THE EASTERN CANADIAN STRONG-MOTION SEISMOGRAPH NETWORK

by

J.H. Rainer, Research Officer and
E.C. Luctkar, Technical Officer
Division of Building Research
National Research Council of Canada
Ottawa, Ontario K1A 0R6

ABSTRACT

The location and characteristics of the 28 strong-motion seismographs in the Eastern Canadian network as of January 1983, are described. Seven instruments are located in the lower St. Lawrence Valley, and five in the region surrounding Ottawa-Montreal. Detailed descriptions are given of the installation of 16 seismographs in dams at Manic 3, Manic 5 and Outardes 2 of Hydro-Québec. Operating and servicing experience of the network is described, including the small record obtained from the St. Fidèle earthquake of 20 August 1980. Blasting tests were monitored at Manic 5 in 1982.

INTRODUCTION

The Eastern Canadian Strong-Motion Seismograph Network was started in 1966 with two "Fairey" strong-motion instruments, one in St. Férêol, Québec and the other in Montréal, and an AR-240 in Ottawa. These have since been replaced by more modern instruments and the network has grown to a total of 28 instruments. Its status in 1974 was reviewed by Rogers (1) together with that of the Western Canadian network.

The Eastern Canadian network can be grouped into those stations whose purpose is primarily to record strong ground motions, and those that record the response of major structures. In the event of a major earthquake, the ground motion stations can be expected to provide information on the following: characteristics of time histories of ground motions, such as peak acceleration, velocity and duration; spectral content of the motion; attenuation of motion with distance; correlation of ground motion and possible damage to buildings and other structures; a quantitative assessment of how Eastern Canadian earthquakes compare with those of other parts of the world. Given a sufficient number of recordings of significant seismic events, the seismic provisions of the National Building Code of Canada could then be confirmed or a more quantitative basis would exist for needed changes.

The instruments installed to record the motion of major structures at present include three dams of Hydro-Québec, to be described later in more detail. Besides detailed records of the motions of these structures and possible correlation with damage, ground motion characteristics would also be obtainable in the event of an earthquake. The possibility of recording reservoir-induced seismic events was also a consideration in these installations.

The instruments installed in New Brunswick in response to the January 1981 Miramichi earthquake are not included in this presentation as they were deployed temporarily by the Division of Seismology and Geomagnetism of Energy, Mines and Resources Canada to monitor that specific series of events.

STATUS OF NETWORK, 1983

Ground Motion Stations

The 1982 status of the network is summarized in Table 1 and the geographical locations are shown in Fig. 1. Instruments employed are the SMA-1 accelerograph which uses 70 mm film, and the AR-240 which uses 300 mm-wide photosensitive paper. Both instruments are self-triggering and battery powered; a trickle charger maintains the necessary battery charge. A more detailed description of various instruments can be found in Ref. 1. An asterisk (*) with some SMA-1 instruments in Table 1 denotes a time code generator which provides a binary-coded edge trace indicating the time of triggering to the nearest second. The crystal oscillator, however, can drift by several seconds over a few months.

Instrumentation of Dams

Strong-motion instruments at three dam sites were installed by Hydro-Québec with the participation of the authors and other members of the Division of Building Research of the National Research Council of Canada. Three major dam sites are presently instrumented: "Manic 3," and "Manic 5" on the Manicouagan River, and "Outardes 2." The latter site is located about 20 km from Baie Comeau, Québec, the former two are 50 and 200 km north thereof.

One SMA-1 was located from December 1978 to April 1981 in the spillway structure of LG-2 of the James Bay Hydroelectric development to monitor possible seismic activity during reservoir filling (2). No record was obtained.

MANIC 5: The Daniel Johnson Dam at Manic 5 impounds a reservoir over 100 km long. The multiple concrete arch dam was completed in 1968; it has a total length of 1310 m and a height of some 200 m at the centre arch. A plan view and elevation of the dam, with the instrument locations, are shown in Fig. 2. Locations 1 to 7 are permanent installations, whereas Locations 8 to 10 were temporary ones for a series of test blasts conducted in June 1982 at the shores of the reservoir. A description of the instruments is given in Table 2. Because of the expanse of the installation, the remoteness of the site and dampness in the lower galleries, some redundancy in the number of instruments was thought desirable. All instruments are interconnected and number 4 serves as the master, providing a common time base and the same time code signal on all records.

MANIC 3: This is an earth-fill dam with a till core built across the 300 m-wide river canyon. The concrete diaphragm curtain wall cuts through the 137 m thick alluvium river bed to the bedrock. A double wall steel gallery on top of the curtain wall extends from an instrumentation room excavated into the left rock abutment, to the right rock abutment. Figure 3 shows a cross section of the dam, with the present seismograph installations. The three seismographs on the exterior of the dam are mounted on a concrete pedestal that extends 2 m into the granular fill; they are covered and heated. Each station is protected by a weather hut.

During construction and reservoir filling, temporary instrumentation consisted of one SMA-1 at the toe of the dam, and one in the instrument room. Sensitive seismometers showed a correlation between seismic activity and reservoir filling, and on 23 October 1975 the largest event, magnitude 4.3, occurred in the vicinity of the reservoir (3). This was clearly felt at the dam site and caused apprehension about the seismic effects of reservoir filling. No records were obtained on the strong-motion seismographs since the motion in the rock gallery did not exceed the trigger level, and on the instrument at the toe of the dam any potential seismic record was among 12 self-triggered records that most likely resulted from nearby construction activity on or before the seismic event. None of the records could be identified visually as a seismic motion and because the instrument did not include a time code generator, positive identification was not possible.

During construction of the dam, an electrical cable from the crest to the gallery was incorporated in the core of the dam for interconnecting the various instruments. This cable was soon penetrated by corrosive liquid and became inoperative. Thus, full interconnection had to be abandoned; the present configuration consists of two interconnected instruments on the crest, two interconnected ones in the gallery and the instrument room, and an independent one on the face of the dam. A practical way of interconnecting all instruments remains to be implemented. One further problem encountered at this site was repeated power surges which were ascribed to lightning strikes, causing damage to the electronic components of the accelerographs. This problem was solved by the installation of a varistor on the power input to the trickle charger.

Outardes 2: This site consists of a series of low-level dykes constructed of a sand-clay mix, a short rock-filled dam and a concrete spillway structure, as shown in Fig. 4. The easterly dyke is constructed on 13 to 16 m of sand underlain by Champlain clay, whereas the westerly dyke rests directly on the clay (4).

Two interconnected instruments are located on the easterly dyke, one at the crest, the other at the base. The other interconnected pair is situated on the crest of the westerly dyke and at the rock foundation inside the spillway structure. Details of the instruments are given in Table 2. The exterior instruments are mounted on a pier embedded in the dam material, surrounded by a 1 m-diameter precast culvert with a cover. The enclosures are supplied with thermostatically-controlled electric heaters.

SERVICING AND OPERATING EXPERIENCE

To assure operational readiness of the instruments for recording seismically-induced motion, a regular and systematic maintenance program needs to be followed. The cost of servicing a widely dispersed network is substantial, however, and travel and accessibility in the winter is difficult. A twice-yearly inspection, once in the spring and again in the fall, proved to be reasonably satisfactory.

Problems encountered in maintaining the Eastern Canadian network can be subdivided into three categories: instrument malfunction, service-related problems, and external factors. Instrument-related faults included cases of key switch mechanism failure, clutch slippage, accelerometer mirror falling off, time mark solenoid failures and failure of trickle chargers. Service-related faults included leaving the key in "off" position, leaving the calibration rule inside the instrument, fogging of mirrors and algae development on film in areas of high humidity, and overdamped galvanometers due to dust in the coil air gap. Among external factors were prolonged power interruption and subsequent battery failure, cutting of interconnecting cables by workmen, power surges causing instrument damage, and flooding in a dam gallery. Although the AR-240 is no longer in production, these instruments are kept in operation until replacements become available. Major problems included motor failure due to excessive paper thickness, galvanometer failure, and charging circuit burning out.

Experience with the Eastern Canadian network demonstrates that the long-term operation of strong-motion seismographs cannot be taken for granted and that periodic, conscientious servicing is essential. While some faults are minor and non-critical, others clearly would have prevented the instrument from recording ground motion had a seismic event occurred. Some redundancy and more frequent servicing would reduce the probability of missing important data.

RECORDS OBTAINED FROM SEISMOGRAPH NETWORK

Seismic Events

Since the establishment of the Eastern Canadian network, only one strong-motion record has been obtained that can be traced unequivocally to a specific seismic event. The St. Fidèle earthquake, of magnitude 5.0, on 20 August 1979 (5) produced a record at Tadoussac, and the time code generator pinpointed the event to within a few seconds of the official time of occurrence. The record is shown in Fig. 5. Since it barely exceeds 1% peak acceleration, the useful signal is substantially contaminated by noise on the traces. This noise is primarily due to electromagnetic pickup from the timing solenoid. Since an unknown portion prior to triggering of the instrument is also lost, the usefulness of this record for engineering applications is questionable.

Computation of response spectra and scaling the record to design levels would clearly be inappropriate.

Two other small records obtained, one at Mercier Dam in 1982, the other on the crest of Manic 3 in 1981, could not be traced to any specific event since no time code was present.

Blasting Records at Manic 5

During a series of test blasts in June 1982, upstream from the Daniel Johnson Dam, the strong-motion seismographs in the dam shown in Fig. 2 were augmented by another SMA-1 and two DSA-1 digital instruments, manufactured by Kinemetrics, Inc. One DSA-1 temporarily replaced the SMA-1 in location 1; another was placed in location 8, but this instrument failed to record. This could not be detected since a field reader was not available on site. The entire interconnected network was triggered manually about 3 s before the blast. A comparison of records from the blasts confirmed that for low level signals, less than about 5% g, the quality of the digital record provides superior resolution and higher frequency response than that produced by the film instruments. Another factor that caused problems in digitizing and interpreting the film records was the presence of frequency components around 100 Hz whenever substantial water shock impinged on the dam.

SUMMARY AND CONCLUSIONS

The Eastern Canadian Strong-Motion Seismograph Network consists of a total of 28 instruments, of which 16 are installed at three dam sites of Hydro-Québec and the remaining 12 are ground motion stations. Operating experience demonstrates the need for a systematic servicing procedure, with due attention paid to such external influences as potential power interruption, power surges, or flooding. In order that the Eastern Canadian network could better fulfil the intended objectives of obtaining attenuation rates and other ground motion characteristics, the number of locations and types of instruments should be expanded.

During monitoring of blast motions the digital seismograph records were found to be greatly superior to those from film instruments, particularly for low levels of motions. A time code generator has proven to be an indispensable accessory to single or interconnected strong-motion instruments. To date (1983), no seismic record of engineering significance has been obtained on the Eastern Canadian strong-motion seismograph network.

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TABLE 1: Strong-motion seismograph sites in Eastern Canada - ground motion stations

	LOCATION	TYPE	SENSITIVITY	TRIGGER, DIRECTION	BUILDING - INSTRUMENT LOCATION	FOUNDATION
1.	St-Féréol-des-Neiges, Qué. Sept Chute Power Station	SMA-1*	1 g	0.0072 g Vertical	Underground seismic vault; on concrete floor.	bedrock
2.	Ottawa, Ontario NRCC, Building M-27	SMA-1*	½ g	0.0068 g Vertical	One-storey reinforced concrete; on concrete pier in basement.	bedrock
3.	Montréal, Québec CIL Building	AR-240	1 g	0.5 mm Horizontal	32-storey steel frame, curtain wall, four basement storeys; on bottom basement floor.	bedrock
4.	Chalk River, Ontario Reactor Building**	AR-240	1 g	0.5 mm Horizontal	Steel frame, poured concrete reactor building; on concrete basement floor slab.	bedrock
5.	Québec City, Qué. Laval University Civil Engineering Bldg.	SMA-1*	½ g	0.0073 g Vertical	Three-storey reinforced concrete; on concrete foundation.	bedrock
6.	La Malbaie, Québec Post Office	AR-240	1 g	0.5 mm Horizontal	One-storey steel frame, masonry walls; on concrete basement floor.	bedrock
7.	St-Pascal, Québec Post Office	AR-240	1 g	0.5 mm Horizontal	Brick masonry; on concrete basement floor.	bedrock
8.	Mont-Laurier, Québec Mercier Dam	SMA-1	½ g	0.0075 g Vertical	Small shack; instrument on concrete floor.	bedrock
9.	Montréal, Québec Jean-de-Brébeuf College	SMA-1*	½ g	0.0058 g Vertical	Four-storey steel frame, curtain wall, poured concrete; in seismic vault in basement.	bedrock
10.	Baie St-Paul, Québec Former Post Office Bldg.	SMA-1*	½ g	0.0079 g Vertical	Two-storey brick; on concrete basement floor.	alluvium
11.	Tadoussac, Québec Post Office Building	SMA-1*	1 g	0.0075 g Vertical	One-storey building; on concrete pier in crawl space.	bedrock
12.	Rivière-du-Loup, Québec Post Office Building	SMA-1*	1 g	0.01 g Vertical	Two-storey reinforced concrete; on concrete basement floor.	bedrock

* Time code generator attached.
** Owned by AECL. All other stations are owned by NRCC.

TABLE 2: Seismograph installations at Hydro-Québec dams

DAM SITE	LOCATION	SENSI-TIVITY	TIME CODE GENERATOR	TRIGGER, DIRECTION
Outardes 2 (Fig. 4)	#1	1 g	✓	.01 g, Vertical
	#2	1 g		.009 g, Vertical
	#3	½ g		.01 g, Vertical
	#4	1 g	✓	.009 g, Vertical
Manic 3 (Fig. 3)	#1	½ g	✓	.01 g, Vertical
	#2	1 g		.0091 g, Vertical
	#3	½ g		.0091 g, Vert. & Horizontal
	#4	½ g		.0095 g, Vert. & Horizontal
	#5	½ g		
Manic 5 (Fig. 2)	#1	½ g		.009 g, Vert. & Horizontal
	#2	½ g		
	#3	½ g		.01 g, Vertical
	#4	½ g	✓	
	#5	½ g		
	#6	½ g		.01 g, Vertical
	#7	½ g		.01 g, Vertical

All instruments are SMA-1's owned by Hydro-Québec.
Brackets indicate interconnected instruments.

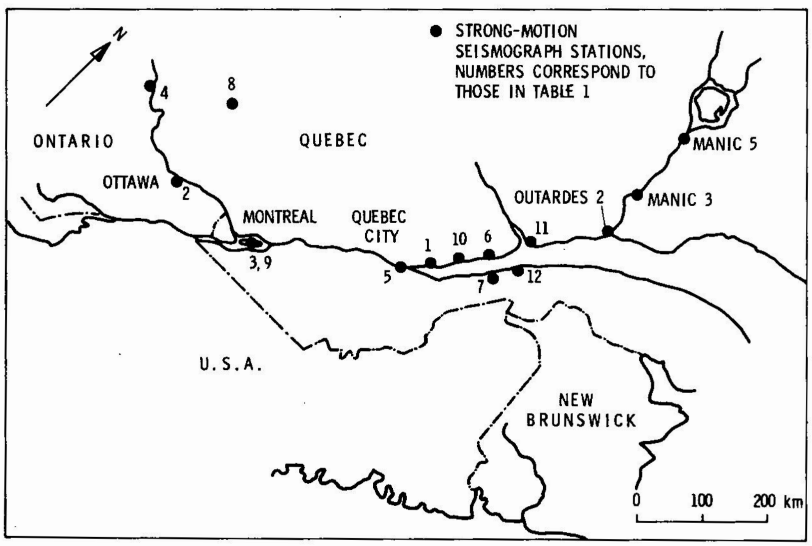

FIGURE 1 STRONG-MOTION SEISMOGRAPH STATIONS IN EASTERN CANADA

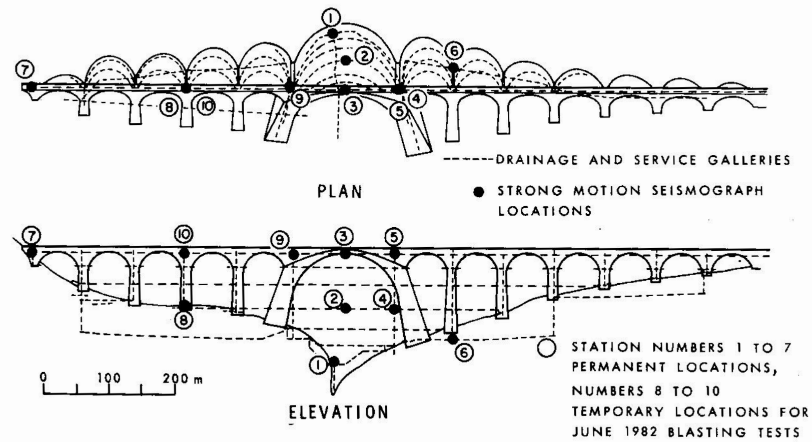

FIGURE 2 STRONG-MOTION SEISMOGRAPH STATIONS IN DANIEL JOHNSON DAM, MANIC 5, QUEBEC

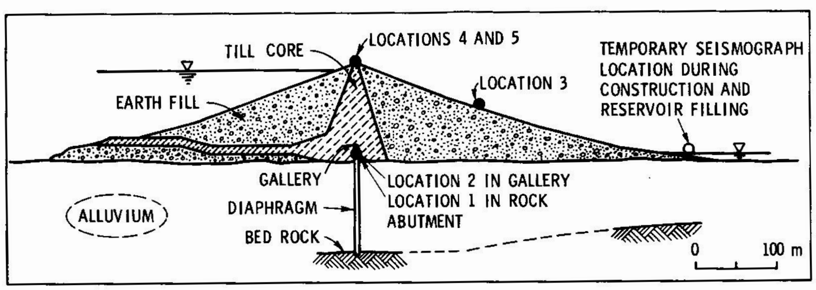

FIGURE 3 SCHEMATIC SECTION OF MANIC 3 DAM AND LOCATIONS OF STRONG-MOTION SEISMOGRAPHS (●,○)

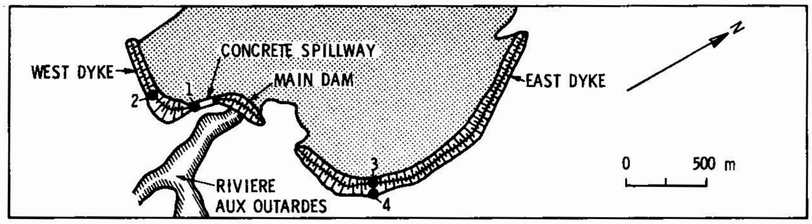

FIGURE 4 PLAN OF OUTARDES 2 DAM SITE AND STRONG-MOTION SEISMOGRAPH LOCATIONS (●)

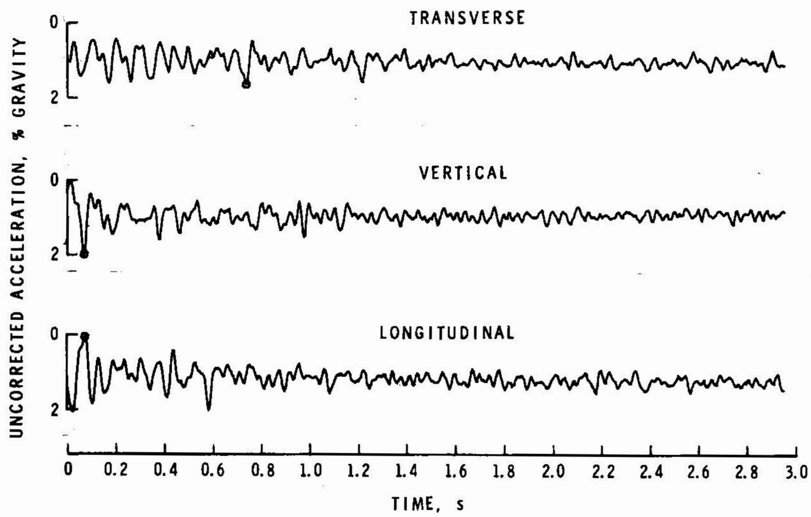

FIGURE 5 ST. FIDELE, P.Q. EARTHQUAKE RECORDED AT TADOUSSAC, P.Q. ON AUGUST 20, 1979