

## SUGGESTED EXTENSIONS OF THE NEW ZEALAND STRONG MOTION ACCELEROGRAPH NETWORK

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### ABSTRACT

The principal aim of the present network of strong motion accelerographs is to record the response of structures to earthquakes, and instruments are concentrated in the larger cities where modern, tall buildings are found. However, the behaviour of structures during earthquakes is now comparatively well understood. At the present time, estimating design ground motions is the weakest part in the process of designing structures to resist earthquakes. There is a strong need for more recordings of ground shaking, particularly sets of several accelerograms from single earthquakes. It is not certain that the present accelerograph network would capture any significant record of strong motion during a major earthquake in New Zealand; and the chance of a set of three or more strong accelerograms being recorded is quite small. It is recommended that 25 additional instruments be installed promptly, to fill the main gaps in the present network, and to extend the capacity of the existing local network in the Wellington area.

### 1. INTRODUCTION

The existing network of strong motion accelerographs which at present covers New Zealand is orientated mainly to the measurement of structural response during earthquakes. Nearly half of the 125 presently-deployed accelerographs are sited in the upper floors of tall buildings, most of which are clustered together in the two or three larger cities. However, work in the last few years has resulted in a good understanding of the behaviour of structures during earthquakes. The greatest difficulty now, in the earthquake-resistant design of a structure is in estimating the ground motions likely to occur during the life of the structure. Our knowledge of strong ground shaking is very meagre. We have a fundamental understanding only of its gross properties; and even on a worldwide basis we lack sufficient data to formulate satisfactory empirical models. The difficulty this poses is particularly acute in New Zealand, where we have recorded no significant strong motion accelerograms.

It follows that the main purpose of the national accelerograph network should be to gather data about ground motion. However, the capacity of the present network to do so is quite low. The distribution of instruments is sparse, and there are some large gaps in the network.

The simple analysis undertaken in this paper shows that with the installation of about 25 additional instruments the major gaps in the network could be closed, and it would become a much more effective means of capturing records of strong ground shaking.

### 2. THE PRESENT NETWORK

The present strong motion accelerograph network comprises 125 M01 or M02 accelerographs installed in 64 separate structures in about 40 different geographical localities<sup>(1)</sup>. In

addition to these sites, there are firm plans to install a further 29 accelerographs in 10 additional sites<sup>(1)</sup>. Except for one, these new sites are all in presently instrumented localities. The 74 existing and planned sites are shown in Figure 1. A more detailed description of the network and instruments, together with some of its history, is given by Hefford et al<sup>(1)</sup>.

As well as the network of time-base M01 and M02 accelerographs, there are 74 scratch plate instruments, similar to the seismoscope, installed about the country<sup>(1)</sup>. Since these do not yield a time-history record they are not considered further in this discussion. Their value is in providing, essentially, one response spectrum ordinate, reliably and cheaply.

It is interesting to study the ownership of accelerographs in the network. Of the 154 present and proposed instruments, only 34 are owned by the Department of Scientific and Industrial Research (DSIR) which has the responsibility for maintaining the network. These are mostly single-instrument stations in rural areas. Of the remainder, which for the most part are installed in the larger cities, 82 are owned by the Ministry of Works and Development, 3 by the New Zealand Electricity Department, 10 by other government departments, 6 by local bodies, and 19 by private owners (presumably installed on the advice of consulting engineers). Thus the present network has been shaped largely by the earthquake engineering community as a whole: the DSIR has followed the apparently-uncoordinated wishes of a number of different groups. Clearly, a coherent plan is needed for future extensions to the network. The proposals made in section 4 are offered as a basis for detailed planning and assignment of priorities.

### 3. COVERAGE OF PRESENT NETWORK

To obtain a useful record of strong ground shaking from a large earthquake, it

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is necessary to have a strong-motion accelerograph in the epicentral region; say, at the very least, within 50 km of the epicentre. To study scatter in strength of motion between sites, and to study attenuation of strong shaking, there must be several accelerographs recorded within this distance.

Figure 2 shows how the present (June 1979) network, together with the planned extensions, meets these criteria. Circles with radii of 50 km are drawn around the present accelerograph sites. Single cross hatching denotes areas within 50 km of one accelerograph; double hatching, areas within 50 km of two instruments; and treble hatching, three or more instruments within 50 km. Only 62 percent of the country is within 50 km of one or more accelerographs, 22 percent is within 50 km of two or more instruments, and 11 percent is covered by 3 or more instruments.

However, seismicity is not uniform throughout New Zealand, and clearly instruments should be more densely distributed where the likelihood of earthquakes is greater. Figure 3 shows faults that have been active in late Quaternary time (Lensen<sup>(2)</sup>), and also indicates the distribution of shallow-focus earthquakes in New Zealand, drawn from data of Smith<sup>(3)</sup>. A region of principal seismic activity based on these data and on Walcott's<sup>(4)</sup> study of the tectonic behaviour of New Zealand is sketched in Figure 2.

Excluding the sparsely-populated Fiordland seismic region, we find that 69 percent of the main seismic region has one or more accelerographs within 50 km, 27 percent has two or more, and 13 percent has three or more instruments within 50 km. Thus even in the principal seismic region of the country, little over two-thirds of the land area is covered according to the quite weak one-instrument-within-50 km criterion. Only a very small part, 13 percent, of the land area of the main seismic region is covered by the 3 or more instruments, and the chance of recording a large set of records needed to yield information about attenuation of shaking with distance and azimuthal variations, is correspondingly small.

The inadequacies of the present network to record ground motion from an earthquake occurring at random, even in the main seismic region, should now be apparent. In the following section, sites for the installation of additional instruments are suggested, based principally on the 50 km criterion. Having one instrument within 50 km is about the minimum that could provide useful data, and it is consistent with the present density of instruments in the better-covered parts of the country. Further discussion of whether or not this level of coverage is sufficient is beyond the scope of this brief article.

#### 4. SUGGESTED SITES

It can be seen from Figure 2 that the main gaps in the network in the principal seismic region are as follows:

- (1) on the east coast of the North Island between Masterton and Napier;

- (2) a band across the northern South Island from Farewell Spit to Kaikoura; and
- (3) the interior of the central South Island, inland from Christchurch.

Lesser gaps also appear between East Cape and Whakatane, between Napier and Taupo, and in the Marlborough Sounds.

To provide minimum coverage to the arbitrary standard of one instrument no further than 50 km from any point in the main seismic region, the nine additional instruments listed in Table 1 are needed. The effect of instrumenting these sites is shown in Figure 4. The Kaikoura site will soon be filled by an array of four accelerographs being installed by the University of Canterbury, for the National Roads Board, on the Cribb Creek Bridge about 20 km inland from Kaikoura. The University also plans to install accelerographs at St. Arnaud and Parangahau. Thus six further instruments are required to complete the basic coverage of the main seismic region.

There is little doubt that the highest priority should be given to extending uniform coverage to the most-seismic region of the country. However, it is not so clear what should be given the next highest priority. On the one hand, emphasis could be placed on improving the quality of the network in the main seismic region, say by improving the areal distribution of instruments in the Wellington region. On the other hand, next priority could be given to providing a more-uniform coverage of the remainder of New Zealand.

The high likelihood of an earthquake occurring in the Wellington region, however, together with the existence of a local network of over 20 instruments, makes the improvement of the Wellington regional network an attractive second task. The present local instruments should give useful information about local variations in shaking. But they are too tightly bunched together to provide much data about attenuation or azimuthal variations in shaking, knowledge of which is vital to fundamental understanding of strong motion. The quality of the regional network could be greatly improved by the addition of a few outlying stations. Some possible sites are listed in Table 2, and shown in Figure 5.

Uniform coverage of the less seismic region of New Zealand could be achieved with accelerographs at the additional 9 sites listed in Table 3, and shown also in Figure 4. Further instruments at Tolaga Bay, Castlepoint, and Hanmer Springs, would close small gaps in the coverage of the main seismic region once the sites listed in Tables 1, 2 and 3 had been instrumented.

#### 5. CONCLUSIONS AND RECOMMENDATIONS

The present accelerograph network is oriented towards the recording of structural response, and the extensions planned for the network suggest that this is still the prime objective of the earthquake engineering community, for whom the DSIR has been acting. Now that the seismic response of structures is comparatively well-understood, obtaining a better understanding of strong ground shaking has become of prime importance in

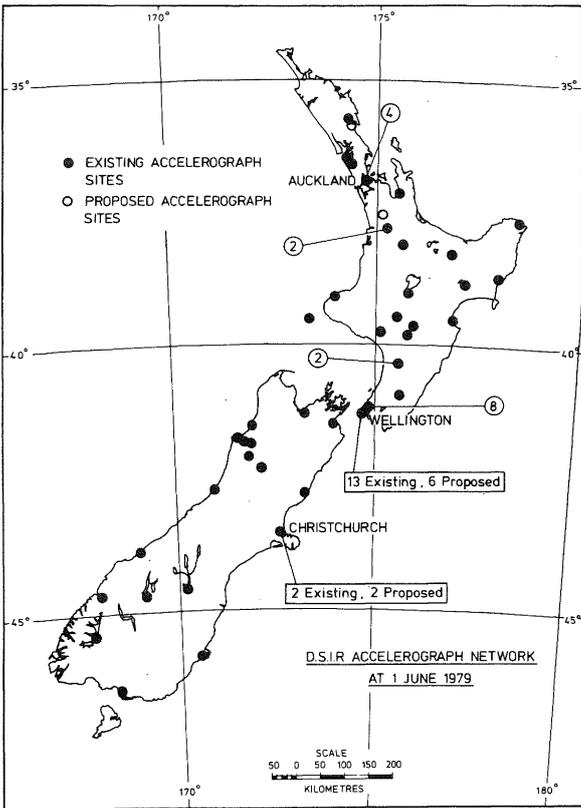


FIG. 1 Locations of the 64 existing and 10 planned ground-level or free-field accelerograph stations in the New Zealand network.

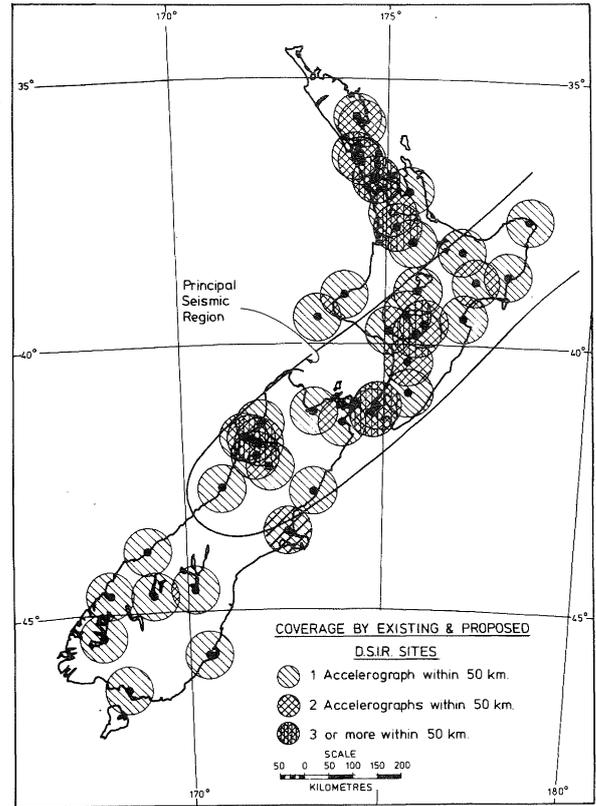


FIG. 2 Coverage of New Zealand by the existing and planned sites, shown in Figure 1, according to the weak criterion of whether or not there is an instrument within 50 km.

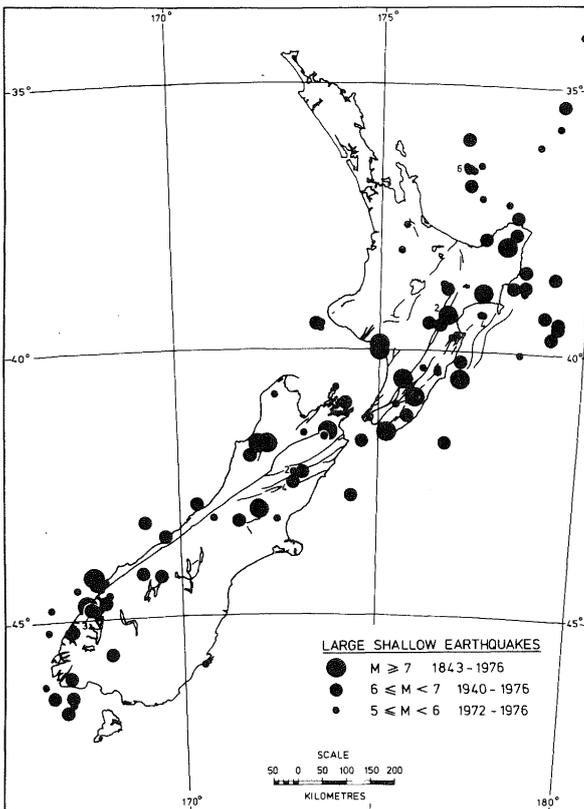


FIG. 3 Faults known to have been active in Late Quaternary time, and distribution of recent epicentres.

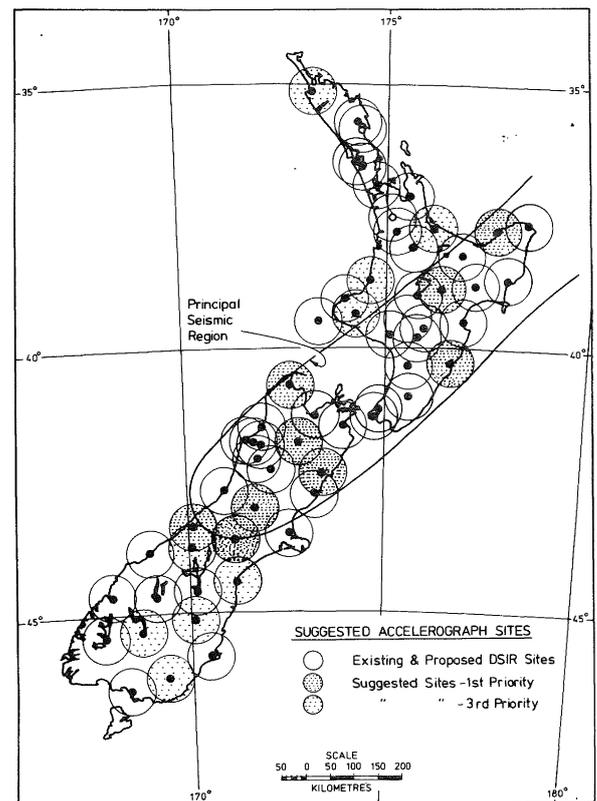


FIG. 4 Suggested accelerograph sites to provide a fairly uniform coverage of New Zealand. Sites in the principal seismic region, denoted by dense stipple and listed in Table 1, should receive highest priority. Sites denoted by a light stipple, and listed in Table 3, complete uniform coverage of the areas outside the main seismic region. It is suggested that they receive a lower priority than improvement of the Wellington regional network (Figure 5).

earthquake engineering. The efficiency of the present network to record a useful set of accelerograms from any moderate or large-sized earthquake, even within the main seismic region, is low. About 15 additional accelerographs are required to extend coverage, at roughly the present average density, to the whole country.

It is recommended that 25 additional accelerograph stations be established promptly. They are, in order of priority:

- (1) The remaining six stations listed in Table 1, to close the main gaps in the principal seismic region.
- (2) The ten stations listed in Table 2, which build upon the existing Wellington local network to create a regional net of a much greater capacity.
- (3) The nine stations listed in Table 3, which extend a fairly uniform coverage to the remainder of the country.

The cost of implementing these suggestions is not high. A simple but modern accelerograph with its own real-time clock, costs about \$3,000 in New Zealand. Thus the capital cost of the 25 instruments is a relatively-small \$75,000. Given the will and a little ingenuity, installation and maintenance costs could be absorbed by interested government departments, as they are by the University of Canterbury in the case of their own seven instruments.

Apart from in the Wellington region, establishment of the stations suggested above would give a network which is still quite sparse. These recommendations provide a minimum upgrading necessary to achieve a fairly uniform network that should yield

one, perhaps several, accelerograms from any major earthquake in New Zealand. The network would still be far from ideal, and capable of much improvement.

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TABLE 1  
SUGGESTED ACCELEROGRAPH SITES TO BRING 50 KM COVERAGE TO ALMOST ALL OF THE MAIN SEISMIC REGION. (THESE SITES ARE PLOTTED IN FIGURE 4 AS "1ST PRIORITY.")

Suggested Priority	Site
1.	St. Arnaud - Lake Rotoiti
2.	Kaikoura
3.	Parangahau
4.	Cass
5.	Hakatere (S. Canterbury)
6.	Collingwood
7.	Franz Josef
8.	Te Kaha
9.	Rangataiki Rr (on Napier-Taupo Road)

TABLE 2

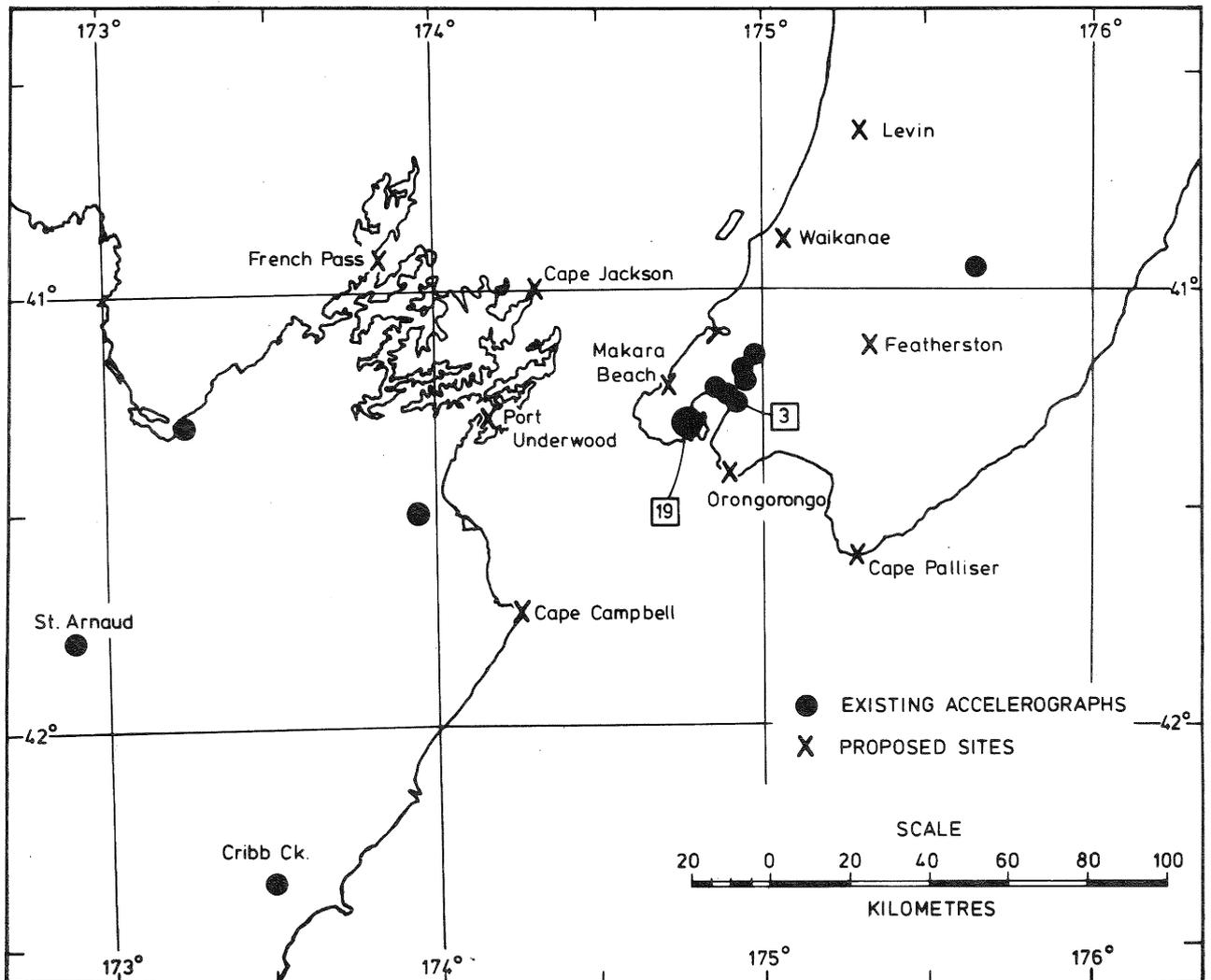
PROPOSED SITES TO IMPROVE AREAL DISTRIBUTION OF INSTRUMENTS IN A MORE-DENSE REGIONAL NETWORK BASED ON EXISTING WELLINGTON LOCAL NETWORK. (SHOWN IN FIGURE 5)

- Cape Palliser
- Levin
- Cape Campbell
- Cape Jackson
- Waikanae
- Featherston
- Orongorongo
- Port Underwood
- French Pass
- Makara Beach

TABLE 3

POSSIBLE INSTRUMENT SITES TO BRING 50 KM COVERAGE TO AREA OUTSIDE THE MAIN SEISMIC REGION. (SHOWN AS "3RD PRIORITY" IN FIGURE 4.)

- Mokau, Taranaki
- Stratford
- Tauranga
- Kaitaia
- Mt. Cook
- Timaru
- Kingston
- Ranfurly
- Clinton



Ten Sites, listed in Table 2, proposed for the Wellington region to improve the capacity of the existing local accelerograph network