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Pacific Northwest National Laboratory

Operated by Battelle for the
U.S. Department of Energy

Annual Hanford Seismic Report for Fiscal Year 1998

D. C. Hartshorn
S. P. Reidel
A. C. Rohay

December 1998

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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Richland, Washington 99352

Summary

Hanford Seismic Monitoring provides an uninterrupted collection of high-quality raw and processed seismic data from the Hanford Seismic Network (HSN) for the U.S. Department of Energy and its contractors. The Seismic Monitoring organization also locates and identifies sources of seismic activity and monitors changes in the historical pattern of seismic activity at the Hanford Site. The data are compiled, archived, and published for use by the Hanford Site for waste management, natural phenomena hazards assessments, and engineering design and construction. In addition, the seismic monitoring organization works with the Hanford Site Emergency Services Organization to provide assistance in the event of a significant earthquake on the Hanford Site.

The HSN and the Eastern Washington Regional Network (EWRN) consist of 42 individual sensor sites and 15 radio relay sites maintained by the Hanford Seismic Monitoring staff. The operational rate for fiscal year (FY) 1998 for stations in the HSN was 99.5%. The operational rate for FY 1998 for stations of the EWRN was 99.7%.

There were 638 triggers during FY 1998. Fifty-nine triggers were local earthquakes; 29 (49%) were in the Columbia River Basalt Group, 8 (14%) were in the pre-basalt sediments, and 27 (46%) were in the crystalline basement. The geologic and tectonic environments where these earthquakes occurred are discussed in this report.

Acronyms

BWIP	Basalt Waste Isolation Project
CRBG	Columbia River Basalt Group
DOE	U.S. Department of Energy
EWRN	Eastern Washington Regional Network
FY	fiscal year
GPS	Global Positioning System
HSN	Hanford Seismic Network
M_c	coda-length magnitude
M_L	local magnitude
NP	number of p-wave and s-wave phases
NS	number of stations
PHMC	Project Hanford Management Contract
PNNL	Pacific Northwest National Laboratory
RMS	root-mean-square
SMA	strong motion accelerometer
USGS	United States Geological Survey
UTC	Universal Time Coordinated
UW	University of Washington
WHC	Westinghouse Hanford Company

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1.0 Introduction

1.1 History of Seismic Monitoring at Hanford

Seismic monitoring at the Hanford Site was established in 1969 by the United States Geological Survey (USGS) under a contract with the U.S. Atomic Energy Commission. In 1975, the University of Washington (UW) assumed responsibility for the network and subsequently expanded it. In 1979, the Basalt Waste Isolation Program (BWIP) became responsible for collecting seismic data for the Hanford Site as part of site characterization activities. Rockwell Hanford Operations, followed by Westinghouse Hanford Company (WHC), operated the local network and were the contract technical advisors for the Eastern Washington Regional Network (EWRN) operated and maintained by the UW. Funding for BWIP ended in December 1988. Seismic Monitoring and responsibility for the University of Washington contract were then transferred to WHC's Environmental Division. Maintenance responsibilities for the EWRN were also assigned to WHC, who made major upgrades to EWRN sites. Effective October 1, 1996, Seismic Monitoring was transferred to the Pacific Northwest National Laboratory (PNNL[1]). Seismic Monitoring is part of PNNL's Applied Geology and Geochemistry Group, Energy Technology Division.

The Hanford Strong Motion Accelerometer network was constructed during 1997 and came on line in May 1997. It operated continuously until September 30, 1997, when it was mothballed due to cancellation of funding. Funding was restored on October 1, 1998, by joint agreement between the U.S. Department of Energy (DOE) and PNNL. Operation of the free-field sites resumed on November 20, 1998.

1.2 Mission

The mission of Seismic Monitoring is to provide an uninterrupted collection of high-quality raw seismic data from the Hanford Seismic Network (HSN) located on and around the Hanford Site. These unprocessed data are permanently archived. Hanford Seismic Monitoring also locates and identifies sources of seismic activity, monitors changes in the historical pattern of seismic activity at the Hanford Site, and builds a "local" earthquake database (processed data) that is permanently archived. Local earthquakes are defined as earthquakes that occur between 46 degrees and 47 degrees north latitude and between 119 degrees and 120 degrees west longitude. Data from the EWRN and other seismic networks in the Northwest provide the Seismic Monitoring team with regional data for seismic hazards analysis at the Hanford Site. The data are used by the Hanford Site contractors for waste management activities, Natural Phenomena Hazards assessments, and engineering design and construction. In addition, the Seismic Monitoring Project works with Hanford Site Emergency Services Organization to provide assistance in the event of an earthquake on the Hanford Site.

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[1] Pacific Northwest National Laboratory is operated by Battelle for the U.S. Department of Energy.

1.3 Documentation

The Seismic Monitoring Project issues quarterly reports of local activity, an annual catalog of earthquake activity for the Hanford Site and vicinity, and special-interest bulletins on local seismic events. The annual catalog also includes the fourth quarter report for the fiscal year. In addition Hanford Seismic Monitoring provides information and special reports to other functions as requested. Earthquake information provided in these reports is subject to revisions if new data become available.

2.0 Network Operations

The Hanford Seismic Monitoring network consists of two designs of equipment and sites: seismometer sites and strong motion accelerometer (SMA) sites. Seismometer sites are designed to locate earthquakes on and near the Hanford Site and determine their magnitude and hypocenter location.

DOE Order 5480.28 requires that facilities or sites that have structures or components in Performance Category 2 with hazardous material, and all Performance Category 3 and 4 facilities shall have instrumentation or other means to detect and record the occurrence and severity of seismic events. In order to comply with DOE Order 5480.28, the Hanford Seismic Monitoring Network was expanded in 1997 to include SMAs to record the ground motion at specific sites. The combined seismometer sites and SMA sites provide the Hanford Site with earthquake information to comply with DOE Order 5480.28.

2.1 Seismometer Sites

The HSN and the EWRN consists of 42 sensor sites. Most sites are in remote locations and require solar panels and batteries for power. Both networks share sixteen sites; the HSN uses 21 sites (Table 2.1 and Figure 2.1) and the EWRN uses 36 sites (Table 2.2 and Figure 2.2). The networks have 46 combined data channels because Gable Butte and Frenchman Hills West are three-component sites, each consisting of one vertical, one north-south horizontal, and one east-west horizontal data channel. Both networks use 15 additional telemetry relay sites. All station data links pass through at least one of the relay sites. Some data links transit as many as three relay sites. The last section of the data link is commercial telephone lines. Three to eight channels are multiplexed per telephone line going to the Seismic Monitoring office in the 337 building.

2.1.1 Station Maintenance

The HSN's maintenance records for the seismic sensor and relay sites are filed in the Hanford Seismic Monitoring office. Periods of major outages are addressed in this report. Table 2.3 shows the operational percentage time for each network.

2.1.2 Data Acquisition

Data from seismometer sites are recorded at the 337 building. The Hanford Seismic Network is divided into subnetworks using weighted factors to minimize false triggers but still allow very small seismic events to be recorded. All events that trigger the acquisition computer are analyzed for complex

Table 2.1. Seismic Stations in the Hanford Seismic Network

The first column is the three-letter seismic station designator. The latitude and longitude, elevation above sea level in meters; and the full station name follow this. An asterisk before the three-letter designator means it is a three-component station. The locations of the stations are all in Washington unless otherwise indicated; locations were derived from a Global Positioning Satellite (GPS).				
Station	Latitude Deg.Min.N	Longitude Deg.Min.W	Elevation (m)	Station Name
BEN	46N31.13	119W43.02	340	Benson Ranch
BRV	46N49.12	119W59.47	920	Black Rock Valley
BVW	46N48.66	119W52.99	670	Beverly
CRF	46N49.50	119W23.22	189	Corfu
ET3	46N34.64	118W56.25	286	Eltopia Three
FHW	46N57.13	119W29.92	463	Frenchman Hills West
*GBB	46N36.49	119W37.62	177	Gable Butte
GBL	46N35.92	119W27.58	330	Gable Mountain
H2O	46N23.75	119W25.38	158	Water
LOC	46N43.02	119W25.85	210	Locke Island
MDW	46N36.79	119W45.66	330	Midway
MJ2	46N33.45	119W21.54	146	May Junction Two
OT3	46N40.14	119W13.98	322	Othello Three
PRO	46N12.73	119W41.15	550	Prosser
RED	46N17.92	119W26.30	366	Red Mountain
RSW	46N23.67	119W35.48	1,045	Rattlesnake Mt.
SNI	46N27.85	119W39.60	312	Snively Ranch
WA2	46N45.32	119W33.94	244	Wahluke Slope
WG4	46N01.85	118W51.34	511	Wallula Gap Four
WIW	46N25.76	119W17.26	128	Wooded Island
WRD	46N58.20	119W08.69	375	Warden

events. Complex events are more than one earthquake or an earthquake contained within a record triggered by another source. Table 2.4 shows the number of each event type recorded during each quarter of the fiscal year and total number for the fiscal year.

2.2 Strong Motion Accelerometer Sites

2.2.1 Location

The Hanford SMA network consists of five free-field SMA Sites (Figure 2.1) and one SMA housed in the 337 Building (Table 2.5). There is one free-field SMA located in each of the 200 Separations Areas, one adjacent to the K Basins in the 100-K Area, one adjacent to the 400 Area where the Fast Flux Test Facility is located, and one at the south end of the 300 Area. In addition, one SMA is housed in the Office of Seismic Monitoring in the 337 building in the 300 Area.

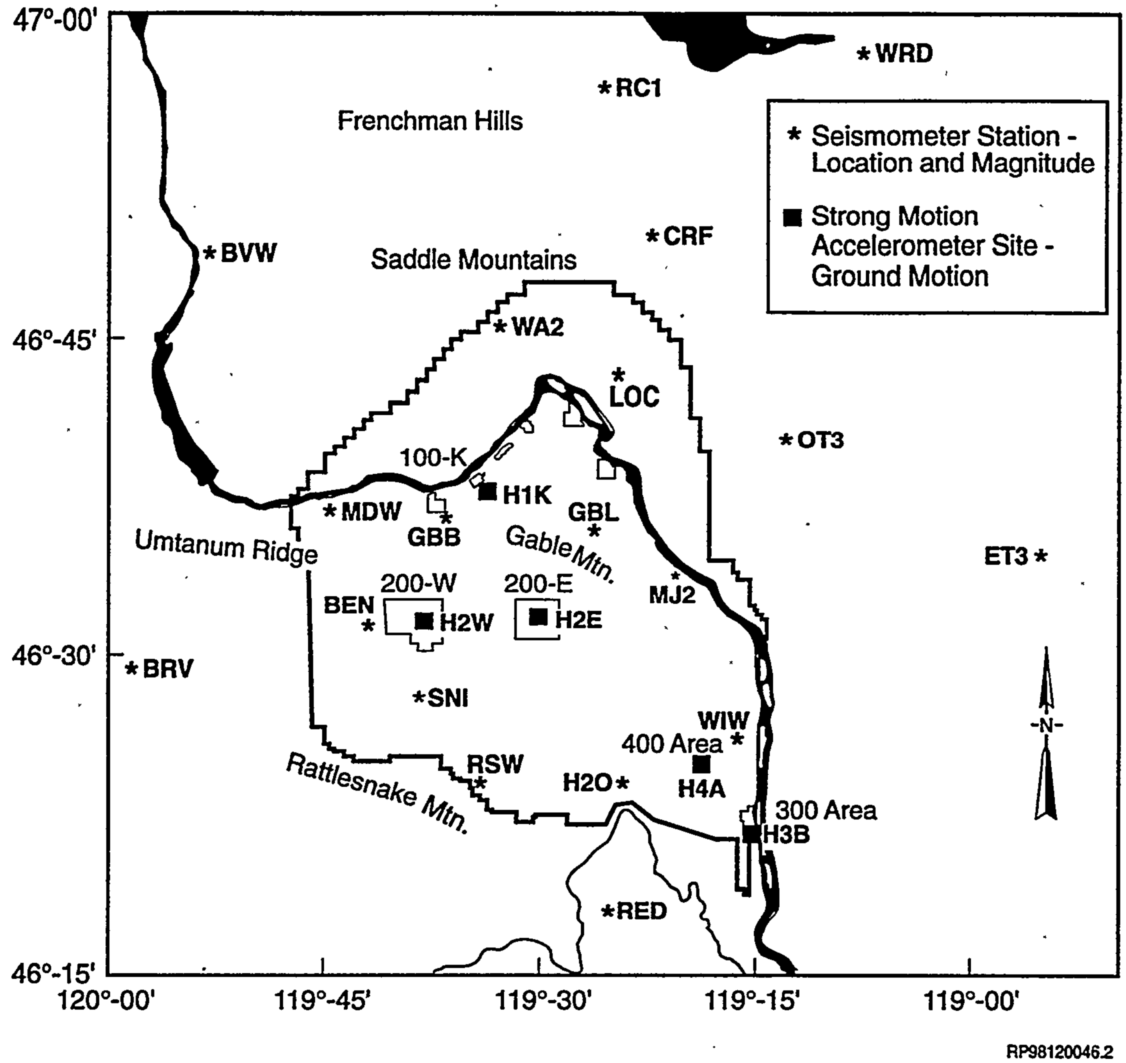

Figure 2.1. Locations of Seismograph Stations and Strong Motion Accelerometer Sites in the Hanford Seismic Network (see Tables 2.1 and 2.5 for description of locations)

Table 2.2. Seismic Stations in the Eastern Washington Regional Network

The first column is the three-letter seismic station designator. The latitude and longitude, elevation above sea level in meters; and the full station name follow this. An asterisk before the three-letter designator means it is a three-component station. The locations of the stations are all in Washington unless otherwise indicated; locations were determined from a Global Positioning Satellite (GPS).

Station	Latitude Deg.Min.N	Longitude Deg.Min.W	Elevation (m)	Station Name
BRV	46N29.12	119W59.47	920	Black Rock Valley
BVW	46N48.66	119W52.99	670	Beverly Washington
CBS	47N48.26	120W02.50	1,067	Chelan Butte, South
CRF	46N49.50	119W23.22	189	Corfu
DPW	47N52.25	118W12.17	892	Davenport
DY2	47N59.11	119W46.28	890	Dyer Hill Two
ELL	46N54.58	120W33.98	789	Ellensburg
EPH	47N21.38	119W35.76	661	Ephrata
ET3	46N34.64	118W56.25	286	Eltopia Three
ETW	47N36.26	120W19.94	1,477	Entiat
FHW	46N57.13	119W29.92	463	Frenchman Hills West
GBL	46N35.92	119W27.58	330	Gable Mountain
LNO	45N52.31	118W17.11	771	Lincton Mt., Oregon
LOC	46N43.02	119W25.85	210	Locke Island
MDW	46N36.79	119W45.66	330	Midway
MJ2	46N33.45	119W21.54	146	May Junction Two
MOX	46N34.64	120W17.89	501	Moxee City
NAC	46N43.99	120W49.42	728	Naches
NEL	48N04.21	120W20.41	1,500	Nelson Butte
OD2	47N23.26	118W42.58	553	Odessa Two
OT3	46N40.14	119W13.98	322	Othello Three
PAT	45N52.92	119W45.14	262	Paterson
PRO	46N12.73	119W41.15	550	Prosser
RSW	46N23.67	119W35.48	1,045	Rattlesnake Mt.
SAW	47N42.10	119W24.03	701	St. Andrews
SNI	46N27.85	119W39.60	312	Snively Ranch
TBM	47N10.20	120W35.88	1,006	Table Mountain
TRW	46N17.32	120W32.31	723	Toppenish Ridge
TWW	47N08.29	120W52.10	1,027	Teanaway
VT2	46N58.04	119W58.95	1,270	Vantage Two
WA2	46N45.32	119W33.94	244	Wahluke Slope Two
WAT	47N41.92	119W57.24	821	Waterville
WG4	46N01.85	118W51.34	511	Wallula Gap Four
WIW	46N25.76	119W17.26	128	Wooded Island
WRD	46N58.20	119W08.69	375	Warden
YA2	46N31.60	120W31.80	652	Yakima Two

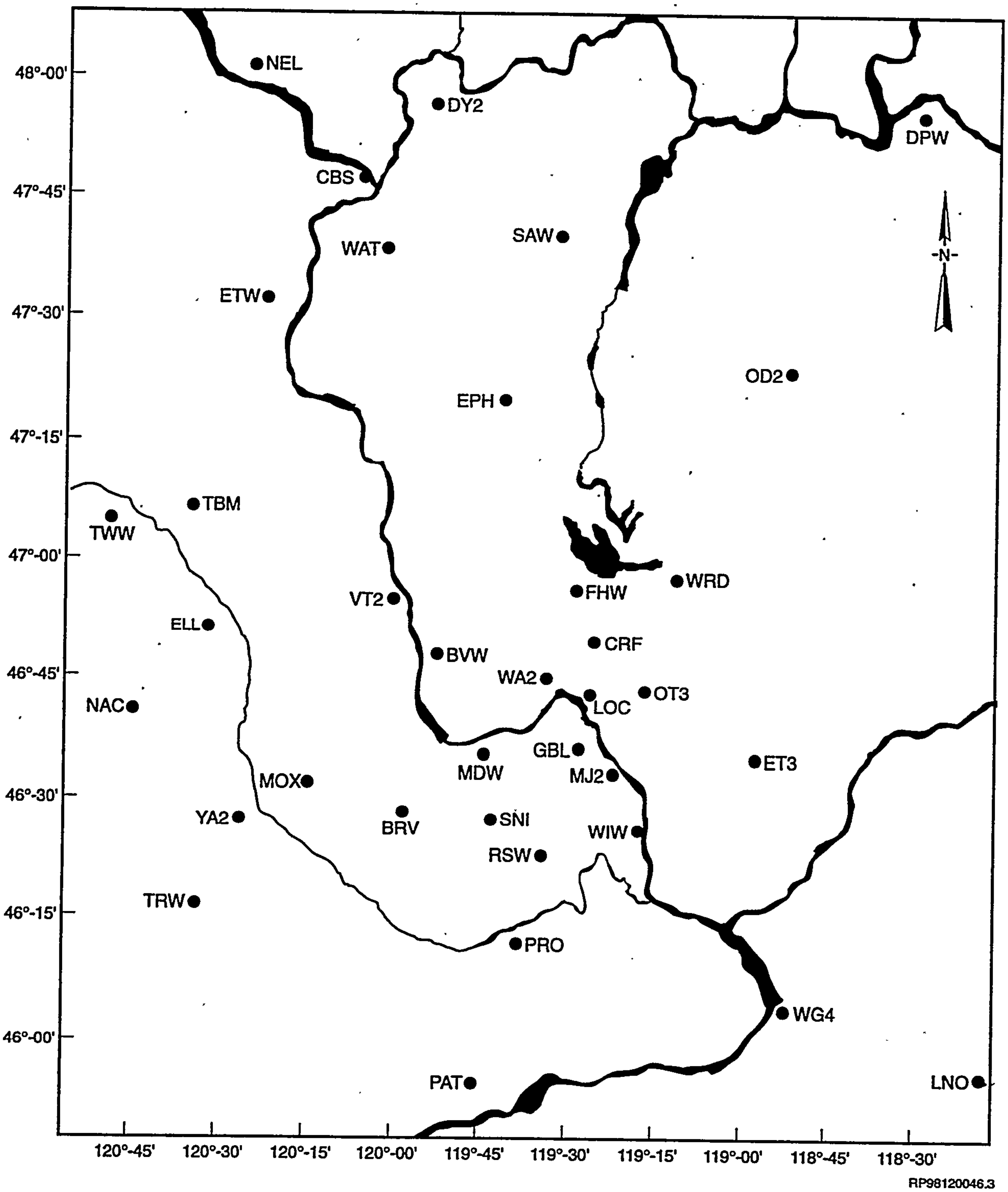

Figure 2.2. Locations of Seismograph Stations in the Eastern Washington Regional Network (see Table 2.2 for location descriptions)

Table 2.3. Seismic Channel Operational Time (%)

Network	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	FY 1998
Hanford	98.46%	99.92%	99.99%	99.70	99.51
Regional	99.06%	99.46%	99.95%	99.85	99.68
Notes: The Hanford Seismic Network's goal is 98%. The Eastern Washington Regional Network's goal is 97%.					

Table 2.4. Acquisition System Recorded Triggers

Event Type	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	FY 1998	Remarks
Local	23	14	10	10	58	Earthquakes within the 46-47 degrees north latitude and 119-120 degrees west longitude
Regional	25	32	31	26	114	Earthquakes surrounding Hanford within the range of 80 to 500 km
Teleseism	86	59	60	61	266	Earthquakes from around the world greater than 500 km in distance.
Acoustical	39	49	9	30	127	Acoustical shock waves from artillery, thunder, and high-performance aircraft sonic booms.
Explosion	7	0	0	0	7	Confirmed blast, usually in borrow pits.
Probable Explosion	3	2	4	1	9	Believed to be a blast because of wave characteristics but cannot be confirmed.
Noise	1	6	19	31	57	Triggers caused by data line circuits, lightning, maintenance triggers during system testing, high winds, coincidental noise at multiple sites within a trigger subnet, etc.
Total Triggers	184	162	133	159	638	

The SMA instrumentation locations were chosen based on two criteria (Moore and Reidel 1996): 1) instruments should be located in areas having the highest densities of people and 2) instruments should be located in areas having hazardous facilities. Some of the highest concentrations of employees at Hanford are 200 East and West Areas, 100-K Area, the Fast Flux Test Facility (400 Area), and the 300 Areas. The 200 Areas are where all high-level radioactive waste from past processing of fuel rods has been stored in single-shell and double-shell tanks. In addition, the Canister Storage Facility that will hold encapsulated spent fuel rods is being constructed in 200 East Area. The 100-K Area presently contains the K Basins where all spent fuel rods from the N Reactor are stored prior to encapsulation. The Cold

Table 2.5. Free-Field Strong Motion Accelerometer Sites

Site	Site ID	Location	Latitude Longitude, Elevation	Design
100 K Area	H1K	South of K Basins outside 100 K Area fence	46° 38.51' 119° 35.53' 152 m	One free-field Kinemetrics ETNA Model SMA housed in a ground vault
200 East Area	H2E	East of B Plant; north of 7th street and east of Baltimore Ave	46° 33.58' 119° 32.00' 210 m	One free-field Kinemetrics ETNA Model SMA housed in ground vault
200 West Area	H2W	Northeast of Plutonium Finishing Plant (PFP); north of 19th street and east of Camden Ave	46° 33.23' 119° 37.51' 206 m	One free-field Kinemetrics ETNA Model SMA housed in ground vault
300 Area	H3A	South end of 300 Area inside fence line. (NE 1/4, SW 1/4, Sec. 11, T10N, R28E)	46° 21.83' 119° 16.55' 119 m	One free-field Kinemetrics ETNA Model SMA housed in ground vault
400 Area	H4A	500 ft from fence line on east side of facility and north of parking area	46° 26.13' 119° 21.30' 171 m	One free-field Kinemetrics ETNA Model SMA house in ground vault
337 Building	H3B	Office of Seismic Monitoring, Room 176	46° 22' 119° 17' 140 m	One Kinemetrics ETNA Model SMA attached to concrete floor

Vacuum Drying Facility is presently being constructed in the 100-K Area to encapsulate spent fuel rods from the K Basins prior to shipment to the Canister Storage Building in 200 East Area.

2.2.2 SMA Site Design

This section describes the designs of the SMA sites as of October 1, 1998. All sites are being upgraded during fiscal year (FY) 1999 to insure continuous operation and low maintenance.

All free-field SMA sites consist of two 113.7 liters drums set in the ground such that the base of the drum is about 1 m below the surface. One drum houses only the SMA; the other drum houses the electronics and communications equipment. A distance of 101.6 cm - 215.9 cm separates the drum containing the electronics and communications equipment from the SMA drum; a sealed conduit connects the two drums.

The SMA instruments are three-component units consisting of one vertical, one north-south horizontal, and one east-west horizontal data channel. The instruments in use are the ETNA system of Kinemetrics, Inc. Instrument specifications are summarized in Table 2.6. In addition to the three-component SMAs, each ETNA SMA unit contains a computer, GPS receiver and a modem (Figure 2.3). These systems are housed in watertight boxes.

Table 2.6. Instrument Parameters for the Kinemetrics ETNA System in the Hanford Strong Motion Accelerometer Network

Parameter	Value or Range
Sensor	
Type	Tri-axial Force Balance Accelerometer orthogonally oriented with internal standard.
Full-Scale	2.0 g[(a)]
Natural Frequency	50± Hz range
Damping	Approximately 67% critical[(a)]
Data Acquisition	
Number of Channels	3
Sample Rate	18-bit resolution @ 200 samples/second
Digital Output	Real-time, RS-232 Output Stream
Seismic Trigger	
Filter	0.1 - 12.5 Hz
Trigger Level	0.04% g to 0.20% g[(b)]
Alarm (call-out) Threshold	4.00% g
Pre-Event Memory	10 sec
Post-Event Time	40 sec

(a) Setting is dependent on instrument calibration.
(b) See Section 3.0 for discussion of trigger thresholds.

Two 100 amp-hour batteries that are housed in the equipment and communications drum (Figure 2.3) power the SMAs. The batteries are charged currently by two solar panels; a regulator is located between the solar panels and the batteries. All sites are being upgraded to four solar panels to provide rapid battery recharge during long winter overcast periods.

The communication link between the SMAs and the data analysis computer system housed in the 337 building is via a cellular telephone/modem connection. The built-in modem in the SMA allows the system to use a cellular telephone to call an accelerometer or for the accelerometer to call out in the event it is triggered. The system is being upgraded to allow pager notification in the event of a system trigger. .

The SMAs have an internal GPS receiver used principally to link it to the National Bureau of Standards timing system. The GPS is internally activated approximately every 4 hours and checks the location of the instrument and the time. Any differences between the internal clock and the GPS time are recorded and saved by the SMA. Any corrections to the internal timing are made automatically. After the first 6 months of operation in 1997, the greatest difference recorded is approximately 4 milliseconds.

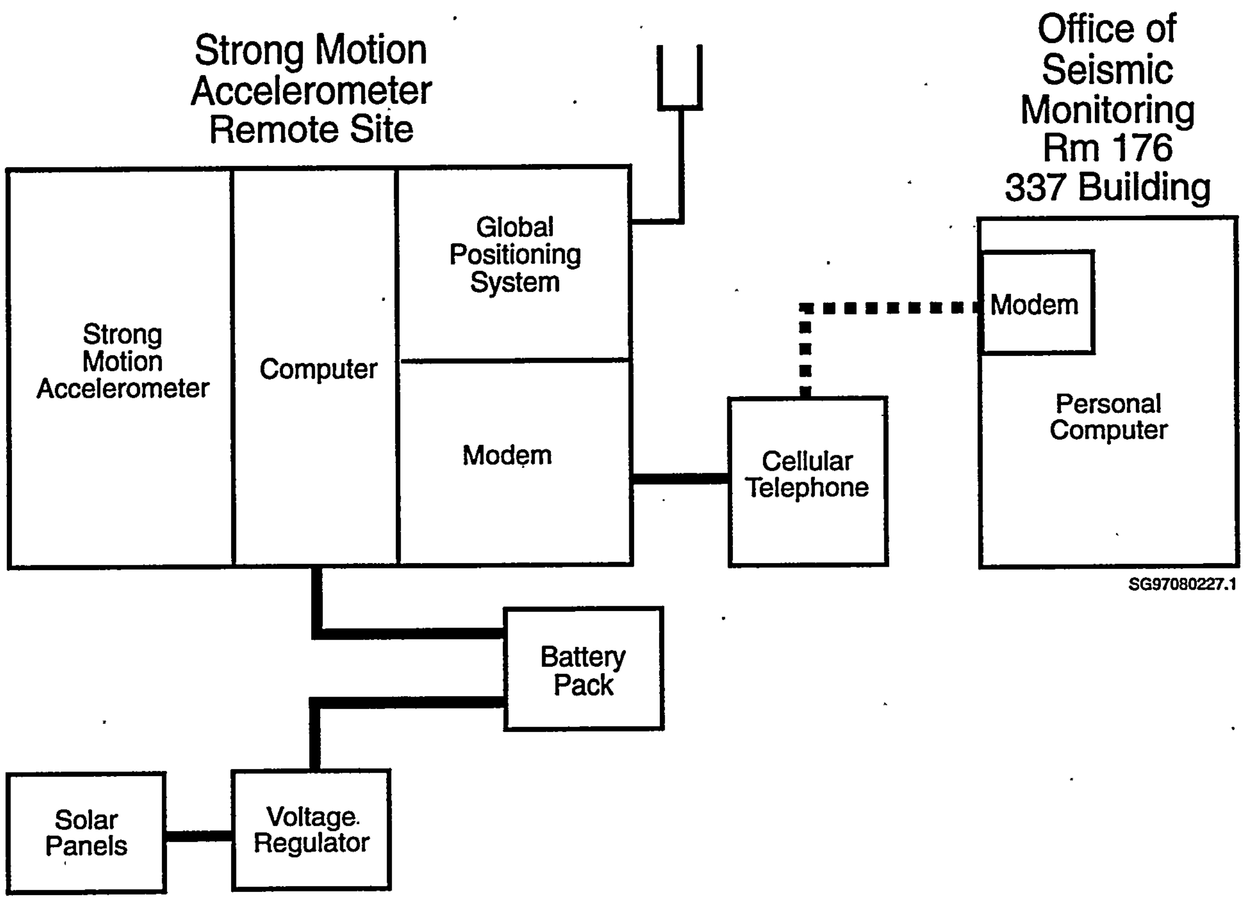

Figure 2.3. Schematic Diagram of a Strong Motion Accelerometer Installation

2.2.3 Strong Motion Accelerometer Operations Center

The combined operations, data recording and interpretation, and maintenance facility is located in the 337 building. PNNL provides an area and point of contact for facility Emergency Response and Safety Personnel and facility managers to receive information in the event of an earthquake.

3.0 Magnitude, Velocity Models, and Quality Factors

3.1 Coda-Length Magnitude

Coda-length magnitude (M_c), an estimate of local magnitude (M_L) (Richter 1958), is calculated using the coda-length/magnitude relationship determined for Washington by Crosson (1972).

3.2 Velocity Model

The velocities and layer depths given in Table 3.1 are used by the program XPED in the SUN operating system. XPED was developed at the UW and the velocity model used in XPED is based on Rohay et al. (1985). XPED is an interactive earthquake seismogram display program used to analyze seismic events.

3.3 Quality Factors (Q)

XPED assigns a two-letter **Quality factor** (Table 3.2) that indicates the general reliability of the solution (A is best quality, **D** is worst). Similar quality factors are used by the USGS for events located with the computer program HYPO71. The first letter of the quality code is a measure of the hypocenter quality based primarily on travel time residuals. For example: Quality A requires a root-mean-square residual (RMS) less than 0.15 seconds while a RMS of 0.5 seconds or more is **D** quality (other estimates of the location uncertainty also affect this quality parameter). The second letter of the quality code is related to the spatial distribution of stations that contribute to the event's location, including the number of stations (NS), the number of p-wave and s-wave phases (NP), the largest gap in event-station azimuth

Table 3.1. Seismic Velocities for Columbia Basin Stratigraphy (see Rohay et al. 1985)

Depth to Top of Velocity Layer (km)	Stratigraphy	Velocity (km/sec)
0.0	Saddle Mountains and Wanapum Basalts and intercalated Ellensburg Formation	3.7
0.4	Grande Ronde Basalt and pre-basalt sediments	5.2
8.5	Crystalline Basement, Layer 1	6.1
13.0	Crystalline Basement, Layer 2	6.4
23.0	Sub-basement	7.1
38.0	Mantle	7.9

Table 3.2. Local Earthquake Data from October 1, 1997 through September 30, 1998

Event ID	Date	Time	Latitude	Longitude	Depth	MAG	NS/NP	GAP	DMIN	RMS	Q	Type	Location
97100416574	97/10/04	16:57:47.13	46N28.24	119W44.05	14.52	1.1	9/14	225	5	0.03	AD		10 km SW of 200-West Area
97100814594	97/10/08	14:59:45.60	46N22.82	119W08.62	0.35	0.5	7/10	236	12	0.05	AD		11 km east of 300 Area
97101323143	97/10/13	23:14:32.73	46N10.04	119W25.66	6.48	0.0	3/06	310	14	0.01	AD	X	Webber Canyon
97101421242	97/10/14	21:24:22.29	46N58.58	119W58.66	20.81	0.0	8/11	329	39	0.03	AD	P	2.1 km NNE of Vantage, WA
97102419004	97/10/24	19:00:55.05	46N27.70	119W42.59	15.36	0.7	10/15	217	3	0.04	AD		11 km SW of 200-West Area
97103104121	97/10/31	04:12:12.42	46N28.80	119W20.36	16.69	0.0	4/05	222	8	0.03	AD		6 km NE of 400 Area
97110100153	97/11/01	00:15:34.54	46N11.17	119W22.61	2.91	0.0	10/16	262	13	0.01	AD	X	Webber Canyon
97110217332	97/11/02	17:33:23.68	46N10.57	119W04.61	9.80	1.4	13/22	162	23	0.06	AC		4.7 km SE of Kennewick, WA
97110523091	97/11/05	23:09:17.84	46N09.32	119W21.09	5.01	1.8	10/16	293	17	0.04	AD	X	Webber Canyon
97110601241	97/11/06	01:24:21.16	46N31.78	119W42.70	20.04	3.5	13/18	80	1	0.05	AA		6 km SW of 200-West Area
97110602145	97/11/06	02:15:02.99	46N32.00	119W42.65	18.18	0.7	10/12	80	1	0.03	AA		4 km SW of 200-West Area
97102901520	97/10/29	01:52:05.14	46N09.94	119W24.26	2.33	1.6	8/09	266	14	0.03	AD	X	Webber Canyon
97110912494	97/11/09	12:49:54.13	46N31:85	119W42.46	18.67	2.8	14/18	79	1	0.06	AA		4 km SW of 200-West Area
97110919203	97/11/09	19:20:42.16	46N32.18	119W42.39	20.14	2.9	18/24	78	2	0.07	AA		4 km SW of 200-West Area
97110919344	97/11/09	19:34:55.20	46N31.87	119W42.31	18.64	1.1	11/13	170	1	0.02	AC		4 km SW of 200-West Area
97111007071	97/11/10	07:07:25.00	46N32.05	119W42.12	18.38	1.1	12/20	76	2	0.04	AA		4 km SW of 200-West Area
97111123274	97/11/11	23:27:50.27	46N08.64	119W25.37	1.18	0.0	8/08	290	17	0.06	AD	X	Webber Canyon
97111511233	97/11/15	11:23:32.19	46N42.82	119W52.90	5.22	1.5	9/15	209	10	0.06	AD		18 km WNW of 100-K Area
97112423483	97/11/24	23:48:38.81	46N10.98	119W27.07	0.03	1.7	11/15	238	12	0.05	AD	X	Webber Canyon
97120400322	97/12/04	00:32:24.33	46N11.17	119W25.88	0.45	1.5	7/08	327	12	0.08	AD	X	Webber Canyon
97121103091	97/12/11	03:09:17.36	46N34.45	119W16.75	21.64	0.7	12/17	163	6	0.03	AC		23 km east of 200-East Area
97121119275	97/12/11	19:27:60.17	46N34.81	119W15.36	24.93	1.1	16/26	97	8	0.05	AB		24 km East of 200-East Area
97121214441	97/12/12	14:44:17.77	46N34.82	119W14.86	22.96	0.3	8/10	156	8	0.03	AC		24 km east of 200-East Area
97121419392	97/12/14	19:39:32.00	46N28.01	119W43.86	15.72	1.2	14/18	102	5	0.03	AB		10 km SW of 200-West Area
97121502145	97/12/15	02:14:54.63	46N34.66	119W15.17	24.14	0.6	11/13	99	16	0.03	AB		14 km east of 200-East Area
97122308493	97/12/23	08:49:31.49	46N57.82	119W22.20	21.68	1.5	8/11	300	27	0.05	AD		34 km NE of 100-N Area
97122622501	97/12/26	22:50:16.12	46N38.82	119W46.00	0.46	-0.3	4/06	298	3	0.03	AD		11 km west of 100-K Area

Table 3.2. (contd)

Event ID	Date	Time	Latitude	Longitude	Depth	MAG	NS/NP	GAP	DMIN	RMS	Q	Type	Location
97122622502	97/12/26	22:50:26.37	46N38.53	119W46.03	0.91	0.5	8/10	239	3	0.01	AD		11 km west of 100-K Area
97122818345	97/12/28	18:35:01.82	46N38.35	119W45.69	0.43	0.4	7/08	230	2	0.06	AD		11 km west of 100-K Area
97122914180	97/12/29	14:18:12.72	46N38.48	119W46.27	0.45	1.2	11/15	169	3	0.03	AC		11 km west of 100-K Area
97123000173	97/12/30	00:17:35.76	46N33.88	119W30.10	2.98	0.2	7/10	105	4	0.03	AB		1 km east of 200-East Area
98010809253	98/01/08	09:25:43.52	46N32.42	119W43.93	10.78	-0.4	4/07	191	2	0.02	AD		7 km west of 200-West Area
98010809425	98/01/08	09:42:56.58	46N32.27	119W42.67	8.65	0.3	4/07	143	2	0.01	AD		6 km west of 200-West Area
98013120213	98/01/31	20:21:39.34	46N43.74	119W31.58	3.13	0.7	13/19	90	4	0.06	AA		7 km NE of 100-N Area
98020408144	98/02/04	08:14:46.00	46N32.00	119W42.52	18.54	0.5	10/13	80	1	0.02	AA		6 km West of 200-West Area
98020520421	98/02/05	20:42:17.35	46N36.88	119W46.00	15.33	0.0	7/12	177	0	0.05	AC		13 km WSW of 100-K Area
98020919355	98/02/09	19:35:49.78	46N35.95	119W00.54	36.25	1.6	8/13	248	18	0.10	BD	P	Connell Quarry
98020923302	98/02/09	23:30:29.09	46N28.59	119W43.23	1.30	1.1	11/15	140	4	0.04	AC		10 km SW of 200-West Area
98021023062	98/02/10	23:06:33.76	46N22.40	119W15.90	0.23	1.0	10/16	227	6	0.05	AD		South end of Johnson Island
98021317052	98/02/13	17:05:24.43	46N40.42	119W28.41	11.98	0.4	6/10	111	5	0.01	AC		5 km SE of 100-N Area
98021608064	98/02/16	08:06:45.21	46N44.65	119W40.84	4.31	1.5	13/17	146	8	0.05	AC		12 km NNW of 100-K Area
98022518520	98/02/25	18:52:12.54	46N44.92	119W41.57	5.07	0.6	7/08	150	9	0.02	AC		13 km NNW of 100-K Area
98022520190	98/02/25	20:19:06.86	46N07.57	119W24.43	0.03	2.0	9/11	278	19	0.07	AD	P	Webber Canyon
98030122010	98/03/01	22:01:05.14	46N19.13	119W53.04	2.12	1.8	15/21	208	19	0.07	AD	P	30 km SW of 200-West Area, Sagebrush Ridge
98030515591	98/03/05	15:59:15.54	46N23.27	119W15.45	0.02	0.7	10/16	222	5	0.08	AD		North end of Johnson Island
98030608065	98/03/06	08:06:54.41	46N50.84	119W17.67	3.71	0.3	6/10	149	7	0.07	AC		28 km NE of 100-N Area
98032323323	98/03/23	23:32:36.57	46N23.54	119W02.54	2.24	1.9	18/25	138	19	0.09	AC		25 km ESE of FFTF; Eltopia, WA
98032613383	98/03/26	13:38:37.90	46N46.10	119W43.27	7.15	0.8	8/13	266	11	0.08	AD		16 km NW of 100-K Area
98040108122	98/04/01	08:12:26.26	46N42.32	119W50.63	0.49	1.6	10/11	190	12	0.05	AD		20 km WNW of 100-K Area
98040520113	98/04/05	20:11:33.92	46N20.34	119W01.42	6.18	0.5	5/08	282	22	0.04	AD		10 km E of 300 Area
98040606575	98/04/06	06:57:55.12	46N44.65	119W40.00	8.29	0.2	10/13	146	7	0.06	AC		11 km NW of 100-K Area
98040606584	98/04/06	06:58:46.18	46N44.25	119W40.06	3.23	0.4	10/10	139	8	0.07	AC		12 km NW of 100-K Area
98040706310	98/04/07	06:31:08.46	46N42.80	119W52.22	0.03	1.9	12/18	154	10	0.07	AC		20 km WNW of 100-K Area
98041904072	98/04/19	04:07:26.08	46N18.07	119W33.49	15.92	1.6	16/26	169	9	0.10	AC		20 km SW of FFTF

Table 3.2. (contd)

Event ID	Date	Time	Latitude	Longitude	Depth	MAG	NS/NP	GAP	DMIN	RMS	Q	Type	Location
98042809033	98/04/28	09:03:40.85	46N44.59	119W40.45	4.94	1.0	11/13	145	8	0.09	AC		12 km NW of 100-K Area
98042903024	98/04/29	03:02:45.27	46N52.54	119W13.15	13.00	1.3	16/25	126	11	0.05	AB		42 km NE of 200-East Area
98051708480	98/05/17	08:48:03.22	46N49.97	119W31.90	22.32	1.1	7/13	272	15	0.10	AD		22 km NE of 100-K Area
98052912103	98/05/29	12:10:41.21	46N34.45	119W30.28	16.50	-0.3	6/07	124	4	0.02	AC		3 km ENE of 200-East Area
98060311523	98/06/03	11:52:35.80	46N44.58	119W39.43	2.78	1.4	14/16	123	7	0.08	AB		12 km NW of 100-K Area
98070803353	98/07/08	03:35:28.31	46N12.72	119W49.94	14.91	1.0	6/09	295	27	0.08	AD		39 km SW of 200-West Area
98071914175	98/07/19	14:18:01.31	46N37.96	119W41.54	0.40	0.4	8/13	147	5	0.04	AC		6 km W of 100-K Area
98080304105	98/08/03	04:10:58.89	46N34.08	119W47.67	18.14	1.2	12/15	107	5	0.05	AB		11 km W of 200-West Area
98080717273	98/08/07	17:27:39.90	46N25.86	119W12.89	0.05	0.1	6/09	294	5	0.08	AD		11 km E of FFTF
98081722015	98/08/17	22:02:01.47	46N09.13	119W32.46	15.12	1.5	15/23	256	13	0.04	AD		37 km S of 200-West Area
98082221244	98/08/22	21:24:44.73	46N12.79	119W28.30	7.73	1.3	10/15	300	20	0.11	AD		36 km S of 200-East Area
98083017535	98/08/30	17:54:00.78	46N41.27	119W28.77	1.88	0.9	13/20	66	4	0.07	AA		6 km E of 100-N Area
98090919235	98/09/09	19:23:54.38	46N25.97	119W14.59	1.06	0.7	7/13	286	3	0.05	AD		11 km E of FFTF
98092323344	98/09/23	23:34:49.44	46N13.67	119W28.43	6.23	1.0	9/13	231	8	0.04	AD		25 km S of 200-East Area
98092706555	98/09/27	06:55:56.87	46N20.02	119W23.52	0.49	0.4	5/09	256	7	0.03	AD		12 km S of FFTF
98092922352	98/09/29	22:35:25.13	46N10.96	119W26.21	4.68	1.1	4/07	257	12	0.03	AD	P	40 km S of 200-East Area

Explanation of Table 3.2

EVENT ID: The identification number is created by the analysis program XPED. XPED uses the year, month, day and time to create a unique number for each event.

DATE: The year and day of the year in Universal Time Coordinated (UTC). UTC is used throughout this report unless otherwise indicated.

TIME: The origin time of the earthquake given in UTC. To covert UTC to Pacific Standard Time, subtract eight hours; to Pacific Daylight Time, subtract seven hours.

LATITUDE: North latitude, in degrees and minutes, of the earthquake epicenter.

LONGITUDE: West longitude, in degrees and minutes, of the earthquake epicenter.

DEPTH: The depth of the earthquake in kilometers (km).

MAG: The magnitude is expressed as M_c, an estimate of M_L (Richter 1958). If Magnitude is blank, no determination could be made.

NS/NP: Number of stations/number of phases used in the solutions.

GAP: Azimuthal gap. The largest angle (relative to the epicenter) containing no stations.

DMIN The distance from the earthquake epicenter to the closest station.

RMS: The root-mean-square residual (observed arrival times minus the predicted arrival times) at all stations used to locate the earthquake. It is only useful as a measure of quality of the solution when five or more well-distributed stations are used in the solution. Good solutions are normally characterized by RMS values of less than about 0.3 seconds.

Q: The Quality Factors indicate the general reliability of the solution/location (**A** is best quality, **D** is worst). See Section 3.3 of this report: Quality Factors.

TYPE P is Probable Blast; X is Confirmed Blast; F is Felt Earthquake; H is hand picked from helicorder; S is surficial event (rock slide, avalanche) and not a explosion or tectonic earthquake; blank is local earthquake.

distribution (GAP), and the closest distance from the epicenter to a station (DMIN). Quality **A** requires a solution with **NP** >8, **GAP** <90°, and **DMIN** <5 km (or the hypocenter depth if it is greater than 5 km). If **NP** ≤5, **GAP** >180°, or **DMIN** >50 km, the solution is assigned Quality **D**.

4.0 Geology and Tectonic Analysis

4.1 Earthquake Stratigraphy

Studies of seismicity at the Hanford Site have shown that the seismicity is related to crustal stratigraphy (layers of rock types) (Rohay et al. 1985, DOE 1988). The main geologic units at Hanford and the surrounding area are:

- The Miocene Columbia River Basalt Group (CRBG)
- The Paleocene, Eocene, and Oligocene sediments
- The crystalline basement (Precambrian and Paleozoic craton; Mesozoic accreted terranes).

4.1.1 Geologic Structure Beneath the Monitored Area

Between the late 1950s and the early 1980s, deep boreholes were drilled for hydrocarbon exploration in the Columbia Basin. These boreholes provided accurate measurements of the physical properties of the CRBG and the pre-basalt sediments (Reidel et al. 1989, 1994), but the thickness of the pre-basalt sediments and nature of the crystalline basement are still poorly understood. The difference between the thicknesses listed in Table 4.1 and the thicknesses of the crustal layers in the velocity model in Table 3.1 reflect data specific to the UW's crustal velocity model for eastern Washington. Table 4.1 is derived from Figure 4.1 and was developed for the geologic interpretation in this section. Figure 4.1 shows north-south and east-west cross sections through the Columbia Basin based on surface mapping, deep boreholes, geophysical data (including the work of Rohay et al. [1985]), and magnetotelluric data obtained as part of BWIP (DOE 1988). The thicknesses of these units are highly variable across the monitored area. Table 4.1 summarizes the approximate thicknesses at the borders of the monitored area.

The thickness of the basalt and the pre-basalt sediments varies as a result of different tectonic environments. The western edge of the North American craton (late Precambrian/Paleozoic continental margin and Precambrian craton) is located in the eastern portion of the monitored area. The stratigraphy on the craton consists of CRBG overlying crystalline basement; the crystalline basement is continental crustal rocks that underlie much of the western North America. The stratigraphy west of the craton consists of 4-5 km of CRBG overlying greater than 6 km of pre-basalt sediments. This, in turn, overlies accreted

Table 4.1. Thickness of Stratigraphic Units Across the Monitoring Area

Stratigraphy	North	South	East	West
Columbia River Basalt Group (includes suprabasalt sediments)	3.0 km	4.5 km	2.2 km	4.2 km
Pre-basalt Sediments	3.0 km	>4.5 km	0	>6.0 km

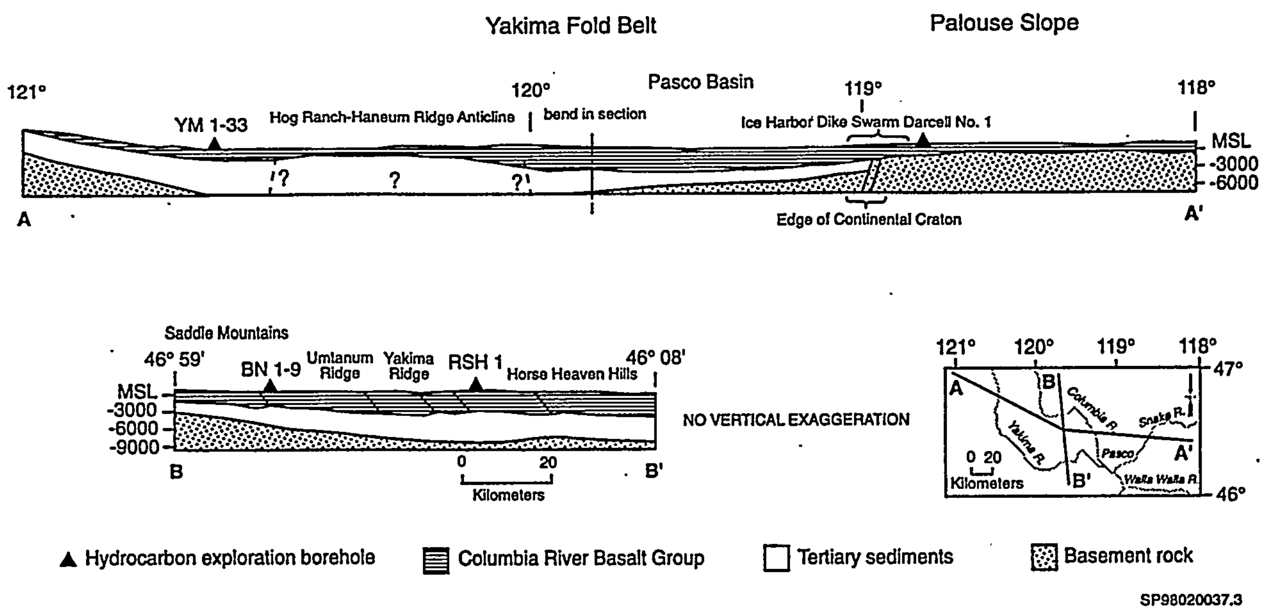

Figure 4.1. Geologic Cross Sections Through the Columbia Basin

terranes of Mesozoic age. The area west of the craton was subsiding during the Eocene and Oligocene, accumulating great thicknesses of pre-CRBG sediments. Continued subsidence in this area during the Miocene resulted in thicker CRBG compared to that on the craton. Subsidence continues today but at a greatly reduced rate (Reidel et al. 1994).

4.1.2 Depth of Earthquakes

Since accurate locations and depths have been available, about 75% of the earthquakes at the Hanford Site have originated in the CRBG layer. The pre-basalt sediments have had about 7% of the events and the crystalline basement has had 18%. Events recorded for FY 1998 are listed in Table 4.2.

Table 4.2. Number of Earthquakes Occurring in Stratigraphic Units

Unit	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	FY 1998
Basalt	6 (26%)	7 (50%)	5 (45%)	6 (55%)	29 (49%)
Pre-Basalt Sediments	1 (4%)	3 (21%)	2 (18%)	2 (18%)	8 (14%)
Crystalline Basement	16 (70%)	4 (29%)	4 (36%)	3 (27%)	27 (46%)
Total	23	14	11	11	59

4.2 Tectonic Pattern

Studies at the Hanford Site have concluded that earthquakes that can affect the Hanford Site can occur in the following six different tectonic environments (earthquake sources) at the Hanford Site (Geomatrix 1996).

- **Reverse/thrust faults.** Reverse/thrust faults in the CRBG associated with major anticlinal ridges such as Rattlesnake Mountain, Yakima Ridge, and Umtanum Ridge could produce some of the largest earthquakes.

- **Secondary faults.** These are associated with the major anticlinal ridges.

- **Swarm areas.** Small geographic areas of unknown geologic structure produce clusters of events (swarms), usually in the CRBG in synclinal valleys. These clusters consist of a series of small shocks with no outstanding principal event. Swarms occur over a period of days or months and the events may number into the hundreds and then quit, only to start again at a later date. This differs from the sequence of foreshocks, mainshock, and trailing-off aftershocks that have the same epicenter or are associated with the same fault system. Three principal swarm areas are known at the Hanford Site. One is the Wooded Island Swarm Area along the Columbia River near the 300 Area. The second area, the Coyote Rapids Swarm Area, extends from the vicinity of the 100-K Area north-northeast along the Columbia River Horn to the vicinity of the 100-N Area. The third major swarm area is along the Saddle Mountains on the northern boundary of the Hanford Site. Other earthquake swarm areas are present, but activity is less frequent.

- **The entire Columbia Basin.** The entire basin, including the Hanford Site, could produce a "floating" earthquake. A floating earthquake is one that, for seismic design purposes, can happen anywhere in a tectonic province and is not associated with any known geologic structure. It is classified as a random event by Seismic Monitoring for purposes of seismic design and vibratory ground motion studies.

- **Basement source structures.** Studies (Geomatrix 1996) suggest that major earthquakes can originate in tectonic structures in the crystalline basement. Because little is known about geologic structures in the crystalline basement beneath the Hanford Site, earthquakes cannot be directly tied to a mapped fault. Earthquakes occurring in the crystalline basement without known sources are treated as random events for seismic hazards analysis and seismic design.

- **The Cascadia Subduction Zone.** This source recently has been postulated to be capable of producing a magnitude 9 earthquake. Because this source is along the western boundary of Washington State and outside the HSN, the Cascadia Subduction Zone is not an earthquake source that is monitored at the Hanford Site, so subduction zone earthquakes are not reported here. Because any earthquake along the Cascadia Subduction zone can have a significant impact on the Hanford Site (Geomatrix 1996), UW monitors and reports on this earthquake source for DOE. Ground motion from any moderate or larger Cascadia Subduction Zone earthquake is detected by seismometers in the HSN.

4.3 Tectonic Activity

The locations for events that occurred in FY 1998 are summarized in Table 4.3 and Figures 4.2 and 4.3. The major geologic and tectronic features of the Hanford Site and vicinity are shown on Figure 4.4 and should be referred to in the following sections.

Table 4.3. Summary of Earthquake Locations

		First Quarter	Second Quarter	Third Quarter	Fourth Quarter	FY 1998
Major Structures along Anticlinal Ridges		0	1	0	0	1
Swarm Areas	Saddle Mountains	0	1	2	0	3
	Coyote Rapids	4	1	0	2	7
	Wooded Island	5	2	0	2	9
	Other	9	0	0	0	9
Random Events		5	8	9	7	29

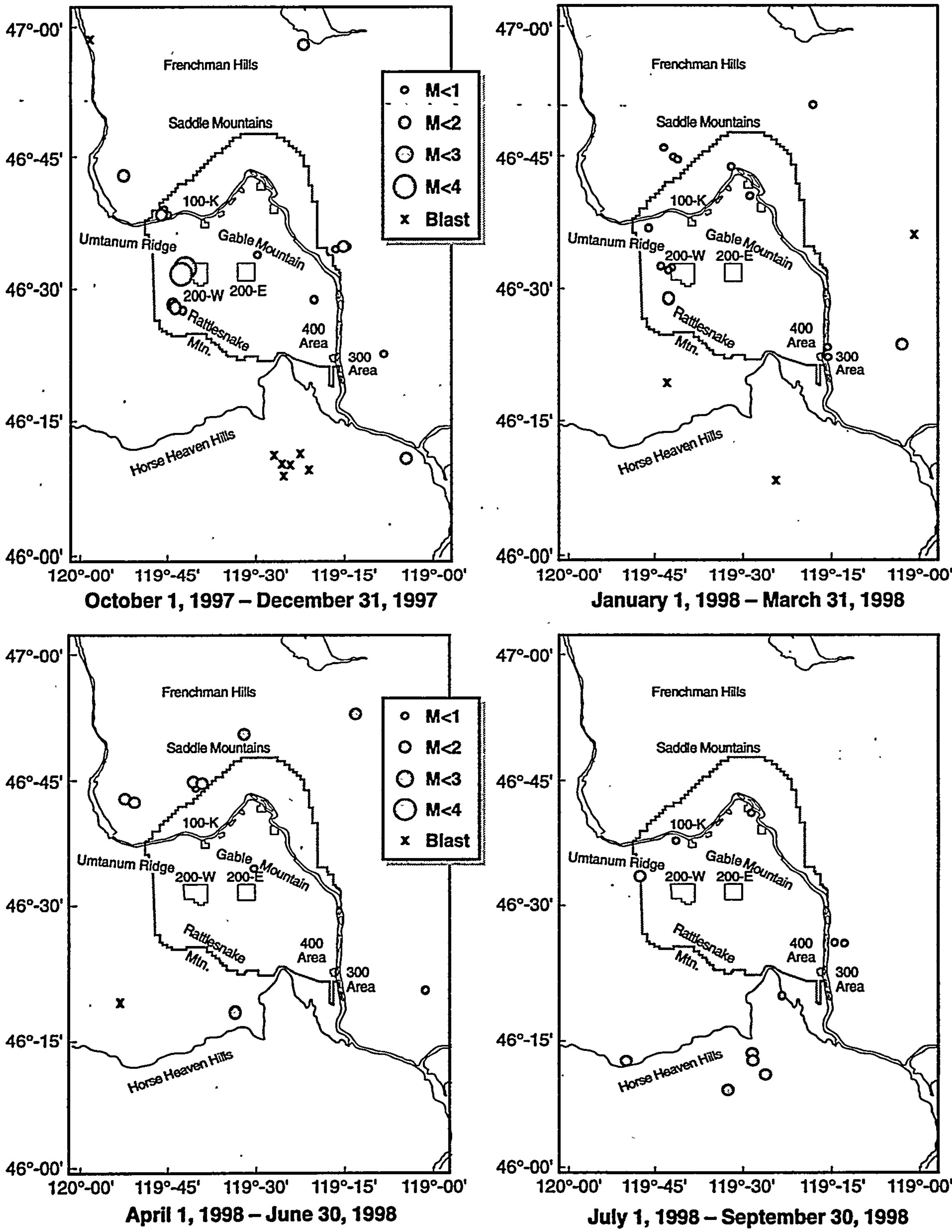

Figure 4.2. All Located Earthquakes Grouped by Quarter for FY 1998. First Quarter - (October 1, 1997 - December 30, 1997; Second Quarter - January 1, 1998 - March 31, 1998; Third Quarter - April 1, 1998 - June 30, 1998; and Fourth Quarter - July 1, 1998 - September 30, 1998. (Coda Length Magnitude (M_c) scale is shown at the side of the map.)

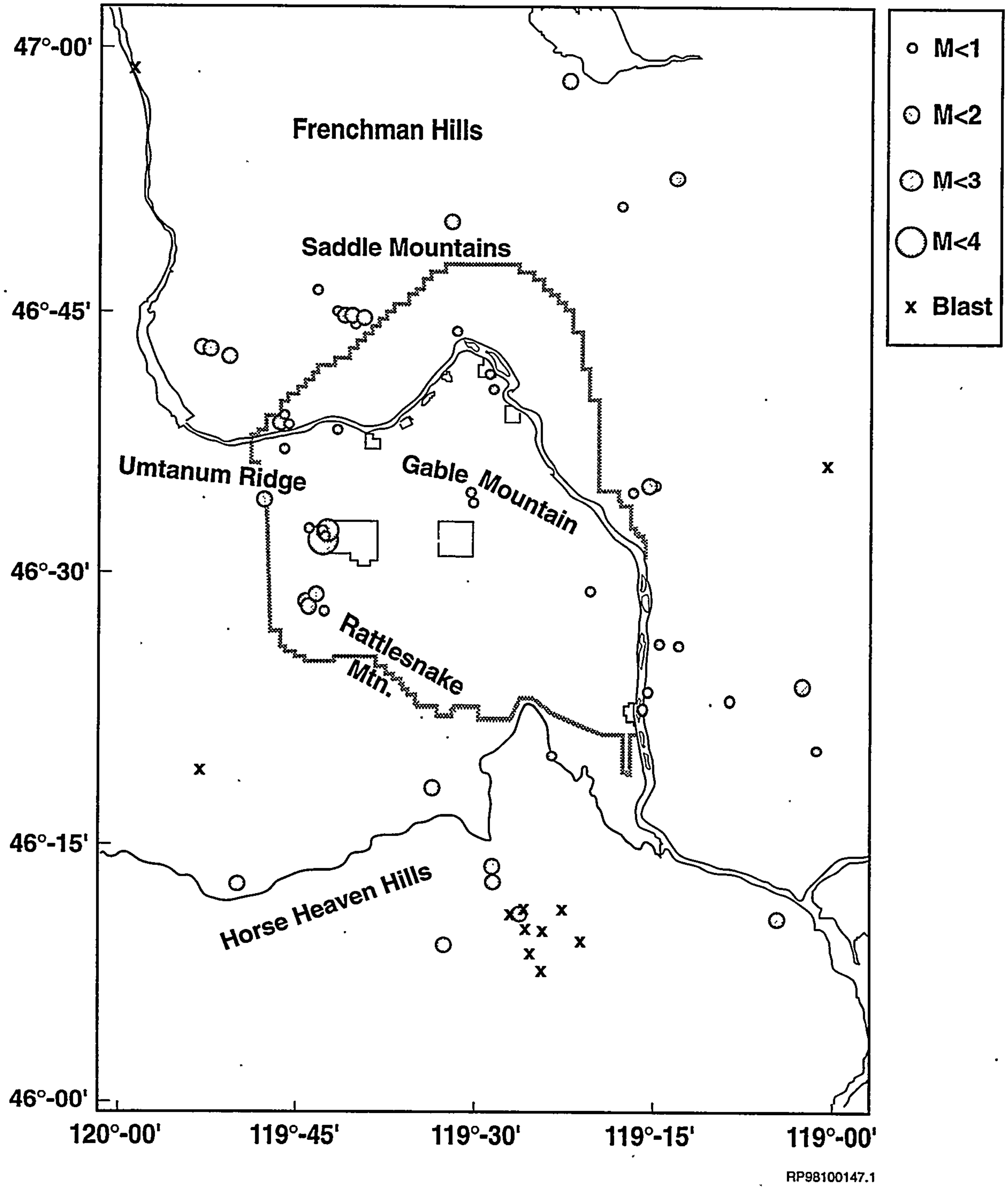

Figure 4.3. Locations of All Events Between October 1, 1997 and September 30, 1998. (Coda-Length Magnitude [M_c] scale is shown at the side of the map.)

4.3.1 First Quarter of FY 1998

Twenty-three events (Figure 4.2 and Table 4.3) occurred during the first quarter of FY 1998 and are described in Hartshorn et al. 1998a. Eighteen events (78%) occurred in earthquake swarm areas: five in the Wooded Island swarm area, four on the west side of the Coyote Rapids earthquake swarm area approximately 11 km west of 100-K Area, and seven in the Cold Creek Depression approximately 4 km SW of the 200 West Area. Two events occurred in Snively Basin, 10 km south of the 200 West Area. Five events were classified as random events because they did not occur near a known swarm or a geologic structure.

4.3.2 Second Quarter of FY 1998

Eleven events (Figure 4.2 and Table 4.3) occurred during the second quarter of FY 1998 and are described in Hartshorn et al. 1998b. One event (7%) appears to have occurred along the Rattlesnake Mountain fault in the Snively basin area. Four events (28%) occurred in earthquake swarm areas: one in the Saddle Mountains swarm about 1.5 km north of the Saddle Mountains thrust fault; two in the Wooded Island swarm area, near Johnson Island and the 300 Area; and one at the north end of the Coyote Rapids earthquake swarm.

Eight events (57%) are classified as random events because they did not occur in a known swarm or on a known geologic structure. Three events occurred west of the 200 West Area; one event occurred 13 km west of 100-K Area; one event occurred southeast of 100-N Area; three events occurred over 12 km northwest of 100-K Area.

An earthquake that was **felt** occurred 25 km east of the Fast Flux Text Facility near Eltopia, Washington. The earthquake was small (1.9 M_c) and shallow (2.2 km). This earthquake does not occur on any known geologic structure so it is classified as a random event.

4.3.3 Third Quarter of FY 1998

Eleven events (Figure 4.2 and Table 4.3) occurred during the third quarter of FY 1998 and are described in Hartshorn et al. 1998c. Two events (18%) occurred in the Saddle Mountains earthquake swarm area. One event occurred along the south flank of the Frenchman Hills north of the Saddle Mountains fault; the second event occurred near Smyrna Bench on the north side of the Saddle Mountains

Nine events (82 %) are classified as random events because they did not occur in a known swarm or on a known geologic structure. Two events occurred in the Wahluke syncline west of 100-K Area. One event occurred 10 km east of the 300 Area. One event occurred in the crystalline basement on the south flank of Rattlesnake Mountain. One event occurred about 3 km north of the 200-East. Four events occurred between 10 km and 12 km northwest of 100-K Area.

4.3.4 Fourth Quarter of FY 1998

Eleven events (Figure 4.2 and Table 4.3) occurred during the fourth quarter of FY 1998. The fourth quarter is reported as part of the annual report so more complete descriptions of these events are included here.

Four events occurred in earthquake swarm areas. Two events occurred in the Coyote Rapids swarm. One small (M_c<1) event occurred on July 19 approximately 6 km west of 100-K Area. A second small event (M_c<1) occurred on August 30 approximately 10 km east of 100-N Area. Two small (M_c<1) events occurred in the Wooded Island earthquake swarm area (Figure 4.2) on August 7 and September 9.

Seven events were classified as random events because of their depth (>4 km) and/or because they cannot be associated with any known geologic structure. Three events occurred near Webber Canyon southeast of Kennewick, Washington on the Horse Heaven Hills. Webber Canyon experienced many explosions during the first part of FY 1998 when the road through the canyon was being widened. The Webber Canyon events occurred on August 22, September 23, and September 29. All but the September 29 event occurred below the basalt and are classified as earthquakes. The September 29 event occurred in the CRBG and may be an explosion but this cannot be confirmed.

Three events occurred in the crystalline basement and are classified as random events. The first event occurred on July 8 and was 11 km west of Prosser, Washington. The second event occurred on August 3 and was along the western boundary of the Hanford Site between Umtanum Ridge and Yakima Ridge. The third event occurred on August 17 and was on the south flank of the Horse Heaven Hills.

One small event occurred in the CRBG along the Yakima River near the Twin Bridges. This event occurred on September 27 and cannot be associated with any known geologic feature.

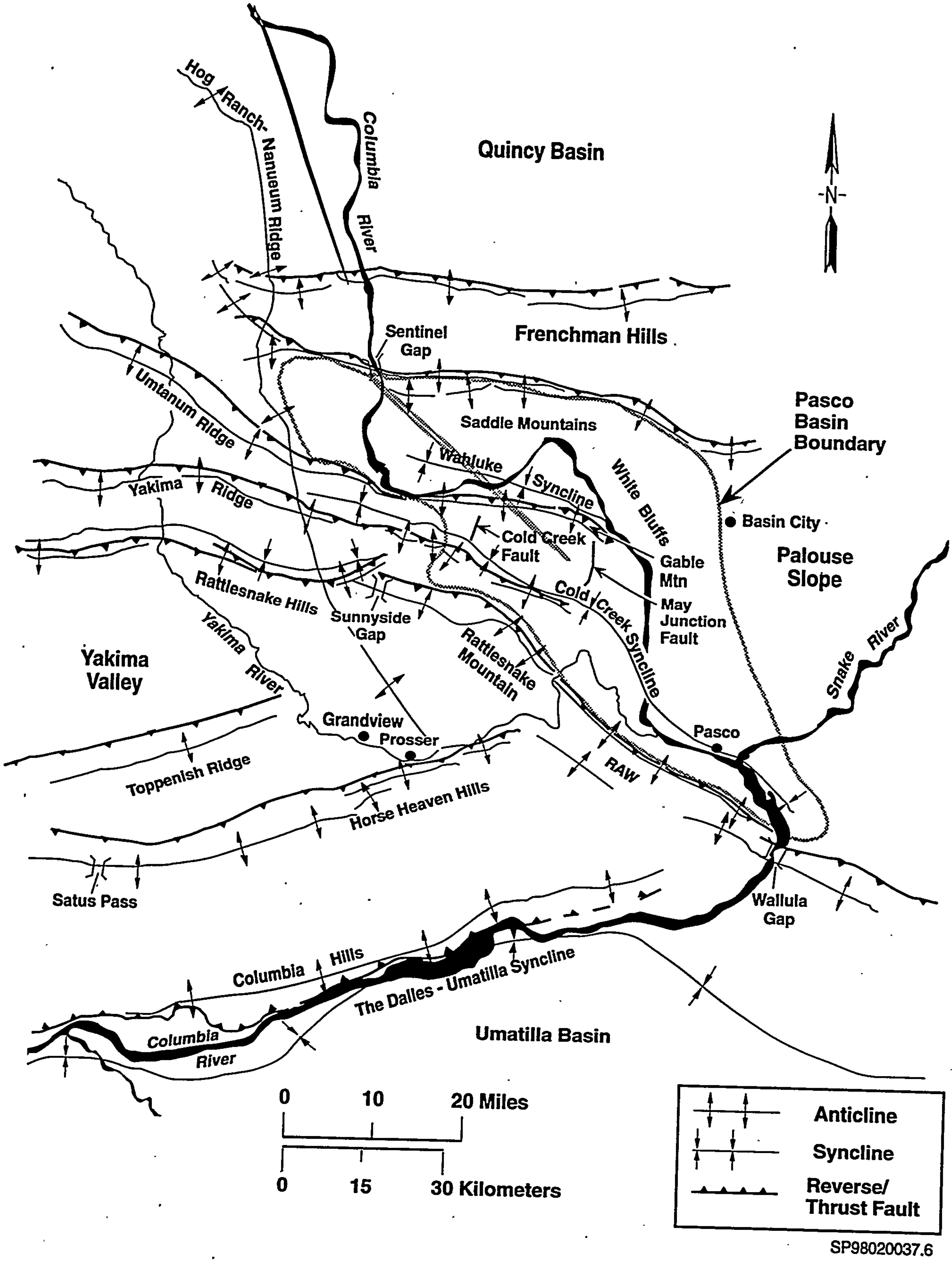

Figure 4.4. Structural and Tectonic Map of Columbia Basin Showing Major Seismic Source Structures

5.0 Strong Motion Accelerometer Operations: May 1997 to September 30, 1997

This chapter summarizes the operation of the SMA network and results obtained between May and October of 1997 during the initial phase of operation prior to being mothballed on September 30, 1997. The Hanford SMA network came back on line November 20, 1999. All future activities and results will be reported as part of the regular quarterly and annual seismic monitoring reports.

5.1 First Months of Operation

A test of the accelerometers was performed from July 16 to July 18, 1997 to check their function and to determine practical trigger threshold levels for continued operation. The objective was to determine the threshold which will result in recording local noise sources approximately once every few months at each system. This provides an additional check of the functioning of the complete system (in addition to routine checks by computer communication channels), and provides an opportunity to record ground motions from smaller earthquakes than could actually be considered to have damage potential to facilities. Such events may be useful in calibrating ground motion relationships from larger events using empirical attenuation relationships.

5.2 Testing and Setting of Trigger Threshold Levels

The results of the test are shown in Table 5.1. All of the trigger thresholds were changed to the lowest possible value, based upon the signal levels observed during several triggers initiated by the computer (these do not relate to any particular level of ground motion). However, it was apparent that the noise environment over a longer time period is highly variable at some sites, due primarily to vehicular activities or loud low-frequency sound waves. For example, at the 200 West Area, the setting at 0.02% g (corresponding approximately to 0.01% full-scale) resulted in triggers approximately every 10 minutes, but at the 100-K Area, there were 3 triggers in 48 hours. Of the 20 triggers observed in 5 days at the 400 Area site, ten occurred between 7:03 and 7:15 a.m. and six occurred between 4:04 and 4:07 p.m. on workdays only. The remaining four triggers occurred between these two workday time periods; no triggers were observed over the weekend.

Since the end of the testing period through September 7, 1997, the trigger thresholds were set as follows:

- The site at the 100-K Area was clearly in the quietest and most remote location and was left at a lower level than any other site. The site at the 200 West Area was very noisy and, thus, was set at a higher level. After about one and one-half months, two of the five sites triggered once. Testing of the SMA system begins again in December, 1998. A four month period of time will be used to reevaluate the SMA settings.

Table 5.1. Trigger Times and Source Types Identified

Site	Trigger Date	Trigger Time	Trigger Threshold (% Full Scale)	Trigger Sources
100-K	7/18/1997	11:06	0.01	Acoustic, < 1 second duration
100-K	7/18/1997	12:23	0.01	Acoustic, < 1 second duration
100-K	7/18/1997	12:42	0.01	Vehicle
100-K	8/29/1997	13:24	0.02	Acoustic, < 1 second duration
200 East	7/17/1997	20:06	0.01	Vehicle
200 West	7/16/1997	20:51	0.01	Vehicle
200 West	7/16/1997	20:51	0.01	Vehicle
200 West	7/16/1997	21:02	0.01	Vehicle
200 West	7/16/1997	21:09	0.01	Vehicle
200 West	7/16/1997	21:17	0.01	Vehicle
200 West	7/16/1997	21:23	0.01	Vehicle
200 West	7/16/1997	21:32	0.01	Vehicle
300	7/16/1997	18:47	0.01	Acoustic, 3-second duration
300	7/16/1997	19:57	0.01	Acoustic, 3-second duration
300	7/16/1997	20:27	0.01	Vehicle
300	7/16/1997	22:04	0.01	Acoustic, 3-second duration
300	7/17/1997	20:09	0.01	Acoustic, 3-second duration
300	7/17/1997	20:29	0.01	Acoustic, 3-second duration
300	7/30/1997	15:14	0.05	Acoustic, 3-second duration
400	7/16/1997	23:04	0.01	Vehicle
400	7/16/1997	23:06	0.01	Vehicle
400	7/17/1997	14:03	0.01	Vehicle
400	7/17/1997	14:05	0.01	Vehicle
400	7/17/1997	14:15	0.01	Vehicle
400	7/17/1997	14:17	0.01	Vehicle
400	7/17/1997	18:29	0.01	Vehicle
400	7/17/1997	18:42	0.01	Vehicle
400	7/17/1997	23:04	0.01	Vehicle
400	7/17/1997	23:06	0.01	Vehicle
400	7/18/1997	14:05	0.01	Vehicle
400	7/18/1997	14:06	0.01	Vehicle
400	7/18/1997	14:15	0.01	Vehicle
400	7/18/1997	23:04	0.01	Vehicle
400	7/18/1997	23:07	0.01	Vehicle
400	7/21/1997	14:03	0.01	Vehicle
400	7/21/1997	14:05	0.01	Vehicle
400	7/21/1997	14:16	0.01	Vehicle
400	7/21/1997	14:45	0.01	Vehicle

5.3 Description of Trigger Sources

Figures 5.1 through 5.5 show examples of the signals recorded during the trigger setting test. Figure 5.1 shows the many triggers recorded mainly at the beginning and end of the workday at the 400 Area. These have the characteristics of vehicles in their envelopes, and their spectra show most of the energy in the frequency range 1-25 Hz. Figure 5.2 shows the triggers at the 300 Area location, where impulsive, 3-second duration signals with power in their spectra from 20-80 Hz are typical of acoustic events. This is considered to be due to the close proximity to a set of shipping containers and the source is probably the slamming doors of containers.

Figures 5.3 and 5.4 show the data from the 200 West and 200 East sites. The signals are again typical of nearby vehicles. Only one trigger was obtained at 200 East before these sites' trigger thresholds were increased, and all three components of motion are shown for this site. The north-horizontal component is shown in all other plots.

Figure 5.5 shows the data from the 100-K site, which has the lowest noise of any of the five locations. At this site, there are a combination of high-frequency, short-duration (<1 second) acoustic events and one vehicle. The last event is the only trigger to occur at this site in six weeks.

Note that in these plots, the apparent maximum signal often exceeds the stated trigger threshold level. The systems actually trigger on a filtered version of the recorded data, so only the signal with power between 0.1 and 12.5 Hz is used to trigger the system. This helps to avoid many of the acoustic noise sources and is expected to enhance the triggering behavior that is expected from actual earthquakes.

5.4 SMA GPS Location Performance

The locations of the five accelerometer sites were measured precisely from 7.5-minute quadrangle maps and compared to the locations determined from the output of the integral GPS element. In practically every case, the GPS measurements are in agreement to better than 100 m. Elevations are expected to have greater errors for the GPS and so the values measured from the maps are used (Table 5.2).

5.5 SMA GPS Clock Performance

The GPS time supplied to the systems was monitored at least weekly throughout the test period and typically was consistent between locking modes (set at about every four hours) to within 1-2 milliseconds. This precision is adequate to maintain the digital time history precision of 5 milliseconds, which is the interval between samples (sampling at 200 samples/second).

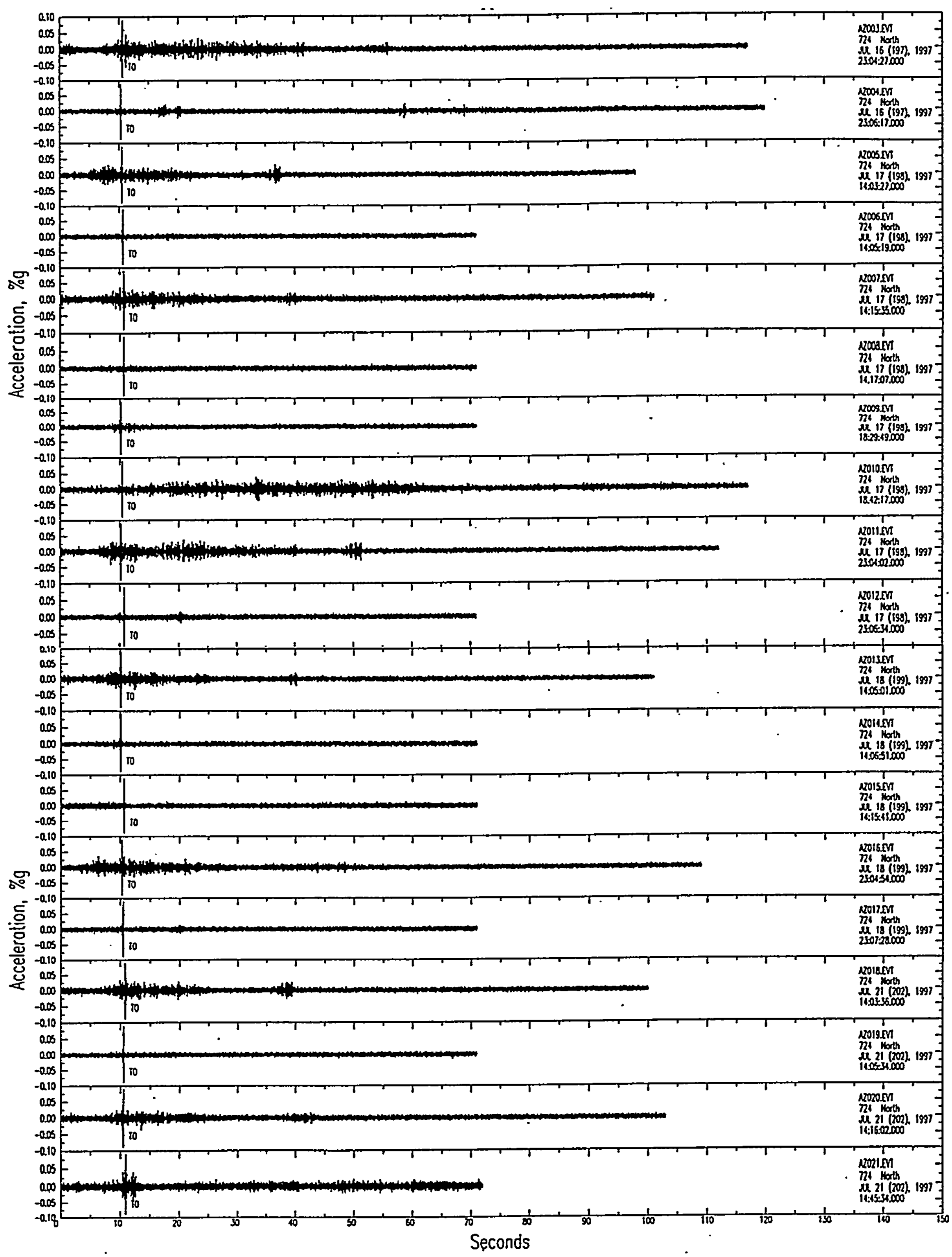

Figure 5.1. Triggers at 400 Area, Threshold–0.02% g (0.01% Full Scale). Trigger time indicated by vertical bar labeled T0.

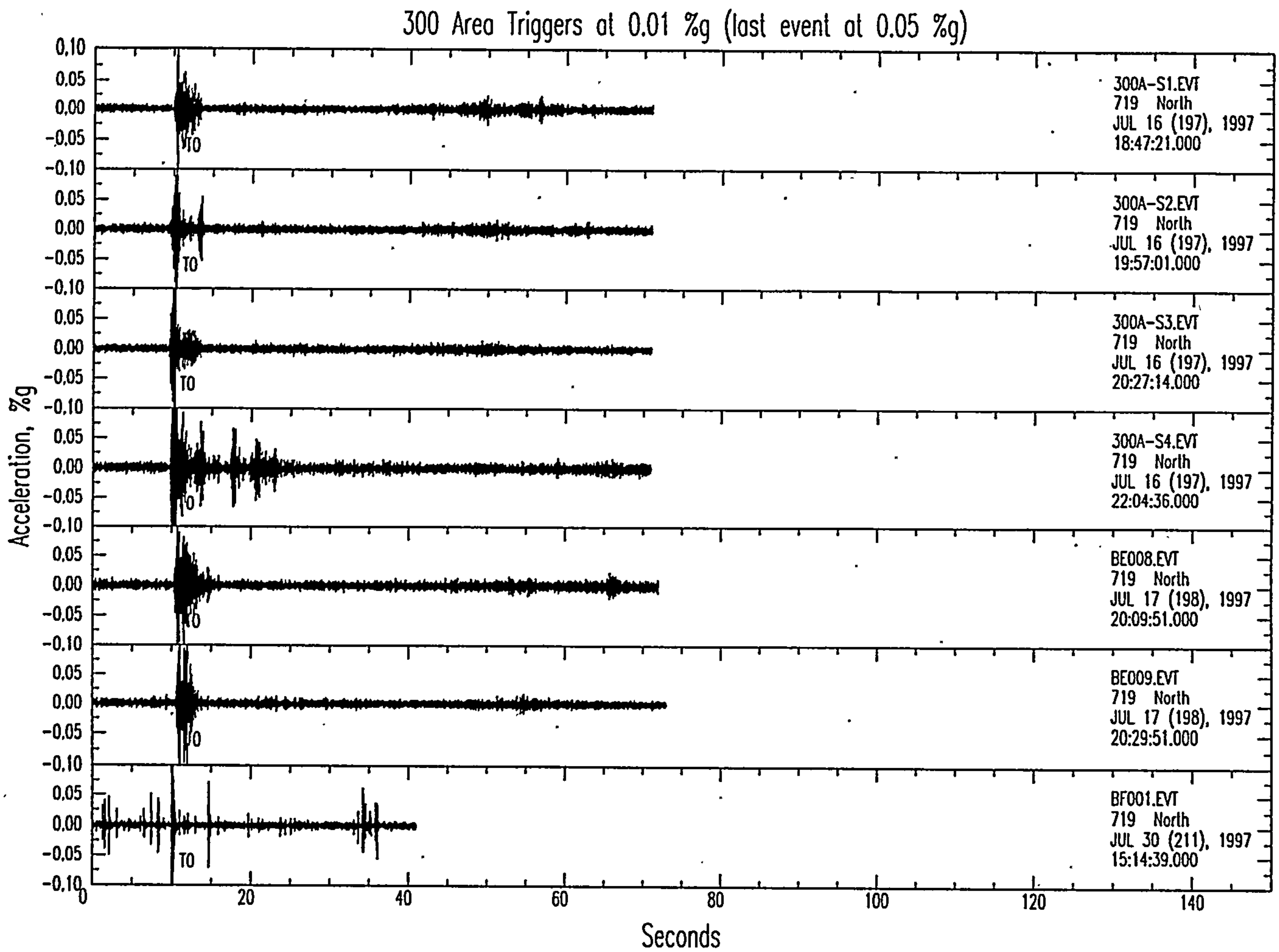

Figure 5.2. Triggers at 300 Area, Threshold–0.02% g (0.01% Full Scale). Trigger time indicated by vertical bar labeled T0.

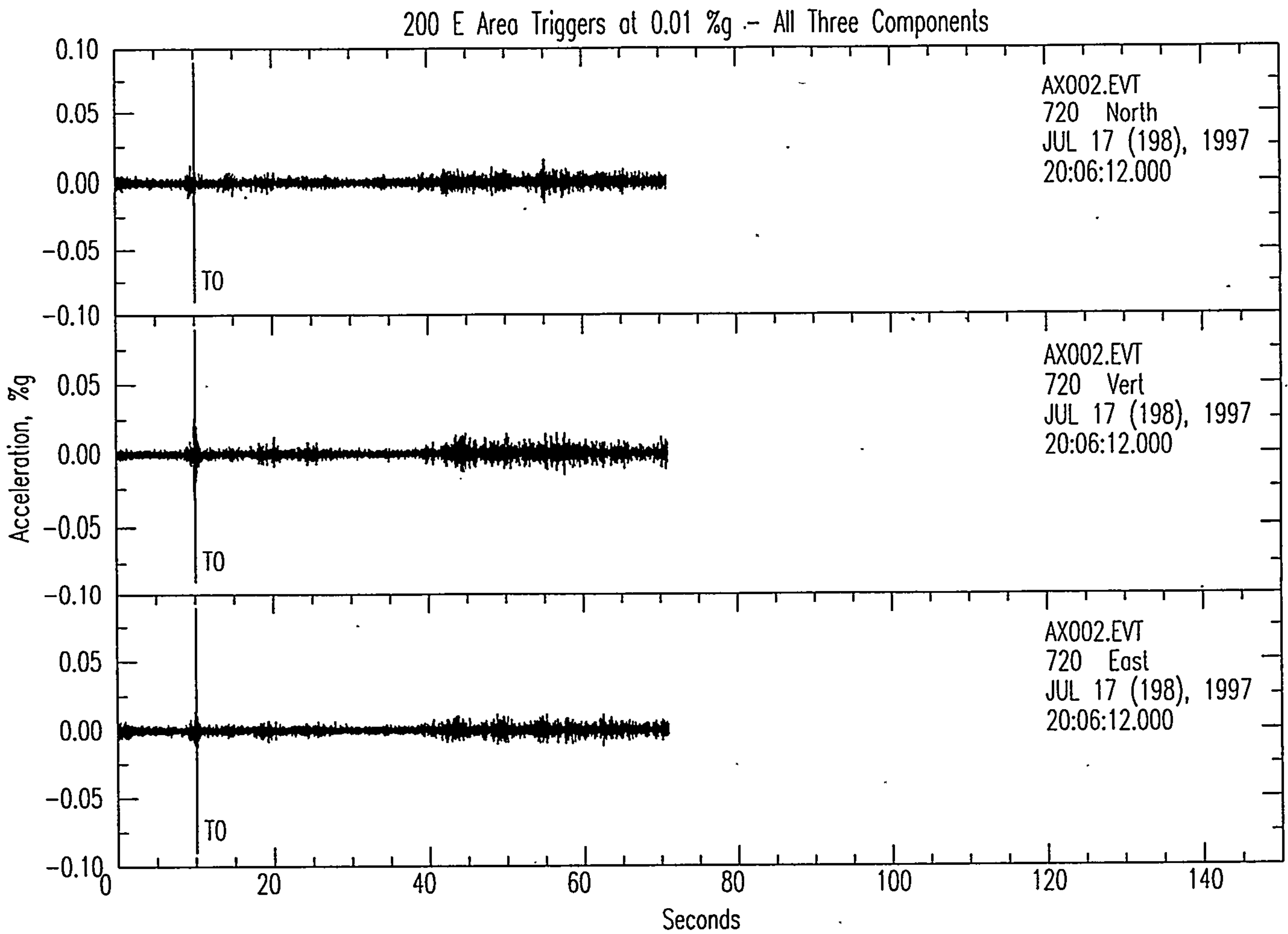

Figure 5.3. Triggers at 200 East, Threshold–0.02% g (0.01% Full Scale). Trigger time indicated by vertical bar labeled T0.

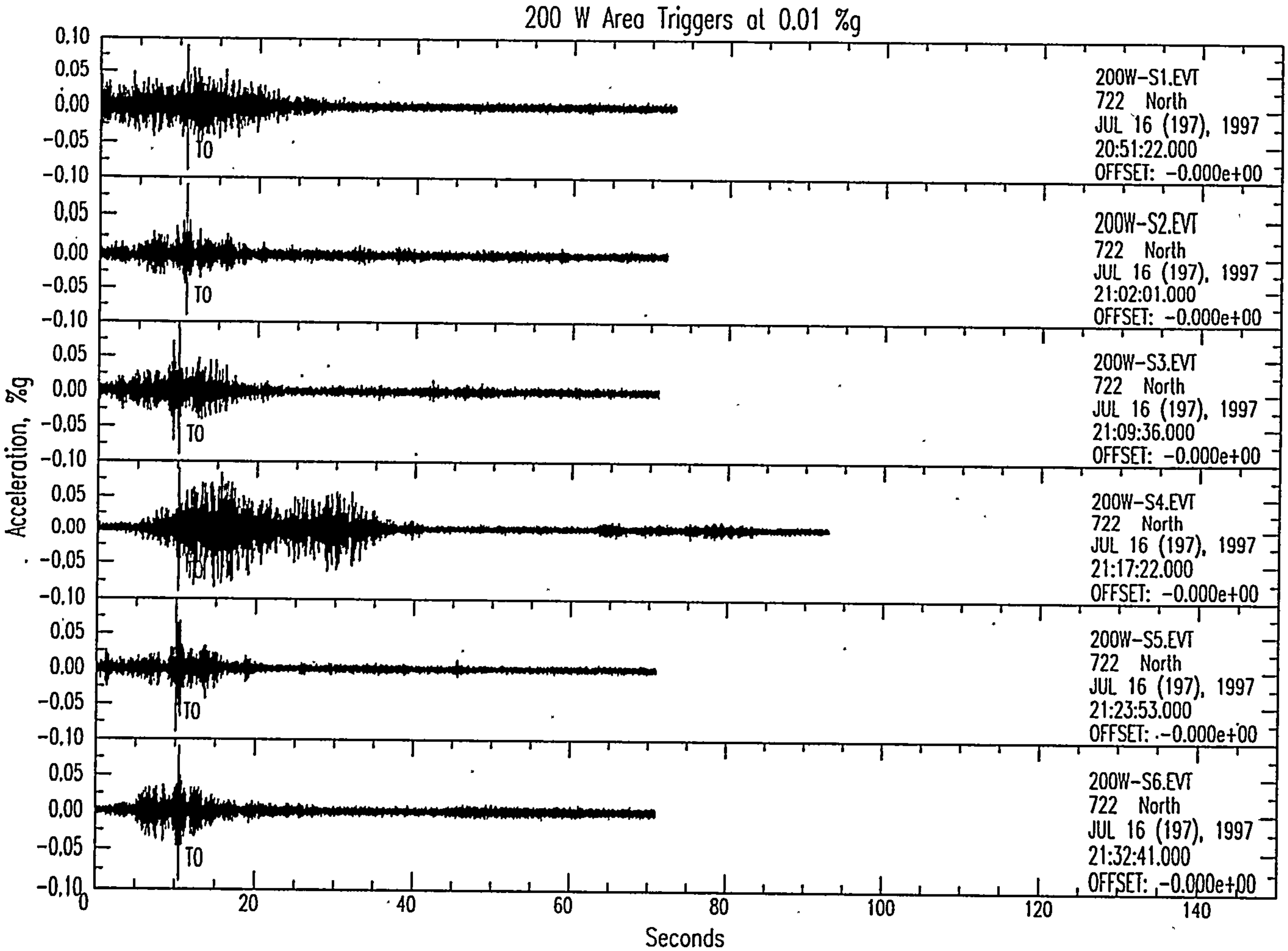

Figure 5.4. Triggers at 200 West, Threshold-0.02% g (0.01% Full Scale). Trigger time indicated by vertical bar labeled T0.

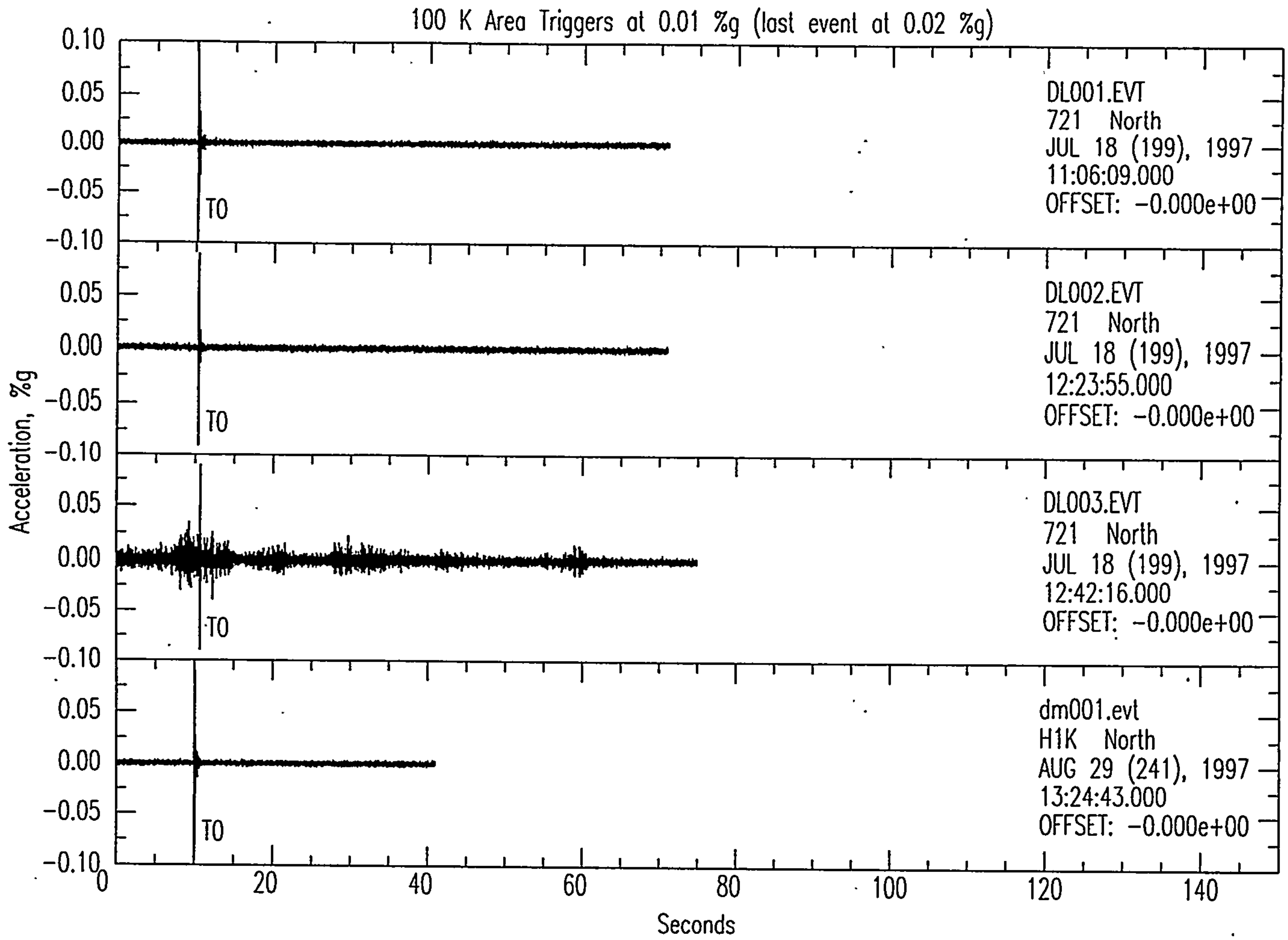

Figure 5.5. Triggers at 100-K, Threshold–0.02% g (0.01% Full Scale). Trigger time indicated by vertical bar labeled T0.

Table 5.2. Comparison of GPS Location and Locations Measured from Maps for Initial Test Period

Station Name	GPS Latitude	Map Latitude	GPS Longitude	Map Longitude	GPS Elevation	Map Elevation
H1K	46.64	46.6418	119.59	119.5922	440 ft	500 ft
H2E	46.55	46.5597	119.53	119.5333	*	690
H2W	46.55	46.5538	119.62	119.6252	260	675
H3A	46.36	46.3638	119.27	119.2758	320	390
H4A	46.43	46.4355	119.35	119.3550	400	560
*Insufficient number of elevations determined for averaging.						

6.0 Capabilities in the Event of a Significant Earthquake

The SMA network was installed to comply with requirements contained in DOE Order 5480.28, *Natural Phenomena Hazards Mitigation*. The SMA network was designed to provide ground motion in areas at Hanford that have high densities of people and/or have hazardous facilities. This section summarizes the capabilities of the Seismic Monitoring Team using the Hanford SMA Network and Seismometer Network in the event of an earthquake at Hanford.

6.1 Use of the SMA Network in the Event of an Earthquake

Historically only a few Hanford sites had instruments that provided data on peak ground accelerations or any type of ground motion at Hanford. The present SMA instruments were located so that if an earthquake occurs, ground motion data will be readily available to assess the damage of the 100-K Area, the 200 East and West Areas, and the 300 and 400 Areas facilities, which have the greatest concentration of people and hazardous materials.

Facilities at Hanford have undergone various degrees of seismic analysis either during design or during re-qualification. Although the seismic design of a building may be known, when an earthquake is "felt" a determination must be made as to the extent of damage before the building can be reoccupied and the systems restarted. A felt earthquake may not cause any damage to a building but without adequate characterization of the ground motion, initial determination of damage may be impossible.

In the event of an earthquake, building managers, emergency directors, and engineers can obtain ground motion data recorded by the SMA network from the Office of Seismic Monitoring. If a SMA is triggered, the Office of Seismic Monitoring will download events that were recorded and determine the peak ground accelerations and the spectral response curves. This information, combined with the location and magnitude obtained from the Seismometer Network, can then be used by the facility engineers to determine if the ground motion exceeded, is equal to, or is less than the building design. This, together with assessments from trained engineers, allows the facility manager to make a rapid and cost-effective determination on whether a building is safe to reoccupy or should be not be used until it has be inspected in more detail. Buildings that have designs exceeding the recorded ground motion could be put back into service very quickly; building that are very close to or less than measured ground motion could be given priority for on site damage inspections.

7.0 References

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