ANNUAL TECHNICAL REPORT: 1996

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CONTENTS

TABLES

FIGURES

APPENDICES

Annual Technical Report for USGS Joint Operating Agreement
1434-95-A-1302
Washington Regional Seismograph Network Operations

SUMMARY

This is the 1996 annual technical report for USGS Joint Operating Agreement 1434-95-A-1302 "*Pacific Northwest Seismograph Network (PNSN) Operations*"). This agreement covers network operations in western Washington and Oregon, routine data processing, and preparation of bulletins and reports. The objective of our work under this operating agreement is to gather data for use in evaluation of seismic and volcanic hazards in Washington and Oregon. This report includes a review of station operations during the contract period, and an update on recent changes in our data acquisition and processing system.

Since 1984, we have issued quarterly bulletins for all of Washington and Oregon. These include catalogs of earthquakes and blasts located in Washington and Oregon, providing up-to-date coverage of seismic and volcanic activity. Appendix 1 contains quarterly bulletins covering this operating agreement period.

INFORMATION -PNSN Response to moderate-sized earthquakes, Emergency Notification and Public Education and Outreach

PNSN Response to moderate-sized earthquakes - Emergency Notification

The magnitude 5.4 Duvall earthquake on May 2, 1996 (local time) was the second magnitude 5+ earthquake within the Puget basin in the past 18 months, and the fourth damaging earthquake in the PNSN operating area during the past 3 years. While the PNSN responds to several dozen felt earthquakes every year, damaging earthquakes occur less frequently but pose special problems from an operational perspective. Recent seismicity (Scotts Mills OR, March 1993; Klamath Falls OR, Sept. 1993; Robinson Point, Jan. 1995; Duvall, May 1996) has tested our procedures, and allowed us to examine what happens at the PNSN during an emergency situation.

A PNSN seismologist is always on duty, and our standard procedure is to respond to pages from our automatic earthquake detection process (for any earthquake within our network of magnitude 2.9 or larger), or from Washington or Oregon emergency management agencies, or the UW police. Our automatic detection process generates PRELIMINARY faxes and electronic mail to emergency managers, operators of adjacent seismograph networks, the National Earthquake Information Center in Colorado, and other high-priority information users for earthquakes that the automatic detection and analysis program judges to be magnitude 2.9 or greater. When the event has been fully processed, the final location and magnitude are communicated via phone calls, faxes, e-mail, and updates to our web-site.

In addition to ordinary phone lines, we now have a radio link to the Washington State Dept. of Emergency Services, and an independent direct phone link to the City of Seattle EOC.

Following the Duvall earthquake, automatically generated e-mail and pager alerts were sent out within 62 seconds (the first preliminary magnitude estimate was 4.3), and the seismologist on duty called the Washington Dept. of Emergency Management (DEM) within 130 seconds. Within 12 minutes, staff (and the press!!) began to arrive at the Lab, and within 16 minutes we were able to provide DEM with a good location estimate and a 5+ estimate of the magnitude. Our audio library was updated 18 minutes after the earthquake and our Web-site was updated with a special section on the Duvall sequence (http://www.geophys.washington.edu/SEIS/EQ_Special/Duvall) within a few hours. Because of the intense interest in our Web information, we now have an automated procedure to initiate a Web-page as soon as a final location is available. Frequent automated updates of information are posted on the Web-page each time the analyst finalizes locations and magnitudes.

Minor operational problems following the Duvall event included congestion in the Lab caused by the press, failure of automatic data-retrieval programs to fetch broad-band data, and a Web server overload caused by intense Web activity. We have taken measures to address these problems.

Following a sizable felt earthquake, we must rapidly provide information to a wide variety of users while continuing data acquisition, analysis, and interpretation. These tasks are tightly interconnected, as we attempt to rapidly calculate and communicate the best estimates of location, depth and magnitude, while simultaneously tracking aftershocks, planning field operations, and interpreting the tectonic significance of the event while staying in close communication with emergency managers.

PNSN Web Site and Public Information

Summary lists for all earthquakes located by the PNSN since 1969 are available via anonymous ftp on **ftp.geophys.washington.edu** in the *pub/seis_net* subdirectory. This information is also available via the PNSN **World-Wide-Web(WWW)** site.

http://www.geophys.washington.edu/SEIS/PNSN/

Our web-server contains text about earthquakes in the Pacific Northwest, maps of stations, catalogs and maps of recent earthquake activity, and maps and text about recent interesting sequences. It also contains links into other sources of earthquake information around the country and world. The most frequently requested information is our "recent earthquakes" list of Pacific Northwest earthquakes magnitude 2.0 or larger. It can be accessed in several ways; Table 1 shows the quarterly usage of our "recent earthquakes" list.

TABLE 1
Quarterly Comparison of Methods of Accessing
PNSN list of most recent earthquakes, M>=2.0

Access Method	94-D	95-A	95-B	95-C	95-D	96-A	96-B	96-C	96-D
Finger Quake	32,000	110,000	93,000	80,000	72,000	83,000	90,300	62,900	63,000
World-Wide-Web	300	2,300	2,500	3,100	4,300	6,300	16,500	10,800	5,400
Remote Login as Quake	3,200	7,600	5,400	3,400	2,900	2,500	1,800	1,100	1,800

The PNSN Web-site is one of several elements of our educational outreach program to better inform the public, policy makers, and emergency managers about seismicity and natural hazards. We provide information sheets, lab tours, workshops, and media interviews, and have an audio library with several tapes, including a frequently updated "recent earthquakes" message. Outreach highlights this reporting period include: 1,500-8,000 calls per quarter to our audio library, and 250,000 public contacts/quarter through our Web-site. This count of Web contacts includes accesses to the CREW Web-site, to the popular Tsunami! site, to the seismosurfing page, and to the Council for the National Seismic Systems (CNSS) Web-site (all hosted on the PNSN web-server) in addition to requests for PNSN information. Tours of the PNSN lab were provided to over 1,000 students, teachers, and parents.

In September of 1996 the PNSN, using funding from FEMA and the USGS, hosted the first annual meeting of the Cascadia Regional Earthquake Workgroup (CREW). CREW provides a forum for an ongoing discussion of the problems that will inevitably occur in a large earthquake, and allows members to improve the coordination of mitigation and preparedness efforts across our entire region. CREW reaches out to a diverse audience; about 200 participants attended the September meeting, representing private corporations, lifeline agencies, social and health services, and engineering firms. Cost-effective measures exist to reduce the economic effects of large earthquakes, and earthquake damages can be substantially reduced by actions taken far in advance of the earthquake itself. In order to function normally businesses and individuals need safe and reliable utilities, transportation, and buildings. Long-term planning is essential if we expect these infrastructure elements to perform adequately. Beyond infrastructure, non-structural mitigation measures and inter-regional mutual aid agreements can lessen damage enormously.

SEISMOMETER LOCATIONS AND NETWORK MAINTENANCE

At the end of 1996, the PNSN was digitally recording 147 channels of seismic data in a triggered mode, and receiving additional data from 11 broad-band stations in the Pacific Northwest. The operation of 85 sites (some with multiple components) are supported under this contract, JOA 1434-95-A-1302. The supported stations cover much of western Washington and Oregon, including the volcanos of the central Cascades. The locations of the stations supported under this contract are given in Tables 2A (short-period) and 2B (broad-band) and shown in Fig. 1. Most of these stations consist of a single, short-period vertical, component which is telemetered continuously in analog form to the UW. The operations of five broad-band stations are also supported, as well as short- and long-period vertical components of WWSSN station LON, and horizontal seismometers with Wood-Anderson-response at station SEA on the campus of the

University of Washington.

Additional stations funded by other contracts are also used in event locations. Quarterly reports contain lists of all stations operated by the PNSN and additional details of station operation. Quarterly reports from January 1, 1996 through December, 1996 are included as Appendix 1.

Aside from station outages, normal maintenance includes a visit to each site at least once every two years to replace batteries and do preventive maintenance. In addition seismometers must be replaced every 4-6 years. More than 30 radio telemetry relay sites are also maintained independently of the seismograph stations.

Table 2A lists short-period stations with continuous telemetry to the PNSN lab which are partially or fully supported under this agreement. Table 2B lists broad-band stations in the Pacific Northwest. The first column in Tables 2A and 2B gives the 3-letter station designator. Column 2 designates the funding agency; operations of stations marked by a % symbol were fully supported by USGS joint operating agreement 1434-95-A-1302. Stations designated # were installed or are maintained by the USGS, but are telemetered to the PNSN lab. Broad-band stations designated ! were installed or are maintained under other support, but data from them are archived at the PNSN. Remaining columns give station north latitude and west longitude (in degrees, minutes and seconds), station elevation in km, and comments indicating landmarks for which stations were named. Additional stations operated by the PNSN under other support are listed in the Quarterly Reports (Appendix 1).

Of the PNSN's broad-band stations LTY, RWW, LON, and GNW record digitally on-site, and data are retrieved via dial-up modem. PNSN broad-band station TTW has continuous real-time digital telemetry to the UW. We also receive continuous near-real time (about a one-minute delay) VSAT telemetry from U.S. National Seismograph Network (USNSN) station NEW in north-eastern Washington. In the fourth quarter of 1995, we began to receive event-triggered data from USNSN station WVOR, in south-eastern Oregon. Data for specific events are provided to the PNSN from broad-band stations PIN, DBO, COR, and RAI (operated by Oregon State University and the University of Oregon).

TABLE 2A

Short-period stations operating under this agreement at the end of the fourth quarter, 1996

STA	F	LAT	LONG	EL	NAME
ASR	%	46 09 09.9	121 36 01.6	1.357	Mt. Adams - Stagman Ridge
AUG	%	45 44 10.0	121 40 50.0	0.865	Augspurger Mtn
BBO	%	42 53 12.6	122 40 46.6	1.671	Butler Butte, Oregon
BHW	%	47 50 12.6	122 01 55.8	0.198	Bald Hill
BLN	%	48 00 26.5	122 58 18.6	0.585	Blyn Mt.
BOW	%	46 28 30.0	123 13 41.0	0.870	Boistfort Mt.
BPO	%	44 39 06.9	121 41 19.2	1.957	Bald Peter, Oregon
BRV	+	46 29 07.2	119 59 28.2	0.920	Black Rock Valley
BVW	+	46 48 39.6	119 52 59.4	0.670	Beverly
CBS	+	47 48 17.4	120 02 30.0	1.067	Chelan Butte, South
CDF	%	46 06 58.2	122 02 51.0	0.780	Cedar Flats
CMM	%	46 26 07.0	122 30 21.0	0.620	Crazy Man Mt.
CMW	%	48 25 25.3	122 07 08.4	1.190	Cultus Mtns.
CPW	%	46 58 25.8	123 08 10.8	0.792	Capitol Peak
CRF	+	46 49 30.0	119 23 13.2	0.189	Corfu
DBO		43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon
DPW	+	47 52 14.3	118 12 10.2	0.892	Davenport
DY2	+	47 59 06.6	119 46 16.8	0.890	Dyer Hill 2
EDM	#	46 11 50.4	122 09 00.0	1.609	East Dome, Mt. St. Helens
ELK	%	46 18 20.0	122 20 27.0	1.270	Elk Rock
ELL	+	46 54 34.8	120 33 58.8	0.789	Ellensburg
EPH	+	47 21 22.8	119 35 45.6	0.661	Ephrata
ET3	+	46 34 38.4	118 56 15.0	0.286	Eltopia (replaces ET2)
ETW	+	47 36 15.6	120 19 56.4	1.477	Entiat
FBO	%	44 18 35.6	122 34 40.2	1.080	Farmers Butte, Oregon
FL2	%	46 11 47.0	122 21 01.0	1.378	Flat Top 2
FMW	%	46 56 29.6	121 40 11.3	1.859	Mt. Fremont
GBL	+	46 35 54.0	119 27 35.4	0.330	Gable Mountain
GHW	%	47 02 30.0	122 16 21.0	0.268	Garrison Hill
GL2	+	45 57 35.0	120 49 22.5	1.000	New Goldendale
GLK	%	46 33 50.2	121 36 30.7	1.320	Glacier Lake
GMO	%	44 26 20.8	120 57 22.3	1.689	Grizzly Mountain, Oregon
GMW	%	47 32 52.5	122 47 10.8	0.506	Gold Mt.
GSM	%	47 12 11.4	121 47 40.2	1.305	Grass Mt.
GUL	%	45 55 27.0	121 35 44.0	1.189	Guler Mt.
HAM	#	42 04 08.3	121 58 16.0	1.999	Hamaker Mt., Oregon
HBO	%	43 50 39.5	122 19 11.9	1.615	Huckleberry Mt., Oregon
HDW	%	47 38 54.6	123 03 15.2	1.006	Hoodsport
HOG	#	42 14 32.7	121 42 20.5	1.887	Hogback Mtn., Oregon
HSO	%	43 31 33.0	123 05 24.0	1.020	Harness Mountain, Oregon
HSR	%	46 10 28.0	122 10 46.0	1.720	South Ridge, Mt. St. Helens
HTW	%	47 48 14.2	121 46 03.5	0.833	Haystack Lookout

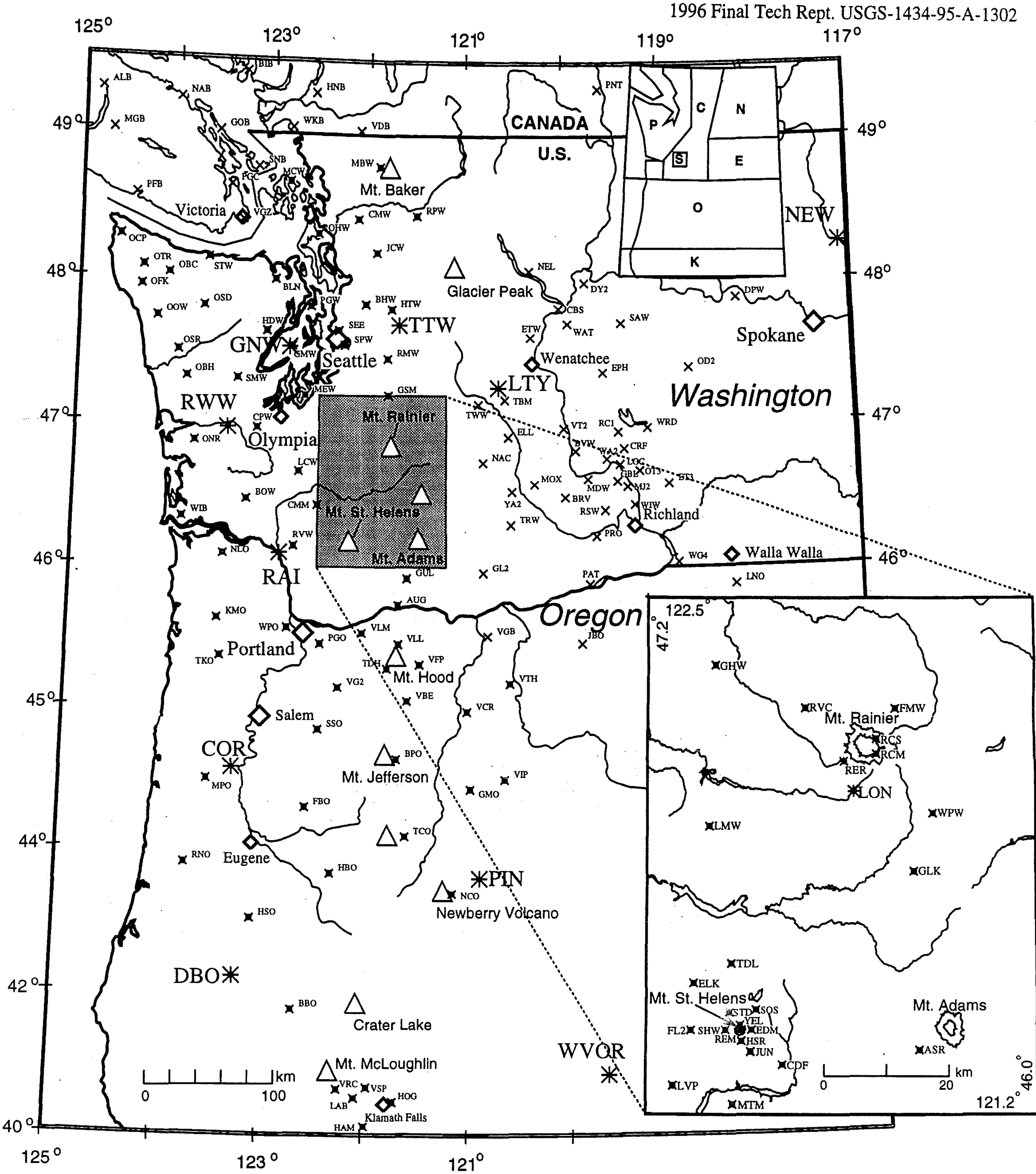

Figure 1. Map view of permanent seismograph stations operated by the Pacific Northwest Seismograph Network during 1996. White triangles show the position of volcanic centers, and white diamonds indicate the locations of a few cities. Stations are shown by "x" symbols. Those supported under USGS 1434-95-A-1302 are emphasised by black squares over the "x"s. Broad-band stations, also supported under USGS 1434-95-A-1302, are indicated by asterisks and larger labels. The upper inset shows seven regions in which different crustal velocity models are used to locate hypocenters (P, Puget Sound; C, Cascades; S, Mount St. Helens; N, northeast Washington; E, eastern Washington; O, Northern Oregon; and K, Southern Oregon). The lower inset is an enlargement of the shaded region on the main map, and shows seismograph stations in the vicinity of Mounts Rainier, St. Helens and Adams.

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
JBO	+	45 27 41.7	119 50 13.3	0.645	Jordan Butte, Oregon
JCW	%	48 11 42.7	121 55 31.1	0.792	Jim Creek
JUN	%	46 08 48.0	122 09 10.8	1.049	June Lake
KMO	%	45 38 07.8	123 29 22.2	0.975	Kings Mt., Oregon
KOS	%	46 27 40.8	122 11 25.8	0.828	Kosmos
LAB	#	42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon (4-comp)
LCW	%	46 40 14.4	122 42 02.8	0.396	Lucas Creek
LMW	%	46 40 04.8	122 17 28.8	1.195	Ladd Mt.
LNO	+	45 52 18.6	118 17 06.6	0.771	Lincton Mt., Oregon
LO2	%	46 45 00.0	121 48 36.0	0.853	Longmire
LOC	+	46 43 01.2	119 25 51.0	0.210	Locke Island
LVP	%	46 04 06.0	122 24 30.0	1.170	Lakeview Peak
MBW	%	48 47 02.4	121 53 58.8	1.676	Mt. Baker
MCW	%	48 40 46.8	122 49 56.4	0.693	Mt. Constitution
MDW	+	46 36 47.4	119 45 39.6	0.330	Midway
MEW	%	47 12 07.0	122 38 45.0	0.097	McNeil Island
MJ2	+	46 33 27.0	119 21 32.4	0.146	May Junction 2
MOX	+	46 34 38.4	120 17 53.4	0.501	Moxie City
MPO	%	44 30 17.4	123 33 00.6	1.249	Mary's Peak, Oregon
MTM	%	46 01 31.8	122 12 42.0	1.121	Mt. Mitchell
NAC	+	46 43 59.4	120 49 25.2	0.728	Naches
NCO	%	43 42 14.4	121 08 18.0	1.908	Newberry Crater, Oregon
NEL	+	48 04 12.6	120 20 24.6	1.500	Nelson Butte
NLO	%	46 05 21.9	123 27 01.8	0.826	Nicolai Mt., Oregon
OBC	%	48 02 07.1	124 04 39.0	0.938	Olympics - Bonidu Creek
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OCP	%	48 17 53.5	124 37 30.0	0.487	Olympics - Cheeka Peak
OD2	+	47 23 15.6	118 42 34.8	0.553	Odessa site 2
OFK	%	47 57 00.0	124 21 28.1	0.134	Olympics - Forks
OHW	%	48 19 24.0	122 31 54.6	0.054	Oak Harbor
ONR	%	46 52 37.5	123 46 16.5	0.257	Olympics - North River
OOW	%	47 44 03.6	124 11 10.2	0.561	Octopus West
OSD	%	47 48 59.2	123 42 13.7	2.008	Olympics - Snow Dome
OSR	%	47 30 20.3	123 57 42.0	0.815	Olympics Salmon Ridge
OT3	+	46 40 08.4	119 13 58.8	0.322	New Othello
OTR	%	48 05 00.0	124 20 39.0	0.712	Olympics - Tyee Ridge
PAT	+	45 52 55.2	119 45 08.4	0.262	Paterson
PGO	%	45 27 42.6	122 27 11.5	0.253	Gresham, Oregon
PGW	%	47 49 18.8	122 35 57.7	0.122	Port Gamble
PRO	+	46 12 45.6	119 41 08.4	0.553	Prosser
RC1	+	46 56 42.6	119 26 39.6	0.485	Royal City (3 comp.)
RCM	%	46 50 08.9	121 43 54.4	3.085	Mt. Rainier, Camp Muir
RCS	%	46 52 15.6	121 43 52.0	2.877	Mt. Rainier, Camp Schurman
REM	#	46 11 57.0	122 11 03.0	2.102	Rembrandt (Dome station)
RER	%	46 49 09.2	121 50 27.3	1.756	Mt. Rainier, Emerald Ridge
RMW	%	47 27 35.0	121 48 19.2	1.024	Rattlesnake Mt. (West)
RNO	%	43 54 58.9	123 43 25.5	0.850	Roman Nose, Oregon
RPW	%	48 26 54.0	121 30 49.0	0.850	Rockport
RSW	+	46 23 40.2	119 35 28.8	1.045	Rattlesnake Mt. (East)
RVC	%	46 56 34.5	121 58 17.3	1.000	Mt. Rainier - Voight Creek
RVN		47 01 38.6	121 20 11.9	1.885	Raven Roost
RVW	%	46 08 53.2	122 44 32.1	0.460	Rose Valley
SAW	+	47 42 06.0	119 24 01.8	0.701	St. Andrews
SEA		47 39 18.0	122 18 30.0	0.030	Seattle (Wood Anderson)
SHW	%	46 11 37.1	122 14 06.5	1.425	Mt. St. Helens
SMW	%	47 19 10.7	123 20 35.4	0.877	South Mtn.
SOS	%	46 14 38.5	122 08 12.0	1.270	Source of Smith Creek
SPW	%	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle
SSO	%	44 51 21.6	122 27 37.8	1.242	Sweet Springs, Oregon
STD	%	46 14 16.0	122 13 21.9	1.268	Studebaker Ridge
STW	%	48 09 02.9	123 40 13.1	0.308	Striped Peak
TBM	+	47 10 12.0	120 35 52.8	1.006	Table Mt.
TCO	%	44 06 21.0	121 36 01.0	1.975	Three Creek Meadows, Oregon.
TDH	%	45 17 23.4	121 47 25.2	1.541	Tom,Dick,Harry Mt., Oregon
TDL	%	46 21 03.0	122 12 57.0	1.400	Tradedollar Lake
TKO	%	45 22 16.7	123 27 14.0	1.024	Trask Mtn, Oregon
TRW	+	46 17 32.0	120 32 31.0	0.723	Toppenish Ridge
LNO	+	45 52 18.6	118 17 06.6	0.771	Lincton Mt., Oregon
TWW	+	47 08 17.4	120 52 06.0	1.027	Teanaway
VBE	%	45 03 37.2	121 35 12.6	1.544	Beaver Butte, Oregon
VCR	%	44 58 58.2	120 59 17.4	1.015	Criterion Ridge, Oregon
VFP	%	45 19 05.0	121 27 54.3	1.716	Flag Point, Oregon
VG2	%	45 09 20.0	122 16 15.0	0.823	Goat Mt., Oregon
VGB	+	45 30 56.4	120 46 39.0	0.729	Gordon Butte, Oregon
VIP	%	44 30 29.4	120 37 07.8	1.731	Ingram Pt., Oregon
VLL	%	45 27 48.0	121 40 45.0	1.195	Laurance Lk., Oregon
VLM	%	45 32 18.6	122 02 21.0	1.150	Little Larch, Oregon
VRC	#	42 19 47.2	122 13 34.9	1.682	Rainbow Creek, Oregon
VSP	#	42 20 30.0	121 57 00.0	1.539	Spence Mtn, Oregon
VT2	+	46 58 02.4	119 59 57.0	1.270	Vantage2
VTH	%	45 10 52.2	120 33 40.8	0.773	The Trough, Oregon
WA2	+	46 45 19.2	119 33 56.4	0.244	Wahluke Slope
WAT	+	47 41 55.2	119 57 14.4	0.821	Waterville
WG4	+	46 01 49.2	118 51 21.0	0.511	Wallula Gap
WIB	#	46 20 34.8	123 52 30.6	0.503	Willapa Bay (3 comp.)
WIW	+	46 25 45.6	119 17 15.6	0.128	Wooded Island
WPO	%	45 34 24.0	122 47 22.4	0.334	West Portland, Oregon
WPW	%	46 41 53.4	121 32 48.0	1.250	White Pass

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
WRD	+	46 58 12.0	119 08 41.4	0.375	Warden
XTL		46 55 47.8	121 29 35.8	1.665	Crystal Mtn.
YA2	+	46 31 36.0	120 31 48.0	0.652	Yakima
YEL	#	46 12 35.0	122 11 16.0	1.750	Yellow Rock, Mt. St. Helens

TABLE 2B

Broad-band three-component stations operating between 10/1/94 and 12/31/95

STA	F	LAT	LONG	EL	NAME
COR	!	44 35 08.5	123 18 11.5	0.121	Corvallis, Oregon (IRIS station, Operated by OSU)
DBO	!	43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon (Operated by UO)
GNW	%	47 33 51.8	122 49 31.0	0.165	Green Mountain, WA (operated by UW)
LON	%	46 45 00.0	121 48 36.0	0.853	Longmire, WA (operated by UW)
LTY	%	47 15 21.2	120 39 53.3	0.970	Liberty, WA (operated by UW)
NEW	!	48 15 50.0	117 07 13.0	0.760	Newport Observatory (USGS-USNSN)
RAI	!	46 02 25.1	122 53 06.4	1.520	Trojan Plant, Oregon (OSU)
RWW	%	46 57 50.1	123 32 35.9	0.015	Ranney Well(operated by UW)
TTW	%	47 41 40.7	121 41 20.0	0.542	Tolt Res, WA (operated by UW)
PIN	!	43 48 40.0	120 52 19.0	1.865	Pine Mt. Oregon (operated by UO)
WVOR	!	42 26 02.0	118 38 13.0	1.344	Wildhorse Valley, Oregon (USGS-USNSN)

PNSN STRONG MOTION PROGRAM

The PNSN received funding from the USGS to acquire, install, and operate six very high-dynamic-range strong-motion instruments (consisting of 3-component accelerometers plus digital data-recorders). Three instruments were funded under a special contract 1434-HQ-96-GR-02714, and three through a supplement to this PNSN-USGS joint operating agreement: 1434-95-A-1302. Terra Technology ISD-24 instruments were chosen. Installation sites being explored include the UW (co-sited with the SEA Wood-Anderson instruments which have operated since 1966), Seward Park in Seattle (site of currently operating station SPW), a Bonneville Power Authority (BPA) substation near Maple Valley, and a seismic pier at the University of Puget Sound in Tacoma. Data from some instruments will be available by real-time telemetry as part of the PNSN data stream. Data from other instruments will be recovered via dial-up, with site visits used as a back-up in case of telemetry failure.

The PNSN strong-motion instrument program is soliciting cooperation from regional utilities and industries for assistance in siting, telemetry, instrumentation and cooperative operations of strong-motion instrumentation within our network area. We are developing procedures for rapid communication of strong-motion parameters of engineering interest to strong-motion program participants and to other interested parties.

DATA PROCESSING

The seismograph network operated by the University of Washington consists of over one hundred and forty short-period, vertical component, telemetered seismographic stations. The seismic recording system operates in an 'event triggered' mode, recording data at 100 samples per sec. per channel. Arrival times, first motion polarities, signal durations, signal amplitudes, locations and focal mechanisms (when possible) are determined in postprocessing. Digital data are processed for all teleseisms, regional events, and all locatable local events. Each trace data file has an associated 'pickfile' which includes arrival times, polarities, coda lengths, and other data.

File formats and software were upgraded in October of 1994 to allow merging of broad-band and short-period data. Our current trace data format (UW-2) accommodates data of varying durations, sample rates, and start times; is extensible without affecting existing processing programs; and is backward-compatible with our original (UW-1) format. In addition to software modifications, we updated our data acquisition hardware and software. The current data acquisition software is called *SUNWORM*, and was developed in cooperation with the *EARTHWORM* project at the USGS in Menlo Park. It runs on a SUN-SparcStation-5 workstation, and replaced our previous *HAWK* software system (which ran on a Concurrent 5600 computer from 1988-1994) at the end of 1994.

Broad-band stations TTW and NEW record continuously, and individual events are extracted from the data. Stations WVOR, LON, GNW, RWW, and LTY have selected time windows of data automatically retrieved. Data from stations COR, DBO, PIN, and RAI are provided to us, and merged with PNSN short-period data by our data analyst as part of the routine processing.

Broad-band data in "raw" formats are stored on ongoing "network-archive" backups along with all unedited network-trigger trace data. Broadband data are also archived in merged and edited format on our "Master Event" tapes along with data from the PNSN short-period network, Our "Master Event" files are also translated to IRIS-SEED format and submitted to the IRIS Data Management Center for archive and distribution. All of our "Master Event" tapes of seismic trace data from 1980-1994 have now been reformatted to the IRIS-SEED format and submitted to the IRIS Data Management Center, where they will be made available through the standard request mechanisms of the IRIS data-base system.

PNSN Quarterly Reports since 1994 have included moment-tensor focal mechanisms for earthquakes larger than magnitude 3.5. These have been provided to us by Dr. John Nabelek of Oregon State University (OSU) under support from USGS NEHRP Grant 1434-93-G-2326. OSU also provides broad-band data for some events from stations COR and RAI. The University of Oregon (UO) provides broad-band data for some events (from stations PIN and DBO. Phase data for earthquakes in northern Washington and southern British Columbia are exchanged with the Canadian Pacific Geoscience Centre promptly for significant events. We also exchange data occasionally with the Montana Bureau of Mines, Boise State University, and CALNET. The entire PNSN catalog has been contributed to the CNSS composite catalog located at the Northern California Earthquake Data Center. The PNSN section of the CNSS catalog is frequently updated.

Publications wholly or partly supported under this operating agreement are listed in Appendix 2.

SEISMICITY

Figure 2 shows earthquakes of magnitude 2.0 or larger located in Washington and Oregon during this reporting period. For comparison purposes, Table 3 gives information on seismic activity recorded at the PNSN annually since 1980. Table 3 included the total number of events processed, including both locatable and unlocatable earthquakes and explosions (blasts), both within and outside the Pacific Northwest Seismograph Network area. The total number of events is approximately equal to the sum of the number of events outside the network, inside the network, and unlocated. It is not exact because a few earthquakes or blasts fall just outside the region that we defined as "Inside the Net" (117-125W, 42-49.5N) but were processed and flagged as if they were local events within the network. The total number of "Located" events within the PNSN Network is the sum of located earthquakes and located blasts.

During this reporting period there were 38 earthquakes reported felt west of the Cascades in Washington, ranging in magnitude from 2.2 to 5.4. One earthquake was felt east of the Cascades. In Oregon, a total of 4 earthquakes were reported felt.

The largest earthquake during this reporting period was the magnitude 5.4 Duvall earthquake of 3 May 1997 at 04:04:23 UTC (2 May 1997 at 9:04:23 PM PDT). The epicenter is located in the Cascade foothills, about 35 km east-northeast of Seattle and 9 km east-northeast of Duvall. In addition to the mainshock, 25 aftershocks were reported felt.

A supplement to this operating agreement provided funding for a followup detailed study of the Duvall sequence (and also for the strong motion instruments mentioned earlier). The supplement began in August of 1996, and runs through November of 1997. George Thomas, a recent graduate, was hired to compile and analyze information on Duvall Sequence. He, and others, are preparing an article entitled "The May 3 1996 M5.4 Duvall, Washington Earthquake: Structure and Tectonic Implications" for submission to BSSA.

Although a mainshock focal depth of about 4 km was determined using a standard PNSN velocity model, a relocation of the mainshock and aftershocks determined that the seismicity was located at depths between of 7 and 11 km. Such depths are consistent with other seismicity in the area; there is an eastward shallowing of seismicity from Puget Sound to the Cascades. The PNSN catalog contains 390 earthquakes for the first 100 days of the Duvall sequence, with 96 aftershocks of magnitude 2.0 or greater, and 9 between magnitude 3.0 and 3.4. An apparently similar earthquake occurred in approximately the same location in 1932 (Bradford, D.B and A.C. Waters, The Tolt River Earthquake and its Bearing on the Structure

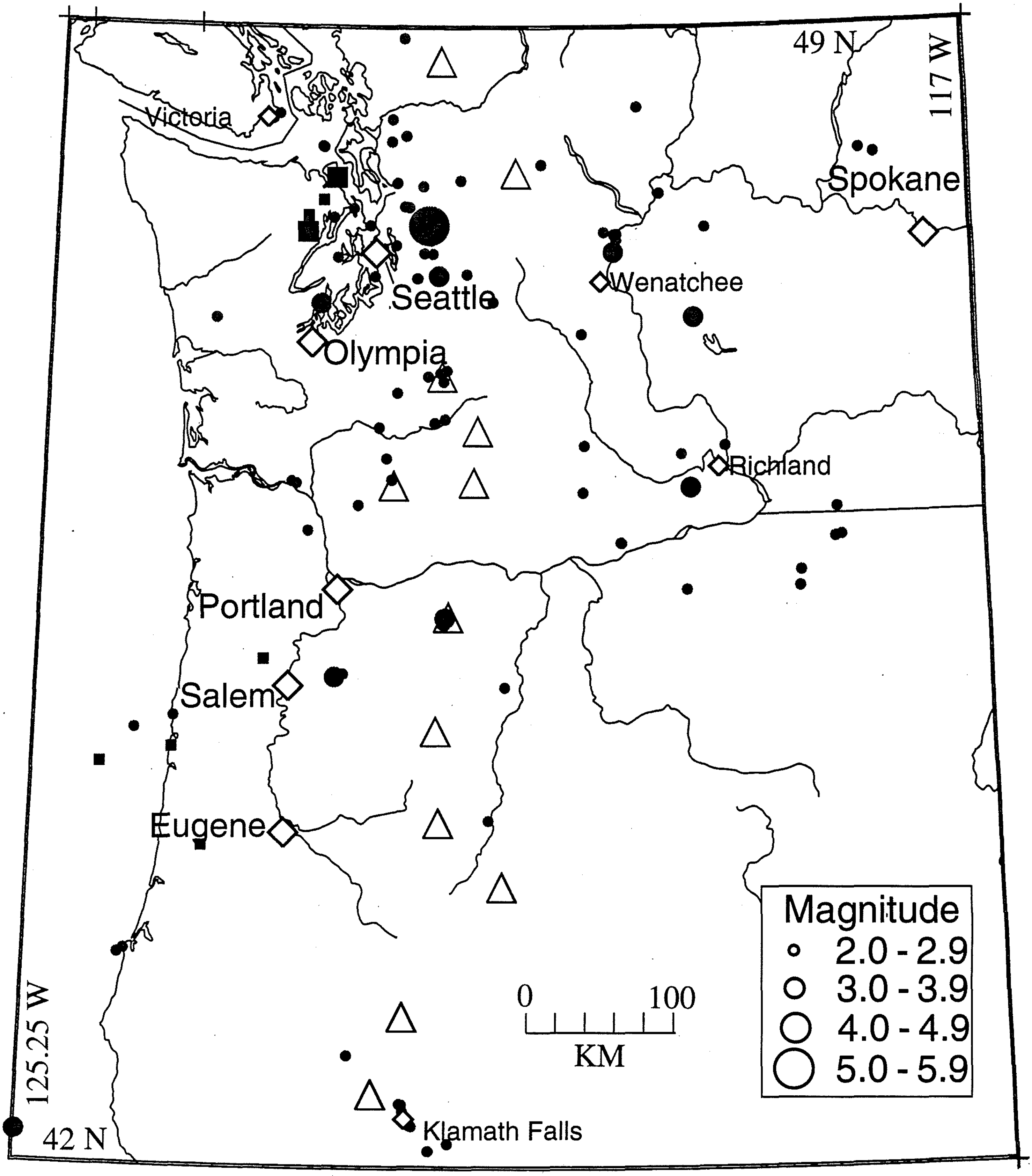

Figure 2. Earthquakes larger than magnitude 2.0 during calandar year 1996. Locations of a few cities are shown as white-filled diamonds. Earthquakes are indicated by circles or squares; circles represent earthquakes at depths shallower than 30 km, and squares represent earthquakes at 30 km or deeper. Cascade volcanic centers are represented by triangles.

of the Cascade Range, BSSA, V. 24, p. 51-62.).

TABLE 3
Annual counts of events recorded by the PNSN, 1980-1996

Year	Total #	Out of Net	Inside Net			
			Unlocated	Located		
				Total	EQs	Blasts
80	4576	253	1075	3246	2874	372
81	5155	291	1474	3385	2672	713
82	4452	329	1824	2297	1948	349
83	4489	405	2338	1745	1356	389
84	3144	267	1095	1780	1409	371
85	3560	266	1168	2122	1890	232
86	2554	318	452	1776	1594	182
87	1981	537	127	1304	966	338
88	2249	507	114	1624	1263	361
89	2781	501	137	2136	1835	301
90	3433	717	204	2505	2096	409
91	3083	675	315	2085	1687	398
92	3522	891	235	2381	1993	388
93	5594	731	626	4224	3877	347
94	6243	900	1518	3816	3424	392
95	5354	959	1462	2915	2539	376
96	4741	911	1192	2628	2214	414

The Duvall mainshock focal mechanism indicates thrust faulting with an east-west compression axis. This is unusual since focal mechanisms from most Puget Sound earthquakes indicate regional north-south compression. A least-squares moment tensor inversion using PNSN broadband seismograms yields a strike = 350 degrees, dip = 53 degrees (to the east), rake = 83 degrees, and a moment magnitude (M_W) of 5.0. This mechanism is consistent with first-motion polarity observations.

ACKNOWLEDGMENTS

Seismic stations, telemetry links, and data acquisition equipment were maintained by Jim Ramey and Allen Strelow at the UW, Patrick McChesney (stationed at CVO in Vancouver, Washington), Pat Ryan (of the University of Oregon in Eugene, Oregon), and Don Hartshorn on the Hanford Reservation. Bill Steele provided information to the public, while Sandra Corso provided routine data analysis and archiving of digital trace data. Ruth Ludwin wrote reports, provided data to investigators at other institutions, and handled administrative tasks. Moment-tensor focal mechanisms for earthquakes larger than magnitude 3.5 have been provided for publication in our quarterly reports by Dr. John Nabelek of Oregon State University (OSU) under support from USGS NEHRP Grant 1434-93-G-2326. OSU also provides broad-band data from station COR, which we archive with our trace-data files. The University of Oregon (UO) provides broad-band data (from stations PIN and DBO), which are likewise archived.

APPENDIX 1

PNSN Quarterly Reports
96-A, 96-B, 96-C, and 96-D

QUARTERLY NETWORK REPORT 96-A
on
Seismicity of Washington and Oregon

January 1 through March 31, 1996

Pacific Northwest Seismograph Network
Geophysics Program
Box 351650
University of Washington
Seattle, Washington 98195-1650

This report is prepared as a preliminary description of the seismic activity in Washington State and Oregon. Information contained in this report should be considered preliminary, and not cited for publication. The views and conclusions contained in this document should not be interpreted as necessarily representing the official policies, either express or implied, of the U.S. Government.

Seismograph network operation in Washington and Oregon is supported by the following contracts:

U.S. Geological Survey
Joint Operating Agreement 1434-95-A-1302

and

Westinghouse Hanford Company
Contract MLA-SVV-208775

Moment-tensor focal mechanisms for earthquakes in the Pacific Northwest were computed by Oregon State University under USGS NEHRP Grant 1434-93-G-2326.

CONTENTS

FIGURES

TABLES

INTRODUCTION

This is the first quarterly report of 1996 from the University of Washington Geophysics Program *Pacific Northwest Seismograph Network* (*PNSN*; formerly known as the *Washington Regional Seismograph Network* or *WRSN*) covering seismicity of all of Washington and western Oregon. These comprehensive quarterlies have been produced since the beginning of 1984. Prior to that we published quarterlies for western Washington in 1983 and for eastern Washington from 1975 to 1983. Annual technical reports covering seismicity in Washington since 1969 are available from the U.W. Geophysics Program.

This quarterly report discusses network operations, seismicity of the region, unusual events or findings, and our educational and outreach activities. This report is preliminary, and subject to revision. Some earthquake locations may be revised if new data become available, such as P and S readings from Canadian or USGS CALNET seismograph stations. Findings mentioned in these quarterly reports should not be cited for publication.

NETWORK OPERATIONS

Table 1 gives approximate periods of time when individual stations were inoperable. Data for Table 1 are compiled from weekly plots of network-wide teleseismic arrivals and automated digital signal checks, plus records of maintenance and repair visits. Fig. 1 shows a map view of stations operating during the quarter. We report a number of station outages in the table below. As is normal at this time of year, many of our stations are inaccessible due to winter weather conditions. These same winter conditions often cause stations to malfunction, due to ice on the antenna, snow on solar panels, etc.

TABLE 1
Station Outages 1st quarter 1996

Station	Outage Dates	Comments
BPO	1/9-End	Dead - Winter conditions
CPW	1/27-3/13	Replaced VCO
GRL	11/29/95-1/13	Dead Winter conditions
MEW	12/21/95-3/15	Repaired - Bad power supply
NEL	2/14-End	Dead - Damaged by snowfall
OSD	12/21/95-End	Dead - Bad VCO
PGO	2/14-3/22	Bad Power Supply
RCM	11/08/95-End	Dead - Power problem
RCS	1/09-End	Dead - Winter conditions
TDH	3/3-End	Dead - Winter conditions
VFP	2/1-End	Dead - Winter conditions
VSP	2/25-End	Dead - Winter conditions
WI2	1/14-End	Dead - Winter conditions
RCM	11/03-End	Dead - power problem

We are continuing the process of updating our data acquisition and processing procedures. Driven by the need to integrate broadband data into our normal data stream, new data formats were implemented at the beginning of the fourth quarter 1994. Early in 1995 we implemented a new data acquisition system, called **SUNWORM**. A backup **SUNWORM** system was implemented in the second quarter, at the beginning of the fourth quarter, we discontinued our old system, **HAWK**. This quarter we completed testing and implementation of automatic recovery of data from our dial-up broad-band stations. To accomplish this, we used our initial, automatic location and magnitude estimates to start a process which recovers the broadband data and also automatically merges it into our real-time-telemetry trace-data files.

All unedited, triggered, network trace data, plus continuous telemetry from station TTW; and other, noncontinuous, event-by-event broadband data are backed up on a network archive tape. In addition to our master archives of event trace data, which are on 2.1 GByte exabyte tape, we are backing up edited trace data on high-speed, high-capacity (20 GByte) digital linear tape (DLT) cartridges. We have on-line trace data for local earthquakes in the last five years, and the DLT allows us to rapidly retrieve additional data as required. We completed archiving data from former years at the IRIS Data Management Center (DMC) in SEED format. All of our data from 1980-1995 has been archived at the IRIS DMC.

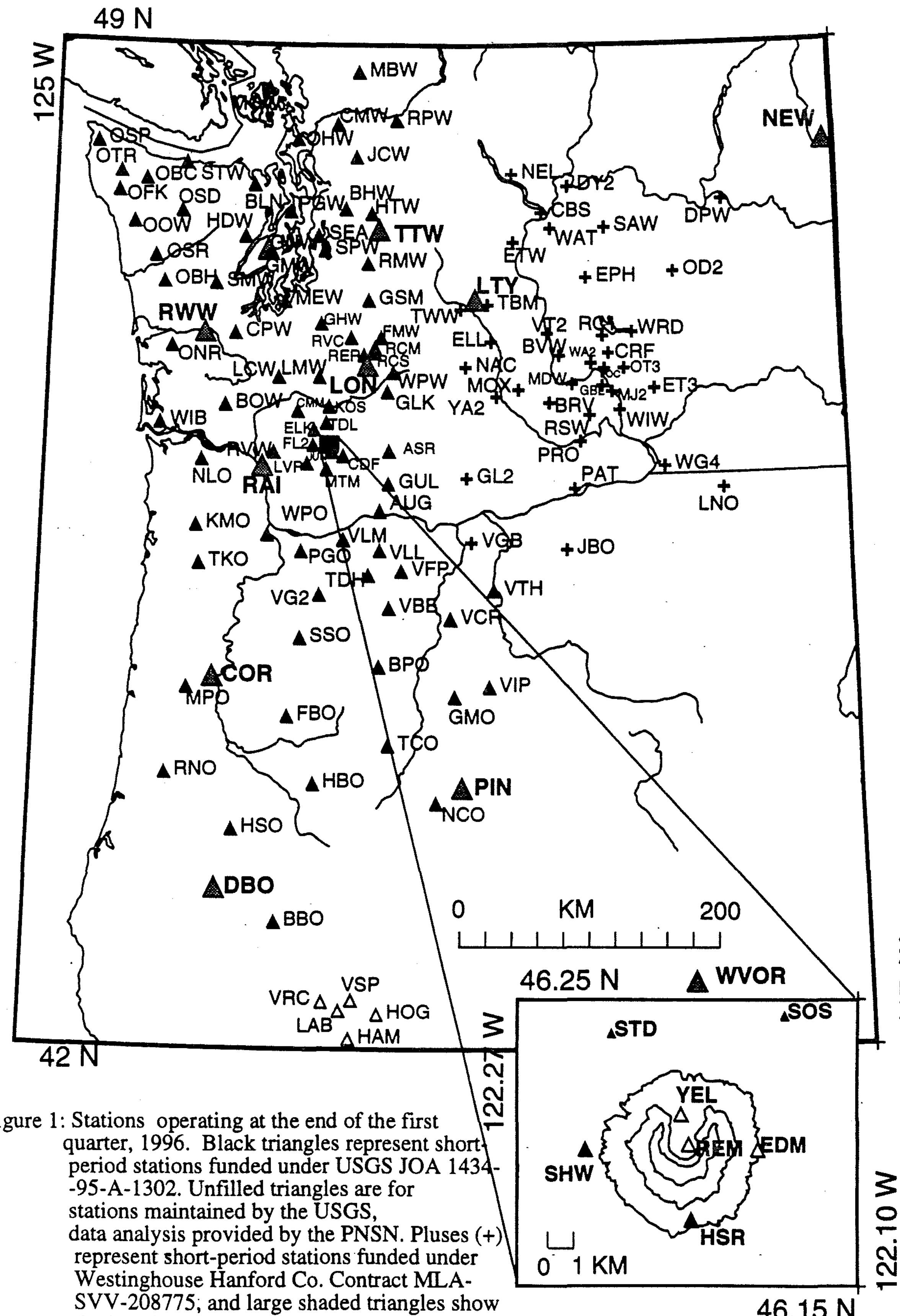

Figure 1: Stations operating at the end of the first quarter, 1996. Black triangles represent short-period stations funded under USGS JOA 1434--95-A-1302. Unfilled triangles are for stations maintained by the USGS, data analysis provided by the PNSN. Pluses (+) represent short-period stations funded under Westinghouse Hanford Co. Contract MLA-SVV-208775; and large shaded triangles show the locations of broad-band three-component instruments, funded either via JOA 1434-92-A-0963, NSF EAR-9207181, DOGAMI, or by the USGS-NSN.

STATIONS USED FOR LOCATION OF EVENTS

Table 2A lists short-period, mostly one-component stations used in locating seismic events in Washington and Oregon. Table 2B lists broad-band, three-component stations operating in Washington and Oregon that provide data to the PNSN. The first column in the table gives the 3-letter station designator, followed by a symbol designating the funding agency; stations marked by a percent sign (%) were supported by USGS joint operating agreement 1434-95-A-1302, and (+) indicates support under Westinghouse Hanford Company Contract MLA-SVV-208775. Other stations were supported from other sources. Additional columns give station north latitude and west longitude (in degrees, minutes and seconds), station elevation in km, and comments indicating landmarks for which stations were named.

TABLE 2A

Short-period Stations Operating during the First Quarter 1996

STA	F	LAT	LONG	EL	NAME
ASR	%	46 09 09.9	121 36 01.6	1.357	Mt. Adams - Stagman Ridge
AUG	%	45 44 10.0	121 40 50.0	0.865	Augspurger Mtn
BBO	%	42 53 12.6	122 40 46.6	1.671	Butler Butte, Oregon
BDM		46 58 05.5	120 57 07.2	1.811	Bald Mountain (temporary)
BHW	%	47 50 12.6	122 01 55.8	0.198	Bald Hill
BLN	%	48 00 26.5	122 58 18.6	0.585	Blyn Mt.
BOW	%	46 28 30.0	123 13 41.0	0.870	Boistfort Mt.
BPO	%	44 39 06.9	121 41 19.2	1.957	Bald Peter, Oregon
BRV	+	46 29 07.2	119 59 28.2	0.920	Black Rock Valley
BVW	+	46 48 39.6	119 52 59.4	0.670	Beverly
CBS	+	47 48 17.4	120 02 30.0	1.067	Chelan Butte, South
CDF	%	46 06 58.2	122 02 51.0	0.780	Cedar Flats
CMK		46 56 04.7	121 13 42.9	1.380	Chipmunk Creek (temporary)
CMM	%	46 26 07.0	122 30 21.0	0.620	Crazy Man Mt.
CMW	%	48 25 25.3	122 07 08.4	1.190	Cultus Mtns.
CPW	%	46 58 25.8	123 08 10.8	0.792	Capitol Peak
CRF	+	46 49 30.0	119 23 13.2	0.189	Corfu
DBO		43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon
DPW	+	47 52 14.3	118 12 10.2	0.892	Davenport
DY2	+	47 59 06.6	119 46 16.8	0.890	Dyer Hill 2
EDM	#	46 11 50.4	122 09 00.0	1.609	East Dome, Mt. St. Helens
ELK	%	46 18 20.0	122 20 27.0	1.270	Elk Rock
ELL	+	46 54 34.8	120 33 58.8	0.789	Ellensburg
EPH	+	47 21 22.8	119 35 45.6	0.661	Ephrata
ET3	+	46 34 38.4	118 56 15.0	0.286	Eltopia (replaces ET2)
ETW	+	47 36 15.6	120 19 56.4	1.477	Entiat
FBO	%	44 18 35.6	122 34 40.2	1.080	Farmers Butte, Oregon
FL2	%	46 11 47.0	122 21 01.0	1.378	Flat Top 2
FMW	%	46 56 29.6	121 40 11.3	1.859	Mt. Fremont
GBL	+	46 35 54.0	119 27 35.4	0.330	Gable Mountain
GHW	%	47 02 30.0	122 16 21.0	0.268	Garrison Hill
GL2	+	45 57 35.0	120 49 22.5	1.000	New Goldendale
GLK	%	46 33 50.2	121 36 30.7	1.320	Glacier Lake
GMO	%	44 26 20.8	120 57 22.3	1.689	Grizzly Mountain, Oregon
GMW	%	47 32 52.5	122 47 10.8	0.506	Gold Mt.
GRL		46 48 51.1	121 19 36.8	1.287	Granite Lake (temporary)
GSM	%	47 12 11.4	121 47 40.2	1.305	Grass Mt.
GUL	%	45 55 27.0	121 35 44.0	1.189	Guler Mt.
HAM	#	42 04 08.3	121 58 16.0	1.999	Hamaker Mt., Oregon
HBO	%	43 50 39.5	122 19 11.9	1.615	Huckleberry Mt., Oregon
HDW	%	47 38 54.6	123 03 15.2	1.006	Hoodsport
HOG	#	42 14 32.7	121 42 20.5	1.887	Hogback Mtn., Oregon
HSO	%	43 31 33.0	123 05 24.0	1.020	Harness Mountain, Oregon
HSR	%	46 10 28.0	122 10 46.0	1.720	South Ridge, Mt. St. Helens
HTW	%	47 48 14.2	121 46 03.5	0.833	Haystack Lookout
JBO	+	45 27 41.7	119 50 13.3	0.645	Jordan Butte, Oregon
JCW	%	48 11 42.7	121 55 31.1	0.792	Jim Creek
JUN	%	46 08 48.0	122 09 10.8	1.049	June Lake
KMO	%	45 38 07.8	123 29 22.2	0.975	Kings Mt., Oregon
KOS	%	46 27 40.8	122 11 25.8	0.828	Kosmos
LAB	#	42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon (4-comp)
LCW	%	46 40 14.4	122 42 02.8	0.396	Lucas Creek
LMW	%	46 40 04.8	122 17 28.8	1.195	Ladd Mt.
LNO	+	45 52 18.6	118 17 06.6	0.771	Lincton Mt., Oregon
LO2	%	46 45 00.0	121 48 36.0	0.853	Longmire

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
LOC	+	46 43 01.2	119 25 51.0	0.210	Locke Island
LVP	%	46 04 06.0	122 24 30.0	1.170	Lakeview Peak
MBW	%	48 47 02.4	121 53 58.8	1.676	Mt. Baker
MCW	%	48 40 46.8	122 49 56.4	0.693	Mt. Constitution
MDW	+	46 36 47.4	119 45 39.6	0.330	Midway
MEW	%	47 12 07.0	122 38 45.0	0.097	McNeil Island
MHL		46 52 56.6	122 03 50.4	1.215	Mashel Creek (temporary)
MJ2	+	46 33 27.0	119 21 32.4	0.146	May Junction 2
MOX	+	46 34 38.4	120 17 53.4	0.501	Moxie City
MPO	%	44 30 17.4	123 33 00.6	1.249	Mary's Peak, Oregon
MTM	%	46 01 31.8	122 12 42.0	1.121	Mt. Mitchell
MUP		46 50 21.4	121 07 31.0	1.456	Mud Springs (temporary)
NAC	+	46 43 59.4	120 49 25.2	0.728	Naches
NCO	%	43 42 14.4	121 08 18.0	1.908	Newberry Crater, Oregon
NEL	+	48 04 12.6	120 20 24.6	1.500	Nelson Butte
NLO	%	46 05 21.9	123 27 01.8	0.826	Nicolai Mt., Oregon
OBC	%	48 02 07.1	124 04 39.0	0.938	Olympics - Bonidu Creek
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OD2	+	47 23 15.6	118 42 34.8	0.553	Odessa site 2
OFK	%	47 57 00.0	124 21 28.1	0.134	Olympics - Forks
OHW	%	48 19 24.0	122 31 54.6	0.054	Oak Harbor
ONR	%	46 52 37.5	123 46 16.5	0.257	Olympics - North River
OOW	%	47 44 03.6	124 11 10.2	0.561	Octopus West
OSD	%	47 48 59.2	123 42 13.7	2.008	Olympics - Snow Dome
OSP	%	48 17 05.5	124 35 23.3	0.585	Olympics - Sooes Peak
OSR	%	47 30 20.3	123 57 42.0	0.815	Olympics Salmon Ridge
OT3	+	46 40 08.4	119 13 58.8	0.322	New Othello
OTR	%	48 05 00.0	124 20 39.0	0.712	Olympics - Tyee Ridge
PAT	+	45 52 55.2	119 45 08.4	0.262	Paterson
PGO	%	45 27 42.6	122 27 11.5	0.253	Gresham, Oregon
PGW	%	47 49 18.8	122 35 57.7	0.122	Port Gamble
PRO	+	46 12 45.6	119 41 08.4	0.553	Prosser
QTZ		47 00 40.4	121 05 20.9	1.054	Quartz Creek (temporary)
RC1	+	46 56 42.6	119 26 39.6	0.485	Royal City (3 comp.)
RCM	%	46 50 08.9	121 43 54.4	3.085	Mt. Rainier, Camp Muir
RCS	%	46 52 15.6	121 43 52.0	2.877	Mt. Rainier, Camp Schurman
REM	#	46 11 57.0	122 11 03.0	2.102	Rembrandt (Dome station)
RER	%	46 49 09.2	121 50 27.3	1.756	Mt. Rainier, Emerald Ridge
RMW	%	47 27 35.0	121 48 19.2	1.024	Rattlesnake Mt. (West)
RNO	%	43 54 58.9	123 43 25.5	0.850	Roman Nose, Oregon
RPW	%	48 26 54.0	121 30 49.0	0.850	Rockport
RSW	+	46 23 40.2	119 35 28.8	1.045	Rattlesnake Mt. (East)
RVC	%	46 56 34.5	121 58 17.3	1.000	Mt. Rainier - Voight Creek
RVN		47 01 38.6	121 20 11.9	1.885	Raven Roost (temporary)
RVW	%	46 08 53.2	122 44 32.1	0.460	Rose Valley
SAW	+	47 42 06.0	119 24 01.8	0.701	St. Andrews
SEA		47 39 18.0	122 18 30.0	0.030	Seattle (Wood Anderson)
SHW	%	46 11 37.1	122 14 06.5	1.425	Mt. St. Helens
SMW	%	47 19 10.7	123 20 35.4	0.877	South Mtn.
SOS	%	46 14 38.5	122 08 12.0	1.270	Source of Smith Creek
SPW	%	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle
SSO	%	44 51 21.6	122 27 37.8	1.242	Sweet Springs, Oregon
STD	%	46 14 16.0	122 13 21.9	1.268	Studebaker Ridge
STW	%	48 09 02.9	123 40 13.1	0.308	Striped Peak
TBM	+	47 10 12.0	120 35 52.8	1.006	Table Mt.
TCO	%	44 06 21.0	121 36 01.0	1.975	Three Creek Meadows, Oregon.
TDH	%	45 17 23.4	121 47 25.2	1.541	Tom,Dick,Harry Mt., Oregon
TDL	%	46 21 03.0	122 12 57.0	1.400	Tradedollar Lake
TKO	%	45 22 16.7	123 27 14.0	1.024	Trask Mtn, Oregon
TRW	+	46 17 32.0	120 32 31.0	0.723	Toppenish Ridge
LNO	+	45 52 18.6	118 17 06.6	0.771	Lincton Mt., Oregon
TWW	+	47 08 17.4	120 52 06.0	1.027	Teanaway
VBE	%	45 03 37.2	121 35 12.6	1.544	Beaver Butte, Oregon
VCR	%	44 58 58.2	120 59 17.4	1.015	Criterion Ridge, Oregon
VFP	%	45 19 05.0	121 27 54.3	1.716	Flag Point, Oregon
VG2	%	45 09 20.0	122 16 15.0	0.823	Goat Mt., Oregon
VGB	+	45 30 56.4	120 46 39.0	0.729	Gordon Butte, Oregon
VIP	%	44 30 29.4	120 37 07.8	1.731	Ingram Pt., Oregon
VLL	%	45 27 48.0	121 40 45.0	1.195	Laurance Lk., Oregon
VLM	%	45 32 18.6	122 02 21.0	1.150	Little Larch, Oregon
VRC	#	42 19 47.2	122 13 34.9	1.682	Rainbow Creek, Oregon
VSP	#	42 20 30.0	121 57 00.0	1.539	Spence Mtn, Oregon
VT2	+	46 58 02.4	119 59 57.0	1.270	Vantage2
VTH	%	45 10 52.2	120 33 40.8	0.773	The Trough, Oregon
WA2	+	46 45 19.2	119 33 56.4	0.244	Wahluke Slope
WAT	+	47 41 55.2	119 57 14.4	0.821	Waterville

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
WG4	+	46 01 49.2	118 51 21.0	0.511	Wallula Gap
WI2		47 08 10.6	121 22 52.0	1.528	Windy Gap (temporary)
WIB	#	46 20 34.8	123 52 30.6	0.503	Willapa Bay (3 comp.)
WIW	+	46 25 45.6	119 17 15.6	0.128	Wooded Island
WPO	%	45 34 24.0	122 47 22.4	0.334	West Portland, Oregon
WPW	%	46 41 53.4	121 32 48.0	1.250	White Pass
WRD	+	46 58 12.0	119 08 41.4	0.375	Warden
XTL		46 55 47.8	121 29 35.8	1.665	Crystal Mtn. (temporary)
YA2	+	46 31 36.0	120 31 48.0	0.652	Yakima
YEL	#	46 12 35.0	122 11 16.0	1.750	Yellow Rock, Mt. St. Helens

TABLE 2B

Broad-band three-component stations operating at the end of the First Quarter 1996

STA	F	LAT	LONG	EL	NAME
COR		44 35 08.5	123 18 11.5	0.121	Corvallis, Oregon (IRIS station, Operated by OSU)
DBO		43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon (Operated by UO)
GNW	*	47 33 51.8	122 49 31.0	0.165	Green Mountain, WA (operated by UW)
LON	*	46 45 00.0	121 48 36.0	0.853	Longmire, WA (operated by UW)
LTY	*	47 15 21.2	120 39 53.3	0.970	Liberty, WA (operated by UW)
NEW		48 15 50.0	117 07 13.0	0.760	Newport Observatory (USGS-USNSN)
RAI		46 02 25.1	122 53 06.4	1.520	Trojan Plant, Oregon (OSU)
RWW	*	46 57 50.1	123 32 35.9	0.015	Ranney Well(operated by UW)
TTW	*	47 41 40.7	121 41 20.0	0.542	Tolt Res, WA (operated by UW)
PIN		43 48 40.0	120 52 19.0	1.865	Pine Mt. Oregon (operated by UO)
WVOR		42 26 02.0	118 38 13.0	1.344	Wildhorse Valley, Oregon (USGS-USNSN)

OUTREACH ACTIVITIES

The PNSN Seismology Lab staff provides an educational outreach program to better inform the public, educators, business, policy makers, and the emergency management community about seismicity and natural hazards. Our outreach includes lab tours, lectures, classes and workshops, press conferences, TV and radio news programs and talk shows, field trips, and participation in regional earthquake planning efforts. We provide an audio library which includes a message describing the seismic hazards in Washington and Oregon, another on earthquake prediction, and a frequently updated message on current seismic activity. Similar information is available via Internet on the World-Wide-Web (WWW):

http://www.geophys.washington.edu/seis1.html

Special Events and Projects

The PNSN Seismology Lab has continued to host and provide logistic support for the Cascadia Regional Earthquake Workgroup (CREW) meetings, hosting three board meetings and two committee meetings during the first quarter. These meetings are supported by the Federal Emergency Management Agency (FEMA) to coordinate public and private efforts to minimize the consequences of future Cascadia subduction earthquakes. Participants represented lifeline agencies (utilities, transportation, emergency services, etc.) and large corporations. FEMA funding for the Geophysics Program's facilitation of this group ended with this quarter. Future funding is being sought and the Seismology Lab will try to continue to provide logistic support.

CREW's first annual meeting/conference will be hosted by the PNSN and the Geophysics Program at The University of Washington in late August or early September. CREW (led by Paul Martin of Dames & Moore Inc., Seattle) has developed a WWW "home page", on the UW Geophysics Program web-server with the support of the PNSN. The CREW Web-page can be accessed through:

http://www.geophys.washington.edu/CREW/index.html

The Washington State Emergency Management Conference was held on March 4th. Dr. Stephen D. Malone and Bill Steele participated in a workshop developed by Dr. Peter Anderson of Simon Fraser

University entitled "The Internet for Emergency Management and Response". and The PNSN presented a program on strong motion seismology and its applications in emergency management. Dr. Malone and Mr. Steele participated with invited guest speakers Donald B. Ballantyne, Associate of EQE International (Seattle), and Dr. Stephanie Chang, Economist with EQE International (Irvine) who gave a presentation on the EPIDAT Geographical Information System developed by EQE with funding from California Office of Emergency Services (OES). EPIDAT(The Early Post-Earthquake Damage Assessment Tool) is capable of modeling building and life-line damage and estimating casualties in near real-time given source parameters for an earthquake.

The PNSN hosted a day-long meeting of UW and USGS Seismologists to review network capabilities and improvements needed to develop a dependable near-source tsunami warning system for the Cascadia Region. Participating scientists concluded that the main difficulty would be to design an automatic system that would be absolutely robust and reliable. Testing and evaluating the reliability of systems which alarm on rare events is difficult. While some additional instrumentation and operating expenses would be likely be required, the system design and engineering poses more substantial difficulties.

Press Interviews, Lab Tours, and Workshops

PNSN staff provided more than 25 interviews broadcast by television and radio stations, either in response to earthquake activity or related to research on geologic hazard assessment, providing background and context for the general audience. During the fourth quarter, 21 K-12 school groups (about 400 individuals), and one Seattle University class (about 25 students), toured the Seismology Lab. PNSN staff also gave presentations to classes at UW, a teacher training workshop in cooperation with The Pacific Science Center and the UW College of Education, and for 5 community and business organizations.

Telephone, Mail, and On-line outreach

The PNSN audio library system received 1,650 calls this quarter. We provide several recordings in our voice library. The most popular is a frequently updated message on current seismic activity. In addition we have a message describing the seismic hazards in Washington and Oregon, and another on earthquake prediction. Callers often request our one-page information and resource sheet on seismic hazards in Washington and Oregon. Thousands of these have been mailed out or distributed, and we encourage others to reproduce and further distribute this sheet. Our information sheet discussing earthquake prediction is also frequently requested. Callers to the audio library can also choose to be transferred to the Seismology Lab, where additional information is available. This quarter we responded to ~40 calls from the emergency management community, ~50 calls from the media, ~45 calls from educators, ~90 calls from the business community, and over 230 calls from the general public.

The list of recent Pacific Northwest earthquakes can be accessed by a variety of methods beyond the audio library described above; directly through Internet, by modem, and via the World-Wide-Web. The computer methods have an advantage over the audio line. Not only are more earthquakes listed, but our automatic alarm system appends a preliminary location for any earthquake large enough to trigger the alarm (magnitude greater than 2.9) to the list; allowing public access to the preliminary location and magnitude estimate within minutes of the earthquake. Table 3A shows the number of times the computerized PNSN list of recent earthquakes magnitude 2.0 or larger was accessed. The Internet UNIX utility "finger quake@geophys.washington.edu" was most popular, followed by access over the WWW. For computer users without direct access to Internet, this information can be accessed via e-mail (by sending e-mail to "quake@geophys.washington.edu"), or by direct dial-up to modem ((206) 685-0889); modem setting: 8 bits, 1 stop bit, No parity; type "quake" at "geoterm" prompt and login as "quake"). The modem and e-mail services are used several hundred times each month.

TABLE 3A
Quarterly Comparison of Methods of Accessing
PNSN list of most recent earthquakes, M>=2.0

Access Method	94-D	95-A	95-B	95-C	95-D	96-A
Finger Quake	32,000	110,000	93,000	80,000	72,000	83,000
World-Wide-Web	300	2,300	2,500	3,100	4,300	6,300
Remote Login as Quake	3,200	7,600	5,400	3,400	2,900	2,485
Via E-mail	786	956	613	444	477	317
Dialup Quake	520	811	580	604	439	406

The PNSN recent earthquake list, and much more, is also available through the World-Wide-Web (WWW) at: **http://www.geophys.washington.edu/seis1.html** which contains information from the PNSN and also links into other sources of earthquake information around the country and world through:

http://www.geophys.washington.edu/seismosurfing.html

Other popular features include our composite listings and maps of recent U.S. earthquakes from The Council of National Seismic Systems (CNSS), and local offerings from the PNSN. Table 3B summarizes WWW activity over the last year. Both Tables 3A and 3B show that usage has increased enormously.

TABLE 3B
World Wide Web Activity per Quarter

Area Accessed	94-D	95-A	95-B	95-C	95-D	96-A
Seismosurfing	5,300	19,100	19,000	20,700	22,000	23,000
CNSS Earthquake Maps	1,300	3,600	3,800	6,200	9,900	18,300
CNSS Earthquake Catalog	1,400	4,300	4,400	5,900	6,600	9,400
PNSN List of most recent earthquakes, M>=2.0	300	2,300	2,500	3,100	4,300	6,300
Local Earthquake Maps	900	1,500	1,000	1,100	2,400	3,647
Other Features	12,800	43,200	46,300	43,100	83,800	136,000
Total for Seismology Area	**22,000**	**74,000**	**77,000**	**86,000**	**129,000**	**203,000**

Quarterly summaries of seismic activity in Washington and Oregon extracted from these quarterly reports can be found in the WWW area:

http://www.geophys.washington.edu/res_repts.html

EARTHQUAKE DATA

There were 796 events digitally recorded and processed at the University of Washington between January 1 and March 31, 1996. Locations in Washington, Oregon, or southernmost British Columbia were determined for 504 of these events; 434 were classified as earthquakes and 70 as known or suspected blasts. The remaining 292 processed events include teleseisms (138 events), regional events outside the PNSN (58), and unlocated events within the PNSN. Unlocated events within the PNSN include very small earthquakes and some known blasts. We are now routinely locating all sizable Centralia blasts, and retrieving and archiving broad-band data for them. Table 4, located at the end of this report, is the catalog of earthquakes and blasts located within the network for this quarter. For the Klamath Falls area, only earthquakes of magnitude 1.6 and larger have been included in Table 4.

Fig. 2 shows all earthquakes with magnitude greater than or equal to 0.0 ($M_c \geq 0$). Fig. 3 shows blasts and probable blasts ($M_c \geq 0$). Fig. 4 shows earthquakes located near Mt. Rainier ($M_c \geq 0$). Fig. 5 shows earthquakes located at Mt. St. Helens ($M_c \geq 0$). Fig. 6 shows a map of broad-band stations used to determine moment-tensor focal mechanisms, and Fig. 7 shows the location and moment-tensor focal mechanisms for earthquakes with M_w >3.5.

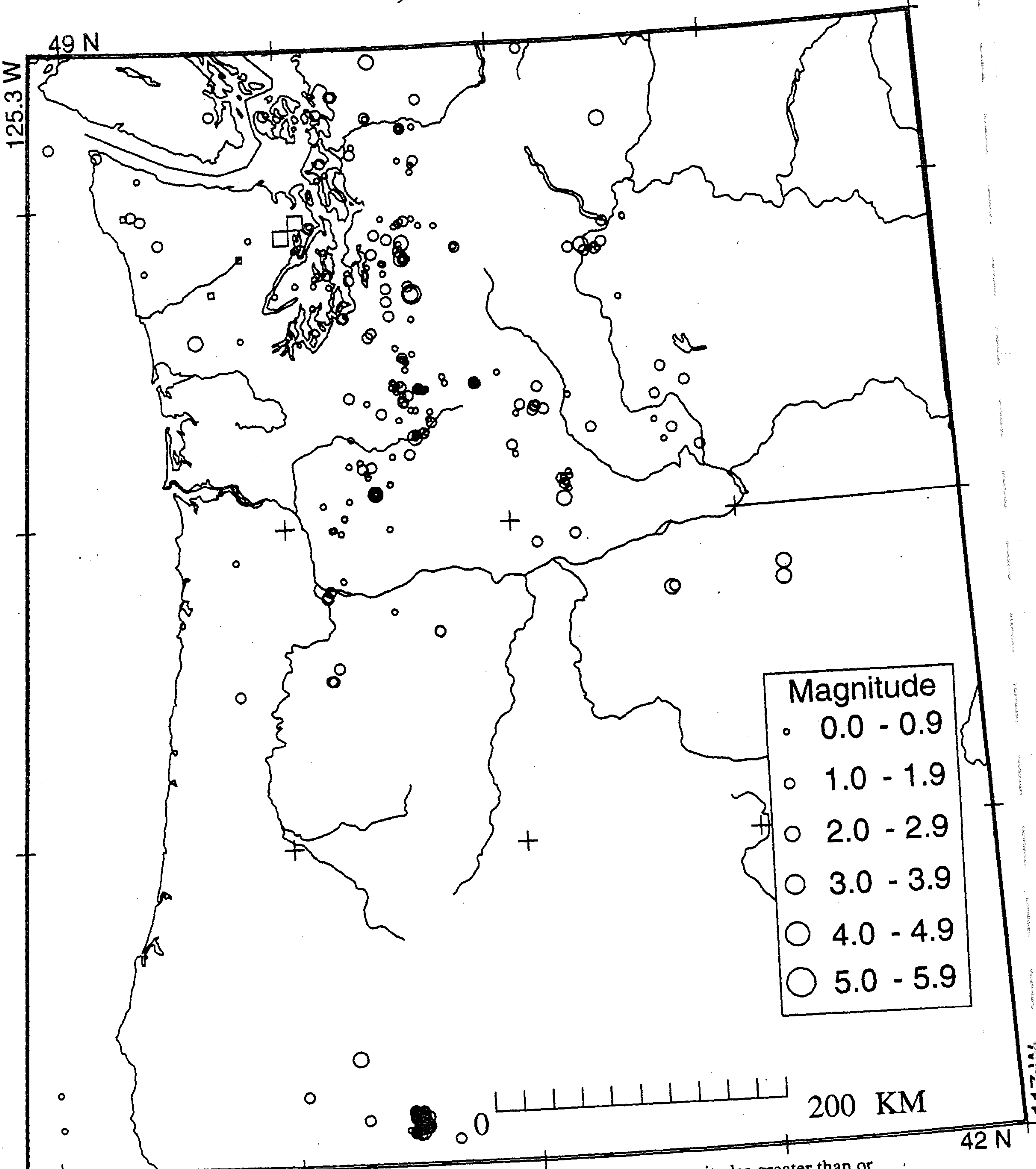

Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the first quarter of 1996. Square symbols indicate events located at depths of 30 km or more.

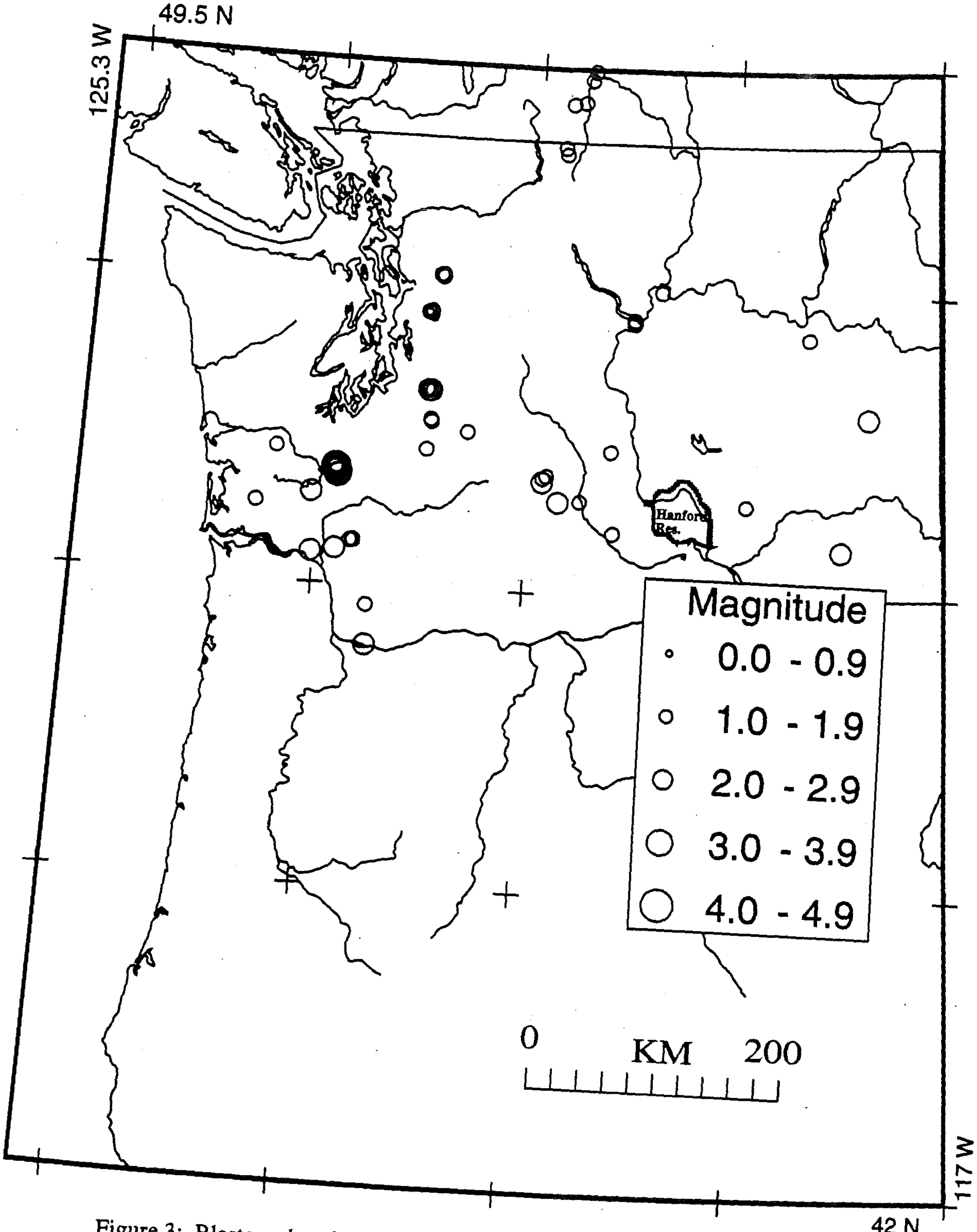

Figure 3: Blasts and probable blasts, first quarter, 1996.

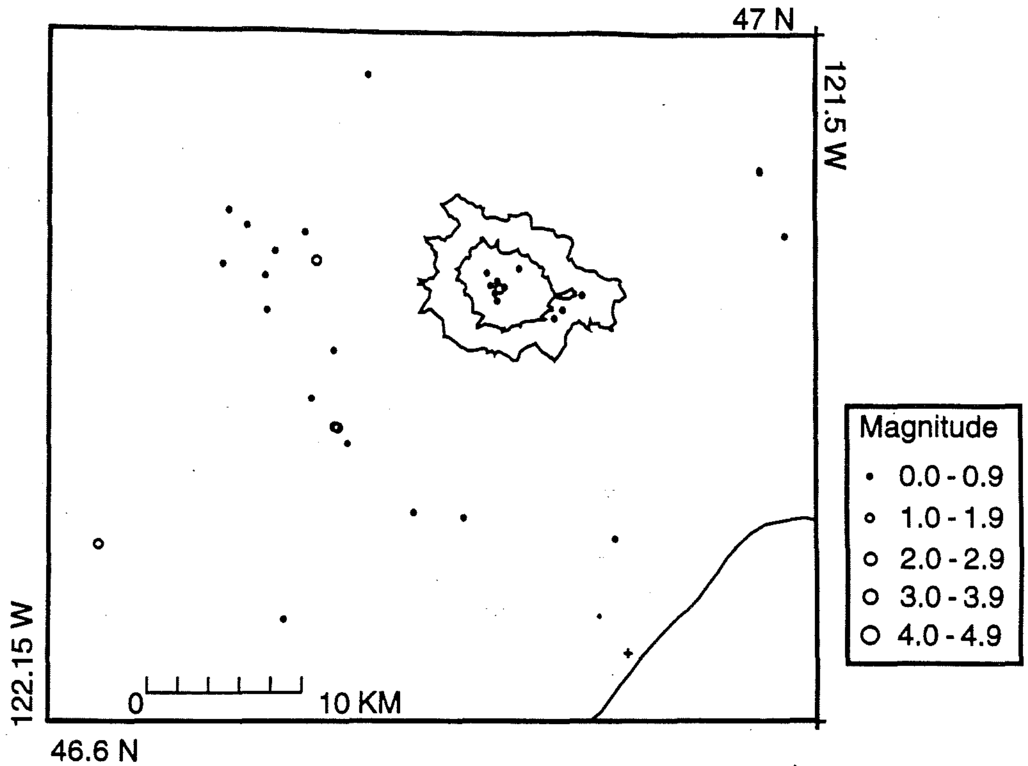

Figure 4: Earthquakes located in the Mt. Rainier area first quarter, 1996. All events shown are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

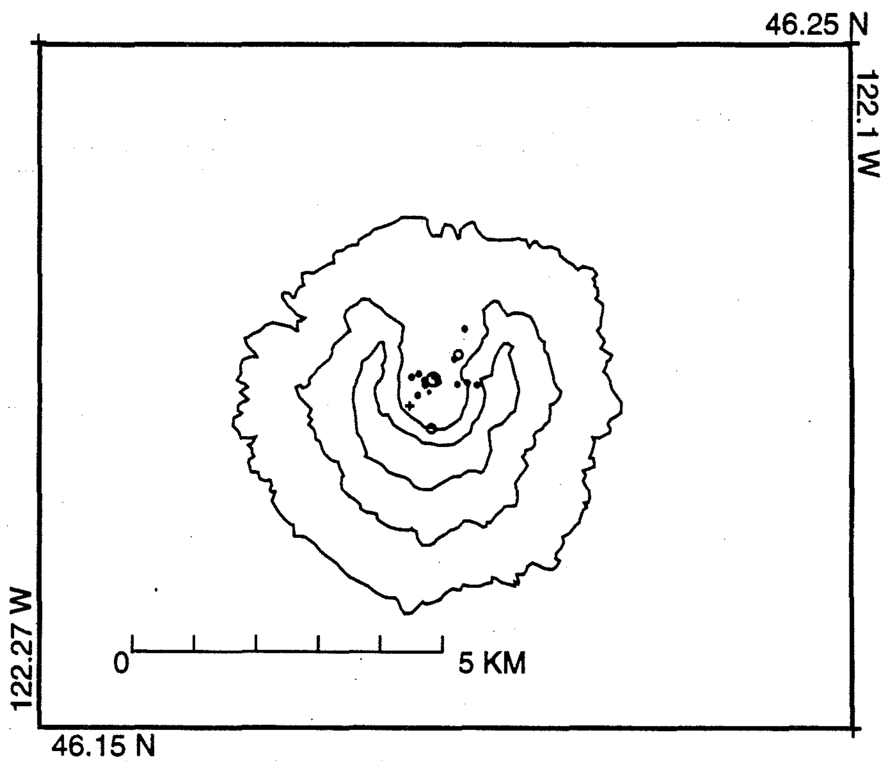

Figure 5: Earthquakes located in the Mt. St. Helens area first quarter, 1996. All events shown are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4.

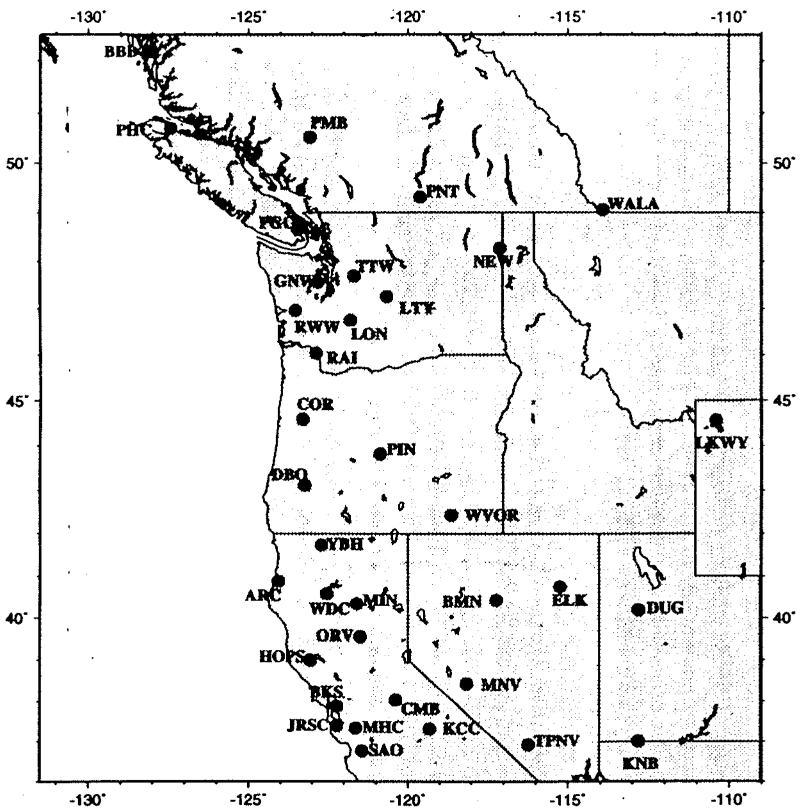

Fig. 6

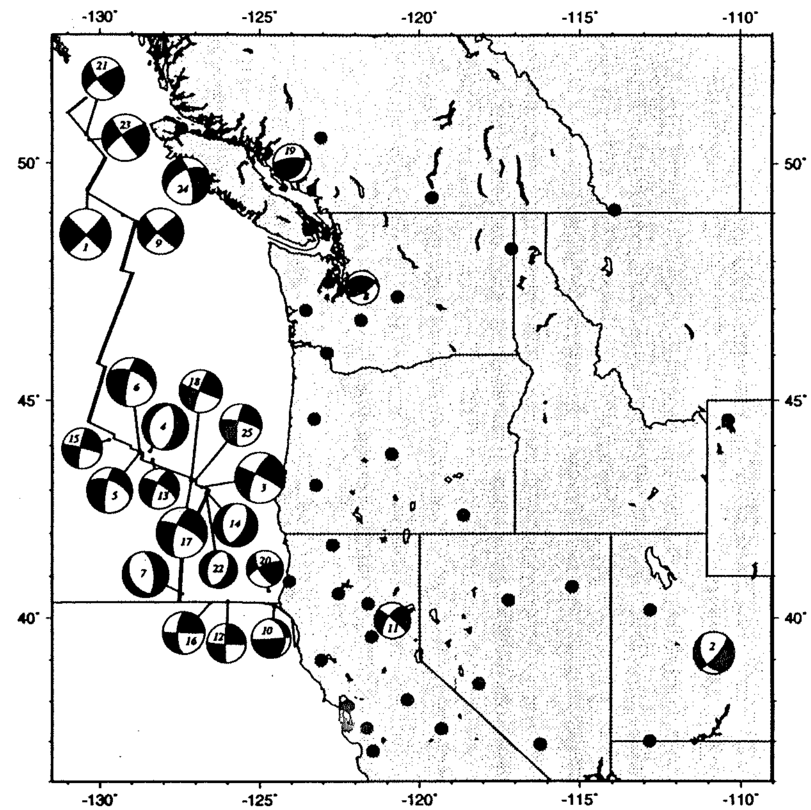

Fig. 7

Figure 6. Map of 3-component broad band stations used to determine moment-tensor focal mechanisms.
Figure 7. Map of best-fit double-couple focal mechanisms.

MOMENT TENSOR FOCAL MECHANISM SOLUTIONS

Moment-tensor focal mechanisms for earthquakes with M_w > 3.5 in the Pacific Northwest are included in this report. These solutions were computed under other support (USGS NEHRP Grant 1434-93-G-2326), at the Oregon State University under the direction of Dr. John Nabelek. The operation of broadband stations in Oregon (COR, RAI, DBO and PIN) was in part supported by a grant from the Oregon Department of Geology and Mineral Industries.

Moment-tensor solutions use data from 3-component broad-band stations in Washington, Oregon, California and British Columbia and from US National Seismic Network Stations in the western states of the US (Figure 6). The inversions are performed in the 0.01 - 0.1 Hz range, with the frequency band adjusted according to the earthquake magnitude and the station epicentral distance.

Moment tensors, best-fit double-couple mechanism, M_w, seismic moment, and depth are given in Table 5. The coordinate conventions of Aki and Richards (Quantitative Seismology: Theory and Methods, W. H. Freeman, San Francisco, 1980) are followed. Figure 7 shows the locations and focal mechanisms for the events listed in Table 5. Events 3-6, 13-15, 17, 18, and 25 were relocated (marked R in Table 5).

An up-to-date catalogue of the moment tensor focal mechanisms is available on the World-Wide-Web server at Oregon State University: **http://quakes.oce.orst.edu.**

OREGON SEISMICITY

During the first quarter of 1996, no earthquakes were reported felt in Oregon. A total of 75 earthquakes were located in Oregon between 42.0° and 45.5° north latitude, and between 117° and 125° west longitude. All but 7 of these were located in the Klamath Falls area, where a pair of damaging earthquakes in September of *1993* (Sept. 21, 03:29 and 05:45 UTC; M_c 5.9 and 6.0 respectively) were followed by a vigorous aftershock sequence which has decreased over time. This quarter, 15 earthquakes of magnitude 1.6 or larger were located in the Klamath Falls area. The largest Oregon earthquake this quarter was magnitude 2.3 and occurred at about 10 km depth near Klamath Falls on Feb. 13 at 20:05 UTC.

WESTERN WASHINGTON SEISMICITY

During the first quarter of 1996, 302 earthquakes were located between 45.5° and 49.5° north latitude and between 121° and 125.3° west longitude. The deepest earthquake this quarter (M 2.0, depth ~48 km, on Jan 23 at 05:21 UTC) occurred near Poulsbo. Two earthquakes were reported felt in western Washington during the first quarter of 1996, both on January 21 when two earthquakes, magnitudes 3.3 and 2.8, at around 21 km depth were located about 5 km south of North Bend. The larger event (at 16:06 UTC) was widely felt in King County, while the smaller event (19:1 UTC) was felt by some people in North Bend, Crystal Mountain, and as far away as Fife.

Mount Rainier Area

Figure 4 shows earthquakes near Mount Rainier. The number of events in close proximity to the cone of Mt. Rainier varies over the course of the year, since the source of much of the shallow surface-type activity is presumably ice movement or avalanching, which is seasonal in nature. Events with very low frequency signals (1-3 Hz) believed to be icequakes are assigned type "L" in the catalog. Emergent, very long duration signals probably due to rockfalls or avalanches are assigned type "S" (see Key to Earthquake Catalog). "L" and "S" type events are not shown in Figure 4.

A total of 56 events (19 of them smaller than magnitude 0., and thus not shown in Fig. 4) were located within the region shown in Fig. 4. Of these, 21 were located in the "Western Rainier Seismic Zone" (WRSZ), a north-south trending lineation of seismicity approximately 15 km west of the summit of Mt. Rainier (for counting purposes, the western zone is defined as 46.6-47° N latitude, 121.83-122° W longitude). Closer to the summit (within 5 km), there were 20 earthquakes, but no type "L" or "S" events this quarter (types L and S are not shown in Fig.4). The remaining events were scattered around the cone of Rainier as seen in Fig. 4.

Mount St. Helens Area

Figure 5 shows tectonic earthquakes near Mount St. Helens. Low frequency (L) and avalanche or rockfall events (S) are not shown. In the first quarter, 82 events (only 18 magnitude 0. or larger), were located at Mt. St. Helens in the area shown in Fig. 5. This quarter, no surficial earthquakes (type "S" or

"L") were located. Of this quarter's earthquakes, 50 (9 of them larger than magnitude 0.) were deeper than 4 km. The largest event at Mount St. Helens, M_c 2.4, (Feb. 22 at 00:51 UTC) was at a depth of ~4km.

EASTERN WASHINGTON SEISMICITY

During the first quarter of 1996, 54 earthquakes were located in eastern Washington. The two largest quakes this quarter were both magnitude 2.9, and neither one was reported felt. The first, on February 13, at 12:48 UTC, and was located 65 km west south-west of Pendleton, Oregon, at a shallow depth of only a few km. It was followed by a nearby earthquake, magnitude 2.6, also shallow, on Feb. 14 at 19:53.

The other magnitude 2.9 earthquake east of the Cascades this quarter occurred in the Okanogan National Forest in the North Cascades. It was on February 24 at 03:51 UTC (at a very shallow depth) at a location about 34 km WNW of the town of Okanogan, near Beaver Ridge.

OTHER SOURCES OF EARTHQUAKE INFORMATION

We provide automatic computer-generated alert messages about significant Washington and Oregon earthquakes by e-mail or FAX to institutions needing such information, and we regularly exchange phase data via e-mail with other regional seismograph network operators. The "Outreach Activities" section describes how to access PNSN data over modem, Internet, and World-Wide-Web. To request additional information by e-mail, contact bill@geophys.washington.edu.

Earthquake information in the quarterlies is published in final form by the Washington State Department of Natural Resources as information circulars entitled "Earthquake Hypocenters in Washington and Northern Oregon" covering the period 1970-1989 (see circulars Nos. 53, 56, 64-66, 72, 79, 82-84, and 89). These circulars, plus circular No. 85, "Washington State Earthquake Hazards", are available from Washington Dept. of Natural Resources, Division of Geology and Earth Resources, Post Office Box 47007, Olympia, Wa. 98504-7007, or by telephone at (360) 902-1450.

A full-color map called "Earthquakes in Washington and Oregon 1872-1993", by Susan Goter (USGS Open-File Report 94-226A), and its companion pamphlet "Washington and Oregon Earthquake History and Hazards", by Yelin, Tarr, Michael, and Weaver (USGS Open-File Report 94-226B) is available from "Earthquake Maps" U.S. Geological Survey, Box 25046, Federal Center, MS 967, Denver, CO 80225, phone (303)273-8420. The price is $12. (including shipping and handling). The pamphlet (USGS Open-File Report 94-226B) is also available separately.

Other regional agencies provide earthquake information. These include the Geological Survey of Canada (Pacific Geoscience Centre, Sidney, B.C.; (604) 363-6500, FAX (604) 363-6565), which produces monthly summaries of Canadian earthquakes; the United States Geological Survey which produces weekly reports called "Seismicity Reports for Northern California" (USGS, attn: Steve Walter, 345 Middlefield Rd, MS-977, Menlo Park, Ca, 94025) and "Weekly Earthquake Report for Southern California" (USGS, attn: Dr. Kate Hutton or Dr. Lucy Jones, California Institute of Technology, Pasadena, Ca.)

Key to Earthquake Catalog in Table 3

TIME Origin time is calculated for each earthquake on the basis of multistation arrival times. Time is given in **Coordinated Universal Time** (UTC), in hours:minutes:seconds. To convert to Pacific Standard Time (PST) subtract eight hours, or to Pacific daylight time subtract seven hours.

LAT North latitude of the epicenter, in degrees and minutes.

LONG West longitude of the epicenter, in degrees and minutes.

DEPTH The depth, given in kilometers, is usually freely calculated from the arrival-time data. In some instances, the depth must be fixed arbitrarily to obtain a convergent solution. Such depths are noted by an asterisk (*) in the column immediately following the depth. A **$** or a **#** following the depth mean that the maximum number of iterations has been exceeded without meeting convergence tests and both the location and depth have been fixed.

MAG Coda-length magnitude M_c, an estimate of local magnitude M_L (Richter, C.F., 1958, Elementary Seismology: W.H. Freeman and Co., 768p), calculated using the coda-length/magnitude relationship determined for Washington (Crosson, R.S., 1972, Bull. Seism. Soc. Am., v. 62, p. 1133-1171). Where blank, data were insufficient for a reliable magnitude determination. Normally, the only earthquakes with undetermined magnitudes are very small ones. Magnitudes may be revised as we improve our analysis procedure.

NS/NP NS is the number of station observations, and **NP** the number of P and S phases used to calculate the earthquake location. A minimum of three stations and four phases are required. Generally, more observations improve the quality of the solution.

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

RMS The root-mean-square residual (observed arrival time minus predicted arrival time) at all stations used to locate the earthquake. It is only useful as a measure of the quality of the solution when 5 or more well distributed stations are used in the solution. Good solutions are normally characterized by **RMS** values less than about 0.3 sec.

Q Two **Quality factors** indicate 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 is a measure of the hypocenter quality based on travel time residuals. For example: **A** quality requires an **RMS** less than 0.15 sec while an **RMS** of 0.5 sec or more is **D** quality (estimates of the uncertainty in hypocenter location also affect this quality parameter). The second letter of the quality code depends on the spatial distribution of stations around the epicenter i.e. number of stations, their azimuthal distribution, and the minimum distance (**DMIN**) from the epicenter to a station. Quality **A** requires a solution with 8 or more phases, **GAP** $\leq 90°$ and **DMIN** $\leq$ (5 km or depth, whichever is greater). If the number of phases, **NP** , is 5 or less or **GAP** $> 180°$ or **DMIN** > 50 km the solution is assigned quality **D.**

MOD The crustal velocity model used in location calculations.

- **P3** - Puget Sound model
- **C3** - Cascade model
- **S3** - Mt. St. Helens model including Elk Lake
- **N3** - northeastern model
- **E3** - southeastern model
- **O0** - Oregon model
- **K3** - Southern Oregon, Klamath Falls area model
- **R0 and J1** - Regional and Offshore models

TYP Events flagged in Table 3 use the following code:

- **F** - earthquake reported to have been felt
- **P** - probable explosion
- **L** - low frequency earthquake (e.g. glacier movement, volcanic activity)
- **H** - handpicked from helicorder records
- **S** - Surficial event (e.g. rockslide, avalanche, sonic boom) not explosion or tectonic earthquake
- **X** - known explosion

QUARTERLY NETWORK REPORT 96-B
on
Seismicity of Washington and Oregon

April 1 through June 30, 1996

Pacific Northwest Seismograph Network
Geophysics Program
Box 351650
University of Washington
Seattle, Washington 98195-1650

Seismograph network operation in Washington and Oregon is supported by the following contracts:

U.S. Geological Survey
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and

Westinghouse Hanford Company
Contract MLA-SVV-208775

Moment-tensor focal mechanisms for earthquakes in the Pacific Northwest were computed by Oregon State University under USGS NEHRP Grant 1434-93-G-2326.

CONTENTS

FIGURES

TABLES

INTRODUCTION

This is the second quarterly report of 1996 from the University of Washington Geophysics Program *Pacific Northwest Seismograph Network* (*PNSN*; formerly known as the *Washington Regional Seismograph Network* or *WRSN*) covering seismicity of all of Washington and western Oregon. These comprehensive quarterlies have been produced since the beginning of 1984. Prior to that we published quarterlies for western Washington in 1983 and for eastern Washington from 1975 to 1983. Annual technical reports covering seismicity in Washington since 1969 are available from the U.W. Geophysics Program.

This quarterly report discusses network operations, seismicity of the region, unusual events or findings, and our educational and outreach activities. This report is preliminary, and subject to revision. Some earthquake locations may be revised if new data become available, such as P and S readings from Canadian or USGS CALNET seismograph stations. Findings mentioned in these quarterly reports should not be cited for publication.

NETWORK OPERATIONS

Table 1 gives approximate periods of time when individual stations were inoperable. Data for Table 1 are compiled from weekly plots of network-wide teleseismic arrivals and automated digital signal checks, plus records of maintenance and repair visits. Fig. 1 shows a map view of stations operating during the quarter. We report a number of station outages in the table below. As is normal at this time of year, damage to stations due to winter weather conditions is being repaired. Winter conditions cause many malfunctions, due to ice on the antenna, snow on solar panels, etc.

TABLE 1
Station Outages 2nd quarter 1996

Station	Outage Dates	Comments
BPO	1/9-6/2	Repaired - Replaced discriminator
GRL	11/29/95-2/1	Functioning again on its own
LTY	6/20-6/10	Dead - Communication problem
NEL	2/14-End	Dead - Damaged by snowfall
OSD	12/21/95-6/20	Repaired - Replaced batteries
RCM	11/08/95-6/10	Repaired - Replaced all electronic parts
RCS	1/09-End	Repaired - Replaced batteries
TDH	3/3-End	Dead - Damaged VCO
VFP	2/1-End	Dead - Winter conditions
VSP	2/25-End	Dead - Winter conditions
WI2	1/14-End	Dead - Winter conditions

Immediately following the May 2 (PDT) magnitude 5.4 Duvall earthquake, the USGS installed portable seismometers in the epicentral region. Initially, the USGS UW office installed analog MEQs. Later, USGS Golden replaced the MEQs with digital instruments. Table 2C lists the locations of the USGS temporary stations operated this quarter.

PNSN Response to moderate-sized earthquakes

The magnitude 5.4 Duvall earthquake was the second magnitude 5+ earthquake within the Puget basin in ~18 months, and the fourth damaging earthquake in the PNSN area during the past ~3 years. Following the Duvall earthquake, an automatically generated e-mail and pager alert was sent out within 62 seconds (the first preliminary magnitude estimate was 4.3), and the seismologist on duty called the Washington Dept. of Emergency Management (DEM) within 130 seconds. Within 12 minutes, staff (and the press!!) began to arrive at the Lab, and within 16 minutes we were able to provide DEM with a good location estimate and a 5+ estimate of the magnitude. Our audio library was updated 18 minutes after the earthquake and our Web-site was updated with a special section on the Duvall sequence within a few hours.

While the PNSN responds to several dozen felt earthquakes every year, damaging earthquakes occur less frequently, but pose special problems from an operational perspective. Recent seismicity (Scotts Mills OR, March 1993; Klamath Falls OR, Sept. 1993; Robinson Point, Jan. 1995; Duvall, May 1996) has provided us a test of our procedures, and a useful opportunity to examine what happens at the PNSN during an emergency situation. Minor operational problems following the Duvall event included congestion in the Lab caused by the press, failure of automatic data-retrieval programs to fetch broad-band data, and a

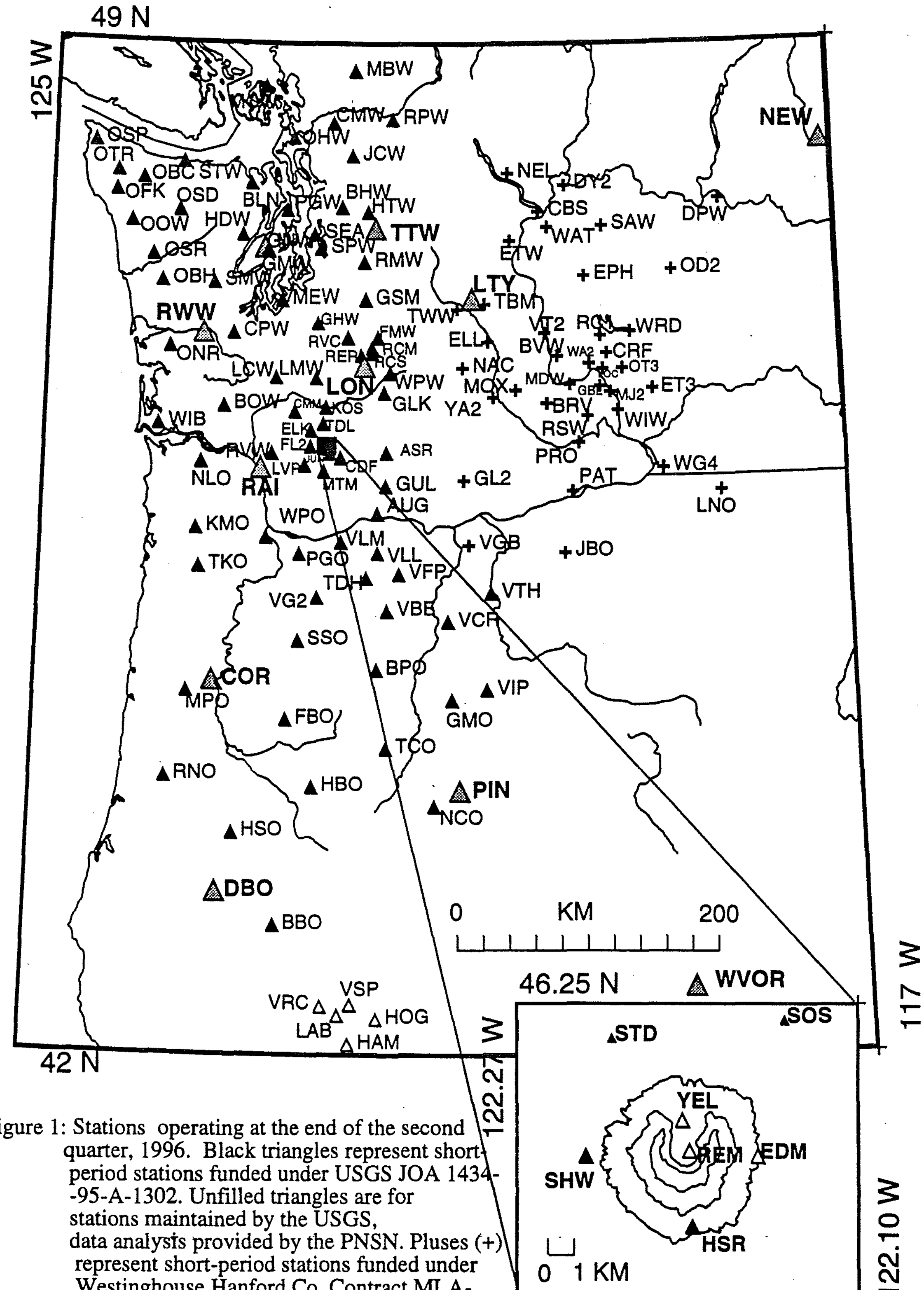


Figure 1: Stations operating at the end of the second quarter, 1996. Black triangles represent short-period stations funded under USGS JOA 1434--95-A-1302. Unfilled triangles are for stations maintained by the USGS, data analysis provided by the PNSN. Pluses (+) represent short-period stations funded under Westinghouse Hanford Co. Contract MLA-SVV-208775, and large shaded triangles show the locations of broad-band three-component instruments, funded either via JOA 1434-92-A-0963, NSF EAR-9207181, DOGAMI, or by the USGS-NSN.

network jam caused by intense Web activity.

In the past few years we have expanded our communications ability to include automatically generated faxes and e-mail messages, and automatic updates of information posted on the World-Wide-Web. In addition we now have a radio link to the Washington State Dept. of Emergency Services, and a direct phone link to the City of Seattle EOC. These enhancements produce new expectations on the part of our clients, and new responsibilities for us.

A PNSN seismologist is always on duty, and our standard procedure is to respond to pages from our automatic earthquake detection process (for any earthquake within our network of magnitude 2.9 or larger), or from Washington or Oregon emergency management agencies, or the UW police. Our automatic detection process generates PRELIMINARY faxes and electronic mail for earthquakes that it judges M>=2.9. Following a sizable felt earthquake, we have many responsibilities all demanding immediate attention. These responsibilities can be grouped as communication, data acquisition and analysis, and interpretation. These areas are tightly interconnected, as we attempt to rapidly calculate and communicate the best estimates of location, depth and magnitude, while simultaneously tracking aftershocks, planning field operations, and interpreting the tectonic significance of the event while staying in close communication with emergency managers.

Data acquisition and processing procedures

We are continuing the process of updating our data acquisition and processing procedures. New data formats were implemented at the beginning of the fourth quarter 1994, and early in 1995 we implemented a new data acquisition system, called **SUNWORM**. We also run a complete backup **SUNWORM** system. In the first quarter of 1996, we implemented automatic data recovery from our dial-up broad-band stations using our initial, automatic location and magnitude estimates to start a process that recovers and automatically merges broad-band data with our real-time-telemetry trace-data files.

All unedited, triggered, network trace data, plus continuous telemetry from station TTW; and other, non-continuous, event-by-event broadband data are backed up on a network archive tape. In addition to our master archives of event trace data, which are on 2.1 GByte exabyte tape, we are backing up edited trace data on high-speed, high-capacity (20 GByte) digital linear tape (DLT) cartridges. We have on-line trace data for local earthquakes for the past several years, and the DLT allows us to rapidly retrieve additional data as required. Trace data from former years is archived at the IRIS Data Management Center (DMC) in SEED format, where it can be retrieved by any investigator via Internet.

STATIONS USED FOR LOCATION OF EVENTS

Table 2A lists short-period, mostly one-component stations used in locating seismic events in Washington and Oregon. Table 2B lists broad-band, three-component stations operating in Washington and Oregon that provide data to the PNSN. Table 2C lists temporary stations operated by the USGS for a few weeks following the Duvall earthquake of May 1996. The first column in the table gives the 3-letter station designator, followed by a symbol designating the funding agency; stations marked by a percent sign (%) were supported by USGS joint operating agreement 1434-95-A-1302, and (+) indicates support under Westinghouse Hanford Company Contract MLA-SVV-208775. Other stations were supported from other sources. Additional columns give station north latitude and west longitude (in degrees, minutes and seconds), station elevation in km, and comments indicating landmarks for which stations were named.

TABLE 2A

Short-period Stations operating during the second quarter 1996

STA	F	LAT	LONG	EL	NAME
ASR	%	46 09 09.9	121 36 01.6	1.357	Mt. Adams - Stagman Ridge
AUG	%	45 44 10.0	121 40 50.0	0.865	Augspurger Mtn
BBO	%	42 53 12.6	122 40 46.6	1.671	Butler Butte, Oregon
BDM		46 58 05.5	120 57 07.2	1.811	Bald Mountain (temporary)
BHW	%	47 50 12.6	122 01 55.8	0.198	Bald Hill
BLN	%	48 00 26.5	122 58 18.6	0.585	Blyn Mt.
BOW	%	46 28 30.0	123 13 41.0	0.870	Boistfort Mt.
BPO	%	44 39 06.9	121 41 19.2	1.957	Bald Peter, Oregon
BRV	+	46 29 07.2	119 59 28.2	0.920	Black Rock Valley
BVW	+	46 48 39.6	119 52 59.4	0.670	Beverly
CBS	+	47 48 17.4	120 02 30.0	1.067	Chelan Butte, South
CDF	%	46 06 58.2	122 02 51.0	0.780	Cedar Flats
CMK		46 56 04.7	121 13 42.9	1.380	Chipmunk Creek (temporary)
CMM	%	46 26 07.0	122 30 21.0	0.620	Crazy Man Mt.
CMW	%	48 25 25.3	122 07 08.4	1.190	Cultus Mtns.
CPW	%	46 58 25.8	123 08 10.8	0.792	Capitol Peak
CRF	+	46 49 30.0	119 23 13.2	0.189	Corfu
DBO		43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon
DPW	+	47 52 14.3	118 12 10.2	0.892	Davenport
DY2	+	47 59 06.6	119 46 16.8	0.890	Dyer Hill 2
EDM	#	46 11 50.4	122 09 00.0	1.609	East Dome, Mt. St. Helens
ELK	%	46 18 20.0	122 20 27.0	1.270	Elk Rock
ELL	+	46 54 34.8	120 33 58.8	0.789	Ellensburg
EPH	+	47 21 22.8	119 35 45.6	0.661	Ephrata
ET3	+	46 34 38.4	118 56 15.0	0.286	Eltopia (replaces ET2)
ETW	+	47 36 15.6	120 19 56.4	1.477	Entiat
FBO	%	44 18 35.6	122 34 40.2	1.080	Farmers Butte, Oregon
FL2	%	46 11 47.0	122 21 01.0	1.378	Flat Top 2
FMW	%	46 56 29.6	121 40 11.3	1.859	Mt. Fremont
GBL	+	46 35 54.0	119 27 35.4	0.330	Gable Mountain
GHW	%	47 02 30.0	122 16 21.0	0.268	Garrison Hill
GL2	+	45 57 35.0	120 49 22.5	1.000	New Goldendale
GLK	%	46 33 50.2	121 36 30.7	1.320	Glacier Lake
GMO	%	44 26 20.8	120 57 22.3	1.689	Grizzly Mountain, Oregon
GMW	%	47 32 52.5	122 47 10.8	0.506	Gold Mt.
GRL		46 48 51.1	121 19 36.8	1.287	Granite Lake (temporary)
GSM	%	47 12 11.4	121 47 40.2	1.305	Grass Mt.
GUL	%	45 55 27.0	121 35 44.0	1.189	Guler Mt.
HAM	#	42 04 08.3	121 58 16.0	1.999	Hamaker Mt., Oregon
HBO	%	43 50 39.5	122 19 11.9	1.615	Huckleberry Mt., Oregon
HDW	%	47 38 54.6	123 03 15.2	1.006	Hoodsport
HOG	#	42 14 32.7	121 42 20.5	1.887	Hogback Mtn., Oregon
HSO	%	43 31 33.0	123 05 24.0	1.020	Harness Mountain, Oregon
HSR	%	46 10 28.0	122 10 46.0	1.720	South Ridge, Mt. St. Helens
HTW	%	47 48 14.2	121 46 03.5	0.833	Haystack Lookout
JBO	+	45 27 41.7	119 50 13.3	0.645	Jordan Butte, Oregon
JCW	%	48 11 42.7	121 55 31.1	0.792	Jim Creek
JUN	%	46 08 48.0	122 09 10.8	1.049	June Lake
KMO	%	45 38 07.8	123 29 22.2	0.975	Kings Mt., Oregon
KOS	%	46 27 40.8	122 11 25.8	0.828	Kosmos
LAB	#	42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon (4-comp)
LCW	%	46 40 14.4	122 42 02.8	0.396	Lucas Creek
LMW	%	46 40 04.8	122 17 28.8	1.195	Ladd Mt.
LNO	+	45 52 18.6	118 17 06.6	0.771	Lincton Mt., Oregon
LO2	%	46 45 00.0	121 48 36.0	0.853	Longmire
LOC	+	46 43 01.2	119 25 51.0	0.210	Locke Island
LVP	%	46 04 06.0	122 24 30.0	1.170	Lakeview Peak
MBW	%	48 47 02.4	121 53 58.8	1.676	Mt. Baker
MCW	%	48 40 46.8	122 49 56.4	0.693	Mt. Constitution
MDW	+	46 36 47.4	119 45 39.6	0.330	Midway
MEW	%	47 12 07.0	122 38 45.0	0.097	McNeil Island
MHL		46 52 56.6	122 03 50.4	1.215	Mashel Creek (temporary)
MJ2	+	46 33 27.0	119 21 32.4	0.146	May Junction 2
MOX	+	46 34 38.4	120 17 53.4	0.501	Moxie City

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
MPO	%	44 30 17.4	123 33 00.6	1.249	Mary's Peak, Oregon
MTM	%	46 01 31.8	122 12 42.0	1.121	Mt. Mitchell
MUP		46 50 21.4	121 07 31.0	1.456	Mud Springs (temporary)
NAC	+	46 43 59.4	120 49 25.2	0.728	Naches
NCO	%	43 42 14.4	121 08 18.0	1.908	Newberry Crater, Oregon
NEL	+	48 04 12.6	120 20 24.6	1.500	Nelson Butte
NLO	%	46 05 21.9	123 27 01.8	0.826	Nicolai Mt., Oregon
OBC	%	48 02 07.1	124 04 39.0	0.938	Olympics - Bonidu Creek
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OD2	+	47 23 15.6	118 42 34.8	0.553	Odessa site 2
OFK	%	47 57 00.0	124 21 28.1	0.134	Olympics - Forks
OHW	%	48 19 24.0	122 31 54.6	0.054	Oak Harbor
ONR	%	46 52 37.5	123 46 16.5	0.257	Olympics - North River
OOW	%	47 44 03.6	124 11 10.2	0.561	Octopus West
OSD	%	47 48 59.2	123 42 13.7	2.008	Olympics - Snow Dome
OSP	%	48 17 05.5	124 35 23.3	0.585	Olympics - Sooes Peak
OSR	%	47 30 20.3	123 57 42.0	0.815	Olympics Salmon Ridge
OT3	+	46 40 08.4	119 13 58.8	0.322	New Othello
OTR	%	48 05 00.0	124 20 39.0	0.712	Olympics - Tyee Ridge
PAT	+	45 52 55.2	119 45 08.4	0.262	Paterson
PGO	%	45 27 42.6	122 27 11.5	0.253	Gresham, Oregon
PGW	%	47 49 18.8	122 35 57.7	0.122	Port Gamble
PRO	+	46 12 45.6	119 41 08.4	0.553	Prosser
QTZ		47 00 40.4	121 05 20.9	1.054	Quartz Creek (temporary)
RC1	+	46 56 42.6	119 26 39.6	0.485	Royal City (3 comp.)
RCM	%	46 50 08.9	121 43 54.4	3.085	Mt. Rainier, Camp Muir
RCS	%	46 52 15.6	121 43 52.0	2.877	Mt. Rainier, Camp Schurman
REM	#	46 11 57.0	122 11 03.0	2.102	Rembrandt (Dome station)
RER	%	46 49 09.2	121 50 27.3	1.756	Mt. Rainier, Emerald Ridge
RMW	%	47 27 35.0	121 48 19.2	1.024	Rattlesnake Mt. (West)
RNO	%	43 54 58.9	123 43 25.5	0.850	Roman Nose, Oregon
RPW	%	48 26 54.0	121 30 49.0	0.850	Rockport
RSW	+	46 23 40.2	119 35 28.8	1.045	Rattlesnake Mt. (East)
RVC	%	46 56 34.5	121 58 17.3	1.000	Mt. Rainier - Voight Creek
RVN		47 01 38.6	121 20 11.9	1.885	Raven Roost (temporary)
RVW	%	46 08 53.2	122 44 32.1	0.460	Rose Valley
SAW	+	47 42 06.0	119 24 01.8	0.701	St. Andrews
SEA		47 39 18.0	122 18 30.0	0.030	Seattle (Wood Anderson)
SHW	%	46 11 37.1	122 14 06.5	1.425	Mt. St. Helens
SMW	%	47 19 10.7	123 20 35.4	0.877	South Mtn.
SOS	%	46 14 38.5	122 08 12.0	1.270	Source of Smith Creek
SPW	%	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle
SSO	%	44 51 21.6	122 27 37.8	1.242	Sweet Springs, Oregon
STD	%	46 14 16.0	122 13 21.9	1.268	Studebaker Ridge
STW	%	48 09 02.9	123 40 13.1	0.308	Striped Peak
TBM	+	47 10 12.0	120 35 52.8	1.006	Table Mt.
TCO	%	44 06 21.0	121 36 01.0	1.975	Three Creek Meadows, Oregon.
TDH	%	45 17 23.4	121 47 25.2	1.541	Tom,Dick,Harry Mt., Oregon
TDL	%	46 21 03.0	122 12 57.0	1.400	Tradedollar Lake
TKO	%	45 22 16.7	123 27 14.0	1.024	Trask Mtn, Oregon
TRW	+	46 17 32.0	120 32 31.0	0.723	Toppenish Ridge
LNO	+	45 52 18.6	118 17 06.6	0.771	Lincton Mt., Oregon
TWW	+	47 08 17.4	120 52 06.0	1.027	Teanaway
VBE	%	45 03 37.2	121 35 12.6	1.544	Beaver Butte, Oregon
VCR	%	44 58 58.2	120 59 17.4	1.015	Criterion Ridge, Oregon
VFP	%	45 19 05.0	121 27 54.3	1.716	Flag Point, Oregon
VG2	%	45 09 20.0	122 16 15.0	0.823	Goat Mt., Oregon
VGB	+	45 30 56.4	120 46 39.0	0.729	Gordon Butte, Oregon
VIP	%	44 30 29.4	120 37 07.8	1.731	Ingram Pt., Oregon
VLL	%	45 27 48.0	121 40 45.0	1.195	Laurance Lk., Oregon
VLM	%	45 32 18.6	122 02 21.0	1.150	Little Larch, Oregon
VRC	#	42 19 47.2	122 13 34.9	1.682	Rainbow Creek, Oregon
VSP	#	42 20 30.0	121 57 00.0	1.539	Spence Mtn, Oregon
VT2	+	46 58 02.4	119 59 57.0	1.270	Vantage2
VTH	%	45 10 52.2	120 33 40.8	0.773	The Trough, Oregon
WA2	+	46 45 19.2	119 33 56.4	0.244	Wahluke Slope
WAT	+	47 41 55.2	119 57 14.4	0.821	Waterville
WG4	+	46 01 49.2	118 51 21.0	0.511	Wallula Gap
WI2		47 08 10.6	121 22 52.0	1.528	Windy Gap (temporary)
WIB	#	46 20 34.8	123 52 30.6	0.503	Willapa Bay (3 comp.)
WIW	+	46 25 45.6	119 17 15.6	0.128	Wooded Island
WPO	%	45 34 24.0	122 47 22.4	0.334	West Portland, Oregon
WPW	%	46 41 53.4	121 32 48.0	1.250	White Pass
WRD	+	46 58 12.0	119 08 41.4	0.375	Warden
XTL		46 55 47.8	121 29 35.8	1.665	Crystal Mtn. (temporary)
YA2	+	46 31 36.0	120 31 48.0	0.652	Yakima
YEL	#	46 12 35.0	122 11 16.0	1.750	Yellow Rock, Mt. St. Helens

TABLE 2B

Broad-band three-component stations operating at the end of the second quarter 1996

STA	F	LAT	LONG	EL	NAME
COR		44 35 08.5	123 18 11.5	0.121	Corvallis, Oregon (IRIS station, Operated by OSU)
DBO		43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon (Operated by UO)
GNW	*	47 33 51.8	122 49 31.0	0.165	Green Mountain, WA (operated by UW)
LON	*	46 45 00.0	121 48 36.0	0.853	Longmire, WA (operated by UW)
LTY	*	47 15 21.2	120 39 53.3	0.970	Liberty, WA (operated by UW)
NEW		48 15 50.0	117 07 13.0	0.760	Newport Observatory (USGS-USNSN)
RAI		46 02 25.1	122 53 06.4	1.520	Trojan Plant, Oregon (OSU)
RWW	*	46 57 50.1	123 32 35.9	0.015	Ranney Well (operated by UW)
TTW	*	47 41 40.7	121 41 20.0	0.542	Tolt Res, WA (operated by UW)
PIN		43 48 40.0	120 52 19.0	1.865	Pine Mt. Oregon (operated by UO)
WVOR		42 26 02.0	118 38 13.0	1.344	Wildhorse Valley, Oregon (USGS-USNSN)

TABLE 2C

Temporary Stations operated by the USGS in the Duvall Area May, 1996

STA	TYPE	LAT	LONG	EL	NAME	AGENCY
CHC	MEQ	47 46 28.7	121 50 19.3	0.226	Cherry Creek	USGS
CKA	MEQ & REFTEK	47 43 37.5	121 52 38.8	0.155	Charak Arabians	USGS
EQ1	REFTEK	47 45 38.0	121 51 55.0	0.250	same as STO	USGS
HNC	MEQ	47 46 07.0	121 52 51.9	0.146	Hannan Crk.	USGS
STO	DR-200	47 45 38.0	121 51 55.0	0.250	same as EQ1	USGS
SWC	DR-200	47 46 37.2	121 51 17.9	0.148	Small Wonder Const.	UW

OUTREACH ACTIVITIES

The PNSN Seismology Lab staff provides an educational outreach program to better inform the public, educators, business, policy makers, and the emergency management community about seismicity and natural hazards. Our outreach includes lab tours, lectures, classes and workshops, press conferences, TV and radio news programs and talk shows, field trips, and participation in regional earthquake planning efforts. We provide an audio library which includes a message describing the seismic hazards in Washington and Oregon, another on earthquake prediction, and a frequently updated message on current seismic activity. Similar information is available via Internet on the World-Wide-Web (WWW):

http://www.geophys.washington.edu/seis1.html

The Duvall Earthquake

PNSN automated systems performed as designed providing preliminary location and magnitude estimates to State emergency management agencies and the USGS, and our audio library system provided accurate, timely information to the public. After the 1995 Robinson Point earthquake, we initiated a "media" phone number, which was very useful following the 1996 Duvall mainshock in allowing us to sort out the calls that needed immediate response. In addition, the World-Wide-Web is a very efficient way of providing information to large numbers of people, and we were able to put it to very effective use in the hours following the mainshock.

The Seismology Lab coordinated field operations following the Duvall earthquake, serving as a communications center for field crews installing strong motion and other instruments to record aftershocks of the Duvall event. Two press conferences were held. The first, organized with the help of L.G. Blanchard of UW News and Information, was a briefing for all media, and was held at UW a few days after the main shock. The second was arranged by the Seismology Lab for television news providers and took place at a temporary USGS seismometer site near the epicenter. Both press conferences resulted in excellent coverage by all regional TV news programs. In addition, PNSN Lab Coordinator Bill Steele arranged many press interviews and one-on-one matching of reporters and scientists to provide press coverage of field operations.

Special Events and Projects

The first Annual CREW (Cascadia Regional Earthquake Workgroup) Conference will be held at The UW Sept. 5 and 6, hosted by the PNSN and Geophysics Program. PNSN Lab Coordinator Bill Steele is organizing the conference for CREW, under support from FEMA (Federal Emergency Management Agency). Mr. Steele provides administrative support for CREW, which was organized to coordinate public and private efforts in regional hazard mitigation to minimize the consequences of future earthquakes including possible great Cascadia Subduction Zone events. CREW members represent lifeline agencies (utilities, transportation, emergency services, etc.) and private corporations and businesses. We anticipate three hundred participants for the first annual CREW conference. In addition to numerous conference planning meetings this quarter, the PNSN participated in three CREW support group meetings, two committee meetings, and a general business meeting in Portland hosted by Michael Cheston, Airport Manager, Port of Portland.

PNSN Lab Coordinator Bill Steele developed and presented a well-attended workshop on the public/private partnership role in hazard mitigation at the April 9th WWEN (Western Washington Emergency Network) conference, and also staffed an educational display with Jack Bernhardsen, CREW chairman.

Press Interviews, Lab Tours, and Workshops

PNSN staff provided more than 150 interviews broadcast by television and radio stations, either in response to earthquake activity or related to research on geologic hazard assessment, providing background and context for the general audience. During the second quarter, 12 K-12 school groups (about 250 individuals), and one UW class of educators from the School of International Studies (about 15 K-12 teachers), toured the Seismology Lab. PNSN staff gave presentations to classes at UW, the University of Minnesota Alumni, the Northwest Chapter of the International Conference of Building Officials, and the Redmond/ Woodinville Emergency Preparedness Fair, the City of Issaquah, and a half-dozen other community organization talks.

Telephone, Mail, and On-line outreach

The PNSN audio library system received 7,601 calls this quarter. We provide several recordings. The most popular is a frequently updated message on current seismic activity. In addition we have a tape describing the seismic hazards in Washington and Oregon, and another on earthquake prediction. Callers often request our one-page information and resource sheet on seismic hazards in Washington and Oregon. Thousands of these have been mailed out or distributed, and we encourage others to reproduce and further distribute this sheet. Our information sheet discussing earthquake prediction is also frequently requested. Callers to the audio library can also choose to be transferred to the Seismology Lab, where additional information is available. This quarter we responded to ~50 calls from the emergency management and government community, ~150 calls from the media, ~65 calls from educators, ~75 calls from the business community, and over 450 calls from the general public.

The list of recent Pacific Northwest earthquakes can be accessed by a variety of methods beyond the audio library described above; by modem, with utilities such as "ftp", and through the Internet and the World-Wide-Web. The computer methods have an advantage over the audio line. Not only are more earthquakes listed, but our automatic alarm system appends a preliminary location for any earthquake large enough to trigger the alarm (magnitude greater than 2.9) to the list; allowing public access to the preliminary location and magnitude estimate within minutes of the earthquake. Table A shows the number of times the computerized PNSN list of recent earthquakes magnitude 2.0 or larger was accessed. The Internet UNIX utility "finger quake@geophys.washington.edu" was most popular, followed by access over the WWW. For computer users without direct access to Internet, this information can be accessed via e-mail (by sending e-mail to "quake@geophys.washington.edu"), or by direct dial-up to modem ((206) 685-0889); modem setting: 8 bits, 1 stop bit, No parity; type "quake" at "geoterm" prompt and login as "quake"). The modem and e-mail services are used several hundred times each month.

TABLE 3A
Quarterly Comparison of Methods of Accessing PNSN list of most recent earthquakes, M>=2.0

Access Method	94-D	95-A	95-B	95-C	95-D	96-A	96-B
Finger Quake	32,000	110,000	93,000	80,000	72,000	83,000	90,255
World-Wide-Web	300	2,300	2,500	3,100	4,300	6,300	16,491
Remote Login as Quake	3,200	7,600	5,400	3,400	2,900	2,485	1,762
Via E-mail	786	956	613	444	477	317	459
Dialup Quake	520	811	580	604	439	406	763

The PNSN recent earthquake list, and much more, is also available through the World-Wide-Web (WWW) at: **http://www.geophys.washington.edu/seis1.html** which contains information from the PNSN and also links into other sources of earthquake information around the country and world through:

http://www.geophys.washington.edu/seismosurfing.html

Other popular features include our composite listings and maps of recent U.S. earthquakes from The Council of National Seismic Systems (CNSS), and local offerings from the PNSN. Table 3B summarizes WWW activity since 1994. Both Tables 3A and 3B show that usage has increased enormously. Upsurges occurred in January 1995 following a significant earthquake in Kobe, Japan and a local magnitude 5.0 (near Robinson Point, Maury Island, WA) and again in May 1996 following the Duvall Earthquake.

WWW information demands following the Robinson Pt. earthquake slowed the Geophysics Program's primary file server, halting critical relocation processing and necessitated cutting off WWW access. To improve capacity and reliability of our Web service the WWW area was moved to another machine. Anticipating continued growth demand for on-line services, the UW provided Geophysics with a Sun Netra computer to handle internet requests. The Duvall Earthquake occurred before its activation, and demand again overwhelmed capacity, crashing another important file server. Access was again denied temporarily, and files transferred to the new machine. The PNSN continues to plan for continued increases in demand and improvements in our computer network's capacity to serve it.

TABLE 3B
World Wide Web Activity per Quarter

Area Accessed	94-D	95-A	95-B	95-C	95-D	96-A	96-B
Seismosurfing	5,300	19,100	19,000	20,700	22,000	23,000	26,369
CNSS Earthquake Maps	1,300	3,600	3,800	6,200	9,900	18,300	20,492
CNSS Earthquake Catalog	1,400	4,300	4,400	5,900	6,600	9,400	10,467
PNSN List of most recent earthquakes, M>=2.0	300	2,300	2,500	3,100	4,300	6,300	16,491
Local Earthquake Maps	900	1,500	1,000	1,100	2,400	3,647	7,712
Other Features	12,800	43,200	46,300	43,100	83,800	136,000	297,459
Total for Seismology Area	**22,000**	**74,000**	**77,000**	**86,000**	**129,000**	**203,000**	**378,990**

Quarterly summaries of seismic activity in Washington and Oregon extracted from these quarterly reports can be found in the WWW area:

http://www.geophys.washington.edu/res_rept.html

The Cascadia Regional Earthquake Workgroup, CREW, has developed Web "home" pages with support from the Geophysics Program and the PNSN. This area, primarily developed by Paul Martin of Dames & Moore Inc., Seattle, is housed in the PNSN educational outreach area of our computer systems, at

http://www.geophys.washington.edu/CREW/index.html

The PNSN also hosts the WWW page for "**Tsunami!**" , a Web page developed by a graduate student, Benjamin Cook, under the direction of UW Civil Engineering's Dr. Katherine Petroff. Further development of the Web page is a joint project between the PNSN and Civil Engineering. The **Tsunami!** page can be found at:

http://www.geophys.washington.edu/tsunami/welcome.html

EARTHQUAKE DATA

There were 1526 events digitally recorded and processed at the University of Washington between April 1 and June 30, 1996. Locations in Washington, Oregon, or southernmost British Columbia were determined for 962 of these events; 864 were classified as earthquakes and 98 as known or suspected blasts. The remaining 564 processed events include teleseisms (182 events), regional events outside the PNSN (58), and unlocated events within the PNSN. Unlocated events within the PNSN include very small earthquakes and some known blasts. We are now routinely locating all sizable Centralia blasts, and retrieving and archiving broad-band data for them. Table 4, located at the end of this report, is the catalog of earthquakes and blasts located within the network for this quarter. For the Klamath Falls area, only earthquakes of magnitude 1.6 and larger have been included in Table 4. For the Duvall area, only earthquakes of magnitude 1.5 and larger have been included in Table 4.

Fig. 2 shows all earthquakes with magnitude greater than or equal to 0.0 ($M_c \geq 0$). Fig. 3 shows blasts and probable blasts ($M_c \geq 0$). Fig. 4 shows earthquakes located near Mt. Rainier ($M_c \geq 0$). Fig. 5 shows earthquakes located at Mt. St. Helens ($M_c \geq 0$). Fig. 6 shows a map of broad-band stations used to determine moment-tensor focal mechanisms. Fig. 7 shows the location and moment-tensor focal mechanisms for earthquakes with M_w >3.5. Fig 8. shows epicenter maps of the Duvall mainshock and selected aftershocks, plus a cross section, and a map of the approximate felt area, and Fig. 9 shows plots of magnitude versus time, and number of events of magnitude >1.5 per day for the Duvall Earthquake sequence, and a preliminary isoseismal map of the Puget Basin.

MOMENT TENSOR FOCAL MECHANISM SOLUTIONS

Moment-tensor focal mechanisms for earthquakes with M_w > 3.5 in the Pacific Northwest are included in this report. These solutions were computed under other support (USGS NEHRP Grant 1434-93-G-2326), at the Oregon State University under the direction of Dr. John Nabelek. The operation of broadband stations in Oregon (COR, RAI, DBO and PIN) was in part supported by a grant from the Oregon Department of Geology and Mineral Industries.

Moment-tensor solutions use data from 3-component broad-band stations in Washington, Oregon, California and British Columbia and from US National Seismic Network Stations in the western states of the US (Figure 6). The inversions are performed in the 0.01 - 0.1 Hz range, with the frequency band adjusted according to the earthquake magnitude and the station epicentral distance.

Moment tensors, best-fit double-couple mechanism, M_w, seismic moment, and depth are given in Table 5. The coordinate conventions of Aki and Richards (Quantitative Seismology: Theory and Methods, W. H. Freeman, San Francisco, 1980) are followed. Figure 7 shows the locations and focal mechanisms for the events listed in Table 5. Events 5, 6, 10, 12, 18 and 20 were relocated (marked R in Table 5).

An up-to-date catalogue of the moment tensor focal mechanisms is available on the World-Wide-Web server at Oregon State University: **http://quakes.oce.orst.edu.**

OREGON SEISMICITY

During the second quarter of 1996 a total of 82 earthquakes were located in Oregon between 42.0° and 45.5° north latitude, and between 117° and 125° west longitude. All but 19 of these were located in the Klamath Falls area, where a pair of damaging earthquakes in September of *1993* (Sept. 21, 03:29 and 05:45 UTC; M_c 5.9 and 6.0 respectively) were followed by a vigorous aftershock sequence which has decreased over time. This quarter, 15 earthquakes of magnitude 1.6 or larger were located in the Klamath Falls area. These are listed in Table 4.0.

Three earthquakes were reported felt in Oregon this quarter, including the largest Oregon earthquake this quarter; a magnitude 3.8 that occurred at about 17 km depth near Klamath Falls on April 7 at 18:33 UTC. The other two felt earthquakes in Oregon occurred on April 7 at 13:17 UTC at Mount Hood (magnitude 3, 4 km depth; only one call was received, from a TV station), and on May 16 at 05:10 UTC (magnitude 2.3, depth 29 km; felt by a few persons in the Charleston area of Coos County). Location quality for the May 16 earthquake is poor, as this event is on the extreme south-western edge of our network area.

WESTERN WASHINGTON SEISMICITY

During the second quarter of 1996, 750 earthquakes were located between 45.5° and 49.5° north latitude and between 121° and 125.3° west longitude. The deepest earthquake this quarter (M 1.1, depth ~82 km, on May 28 at 23:27 UTC) occurred near Skykomish.

The largest event in Western Washington this quarter was the magnitude 5.4 Duvall earthquake on May 3 at 04:04 UTC (May 2, at 9:04 PM PDT). This earthquake was the largest to occur in the Puget Basin since the 1965 magnitude 6.5. A special report on the Duvall sequence follows. Also see the sections on **Network Operations** and **Outreach Activities** for information about the earthquake's impact on network operations. Of the 28 earthquakes reported felt in western Washington this quarter, all but 2 of were in the Duvall sequence. However, our listing of felt events in Duvall is incomplete. The early part of the sequence included many events that were probably felt, but with such an active sequence it was hard to distinguish exactly which events were being reported. Several other effects add to the confusion; after such a widely felt shock the population becomes simultaneously jaded and hyper-sensitive; we receive felt reports for times when no earthquakes occurred, but sometimes do not receive felt reports although

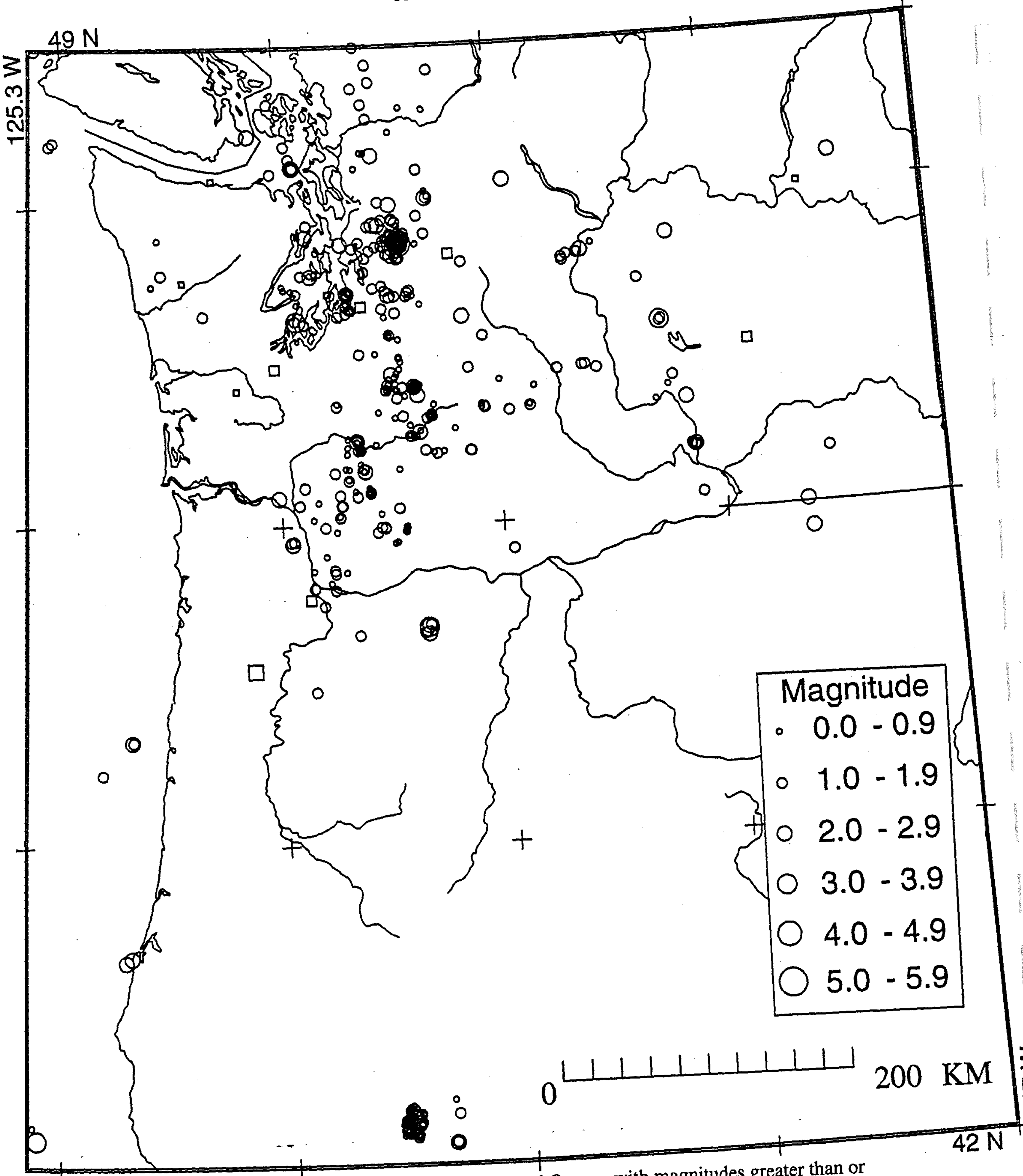


Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the second quarter of 1996. Square symbols indicate events located at depths of 30 km or more.

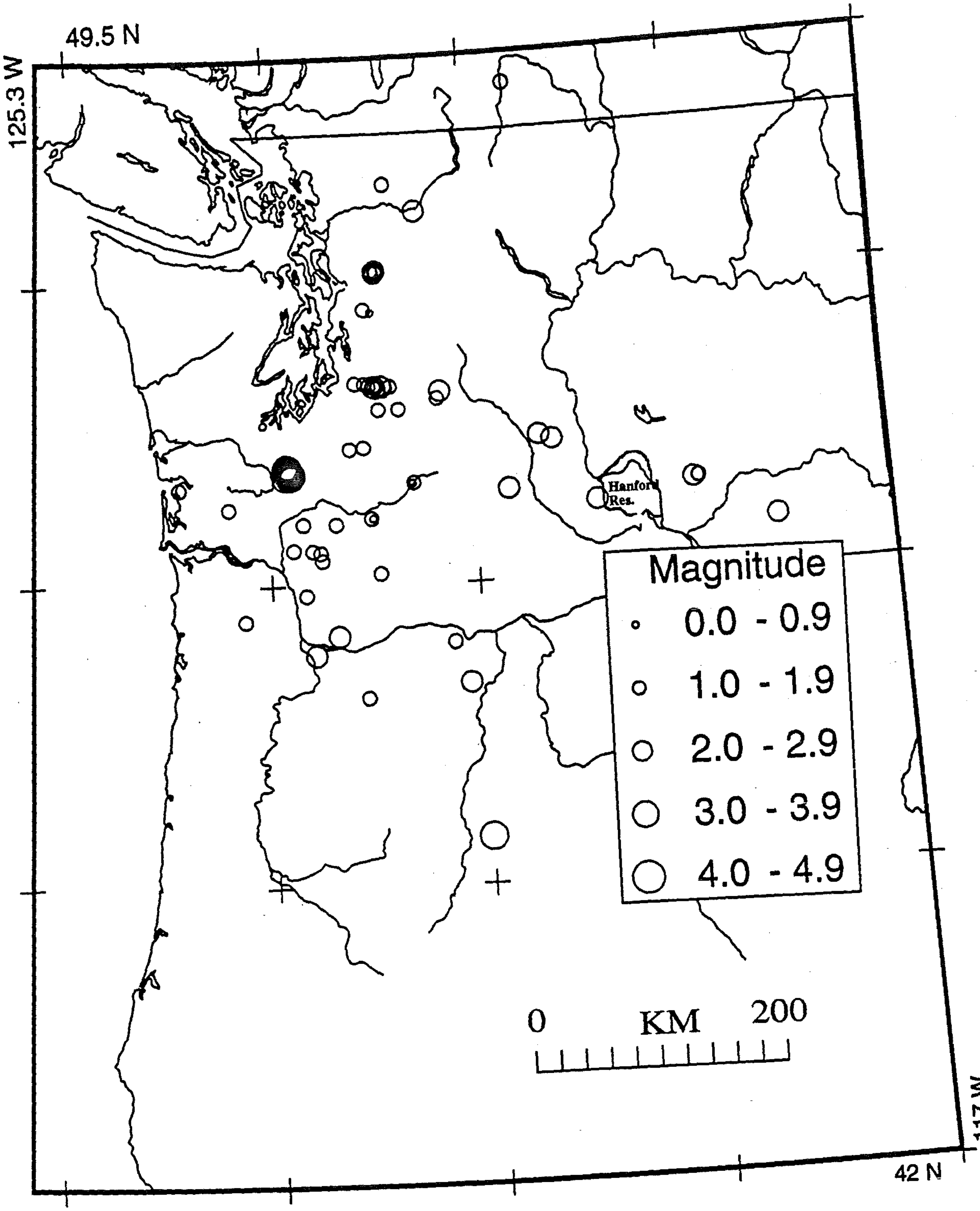


Figure 3: Blasts and probable blasts, second quarter, 1996.

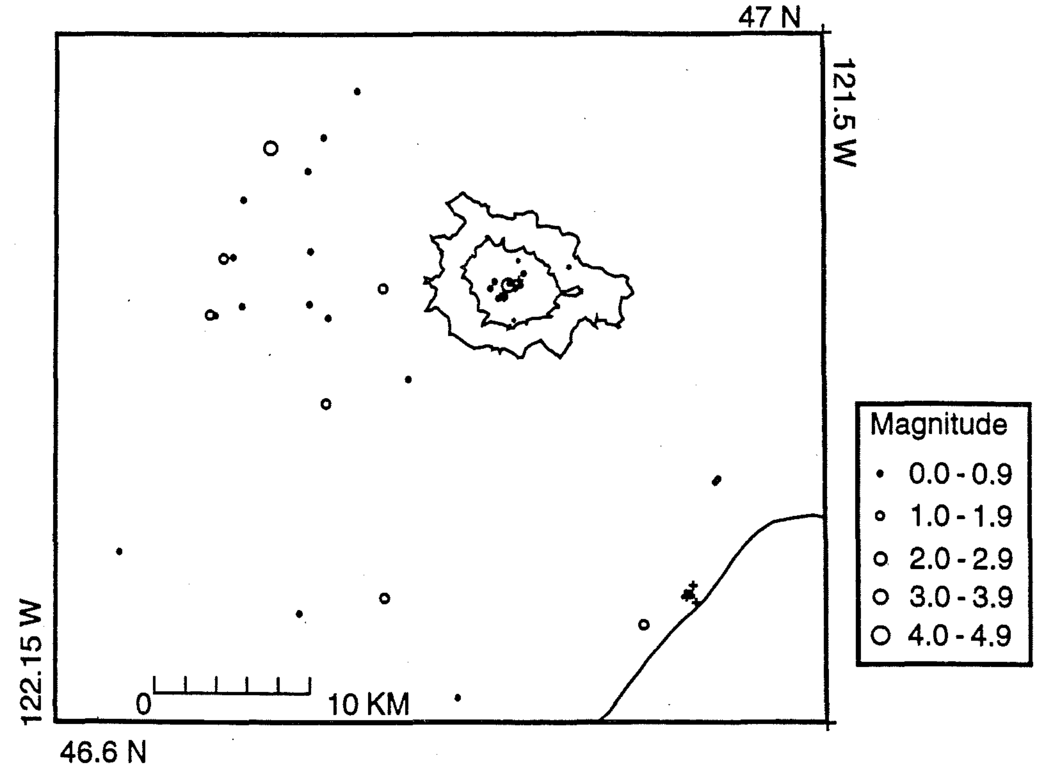


Figure 4: Earthquakes located in the Mt. Rainier area second quarter, 1996. All events shown are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

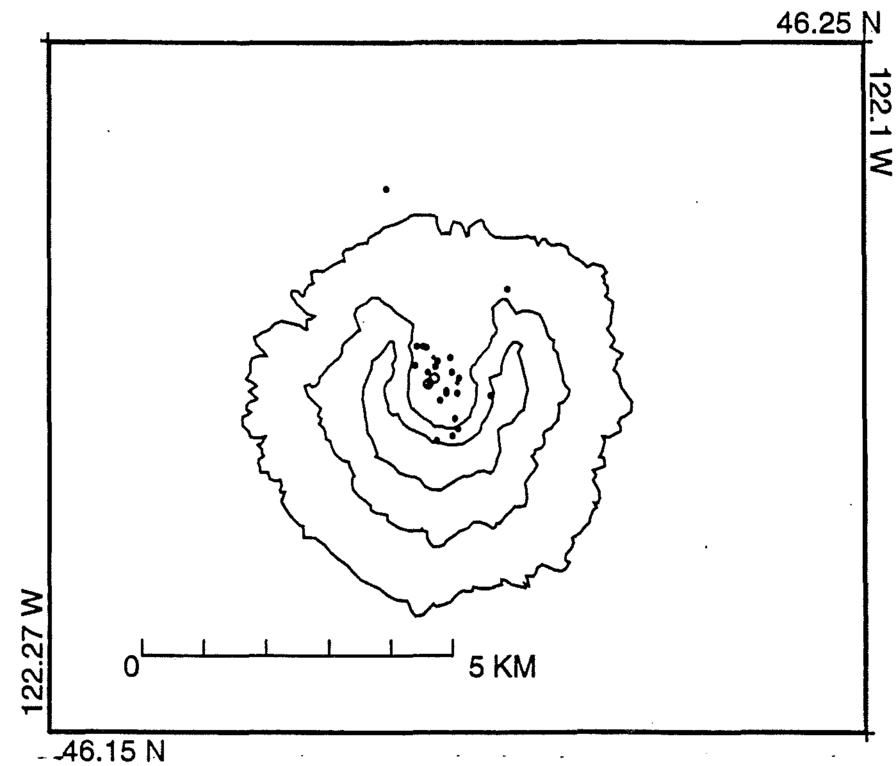


Figure 5: Earthquakes located in the Mt. St. Helens area second quarter, 1996. All events shown are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4.

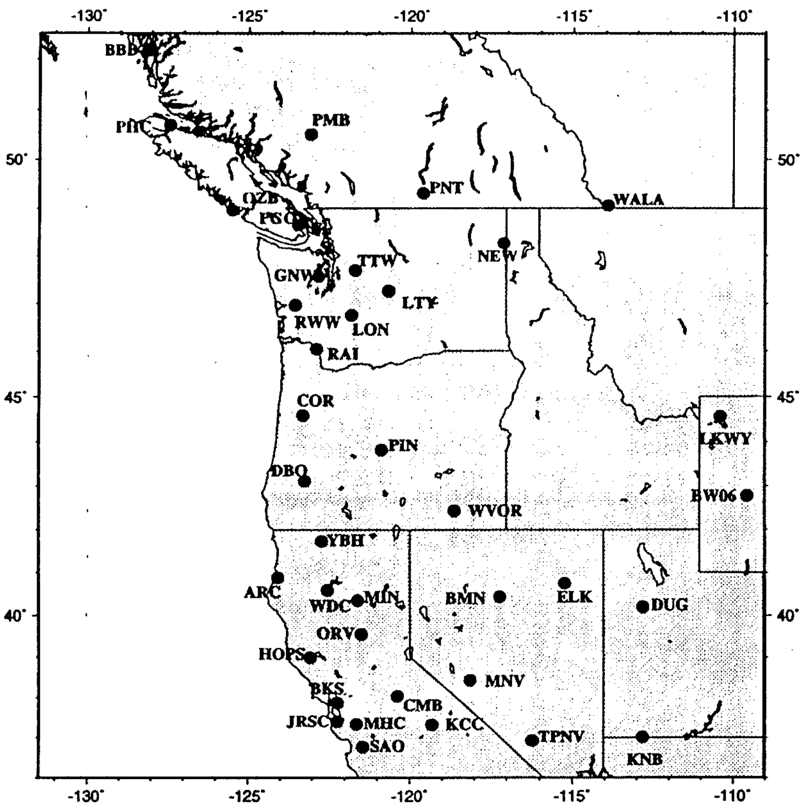


Fig. 6

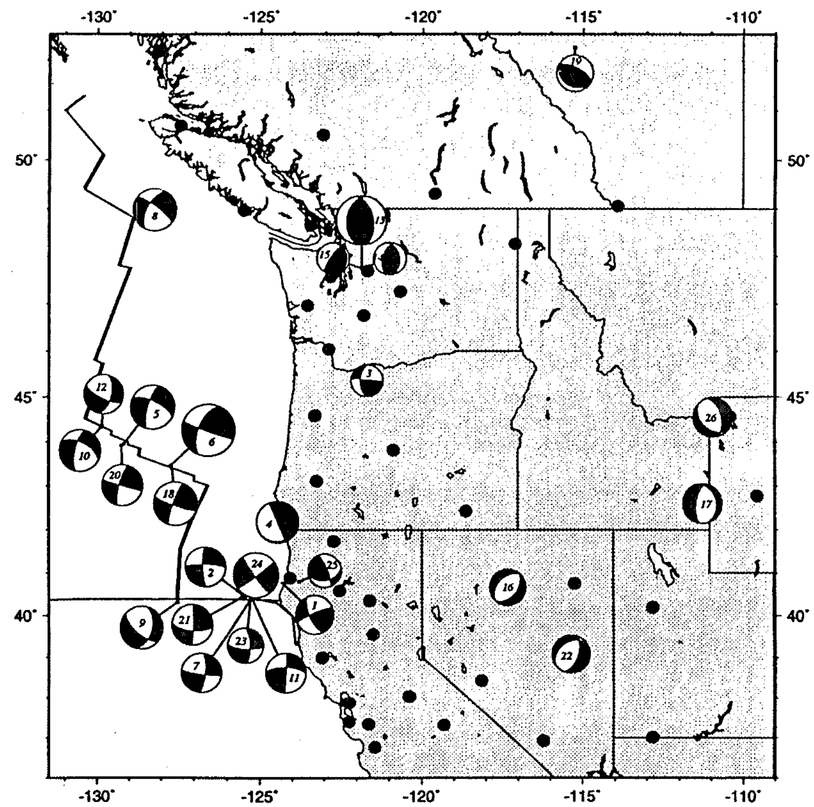


Fig. 7

Figure 6. Map of 3-component broad band stations used to determine moment-tensor focal mechanisms.
Figure 7. Map of best-fit double-couple focal mechanisms.

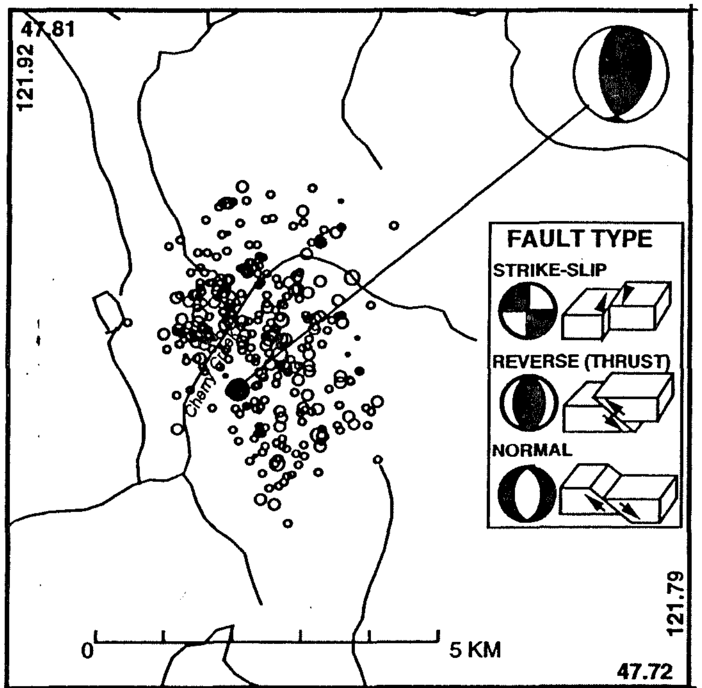


Fig. 8A Standard PNSN (P3 velocity model) locations for the Duvall Mainshock of 5/2/96 and the subset of aftershocks shown in Figs. 8C and 8D.

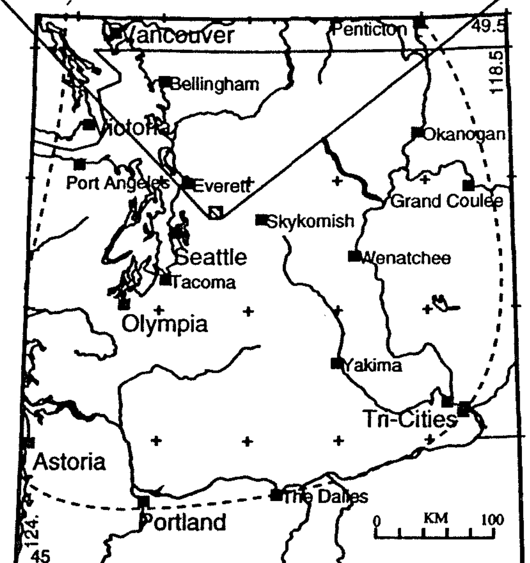


Fig. 8B Index map showing location of Duvall area. Dashed line shows approximate felt extent of the mainshock.

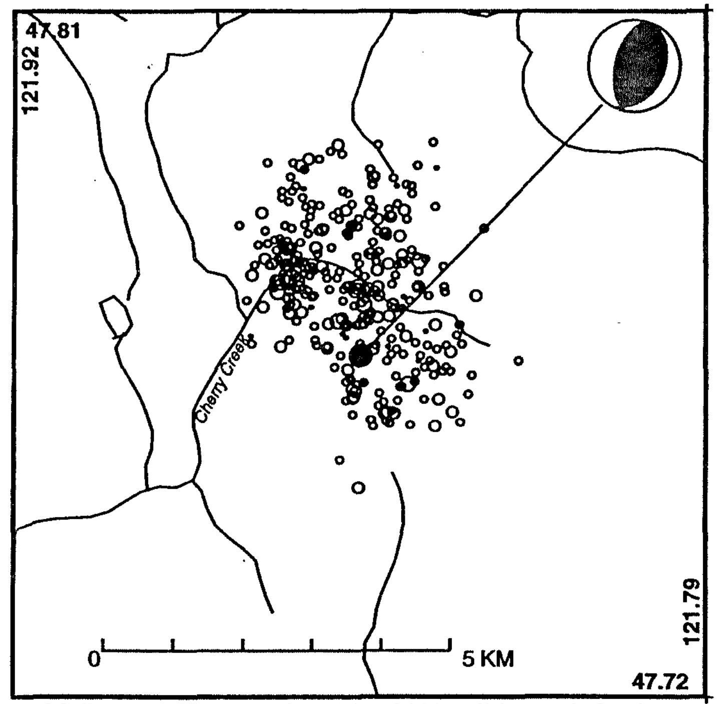


Fig 8C. Duvall Mainshock of 5/2/96 and 311 well-locatsed aftershocks (solution quality BB and better, relocated using a specialized velocity model and station set; vel.CE and sta.CE; no S phases used).

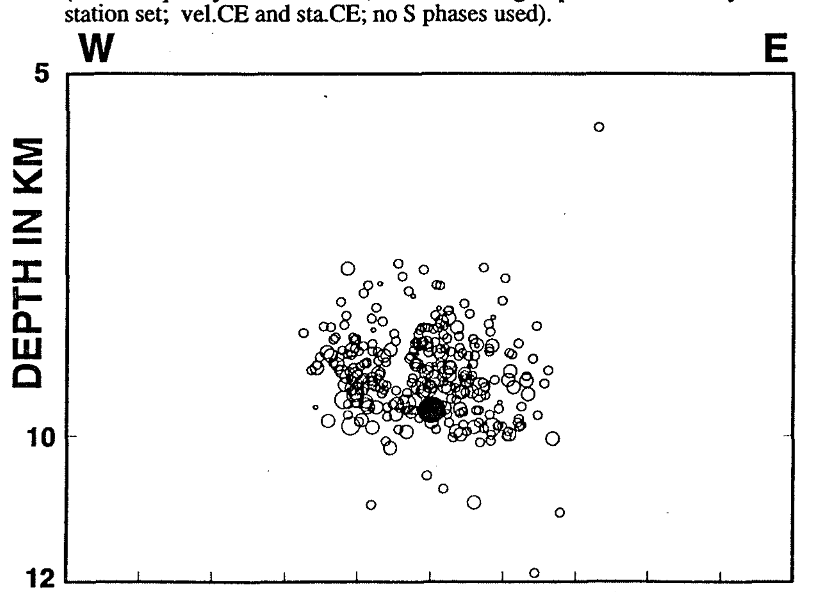


Fig. 8D. West to East cross-section of the Duvall Mainshock of 5/2/96 and the 311 well-located aftershocks shown above. Depth range shown is 5-12 km.

Fig. 9A Magnitude of Duval earthquakes as a function of time.

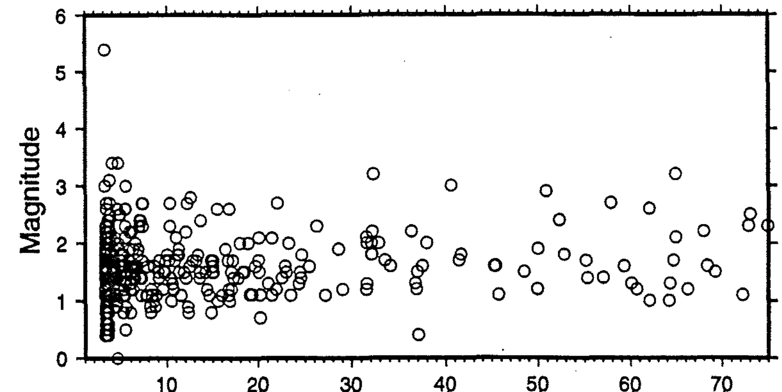


Fig. 9B Number of Duvall earthquakes with magnitude >1.5 as a function of time.

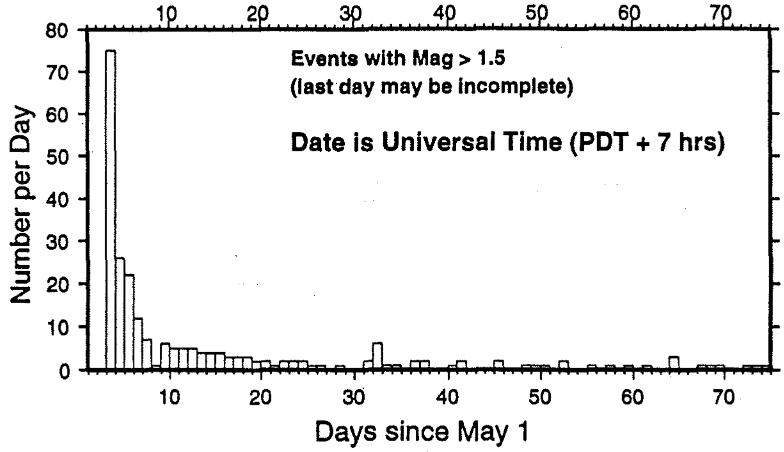
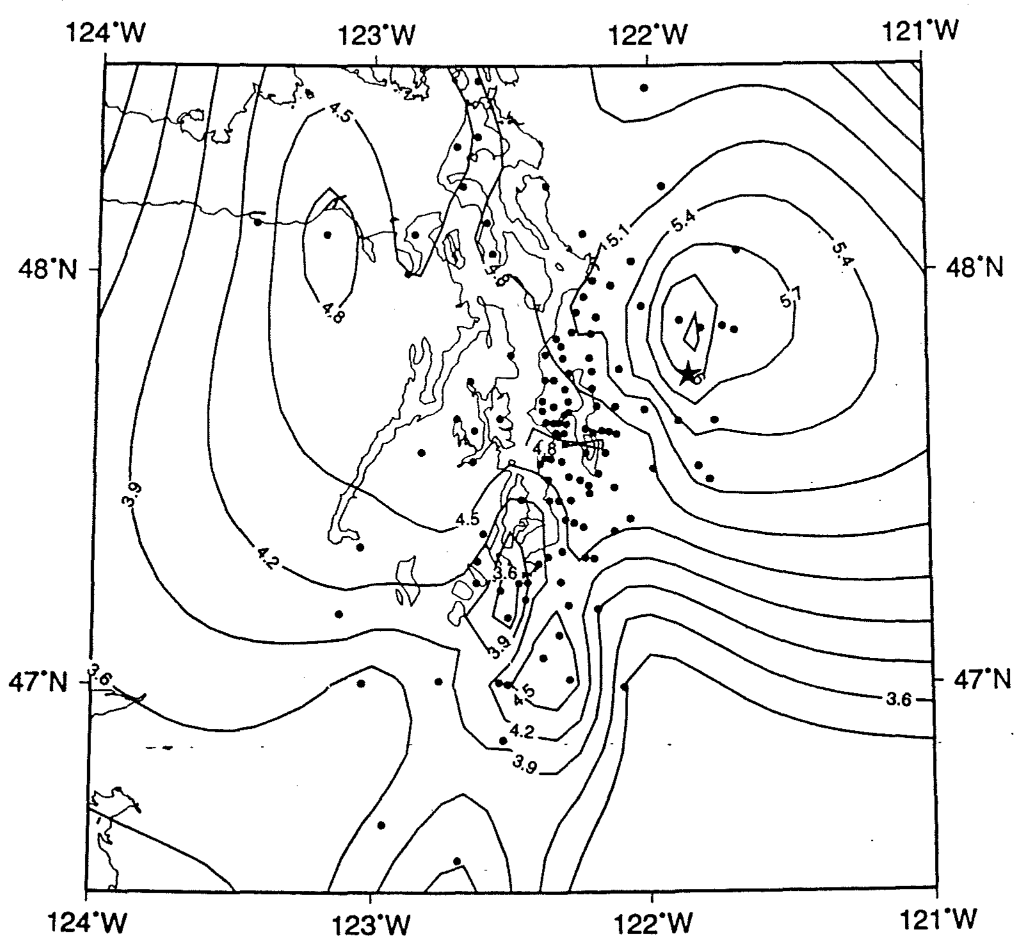


Fig. 9C Preliminary Isoseismal Contours for the Duvall mainshock. Contours based on World-Wide-Web responses received at PNSN, averaged over zip-code and plotted at the geographic center of each zip code.



earthquakes likely to have been felt occurred.

The remaining two felt events were both deep crustal earthquakes; magnitude 2.9 on April 2 at 17:29 UTC at about 23 km depth - felt by a few persons in Carnation, North Bend and Snoqualmie; and magnitude 3.0 on June 23 at 23:37 UTC at about 19 km depth - felt in Hoodsport and Port Orchard.

The Duvall Earthquake Sequence

The magnitude 5.4 Duvall mainshock occurred on May 2 at 9:04 PM PDT (May 3, 04:04 UTC). The epicenter, approximately 9 km east-northeast of Duvall, Washington, is nearly coincident with the epicenter estimated for the similar sized 1932 earthquake discussed below. The epicentral region is sparsely populated, and only one residence is located within 2 km of the mainshock. Structural damage appears to be restricted to a single facility, a BPA power station located near Monroe, Washington. Earthquake related road failure occurred on two unpaved roads east of the epicentral area (sections 19 and 33, T27N, R8E). The larger failure was about 140 m in length with about 45 cm lateral and vertical displacement. Additionally, evidence for several earthquake-induced rock failures was observed on a hill south-southeast of Cedar Ponds Lake (section 29, T27N, R8E). Ralph Haugerud, USGS geologist, estimated the largest failure to have a volume between 200 and 2,000 cubic meters. He noted no evidence of liquefaction during an aerial reconnaissance. Reports of subsequent earthquake-related failure in a parking structure in Bellevue were erroneous; City of Bellevue Building Officials attribute the failure to gravity and construction techniques. No evidence of mainshock-related surface rupture in the epicentral area has been reported.

The mainshock was felt most strongly in the Duvall-Monroe area where residents reported items knocked from shelves and broken china and glassware. The earthquake was felt moderately by many residents throughout the Puget Sound area from Olympia to southern British Columbia. The earthquake was felt by a few as far away as Portland, Oregon, and Pasco, Washington. The total area over which the earthquake was felt, shown in Figure 8B, was over 200,000 square kilometers.

Isoseismal "Intensity" Maps

Figure 9C shows preliminary isoseismal contours for the Duvall mainshock. It was generated by averaging over all responses from one zip-code and using that average at the geographic center of the zip code (dots on the map) and then producing a smooth contour of those values.

The map was compiled from 845 individual intensities computed from a questionnaire which the UW provided via the World-Wide-Web. The questionnaire consisted of short questions with multiple choice answers, and the numeric intensity was computed by assigning point values to the possible responses, and weighting the questions. The "felt form" and the algorithm for interpreting it was suggested to us by Dr. Lori Dengler of Cal. State Humboldt. Some individual reports were for shaking stronger than the value shown on Fig. 9 C, which shows averages over a zip-code district, and so will not represent the worst shaking in an area. Figure 9C shows that ground motion intensity of 6.3 (strong intensity) occurred in the epicentral area, and that most of the Puget Sound region had experienced intensities between 4.5 and 5 (moderate intensity).

Focal Mechanisms

Both P-wave first motions recorded on the short-period array and moment-tensor solutions from three-component seismograms recorded on the broadband array reveal that the mainshock had a thrust mechanism with an east-west compression axis. First-motion focal mechanisms are shown in figures 8A and 8C. Seismograms from the PNSN broadband array provide an independent estimate of the focal mechanism and also allow determination of the total seismic moment, which can provide insight into the stress release during the earthquake as well as the rupture area. Moment tensor inversions were carried out by three independent research groups (OSU, UW, and UC Berkeley) using slightly different procedures and data. All three groups obtained very similar results, and the OSU solution is shown as Event 13 in Table 5. The estimated moment is around 5.5x10^23 dyne-cm which corresponds to a moment magnitude of 5.1. The UW solution indicates the mainshock rupture time was around 2 seconds, suggesting the fault radius was less than 5 km.

Aftershock activity versus time is shown in Figures 9A and 9B. These plots show that the aftershock activity decreased significantly after the first week following the mainshock. Aftershocks with magnitudes around 2.0 have continued to occur several weeks after the mainshock. For the period of May 2 through June 30, there are 377 Duvall area earthquakes in the PNSN catalog. Of these events, there are 342 earthquakes of magnitude 1.0 or larger, 92 of magnitude 2.0 or larger, and 9 of magnitude 3.0 or larger. Most (7 out of 9) of the magnitude 3.0 or larger aftershocks occurred in the first week following the mainshock. The largest aftershock was a magnitude 3.4 which occurred on May 5 at 7:38 AM PDT (14:38 UTC). OSU moment tensor inversions for the two largest aftershocks are presented as Events 14 and 15 in Table 5.

Preliminary analyses of aftershock locations do not indicate an alignment of aftershocks along a fault plane. Figures 8C and 8D show a map and cross section, respectively, of relocated events resulting from an analysis (discussed below) that incorporates additional data from some of the temporary stations. The cross section in Figure 8D shows that most of the earthquake depths are between 7 and and 11 km. The shallow depths and continued activity for the Duvall earthquake sequence are consistent with the assertion that deeper crustal mainshocks (e.g., 1995 Robinson Point, 20 km; and 1989 Storm King Mountain, 18 km) have very few aftershocks (<30) which have small magnitudes (<2.4), while shallow crustal mainshocks (e.g., 1995 Scotts Mills, 15 km; 1990 Deming, <5 km; and 1981 Elk Lake, 7 km) have a significant number of aftershocks (70-600) and generally exponential decay in aftershock activity.

Relocation of Duvall Earthquakes

The mainshock and aftershocks were relocated using a master-event technique to improve the precision of locations and depth estimates. A set of 27 well-located earthquakes with readings from close-in USGS temporary stations within 1 or 2 km of the epicentral locations was used to determine station corrections. Results are presented in Figures 8C and 8D, and the methodology is discussed below.

Step 1: A subset of 10 stations with good azimuthal coverage and reading quality was selected, for which 6 of the well-located events had "good" readings on all ten stations (i.e. residuals low enough that the reading was used in the solution). The six events were relocated using the C0 (Cascade) velocity model without station corrections, and P readings from the ten stations which were common to all six master events. The azimuthal gaps (after relocation) ranged from 68-78 degrees. and the nearest station was within 1 km for all six of the master events. Magnitudes of master events ranged from 2.5-3.2.

Stations used were : CHC, HTW, BHW, TTW, RMW, JCW, BLN, FMW, SMW, CKA.

Events used were: 96050314153p, 96050316021p, 96050316070p, 96050412163p, 96050419574p, 96050507253p.

Step 2: The average residual determined for each of the 10 stations from Step 1 was set as the station correction, and the full set of 27 events with close-in readings was relocated using P waves only, and the station set of 10 stations with newly-determined station corrections. The locations were then fixed, and another location run performed to compute average station residuals for additional stations. An expanded station set (sta.CE) and an improved version of the Cascade velocity model (vel.CE) was formulated by adding station corrections for stations on which at least 10 P-wave readings were available from among the set of 27, and for which the standard deviation between the residuals was .1 seconds or less.

Corrections were determined for additional stations: GSM, RPW, HDW, XTL, QTZ, TWW, CMK, RER, MBW, LO2, ELL, WAT, CKA, GRL, TBM, MUP, WPW, CBS, MCW.

Step 3: The revised set of stations (sta.CE) and velocity model (vel.CE) were used to relocate all events in the map area shown. Events of location quality "BB" or better are shown in both map views and in the cross sections. Even after careful relocation, no obvious single fault plane can be discerned. Several features of the earthquake cluster can be noted. The relocated earthquakes are grouped in a very narrow depth range, from 8 to 10 km. In map view, the cluster of relocated events is elongated in the NW-SE direction, with the mainshock closer to the southeast end. Comparing the relocated events in Fig. 8B to the standard network locations shown in Fig. 8A, shows that the relocated events shift about 2 km to the northeast relative to the standard locations, and cluster somewhat more tightly.

Earthquake History of the Duvall Area

The most significant historic earthquake in the Duvall Area prior to May, 1996 was the well known "Tolt River Earthquake", which occurred on the evening of July 17, 1932, at 10:30 PM. The estimated location of the 1932 earthquake, based on instrumental recordings at Victoria and Seattle, and on the area of greatest intensity of shaking, was 47.75N 121.83W (Bradford and Waters, 1934, *Bull. Seism. Soc. Am., V. 24, pp. 51-62*); almost exactly at the location of the May 2, 1996 event (47.76N, 121.85W). Magnitude estimates for the 1932 earthquake have been based on the total area over which the earthquake was felt using a simple formula proposed by Toppozada (1975):

$$\text{Magnitude} = -1.88 + 1.53 \log (A)$$

Where A is the felt area in square km. The estimated magnitude of the 1932 earthquake range from 5.1 to 6.2, the wide variation is because there are huge discrepancies in the felt areas given by various sources.

Bradford and Waters (1934) conducted the most extensive investigation of the felt area, and their estimate was that the earthquake was felt over an area of 70,000 square miles, corresponding to a circle of radius 150 miles (240 km). This would suggest a magnitude of 6.2. Bradford and Waters state that the 1932 earthquake was felt as far as Chehalis and Centralia in the south (150 miles), to Coulee City and Concunully to the east (150 miles), to Bellingham and Vancouver to the north (75 miles), and that the western felt extent was not known. The lower magnitude estimate of 5.1 results from the felt area of 14,000 square miles (corresponding to a circle of radius 67 miles) given in *Earthquake History of the United States (1973)*, which references the felt-area map given in *US Earthquakes (1932)*. The true magnitude is likely to lie somewhere between these estimates, as Bradford and Waters appear to have overestimated the felt area, and *US Earthquakes* has clearly underestimated it.

The felt area of the 1932 earthquake, as described by Bradford and Waters, approximates that of the 1996 earthquake. However their isoseismal contours are quite dissimilar to those estimated by our preliminary analysis of our World-Wide-Web intensity survey. Our estimated intensities for the 1996 event in Seattle are about one unit higher than Bradford and Waters' estimates for the 1932 event. Because techniques for assigning intensities have varied over time, and were still being developed in 1932, differences in the isoseismal contours for the 1932 and 1996 events could result solely from differences in the survey techniques used.

The 1932 earthquake, according to Bradford and Waters, was almost everywhere described as being accompanied by a roar, a noise like the "rushing of wind", or by explosive-like noises. Similarly, observers near the epicenter of the 1996 Duvall earthquake reported hearing loud noises during the quake.

US Earthquakes, an annual publication of the Coast and Geodetic Survey, describes a significant sequence of foreshocks prior to the 1932 Tolt River earthquake. The table below lists earthquakes reported by *US Earthquakes* in the vicinity between 1928 and 1932. No further earthquakes were reported in that immediate area until 1952.

The sequence began in 1928 with a 4:52 AM earthquake that cracked plaster in Startup, WA. A newspaper report from the Seattle Post-Intelligencer of Feb. 3, 1928 reports: "Residents of all parts of Seattle, Issaquah, Sultan, and other sections of northwest Washington reported the temblor which awakened them during the night. The university scientists first reported that no quake was registered, but continued reports of the upheaval caused a second check with the magnifying glass, and it was then learned that a quake had occurred." They go on to state that "Two sharp shocks were reported at Index, Sultan, Startup, Goldbar and Monroe...Stephen Mitchell, Everett city building inspector, reported that another shock at 3:30 rocked his bed."

No earthquakes were reported in *US Earthquakes* in 1929, one was reported in 1930 and five in 1931. In January 1932, an earthquake near Sultan was strong enough to stop a pendulum clock at the Seattle weather bureau and disturb pictures in Everett (Everett Daily Herald, Jan. 6, 1932), and was described as a "hair raising thrill" in Monroe (Monroe Monitor, Jan. 8, 1932). According to *US Earthquakes*, this was followed by three additional foreshocks, the mainshock, and three aftershocks, all in 1932. (However, no newspaper account could be found that mentioned the largest listed aftershock, Aug. 6; nor was it mentioned in the Bradford and Waters (1934) article).

TABLE I.
List of Earthquakes reported by *US Earthquakes* in the Sultan area, 1928-1932

Year	Date	Local Time	Place	Description
1928	Feb. 2	04:52	Startup (47.8N, 121.7W)	Generally felt. Strong shake and roaring. Cracking of plaster and paper. People generally alarmed.
1930	Aug. 18	23:05	Sultan (47.8N, 121.8W)	Slight
1931	Jan. 20	23:10	Sultan (47.8N, 121.8W)	Slight
1931	May 28	23:10	Sultan (47.8N, 121.8W)	Feeble
1931	June 11	23:30	Sultan (47.8N, 121.8W	Feeble
1931	Aug. 19	07:05	Sultan (47.8N, 121.8W)	Feeble
1931	Dec. 29	00:27	Sultan (47.8N, 121.8W)	Feeble
1932	Jan. 5	15:13	Sultan (47.8N, 121.8W)	Moderate, superficial damage in Monroe
1932	Feb. 10	23:10	Sultan	MM Intensity III
1932	Feb. 19	12:13	Sultan	MM Intensity III
1932	June 13	10:30	Sultan	Feeble
1932	July 17	22:03	Sultan	Mainshock, see comments
1932	Aug. 6	22:00	Sultan	Moderate, MM Int. IV
1932	Aug. 30	23:50	Sultan	MM Intensity III
1932	Sept. 19	23:05	Sultan	MM Intensity III,Slight
1952	Feb. 23	01:07	Duvall	Reported felt

Mount Rainier Area

Figure 4 shows earthquakes near Mount Rainier. The number of events in close proximity to the cone of Mt. Rainier varies over the course of the year, since the source of much of the shallow surface-type activity is presumably ice movement or avalanching, which is seasonal in nature. Events with very low frequency signals (1-3 Hz) believed to be icequakes are assigned type "L" in the catalog. Emergent, very long duration signals probably due to rockfalls or avalanches are assigned type "S" (see Key to Earthquake Catalog). "L" and "S" type events are not shown in Figure 4.

A total of 59 events (11 of them smaller than magnitude 0., and thus not shown in Fig. 4) were located within the region shown in Fig. 4. Of these, 21 were located in the "Western Rainier Seismic Zone" (WRSZ), a north-south trending lineation of seismicity approximately 15 km west of the summit of Mt. Rainier (for counting purposes, the western zone is defined as 46.6-47° N latitude, 121.83-122° W longitude). Closer to the summit (within 5 km), there were 20 earthquakes, but no type "L" or "S" events were located this quarter (types L and S are not shown in Fig.4). The remaining events were scattered around the cone of Rainier as seen in Fig. 4.

Mount St. Helens Area

Figure 5 shows tectonic earthquakes near Mount St. Helens. Low frequency (L) and avalanche or rockfall events (S) are not shown. In the second quarter, 69 events (only 27 magnitude 0. or larger), were located at Mt. St. Helens in the area shown in Fig. 5. This quarter, no surficial earthquakes (type "S" or "L") were located. Of this quarter's earthquakes, 34 (12 of them larger than magnitude 0.) were deeper than 4 km. The largest event at Mount St. Helens, M_c 1.6, (May 19 at 02:17 UTC) was at a depth of ~2 km.

EASTERN WASHINGTON SEISMICITY

During the second quarter of 1996, 40 earthquakes were located in eastern Washington. The largest quake in eastern Washington this quarter was on June 25 at 07:30 UTC. It was magnitude 3.0 and was located at a depth of ~17 km near Ephrata, where it was reported felt to the Grant County Dept. of Emergency Management.

OTHER SOURCES OF EARTHQUAKE INFORMATION

We provide automatic computer-generated alert messages about significant Washington and Oregon earthquakes by e-mail or FAX to institutions needing such information, and we regularly exchange phase data via e-mail with other regional seismograph network operators. The "Outreach Activities" section describes how to access PNSN data over modem, Internet, and World-Wide-Web. To request additional information by e-mail, contact bill@geophys.washington.edu.

Earthquake information in the quarterlies is published in final form by the Washington State Department of Natural Resources as information circulars entitled "Earthquake Hypocenters in Washington and Northern Oregon" covering the period 1970-1989 (see circulars Nos. 53, 56, 64-66, 72, 79, 82-84, and 89). These circulars, plus circular No. 85, "Washington State Earthquake Hazards", are available from Washington Dept. of Natural Resources, Division of Geology and Earth Resources, Post Office Box 47007, Olympia, Wa. 98504-7007, or by telephone at (360) 902-1450.

A full-color map called "Earthquakes in Washington and Oregon 1872-1993", by Susan Goter (USGS Open-File Report 94-226A), and its companion pamphlet "Washington and Oregon Earthquake History and Hazards", by Yelin, Tarr, Michael, and Weaver (USGS Open-File Report 94-226B) is available from "Earthquake Maps" U.S. Geological Survey, Box 25046, Federal Center, MS 967, Denver, CO 80225, phone (303)273-8420. The price is $12. (including shipping and handling). The pamphlet (USGS Open-File Report 94-226B) is also available separately.

Other regional agencies provide earthquake information. These include the Geological Survey of Canada (Pacific Geoscience Centre, Sidney, B.C.; (604) 363-6500, FAX (604) 363-6565), which produces monthly summaries of Canadian earthquakes; the United States Geological Survey which produces weekly reports called "Seismicity Reports for Northern California" (USGS, attn: Steve Walter, 345 Middlefield Rd, MS-977, Menlo Park, Ca, 94025) and "Weekly Earthquake Report for Southern California" (USGS, attn: Dr. Kate Hutton or Dr. Lucy Jones, California Institute of Technology, Pasadena, Ca.)

QUARTERLY NETWORK REPORT 96-C
on
Seismicity of Washington and Oregon

July 1 through September 30, 1996

Pacific Northwest Seismograph Network
Geophysics Program
Box 351650
University of Washington
Seattle, Washington 98195-1650

This report is prepared as a preliminary description of the seismic activity in Washington State and Oregon. Information contained in this report should be considered preliminary, and not cited for publication. The views and conclusions contained in this document should not be interpreted as necessarily representing the official policies, either express or implied, of the U.S. Government.

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CONTENTS

FIGURES

TABLES

INTRODUCTION

This is the third quarterly report of 1996 from the University of Washington Geophysics Program *Pacific Northwest Seismograph Network* (PNSN), covering seismicity of all of Washington and western Oregon. These comprehensive quarterlies have been produced since the beginning of 1984. Prior to that we published quarterlies for western Washington in 1983 and for eastern Washington from 1975 to 1983. Annual technical reports covering seismicity in Washington since 1969 are available from the U.W. Geophysics Program.

This quarterly report discusses network operations, seismicity of the region, unusual events or findings, and our educational and outreach activities. This report is preliminary, and subject to revision. Some earthquake locations may be revised if new data become available, such as P and S readings from Canadian or USGS CALNET seismograph stations. Findings mentioned in these quarterly reports should not be cited for publication.

NETWORK OPERATIONS

Table 1A gives approximate periods of time when individual stations were inoperable. Data for Table 1 are compiled from weekly plots of network-wide teleseismic arrivals and automated digital signal checks, plus records of maintenance and repair visits. Fig. 1 shows a map view of stations operating during the quarter. During the third quarter, repairs were made to stations damaged last winter and visits were made to many other stations for routine maintenance and in preparation for the coming winter. The telephone cable that runs from station SPW (at Seward Park in Seattle) to the UW was severed in August by a boater dragging an anchor during Seattle's summer "Seafair" celebration. On the northwest tip of the Olympic Peninsula, the station at Sooes Peak was resited to Cheeka Peak in late August after being vandalized. The Cheeka Peak site is more secure, and the seismograph is co-located with a UW Atmospheric Sciences research facility and a continuously operating Global Positioning System receiver installed by the UW Geophysics Program in 1995.

This quarter, six temporary stations were removed. These are listed in Table 1B. The stations had been installed as part of a special study called "Seismic Velocity Structure of the Greater Mount Rainier Area" (funded by NEHRP 1434-95-G2571) which began in the first quarter of 1995. Two additional stations (RVN and XTL) installed during this study have been retained as permanent PNSN stations.

At the UW, the PNSN completed installation of a generator to provide backup power. This system supplements an existing "Uninterrruptible Power Supply" (UPS), which provides about 45 minutes of power backup. The combination of UPS and generator will allow us to power our data-acquisition equipment through even a lengthy power outage. We are continuing mitigation activities in the PNSN lab that will increase our ability to remain functional should a local damaging earthquake occur.

Strong-motion Instrumentation Plans

The PNSN has received funding from the USGS to acquire, install, and operate six very high-dynamic-range strong-motion instruments (consisting of 3-component accelerometers plus digital data-recorders). Three instruments were funded under a special contract 1434-HQ-96-GR-02714, and three through a supplement to the existing PNSN-USGS joint operating agreement: 1434-95-A-1302. The request for bids was sent out this quarter, and Terra Technology ISD-24 instruments were chosen. Delivery of the units is expected during the fourth quarter of this year. Installation sites are being selected. Tentative sites selected to date include the UW (co-sited with the SEA Wood-Anderson instruments which have operated since 1966), Seward Park in Seattle (site of currently operating station SPW), and a Bonneville Power Authority (BPA) substation near Maple Valley. Data from some instruments will be available by real-time telemetry as part of the PNSN data stream. Data from other instruments will be recovered via dial-up or site visits.

The PNSN strong-motion instrument program is soliciting cooperation from regional utilities and industries for assistance in siting, telemetry, instrumentation and cooperative operations of strong-motion instrumentation within our network area. We are developing procedures for rapid communication of strong-motion parameters of engineering interest to strong-motion program participants and to other interested parties.

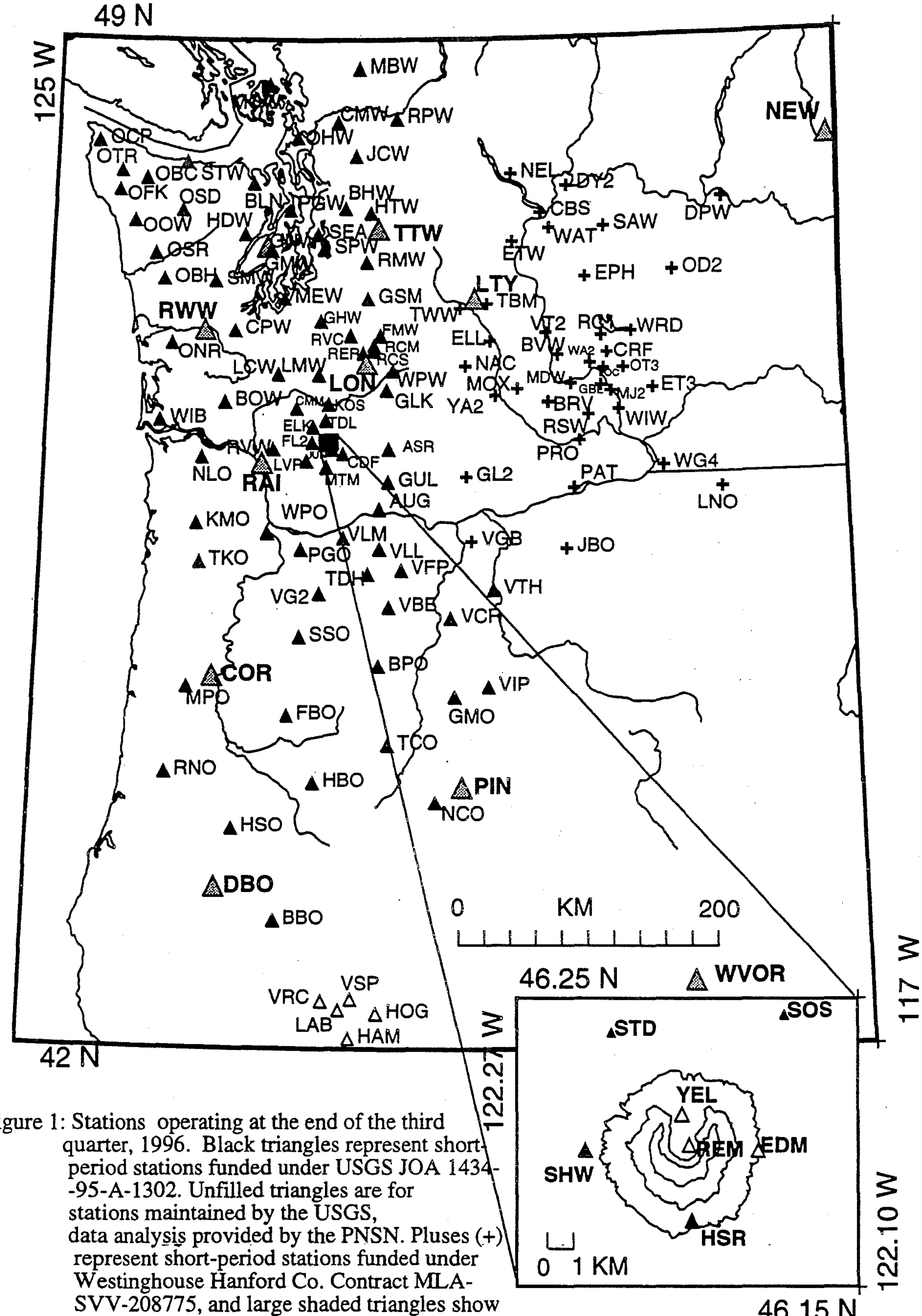

Figure 1: Stations operating at the end of the third quarter, 1996. Black triangles represent short-period stations funded under USGS JOA 1434--95-A-1302. Unfilled triangles are for stations maintained by the USGS, data analysis provided by the PNSN. Pluses (+) represent short-period stations funded under Westinghouse Hanford Co. Contract MLA-SVV-208775, and large shaded triangles show the locations of broad-band three-component instruments, funded either via JOA 1434-92-A-0963, NSF EAR-9207181, DOGAMI, or by the USGS-NSN.

TABLE 1A
Station Outages 3rd quarter 1996

Station	Outage Dates	Comments
CMW	07/11-10/09	Repaired - Repaired VCO
LTY	6/20-08/08	Repaired - Replaced damaged cables
NEL	2/14-08/09	Repaired
OCP	8/28	INSTALLED - Replaces OSP
OSP	8/28	REMOVED - Replaced by OCP
OTR	06/26-09/24	Repaired - Replaced receiver at OFR
SPW	08/05-08/23	Repaired - Damaged phone line
TDH	3/3-End	Dead - Damaged VCO
VFP	2/1-End	Dead - Winter damage
VSP	2/25-End	Dead - Winter damage

TABLE 1B
Temporary Stations Removed, 3rd quarter 1996

Station	Removal Date	Comments
BDM	7/16	Temporary Station REMOVED
CMK	7/16	Temporary Station REMOVED
GRL	7/16	Temporary Station REMOVED
MUP	7/16	Temporary Station REMOVED
QTZ	7/17	Temporary Station REMOVED
WI2	7/17	Temporary Station REMOVED

Data acquisition and processing procedures

We have completed the process of updating our data acquisition and processing procedures which began with a change to "UW-2" data formats in the fourth quarter of 1994, and continued with a new data acquisition system, called **SUNWORM** in 1995, and automatic recovery and integration of data from National Net and dial-up broad-band stations this year. The **SUNWORM** system is based on concepts developed by the USGS as part of their concurrent development of the **EARTHWORM** system. This quarter, Alex Bittenbinder and Barbara Bogaert of the USGS visited the PNSN, and presented a detailed description of the **EARTHWORM** system. **EARTHWORM** and **SUNWORM** are both modular systems with some common software. **EARTHWORM** modules which provide real-time high-accuracy phase timing, sophisticated association of phases to events, and adaptable alarm and notification capabilities are features not currently in **SUNWORM**. We plan to adapt more of the **EARTHWORM** system to **SUNWORM** to gain capabilities and to be more compatible with future growth in this area.

All unedited triggered network trace data, plus continuous telemetry from station TTW, and other, non-continuous event-by-event broadband data, are backed up on a network archive tape. Edited event trace data are archived on large disks, and kept on 2.1 GByte exabyte tape. We also archive the edited trace data on high-speed, high-capacity (20 GByte) digital linear tape (DLT) cartridges. Trace data are archived at the IRIS Data Management Center (DMC) in SEED format, where they can be retrieved by any investigator via the standard IRIS data request mechanisms. During this quarter, at the request of the USGS, we have begun archiving continuous data from the broad-band station TTW.

STATIONS USED FOR LOCATION OF EVENTS

Table 2A lists short-period, mostly one-component stations used in locating seismic events in Washington and Oregon. Table 2B lists broad-band, three-component stations operating in Washington and Oregon that provide data to the PNSN. The first column in the table gives the 3-letter station designator, followed by a symbol designating the funding agency; stations marked by a percent sign (%) were supported by USGS joint operating agreement 1434-95-A-1302, and (+) indicates support under Westinghouse Hanford Company Contract MLA-SVV-208775. Other stations were supported from other sources. Additional columns give station north latitude and west longitude (in degrees, minutes and seconds), station elevation in km, and comments indicating landmarks for which stations were named.

TABLE 2A
Short-period Stations operating during the third quarter 1996

STA	F	LAT	LONG	EL	NAME
ASR	%	46 09 09.9	121 36 01.6	1.357	Mt. Adams - Stagman Ridge
AUG	%	45 44 10.0	121 40 50.0	0.865	Augspurger Mtn
BBO	%	42 53 12.6	122 40 46.6	1.671	Butler Butte, Oregon
BDM		46 58 05.5	120 57 07.2	1.811	Bald Mountain (temporary)
BHW	%	47 50 12.6	122 01 55.8	0.198	Bald Hill
BLN	%	48 00 26.5	122 58 18.6	0.585	Blyn Mt.
BOW	%	46 28 30.0	123 13 41.0	0.870	Boistfort Mt.
BPO	%	44 39 06.9	121 41 19.2	1.957	Bald Peter, Oregon
BRV	+	46 29 07.2	119 59 28.2	0.920	Black Rock Valley
BVW	+	46 48 39.6	119 52 59.4	0.670	Beverly
CBS	+	47 48 17.4	120 02 30.0	1.067	Chelan Butte, South
CDF	%	46 06 58.2	122 02 51.0	0.780	Cedar Flats
CMK		46 56 04.7	121 13 42.9	1.380	Chipmunk Creek (temporary)
CMM	%	46 26 07.0	122 30 21.0	0.620	Crazy Man Mt.
CMW	%	48 25 25.3	122 07 08.4	1.190	Cultus Mtns.
CPW	%	46 58 25.8	123 08 10.8	0.792	Capitol Peak
CRF	+	46 49 30.0	119 23 13.2	0.189	Corfu
DBO		43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon
DPW	+	47 52 14.3	118 12 10.2	0.892	Davenport
DY2	+	47 59 06.6	119 46 16.8	0.890	Dyer Hill 2
EDM	#	46 11 50.4	122 09 00.0	1.609	East Dome, Mt. St. Helens
ELK	%	46 18 20.0	122 20 27.0	1.270	Elk Rock
ELL	+	46 54 34.8	120 33 58.8	0.789	Ellensburg
EPH	+	47 21 22.8	119 35 45.6	0.661	Ephrata
ET3	+	46 34 38.4	118 56 15.0	0.286	Eltopia (replaces ET2)
ETW	+	47 36 15.6	120 19 56.4	1.477	Entiat
FBO	%	44 18 35.6	122 34 40.2	1.080	Farmers Butte, Oregon
FL2	%	46 11 47.0	122 21 01.0	1.378	Flat Top 2
FMW	%	46 56 29.6	121 40 11.3	1.859	Mt. Fremont
GBL	+	46 35 54.0	119 27 35.4	0.330	Gable Mountain
GHW	%	47 02 30.0	122 16 21.0	0.268	Garrison Hill
GL2	+	45 57 35.0	120 49 22.5	1.000	New Goldendale
GLK	%	46 33 50.2	121 36 30.7	1.320	Glacier Lake
GMO	%	44 26 20.8	120 57 22.3	1.689	Grizzly Mountain, Oregon
GMW	%	47 32 52.5	122 47 10.8	0.506	Gold Mt.
GRL		46 48 51.1	121 19 36.8	1.287	Granite Lake (temporary)
GSM	%	47 12 11.4	121 47 40.2	1.305	Grass Mt.
GUL	%	45 55 27.0	121 35 44.0	1.189	Guler Mt.
HAM	#	42 04 08.3	121 58 16.0	1.999	Hamaker Mt., Oregon
HBO	%	43 50 39.5	122 19 11.9	1.615	Huckleberry Mt., Oregon
HDW	%	47 38 54.6	123 03 15.2	1.006	Hoodsport
HOG	#	42 14 32.7	121 42 20.5	1.887	Hogback Mtn., Oregon
HSO	%	43 31 33.0	123 05 24.0	1.020	Harness Mountain, Oregon
HSR	%	46 10 28.0	122 10 46.0	1.720	South Ridge, Mt. St. Helens
HTW	%	47 48 14.2	121 46 03.5	0.833	Haystack Lookout
JBO	+	45 27 41.7	119 50 13.3	0.645	Jordan Butte, Oregon
JCW	%	48 11 42.7	121 55 31.1	0.792	Jim Creek
JUN	%	46 08 48.0	122 09 10.8	1.049	June Lake
KMO	%	45 38 07.8	123 29 22.2	0.975	Kings Mt., Oregon
KOS	%	46 27 40.8	122 11 25.8	0.828	Kosmos
LAB	#	42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon (4-comp)
LCW	%	46 40 14.4	122 42 02.8	0.396	Lucas Creek
LMW	%	46 40 04.8	122 17 28.8	1.195	Ladd Mt.
LNO	+	45 52 18.6	118 17 06.6	0.771	Lincton Mt., Oregon
LO2	%	46 45 00.0	121 48 36.0	0.853	Longmire
LOC	+	46 43 01.2	119 25 51.0	0.210	Locke Island
LVP	%	46 04 06.0	122 24 30.0	1.170	Lakeview Peak
MBW	%	48 47 02.4	121 53 58.8	1.676	Mt. Baker
MCW	%	48 40 46.8	122 49 56.4	0.693	Mt. Constitution
MDW	+	46 36 47.4	119 45 39.6	0.330	Midway
MEW	%	47 12 07.0	122 38 45.0	0.097	McNeil Island
MHL		46 52 56.6	122 03 50.4	1.215	Mashel Creek (temporary)
MJ2	+	46 33 27.0	119 21 32.4	0.146	May Junction 2
MOX	+	46 34 38.4	120 17 53.4	0.501	Moxie City

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
MPO	%	44 30 17.4	123 33 00.6	1.249	Mary's Peak, Oregon
MTM	%	46 01 31.8	122 12 42.0	1.121	Mt. Mitchell
MUP		46 50 21.4	121 07 31.0	1.456	Mud Springs (temporary)
NAC	+	46 43 59.4	120 49 25.2	0.728	Naches
NCO	%	43 42 14.4	121 08 18.0	1.908	Newberry Crater, Oregon
NEL	+	48 04 12.6	120 20 24.6	1.500	Nelson Butte
NLO	%	46 05 21.9	123 27 01.8	0.826	Nicolai Mt., Oregon
OBC	%	48 02 07.1	124 04 39.0	0.938	Olympics - Bonidu Creek
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OCP	%	48 17 53.5	124 37 30.0	0.487	Olympics - Cheeka Peak
OD2	+	47 23 15.6	118 42 34.8	0.553	Odessa site 2
OFK	%	47 57 00.0	124 21 28.1	0.134	Olympics - Forks
OHW	%	48 19 24.0	122 31 54.6	0.054	Oak Harbor
ONR	%	46 52 37.5	123 46 16.5	0.257	Olympics - North River
OOW	%	47 44 03.6	124 11 10.2	0.561	Octopus West
OSD	%	47 48 59.2	123 42 13.7	2.008	Olympics - Snow Dome
OSP	%	48 17 05.5	124 35 23.3	0.585	Olympics - Sooes Peak
OSR	%	47 30 20.3	123 57 42.0	0.815	Olympics Salmon Ridge
OT3	+	46 40 08.4	119 13 58.8	0.322	New Othello
OTR	%	48 05 00.0	124 20 39.0	0.712	Olympics - Tyee Ridge
PAT	+	45 52 55.2	119 45 08.4	0.262	Paterson
PGO	%	45 27 42.6	122 27 11.5	0.253	Gresham, Oregon
PGW	%	47 49 18.8	122 35 57.7	0.122	Port Gamble
PRO	+	46 12 45.6	119 41 08.4	0.553	Prosser
QTZ		47 00 40.4	121 05 20.9	1.054	Quartz Creek (temporary)
RC1	+	46 56 42.6	119 26 39.6	0.485	Royal City (3 comp.)
RCM	%	46 50 08.9	121 43 54.4	3.085	Mt. Rainier, Camp Muir
RCS	%	46 52 15.6	121 43 52.0	2.877	Mt. Rainier, Camp Schurman
REM	#	46 11 57.0	122 11 03.0	2.102	Rembrandt (Dome station)
RER	%	46 49 09.2	121 50 27.3	1.756	Mt. Rainier, Emerald Ridge
RMW	%	47 27 35.0	121 48 19.2	1.024	Rattlesnake Mt. (West)
RNO	%	43 54 58.9	123 43 25.5	0.850	Roman Nose, Oregon
RPW	%	48 26 54.0	121 30 49.0	0.850	Rockport
RSW	+	46 23 40.2	119 35 28.8	1.045	Rattlesnake Mt. (East)
RVC	%	46 56 34.5	121 58 17.3	1.000	Mt. Rainier - Voight Creek
RVN		47 01 38.6	121 20 11.9	1.885	Raven Roost
RVW	%	46 08 53.2	122 44 32.1	0.460	Rose Valley
SAW	+	47 42 06.0	119 24 01.8	0.701	St. Andrews
SEA		47 39 18.0	122 18 30.0	0.030	Seattle (Wood Anderson)
SHW	%	46 11 37.1	122 14 06.5	1.425	Mt. St. Helens
SMW	%	47 19 10.7	123 20 35.4	0.877	South Mtn.
SOS	%	46 14 38.5	122 08 12.0	1.270	Source of Smith Creek
SPW	%	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle
SSO	%	44 51 21.6	122 27 37.8	1.242	Sweet Springs, Oregon
STD	%	46 14 16.0	122 13 21.9	1.268	Studebaker Ridge
STW	%	48 09 02.9	123 40 13.1	0.308	Striped Peak
TBM	+	47 10 12.0	120 35 52.8	1.006	Table Mt.
TCO	%	44 06 21.0	121 36 01.0	1.975	Three Creek Meadows, Oregon.
TDH	%	45 17 23.4	121 47 25.2	1.541	Tom,Dick,Harry Mt., Oregon
TDL	%	46 21 03.0	122 12 57.0	1.400	Tradedollar Lake
TKO	%	45 22 16.7	123 27 14.0	1.024	Trask Mtn, Oregon
TRW	+	46 17 32.0	120 32 31.0	0.723	Toppenish Ridge
LNO	+	45 52 18.6	118 17 06.6	0.771	Lincton Mt., Oregon
TWW	+	47 08 17.4	120 52 06.0	1.027	Teanaway
VBE	%	45 03 37.2	121 35 12.6	1.544	Beaver Butte, Oregon
VCR	%	44 58 58.2	120 59 17.4	1.015	Criterion Ridge, Oregon
VFP	%	45 19 05.0	121 27 54.3	1.716	Flag Point, Oregon
VG2	%	45 09 20.0	122 16 15.0	0.823	Goat Mt., Oregon
VGB	+	45 30 56.4	120 46 39.0	0.729	Gordon Butte, Oregon
VIP	%	44 30 29.4	120 37 07.8	1.731	Ingram Pt., Oregon
VLL	%	45 27 48.0	121 40 45.0	1.195	Laurance Lk., Oregon
VLM	%	45 32 18.6	122 02 21.0	1.150	Little Larch, Oregon
VRC	#	42 19 47.2	122 13 34.9	1.682	Rainbow Creek, Oregon
VSP	#	42 20 30.0	121 57 00.0	1.539	Spence Mtn, Oregon
VT2	+	46 58 02.4	119 59 57.0	1.270	Vantage2
VTH	%	45 10 52.2	120 33 40.8	0.773	The Trough, Oregon
WA2	+	46 45 19.2	119 33 56.4	0.244	Wahluke Slope
WAT	+	47 41 55.2	119 57 14.4	0.821	Waterville
WG4	+	46 01 49.2	118 51 21.0	0.511	Wallula Gap
WI2		47 08 10.6	121 22 52.0	1.528	Windy Gap (temporary)
WIB	#	46 20 34.8	123 52 30.6	0.503	Willapa Bay (3 comp.)
WIW	+	46 25 45.6	119 17 15.6	0.128	Wooded Island
WPO	%	45 34 24.0	122 47 22.4	0.334	West Portland, Oregon
WPW	%	46 41 53.4	121 32 48.0	1.250	White Pass
WRD	+	46 58 12.0	119 08 41.4	0.375	Warden
XTL	--	46 55 47.8	121 29 35.8	1.665	Crystal Mtn.
YA2	+	46 31 36.0	120 31 48.0	0.652	Yakima
YEL	#	46 12 35.0	122 11 16.0	1.750	Yellow Rock, Mt. St. Helens

TABLE 2B

Broad-band three-component stations operating at the end of the third quarter 1996

STA	F	LAT	LONG	EL	NAME
COR		44 35 08.5	123 18 11.5	0.121	Corvallis, Oregon (IRIS station, Operated by OSU)
DBO		43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon (Operated by UO)
GNW	*	47 33 51.8	122 49 31.0	0.165	Green Mountain, WA (operated by UW)
LON	*	46 45 00.0	121 48 36.0	0.853	Longmire, WA (operated by UW)
LTY	*	47 15 21.2	120 39 53.3	0.970	Liberty, WA (operated by UW)
NEW		48 15 50.0	117 07 13.0	0.760	Newport Observatory (USGS-USNSN)
RAI		46 02 25.1	122 53 06.4	1.520	Trojan Plant, Oregon (OSU)
RWW	*	46 57 50.1	123 32 35.9	0.015	Ranney Well (operated by UW)
TTW	*	47 41 40.7	121 41 20.0	0.542	Tolt Res, WA (operated by UW)
PIN		43 48 40.0	120 52 19.0	1.865	Pine Mt. Oregon (operated by UO)
WVOR		42 26 02.0	118 38 13.0	1.344	Wildhorse Valley, Oregon (USGS-USNSN)

OUTREACH ACTIVITIES

The PNSN Seismology Lab staff provides an educational outreach program to better inform the public, educators, business, policy makers, and the emergency management community about seismicity and natural hazards. Our outreach includes lab tours, lectures, classes and workshops, press conferences, TV and radio news programs and talk shows, field trips, and participation in regional earthquake planning efforts. We provide an audio library which includes a message describing the seismic hazards in Washington and Oregon, another on earthquake prediction, and a frequently updated message on current seismic activity. Similar information is available via Internet on the World-Wide-Web (WWW):

http://www.geophys.washington.edu/SEIS

Special Events

The first Annual CREW (Cascadia Regional Earthquake Workgroup) Conference was held at The UW Sept. 5 and 6, hosted by the PNSN and Geophysics Program under support from FEMA (Federal Emergency Management Agency) and the USGS. CREW is a private/public partnership to advocate and communicate earthquake hazard mitigation activities within our region. Seismology Lab Coordinator Bill Steele coordinated the conference for CREW chairman Jack Bernhardsen (Tacoma Public Utilities). The conference theme was "Cascadia Storms: A Dress Rehearsal". About 200 participants, representing lifeline agencies (utilities, transportation, emergency services, etc.), private corporations and businesses, and geoscientists and engineers attended. Mitigation lessons have been learned from recent flooding, landslides and windstorms. The aim of the conference was to discuss and evaluate the effectiveness and transferability of existing mitigation projects and to develop further cost-effective mitigation strategies.

The PNSN Seismology Lab has provided administrative services to the Cascadia Regional Earthquake Workgroup (CREW) since its inception in September of 1995, under contract with FEMA (Dr. Anthony Qamar, P.I.). Other CREW activities this quarter included CREW Business Team meetings on June 25 and August 20, and many conference-planning meetings. The next CREW Business Team meeting is on November 15, 1996 at Humboldt State University. CREW WWW pages are hosted on the Geophysics Program web server, and maintained by Paul Martin of Dames & Moore Inc. with some support from PNSN staff. The CREW pages can be found at:

http://www.geophys.washington.edu/CREW/index.html

The PNSN, CREW, and UW Computing and Communications Department jointly hosted a meeting of Contingency Planners and Emergency Response Managers at UW. Seismology Lab Coordinator Bill Steele was invited to serve on the Earthquake Engineering Research Institute (EERI) Operations/Publicity Committee preparing for the 1998 EERI 6th National Conference, to be held in Seattle.

Press Interviews, Lab Tours, and Workshops

PNSN staff provided more than 25 interviews broadcast by television and radio stations, either in response to earthquake activity or related to research on geologic hazard assessment, providing background and context for the general audience. During the third quarter, 6 K-12 school groups (about 120 individuals), toured the Seismology Lab.

Telephone, Mail, and On-line outreach

The PNSN audio library system received about 2,500 calls this quarter. We provide several recordings. The most popular is a frequently updated message on current seismic activity. In addition we have a tape describing the seismic hazards in Washington and Oregon, and another on earthquake prediction. Callers often request our one-page information and resource sheet on seismic hazards in Washington and Oregon. Thousands of these have been mailed out or distributed, and we encourage others to reproduce and further distribute this sheet. Our information sheet discussing earthquake prediction is also frequently requested. Callers to the audio library can also choose to be transferred to the Seismology Lab, where additional information is available. This quarter we responded in person to ~40 calls from emergency management and government, ~50 calls from the media, ~50 calls from educators, ~120 calls from the business community, and over 250 calls from the general public.

The list of recent Pacific Northwest earthquakes can be accessed by a variety of methods beyond the audio library described above; by modem through the Internet with utilities such as "ftp" and the World-Wide-Web. The computer methods have an advantage over the audio line. Not only are more earthquakes listed, but our automatic alarm system appends a preliminary location for any earthquake large enough to trigger the alarm (magnitude greater than 2.9) to the list; allowing public access to the preliminary location and magnitude estimate within minutes of the earthquake. Table 2A shows the number of times the computerized PNSN list of recent earthquakes magnitude 2.0 or larger was accessed. The Internet UNIX utility "finger quake@geophys.washington.edu" was most popular, followed by access over the WWW. For computer users without direct access to Internet, this information can be accessed via e-mail (by sending e-mail to "quake@geophys.washington.edu"), or by direct dial-up to modem ((206) 685-0889); modem setting: 8 bits, 1 stop bit, no parity; type "quake" at "geoterm" prompt and login as "quake"). The modem and e-mail services are used several hundred times each month.

TABLE 3A
Quarterly Comparison of Methods of Accessing PNSN list of most recent earthquakes, M>=2.0

Access Method	94-D	95-A	95-B	95-C	95-D	96-A	96-B	96-C
Finger Quake	32,000	110,000	93,000	80,000	72,000	83,000	90,300	62,900
World-Wide-Web	300	2,300	2,500	3,100	4,300	6,300	16,500	10,800
Remote Login as Quake	3,200	7,600	5,400	3,400	2,900	2,500	1,800	1,100
Via E-mail	786	956	613	444	477	317	459	264
Dialup Quake	520	811	580	604	439	406	763	364

The PNSN recent earthquake list, and much more, is also available through the World-Wide-Web (WWW) at: **http://www.geophys.washington.edu/SEIS** which contains information from the PNSN and also links into other sources of earthquake information around the country and world through:

http://www.geophys.washington.edu/seismosurfing.html

Other popular features include our composite listings and maps of recent U.S. earthquakes from the Council of National Seismic Systems (CNSS), and local offerings from the PNSN. Table 3B summarizes WWW activity since 1994. Both Tables 3A and 3B show that usage has increased enormously. Upsurges occurred in January 1995 following a significant earthquake in Kobe, Japan and a local magnitude 5.0 (near Robinson Point, Maury Island, WA) and again in May 1996 following the Duvall Earthquake.

TABLE 3B
World Wide Web Activity per Quarter

Area Accessed	94-D	95-A	95-B	95-C	95-D	96-A	96-B	96-C
Seismosurfing	5,300	19,100	19,000	20,700	22,000	23,000	26,400	21,200
CNSS Earthquake Maps	1,300	3,600	3,800	6,200	9,900	18,300	20,500	14,200
CNSS Earthquake Catalog	1,400	4,300	4,400	5,900	6,600	9,400	10,500	7,300
PNSN List of most recent EQs, M>=2.0	300	2,300	2,500	3,100	4,300	6,300	16,500	10,800
Local Earthquake Maps	900	1,500	1,000	1,100	2,400	3,600	7,700	3,300
Other Features	12,800	43,200	46,300	43,100	83,800	136,000	297,500	362,500
Total for Seismology Area	**22,000**	**74,000**	**77,000**	**80,100**	**129,000**	**196,600**	**379,100**	**419,300**

Quarterly summaries of seismic activity in Washington and Oregon extracted from these quarterly reports can be found in the WWW area:

http://www.geophys.washington.edu/SEIS/PNSN/REPTS/res_rept.html

The PNSN hosts the WWW page for **"Tsunami!"** , a Web page developed by a graduate student, Benjamin Cook, under the direction of UW Civil Engineering's Dr. Catherine Petroff. Further development of the Web page is a joint project between the PNSN and Civil Engineering. The **Tsunami!** page can be found at:

http://www.geophys.washington.edu/tsunami/welcome.html

EARTHQUAKE DATA

There were 1,440 events digitally recorded and processed at the University of Washington between July 1 and September 30, 1996. Locations in Washington, Oregon, or southernmost British Columbia were determined for 696 of these events; 544 were classified as earthquakes and 152 as known or suspected blasts. The remaining 744 processed events include teleseisms (175 events), regional events outside the PNSN (73), and unlocated events within the PNSN. Unlocated events within the PNSN include very small earthquakes and some known blasts. We are now routinely locating all sizable Centralia blasts, and retrieving and archiving broad-band data for them. Table 4, located at the end of this report, is the catalog of earthquakes and blasts located within the network for this quarter. For the Klamath Falls area, only earthquakes of magnitude 1.6 and larger have been included in Table 4. For the Duvall area, only earthquakes of magnitude 1.5 and larger have been included in Table 4.

Fig. 2 shows all earthquakes with magnitude greater than or equal to 0.0 ($M_c \geq 0$). Fig. 3 shows blasts and probable blasts ($M_c \geq 0$). Fig. 4 shows earthquakes located near Mt. Rainier ($M_c \geq 0$). Fig. 5 shows earthquakes located at Mt. St. Helens ($M_c \geq 0$). Fig. 6 shows a map of broad-band stations used to determine moment-tensor focal mechanisms. Fig. 7 shows the location and moment-tensor focal mechanisms for earthquakes with $M_w > 3.5$.

MOMENT TENSOR FOCAL MECHANISM SOLUTIONS

Moment-tensor focal mechanisms for earthquakes with $M_w > 3.5$ in the Pacific Northwest are included in this report. These solutions were computed under other support (USGS NEHRP Grant 1434-93-G-2326), at the Oregon State University under the direction of Dr. John Nabelek. The operation of broadband stations in Oregon (COR, RAI, DBO and PIN) was in part supported by a grant from the Oregon Department of Geology and Mineral Industries.

Moment-tensor solutions use data from 3-component broad-band stations in Washington, Oregon, California and British Columbia and from US National Seismic Network Stations in the western states of the US (Figure 6). The inversions are performed in the 0.01 - 0.1 Hz range, with the frequency band adjusted according to the earthquake magnitude and the station epicentral distance.

Moment tensors, best-fit double-couple mechanism, M_w, seismic moment, and depth are given in Table 5. The coordinate conventions of Aki and Richards (Quantitative Seismology: Theory and Methods, W. H. Freeman, San Francisco, 1980) are followed. Figure 7 shows the locations and focal mechanisms for the events listed in Table 5. Events 2, 6, and 18, were relocated (marked R in Table 5).

An up-to-date catalogue of the moment tensor focal mechanisms is available on the World-Wide-Web server at Oregon State University: **http://quakes.oce.orst.edu**.

OREGON SEISMICITY

During the third quarter of 1996 a total of 67 earthquakes were located in Oregon between 42.0° and 45.5° north latitude, and between 117° and 125° west longitude. Thirty-three of these were located in the Klamath Falls area, where a pair of damaging earthquakes in September of *1993* (Sept. 21, 03:29 and 05:45 UTC; M_c 5.9 and 6.0 respectively) were followed by a vigorous aftershock sequence which has decreased over time. This quarter, 11 earthquakes of magnitude 1.6 or larger were located in the Klamath Falls area. These are listed in Table 4.0.

Only one earthquake was reported felt in Oregon this quarter. A magnitude 3.3 earthquake on August 2 at 11:46 UTC was located at a depth of about 27 km. Although it was felt by only a few people, this event was within a few km of the epicenter of the March 1993 magnitude 5.6 Scotts Mills earthquake, and is the largest aftershock to occur in the the immediate vicinity of the mainshock since June 1993.

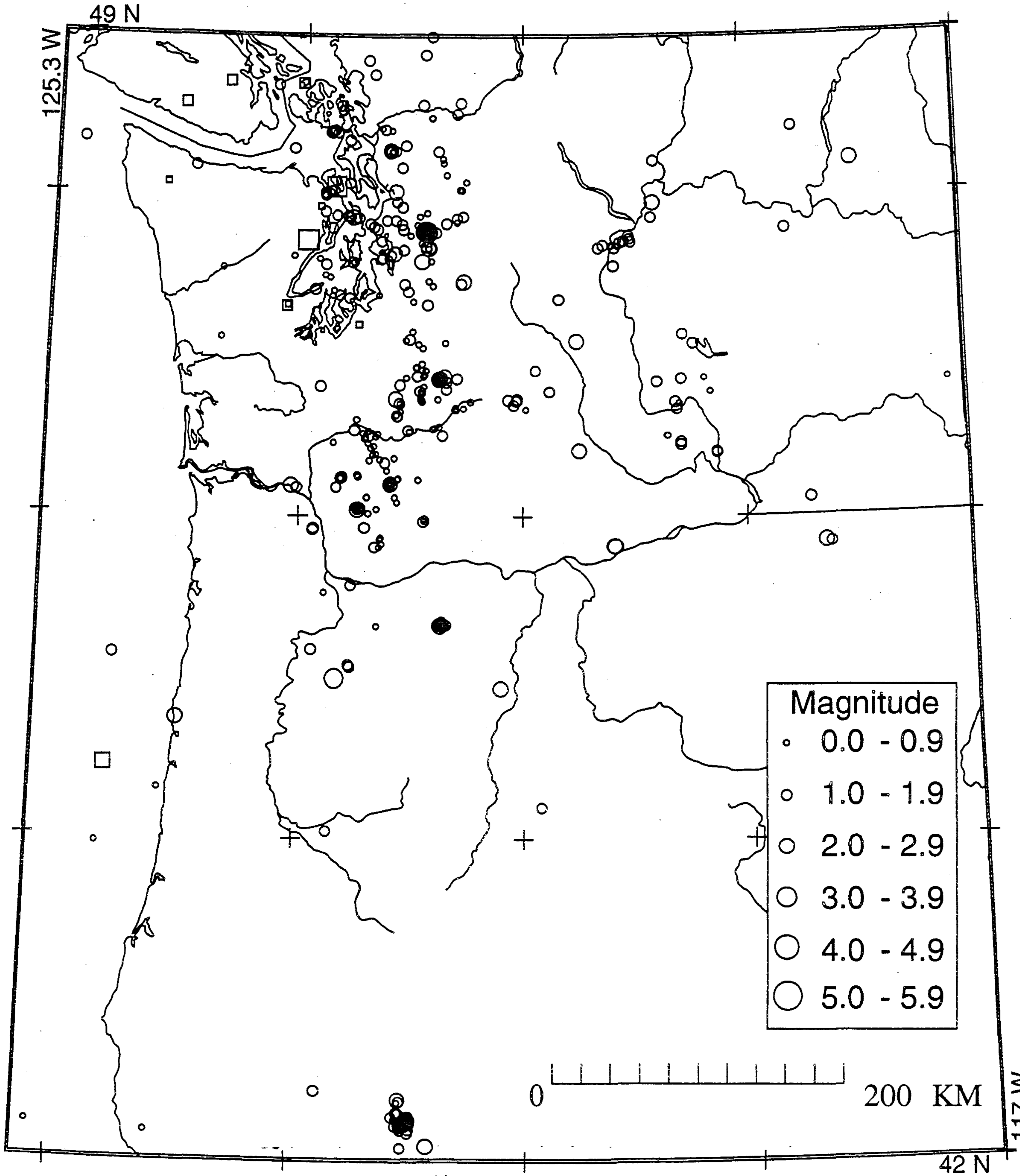

Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the third quarter of 1996. Square symbols indicate events located at depths of 30 km or more.

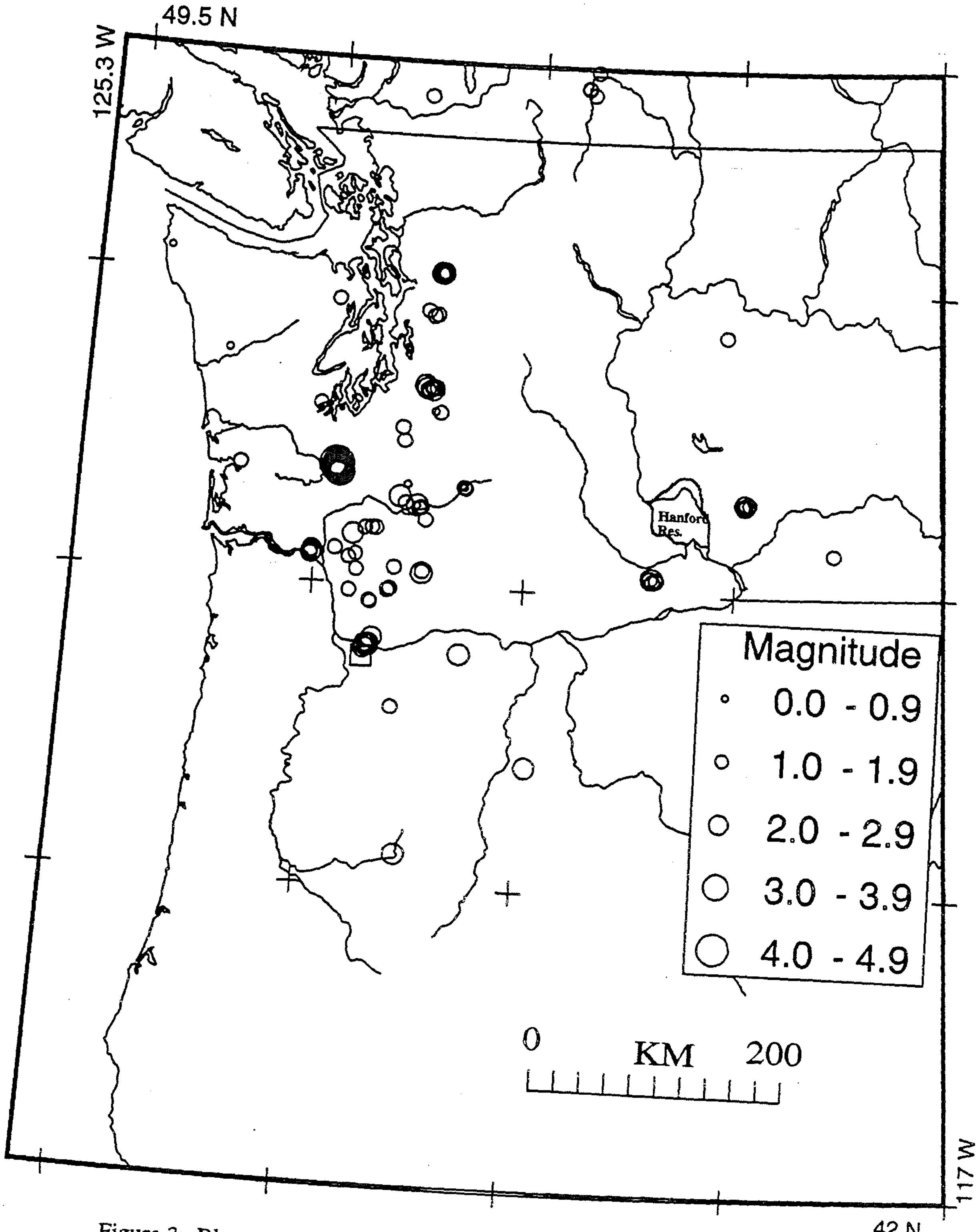

Figure 3: Blasts and probable blasts, third quarter, 1996.

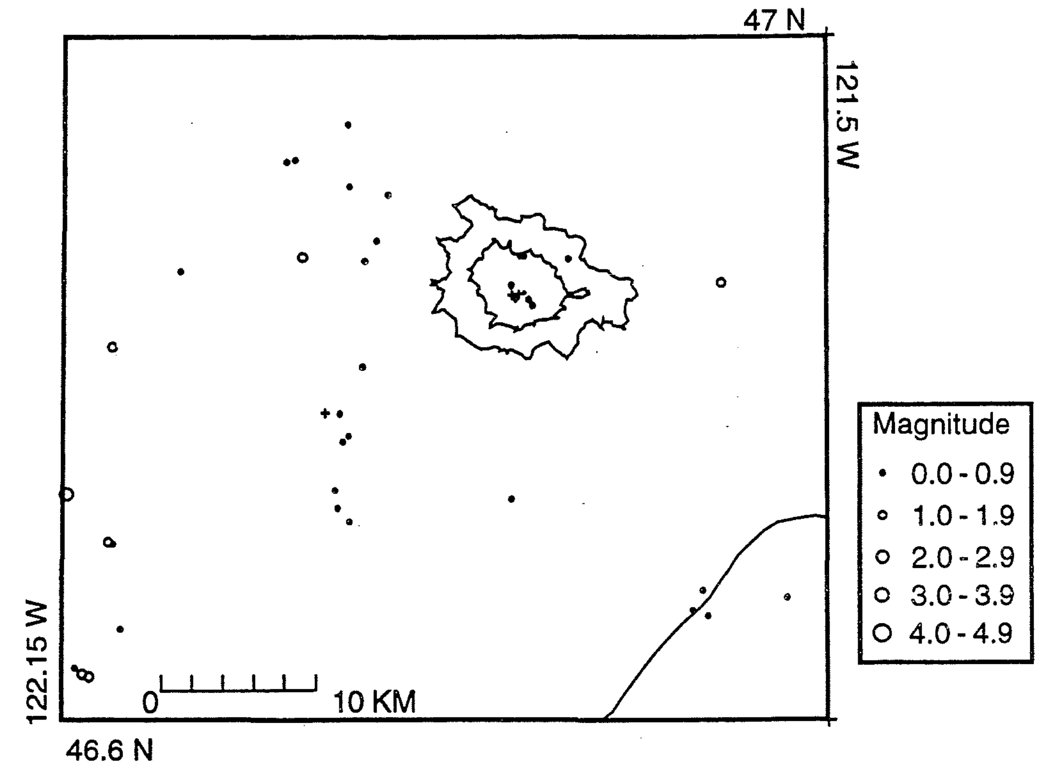

Figure 4: Earthquakes located in the Mt. Rainier area third quarter, 1996. All events shown are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

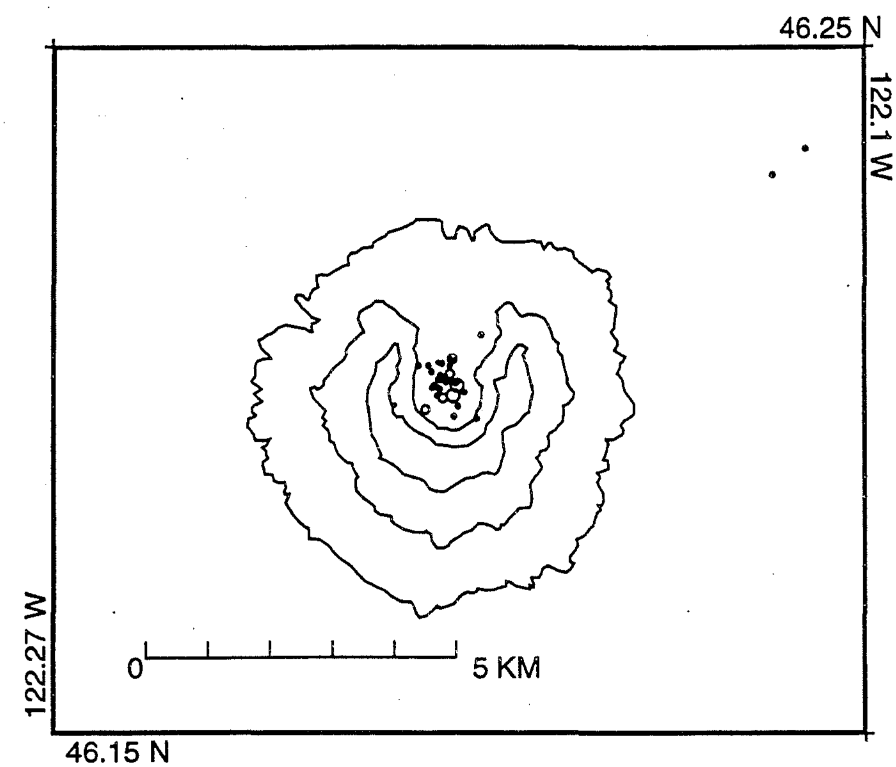

Figure 5: Earthquakes located in the Mt. St. Helens area third quarter, 1996. All events shown are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4.

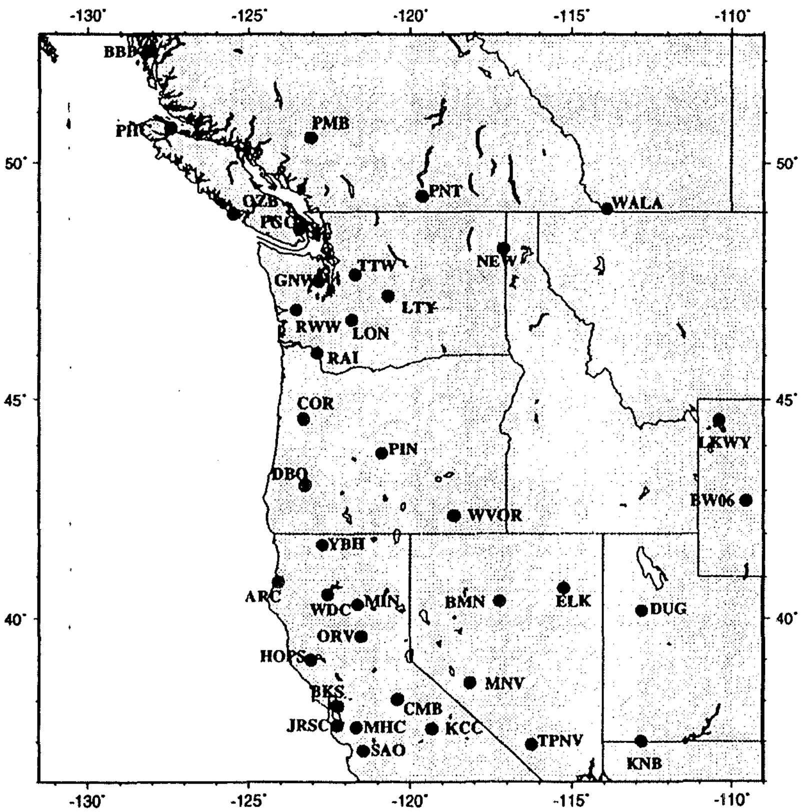

Fig. 6

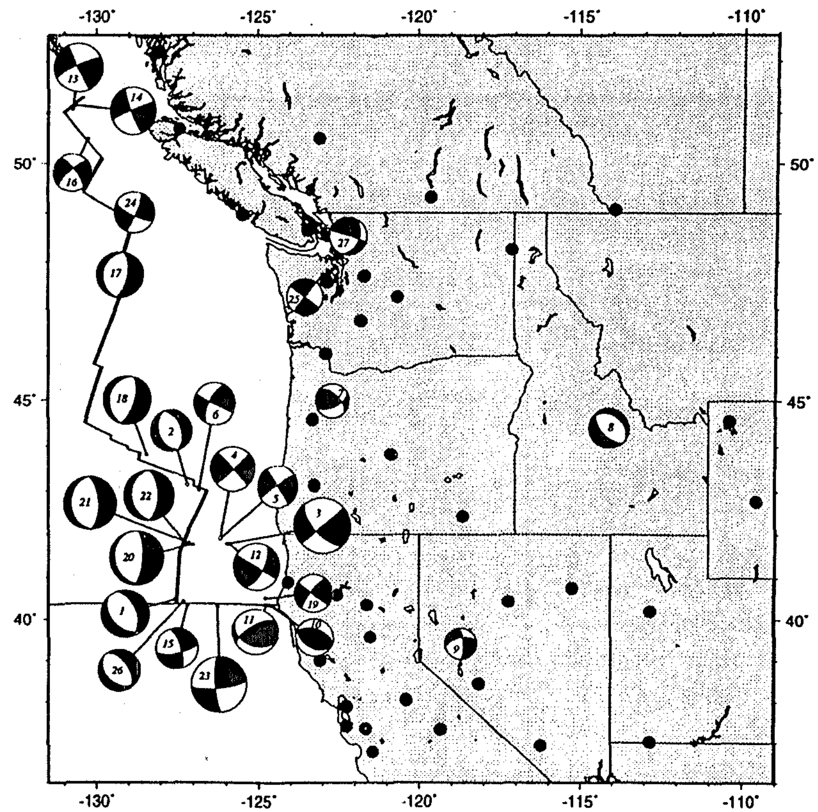

Fig. 7

Figure 6. Map of 3-component broad band stations used to determine moment-tensor focal mechanisms.
Figure 7. Map of best-fit double-couple focal mechanisms.

In Figure 2, a cluster of activity is visible in northern Oregon at Mt. Hood. There were two small earthquake swarms, one in July starting with a single located event on July 16th and following with six located events on July 22. The two largest events were magnitude 2.0, and depths ranged from 2 to 6 km. The second swarm was observed between Sept. 6 and 17, with a total of six located events, none larger than magnitude 1.1, and with depths around 6 km.

WESTERN WASHINGTON SEISMICITY

During the third quarter of 1996, 426 earthquakes were located between 45.5° and 49.5° north latitude and between 121° and 125.3° west longitude. The deepest earthquake this quarter was also one of the largest, M 3.5, at a depth of ~56 km, on Sept. 29 at 23:06 UTC). It was located about 36 km north of Poulsbo, and was reported felt.

Six earthquakes were reported felt in western Washington this quarter. The largest were two events, both magnitude 3.5, on the eastern edge of the Olympic Peninsula. These occurred on Sept. 24 at 12:45 UTC, and Sept. 29 at 23:07 UTC at depths of 47 and 56 km respectively. The first was felt in Bremerton, and the second on the west side of Whidbey Island, and as far away as downtown Vancouver, B.C. The remaining felt events this quarter included two shallow (depths <10 km) earthquakes in the Duvall area; magnitudes 3.2 (July 3, 22:04 UTC), and 2.5 (July 12 00:17 UTC); a magnitude 2.3 event felt in North Bend (August 5, 06:08 UTC, depth about 12 km) and a magnitude 2.6 earthquake near Alden (August 20, 23:55 UTC, depth about 18 km).

In the Duvall area, activity this quarter included 57 earthquakes. Last quarter 382 were located in the same area following a magnitude 5.4 earthquake at O4:04 May 3 (UTC). The largest earthquake in the Duvall vicinity this quarter was the magnitude 3.2 event discussed above.

Mount Rainier Area

Figure 4 shows earthquakes near Mount Rainier. The number of events in close proximity to the cone of Mt. Rainier varies over the course of the year, since the source of much of the shallow surface-type activity is presumably ice movement or avalanching, which is seasonal in nature. Events with very low frequency signals (1-3 Hz) believed to be icequakes are assigned type "L" in the catalog. Emergent, very long duration signals probably due to rockfalls or avalanches are assigned type "S" (see Key to Earthquake Catalog). "L" and "S" type events are not shown in Figure 4.

A total of 75 events (21 of them smaller than magnitude 0., and thus not shown in Fig. 4) were located within the region shown in Fig. 4. Of these, 19 were located in the "Western Rainier Seismic Zone" (WRSZ), a north-south trending lineation of seismicity approximately 15 km west of the summit of Mt. Rainier (for counting purposes, the western zone is defined as 46.6-47° N latitude, 121.83-122° W longitude). Closer to the summit (within 5 km), there were 30 tectonic-style earthquakes, and 6 "L" or "S" events were located this quarter (types L and S are not shown in Fig.4). The remaining events were scattered around the cone of Rainier as seen in Fig. 4.

Mount St. Helens Area

Figure 2 shows a prominent alignment of epicenters striking NW through the Mount St. Helens area. This activity roughly delineates the St. Helens seismic zone (SHZ), a well-known 90 km long zone of seismic activity (Weaver and Smith, 1983, Jour. Geophys. Res., Vol. 88, No. B12, pp. 10,371-10,383) which has generated several magnitude 5+ earthquakes in the last 50 years Although seismicity on the SHZ looks very prominent on Fig. 2, in fact activity this quarter (19 events excluding the activity at Mount St Helens shown in Fig. 5) is about average (11-36 events per quarter since 1990). Although distributed along the entire length of the SHZ, this quarter's events are all very small, the largest only magnitude 1.4.

Figure 5 shows tectonic earthquakes near Mount St. Helens. Low frequency (L) and avalanche or rockfall events (S) are not shown. In the third quarter, 83 events (only 33 magnitude 0. or larger), were located at Mt. St. Helens in the area shown in Fig. 5. This quarter, no type "S" or "L" events were located. Of this quarter's earthquakes, 35 (14 of them larger than magnitude 0.) were deeper than 4 km. The largest event at Mount St. Helens, magnitude 2.4, (September 21 at 06:26 UTC) was at a depth of ~4 km.

EASTERN WASHINGTON SEISMICITY

During the third quarter of 1996, 48 earthquakes were located in eastern Washington. None were reported felt. The largest quake in eastern Washington this quarter was on July 29 at 11:02 UTC. It was magnitude 2.5 and was located at a depth of ~11 km near Ellensburg.

OTHER SOURCES OF EARTHQUAKE INFORMATION

We provide automatic computer-generated alert messages about significant Washington and Oregon earthquakes by e-mail or FAX to institutions needing such information, and we regularly exchange phase data via e-mail with other regional seismograph network operators. The "Outreach Activities" section describes how to access PNSN data over modem, Internet, and World-Wide-Web. To request additional information by e-mail, contact seis_info@geophys.washington.edu.

Earthquake information in the quarterlies is published in final form by the Washington State Department of Natural Resources as information circulars entitled "Earthquake Hypocenters in Washington and Northern Oregon" covering the period 1970-1989 (see circulars Nos. 53, 56, 64-66, 72, 79, 82-84, and 89). These circulars, plus circular No. 85, "Washington State Earthquake Hazards", are available from Washington Dept. of Natural Resources, Division of Geology and Earth Resources, Post Office Box 47007, Olympia, Wa. 98504-7007, or by telephone at (360) 902-1450.

A full-color map called "Earthquakes in Washington and Oregon 1872-1993", by Susan Goter (USGS Open-File Report 94-226A), and its companion pamphlet "Washington and Oregon Earthquake History and Hazards", by Yelin, Tarr, Michael, and Weaver (USGS Open-File Report 94-226B) is available from "Earthquake Maps" U.S. Geological Survey, Box 25046, Federal Center, MS 967, Denver, CO 80225, phone (303)273-8420. The price is $12. (including shipping and handling). The pamphlet (USGS Open-File Report 94-226B) is also available separately.

Other regional agencies provide earthquake information. These include the Geological Survey of Canada (Pacific Geoscience Centre, Sidney, B.C.; (604) 363-6500, FAX (604) 363-6565), which produces monthly summaries of Canadian earthquakes; the United States Geological Survey which produces weekly reports called "Seismicity Reports for Northern California" (USGS, attn: Steve Walter, 345 Middlefield Rd, MS-977, Menlo Park, Ca, 94025) and "Weekly Earthquake Report for Southern California" (USGS, attn: Dr. Kate Hutton or Dr. Lucy Jones, California Institute of Technology, Pasadena, Ca.)

QUARTERLY NETWORK REPORT 96-D
on
Seismicity of Washington and Oregon

October 1 through December 31, 1996

Pacific Northwest Seismograph Network
Geophysics Program
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and

Westinghouse Hanford Company
Contract MLA-SVV-208775

Moment-tensor focal mechanisms for earthquakes in the Pacific Northwest were computed by Oregon State University under USGS NEHRP Grant 1434-93-G-2326.

CONTENTS

FIGURES

TABLES

INTRODUCTION

This is the fourth quarterly report of 1996 from the University of Washington Geophysics Program *Pacific Northwest Seismograph Network* (PNSN), covering seismicity of all of Washington and western Oregon. These comprehensive quarterlies have been produced since the beginning of 1984. Prior to that we published quarterlies for western Washington in 1983 and for eastern Washington from 1975 to 1983. Annual technical reports covering seismicity in Washington since 1969 are available from the U.W. Geophysics Program.

This quarterly report discusses network operations, seismicity of the region, unusual events or findings, and our educational and outreach activities. This report is preliminary, and subject to revision. Some earthquake locations may be revised if new data become available, such as P and S readings from Canadian or USGS CALNET seismograph stations. Findings mentioned in these quarterly reports should not be cited for publication.

NETWORK OPERATIONS

Figure 1 shows a map view of stations operating during the quarter. Table 1 gives approximate periods of time when individual stations were inoperable. Data for Table 1 are compiled from weekly plots of network-wide teleseismic arrivals and automated digital signal checks, plus records of maintenance and repair visits. During the fourth quarter, several stations lost function due to winter conditions.

Strong-motion Instrumentation Plans

The PNSN received funding from the USGS to acquire, install, and operate six very high-dynamic-range strong-motion instruments (consisting of 3-component accelerometers plus digital data-recorders). Three instruments were funded by the USGS under special contract 1434-HQ-96-GR-02714, and three through a supplement to the existing PNSN-USGS joint operating agreement (1434-95-A-1302). Terra Technology ISD-24 instruments were chosen. The units were delivered this quarter, and are now operating in test mode on our pier. The first three sites have been selected. These are at the UW (the accelerometers will be co-sited with the SEA Wood-Anderson instruments which have operated since 1966), at a Bonneville Power Authority (BPA) substation near Maple Valley, and on a pier at the University of Puget Sound in Tacoma. Data from these instruments will be available by real-time telemetry as part of the PNSN data stream. The remaining instruments should be sited and operational by the end of the summer.

TABLE 1
Station Outages 4th quarter 1996

Station	Outage Dates	Comments
CDF	10/01-End	Dead - Winter conditions
GLK	09/05-End	Dead - Vandalized
KOS	12/22-End	Dead - Winter conditions
NCO	12/10-End	Dead - Winter conditions
OSR	11/04-End	Dead - Winter conditions
TBM	10/01-11/04	Repaired - Bad transmitter
TCO	12/06-End	Dead - Winter conditions
TDH	03/07-07/11	Repaired - Replaced VCO
VFP	02/01-End	Dead - Damaged seismometer
VSP	02/25-End	Dead - Winter conditions

Data Backup

All triggered network trace data in raw unedited format, plus continuous telemetry from stations TTW (3 component broad-band) and LON.LHZ, and other non-continuous event-by-event broadband data, are backed up on a network archive tape. Edited event trace data are archived on large disks, and kept on 2.1 GByte exabyte tapes. We also archive the edited trace data on high-speed, high-capacity (20 GByte) digital linear tape (DLT) cartridges. In addition, the IRIS Data Management Center (DMC) archives the data in SEED format, where they can be retrieved by any investigator via the standard IRIS data request mechanisms.

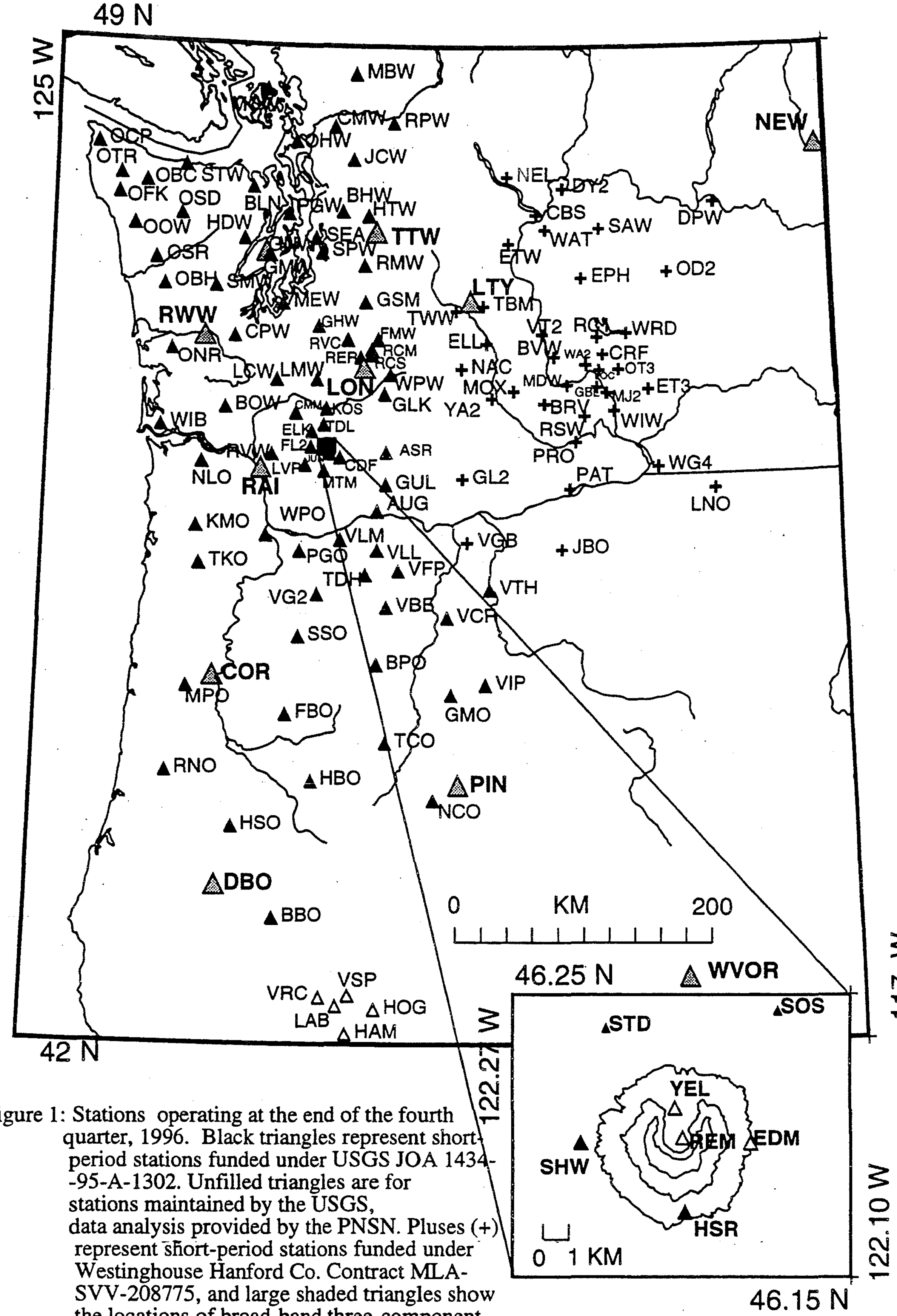

Figure 1: Stations operating at the end of the fourth quarter, 1996. Black triangles represent short-period stations funded under USGS JOA 1434--95-A-1302. Unfilled triangles are for stations maintained by the USGS, data analysis provided by the PNSN. Pluses (+) represent short-period stations funded under Westinghouse Hanford Co. Contract MLA-SVV-208775, and large shaded triangles show the locations of broad-band three-component instruments, funded either via JOA 1434-92-A-0963, NSF EAR-9207181, DOGAMI, or by the USGS-NSN.

STATIONS USED FOR LOCATION OF EVENTS

Table 2A lists short-period, mostly one-component stations used in locating seismic events in Washington and Oregon. Table 2B lists broad-band, three-component stations operating in Washington and Oregon that provide data to the PNSN. The first column in the table gives the 3-letter station designator, followed by a symbol designating the funding agency; stations marked by a percent sign (%) were supported by USGS joint operating agreement 1434-95-A-1302, and (+) indicates support under Westinghouse Hanford Company Contract MLA-SVV-208775. Other stations were supported from other sources. Additional columns give station north latitude and west longitude (in degrees, minutes and seconds), station elevation in km, and comments indicating landmarks for which stations were named.

TABLE 2A

Short-period Stations operating during the fourth quarter 1996

STA	F	LAT	LONG	EL	NAME
ASR	%	46 09 09.9	121 36 01.6	1.357	Mt. Adams - Stagman Ridge
AUG	%	45 44 10.0	121 40 50.0	0.865	Augspurger Mtn
BBO	%	42 53 12.6	122 40 46.6	1.671	Butler Butte, Oregon
BHW	%	47 50 12.6	122 01 55.8	0.198	Bald Hill
BLN	%	48 00 26.5	122 58 18.6	0.585	Blyn Mt.
BOW	%	46 28 30.0	123 13 41.0	0.870	Boistfort Mt.
BPO	%	44 39 06.9	121 41 19.2	1.957	Bald Peter, Oregon
BRV	+	46 29 07.2	119 59 28.2	0.920	Black Rock Valley
BVW	+	46 48 39.6	119 52 59.4	0.670	Beverly
CBS	+	47 48 17.4	120 02 30.0	1.067	Chelan Butte, South
CDF	%	46 06 58.2	122 02 51.0	0.780	Cedar Flats
CMM	%	46 26 07.0	122 30 21.0	0.620	Crazy Man Mt.
CMW	%	48 25 25.3	122 07 08.4	1.190	Cultus Mtns.
CPW	%	46 58 25.8	123 08 10.8	0.792	Capitol Peak
CRF	+	46 49 30.0	119 23 13.2	0.189	Corfu
DBO		43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon
DPW	+	47 52 14.3	118 12 10.2	0.892	Davenport
DY2	+	47 59 06.6	119 46 16.8	0.890	Dyer Hill 2
EDM	#	46 11 50.4	122 09 00.0	1.609	East Dome, Mt. St. Helens
ELK	%	46 18 20.0	122 20 27.0	1.270	Elk Rock
ELL	+	46 54 34.8	120 33 58.8	0.789	Ellensburg
EPH	+	47 21 22.8	119 35 45.6	0.661	Ephrata
ET3	+	46 34 38.4	118 56 15.0	0.286	Eltopia (replaces ET2)
ETW	+	47 36 15.6	120 19 56.4	1.477	Entiat
FBO	%	44 18 35.6	122 34 40.2	1.080	Farmers Butte, Oregon
FL2	%	46 11 47.0	122 21 01.0	1.378	Flat Top 2
FMW	%	46 56 29.6	121 40 11.3	1.859	Mt. Fremont
GBL	+	46 35 54.0	119 27 35.4	0.330	Gable Mountain
GHW	%	47 02 30.0	122 16 21.0	0.268	Garrison Hill
GL2	+	45 57 35.0	120 49 22.5	1.000	New Goldendale
GLK	%	46 33 50.2	121 36 30.7	1.320	Glacier Lake
GMO	%	44 26 20.8	120 57 22.3	1.689	Grizzly Mountain, Oregon
GMW	%	47 32 52.5	122 47 10.8	0.506	Gold Mt.
GSM	%	47 12 11.4	121 47 40.2	1.305	Grass Mt.
GUL	%	45 55 27.0	121 35 44.0	1.189	Guler Mt.
HAM	#	42 04 08.3	121 58 16.0	1.999	Hamaker Mt., Oregon
HBO	%	43 50 39.5	122 19 11.9	1.615	Huckleberry Mt., Oregon
HDW	%	47 38 54.6	123 03 15.2	1.006	Hoodsport
HOG	#	42 14 32.7	121 42 20.5	1.887	Hogback Mtn., Oregon
HSO	%	43 31 33.0	123 05 24.0	1.020	Harness Mountain, Oregon
HSR	%	46 10 28.0	122 10 46.0	1.720	South Ridge, Mt. St. Helens
HTW	%	47 48 14.2	121 46 03.5	0.833	Haystack Lookout
JBO	+	45 27 41.7	119 50 13.3	0.645	Jordan Butte, Oregon
JCW	%	48 11 42.7	121 55 31.1	0.792	Jim Creek
JUN	%	46 08 48.0	122 09 10.8	1.049	June Lake
KMO	%	45 38 07.8	123 29 22.2	0.975	Kings Mt., Oregon
KOS	%	46 27 40.8	122 11 25.8	0.828	Kosmos
LAB	#	42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon (4-comp)
LCW	%	46 40 14.4	122 42 02.8	0.396	Lucas Creek
LMW	%	46 40 04.8	122 17 28.8	1.195	Ladd Mt.
LNO	+	45 52 18.6	118 17 06.6	0.771	Lincton Mt., Oregon
LO2	%	46 45 00.0	121 48 36.0	0.853	Longmire
LOC	+	46 43 01.2	119 25 51.0	0.210	Locke Island
LVP	%	46 04 06.0	122 24 30.0	1.170	Lakeview Peak
MBW	%	48 47 02.4	121 53 58.8	1.676	Mt. Baker
MCW	%	48 40 46.8	122 49 56.4	0.693	Mt. Constitution
MDW	+	46 36 47.4	119 45 39.6	0.330	Midway
MEW	%	47 12 07.0	122 38 45.0	0.097	McNeil Island
MJ2	+	46 33 27.0	119 21 32.4	0.146	May Junction 2
MOX	+	46 34 38.4	120 17 53.4	0.501	Moxie City

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
MPO	%	44 30 17.4	123 33 00.6	1.249	Mary's Peak, Oregon
MTM	%	46 01 31.8	122 12 42.0	1.121	Mt. Mitchell
NAC	+	46 43 59.4	120 49 25.2	0.728	Naches
NCO	%	43 42 14.4	121 08 18.0	1.908	Newberry Crater, Oregon
NEL	+	48 04 12.6	120 20 24.6	1.500	Nelson Butte
NLO	%	46 05 21.9	123 27 01.8	0.826	Nicolai Mt., Oregon
OBC	%	48 02 07.1	124 04 39.0	0.938	Olympics - Bonidu Creek
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OCP	%	48 17 53.5	124 37 30.0	0.487	Olympics - Cheeka Peak
OD2	+	47 23 15.6	118 42 34.8	0.553	Odessa site 2
OFK	%	47 57 00.0	124 21 28.1	0.134	Olympics - Forks
OHW	%	48 19 24.0	122 31 54.6	0.054	Oak Harbor
ONR	%	46 52 37.5	123 46 16.5	0.257	Olympics - North River
OOW	%	47 44 03.6	124 11 10.2	0.561	Octopus West
OSD	%	47 48 59.2	123 42 13.7	2.008	Olympics - Snow Dome
OSR	%	47 30 20.3	123 57 42.0	0.815	Olympics Salmon Ridge
OT3	+	46 40 08.4	119 13 58.8	0.322	New Othello
OTR	%	48 05 00.0	124 20 39.0	0.712	Olympics - Tyee Ridge
PAT	+	45 52 55.2	119 45 08.4	0.262	Paterson
PGO	%	45 27 42.6	122 27 11.5	0.253	Gresham, Oregon
PGW	%	47 49 18.8	122 35 57.7	0.122	Port Gamble
PRO	+	46 12 45.6	119 41 08.4	0.553	Prosser
RC1	+	46 56 42.6	119 26 39.6	0.485	Royal City (3 comp.)
RCM	%	46 50 08.9	121 43 54.4	3.085	Mt. Rainier, Camp Muir
RCS	%	46 52 15.6	121 43 52.0	2.877	Mt. Rainier, Camp Schurman
REM	#	46 11 57.0	122 11 03.0	2.102	Rembrandt (Dome station)
RER	%	46 49 09.2	121 50 27.3	1.756	Mt. Rainier, Emerald Ridge
RMW	%	47 27 35.0	121 48 19.2	1.024	Rattlesnake Mt. (West)
RNO	%	43 54 58.9	123 43 25.5	0.850	Roman Nose, Oregon
RPW	%	48 26 54.0	121 30 49.0	0.850	Rockport
RSW	+	46 23 40.2	119 35 28.8	1.045	Rattlesnake Mt. (East)
RVC	%	46 56 34.5	121 58 17.3	1.000	Mt. Rainier - Voight Creek
RVN		47 01 38.6	121 20 11.9	1.885	Raven Roost
RVW	%	46 08 53.2	122 44 32.1	0.460	Rose Valley
SAW	+	47 42 06.0	119 24 01.8	0.701	St. Andrews
SEA		47 39 18.0	122 18 30.0	0.030	Seattle (Wood Anderson)
SHW	%	46 11 37.1	122 14 06.5	1.425	Mt. St. Helens
SMW	%	47 19 10.7	123 20 35.4	0.877	South Mtn.
SOS	%	46 14 38.5	122 08 12.0	1.270	Source of Smith Creek
SPW	%	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle
SSO	%	44 51 21.6	122 27 37.8	1.242	Sweet Springs, Oregon
STD	%	46 14 16.0	122 13 21.9	1.268	Studebaker Ridge
STW	%	48 09 02.9	123 40 13.1	0.308	Striped Peak
TBM	+	47 10 12.0	120 35 52.8	1.006	Table Mt.
TCO	%	44 06 21.0	121 36 01.0	1.975	Three Creek Meadows, Oregon.
TDH	%	45 17 23.4	121 47 25.2	1.541	Tom,Dick,Harry Mt., Oregon
TDL	%	46 21 03.0	122 12 57.0	1.400	Tradedollar Lake
TKO	%	45 22 16.7	123 27 14.0	1.024	Trask Mtn, Oregon
TRW	+	46 17 32.0	120 32 31.0	0.723	Toppenish Ridge
LNO	+	45 52 18.6	118 17 06.6	0.771	Lincton Mt., Oregon
TWW	+	47 08 17.4	120 52 06.0	1.027	Teanaway
VBE	%	45 03 37.2	121 35 12.6	1.544	Beaver Butte, Oregon
VCR	%	44 58 58.2	120 59 17.4	1.015	Criterion Ridge, Oregon
VFP	%	45 19 05.0	121 27 54.3	1.716	Flag Point, Oregon
VG2	%	45 09 20.0	122 16 15.0	0.823	Goat Mt., Oregon
VGB	+	45 30 56.4	120 46 39.0	0.729	Gordon Butte, Oregon
VIP	%	44 30 29.4	120 37 07.8	1.731	Ingram Pt., Oregon
VLL	%	45 27 48.0	121 40 45.0	1.195	Laurance Lk., Oregon
VLM	%	45 32 18.6	122 02 21.0	1.150	Little Larch, Oregon
VRC	#	42 19 47.2	122 13 34.9	1.682	Rainbow Creek, Oregon
VSP	#	42 20 30.0	121 57 00.0	1.539	Spence Mtn, Oregon
VT2	+	46 58 02.4	119 59 57.0	1.270	Vantage2
VTH	%	45 10 52.2	120 33 40.8	0.773	The Trough, Oregon
WA2	+	46 45 19.2	119 33 56.4	0.244	Wahluke Slope
WAT	+	47 41 55.2	119 57 14.4	0.821	Waterville
WG4	+	46 01 49.2	118 51 21.0	0.511	Wallula Gap
WIB	#	46 20 34.8	123 52 30.6	0.503	Willapa Bay (3 comp.)
WIW	+	46 25 45.6	119 17 15.6	0.128	Wooded Island
WPO	%	45 34 24.0	122 47 22.4	0.334	West Portland, Oregon
WPW	%	46 41 53.4	121 32 48.0	1.250	White Pass
WRD	+	46 58 12.0	119 08 41.4	0.375	Warden
XTL		46 55 47.8	121 29 35.8	1.665	Crystal Mtn.
YA2	+	46 31 36.0	120 31 48.0	0.652	Yakima
YEL	#	46 12 35.0	122 11 16.0	1.750	Yellow Rock, Mt. St. Helens

TABLE 2B

Broad-band three-component stations operating at the end of the fourth quarter 1996

STA	F	LAT	LONG	EL	NAME
COR		44 35 08.5	123 18 11.5	0.121	Corvallis, Oregon (IRIS station, Operated by OSU)
DBO		43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon (Operated by UO)
GNW	*	47 33 51.8	122 49 31.0	0.165	Green Mountain, WA (operated by UW)
LON	*	46 45 00.0	121 48 36.0	0.853	Longmire, WA (operated by UW)
LTY	*	47 15 21.2	120 39 53.3	0.970	Liberty, WA (operated by UW)
NEW		48 15 50.0	117 07 13.0	0.760	Newport Observatory (USGS-USNSN)
RAI		46 02 25.1	122 53 06.4	1.520	Trojan Plant, Oregon (OSU)
RWW	*	46 57 50.1	123 32 35.9	0.015	Ranney Well (operated by UW)
TTW	*	47 41 40.7	121 41 20.0	0.542	Tolt Res, WA (operated by UW)
PIN		43 48 40.0	120 52 19.0	1.865	Pine Mt. Oregon (operated by UO)
WVOR		42 26 02.0	118 38 13.0	1.344	Wildhorse Valley, Oregon (USGS-USNSN)

OUTREACH ACTIVITIES

The PNSN Seismology Lab staff provides an educational outreach program to better inform the public, educators, business, policy makers, and the emergency management community about seismicity and natural hazards. Our outreach includes lab tours, lectures, classes and workshops, press conferences, TV and radio news programs and talk shows, field trips, and participation in regional earthquake planning efforts. We provide basic information through information sheets, an audio library, and the Internet on the World-Wide-Web (WWW):

http://www.geophys.washington.edu/SEIS

Special Events

- A CREW Business Team meeting, attended by UW's Dr. Anthony Qamar and Bill Steele, was held at Humboldt (CA) State University.
- Dr. Stephen Malone made a presentation to about 75 participants at a meeting of the American Society of Civil Engineers.
- Dr. Anthony Qamar attended a meeting of the Washington State Seismic Safety Advisory Committee.
- State Representative Valle met with UW and DNR representatives to discuss science education.

Press Interviews, Lab Tours, and Workshops

PNSN staff provided only a few television or radio interviews this quarter, but many outside presentations were given. • Three presentations at US West, Boeing, and Seafirst reached several dozen executives responsible for data facility management and emergency response and recovery. •"Train the Trainers" earthquake hazards talks were given at King County Red Cross and to the Bellevue Fire Department. • A 2-hour seminar for the Washington Insurance Council reached an audience of several hundred.• About 30 participants attended a workshop conducted for the Washington Association of Science Teachers. • For the general public, presentations were made to the Shoreline Rotary Club and to two classes at Hamilton Middle School.

During the fourth quarter, 15 K-12 school groups and 1 college-age group (about 300 individuals total) toured the Seismology Lab.

Telephone, Mail, and On-line outreach

The PNSN audio library system received about 1,600 calls this quarter. We provide several recordings. The most popular is a frequently updated message on current seismic activity. In addition we have a tape describing the seismic hazards in Washington and Oregon, and another on earthquake prediction. Callers often request our one-page information and resource sheet on seismic hazards in Washington and Oregon. Thousands of these have been mailed out or distributed, and we encourage others to reproduce and further distribute this sheet. Our information sheet discussing earthquake prediction is also frequently requested. Callers to the audio library can also choose to be transferred to the Seismology Lab, where additional information is available. This quarter we responded in person to ~30 calls from emergency management and government, ~30 calls from the media, ~35 calls from educators, ~115 calls from the business community, and over 250 calls from the general public.

The list of recent Pacific Northwest earthquakes can be accessed by a variety of methods beyond the audio library described above; by e-mail or modem, via our World-Wide-Web site, and through the Internet with the UNIX "finger" utility. The computer methods have an advantage over the audio library. Not only are more earthquakes listed, but update is automated, and the location and magnitude information is available more rapidly. Table 3 shows the number of times the computerized PNSN list of recent earthquakes magnitude 2.0 or larger was accessed. The Internet UNIX utility "finger quake@geophys.washington.edu" was most popular, followed by access over the WWW. For computer users without direct access to Internet, this information can be accessed via e-mail (by sending e-mail to "quake@geophys.washington.edu"), or by direct dial-up to our computer "quake" via modem ((206) 685-0889); modem setting: 8 bits, 1 stop bit, no parity; type "quake" at "geoterm" prompt and login as "quake"). The modem and e-mail services are used several hundred times each month.

The PNSN recent earthquake list, and much more, is also available through the World-Wide-Web (WWW) at:

http://www.geophys.washington.edu/SEIS

TABLE 3
Quarterly Comparison of Methods of Accessing PNSN list of most recent earthquakes, M>=2.0

Access Method	95-A	95-B	95-C	95-D	96-A	96-B	96-C	96-D
Finger Quake	110,000	93,000	80,000	72,000	83,000	90,300	62,900	63,000
World-Wide-Web	2,300	2,500	3,100	4,300	6,300	16,500	10,800	5,400
Remote Login as Quake	7,600	5,400	3,400	2,900	2,500	1,800	1,100	1,800
Via E-mail	956	613	444	477	317	459	264	223
Dialup Quake	811	580	604	439	406	763	364	384

During the fourth quarter, we improved our web site file organization. Web usage continues to increase, with about 25,000 accesses per month to PNSN offerings, which include a map and list of the most recent PNW earthquakes, plus general information on earthquakes and PNW earthquake hazards, information on past damaging PNW earthquakes, and catalogs of earthquake summary cards since 1970. The PNSN has a great deal of educational material that can be quite easily adapted for the web, and we will be adding features to our website as time permits. Quarterly summaries of seismic activity in Washington and Oregon extracted from these quarterly reports can be found in the WWW area:

http://www.geophys.washington.edu/SEIS/PNSN/REPTS/res_rept.html

In addition to the PNSN web site, the UW Geophysics Program and the PNSN host several other earthquake-related web sites:

- **Seismosurfing** is probably the most popular single page on our server. It is a comprehensive listing of sites worldwide that offer substantive seismology data and information. About 10,000 visits are made to this page each month.

  http://www.geophys.washington.edu/seismosurfing.html

- The **Council of National Seismic Systems** (CNSS) site features composite listings and maps of recent U.S. earthquakes, and is visited about 15,000 times per month.

  http://www.geophys.washington.edu/CNSS/cnss.cat.html

- The **"Tsunami!"** web site offers many pages of information, including an excellent discussion on the physics of tsunamis, and short movie clips. **"Tsunami!"** was developed by Benjamin Cook under the direction of Dr. Catherine Petroff (UW Civil Engineering). It is very popular, with about 35,000 visits per month.

  http://www.geophys.washington.edu/tsunami/welcome.html

- **CREW (Cascadia Regional Earthquake Workgroup)** is a public-private partnership for earthquake damage mitigation, and receives about 7,000 access requests per month.

  http://www.geophys.washington.edu/CREW/index.html

EARTHQUAKE DATA

There were 974 events digitally recorded and processed at the University of Washington between October 1 and December 31, 1996. Locations in Washington, Oregon, or southernmost British Columbia were determined for 476 of these events; 387 were classified as earthquakes and 89 as known or suspected blasts. The remaining 498 processed events include teleseisms (135 events), regional events outside the PNSN (91), and unlocated events within the PNSN. Unlocated events within the PNSN include very small earthquakes and some known blasts. Frequent mining blasts occur near Centralia, and we routinely locate and retrieve broad-band data for some of them.

The largest earthquake within our network this quarter (on December 15 at 08:34 UTC) was only magnitude 2.9. However, an earthquake of magnitude 6.2 occurred on the Nootka fault, off of the west coast of Vancouver Island, British Columbia. This earthquake occurred at 20:13 UTC on October 6, and was located (by the NEIC) at a shallow depth at 48.8 degrees north latitude and 128.4 degrees west longitude. It is not listed in Table 4 because it is outside our reporting area.

Table 4, located at the end of this report, is the catalog of earthquakes and blasts located within the network for this quarter. For the Klamath Falls area, only earthquakes of magnitude 1.6 and larger have been included in Table 4. For the Duvall area, only earthquakes of magnitude 1.5 and larger have been included in Table 4.

Fig. 2 shows all earthquakes with magnitude greater than or equal to 0.0 ($M_c \geq 0$). Fig. 3 shows blasts and probable blasts ($M_c \geq 0$). Fig. 4 shows earthquakes located near Mt. Rainier ($M_c \geq 0$). Fig. 5 shows earthquakes located at Mt. St. Helens ($M_c \geq 0$). Fig. 6 shows a map of broad-band stations used to determine moment-tensor focal mechanisms. Fig. 7 shows the location and moment-tensor focal mechanisms for earthquakes with $M_w > 3.5$.

MOMENT TENSOR FOCAL MECHANISM SOLUTIONS

Moment-tensor focal mechanisms for earthquakes with $M_w > 3.5$ in the Pacific Northwest are included in this report. These solutions were computed under other support (USGS NEHRP Grant 1434-93-G-2326), at the Oregon State University under the direction of Dr. John Nabelek. The operation of broadband stations in Oregon (COR, RAI, DBO and PIN) was in part supported by a grant from the Oregon Department of Geology and Mineral Industries.

Moment-tensor solutions use data from 3-component broad-band stations in Washington, Oregon, California and British Columbia and from US National Seismic Network Stations in the western states of the US (Figure 6). The inversions are performed in the 0.01 - 0.1 Hz range, with the frequency band adjusted according to the earthquake magnitude and the station epicentral distance.

Moment tensors, best-fit double-couple mechanism, M_w, seismic moment, and depth are given in Table 5. The coordinate conventions of Aki and Richards (Quantitative Seismology: Theory and Methods, W. H. Freeman, San Francisco, 1980) are followed. Figure 7 shows the locations and focal mechanisms for the events listed in Table 5. Events 1-4 were relocated (marked R in Table 5).

An up-to-date catalogue of the moment tensor focal mechanisms is available on the World-Wide-Web server at Oregon State University: **http://quakes.oce.orst.edu**.

OREGON SEISMICITY

During the fourth quarter of 1996 a total of 38 earthquakes were located in Oregon between 42.0° and 45.5° north latitude, and between 117° and 125° west longitude. 29 of these were located in the Klamath Falls area, where a pair of damaging earthquakes in September of *1993* (Sept. 21, 03:29 and 05:45 UTC; M_c 5.9 and 6.0 respectively) were followed by a vigorous aftershock sequence which has decreased over time. This quarter, only six earthquakes of magnitude 1.6 or larger were located in the Klamath Falls area. These are listed in Table 4.0. No earthquakes were reported felt in Oregon this quarter.

WESTERN WASHINGTON SEISMICITY

During the fourth quarter of 1996, 312 earthquakes were located between 45.5° and 49.5° north latitude and between 121° and 125.3° west longitude. The deepest earthquake this quarter was a magnitude 2.7 event on December 17 at 05:53 UTC at a depth of about 57 km. Its epicenter falls between San Juan and Waldron Islands.

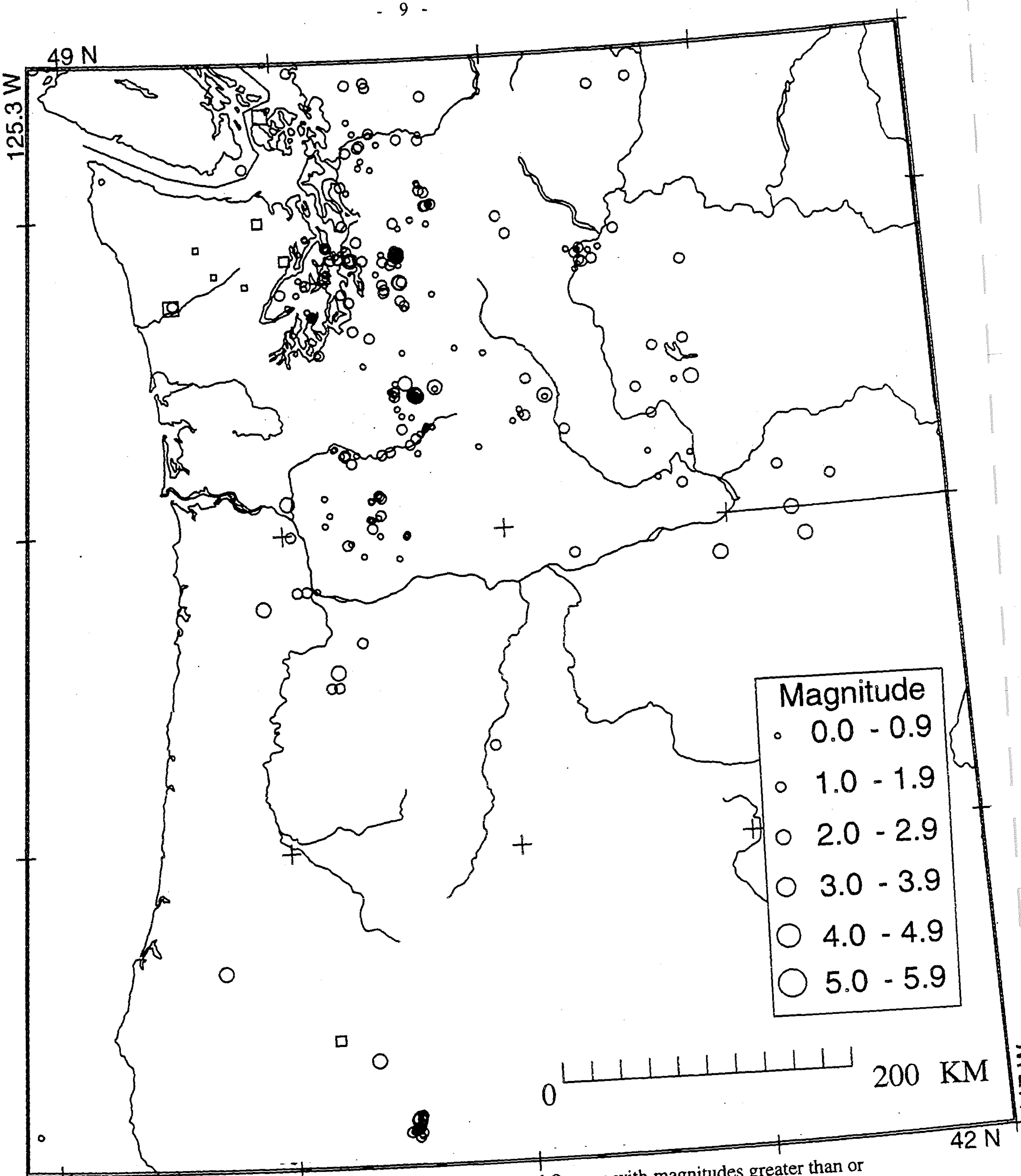

Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the fourth quarter of 1996. Square symbols indicate events located at depths of 30 km or more.

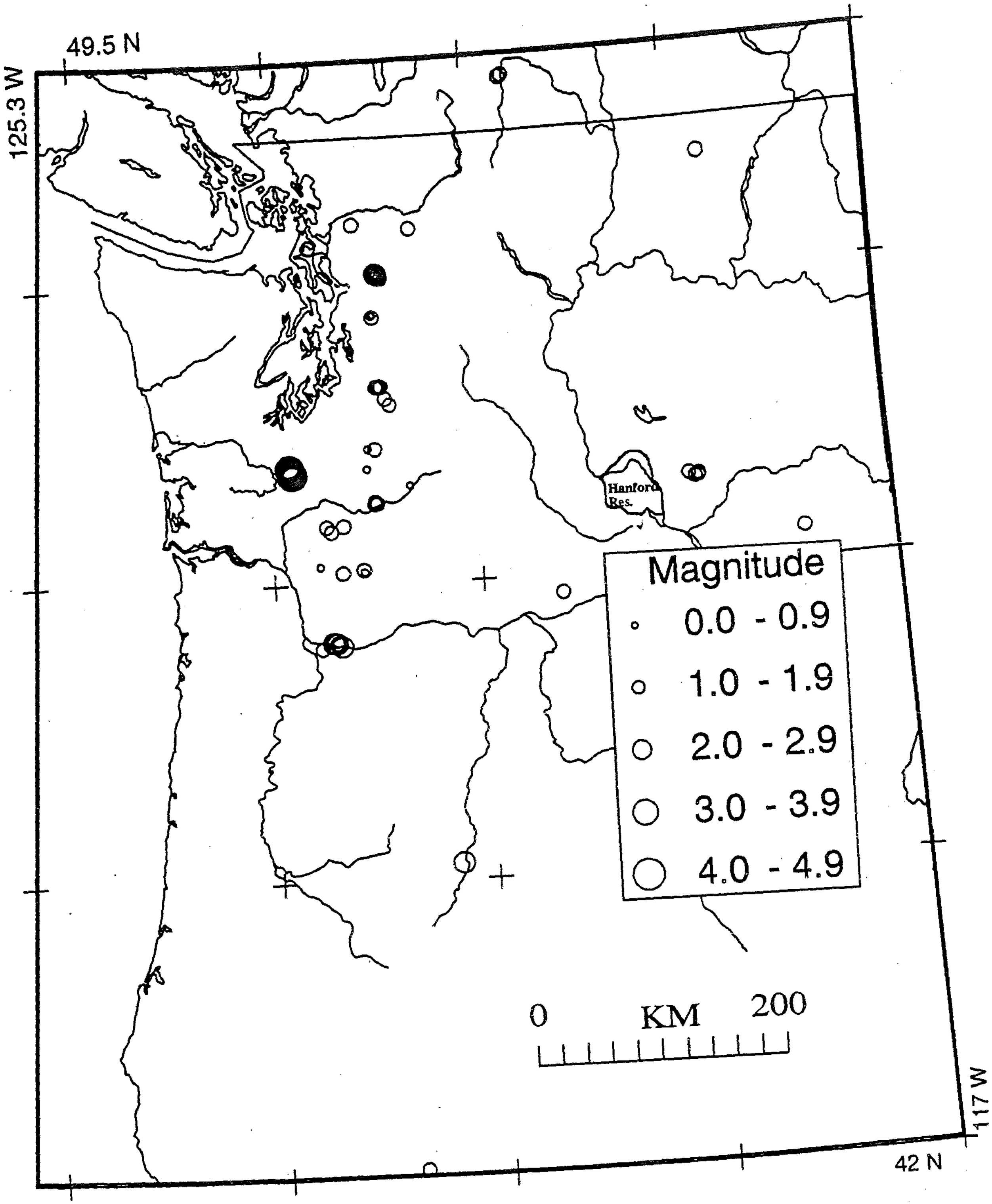

Figure 3: Blasts and probable blasts, fourth quarter, 1996.

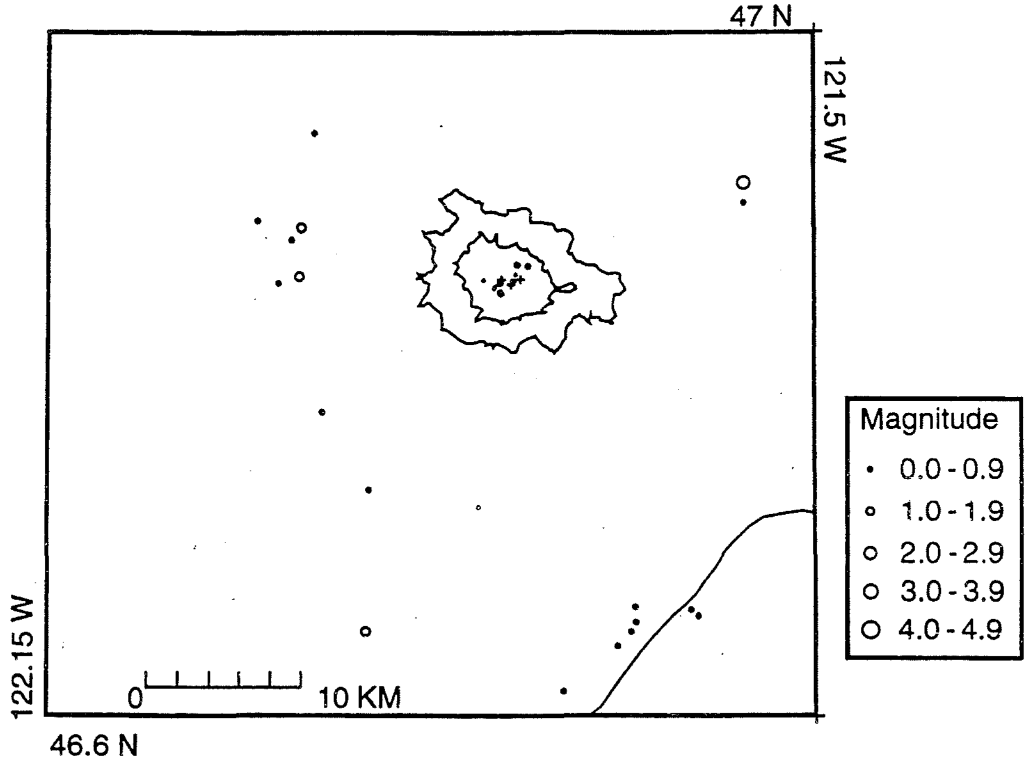

Figure 4: Earthquakes located in the Mt. Rainier area fourth quarter, 1996. All events shown are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

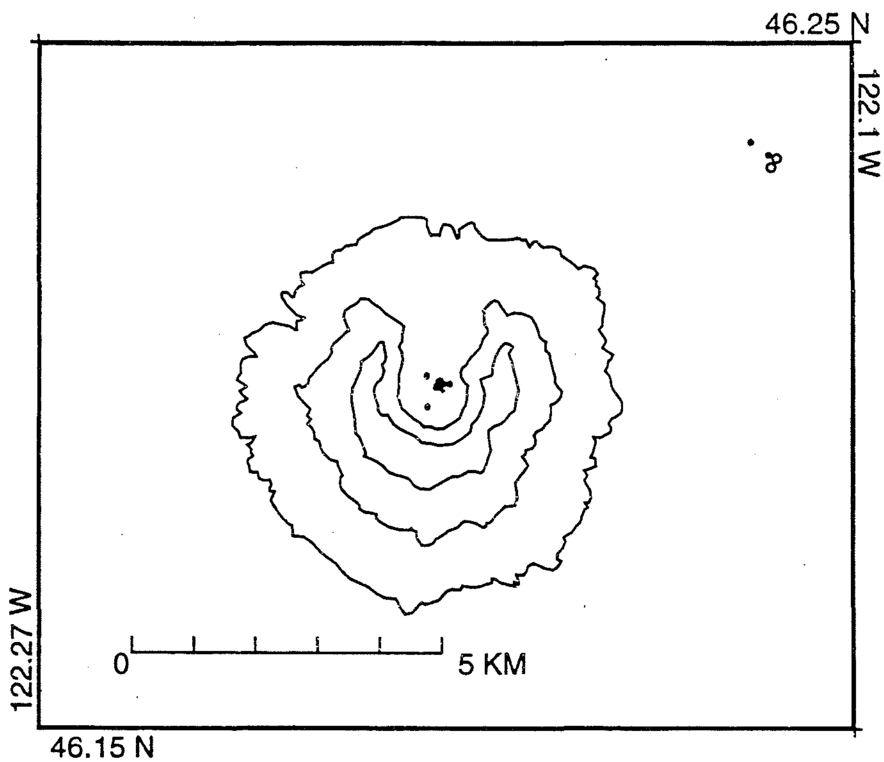

Figure 5: Earthquakes located in the Mt. St. Helens area fourth quarter, 1996. All events shown are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4.

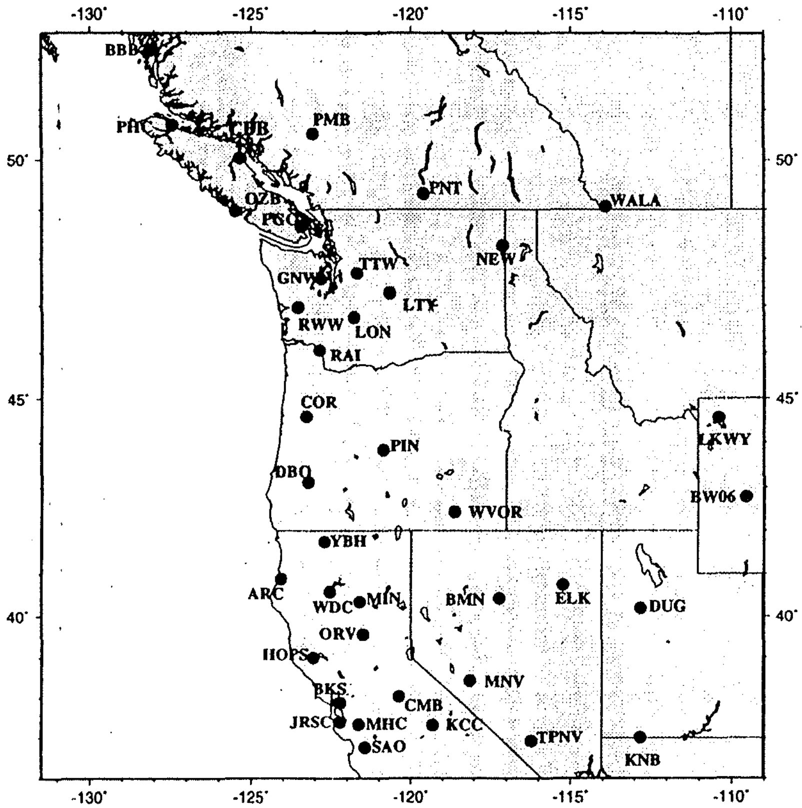

Fig. 6

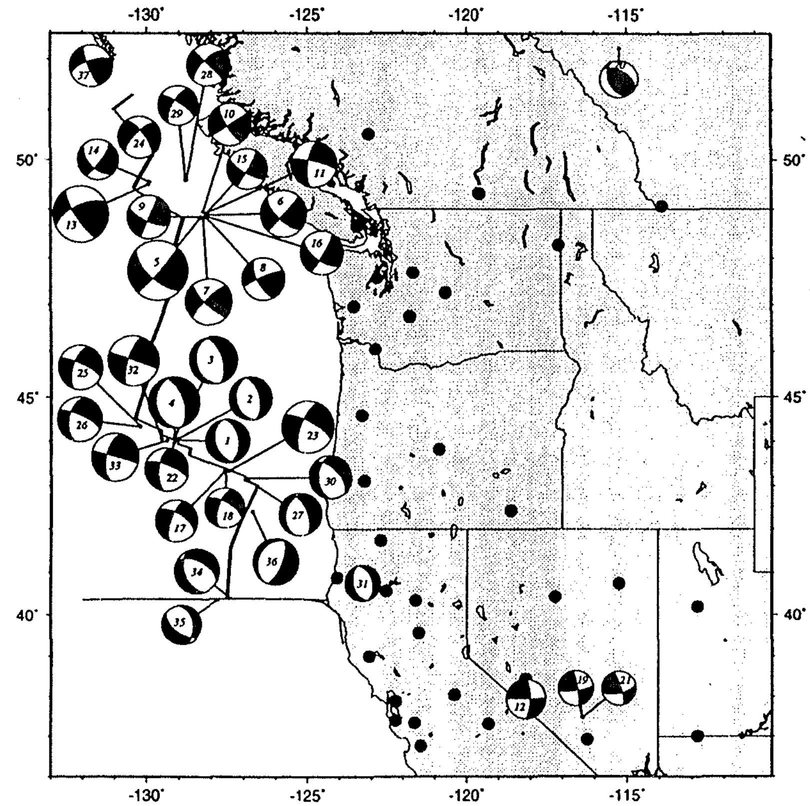

Fig. 7

Figure 6. Map of 3-component broad band stations used to determine moment-tensor focal mechanisms.
Figure 7. Map of best-fit double-couple focal mechanisms.

Two small earthquakes were reported felt in western Washington this quarter. Both were located at shallow depths (around 5 km) near Duvall, where a magnitude 5.4 earthquake occurred on May 3 at 04:04 UTC. This quarter's larger event, magnitude 2.6, occurred on Oct. 27 at 07:53 UTC and the smaller event was magnitude 2.3 on November 13 at 06:12 UTC.

In the Duvall area, activity this quarter included 25 earthquakes. For comparison, 382 were located in the same area during the second quarter, and 57 earthquakes during the third quarter. The largest earthquake in the Duvall vicinity this quarter was the magnitude 2.6 felt event discussed above.

Mount Rainier Area: Figure 4 shows earthquakes near Mount Rainier. The number of events in close proximity to the cone of Mt. Rainier varies over the course of the year, since the source of much of the shallow surface-type activity is presumably ice movement or avalanching, which is seasonal in nature. Events with very low frequency signals (1-3 Hz) believed to be icequakes are assigned type "L" in the catalog. Emergent, very long duration signals probably due to rockfalls or avalanches are assigned type "S" (see Key to Earthquake Catalog). "L" and "S" type events are not shown in Figure 4.

A total of 59 events (21 of them smaller than magnitude 0., and thus not shown in Fig. 4) were located within the region shown in Fig. 4. Of these, 16 were located in the "Western Rainier Seismic Zone" (WRSZ), a north-south trending lineation of seismicity approximately 15 km west of the summit of Mt. Rainier (for counting purposes, the western zone is defined as 46.6-47° N latitude, 121.83-122° W longitude). Closer to the summit (within 5 km), there were 25 tectonic-style earthquakes, and 5 "L" or "S" events were located this quarter (types L and S are not shown in Fig.4). The remaining events were scattered around the cone of Rainier as seen in Fig. 4.

Mount St. Helens Area: Figure 5 shows tectonic earthquakes near Mount St. Helens. Low frequency (L) and avalanche or rockfall events (S) are not shown. In the fourth quarter, 65 events (only 14 magnitude 0. or larger), were located at Mt. St. Helens in the area shown in Fig. 5. This quarter, no type "S" or "L" events were located. Of this quarter's earthquakes, 35 (7 of them larger than magnitude 0.) were deeper than 4 km. The largest event at Mount St. Helens, magnitude 1.8, on November 16 at 19:09 UTC, was at a depth of about 10 km.

EASTERN WASHINGTON SEISMICITY

During the fourth quarter of 1996, 45 earthquakes were located in eastern Washington. None were reported felt. The largest quake in the area that we refer to as "eastern Washington" for reporting purposes, actually occurred in Oregon this quarter. It was on December 14 at 21:50 UTC, had magnitude 2.3 and was located at a depth of about 2 km between Pendleton and Umatilla.

OTHER SOURCES OF EARTHQUAKE INFORMATION

We provide automatic computer-generated alert messages about significant Washington and Oregon earthquakes by e-mail or FAX to institutions needing such information, and we regularly exchange phase data via e-mail with other regional seismograph network operators. The "Outreach Activities" section describes how to access PNSN data over modem, Internet, and World-Wide-Web. To request additional information by e-mail, contact seis_info@geophys.washington.edu.

Earthquake information in the quarterlies is published in final form by the Washington State Department of Natural Resources as information circulars entitled "Earthquake Hypocenters in Washington and Northern Oregon" covering the period 1970-1989 (see circulars Nos. 53, 56, 64-66, 72, 79, 82-84, and 89). These circulars, plus circular No. 85, "Washington State Earthquake Hazards", are available from Washington Dept. of Natural Resources, Division of Geology and Earth Resources, Post Office Box 47007, Olympia, Wa. 98504-7007, or by telephone at (360) 902-1450.

A full-color map called "Earthquakes in Washington and Oregon 1872-1993", by Susan Goter (USGS Open-File Report 94-226A), and its companion pamphlet "Washington and Oregon Earthquake History and Hazards", by Yelin, Tarr, Michael, and Weaver (USGS Open-File Report 94-226B) is available from "Earthquake Maps" U.S. Geological Survey, Box 25046, Federal Center, MS 967, Denver, CO 80225, phone (303)273-8420. The price is $12. (including shipping and handling). The pamphlet (USGS Open-File Report 94-226B) is also available separately.

Other regional agencies provide earthquake information. These include the Geological Survey of Canada (Pacific Geoscience Centre, Sidney, B.C.; (604) 363-6500, FAX (604) 363-6565), which produces monthly summaries of Canadian earthquakes; the US Geological Survey which produces weekly reports called "Seismicity Reports for Northern California" (USGS, attn: Steve Walter, 345 Middlefield Rd, MS-977, Menlo Park, Ca, 94025) and "Weekly Earthquake Report for Southern California" (USGS, attn: Dr. Kate Hutton or Dr. Lucy Jones, CalTech, Pasadena, Ca.)