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Hanford Seismic Report for Fiscal Year 2017
(October 2016 – September 2017)
HNF-61610 Revision 0

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

Contractor for the U.S. Department of
Energy under Contract DE-AC06-09RL14728

Box 650
Richland, Washington 99352

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Hanford Seismic Report for Fiscal Year 2017 (October 2016 – September 2017)

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Prepared for Mission Support Alliance

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Executive Summary

The Pacific Northwest Seismic Network (PNSN) and Mission Support Alliance (MSA) continue to 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 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 39 individual sensor sites and 24 radio relay sites maintained by the PNSN.

During FY2017, seismic activity was relatively quiet throughout eastern Washington. 280 earthquakes were cataloged in the region, of which about 39% (108) took place on or in the immediate vicinity of the Hanford Site. While no damaging earthquakes took place in the region, a handful of notable or significant earthquakes illustrated interesting features of regional seismotectonics. 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 Wye and Horse Heaven Hills Swarm Areas.

Abbreviations and Acronyms

ANSS	Advanced National Seismic System
AQMS	ANSS Quake Management System
BB	broad band (type of seismic station)
BPA	Bonneville Power Administration
CRBG	Columbia River Basalt Group
Dmin	Minimum distance (closest distance from an earthquake epicenter to a station)
DOE	U.S. Department of Energy
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
HSN	Hanford Seismic Network
Lat	Latitude
Lon	Longitude
Km	kilometer
M_d	coda-duration magnitude
M_L	local magnitude
Mag	Magnitude of earthquake
MMI	Modified Mercalli Intensity
MOD	Velocity model
Mtyp	Magnitude type
NS/NP	Number of stations/number of phases
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
SMA	strong motion accelerometer (type of seismic station)
USGS	U.S. Geological Survey
UTC	Coordinated Universal Time
UW	University of Washington
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) 2017 (October 2016 through September 2017). The Mission Support Alliance (MSA), Public Safety and Resource Protection (PSRP) program manages seismic monitoring for the Hanford Site with the monitoring work being performed under a sub-contract with the University of Washington (UW), PNSN.

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 the U.S. Department of Energy (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 FY2011, 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 Columbia River Basalt Group (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.

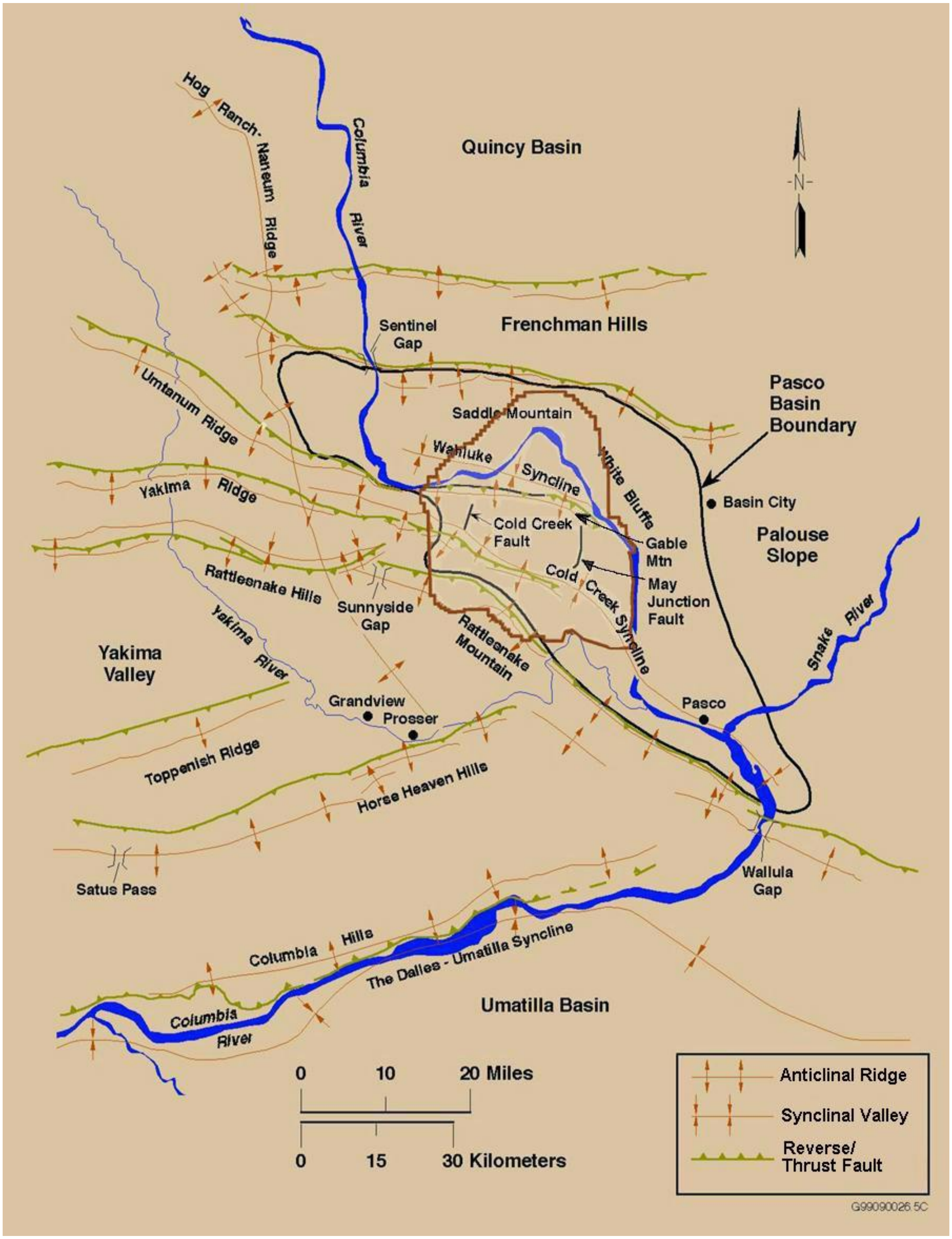
Basement Source Structures. Studies (Geomatrix 1996) suggest that major earthquakes can originate in tectonic structures in the basement. Because little is known about geologic structures in the basement beneath the Hanford

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, several HLSMP short-period stations record 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. Moreover, several HLSMP stations are now capable of recording 4 channels of seismic data. These sites will record 3 orthogonal components of strong motion and a vertical component of high-gain short period motion. The high-gain data is used to detect and locate earthquakes too small to generate ground motions above the strong-motion channels' noise level.

We further divide the seismic stations supported by MSA 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 39 stations. Most stations reside in remote locations and require solar panels and batteries for power. The HSN includes 17 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)
6-Channel Station				
WA2	46.7552	-119.5668	244	Wahluke Slope
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
3-Channel Station				
GBB	46.6087	-119.6290	185	Gable Butte
Single Channel Analog (Short Period)				
BEN	46.5186	-119.7185	335	Benson Ranch
H2O	46.3956	-119.4241	175	Water Station
LOC	46.7169	-119.4320	210	Locke Island
MDW	46.6130	-119.7622	330	Midway
RSW	46.3944	-119.5925	1045	Rattlesnake Mountain
SNI	46.4639	-119.6609	323	Snively Ranch

Figure 3.1. Hanford Seismic Network Onsite Stations

Red squares and text are strong motion accelerographs (SMA) stations
Red square and orange triangle is 6-channel broadband and SMA station
Black text and plusses are short period stations
HAWA is a broadband and SMA US National Seismic Network station

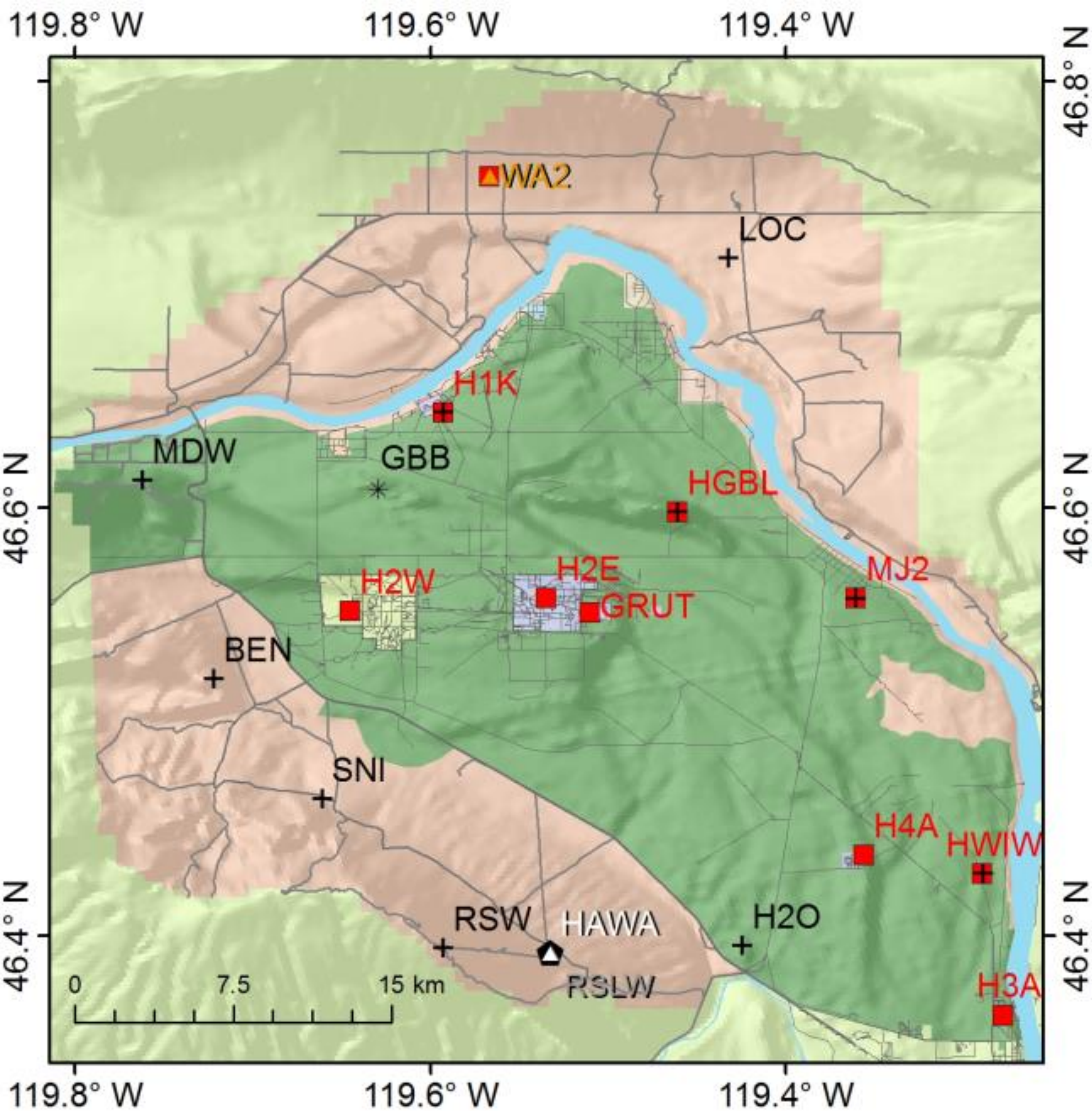
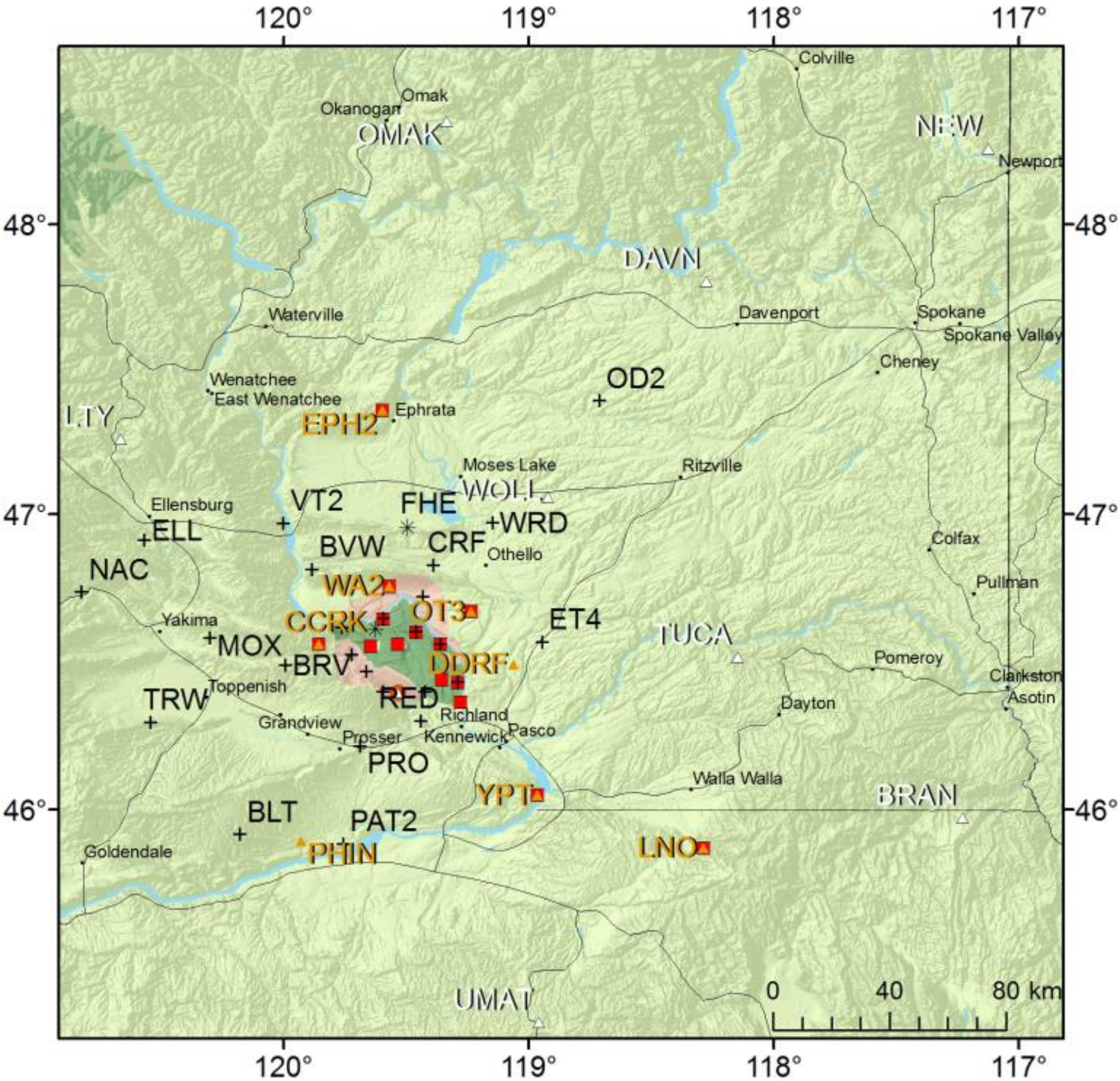


Table 3.2. Hanford Seismic Network Offsite Stations

Station	Latitude	Longitude	Elevation (m)	Station Name
Strong Motion Accelerometer, 3-Channel Station				
DDRF	46.4911	-119.0595	233	Didier Farms
PHIN	45.8950	-119.9280	227	Phinney Hill
3-Channel Weak Motion Analog (Short Period)				
FHE	46.9518	-119.4981	455	Frenchman Hills East
6-Channel				
CCRK	46.5585	-119.8548	561	Cold Creek
EPH2	47.3562	-119.5972	661	Ephrata
LNO	45.8717	-118.2862	771	Lincton Mountain Oregon
OT3	46.6689	-119.2341	322	Othello 3
YPT	46.0487	-118.9634	325	Yellepit
Single-Channel Analog (Short Period)				
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
ET4	46.5634	-118.9451	236	Eltopia 4
MOX	46.5772	-120.2993	501	Moxee City
NAC	46.7330	-120.8249	728	Naches
OD2	47.388	-118.7108	553	Odessa 2
PAT2	45.8836	-119.7578	259	Paterson 2
PRO	46.2125	-119.6868	553	Prosser
RED	46.2974	-119.4388	330	Red Mountain
TRW	46.2921	-120.5431	723	Toppenish Ridge
VT2	46.9672	-120.0003	385	Vantage 2
WRD	46.9699	-119.1460	375	Warden

Figure 3.2. Hanford Seismic Network Stations of the Eastern Washington Region Sub-Network

Black font and pluses are short-period EWRSN stations.
Red square and orange triangle is 6-channel broadband and SMA station
Gold font and triangles are EWRSN broadband stations.
White font and triangles are broadband stations contributed by other agencies.



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 100 combined data channels because the 4 three-component seismometer sites (GBB, FHE, DDRF, and PHIN), the 6 six-component sites (WA2, CCRK, EPH2, LNO, OT3, and YPT) and 9 other sites in the HSN (H1K, H2E, H2W, H3A, H4A, MJ2, GRUT, HGBL, and HWIW) require additional data channels at each station. The tri-axial stations record motion in the vertical, north-south horizontal, and east-west horizontal directions. Seventeen 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 11 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 are three-component units consisting of vertical, north-south horizontal, and east-west horizontal seismometers manufactured by Kinemetrics, Inc., Pasadena, California, and known as the Etna system. Each Etna unit contains a digital recorder, a data storage unit, and a Global Positioning System (GPS) receiver with the equipment housed in a watertight box. At five sites, now, (H1K, HWIW, HGBL, GRUT, and MJ2) 3 SMA channels are supplemented by a high-gain vertical component.

The cell modem 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 (ms).

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/s. 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 Etna 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 Etna. 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 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.

3.2.4 New Strong Motion and Broadband Installations

In an effort to improve and upgrade network stations, new instruments were installed at many existing stations. At the end of FY2017, six stations had been replaced with the new equipment. These stations are WA2, CCRK, EPH2, LNO, OT3, and YPT. Tables 3.1 and 3.2 and Figures 3.1 and 3.2 reflect the upgrades. At the time of the writing of this report, six more have been installed and their updates will be reflected in the FY2018 report. The new equipment is a Centaur digital recorder that acquires 6-channels of data produced by a posthole-installed sensor, the Trillium Cascadia. The Trillium Cascadia combines strong-motion and broadband data. There are 3 channels of a Titan SMA and 3 channels of a TrilliumCompact BB instrument. The data quality of these new installations and benefit to our network will be discussed more in section 6.0 of this report.

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 U.S. Geological Survey (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. We currently run Earthworm Versions 7.4 through 7.6 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 on a SUN workstation (Sun Microsystems, Santa Clara, California) 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. 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 (46°-47° north latitude, 119°-120° west longitude) are reported in Table 4.1. 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 Velocity 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 "velocity model" (MOD), to solve for the most likely location for the earthquake source. AQMS divides the eastern Washington region into 4 sub-regions. The velocity 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 velocity 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. Velocity Model for Eastern Washington
(from Rohay et al. 1985)

Depth to Top of Layer (km)	Layer	Velocity (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 regional broadband stations (CCRK, DDRF, PHIN, HAWA), or approximately M2.5. 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 a **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 2017 Earthquake Catalog for Eastern Washington

Day	Time	Latitude	Longitude	Depth	Mag	Mtyp	NS/NP	Gap	Rms	Q	Mod	Etyp
October 2016												
02	00:35:55	47.6533	-120.1575	3.9	0.5	Md	004/007	177	0.07	BC	N3	eq
03	19:38:20	44.3905	-121.0820	-1.7*	2.0	Ml	006/006	291	0.15	CD	N3	px
03	22:15:04	45.4662	-117.2223	3.7*	1.7	Ml	005/008	186	0.56	DD	N3	px
04	01:31:12	47.6702	-120.2867	1.9	0.8	Ml	007/010	124	0.11	AB	N3	eq
05	23:55:37	46.6037	-119.8780	-0.4	0.6	Ml	006/008	223	0.04	AD	E3	eq
06	19:33:49	45.6135	-120.2678	-0.5*	1.7	Ml	015/016	96	0.25	CC	E3	px
06	20:49:46	47.1140	-120.7795	-0.8*	1.3	Ml	007/005	148	0.06	CD	C3	px
06	21:38:42	47.5467	-120.2707	-1.1*	1.5	Ml	009/010	102	0.31	CB	N3	px
08	00:07:18	46.7100	-120.0850	-0.2*	-5.0	Mh	004/000	0	0.00	AD	E3	px
09	01:53:50	47.7250	-120.2615	-0.7*	1.1	Ml	009/012	80	0.08	CC	N3	eq
09	04:25:08	47.2478	-121.3797	9.3*	1.2	Ml	015/019	83	0.11	CC	C3	eq
09	08:57:36	47.5290	-119.7913	0.3*	0.8	Ml	006/007	140	0.14	CC	N3	eq
09	23:22:56	47.7365	-120.2160	-0.3*	0.9	Ml	009/011	110	0.12	CC	N3	eq
10	01:53:15	46.3162	-119.6005	16.1	0.7	Ml	014/017	128	0.09	AB	E3	eq
10	06:56:27	47.5330	-120.3672	5.4	2.1	Ml	018/019	97	0.13	AB	N3	eq
10	09:15:08	46.9172	-120.4357	7.8	3.1	Ml	039/042	64	0.16	BB	E3	eq
10	18:22:00	46.9210	-120.4567	6.6	1.4	Ml	014/018	135	0.21	BB	E3	eq
10	21:11:12	47.6935	-120.1040	4.5	0.4	Md	008/010	154	0.08	AC	N3	eq
16	12:48:02	46.1262	-119.6530	16.0	2.3	Ml	041/042	45	0.14	AB	E3	eq
16	12:57:56	46.1393	-119.6737	8.0	0.8	Ml	008/011	160	0.07	AC	E3	eq
16	14:09:17	46.1392	-119.6697	8.6	0.9	Ml	011/015	152	0.06	AC	E3	eq
16	20:14:01	46.1338	-119.6515	8.0	1.1	Ml	012/015	157	0.14	AC	E3	eq
18	20:07:35	46.6505	-120.4958	-0.7*	1.7	Ml	013/013	78	0.26	CC	E3	px
19	12:10:29	47.6737	-120.3953	2.2	0.7	Ml	006/010	110	0.19	BB	N3	eq
20	00:40:15	46.4163	-119.2720	2.2	0.9	Ml	014/018	87	0.12	AA	E3	eq
23	04:23:01	46.6092	-119.8113	7.4	1.0	Ml	010/010	203	0.06	AD	E3	eq
23	13:50:56	45.8492	-120.3038	13.3	1.7	Ml	008/011	117	0.14	AB	E3	eq
24	01:43:50	46.4097	-119.2805	0.3*	0.8	Ml	011/014	164	0.11	CC	E3	eq
24	20:49:49	47.5013	-120.2973	-1.2*	1.1	Ml	007/010	120	0.13	CC	N3	px
26	21:19:16	46.1350	-119.1872	-0.4*	1.6	Ml	009/010	165	0.15	CC	E3	px
27	20:56:53	46.3333	-119.6882	4.8	0.8	Ml	016/020	125	0.15	BB	E3	eq
28	03:52:57	47.6602	-120.1780	-0.3*	0.9	Ml	010/010	125	0.07	CC	N3	eq
November 2016												
02	05:59:42	48.3493	-120.2510	1.4*	1.7	Ml	011/010	170	0.14	CC	N3	eq
07	19:25:48	46.6050	-119.8617	3.2	0.7	Ml	011/016	218	0.13	AD	E3	eq
09	11:44:05	46.5763	-119.8277	8.2	0.4	Ml	005/005	272	0.00	AD	E3	eq
09	16:42:49	47.6238	-120.4223	-0.2*	-0.4	Md	002/004	225	0.14	CD	N3	eq
10	21:26:29	44.3772	-120.9525	-1.4*	1.9	Ml	009/011	181	0.22	CD	N3	px
15	20:23:32	47.6948	-121.4907	11.4	1.5	Ml	016/014	157	0.04	AC	C3	eq
17	23:05:35	46.8533	-117.6365	-0.5*	2.2	Ml	006/007	313	0.48	DD	E3	px
19	17:37:58	47.6968	-120.0392	-0.4*	0.7	Md	005/006	158	0.05	CC	N3	eq
21	04:04:12	46.6040	-119.8440	7.3	0.3	Ml	005/006	216	0.03	AD	E3	eq
22	06:40:12	46.6052	-119.8667	6.0	0.2	Ml	005/006	306	0.04	BD	E3	eq
23	16:56:04	46.0488	-120.4958	19.5	1.9	Ml	015/020	115	0.22	BB	E3	eq
23	21:54:35	46.8360	-120.6408	8.0	1.4	Ml	010/007	197	0.11	BD	E3	eq
24	03:50:26	48.0483	-120.7178	8.5*	1.0	Ml	010/013	159	0.12	CC	C3	eq
24	05:51:26	46.0537	-120.4875	19.8	1.4	Ml	012/016	115	0.21	BB	E3	eq
24	09:02:51	48.7905	-119.6125	-0.4	2.0	Ml	008/010	156	0.25	BD	N3	eq
26	07:34:52	47.7060	-120.1945	0.1	0.8	Ml	007/008	124	0.03	CC	N3	eq

27	20:05:07	46.6102	-119.8477	6.5	0.8	Ml	010/011	204	0.06	AD	E3	eq
28	13:48:56	47.7388	-120.2005	2.5	1.1	Ml	008/009	126	0.07	BC	N3	eq
29	09:48:45	47.6075	-120.2547	5.4	1.4	Ml	011/012	78	0.14	AB	N3	eq
30	20:35:06	46.9807	-119.1095	-0.3*	1.6	Ml	007/006	155	0.25	CC	E3	px
December 2016												
01	17:38:27	47.6668	-120.2825	-0.7*	1.2	Ml	008/012	128	0.12	CB	N3	eq
06	19:08:11	47.6467	-120.2288	4.7	0.1	Md	003/006	166	0.07	AC	N3	eq
09	03:08:44	46.4285	-119.2218	10.9	0.5	Md	009/011	259	0.09	AD	E3	eq
09	22:00:32	46.2735	-119.3987	-0.4*	1.6	Ml	013/014	266	0.12	CD	E3	px
11	05:06:23	47.9607	-119.7690	13.5	0.9	Ml	008/012	100	0.29	BB	N3	eq
12	02:18:23	46.6965	-121.4675	6.2	1.3	Ml	016/019	141	0.10	AC	C3	eq
12	07:17:09	46.6095	-119.8080	7.3	0.9	Ml	014/018	201	0.07	AD	E3	eq
13	00:22:41	46.5592	-119.8473	8.4	0.6	Ml	005/006	274	0.03	AD	E3	eq
13	01:21:40	46.5555	-119.8385	7.8	0.8	Ml	010/011	117	0.06	AB	E3	eq
13	03:29:08	47.6648	-120.3058	-0.6*	0.4	Md	005/007	117	0.05	CB	N3	eq
14	05:36:46	46.6970	-121.0063	6.8	1.4	Ml	014/018	100	0.13	AC	C3	eq
14	06:44:36	47.9568	-119.7860	13.0	0.9	Ml	009/011	91	0.13	AB	N3	eq
14	16:19:51	46.7055	-121.0062	4.3	1.5	Ml	011/013	99	0.05	AC	C3	eq
16	03:34:16	46.1075	-120.7498	1.1	2.3	Ml	023/024	53	0.16	BC	C3	eq
17	04:44:13	48.0943	-120.9300	8.7	1.0	Ml	007/009	137	0.12	AC	C3	eq
17	12:37:32	47.6778	-120.2522	1.5	1.3	Ml	008/010	127	0.08	BB	N3	eq
19	06:57:31	47.7410	-120.1658	6.0	0.8	Ml	006/010	114	0.12	AB	N3	eq
24	16:38:23	46.6100	-119.7317	13.9	0.7	Ml	014/017	118	0.10	AB	E3	eq
25	11:44:52	46.6018	-119.8445	6.4	0.1	Ml	005/007	272	0.07	AD	E3	eq
29	01:55:24	46.4902	-119.6065	17.9	0.3	Md	011/016	84	0.10	AA	E3	eq
January 2017												
03	00:42:22	47.7192	-120.0372	5.8	1.0	Ml	009/011	101	0.09	AB	N3	eq
08	02:03:15	46.4563	-119.6260	15.1	0.4	Ml	005/008	250	0.10	AD	E3	eq
09	16:02:04	47.6963	-120.2363	-0.7*	1.2	Ml	008/013	125	0.07	CC	N3	eq
09	19:14:48	47.1545	-121.3675	10.2	0.9	Ml	014/019	160	0.12	CC	C3	eq
09	19:25:14	47.7105	-120.0380	4.7	0.9	Ml	007/009	141	0.05	AC	N3	eq
10	21:29:09	48.0082	-119.8813	-1.0*	1.8	Ml	010/012	124	0.19	CB	N3	px
12	12:21:15	46.7205	-121.0590	0.0	1.2	Ml	014/018	127	0.15	BC	C3	eq
12	12:30:39	46.7153	-121.0617	0.6	1.6	Ml	017/021	78	0.21	BC	C3	eq
12	12:33:34	46.6998	-121.0707	4.8	1.1	Ml	017/024	101	0.32	CC	C3	eq
14	06:53:29	47.6780	-120.2502	4.1	0.8	Ml	007/010	131	0.15	BB	N3	eq
15	20:38:16	47.5657	-120.3598	5.1	2.1	Ml	019/022	96	0.17	BB	N3	eq
20	07:49:25	48.0380	-119.6403	11.9	1.2	Ml	008/011	145	0.19	BC	N3	eq
21	21:50:50	46.6082	-119.8523	6.0	0.4	Ml	010/012	215	0.09	AD	E3	eq
23	20:29:36	48.4810	-121.2742	6.4	1.0	Ml	006/009	200	0.32	CD	C3	eq
24	06:45:22	46.4325	-119.2807	0.2*	0.4	Ml	010/011	152	0.09	CC	E3	eq
24	10:16:04	46.4188	-119.2660	2.1	1.2	Ml	017/021	126	0.08	AB	E3	eq
24	10:16:19	46.4183	-119.2663	1.2	1.5	Ml	015/018	126	0.08	AB	E3	eq
24	21:00:50	48.0070	-119.8848	-1.0*	1.2	Ml	007/010	124	0.11	CB	N3	px
25	23:43:42	47.3592	-117.9133	-0.4*	1.9	Ml	016/019	219	0.42	CD	N3	px
26	22:02:11	47.7170	-117.6192	-0.5*	2.0	Ml	007/009	276	0.37	CD	N3	px
28	05:11:44	48.0498	-119.7127	14.1	0.7	Md	007/010	142	0.19	BC	N3	eq
28	06:12:39	48.0450	-119.7072	14.3	1.0	Ml	009/011	135	0.17	BB	N3	eq
30	19:58:47	46.3658	-120.4927	7.0	0.9	Ml	008/009	135	0.11	AB	E3	eq
February 2017												
01	18:35:31	46.7677	-119.7588	-0.2*	1.0	Ml	009/009	223	0.06	CD	E3	px
04	08:11:04	46.6027	-119.8445	6.2	0.5	Ml	008/011	271	0.10	AD	E3	eq

06	16:55:31	46.0228	-118.6167	11.9	1.4	Ml	010/011	90	0.16	BC	E3	eq
08	06:25:01	48.3388	-120.9885	0.8	1.0	Md	005/009	182	0.32	CD	C3	eq
08	10:10:21	46.5978	-119.8020	4.3	0.4	Ml	008/012	277	0.10	AD	E3	eq
08	10:19:32	46.5963	-119.8062	6.0	0.9	Ml	015/020	204	0.10	AD	E3	eq
08	12:43:13	46.5963	-119.7978	6.0	0.6	Ml	011/014	201	0.13	AD	E3	eq
08	21:49:51	46.6547	-121.4880	-1.6*	0.9	Ml	006/008	161	0.16	CC	C3	px
10	20:20:27	45.9460	-119.7657	-0.4*	1.6	Ml	006/006	212	0.18	CD	E3	px
11	17:56:44	45.8715	-120.3490	4.8	1.6	Ml	013/014	69	0.23	BC	E3	eq
12	03:30:51	46.6945	-119.5698	-0.2	0.5	Ml	013/020	122	0.14	AB	E3	eq
14	10:08:59	47.6268	-120.2055	3.5	0.9	Ml	007/010	92	0.16	BB	N3	eq
15	21:56:10	45.7528	-118.5953	7.0	2.9	Ml	013/020	134	0.25	BC	E3	eq
15	22:51:47	46.1492	-119.2035	-0.2*	1.7	Ml	019/032	250	0.26	CD	E3	px
16	05:18:59	47.7393	-120.2020	1.6	1.1	Ml	010/012	111	0.05	BC	N3	eq
19	02:51:24	46.5850	-119.8393	7.2	1.0	Ml	016/020	126	0.09	AB	E3	eq
19	03:45:50	46.5838	-119.8325	7.5	0.7	Ml	009/012	123	0.06	AB	E3	eq
19	03:55:15	46.5815	-119.8372	7.2	0.7	Ml	013/016	124	0.07	AB	E3	eq
19	09:48:12	47.6402	-120.4158	6.3	1.0	Ml	009/007	82	0.04	AB	N3	eq
19	18:58:22	46.5853	-119.8375	7.4	0.6	Ml	011/013	126	0.06	AB	E3	eq
26	13:59:46	47.0757	-120.9967	4.0	3.1	Ml	040/044	47	0.17	BC	C3	eq
27	04:14:18	47.0785	-120.9982	-0.4	1.2	Ml	019/022	72	0.29	BC	C3	eq
28	19:45:36	48.9452	-119.3818	-0.1*	1.7	Ml	006/011	168	0.31	CC	N3	eq
March 2017												
01	18:39:29	46.1293	-119.2222	-0.4*	1.1	Ml	009/012	325	0.25	CD	E3	px
01	23:33:13	46.9573	-119.5882	-0.3*	1.3	Ml	010/009	132	0.25	CB	E3	px
02	02:07:39	47.1652	-121.2997	8.8*	1.3	Ml	014/018	128	0.11	CC	C3	eq
03	08:02:46	46.6068	-119.8427	4.7	1.3	Ml	014/019	115	0.16	BC	E3	eq
03	08:05:54	46.6067	-119.8440	0.2*	0.7	Ml	008/010	213	0.13	CD	E3	eq
03	08:52:36	46.6073	-119.8458	6.7	1.3	Ml	012/014	213	0.08	AD	E3	eq
04	13:38:58	46.6642	-121.4903	-1.3*	1.8	Ml	019/022	121	0.17	CB	C3	eq
04	18:33:44	46.6080	-119.8485	6.6	1.1	Ml	009/012	214	0.07	AD	E3	eq
05	05:11:01	46.6695	-121.4947	-0.0	0.8	Ml	014/015	147	0.10	BC	C3	eq
05	08:20:08	46.6702	-121.4845	0.0	1.6	Ml	019/024	121	0.19	BB	C3	eq
06	04:59:58	46.6092	-119.8470	6.8	1.1	Ml	014/016	213	0.07	AD	E3	eq
10	23:11:50	44.0088	-121.2813	-1.7*	1.7	Ml	007/007	161	0.44	CC	E3	px
13	19:34:20	46.0788	-118.7523	-0.3*	1.8	Ml	010/011	137	0.37	CC	E3	px
14	22:13:25	47.8600	-120.8047	6.0	1.2	Ml	007/010	96	0.26	BB	C3	eq
15	19:18:46	44.4057	-120.9628	3.3*	2.2	Ml	010/009	299	0.24	CD	C3	px
16	10:37:24	46.6152	-119.8398	6.6	1.0	Ml	011/014	213	0.04	AD	E3	eq
16	12:04:28	46.5933	-119.8435	4.7	0.2	Md	006/009	277	0.12	AD	E3	eq
17	15:54:06	47.1620	-118.3720	-0.4*	1.4	Ml	007/008	161	0.19	CC	N3	px
19	20:26:39	46.6112	-119.8493	6.3	0.8	Ml	008/010	219	0.06	AD	E3	eq
20	17:20:51	46.8890	-117.2715	2.6	1.6	Ml	009/011	235	0.16	BD	E3	eq
21	07:25:22	46.1248	-120.6713	16.5	1.5	Ml	012/017	79	0.22	BB	E3	eq
22	05:09:11	46.6668	-121.4900	-1.4*	0.6	Ml	009/009	257	0.15	CD	C3	px
22	21:14:38	46.2853	-118.7390	-0.4*	1.5	Ml	009/011	139	0.73	DC	E3	px
23	21:37:13	46.6532	-120.5242	-0.7*	1.7	Ml	012/013	81	0.24	CC	E3	px
24	00:19:08	46.7138	-121.0722	1.3	1.1	Ml	014/016	98	0.21	BC	C3	eq
25	16:56:05	46.5910	-119.8478	4.9	0.7	Ml	008/010	216	0.12	AD	E3	eq
26	00:08:39	46.6295	-119.8430	7.6	0.4	Md	005/007	274	0.07	AD	E3	eq
26	00:08:51	46.6157	-119.8410	7.0	0.2	Md	005/007	214	0.06	AD	E3	eq
26	08:44:20	46.6088	-119.8417	6.7	0.7	Ml	007/010	297	0.09	AD	E3	eq
30	17:27:34	46.2957	-117.9978	-0.4*	2.4	Ml	018/020	184	0.30	CD	E3	px

30	21:43:13	47.3780	-117.8715	-0.4*	2.0	Ml	010/015	164	0.45	CD	N3	px
April 2017												
06	20:35:11	45.8847	-119.1455	-0.3*	2.0	Ml	018/024	104	0.36	CC	E3	px
12	01:38:40	47.6970	-120.1262	4.9	0.8	Md	008/009	102	0.04	AC	N3	eq
12	12:38:53	46.6757	-120.8962	7.7	1.5	Ml	019/022	102	0.24	BC	C3	eq
14	22:29:05	47.6787	-120.1513	-0.2*	0.8	Md	004/006	158	0.02	CC	N3	eq
15	06:28:27	46.6095	-119.8440	6.7	1.2	Ml	018/019	92	0.08	AB	E3	eq
17	19:26:04	47.3802	-117.8642	-0.5*	1.8	Ml	010/013	201	0.63	DD	N3	px
18	05:34:56	45.6720	-118.5458	12.7*	1.6	Ml	005/008	176	0.38	CC	E3	eq
19	22:41:25	44.2128	-121.3393	-1.8*	2.0	Ml	006/006	235	0.55	DD	E3	px
20	20:13:09	46.6487	-119.6123	23.2	0.9	Ml	017/020	74	0.06	AA	E3	eq
22	04:45:02	47.7248	-120.0562	-0.5*	1.6	Md	004/007	127	0.07	CB	N3	eq
23	00:27:07	47.7278	-120.0442	3.8	1.8	Md	006/009	123	0.06	AB	N3	eq
25	19:24:53	46.1612	-119.2795	-0.4*	0.7	Md	007/007	165	0.20	CC	E3	px
May 2017												
01	03:55:11	47.5958	-120.3308	4.8	1.1	Ml	008/012	101	0.08	AB	N3	eq
01	17:57:08	47.7578	-117.5551	-0.6*	-5.0	Mh	006/000	0	0.00	AD	N3	px
01	19:29:38	44.9730	-121.2868	12.9	1.5	Ml	010/014	89	0.12	BC	N3	eq
02	19:28:38	47.0428	-120.4233	-0.5*	1.6	Ml	011/012	163	0.31	CC	N3	px
02	21:44:02	46.9658	-120.3625	-0.6*	1.3	Ml	008/009	197	0.19	CD	E3	px
03	15:09:18	47.6638	-120.1267	-0.2*	0.2	Md	004/006	174	0.09	CC	N3	eq
05	21:37:47	46.4618	-119.7415	17.3	1.9	Ml	031/039	107	0.11	AB	E3	eq
05	23:20:36	46.4623	-119.7495	17.3	1.1	Ml	012/012	176	0.11	AC	E3	eq
09	19:41:03	46.6000	-118.9118	-0.2*	1.7	Ml	014/015	175	0.29	CC	E3	px
11	16:43:23	48.1858	-120.9530	-0.1*	1.0	Md	006/009	151	0.30	CC	C3	eq
13	03:22:45	47.6968	-121.4960	11.9	1.3	Ml	012/015	98	0.10	AB	C3	eq
15	08:40:16	48.4032	-120.6667	-0.3	1.4	Ml	009/010	200	0.16	BD	C3	eq
16	17:11:02	46.3103	-119.3310	19.1	1.3	Ml	018/018	191	0.10	AD	E3	eq
20	03:06:01	46.4080	-119.2605	-0.1	1.1	Ml	018/024	91	0.15	BB	E3	eq
21	23:47:26	46.6658	-121.4910	1.4	1.2	Ml	015/017	137	0.13	AC	C3	eq
22	09:00:33	48.1378	-120.9220	-0.4	1.1	Ml	009/011	133	0.20	BC	C3	eq
23	05:33:20	46.0723	-118.7772	17.7	1.7	Ml	022/023	76	0.14	AA	E3	eq
23	16:27:43	45.0665	-117.8938	-1.1*	2.1	Ml	005/006	189	0.34	CD	E3	px
24	01:16:40	46.6875	-119.3903	18.9	0.7	Ml	011/012	130	0.08	AB	E3	eq
24	07:17:22	47.6367	-120.3505	4.8	1.5	Md	008/008	153	0.10	AC	N3	eq
25	05:20:08	48.7300	-119.5287	3.9*	1.9	Ml	008/011	279	0.14	CD	N3	eq
27	09:10:53	46.7047	-119.7347	14.8	0.6	Ml	012/014	125	0.19	BB	E3	eq
28	04:26:27	46.6058	-119.8465	6.8	1.1	Ml	017/022	133	0.08	AB	E3	eq
June 2017												
03	22:27:40	46.7848	-119.5723	13.3	0.8	Ml	014/018	98	0.09	AB	E3	eq
04	08:58:49	46.4338	-119.4425	0.3*	-0.2	Md	011/012	86	0.24	CB	E3	eq
05	07:22:23	48.8000	-121.3413	-0.1	1.3	Ml	006/008	213	0.12	BD	C3	eq
05	15:27:27	45.7503	-120.6860	8.4	1.7	Ml	008/008	112	0.16	BB	E3	eq
06	06:24:26	47.6947	-120.0807	-0.3*	0.6	Md	006/010	156	0.12	CC	N3	eq
06	12:34:00	48.2462	-121.3392	6.9	2.4	Ml	023/023	123	0.19	BC	C3	eq
11	00:19:29	47.7253	-119.9278	2.8	0.5	Md	004/006	122	0.10	BC	N3	eq
12	18:25:29	48.8495	-118.8938	-0.7*	2.2	Ml	009/010	230	0.26	CD	N3	px
12	22:26:05	46.6157	-119.8477	6.1	1.3	Ml	015/017	205	0.12	AD	E3	eq
13	12:30:13	46.6102	-119.8465	3.8	1.0	Ml	012/014	134	0.14	AB	E3	eq
13	16:26:11	47.7975	-120.8218	5.5	0.9	Ml	007/009	117	0.30	CB	C3	eq
13	21:25:00	47.3683	-117.8447	-0.5*	2.1	Ml	014/015	205	0.45	CD	N3	px
14	18:56:57	46.6105	-119.8508	5.6	1.4	Ml	016/016	101	0.08	AB	E3	eq

15	05:08:18	48.6845	-120.3660	9.3*	1.4	Ml	010/015	193	0.53	DD	C3	eq
16	09:10:23	46.7277	-119.4358	13.9	0.8	Ml	011/016	106	0.14	AB	E3	eq
16	09:10:28	46.7347	-119.4292	15.3	0.6	Md	010/012	134	0.20	BB	E3	eq
16	22:12:17	48.6643	-120.3765	9.3*	1.7	Ml	011/013	190	0.45	CD	C3	eq
19	22:55:20	47.6677	-120.3548	0.1	0.6	Ml	007/011	132	0.08	CB	N3	eq
20	07:04:43	46.8342	-119.7603	0.2*	0.7	Ml	009/011	106	0.22	CB	E3	eq
20	16:55:41	46.0615	-119.3485	-0.3*	1.5	Ml	017/019	154	0.20	CC	E3	px
21	02:08:20	46.8090	-119.3668	-0.2	0.7	Ml	006/009	178	0.46	CC	E3	eq
21	21:32:54	47.6672	-120.2768	-0.3*	1.1	Ml	005/006	141	0.04	CC	N3	eq
22	20:54:02	46.7980	-120.8713	-1.0*	1.4	Ml	011/013	103	0.30	CC	C3	px
22	21:02:04	47.2777	-121.1717	-1.0*	1.0	Md	006/006	130	0.09	CC	C3	px
25	19:31:49	47.6273	-120.3495	-1.2	0.9	Ml	008/010	92	0.07	AB	N3	eq
25	23:00:51	46.9313	-119.0188	-0.3*	1.0	Ml	008/010	145	0.65	DC	E3	px
28	16:37:57	47.6628	-120.2305	3.3	1.2	Ml	012/014	73	0.09	AB	N3	eq
28	19:23:36	47.4712	-120.6693	-1.0*	1.3	Ml	008/010	116	0.13	CC	C3	px
29	00:13:07	47.6052	-117.4827	-0.6*	2.1	Ml	010/011	183	0.60	DD	N3	px
30	20:21:00	47.8402	-120.8575	-1.6*	1.4	Ml	011/010	90	0.13	CA	C3	px
July 2017												
01	16:01:12	44.9373	-117.5765	7.2*	1.7	Ml	004/007	182	0.24	CD	C3	eq
01	20:35:57	46.8363	-119.7535	4.3	0.6	Ml	010/013	108	0.16	BB	E3	eq
02	12:44:40	47.6750	-120.1480	3.9	0.2	Md	004/008	162	0.08	BC	N3	eq
02	15:29:17	46.6788	-121.4978	5.5	1.5	Ml	019/022	138	0.16	BC	C3	eq
03	14:12:25	48.6013	-121.3848	3.0	2.1	Ml	008/010	192	0.11	AD	C3	eq
03	16:36:22	48.5967	-121.3695	-1.1	3.1	Ml	017/018	165	0.13	AC	C3	eq
05	05:11:40	46.5833	-119.8845	0.3*	0.4	Ml	007/009	232	0.20	CD	E3	eq
06	16:56:10	46.0130	-120.5417	16.5	1.0	Md	007/010	117	0.19	BB	E3	eq
07	02:35:36	47.4695	-120.6590	-1.2*	1.3	Ml	011/011	113	0.22	CC	C3	px
07	13:16:56	47.6705	-120.3128	-0.0*	0.6	Ml	006/008	110	0.04	CB	N3	eq
07	16:15:34	46.6750	-121.4967	4.2	2.1	Ml	027/035	119	0.18	BC	C3	eq
07	17:17:36	48.6050	-119.5887	3.8	1.9	Ml	013/019	113	0.63	DD	N3	eq
08	03:44:10	47.6590	-120.1795	2.1	1.8	Ml	013/014	66	0.08	BC	N3	eq
08	17:25:29	46.6133	-119.8565	6.2	1.2	Ml	018/022	128	0.10	AB	E3	eq
09	04:25:16	47.0543	-117.0408	-0.3*	2.1	Ml	011/012	297	1.14	DD	N3	px
09	16:04:10	48.5808	-119.5625	3.8	2.9	Ml	023/025	103	0.24	BD	N3	eq
09	16:08:38	48.6015	-119.5598	-0.9	2.2	Ml	015/017	111	0.26	BD	N3	eq
09	16:20:02	48.5857	-119.6412	-0.6	1.6	Ml	009/010	137	0.30	CD	N3	eq
10	03:11:01	48.6122	-119.6888	-1.0	1.3	Ml	007/011	183	0.24	BD	N3	eq
10	05:32:28	46.1242	-119.6580	0.4*	0.9	Md	005/008	318	0.25	CD	E3	eq
10	05:51:13	46.1670	-119.7823	0.2*	0.7	Ml	005/006	312	0.15	CD	E3	eq
10	06:58:33	46.1835	-119.7008	5.9	1.0	Ml	010/013	149	0.10	AC	E3	eq
11	03:37:10	48.5717	-119.6238	0.1	2.0	Ml	013/016	130	0.48	CD	N3	eq
11	13:10:05	48.5905	-119.6193	-1.0	1.6	Ml	010/011	130	0.18	BD	N3	eq
13	09:15:25	47.6592	-120.3765	-0.5*	1.2	Ml	011/011	73	0.11	CB	N3	eq
13	15:56:30	47.6615	-120.3705	1.9	1.2	Ml	008/011	141	0.08	BC	N3	eq
13	19:33:36	46.6083	-119.8638	6.3	0.8	Ml	010/013	92	0.11	AB	E3	eq
14	01:51:04	46.2217	-119.5272	-0.5*	0.7	Ml	013/014	217	0.39	CD	E3	px
14	12:13:03	48.6000	-119.6128	-1.0	1.4	Ml	010/012	170	0.44	CD	N3	eq
15	08:59:50	48.5968	-119.5962	0.6	1.6	Ml	012/014	132	0.31	CD	N3	eq
15	09:35:45	48.6030	-119.6200	-0.3	2.2	Ml	016/019	131	0.18	BD	N3	eq
15	18:04:02	46.5663	-119.6553	-0.5*	0.5	Ml	009/008	133	0.06	CB	E3	px
16	17:36:05	48.5997	-119.5513	0.5	2.2	Ml	016/023	114	0.45	CD	N3	eq
18	07:49:00	47.8857	-119.3590	-0.9*	1.3	Ml	011/009	166	0.09	CC	N3	px

18	15:01:28	46.6117	-119.8540	6.2	1.8	Ml	024/025	64	0.15	BC	E3	eq
18	16:06:28	46.0690	-119.3580	-0.3*	1.4	Md	008/008	238	0.24	CD	E3	px
18	19:39:54	46.6758	-119.6813	1.9	0.5	Ml	006/009	289	0.08	BD	E3	eq
18	22:23:01	46.6088	-119.8092	7.2	1.2	Ml	016/021	120	0.09	AB	E3	eq
19	22:51:36	44.3488	-121.0258	-1.6*	2.0	Ml	009/015	145	0.44	CC	E3	px
20	03:21:34	48.5897	-119.5262	-0.5	2.5	Ml	017/019	105	0.31	CD	N3	eq
20	03:30:15	48.6017	-119.5917	0.8	1.6	Ml	011/012	164	0.30	CD	N3	eq
20	21:54:55	46.6073	-119.8048	7.7	1.2	Ml	014/016	200	0.08	AD	E3	eq
20	22:12:09	46.6068	-119.8183	4.7	0.9	Ml	008/011	206	0.19	BD	E3	eq
21	00:48:00	46.6042	-119.8130	7.3	1.2	Ml	013/014	204	0.09	AD	E3	eq
21	00:59:55	46.6035	-119.8160	7.2	1.0	Ml	010/012	205	0.07	AD	E3	eq
21	01:09:20	46.5615	-119.7442	5.8	0.4	Ml	007/008	257	0.07	BD	E3	eq
21	21:35:02	46.6035	-119.8138	7.5	1.6	Ml	026/026	84	0.09	AA	E3	eq
21	21:35:39	46.6062	-119.8097	7.6	1.5	Ml	018/027	83	0.10	AA	E3	eq
21	21:44:26	46.5995	-119.8028	8.5	1.1	Ml	013/021	117	0.19	BB	E3	eq
21	22:42:16	46.5983	-119.8332	7.7	0.7	Ml	009/012	211	0.09	AD	E3	eq
22	02:41:59	46.6045	-119.8107	7.3	1.2	Ml	018/017	83	0.07	AB	E3	eq
22	17:35:22	46.5785	-119.7887	0.1*	0.5	Md	008/009	202	0.09	CD	E3	eq
24	13:04:19	46.5425	-120.2202	5.9	1.0	Ml	013/019	114	0.27	BB	E3	eq
24	19:53:43	47.7025	-120.0192	2.1	3.3	Ml	028/018	59	0.08	AA	N3	eq
24	21:38:06	47.7043	-120.0230	-0.1*	1.7	Md	005/008	128	0.08	CB	N3	eq
25	00:19:39	47.6972	-120.0225	-1.0	1.1	Ml	007/009	86	0.05	AA	N3	eq
25	06:54:31	47.7015	-120.0183	2.2	1.9	Ml	018/013	59	0.07	AA	N3	eq
25	11:57:26	47.6967	-120.0157	2.9	1.0	Ml	010/016	87	0.08	AA	N3	eq
25	13:08:35	46.6888	-121.4995	3.8	1.3	Ml	021/025	118	0.13	AC	C3	eq
25	17:51:29	46.6335	-119.8440	7.0	0.5	Md	005/007	209	0.18	BD	E3	eq
25	19:21:01	47.6943	-120.0058	2.8	0.9	Ml	008/010	138	0.12	AC	N3	eq
26	02:31:13	47.6917	-120.0593	6.7	0.4	Md	004/007	161	0.13	AC	N3	eq
26	02:32:50	47.6973	-120.0688	4.0	0.7	Md	004/006	154	0.07	BC	N3	eq
27	05:52:40	47.6718	-120.1322	-0.5*	1.4	Ml	010/011	92	0.07	CC	N3	eq
27	07:52:22	46.4367	-119.2617	0.1*	0.6	Ml	009/012	245	0.18	CD	E3	eq
28	00:37:27	48.6142	-119.6775	0.6	1.6	Ml	010/014	166	0.44	CD	N3	eq
29	14:45:42	46.1358	-119.5178	13.4	0.9	Ml	009/011	202	0.10	AD	E3	eq
29	15:13:27	46.1157	-119.4877	10.4	1.2	Ml	011/012	151	0.10	AC	E3	eq
29	15:17:14	46.1228	-119.4900	11.2	1.2	Ml	011/014	149	0.14	AC	E3	eq
30	07:21:42	46.1268	-119.5118	11.3	2.0	Ml	022/024	94	0.13	AB	E3	eq
30	07:39:15	47.3053	-121.4782	12.5	1.8	Ml	020/032	106	0.15	BC	C3	eq
30	08:07:40	46.1270	-119.5063	14.2	1.3	Ml	010/012	90	0.16	BB	E3	eq
August 2017												
01	03:05:58	47.5125	-120.2990	-1.2*	1.5	Ml	014/015	87	0.11	CC	N3	px
01	08:08:55	47.6698	-120.2873	-0.4*	0.9	Ml	006/008	143	0.12	CC	N3	eq
02	11:48:23	46.4215	-119.2867	-0.1	0.2	Md	003/004	265	0.24	CD	E3	eq
02	16:34:48	46.1307	-119.1952	-0.4*	1.3	Ml	008/008	168	0.35	CC	E3	px
03	03:36:31	47.6773	-120.3242	3.1	1.4	Ml	012/013	94	0.06	AB	N3	eq
03	04:11:14	47.7290	-120.0937	-0.7*	1.3	Ml	016/017	112	0.51	DB	N3	eq
03	20:40:20	47.3688	-117.9023	-0.5*	2.3	Ml	012/011	202	0.24	CD	N3	px
05	16:19:04	48.1783	-121.2023	9.0	0.9	Ml	007/009	128	0.12	AB	C3	eq
07	11:26:38	47.7025	-120.0268	4.3	0.7	Ml	007/010	108	0.06	AC	N3	eq
08	08:40:01	47.6980	-120.0182	-0.2*	1.9	Ml	020/018	60	0.08	CA	N3	eq
09	05:37:22	46.3157	-119.6112	15.5	0.7	Ml	012/015	133	0.08	AB	E3	eq
09	15:50:40	47.6643	-120.3423	0.7	1.1	Ml	008/009	92	0.10	CB	N3	eq
10	15:21:07	47.6690	-120.1225	2.5	0.1	Md	004/006	171	0.04	BC	N3	eq

11	10:12:26	47.7622	-120.6508	7.0	0.9	Ml	007/009	75	0.11	AB	C3	eq
11	21:03:38	46.6317	-118.8808	-0.2*	1.2	Ml	014/014	238	0.09	CD	E3	px
11	23:32:50	46.5332	-119.6292	22.5	0.9	Ml	024/029	59	0.12	AA	E3	eq
14	07:21:27	45.0448	-117.2135	8.4	3.1	Ml	009/011	199	0.23	BD	E3	eq
15	02:09:29	45.0602	-117.2007	2.2	2.6	Ml	005/008	224	0.63	DD	E3	eq
15	05:09:26	45.0263	-117.1933	14.5	2.4	Ml	010/011	228	0.28	BD	E3	eq
15	11:46:06	47.6748	-120.1365	-0.6*	0.8	Ml	007/012	143	0.08	CC	N3	eq
17	08:06:34	47.5748	-120.3222	5.5	1.8	Ml	014/016	90	0.09	AA	N3	eq
17	14:09:41	46.9085	-121.4837	-1.8*	1.0	Ml	004/004	310	0.02	CD	C3	px
18	18:22:31	48.0170	-120.4650	2.0	1.2	Ml	007/008	134	0.04	BC	C3	eq
18	22:59:29	46.6073	-119.8647	-0.5	0.8	Ml	011/013	141	0.14	AC	E3	eq
19	00:31:17	47.6292	-120.3228	5.1	1.7	Ml	012/014	57	0.09	AA	N3	eq
19	04:50:58	47.7262	-120.2877	7.0	1.0	Ml	009/011	99	0.10	AB	N3	eq
20	16:08:24	45.0738	-117.1307	1.3	2.5	Ml	007/012	214	0.69	DD	N3	eq
20	16:29:53	45.0762	-117.1043	3.8*	1.6	Ml	004/006	218	0.31	DD	N3	eq
20	18:01:49	45.0823	-117.1327	2.0	3.0	Ml	010/015	213	0.77	DD	N3	eq
20	23:18:38	47.6903	-120.3068	4.3	0.8	Ml	005/007	135	0.09	AB	N3	eq
21	18:33:29	45.0680	-117.1320	4.5*	2.2	Ml	004/007	214	0.46	DD	N3	eq
22	00:16:00	46.5440	-119.0730	12.6	0.9	Ml	012/014	112	0.09	AB	E3	eq
22	09:56:57	47.6825	-121.4387	5.3	2.6	Ml	037/050	40	0.39	CC	C3	eq
24	19:00:51	47.7010	-120.3200	-0.4*	0.8	Md	004/007	212	0.06	CD	N3	eq
25	19:55:45	46.6522	-120.5047	-0.8*	1.1	Ml	009/010	140	0.46	CC	E3	px
28	18:32:43	47.7388	-120.1992	-0.6*	0.9	Ml	006/008	132	0.03	CC	N3	eq
29	18:37:43	46.9258	-121.4682	-1.6*	1.1	Ml	008/009	219	0.08	CD	C3	px
31	11:19:43	48.2973	-121.1358	3.0	1.1	Ml	007/009	227	0.10	BD	C3	eq
31	16:11:21	47.6918	-121.4970	11.4	1.4	Ml	011/012	98	0.06	AB	C3	eq
September 2017												
01	03:06:31	47.6707	-120.1393	1.7	1.4	Ml	010/014	73	0.09	BC	N3	eq
04	09:21:35	47.6720	-120.1338	-0.7*	1.3	Ml	009/007	117	0.05	CC	N3	eq
05	21:15:04	46.6373	-120.5262	-0.8*	1.7	Ml	014/015	110	0.35	CC	E3	ex
06	23:25:40	47.3782	-117.9525	-0.5*	2.2	Ml	012/014	200	0.31	CD	N3	px
08	21:03:45	44.4428	-121.0652	-1.6*	1.9	Ml	009/010	92	0.64	DB	N3	px
13	14:44:57	47.6693	-120.3283	4.4	0.8	Ml	007/011	101	0.08	AB	N3	eq
13	22:51:32	44.0908	-121.3478	-1.6*	1.6	Ml	008/008	191	0.44	CD	N3	px
14	17:11:28	47.6328	-120.3548	6.0	0.5	Md	005/008	194	0.05	BD	N3	eq
14	18:14:47	45.6298	-121.3855	-1.6*	1.1	Ml	005/006	314	0.08	CD	C3	px
15	01:17:00	45.9508	-119.2608	-0.3*	1.4	Ml	008/007	164	0.09	CC	E3	px
15	08:57:08	46.6110	-119.8442	6.6	0.8	Ml	009/011	212	0.17	BD	E3	eq
15	09:01:53	46.6097	-119.8455	7.1	0.9	Ml	010/013	213	0.15	BD	E3	eq
15	09:06:37	46.6012	-119.8525	6.7	0.9	Ml	010/012	217	0.11	AD	E3	eq
15	09:30:53	46.6128	-119.8418	7.1	0.7	Ml	009/011	211	0.17	BD	E3	eq
15	10:08:03	46.6078	-119.8425	7.4	0.6	Ml	008/009	213	0.07	AD	E3	eq
15	10:14:50	46.6003	-119.8495	6.6	0.7	Ml	007/008	215	0.07	AD	E3	eq
15	10:20:21	46.6110	-119.8325	11.8	0.6	Ml	006/007	209	0.19	BD	E3	eq
17	00:30:27	47.6715	-120.3073	-0.6*	0.7	Ml	005/009	112	0.06	CB	N3	eq
18	20:03:18	46.3245	-119.5400	-0.5*	1.5	Ml	012/012	142	0.06	CC	E3	px
19	23:26:26	46.6523	-120.7723	-0.8*	1.9	Ml	014/014	153	0.23	CC	C3	px
20	20:40:27	47.3760	-117.9200	-0.5*	2.3	Ml	012/015	201	0.36	CD	N3	px
22	14:04:50	45.8418	-118.3753	-0.7*	2.0	Ml	010/013	92	0.45	CB	E3	px
22	21:00:56	45.5895	-121.3432	1.9*	0.9	Ml	004/006	291	0.77	DD	C3	eq
23	01:25:57	46.3472	-119.3223	8.9	0.4	Ml	010/016	234	0.12	AD	E3	eq
23	11:29:44	47.6747	-120.1350	3.4	0.4	Ml	006/008	165	0.05	BC	N3	eq

24	09:35:47	46.4550	-119.3825	17.1	1.3	Ml	027/035	50	0.09	AA	E3	eq
25	03:53:01	48.5893	-119.9438	4.0*	1.4	Ml	009/011	142	0.26	CD	N3	eq
25	21:24:08	46.9087	-121.4272	-2.1*	0.8	Ml	009/009	318	0.08	CD	C3	px
28	08:55:04	47.6718	-120.1590	2.5	0.5	Ml	006/009	134	0.09	BC	N3	eq
28	22:34:45	45.6243	-121.4178	-1.3*	1.8	Ml	011/014	232	0.45	CD	C3	px
30	22:50:11	46.9225	-120.8868	17.8	0.8	Ml	009/010	111	0.11	AB	C3	eq

5.0 Discussion of Seismic Activity – FY 2017

5.1 Summary

During FY2017, seismic activity was relatively quiet throughout eastern Washington. 280 earthquakes were cataloged in the region, of which about 39% (108) 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 Wye and Horse Heaven Hills 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 2017

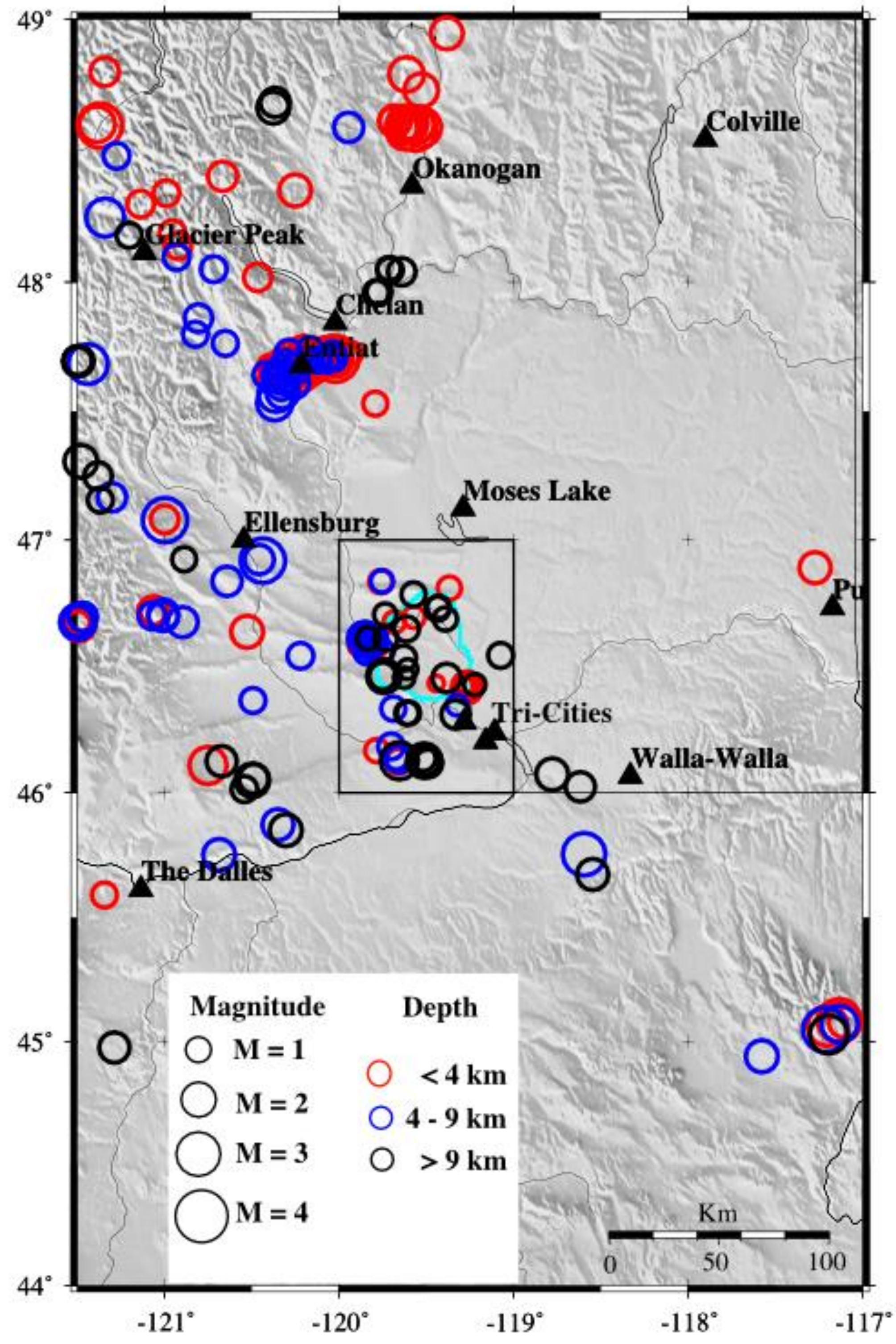
Category	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	FY 2017
Shallow (0-4 km deep)	21	18	21	59	119
Intermediate (4-9 km deep)	26	33	11	42	112
Deep (greater than 9 km deep)	12	7	15	15	49
Total	**59**	**58**	**47**	**116**	**280**
Felt	1	1	0	1	0
Probable Blast	13	19	18	26	76

Table 5.2. Earthquake Counts for FY 2017 for Earthquakes near the Hanford Site

Seismic Sources	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	FY 2017
Frenchman Hills	0	0	0	0	0
Saddle Mountains	0	0	0	0	0
Wahluke Slope	0	0	1	0	1
Coyote Rapids	0	1	1	0	2
Wye	2	3	1	2	8
Cold Creek	2	1	0	0	3
Rattlesnake Mountain	1	0	0	0	1
Horse Heaven Hills	4	0	0	3	7
Total for swarm areas	9	5	3	5	22
Random Events	13	21	15	37	86
Total For All Earthquakes	**22**	**26**	**18**	**42**	**108**

Figure 5.1. Hanford and Regional Epicenters of Earthquakes Recorded during FY 2017

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



6.0 Status of Monitoring

The seismic monitoring network underwent significant enhancements during FY2017; an effort that continues into FY2018. Station improvements and upgrades accomplished through the end of FY2017 will be reported herein, while those currently in progress will be described in a subsequent annual report.

In the annual report for FY2016, an effort to upgrade as many network stations as possible with the aim of fire protection as well as enhanced seismic performance was described. That effort is now mostly complete. The upgrades completed in FY2017 include the replacement of CCRK (destroyed by fire in 2015) and the conversion of previously single-channel short period analog stations WA2, EPH2, LNO, OT3, and YPT to 6-channel posthole BB/SMA hardware and full bi-directional digital telemetry. The conversion of a further 7 analog stations and the upgrade of 5 on-site SMA sites will complete the project.

While the new stations illustrated in Figures 3.1 and 3.2 and discussed in Section 3.0 have not been operating long enough to assess their performance, we anticipate that by the time the next annual report will be prepared, such an analysis will be possible. Perhaps unfortunately, no local earthquake large enough has occurred at the time of this report to illustrate the capabilities of the new stations. However, Figure 6.1 illustrates the wide bandwidth of information recoverable from the newly upgraded stations, showing vertical trace data from a moderate earthquake a quarter of the globe away from Hanford.

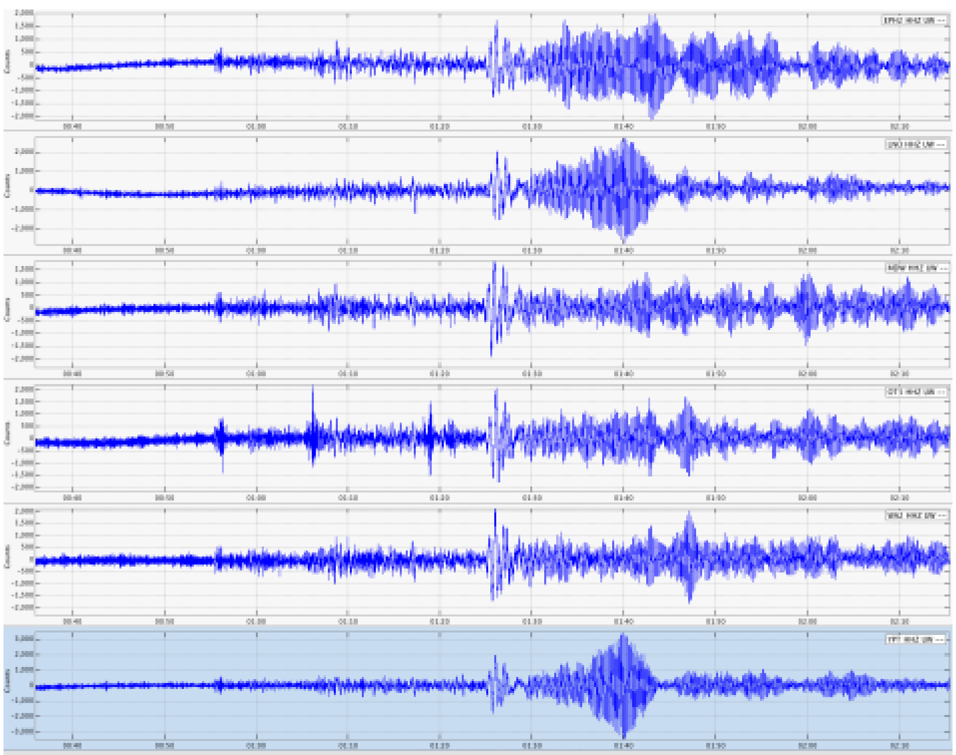


Figure 6.1. Illustration of upgraded station capabilities. Vertical broad band seismograms at (from top) stations EPH2, LNO, MDW, OT3, HHZ, WA2, and YPT, from a magnitude 6.8 shallow earthquake about 93 degrees distant near New Caledonia. The time span shown here is about 100 minutes.

The impact on the data quality (and quantity) and usefulness, and on the robustness and operability of the network is profound. The technology and design employed in the upgraded stations will extend the life of the network, improve the quality of network products (such as ShakeMap, ShakeCast, and ShakeAlert) and reduce the threat from environmental concerns such as range fire.

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