Tectonophysics, 167 (1989) 133–138
Elsevier Science Publishers B.V., Amsterdam – Printed in The Netherlands

United States National Seismograph Network

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(Received January 26, 1988; accepted April 12, 1988)

Abstract

Massé, R.P., Filson, J.R. and Murphy, A., 1989. United States National Seismograph Network. In: M.J. Berry (Editor), Earthquake Hazard Assessment and Prediction. *Tectonophysics*, 167: 133–138.

The USGS National Earthquake Information Center (NEIC) has planned and is developing a broadband digital seismograph network for the United States. The network will consist of approximately 150 seismograph stations distributed across the contiguous 48 states and across Alaska, Hawaii, Puerto Rico and the Virgin Islands. Data transmission will be via two-way satellite telemetry from the network sites to a central recording facility at the NEIC in Golden, Colorado. The design goal for the network is the on-scale recording by at least five well-distributed stations of any seismic event of magnitude 2.5 or greater in all areas of the United States except possibly part of Alaska. All event data from the network will be distributed to the scientific community on compact disc with read-only memory (CD-ROM).

Introduction

The frequency of occurrence, geographical distribution and magnitude of earthquakes are important parameters for assessing the seismic hazard of a region and for establishing the design and construction criteria for critical facilities. These parameters are known collectively as the seismicity of a region and can only be determined through the operation of seismograph networks. For many years, scientists and government agencies have recognized the need for a high quality national seismograph network in the United States. Such a network is now becoming a reality through a cooperative effort between the U.S. Geological Survey (USGS) and the Nuclear Regulatory Commission (NRC). The network is being installed and will be operated by the USGS. The NRC is providing funds to the USGS for the completion of the network east of the Rockies.

The network will consist of approximately 150 seismograph stations distributed across the contiguous 48 states and across Alaska, Hawaii, Puerto Rico and the Virgin Islands. This network should provide the capability to detect, locate and quantify the energy release of earthquakes of magnitude 2.5 and greater in all states except possibly part of Alaska. This capability to characterize earthquakes will be greater than exists today in most parts of the United States. However, the U.S. network will not, even when complete, eliminate the need for additional very dense networks of seismograph stations in certain specific locations. Such dense local networks exist today in areas within the United States (for example, in parts of California, Utah and around the city of St. Louis). The purpose of these dense local networks is to detect earthquakes down to very low magnitude levels (below the 2.5 threshold for the national network) and to achieve very high loca-

0040-1951/89/$03.50

tion accuracy. The dense local networks are thus targeted against a few specific identified seismic risk areas with the objective of acquiring data important for research in subjects such as earthquake prediction and ground motion estimation.

Data from the National Network will be of very high quality and will provide, for the first time, near uniform coverage to fairly low magnitude levels for the entire country. All future seismic studies of the United States, including those studies using data from the very dense local networks, can be expected to rely very heavily on the high quality database obtained from the National Network. The relationship between the National Seismograph Network and the dense local seismograph networks can therefore be considered complementary in nature.

In the following discussions, the design objectives and features of the National Seismograph Network will be given and the proposed station locations will be shown. Data transmission, processing and distribution plans will also be presented.

National Seismograph Network design objectives

The National Seismograph Network is being designed to meet the following objectives:

(1) To detect and locate all earthquakes of $m_b \geq 2.5$ in the United States.

(2) To report all earthquakes of $m_b \geq 2.5$ in the United States within 30 minutes.

(3) To minimize development risk and to achieve low development cost of the network.

(4) To minimize operational cost of the network.

(5) To locate stations at low noise sites.

(6) To acquire full waveform data.

(7) To provide for rapid distribution of the data.

The capability to detect and locate earthquakes of $m_b \geq 2.5$ in the United States will ensure that most felt earthquakes are located with good accuracy. The capability to report information on these earthquakes within 30 minutes is important in order that the National Earthquake Information Center (NEIC) can issue rapid earthquake reports to emergency offices, to government agencies and to the public.

In order to ensure that a high quality National Seismograph Network is deployed during the next 6 years, given a restricted funding climate, it is essential that the development risk and cost of the network be kept very low. The greatest development risk in projects such as this network is generally in the implementation of the central processing capability. For the National Seismograph Network, the USGS will eliminate this risk by using a state-of-the-art seismic processing system recently developed for the NEIC. All station hardware will be off-the-shelf.

From past history, the termination of operation of seismograph networks and arrays is generally the result of high operation costs. To ensure the long-term stability of the National Seismograph Network, it is essential that the operational cost of the network be minimized. If the operational costs can be made very low, the network will be more likely to survive times when funding levels are low.

To the extent possible, seismograph stations should be located at low noise sites. The lower the background seismic noise at the stations, the better the overall detection capability of the network will be.

The National Seismograph Network should produce high quality seismic data. It is planned that the dynamic range of the data will be very large and that the data will be as broadband as possible (15 Hz to DC). Three-component data will be available from the network stations as will strong motion data.

The NEIC has taken a leadership role in distributing national and global seismic data to the scientific community. For data from the National Seismograph Network, the NEIC will establish procedures to ensure rapid distribution and equal access to the network waveform event data for all interested users. Distribution of data from the National Seismograph Network will be considered in more detail later in this paper.

Network configuration

Earthquakes are a fairly common occurrence in much of the United States. Figure 1 shows some

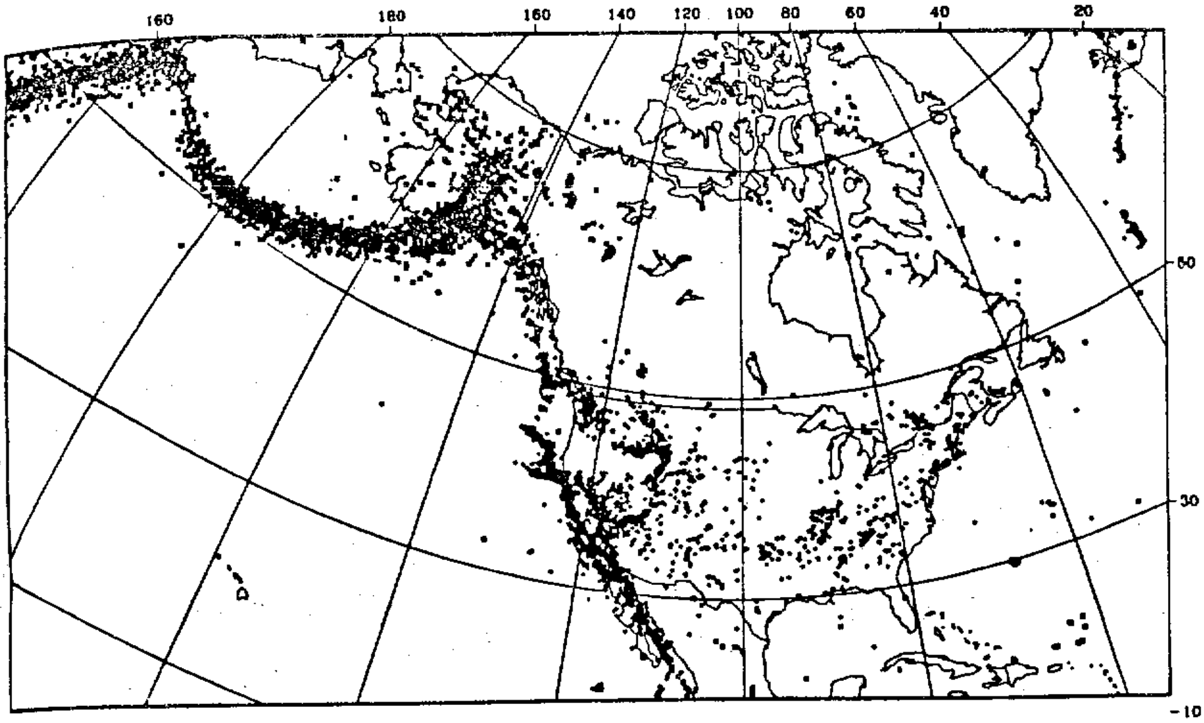

Fig. 1. Seismicity of Alaska, Canada and the United States, 1971–1986.

of the felt earthquakes which have occurred during the years 1971–1986.

There are, of course, many reasons for monitoring this seismicity. The USGS has as part of its mission the responsibility to notify emergency offices regarding the occurrence and location of earthquakes and to evaluate seismic hazard. In addition, improved knowledge of the tectonics and structure of the United States will result from analysis of high-quality earthquake data from earthquakes within the United States. The public also has a strong interest in the occurrence of earthquakes.

To monitor the seismicity shown in Fig. 1, a network of about 150 seismograph stations will be deployed in the United States over the next 6 years. The proposed locations of these stations are shown in Figs. 2–5.

To obtain accurate locations of earthquakes near the margins of the United States, it is necessary to have a few seismograph stations located outside of the United States. These stations will function as "control" stations.

Station characteristics

Each station will have three-component seismometers. The seismometers chosen will be very broadband (15 Hz to DC) and have as high a dynamic range as possible within certain operational and funding constraints. The data will be digitized on site at about 80 samples/s, reduced to 40 samples/s, and signals will be detected using software in a small computer at the station. The event data from the three-component broadband systems will be transmitted to the NEIC.

The seismograph stations will also have a microcomputer, a clock, a satellite transmitter and antenna, and a solar panel and battery system. The data will be time-tagged at the station.

In addition to the systems described above, the National Seismograph Network stations will also be equipped with three-component strong motion sensors. Strong motion data will be sampled at about 80 samples/s for very large signals. Data from these strong motion sensors will be signal-

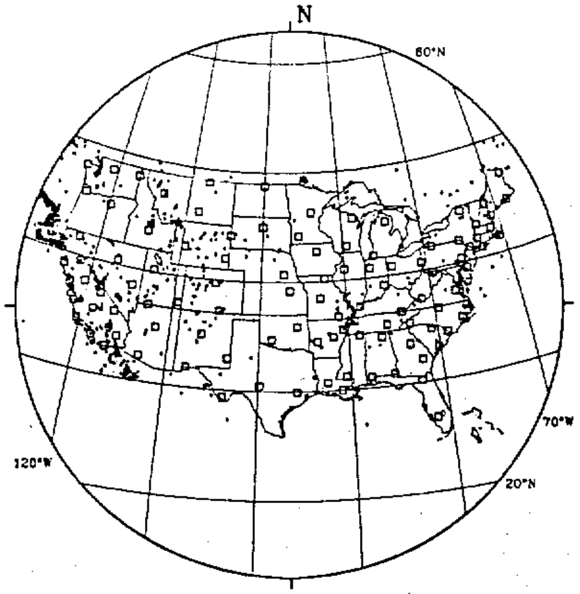

Fig. 2. United States digital seismograph sites and seismicity.

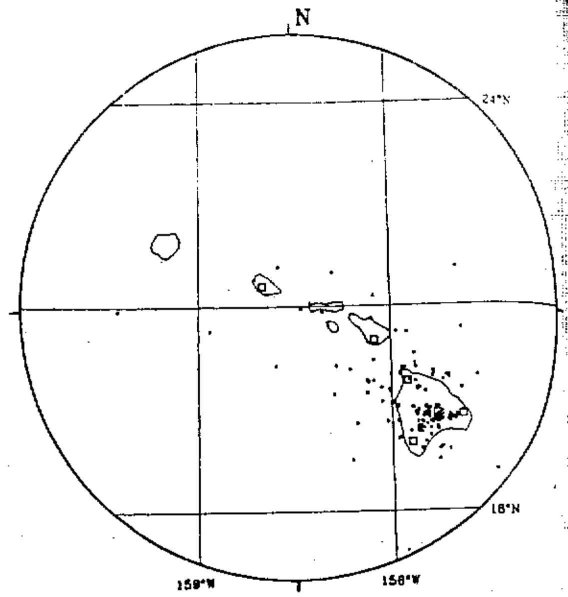

Fig. 4. Hawaii digital seismograph sites and seismicity.

detected at the stations. The total dynamic range of the system is planned to be about 210 dB. At most stations, this large dynamic range will permit even very large earthquakes to be recorded without clipping.

Continuous very long period, three-component data will also be transmitted from all stations to the NEIC. The sampling rate for this data will be low (about 1 sample/s).

Data transmission

Data will be transmitted from the station to the NEIC using satellite transmission. Each station will be equipped with a small satellite antenna (less than 2 m diameter). The NEIC will receive data from all the seismograph stations using a large satellite dish with associated electronics. This master satellite receiving station will be located in the Denver area. This data transmission concept

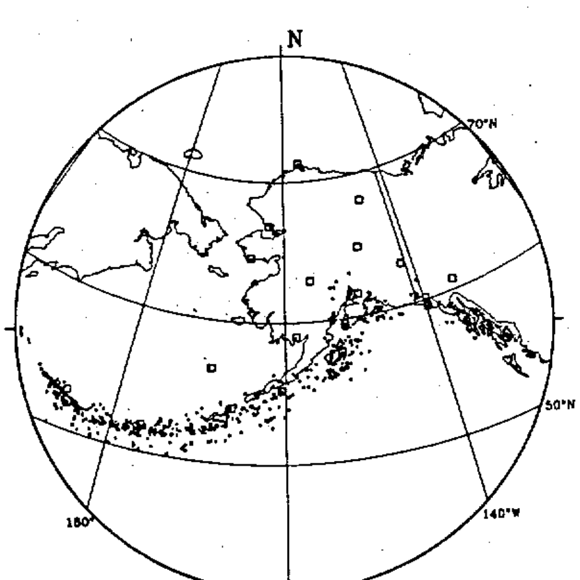

Fig. 3. Alaska digital seismograph sites and seismicity.

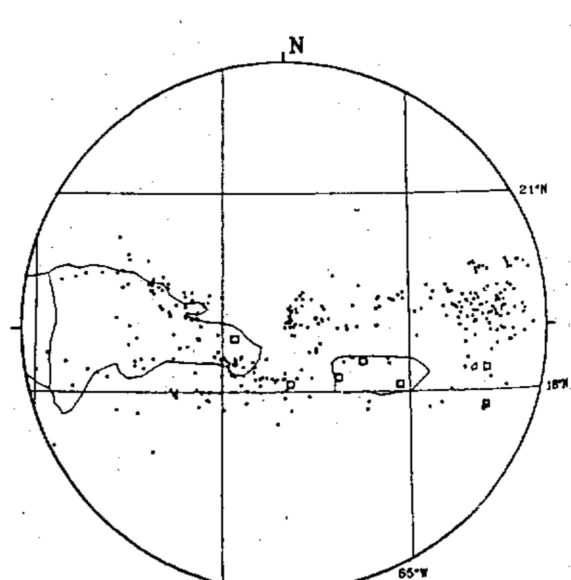

Fig. 5. Puerto Rico digital seismograph sites and seismicity.

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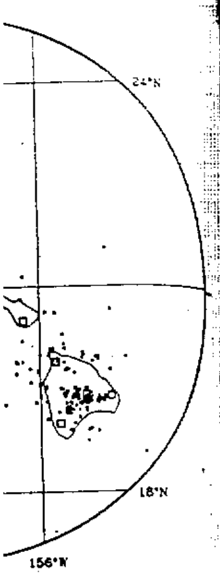

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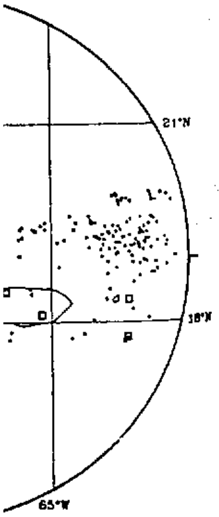

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will allow the seismograph stations to be placed at sites which have low background noise. The location of most of these sites will probably not be convenient near telephone lines. By using near real-time transmission of the data, the NEIC data processing system can be used as it is without the necessity of costly and risky modifications. In addition, the satellite transmission costs are less than those of using long-distance telephone lines.

For most of the network, the use of Ku band (14–16 GHz) time division multiple access (TDMA) satellite telemetry technology will minimize operational cost. The master satellite transmission station at the NEIC will control the multiplexing of 56–96 Kbps satellite channels. The system is being designed with sufficient capacity to telemeter all data simultaneously in the event of a great earthquake near North America.

Data processing

A real-time seismic processing system has recently been installed at the NEIC. This system is very modular and can be easily expanded to meet all the National Seismograph Network requirements by adding hardware components.

The functions of the NEIC processing system include refining the signal detection, determining signal parameters, associating signals, determining preliminary earthquake locations, archiving the signal waveform data with associated epicenter information, providing an interactive capability for analyst review of all automatic event determinations, and producing final epicenter bulletins.

The real-time processing will be handled by high-end 32-bit microcomputers linked through a local area network (LAN). These microcomputers will share a common on-line database. The use of 32-bit microcomputer-based work stations linked to the system through the LAN will meet all requirements for rapid analysis of significant event data.

In addition to the NEIC processing capability, special processing capability will be provided to the NRC in Rockville, Maryland and to the USGS in Reston, Virginia.

Installation schedule

1987. Because of the importance of the data processing system to the success of this project and the need for this processing system to fully test the network as it is being installed, most of the processing system was completed in this first year. The processing system was tested using two seismograph stations which were deployed in the first year. Because the master satellite station was not available the first year, some telephone circuits were used in the testing phase.

1988. The design of USNSN was finalized.

1989. The master satellite system was obtained and checked. Hardware for about five stations was obtained.

1990. Additional stations will be obtained and deployed in the United States and control stations will be installed.

1991 and 1992. Additional stations will be obtained and deployed.

In addition to these installed systems, the NEIC will maintain a few spare seismograph stations together with the satellite transmission equipment. These systems can be quickly deployed to augment the permanent National Seismograph Network for special studies, such as earthquake aftershock monitoring.

Data distribution

Rapid access to data from the National Seismograph Network will be provided to the scientific community by the USGS. Waveform data for earthquakes will be available in near real-time through a high-speed dial-up capability into the event waveform database at the NEIC. The USGS will provide a free (800) telephone number for this purpose. Waveform data for all earthquakes recorded by the National Network will also be provided by the NEIC on compact disc with read-only memory (CD-ROM). Satellite links to participating local networks will also be provided.

Processed results for the National Network in the form of epicenter bulletins will be available as part of the NEIC's Quick Epicenter Determination (QED) Program. The QED bulletin is already available through a dial-up system to the NEIC computers with a free (800) telephone number. The QED information is also transmitted over the World Meteorological Organization (WMO) communications channels to countries all around the world. The NEIC also now makes the final monthly listing of epicenters available in each issue of the *Seismological Research Letters* of the Seismological Society of America.