STRATEGIES FOR STRONG MOTION EARTHQUAKE RECORDING IN NEW ZEALAND

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ABSTRACT

The problem of how to record future strong earthquakes in New Zealand is examined by considering what data is required, how effective the present network will be in gathering that data, and what new technology is now available.

It is concluded that present methods result in an unsatisfactory use of funds. There is a current emphasis on frequent expert servicing which, while it leads to a high probability of any recorder operating, restricts the number of installations able to be serviced. Thus we have a high probability of any given recorder working, coupled with a small probability of any given earthquake being within range of a recorder.

The suggested future strategy is to first develop a new accelerograph of high reliability and the capability of self testing. This would incorporate a non volatile no moving parts electronic memory. Servicing of this would be at infrequent intervals, but a program of reporting the self test results by postcard would be adopted.

By thus cutting down on recorder servicing and record processing times, we could force the major factor to be capital cost, and thus allow the network to expand until a realistic probability of recording a major earthquake was reached. The installation of about 70 additional strong motion accelerographs in the main seismic region would allow a good chance of recording our next major earthquake.

INTRODUCTION

A programme of recording strong earthquakes in New Zealand was commenced seriously in about 1965. With the passing of 14 years insight into the topic has been obtained, and new technology has become available. Therefore, it is now appropriate to examine the desired aims of the programme with a critical eye for new techniques, bearing in mind that many previously unknown costs have now become clear[1]. This paper is intended to open discussion on the programme, using all of the currently available information.

CLASSES OF STRONG MOTION RECORDS

Every researcher with his own programme in mind, could doubtless specify the parameters he considers worthy of recording during an earthquake. He may even know which make and model of recorder he would like to use. By surveying the needs of many researchers it would be possible to derive a set of specifications for each type of recorder which is in demand. However, it would be ineffective and uneconomic to develop and operate the profusion of different recorders which would result from such an approach. Though it would be possible to produce a single recorder meeting all expressed demands, the cost of such a universal instrument would be very high, and it would have features which would often be unused for specific tasks.

An alternative approach to be developed in this paper, is to divide the types of desired record into broad classes hence to identify which sets of recorder properties will frequently be in demand. By adopting this approach it will at least be possible to find out what specifications the second generation of strong motion recorders will have.

The obvious initial division of records is into "Drive" and "Response". These classifications relate to the purpose for which each recording is made, rather than to the record itself, and may be thought of in terms of cause and effect respectively. The essential difference is that a "Response" is site dependent whereas a "Drive" may be site independent.

A subdivision into "Statistical" and "Extreme" is possible. Again, these classifications relate to the use of the record rather than the record itself. "Statistical" records are those which give information on how often a relatively common phenomenon occurs, while "Extreme" records are those which give information on relatively rare, destructive earthquakes.

The following examples are cited to clarify these definitions:

A worker trying to prepare risk maps will be interested in "statistical", "drive", records while a designer interested in the performance of a structure will be interested in "statistical", "response" and possibly also "statistical", "drive", if he wants to perform detailed modelling. The outstanding

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problem of the epicentral ground motion during a great earthquake is of course "extreme", "drive" and that of nonlinear soil response "extreme", "response". This may be shown diagramatically as:-

	EXTREME	STATISTICAL
DRIVE	Epicentre of great earthquake	Risk maps
RESPONSE	Nonlinear soils	Structural performance

CHARACTERISTICS OF RECORD CLASSES

The above classification of records into classes now allows us to make remarks on the unique attributes of each class.

The classification "Drive" implies site independence, and the classification "Response" implies site dependence. "Statistical" implies no great concern over lost records - a correction factor can be applied later. "Extreme" suggests a need for a high probability of recording a strong event, but the desirable probability is not immediately obvious. We may now write:

	EXTREME	STATISTICAL
DRIVE	Site variable More reliable	Site variable Less reliable
RESPONSE	Site fixed More reliable	Site fixed Less reliable

suggesting that for the case of "statistical", "drive", failure of one instrument to record, could in a sufficiently dense network be thought of as undesirable rather than calamitous.

Of the four classes identified, it appears that obtaining "extreme", "drive", records is a national matter, statistical, drive a regional matter, and both response cases individual matters. In a sense all overall planning and financing is a national matter, but as the importance of three of the classes of record relates to a region or individual, then regional or individual responsibility for operation may be appropriate. The advantages of one group specialising in recorder operation may outweight the advantages of spreading the load in this manner.

RELIABILITY

Before proceeding further it is desirable to go into the topic of reliability of strong motion earthquake recorders. An important preliminary remark is that we are examining the reliability of the whole system (recorder/installation/maintenance/processing). The actual identity and performance of a recorder may not be closely related to this.

With our present technology it would be possible to build a recorder which would have an intrinsic probability of recording strong ground motion, of over 99.9% with a service interval of 10 years, provided that correct operation had been verified at setup. This would be done using a non-volatile, no moving parts memory (e.g.: the old computer core memory) and a high reliability vented nickel-cadmium battery. The transducers for the case of a strong motion accelerograph would be force-balance accelerometers, which by virtue of their small displacements would be unlikely to fail.

The low cost of operating such a recorder would be attractive, if the actual probability of recording strong ground motion could match the intrinsic probability. In practise, in a case such as this the actual probability decreases:- all the memory is used when a jack hammer is operated next door, or the recorder is rendered inoperative by human interference. In our culture, any object left unattended for a given time becomes regarded as abandoned, and is interfered with.

It is likely that a network of such high reliability recorders could be operated successfully by providing each one with a test button which allows significant information (battery voltage + fraction of memory used) to be displayed briefly. Then by entrusting a local person with returning this information on a postcard once a month, operation at the intrinsic reliability would be ensured in two ways. Firstly, the periodic presence of somebody at the site would deter the curious from forcing entry. Secondly, in the event that any malfunction had occurred, remedial action would be delayed a maximum of a month, thus reducing the chance of the recorder being inoperative during an earthquake.

It is highly probable that such a scheme would be a less costly way of obtaining the desired data on strong earthquakes.

DESIRED PROBABILITY - STATISTICAL DATA

What probability of correct operation of a recorder should be considered adequate? The answer is readily obtained for the case of statistical information, and may be surprising.

Consider a network which operates at 95% reliability when it is serviced at six monthly intervals. Suppose that by extending the service interval to a year we decrease this reliability to 90%, but that at the same time we halve the service cost. Then in terms of maintenance costs per record obtained, the less reliable network is cheaper by a factor of 2 x 90/95.

In this case of statistical data, failure to record a particular event is of little consequence. During analysis one merely assumes the recorder to have been inoperative since the last servicing, and uses the appropriate shorter time base in calculations.

It follows that to obtain such information as the return period for a certain peak acceleration, it is appropriate to adopt an infrequent servicing schedule in order to obtain adequate data at low cost. If this is done there is no advantage to be gained from deploying intrinsically reliable instruments, for failures will be due to false triggers, power supply failures, and human interference.

DESIRED PROBABILITY - EXTREME DATA

If we define our object as getting

acceleration data near the epicentre of the next severe earthquake in the main seismic region of New Zealand, we can again be confronted with a surprising requirement for reliability.

The probability of obtaining such a record is the product of the probability of a recorder being situated in the epicentral area, and the probability of a triggered recorder successfully operating. Bearing in mind the likely meisoseismal area, and the present distribution of MO2 accelerographs, there is about a 10% probability that an MO2 will be situated in the meisoseismal area, and about a 95% chance that it will operate in the event of an earthquake.

It therefore appears that there is little to gain by operating the present network at much more than 70% probability level. Doing so would reduce the chances of recording an extreme value from 1 in 10 to 1 in 14.

It follows from these statistics that the correct strategy for recording an "extreme", "drive" type of record is therefore to deploy many more instruments in the main seismic region, and to service them relatively infrequently.

If the number of instruments was increased by an order of magnitude, and the service interval extended to 7 years (to maintain constant servicing cost) the probability of having an instrument in the meisoseismal area would be approaching 100% but the chances of any instrument operating correctly, very low.

In the event of adequate capital being available, it would be possible to achieve very high probability of recording an extreme, drive event at present running costs by deploying recorders of high instrinsic reliability with non-volatile memory and non-destruct readout in a dense grid. This grid would have a spacing of 30km in a NW - SE direction and 50km in a NE - SW direction with alternate rows offset. This would allow for the expected NE - SW aligned elliptical meisoseismal area. Such an arrangement is shown in fig. 1.

Such a network would normally be monitored by return of postcards as discussed earlier, and only serviced in the rare event that an earthquake has occurred, or when postcard monitoring indicates the need.

DESIRED PARAMETERS

From the inception of all strong motion earthquake programmes the convention has been to record acceleration. This is because the immediate motive has been to examine inertia-generated forces which cause structures to fail. Such reasoning is still valid today, but extra needs have arisen, particularly with respect to displacement. Such needs arise for instance in source mechanism studies, system identification studies and liquifaction studies where rotation, displacement and pore presssure are parameters of interest. The need for such studies is undeniable. They stand in relation to acceleration measurements as development stands to research - ultimately the greatest investment but not helping to solve immediate problems.

The need for acceleration measurements is important nationally because acceleration measurements from other countries will never be successful substitutes. However, the results of source mechanism, system identification and liquefaction studies can be imported.

Thus the immediate aim in New Zealand should be to measure 3 components of acceleration keeping in mind that some displacement information will be available from high grade accelerograms, but not investing any large sum in trying to make all accelerographs function as precision displacement recorders. Specifically required displacement, rotation and pore pressure measurements would then be separately logged as appropriate.

Strong motion seismic displacement measurements are difficult to make, especially at long periods. The problem is defining an inertial reference if the measurement is made directly, or eliminating instrument tilt and baseline drift if an integrating method is used. Technically the problem is soluble (submarine inertial navigation systems demonstrate this) but only at high cost.

FUNDING AND OPERATION

Several government and university groups have a current active interest in strong motion studies, so a useful move would be to form a planning group composed of representatives of all such groups. The group would attempt to agree on strategies and prepare a report.

Topics which the planning group might consider are:-

(i) Numbers, locations and types of recorders
(ii) Capital fuding
(iii) Maintenance funding and staff
(iv) Record formats and distribution.

A model for the operation of the planning group could well be the workshop on strong-motion arrays,[2].

Some immediate thoughts on these topics are:-

(i) The ideas of this paper on instrumentation
(ii) Some agencies find it easier to fund capital amounts rather than continuing expenses
(iii) Other agencies can more easily supply staff and backup
(iv) As recommended in reference 1 a standard for the exchange of individual strong motion records is urgently required.

CONCLUSIONS

The chances of recording strong ground motion in the meisoseismal area of a large New Zealand earthquake are at the moment small. However, the installation of an additional approximately 70 intrinsically reliable accelerographs in the seismic region, with a new servicing philosophy, will dramatically increase these chances.

See fig. 1.

Studies requiring data of a more statistical nature can be adequately pursued by the use of existing accelerographs serviced less often.

Studies which are more in the nature of individual experiments are best carried out by the people most directly involved. However, there are strong grounds once again for adopting a philosophy of high intrinsic reliability and monitoring by postcard.

Special earthquake instrumentation should be developed, installed and serviced as required.

A planning group of all interested agencies should be set up to agree on definite policies and procedures to ensure that strong earthquake measurements are reliably obtained, and quickly and widely circulated.

REFERENCES

1. Hefford, R. T., et al: "The New Zealand Strong Motion Earthquake Recorder Network". Proceedings of the South Pacific Regional Conference on Earthquake Engineering, V3, p625, 1979.
2. Proceedings of the International Workshop on Strong-Motion Earthquake Instrument Arrays. May 2-5, 1978, Honolulu, Hawaii. Editor W. D. Iwan. Publisher California Institute of Technology.

Paper received 3 August, 1979.

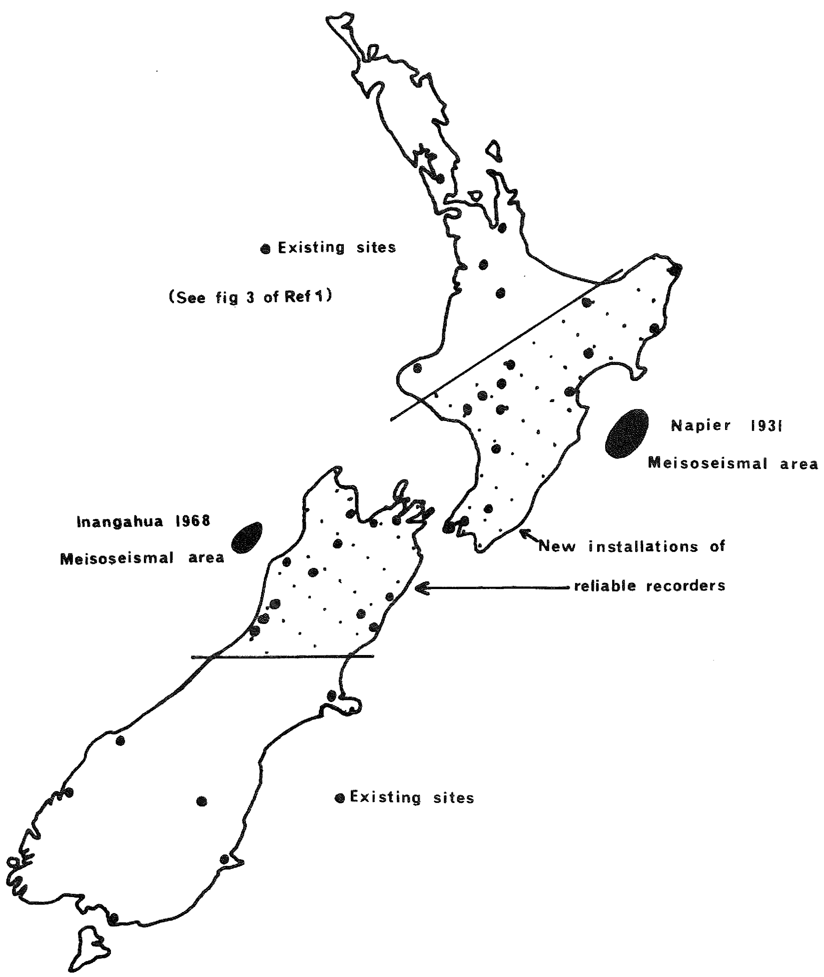

Fig. 1. Suggested distribution of strong-motion accelerographs