbe and environs or in Te Teko. These included 11 houses critically damaged and later demolished. A further 20 or so houses suffered serious structural damage.

Conditions in many dwellings which remained occupied after the earthquake were bad. Roof damage, sustained by some, caused serious inconvenience. Communities suffered loss of water, power supplies and sanitary drainage for lengthy periods. Residents camped in their houses, enduring harsh conditions and relying on water tankers, portaloos and emergency feeding stations for health and hygiene. In Kawerau, on the afternoon of the earthquake, a threat to some 40 or so houses from landslip was identified, and residents were evacuated. Elsewhere, people were compulsorily displaced only from housing which had been declared uninhabitable. Alternative accommodation found for them included several vacant, undamaged, Railways owned houses in Kawerau (Beacon, 13 March 1987). Others chose to leave their houses and not to return before aftershock activity abated. Some of these left the district temporarily.

There was nothing new in the record of seismic response of dwellings that was not understood before this moderate earthquake occurred. However, the Edgecumbe earthquake is the first of New Zealand’s earthquakes for which a comprehensive statistical survey of damage has been carried out (Dowrick and Rhoades 1990), and this is a notable first. Although more studies are needed to establish the reliability of using results from this earthquake for other regions (where seismic regimes, topography and building stocks are different), a very useful start has been made.

Chimneys
Approximately 2500 chimneys of unit masonry construction were said to have been damaged in the earthquake (Beacon, 20 March, 1987), but fewer than a thousand of these were identified in initial surveys. Most defects were not discovered until detailed inspections and smoke testing, conducted by territorial authorities and the Fire Service, disclosed their presence.

Wholesale chimney demolition occurred in the first few weeks after the earthquake. Arbitrary demolition orders, of doubtful validity after the State of Emergency had been lifted on 5 March, continued to be issued and executed, especially in Kawerau. There, and elsewhere, when chimney damage was identified in the programme of evaluation, it was often the only recorded earthquake damage a dwelling suffered. Many sites of allegedly earthquake-damaged chimneys were in zones of relatively low intensity shaking.

Chimney damage was indiscriminately attributed to the effects of earthquake shaking, mistakenly in very many cases, for the unrecognised cause must often have been heat burst. Heat burst is a ubiquitous condition caused by differential internal expansions which thermal gradients generate in flue masonry. It differs conspicuously from earthquake damage, and it is easily recognised. However, in a large random sample of Earthquake and War Damage Commission claims we examined, heat burst was never once mentioned, nor was there a record of a chimney claim having been declined.

The circumstances suggest very strongly that a huge aggregate cost was incurred for restoration of chimney damage which the earthquake did not inflict. The amount can never be known, but several millions of dollars is entirely credible. It is fair to note that many (but by no means all) condemned chimneys were demolished
before insurance assessors were given the opportunity for observation, and also that, although many assessors knew nothing about heat burst damage in chimneys, there were a few who were better informed.

The restoration programme for precast concrete block chimneys faltered because dimensions of production units had been changed when metrication of building measurements was introduced. No chimney blocks suitable for repairing most concrete masonry flues were available until May, when a precaster was persuaded to re-equip with imperial measure moulds for casting the older style of blocks (Beacon, 12 May 1987).

### Unbraced foundations

Unbraced foundation failures are distressingly familiar in houses and in timber-framed buildings which have succumbed to moderately intense shaking in New Zealand’s recent seismic history. Almost all failures of this kind in the Edgecumbe earthquake were in houses built before the introduction in 1978 of a bylaw requiring provision of means for transmitting horizontal forces from floor to ground. In those few failures caused by absence of bracing which occurred in houses built since 1978 the bracing bylaw had been either overlooked or flouted.

### Sliding buildings

Cooney (Pender and Robertson, 1987) observed that the construction fault responsible for allowing two buildings to slide (see Part 1, page 8) was not proscribed by the then current standard for those light timber framed buildings that do not require specific design (NZS 3604). This defect was remedied in the 1990 edition of the standard (Olley, 1996). Suitably strong connections are now mandatory.

Buildings that rested unrestrained on slippery bases before the earthquake were not constructed in a traditional way. Not surprisingly, bylaws in force when they were built did not forbid the defect that made them vulnerable as that would not have been foreseen by the bylaws’ authors. The measure which Standards New Zealand has taken to prevent recurrence, although adequate, is specific to the defect. It does not contemplate other defective innovations and so will not protect against them. Devising codes to control construction which is deemed not to need strength design has this problem — these codes must evolve in the wake of failures, unlike codes for rationally designed buildings.

### Roofs

Many heavy tile roofs lost their ridge cap tiles and their hip cap tiles, and more than a few lost areas of tiling in roof planes, either by impact from collapsing chimney stalk debris or because tile securing devices were absent or had corroded. Tile manufacturers and the roofing industry now provide more adequate and durable tile fixings than they formerly did, but for ridge, hip, and apex cap tiles Edgecumbe’s lesson has not been heeded. Mortar bedding, which is not effective for securing against earthquake dislodgement, remains the industry’s accepted fixing method for most cap tiles.

According to a code of practice published since the Edgecumbe earthquake (NZS 4206:1992 “Concrete interlocking roof tiles”), cap tiles do occasionally need “mechanical” fixings, but only at end tiles of ridges in ordinary circumstances. All ridge tiles need “mechanical” fixings when roofs are exposed to very high velocity winds, but the code makes no mention of earthquakes in this context, and it does not define “mechanical”. Presumably, what is contemplated is a positive cap tile tie-down which is as strong as are the nailed and screwed fixings specified for ordinary tiles in a roof plane. This code provision should be replaced by one requiring a positive tie-down fixing for every cap tile.

Tarpaulins, supplied by Railways and the New Zealand Fire Service, were pressed into service to patch damaged roofs. They remained, some for several months, until repairs were effected. Relatively few were recovered by their owners after the roofs they had been protecting had been repaired. Roofing repair work was given priority in the reconstruction scheme announced and directed by the Restoration Committee (Beacon, 25 March 1987).

### Reconstruction

Reconstruction was, in the main, achieved through the efforts of the local building industry, which, before the earthquake, had been suffering a mini-recession, so had spare capacity and was ready and eager for the task. There was some participation by building firms not normally active in the Rangitaiki Plains region.
Cost
Assessed costs reported in this section are derived from amounts determined for insurance purposes, so all are indemnity values because the natural disaster cover offered by the Earthquake and War Damage Commission at the time of Edgecumbe earthquake was indemnity value insurance. Domestic policy holders could, but rarely did, purchase replacement value cover then. The indemnity value of a dwelling was its market value, used for total losses and to limit insurance compensation for large-scale restoration of gravely damaged dwellings. The notional indemnity values of other repairs depended upon their nature. Actual cost, not diminished in any way, was appropriate for a repair to a component like a masonry veneer, durable enough to outlast the dwelling, or for a component like a single sheet of galvanised steel roofing replacing a damaged sheet in a roof, because the life of the roof is not extended by the replacement. For most components with shorter lives, like wallpaper for example, the indemnity value was generally considered to equal the product of actual replacement cost and the ratio of unexpired life to total expected life, as this ratio would have been assessed before the damage occurred.

To the sum of $20.15 million reported in *Insurance* must be added the aggregate of deductions from each claim (1%, with a minimum of $200, borne by the claimant), $0.98 million on the 3645 claims which included building restoration, and $0.19 million for the remaining contents only claims, making the total $21.32 million for assessed indemnity value of the loss in insured dwellings.

There is no extant record to help with estimating insurable but uninsured domestic losses, except for those losses incurred in dwellings owned by Housing New Zealand, so this amount must be guessed. The number of these losses is thought to have been between 500 (*Beacon*, 2 April 1987) and 750 (Allwood 1988c). Allowing for the probability that uninsured assets would have been substantially less valuable than insured assets, and that damage to them therefore would have been less costly, the estimate of loss in this category is for 600 items at an average of $2500, which is $1.5 million. Most of this uninsured loss was a charge against a relief fund.

The New Zealand Government’s assets in Housing New Zealand were not insured by commercial insurers and so losses through damage to this housing stock were not reimbursed by the Earthquake and War Damage Commission. They totalled $1.13 million (Dowrick, 1991).

Fences, paving, power line connections, swimming pools and like items were excluded from cover the Earthquake and War Damage Commission provided. No reliable estimate of the cost of repairing damage they suffered has been made and $1.7 million is allowed here.

In summary, domestic losses were $25.7 million. Assessors’ fees and related costs chargeable to dwellings investigation were an additional $1.5 million. Excluded from this summary is insurance totalling a little more than $1.1 million paid to landlord claimants on account of the additional expense of accelerated reconstruction for more than 250 dwellings. Topping up indemnity value payments to reflect some replacement value costs, according to policy provisions affecting approximately 300 dwellings, is also excluded. These are exclusions from this category only. Their costs, because they were insured, do contribute to the total shown in Table 14, page 105.

Observations
• The housing stock behaved predictably. Although the Edgcombe earthquake taught us little, it reminded us of precautions we ought to take, but do not, with construction and with securing the contents of buildings and continued neglect will leave us vulnerable. Residential construction control specifications have already been amended to require anchoring for floor slabs on grade. Tile roof construction details need review to provide for securing cap tiles positively. The merits of simple framing systems and regularity should be more widely appreciated.

Commercial buildings
Detailed surveys of the few commercial buildings structurally damaged in the earthquake are not available. Concerning the Riverslea Shopping Centre in Edgecumbe (see Part 1, page 12), it is known that absence of foundation ties was blamed for the poor performance of multi-bay pitched portal steel framing, and that gross
permanent ground deformation also contributed to the loss. The Riverslea building was a controversial one. Neither its style nor its architectural form were universally admired (Muller, 1987b), and its owners had such apprehensions about its durability (having encountered numerous expensive maintenance problems) that they had commissioned wide-ranging engineering studies of its design and construction. Matters relating to this investigation were incomplete at the time of the earthquake. Whatever shortcomings there may have been in the Riverslea building, most (apart from the absence) would not have affected its performance in the Edgecumbe earthquake. Ground deformation damage was unavoidable, and it was fatal to this building.

There is nothing new to be learned from what little is reliably known about the total loss of the old timber-framed Plains Hotel in Edgecumbe, the only other commercial building to have suffered significant structural damage.

Windows were broken in commercial buildings, among them angled display windows in retail stores, which suffered in the Edgecumbe earthquake as they have always suffered whenever New Zealand commercial districts have felt moderately intense or stronger earthquake shaking. Window angles are commonly now made with silicone jointing, glass to glass, at the intersection of vertical, non-coplanar glazing planes where formerly metal clips were used. Neither jointing method has good earthquake survival prospects, but the vulnerability of this arrangement is not a serious concern because display windows are never so far above ground level that shattering glass creates a serious hazard. When glazing planes meet at higher elevations than in ground floor walls, panes should be framed to prevent breakage by allowing in-plane racking movement between frame and glass. Direct glass-to-glass corner connections are not suitable and should never be used at these greater heights.

Costs of losses for commercial buildings are not known separately. They are included with industrial buildings and plant losses, all reported as industrial building losses. (Refer to Part 1, page 11, for a definition of the class “commercial building” for this report.)

**Schools**

An early estimation, made within a few weeks of occurrence of the earthquake, of the cost of restoring damage to schools, was for $1.25 million (Beacon, 22 April 1987). The amount actually expended has not been reported and cannot now be discovered.

**Insurance**

**Houses and contents**

In all, 4641 valid insurance claims were lodged with the Earthquake and War Damage Commission for domestic property restoration, dwellings and contents. The total paid in settlement for damaged dwellings was $13.66 million (almost half of which was for chimney damage), and $6.49 million was paid for contents of dwellings.

The Earthquake and War Damage Commission, which through payments to its policy holders, funded most of the housing restoration, was the target of criticism alleging that its procedures caused unnecessary delays and hardship. The Commission’s response was that delays were rarely, if ever, attributable to its action or inaction; inertia and error amongst householders, who were often inexplicably tardy, or who did not know with whom they were insured and were thus unable to file a claim correctly, were the potent contributors to almost every delay.

The Commission defended its record vigorously and, in the main, justifiably for its record is creditable. It had opened an office in Whakatane in the morning of the day after the earthquake, and, assisted by State Insurance and by Farmers Mutual Group, soon had three additional agencies operating; it assembled and put to work a team of 45 assessors promptly. Although most assessing and support work seems to have been expeditiously done, it is understandable that some delays, confusions and anomalies would occur to annoy claimants, who, bewildered by their experiences and anxious about their losses, would have been predisposed to be critical of the Commission. Irritations were exacerbated by resentment springing from most insured people’s ignorance about the nature of their insurance cover: they were not aware that a deductible applied to each
claim, that insurance was for indemnity value rather than for replacement value, and that services to their
dwellings were not insured, and neither were site improvements such as paving, fencing and swimming pools.
They were dismayed to find themselves out-of-pocket after completing ordinary restoration work.

Community concerns were exploited in one politician’s opportunistic comment questioning the competence
of the Commission. Even the government appointed Disaster Recovery Co-ordinator was a Commission
critic, although perhaps a little less hostile than the politician and than some disgruntled insured people, he
was strident (Coup, 1987). Most criticism was misdirected and uninformed.

Some tradesmen disliked the Commission’s policy for settling those dwelling claims for which restoration
costs exceeded $2000. For such claims the Commission followed then-standard insurance practice by
determining the settlement sum as the more attractive (usually the lower) of at least two genuinely competitive
tenders. This insistence on tendering, the critics said, impeded recovery by diverting skilled tradesmen from
productive work that they should have been doing. Because $2000 is near the median restoration cost for all
dwellings for which valid claims were filed, the tenders policy was applied to about half the dwellings claims.

Criticism of the Commission should (if tenable) have been directed at commercial insurers. The Commission
underwrites the earthquake risk part of domestic insurance that commercial insurers sell to property owners.
This is done in a manner specified quite rigidly by government regulation which the Commission has no power
to vary. Commercial insurers, who may elect to accept some risk themselves, are accountable to their clients.
They must keep clients informed about whatever is regulated; their failure to do this, if they failed, might have
exposed them to valid claims for differences between perceived damage costs and that part of them reimbursed
by the Commission. Most, perhaps all, commercial insurers did safeguard themselves by giving reliable
information to policy holders concerning the nature and extent of earthquake cover; but policy holders’
recollections were very often imperfect.

Commercial and Industrial buildings, loss of profits
Earthquake and War Damage Commission’s indemnity value cover for commercial buildings was extended
by many insured commercial and industrial enterprises to provide for top-up from indemnity value to
replacement value, for extra costs of accelerated repairs to earthquake damage and for loss of profits. These
policies were written by commercial insurers. Most commercial and industrial claims were settled without
undue difficulty or delay, and few problems arose concerning the boundary between Commission’s and co-
insurers’ responsibilities, but one claim for exceptionally costly restoration involved complex, almost
intractable problems, which required more than nine years of negotiation and litigation before settlement.

Observations
Insurance of buildings for earthquake damage was so substantially revised in 1993 that there is nothing of
practical importance to be gained from studying insurance performance in 1987 except, perhaps, that public
misconceptions of cover and the difficulties they caused might have been avoided, or at least lessened, by a
more comprehensive public relations programme. But the Commission, then more strictly controlled by
Government than it is now, could do no more than supply information leaflets. These had been prepared with
Insurance Council co-operation and distributed to all policy holders by commercial insurers before the time
of the Edgecumbe earthquake. Not until Government gave it more autonomy in 1988 could the Commission
disregard a Treasury sanction that forbade effective advertising.

Recent initiatives by the Earthquake Commission
The present General Manager of the Commission has commented (Middleton 1997) on a number of recent
initiatives which have been taken by the Commission in planning its disaster response as follows:

• The Commission is at present considering the matter of salvage items, how they may be collected, stored
  and re-used when the opportunity presents itself.

• The Commission’s new catastrophe response plan is based on the fact that considerable external human
  resources of many different skills and levels of expertise will be required to deal with an earthquake event
  of any size.
Suggestions on early claim acknowledgement, a site office for assessors and greater co-ordination of assessor movements have all been taken up in the Commission’s catastrophe response planning.

One of the ten principles upon which the Commission’s plan is based is that public relations and notifications are vital to the success of the Commission’s response and must be planned and prepared for before the event.

In regard to the provision of space at disaster sites, the Commission has already arranged with a contractor for the supply and management of office space in any of 12 centres in the country so that the Commission is independent of Government or territorial authorities in this regard.

The Commission has now identified promotion as one of the key areas of its operations.

The Commission’s proposed claims handling procedures include a three-step priority process based upon the safety and habitability of homes. A fast track procedure may be adopted for settling trivial claims as quickly as possible, but without holding up action on priority claims.

A key part of the new claims handling process will be a geographic information system and one of its main uses in a catastrophe situation will be to allocate areas to individual assessors or teams of claims inspectors.

Part of the Commission’s catastrophe training response planning is to set up a routine of training, educating and testing. Training, both pre- and post-event for participants in catastrophe response, is recognised as one of the Commission’s most important ongoing roles.

An expert group is working on the Commission’s claims quantification process, tasked with suggesting a system which does not divert the construction industry away from getting on with rebuilding and repairing peoples’ homes.

**Whakatane Hospital**

Hospital buildings survived the earthquake in sound structural condition but damage to services and contents made the six-storey Medical Services Block unserviceable (see page 15). For hospital purposes it was completely taken out of service until restored.

Patients were evacuated from this building by the staff with assistance from volunteers, and water in the basement was pumped out by the Fire Service only minutes before the telephone equipment installed there would have been inundated.

![Figure 45: New Zealand Fire Service appliances pumped out the basement of the Medical Services block which was inundated with water as a result of fractured water lines to unsecured tanks on the sixth floor of the building (Whakatane Beacon)](image-url)
Fortunately it was possible, at some inconvenience, to accommodate most patients and to relocate facilities elsewhere in the hospital. A few patients were moved to an adjacent hall. By the evening of 4 March, two days after the earthquake, a temporary accident and emergency department had been set up and was operational, as was an X-ray department with a portable X-ray machine and an ultra scanner. In addition, the computer system was functioning. Rotorua Hospital assisted with the supply of sterilised equipment and supplies. Fifty-six patients were discharged to reduce the number of beds occupied. Several patients requiring surgery were sent to Opotiki Hospital while more serious cases were sent to either Rotorua or Tauranga Hospitals. For the next few weeks, Whakatane Hospital admitted urgent cases only.

Unlike most disasters, this one caused few casualties, so medical, nursing and ancillary hospital services, augmented by volunteer services, were not extended. By contrast, the engineering staff and hospital maintenance team played a key role in the provision of temporary facilities and their resources were severely stretched.

As the hospital was a critical facility, management was able to arrange for the hospital’s professional advisors from Auckland to be on site within four hours of the earthquake. At the same time (5 pm), Civil Defence Headquarters at Whakatane was trying to contact a MWD geotechnical engineer, Mr David Jennings, who was flying by helicopter to inspect the Matahina dam, to divert him from that task to carry out an inspection of the hospital buildings for possible structural damage (see also page 83). Radio reception at the time was poor, the diversion did not take place, and Mr Jennings carried on with his original task. The incident raises the important question of conflicting priorities and instructions (Jennings, 1998).

Repairs and reinstatement of the medical services block began soon after the evacuation with priority given to the floor housing the operating theatres. The operating theatres were returned to service about three weeks after the earthquake. Floors were subsequently repaired and reinstated progressively, but it was nearly a year before the work was completed. A major cost item and the biggest single time delay was due to the removal of the asbestos fire insulation from the secondary structural steel supporting the floor slabs and its replacement with a fire retardant coating. The work also involved reinstatement and upgrading of lifts, the provision of new fire detectors, seismic restraint to plant items, the reinstatement of interior and exterior finishes and fittings, and the repair and reinstatement of mechanical services (Ridings in Anon, 1987b; Davy, 1992).

Costs
The Hospital Board and the Department of Health, perhaps prompted by the earthquake to evaluate the risk from stronger but credible shaking, took advantage of the period of damage restoration and extended it by commissioning substantial new work. This was designed to reduce the hospital’s vulnerability and to make other improvements, among them the removal of all asbestos fire proofing and its replacement with another protection system.
Since the time of the earthquake sweeping changes have been made to hospital and health administration. Although expenditure on repairs and reinstatement, and additional work on buildings and mechanical services is believed to have been about $2.1 million, costs specifically for earthquake damage restoration cannot now be clearly identified. A reasonable analysis suggests that approximately one-half of this reported expenditure is a fair indemnity valuation of the damage hospital buildings sustained. This sum has been increased to $1.5 million by adding the estimated indemnity value of hospital contents damaged or destroyed in the accounting given in Table 14 (page 105). These contents included medical, surgical and laboratory equipment and stocks.

We have established that the hospital did not have fire insurance, which, in 1987, would have qualified it for reimbursement of indemnity value earthquake loss from the Earthquake and War Damage Commission. There is a report that a substantial insurance sum was paid for a loss incurred by the hospital, but details are elusive, and we have not succeeded in finding them. We have therefore treated the $1.5 million cost of restoration as an uninsured loss.

Finally, the hospital incurred costs for patient surgery, care and other services (including laundry) which were provided by other hospitals in the Bay of Plenty region. Except for patient transport costs and some associated administrative and miscellaneous expenses, these costs are not earthquake losses. The patients were not victims, and their surgical and medical needs would have cost the Whakatane Hospital directly, rather than indirectly, had there been no earthquake. Details of administrative costs, patient transfer costs and miscellaneous costs is not so well known that an increment attributable to the earthquake can be identified. For that increment and for the cost of providing and then dismantling temporary facilities, a liberally guessed economic loss of $0.5 million is shown on Table 12 (page 102).

The above costs were met as part of a special grant of $3.16 million which Whakatane Hospital received from the Department of Health following the earthquake.

Observations

- In this earthquake, with few casualties but extensive damage to key medical and surgical departments, engineering services became the critical factor in the time taken to restore hospital functions.

- In carrying out pre-earthquake structural and mechanical services checks on critical facilities for response planning, the effect of collateral or consequential damage to secondary elements on the time taken to restore services needs to be considered.

Industrial facilities

**Tasman Pulp and Paper Company Ltd and Tasman Lumber Company Ltd**

No strong motion accelerographs were in Kawerau, where the Tasman Mill is sited, but ground accelerations recorded at Matahina dam are believed to be similar to those experienced in Kawerau. Modified Mercalli intensities of between MM VIII and IX were felt in the region of the mill, which is within the MM IX isoseismal of Figure 4. The general settlement of the site, as a result of the earthquake, was uniform and of the order of 200 mm to 250 mm. A plan of the mill site is shown in Figure 47.

Immediately following the earthquake, a large team of engineers from a number of consulting engineering offices in Auckland was engaged to assist Tasman engineering staff with earthquake damage assessments and for the design of measures to secure and reinstate damaged structures. Tasman also redeployed staff from their capital works programme to the reconstruction. These measures allowed planning for the reinstatement to proceed immediately and contributed significantly to the success of the mill’s recovery programme.

As structural damage was widespread and there were unsafe areas within the mill, a priority system for securing and reinstatement together with associated design was adopted. The three categories in the priority system were:

Priority 1: items which required securing to enable safe access;

Priority 2: items which required reinstatement before the plant became operational; and
Figure 47: Plan of the Tasman pulp and paper mill at Kawerau
(Jury and Sharpe, 1987)
Priority 3: items which could be repaired after the plant became operational.

In some instances, to meet the timetable for the plant to become operational, items with priority 1 and 2 were secured temporarily and permanent repairs carried out later.

The design objective was to reinstate the structures in a way that ensured their strength was at least as great as that prior to the earthquake, unless this was obviously inadequate. Where a higher strength level was necessary, the basis for design was the New Zealand National Society for Earthquake Engineering *Earthquake Risk Buildings* (December 1985). Where it did not delay the repair work, efforts were made to provide details to increase ductility.

**Repairs to Structural Elements**

Concrete masonry walls were restrained where appropriate by attachment to steel frames, or demolished and replaced with timber-framed walls where practicable. For the bulk of the repairs, walls were demolished and replaced with fully-grouted reinforced concrete masonry walls.

In several areas during the earthquake, roof collapse was very close due to dislodgement of trusses from their supports. In the reinstatement, lateral restraints were provided at all damaged truss seatings and other measures were employed to ensure gravity support is maintained in a future earthquake. Design now provides for safe flexural yielding to occur in the support structure whenever the new restraints operate to limit sliding that would otherwise unseat trusses. Repairs to spalled seatings consisted of steel plates bolted to the faces of columns and corbels using epoxy-grouted bolts with the gaps behind the plates filled with non-shrink grout.

Steel braces with small deformations were straightened in place while those with more severe damage were replaced. Where possible, connections were welded to allow each brace to develop its full strength. Attempts were made to plumb some buildings before reinstatement of the bracing, but most buildings were left in a deformed state because there were practical difficulties and because the small permanent deformations were tolerable.

The replacement of stretched or sheared holding-down bolts in buildings and on vessels and equipment presented difficulties. Holes for new bolts were mostly drilled adjacent to the original bolts and the base plates extended and gusseted where necessary. The importance of controlling eccentricities and of providing clearance for drilling, meant that in many cases plates were extended down the faces of columns and bolts were set horizontally. Quality assurance testing was carried out on selected replacement bolts and a number of stretched holding-down bolts were also tested to failure to determine their remaining capacity. Expanding type bolt anchors performed poorly and were replaced with epoxy-grouted threaded rods.

Many reinforced concrete elements had cracked and spalled and plastic hinges had formed in some beams and columns. In general, cracked concrete was injection grouted and spalled concrete replaced with non-shrink grout or epoxy mortar. It is estimated that over one cubic metre of epoxy was used in the reinstatement work. Where secondary steel provided inadequate binding, external steel plates were installed and grouted in place.

Buckled structural steel members were generally replaced but minor flange buckling to members was treated by heating and straightening. More severe local buckling was repaired by cutting out the damaged portions and butt-welding in replacement plates, or by welding on splice plates.

In many instances bridges, walkways, and connections between structures had fallen or were close to losing vertical support. Reinstatement design was similar to the design for restoring roof truss supports.

**Repairs to plant items**

Mechanical damage occurred in a variety of ways and in some cases was partly obscured from initial inspections by debris from failures at higher levels. Damage to plant and equipment was still being discovered nearly a year after the earthquake.

After stripping of insulation and ductwork of the No. 1 recovery boiler, extensive damage was found to the reinforced concrete shells of the precipitator chambers. After analysis of the construction times for precipitator chambers in reinforced concrete and steel, it was decided to adopt the steel alternative which, while it was more expensive by $1,660,000, accelerated the commissioning of the boiler by about 70 days.
This represented savings in consequential losses of nearly $4,000,000 plus the value of the steam generated and the by-products produced for chemical recovery. The boiler was recommissioned on 19/20 August 1987.

Many of the earthquake stops or snubbers to the No. 2 recovery boiler were damaged. Some were distorted and some failed at the connection to the support structure. These were all reinstated to the original details because these successfully protected the boiler and prevented impact between tubes and the support frame, thus averting the risk of explosion. Recommissioning of the boiler started on 5 April 1987.

Repair of the three newsprint machines was the major task in the mill reinstatement programme. The nature of the damage was common to all three paper machines, but the No. 3 Machine suffered the greatest damage. The No. 1 Machine was least damaged and was given priority for recommissioning. Staff from machine suppliers in Europe and the United States were immediately brought to the site to assist with earthquake damage assessment, advice on repairs, and assistance in the procurement of replacement parts. Where necessary, drawings and specifications were made available to allow replacement parts to be manufactured in selected workshops in New Zealand and Australia. Parts not available from the mill’s extensive spares inventory were obtained on an emergency basis from suppliers in the UK, Australia and New Zealand. The levels and alignment of all three machines were accurately checked and, where necessary, settlement compensated for by machined packers and shims. The extensive damage to the No. 3 Machine meant that a major rebuild was necessary. It took 57 days to dismantle the machine and 59 days to rebuild it. A replacement machine would have taken 2 years to supply. Details of paper machine start up and production are shown in Table 2.

Damage to overhead gantry cranes was restricted to rail studs where cranes were parked. Registered pressure vessels throughout the mill did not appear to have suffered damage although in a few cases holding-down bolts to vessels yielded.

<table>
<thead>
<tr>
<th>Machine</th>
<th>Start Up</th>
<th>Production and Downtime</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>9 April 87</td>
<td>EQ related downtime from 12 April 43.6 hours</td>
</tr>
<tr>
<td>No. 2</td>
<td>15 April 87</td>
<td>To 30 August production 88% capacity</td>
</tr>
<tr>
<td>No. 3</td>
<td>23 July 87</td>
<td>EQ related downtime from 23 July 14.5 hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td>July production 73% capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>August production 92.6% capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>September production 96.4% capacity</td>
</tr>
</tbody>
</table>

Table 2: Paper machine start up and production at Tasman Pulp and Paper Company

Maintenance costs and increased costs following start up

Following start up, there was a wide range of effects on the quality of the finished product directly attributable to the earthquake, resulting in increased costs. The effects included both technical problems (e.g. winder tension upsets, paper breaks on the newsprint machines and uneven drying) and other problems such as the control of emissions.

Plant

A premature failure of a suction press roll shell on a paper machine occurred shortly after start up. There were also unexplained roll and bearing failures which happened suddenly, even though the rolls and bearings had been subject to intensive vibration monitoring during recommissioning and running.

Earthquake repairs sometimes revealed hidden defects not related to the earthquake. The most notable were the near failures by fatigue of the journals on the rotary cascade evaporator to the No. 1 Recovery boiler.

Building services and lifelines

Post start up failures occurred in steam mains, in underground water mains and in bleach plant sewers. In the case of the last-named, there were some instances of minor chlorine dioxide emissions. There was no subsequent serious loss of services.
Structures

There were a few instances of structural damage caused by the earthquake not being discovered until after start up. These included leaks in built-up roofing systems, structural damage to a pre-evaporator support frame, and badly damaged foundation beams to the No. 2 Pulp Drier discovered two years after the earthquake when the drier was being replaced. The replacement drier weighed 400 tonnes compared to the old drier's 300 tonnes, but it was intended to reuse the existing foundations. Fortunately the drier was not on the critical path for the shutdown and the foundations were repaired at a cost of about $30,000.

Increased maintenance — duration and cost

Maintenance problems occurred over the first 12 months after start up but with diminishing frequency and severity. About 80% of the incidents occurred in the first six months and the balance in the second six months. By the end of 12 months all significant maintenance would have been through the full cycle. A reasonable estimate of the increased maintenance cost, post start up, would be 3% of the total material damage (Jury and Sharpe, 1987; Hodge and Macfarlane, 1988; Hodge, 1989).

Costs

The total cost, under the insurance cover, for repairs and reinstatement of the mill only, was $40,445,744. Included is the cost of accelerating the reinstatement programme of $2,169,934, which represents 5.4% of the total. In addition, the cost of repairs and reinstatement of housing was $6,002,997 and to the Mt Manganui Store, $529,036, both also insured.

An approximate composition of costs is shown in Table 3.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mill buildings and departments</td>
<td>$24,580,000</td>
</tr>
<tr>
<td>Mechanical and process equipment</td>
<td>$13,500,000</td>
</tr>
<tr>
<td>Power supply and distribution</td>
<td>$700,000</td>
</tr>
<tr>
<td>Steam supply and distribution</td>
<td>$260,000</td>
</tr>
<tr>
<td>Water supply and distribution</td>
<td>$1,180,000</td>
</tr>
<tr>
<td>Sewers and effluent</td>
<td>$190,000</td>
</tr>
<tr>
<td>Geothermal steam supply and distribution</td>
<td>$30,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>40,440,000</strong></td>
</tr>
</tbody>
</table>

Table 3: Cost of material damage at the Tasman Pulp and Paper Company

Indirect costs may have increased the total to about $47 million (Hodge, 1994).

Observations

- The early decision to employ a large team of engineers on site to augment Tasman engineering staff in the carrying out of earthquake damage assessments, and the design of measures to secure and reinstate damaged structures and process plant, was a significant factor in the success of the mill’s recovery programme. It was vital to the early planning and commitment of the recovery programme.

- In tall buildings and particularly those with high studs, the shedding of cover concrete from corbels, plastic hinge areas and elsewhere, can be a significant hazard to occupants.

- Sprinkler systems and heavy light fittings that were not adequately restrained and supported, fell during the earthquake and presented a particularly dangerous hazard to occupants.

Recovery period management and administration organisation

The management and administrative organisation and systems utilised in the repair and reinstatement of the Tasman Mill were important to its early commissioning. They are useful models to consider for the future.

The management systems were adapted from normal operations to meet the objectives of a large insurance claim. The recovery was treated as a major project with the necessary restructuring of specialist personnel
organisations to meet the needs of the reinstatement. Project teams, which included consultants’ resources, were formed and made responsible for specific areas of the mill. Each team handled redesign, procurement, scheduling and overview of construction.

Construction was organised in two divisions. All civil and structural work was carried out by Fletcher Construction under their own Construction Manager and all mechanical, electrical, instrumentation and rigging work was controlled by the Tasman Maintenance Manager.

The area engineers created work orders based on the damage assessments/inspection reports. The work orders were recorded in the maintenance programme so that each job could be tracked for the insurance claim. The cost system coding was modified by creating additional codes to identify the repair costs of items covered by EQ&WDC, the repair costs of items not covered by EQ&WDC, and betterment arising from the repair of items covered by EQ&WDC.

To overcome possible problems from mis-coding, the process was audited by the adjusters.

Code headings used were: underwriters debris removal; commission repair; commission make safe; joint replacement; joint repair; and underwriters repair.

Once this information was entered into the computer, the area engineers progressed the job as they would a normal mill project. Estimates and critical path programmes were prepared, and in turn these were coordinated by the project managers before consolidation and overview by management and the insurance assessors. Financial authority levels were relaxed somewhat compared to normal project controls, to avoid bottlenecks created by the large volume of urgent work. All procurement orders were processed through a single purchasing officer, who also had the responsibility to co-ordinate the transport of materials to the site. Transport from overseas was by air freight.

The diverse operations, large labour force, and the number of organisations involved, necessitated the holding of a large number of meetings. Special meetings were held to deal with specific problems and the routine for normal operations and communications concerned with the reinstatement.

Special meetings included those to make decisions on the No. 1 Recovery Boiler precipitator, alignment tolerances on the No. 3 Paper Machine, planning roll shop priorities for paper machine rolls, and for discussions with overseas insurance assessors, suppliers and local authorities.

Routine meetings included daily progress meetings (involving the construction, maintenance, and industrial managers, procurement and safety officers and production personnel), twice weekly meetings with insurance assessors, weekly design meetings with consultants, a weekly mill overview, and regular meetings with various unions. The organisational structure changed more than once during the recovery period (Hodge, 1989).

**Caxton Paper Mills Ltd**

The Caxton mill, a neighbour of the Tasman mill and on a similar site, would have experienced the felt intensity of shaking and the ground accelerations that the Tasman mill did. A plan of the mill site is shown in Figure 48.

After evacuation of the mill and a check on personnel, a preliminary damage assessment was carried out. This disclosed that there was very little damage to mechanical plant. There was some damage to sprinkler systems, a 100 mm steel water main had fractured, light fittings had fallen, ducting had collapsed and racking in the stores had overturned. Electrical switchboards and motor control centres had moved about but were still operable, and the most serious mechanical damage was that cranes had jumped their rails though they had not fallen. The steam plant, including boilers, was still functioning, and the water treatment plant was undamaged. In the opinion of management, had power and staff had been available, the mill could have been operating within 24 hours of the event, albeit with limited production.

Volunteers were called from the maintenance staff to carry out immediate repairs to plant to get the mill running again. Six tradesmen volunteered and in the next few days worked hard and for long hours in spite of the uncomfortable working conditions caused by the many aftershocks. The electricity supply was out for four days and for the next few days was only available for limited periods.
Figure 48: Plan of the Caxton Paper Mills at Kawerau (1987)
(Kerslake and Partners, 1987)
There was quite extensive damage to structures and civil construction and a team of engineers familiar with the layout, design and construction of the mill commenced an earthquake damage assessment on the day after the earthquake. The initial damage assessment took four weeks.

The mill started production 10 days after the earthquake as follows:

- No. 1 Paper machine 12 March
- No. 2 Paper Machine 13 March
- No. 3 Paper machine 14 March

Full production was achieved on 15 March 1987.

The main elements of the reinstatement programme were as follows.

- **Pulp Mill buildings and Steam Plant:** replace wall bracing, damaged wall panel fixings, damaged cladding and flashings and glazing; repair spalled concrete at connections and edges of pre-cast wall panels; repair spalled concrete at pre-cast concrete panel fixings and replace fixings; replace holding down bolts on chip silos; replace or reinstate roof bracing; reinstate and weather-proof cladding.

- **Paper Machines buildings:** repair and reinstate blockwork, tie blockwork to the structural steel frames and weather proof; reinstate concrete bases to structural steel columns and grout in new holding down bolts. Replace pre-cast concrete shear walls with structural steel bracing; repair fixings to pre-cast concrete wall panels; replace bolts in crane beams and in crane beam to column corbels; seal cracks in basement floor joints and repair spalled concrete.

- **General:** check and replace roof level light fittings; check and reinstate sprinkler systems; demolition, temporary repairs, clean up and removal of debris (Kerslake and Partners, 1987; interview Caxton, 1995).

**Costs**

Repairs to buildings and services cost $10.75 million, and to plant and mechanical items approximately $1.0 million, the latter a writer’s estimate. The assets were insured.

**Observations**

- The problem in recommissioning the mill was not a technical one but a social one and a matter of encouraging the labour force back to work in spite of all the emotive issues involved.

- Certain types of damage did not become apparent until some time after start up. For instance, level and alignment checks on the paper machines at the time failed to disclose serious misalignment that was discovered a year later. Also, underground services began to fail with time.

**Bay Milk Products**

The Bay Milk Products (BMP) plant is within the MM IX isoseismal of Figure 4. Following the earthquake, whole milk normally processed at Edgecumbe was diverted to the BMP plant at Opotiki which was undamaged but had only limited capacity, and to other dairy factories in Thames Valley and the Waikato region as far south as Cambridge. BMP had 928 dairy farm suppliers at the time of the earthquake. Most farms were back in production after two or three days, although output was down substantially for about ten days. At this time of the year whole milk production normally processed at Edgecumbe was about 1,600,000 l per day.

The BMP Opotiki factory processed whole milk and produced cream, milk powder, casein and modified caseinates. It had a capacity of under 600,000 l of whole milk per day which, after modifications in mid-1987 and with some additional plant items from the Edgecumbe factory, was increased to 1,200,000 l per day.

The BMP factory at Te Puke, also undamaged, produced fat mixes for the Japanese market and, in conjunction with Edgecumbe, butter and anhydrous milk fat (AMF). Cream from Opotiki was processed at Te Puke and, after the earthquake, some of the cream from whole milk was diverted to other processors.
In the 1987/1988 season, the daily whole milk volume from Bay Milk dairy farm suppliers was expected to exceed the 1,200,000 l expanded capacity of the Opotiki factory by mid-August 1987, then rise to 2,000,000 l by mid-September and reach a peak of 2,600,000 l in mid-October. It was expected to fall to 1,200,000 l about the end of April 1988. The maximum daily volume of whole milk previously processed by BMP was 2,800,000 l. To allow for the additional distances involved in transporting milk to other processors, BMP had to expand its tanker fleet by 16 tractor units and 32 trailers and semi-trailers and to operate two shifts.

Immediately following the earthquake, there were questions and decisions facing BMP with regard to the plant at Edgecumbe and its site. These were set out succinctly by Larsen, then Chief Executive of BMP, at an earthquake seminar in 1990 and were as follows:

- What was the extent of the damage to buildings and plant at Edgecumbe?
- How comprehensive was the insurance cover?
- Did the company rebuild/repair the assets or not?
- If yes, did we rebuild at Edgecumbe or somewhere else?
- If yes, what assets were to be rebuilt?
- Could the company do all this sufficiently within the 18 months business interruption time period and survive financially?

Work on a new casein extension, which was under construction at the time of the earthquake, was discontinued.

To answer the question of whether to rebuild on the existing site, the insurers and BMP engaged geotechnical consultants on 8 March 1987 to report on the post-earthquake suitability of the Edgecumbe site. The consultants concluded that “From an aspect of stability and foundation support, there is no evidence to suggest that the BMP site is any less suitable now that it was prior to the 2 March 1987 earthquake.” As a result, the Directors of Bay Milk on 10 April 1987 approved the repair of reusable facilities and the redevelopment of the factory on the existing site in stages. The stages were as follows:

- **Preliminary Stage** the repair and commissioning of reusable and repairable processing plant and equipment and the provision of necessary temporary facilities.
- **Stage I Rebuild** casein/caseinate redevelopment including skim milk-powder processing and powder production. Cream to be transported to other plants.
- **Stage II Rebuild** fat processing redevelopment.
- **Stage III Rebuild** site services redevelopment. Because of the redevelopment, or as a result of repair costs exceeding replacement cost, a number of buildings and plant items were demolished. These included the: casein building; spray dryer building; evaporator hall; engineers workshop; water treatment plant; cream treatment unit; laboratory; fire station; and warehouse.

A site plan of the BMP Edgecumbe plant at 2 March 1987 and a second showing the redevelopment as at March 1990 are given in Figures 49 and 50 respectively.

All reusable plant and equipment was transferred from the buildings to be demolished to one of the warehouses for damage evaluation, repair cost estimates and repair. Some plant was transported back to suppliers for repair while surplus plant and items beyond repair were sold off.

The repaired ultrafiltration or whey products unit was able to resume production about 12 months after the earthquake. The casein/caseinate plant was commissioned in August 1988, ready for the start of the 1988/1989 season, nearly 18 months after the earthquake, and the fats processing plant about one year after that.

No BMP staff lost their jobs as a result of the earthquake but many were redeployed (Larsen and other contributors, 1990).
Figure 49: Plan of the Bay Milk Products site at Edgecumbe 2 March 1987
(Larsen and other contributors, 1990)
Figure 50: Plan of the Bay Milk Products site at Edgecumbe as rebuilt March 1990 (Larsen and other contributors, 1990).
Costs
Bay Milk Products’ insurance claim for $153 million for restoring its Edgecumbe assets was contested by the insurers, and, after litigation, settled for $113 million. The company elected to redevelop, rather than simply to restore earthquake damage, and spent perhaps more than $190 million in total (writer’s estimate).

Observations
- The resolving of the insurance claim was protracted due partly to the great difficulties, real or perceived, in the interpretation of the Earthquake and War Damage Act and Regulations with regard to “Indemnity”, “Regulatory upgrade” (and particularly the hygiene requirements of the dairy division of the Ministry of Agriculture), “Betterment”, “Future Intentions of the Insured”, “damage to land”, and the “Status of schedules attached to the Valuation Certificate”. Some of these matters remain unresolved. Others were determined in the High Court and the Court of Appeal. The changes that have occurred to the Act and the staged withdrawal of EQC from the commercial market now make these matters of academic interest only.
- There is a need for an early, accurate and, if possible, mutually agreed “Damage Assessment”, or in lawyers’ parlance “evidence”.

New Zealand Distillery Company Ltd
The distillery site, being adjacent to the BMP site, was also in the centre of the MM IX isoseismal of the main shock.

The programme for repairs and reinstatement of the earthquake damage to the distillery was based upon a decision made by BMP soon after the earthquake to provide limited temporary services of steam, cooling water and effluent disposal by 3 May 1987. The temporary services operated on an interim basis until the BMP energy centre was recommissioned. Crucial to the reinstatement of the plant and the rapid implementation of repairs was the decision made within 48 hours of the earthquake to order the stainless steel for the fabrication of new digesters.

The reinstatement work involved:
- Civil and structural: the demolition, repair or replacement of drains, kerb and channel, roadways, footpaths, paved areas, foundation pads, and concrete masonry bunds and walls caused by ground damage and scour; the dismantling where necessary, repairs to, and re-erection of damaged steelwork, hoppers, bulk storage and platforms; and, repairs to the office and laboratory. Repairs to piles, damaged where they join to pile caps (investigated some time after the earthquake), including tunnelling under the foundations.
- Plant items: the removal of the severely damaged fermenters, repair of the damaged fermenter, fabrication and installation of three replacement fermenter vessels, repair and replacement of piping which had yielded, and pressure and leak testing of all items.
- Pipework: the removal of the damaged piping and pipe bridge and its replacement within the NZDC compound, removal and replacement or repair of damaged pipework, and the repair or installation of pipe insulation. Provision of temporary pipework to connect to BMP.
- Electrical: replacement of wiring and fittings which had been damaged and the checking and testing of the electrical installation.
- Instrumentation: the removal, servicing, repair, and, in some cases, the replacement of instruments.

Costs
The New Zealand Distillery Company Ltd paid $633,823 to repair earthquake damage, and to effect small improvements. The cost of restoration was an insured loss.

Observations
- There are several modes of failure of seismic holding-down bolts, all of which need to be explored to produce an adequate design.
- The protection of vertical tanks and silos from collapse with resulting collateral damage to adjacent
structures and pipework, is an important element in the application of capacity design to industrial facilities.

- There was no indication of a shortage of resources following the earthquake leading to inflation of prices and rates. To meet the commissioning date, the reinstatement programme was accelerated and additional costs in the form of penal rates were incurred in the fabrication of the fermenters and for some work on site. The additional cost of accelerating the programme amounted to only 2.6% of the total cost.

- Design improvements in the form of additional seismic restraint to plant items including tanks, and process design improvements, represented only 2.3% of the total cost of reinstatement.

**Whakatane Board Mills**

The mill site is within the MM VII isoseismal of Figure 4.

Apart from the reinforced concrete buildings built in 1916, the main structures on the site have been constructed since 1950 and should have been designed for seismic loads.

The work involved in the reinstatement of the mill consisted of the following:

- **Buildings:** tighten or replace bolts to bracing systems and in some cases straighten or replace bracing elements; repair spalled concrete to precast panel to column connections and also concrete plinths to braced bay columns; replace collapsed unreinforced concrete masonry walls with partitions in lightweight drywall construction; reseal construction joints; to weatherproof walls, grout the cracks in concrete masonry and precast double tee infill panels; replace glazing in external windows that was broken due to structural deformations.

- **Tanks:** replace the damaged concrete skirt to the flocculation tank with a new steel skirt and replace the bridge; replace tank holding-down bolts that pulled out of the concrete base plinth; reposition the sprinkler storage tank on its supporting tower and inspect and test the connecting pipework for fractures and leaks.

- **Boilers:** replace the damaged and dislodged firebricks inside the coal-fired boiler and the damaged insulation to pipework.

- **Rail sidings:** regrade ballast and relay tracks.

- **Services:** repairs to the fractured 50 mm water supply ring-main.

- **Electrical:** replacement of dislodged and fallen light fittings.

- **No. 2 Paper Board Machine:** repair fractures in ten intermediate dryer support frames and in two transverse beams in the calendar stack.

**Costs**

The insured cost of repairs and reinstatement of the mill was approximately $1,000,000.

The replacement cost of all the buildings on the mill site was estimated at $96.5 million in 1986.

**Observations**

- Unreinforced masonry walls and infill panels performed poorly.

- Support systems for light fittings need more effective hangers, restraints and fixings.

**Industrial plant, equipment and services**

Damage to plant and equipment resulted in increased attention to seismic restraint of items and changes in structural concepts. Previously many plant items and their support structures were free standing, but after the earthquake were redesigned with restraint at the highest points provided by the building structure. This places an increased demand on the building which in many instances required the redesign of the building structure or the horizontal load resisting system. Consideration of relative stiffnesses becomes important under these circumstances.
In the repairs and reinstatement, the current (1987) codes were used for the design of new equipment, for the checking of items to be recommissioned, and for the design of associated structures. The relevant codes were NZS 4203:1984, NZS3101:1982, NZS 3404:1987 and NZS 4219:1983 (Clifton and Hall, 1990).

There are several issues arising from this experience that have a significant impact on costs and production, but do not appear to have been studied in detail to provide assistance in future events. They include:

- What proved to be the best methods for the recording, tracking and protecting of plant items and equipment removed to storage or workshops for safe keeping, overhaul or repair?

- What criteria need to be applied to determine whether individual plant items and equipment should be completely stripped down and rebuilt using new parts and bearings? What level of testing (performance and non-destructive testing) is appropriate prior to reinstatement?

- Is it more economic to recommission plant quickly, with only essential repairs carried out, and accept increased maintenance costs and down time in the first year after start-up? Hodge (1994) states that the experience at the Tasman Mill was that:
  - most maintenance incidents occurred over the first 12 months, with diminishing frequency and severity, 80% in the first six months and the remainder in the second six months;
  - a reasonable estimate of the increased maintenance cost would be 3% of the total material damage;
  - most quality control problems were short term and occurred in the first two months from start-up.

This should be compared with the experience of other mills such as Caxton, and with plants processing other raw materials where the benefits of early start-up need to be assessed against the potential for unacceptable deterioration in quality or losses in production.

- What was the post-earthquake maintenance record of plant and equipment in comparison with the pre-earthquake record, particularly for items such as steam turbines, separators, pumps, and for those items that did not need repair, or were not repaired before start-up?

- Can spares, such as bearing races, which have been subjected to the earthquake shaking, and in some instances thrown from storage shelves, be safely used for repairs?

**Recommendations**

The authors recommend that a detailed study be made of the performance of plant machinery and equipment during the earthquake and also the post-earthquake repair, reinstatement and performance of these items. The authors further suggest that the Centre for Advanced Engineering initiate such a study.

The issues identified above could be used as the basis for the preparation of a study brief.

**Farms and orchards**

The initial response in the rural areas was from Rural Support Groups that had been set up six months previously. As soon as family members were accounted for, members of groups went to check on neighbours.

On Wednesday 4 March, arrangements were made at Civil Defence HQ Edgecumbe for the Whakatane Branch of Federated Farmers to organise a survey of the rural area to determine the extent of damage and the type of help most urgently required. Contact was made with service clubs, branches of Federated Farmers and others who had offered assistance in providing interviewers for the survey. On the same day and at the same HQ, the Minister of Civil Defence advised Federated Farmers on the procedures they should adopt to seek financial assistance and resources from central government for the rural sector. The main recommendation was that an earthquake damage assessment with an estimate of costs should be forwarded to the Prime Ministers Department as quickly as possible.

On 5 March at 9.30 am, 150 interviewers were addressed by the Chairman of Federated Farmers and instructed...
on the survey form, and by an officer of the Social Welfare Department who advised on how to approach people, and what to expect. They were also asked to report abnormal behaviour and immediate safety needs.

The interviewers returned 600 survey forms and these were analysed by Federated Farmers to determine priorities for assistance. About 10% of the households required the services of psychologists and social workers. The most urgent cases were visited by specialists immediately and the remainder on the following day. Social Welfare provided a large number of social workers for this task, but in the end it was found that local people known to those in need were the most effective. The use of local people in this manner, when they have suffered also, is not generally possible.

Over the next few days Federated Farmers were able to arrange visits by dairy instructors, Dairy Board advisors, MAF advisory officers and milking machine servicemen to farmers who needed advice, counselling and assistance. They organised teams of Federated Farmer members from neighbouring branches to travel from farm to farm to assist in the repair and restoration of essential services and facilities like water supplies and cow sheds. A typical team consisted of two people in a utility vehicle with the necessary tools and spares. Two groups of pre-employment programme (PEP) workers from Opotiki also participated. In the first few days, there were up to 100 people involved, but over the next two weeks there was an average of 20 people per day.

In the two weeks following the earthquake, information was gathered from the survey and from a number of other sources including the Whakatane Fruit Growers’ Association. The information was collated to form an earthquake damage assessment and used as the basis for estimating the cost of the damage to farmers and horticulturists. The survey identified drainage correction and flood control reinstatement as needing the most restoration resources. The cost of repairs and reinstatement of the approximately 600 properties was estimated at $20 million (about three-quarters of this was estimated to be for drainage systems and structures). It was also estimated that of this total, all but $5.5 million would be covered by insurance.

In conjunction with the preparation of the damage assessment, on 11 March 1987, at the instigation of Federated Farmers, a committee was set up to make submissions to government, and to administer any funds that were made available. The committee had representatives from Federated Farmers, MAF, BMP, farm advisers, and the Whakatane Fruit Growers’ Association (Kyle, 1989). Mr D J McLeod of Federated Farmers, whom we interviewed in 1996, had a leading role in damage survey planning and execution, and in preparing and lodging farmers’ and orchardists’ requests for government assistance.

The committee defined the area covered by the submission which totalled 16,000 ha and included 14,600 ha of pasture and forest, and 1,400 ha of horticultural enterprises. It covered an area from the Matahina Dam and Kawerau in the south, northwards to the sea, and from the Whakatane River in the east, to Matata and Lake Rotoma in the west. Five groups were set up, each with an allocated area for which they were responsible. These area groups were required to verify that the damage for which the grant-in-aid from government might be sought was caused by the earthquake, that restoration was necessary, and that the work was carried out only to the extent required.

On 18 March, a ministerial committee agreed to offer government assistance of up to $4.8 million to restore the operational integrity of farm properties as quickly as possible. Grants from the fund were subject to conditions, the more important of which were that assistance was limited to the minimum necessary to re-establish operational conditions, that it was applied only to uninsurable items, and that assisted drainage work was properly integrated with the district drainage scheme. Each grant was for $1000 less than the corresponding verified claim. This deduction was a cost to be borne by the claimants.

The assistance scheme was administered by the Bay of Plenty Earthquake Restoration Steering Committee, popularly known as the Adverse Events Committee (AEC), responsible to MAF. The committee commenced work on 1 April and ceased on 2 March 1989, exactly two years after the earthquake. In that period, the committee disbursed approximately $1.6 million for farm and orchard restoration and for on-farm drainage works, and approximately $3.0 million for the district drainage scheme off-farm (see page 78). The unexpended portion of the fund, amounting to $160,000, was returned to the government.

In an early attempt to determine the extent and cost of uninsured rural losses, a survey form (reproduced in the Appendix) was sent to all 600 farms and orchards in the earthquake affected area. Completed forms were
received from 170 farmers and orchardists. Their estimates of losses totalled $690,000, which extrapolates to $2.4 million for 600 properties (assuming average losses over the 170 properties apply to the remaining 430 properties).

**Costs**

Restoration costs for residences, their contents, insured farm buildings and their contents, vehicles and farm machinery that was insured against fire loss, together with the value of deductions from insurance payments and costs for insurable but uninsured domestic property, are accounted for in costs for houses (see page 39). For farming interruption, insurers paid out about $200,000, and this is reported in economic losses on page 103 (Table 12).

Uninsured losses are estimated to have totalled $4.1 million, comprising $1.6 million disbursed by AEC and $2.5 million met by farmers and orchardists from their private resources.

**Lifelines**

**General**

With the aid of the Whakatane District Council radio telephone network, which remained operational, an initial impact assessment of the effect of the earthquake on lifelines in the Whakatane District was prepared and passed on to Civil Defence HQ by 5 pm on 2 March, about 3.5 hours after the earthquake (Lloyd, 1987).

**Water supply**

*Water sources*

The yield of the Braemar spring supplying Edgecumbe doubled immediately after the earthquake, but over the next few days settled down to about 30% above normal flow. Springs supplying Edgecumbe and Te Teko were heavily contaminated and the water mains damaged, so drinking water was supplied to these towns by tanker (see Figure 51) and to other areas by the Army using jerry cans.

Alternative sources of water for Edgecumbe and Te Teko were eventually obtained from artesian bores, drilled but not developed, as part of an on-going MWD feasibility study for irrigation of an area of the Plains. The bores were located 8 km south-west of Edgecumbe within 1 km of the existing water supply network. The water quality was similar to the Braemar Springs, indicating that the supply was from the same aquifer, but
fortunately there was no bacterial contamination. The use of water from the bores, some 50 days after the earthquake, allowed the Te Teko spring to be abandoned and the off-take from the Braemar spring to be reduced to one third; but water for drinking still needed to be boiled. The requirement to boil water was lifted 20 days later. It was not realised in the period immediately after the earthquake that a private irrigation scheme located just south of Edgecumbe and which drew water from the Rangitaiki River was still operational. The main for this scheme passed within 50 m of the southern limit of the town. Although the water was not potable, it could have been connected into the system reducing the time taken for water to be made available for general use and for testing for leaks during repairs to the reticulation.

The alternative supply for Kawerau involved pumping water for a period of about 30 days until the Holland springs source cleared.

**Water reticulation**

The initial repair strategy was simple and placed priority on restoring the pressurised supply to Edgecumbe township and the large number of rural consumers. Once water supply was restored to the town boundary, the next priority was the restoration of the reticulation in Edgecumbe township followed by the reticulation in Te Teko.

Repairs to the water pipeline supplying Edgecumbe were undertaken by specialist water repair crews from the Whakatane District Council and local contractors. A resource office was set up and senior staff were employed in a procurement role. With their experience and knowledge, they were able to contact suppliers and arrange large-scale ordering and fast delivery. They were also able to make use of spares held by the larger industrial plants in the region, such as Bay Milk Products and Tasman Pulp and Paper.

By the evening of 3 March, about 30 hours after the earthquake, repairs to the main from the Braemar Springs had progressed to the stage where it was possible to charge the main to the incoming supply point for the Edgecumbe reticulation. An aftershock on the night of 3/4 March caused further damage to the pipeline and mains pressure was not restored to the incoming valve until about 1.30 pm on 4 March, some 48 hours after the earthquake main shock.

During the afternoon of 3 March, Whakatane Civil Defence sought assistance from the Rotorua District Council and the Tauranga City and County Councils for restoration of the Edgecumbe water supply. The request was to supply repair crews, supervisors, a digger and operator and any materials considered likely to be required. It was known from the ground failures and the loss of supply that damage had occurred, but the extent and type of damage was not known. It was also known that the reticulation consisted of AC pipes of 100 mm and 50 mm diameter with galvanised iron riders and service mains. The Rotorua District Council crews, supervisors and plant, together with a truck load of fittings and pipes, left Rotorua at 7.00 am on 4 March.

In the first stages of the repairs the personnel engaged were:

- Whakatane District Council 3 water repair crews.
- Rotorua District Council 2 three-man water repair crews.
- Tauranga City Council 1 water repair crew
- Tauranga County Council 1 water repair crew
- Local contractors.

As soon as mains pressure was restored to the incoming valve, the work of restoring the water supply commenced and continued daily through to the evening of 12 March. The procedure was to charge the main, locate the rupture or break, excavate and repair the damage, and recharge the main to locate further leaks. There were a few non-standard sluice valves in the reticulation. These, by opening when a workman thought he was closing them (and vice versa), slowed the progress of pressure testing.

Over a period of eight days, the two crews and associated personnel, with the addition of a further two crews
for two days, carried out more than 80 mains repairs, relaid several hundred metres of 100 mm, 50 mm and 25 mm diameter pipe, installed several sluice valves, and undertook the associated repairs to services.

Most of the damage to the 100 mm AC pipes was due to splitting of the collars and the telescoping of the pipe ends for distances of up to 200 mm. Damage to the 50 mm pipe was similar but, in addition, pipes generally fractured where tapping bands were fitted. Galvanised iron rider mains and service pipes bowed up out of the ground, were sharply folded and creased, torn away from fittings and fractured at unions. Side movement at some locations resulted in the service pipes breaking away from tapping ferrules and being found 200 mm to 300 mm to one side of the main, with both main and service pipes still appearing straight and undamaged.

The valves in the water reticulation system at Te Teko were turned off by Army personnel. This was a good idea, but for some reason the information was not communicated to the engineering staff in the field. When the supply mains were recharged, time and resources were wasted in trying to find out why the water was not getting through. A less serious problem was that some valves were damaged by being turned off too tightly (Lloyd, 1987; Haycock in Anon, 1987j; Nicholson, 1987; Kelly 1994).

At Kawerau the repairs to the water reticulation were minor. Labour for repairs was estimated at 80 to 100 man-hours (McDowall, 1988).

**Costs**

Whakatane District Council expended $668,761 to restore earthquake damage to its water supply system. Kawerau Borough’s costs are not available. They have been estimated by the writer at $3000 for repairs and $5000 for temporary pumping.

**Observations**

- The absence of good plan records of the reticulation and valving slowed the progress of repair and reinstatement.

- The initial lack of information on the extent of damage caused a delay in assessment of materials and fittings required. Once a pattern of damage had been determined there were further delays in delivery of items to site.

- Some items supplied, particularly Gibault joints, did not fit or required interchanging or machining. While this permitted work to proceed, it was at a reduced rate.

- The ability to isolate rider mains, larger diameter connections, and fire mains would have hastened progress and resulted in less water damage to some properties.

- At some locations, telephone cables were positioned parallel to and almost directly above water mains which prevented or seriously hindered excavation with plant. Even with considerable care, cables were damaged and coatings nicked by shovels and hand tools.

- Specific scour points should be designed into networks, as hydrants make poor scour points when required to handle more than just silt.

- Because there were too few cross loops, repairs to the network could only proceed on a limited number of fronts.

- Mains valves were too far apart, which meant that charging the lines took longer and time was lost.

- Decision making on whether to abandon badly damaged mains or repair them was too conservative. More mains should have been replaced.

- The splitting up of specialist or experienced crews and units, and their dilution with inexperienced personnel, was ineffective and counterproductive.

- Priorities once set must be reviewed regularly and teams fully utilised where the need is greatest.

- The maintenance of morale of all involved is essential. Staff, including senior staff, must be given time
off after the event to check on immediate family and their needs and must have regular scheduled stand-
down periods. Crews should be rotated as appropriate to allow all to participate in identifiable and clearly
worthwhile tasks as well as the small and more mundane tasks, which also have to be done.

- The decision to use senior staff in a procurement and expediting role was the correct one and worked very
  well.

- A computerised database for information on stocks of materials and fittings available throughout the
country, and also for damage assessment and information vital to the repair and reinstatement operation,
would have been of great assistance and would have shortened the recovery period.

- Mutual aid agreements with nearby territorial authorities, which included provisions for regular liaison
and the sharing and maintenance of detailed information on each others’ systems and procedures, would
have saved time and increased the efficiency of the response.

**Gas supply**
The natural gas transmission pipelines in the region are shown in Figure 52. Immediately following the
earthquake, Petrocorp staff in the region began the inspection of sales gates at Te Teko, Edgecumbe and
Opotiki and the valves on the natural gas pipeline to Gisborne through the Waioeka Gorge. Due to the severe
damage caused to the Bay Milk Products plant at Edgecumbe, the gas supply to the plant was shut off at the
Edgecumbe sales gate.

Inspectors on foot examined the Kawerau to Whakatane lateral on the day of the earthquake and during the
following day, and identified two points of major displacement where the Edgecumbe fault scarp intersected the
lateral. The entire length of the lateral was also inspected from a helicopter which flew over the line on 3 March.

At 8 pm on 2 March, gas pressure in the Edgecumbe and Whakatane lateral was reduced to about 1 MPa as
a safety measure until a more complete investigation could be carried out at the points of major displacement.
At the same time, the Te Teko distribution supply was isolated.

The natural gas pipeline from Kinleith to Kawerau and a section of the Kawerau to Gisborne pipeline as far
as Waimana, were inspected from a helicopter which flew over the lines on 2 and 3 March.

During 4 to 6 March, sections of these pipelines were inspected on the ground and checked for leaks with the
gas pressure at 8 MPa. Minor ground surface cracking, no more than one metre deep and mainly in the top
layer of pumice, was observed running parallel to and along ridges within the pipeline easements. This was
not considered a danger to the pipelines.

Excavation to expose the pipe and allow the pipe and protective wrapping to be inspected, was carried out at
the two points on the Kawerau to Whakatane lateral intercepted by the fault scarp (see Figure 53).

South of Edgecumbe, the pipeline was displaced in the loose pumice material and was under tension. The tension
was relieved by further excavation after exposure of the first 20 m of pipe south of the fault scarp. The pipe was
exposed over a length of 61 m and no indication of damage to the pipe or wrapping was found. The movement
on the fault here was surveyed and assessed as a throw of about 2.2 m, a heave of about 1.2 m (extension), and
a strike-slip of approximately 0.6 m. The direction of the strike-slip is not clear from the reports.

The Edgecumbe to Whakatane section was also under tension at the fault crossing when first excavated but
this was relieved after more than 12 m was exposed. In all, 56 m of pipe was exposed, but again there was
no indication of damage to the pipe or wrapping. The fault movement and ground cracking at this location were
spread over a width of 30 m. The throw was estimated to be 1.7 m and the heave 1 m (extension) but there
was no indication of a strike-slip movement.

Near fault traces, sags in unsupported pipe lengths spanning drains were reduced by tension induced in the
pipe by ground movement. As a further check on the integrity of the pipes at each of these locations, the welds
in three pipe lengths (36 m) were subject to external x-ray examination and internal gauging checks were made
using a pipeline gauging pig with an 85% sizing plate. The cathodic protection was also checked and found to
be still working.

By 31 March, the Kawerau compressor and meter stations were operating normally and the Tasman and
Figure 52: Bay of Plenty natural gas transmission pipelines
Caxton mills were taking gas. The Kawerau to Whakatane lateral was still operating at a reduced pressure of 1.5 MPa, the Te Teko sales gate was operating normally and at Edgecumbe the metering station was repaired and restored to its foundations and the metering and instrumentation overhauled and ready for use.

Perhaps the most effective commendation that can be given to the gas supply and distribution system for its robust performance in the earthquake is that the system escaped the notice of most teams of engineer investigators (three are known to have been working in the area and only one team apparently knew of its existence), and of insurance assessors. In the minutes of a meeting debriefing insurance assessors after their work was done (Anon, 1987i) is a record of an unchallenged assertion that the Plains had no gas supply and this had put an end to some tentative discussion. The existence of a gas reticulation system in the towns in the strong motion area also does not appear to have been recognised by a research engineer (Dowrick, 1988). Ineloquent and involuntary though this testimony to the gas system’s endurance is, it can scarcely be bettered!

**Costs**

The total cost of the investigation of the integrity of the natural gas supply and distribution systems and the minor repairs involved, is estimated at $25,000. Approximately $15,000 was for external costs for helicopter hire, digger hire and radiography charges, and $10,000 was internal costs for staff, services, equipment, and overheads (McGill, 1987; McCarthy, 1987; Hammond, 1996).

**Observations**

- The gas reticulation in each of the townships was undamaged and reflects the merits of ductile plastic materials (MDPE in this case) and ductile steel pipe, welded joints, good detailing, and good workmanship. It is also a distinctly different experience from that in more recent overseas earthquakes, e.g. Loma Prieta (1989), Northridge (1994) and Great Hanshin (1995, Kobe).

**Sanitary drainage**

**Treatment facilities**

The damage to the ponds at Whakatane and Edgecumbe did not cause any great problems and was quickly repaired.

At no time was there any concern for public health. The Medical Officer of Health reported on 11 March 1987, “Because of the efficient action taken from the outset by local authority health inspectors and engineers, the main function of the District Office of the Department of Health has been (and continues to be) to offer support and assistance when and where needed...” (Millar in Anon, 1987j).
Costs
The cost of repairs to the treatment ponds was about $7,100 (Lloyd, 1987).

Sewerage
The massive reinforced concrete inlet valve chamber to the No. 1 Pump Station at Whakatane was apparently displaced by the foreshock, and the inlet line fractured because the pumps continued to operate until the power failed. This caused many tonnes of sand and silt to enter the station, much of which was pumped into the rising main. Fortunately, the pump station itself remained plumb and showed no sign of damage.

An emergency overflow was installed using a large capacity pump which pumped sewage from a manhole upstream of the station into an adjoining stormwater system. The stormwater system discharged into a drainage canal and the contents of the canal were pumped into the Whakatane River. According to Lloyd, at no stage did the discharge create a nuisance, in the canal or in the river (Lloyd, 1987). Others had different opinions and there were reports of a putrid smell in still conditions a fortnight after the emergency discharge began (Beacon, 20/3/87). People were warned not to fish or swim in the river (Beacon, 15/4/87).

Repairs to the pump station involved the removal of the inlet chamber which was on poor foundations and also too big and heavy to reposition as a unit. The inlet pipe was then connected directly into the pump well. Video inspection of the inlet pipe following flushing, showed that although a little out of line, the pipe was in good condition and only a small section needed to be relaid to grade.

An air test on the steel rising main indicated at least one break under the main river channel at a depth of about 6.5 m below the surface. The water at this point was 5 m deep and a diver identified a ruptured flexible joint as the cause. The joint had failed when the pipe moved 75 mm laterally out of alignment. The remainder of the under-river crossing was inspected after the cover material had been removed with an airlift and further buckling was found. A 53 m section of steel pipe was removed and replaced with 450 mm diameter HDPE pipe which had to be weighted down. Repairs were completed 88 days after the earthquake on 29 May 1987, and the flow of untreated sewage into the river ceased on that date.

In Edgecumbe it was known that damage had been done to the reticulation, but its extent (apart from the glazed earthenware sections) could only be determined once more detailed investigations had been carried out. Temporary communal toilet facilities were provided using commercially available “Portaloos” which were trucked to Edgecumbe from Auckland and were strategically located around the township and in the schools (Muller, 1987).

The temporary repair strategy was to replace the two collapsed GEW lines in PVC, and repair the AC pipes as sewer blockages were located. This strategy enabled the system to be repaired temporarily and to become operational in stages, with the first section being available on 10 March, eight days after the event, and the last section on 20 March, ten days later.

In order to investigate the damage to the reticulation in detail and carry out permanent repairs, it was decided to video the lines to obtain a continuous record of the condition of the pipe. In all, approximately 9 km of lines 150 mm diameter and over were videoed over a period of 5 weeks at a cost of about $60,000. It took about ten days to analyse the film. The information obtained, together with the manhole invert levels, enabled a schedule of repairs to be drawn up for pricing by contractors (Nicholson, 1987; Beacon, 15/4/87). Mr K Lloyd advised during an interview in 1997 that the permanent repairs took more than a year to complete.

There were still problems with the Edgecumbe reticulation system as late as 1997, including sewage overflows during storms. Inspections of sanitary sewers and household drainage were carried out in 1995 and at the beginning of 1996. Inspections included inflow and infiltration investigations and identified faults in about 27% of buildings inspected, of which about two-thirds could have been caused by movement following post earthquake repairs. The Whakatane District Council proposes to carry out closed-circuit TV investigations in a five year cycle, to assess the physical condition and alignment of pipes in the system (Lloyd, 1996).

Costs
The cost of the earthquake repairs and reinstatement of sewerage and land drainage in the Whakatane District Council area, amounted to $1,252,316 (Kelly, 1994).
Observations

- Many of the lessons identified earlier for repairs and restoration of water supply apply equally well to sanitary drainage.

- Where there is insufficient storage at sewage pump stations to allow for long-term power outages and standby generators are not provided, permanent emergency discharge pipelines should be installed to control the discharge and ensure stations do not overflow.

Mains electricity

Grid power to the region was lost at 1.42 pm on 2 March when the main shock occurred and protection equipment tripped the 220 kV and 110 kV supply lines.

The No. 1 generator at the Aniwhenua Power Station was undamaged but became disconnected from the grid when the protection equipment on the 110 kV line to Matahina operated. Maintenance staff at the station carried out an immediate inspection of the plant and civil engineering structures. Continuous readings were kept of water levels in standpipes and the discharge of drains. Flow from the drains increased initially, but was back to normal by evening. The No. 1 generator remained in service and continued to supply Murapara and, as shown in the restoration schedule, later supplied the Whakatane MED, and energised the 11 kV busbars and substations at Kawerau, Ohope and elsewhere. The No. 2 generator was reinstated at an accelerated rate and recommissioned shortly after midnight. Feeders were livened and supply restored progressively.

Grid power was restored at 0600 hours on 3 March and the two generators at Aniwhenua were synchronised to the grid.

Edgecumbe and Kawerau substations

The Edgecumbe and Kawerau substations were extensively damaged. Damage was confined mainly to equipment installed before new seismic design requirements were introduced in 1968 and 1969. Much of the damage could have been avoided if the then current seismic design criteria had been applied and better workmanship adopted for even simple elements like the holding down details for control panels and transformers.

Damage to some transformers showed yet again that an earthquake will search out and expose the weakest link in any structure which, in this instance, was the fixing of the transformer tank to the undercarriage. A similar problem was found with the fixings for the internal windings of current transformers. Capacity design procedures, initially developed for building structures, have application and are equally important to the survival of equipment and plant items. Problems were also encountered with some circuit breakers and isolators having electrical connections which did not have enough slack to allow for the deformation (Rutledge, 1988).

Service capacity restoration was commenced at both substations almost immediately and the results achieved are shown in Table 4.

<table>
<thead>
<tr>
<th>Time after Event</th>
<th>Kawerau Substation</th>
<th>Edgecumbe Substation</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 hours</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>5 hours</td>
<td></td>
<td>20%</td>
</tr>
<tr>
<td>10 hours</td>
<td>91%</td>
<td></td>
</tr>
<tr>
<td>28 hours (6 pm, 3 March)</td>
<td></td>
<td>75%</td>
</tr>
</tbody>
</table>

Table 4: Service capacity restoration at Edgecumbe and Kawerau substations  
(AC Power, 1994)

Costs

The cost of repairs and reinstatement to the substations at Kawerau and Edgecumbe, to Matahina switchgear, and to transmission lines in the region, was about $2.25 million.
Electricity distribution system

Restoration of supply was governed by two priorities.

Priority 1: The provision of secure supply to hospitals, Civil Defence and service stations (for fuel supply).

Priority 2: The provision of secure supply as soon as possible to customers for cow sheds, streetlighting and domestic power.

Five distinct phases were adopted in the restoration process, many of which overlapped. The phases are shown in Table 5.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Activity</th>
<th>Time after Main Shock</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>— occupy control room</td>
<td>2 hours</td>
</tr>
<tr>
<td></td>
<td>— establish communications</td>
<td></td>
</tr>
<tr>
<td></td>
<td>— contact staff</td>
<td></td>
</tr>
<tr>
<td></td>
<td>— carry out damage assessment</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>— supply to Zone substations</td>
<td>24 hours</td>
</tr>
<tr>
<td></td>
<td>— 33kV Transmission Lines</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>— restore 11 KV feeders</td>
<td>40 hours</td>
</tr>
<tr>
<td></td>
<td>— disconnections for safety</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>— connect Customers</td>
<td>1 week</td>
</tr>
<tr>
<td></td>
<td>— repairs to service lines</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>— house inspections</td>
<td>4 weeks</td>
</tr>
<tr>
<td></td>
<td>— appliance inspections</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Phases in the restoration of electricity supplies

At the time of the earthquake, staff were employed throughout the Board’s area but fortunately a large number of the line staff were at the Whakatane Depot. Where possible, staff were sent home to check on their families or, for those in the field, messages were relayed on their behalf. Zone substations were made safe and staff in the field and at Aniwhavena immediately commenced inspection of the substations and the power station.

Damage assessment and restoration commenced about one hour after the main shock. The extent of the damage to the Kawerau and Edgecumbe substations led to the decision to supply the emergency services at Whakatane from the Aniwhavena Power Station. The sequence of events including restoration is shown in Table 6.

Initial repairs were of a temporary nature to allow power to be restored as quickly as possible. These repairs had to be adjusted or replaced and a lot of work done before the Board’s system was back to its pre-earthquake standards.

The repair and restoration programme, an operational task, was co-ordinated mainly by the Board’s staff. There was, however, liaison with Civil Defence.

Liaison with Civil Defence and representation on the welfare and housing committees established under the Disaster Recovery Co-ordinator were both helpful in dealing with the problems that financially embarrassed consumers had. It was possible to provide some degree of direction to where assistance could be available (van Brink, 1988; Brennan, 1987).

Costs

The total cost of repairs and reinstatement of the Board’s system, buildings, plant and equipment is estimated at $760,000, of which $240,000 was insured cost, $416,000 was government grant, and $104,000 was financed by the Board.

The cost of damage to the Plains Substation was the biggest single item in the physical loss to the system. Fortunately it was totally insured under the Board’s Industrial All Risks Policy.
Table 6: Sequence of events in power restoration

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 March</td>
<td>1.41pm</td>
<td>Loss of supply</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supply to Murupara maintained</td>
</tr>
<tr>
<td>7.31pm</td>
<td></td>
<td>Supply to Whakatane MED</td>
</tr>
<tr>
<td>10.46pm</td>
<td></td>
<td>Kawerau 11kV bus energised</td>
</tr>
<tr>
<td>10.53pm</td>
<td></td>
<td>Station Rd Zone sub energised</td>
</tr>
<tr>
<td>3 March</td>
<td>0.17am</td>
<td>Ohope Zone sub energised</td>
</tr>
<tr>
<td>1.34am</td>
<td></td>
<td>Kawerau 11kV Borough feeders livened</td>
</tr>
<tr>
<td>4.06am</td>
<td></td>
<td>Supply restored to Opotiki/Te Kaha</td>
</tr>
<tr>
<td>6.00am</td>
<td></td>
<td>Grid power restored</td>
</tr>
<tr>
<td>6.01am</td>
<td></td>
<td>Aniwhenua synchronised to grid</td>
</tr>
<tr>
<td>8.14am</td>
<td></td>
<td>33kV supply to Board Mills restored</td>
</tr>
<tr>
<td>5.28pm</td>
<td></td>
<td>Plains Zone sub livened</td>
</tr>
<tr>
<td>6.00pm</td>
<td></td>
<td>Te Teko and Matata 11kV restored</td>
</tr>
<tr>
<td>8.23pm</td>
<td></td>
<td>Part of Edgecumbe livened</td>
</tr>
<tr>
<td>4 March</td>
<td>7.30am</td>
<td>Edgecumbe 11KV restored</td>
</tr>
<tr>
<td>2.16pm</td>
<td></td>
<td>11kV restoration completed</td>
</tr>
<tr>
<td>6 March</td>
<td></td>
<td>Restoration of power to all milking sheds in the region completed</td>
</tr>
</tbody>
</table>

Observations

- The effect of the earthquake was a further reminder that electrical equipment is very vulnerable to damage if it is not designed to withstand earthquake generated forces and is not adequately restrained.

- Mitigation measures, including the upgrading and retrofitting of existing electrical equipment to reduce the impact of earthquake damage can, in most instances, be carried out easily and at low cost. Importantly, it is not difficult to justify mitigation measures and the costs involved.

Telephone system

The Telecom network within the Bay of Plenty suffered from physical damage and traffic congestion. The loss of power supply at exchanges without standby generator sets was an immediate problem until portable sets could be delivered to re-establish services. However, communications were maintained in critical areas throughout the emergency and all repairs were completed within a few weeks of the end of the emergency. Significant underground cable damage was caused during repairs and reinstatement of other lifeline services in the response and recovery periods.

A local network control centre was established in Whakatane to co-ordinate the Telecom effort in the area. In addition, a temporary construction and maintenance headquarters was established in Edgecumbe to facilitate liaison with Civil Defence and Territorial Authorities, and to co-ordinate restoration work on the network. The Telecom organisation and procedures generally worked well but there were some problems. For instance, staff at Edgecumbe found they could not refuel their vehicles due to the power outage and the fact that fuel pumps had no provision for connection to portable generator sets or for manual supply. This resulted in some minor delays in crews reaching trouble spots.

The national network suffered congestion soon after the first news of the earthquake was broadcast. The problem was exacerbated by early broadcasts greatly exaggerating the damage and causing many more people to call into the area. Figure 54 is a plot of restrictions applied nationally at the request of Whakatane, Rotorua...
and Tauranga exchanges. Announcements on congestion and the influence of radio and TV news coverage are clearly visible.

International calls added to the congestion as the news of the earthquake, with only a vague reference to the area of New Zealand affected, was broadcast around the world. As a result, international calls went to all parts of the country producing further congestion in an already heavily loaded national network. Australia, Britain and the USA implemented network management controls to prevent congestion from New Zealand-bound traffic causing problems within their own networks (Laytham, 1988).

Telephone traffic volumes returned to normal about two weeks after the earthquake (Beacon, 17/3/87).

**Costs**

The cost of repairs and reinstatement was about $1.8 million.

Telecom expects to be obliged to meet increased maintenance costs of approximately $20,000 per year for a small (but unknown) number of years. The estimate of restoration costs is increased to $1.9 million to account for this expectation.

**Observations**

- All remote stations should be provided with helicopter landing pads to provide an alternative to road access which may become difficult or dangerous.

- Any site without a permanent standby generator should be provided with an access point and change over switch to allow a portable generator set to be quickly and easily installed. This should also be extended to include fuel pumps at depots or normal fuel suppliers.

**Roading**

Earthquake damage assessment of all state highways (SH) in the region began soon after the earthquake. Work
on clearing the slips on SH 2 near Matata and SH 30 at Rotoma Hills began as soon as plant could be assembled on site.

At 6 pm on 2 March it was reported that SH 2 between Whakatane and Opotiki and also the Whakatane to Ohope road were open to all traffic.

SH 30 was reopened as a single lane for light traffic at 5 pm on 2 March, closed by further slips three hours later, and reopened to all traffic at 3 pm the next day. The wet weather caused further slips and delays the next day, 4 March. SH 2 was reopened to light traffic at 6.05 pm on 2 March, and for all traffic at 9.40 am the next morning.

There is no data available on the reduced pavement life suffered by state highways in the area where ground damage occurred, but it is believed to have been significant (Interview Coup, 1995).

Roading damage in Whakatane was mainly to two causeways. These causeways were constructed on an abandoned meander of the Whakatane River and had cracked and settled differentially. Concrete footpaths in some areas were fractured and required replacement. Some clearing of slips and batter protection was also carried out in the eastern side of the town.

Road pavements in Edgecumbe were extensively fissured in tension or ridged in compression. Kerb and channel moved independently of sealed areas and pushed the seal into mounds. Concrete footpaths and vehicle crossings buckled and shattered beyond repair (see Part 1, Figures 34, 36 and 37). The extent of the damage was probably doubled because of excavation related to the repair and reinstatement of other lifelines — water, sewerage, stormwater, power and telephone services.

The reinstatement of rural roading in the Whakatane District Council area involved making good in two places roads intersected by the fault scarp, repairs to bridge approaches, the clearing of slips and batter protection, repairs to cracks in sealed pavements, correction to drainage and sealing work.

Roads on the plains were subjected to continuing ground settlement due to pore pressure correction which delayed final reinstatement of sections of sealed pavement up to 500 m in length. Only temporary repairs were made to the worst sections, where cracking, loss of camber, or dishing was severe, until more permanent shape correction could be carried out at a later date when ground movement ceased. The programme of shape correction of sections of road damaged by the earthquake was expected to be completed in the 1996/1997 season. The cost of this programme was about $150,000.

It is estimated that, in general, the reduction in pavement life in the Plains area was of the order of 20% to 25%. The increase in maintenance cost of all roading in the Whakatane District Council area following the earthquake is estimated at $15,000 per year over the past eight to ten years (Interview Tailby, 1995).

In most instances, alternative routes were available for emergency traffic immediately after the earthquake (Lloyd, 1987; Bailey, 1995; Kelly, 1994).

In Kawerau Borough, slips in road cuttings to the west of the town required major earthworks for benching and disposal of soil and clearing of debris. Roads in the township required repairs to cracks in sealed pavements, to cracks due to differential settlement at the interface of embankments and original ground surface, and to gaps caused by sideways movement of kerb and channel from the seal on side embankments.

The earthquake caused comparatively little damage to roads in the Rotorua District Council area, but two roads suffered from major subsidence and slips.

**Costs**
The costs of roading restoration are shown in Table 7.

**Observations**
- In urban areas, considerable traffic interruptions and damage to pavements and road structures is likely as a result of excavation necessary for the repair and reinstatement of underground services.
In general, damage to bridge structures was minor. Highway and road bridges were open, apart from two, and could be used with care.

The two bridges closed to traffic immediately after the earthquake were the bridge over the Rangitaiki River at Te Teko on SH 30, and the bridge over the Whakatane River at Whakatane on what was then SH 2.

The Te Teko bridge was closed to all but pedestrian traffic and single emergency vehicles. There was an alternative route through Edgecumbe. The bridge was repaired and re-opened at 3.30 pm on 4 March, 50 hours after the earthquake.

The Whakatane bridge was re-opened to emergency traffic at 7.10 pm on 2 March, about 5.5 hours after the earthquake when repairs to the approaches were sufficiently advanced.

The piles to the piers of the bridge over the Rangitaiki River at Edgecumbe were displaced towards the centre of the river and tilted the piers slightly, but the damage was not regarded as sufficiently serious to close the bridge.

In Kawerau Borough, the piles at the western end of a bridge over the Tarawera River were displaced towards the river and buckled an end support beam which required replacement.

While slumping of up to 300 mm occurred at the approaches of most rail bridges, there was no damage to bridge structures, apart from three bridges which suffered minor damage. They were the combined road/rail bridge over the Whakatane River at Taneatua (which required repairs to the pile/pile cap interface of two piers), the bridge over the Rangitaiki River at Edgecumbe (which suffered differential settlement and required relevelling), and a bridge which had one pier slightly misaligned. Bridge repairs were completed by 1991.

**Costs**

The cost of bridge repairs to state highways, Whakatane District and Kawerau Borough are included in the respective roading figures. Railway bridge repair costs are reported below.

**Observations**

- Bridge structures generally performed well but the reasons for the good performance have not been clearly identified.
- Bridge approaches suffered considerable damage and need further investigation to evaluate the merits of providing settlement or relieving slabs.
- The importance of construction being in accordance with the drawings was highlighted once again by the experience with the displacement of bearings on the Te Teko bridge.

**Railways**

The task of reinstating the track was relatively simple and consisted mainly of straightening or lifting the track and the supply and tamping of ballast.
Signal, electrical and communication equipment was damaged and a number of systems failed. Although no poles were lost, a considerable number of line faults developed, due mainly to wire wraps and the clearing of these required considerable effort. Extensive cable testing was required to ensure that insulation was still within allowable limits. Anti-seismic bars on a battery rack at Edgecumbe did not prevent three cells falling, and a standby generator at Kawerau lost its fuel supply when the tank fell from a shelf.

The railway network in the Eastern Bay of Plenty was reported as functioning, apart from the link between Awakeri and Taneatua (Beacon, 13/3/87). Repairs to the railway network were reported as complete on 10 June 1987 (Beacon, 10/6/87).

**Costs**
The cost for reinstatement of track is estimated at $73,000 and for repairs to signals etc., $10,000. The cost of repairs to rail bridges is estimated at $54,000.

**Observations**
- There were few new lessons from the earthquake apart from the necessity to attach signal, electrical and communication equipment and components securely to floor slabs or supporting structures.

**Radio Station 1XX**
1XX is the Whakatane commercial radio station. Neither the building it occupied nor broadcasting equipment in service was damaged in the earthquake, but the station was off air for the first five minutes after the earthquake. Thereafter it operated with reduced signal strength, because the cable carrying the signal from studio to transmitter was impaired by strain at the Whakatane River bridge, where it emerged from burial in earthquake-disturbed approach fill to be fixed to the span. A radio link replacing the land line was established within 30 minutes, and normal signal-strength service resumed. Except for the 5-minute hiatus, broadcasting was continuous and effective and the duty announcer earned praise for providing reassurance to listeners (Beacon, 6 March 1987).

For several days following the earthquake the station abandoned its commercial activities and devoted its entire 24 hour daily service to broadcasting community information. Then, and subsequently, broadcasts contained messages from Civil Defence, from territorial authorities and from the Earthquake and War Damage Commission. These messages were addressed to the community for its information, and to field parties engaged in relief and restoration work. The station provided this emergency communication service in accordance with a prearranged plan, which had contemplated both information dissemination and communications roles for 1XX. Civil Defence compiled much of the broadcast material, and it controlled material from other sources. The radio station maintained a desk at Civil Defence headquarters in Edgecumbe (Muller, 1987b).

There is a repeater on Whale Island, offshore from Whakatane, and this valuable resource was used by 1XX to maintain two-way communication for broadcasts outside the station’s district during the post-earthquake emergency period.

Advertising revenue lost during the emergency contributed to a significant drop in net profit reported by 1XX for the financial year of the earthquake (Beacon, 28 October 1987). The station was reimbursed ($33,667) by Civil Defence for 36 hours of community service broadcasting (Beacon, 30 October 1987).

**Lifelines — recovery of services**
Table 8 sets out a summary of the time taken for each lifeline to recover service. The format and definitions are the same as those used in the Wellington and Christchurch lifelines studies. These facilitate comparison of times for services recovery from the Edgecumbe earthquake with corresponding projected times for recovery from Wellington and Christchurch scenario earthquakes (Centre for Advanced Engineering, 1991; Christchurch Engineering Lifelines Group, 1997).
## Table 8: Lifelines — recovery of service

<table>
<thead>
<tr>
<th>Service</th>
<th>Recovery of Basic Service or Control</th>
<th>Provision 50% Service</th>
<th>Provision of Full Service</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Water Supply</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whakatane</td>
<td>No interruption of supply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edgecumbe &amp; Rural Area</td>
<td>+2 days (^1). Untreated water to town boundary. Potable water by tanker and jerrycan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Te Teko</td>
<td>No interruption but spring contaminated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kawerau</td>
<td>No interruption but spring contaminated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2. Sanitary Drainage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whakatane</td>
<td>Restrictions on use of sewerage system for 4 days</td>
<td></td>
<td>+4 days. Rare sewerage discharged into Whakatane river</td>
<td>+68 days. No restrictions</td>
</tr>
<tr>
<td>Edgecumbe</td>
<td>Communal facilities provided in first few days in the form of “portaloos”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Te Teko</td>
<td>Mainly septic tanks—many of which were damaged</td>
<td></td>
<td>+4 days. Last section +16 days</td>
<td></td>
</tr>
<tr>
<td>Kawerau</td>
<td>Minor damage. No restrictions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3. Storm Damage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whakatane</td>
<td>+44 hours. +16 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edgecumbe</td>
<td>+44 hours. +16 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Te Teko</td>
<td>+44 hours. +16 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kawerau</td>
<td>+44 hours. +16 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>+44 hours. +16 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>4. Gas Supply</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whakatane</td>
<td>+29 days. System operating normally.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edgecumbe</td>
<td>+29 days. System operating normally.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Te Teko</td>
<td>+29 days. System operating normally.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kawerau</td>
<td>+29 days. System operating normally.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>5. Mains Electricity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grid Power</td>
<td>+16 hours. +6 hours</td>
<td></td>
<td>+6 days (^2)</td>
<td></td>
</tr>
<tr>
<td>Electricity Distribution System</td>
<td>+10 hours. +28 hours</td>
<td></td>
<td>+6 days (^2)</td>
<td></td>
</tr>
<tr>
<td>Whakatane</td>
<td>+10 hours. +28 hours</td>
<td></td>
<td>+6 days (^2)</td>
<td></td>
</tr>
<tr>
<td>Edgecumbe</td>
<td>+10 hours. +28 hours</td>
<td></td>
<td>+6 days (^2)</td>
<td></td>
</tr>
<tr>
<td>Te Teko</td>
<td>+10 hours. +28 hours</td>
<td></td>
<td>+6 days (^2)</td>
<td></td>
</tr>
<tr>
<td>Kawerau</td>
<td>+10 hours. +28 hours</td>
<td></td>
<td>+6 days (^2)</td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>+10 hours. +28 hours</td>
<td></td>
<td>+6 days (^2)</td>
<td></td>
</tr>
<tr>
<td><strong>6. Telephone System</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whakatane</td>
<td>+30 mins. Traffic congestion in first few days</td>
<td></td>
<td>+14 days (^4)</td>
<td></td>
</tr>
<tr>
<td>Edgecumbe</td>
<td>+30 mins. Traffic congestion in first few days</td>
<td></td>
<td>+14 days (^4)</td>
<td></td>
</tr>
<tr>
<td>Te Teko</td>
<td>+30 mins. Traffic congestion in first few days</td>
<td></td>
<td>+14 days (^4)</td>
<td></td>
</tr>
<tr>
<td>Kawerau</td>
<td>+30 mins. Traffic congestion in first few days</td>
<td></td>
<td>+14 days (^4)</td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>+30 mins. Traffic congestion in first few days</td>
<td></td>
<td>+14 days (^4)</td>
<td></td>
</tr>
<tr>
<td><strong>7. Roading</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>State Highways</td>
<td>+45 hours light traffic.</td>
<td></td>
<td>+20 hours (^6)</td>
<td></td>
</tr>
<tr>
<td>SH 2</td>
<td>+45 hours light traffic.</td>
<td></td>
<td>+20 hours (^6)</td>
<td></td>
</tr>
<tr>
<td>SH 30</td>
<td>+35.5 hours light traffic. +25.5 hours all traffic (^3)</td>
<td></td>
<td>+20 hours (^6)</td>
<td></td>
</tr>
<tr>
<td>Rural roads</td>
<td>In most instances alternative routes were available</td>
<td></td>
<td>+20 hours (^6)</td>
<td></td>
</tr>
<tr>
<td><strong>8. Bridges</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Te Teko</td>
<td>Pedestrian traffic and simple emergency vehicles</td>
<td></td>
<td>+50 hours (^8)</td>
<td></td>
</tr>
<tr>
<td>Whakatane</td>
<td>Pedestrian traffic and emergency vehicles</td>
<td></td>
<td>+50 hours (^8)</td>
<td></td>
</tr>
<tr>
<td><strong>9. Railways</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whakatane</td>
<td>+9 days railway network in Eastern Bay of Plenty operating apart from Awakeri - Taneatua</td>
<td></td>
<td>+44 days repairs and reinstatement complete</td>
<td></td>
</tr>
<tr>
<td><strong>10. Broadcasting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radio station 1XX Whakatane</td>
<td>+5 mins.</td>
<td></td>
<td>+30 mins (^10)</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Initially 30 hours but pipeline damaged by aftershock
\(^2\) Subsequently making good temporary repairs over next few months
\(^3\) House inspections continued over the next month
\(^4\) Of which half telephones off their cradles
\(^5\) PABX Bay Milk operational +2 days

**Definitions**
- Ability to provide a basic manageable service for priority use
- Provision of general service to most areas. Some queuing or overload. Temporary fixes in place.

- Water Supply
- Sanitary Drainage
- Storm Damage
- Gas Supply
- Mains Electricity
- Telephone System
- Roading
- Bridges
- Railways
- Broadcasting

Table 8: Lifelines — recovery of service
**Matahina dam**

The damaged state of Matahina dam after the earthquake, reported to the Regional Civil Defence Office in Rotorua, was one of a number of important considerations leading to a decision to proclaim a state of Regional Civil Defence Emergency. The Regional Civil Defence Emergency superseded the Whakatane District Civil Defence Emergency, which had been declared 68 minutes after the main shock by Whakatane mayor Mr Bob Byrne, but concerns for the integrity of Matahina dam were not material to the declaration (Miles, 1995).

Anxiety dissipated, but the Regional Civil Defence Emergency still remained in effect when it became known that the dam had survived both the earthquake and aftershocks with little apparent and no threatening damage. The anxiety was revived several months later when political comment, disparaging of engineering opinion and questioning the integrity of the dam, was offered.

When the dam was first commissioned there had been a problem with cracking of its impervious core and with associated leakage and internal erosion in the vicinity of the east abutment. This needed extensive remedial work. Recurrence was a possibility to be considered by engineers responsible for the dam, who instituted a programme of intensive performance monitoring immediately after the earthquake (Gillon and Newton, 1991). Although no abnormal leakage flows were observed then or at any other time in the ensuing months of enhanced surveillance, evidence of core cracking was discovered near the west abutment, similar to the evidence for cracking observed at the east abutment when the lake was first filled. Investigation did not determine whether this damage was attributable to strain at first filling in 1967, or to the 1987 earthquake, or to both. Nor did it establish whether leakage and internal erosion persisted. However, in December 1987, while investigative work was incomplete and the lake remained drawn down below normal operating level, appearance of an erosion cavity in the surface above the damage answered this question — erosion was active. Surface subsidence, noticeable for many years and previously thought to have been caused by heavy traffic, was then attributed by the investigators to erosion, at least some of which must have occurred before the earthquake.

When evidence for internal erosion at Matahina dam appeared in December 1987, power generation ceased and the lake, having been drawn down 2.5 m after the earthquake and held at that lower level throughout the subsequent months of intensive investigation, was drawn down a further 6 m to permit repair work to be done. The opportunity was taken to make performance enhancing modifications. This was done not only in reconstruction where the dam was damaged (whether by earthquake or otherwise), but elsewhere to remove latent flaws with a potential for causing trouble. Restoration and improvement unrelated to earthquake damage contributed significantly to the extent and cost of the repair work.

Important features of the restoration were:

- the substitution in core damage zones of softer, more plastic material, better able to accommodate strains, for the stiff, brittle material of the 1967 core construction;

- the use of more suitable transition material between core and shoulders; and

- smoothing the profile of the concrete surface at the junction between earth core and concrete abutment, improving the originally stepped, crack-inducer profile of the 1967 construction, which had been built that way because excavations for it were benched.

The reconstruction cost was $16.5 million, of which the cost of making performance enhancing improvements was $7 million, so the earthquake restoration cost was $9.5 million.

Power production loss was valued at $3.2 million. However, the energy provider satisfied the entire market demand by increasing production at its other generating stations, so there was neither loss of product nor diminution of the volume and value of sales to energy consumers. The cost of generation of this power elsewhere did, however, exceed the cost of Matahina generation by an estimated $2 million, and this is the gross loss the supplier suffered. The proportion of it attributable to the earthquake is the ratio of earthquake repair cost at Matahina to the total cost of repairs and improvements, 9.5/16.5 or about 0.576, and the amount is $1.15 million. It came to charge about 16 months after the earthquake and must be discounted to the date of the earthquake at interest rates then prevailing (about 15% per annum) compounded monthly. The adjusted loss for inclusion in the total economic loss caused by the earthquake is $0.95 million.
Matahina dam, 1997 postscript

Matahina dam survived the earthquake, damaged but secure. Although apprehension about catastrophic failure of the dam and inundation downstream from it had alarmed and panicked dwellers in Rangitaiki riverside settlements and had caused spontaneous evacuation, fears abated. The affected community, by and large, accepted expert opinion it was given that the dam had capacity to resist this earthquake and foreseeable similar earthquakes.

However, Matahina dam has more to contend with. It is in a valley eroded along the Waiohau fault, one of the faults of the North Island Shear Belt system. Four traces of the Waiohau fault run through the base of the dam. This fault poses a threat to the dam that the faults in the Whakatane graben of the Taupo Volcanic Zone, where the Edgecumbe earthquake was generated, do not.

In a reappraisal of seismicity at the site, and of the behaviour of the dam in the type of earthquake that can occur from displacement on the Waiohau fault at Matahina, risk of calamitous failure was identified, associated with rupture of the impervious core of the dam. The risk is tiny, because the mean recurrence interval for Waiohau fault earthquakes is very large; but the vulnerability of the construction to these earthquakes and the depth and volume of Lake Matahina make the hazard unacceptable.

Accordingly, the dam’s owner, Electricity Corporation of New Zealand, has commissioned a design to mitigate effects of a Waiohau earthquake. In this work, a Safety Evaluation Earthquake (SEE) was identified, with characteristics more intense than the mean of expected Waiohau earthquakes. Provisions were made to protect downstream populations and property, including property owned by the Corporation, from the effects of an SEE, but not to ensure serviceability survival of the dam itself. Anticipated by the design is that substantial dam reconstruction will be needed after a Waiohau fault earthquake. All proposals have been endorsed by an International Review Board (Howie and Everitt, 1997).

In preparation for the work, the lake was emptied in July 1996.

Thiess Contractors has been awarded a $50 million contract to modify Matahina dam. Work is to start immediately (Anon 1997) and is due for completion in mid-1998.

Flood protection structures

Soon after the earthquake, senior staff from the Bay of Plenty Catchment Commission and Rangitaiki Drainage Board carried out a helicopter reconnaissance of the region to provide an earthquake impact assessment. The next day, two helicopters were used to complete the impact assessment on rivers and flood protection works. The information gained was used to brief engineering teams and position them by helicopter to carry out on the ground inspections and earthquake damage assessment. All this information was incorporated into the report of 13 March 1987, which provided details of the earthquake and its effect on flood protection and drainage schemes. Soils testing and hydraulic studies were not carried out and historical information was used to determine order of magnitude estimates of cost. The report required an input of about 1200 man hours over the 10 days it took to complete.

At an early stage it became apparent that extensive settlement had occurred on the Rangitaiki Plains, the extent and magnitude of which could not be determined without the re-establishment of the benchmark network and extensive survey work. This meant that a separate detailed review of the Rangitaiki-Tarawera Scheme, the major flood control scheme on the Plain, would be required, including all the drainage schemes affected by the settlement. Such a review, and related investigations, was, at the time, estimated to take up to a year to complete.

The remedial works identified in the March 1987 report covered only the emergency work necessary to restore the various schemes to a functional condition.

Although many different failure modes were found in stopbanks, Tarawera River failures were generally of the kind shown in Figure 55, and Rangitaiki River banks suffered most severely where they were disrupted by the Edgecumbe fault. A drawing showing a typical cross-section and plan view of one type of stopbank damage is shown in Figure 56. A summary of the lengths of damaged stopbanks requiring remedial work is shown in Table 9.
Block slumping — reduction in height up to 1 m

Sand boils

Figure 55: Tarawera River stopbank damage

Longitudinal cracks up to 75 mm

Figure 56: Rangitaiki River typical stopbank damage
(drawing prepared by the Bay of Plenty Catchment Commission)

<table>
<thead>
<tr>
<th>River</th>
<th>Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rangitaiki River</td>
<td>5.9</td>
</tr>
<tr>
<td>Tarawera River</td>
<td>12.2</td>
</tr>
<tr>
<td>Omehu/Awaiti Canal System</td>
<td>3.5</td>
</tr>
<tr>
<td>Reids/Central/Kope West Canal</td>
<td>0.6</td>
</tr>
<tr>
<td>Whakatane River</td>
<td>4.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>26.3 km</strong></td>
</tr>
</tbody>
</table>

Table 9: Lengths of damaged stopbanks requiring remedial work
Fortunately, there were no major problems in relation to water quality or soil conservation resulting from the earthquake.

Central government funding by way of a 100% grant for the “Phase 1 Repair” covered by the March 1987 Report was approved by Cabinet and the work proceeded.

Priorities for repair were set on the basis of the assessed risk of a flood breaching the earthquake damaged banks. On the Rangitaiki River, the highest priority was the fault scarp intersection of the stopbanks. On the Whakatane River, a section of stopbank which could have been breached during floods with a return period of less than one year (thus threatening the town of Whakatane), was repaired within a few days of the earthquake.

Fortunately, during the period of repairs, there was no significant flood threat. Usually big floods in the region occur in the October to December period (the cyclone season in the South Pacific). Because the risk was low and there would be sufficient warning time of possible flooding, no formal contingency plan was put in place. There would be time to breach weakened stopbanks to avoid catastrophic failures if this became necessary.

The Tarawera and Whakatane Rivers on the edges of the Rangitaiki Plains suffered no overall settlement and the Stage 1 repairs restored them to the 100 year return period design level of flood protection.

The effect of the Rangitaiki Plains settlement on the Rangitaiki River was that, even after repair, the flood capacity was considerably reduced from the original 100 year design capacity. During a flood between a 20 year and 50 year event, the stopbanks on each side of the river downstream from the fault scarp to the Edgecumbe bridge would be overtopped and water would flow to the low lying areas away from the river. This level of flood protection was unacceptable for Edgecumbe and the rural area. In 1988 it was proposed that the stopbanks on the river and the floodway be upgraded to restore the scheme to about the original design capacity of a 100 year return period flood which had been reassessed at 755 cumecs. On 14 April 1989, the Minister for the Environment approved a grant of $1.47 million at a subsidy rate of 70% of the estimated cost of $2.1 million. The work was substantially completed by 30 June 1992. In early 1992 there were proposals for design changes which were discussed with landowners and the Whakatane Branch of Federated Farmers. Concerns were expressed at the design changes, the projected costs, and the financial management of the project. After meetings, including a public meeting in Edgecumbe, and correspondence, the Audit Office became involved, firstly to conduct a preliminary review based on the information available to determine whether a comprehensive review was justified or not and, secondly, to prepare terms of reference for a full-scale review. The review as conducted was not an efficiency and effectiveness audit as first requested by ratepayers because most of the scheme was already completed and there was now little opportunity to change efficiency and effectiveness. Instead, the Audit office summarised the ratepayers concerns into a number of issues and audited the project in terms of these issues.

In summary the Audit Office concluded:

- to achieve the original objective of providing protection against a 100 year flood, the Regional Council had to modify its original design and undertake extra work;
- the project cost 26% more than estimated, the construction work undertaken was necessary to complete the scheme, the estimates [for outstanding work] are reasonable, and the Regional Council obtained all the subsidy possible; and
- the Regional Council/Catchment Commission did not have adequate reporting systems to identify the error in the original estimates.

**Costs**

The first phase of repair work was undertaken to restore flood protection stop banks to a functional condition at a cost of $1.41 million.

Second phase work re-established the level of protection afforded by the pre-earthquake stop bank system. By 1992 it had cost an additional $3.14 million, an amount that needs to be discounted to the time of the earthquake at the interest rates then prevailing for inclusion in earthquake damage cost totals.
The discounted value of second phase work is $1.63 million. The total earthquake-time value of the restoration is therefore about $3.0 million.

Funding was shared approximately equally between government grant and rates.

**Observations**

- The Bay of Plenty Regional Council took over the responsibilities and roles of the Catchment Commission and the Drainage Board in the local government reforms of 1989 when a number of local authorities were merged to form the Regional Council. With the completion of major flood control schemes and a reduction in engineering staff, the Regional Council would now not be able to produce a report in the same time frame and with the same technical input as the 1987 report without the use of consultants. One option would be a mutual aid agreement for technical input from neighbouring regional councils with similar requirements for technical staff.

**Drainage works**

Emergency repairs and urgent survey work were carried out by Drainage Board staff under the engineering supervision of the Catchment Commission, with the immediate objective of restoring the pumping stations to an operational state, at least on a temporary basis. Substantial further work was necessary to restore the facilities to their pre-earthquake state of reliability.

Fortunately, the district had two relatively dry winters in the period following the earthquake, apart from a localised flood event in February 1988, which allowed planning and repairs to proceed without serious loss of farm production.

Individuals requiring assistance in restoring on-farm or orchard damage undertook approved repairs and then completed a claim form. The claim, together with receipts or accounts for the work carried out, were forwarded to the Adverse Events Committee (AEC) (the Bay of Plenty Earthquake Assistance Steering Committee — see the section on “Farms and Orchards”, p 57).

By November 1987, only about $1.3 million had been expended for on-farm and orchard damage, and very little of this was for drainage restoration. This was in spite of the initial estimates prepared following the earthquake that suggested three-quarters of the total cost of the damage was to the drainage system and structures. The reason for the delay in approving drainage restoration was the realisation that on-farm and off-farm works required integration and drainage catchments needed to be treated as a whole. To enable the design to be completed and the works to proceed, additional survey information, including new contour maps, were required due to changes in ground surface and water table levels caused by the earthquake. Because the aerial mapping and contour project was not commissioned until July and unsuitable weather followed, the information was not available until November 1987. In addition, it was necessary to obtain ministerial approval for funds previously allocated for the restoration of the operational integrity of on-farm drainage to be used for major integrated off-farm drainage.

Catchment Board staff and consulting engineers were engaged for the investigation of major canals, pumping schemes, and pumped and gravity drains. Major projects were identified and studies and design work proceeded with. Where necessary, hydraulic modelling was carried out using the Catchment Board facilities.

A total of 15 contracts were let for major works as part of off-farm drainage restoration. In addition, 18 pump stations required significant repairs, and a considerable number of minor works were undertaken.

The drainage repair and restoration work based on the original grant was completed early in 1989, nearly two years after the earthquake and, appropriately, the AEC ceased to exist on 2 March 1989 (Kyle, 1989).

The works have not been free of controversy and legal challenges. Litigation has been the end result of problems following the earthquake associated with subsidence of land in Awaiti East, and the consequential changes in water flows. A new pump station was constructed in 1990 at a cost of about $212,000, a year after the AEC ceased to exist. For a number of reasons, a judicial review in late 1995 ruled against the Regional
Council stating that the council had erred in law in purporting to strike a rate to finance expenditure which had already been incurred. It is not clear whether the decision will result in further litigation.

**Costs**

Expenditure by the AEC on the off-farm drainage system repair and restoration work reached almost $3.0 million by 1989. The cost of an extra pumping station built in 1990 was $212,000, which discounts to $131,803 at earthquake time. Emergency drain repairs cost $104,090. Extra pumping is needed to lift water from drains in land that subsided in the earthquake. This is estimated to cost $10,000 (1987 dollars) each year henceforth. A fund of $93,500, invested in 1987 at an interest rate 5% below the abnormally high government 10-year bond rate then prevailing, will generate this annual amount, and may therefore be taken to represent the 1987 value of all future extra pumping costs.

The sum of all these is $3.3 million.

The cost of a relatively small amount of drainage work on farms and orchards that was funded by AEC is included in expenditure of $1.6 million for farm restoration (see page 59).

**Observations**

- The early and detailed on-farm earthquake damage assessment and submissions to government meant that financial and other resources were made available and ensured repairs and restoration proceeded without delay.

- Drainage repairs and reinstatement needs to be considered on a catchment basis, particularly where significant ground damage occurs, including subsidence. It is important that the commissioning of survey control work and aerial photography is undertaken as soon as practicable after the event to allow investigation and design to be finalised with a minimum of delay.

**Recovery management**

**The response phase**

**Summary of key decisions**

The summary given below of decisions taken during the first day following the Edgecumbe earthquake in relation to the declaration has been obtained from a study of available written material and from conversations with key people involved, based on their recollections several years later. Some written records were no longer available, having subsequently been lost in a fire.

**Whakatane District**

On the afternoon of 2 March 1987, a full meeting of the Whakatane District Council was in progress in Whakatane. The meeting was interrupted by the foreshock which occurred seven minutes before the main shock at 1.42 pm.

The Mayor, Mr R Byrne, who was local civil defence controller, declared a state of Local Civil Defence Emergency covering the Whakatane District at 2.50 pm on 2 March (Anon, 1987j; Davy, 1992). At that time the full extent of the damage within the District was not known; reconnaissance operations and damage reports were still being received and interpreted (Davy, 1992).

The General Manager of the Whakatane District Council and current local controller has advised that the declaration of a state of civil emergency was made on the strength of reports of damage in the District, particularly in Edgecumbe. Concern for the integrity of the Matahina dam was not material to the declaration. This arose as more information came to hand (Miles, 1995).

**Kawerau Borough**

The Mayor of the adjacent Kawerau Borough, Mrs Lynn Hartley, acting on the basis of the property damage
as sufficient cause for concern for its effect on public safety and distress, declared a state of Local Civil Defence Emergency in the Kawerau Borough a few minutes earlier at 2.45 pm (Davy, 1992). The legality of the declaration is debatable because at that time Kawerau did not have an operative civil defence plan.

Bay of Plenty Region

About 30 minutes after their local declarations, both Whakatane District and Kawerau Borough came under a state of Regional Civil Defence Emergency declared at 3.17 pm by Mr John Lepper, Chairman of the Bay of Plenty United Council and Regional Civil Defence Controller who was in Rotorua at a meeting at the time of the earthquake. The civil defence headquarters for the Region was located in the Rotorua District Council offices and was staffed by personnel drawn from the District Council staff. The Regional civil defence emergency declaration was made after close consultation with both Police and Fire Service officers and the reasons are listed in the Regional Civil Defence Officer’s report as follows (Anon, 1987j):

“(a) A 6.5 Richter Scale earthquake had occurred and many violent aftershocks were continuing. It was not known if more severe earthquakes were likely to be experienced.

(b) Matahina Dam was reported to be severely damaged.

(c) Te Mahoe settlement being evacuated.

(d) Whakatane town, damaged with essential services out.

(e) Kawerau town, damaged, chimney fallen, glass smashed. Tasman Mill severely damaged, injured workmen.

(f) Report of a chlorine leak at mill.

(g) Matata State Highway 2 blocked due to slips.

(h) Whakatane District has made a local declaration at 14.50 hrs.

(i) Rotoma’s blocked State Highway 30, as many as 19 slips.” [sic]

An important factor, but not listed above, was the absence of an operative civil defence plan for Kawerau Borough.

Rotorua District Civil Defence Headquarters was activated at about 3 pm on 2 March and all civil defence personnel were immediately placed on standby. At the request of the Regional HQ, Rotorua District had personnel and equipment ready to be sent to the Whakatane-Kawerau area to assist where necessary. Among the personnel sent immediately were volunteers from the Amateur Radio Emergency Corp (AREC), and two rescue squads. On 3 March, personnel on standby were stood down but the Rotorua HQ continued to monitor the situation and provided assistance and resources as required (Davy, 1992).

Tauranga District Civil Defence HQ was also activated when damage reports started to come in from Whakatane and Kawerau. During the first twenty-four hours, Tauranga assisted with the clearing of transport routes working from the north-western end of the Bay of Plenty. On 3 March, the number of personnel on duty was reduced, but Tauranga HQ also continued to monitor the situation and provided assistance and resources as required. In addition, Tauranga HQ answered many of the public enquiries during the period of the emergency (Davy, 1992).

The Regional Civil Defence Officer’s report also states (Anon, 1987j) that as the emergency continued, it became increasingly obvious that the township of Edgecumbe had borne the brunt of the earthquake. The township was left with no power, sewerage or water. No communication systems were operational and it was extremely fortunate that there were no deaths or serious injuries, bearing in mind the amount of structural damage that occurred to the commercial and residential properties. The structural damage applied to a lesser degree to both Whakatane and Kawerau, where numerous chimneys, roofs and windows were badly damaged.

Cessation of state of emergency

The state of Regional Civil Defence Emergency was lifted at 6 pm on 5 March 1987, but because of the severe damage to lifelines and the public distress still evident in the Whakatane District, at the same time a state of Local Civil Defence Emergency was reimposed there. This remained in force until 12 March.
Disaster recovery co-ordination

Appointment of a co-ordinator

It was evident early in the response phase that the damage, particularly in the Edgecumbe-Te Teko area, was so widespread that recovery from the effects of the earthquake would be protracted and require mobilisation and co-ordination of considerable resources. On 4 March, the Director of Civil Defence recommended to the Minister of Civil Defence the appointment of a disaster recovery co-ordinator (DRC) in terms of the Civil Defence Act. The appointment of Mr Muir Coup, Resident Manager for the Ministry of Works and Development (MWD) Rotorua, as DRC was confirmed on 5 March. On the same day, a disaster recovery centre was established in Edgecumbe.

The role of elected representatives

There is a fundamental weakness in civil defence procedures when councillors, as policy makers, move one step down and become heavily involved in operations and the detail of immediate emergency management. The lack of training, the 8 hour shifts based upon the three alternate controllers, and attempts to appoint councillors to the position of controller contrary to the Civil Defence Act, are highlighted as problems by the Whakatane District Council Civil Defence Officer (Burrell, 1987). The subject of “who should run an emergency” was also discussed at the debriefing in Rotorua on 24 June 1987. It was argued by Lepper that a politician is needed “somewhere near the top who is accountable (to the people) for expenditure, and that is the only politician who should be there” (Ferguson, 1987).

The 1995 Whakatane District Civil Defence District Base Plan designates the General Manager as Local Controller, and the Deputy Mayor, a councillor and a Council executive officer as alternate controllers. It can be questioned whether the two councillors as well as the General Manager should have their focus purely on operational matters, even if this only involves management of details of the immediate emergency phase of the response.

The need for local input into decision making

It is considered to be essential that councillors as elected representatives and as policy makers, concentrate from the very start of an emergency on policy and planning for all stages of the disaster response and recovery phases even if a disaster recovery coordinator is later appointed to assist. This includes the strategies to ensure that resources of all types are made available in a co-ordinated manner by central government, government departments, regional councils, other territorial authorities, organisations, and suppliers for restoration and reconstruction.

It is also important that councils adopt measures to ensure there is strong and continuing local input into all aspects of disaster recovery. Problems of local representation that arose at Edgecumbe are discussed further in the Recovery Phase (p 90) and Welfare (p 93).

Observations

In developing future procedures for disaster recovery co-ordination, the following should be noted:

- While civil defence response measures in an emergency must receive all the resources and precedence necessary to meet the priorities set by the Civil Defence Act, it is of importance that disaster recovery planning by territorial authorities commence immediately after the event and not be delayed until the emergency situation has been stabilised.

- Councils should seek to ensure that there is strong and continuing local input into all aspects of disaster recovery.

- Councils should reconsider whether it is desirable that councillors as elected representatives should be involved in the detailed management of the immediate emergency as controllers and alternate controllers in civil defence organisations.
Emergency services

Civil Defence (including Matahina Dam evaluation)

Immediately following the earthquake, steps were taken to activate the National Civil Defence Headquarters in the basement of the Beehive in Wellington. The headquarters was operational within the hour and carried out its role under a local or regional state of civil defence emergency of monitoring the situation and keeping central government agencies informed and their activities co-ordinated. An important department not kept informed, however, was the Ministry of Foreign Affairs, and this omission together with exaggerated media reports overseas, caused many problems in the Ministry. The headquarters remained partially activated until 5 March (Davy, 1992; Anon, 1987k).

The Minister of Civil Defence and the Director, together with the Minister of Works, flew to the disaster area on the afternoon of 2 March.

The Northern Zone headquarters of the Ministry of Civil Defence in Auckland was notified of the earthquake in reports from Rotorua and Tauranga at about 3 pm on 2 March. These reports indicated that the earthquake impact was expected to be severe, but did not give damage assessments. It was about two hours after the earthquake before more detailed information was received. This concerned damage to the Whakatane hospital, specific information on blocked highways and damage to rail track, and the possibility of damage to the Matahina Dam.

The Civil Defence Commissioner for the Northern Zone moved to the Bay of Plenty Region late on the evening of 2 March and acted in an advisory role at a number of locations until the local civil defence emergency was terminated on 12 March (Davy, 1992; Anon, 1987k).

The Whakatane District Civil Defence headquarters was not established in the Council Chambers until the early hours of the morning of Tuesday 3 March, and at that stage it was discovered there were difficulties with the layout (Burrell, 1987). The headquarters remained there until late on 4 March when the move was made to Edgecumbe. The headquarters was co-located there with the disaster recovery centre until the state of local civil defence emergency was terminated at 6 pm on 12 March 1987.

In Kawerau Borough, a Civil Defence headquarters was set up in the social room of the fire station and immediate liaison was established with the Fire Service. It took until 4.35 pm, almost three hours after the earthquake, for radio communications to be established and three telephones to be installed. Assistance with radio links was later provided by volunteers from AREC. The early priorities were communications, essential services, accounting for school children, damage reports, and accounting for Kawerau residents. Volunteers were used as wardens and after the town was marked off into sectors and the teams briefed, a house-by-house search was commenced. By 5.25 pm, it was established with some certainty that everyone in Kawerau was accounted for. Only one person was found who required help. Houses were evacuated in several streets in Kawerau and continuous security was provided by four-person teams of volunteers. At the time, insufficient police were available for such a task (Verrall in Anon, 1987j).

The greatest concern for the people of the Rangitaiki Plains in the days immediately after the earthquake was the possibility of damage to and the catastrophic failure of the Matahina Dam. This was revived several months later (see p 74). The dam has been again (since 1996) the subject of further investigation and repair (see Matahina Dam, 1997 Postscript, p 75).

No prior risk assessment or planning for an immediate post-earthquake safety assessment of the dam appears to have been carried out for civil defence purposes.

The Dam Surveillance Engineer for the Ministry of Works and Development in Wellington learned of the earthquake from the Electricity Division of the Ministry of Energy at 2.15 pm, 33 minutes after its occurrence, and dam engineering staff met to be briefed. By about 2.30 pm the power station operators advised of slight damage (cracks in the road, minor displacements, turbid seepage from the spillway drainage drive) but the main dam drain flow was normal.

Because of the known susceptibility of the dam to cracking and internal erosion, MWD advised the Electricity Division that a dam design engineer should go from Wellington to the site and this was agreed. Mr Murray Gillon left at 3.30 pm on a flight to Hamilton and was met on arrival by a helicopter arranged by the Electricity
Division which then flew to Rotorua where bad weather forced completion of the journey by road and Mr Gillon arrived on site at 6.30 pm.

The first known reconnaissance of the dam was by the local policeman from Taneatua, who flew over the area by helicopter about one hour after the earthquake (Interview Fleming, 1996). The first recorded reference to the state of the Matahina Dam is an entry which appears in the Civil Defence precis of events (Anon, 1987j) on 2 March 1987 which records for 3.11 pm “Dam cracked. Te Mahoe being evacuated. Flood gates opened.” The Declaration of a State of Regional Civil Emergency followed six minutes later. An earlier cryptic entry for 2.50 pm is “Check Matahina dam (DSIR)”. The evacuation of Te Mahoe was completed by 4.50 pm. People from Te Teko were evacuated also that afternoon with the assistance of vehicles and personnel from an Army Territorial unit in a training area near Lake Rotoma. About 500 people were evacuated from the Matahina-Te Teko area to Te Hahuru Marae.

The first known technical assessment by flying over the dam was made by the Chief Engineer of the Bay of Plenty Catchment Commission, Mr Jeff Jones, who was an observer on the first Air Force Iriquois flight from Whakatane at about 4.30 pm, some three hours after the earthquake. He had been asked by Civil Defence to investigate two major concerns stemming from rumours. These were:

- The Matahina dam had been severely damaged and was about to fail, sending a flood wave through Te Teko and on to the Rangitaiki Plains. Apparently, a young, unidentified, latter-day “Paul Revere” had already ridden through Te Teko on a motorcycle warning residents that the dam had burst, and the town had self-evacuated (Muller, 1987b).

- A landslide had occurred on the Tarawera River just downstream from the lake outlet and water was building up behind this natural dam threatening the residents of Kawerau.

The helicopter flew directly to the Matahina dam and, from a height of between about 150 and 300 metres, the dam did not appear to be in imminent danger of collapse. There was no observable deformation of the structure and the outflow of water was not unduly dirty.

The helicopter then flew over Mt Edgecumbe to the outlet of Lake Tarawera and down the Tarawera River to Kawerau to verify there was no landslide damming the river.

Mr Jones reported to the Regional Civil Defence Controller and, at his request, contacted the Electricity Division in Wellington (Jones, 1997).

While Mr Gillon was travelling to the site, the Electricity Division’s Hamilton office requested the office of the MWD in Hamilton to arrange an immediate inspection. Mr David Jennings, an experienced geotechnical engineer with dam experience, went to inspect the dam, travelling in a helicopter with NGC personnel who were inspecting the gas pipe line to the Bay of Plenty area. He landed at Matahina at about 5 pm and undertook an inspection of the dam crest before flying on to Whakatane where he reported to CD officials (Jennings, 1998). Conditions allowed only a brief inspection due to the weather and the imminent grounding of the helicopter, and the instruction to proceed to Whakatane. Mr Jennings’ observations confirmed those made earlier (2.30 pm) by the Electricity Division’s power station operators.

After arriving on site, Mr Gillon carried out a full visual examination of the dam between 6.30 pm and 8.30 pm and at about 8.30 pm he reported to Mr G Grilli (a senior Electricity Division engineer from Hamilton who had travelled to the site) that the immediate damage was minor and that the dam would need to remain under close surveillance for several days in case leakage due to internal erosion developed.

The Civil Defence precis of events (Anon, 1987j) records that at 3.10 am on Tuesday 3 March “Matahina dam clearance given.” The Ministry of Works summary of significant messages (Anon, 1987j) for Tuesday 3 March, however, reports for 7.30 am “Further inspection of Matahina Dam in hand by MWD engineers to be followed by telephone discussion with MWD head office and report direct to CD Controller at 1000 hrs.” and again, 9.50 am “Matahina Dam cleared for safety (telephone message direct to controller)”. However, 25 minutes later, the Regional Civil Defence Log records, 10.15 am “Prime Minister concerned re state of Matahina Dam. No person to return unless total safety can be assured.” The Prime Minister visited the disaster area that day.
The purpose of the above discussion of the Matahina dam emergency response from a civil defence perspective is to help ensure that adequate procedures are implemented to minimise the impact on people after similar emergencies in the future in New Zealand. The individuals involved in checking the safety of the dam clearly did their very best to resolve safety issues speedily, but there does seem to have been a lack of preparedness and prior contingency planning by the various organisations directly concerned with decision making regarding the post-earthquake safety of the dam and, in particular, as to who should be making the decisions.

As part of their contingency planning, ECNZ, who are now the owners, have in place (1996) specific procedures covering the Matahina dam. These will ensure an appropriate and rapid response when an earthquake is felt in the area. The system involves personnel on site, as well as appropriate people in ECNZ offices in Hamilton, Tokaanu and Wellington, with alternative communication systems and dedicated helicopter support from Hamilton and Whakatane. The system is integrated with the local and regional Civil Defence plans and an inundation map for the Rangitaiki Plains has been prepared to cover the extreme situation of failure of the dam.

Commissioners’ Support Teams

Some problems and criticism arose with the deployment of Commissioners’ Support Teams (CST) to the Civil Defence headquarters in the Region. The criticisms related to the fact that the teams arrived unannounced and without proper briefing, the composition, experience and tasking of the CST was not appropriate to the problems on the ground, the turnover of team members was too rapid, and the teams, when deployed, were inadequately equipped, particularly in respect of radio and communication equipment (Burrell, 1987; Verrall, in Anon, 1987j; Staff of Bay of Plenty United Council, 1987; Davy, 1992).

Costs

Civil Defence emergency expenditure was $1,171,670, costs for accommodation and the Edgecumbe Memorial Hall were $150,000, and costs for the Bay of Plenty United Council were $52,000 (Chapman, 1995).

Observations

- Lessons have been learned and detailed earthquake response procedures are in place covering the Matahina dam.

- Dams and other facilities where damage or collapse could threaten life and safety and require the evacuation of people, need to receive special attention in civil defence planning. They should receive pre-earthquake assessment like other critical facilities and procedures or agreements made for immediate and appropriate response, including damage assessment and safety evaluation, following an earthquake.

- Care and judgement is needed in using an actual emergency as a training exercise for personnel with little or no experience.

New Zealand Police

The priority role of the police in the response phase was to ensure public safety and earthquake impact assessment, and to provide an element of security for public and private property.

Immediately following the earthquake, all local police personnel endeavoured to report to their stations or Civil Defence posts. Two officers were trapped by landslides in the Tarawera forest, and had to be lifted out by helicopter. During the afternoon, a police team including senior personnel was flown into the area from Rotorua. Further police support arrived the next day from Auckland and Hamilton, and Police Operations Rooms were set up at District Headquarters at Hamilton and the Tauranga Police Station. The role of the operations room was to monitor the situation and provide assistance where necessary.

Much of the initial reconnaissance and earthquake impact assessment was done by the police using helicopters. During the first few hours after the earthquake, Civil Defence and government departments in Wellington were dependent on police alone for information. The local policeman at Taneatua made use of a helicopter based nearby at Waimanu for a reconnaissance of the Matahina Dam and the Rangataiki River,
about one hour after the earthquake. The helicopter flew over the dam but did not land at the dam site to obtain
detailed information. According to the pilot, the fault scarp appeared to head directly towards the dam
(Interview Fleming, 1996). With the benefit of hindsight, there was internal police comment that more on-
the-ground reconnaissance should have been carried out (Davy, 1992).

Difficulties were experienced with police communications in the area after power was lost to the transmitter
at Te Teko station and the repeaters on Mt Edgecumbe and Manewehe. Police station telephone systems were
overloaded with a flood of enquiries concerning the welfare of friends and relatives. The situation was
exacerbated by the inaccuracy of much of the early information going out to the public from unknown sources
which generated unnecessary alarm locally and overseas (Davy, 1992; Hamilton, in Ferguson, 1987).

There were some security problems in the region with looting by gang members in Te Teko and looting also
in Kawerau. The situation was serious enough for the policeman at Te Teko to request assistance from an Army
Territorial unit which was camped nearby in a training area at Lake Rotoma. Security of areas that had been
evacuated was also a problem as only four constables were available throughout the region for such work.
Four-man civilian patrols were set up to take over this responsibility (Davy, 1992; Hamilton, in Ferguson,
1987; Verrall in Anon, 1987j).

Police facilities in the region suffered damage. The police station at Kawerau was assessed as unsafe and a
caravan and portable generator were set up adjacent to the station. The stations at Te Teko and Edgecumbe
were severely damaged with the latter having to be replaced. At Whakatane, only slight damage was caused
to concrete walls and roofing of the police station.

**Costs**
The cost of repairs and reinstatement to Police facilities was $263,500 and operational costs were $30,000
(writer’s estimate).

**Observations**

- Helicopters and video cameras are invaluable in an emergency for reconnaissance purposes to obtain an
overview and impact assessment in the early stages, particularly for lifelines, when used by people with
the necessary technical expertise. For detailed earthquake damage assessment aerial reconnaissance
should be supplemented by ground inspection.

- Inaccurate information and ill-informed assessment of information is more dangerous than a nil report.

**New Zealand Fire Service**

After the earthquake, staff throughout the Fire Service Area began arriving at the nearest fire station.

The Whakatane Brigade (assisted by the Ohope Brigade, an appliance from the Opotiki Brigade, and off-duty
permanent staff from Kawerau resident in Whakatane) was immediately involved in the evacuation of patients
from the Whakatane Hospital, pumping out the basement and cleaning up.

The Edgecumbe Brigade assisted families in the most devastated areas and commenced the initial cleanup.
Many of the brigade members were attending to the requirements of their families and the securing of their
houses as a result of the severe damage caused in the town and were not immediately available. Two incidents
were reported at the science laboratory of Edgecumbe College and these were satisfactorily attended to by the
Edgecumbe Brigade. Staff from the brigade drove a milk tanker to Matata to obtain fresh water for the town
as the supply of potable water had been cut off by the earthquake. The spillage of chemicals in a warehouse
at the Bay Milk Product’s plant at Edgecumbe was also reported. Staff from the Kawerau Brigade were sent
to assist in the site inspection. As it was near nightfall, aftershocks were still occurring, the buildings were
believed to be close to collapse, and the storage stacks inside were in an unsafe state, instructions were issued
to carry out an external inspection only and to secure or evacuate the area.

Fear that a chlorine plant at the Tasman Mill was damaged and dangerous was shown to be groundless after
an investigation by the Kawerau Brigade. The Brigade also dealt with a chemical spill at the Kawerau College
science laboratory.
A Fire Service task force of people who were skilled in handling chemical hazards was assembled and equipped in Auckland and Hamilton, and despatched to deal with concentrated acid and caustic solution spills and with other chemicals at Bay Milk Product’s plant in Edgecumbe. There, some dangerous chemicals had escaped from collapsed and ruptured vessels of various capacities, up to 10,000 l, and other chemicals were in precarious storage. Areas cleansed were a warehouse, an open drum store, a dangerous goods store, and a veterinary laboratory. These clean-up assignments, and some others, were completed by the afternoon of 5 March. The force then withdrew and dispersed.

In Kawerau there were many calls for emergency assistance involving the covering of roofs with salvage sheets and tarpaulins and the demolishing of hazardous chimneys. It was reported that many chimneys were cracked, and many more were already down either inside the houses or outside (Verrall in Anon, 1987j). In an effort to use the resources available more efficiently, the Fire Service, in conjunction with the Kawerau Civil Defence staff, divided the township into sectors allocated to a task force. Each task force was given the responsibility of working street by street and checking each building for damage. Hence it would not be necessary to wait or rely on returning residents to check for damage and call for assistance. It was believed that this would have the effect of limiting the travel distance between buildings requiring emergency work, and be more efficient. The other benefits claimed were that enquirers could be advised of the following:

- that their premises had been checked and considered safe or work had been carried out in their absence;
- if their premises had not been checked, when was this likely to occur; and
- whether the premises should remain unoccupied. Civil Defence was advised so that welfare assistance and engineering advice could be provided.

The Fire Service resources were supplemented with equipment, plant and trucks from the Kawerau Borough Council and the Tasman Mill together with volunteer labour. A task force had two pump appliances mainly for transporting personnel, small gear, tarpaulins, a 10.5 m extension ladder, and a 20/30 tonne crane. Dump trucks and small plant items were available as required. Inspections were carried out by a group of building inspectors from Kawerau, Rotorua and Tauranga (Willis, 1997).

The emergency calls involved almost entirely the making safe of chimneys and the covering of roofs. If the call was for roof covering only, this was due to the chimney having fallen, or tiles broken or the roof having opened up. Salvage sheets and/or tarpaulins were spread over the area affected and tied off securely. When the call involved a chimney, it was checked by Fire Service staff and either demolished to roof level by the use of hand tools, or lifted out completely by crane.

The necessity for such extensive chimney demolition has been questioned by Robinson (Robinson, 1988). Whether all the damage to chimneys was likely to have been caused by the earthquake is discussed in detail in the Houses section of Part 2 (p 37).

All the urgent work of checking buildings and of making any necessary re-checks was completed by about 5 pm on Sunday 8 March. It should be noted that the Regional Civil Defence Emergency covering Kawerau Borough had been terminated almost exactly three days earlier, at 6 pm on Thursday 5 March. However, a State of Local Civil Defence Emergency covered the Whakatane District until 12 March.

The Fire Service Area headquarters was at the Kawerau Fire Station and the co-location of the Kawerau Borough Civil Defence Headquarters in the same building appears to have had a number of advantages. On the day following the earthquake, a “Fire Service Earthquake Operations Command” or “Resource Centre” was set up within the headquarters to deal with earthquake related duties including mechanical repairs, reinforcements, CD Liaison and welfare. The “Earthquake Operations Command” was separate from the “Fire Command” which retained the normal on-going responsibility for fire incidents. Both commands had direct communication and liaison links and were controlled by the Fire Service Area Commander. The Resource Centre commenced operations at 2.30 pm on Tuesday 3 March and finally closed at 5 pm on Sunday 8 March 1987.

For the period Monday 2 March to Tuesday 31 March 1987, Table 10 lists the calls attended to and the major resources involved.

Fire Stations in the area suffered some damage as follows.
### Table 10: Fire Service callouts and use of resources for the period 2-31 March 1987

- Whakatane: there was superficial cracking and some fallen plaster and electricity and telephone services were cut. A portable generator was installed.
- Taneatua: no damage.
- Ohope: no damage.
- Edgecumbe: cracking occurred in concrete masonry walls, concrete floors and paving and doors came off their hinges. There was some damage to building services — electricity, telephone, water and sewerage services were cut and all public fire alarms were out of action. A portable generator was installed and the station remained operational.
- Kawerau: cracking occurred in concrete masonry infill panels and light fittings fell from the ceilings. The electricity supply was cut, telephones were out for two to three hours and all public fire alarms were out of action. The station remained operational on power from an emergency generator.

During the whole of the emergency, radio contact on the Fire Service frequency was maintained, and radio telephone services remained operational throughout the area and in contact with other areas in Rotorua and Taurang (Gunn, 1987; Verrall in Anon, 1987j).

### Costs
Costs for the period 2 March to 31 March 1987 are shown in Table 11.

<table>
<thead>
<tr>
<th>Description</th>
<th>$NZ</th>
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<tbody>
<tr>
<td>Damage to Buildings and Contents</td>
<td>17,417</td>
</tr>
<tr>
<td>Overtime</td>
<td>74,680</td>
</tr>
<tr>
<td>Other operational costs</td>
<td>30,931</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>123,028</strong></td>
</tr>
</tbody>
</table>

Table 11: Fire Service costs for the period 2 March to 31 March 1987
Note: Normal salaries and wages of about $36,000 are not included and while extensive use was made of volunteers, the cost of their services is also not included (Gunn, 1987; Verrall in Anon, 1987j; Stephens, 1996).

**Observations**

- The response to the chemical spillage at Edgecumbe was a good example of conserving resources outside the emergency area until a specific task is identified. The Task Force was assembled with the necessary vehicles, equipment and personnel, moved into the area, carried out the task, and moved out. Resources were used efficiently and not dissipated. In contrast, two Fire Service appliances from Rotorua and the ST Johns Ambulance Detachment were sent into the area without specific tasks and as a result resources were wasted.

- It is important that, even during the state of civil defence emergency, organisations undertaking tasks involving building safety and demolition endeavour to work within their expertise or obtain adequate technical advice to enable them to do so. Such tasks undertaken when the emergency has been terminated will be subject to normal legal constraints.

**Ambulance Services**

The Ambulance Service was activated soon after the earthquake occurred at 1.42 pm on 2 March 1987. At 3 pm, in the absence of a request or directive from Civil Defence, executives of the Auckland and Hamilton ST John Ambulance Regions decided to dispatch a back-up fleet of ambulances to the disaster area. This action was taken 17 minutes before the regional state of emergency was declared. Auckland Region sent six ambulances, a command car, and a command/communications vehicle, and Hamilton three ambulances. Ambulances from several towns in the Bay of Plenty were also dispatched. The rescue helicopter from Taupo also went to the area. Road access to the disaster area was hindered by slips and the damage to bridge approaches.

Local ambulances were kept busy during the afternoon and evening of 2 March. The tasks included the evacuation of the main building at Whakatane Hospital which was carried out with the assistance of outside ambulance crews. Six helicopter transfers were made during the first day after the earthquake.

Ambulance communication was good within the area and between the regions, and no major problems were encountered by ambulance staff.

At 1 pm on 4 March all the remaining outside ambulances were returned to their stations and procedures returned to normal (Davy, 1992.)

In discussing whether organisations should move into a disaster area when an emergency is declared or wait for directives from local (CD) controllers, Latter (then Director of Civil Defence), felt that resources should be readied but not moved in until requested. He used the St John Ambulance organisation as an example where Civil Defence had received a large bill for a resource that had not in fact been used. A need had been anticipated but they (St John) had moved ahead too quickly. However, if there had been a more severe aftershock, every ambulance would have been needed (Latter, in Ferguson, 1987).

**Costs**

Included in Civil Defence costs.

**Observations**

- Resources should be prepared and put on a state of readiness but not sent into the disaster area until requested by the emergency headquarters for carrying out designated tasks. The resources should be organised for the particular task before being dispatched. See, for example, the successful use of a chemical task force by the New Zealand Fire Service discussed earlier.

**New Zealand Defence Forces**

Defence Forces support for Civil Defence following the declaration of the civil defence emergency included:
• Defence Forces manning at the Northern Zone Civil Defence Headquarters;
• deployment of a 100 man plus Northern Region Task Force (NRTF) (Army), from Papakura Military Camp, into the disaster area;
• preparation for deployment of a 100 man NRTF (Navy);
• air support by UH1H Iroquois and P3 Orion aircraft;
• diversion of RNZN units from exercises in the Hauraki Gulf to the Bay of Plenty; and
• involvement as necessary by 6 Hauraki Infantry Battalion.

During the afternoon of 2 March 1987, an RNZAF Orion aircraft made a general reconnaissance flight over the disaster area. The results of this flight, including any earthquake impact assessment and earthquake damage assessment, and how the information was disseminated and utilised in the response and recovery phases, are not known.

At 4.45 pm on 2 March, two RNZAF Iroquois helicopters from Auckland were sent to the area with servicing and medical personnel and equipment. The Search and Rescue helicopter which had arrived at the area earlier, was integrated into the RNZAF detachment. Aviation fuel was not available from the underground tanks at Whakatane Airport because the fuel pumps were inoperative due to the power outage. No pre-planning had been done by way of provisions for installing a portable generator and the electricity supply to the airport was not restored until 24 hours after the earthquake. In addition, at that stage, access to the airport was restricted by the damage to the approaches to the bridge over the Whakatane River, communications were difficult and the telephone system overloaded. Consequently, a fuel tanker and a communications team to provide control of the aircraft in the local area and reliable rear link communications were requested from Auckland and were dispatched from there at 7 pm that evening.

For the first few days, a helicopter landing site was established on a small domain about 300 m from the Civil Defence Headquarters in the Council Chambers in Whakatane. When the Civil Defence Headquarters moved to Edgecumbe on the morning of 5 March, the detachment, personnel and vehicles were deployed there also.

Tasks flown by the helicopters were:
• area reconnaissance for Civil Defence and the Police;
• searching isolated areas for trapped people;
• searching for school parties;
• VIP reconnaissance (Prime Minister, Cabinet Ministers, and the Police Commissioner);
• moving freight from Rotorua to Edgecumbe; and
• positioning of engineer teams for the damage assessment of flood protection works.

A total of 34 Iroquois sorties were flown carrying 129 passengers and 700 pounds of freight. The total Iroquois flying time was 22.3 hours, including transits to and from the area. The Search and Rescue helicopter, a Bell Jetranger, was utilised instead of the Iroquois because of the nature of some of the tasks and the small number of passengers to be carried. The total Jetranger hours flown was between 20 and 25 hours.

A Territorial Force unit, 6 Hauraki Infantry Battalion, was engaged in annual camp activities and training in the Lake Rotoma area at the time of the earthquake.

Within 30 minutes of the Headquarters of 1 Task Force at Papakura being alerted to the emergency, the Battalion was told to stand by for Civil Defence tasks, if required. This deferred the departure of the unit from its training area at Lake Rotoma. Some 30 soldiers who were resident in the Bay of Plenty were advised that should they wish to return to their homes, they would be released. About 25 accepted but 20 returned to the unit the next day.

Vehicles and volunteer drivers from the Battalion transported people from Te Teko township to a local marae.
A request from the policeman at Te Teko for 150 soldiers from the Battalion to provide town security was not actioned, but referred to the Civil Defence authorities. Eventually Northern Zone Civil Defence sought 50 personnel. Approval was given for the commitment of 40 volunteers on condition that duties were to be performed under the supervision of the police and no weapons were to be carried. The assistance was in fact provided at dawn the next morning, 3 March, by regular soldiers from NRTF.

The NRTF (Army) sent to the disaster area at 1.00 am on 3 March comprised a Headquarters, two liaison officers, two independent signals detachments, four platoons each of 25 men and a shower unit — a total of 123 personnel and 26 vehicles. On standby, if required, were further troops for security tasks and general duties, field kitchens and cooks, mechanics, engineer tradesmen and medical staff. Within 36 hours of their arrival, the headquarters and the four platoons were withdrawn as the local Civil Defence resources were adequate. A total of 349 man days was spent by Army personnel in direct support of Civil Defence during the period of deployment. The task force had some difficulties in communications with the various headquarters, both Army and Civil Defence.

Dudman, the Commander of Land Force Command in Auckland, was critical of one aspect of the Civil Defence organisation, and stated in his post operation report “A feature of the CD organisation at local and regional level was that key personnel were not manning their CPs [command posts] and were more interested in seeing things for themselves. As a result, 1TF were not able to get any direction at all and, ultimately, acted on its [sic] own initiative in deploying the 100 man task force and, in the case of 6 Hauraki, helping in the evacuation of Te Teko.” (Dudman, 1987; Walker Annex A to Dudman, 1987; Martin in Anon, 1987b).

**Costs**

Operational costs for the New Zealand Defence Forces are estimated at $60,000 (writer’s estimate). Salaries and wages and loss of training time are not included in this.

**Observations**

- Emergency organisations held in readiness to provide support and resources need to be regularly briefed on the situation and be allocated tasks before they are deployed.

- There was a need to improve the reconnaissance capability of the task group by the addition of engineers and military police. The reconnaissance element, together with the task force commander and liaison officers should be deployed ahead of the main body.

- Deployment of a communications team and vehicle is essential for reliable communications with aircraft and to provide a rear link.

- A Civil Defence headquarters requires the attachment of an RNZAF representative or similar experienced person to assist staff in the efficient utilisation of all air assets.

- A greater use could have been made of the available helicopter capacity for reconnaissance and earthquake damage assessment, particularly for engineering lifelines.

**The Recovery Phase**

**Appointment and role of the Disaster Recovery Co-ordinator**

Under Section 69 of the Civil Defence Act 1983, the Minister of Internal Affairs has powers to appoint a Disaster Recovery Co-ordinator to facilitate the recovery of the community. Mr Muir Coup, the MWD Rotorua Office Resident Manager, was appointed to this position by the Minister, at 4.18 pm on 5 March 1987. A little later, at 6 pm, the state of Regional Civil Defence Emergency was terminated and at the same time a state of Local Civil Defence Emergency was declared, covering the Whakatane District.

The role and responsibilities of a Disaster Recovery Co-ordinator were covered by Sections 71 and 72 of the Act. The initial appointment was for 14 days, but this was later extended to 28 days. There had been two disaster recovery co-ordinator appointments made previously under the Act, but this was the first made following a major earthquake. At the time, there was no written brief covering the role of the co-ordinator and
the supporting organisation. After discussion with a previous co-ordinator, and based upon the approach taken during the Aorangi and Southland floods, a detailed establishment and organisation was developed to meet the needs of the Bay of Plenty disaster.

The role of the co-ordinator, as identified by Mr Coup, was to:

- provide an interim management structure to co-ordinate relief measures for the various central and local government agencies until such time as they are able to establish, or in some cases, re-establish themselves in the area;
- co-ordinate the work of the wide range of public agencies involved in the rebuilding process;
- identify areas where existing government policy provisions are likely to be insufficient, inadequate, or inappropriate to handle the effects of the disaster;
- report to government on the areas where further action would appear necessary; and
- provide a local focus for the recovery operation and to act as an information agency.

The local civil defence emergency in Whakatane District remained in force until 6 pm on 12 March. Consequently, the co-ordinator had the opportunity to get established and obtain a broad overview of the situation before taking on the overall co-ordination of the recovery phase for the whole of the disaster area.

The Disaster Recovery Centre, the focal point for the recovery operation, was set up in a small vacant shop with additional accommodation in portable buildings on the main street of Edgecumbe adjacent to the Cosmopolitan Club where it was easily found, an essential prerequisite for a disoriented community.

The lack of hard information on which to assess the full extent of the problem and make decisions was immediately apparent, even though there were lots of pieces of paper, numerous personal opinions, and “gut” feelings. One way to bring the various bits of information together and to identify the areas where further information was required was to establish a computerised database. This is discussed further in Information Services (page 92).

Because of the wide range of activities being undertaken, four committees were established: welfare; housing; technical; and rural affairs. The committees were made up of local representatives of community organisations or local officers of government departments. The composition was intended to ensure that the committees could relate to the local community and the underlying concerns of the community could be addressed. The three major employers in the area, Tasman Pulp and Paper Company, Caxton Paper Mill and Bay Milk Products, were considered large enough to organise their own recovery and a committee covering industry and commerce was not considered necessary. Another factor was that many of the small business enterprises and much of the commercial activity was based in Whakatane which had suffered relatively little damage.

The Disaster Recovery Centre continued operations until May 1987.

Cabinet established an Officials Committee in Wellington composed of senior representatives of government departments involved in the recovery operation chaired by the Secretary of Internal Affairs. All submissions requiring policy changes or those covering new initiatives were considered by the committee before recommendations were made to Cabinet. The Co-ordinator initially reported progress to government through a private secretary to the Prime Minister and later through the Department of Internal Affairs.

Dissemination of information was a vital part of the co-ordinator’s role and was achieved by public meetings, special information bulletins, and regular bulletins in the local newspaper and on the radio station. A media officer on the Co-ordinator’s staff proved invaluable.

On the whole, the welfare, rural restoration and technical activities went fairly well, but the rate of progress of housing repairs remained the major problem. It is understood that in two previous flood disasters where co-ordinators have been appointed, the rate of progress of housing repairs has also been the major problem.

Material supply and labour were not the problem initially predicted. The Disaster Recovery Centre kept a
register of contractors available from inside and outside the area and these contractors proved their ability to handle the workload. Manufacturing industries and contractors assisted with the material supply problem. The key to rapid progress in housing repairs is early claims by the insured and speedy processing of insurance claims so that work can proceed and additional funding can be arranged where necessary.

In a 1994 paper on his role, on the opportunity the emergency gave to review the current planning for civil defence emergencies, and on the importance of being better prepared, Coup recognised how different the results could have been. He stated “I think, however, that the Ministry of Civil Defence and I both recognised that we only just coped with a major earthquake on a relatively small community. A similar disaster in a major urban area would present a much greater challenge...”.

Costs
Costs for the Disaster Recovery Co-ordinator were $97,966, which was paid from the Ministry of Civil Defence Budget (Chapman, 1995).

Observations
• It was the opinion of the Disaster Recovery Co-ordinator that he and the Ministry of Civil Defence, “only just coped” with the earthquake.
• It was fortunate that most local body and government department officers employed in the frontline operations had not suffered personal loss in the earthquake. As a result they were able to put in long hours to ensure that the restoration of vital community services could occur without having to worry about their own personal situations (Coup, 1994; Davy, 1992).

Information services
It is claimed for the Edgecumbe earthquake that it is “probably a world-first” among disasters to have had comprehensive computerised information compiled quickly enough to be used in the recovery period (Ruscoe, 1988). The information was used for planning, resource management and social welfare work. No pre-programmed computer resource was available in the region for this purpose. Rather, the value of a suitable database of information having been recognised by the Disaster Recovery Co-ordinator, a scheme for recording survey damage and social need information was improvised, and equipment was borrowed to implement it.

Edgecumbe College had a strong computer department which was able to provide eight personal computers and volunteers from knowledgeable sixth and seventh form pupils to operate them. A computer section was established at the Recovery Centre, where college pupils enthusiastically worked long hours, while their school remained closed for essential refurbishing after the earthquake, transferring records from field observations and surveys into computer files. These files were then reprocessed and amalgamated by Ministry of Works computer specialists into a single database, which rapidly proved its worth for damage evaluation, for reinstatement of services and for other recovery work management, and, later, for the provision and management of social welfare services in Edgecumbe.

The database record made then was perhaps more comprehensive than could be made now that the Privacy Act is in force. This is a consideration needing study (Upton, 1996), for nothing was superfluous in the record — nothing could have been eliminated from it without lessening its value for some aspect of recovery work. It will be a pity if a comparably useful record cannot be available to assist recovery from future catastrophes.

Improvements could have been made had it been possible to access territorial authorities’ computer files for the property information they contain, and to access data collected by other agencies working in the region, for example data gathered by loss adjusters. A practical scheme for information sharing is worth developing, especially one that diminishes the number of times disaster survivors are canvassed for personal and property information, for then it is doubly beneficial — it reduces the irritation that repetitive questioning induces in survivors (Davy, 1992), and it saves effort. But pre-planning on a national scale is needed for the maximum benefit to be realised. The Office of the Privacy Commissioner advises that there is no reason why a database operated by the Ministry of Civil Defence and subject to the Official Information Act should not be fully utilised. However, if the database is operated by an agency outside the public sector, the Office advises that
it might still be possible for such an agency to use and disclose information without necessarily being in breach of the Act (Privacy Commissioner, 1997). This does introduce an element of uncertainty as to whether or not the database could be operated by an agency outside the public sector.

Welfare

Physical welfare in the immediate aftermath

Not one fatality was directly attributable to the earthquake, and few people suffered physical injury severe enough to require emergency medical attention. Those who were seriously injured (there were some) were taken to hospitals in Tauranga, Rotorua and Opotiki. Medical services and institutions in the earthquake affected region were not overtaxed.

At the village of Te Mahoe, on the Rangitaiki River immediately downstream from the Matahina dam, and at the township of Te Teko, 5 km further downstream, apprehension about the stability of the dam, and fear of massive inundation should it fail, was fuelled by persistent alarming rumour and by a false report broadcast on radio. Rumour prompted spontaneous flight. Credence for it grew with swelling flow in the Rangitaiki River, caused by deliberate discharge of spill water at the dam, and that persuaded riverbank lingerers to flee. Refugees did not know that the lowering of the water level behind the dam by spilling lake water into the river was a planned precaution; to them increasing river flow confirmed the menace of an impending unthinkable catastrophe. Not all were mollified when, next day, reassuring reports were published that investigations had established dam safety.

Te Teko children were conducted from their river bank school across 5 km of pastureland to Te Hahuru marae, a place safely remote from the Rangitaiki River. There they were joined by others — the marae was refuge for about 1000 people by the evening of 2 March, and hundreds more were to arrive on 3 March and later for temporary residence, for safety and for the comfort of the company of other people. Their number was never established by rigorous official count, but it was estimated to have reached 5000 people at peak, a time when Civil Defence was referring refugees to this marae (Ruscoe, 1988; Davy, 1992).

Many Rangitaiki riversiders spent the night of 2 March in the hills, temporarily accommodated in wool sheds and whatever else offered, before drifting to billet accommodation or to one or another of the maraes in the district. The weather deteriorated and heavy rain worsened the plight of homeless people.

From Edgecumbe, school children and college pupils who, for various reasons, were not quickly reunited with their families after the earthquake, were taken under control of school and college authorities to a marae at Matata. Understandable caution about discounting rumours of impending inundation from Matahina dam failure prompted this evacuation to safer territory.

An unfounded and irresponsibly launched rumour that noxious concentrations of chlorine gas had escaped from ruptured vessels or from pipework in the Tasman plant spread alarm in Kawerau. This was slow to abate. In Kawerau also, recognition of potential for dangerous hill slope instability, in aftershocks or after heavy rain, prompted compulsory evacuation from about 40 threatened homes. Some evacuees found shelter, while others spent a less comfortable and very wet night of 2 March camping or in the open.

Some people and families left their homes in the Rangitaiki Plains region and remained away while aftershock activity persisted. However, most stayed in the district, in their own homes where that was possible, or returned to their homes within a few days, and they wasted no time before starting restoration and rehabilitation activities and developing the helpful cooperative community spirit which, despite a few setbacks and lapses, characterised and assisted the recovery.

A state of Civil Defence Emergency having been proclaimed, responsibility for initiating and controlling measures to preserve life, to prevent injury and distress and to mitigate harmful effects rested with the Civil Defence Controller and the Civil Defence organisation. Civil Defence supported and assisted teams initially from the Salvation Army and the Red Cross. These teams arranged for emergency accommodation when it was needed, supplied and distributed food and clothing, and supplied bedding to temporary visitors at maraes and other refuges in the region. They were later joined and supported by groups from work schemes and by others representing churches, local and national service clubs and organisations. In rural areas, loosely organised teams of altruistic people from the farming community, determined to support with practical
emergency work those of their fellow farmers and orchardists whose plight they thought worse than their own, worked very efficiently and effectively. Much early emergency farm restoration was done this way.

Electricity supply was disrupted, at least temporarily, by the earthquake everywhere in the Rangitaiki Plains region. The water supply failed in many areas, and water was contaminated or turgid in others and therefore unsafe to use. Sanitary and storm drainage, public transport, retail food supply and other essential services all either ceased or were seriously impaired in the most intensely shaken towns and environs of Edgecumbe, Te Teko and Kawerau. Emergency public kitchens and feeding points, water supply by tanker and jerry can and portable public toilets were soon available to alleviate suffering. These were to be a feature in the lives of many people for some time in Edgecumbe and in Te Teko.

**Organisation**

A Welfare Committee, set up by Civil Defence, operated under Civil Defence aegis to monitor and coordinate welfare activities from the requisitioned Cosmopolitan Club building in Edgecumbe. It met daily, was chaired by a Whakatane District Councillor, and had representation from territorial authorities, Civil Defence, providers of welfare and health care, service organisations, farmers, education, employment and Maori interests, and government departments. The executive head of its operations and all who served on this Committee were Rangitaiki Plains people who knew the district and its people well.

The Welfare Committee, the most important and effective of a number operating at the time, survived the cessation of activities of its parent, Civil Defence, at the expiry on 5 March of the regional state of emergency, and then on 12 March of the Whakatane District state of emergency, which had been reimposed. It continued working from the same premises, now renamed the Disaster Recovery Centre, which, since 5 March, had also housed the government-appointed Disaster Recovery Co-ordinator, who was charged with review and co-ordination of government’s activities.

The committee worked vigorously and very persistently to persuade government to provide finance and resources for rapid recovery. Also, in addition to the welfare coordination responsibility the committee had when under Civil Defence, which was continued, it provided a community advisory service to assist people with insurance, housing restoration, accommodation and other welfare problems. However, it was denied both an advisory role and the administrative function it had been looking for when government’s relief package became available (*New Zealand Herald*, 7 April, 1987). Funds from the relief package were allocated directly to those government departments providing welfare services (Housing Corporation, Social Welfare Department and Maori Affairs Department), and to the Eastern Bay of Plenty Emergency Relief Trust Fund.

Lacking funds, the committee was reduced to offering advisory services, to monitoring, and to making representations, wherever there was a prospect for success, on behalf of people who had suffered in the earthquake and for whom the recovery was especially difficult. Advisory aspects of its activities were occasionally controversial — they attracted criticism for encouraging unfounded belief that government gifts or grants would solve problems for underinsured and uninsured people and that trauma payments were available (Muller 1987b). The sincerity of concerned motivation that prompted this groundless optimism cannot be doubted, but it is also beyond doubt that such semi-official misinformation caused unrest and ill-will that was both persistent and unhelpful.

After two intensive months since its formation, the committee’s work was abruptly and controversially terminated. Its functions were assumed by the Department of Social Welfare, which declared, through its Rotorua District manager, that the Welfare Committee’s important work had been well done and that this organisational change did not carry any implication of criticism of the committee or of its work (*Beacon*, 5 May 1987). Nevertheless, the circumstances of the committee’s demise engendered bitterness and anger, principally because there had been no warning that change was contemplated, nor had there been consultation. Locals rued their lost representation. Despite publicly declared appreciation of the work that the committee had done, many were unhappy.

A Housing Advisory Centre (successor to the Welfare Committee) continued from Edgecumbe with assistance offers where problems might yet be encountered. Problems were anticipated mainly in connection with insurance, with housing restoration work and with its financing. Government’s temporary agencies, set up in Edgecumbe after the earthquake, had either been withdrawn from the town or were being withdrawn, and services they offered were less accessible than they had been.
In its turn, the Housing Advisory Centre was then directed to cease functioning by 26 June. This, many locals believed, was much too early. There was criticism of a stalled recovery for which, it was said, “red tape” was largely responsible. Some people blamed the government and its agencies, especially the Earthquake and War Damage Commission (whose regulation prescribed co-insurance role was almost universally misunderstood to be a welfare service role), and the Department of Social Welfare. What was seen to be a void in the wake of premature withdrawals of welfare and advisory services was filled by the activity of yet another welfare advisory group, the Eastern Bay of Plenty Earthquake Recovery Information Centre, ERIC (Beacon, 1 July 1987). ERIC commenced operations early in July from the building that was formerly the Edgecumbe Presbyterian Manse.

ERIC’s members were community volunteers. Its initial funding was a private donation from one of the volunteers. Not until it was operating and had demonstrated its worth, was there monetary support provided from government. ERIC supported and advised people, assisted them to make appropriate welfare and insurance applications, helped with building problems and investigated alleged inconsistencies in insurance assessments. ERIC continued to serve while there was a need for it, as a fine example of useful community self-help and cooperation.  

**Physical welfare in ensuing weeks**

Residents of the most severely stricken localities in the region endured adversity, almost all with stoicism and resilience, but some with apparent trauma. Aftershocks were frequent and intense, essential services took some time to restore, many dwellings were strewn with badly damaged contents, difficult and distressing to clear away, and some houses needed immediate makeshift repair to make them habitable. Conditions were exacerbated by deteriorating weather.

Ground levels altered by the earthquake continued to adjust in the Rangitaiki Plains for months, movements sometimes stimulated by aftershock activity. Before equilibrium was established much of the permanent restoration work could not be begun. Delays for this and for other reasons contributed to the troubles and to the stress people had to endure.

Many families suffered substantial financial loss through damage to uninsured or underinsured possessions, or because restoration and replacement costs exceeded indemnity value amounts, reduced by the excess deducted in compliance with Commission regulations, paid to them by the insurer. Financial uncertainty and apprehension was a cause for serious concern to add to other troubles people faced. Whether the stress showed or was concealed, they were affected by it to varying degrees. For those who were so affected that symptoms appeared, help was available from social workers and from psychologists. It was available also to volunteer helpers some of whom, working strenuously to relieve suffering, had themselves succumbed to effects of overwork and anxiety, and to school teachers who had added responsibilities with some pupils and their families which they were obliged to accept in addition to having to cope with other abnormal difficulties.

Emergency financial help was available from the Department of Social Welfare and through the Emergency Relief Trust Fund, and other material help was also available, such as provision of supplies to restock larders and dinner sets to replace sets destroyed in the earthquake. Housing loans were also offered by the Housing Corporation and by the Maori Affairs Department.

Schools closed by the earthquake were all reopened within two weeks. While they were closed, organised programmes and day care was provided for young school children whose presence might otherwise have impeded the activities of those of their families who were engaged in salvage and in restoring the family home. When schools reopened, most of them had help from support teachers, from welfare activities of schools in other districts, and from other organisations. However, teachers and pupils had to contend with adverse conditions caused by loss of equipment and by the clamour of restoration work in progress.

Before sanitary drainage systems and good quality water reticulation were put in order and were functioning, danger of epidemic diseases existed. This peril was averted by the supply and maintenance of an adequate number of portable toilets, by daily distribution (by the Army in the first few post-earthquake days) of jerry cans of potable water to householders, by hygienic handling of food, by attention to cleanliness at bulk feeding stations and by discipline in the community exposed to risk concerning such things as boiling water before use whenever it was possible that the source was tainted. Fortunately, there was no outbreak of any serious illness.
**Government departments**

Of all government departments, Social Welfare had the heaviest commitment to welfare in the earthquake affected region. Housing Corporation and the Maori Affairs Department also contributed.

The Department of Social Welfare has responsibilities, in a civil defence emergency, to arrange payments that meet immediate and on-going needs of disaster victims including the costs of billeting evacuees, to help and advise distressed and displaced people and to maintain its normal social security benefit activity and its statutory social work. It augmented its administrative staff and its social worker teams to cope with additions to the normal work load.

Social Welfare made emergency payments to provide for the essential needs of earthquake victims. These became known as “trauma payments”, an unfortunate name apparently coined in the community (it did not originate with the Department). That name was, at least in part, responsible for widespread misunderstanding, for envy, bickering and sniping, and even for inertia among people, causing some of them to wait vainly for government handouts when they could have improved their situations by their own efforts. No payments were made to compensate people for distress or stress they endured. Payments, typically of up to about $200, were made to applicants for special needs — for emergency food, clothing and petrol, and for miscellaneous emergency expenses. The Department also supplied material assistance, such as dinner sets to families. Substantial payments were made for restoring earthquake damaged dwellings of welfare beneficiaries and for billeting evacuees. In a few cases, loss of livelihood payments were made to people whose employment was terminated by the effects of the earthquake.

The Regional Psychologist’s team made an early survey which indicated community needs, guided preparation of strategies for providing immediate and long-term social welfare, psychological and advice service to the Rangitaiki Plains people, and predicted the specialist staff and other resources that would be needed for the task. Much of the early advice service had been offered on a door-to-door basis, but was uncoordinated and less effective than it might have been, and was occasionally resented. As needs became better defined and with the passage of time, control, efficiency and effectiveness all improved, and a service valuable to and appreciated by the community was given by dedicated, skilful and caring workers.

At the invitation of the Prime Minister and the Social Welfare Department, two eminent psychologists, both experienced managers of disaster effects, visited the region early in the second week after the earthquake. In their view, local support networks were working well, and the community was resilient and recovering. They advised against seeking help from or allowing intervention by teams of outside experts (Taylor, in Ruscoe, 1988).

**Relief funds**

As soon after the main shock as an appreciation of the extent of damage to property began to form, the Whakatane mayor launched an appeal for funds for relief of distress. Generous contributions from around the country and from overseas quickly boosted regional collections to a substantial sum and the government contributed $380,000. Finally, more than $1.6 million was available. This was used by the Eastern Bay of Plenty Earthquake Relief Trust to help those who had exhausted all other assistance prospects and were desperately in need. These were typically people without financial resources whose uninsured or underinsured property had been damaged, but these people were not the only beneficiaries of grants.

Some organisations, active in the region and elsewhere (Lions, Rotary and other service clubs, churches and the like), channelled at least part of their relief contribution to recipients through the Rangitaiki Plains branches of their own organisations.

**Earthquake conditioned attitudes**

Observers claim to have evidence of domestic problems, of sexual abuse, of crime and of bizarre behaviour attributable to the earthquake, its aftershocks and their effects (Muller, 1987b), but apparently no statistical connection has been made. Conversely, the events have been credited with generating a cooperative, generous, caring spirit in the community, allowing all to benefit from the therapy of a huge mutual help effort.

Some people certainly became hypercritical. Prime targets for their reproach were the Social Welfare Department, the Earthquake and War Damage Commission, and the Earthquake Relief Fund Trustees. All
these suffered principally because they were misunderstood and because misinformation was allowed to circulate uncorrected. Even geologists from the Department of Scientific and Industrial Research were obliged to defend themselves against irrational attack that must have bewildered them (Beacon, 7 April, 1987).

Neighbours’ activities were carefully observed by so many people who were quick to report suspicions that relief grants of money, goods and services were being abused, that welfare agencies were swamped with complaints, and the Whakatane manager of Social Welfare was obliged to berate accusers publicly for their pettiness (Beacon, 11 March, 1987). There were, however, fraudulent applications lodged for relief assistance (Beacon, 22 August, 1987), and, almost certainly in the nature of such things, there would have been some abuse of benefit grants.

In what has been called the “stalled recovery period” there was some apathy. People were reluctant to seek help, did not apply for available loan money despite having a need for it, and were tardy with insurance claims. But in most respects the people of the Plains region came through their period of trial well. They absorbed its punishing phase, rebuilt, and resumed their lives, almost all of them without indelible scars. They had learned the values and the satisfactions of cooperation.

Recovery management now and in the future
During the 1980s decade the New Zealand government developed a policy with the objectives of:

• containing the government’s share of the cost of recovery from natural disasters and emergencies; and
• encouraging local authorities, communities and individuals to take responsibility for protecting their assets from disaster.

The evolution of this policy over recent years has resulted in the clarification of a greater degree of preparedness now expected from territorial local authorities in planning for emergency response and recovery, and to define more onerous controls that now determine their eligibility for post-disaster assistance.

There have been significant policy changes from those existing a decade ago. Territorial authorities should be fully aware of these changes and plan to ensure that the communities they administer do not suffer any effects from neglect to observe them.

Economic considerations

General
This section of the report attempts to estimate the total cost of the Edgecumbe Earthquake. The total cost of the earthquake has been considered under three headings: economic impact; welfare costs and volunteer labour; and value of damage to physical infrastructure and assets.

Economic impact
The economic impact is that effect on the economy, both local and national, due to the net gain/loss of production and income, and includes business interruption.

Welfare costs
Welfare costs include all payments made to people in the region immediately after the earthquake, to cover daily living expenses, food, accommodation and emergency repairs to housing (but not long-term repair). Volunteer labour and the operational costs of the police, fire service and defence forces are included under this heading.

Physical damage
The value of the damage to physical infrastructure and assets, already considered elsewhere in this report, is included under this heading.
Insurance

Insurance transfers the burden of a financial loss from one party (the business) to another (the insurance company). The insurance company in turn transfers the burden via reinsurance to other insurance companies, who may be off-shore, and to present and future policy holders. Insurance is a transfer payment or a pecuniary effect. Such pecuniary effects are not included directly in the economic effect. The excess of insurance loss paid by the insured is included as part of the loss in all the insurance calculations.

Insurance does have a regional economic effect in that the wages of workers temporarily unable to be economically employed are paid from the business interruption insurance, and their wages are spent in the region, thereby maintaining the retail and commercial sectors. Similarly, during reconstruction of damaged infrastructure and buildings, builders’ wages and the cost of locally purchased materials, all covered by insurance, are fed into the local economy.

Economic impact

Estimation

The economic impact of any local or regional disaster is difficult to measure for a number of reasons.

- The economic effect of most disasters is relatively small compared with the regional or national economy. In the case of the Edgecumbe Earthquake, the cost of the damage to assets and infrastructure is estimated in Table 14 at $312 million, which was approximately 0.5% of the national gross domestic product (GDP) ($55,000 million), for the year ended March 1987. This is less than the annual fluctuations about the growth trend for GDP and hence it is extremely difficult to measure any impact. The value of the damage to assets and infrastructure is under 3% of New Zealand’s Annual Gross Fixed Capital Formation for 1987.

- Equivalent statistics are not available at the regional level.

- The economic impact of the disaster will, in the short term, be offset by the induced economic activity, particularly in the building industry, as repair and restoration work is carried out. In the short term (0 to 6 months), this activity may be greater than the negative direct impact of the disaster as measured by loss of income and production. In the medium to longer term (6 months to 5 years), as the repair activity diminishes, the regional economy may suffer, because firms may have left the area, have failed to rebuild, have become bankrupt or have increased their debt burden, etc.

- For a relatively small disaster, the economic effects may be localised to the region, while for a larger disaster resources such as skilled and unskilled labour, building materials, etc., may be sourced from elsewhere in the country and internationally. These effects are extremely difficult to trace and are lost at the level of national statistics.

Stage of business cycle

Cochrane (1995) states that the regional and national effects (and their time patterns) of a disaster such as an earthquake or a flood, will depend on the stage of the business cycle for the region and the nation at the time of the disaster. The stage of the business cycle will determine the quantity and nature of the resources available to undertake the repair and replacement programme. If the regional and national economy are in the lower section of the cycle, there will be idle resources (labour, materials, etc.) which will be employed in the repair programme and the economic effect of the disaster may be very small or, as analysed by Cochrane, positive in the short term.

Offsetting this effect is that some resources made idle by the disaster may be difficult to re-employ locally or even nationally due to the state of the economy.

If, however, the regional and national economies are in the upper section of their cycles, resources may be fully employed and not immediately available for either capital restoration or continuing production, as firms seek other sources of supply. Typically in the latter circumstances, local prices of some resources may increase. (Anecdotal evidence following the Darwin Cyclone Disaster of 1974 suggested the hourly rate of plumbers increased by up to 100%.)

An analysis (Kim et al., 1994) identifies the turning points in the New Zealand business cycle based on production, expenditure and real gross domestic product. All available methods for establishing the stage of
the cycle show it to have been at bottom in March 1987, having previously peaked in the second quarter of 1986. The cycle shows a long slow upturn to peak again in the first quarter of 1989. Cochrane’s analysis would suggest that at the time of the Edgecumbe Earthquake there would be idle resources available for supply to firms that had lost their own sources of supply, and available for repair and replacement. Hence the impact of the earthquake would be lower than might otherwise have occurred.

This is confirmed by anecdotal evidence from Edgecumbe in the months following the earthquake. Retailers, contractors, builders and other tradesmen in the area all claimed that there were few shortages of skilled or unskilled labour, or materials, and little evidence of price increases. Anecdotal evidence also suggests that resources made idle by the earthquake, particularly labour, were not difficult to employ. Most available personnel were utilised for clean up and repair following the earthquake. Bay Milk Products took the opportunity provided by the earthquake to centralise milk processing in Edgecumbe and to carry out more sophisticated processing.

Local inflation

There was no evidence to suggest that local building and construction prices and rates rose in the aftermath of the earthquake. There was some anecdotal evidence of exploitation of the situation by outside tradesmen and contractors who moved into the region immediately after the earthquake. There was also a claim that local labour costs increased to the same level as out of town labour. This was particularly the case after the locals became aware that others were being paid more, no matter for what reason, e.g. to cover travel or accommodation (Crowther, 1995). There is now no evidence available to support or refute such a claim.

Builders and contractors in a smaller town or region have their reputations and future livelihood to consider, and this is a strong and effective moral restraint against excesses. In addition, surplus resources, manpower, and plant were available in the region as the rural economy was depressed and there was a shortage of work for builders and contractors. For many local builders, the earthquake came at the bottom of the trough and acted as a springboard to get them out of it (Interview John Pullar, 1995).

One feature of the earthquake, based upon previous New Zealand experience, was also a significant factor. That feature was that severe damage was inflicted on the smaller towns and rural areas of the region, while only minor damage occurred in the largest town and the main resource centre of the region, only a few kilometres away.

There are at least three references to a local inflationary “Edgecumbe Factor” or “Earthquake Factors” in the construction industry in the region. Not one of them seems to be supportable from the records now available. The term “Edgecumbe Factor” was first used in the Bay Milk Products insurance claim and litigation related to it, to mean “the upsurge in labour and material costs, due to the earthquake repair work throughout the region” (Crowther, 1995). It was claimed, that for the repairs to Tasman Mill housing in Kawerau, local labour costs increased to the same level as out of town labour and that the cost of locally supplied materials increased also. No information is currently available to support the claim.

Another inflation report, unquantified, was in a published paper written by an insurance officer (Scott, 1988). The third inflation claim was made in a published paper by Agius on the issues arising from the Bay Milk Products claim. Agius states “As part of the evidence prepared for this claim, Beca estimate that the increase in cost of reinstating the site as a result of the ‘earthquake factors’ was in the order of 18% of all building costs” (Larsen and other contributors, 1990). Agius modified the terminology developed during the earlier claim process (Crowther, 1995) and referred to the Edgecumbe Factor as the greater cost involved in reinstating a dairy plant in Edgecumbe than reinstating the same plant in Auckland. Agius also stated “The 18% given above, is over and above the ‘Edgecumbe Factor’.” Details of the basis for quantifying such a high inflation rate were not disclosed and information which might or might not support the claim is no longer available.

Additional costs were incurred by accelerating the reinstatement programmes and by expediting the delivery of materials and machinery to meet deadlines for recommissioning a number of plants in the region. This should not be confused with the idea of local inflation as a result of the earthquake. The option for quicker reinstatement at a higher cost is usually taken for the purpose of limiting business losses. It is attractive when loss reduction has a prospect of exceeding acceleration cost.

For the Tasman Mill, the additional cost of accelerating the programme amounted to 5.3%, and for the New Zealand Distillery Company Limited, 2.6% of the reinstatement cost.
House prices
For Whakatane/Bay of Plenty, the cost in dollars per square metre for the modal ("standard") house rose by the equivalent of 3.7% per annum between March 1987 and December 1987 (Gibson, 1990). The equivalent national figure rose by 3.8% per annum for the same period. This may be compared with the national rate of inflation as measured by the Consumer’s Price Index (CPI), which rose by 9% on an annual basis for the same period.

This information tends to confirm the view that there were idle resources available for at least house reinstatement, and for civil construction, and that these resources could cope with the increased demand. There was little evidence that home building resources flowed into the Bay of Plenty area.

Employment
Local employment statistics show insignificant increases in local unemployment in the period immediately following the earthquake.

Economic impact on major enterprises
Edgecumbe earthquake effects on production from the Matahina Dam
ECNZ has stated that the loss of energy production was $3.2 million (Everitt, 1994). This figure is interpreted as being the total value of the reduction in energy produced following the earthquake. A more realistic loss figure would be the difference in generation costs between Matahina (a hydro-electric power station) and a thermal station. On this basis, the cost to ECNZ was likely to be of the order of $2 million, but this is not all attributable to the earthquake (see page 74).

Electricity Supply Authorities
The loss of “value added” to electrical power by the electricity supply authorities has been estimated by totalling the loss of electricity supply to all of the major enterprises and households in the region following the earthquake. The estimate of this loss of value added is $1 million.

Telecom (NZPO at the time of the earthquake)
An examination of the log of traffic congestion and restrictions for the exchanges at Te Teko, Edgecumbe, Waihau Bay, Te Kaha, Waitapu, Matata, Rerewhakaaitu, Kawerau and Waimanu applied after the earthquakes shows that the percentage of restrictions for calls to Whakatane varied from 75% to 100% for approximately 48 hours and for calls to Rotorua the percentage restriction varied from 50% to 100% for approximately 24 hours. Calls to Australia and the United Kingdom were restricted to 50% for some 12 hours.

An interesting economic sidelight is the value of telephone traffic lost because the system was saturated at times. The result is not, of course, a loss ascribable to the earthquake. Rather, it is the value of an opportunity which could not be realised because system capacity was too small. An estimate of the value of the calls restricted, assuming that the weighted average value of local calls, internal toll calls, and international calls is some $4.00 per minute, and assuming that toll charges accurately reflect the cost of the provision of the service, is approximately $650,000. The increased number of telephone calls, both into and out of the area following the earthquake, is an example of the generation of increased economic activity which to some extent offsets the loss caused by the earthquake.

Bay Milk Products
Bay Milk Products had 947 suppliers in 1987 and received some 450 million litres of milk, with a large proportion of the processing facilities on the Edgecumbe site. The disruption to the dairy industry following the Edgecumbe earthquake occurred on the 2 March 1987 and hence covered the end of the 1986/87 season, March to May 1987 and part of the 1987/88 season.

The earthquake destroyed the majority of operating equipment and buildings at Bay Milk Product’s Edgecumbe site. As there were milk fat processing facilities available at Te Puke and limited solids-not-fat
(SNF) capacity at Opotiki, the milk was diverted to these and other facilities. Total milk volume varied from 1.2 million litres per day at the beginning of the season to 2.6 million litres at the peak of the season in mid-October. The Ultrafiltration plant at Edgecumbe (whey processing) was recommissioned in March 1988, and the Casein/Caseinate plant in August 1988. Whole milk was transported to Opotiki (600,000 l/day 1986/87 and 1,200,000 l/day 1987/88), and to the plants in the Waikato. The additional cost of road transport of milk and milk products period was estimated to be $3 m, made up of a capital cost of $1.5 m, and an operating cost of approximately $10,000 per day, for 150 days. Approximately 90% of the additional transport cost would have been met by business interruption insurance.

Because of the alternative processing facilities available, there would have been relatively little loss in the value of output compared with production still being at the Edgecumbe site. The trading surplus per owner-supplied kilogram of milk fat in 1987 to Bay Milk Product was 348¢ per kilogram. If the diversion of milk fat from Edgecumbe to other facilities had depressed the value of the trading surplus by, say, 60¢ per kilogram of milk fat in that year, this would have an aggregate value of approximately $14 m for a full season.

The Bay Milk Products’ 1989 Annual Report states that “while Bay Milk Products’ milk intake for the year was 1.5% below the previous season, this figure was positive in relative terms within the industry”. From this it can be inferred that the earthquake had a relatively minor direct effect on the quantity of milk produced.

**Tasman Pulp and Paper Company Limited**

It was reported that, for Tasman Pulp and Paper Company, total product to the market at that time made up of various grades of both pulp and paper was some 499,000 tonnes per annum. Each product line was out of action for varying periods with the total loss of production of approximately 118,000 tonnes. This represented the total tonnage that could not be made by the mill because of the earthquake. However, in terms of the actual loss of turnover, part of the tonnage was offset by purchasing tonnage in mitigation of the loss.

The reported loss of turnover with adjustments for the above purchased newsprint was $91 m (Hodge, 1994). This figure overestimates the economic value of the lost production, as it is based on turnover, and hence includes the cost of raw materials (which were not used). An estimate of the value added in the pulp and paper industry, is approximately 35% of turnover. Hence, an approximate estimate of the loss of production to Tasman is $32 m.

**Whakatane Board Mills**

As discussed Part 1, Whakatane Board Mills were out of production for some three days. The estimate of the value added of the lost production is $0.35 m.

**Caxton Paper Mill**

Damage to the Caxton Paper Mill was moderate, and power was lost during the earthquake. The plant was out of production for about 10 days. Production losses are estimated to be $7 m.

**Kiwifruit**

The value of the damage to kiwifruit support structures is estimated, from extrapolation from the grower response to the survey, to be $150,000. The earthquake occurred on the 2 March 1987, and harvesting of the crop commences at the end of April; hence, the fruit crop was in place. Even where support structures collapsed, the great majority of the fruit was harvested. Production losses are therefore estimated to have been small.

**Livestock farming**

For sheep and beef farming in the area, the direct production losses due to the earthquake are believed to be negligible. It has not been possible to determine any direct effect of the earthquake on livestock prices in the months subsequent to the event.

As Bay Milk Products were able to direct milk to Opotiki and other processing facilities, there was little loss of milk production. A proportion of dairy farms was unable to milk for up to a maximum of four days, due to a loss of electric power. This would have had only a relatively small effect on the total season’s production.
Railways
The direct production losses to the Railways are believed to be small as all services were restored by Wednesday, 11 March.

Road transport
The estimate of damage to state highways was $261,000. It is estimated that disruption to traffic as consequence of the state highway damage would be of similar order and has been taken as $260,000.

Whakatane Hospital
As noted on page 44, the economic loss has been liberally guessed at $0.5 million.

Retail/commercial sector
Anecdotal evidence suggests that the earthquake had relatively little effect on the retail sector in the area, with the exception of the occupants of the Riverslea Shopping Centre in Edgecumbe.

For retailers in the shopping centre, the experience of the TrustBank was fairly typical. The branch was temporarily closed immediately following the earthquake, and because of security problems and the difficulties of arranging the transfer of the cash to more secure facilities, the acting manager and her husband slept in deck-chairs on the premises overnight. The branch was closed to customers for two or three days and then re-opened in the existing premises. About two weeks later, the Shopping Centre was closed because of earthquake damage and the TrustBank moved into temporary premises, firstly a caravan which was broken into, and then into a shop shared with a draper. These facilities provided only basic services to customers as personal files had been sent to Whakatane. At the end of the next financial year, even these facilities were closed. The Bank received many letters and a petition from customers to retain its services at Edgecumbe, but was determined not change its decision. Immediately following the earthquake, the Edgecumbe agency of the Bank of New Zealand had also been closed (Interview Goldsmith, 1995).

The earthquake and the subsequent demolition of the Riverslea Shopping Centre influenced the closure of the TrustBank Branch and eventually the Agency.

From the bank’s perspective, there was no real financial distress for local businesses as a result of the earthquake. The bank did, however, provide a number of loans to farmers for residential work on drainage and other problems which followed (Interview Robertson, 1995).

Land values
Prior to the earthquake, the downturn in the economy and the reduced turnover and more stable staffing in government departments resulted in the urban property market and property values being depressed.

<table>
<thead>
<tr>
<th></th>
<th>$ million</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECNZ</td>
<td>1.0</td>
</tr>
<tr>
<td>Electrical Supply Authorities</td>
<td>1.0</td>
</tr>
<tr>
<td>Bay Milk Products</td>
<td>14.0</td>
</tr>
<tr>
<td>Tasman Pulp &amp; Paper</td>
<td>32.0</td>
</tr>
<tr>
<td>Whakatane Board Mills</td>
<td>0.4</td>
</tr>
<tr>
<td>Caxton</td>
<td>7.0</td>
</tr>
<tr>
<td>Farming</td>
<td>0.2</td>
</tr>
<tr>
<td>Railways</td>
<td>Negligible</td>
</tr>
<tr>
<td>Road Transport</td>
<td>0.3</td>
</tr>
<tr>
<td>Whakatane Hospital</td>
<td>0.5</td>
</tr>
<tr>
<td>Retail/Commercial</td>
<td>Negligible</td>
</tr>
<tr>
<td><strong>Total Economic Effect</strong></td>
<td><strong>56.4</strong></td>
</tr>
</tbody>
</table>

Table 12 : Economic effects (in 1987 NZ dollars)
After the earthquake, there were few, if any, property sales in Edgecumbe. Kawerau was less affected and Whakatane not at all. The situation in Edgecumbe has improved in the last few years.

In the rural sector on the other hand, land prices and property sales were hardly affected by the earthquake (Interview Gordon and French, 1995).

**Total economic effect**

The economic effects listed above are summarised in Table 12.

The financial losses to the insurance companies and to the shareholders of Fletchers (Tasman), Telecom (New Zealand Government), ECNZ (New Zealand Government), would all have been spread throughout New Zealand and overseas, and hence have very little effect in the region.

Analyses of losses from comparable earthquakes overseas have been reported as showing the business component to be from one to ten times greater than the physical component (Jacob, 1989), but at Edgecumbe the business component was less than one quarter of all other components, and the physical component strongly dominated these others. Judged against overseas experience, then, the Edgecumbe earthquake was atypical.

**Welfare**

*Eastern Bay of Plenty Regional Earthquake Relief Trust Fund*

Immediately after the earthquake, donations were received from all parts of New Zealand and from overseas for the relief of distress and suffering of the people of the region. A Trust Fund was set up with 12 prominent local people as trustees, including the Mayor of the Whakatane District Council.

On 3 March 1987, the Minister of Civil Defence announced an initial contribution to the fund of $50,000 and a decision was later made by a Cabinet Committee to contribute a further $330,000, which had conditions attached. A national appeal was also launched. The fund became known locally as the Mayoral Relief Fund and had a full-time administrator who was assisted where necessary by specialists, including a retired civil engineer who carried out earthquake damage assessments on claims.

Claims were made in the media that the funds contributed by Government had been used to provide interest free loans to get housing repairs under way, while claims were considered by EQ&WDC and while waiting for payments, in effect as “bridging finance”. The administrator, however, has no knowledge of the funds being used in this way (Willis, 1996).

The Trust Fund Advisory Committee had 30 meetings to consider applications for funds, the first meeting on 3 April 1987, and the last on 10 March 1989. More than 600 grants were made, the average about $2,300, the smallest about $200, and the largest $48,670.

Payments made by year were as follows:

<table>
<thead>
<tr>
<th>Year Ending</th>
<th>$NZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 March 1988</td>
<td>1,245,000</td>
</tr>
<tr>
<td>31 March 1989</td>
<td>171,600</td>
</tr>
<tr>
<td>31 March 1990</td>
<td>187,800</td>
</tr>
<tr>
<td>31 March 1991</td>
<td>700</td>
</tr>
<tr>
<td>31 March 1992</td>
<td><em>22,700</em></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,627,800</strong></td>
</tr>
</tbody>
</table>

*Includes a donation of $20,400 made to the Whakatane District Council for the Edgecumbe Hall Restoration Fund.

Almost all this money was used for reconstruction or replacement of uninsured or underinsured domestic property. It is accounted for in Table 14.
Volunteer labour

The estimates of damage do not include volunteer labour, which was used extensively immediately after the earthquake.

Individuals travelled around damaged farms and assisted where they could. They used their own transport and tools. In addition, the Fire Service, Civil Defence, Salvation Army, Red Cross and other organisations also used volunteers. It is estimated that for farming and horticulture, there were approximately 100 volunteer workers for the first two days, and an average of ten for the next 14 days, a total of 340 person days.

For Civil Defence, there were approximately 50 people for five days, or 250 person days. For the Fire Service there were 274 permanent employees and volunteers, who worked over a period from 2 March to 31 March 1987. On average, this is estimated to be 150 people for 10 days or 1,500 person days. The Amateur Radio Emergency Corps was all volunteer, and 17 members worked 429 person hours.

The total volunteer labour is estimated to have been some 2,000 person days. At the average wage of $5/hour in 1987, this volunteer labour would have an economic value of approximately $80,000.

Total welfare expenditure, including volunteer labour, is summarised in Table 13.

<table>
<thead>
<tr>
<th>Department</th>
<th>$ million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department of Maori Affairs</td>
<td>0.7</td>
</tr>
<tr>
<td>Social Welfare</td>
<td>2.5</td>
</tr>
<tr>
<td>Civil Defence</td>
<td>1.5</td>
</tr>
<tr>
<td>New Zealand Fire Service operations</td>
<td>0.1</td>
</tr>
<tr>
<td>New Zealand Police operations</td>
<td>0.0 Note 1</td>
</tr>
<tr>
<td>Ministry of Defence</td>
<td>0.1</td>
</tr>
<tr>
<td>Volunteer Labour</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Total Welfare Expenditure</strong></td>
<td><strong>5.0</strong></td>
</tr>
</tbody>
</table>

Note 1: The cost was less than $50,000, so is zero here.

Table 13: Welfare expenditure (in 1987 NZ dollars)

Value of damage

The value of damage to physical infrastructure, and assets, which has been described in Part 1 of this report, is set out in Table 14. The costs for lifelines repairs and reinstatement are shown in Table 15 and these costs are included within those given in Table 14. A summary of the estimated total cost of the Edgecumbe Earthquake is given in Table 16.

Where it is considered that the infrastructure and assets were replaced to a higher standard, than that existing prior to the earthquake, an attempt has been made to separate out this “betterment” leaving only genuine replacement.

Comparison of losses from the Edgecumbe Earthquake with recent Californian Earthquakes

Figure 57 shows the estimated losses from the Edgecumbe earthquake adjusted by the New Zealand Capital Goods Price Index to 1994, and expressed in United States dollars, graphed against earthquake magnitude, compared with losses from recent Californian earthquakes, expressed on the same basis (see Table 17). It will be seen that the Edgecumbe earthquake was a significant event judged by this comparison and at the higher end of losses caused by Californian earthquakes of a similar earthquake magnitude.

Comparison with an earlier estimate of the total cost of the Edgecumbe Earthquake

As summarised on Table 16, this present report estimates the total cost of the Edgecumbe earthquake to be $373 million (1987 NZ dollars). Early estimates of the total cost, made by people well positioned to assess this, were of a similar order to the present estimate; but, when the dust had settled, and greater reliability could have been expected, a substantial overstatement of cost appeared, authoritatively supported, and this has
### Table 14: Value of damage to physical infrastructures and assets (in 1987 NZ dollars)

<table>
<thead>
<tr>
<th>Description</th>
<th>$ (million)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dwellings and contents:</strong></td>
<td></td>
</tr>
<tr>
<td>Insured losses</td>
<td>20.2</td>
</tr>
<tr>
<td>Assessing fees</td>
<td>1.5</td>
</tr>
<tr>
<td>Uninsured losses</td>
<td>5.5</td>
</tr>
<tr>
<td>Uninsured losses, Police stations &amp; houses</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>27.5</td>
</tr>
<tr>
<td><strong>Insured losses, other than dwellings and contents losses:</strong></td>
<td></td>
</tr>
<tr>
<td>Earthquake &amp; War Damage Commission</td>
<td>111.0</td>
</tr>
<tr>
<td>EQ&amp;WDC assessing fees</td>
<td>3.1</td>
</tr>
<tr>
<td>Co-insurers, includes fees</td>
<td>192.0</td>
</tr>
<tr>
<td>Less business interruption losses</td>
<td>(53.6)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>252.5</td>
</tr>
<tr>
<td><strong>Repairs to schools</strong></td>
<td></td>
</tr>
<tr>
<td>Whakatane Hospital</td>
<td>1.2</td>
</tr>
<tr>
<td>Whakatane and Rotorua District Councils and Kawerau</td>
<td>1.5</td>
</tr>
<tr>
<td>Borough Council — roads, bridges and services</td>
<td>3.5</td>
</tr>
<tr>
<td>Ministry of Works and Development</td>
<td>0.1</td>
</tr>
<tr>
<td>State Highways, including bridges</td>
<td>0.2</td>
</tr>
<tr>
<td>BoP Electricity, uninsured restoration costs</td>
<td>0.5</td>
</tr>
<tr>
<td>Restoration, farms and orchards</td>
<td>4.1</td>
</tr>
<tr>
<td>Flood protection works</td>
<td>3.0</td>
</tr>
<tr>
<td>Off-farm drainage work, Drainage Board</td>
<td>3.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>25.5</td>
</tr>
<tr>
<td><strong>Matahina dam:</strong></td>
<td></td>
</tr>
<tr>
<td>Observe and investigate</td>
<td>0.9</td>
</tr>
<tr>
<td>Restore earthquake damage</td>
<td>9.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>10.4</td>
</tr>
<tr>
<td><strong>NZ Railways, track, bridges and signals</strong></td>
<td></td>
</tr>
<tr>
<td>ECNZ, substations and sundry</td>
<td>2.2</td>
</tr>
<tr>
<td>Telecom</td>
<td>1.9</td>
</tr>
<tr>
<td>Natural Gas Corporation</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>4.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>312.0</td>
</tr>
</tbody>
</table>

**Notes:**

1. Grants from the Eastern Bay of Plenty Regional Earthquake Relief Fund to people in need were used for restoration of uninsured domestic properties and for insurance shortfalls.
2. $53.6 million insurance for business interruption paid to BMP, Tasman, Whakatane Board Mill, Caxton and farmers is accounted for in Table 12 and deducted here.
3. A government grant of $1.6 million, administered by the Adverse Events Committee, funded part of this item.
4. A government grant of approximately $3.0 million, administered by the Adverse Events Committee, funded most of this item.
5. This is the remainder from $16.5 million spent on the dam after deducting $7 million costs for performance enhancing improvements.
6. A liberal allowance for correcting yet undiscovered cable stretch faults is included in this item.
7. The cost was less than $50,000, and so is zero here.
prevailed in the literature. In the May 1994 issue of *Tephra* magazine (published by the Ministry of Civil Defence), on page 29, the total costs of the Bay of Plenty Earthquake are stated to be $880 million (in 1987 NZ dollars), converted to $1105 million (in 1993 NZ dollars). The $880 million estimate was originally given by Mr Lloyd Falck, a former Chairman of EQ&WDC, in a paper on disaster insurance in New Zealand presented to a World Bank sponsored colloquium on environmental and disaster management held in Washington in June 1990 (Falck, 1990). A breakdown of this estimate is given on page 108. The same estimate, but in 1993 NZ dollars ($1105 million) was included in a New Zealand National Statement for an international meeting in Yokohama, Japan, in 1994.

It is noted that the 1990 estimate for government costs given in the Falck paper of $400 million (in 1987 NZ dollars) given on page 108 is more than an order of magnitude greater than an estimate of payments from central government and costs to government agencies of around $25 million based on the information contained in this present report. This accounts for the majority of the difference between this 1990 estimate and the estimate given in the present report.

<table>
<thead>
<tr>
<th>Lifeline costs for repairs and reinstatement</th>
<th>$ million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic impact</td>
<td>56</td>
</tr>
<tr>
<td>Welfare expenditure, including volunteer labour</td>
<td>5</td>
</tr>
<tr>
<td>Value of damage to physical infrastructure and assets</td>
<td>312</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>373</strong></td>
</tr>
</tbody>
</table>

Table 16: Total cost of the Edgecumbe Earthquake — summary
(in 1987 NZ dollars)
<table>
<thead>
<tr>
<th>Location</th>
<th>Year</th>
<th>Magnitude</th>
<th>Damage (US$million 1994)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northridge</td>
<td>1994</td>
<td>6.8</td>
<td>44,000</td>
</tr>
<tr>
<td>Big Bear</td>
<td>1992</td>
<td>6.7</td>
<td>48.5</td>
</tr>
<tr>
<td>Landers</td>
<td>1992</td>
<td>7.6</td>
<td>48.5</td>
</tr>
<tr>
<td>Cape Mend</td>
<td>1992</td>
<td>7.1</td>
<td>51.5</td>
</tr>
<tr>
<td>Joshua Tree</td>
<td>1992</td>
<td>6.1</td>
<td>0.04</td>
</tr>
<tr>
<td>Sierra Madrid</td>
<td>1991</td>
<td>5.8</td>
<td>36</td>
</tr>
<tr>
<td>Upland</td>
<td>1990</td>
<td>5.5</td>
<td>11.2</td>
</tr>
<tr>
<td>Loma Prieta</td>
<td>1989</td>
<td>7.1</td>
<td>6,500</td>
</tr>
<tr>
<td>Imperial County</td>
<td>1987</td>
<td>6.6</td>
<td>3.2</td>
</tr>
<tr>
<td>Whittier</td>
<td>1987</td>
<td>5.9</td>
<td>430</td>
</tr>
<tr>
<td>Chalfant</td>
<td>1986</td>
<td>6.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Oceanside</td>
<td>1986</td>
<td>5.3</td>
<td>0.9</td>
</tr>
<tr>
<td>Palm Springs</td>
<td>1986</td>
<td>5.9</td>
<td>6.6</td>
</tr>
<tr>
<td>Morgan High</td>
<td>1984</td>
<td>6.2</td>
<td>13.2</td>
</tr>
<tr>
<td>Coalinga</td>
<td>1983</td>
<td>6.4</td>
<td>42</td>
</tr>
<tr>
<td>Eureka</td>
<td>1980</td>
<td>7.0</td>
<td>2.7</td>
</tr>
<tr>
<td>Owens Valley</td>
<td>1980</td>
<td>6.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Livermore</td>
<td>1980</td>
<td>5.5</td>
<td>17.5</td>
</tr>
<tr>
<td>Imperial Valley</td>
<td>1979</td>
<td>6.4</td>
<td>50.6</td>
</tr>
<tr>
<td>Gilroy-Hoy</td>
<td>1979</td>
<td>5.9</td>
<td>1</td>
</tr>
<tr>
<td>Oroville</td>
<td>1975</td>
<td>5.7</td>
<td>14</td>
</tr>
<tr>
<td>Pt. Mugu</td>
<td>1973</td>
<td>5.9</td>
<td>3</td>
</tr>
<tr>
<td>San Fernando</td>
<td>1971</td>
<td>6.4</td>
<td>1,766</td>
</tr>
<tr>
<td><strong>Edgecumbe</strong></td>
<td><strong>1987</strong></td>
<td><strong>6.3</strong></td>
<td><strong>295</strong></td>
</tr>
</tbody>
</table>

Table 17: California earthquakes since 1971 (Eguchi, 1996) compared with Edgecumbe

Figure 57: The earthquake losses at Edgecumbe compared with earthquake losses in recent California history.
The 1990 Falck paper gave a breakdown of the estimate of cost figures as follows:

<table>
<thead>
<tr>
<th>Category</th>
<th>NZ$million (1987)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthquake Commission</td>
<td>130</td>
</tr>
<tr>
<td>Other Insurance</td>
<td>300</td>
</tr>
<tr>
<td>Uninsured losses</td>
<td>50</td>
</tr>
<tr>
<td>Government</td>
<td>400</td>
</tr>
<tr>
<td><strong>Total losses</strong></td>
<td><strong>880</strong></td>
</tr>
</tbody>
</table>

Information on the basis and source of this 1990 estimate in the Falck paper of $880 million (1987 NZ dollars) is no longer available, but the figures are thought to have been compiled and supplied by a government department (Falck, 1995).


Anon, undated, Bay of Plenty Earthquake - General observations and summary, an unpublished building inspector’s report about damage to houses and smaller buildings, compiled after inspection 5-7 March 1987, Building Research Association of New Zealand files.


Lloyd K (1987). "Eastern Bay of Plenty earthquake, 2 March 1987, effect upon services and roading", paper read to the *Annual Conference of the New Zealand Institute of County Engineers*.

Lowry M A (editor), undated, *Edgecumbe*, Alpha 60 DSIR Extension Information.


New Zealand Rail. *Report on Damage to Signal/Electrical Communication Equipment in Bay of Plenty Earthquake*.


### Magazine and Newspaper Articles


Appendix
Survey of Damage to Uninsured Rural Property

The survey form reproduced below was sent on 23 March 1987 to about 600 farms and orchards in the earthquake affected area. Completed forms from 170 farmers and orchardists were received by 29 March 1987.

| URGENT SURVEY OF RURAL PROPERTIES OF ON FARM, ORCHARD, UNINSURED EARTHQUAKE DAMAGE |
| (Please complete and return by 23 March 1987 to Scottie McLeod, Chairman, Whakatane Federated Farmers, Te Rahu Road, R D 3, Whakatane, or hand to Disaster Recovery Centre - the old Farmers Mutual Insurance Building - FMI) |
| This is important information needed to more accurately assess the cost and make submissions to Government. |
| PLEASE HAND THESE FORMS to the Owners of Properties. Fill in even if the answers are "NO". |

| PROPERTY OWNER: | PHONE NO: |
| ROAD THE PROPERTY IS ON: | |
| TOTAL NO OF HECTARES OF PROPERTY: |

| 1. BUILDINGS (Including Yards) still to be repaired or restored | YES/NO |
| IF YES, What is the damage? | |
| Estimated or quoted cost - $ | |

| 2. ACCESSWAYS OR RACES Damage to be repaired | YES/NO |
| IF YES, What is the nature of the damage? | |

| 3. CULVERTS & BRIDGES Damaged to be repaired | YES/NO |
| IF YES, Nature of Damage. | |
| Estimated or quoted cost - $ | |

| 4. LAND CRACK OR FISSURES ETC. DAMAGE | YES/NO |
| IF YES, size of cracks | |
| Number of ha covered? | |
| Estimated or quoted cost to rectify cracks excluding seeding costs - $ | |

| 5. STOCK WATER RETICULATION Damage? | YES/NO |
| IF YES, What is the nature of damage? | |
| Cost of damage - $ | |

| 6. LOSS OF WATER SOURCE i.e. Bores and Springs | YES/NO |
| What is the nature of damage? | |
| Cost of restoration - $ | |
7. **HORTICULTURE** - Damage to Support Systems? **YES/NO**
   IF YES, What is the nature of damage?
   Estimated or quoted restoration Cost - $

8. **IRRIGATION** - Was this damaged? **YES/NO**
   IF YES, What is the nature of the damage?
   Estimated or quoted restoration cost - $

9. **UNINSURED MACHINERY & VEHICLE DAMAGE?** **YES/NO**
   What was damaged?
   Cost of repair - $

10. **DRAINAGE**
    We realise that levels have not been shot yet, but please answer the best way possible
    (a) Has any areas of your property sunk? **No ha?** What depth?
    (b) Springs and artesian water have come since the quake? **YES/NO**
    (c) Has the drainage of your property suffered since the quake? **YES/NO**
       IF YES - Do new drains need digging? **YES/NO**
       Does an improved pumping system need to be installed? **YES/NO**
       IF YES - Are you already in a pumping scheme? **YES/NO**
       Are the pumps your own? **YES/NO**
    (d) Is there any damage to the stopbank around your property? **YES/NO**
       IF YES - Where?
    (e) Are drains flowing in opposite directions? **YES/NO**
    (f) Have you notified the Drainage Board? **YES/NO**

11. **ANY OTHER UNINSURABLE DAMAGE - PLEASE SPECIFY**
    i.e. Underground Drainage - No of Kms Costs:

    I have answered these questions to the best of my knowledge.

    PLEASE SIGN: __________________________

    PLEASE RETURN PROMPTLY.

---

**Summary from 170 farmers’ and orchardists’ responses**

<table>
<thead>
<tr>
<th>Description</th>
<th>NZ$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildings and yards</td>
<td>83,343</td>
</tr>
<tr>
<td>Accessways and races</td>
<td>12,370</td>
</tr>
<tr>
<td>Culverts and bridges</td>
<td>29,950</td>
</tr>
<tr>
<td>Land cracks and fissures</td>
<td>80,070</td>
</tr>
<tr>
<td>Stock water reticulation</td>
<td>38,270</td>
</tr>
<tr>
<td>Loss of water - bores and springs</td>
<td>58,630</td>
</tr>
<tr>
<td>Support systems in orchards</td>
<td>98,400</td>
</tr>
<tr>
<td>Irrigation</td>
<td>13,300</td>
</tr>
<tr>
<td>Machinery and vehicles</td>
<td>1,075</td>
</tr>
<tr>
<td>Drainage</td>
<td>77,885</td>
</tr>
<tr>
<td>Underground pipes and cables</td>
<td>193,280</td>
</tr>
<tr>
<td>Miscellaneous - fuel and power</td>
<td>3,470</td>
</tr>
</tbody>
</table>

**Total**                                           | **690,043**
The Edgcumbe Earthquake

A Review of the 2 March 1987 Eastern Bay of Plenty Earthquake

More than a decade has now passed since the Edgcumbe earthquake (also commonly known as the Eastern Bay of Plenty earthquake) occurred in a region of New Zealand with relatively low population density. It caused substantial and widespread damage in Edgcumbe, Te Teko and Kawerau and surrounding areas, but a considerably smaller amount of damage in the nearby town of Whakatane.

While such a damaging earthquake has not occurred in New Zealand since, there is still much to be gained from studying this earthquake, especially in the area of disaster response and recovery. This book, written by consulting engineers George Butcher and Latham Andrews and economist Graham Cleland, combines:

- a study of the damage caused by the earthquake to domestic, commercial and industrial buildings and infrastructure in the region and the estimated costs involved, together with an estimate of the economic impact; and

- some analysis and comment on how the response, recovery and reconstruction phases were handled.

This information suggests that neither the central government of the day nor the local community were as well prepared as they could have been to respond to a disaster of the magnitude of the 1987 Edgcumbe earthquake. While some lessons have been learned in the intervening years, New Zealand's preparedness to cope with a similar earthquake in a major urban area remains in doubt.

The Edgcumbe earthquake is estimated by the authors to have cost about $373 million (1987 NZ dollars). Had it occurred in a more populated area, the losses would have been considerably greater. This cost versus earthquake magnitude (6.3) is compared with that of a number of recent Californian earthquakes. It is shown that this earthquake was a significant event judged by this comparison.

The Edgcumbe Earthquake: a Review of the 2 March 1987 Eastern Bay of Plenty Earthquake will provide a valuable source of information to assist with the educational process in making people more aware of the need to raise the level of preparedness of New Zealand institutions and citizens to cope with the country's next major earthquake.

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