CONTINGENCY PLANNING AND RESPONSE OF SEISMOLOGY DIVISION TO SIGNIFICANT CANADIAN EARTHQUAKES

by

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Contingency Planning and Response of Seismology Division to Significant Canadian Earthquakes

1. Introduction

In the past, the small numbers of scientists involved in this Division in post-earthquake activity allowed an informal approach to the study of each individual Canadian earthquake as it occurred, such as the significant earthquakes in 1925, 1929, 1935, 1944 and 1946. While this was the best that could be done, it no longer appears adequate. On one hand, the increasing population density in earthquake-prone areas and the increasing number and types of buildings susceptible to earthquake damage demand a better planned approach to avoid loss of vital information. On the other hand, the numbers of people in the Division, the available resources and instrumentation have grown and become more complex, to the point where positive pre-planned reaction to earthquakes may become mandatory. Moreover, as the time interval since the last major Canadian earthquake increases, we might expect the probability of the next one occurring within our generation of seismologists to become appreciable.

This study group was set up to collect and to disseminate to a broader group the experience and information available within the Division; to discuss and evaluate the desired and realistic Divisional response to a variety of hypothetical Canadian earthquake scenarios, and to make recommendations leading to an improved state of preparedness and more concerted action when the contingency arises.

The group discussed the aims and the general policy of earthquake-connected Divisional activity; this is reported in Section (2). Section (3) is a general account of response to different scenarios; although primarily based on a report by Dr. Milne and reflecting his experience with western earthquakes, it is supported by experience in the east. Divisional response to an earthquake is not only a continuously varying function of earthquake magnitude and location, but also of time, both seasonal and secular. It has, therefore, proved to be difficult to adhere to the sharp distinctions between earthquake scenarios as laid out in the terms of reference for this group.

Sections 4 to 10 summarizes the discussions and recommendations made by the group for immediate action in preparation for the contingency, as well as plans for Divisional post-earthquake activities in general terms. The breakdown of the recommendations into these Sections tries to adhere to the discussed topics in some logical manner, but is nevertheless arbitrary and therefore results in some overlap.

The group considered drawing up much more detailed plans, but this not only ran into difficulties due to the many variables to be considered, but also does not appear to be encouraged by the terms of reference.

2. Aims and General Policy of Post-Earthquake-related Divisional Activity

a) Seismological Aims: Projects and aims listed below are considered the prime responsibility of this Division, although it is recognized that even here exists overlap with other

Canadian agencies, such as other government and university groups, or foreign expeditions in the case of major earthquakes. Grouping of aims under the following headings may be helpful, but is certainly not unique.

Identification of source and source region:

- improving estimates of the location of aftershocks and their depths;
- lowering the detection threshold to give more complete lists of all events for statistical purposes;
- shape of the source area, its relation to geologic structure, possible definition of fault lines or other active tectonic features;
- isoseismal surveys and maps.

Focal mechanism studies:

- conventional first P motion studies
- S polarization
- surface wave studies for mag 5 or greater
- spectral studies
- stress drop.

Data for input to building code:

- maximum accelerations and velocities
- typical earthquake ground motion spectrum for the epicentral region
- microzonation studies
- ground motion on different soil types
- intensity surveys.

Data for public relations:

- quotable epicenter and magnitude of main shock at the earliest possible time
- possibility of aftershocks, their magnitude & duration,

Early publication of results from all studies.

These are the aims; another useful grouping might have been according to the primary means for achieving them, for instance:

standard network

strong motion networks

additional instrumentation for aftershocks

personal surveys

The first two entries, however, are on-going projects and only the last two are considered in this report. Further comments on Canadian post-earthquake programs are attached to this report as Appendix B in the form of two papers by Dr. Stevens given as oral presentation over the last years.

b) Initiative and coordination of related-studies. A variety of scientific/engineering surveys will have to be conducted following a major earthquake, for which this Division has neither the expertise nor the manpower. It appears, nevertheless, important that this Division actively watches, if necessary initiates and coordinates some of these activities. In this category, we list

study of geologic phenomena

tidal effects

hydrographic surveys - coastline changes

crustal movements

precise levelling - tilts

triangulation - shear

geomagnetic effects

building damage survey

If this expanded responsibility is accepted by management, a departmental or interdepartmental workshop should be arranged with representatives of the appropriate agencies to establish contingency plans and lines of communication.

In the event of a major ($M>7$) earthquake, we must expect a number of foreign expeditions of experts to arrive in the area. This Division, in particular the Chief or his designate, should then accept a lead role in coordinating all such scientific research.

c) Public Relations. This is a duty we cannot and do not want to avoid, although it can be a burden, especially during the initial period after a shock in a populated area. It is recommended that a fairly definite protocol be established, governing the release of news to the media. In the western office, the small number of people requires a considerable overlap of duties and does not allow too rigid planning. Unfortunately, it also creates difficulties with too much to be done by too few persons. In the eastern office, perhaps Dr. A.E. Stevens and 2 other professionals (e.g., Dr. G. Leblanc and P.W. Basham) should be designated PR contacts. As long as any of these people are available, no one else should give statements to the press or general public.

For efficient contact with the media, phone numbers and possibly names should be available in advance for the various wire services, e.g. Canadian Press, together with an indication of coverage of each, to avoid unnecessary duplication.

Since it is important to give timely and credible information on the epicenter, expected damage, magnitude, possibility of aftershocks, their number and magnitudes, it may be best to refrain initially from any statements, except that yes, an earthquake has occurred and that we are working on it, until such time as we can give a numerical answer with a stated reliability. Standard scripts, in English and French as necessary, should then be used for all callers.

d) Role in context of National Emergency Planning Establishment (NEPE). NEPE has created the terms of "resource agency" and "lead agency" for national emergencies. Although not asked to consider these roles explicitly, we have given them passing attention. It appears that the requirements of a "resource agency" are already well taken care of by our role as described under (b) and (c) above. However, we would be much better prepared for our work, and especially for such a role, if some of our Division members could acquire some first-hand experience at the site of some large international earthquake. This is recommended under Personnel Training.

It is assumed that all seismologists have acquired some indirect, but useful experience by reading reports on recent foreign earthquakes. This should be supplemented by reading reports of all past damaging Canadian earthquakes.

Should we be designated a "lead agency", major rethinking would become necessary. Currently, we believe this Division to be entirely unsuited for a leading role in disaster relief. Whether we should, therefore, avoid such a role depends on other considerations and conjectures. Would, for instance, some other equally unsuited group be designated, and then direct ou- activities; would the lead agency be a Divisional, or Departmental role, in which case a Deputy Minister would surely be in charge? This study group has divided opinions on this question and no recommendation is made. The current plans do not consider it further.

3. Responses to Different Earthquake Scenarios

When an earthquake occurs in southern Canada, the Ottawa and/or Victoria offices may be required to concentrate on a number of things. The degree of involvement is a function of the size of the earthquake. If it was felt, the telephone will ring almost immediately, and keep ringing for some time. In 1965, an earthquake of magnitude 6½ near Seattle but felt over the Victoria area, caused the office telephone to be busy for some 3 hours. This will tie up the service of at least one person, and, unless a private unlisted telephone exists, it will eliminate any outgoing telephone calls, and may also disrupt service in adjacent offices. The planning committee for Pat Bay for instance must continually be reminded of this because they are inclined to favour a general switchboard at that site, which of course will be overloaded at the time of an earthquake.

During this initial period, the seismologist will be desperately trying to determine the approximate epicentre of the earthquake, its magnitude, and the degree of damage. Since one person will be answering telephones, it is necessary to have more than one staff member on duty. For this reason, members of the seismicity sections and knowledgeable others, should automatically respond to significant events if it is at all possible. The seismologist will need to use the data which are available at the station to determine the epicentral parameters, as well as intelligent use of felt reports. The private telephone line can be used to contact other seismograph stations where data may be available. Thus, in a well known place, a list must be kept of telephone numbers and personnel at institutions from which additional information can be obtained during office hours and also outside regular hours.

Of these initial, and continuing telephone calls, some will be Civil Defense groups, some will be the news media, and some will be interested citizens. The radio news are likely to wish to connect the telephone call directly, or by tape, to a live broadcast, so the person who is manning the telephone will need to be kept informed of decisions in the lab, and will need to be cautious with information which is passed to the media. There will be enquiries about aftershocks, about tidal waves, about safety, with descriptions of unusual observations, etc.

In addition to the telephone calls, a larger than usual earthquake will bring out a number of reporters with photographers for a story. These are no problem except they again rob the scientific team of one person; but, a word of caution is needed because some reporters may attempt to lure the scientist into some sensational statement or photographic setting, beyond that which is real. The TV news will also be on hand.

For a regional earthquake, in the magnitude range 3 to 4.5, the WCTN or ECTN may provide data for a fast and accurate estimation of the epicentre and magnitude. The extent of the felt area should be obvious. At the top of this magnitude range it may be necessary to use a low gain helicorder or torsion seismometer to estimate a magnitude. Within this range it is unlikely that outside stations will need to be contacted for data, although this should be possible.

In the magnitude range 4.5 to 5.5 the WCTN or ECTN should provide epicentral data, but there is some possibility that the sensing stations may overload. In the short term, the two TN's will have only visual output, with its normal restriction on dynamic range, resulting in saturation at 100 km distance for about mag. 4., i.e. both P and S saturate, making identification & measurement of arrival time very difficult and often impossible for anything but the initial P. There is a similar possibility that the low gain helicorder, or torsion systems will also overload. Although the accelerographs in the strong motion program will trigger, data from these are not readily available. Thus it will be necessary to get amplitude data for magnitude estimates from peak intensity observations, or from distant stations (<1000 Km) where personnel are available. A list of these should be kept in a known place. As indicated in group 1 report, this is one reason why a visual at PHC is favoured as they have 24-hour watch. The other stations at PNT, FSJ, etc. are not always manned, and gathering of data from them is frustrating. The visual ECTN at HTV (to become MNQ) serves the purpose of a visual from a somewhat distant station available in Ottawa at all times.

Beyond magnitude 5.5, a regional local earthquake provides problems of another order of magnitude. Damage may be heavy, so heavy that the telemetered networks become inoperational. If not then the TN's should provide an epicentre, but certainly a magnitude will only be acquired from stations at a distance. In this case a roster of personnel to contact in Ottawa, Yellowknife, Palmer, Berkeley, etc. should be on file. In the west, Seattle will be useful but they are extremely difficult to raise by telephone.

For all events, hopefully, in two or three hours after the earthquake, an epicentre, a magnitude, peak intensity, area of damage, etc. should be reasonably well known. During this time, one must make decisions about mounting an observational program in the epicentral region. This program may include aftershock studies, isoseismal studies which includes special studies of critical structures, and the systematic gathering of scientific data such as other records, and observations.

It seems reasonable that a major aftershock program should not be considered if the magnitude is less than 5, except under special local conditions where there may be some gain from a small field project. If the magnitude is between 5 and 6.5, the preparation for an aftershock program should begin, but a decision will be needed by someone in authority before a program begins. Beyond magnitude 6.5, the program should begin automatically. It should be kept in mind, however, that few if any aftershocks were recorded with some of our larger events, although this could have been due to insufficient sensitivity of the instrumentation at that time.

4. Communication

a. Address lists, contingency file

In the event of an isoseismal mail survey, a list of postmasters, or post offices, clergy, etc., would be useful. The S. & S.H. Section has address lists of clergy in Canada. The west coast office has a map and address list for the whole of B.C. to which questionnaire forms are sent, such as weather observers, RCMP, forestry stations, post offices, light houses, etc., for a total of 1500. It is recommended to do this for all Canadian earthquake areas. The Canadian Almanac lists all post offices and newspapers: a current edition should be available.

In the event of a sizeable earthquake, the number of questionnaires would be large and manpower in short supply. Address lists should therefore be computerized, i.e., kept on cards or magnetic tape with a latitude & longitude given. This would speed up the mechanics of address selection according to epicentral area, and enable us to print labels automatically. In addition, secretarial help (min. 2) from within the Branch should be made available to mail questionnaires; for smaller earthquakes one secretary from within the Division would be sufficient.

b. Telephone

Arrival time and amplitude data will be required from outlying stations or other agencies in addition to telemetered networks. Moreover, general communication must be maintained with the outside. In view of heavy telephone load expected after a major shock in a populated area, an unlisted number must be maintained and guarded in the Ottawa and Victoria offices. A directory of relevant telephone numbers must be compiled and kept updated. This must, of course, extend beyond the EPB telephone directory to include our own stations, our unlisted numbers, and also those of neighboring seismological organizations (e.g., Boulder (NEIS), Berkeley, Palmer, Lamont, Weston); names and numbers of contacts with Civil Defence Groups should be included as well as numbers of the news media as recommended under 2c. Several copies of the directory must be available and be kept in known places.

c. Telex, facsimile, computer links, Arpanet

None of the advanced communication media appears relevant to current plans. There will be a link between the Yellowknife and Ottawa computers in early 1975; its usefulness for Canadian earthquakes remains to be seen. The ECTN and WCTN computers may also be linked at a later date. An experimental facsimile terminal will be used in Ottawa in 1975 for transmission of arrival data and seismic traces. These developments should be watched, but no recommendations are made.

d. Establishment of Contacts

Many of the telephone numbers required under (4b) are readily available. In other cases it will require considerable effort to establish and to maintain a useful contact. As an example, Dr. Milne has about monthly personal contact with the Victoria-EMO official. We should contact the national organization (NEPE) and their provincial counterparts; in particular, we should obtain telephone numbers and names of the local EMO's in the most earthquake-prone areas. In cases of major disasters, we will need, most likely, some authorization to get near the epicenter. This can only be obtained easily and speedily if we are well visible and our mission known to those with or near authority.

5. Epicentre, Magnitude Determination

At least two stages of development are envisaged. Currently, preliminary epicentres would be calculated by hand during off-hours of the CSC computing center. Considering that some of the local seismicity experts may be designated PR officers or may be occupied with overall coordination of response, it is recommended to write down agreed formulae for local epicenter and magnitude calculation, to be kept in cookbook fashion, perhaps together with telephone directory, etc., in the contingency file. In this way, staff other than the traditional experts, who will have the last say on event parameters, will be enabled to produce consistent numbers that can be released to the media, without the danger of later major revision or recall. Since magnitude and epicentre are an important input for further decision on action, their consistent and speedy determination are also an internal requirement. An initial and occasional later workshop on this subject should be held for those seismologists not in daily contact with this aspect of the Divisional efforts.

During early 1975, it is desirable to make epicentre programs available on one of our round-the-clock available computers. Suggestions were made to implement the EPDET program, using P phases only, and a version of CANSESS or HYPO71. A sufficient number of staff must be designated to learn accessing and operating these programs and then to exercise them regularly, perhaps twice or three times a year.

The final sophistication may come from further development of the telemetered networks. At present, ECTN gives visual arrival times for the Ottawa River zone and Heuterive (lower St. Lawrence). WCTN will accomplish the same for the Gulf of Georgia small magnitude events and large magnitudes along the whole west coast. In the more distant future, the lower St. Lawrence coveragein real time from Ottawa headquarters may be increased. Currently, these on-line arrival times already represent a definite advance over stage I or II above: although the records must still be processed semi-manually, the entire record of a remote station is available in Ottawa. Automatic epicenter and magnitude determination by the (E,W) CTN computers, and its reliability is a research project and no recommendation can be made beyond giving it high priority.

6. <u>The Field Program Go/No Go Decision</u>

Two types of field programs must be differentiated: isoseismal surveys which may only involve one or two persons, or the more massive and expensive deployment of equipment for an aftershock survey. With regard to the first type, it is recommended to increase our efforts. Above mag. 5 personal surveys should always be conducted. Mail surveys should also be initiated more frequently, especially in the north. With more mechanical address selection (computerized) and labelling, this should be possible without greatly increased expense.

Serious attention was given to an attempt to pre-program the instrumental aftershock survey go/no go decision in a quantitative manner. For instance, a suggestion was considered to draw contours on a map of Canada and enter magnitudes above which aftershock surveys should be conducted. It is clear that a "tentative" warning label would have to be attached to such a detailed quantitative plan in any case; even so, this attempt was abandoned, and the group recommends to maintain a more flexible policy with regard to commitment of manpower and money to post-earthquake field work. Decisions, whether to go into the field, and the extent of the commitment, should be made by the Division Chief or someone delegated by him ahead of time for this purpose. Perhaps a delegation to the second or third order should be pre-arranged, and would avoid serious indecision in case of the contingency. Decisions will be based on the consideration outlined in Section 3. Except perhaps for inaccessible Arctic epicenters, these can be summarized roughly as follows:

No field program
M5 – M6.5: Prepare automatically, but await decision
Program should begin automatically.

The decision in the intermediate range will be based on such factors as location, accessability, public reaction, availability of men and equipment. Should the location be near the Canada/US border, we should react as if it was a Canadian earthquake until proven wrong. If the epicenter is clearly outside Canada, offer of assistance to the US agency should be considered, and the Canadian area near the epicenter still be instrumented. In convenient areas, small expeditions should perhaps be sent near the lower end of the scale, if only for training purposes if this is compatible with other projects. In some areas, it will be worth while to confirm that no aftershocks occur in the lower part of the undecided magnitude range, with a consequent raising of the decision level.

7. Instrumentation, field communication

The available equipment for aftershock studies is judged to be sufficient. The first units to be deployed would be the Smoke Recorder Units (see Appendix A). Ink scriber conversion kits are on order, as recording on smoked paper is sometimes not suitable. The distribution of smokers is about right: 5 units each in Victoria and Ottawa, except during field seasons. There is no remedy for this situation except duplication of equipment; this is not thought to be necessary. The next units to be deployed would be the high and low speed tape systems and the helicorder packages occasionally available. If, after the first 24-36 hours, it appears to be useful to deploy the array, it will be moved and set up by the Instrument Section, on orders by the Division Chief or his designate and at sites selected by the field seismologists. Estimates of manpower and time for instrument deployment and other details are given in Appendix A.

Communication between field parties is essential, especially in the early stages. Readings must be transmitted to a liaison centre to analyze instrument deployment with respect to location of recorded events, instructions for instrument relocations must be communicated, etc. The Division has some 2-way communication gear and several radio receivers; however, great reliance is placed on availability of telephone communication. Should they not be available or be destroyed, it may be necessary to request help from other sources.

8. Transportation

There should be some plan for moving instruments and people to the epicentral area. However, too much detail does not appear warranted. It should be sufficient to determine priority of transportation media usage beforehand for certain families of events. We should investigate what services and contacts might be available to us beyond commercial transportation; for instance, in 1970 MOT helicopters could be used around Hecate Strait. A Division-owned 4-wheel drive would be useful. In cases of major disaster our contacts with EMO and visibility to other agencies may be necessary to get us near the disaster zone. If instruments are transported cross-country (to the west, to the Maritimes), the proper distribution center for collective shipments must be selected; e.g., Prince Rupert instead of Victoria. In the case of smokers, it may be best to let every party worry about its packing cases itself, instead of putting all eggs into one transport basket. Transport and setup of the array should be left to the Instrument Section. Use of the array will likely be restricted to eastern Canada in any case, unless a Hercules transport could be arranged through the Forces, as preliminary investigations show its western deployment to be prohibitively expensive by commercial carrier (See Appen. B.4.2)

Methods of payment were discussed. The only recommendation is to prearrange methods of obtaining quick cash advances and to clear the use of private cars at reasonable mileage rates.

9. Site Pre-selection

It is recommended to use every opportunity to search for, and document, good instrumental sites in advance. This can often be done in combination with field experiments, or in short training exercises. The La Malbaie area should now be well in hand, but it must be ensured that more than one person has access to a description and maps of established sites. Site selection is not merely a matter of looking at a map, but often has proven to involve access negotiations with unwilling farmers! Since preselection is expensive, it will necessarily be restricted to a few strategic areas; for instance, the Val d'Or, Mr. Tremblant, Cornwall areas to name a few. The same recommendations are made for array sites, but at a lower level, proportionate to the lower probability of deployment.

Maps of earthquake-prone areas should be held available in the Division. The S. & S.H. Section already has stored six sets of maps for the East.

10. Personnel, Training and Assignment

a. Chain of Command. This is not a problem in the Victoria office because of the small number of staff. In the east, the Division Chief is responsible for decisions with regard to news releases, aftershock programs and logistics in the field, including liaison with other groups as indicated earlier. He should delegate some of these duties and, in particular, set up a chain of command for cases of personal absence. It may be most logical to utilize the most experienced scientists for coordination in the field. With a view to language problems in Quebec, this should be Drs. Leblanc and Stevens, possibly Dr. Buchbinder. The go/no go decision should be delegated to the section heads most involved, i.e., Basham and Buchbinder. These are also the logical people to look after headquarter liaison. A strong recommendation was made to send some members of the Division to the scene of the next suitable international earthquake to gain on-site experience. Dr. Milne will make contact with a US agency (EERI) to arrange for an invitation to join one of their expeditions. A person from each of the eastern and western offices should be selected and told to be ready to travel anytime with passports, shots, etc., up to date.

b. Training. Almost everyone in the Division should be able to take a smoker out on short notice, set it up and keep it working. It may also be worthwhile to establish beforehand a definite list of people who can or should not go into the field. Since limited field experience tends to wear off, it is recommended that a schedule of exercises be set up according to which all able-bodied persons in the Division take a smoker off the shelf at least once, better twice, a year and produce acceptable records for three consecutive days in the field. The same applies to helicorder systems. Operation of tape systems is more involved and fewer people should be kept in training; perhaps only 1 per instrument, with 1 or 2 spare people.

Since the array will probably not be used except in very special cases, it is better to leave its erection to the laboratory.

At least three, better maybe five, people must become, and remain, familiar with operation of the epicenter determination programs on the in-house computer. An occasional workshop should be held to train people to read local records and make manual epicentre determination.

It has not been judged wise to set up a tentative duty roster without consultation with management and the people involved. Perhaps this should be done eventually, after the immediate recommendations for training, etc., have been accepted and informally advanced to the point where personal preferences and talents can better be taken into account.

c. Manpower demands. Numbers of staff in the Victoria and Ottawa offices are very different, leading to different problems in the two offices. The Victoria office will require additional manpower for a much lower-magnitude earthquake than the Ottawa office. In the past, help has been flown to the west from headquarters. It should be considered whether personnel from other divisions of EPB located at Victoria could be made to volunteer to run recording stations in the west. In the eastern regions, only a very large, say mag 6.5, event might exhaust divisional manpower resources. One might estimate the overall manpower for an initial field program with smokers, tape systems, a few days later a decision to deploy the array. It suffice to say that at least during the first few days Divisional resources could easily become overtaxed; management should therefore consider the possibility of obtaining help from other EPB divisions.

11. Summary

In conclusion, it can be said that initial group discussions appeared to indicate both the need and willingness of the group for rather detailed contingency planning. During the course of the discussions, it became apparent that the many variables affecting decisions could make nonsense out of many such preplanned details. More emphasis was therefore placed on general considerations and preparations and more reliance on proper leadership at the time of emergency actions. In rereading the original memo which set up this group, it is found that this attitude is really more in keeping with the terms of reference contained in that memo.

The general conclusions and recommendations can perhaps be summed up thus: In case of a significant earthquake, we should be prepared to play the lead role in the scientific studies, but should only consider an overall lead role if this is a departmental assignment, giving us access to expert assistance and resources. For better preparation for future post-earthquake activity, a number of decisions should be taken now and the the following action initiated.

Outside Seismology Division:

- circulate this report to other interested agencies to obtain reaction.
- set up a workshop of representatives from the above agencies to discuss in more detail plans of cooperation.

Within the Division:

1. Designate a command hierarchy to 3rd order.
2. Appoint officers to implement the following:
   - collect telephone numbers for arrival time data
   - news media contacts
   - contact with NEPE, EMO
   - prepare "contingency file"
   - prepare epicenter determination programs
   - organize workshops
   - set up and computerize address lists for mail surveys
   - keep up in-house map supply
   - assign officers to visit next suitable foreign earthquake
   - appoint public relations officers
   - set up and supervise operator training plan
3. Decide on level of site preselection activity and appoint responsible officers.
4. Ensure that at least within the Division everybody reads the contingency plans occasionally in order that the discussion of our options remains a current topic, so that intelligent decisions are made and accepted when the occasion arises.

APPENDIX A

INSTRUMENTATION AND EQUIPMENT

A.1 Quantity

10 - Smoke Recorder Units (4 with vertical or horizontal option)

1 - Transportable Array (6 single-station components with vertical or horizontal option)

3 - High Speed Tape Systems (3-component)

3 - Low Speed Tape Systems (3 component)

Some helicorders available from time to time.

A.2 Equipment Description:

- a complete list of instrumentation available is kept in file 6082-5-7; the relevant sections are 5, 6, 7 and 8.

- power requirements for different instruments as used in the field (La Malbaie 74) can be found in file 6082-5-10/15.

- The smoke recorders will run about 5 days on internal and spare batteries included in the kits. Stored kits are inspected and batteries recharged according to schedule.

A.3 Distribution of Equipment

3.1 - The smoker recorders are equally divided between Ottawa and Victoria (5 units each, two of which are horizontal or vertical systems),

- Ottawa units are 26, 28, 51, 63H, 64H

- Victoria units are 27, 50, 61H, 62H, 65.

- The Ottawa smokers are kept on two sets of shelves in the storage area of the tunnel adjacent to the LAB (Seismology Bldg.) All smoke recording equipment is labelled with an orange coloured triangle for identification. The shelves are identified by signs bearing the following:

SMOKE RECORDERS
READY TO CO

- Each smoker recording unit consists of three pieces:

  1 - fibre case containing a recorder
  1 - fibre case containing accessories
  1 - smoking kit with spare drum

N.B. - Equipment spares and supplies are held in the Ottawa LAB .

3.2 - The transportable array is also kept in a state of readiness and is stored in the Laperriere building at 1517 Laperriere Ave. in Ottawa. The outstation equipment is kept on shelves adjacent to the base station trailer. A location map of specific items in the Laperriere Storage area should be included in contingency file or handbook.

- Outstations are colour coded for identification and operating manuals are supplied with the equipment. Additional information regarding the array is available from the files in the LAB.

3.3 - The high and low speed tape systems are stored in the Laperriere Bldg. and are not normally kept in a state of readiness, but can be made operational on very short notice.

A.4 Deployment of Equipment:

4.1 - Smoke recorders can be deployed by anyone in the Division who is familiar with their operation. Their portability allows quick dispatch using light vehicles for transportation (car, econoline, etc.).

4.2 - The transportable array base station being a complex piece of equipment, should only be deployed by personnel from the LAB. The base station is presently placed in a trailer, but can be put into wooden boxes for remote shipping if required, which would take approximately two man-days. The outstations do not require a technician; however, two persons are probably needed if more than one 10-foot antenna mast is required.

- The trailer is normally moved by a commercial carrier. The cost of moving the trailer from Ottawa to Lapocatière was approximately $450. A quotation for shipment from Ottawa to Victoria is about $3700 - delivery 4-5 days, weather permitting.

- Each outstation of the array is packaged into three boxes (colour-coded) which can be handled by one person (preferably by two). Set-up time for a remote station varies, depending on location, but an "on the air" condition should be possible within an hour of being on location, providing the site has been carefully selected.

- The array base station requires at least four people to allow safe erection of the 40-foot antenna tower and this can be done in approximately 4 hours. The base station should be fully operational 6 hours after arriving on location.

all the equipment associated with the array requires a ck or two large econolines. In addition, the base trailer moved by a commercial carrier.

h and low speed tape systems can only be deployed by person- iliar with their operation. One person can do the job which s about 4 hours once on location.

stem consists of about ten wooden boxes which can be handled person (two preferred).

t Shipping Weights (DOES NOT INCLUDE BATTERIES)

-Smoke Recorder Unit	Lbs.	
1) Recorder case	50	
2) Accessory	60	
3) Smoking kit	12	total 122 lbs.

-Transportable Array		
1) Trailer	6000	
2) Outstation:		
a) Amplifier box	60	
b) Antenna box	60	
c) Siesmo (S-13)	38	158 lbs x 6 = 948 lbs

-High Speed Tape System		
1) Tape recorder	46	
2) Amplifier box	40	
3) Control box	65	
4) Sanborn recorder	23	
5) Willmore Seismo (3)	50	
6) Sanborn inverter	10	total 234

-Low Speed Tape System		
1) Tape recorder	46	
2) Control unit	65	
3) Sanborn recorder	23	
4) Sanborn inverter	10	
5) Willmore Seismos. (3)	50	total 194

Appendix B

Symposium: The Response of Eastern United States Institutions to the Occurrence of a Large Earthquake in their Region.

Eastern Section - Seismological Society of America
Cornell University, Ithaca, New York, October 10, 1972

CANADIAN PROGRAMMES FOR POST-EARTHQUAKE STUDIES IN EASTERN CANADA

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INTRODUCTION

I wish to speak this morning about Canadian plans for aftershock surveys following large earthquakes in Eastern Canada, although I realize that the main purpose of this symposium is to discuss the response to large earthquakes in the eastern United States. We have no fixed policy on participation in joint aftershock programmes. Each event will be considered individually as it occurs. However, in general, I would say that, if a large earthquake occurred in Eastern Canada for which we felt our own resources were insufficient to gather the essential data, then we would invite one or more institutions in the United States to join our programme. Similarly, when a large earthquake occurred in the northern United States, we would consider seriously an invitation to assist in your programme.

In Canada the national seismograph network is maintained by the federal government through the Earth Physics Branch (known formerly as the Dominion Observatory), Department of Energy, Mines and Resources. Our main office is in Ottawa, with a smaller office in Victoria, British Columbia. The Victoria office is responsible for aftershock programmes in British Columbia and did mount a short field programme early in July this year after a magnitude 6 earthquake near the west coast of Vancouver Island.

Some of the Canadian universities have staff and equipment available for participation in aftershock programmes. However, the main responsibility for organizing and carrying through a field programme rests with the Earth Physics Branch. Thus I shall concentrate on the federal programme bearing in mind that it might be supplemented by one or more of our universities.

When I speak now in more detail about aftershock studies, I refer specifically to recording aftershocks on seismograph networks-permanent or temporary. I am assuming that we would also gather intensity data for the main shock as we now do several times a year for minor felt shocks. The strong-motion network in Eastern Canada and engineering and geologic field surveys are the responsibility of other government agencies.

Purpose of Aftershock Programme

The purpose of our aftershock programme is four-fold.

1. better location of epicentres in order to determine the size and shape of the active area and to relate it to tectonic features if possible.

This is particularly important in Eastern Canada where there are no known active surface faults.

2. better estimate of focal depth, in particular to determine how shallow the active region is.

This is important for better estimates of maximum acceleration in seismic risk calculations.

3. detection of more small magnitude events than is possible with the standard network.

This permits a study of frequency-magnitude and energy-magnitude relations.

4. study of the focal mechanism of the aftershocks.

Area Considered

On the basis of past seismicity, aftershock studies in Eastern Canada are most likely to be conducted in the Ottawa and St. Lawrence Valleys and in the Atlantic Provinces.

History of Large Shocks 1900-1972

Mag. 7	1925 - St. Lawrence Valley near La Malbaie.
	1929 - Grand Banks, south of Nfld.
Mag. 6	1935 - Temiskaming, upper Ottawa Valley
	1944 - Cornwall-Massena
Mag. 5	many, scattered through region.

Aftershock Series

Canadian earthquake catalogues contain extensive aftershock sequences only for some of the large earthquakes. The last large shock occurred in 1944. At that time and previously there were few seismograph stations in Eastern Canada and few short-period instruments. The lack of catalogued aftershocks is more due to the lack of records than to the non-occurrence of aftershock sequences themselves.

Even the largest events in the past 10 years, the approximately five events of magnitude 4, have had no reported aftershocks. But, with the exception of the Mont Tremblant earthquake of December 1971, the events of magnitude 4 occurred in places where at that time events smaller than M_L 3 or 3½ could not have been detected with the existing network. The December 1971 quake was close enough to Ottawa and Montreal so that aftershocks as small as M_L 2 could have been detected. But none occurred.

Standard Network Capability

When considering an aftershock programme, it is useful to determine the detection limit of the standard network in the various areas likely to be involved in order to see how well the objectives of the aftershock programme might be met without any temporary field stations.

At present the Canadian seismograph network can detect earthquakes down to magnitude 3 in the entire Ottawa and St. Lawrence Valleys and the Maritime Provinces. The Grand Banks area and Newfoundland is monitored to about the magnitude 4 level, with better coverage close to the seismograph station at St. John's.

For magnitude 2 events, the network covers the Maritime Provinces and the St. Lawrence Valley down to the western limit of the Gulf of St. Lawrence. The Ottawa Valley is monitored well except in the vicinity of Deep River about 100 miles northwest of Ottawa where magnitude 2 coverage does not extend east of the river, since it is near the detection limits of both the Ottawa and Sudbury stations.

Thus at present any event of magnitude 5 or greater in Eastern Canada, as defined earlier, should have its larger aftershocks detected by the standard network, since the detection limit is 2 in many areas, which is at least three magnitude units smaller than the main shock.

Portable Instruments

We have four types of portable seismograph systems available for aftershock studies - two types of visually-recording systems and two types of tape systems. We would not necessarily deploy all these systems, but only those most suitable for the particular epicentral region and for the extent of the aftershock survey desired.

1. The first type of visual system uses Willmore, Geotech or Hall-Sears seismometers and records on heat-sensitive paper. This system has been used since 1968 in summer microearthquake surveys in Quebec, British Columbia and the Yukon. We are gradually phasing out these helicorder systems as standard field equipment in favour of the following more compact, lower power system.

2. The second type of visual system is the smoked paper microearthquake system manufactured by Sprengnether. We received three instruments during the summer and have seven more on order. Five will remain in Ottawa and five will be based in Victoria. (When necessary the Ottawa and Victoria offices loan each other field equipment and personnel.) We have been testing the Sprengnether systems in the lab and will be using one in a field survey this fall.

3. A third portable system is a 3-component slow-speed 7-track tape system normally used by our crustal studies section in refraction surveys. We used two sets for a seismicity survey in the Yukon and N.W.T. this summer. The chief disadvantage of the system is the absence of a continuous visual monitor.

4. The fourth system is a radio-linked array of 6 seismometers which transmit data to the base station for recording on 14-track tape. There is a continuous visual display of any 3 of the 6 seismometers. The array can monitor an area of about 20 miles radius. This equipment has been designed and built in the laboratory in our Division. We are planning to start the first field test of the complete array before the end of this month. Under favorable circumstances we would plan to deploy this system near the centre of an aftershock area. The other equipment would be placed at larger epicentral distances.

Personnel

The Canadian Seismicity Section of our Division has only four members in Ottawa. However, many seismologists of the Division have had field experience with some of the equipment just described or with similar equipment. Thus we could in an emergency find a dozen or a dozen and a half experienced people and could if necessary deploy all the equipment available.

When to Activate an Aftershock Programme

I have now indicated where we might expect to conduct aftershock field programmes and what equipment and personnel we have available. However, I have not yet indicated when we would activate an aftershock programme.

It seems clear that events of magnitude 6 or greater will have extensive aftershock sequences. A temporary seismograph network which augments the permanent network should gather very significant data. However, it is not as clear when smaller magnitude events might have interesting aftershock sequences. I think that at present we would not go into the field after an earthquake smaller than magnitude 5 unless numerous aftershocks were being detected by our standard network or felt by the general public. This leaves events of magnitude 5 to consider. As I indicated earlier, most previously known events of this magnitude have occurred at times and in places where detection of aftershocks more than two units smaller than the main shock has been impossible with the existing network. Thus we do not know whether aftershocks of similar events should occur in those areas in the future. In the Laurentians just north of Ottawa and Montreal, earthquakes of magnitude 2 to 5 seem to occur as single isolated events. It is possible of course that seismographs placed very close to the epicentre within a day of the main shock might detect microearthquakes, but we have no plans for such an aftershock programme at present.

Conclusion

In conclusion, we will have available within the next six months a sufficient number of portable seismograph systems to conduct a useful aftershock field programme. We expect to deploy this equipment promptly after earthquakes of magnitude 6 or greater in Eastern Canada, and also for some smaller events. As in the past, we will continue to use our aftershock systems for summer programmes of microearthquake and regional seismicity surveys in order to ensure that our personnel remain familiar with the equipment and in order to make improvements in the various systems that will make them even more suitable for aftershock programmes.

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EARTHQUAKE AFTERSHOCK PROGRAMMES IN CANADA

Anne E. Stevens

1. Introduction.
2. Examples of large earthquakes in Eastern Canada, 1925-1944.
3. Detailed seismic zoning - precise aftershock location.
4. Aftershock capability of the Canadian Seismograph Network - Melville Island series 1972-73.
5. Vancouver Island aftershock programme - July 1972.
6. Conclusions.

Earthquake Aftershock Programmes in Canada.

ANNE E. STEVENS. Earth Physics Branch, Dept. Energy, Mines and Resources, Ottawa. Earthquakes of magnitude greater than 6 are usually followed by a series of smaller earthquakes (aftershocks) in the same region, which may continue for several months or more. Special studies of aftershock series may permit a more precise determination of the boundaries of the active area and its relation to tectonic features, which are important in analyses of seismic risk and seismic zoning. The Earth Physics Branch maintains a national network of permanent seismograph stations and in the past five years has acquired additional portable stations for deployment in special aftershock studies. In 1972 the aftershock region of a large earthquake near Vancouver Island in early July was monitored by portable stations about one week. A small radio-linked seismograph array was field-tested in the Laurentians near Montreal in late fall. An earthquake series, which began in mid-November 1972 northeast of Melville Island in the Canadian Arctic and has continued for more than two months, has been monitored by permanent stations of the national network.

Introduction

Earthquakes of magnitude greater than 6 are usually followed by a series of smaller earthquakes. Earthquakes of magnitude less than 6 may also by followed by an extensive aftershock series or may be followed by few, if any, smaller earthquakes, depending on the seismic region. When a series of earthquakes does occur in one region over a period of weeks or months, it is assumed that these earthquakes may be related more closely to each other than to other earthquakes which occur in the same region, but are much more widely separated in time. In the past, no aftershock series following large earthquakes in Canada have been studied in detail because of the lack of sufficient instrumental data or sufficient aftershocks. I will be giving examples of both and also referring briefly to our present capabilities for recording the smaller earthquakes that may follow larger shocks.

Examples of large earthquakes in Eastern Canada, 1925-1944.

In 1925 a major earthquake, magnitude 7, occurred in the St. Lawrence Valley near La Malbaie, which is between Quebec City and the mouth of the Saguenay. At least 55 earthquakes were felt in the same region in the next five months; the largest of these aftershocks had a magnitude of 5. Prior to this major earthquake of 1925 only three seismograph stations existed in Eastern Canada - at Ottawa, Halifax and Toronto. A temporary station was installed at St. Anne-de-la-Pocatière in the epicentral region several weeks after the main shock and was maintained for three months. However these four stations operated at relatively low magnifications and the seismographs were more suitable for recording large distant earthquakes than minor nearby events. We have a record of many of the aftershocks simply because they were reported felt in some of the many towns and villages in the epicentral region. However, we have no detailed information on the aftershocks of this 1925 St. Lawrence earthquake. For example, we do not know whether the earthquake epicentres defined an elongated area which might indicate that the earthquakes were associated with motion on a fault within the crust, even though no surface break was observed.

In 1929 a major earthquake occurred on the Grand Banks about 240 km south of Newfoundland. Five aftershocks were recorded in the next month by the Halifax seismograph station, which was about 480 km to the west. Undoubtedly, many more aftershocks occurred. But since the epicentral region was so far off the coast, we know virtually nothing about the aftershocks although we do know that the main shock caused a number of trans-Atlantic cables to be broken and generated a tsunami that drowned 27 people in a Newfoundland fishing village.

In 1935 and 1944 large earthquakes occurred at Temiskaming in the upper Ottawa Valley and between Cornwall and Massena in the St. Lawrence River about 100 km west of Montreal. Many smaller earthquakes were felt in each region for several months after the main shock but we have no detailed instrumental records that would permit accurate locations of the aftershocks. In western and northern Canada aftershock sequences have also been noted after certain large earthquakes but no detailed studies have been possible.

<u>Detailed seismic zoning - precise aftershock location.</u>

In the past 10 years our capabilities to detect and locate earthquakes in Canada have improved dramatically so that we are potentially able to study in detail the minor earthquakes that follow a major earthquake. In the past 30 years, since 1944 no major nor large earthquakes has occurred in the southern parts of Eastern Canada. However, there has been an increase in the population in the seismic areas, an increase in the number of high-rise office and apartment buildings and in engineered structures such as major bridges, tunnels, nuclear power stations, hydro dams and reservoirs. It is important that these structures be designed and constructed to avoid collapse or serious structural damage in future large earthquakes, thus minimizing deaths, injuries and serious disruption to the economic activity of the affected area.

It is not economically practical to insist that the earthquake risk is equally high everywhere in the country or even everywhere that earthquakes are known to have occurred in the country. The present seismic zoning map for Canada is based on an analysis of the magnitude and number of previous earthquakes in various areas. The zoning could be further refined if it were possible to show that most earthquakes in a particular area were confined to certain specific faults or associated with some well-defined tectonic feature, instead of assuming, as a present, that the earthquakes occur at random over an entire area. Data for such detailed zoning are not available at present. However, as I have suggested, a study of aftershocks is one step towards this goal.

The aftershocks must be located quite precisely if we hope to see any correlation with tectonics. In routine work now the precision is of the order of 10 or 20 km. But a precision of several kilometres in latitude, longitude and depth is required in order to delineate the active area unambiguously. The amplitudes of the potentially damaging ground motions usually decrease quite rapidly beyond 10 kilometres from the epicentre. In terms of seismic zoning it would be a significant advance to know whether one is planning to build at least 10 km away from an active area or whether one is right on top of future activity. I must emphasize that such detailed zoning is not possible at present and that many other factors in addition to epicentral distance influence the determination of seismic risk.

Aftershock Capability of the Canadian Seismograph Network - Melville Island series.

The Earth Physics Branch of the federal Department of Energy, Mines and Resources in cooperation with several other government departments and universities maintains a national seismograph network spread out across the country so that no point is more than 800 km from a seismograph station. A few universities operate other seismographs intermittently, separate from the Canadian network. With the present network all earthquakes in Canada of magnitude 4 and greater can now be located. Thus the minor aftershocks of major earthquakes may be routinely detected and located, although additional analyses are required to increase the precision of location and to study other parameters.

For example, a series of small to moderate earthquakes began in mid-November 1972 in the western Arctic Islands, northeast of Melville Island. About 60 earthquakes occurred from the middle of November to the end of December with magnitudes between 3 and 5. The sequence has continued into 1973. Several earthquakes had a magnitude of 5, so it is difficult to select one as the main shock. Nevertheless it is a remarkable sequence of earthquakes providing an opportunity for detailed study to see whether, for example, there is an active fault not yet mapped as a surface feature on geologic maps, and whether the active area lies within the sedimentary basin or near the base of the crust.

Questions of detailed seismic zoning may seem at first glance of no practical importance in the Arctic. In fact, seismic zoning is becoming as relevant in northern as in southern Canada. Preliminary studies are already underway for the development of known mineral and gas deposits in the Arctic Islands. Thus one should determine the extent to which earthquake - resistant construction may be required in pipeline and harbour facilities in the north.

Vancouver Island aftershock programme - July 1972

In the more readily accessible parts of Canada it may be practical after a large earthquake to install temporary stations to augment the national network. Major earthquakes of magnitude 7 or more are certain to be followed by numerous aftershocks, but these major shocks have been rare in Canada. In some seismic areas earthquakes of magnitude near 6 or less have not been followed by a lengthy series of aftershocks.

As an example, an earthquake of magnitude nearly 6 occurred about 50 km off the west coast of central Vancouver Island in early July 1972. Four earthquakes with magnitudes between 2 and 3 were recorded within two hours of the main shock. A fifth aftershock of similar magnitude occurred twelve hours after the main event. Our Victoria office organized a field programme in which four temporary stations were operated for a week on Vancouver Island near the epicentral region, starting a day and a half after the main shock. Only one further aftershock was recorded, one week later, with magnitude $3\frac{1}{2}$. Although these temporary instruments were deployed, nothing was recorded that would not have been detected by at least one station of the standard network.

By contrast almost three weeks later an earthquake of only slightly larger magnitude occurred about 160 km west of Vancouver Island, too far off the coast to make temporary stations along the coast very useful. Over 100 aftershocks were recorded on at least one permanent station.

The point here is that although temporary stations can augment the data available for aftershock studies, there is no guarantee that activity will occur unless the main earthquake was very large. It becomes a matter of scientific judgment whether additional stations are likely to be useful or whether the permanent network is adequate for the limited activity anticipated. When temporary stations are desirable, then whether the aftershocks are expected to be many or few, stations should be deployed as quickly as possible, as the activity normally decreases substantially after the first day. Such a rapid response is complicated in a country as large as Canada by the time required to travel from Ottawa or Victoria to the active area, quite apart from problems involved in organizing a field trip at short notice in an area where no field work may have been previously conducted by the participants.

I have not described the various types of portable equipment available for our aftershock work, but I can discuss this point later with any of you who may be particularly interested.

Conclusions

In conclusion, a detailed examination of aftershock sequences may provide better estimates of seismic risk in certain areas of Canada. Precise location is only one example of many possible relevant studies of aftershocks.

Major earthquakes in Canada have been rare in the past thirty years. Large and moderate earthquakes are somewhat more frequent but are not always followed by numerous aftershocks or are not always in easily accessible regions.

The Earth Physics Branch is attempting to acquire and maintain a capability to deploy temporary seismograph stations at short notice close to the epicentre of large and major earthquakes. We may be able at a future CAP meeting to report on the results of such a field programme.