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Revision 0

Hanford Seismic Report for Fiscal Year 2021 (October 2020 - September 2021)

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract 89303320DEM000031

P.O. Box 943
Richland, Washington 99352

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Executive Summary

The Pacific Northwest Seismic Network (PNSN) and Hanford Mission Integration Solutions (HMIS) provide uninterrupted collection of high-quality raw and processed seismic data from the Hanford Seismic Network (HSN). The HSN includes both onsite and offsite [Eastern Washington Regional Sub-Network (EWRSN)] stations that are operated for the U.S. Department of Energy (DOE) and its contractors. The team is responsible for identifying and locating sources of seismic activity that might affect the Hanford Site, monitoring changes in the historical pattern of seismic activity surrounding the Hanford Site, and monitoring ground motion to provide data to constrain studies of earthquake effects on the Hanford Site. Seismic data are compiled, archived, and published for use by the Hanford Site for waste management, natural phenomena hazards assessments, and engineering design and construction. In addition, the team works with the Hanford Site Emergency Services Organization to provide assistance in the event of a significant earthquake on the Hanford Site. The HSN and the EWRSN together consist of 40 individual sensor sites and 14 radio relay sites maintained by the PNSN.

During FY2021, seismic activity was relatively quiet throughout eastern Washington. 265 earthquakes were cataloged in the region, of which about 20% (53) took place on or in the immediate vicinity of the Hanford Site. Several earthquakes took place in the historically active area of Entiat and Chelan. Within the vicinity of the Hanford Site, there was typical swarm-type activity, most strongly observed near the Cold Creek and Wye Swarm Areas.

Abbreviations and Acronyms

ANSS	Advanced National Seismic System
AQMS	ANSS Quake Management System
BB	Broadband (type of seismic station)
BPA	Bonneville Power Administration
BWIP	Basalt Waste Isolation Project
CRBG	Columbia River Basalt Group
Dmin	Minimum distance (closest distance from an earthquake epicenter to a station)
DOE	U.S. Department of Energy
EEW	Earthquake early warnings
Etyp	Event type
EWRSN	Eastern Washington Regional Sub-Network
FY	Fiscal Year
g	typical value of gravitational acceleration at Earth's surface (~978 cm/sec/sec)
GPS	Global Positioning System
HLSMP	Hanford Lifecycle Seismic Monitoring Program
HMIS	Hanford Mission Integration Solutions, LLC
HNF	Hanford Nuclear Facility
HSN	Hanford Seismic Network
IRIS	Incorporated Research Institutions in Seismology
LAT	Latitude
LON	Longitude
Km	kilometer
M_d	Coda-duration magnitude
M_L	Local magnitude
Mag	Magnitude of earthquake
MMI	Modified Mercalli Intensity
MOD	Wavespeed model
MSA	Mission Support Alliance
Mtyp	Magnitude type
NS/NP	Number of stations/number of phases
PNNL	Pacific Northwest National Laboratory
PNSN	Pacific Northwest Seismic Network
Q	Quality factor (of earthquake location)
RMS	Root Mean Square (error of earthquake location)
RSLW	Lower Rattlesnake (Mountain) data acquisition/telemetry site
SHPS	Safety and Health Programs Support
SMA	Strong Motion Accelerometer (type of seismic station)
USGS	U.S. Geological Survey
UTC	Coordinated Universal Time
UW	University of Washington
WHC	Westinghouse Hanford Company
WSUR	Washington State University Richland

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1.0 Introduction

This annual report documents the locations, magnitudes, and seismic interpretations of earthquakes recorded for the Hanford monitoring region of south-central Washington during the fiscal year (FY) 2021 (October 2020 through September 2021). Hanford Mission Integration Solutions, LLC manages seismic monitoring for the Hanford Site with the monitoring work being performed by the PNSN under a subcontract with the University of Washington (UW).

1.1 Mission

The mission of the Hanford Lifecycle Seismic Monitoring Program (HLSMP) is to maintain seismic stations, report data from measured events, and to provide assistance in the event of an earthquake. This mission supports DOE and the other Hanford Site contractors in their compliance with DOE Order 420.1C, Chapter IV, Section 3.e, "Seismic Detection," and DOE Order G 420.1-1A, Section 5.4.8, "Design for Emergency Preparedness and Emergency Communications." DOE Order 420.1C requires facilities or sites with hazardous materials to maintain instrumentation or other means to detect and record the occurrence and severity of seismic events. The HLSMP maintains the seismic network located on and around the Hanford Site. The data collected from the seismic network can be used to support facility or site operations to protect the public, workers, and the environment from the impact of seismic events.

In addition, the HLSMP provides an uninterrupted collection of high-quality raw seismic data from the HSN and the EWRSN and provides interpretations of seismic events from the Hanford Site and the vicinity. The program locates and identifies sources of seismic activity, monitors changes in the historical pattern of seismic activity, and builds a "local" earthquake database (processed data) that is permanently archived. The focus of this report is the precise location of earthquakes and explosions proximal to or on the Hanford Site, specifically, between 46°-47° north latitudes (LAT) and between 119°-120° west longitudes (LON). Data from the EWRSN and other seismic networks in the Northwest provide the HLSMP with necessary regional input for the seismic hazards analysis at the Hanford Site. These seismic data are used to support Hanford Site contractors for waste management activities, natural phenomena hazards assessments, and engineering design and construction.

1.2 History of Monitoring Seismic Activity at Hanford

The U.S. Geological Survey (USGS) under a contract with the U.S. Atomic Energy Commission initiated monitoring seismic activity at the Hanford Site in 1969. In 1975, the UW assumed responsibility for the network and subsequently expanded it. In 1979, the Basalt Waste Isolation Project (BWIP) became responsible for collecting seismic data for the Hanford Site as part of site characterization activities. Rockwell Hanford Operations, followed by Westinghouse Hanford Company (WHC), operated the local network, and were the contract technical advisors for the EWRSN operated and maintained by UW. Funding ended for BWIP in December 1988; the seismic program (including the UW contract) was transferred to the WHC Environmental Division. Maintenance responsibilities for the EWRSN also were assigned to WHC, who made major upgrades to EWRSN sites. Effective October 1, 1996, all seismic assessment activities were transferred to the Pacific Northwest National Laboratory (PNNL).

The Hanford Strong Motion Accelerometer (SMA) network was constructed during 1997, becoming operational in May 1997. It was shut down in FY 1998 due to lack of funding but became operational again in FY 1999 and has operated continuously since that time. During the third quarter of FY 2011, operations of the seismic monitoring networks were assumed by HLSMP.

1.3 Documentation and Reports

The HLSMP issues quarterly reports of local activity, an annual catalog of earthquake activity in southeastern Washington, and special-interest bulletins on local seismic events. This includes information and special reports as requested by DOE and Hanford Site contractors. Earthquake information provided in these reports is subject to revision as new information becomes available. An archive of all cataloged seismic event locations and magnitudes and related waveform data from the HLSMP is maintained by PNSN on computer servers at the UW. Continuous waveform data and associated station metadata from all available seismic stations is permanently archived at the Incorporated Research Institutions in Seismology (IRIS) seismic data archive in Seattle, with backup copies at IRIS facilities in Seattle and in Boulder, Colorado.

2.0 Geology and Tectonic Analysis

The Hanford Site lies within the Columbia Basin, an intermontane basin between the Cascade Range and the Rocky Mountains filled with Cenozoic volcanic rocks and sediments. This basin forms the northern part of the Columbia Plateau physiographic province (Fenneman 1931) and the Columbia River flood-basalt province (Reidel *et al.* 1989). In the central and western parts of the Columbia Basin, the Columbia River Basalt Group (CRBG) overlies Tertiary continental sedimentary rocks and is overlain by late Tertiary, Quaternary fluvial, and glaciofluvial deposits (Campbell 1989; Reidel *et al.* 1989, 1994; DOE 1988). In the eastern part, little or no sediment separates the basalt and underlying crystalline basement, and a thin (<10 m) veneer of eolian sediments overlies the basalt (Reidel *et al*. 1989, 1994).

The Columbia Basin has two structural subdivisions or sub provinces—the Yakima Fold Belt and the Palouse Slope. The Yakima Fold Belt includes the western and central parts of the Columbia Basin and is a series of anticlinal ridges and synclinal valleys with major thrust faults typically along the northern flanks (Figure 2.1) (Reidel and Fecht 1994a, 1994b). The Palouse Slope is the eastern part of the basin and is less deformed than the Yakima Fold Belt, with only a few faults and low-amplitude long-wavelength folds on an otherwise gently westward dipping paleoslope.

2.1 Earthquake Stratigraphy

Seismic studies at the Hanford Site have shown that the earthquake activity is related to crustal stratigraphy (large groupings of rock types) (Rohay *et al.* 1985; DOE 1988). The main geologic units important to earthquakes at the Hanford Site and the surrounding area are:

- Miocene Columbia River Basalt Group
- Sub-basalt sediments of Paleocene, Eocene, Oligocene, and Early Miocene age
- Precambrian and Paleozoic cratonic basement
- Mesozoic accreted terranes forming the basement west of the craton margin

2.2 Geologic Structure Beneath the Monitored Area

Between the late 1950s and the mid-1980s, deep boreholes were drilled for hydrocarbon exploration in the Columbia Basin. These boreholes provided accurate measurements of the physical properties of the CRBG and the pre-basalt sediments (Reidel *et al.* 1989, 1994), but the thickness of the sub-basalt sediments and nature of the basement are still poorly understood. Table 2.1, derived from Reidel *et al.* (1994), was developed for the geologic interpretation in this report. The thicknesses of these units are variable across the monitored area. Table 2.1 summarizes the approximate thickness at the borders of the monitored area.

Table 2.1. Thicknesses of Stratigraphic Units in the Monitoring Area

(from Reidel et al., 1994)

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

The thickness of the basalt and the sub-basalt sediments varies because of different tectonic environments. The western edge of the North American craton (late Precambrian/Paleozoic continental margin and Precambrian craton) is located in the eastern portion of the monitored area (Reidel *et al.* 1994). The stratigraphy on the craton consists of CRBG overlying basement; the basement is continental crustal rock that underlies much of western North America. The stratigraphy west of the craton consists of 4 to 5 km of CRBG overlying up to 6 km of pre-basalt sediments. This in turn overlies accreted terranes of Mesozoic age. The area west of the craton was subsiding during the Eocene and Oligocene, accumulating great thickness of pre-CRBG sediments. Continued subsidence in this area during the Miocene resulted in thicker CRBG compared to that on the craton. Subsidence continues today but at a greatly reduced rate (Reidel *et al.,* 1994).

2.3 Tectonic Pattern

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

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

Secondary Faults. These faults are typically smaller (1 to 20 km in length) than the main reverse/ thrust faults that occur along the major anticlinal ridges (up to 100 km in length). Secondary faults can be segment boundaries (tear faults) and small faults of any orientation that formed along with the main structure.

Swarm Areas. Small geographic areas produce clusters of events (swarms); usually located in synclinal valleys not known to contain any mapped geologic faults. These clusters consist of a series of small shocks with no outstanding principal event. Swarms occur over a period of days or months, and the events may number into the hundreds and then quit, only to start again later. This differs from the sequence of foreshocks, mainshock, and trailing-off aftershocks that have the same epicenter or are associated with the same fault system. In the past, swarms were thought to occur only in the CRBG. Most swarm areas are in the basalt, but swarm events also appear to occur in all geologic layers. However, typically a swarm event at a specific time is usually restricted to one layer. It is traditional to regard swarms as occurring within one of seven earthquake swarm areas in the HSN area. The Saddle Mountains, Wooded Island, Wahluke, Coyote Rapids, and Horse Heaven Hills swarm areas are typically active at one time or another during the year. The other earthquake swarm areas are active less frequently. There is, however, no compelling theory to suggest a generative mechanism active within these swarm areas. They are deduced purely empirically, are rather conjectural, and will likely be updated or reconfigured as new swarm areas develop.

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

Basement Source Structures. Studies (Geomatrix 1996) suggest that major earthquakes can originate in tectonic structures in the basement. Because little is known about geologic structures in the basement beneath the Hanford Site, earthquakes cannot be directly tied to a mapped fault. Earthquakes occurring in the basement without known sources are treated as random events.

Cascadia Subduction Zone. This source has been postulated to be capable of producing a magnitude 9 earthquake. Because this source is along the western boundary of Washington State and outside the HSN, the Cascadia subduction zone is not an earthquake source that is monitored at the Hanford Site, so subduction zone earthquakes are not reported here. Because any earthquake along the Cascadia subduction zone can have a significant impact on the Hanford Site or can be felt like the February 2001 Nisqually earthquake, UW monitors and reports on this earthquake source for the DOE. Ground motion from any moderate or larger Cascadia subduction zone earthquake is detected by Hanford SMAs and reported.

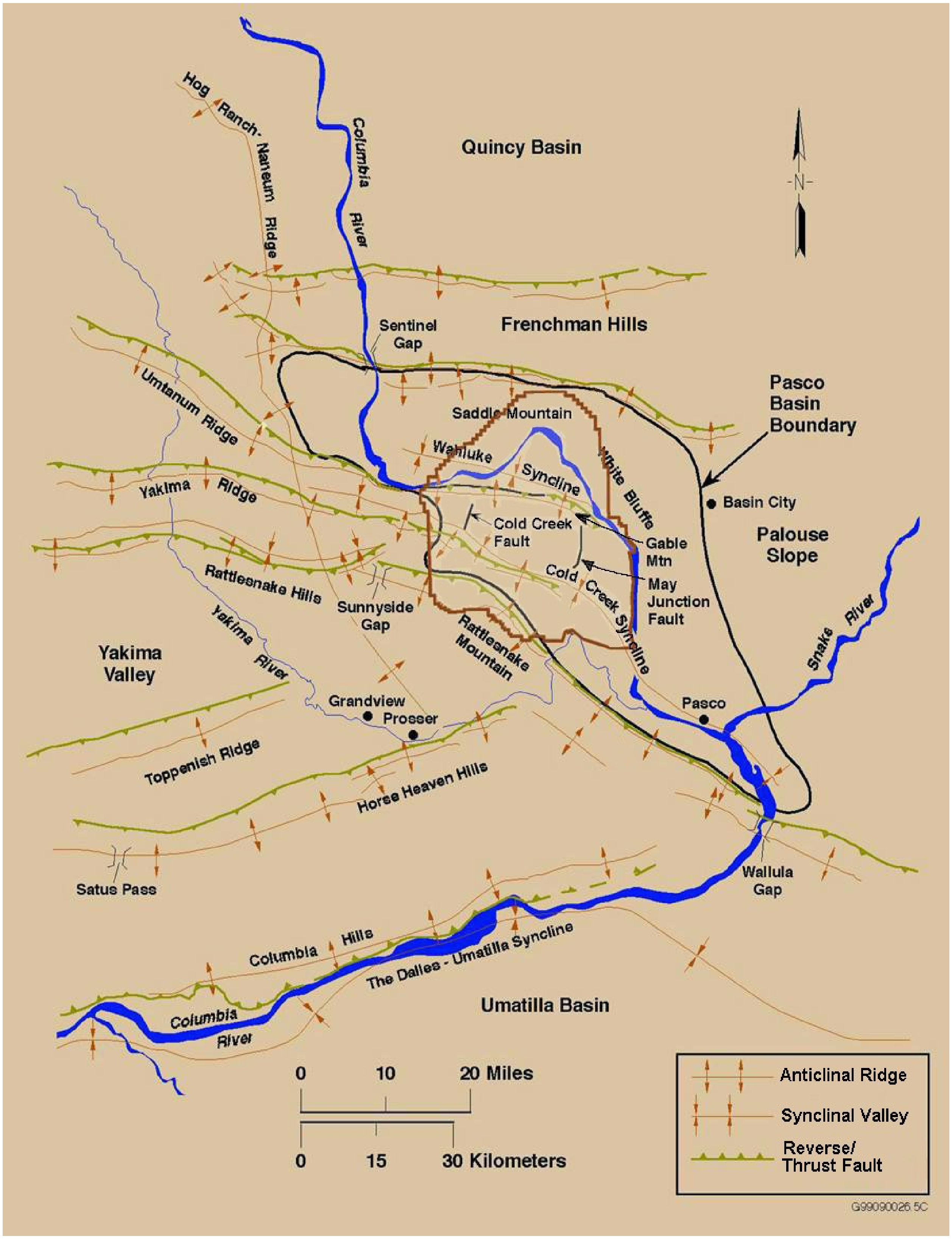


Figure 2.1. Tectonic Features of the Hanford Site within Eastern Washington

(from Rohay et al., 2010b)

3.0 Network Operations

3.1 Seismic Station Overview

The seismic network consists of three types of earthquake sensors—short-period seismometers, broadband seismometers, and strong motion accelerometers (SMAs).

Short-period seismometers are very sensitive passive sensors (they do not use external electric power) designed primarily to detect micro earthquakes. While most short-period stations have a single component, sensitive only to the vertical motion of the ground, one HLSMP short-period station records the ground in three orthogonal directions. In a regional network like the HLSMP networks, the time of arrival of waves and the signal duration derived from short-period stations are used to determine the locations and magnitudes of seismic events; the polarities of ground motions may be used to constrain estimates of the geometry of fault that ruptured in an earthquake.

Broadband seismometers are active sensors (they use electricity to power advanced electronic circuitry that is integral to the sensor) that faithfully record ground motions over a wide frequency range. The data they produce are acquired digitally with 24-bit dynamic range; a broadband system will therefore stay "on-scale" over a much broader range of ground motions than a short-period sensor. In addition to locations and magnitudes derived from signal durations, details of the observed waveforms are used to reveal the source processes of small to moderately large earthquakes. HLSMP broadband stations are all 3-component.

Both short-period and broad-band sensors will ultimately "clip", or fail to record properly, if subjected to more than moderate levels of shaking (well below damaging levels). SMA stations; however, are designed to measure even the damaging ground motions from larger earthquakes. They are 3-component stations and must be carefully and strongly anchored to the ground so that the details of ground shaking up to 2g (twice the vertical acceleration of gravity) are accurately recorded. In addition to helping to characterize the earthquake source, they are critically important in measuring the ground motions that impact a particular site. They aid in determining what the built environment has been exposed to for earthquake response activities and engineers and others use them in designing appropriate structures. Because of their importance to seismic monitoring on the Hanford Site, the distribution, design, and operations of SMA stations within the HLSMP is discussed separately in Section 3.2.

Five HLSMP stations are now capable of recording four channels of seismic data. These sites will record three orthogonal components of strong motion and a vertical component of high-gain short period motion. An additional 15 sites record 6 channels of seismic data, three components of strong motion accelerometer data and three components of high-gain broadband data. The high-gain data is used to detect and locate earthquakes too small to generate ground motions above the strong-motion channels' noise level.

The seismic stations supported by HMIS are further divided into two geographic sub-networks for discussion: HSN, which are sites located on the Hanford Site itself, and the EWRSN, which includes sites that surround the Hanford Site.

Combined, the HSN and the EWRSN include 40 stations. Most stations reside in remote locations and require solar panels and batteries for power. The HSN includes 18 stations (Table 3.1 and Figure 3.1), and the EWRSN consists of 22 stations (Table 3.2 and Figure 3.2).

Table 3.1. Hanford Seismic Network Onsite Stations

Station	Latitude	Longitude	Elevation (m)	Station Name
Strong Motion Accelerometer, 3-Channel Station				
H2E	46.5578	-119.5345	210	200 East Area (SMA)
H2W	46.5517	-119.6453	201	200 West Area (SMA)
H3A	46.3632	-119.2775	119	300 Area (SMA)
H4A	46.4377	-119.3557	171	400 Area (SMA)
Strong motion and Broadband, 6-Channel Station				
GBB	46.6087	-119.6290	185	Gable Butte
H2O	46.3956	-119.4241	175	Water Station
MDW	46.6130	-119.7622	330	Midway
SNI2	46.4648	-119.6552	267	Snively Ranch
WA2	46.7552	-119.5668	244	Wahluke Slope
Strong motion and Short Period, 4-Channel Station				
H1K	46.6447	-119.5929	152	100 K Area (SMA)
HGBL	46.5982	-119.4610	330	Gable Mountain
HWIW	46.4292	-119.2888	128	Wooded Island
GRUT	46.5512	-119.5102	219	Wet-Grout Plant
MJ2	46.5574	-119.3601	146	May Junction Two
Broadband, 3-Channel Station				
LIGO	46.4617	-119.4177	158	LIGO Observatory
Short Period, Single Channel Analog				
BEN	46.5186	-119.7185	335	Benson Ranch
LOC	46.7169	-119.4320	210	Locke Island
RSW	46.3944	-119.5925	1045	Rattlesnake Mountain

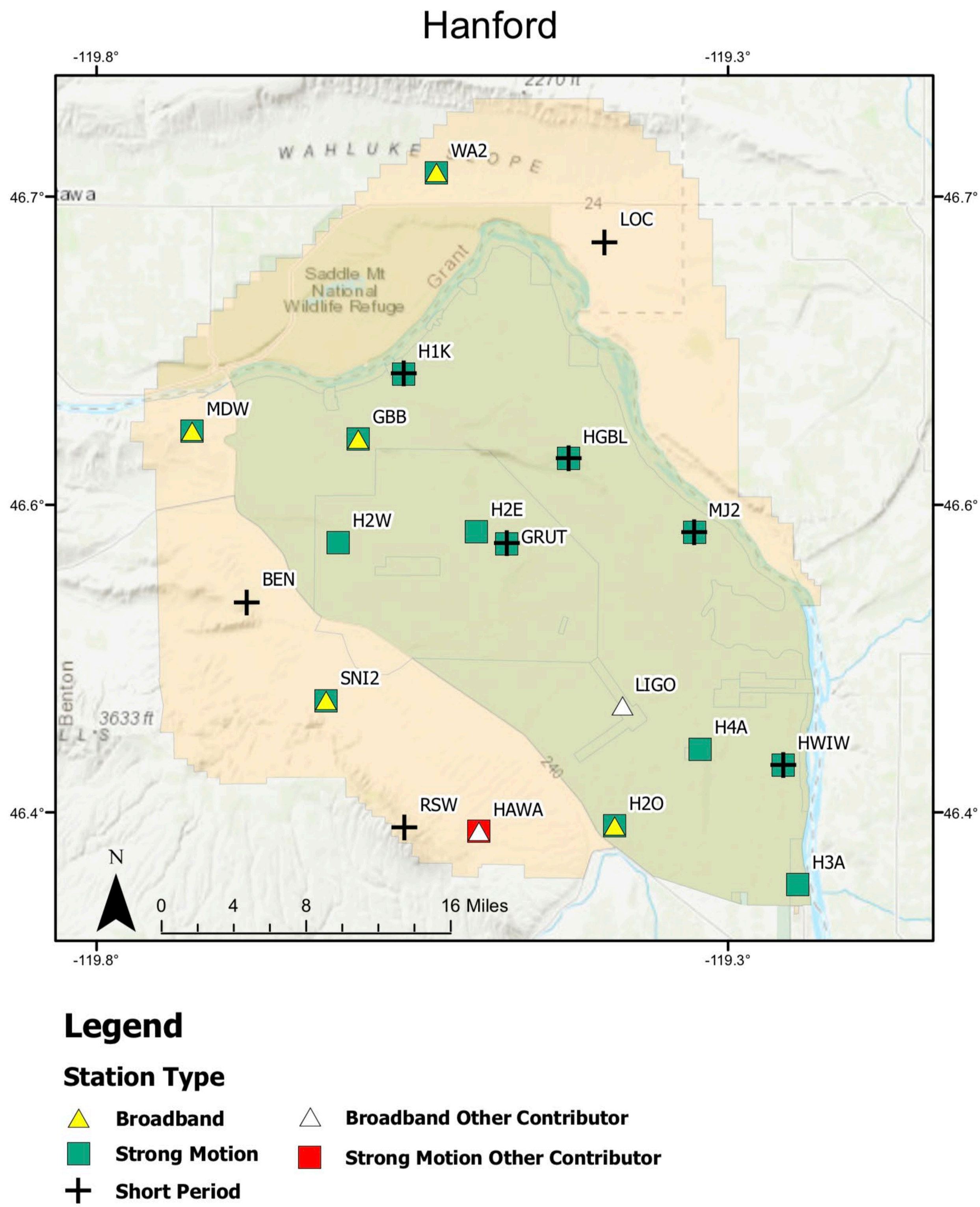
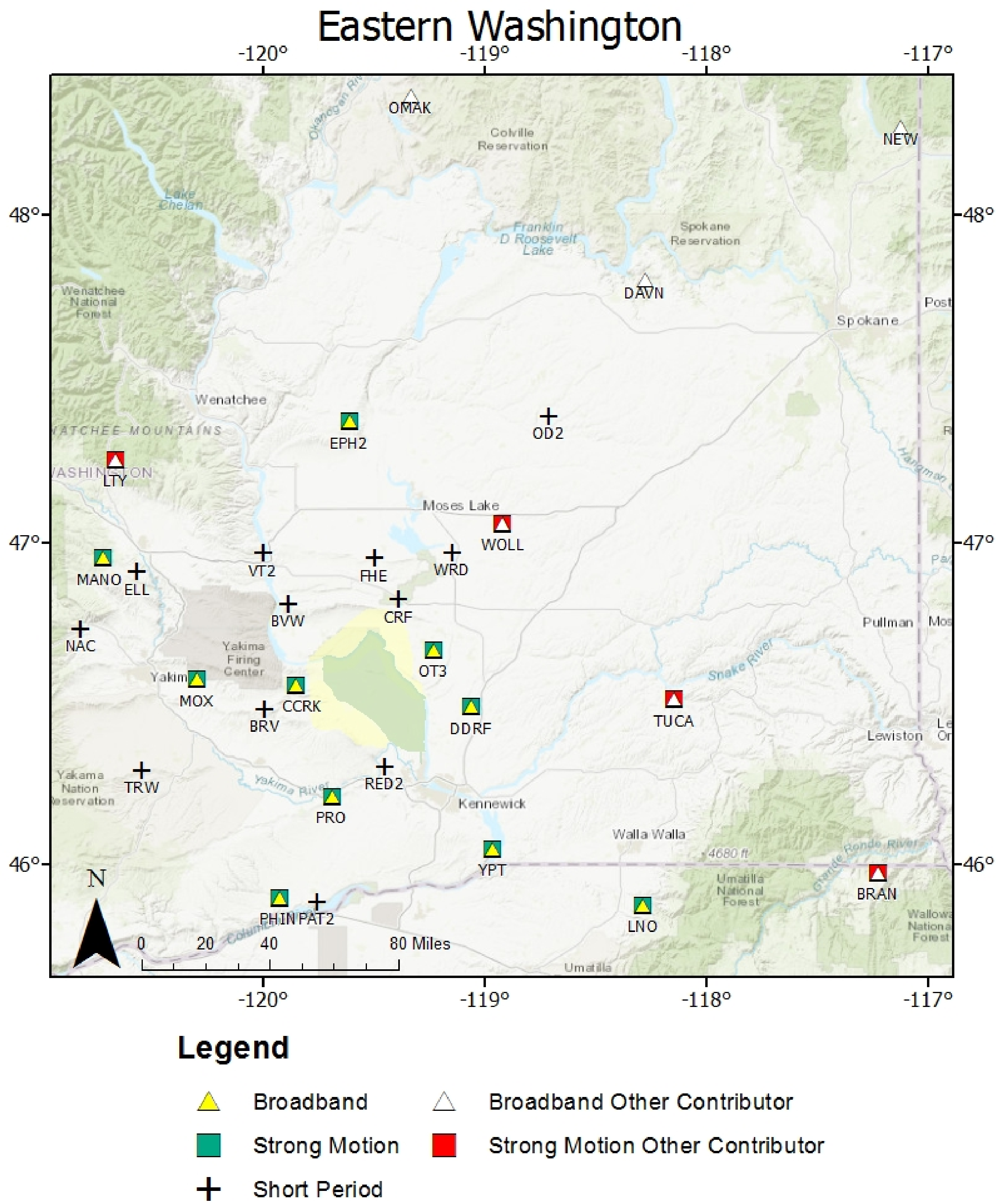


Figure 3.1. Hanford Seismic Network Onsite Stations

Table 3.2. Hanford Seismic Network Offsite Stations

Station	Latitude	Longitude	Elevation (m)	Station Name
Strong Motion and Broadband, 6-Channel Station				
CCRK	46.5585	-119.8548	561	Cold Creek
DDRF	46.4911	-119.0595	233	Didier Farms
EPH2	47.3562	-119.5972	661	Ephrata
LNO	45.8717	-118.2862	771	Lincton Mountain Oregon
MANO	46.9511	-120.7247	1200	Manatash Ridge Observatory
MOX	46.5772	-120.2993	501	Moxee City
OT3	46.6689	-119.2341	322	Othello 3
PHIN	45.8950	-119.9280	227	Phinney Hill
PRO	46.2125	-119.6868	553	Prosser
YPT	46.0487	-118.9634	325	Yellepit
Short Period, Single-Channel Analog				
BRV	46.4852	-119.9923	920	Black Rock Valley
BVW	46.8108	-119.8835	670	Beverly
CRF	46.8249	-119.3881	189	Corfu
ELL	46.9095	-120.5675	789	Ellensburg
NAC	46.7330	-120.8249	728	Naches
OD2	47.388	-118.7108	553	Odessa 2
PAT2	45.8836	-119.7578	259	Paterson 2
RED2	46.3053	-119.4526	330	Red Mountain 2
TRW	46.2921	-120.5431	723	Toppenish Ridge
VT2	46.9672	-120.0003	385	Vantage 2
WRD	46.9699	-119.1460	375	Warden
Short Period, 3-Channel Analog				
FHE	46.9518	-119.4981	455	Frenchman Hills East


Eastern Washington
-120°
-119°
-118°
-117°
48°
47°
46°
OMAK
Colville Reservation
NEW
Lake Chelan
Franklin D Roosevelt Lake
Spokane Reservation
DAVN
Wenatchee National Forest
Spokane
Post
Wenatchee
EPH2
OD2
LTY
Moses Lake
WOLL
MANO
ELL
VT2
FHE
WRD
BVW
CRF
NAC
Pullman
Yakima Firing Center
OT3
Yakim
MOX
CCRK
BRV
Snake River
TUCA
DDRF
Lewiston
Yakama Nation Reservation
TRW
Yakima River
RED2
PRO
Kennewick
Walla Walla
4680 ft
Grande Ronde River
YPT
Umatilla National Forest
BRAN
N
PHIN
PAT2
LNO
Wallowa National Forest
0
20
40
80 Miles
Umatilla
Legend
Broadband
Broadband Other Contributor
Strong Motion
Strong Motion Other Contributor
Short Period

The EWRSN is used by the HLSMP for two major reasons. A large earthquake located in the Pacific Northwest outside of Hanford could produce significant ground motion and damage to structures at the Hanford Site. For example, the magnitude 7.0 earthquake that occurred in 1872 near Chelan/Entiat or other earthquakes located in the region (e.g., eastern Cascade Mountain Range) could have such an effect. The EWRSN would provide valuable information to help determine the impacts of such an event. Additionally, the characterization of seismicity throughout the surrounding areas, as required for the Probabilistic Seismic Hazard Analysis, supports facility safety assessments at the Hanford Site. Both the HSN and the EWRSN are fully integrated within the Pacific Northwest Seismic Network managed by the University of Washington.

The HSN and EWRSN networks have 142 combined data channels from: 14 single channel sites, 2 three-component seismometer sites (FHE and LIGO), 15 six-component sites (CCRK, DDRF, EPH2, GBB, H2O, LNO, MANO, MDW, MOX, OT3, PHIN, PRO, SNI2, WA2, and YPT) and 9 other sites in the HSN (H1K, H2E, H2W, H3A, H4A, MJ2, GRUT, HGBL, and HWIW) that require additional data channels at each station. The three component sensors record motion in the vertical, north-south horizontal, and east-west horizontal directions. Fourteen radio telemetry relay sites are used by both sub-networks to transmit seismogram data continuously to the PNSN in Seattle, Washington, for processing and archiving.

3.2 Strong Motion Accelerometer Stations

3.2.1 Strong Motion Station Location

SMAs provided ground motion observations critical to understand the impacts of strong ground shaking that affect the Hanford Site itself. The Hanford SMA network consists of 15 free-field SMA stations (see Figure 3.1; Table 3.1). SMAs are located in the 200 East and 200 West Areas, in the 100-K Area adjacent to the K Basins, in the 400 Area near the former Fast Flux Test Facility, and at the south end of the 300 Area.

The locations of SMA stations were chosen based on two criteria: 1) density of workers, and 2) sites of hazardous facilities (Moore and Reidel 1996). The 200 East and 200 West Areas contain single-shell and double-shell tanks in which high-level radioactive wastes from past processing of fuel rods are stored. In addition, the Canister Storage Facility (holding encapsulated spent fuel rods) and the new Waste Treatment and Immobilization Plant being constructed are both located in the 200 East Area. The 100-K Area contained the K Basins, where spent fuel rods from the N Reactor were stored prior to encapsulation. The now inactive Fast Flux Test Facility is located in the 400 Area.

3.2.2 Strong Motion Station Design

All free-field SMA stations consist of a four-panel solar array and two 30-gallon galvanized drums that contain equipment. Each panel has a maximum 42-watt output. The two drums are set in the ground such that the base of each drum is about 1 m below the ground surface. One drum houses only the SMA; the other drum, which is connected via a sealed conduit to the SMA drum, contains the batteries. Cellular modems provide communication from all five SMAs. The enclosure serves as a junction box for all cabling that is routed through conduit inside and outside the equipment drums. The antenna for the cell modem is mounted on top of the enclosure. The enclosure permits quick access to check battery conditions and a connection directly to the RS-232 port of the SMA without removing the drum lids. However, with continuous data telemetry via cell modem, most interrogation of the system is accomplished remotely.

Four of the SMA stations (H3A, H4A, H2E, H2W) are three-component units consisting of vertical, north-south horizontal, and east-west horizontal seismometers manufactured by Nanometrics, Inc., and known as the Titan system. Each Titan unit contains a digital recorder, a data storage unit, and a Global Positioning System (GPS) receiver with the equipment housed in a watertight box. Five sites (H1K, HWIW, HGBL, GRUT, and MJ2) have Kinemetrics Basalts with 3 SMA channels that are supplemented by a high-gain vertical short-period sensor. Five sites have a broadband and strong-motion sensor packaged in a single casing that is deployed in a shallow posthole, Nanometrics Trillium Cascadia and a Centaur datalogger (GBB, H2O, MDW, SNI2, WA2).

A cell modem or digital radio system provides the Internet address connection to access the system. Stations can be monitored from any computer with appropriate access, and data are continuously telemetered to UW. The data also can be downloaded directly at each site, via a built-in cable connection at the enclosure in case of communication failure. The GPS receiver provides timing of the ground motions accurate to several microseconds, coordinated to Universal Coordinated Time (UTC). The GPS receiver antenna is mounted on the enclosure at the rear of the solar array. The GPS receiver is activated internally approximately every 4 hours and checks the "location of the instrument" and the time. The SMA records any differences between the internal clock and the GPS time. Any corrections to the internal timing are made automatically. Typically, the greatest correction recorded is approximately 4 milliseconds.

The combined operations, data recording, data interpretation, and maintenance facility is located in the PNSN offices at the UW in Seattle.

3.2.3 Strong Motion Operational Characteristics

Signals from the three-channel SMA stations use an 18-bit digitizer with data sampled at 200 samples. Data are sent continuously in real-time to the PNSN offices at the UW in Seattle. This permits the recording of ground motion data for smaller, non-damaging earthquakes that can be useful in estimating impacts of larger earthquakes. It also helps confirm the correct operation of the instruments.

For security and robustness, the Titan also stores triggered event files. When one of the accelerometer channels exceeds the trigger threshold (0.02%g), the recorders save information within the data buffers on memory cards within the Titan. Data recording begins 10 s before the actual trigger time, continues until the trigger threshold is no longer exceeded, and ends with an additional 40 s of data. The files created by a triggered event can be retrieved and examined by HLSMP staff, in the event of telemetry failure. The retrieval can be accomplished either remotely when telemetry is re-established, or manually by a technician traveling to the site.

Data from the SMA channels of the 4-channel and 6-channel stations are treated in a similar fashion. The primary difference is that the data from these channels (as well as the vertical high-gain channel) are digitized with 24-bit resolution.

3.3 Data Analysis

Signals from the seismometers are monitored in real time for changes in signal amplitudes and frequency that are expected from earthquakes. The seismic network is subdivided into spatial groupings of stations that are monitored for nearly simultaneous amplitude changes, triggering a permanent recording of the events. The groupings and associated weighting schemes are designed to allow very small seismic events to be recorded and to minimize false triggers. Events are classified as local (south-central Washington near the Hanford Site), regional (western United States and Canada), and teleseisms (from farther distances around the world). Local and regional events are usually earthquakes, but quarry and mining explosions also are recorded. Quarry and mining explosions usually can be identified from wave characteristics and the time of occurrence and may be confirmed with local government agencies and industries. Frequently, military exercises at the U.S. Army Yakima Training Center produce a series of acoustic shocks that trigger the recording system. Sonic booms and thunder also produce acoustic signals that may trigger the recording system. All data, whether triggered or not, is saved in a permanent seismic data archive at the Seattle-based IRIS data management center and is available for download and analysis.

The HLSMP uses Earthworm, an automated computer-based software system developed by the USGS and used throughout the region by the Pacific Northwest Seismic Network at the UW, to acquire seismic data and automatically detect and locate events (Hartog et al., 2020). We currently run Earthworm version 7.10 on a variety of computer servers. Redundant Earthworm systems run continuously at the PNSN. If one fails, a second one serves as a "backup." Two complete systems are located in different buildings on separate computer servers with redundant power supplies, backed up by different uninterruptable power supplies and a diesel-powered electric generator capable of powering the network until refueling is needed. Seismic data from triggered events are collected for assessment by HLSMP staff. This information is evaluated to determine if the event is "false" (for example, due to a sonic boom) or is an earthquake or ground-surface or underground blast. Earthquake events are evaluated to determine epicenter locations, focal depths, and magnitudes (Section 4).

Data from HLSMP-operated seismic stations are combined at the UW analysis center with seismic data from regional seismic stations operated by other entities and contributed in real-time to PNSN. The earthquake locations and ground motion we report in this catalog include these valuable contributed data. This contributed data improves the accuracy of the seismic products we provide at Hanford and adds to the robustness of the entire network in the event that any particular portion of the network suffers temporary data loss from environmental or other causes.

4.0 Earthquake Catalog

Within the Advanced National Seismic System (ANSS) Quake Management System (AQMS) seismic network processing software, an interactive program called Jiggle is used to manually review and revise automatic phase arrival picks and signal durations, as well as their polarities, uncertainties and quality factors (Hartog et al., 2020). Arrival and duration times and uncertainties are used as input to an earthquake location program (Klein, 2002) to compute locations and magnitudes of the seismic events. Resulting locations for local earthquakes (44°-49° north latitude, 117°-121.5° west longitude) are reported in Table 4.2. Additional seismic events located outside the reporting region for this report are also evaluated. These surrounding events are not reported in this document, but are used as a check to confirm that the HSN and EWRSN are functioning properly (e.g., quality checks on data recording). All processing results are available through the PNSN at www.pnsn.org.

4.1 Wavespeed Models

Earthquake location uses the arrival times of seismic phases at seismic stations and a model of the seismic wave speeds of crustal rocks of eastern Washington called a "wavespeed model" (MOD), to solve for the most likely location for the earthquake source. AQMS divides the eastern Washington and Oregon region into 3 sub-regions. The wavespeed models for each sub-region were developed using available geologic information and calibrated from seismic data recorded from accurately located earthquake and blast events in eastern Washington. Time corrections (delays) are incorporated into the wavespeed models to account for significant deviations in station elevations or stations situated on sedimentary layers. Station delays also are determined empirically from accurately located earthquakes and blast events in the region.

Table 4.1. Wavespeed Model for Eastern Washington
(from Rohay et al. 1985)

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

4.2 Earthquake Magnitudes

AQMS computes several different magnitude estimates (Mtyp) for earthquakes. Table 4.1 shows the analyst-preferred value of either: 1) the coda-duration magnitude (M_d), or 2) the local magnitude (M_L) (Richter 1958). We report the median magnitude provided by all stations contributing estimates for an event.

The coda duration magnitude is based on a relationship developed for Washington State by Crosson (1972), modified for application within the AQMS software. The formula we use for M_d is:

$$M_d = -1.61 + 2.82 \log(D) - 2.46$$

Where D is the duration of the observed event (in seconds), starting from the P-wave arrival. Many earthquakes yield magnitude determinations that are very small ($M_d < 0$) and highly uncertain. Earthquakes with magnitudes (M_d) smaller than 3.0 are defined as "minor." Coda-duration magnitudes for events classified as explosions are reported although they may be biased by a prominent surface wave that extends the apparent duration in a way inconsistent with coda-length measurement.

M_L is computed from the maximum amplitudes of the signals on the horizontal components recording an event, filtered to mimic the instrument response of a Wood-Anderson torsion seismograph. The formula is:

$$M_L = \log(A) - \log(A_0) + S$$

Where A is the average zero-to-peak amplitude of the two horizontal components at a station after they have been converted to pseudo-Wood-Anderson traces. Log (A_0) is a distance correction, for which we use the Jennings and Kanamori (1983) values, and S is a site correction term that accounts for differences in local geological conditions amongst stations.

The choice of preferred magnitude type involves some subjectivity, as the relative strength of each depends on conditions that differ from event to event. In general, M_L is preferred for an event that is well recorded on a sufficient number of suitable channels. [This is because there may be subjectivity in determining the durations used by the M_d algorithm (although AQMS does this in a largely automatic, and hence objective, way), and because the determination of the duration is biased by background noise levels.] In practice, this usually means that M_L is preferred for earthquakes sufficiently large to be observed at several three-component broadband stations. Although occasionally smaller earthquakes yield robust M_L estimates, depending on the background noise level at the time of the earthquake. M_d, on the other hand can be obtained from smaller earthquakes, even if the recording should "clip." For earthquakes larger than about M4.5, only the M_L should be used. The two magnitude scales are defined to be consistent for the events for which they overlap.

4.3 Quality Factors

Table 4.1 tabulates a two-letter **Quality factor** (Q) for each event that indicates the general reliability of the solution (**A** is best quality, **D** is worst). The first letter of the quality code is a measure of the hypocenter quality based primarily on arrival time residuals. For example, quality **A** requires a root-mean-square residual (**RMS**) less than 0.15 s, while an **RMS** of 0.5 s or more is **D** quality (other estimates of the location uncertainty also affect this quality parameter). The second letter of the quality code is related to the spatial distribution of stations that contribute to the event location, including the number of stations (**NS**), the number of p-wave and s-wave phases (**NP**), the largest gap in event-station azimuth distribution (**GAP**), and the closest distance from the epicenter to a station (**Dmin – not shown**). Quality A requires a solution with NP >8, GAP <90˚, and Dmin <5 km (or the hypocenter depth if it is greater than 5 km). If NP ≤ 5, GAP >180˚, or Dmin >50 km, the solution is assigned Quality D. Uncertainties associated with estimated depths depend upon the number of stations and number of phase measurements (NS/NP) utilized by the Hypoinverse location program. If the number of phases exceeds 10 measurements, the depth estimate is considered reliable. In this case, the second letter in the quality evaluation is either "A" or "B" (cf. Table 4.1). For example, the number of phase measurements from earthquakes ultimately classified as "deep" events typically falls within the 10-20 measurement range; these depth estimates are considered reliable. However, the number of phase measurements from earthquakes classified as "shallow" or "intermediate" may be less than 10 readings; in this case the depth estimate is less certain and the event could be classified as occurring in the CRBG or pre-basalt layers.

4.4 FY 2021 Earthquake Catalog for Eastern Washington

Table 4.2. Seismicity in the region 44° to 49° N latitude, -121.5° to -117° E longitude.

October 2020												
Day	Time	Lat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Type
01	20:25:45	46.2948	-118.0310	-0.5*	1.7	Ml	013/014	222	0.24	CD	E3	px
02	05:59:39	47.6870	-120.1997	4.7	0.9	Ml	008/012	111	0.05	AB	N3	eq
02	18:30:34	47.6860	-120.3532	5.5	0.8	Ml	009/015	96	0.09	AB	N3	eq
03	11:49:06	47.3242	-121.4655	9.4*	1.1	Ml	012/020	119	0.14	CC	C3	eq
03	13:18:10	47.7373	-120.1983	0.9	0.5	Ml	008/011	131	0.04	BC	N3	eq
03	19:00:31	47.6745	-120.1403	3.9	-0.1	Md	005/008	144	0.06	BC	N3	eq
05	02:31:51	47.6960	-120.0113	2.8	-0.3	Md	003/005	137	0.04	AD	N3	eq
06	00:26:50	45.6893	-119.1620	13.5	1.1	Ml	013/015	151	0.07	AC	E3	eq
07	18:22:02	46.9528	-119.1000	-0.3*	1.5	Ml	008/010	150	0.09	CC	E3	px
07	23:26:40	46.5888	-120.7647	-0.8*	1.7	Ml	011/014	233	0.42	CD	C3	px
08	21:03:39	46.2910	-118.8823	-0.2*	1.6	Ml	011/012	203	0.24	CD	E3	px
09	02:32:10	47.6437	-120.2468	4.2	0.9	Ml	008/010	98	0.08	AB	N3	eq
09	16:24:31	47.4930	-120.2857	-1.3*	0.7	Md	004/005	287	0.10	CD	N3	px
11	08:00:19	47.6830	-120.1178	2.1	0.1	Md	004/008	140	0.04	BC	N3	eq
11	12:25:57	46.8765	-120.8325	4.7	1.1	Ml	011/014	107	0.18	BC	C3	eq
11	19:28:56	47.6735	-120.2933	-0.2*	0.3	Ml	004/007	113	0.02	CB	N3	eq
12	21:06:58	46.1755	-119.2670	-0.2*	1.4	Ml	013/017	158	0.22	CC	E3	px
13	16:43:54	46.8792	-120.8207	-0.9	1.1	Ml	009/011	106	0.15	BC	C3	eq
14	19:08:43	47.7313	-120.2110	3.2	0.9	Ml	010/016	65	0.07	AC	N3	eq
20	06:26:39	47.6663	-120.0430	5.1	0.5	Ml	006/011	165	0.08	AC	N3	eq
20	22:19:09	48.1062	-117.8257	-0.6*	1.8	Ml	012/014	114	0.37	CC	N3	px
21	06:54:08	47.6777	-120.0515	2.9	0.1	Md	003/006	178	0.04	BC	N3	eq
21	20:09:51	44.1058	-121.3592	-1.4*	2.3	Ml	013/011	132	0.12	CC	N3	px
23	16:53:46	46.5325	-121.4073	0.1	2.0	Ml	037/047	89	0.16	BC	C3	eq
24	16:47:45	47.6737	-120.2947	4.5	0.6	Md	006/009	113	0.03	AB	N3	eq
25	17:22:16	47.6120	-120.2505	6.5	0.6	Ml	006/008	179	0.05	AC	N3	eq
26	09:36:51	47.6707	-120.1755	-0.6*	1.0	Ml	010/012	95	0.10	CB	N3	eq
28	16:07:08	47.0117	-120.3523	-0.9*	1.4	Ml	008/006	162	0.06	CC	N3	px
28	18:57:19	46.9105	-120.5685	-0.9*	1.1	Ml	007/008	146	1.01	DC	E3	px
29	09:03:15	48.2457	-121.3172	8.5	0.8	Ml	008/009	168	0.04	AC	C3	eq
29	20:11:23	47.7027	-120.3595	2.3	0.1	Md	003/006	255	0.03	BD	N3	eq
30	02:02:37	47.6835	-120.0292	7.9	0.6	Ml	006/009	106	0.07	AB	N3	eq
31	07:33:44	48.3883	-119.9065	1.6*	1.2	Ml	008/012	218	0.22	CD	N3	eq
November 2020												
Day	Time	Lat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Type
02	07:53:37	46.0642	-120.7287	19.0	1.2	Ml	006/008	244	0.41	DD	C3	eq
02	19:38:50	47.0207	-120.3485	-0.9*	1.1	Ml	009/007	165	0.18	CC	N3	px
03	03:19:28	47.6553	-120.4028	0.1	0.6	Ml	006/010	185	0.22	CD	N3	eq
05	21:20:10	47.6910	-120.0617	5.5	1.0	Ml	009/015	124	0.09	AB	N3	eq
07	17:10:04	47.6672	-120.3035	-0.2*	1.1	Ml	008/011	104	0.07	CB	N3	eq
09	22:08:10	47.7387	-117.5440	-0.6*	2.1	Ml	008/010	171	0.18	CD	N3	px
12	18:29:45	46.9667	-120.3750	-0.9*	1.6	Ml	012/015	112	0.44	CC	E3	px
12	18:51:05	47.0168	-120.3537	-0.7*	0.9	Ml	009/009	121	0.34	CC	N3	px
12	19:35:28	46.9342	-119.4933	14.0	0.8	Ml	014/016	92	0.16	BB	E3	eq
13	20:01:29	46.1633	-119.2722	-0.3*	1.4	Ml	009/009	113	0.08	CC	E3	px
18	22:47:35	47.3928	-117.7210	-0.5*	1.7	Ml	007/011	268	0.77	DD	N3	px
20	14:18:47	47.7382	-120.2027	1.5	0.8	Ml	009/013	69	0.08	BC	N3	eq
20	20:46:30	46.1532	-119.1230	-0.2*	1.7	Ml	013/016	146	0.09	CC	E3	px
23	01:16:54	46.3915	-119.1977	5.0	1.1	Ml	017/024	198	0.14	AD	E3	eq

23	07:03:20	45.1178	-120.7648	20.3	2.4	Ml	015/019	155	0.17	BC	E3	eq
23	07:10:15	45.1212	-120.7968	16.3	2.1	Ml	013/020	163	0.21	BC	E3	eq
23	07:31:05	46.4005	-119.1867	1.0*	0.5	Ml	005/007	198	0.03	CD	E3	eq
23	08:06:26	46.3957	-119.1838	3.0	0.7	Ml	009/013	203	0.09	AD	E3	eq
23	12:44:51	46.5023	-119.3375	13.8	0.4	Ml	016/024	62	0.11	AA	E3	eq
24	03:59:15	46.4555	-120.7097	7.8*	1.0	Ml	012/010	152	0.11	CC	C3	eq
24	18:56:30	45.1223	-120.8212	-0.9	1.1	Ml	006/009	172	0.29	BC	C3	eq
24	21:18:15	45.8360	-118.3585	-0.8*	2.0	Ml	019/020	139	0.23	CC	E3	px
26	19:32:13	46.1588	-120.4003	18.1	1.3	Ml	015/017	177	0.27	BC	E3	eq
26	19:59:10	46.1633	-120.4052	19.6	1.3	Ml	014/019	177	0.18	BC	E3	eq
27	00:57:02	45.1328	-120.8098	11.5	1.8	Ml	015/020	165	0.21	BC	E3	eq
27	08:15:27	47.6513	-120.2488	3.6	0.4	Ml	005/009	123	0.07	AB	N3	eq
27	12:14:10	46.4002	-119.1927	3.6	0.5	Ml	012/016	192	0.07	AD	E3	eq
29	07:20:42	47.0372	-121.0152	4.3	1.1	Ml	021/032	115	0.30	CC	C3	eq
30	03:31:11	47.2453	-119.6020	21.7	0.9	Ml	010/013	103	0.10	AB	N3	eq
30	07:54:25	46.7527	-120.2425	6.0	1.4	Ml	018/024	84	0.10	AC	E3	eq
30	08:08:15	45.8188	-120.3437	20.0	1.5	Ml	014/019	125	0.12	AB	E3	eq
December 2020												
Day	Time	Laat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Type
01	10:45:18	46.7118	-121.0672	2.7	1.0	Ml	029/036	86	0.13	AC	C3	eq
02	14:57:52	45.4280	-117.5983	20.8*	1.8	Ml	005/007	135	0.24	CD	C3	eq
03	10:10:12	47.9540	-119.8200	3.9	0.7	Ml	009/014	140	0.08	AC	N3	eq
03	20:36:45	47.6305	-120.2800	7.8	0.7	Ml	009/014	115	0.10	AB	N3	eq
03	21:45:15	46.5160	-121.3140	-0.2	1.6	Ml	035/047	113	0.13	AC	C3	eq
04	03:15:20	46.8055	-119.7062	14.6	1.0	Ml	016/024	93	0.05	AB	E3	eq
04	04:50:28	46.5158	-121.3287	-0.9	1.1	Ml	019/023	245	0.15	BD	C3	eq
04	18:47:06	45.1275	-120.7915	16.8	1.4	Ml	010/016	180	0.22	BC	C3	eq
05	16:30:47	47.6802	-120.3327	3.1	0.1	Md	005/009	123	0.03	AB	N3	eq
06	23:43:06	48.4288	-121.2618	0.8*	0.1	Md	004/006	214	0.15	CD	C3	eq
09	07:58:00	46.8495	-119.7423	2.5	1.4	Ml	012/017	169	0.29	BC	E3	eq
09	19:57:48	46.2483	-119.4733	-0.3*	1.8	Ml	014/012	138	0.06	CC	E3	px
10	20:33:09	46.7073	-119.4608	0.2*	0.5	Ml	011/015	79	0.14	CA	E3	eq
11	13:04:53	45.4263	-117.6602	11.1*	1.5	Ml	003/006	128	0.29	CD	E3	eq
13	16:21:14	44.0443	-121.3567	-1.6*	1.2	Ml	010/013	229	0.27	CD	E3	px
15	02:26:46	47.7512	-120.0610	4.3	2.4	Ml	013/015	74	0.07	AB	N3	eq
15	20:51:52	48.6885	-119.5418	1.8*	1.8	Ml	008/013	178	0.26	CD	N3	eq
15	21:05:09	46.1385	-119.2005	-0.2*	1.7	Ml	011/012	165	0.19	CC	E3	px
16	14:21:38	46.4093	-119.2885	2.5	1.1	Ml	016/021	85	0.10	AA	E3	eq
17	11:24:11	47.6483	-120.1390	5.0	0.2	Md	004/007	130	0.04	AB	N3	eq
17	20:48:15	47.6953	-120.0988	4.4	0.5	Ml	007/012	100	0.14	AB	N3	eq
18	12:31:51	45.4193	-117.6397	11.2*	2.2	Ml	004/008	130	0.32	CD	N3	eq
19	00:26:48	48.0623	-121.0040	11.1	1.1	Md	008/010	152	0.10	CC	C3	eq
19	03:27:44	46.0380	-119.6798	6.9	1.4	Ml	013/017	124	0.10	AC	E3	eq
20	02:10:37	46.6540	-120.9162	5.2	2.0	Ml	028/038	73	0.32	CC	C3	eq
21	08:36:45	46.1880	-119.5565	6.8	1.1	Ml	019/031	170	0.12	AC	E3	eq
23	10:34:49	47.6480	-120.1447	1.8	0.2	Ml	005/009	109	0.05	AB	N3	eq
23	23:55:50	47.1355	-120.7710	-0.9*	1.2	Ml	006/007	117	0.09	CB	C3	px
25	11:13:38	46.7985	-120.8228	7.6	1.1	Ml	011/014	100	0.09	AB	C3	eq
26	21:46:24	46.7582	-120.2268	6.3	1.5	Ml	023/034	133	0.12	AC	E3	eq
27	22:26:20	47.6430	-120.1580	2.2	0.8	Ml	008/014	125	0.09	AB	N3	eq
28	22:35:45	47.6462	-120.1662	-0.7*	0.6	Ml	006/010	124	0.11	CB	N3	eq
28	22:59:55	47.6530	-120.1503	-0.5*	0.2	Md	004/007	136	0.04	CC	N3	eq
29	19:05:03	45.0795	-121.0402	23.1	1.6	Ml	011/018	133	0.31	CB	N3	eq
30	00:34:28	45.0812	-121.0435	11.2	1.0	Ml	007/010	146	0.10	AC	N3	eq
31	18:14:26	47.6747	-120.3488	3.3	0.3	Md	004/006	247	0.04	BD	N3	eq

January 2021												
Day	Time	Lat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Type
05	07:30:56	45.4185	-117.6025	1.7	2.4	Ml	008/012	134	0.46	CD	N3	eq
05	09:25:13	45.4300	-117.5735	10.0*	1.7	Ml	005/006	142	0.11	CD	N3	eq
07	05:34:38	46.6095	-119.8437	6.6	0.7	Ml	011/016	164	0.07	AC	E3	eq
07	07:22:38	46.6045	-119.8293	-0.5	1.0	Ml	016/029	126	0.30	CB	E3	eq
07	07:30:45	47.7005	-120.1447	4.6	1.6	Ml	018/021	90	0.14	AB	N3	eq
08	09:59:51	47.6088	-120.3843	4.4	1.0	Ml	009/011	104	0.14	AB	N3	eq
08	13:31:45	46.3142	-119.9878	10.7	1.7	Ml	025/028	54	0.14	AB	E3	eq
13	07:44:41	46.7542	-120.5382	15.1	1.3	Ml	014/019	83	0.24	BB	E3	eq
15	13:20:55	47.6583	-120.1515	5.7	1.0	Ml	008/009	109	0.04	AB	N3	eq
20	21:49:57	46.3043	-119.9892	7.9*	1.2	Ml	012/017	125	0.09	CC	E3	eq
20	21:58:42	45.9705	-118.7388	-0.7*	1.7	Ml	010/011	145	0.36	CC	E3	px
20	23:28:39	46.3237	-119.9835	-0.1*	0.8	Ml	009/014	243	0.44	CD	E3	eq
21	00:19:52	47.3922	-117.8967	-0.5*	1.9	Ml	009/011	208	0.59	DD	N3	px
21	00:49:43	46.3202	-119.9788	17.4	0.5	Ml	011/015	150	0.13	AC	E3	eq
21	17:54:55	47.6408	-120.2488	1.7	0.2	Md	007/009	136	0.06	BC	N3	eq
22	05:10:57	47.6957	-120.0938	5.3	0.7	Ml	007/010	94	0.07	AB	N3	eq
23	20:10:52	47.6922	-120.3625	-0.1*	0.4	Md	007/010	136	0.07	CC	N3	eq
24	04:05:17	46.7052	-120.8090	12.5	0.9	Ml	016/025	119	0.18	BB	C3	eq
24	06:39:56	47.0698	-119.4358	15.4	0.7	Ml	012/015	109	0.11	AB	N3	eq
24	22:26:36	47.0710	-119.4337	15.4	1.0	Ml	011/014	109	0.10	AB	N3	eq
25	07:10:05	48.4435	-120.7553	9.7*	1.0	Ml	010/016	179	0.36	CC	C3	eq
25	23:21:15	45.9188	-119.3227	-0.3*	1.5	Ml	013/015	187	0.18	CD	E3	px
26	03:54:53	46.7018	-121.0713	3.4	1.6	Ml	021/025	138	0.13	AC	C3	eq
26	07:04:54	46.7123	-121.0677	3.1	0.9	Ml	019/031	135	0.20	BC	C3	eq
29	01:19:58	47.6495	-120.1655	3.4	0.1	Md	004/007	119	0.01	AB	N3	eq
29	18:09:26	45.0590	-121.0623	20.2	1.3	Ml	009/014	101	0.28	BB	N3	eq
February 2021												
Day	Time	Lat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Type
03	05:34:16	47.8348	-120.2730	-0.5*	0.7	Ml	008/010	177	0.05	CC	N3	eq
04	20:35:35	44.3777	-121.0352	-1.6*	1.8	Ml	008/014	273	0.27	CD	N3	px
06	19:01:53	44.2477	-121.2380	9.7	1.4	Ml	012/018	200	0.20	BD	N3	eq
07	12:39:47	47.7110	-120.1580	4.7	0.7	Ml	006/010	105	0.07	AC	N3	eq
11	01:53:07	47.6767	-120.3203	2.8	0.5	Ml	007/011	112	0.08	AB	N3	eq
11	05:41:29	47.8310	-120.2710	0.6*	0.2	Ml	005/008	210	0.04	CD	N3	eq
12	07:15:13	45.9978	-118.9852	17.9	1.6	Ml	020/027	84	0.17	BA	E3	eq
16	18:45:53	46.4877	-117.9058	11.3	1.5	Ml	011/015	298	0.21	BD	E3	eq
16	20:19:19	46.4442	-119.0253	-0.2*	1.3	Ml	010/010	222	0.15	CD	E3	px
17	13:16:32	45.8928	-120.1843	13.3	1.4	Ml	015/015	240	0.08	AD	E3	eq
17	17:34:15	47.9147	-120.6203	1.5*	0.8	Md	004/006	192	0.16	CD	C3	eq
17	20:30:05	47.9282	-120.6177	-0.2*	1.1	Ml	006/010	168	0.24	CC	C3	eq
17	21:19:42	47.9108	-120.6237	1.2*	0.5	Md	004/006	190	0.16	CD	C3	eq
18	21:39:54	44.2533	-120.9102	-1.5*	2.3	Ml	010/010	257	0.09	CD	C3	px
20	21:43:27	47.6312	-120.2478	5.1	1.2	Ml	010/011	98	0.08	AB	N3	eq
22	23:22:27	46.6620	-120.5165	-0.5*	1.3	Ml	008/011	104	0.40	CC	E3	px
23	21:43:09	45.9083	-119.3130	-0.3*	1.7	Ml	014/017	174	0.28	CC	E3	px
28	02:34:19	47.8785	-119.9022	22.6	0.6	Md	005/009	153	0.09	AC	N3	eq
March 2021												
Day	Time	Lat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Type
01	17:55:28	46.0252	-118.6882	-0.4*	2.0	Ml	013/014	147	0.21	CC	E3	px
02	03:06:58	46.4073	-119.6345	15.7	0.2	Ml	012/016	205	0.06	AD	E3	eq
06	22:24:29	46.6058	-119.8387	6.7	0.5	Ml	009/014	158	0.06	AC	E3	eq
07	19:53:13	47.7083	-120.0520	2.8	0.3	Md	004/007	121	0.03	AB	N3	eq
09	23:29:32	47.3165	-119.8315	-0.8*	1.0	Ml	015/016	82	0.30	CC	N3	px

10	09:35:59	47.7202	-120.0673	3.2	0.5	Ml	007/011	93	0.05	AB	N3	eq
11	03:51:59	47.6733	-120.3040	-0.1*	0.6	Ml	006/008	110	0.02	CB	N3	eq
15	18:31:23	48.5677	-119.6013	0.3*	1.2	Md	009/011	140	0.13	CC	N3	eq
15	21:19:06	46.2707	-120.5375	-0.7*	1.8	Ml	005/007	298	0.90	DD	E3	px
16	12:03:07	48.5852	-119.5940	0.4*	1.4	Ml	013/017	132	0.21	CC	N3	eq
16	21:04:52	45.6232	-120.8033	1.7	1.4	Ml	016/016	106	0.05	AC	C3	eq
16	21:35:49	47.6345	-119.2077	-0.7*	1.0	Ml	011/010	102	0.06	CC	N3	px
17	11:36:55	47.7747	-120.0883	2.6	1.7	Ml	020/026	53	0.08	AA	N3	eq
17	18:35:00	47.7105	-120.0615	4.4	1.0	Ml	005/009	126	0.04	AB	N3	eq
17	22:39:01	44.4092	-120.9880	-1.6*	1.9	Ml	007/010	304	0.22	CD	N3	px
18	12:24:53	47.7122	-120.0292	5.8	0.6	Ml	012/017	80	0.08	AB	N3	eq
18	17:47:26	46.6418	-120.2210	-0.1*	1.4	Ml	007/010	94	0.57	DB	E3	eq
18	20:52:44	47.6852	-120.0795	4.2	0.4	Md	007/011	113	0.06	AB	N3	eq
23	14:48:57	45.4260	-117.5617	6.6	2.7	Ml	012/015	139	0.32	CD	N3	eq
23	18:24:14	45.4118	-117.6437	12.1*	1.2	Ml	004/007	129	0.43	CD	N3	eq
23	20:07:20	44.0873	-121.3865	-1.5*	2.1	Ml	016/015	145	0.09	CC	N3	px
27	11:51:12	46.8360	-119.7408	-0.1	1.5	Ml	024/028	53	0.18	BC	E3	eq
30	19:22:41	46.8657	-121.0003	6.4	1.0	Ml	014/018	151	0.10	AC	C3	eq
31	21:17:33	44.0490	-120.7593	-1.8*	2.3	Ml	010/010	296	0.15	CD	C3	px
April 2021												
Day	Time	Lat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Type
04	02:39:44	47.6513	-120.1817	1.8	0.0	Md	005/009	122	0.08	AB	N3	eq
05	20:54:33	46.6145	-120.5072	-0.7*	1.0	Ml	005/006	127	0.40	CC	E3	px
07	00:25:59	45.9738	-118.3402	8.0	1.8	Ml	016/011	77	0.08	AB	E3	eq
09	15:57:17	47.8277	-119.9022	3.5	1.0	Ml	012/017	82	0.07	AC	N3	eq
12	07:42:25	46.6628	-119.5172	14.1	0.9	Ml	017/026	49	0.12	AA	E3	eq
12	15:38:12	47.8312	-119.9078	5.2	1.4	Ml	016/023	80	0.06	AC	N3	eq
12	17:04:11	45.8622	-120.0038	-0.5*	1.6	Ml	006/007	212	0.15	CD	E3	px
15	01:33:03	48.6553	-119.9040	0.0*	1.4	Ml	011/012	145	0.13	CC	N3	eq
15	13:00:23	48.3173	-120.7193	-0.1	1.4	Md	008/013	145	0.25	BC	C3	eq
16	17:35:48	46.6068	-119.8382	6.8	0.6	Ml	011/015	87	0.05	AA	E3	eq
17	05:17:38	46.3300	-119.3615	15.6	0.3	Ml	013/020	197	0.07	AD	E3	eq
17	23:35:06	47.6708	-121.3000	12.5	1.0	Ml	011/014	153	0.07	AC	C3	eq
18	02:23:09	47.2222	-121.2028	9.1*	0.8	Ml	018/030	119	0.23	CC	C3	eq
18	11:05:26	46.2593	-119.5233	6.8	0.3	Ml	007/011	202	0.03	AD	E3	eq
19	01:42:52	46.6148	-120.4110	9.2	0.6	Ml	008/009	111	0.07	AB	E3	eq
21	02:00:53	47.8262	-119.9012	4.7	0.3	Ml	011/018	82	0.08	AC	N3	eq
21	11:39:09	46.1212	-120.4023	18.7	2.5	Ml	034/043	58	0.21	BB	E3	eq
23	17:32:52	45.8868	-120.2620	-0.5*	1.7	Ml	014/018	132	0.21	CB	E3	px
23	17:36:39	47.7863	-117.3520	-0.6*	1.5	Ml	008/010	87	0.31	CC	N3	px
24	01:01:26	44.1302	-121.2740	-1.5*	1.4	Ml	014/012	156	0.13	CC	N3	px
25	00:31:12	46.1568	-120.4112	18.7	2.1	Ml	030/041	55	0.19	BA	E3	eq
26	07:01:52	46.5973	-119.8567	6.9	0.7	Ml	012/020	89	0.08	AA	E3	eq
27	00:09:40	44.1565	-121.3753	-1.5*	1.0	Ml	009/009	158	0.36	CC	E3	px
27	01:18:43	46.4480	-119.3273	16.6	0.3	Ml	018/026	71	0.21	BA	E3	eq
27	11:10:29	47.6742	-120.3337	-1.1	0.6	Ml	009/015	95	0.08	AB	N3	eq
28	20:11:02	46.4527	-119.5920	11.1*	-0.2	Md	002/004	360	0.12	DD	E3	eq
29	01:10:51	44.1232	-121.3218	-1.5*	1.2	Ml	013/012	164	0.22	CC	E3	px
29	20:09:19	45.8290	-118.3407	-0.7*	2.1	Ml	012/012	141	0.13	CC	E3	px
30	04:35:58	46.6055	-119.7660	16.3	0.6	Ml	012/019	74	0.08	AA	E3	eq
30	17:48:10	45.7610	-118.3547	-0.7*	1.6	Ml	013/015	157	0.31	CC	E3	px
30	20:06:45	46.4397	-119.5670	13.4*	0.1	Ml	003/005	311	0.01	DD	E3	eq
30	20:08:05	46.3030	-119.5632	10.7	0.4	Ml	005/007	325	0.02	BD	E3	eq
30	20:57:39	45.0848	-121.3078	-1.3*	1.7	Ml	008/007	150	0.04	CC	E3	px
May 2021												

Day	Time	Lat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Type
01	00:00:59	46.3073	-119.5797	9.2	0.3	Ml	009/014	128	0.08	AB	E3	eq
01	13:15:15	46.2900	-119.5772	8.0	0.5	Ml	011/017	146	0.08	AC	E3	eq
03	11:25:57	46.2952	-119.5873	7.7	0.3	Ml	008/012	137	0.05	AC	E3	eq
04	13:39:02	45.4218	-117.6033	6.6	2.2	Ml	006/009	104	0.37	CD	E3	eq
04	13:53:57	45.4208	-117.6237	6.9	1.8	Ml	005/008	105	0.30	CD	E3	eq
04	18:21:44	46.7087	-121.0707	4.2	1.7	Ml	038/056	76	0.28	BC	C3	eq
04	22:03:50	47.7213	-120.0670	4.9	0.2	Md	003/006	173	0.04	AC	N3	eq
04	23:32:05	46.7068	-121.0725	0.0	1.2	Ml	022/030	137	0.24	BC	C3	eq
05	20:35:15	46.6923	-121.0775	7.7	0.8	Ml	017/022	164	0.20	BC	C3	eq
05	20:59:39	47.3960	-117.8627	-0.6*	2.2	Ml	014/017	63	0.25	CC	N3	px
07	22:19:34	47.4798	-120.7077	-1.1*	1.3	Ml	011/013	164	0.27	CC	C3	px
09	09:08:40	47.6390	-120.1940	4.9	0.5	Ml	005/010	141	0.06	AC	N3	eq
09	19:14:04	47.6968	-120.2472	3.1	0.1	Md	007/008	199	0.03	AD	N3	eq
10	20:00:17	47.6578	-120.1802	3.2	1.5	Ml	020/023	70	0.08	AA	N3	eq
12	11:19:27	47.7023	-120.0552	3.1	0.6	Ml	011/017	63	0.06	AB	N3	eq
12	17:10:58	47.3018	-119.9402	-0.8*	1.6	Ml	020/022	144	0.23	CC	N3	px
12	20:15:33	47.7212	-120.0142	5.6	1.4	Ml	014/017	97	0.06	AB	N3	eq
13	21:58:11	47.4690	-120.6507	-1.0*	0.9	Ml	006/007	156	0.06	CC	C3	px
16	07:03:17	46.9588	-120.9100	6.2	1.1	Ml	020/027	88	0.27	BC	C3	eq
16	19:52:37	46.9592	-120.9050	7.0	1.2	Ml	025/032	80	0.23	BC	C3	eq
17	22:54:29	48.7018	-120.3730	1.1	1.7	Ml	010/015	189	0.26	BD	C3	eq
18	10:31:49	47.6608	-120.2132	3.2	-0.4	Md	004/007	115	0.06	AB	N3	eq
19	16:10:42	45.6452	-120.7735	-0.8*	1.9	Ml	015/014	116	0.25	CC	C3	px
19	23:29:05	44.1625	-121.3620	-1.5*	1.4	Ml	006/008	344	0.37	CD	C3	px
21	18:03:48	45.6247	-121.0360	-1.4*	1.8	Ml	007/009	287	0.10	CD	C3	px
21	21:27:06	47.4633	-120.6630	-1.2*	1.3	Ml	007/007	159	0.10	CC	C3	px
22	23:33:12	47.5978	-121.4867	93.4	1.3	Ml	024/036	60	0.16	BA	C3	eq
24	02:45:08	46.5663	-119.4873	4.2*	0.3	Ml	003/005	334	0.03	CD	E3	eq
26	10:23:40	46.2253	-119.4690	5.2	0.7	Ml	010/014	254	0.06	AD	E3	eq
26	10:55:55	46.6188	-119.7903	7.3	0.6	Ml	012/018	175	0.09	AC	E3	eq
26	12:29:48	46.2325	-119.4522	6.5	0.9	Ml	013/019	146	0.15	BC	E3	eq
26	17:30:20	48.4627	-121.1967	80.7	1.5	Md	005/007	183	0.67	DD	C3	eq
28	17:58:11	47.6188	-120.2262	-0.9*	1.1	Md	009/009	171	0.22	CC	N3	px
29	12:37:30	46.3233	-119.5685	15.1	0.1	Ml	009/015	116	0.08	AB	E3	eq
29	14:34:10	47.1505	-121.2742	1.9	1.2	Ml	025/036	125	0.26	BC	C3	eq
29	21:57:43	48.8203	-120.5955	9.3*	1.4	Ml	010/014	137	0.35	CD	C3	eq
31	22:19:38	46.7575	-119.8215	15.1	1.4	Ml	025/035	77	0.18	BA	E3	eq
June 2021												
Day	Time	Lat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Type
02	05:23:47	46.5812	-119.8323	7.3	0.6	Ml	009/015	176	0.06	AC	E3	eq
02	10:37:09	45.8442	-120.1732	17.1	1.2	Ml	015/020	136	0.11	AC	E3	eq
03	12:43:39	46.4583	-119.6080	17.4	0.3	Ml	007/012	146	0.08	BC	E3	eq
03	20:58:06	47.8297	-119.8035	-0.8*	0.5	Md	004/006	108	0.12	CC	N3	px
07	07:45:54	45.4162	-117.6142	14.3	1.8	Ml	005/008	105	0.23	BD	N3	eq
07	08:25:36	45.4140	-117.6233	8.8*	1.5	Ml	005/008	105	0.29	CD	N3	eq
07	21:09:00	47.3748	-117.8418	-0.5*	2.2	Ml	012/013	62	0.63	DC	N3	px
07	22:31:49	46.3137	-120.0510	-0.5*	1.5	Ml	007/011	320	1.01	DD	E3	px
08	00:13:16	46.2470	-117.8777	-0.2*	1.9	Ml	013/013	300	0.21	CD	E3	px
08	03:40:18	46.4788	-120.4832	15.7	0.3	Ml	006/007	141	0.03	AC	E3	eq
08	10:42:22	47.6767	-120.3197	3.3	0.6	Ml	009/015	106	0.09	AB	N3	eq
09	22:00:10	47.5087	-120.2993	-1.1*	1.3	Md	008/009	119	0.11	CC	N3	px
09	22:37:24	46.1275	-119.0282	-0.2*	1.9	Ml	021/023	152	0.20	CC	E3	px
10	09:11:38	46.8225	-120.5783	14.6	1.3	Ml	029/038	66	0.29	BA	E3	eq
10	22:16:03	48.8260	-120.1550	7.0	1.4	Ml	008/013	121	0.30	CC	N3	eq

11	07:15:39	47.6595	-120.1757	3.3	0.4	Md	006/010	110	0.03	AB	N3	eq
12	00:40:56	47.9145	-120.8120	0.4*	0.9	Md	003/004	266	0.04	CD	C3	eq
12	11:21:00	47.5953	-120.1528	6.0	0.5	Ml	008/013	174	0.05	AC	N3	eq
15	03:06:55	45.4170	-117.6040	3.3	2.0	Ml	011/016	104	0.35	CD	N3	eq
16	17:46:55	48.5938	-117.9568	-0.6*	1.9	Ml	009/010	175	0.12	CD	N3	px
16	18:56:21	46.2737	-119.3848	-0.4*	2.2	Ml	012/015	251	0.10	CD	E3	px
16	20:35:12	47.5567	-120.2815	-1.2*	1.4	Ml	013/015	95	0.14	CB	N3	px
17	07:27:51	46.7605	-120.6672	9.2	0.7	Ml	008/012	101	0.06	AB	E3	eq
17	07:35:21	46.7635	-120.6632	8.6	1.0	Ml	012/016	86	0.08	AB	E3	eq
18	07:01:54	47.7333	-120.1995	-0.2*	1.8	Ml	018/020	63	0.08	CB	N3	eq
18	07:52:36	47.7350	-120.2005	-0.3*	1.4	Ml	015/015	80	0.08	CB	N3	eq
18	09:34:04	47.7342	-120.2033	-0.3*	0.2	Ml	006/010	139	0.06	CC	N3	eq
18	09:59:37	47.7330	-120.2013	-0.4*	1.3	Ml	013/017	80	0.06	CB	N3	eq
18	14:16:27	47.7377	-120.2010	1.9	0.4	Ml	004/006	140	0.03	BC	N3	eq
18	18:26:11	46.1342	-119.4723	-0.3*	1.6	Ml	020/022	116	0.15	CC	E3	px
20	10:02:34	47.6702	-120.3797	4.4	0.4	Ml	006/011	107	0.09	AB	N3	eq
20	10:31:52	46.3242	-119.6248	16.4	0.7	Ml	012/017	140	0.07	AC	E3	eq
22	20:55:32	46.2573	-119.6595	-0.5*	1.6	Ml	007/009	157	0.05	CC	E3	px
23	19:25:15	44.0988	-121.3508	-1.5*	2.0	Ml	013/014	151	0.24	CC	E3	px
25	16:34:57	47.7465	-120.2380	2.7	1.1	Ml	011/016	70	0.05	AB	N3	eq
26	09:16:45	47.6718	-120.0747	4.8	2.2	Ml	017/020	54	0.08	AA	N3	eq
26	13:26:48	47.6708	-120.0757	4.7	0.7	Ml	010/013	86	0.05	AA	N3	eq
26	19:03:53	47.5597	-120.2328	8.4	2.8	Ml	031/030	79	0.09	AB	N3	eq
26	19:14:53	47.5547	-120.2282	8.1	0.5	Md	007/012	192	0.10	AD	N3	eq
26	23:30:14	47.5600	-120.2305	8.3	2.1	Ml	029/027	80	0.08	AB	N3	eq
29	03:11:19	48.7750	-121.3037	-1.2*	0.8	Md	005/005	242	0.38	CD	C3	px
29	06:51:56	46.5633	-119.6545	16.0	0.1	Ml	011/014	73	0.06	AA	E3	eq
July 2021												
Day	Time	Lat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Type
01	16:34:58	48.6948	-120.2030	12.2	1.2	Ml	008/013	135	0.39	CC	N3	eq
02	03:34:56	44.5222	-117.4108	-1.1*	1.9	Ml	006/007	92	0.63	DC	N3	px
02	21:16:23	47.6997	-120.3570	1.5	1.0	Ml	008/012	92	0.05	BC	N3	eq
02	22:13:36	48.6552	-119.9182	0.3*	1.4	Ml	008/012	143	0.36	CC	N3	eq
04	17:28:03	47.0817	-120.4733	-0.8	1.0	Ml	013/016	88	0.50	DC	N3	eq
07	16:52:36	47.6215	-120.2353	-0.9*	0.6	Md	005/007	166	0.09	CC	N3	px
08	09:04:06	45.4105	-117.6250	9.4	2.1	Ml	007/011	107	0.30	CD	N3	eq
08	21:25:43	46.1295	-119.7717	-0.5*	1.7	Ml	012/013	154	0.12	CC	E3	px
09	14:04:30	47.7008	-120.0307	2.8	1.7	Ml	020/025	67	0.07	AB	N3	eq
11	21:28:57	47.9135	-121.3105	1.1*	0.9	Md	003/004	276	0.21	CD	C3	eq
12	12:13:48	47.6752	-120.4150	8.7*	-0.1	Md	002/004	183	0.02	DD	N3	eq
15	17:43:50	47.1865	-120.7113	-1.0*	1.6	Ml	014/008	148	0.17	CC	C3	px
17	20:20:32	46.2290	-119.5662	17.0	0.7	Ml	011/021	214	0.09	AD	E3	eq
20	05:36:45	47.7432	-120.2778	-0.4*	0.9	Ml	011/015	134	0.09	CB	N3	eq
21	23:29:19	48.0452	-120.7240	7.3	1.6	Ml	015/017	95	0.13	AC	C3	eq
23	17:03:56	46.1575	-119.2787	-0.3*	1.4	Ml	016/015	166	0.13	CC	E3	px
27	03:52:24	46.8905	-120.6458	10.8	0.6	Ml	006/008	100	0.23	BB	E3	eq
27	10:05:30	47.7597	-120.0233	-0.7	1.6	Ml	026/022	61	0.08	AA	N3	eq
27	19:21:37	45.6108	-121.0657	-1.4*	1.9	Ml	007/011	284	0.22	CD	C3	px
27	21:43:49	47.9928	-119.8812	-0.9*	1.1	Md	007/006	114	0.03	CC	N3	px
28	15:59:30	47.0292	-120.6928	-1.0*	1.5	Ml	011/010	115	0.45	CB	C3	px
28	20:38:38	45.9252	-119.3325	-0.3*	1.6	Ml	009/013	199	0.50	DD	E3	px
29	20:52:44	48.1888	-120.2155	7.3	0.9	Md	007/010	133	0.10	AC	N3	eq
30	09:18:01	48.0558	-120.7102	3.2	1.6	Ml	014/018	97	0.21	BC	C3	eq
30	13:37:30	46.6693	-119.6937	22.4*	0.9	Ml	006/008	288	3.35	DD	E3	eq
30	18:18:02	46.2595	-119.4858	-0.3*	2.1	Ml	017/017	102	0.22	CB	E3	px

August 2021												
Day	Time	Lat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Type
02	11:18:35	48.0203	-120.8038	-0.1*	0.8	Md	006/008	111	0.07	CC	C3	eq
02	19:51:26	46.6083	-121.4487	3.0	1.1	Ml	027/040	155	0.16	BC	C3	eq
02	20:07:28	46.6243	-121.4350	7.0	1.5	Ml	033/047	155	0.15	BC	C3	eq
03	23:02:47	46.8247	-119.4962	2.8	0.9	Ml	017/019	129	0.08	AB	E3	eq
05	20:44:53	47.6417	-120.1610	6.7	0.6	Ml	007/010	98	0.06	AB	N3	eq
05	21:17:23	47.8578	-120.8562	-1.2*	1.3	Ml	008/006	116	0.03	CC	C3	px
06	09:10:41	47.6933	-120.2395	3.3	-0.0	Md	005/009	193	0.12	AD	N3	eq
06	12:12:16	46.6010	-119.8600	6.6	1.3	Ml	015/012	91	0.05	AB	E3	eq
06	21:02:46	47.3825	-117.8590	-0.6*	2.2	Ml	010/010	134	0.24	CC	N3	px
08	13:30:05	46.8880	-120.6897	13.4	1.9	Ml	028/038	67	0.25	BA	E3	eq
09	22:45:42	47.6407	-120.1890	6.1	0.4	Md	006/010	138	0.05	AC	N3	eq
13	17:43:01	47.6887	-120.1227	8.2	-0.2	Md	004/005	166	0.02	AD	N3	eq
13	21:36:24	44.3073	-120.7833	-1.5*	2.1	Ml	008/009	286	0.21	CD	N3	px
14	04:25:09	47.7118	-120.3187	4.7	1.6	Ml	027/026	82	0.07	AB	N3	eq
14	06:23:08	47.6268	-120.4085	3.2	0.5	Ml	011/012	100	0.12	AB	N3	eq
15	18:11:02	46.7000	-121.0760	6.1	1.4	Ml	033/048	97	0.21	BC	C3	eq
15	19:35:48	46.8752	-120.8368	4.4	1.1	Ml	015/020	99	0.27	BC	C3	eq
16	16:16:44	48.1758	-117.8417	-0.6*	1.6	Ml	010/014	124	0.65	DC	N3	px
17	10:43:36	47.6673	-120.3240	-0.2*	0.1	Md	005/009	227	0.09	CD	N3	eq
17	10:55:27	47.7175	-120.0728	4.5	0.6	Ml	009/015	130	0.08	AB	N3	eq
18	01:46:59	47.6557	-120.1917	3.3	0.5	Md	005/008	118	0.04	AB	N3	eq
18	19:39:43	47.9853	-119.8665	-0.9*	1.4	Md	010/010	109	0.19	CB	N3	px
21	23:56:35	47.7147	-120.2225	-0.4*	0.5	Ml	007/012	125	0.05	CB	N3	eq
24	20:10:12	44.8482	-117.7360	18.6	2.1	Ml	010/011	65	0.27	BB	N3	eq
25	15:51:04	48.2250	-120.9585	12.8	0.8	Md	005/009	197	0.09	BD	C3	eq
25	18:06:15	46.1573	-119.2775	-0.2*	1.3	Ml	010/012	202	0.14	CD	E3	px
25	20:39:28	47.6088	-121.3100	9.4	0.9	Ml	013/017	79	0.11	AB	C3	eq
25	21:19:14	46.7648	-118.5720	-0.3*	1.7	Ml	010/010	239	0.29	CD	E3	px
26	18:42:14	47.3468	-117.8568	-0.6*	2.3	Ml	009/011	140	0.39	CC	N3	px
26	21:35:51	44.3265	-120.9800	-1.5*	1.5	Md	007/007	239	0.12	CD	N3	px
28	09:57:36	46.9098	-119.3022	2.9	2.2	Ml	009/011	132	0.08	BC	E3	eq
31	08:48:38	46.0483	-118.7675	14.3	1.0	Ml	010/017	120	0.20	BB	E3	eq
31	18:46:24	46.1650	-119.2842	-0.3*	1.7	Ml	010/011	163	0.08	CC	E3	px
September 2021												
Day	Time	Lat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Type
03	03:51:06	46.0957	-119.2492	13.1	1.0	Ml	018/025	159	0.13	BC	E3	eq
03	17:40:09	45.9045	-119.3067	-0.3*	1.6	Ml	020/025	143	0.17	CC	E3	px
07	02:12:20	47.8655	-120.0978	4.6*	-0.6	Md	002/004	188	0.03	DD	N3	eq
08	00:25:52	47.6365	-120.3447	10.0	0.3	Md	007/011	105	0.40	CB	N3	eq
09	08:32:34	47.4023	-120.5075	5.1	1.3	Ml	021/029	113	0.30	CC	N3	eq
10	20:34:38	45.9055	-120.2447	-0.6*	1.3	Ml	007/008	239	0.23	CD	E3	px
13	18:25:00	45.6078	-121.0650	-1.5*	1.9	Ml	006/009	283	0.13	CD	C3	px
13	22:24:07	46.1433	-119.2675	-0.2*	1.5	Ml	010/013	205	0.27	CD	E3	px
14	20:48:22	45.8780	-119.1100	-0.3*	1.4	Ml	010/012	139	0.27	CC	E3	px
15	07:15:26	45.5178	-118.7825	13.8	1.6	Ml	013/019	165	0.26	BC	E3	eq
15	09:01:03	45.3855	-117.6668	18.9	1.6	Ml	006/009	137	0.10	AC	E3	eq
15	11:50:24	45.4205	-117.6223	14.2	1.3	Ml	006/008	132	0.20	BC	E3	eq
17	02:24:59	46.2472	-119.7195	6.0	0.4	Ml	010/016	198	0.08	AD	E3	eq
17	04:52:04	47.7940	-120.1653	5.5	0.2	Ml	008/015	86	0.10	AB	N3	eq
18	10:27:38	47.5267	-121.2750	2.3	1.7	Ml	013/016	91	0.19	BC	C3	eq
19	20:25:13	46.6207	-119.8435	6.0	0.9	Ml	010/017	226	0.06	AD	E3	eq
20	11:29:22	47.6523	-119.9957	8.4	1.4	Ml	017/025	93	0.13	AB	N3	eq
22	19:49:22	46.0498	-118.7828	-0.4*	1.6	Ml	009/009	153	0.08	CC	E3	px

22	22:14:22	46.1485	-119.2733	-0.3*	1.8	Ml	011/016	169	0.13	CC	E3	px
24	20:09:54	47.8017	-120.7663	-1.2*	1.1	Md	003/004	201	0.05	CD	C3	px
24	23:03:40	47.1525	-120.9628	-0.9*	1.4	Ml	014/013	203	0.45	CD	C3	px
27	17:04:22	46.1662	-119.2802	-0.3*	1.5	Ml	011/015	162	0.09	CC	E3	px
28	09:06:01	48.2150	-120.5970	7.0	1.0	Md	008/013	156	0.17	BC	C3	eq
29	06:28:42	48.7590	-119.6927	0.6*	1.5	Ml	011/013	180	0.11	CC	N3	eq
29	23:51:20	44.2420	-121.3225	-1.7*	1.5	Ml	011/011	172	0.27	CC	N3	px
30	06:46:45	46.5982	-119.8627	6.7	1.1	Ml	017/023	95	0.07	AB	E3	eq

5.0 Discussion of Seismic Activity – FY 2021

5.1 Summary

During FY2021, seismic activity was relatively quiet throughout eastern Washington. 265 earthquakes were cataloged in the region, of which 20% (53) took place on or in the immediate vicinity of the Hanford Site (Tables 5.1 and 5.2). Several earthquakes took place in the historically active area of Entiat and Chelan. Within the vicinity of the Hanford Site, there was typical swarm-type activity, most strongly observed in the Cold Creek and the Wye Swarm Areas.

The depth distribution and geographic pattern of the earthquakes for the year are tabulated in Tables 5.1 and 5.2 and plotted on Figure 5.1.

Table 5.1. Depth Distribution of Eastern Washington Earthquakes for FY 2021

Category	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	FY 2021
Shallow (0-4 km deep)	35	23	22	19	99
Intermediate (4-9 km deep)	23	14	32	20	89
Deep (greater than 9 km deep)	20	16	26	15	77
Total	**78**	**53**	**80**	**54**	**265**
Felt	0	0	1	0	1
Probable Blast	22	15	32	31	100

Table 5.2. Earthquake Counts for FY 2021 for Earthquakes near the Hanford Site

Seismic Source Zones	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	FY 2021
Frenchman Hills	1	0	0	0	1
Saddle Mountains	1	0	0	0	1
Wahluke Slope	1	0	0	0	1
Coyote Rapids	1	0	1	0	2
Wye	2	0	1	0	3
Cold Creek	0	0	3	0	3
Rattlesnake Mountain	0	0	0	0	0
Horse Heaven Hills	0	0	0	0	0
Total for swarm areas	6	0	5	0	11
Random Events	6	9	18	9	42
Total For All Earthquakes	**12**	**9**	**23**	**9**	**53**

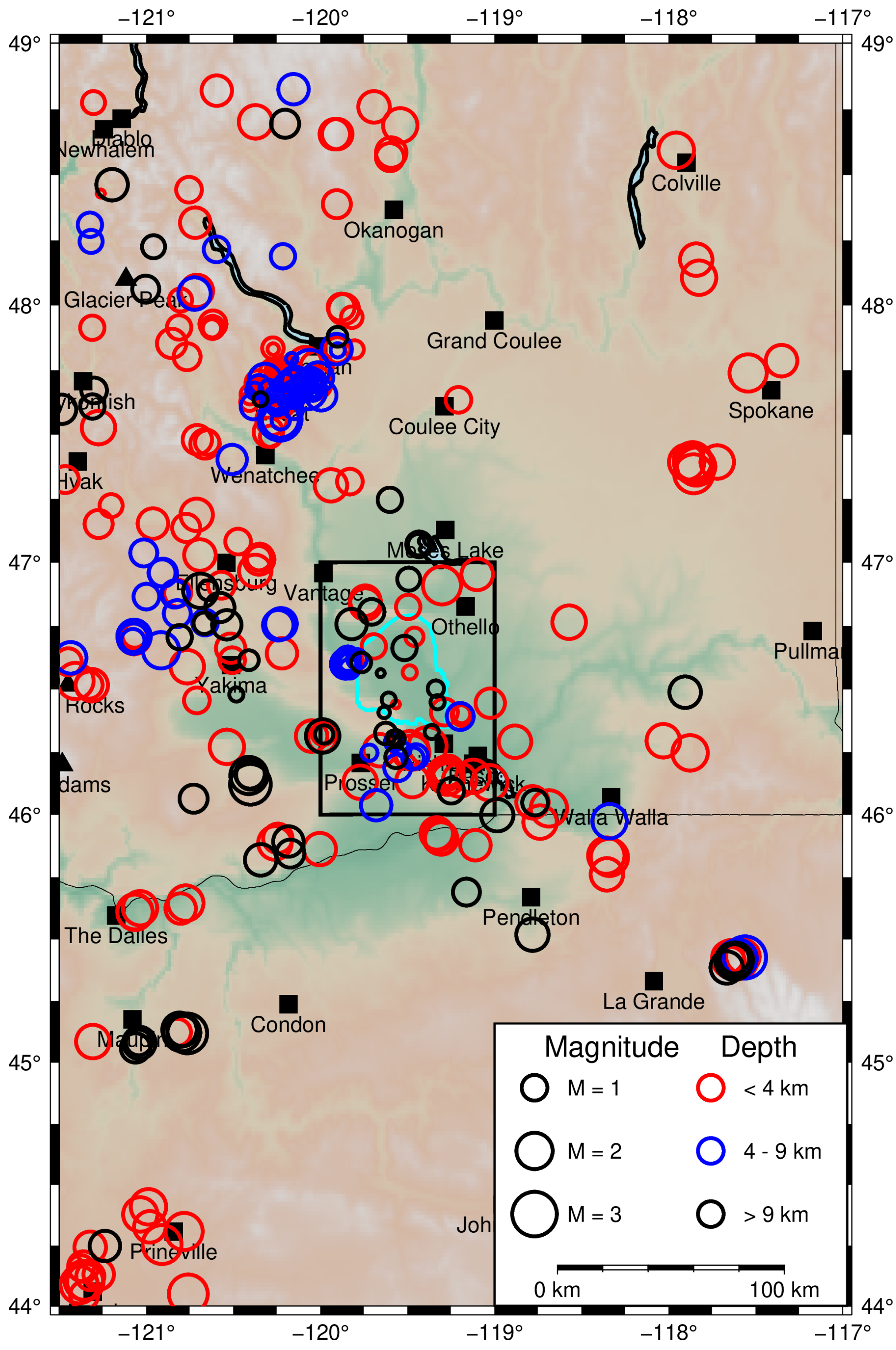


Figure 5.1. Hanford and Regional Epicenters of Earthquakes Recorded during FY 2021. Background color indicates elevation.

Red circles stand for shallow earthquakes (0-4 km). Blue circles for intermediate-depth earthquakes (4-9 km).

6.0 Status of Monitoring

In large part thanks to the significant enhancements of the seismic monitoring network during FY2017 and FY2018, the monitoring capability remains strong. FY2021, same as last year, has been a year marked by continuity in field activity, not station upgrades as in previous years. Network enhancements have been more focused on processing techniques and in-shop procedural advancements.

As of May 4th, 2021, ShakeAlert^{TM} powered Earthquake Early Warnings are available to individuals in WA state with smart phones, via the federal Wireless Emergency Alert (WEA) system or the Android operating system. Additional cell phone apps are expected to become available in the future. Data from twenty-six stations operated and maintained under the current contract are of sufficient quality and low-latency that they are forwarded by the PNSN to contribute to the ShakeAlert^{TM} system, resulting in a higher probability of timely, useful, warnings for personnel at the Hanford Site. Likewise, improvements made to ShakeMap (which are maps of observed shaking produced after an earthquake) benefit Hanford Site operations. In the previous annual report, it was noted that PNSN is developing new methods to monitor the quality and data latency of their growing network. These improvements benefit the HSN and EWRSN as well. Figure 6.1, which is the same as shown in last year's report shows the latency for one single channel of data (vertical strong-motion from station MDW). Figure 6.1 is a time series of data latency**,** i.e., the time difference between when the ground moves at the station and when information about it is useable in PNSN's Seattle office. A one-day record is shown, each line covers 30 minutes and overall patterns of occasional periodic and random latency spikes can be seen. The inset is an expansion of the time period in yellow highlight and shows that the base latency is about a very healthy 1 second, and the larger periodic spikes are 2-3 seconds long and about 2-3 seconds in duration. This information is critical to tracking and fixing the source of the spikes.

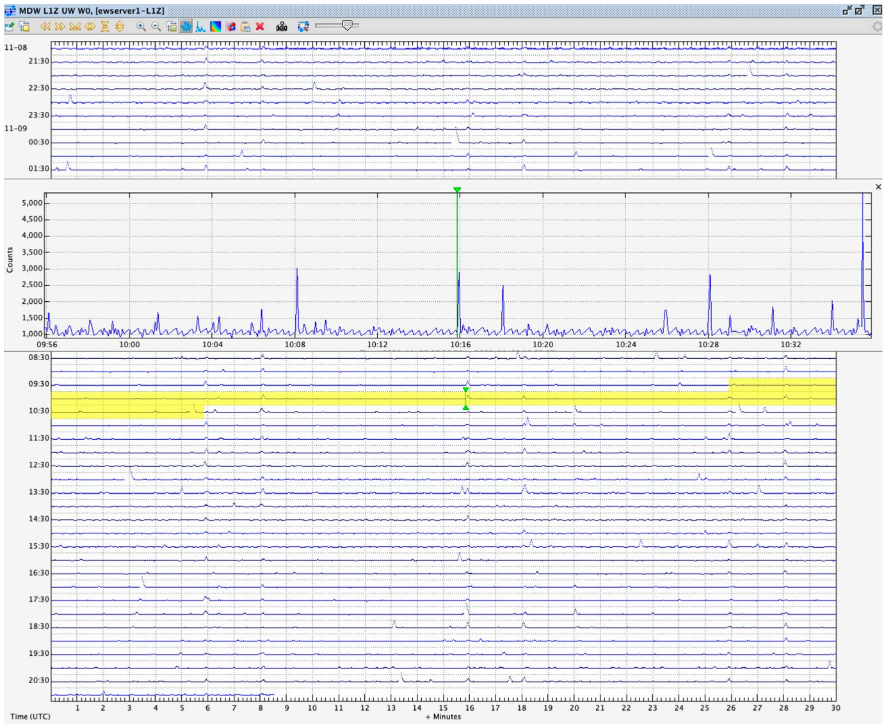


Figure 6.1. Illustration of Data Delivery Latency

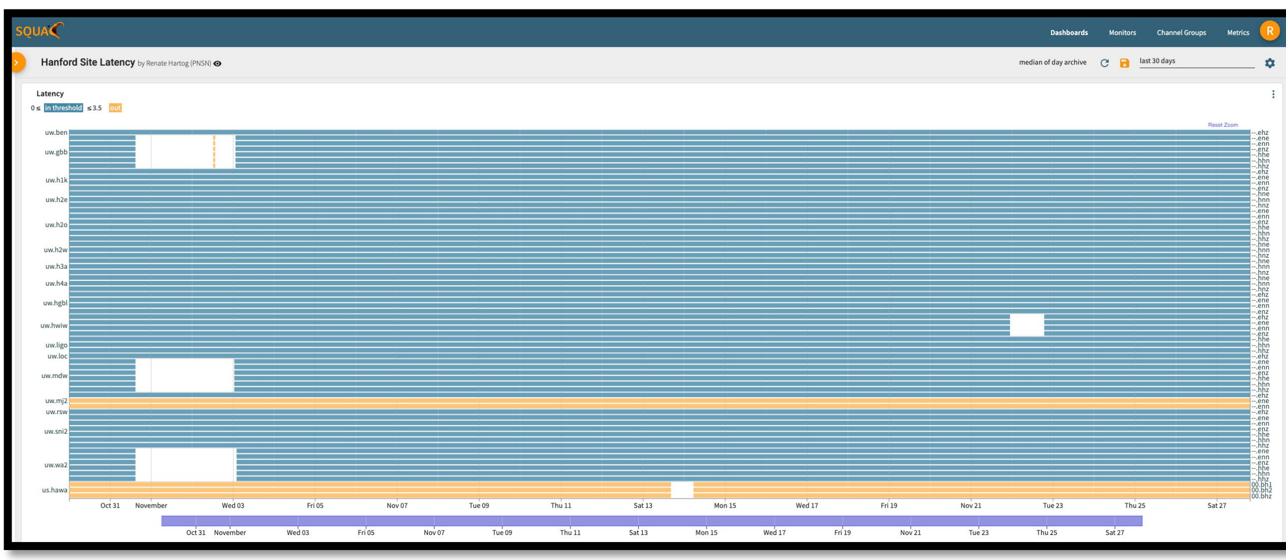


Figure 6.2. Month-long daily median data-latency

Figure 6.2 shows a new tool for network-wide monitoring of various metrics, in this case the median data latency per day of each of the channels recorded on the Hanford Site for a month's long period. Figure 6.2 illustrates that data from most channels recorded on the Hanford Site arrive at the University of Washington-Seattle site within 3.5s. It also illustrates a data-outage from three sites that share a telemetry node (GBB, MDW, and WA2) in early November. A computer at the telemetry node went down on October 31, 2021 (UTC) due to a power-outage.

Hardening telemetry nodes against power-outages and other issues is an on-going effort of the network staff.

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