Second Quarter Hanford Seismic Report for Fiscal Year 2013 (January 2013–March 2013)

Prepared for the Mission Support Alliance, LLC under award 44955 by the

Pacific Northwest Seismic Network,

University of Washington

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April 2013

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Summary

The Pacific Northwest Seismic Network/Mission Support Alliance (PNSN/MSA) team continues to provide uninterrupted collection of high-quality raw and processed seismic data from the combined Hanford Seismic Network (HSN) and Eastern Washington Regional Sub-Network (EWRSN) 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 49 individual sensor sites and 15 radio relay sites maintained by the PNSN.

Overall, the seismicity throughout the 2nd quarter of FY2013 was very similar to the 1st quarter of FY2013, both in the vicinity of the Hanford site as well as the regional area. While there was not a significant increase or decrease in seismicity in the vicinity of the Hanford site, there were fewer earthquakes within the Wye swarm area.

The networks detected five (5) events within the Hanford vicinity that have been categorized as probable surface explosions.

The largest event (M_L = 2.9) took place on 8 January 2013 at a depth of 1 km with epicenter located 30 km northwest of Okanogan, WA.

Abbreviations and Acronyms

ANSS - Advanced National Seismic System
AQMS - ANSS Quake Monitoring System
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).
HLSMP - Hanford Lifecycle Seismic Monitoring Program
HSN - Hanford Site Network
Lat - Latitude
Lon - Longitude
km - kilometer
M_d - coda-duration magnitude
M_L - local magnitude
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)
SMA - strong motion accelerometer
UTC - Coordinated Universal Time

1.0 Introduction

This quarterly report documents the locations, magnitudes, and seismic interpretations of earthquakes recorded for the Hanford monitoring region of south-central Washington during the second quarter of fiscal year (FY) 2013 (January 2013 through March 2013). Since April 1st, 2011, seismic monitoring for Public Safety and Resource Protection (PSRP) at the Hanford site has been carried out by the Hanford Lifecycle Seismic Monitoring Program (HLSMP). HLSMP is managed by Mission Support Alliance (MSA) with the monitoring work being performed under a sub-contract to the Pacific Northwest Seismic Network (PNSN).

1.1 Mission

The mission of the HLSMP is to maintain seismic stations, report data from measured events, and 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 420.1B, Chapter IV, Section 3.d "Seismic Detection" and DOE Order G 420.1-1, Section 4.7, "Emergency Preparedness and Emergency Communications." DOE Order 420.1B 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 Hanford Site Network (HSN) and the Eastern Washington Regional Sub-Network (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 and between 119-120° west longitudes. 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.

2.0 Network Operations During the Second Quarter of FY2013

2.1 Description of Seismic Stations

HLSMP seismic stations supported by MSA are divided into two geographic sub-networks, the Hanford Site Network (HSN), comprised by stations located on the Hanford site itself, and the Eastern Washington Regional Sub-Network (EWRSN), which includes stations that surround the Hanford site.

The HSN and EWRSN networks provide a total of 69 combined data channels because the 5 three-component seismometer sites (GBB, FHE, CCRK, DDRF, and PHIN), and the 5 Strong Motion Accelerometer SMA sites in the HSN (H1K, H2E, H2W, H3A, and H4A) require two additional data channels per station. The tri-axial stations record motion in the vertical, north-south horizontal, and east-west horizontal directions. Stations CCRK, DDRF, and PHIN are broad-band seismometers with digital telemetry via cellular telephone. GBB and FHE are tri-axial sites with 1-Hz seismometers and analog

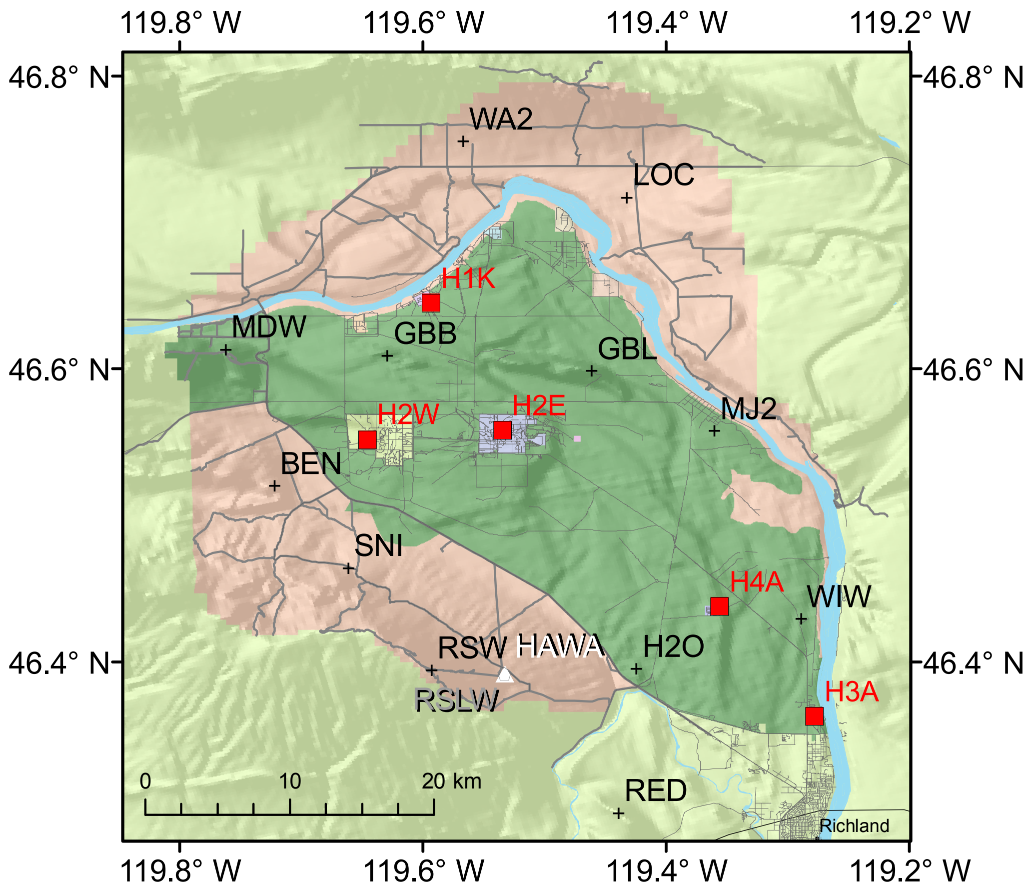

Figure 2.1 Seismic monitoring stations of the Hanford Seismic Network, on the Hanford site. Station RED is off-site, but shown on this figure for convenience. Red squares and text are strong motion accelerographs (SMA) stations. Black text and plusses are short period stations. HAWA is a broadband and SMA US National Seismic Network Station operated by the US Geological Survey (USGS). RSLW

radio telemetry. The other 39 stations are single vertical component seismometers. Fifteen radio telemetry relay sites are used by both networks to continuously transmit seismogram data to the PNSN in Seattle, Washington, for processing and archiving.

*Table 1. Hanford Site Network (HSN) Stations. Italic font indicates a 3-channel station, **bold font** indicates a Strong Motion Accelerometer.*

	Latitude	Longitude	Elevation (m)	Station Name
BEN	46.5186	-119.7185	335	Benson Ranch
GBB	*46.6087*	*-119.6290*	*185*	*Gable Butte*
GBL	46.5982	-119.4610	330	Gable Mountain
H1K	***46.6447***	***-119.5929***	***152***	***100 K Area (SMA)***
H2E	***46.5578***	***-119.5345***	***210***	***200 East Area (SMA)***
H2O	46.3956	-119.4241	175	Water Station
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)***
LOC	46.7169	-119.4320	210	Locke Island
MDW	46.6130	-119.7622	330	Midway
MJ2	46.5574	-119.3601	146	May Junction Two
RSW	46.3944	-119.5925	1045	Rattlesnake Mountain
SNI	46.4639	-119.6609	323	Snively Ranch
WA2	46.7552	-119.5668	244	Wahluke Slope
WIW	46.4292	-119.2888	128	Wooded Island

Table 2. Eastern Washington Regional Sub-Network (EWRSN) Stations. Italic font indicates a 3-channel station.

	Latitude	Longitude	Elevation (m)	Station Name
BLT	45.9150	-120.1770	659	Bickleton
BRV	46.4852	-119.9923	920	Black Rock Valley
BVW	46.8108	-119.8835	670	Beverly
CBS	47.8047	-120.0429	1067	Chelan Butte South
CCRK	*46.5585*	*-119.8548*	*561*	*Cold Creek*
CRF	46.8249	-119.3881	189	Corfu
DDRF	*46.4911*	*-119.0595*	*233*	*Didier Farms*
DPW	47.8705	-118.2039	892	Davenport
DY2	47.9850	-119.7725	890	Dyer Hill Two
ELL	46.9095	-120.5675	789	Ellensburg
EPH	47.3562	-119.5972	661	Ephrata
ET4	46.5634	-118.9451	236	Eltopia Four
ETW	47.6042	-120.3335	1477	Entiat
FHE	*46.9518*	*-119.4981*	*455*	*Frenchman Hills East*
LNO	45.8717	-118.2862	771	Lincton Mountain Oregon
MOX	46.5772	-120.2993	501	Moxee City
NAC	46.7330	-120.8249	728	Naches
NEL	48.0700	-120.3414	1500	Nelson Butte
OD2	47.3875	-118.7108	553	Odessa Two
OT3	46.6689	-119.2341	322	Othello Three

PAT2	45.8836	-119.7578	259	Paterson Two
PHIN	*45.895*	*-119.928*	*227*	*Phinney Hill*
PRO	46.2125	-119.6868	553	Prosser
RED	46.2974	-119.4388	330	Red Mountain
SAW	47.7015	-119.4017	701	St. Andrews
TBM	47.1699	-120.5992	1006	Table Mountain
TRW	46.2921	-120.5431	723	Toppenish Ridge
TWW	47.1380	-120.8695	1027	Teanaway
VT2	46.9672	-120.0003	385	Vantage Two
WAT	47.6985	-119.9552	821	Waterville
WRD	46.9699	-119.1460	375	Warden
YA2	46.5265	-120.5312	652	Yakima Two
YPT	46.0487	-118.9634	325	Yellepit

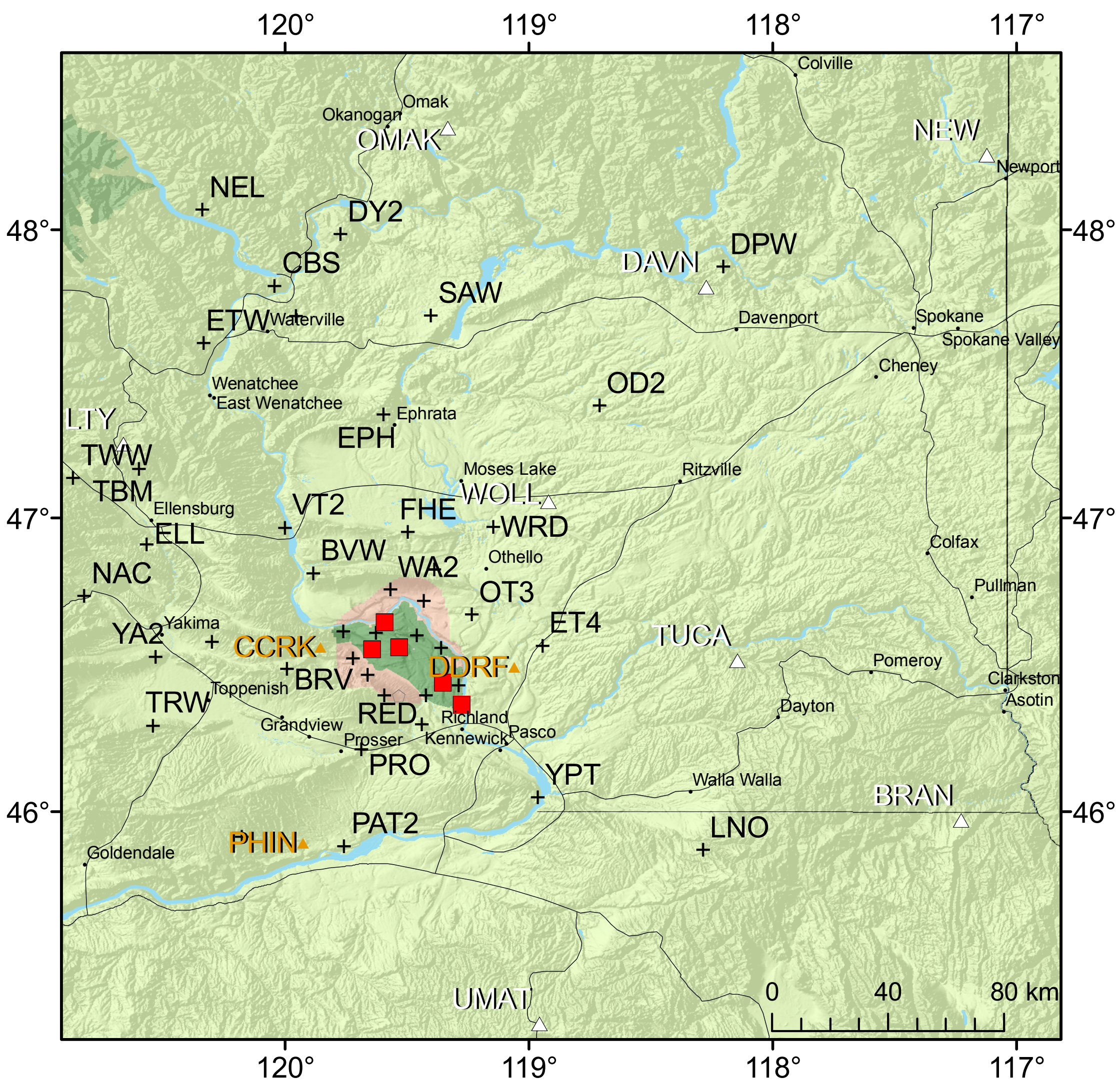

Figure 2.2 Seismic stations of the Eastern Washington Region Sub-Network. Black font and pluses are short-period EWRSN stations. Gold font and triangles are EWRSN broadband stations. White font and triangles are broadband stations contributed by other agencies to the PNSN data collection in eastern Washington.

2.2 Station Maintenance During the Second Quarter of FY2013

Seismic station maintenance taking place during the 2nd quarter of 2013 include:

- Batteries were replaced at stations YA2, GBL, TRW, BLT, LNO, H4A, PAT2, ET4, WRD, SAW, BEN, WIW, and LOC.
- Antenna repairs took place at stations GBB, TRW, BLT, and YA2.
- Stations H2O and WIW were upgraded with new antenna mounts.
- Station RED's receiver antenna was switched from antenna system2 to antenna system1 at repeater station RSLR.
- A solar panel was repaired at station LNO.
- Station BEN received new anchors, guy wires, and most importantly a new telemetry path through station GBB.
- A solar controller that suffered fire damage was repaired at LOC.
- Overall diagnosis was made at RSLR before and after telemetry changes were implemented.
- RSWR work was assessed and equipment assigned for future electronics package replacement.

2.3 Other Network Activities during the Second Quarter of FY2013

In the previous quarterly report, we noted the potential threat posed by Puget Sound Energy's acquisition of FM radio bandwidth for use in for mobile emergency communication that might unpredictably interfere with seismic network data transmissions (and vice versa). During the 2nd quarter of FY2013, we entered a period of "watchful waiting" to determine the impact, if any, on our monitoring activities. To date, we have not seen any systematic degradation in system performance due to increased radio frequency interference. Nor have we been contacted by PSE that they have seen problems. For the moment we seem to be coexisting peacefully.

In the 2nd quarter of FY2013, we began a systematic accounting of seismic monitoring field sites with an eye to assessing the overall physical and functional condition of the hardware at each site. At the same time, the site visits present an opportunity to collect information needed for considering the role of each site in the overall seismic monitoring effort, as well as evaluating the need and potential to upgrade hardware, or even eliminate stations at which conditions have changed such that their role is no longer needed. Several of the on-site visits included an observer from the DOE Office of River Protection.

We have been contacted by, and have been coordinating with, a Hanford Probabilistic Seismic Hazard Assessment study sponsored by the DOE. The overall Hanford hazard study encompasses many different smaller sub-elements, several of which will use seismic data from the EWRSN and the HSN and others that will entail activities that might potentially impact our monitoring. In the 2nd quarter of FY2013, we had several teleconferences with study participants to safeguard our monitoring and to explore how we can best support the studies.

3.0 Earthquake Catalog Description

Within the Advanced National Seismic System (ANSS) Quake Monitoring 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) and the surrounding region are reported in Table 4.1. Additional seismic events located outside the region are not reported in this document, but are evaluated 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.

3.1 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") 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.

3.2 Earthquake Magnitudes

AQMS computes several different magnitude estimates for earthquakes. Table 4.1 shows the analyst-preferred value of either: 1) the coda-duration magnitude (Md), 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 Md is:

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

where *D* is the duration of the observed event, starting from the P-wave arrival. Many earthquakes yield magnitude determinations that are very small (Md < 0) and highly uncertain. We define earthquakes with magnitudes (Md) smaller than 3.0 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 Md 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. Md, 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.

3.3 Quality Factors (Q)

Table 4.1 tabulates a two-letter **Quality factor** 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. Generally speaking, if the number of phases exceeds 10 measurements, the depth estimate is considered to be 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 (Columbia River Basalt Group) CRBG or pre-basalt layers.

4.0 Seismic Activity – Second Quarter FY 2013

4.1 Catalog of Seismic Events

Table 4.1. *Regional Seismic Data, January 1 – March 31, 2013*

Day	Time	Lat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Etyp
January 2013												
04	20:52:24	47.8810	-118.9240	0.0*	1.0	Md	012/016	100	0.29	CC	N3	px
06	14:16:43	47.6418	-120.3765	5.2	1.0	Md	007/006	106	0.06	AC	N3	le
07	17:44:42	46.4175	-119.2630	1.0*	0.6	Md	005/008	197	0.13	CD	E3	le
07	17:59:35	46.3990	-119.2628	2.2	1.3	Md	010/015	213	0.19	BD	E3	le
08	13:39:46	48.5327	-119.8930	1.0	2.9	Ml	023/026	102	0.31	CC	N3	le
08	23:51:24	47.7502	-120.0622	7.2	0.9	Md	005/007	205	0.04	AD	N3	le
11	20:40:16	46.9525	-119.0860	0.0*	1.4	Md	010/009	130	0.18	CB	E3	px
12	02:52:18	44.7238	-117.3855	3.4	1.1	Md	003/006	275	0.31	CD	E3	le
12	15:17:15	47.6062	-120.2460	4.6	1.9	Md	020/022	49	0.17	BB	N3	le
13	06:17:53	46.3978	-119.3960	19.2	0.6	Md	011/016	183	0.46	CD	E3	le
13	16:29:40	47.7377	-120.0963	5.7	0.4	Md	006/008	119	0.08	AB	N3	le
14	22:14:09	46.1000	-119.0223	0.0*	1.1	Md	007/009	167	0.22	CC	E3	px
15	13:20:08	46.5895	-119.7752	15.9	2.2	Ml	030/039	38	0.39	CA	E3	le
15	14:25:51	46.5747	-119.6832	18.8	0.2	Md	005/008	125	0.13	AB	E3	le
15	21:34:31	47.9158	-118.9115	0.0*	1.7	Md	009/011	136	0.29	CC	N3	px
17	21:27:40	44.6545	-121.1292	0.0*	1.6	Md	012/013	96	0.40	CC	N3	px
18	20:44:22	46.5462	-119.7752	0.0*	1.8	Md	018/020	105	0.45	CB	E3	px
22	07:37:01	47.3367	-120.0225	4.6	1.6	Md	018/021	65	0.16	CC	N3	le
24	00:04:32	44.3712	-121.0420	0.0*	1.9	Md	007/007	213	0.40	CD	N3	px
25	19:17:35	47.6628	-120.3217	4.4	0.4	Md	005/007	136	0.06	AC	N3	le
27	12:37:03	47.7598	-120.4365	6.5	0.5	Md	007/010	73	0.12	AB	N3	le
28	10:05:42	47.0022	-120.5753	1.3	1.6	Md	012/015	161	0.15	BC	N3	le
31	00:37:47	47.7138	-120.1913	6.9	0.5	Md	008/011	123	0.07	AC	N3	le
31	08:13:02	46.6200	-119.3508	13.6	0.2	Md	013/016	128	0.08	AB	E3	le
31	21:15:39	45.7197	-121.3955	0.0*	1.1	Md	011/013	188	0.33	CD	C3	px
31	23:10:03	47.6910	-120.0602	7.0	1.5	Md	009/012	136	0.08	AC	N3	le
February 2013												
Day	**Time**	**Lat**	**Lon**	**Depth**	**Mag**	**Mtyp**	**NS/NP**	**Gap**	**RMS**	**Q**	**Mod**	**Etyp**
01	17:41:46	47.7103	-120.1837	0.6*	1.7	Md	006/008	130	0.04	CC	N3	le
04	03:46:42	48.9313	-119.5802	1.2*	2.3	Md	008/011	166	0.15	CC	N3	le
04	23:37:07	44.3013	-120.8705	0.0*	1.0	Md	014/015	146	0.51	DC	N3	px
05	21:39:49	48.8782	-119.4202	0.8*	2.2	Md	009/012	160	0.24	CD	N3	le
07	07:55:51	47.7565	-120.0847	6.7	0.6	Md	005/009	105	0.04	AB	N3	le
07	14:33:28	47.7290	-120.1860	4.8	0.6	Md	004/006	192	0.03	BD	N3	le
07	20:04:53	47.6802	-120.2208	3.3	0.8	Md	007/011	142	0.10	BC	N3	le
07	22:51:05	46.1660	-119.4255	0.0*	1.9	Md	013/017	196	0.28	CD	E3	px
08	23:36:55	47.7748	-117.7033	0.0*	2.1	Md	008/009	156	0.41	CC	N3	px
09	01:54:43	47.6793	-120.2207	4.4	0.8	Md	008/015	129	0.11	AC	N3	le
11	06:33:15	47.7197	-120.2615	3.3	0.9	Md	007/010	149	0.12	BC	N3	le
13	08:13:48	46.5875	-119.8662	6.5	0.8	Md	005/008	270	0.10	AD	E3	le
13	09:19:07	47.6825	-120.2252	4.2	0.8	Md	005/007	132	0.07	BC	N3	le
14	15:42:48	47.6812	-120.2237	0.8*	1.1	Md	006/010	132	0.13	CC	N3	le
16	22:09:30	46.5987	-119.8623	7.1	1.3	Md	014/015	138	0.08	AC	E3	le
20	21:45:26	46.6278	-120.7538	0.0*	0.9	Md	012/013	180	0.58	DC	C3	px
23	08:31:21	47.1682	-120.5517	2.5	1.8	Md	022/022	88	0.66	DA	N3	le
25	10:19:59	46.6563	-119.6103	0.5*	0.6	Md	007/010	128	0.29	CB	E3	le
25	23:06:11	46.4190	-119.0195	0.0*	1.7	Md	010/012	229	0.21	CD	E3	px
26	07:25:01	48.3610	-119.6197	2.4*	0.8	Md	005/008	210	0.10	CD	N3	le
28	00:44:44	46.6473	-120.4980	0.0*	1.7	Md	016/014	100	0.21	CC	E3	px
28	07:34:21	46.6015	-119.8645	7.0	1.7	Md	026/028	64	0.14	AA	E3	le

Day	Time	Lat	Lon	Depth	Mag	Mtyp	NS/NP	Gap	RMS	Q	Mod	Etyp
28	13:19:11	46.9037	-120.0647	3.1	1.5	Md	016/014	104	0.11	AB	E3	le
March 2013												
Day	**Time**	**Lat**	**Lon**	**Depth**	**Mag**	**Mtyp**	**NS/NP**	**Gap**	**RMS**	**Q**	**Mod**	**Etyp**
02	18:21:00	46.2785	-118.7827	0.8	1.2	Md	012/013	215	0.11	AD	E3	le
03	15:22:15	46.9993	-120.4733	8.3	1.7	Md	008/009	242	0.10	AD	E3	le
05	21:18:49	46.8985	-118.1077	0.0*	2.1	Md	021/030	213	0.38	CD	E3	px
06	18:54:15	47.7343	-120.2143	1.7	1.1	Md	006/009	111	0.04	CC	N3	le
07	01:47:31	45.7235	-118.5825	11.8	1.8	Md	010/012	79	0.30	CC	E3	le
08	01:59:41	45.8463	-118.3313	0.0*	1.9	Md	011/017	139	0.55	DD	E3	px
11	20:03:24	47.6267	-120.2070	7.0	0.2	Md	005/008	154	0.12	AC	N3	le
13	14:52:44	46.3853	-119.2545	0.5*	0.4	Md	006/008	222	0.12	CD	E3	le
15	14:01:26	46.1592	-119.5443	17.8	0.9	Md	013/015	193	0.10	AD	E3	le
16	08:11:16	45.9733	-120.6685	15.7	1.4	Md	012/016	91	0.20	BB	E3	le
16	23:34:55	47.7192	-120.0143	5.0	1.0	Md	006/010	126	0.06	AB	N3	le
18	20:12:55	47.9845	-121.4885	10.3*	0.8	Md	004/006	141	0.14	CC	C3	le
19	08:02:14	48.4195	-119.2068	15.5	1.6	Md	009/012	236	0.35	CD	N3	le
22	04:19:24	46.6045	-119.8523	7.2	1.0	Md	008/011	172	0.04	AC	E3	le
25	09:17:05	48.5360	-119.9238	2.3*	1.6	Md	008/009	162	0.11	CC	N3	le
25	18:05:30	45.9393	-119.9372	0.0*	1.8	Md	014/014	108	0.25	CB	E3	px
26	23:56:22	44.3963	-121.0108	0.0*	2.1	Md	018/020	72	0.47	CB	E3	px
28	20:40:36	46.6537	-120.4992	0.0*	2.0	Md	028/023	63	0.37	CC	E3	px
29	01:38:08	46.5957	-119.8587	7.4	1.1	Md	015/016	136	0.07	AC	E3	le
31	17:26:06	45.8668	-120.1327	15.1	1.6	Md	027/024	63	0.11	AA	E3	le

Explanation of Table 4.1 – also see section 3.3 of this report

Etyp	Event Type. le is local earthquake, px is Probable Blast; ex is Confirmed Blast
Day	The year and date in Universal Time Coordinated (UTC). UTC is used throughout this report unless otherwise indicated.
Time	The origin time of the earthquake given in Coordinated Universal Time (UTC). To covert UTC to Pacific Standard Time, subtract eight hours; to Pacific Daylight Time, subtract seven hours.
Lat	Latitude of the earthquake epicenter, in decimal degrees
Lon	Longitude of the earthquake epicenter, in decimal degrees
Depth	The depth of the earthquake in kilometers (km). * = Depth constrained by location program, $ = location program had trouble converging and constrained both location and depth.
Mag	The analyst-preferred magnitude. If magnitude is blank, a determination was not made.
Mtype	Preferred magnitude type (see section 3.2, "Earthquake Magnitudes")
NS/NP	Number of stations/number of phases used in the location.
Gap	Azimuthal gap; the largest horizontal angle (relative to the epicenter) containing no stations.
Mod	Primary velocity model used in the location. (see section 3.1, "Velocity Models")
Rms	Average misfit, in seconds, between the model-predicted and observed travel time. Computed as the square root of the summed squares of individual phase time residual (observed phase arrival time minus predicted arrival time) of all phases used to locate the earthquake. It is a meaningful measure of quality of the solution only when five or more well-distributed stations are used in the solution. Good solutions are normally characterized by Rms values smaller than ~ 0.3 s.
Q	Quality factors; indicate the general reliability of the solution/location (A is best quality, D is worst). See Section 3.3 of this report, "Quality Factors."

4.2 Summary

Overall, the seismicity throughout the 2nd quarter of FY2013 was very similar to the 1st quarter of FY2013, both in the vicinity of the Hanford site as well as the region surrounding it. While there was not a significant increase or decrease in seismicity in the vicinity of the Hanford site, there were fewer earthquakes within the Wye swarm area.

4.3 Discussion of Second Quarter FY 2013 Earthquakes

The EWRSN and HSN recorded 50 eastern Washington earthquakes during the second quarter of FY 2013, 14 local to the Hanford site (local), and 36 off of the site (regional). Of the local earthquakes, 4 were located at shallow depths (less than 4 km), 5 at intermediate depths (between 4 and 9 km), most likely in the pre-basalt sediments, and 5 deeper than 9 km, within the basement. Geographically, there were 3 shallow local earthquakes located in the Wye swarm area, 1 in the Coyote Rapids swarm area, and 1 in the Horseheaven Hills swarm area. Nine other local earthquakes were classified as random events. Of the regional earthquakes, 15 were shallow, 16 intermediate, and 5 deep. The network also located 19 local and regional events that have been categorized as probable surface explosions. (Tables 4.1 & 4.2).

The largest event (M_L = 2.9) took place on 8 January 2013 at a depth of 1 km with epicenter located 30 km northwest of Okanogan, WA.

Epicenters of the earthquakes in Table 4.1 are plotted in Figures 4.1 and 4.2. The depth distribution and geographic pattern of the earthquakes are tabulated in Table 4.2. Epicenters of earthquakes in the immediate vicinity of the Hanford site, and their relationship to known faults and swarm areas are shown on Figure 4.2. Figure 4.3 is a perspective plot showing the hypocenters in the vicinity of the Hanford site and their location at depth and their relationship to the surface topography.

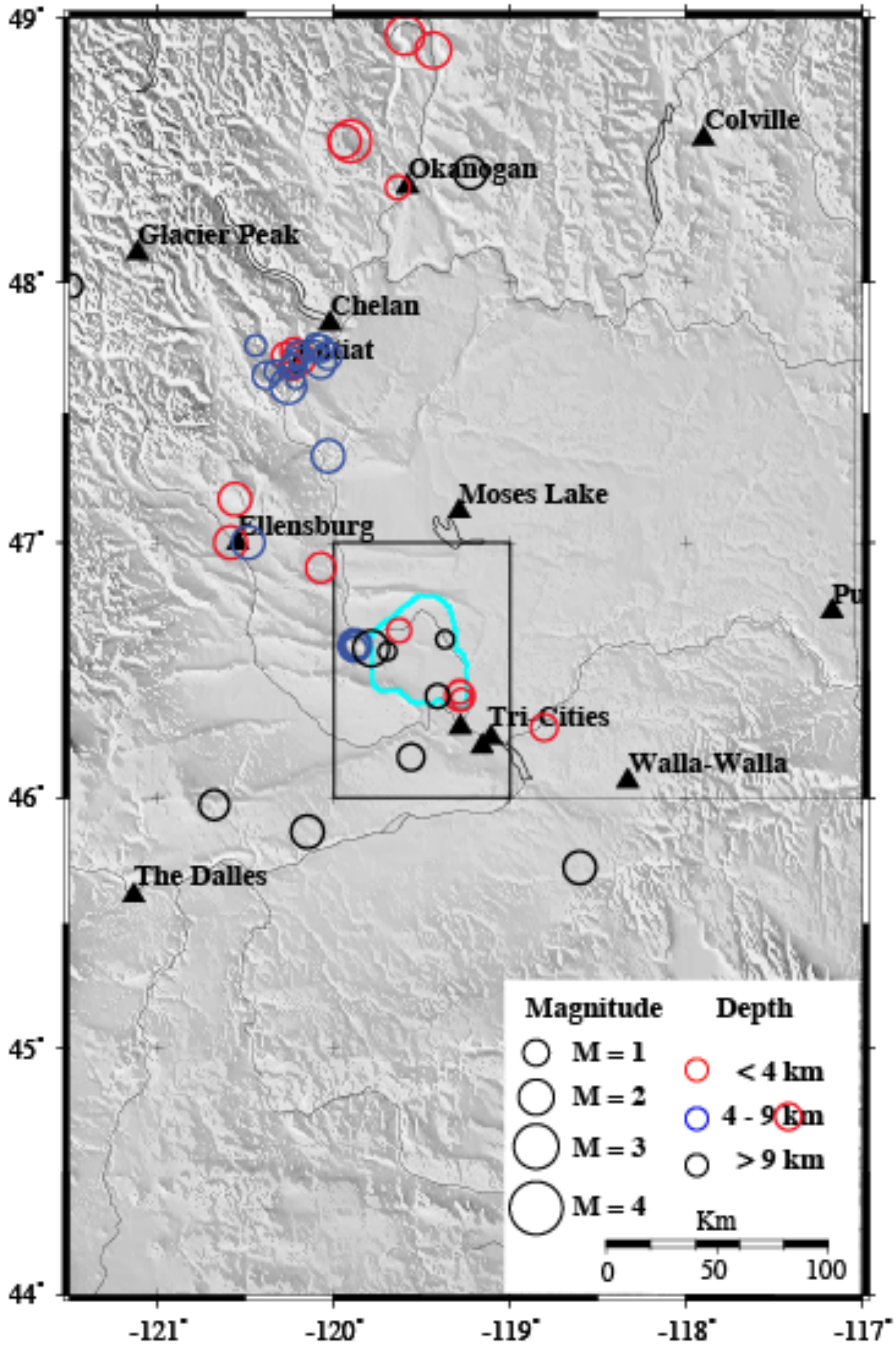

*Figure 4.1 Epicenters of earthquakes recorded in the Eastern Washington region during the 2nd Quarter of FY2013. Black triangles show locations of cities, towns, and volcanoes. Light blue line is the outline of the Hanford site. Black rectangle outlines area mapped in Figure 4.2. Circles are earthquake epicenters, with size scaled by magnitude [radius (in inches) = 0.05*M + 0.1]. Representative symbols for magnitudes 1-4 are shown in the legend. Epicenter symbols are colored by depth, as shown in legend.*

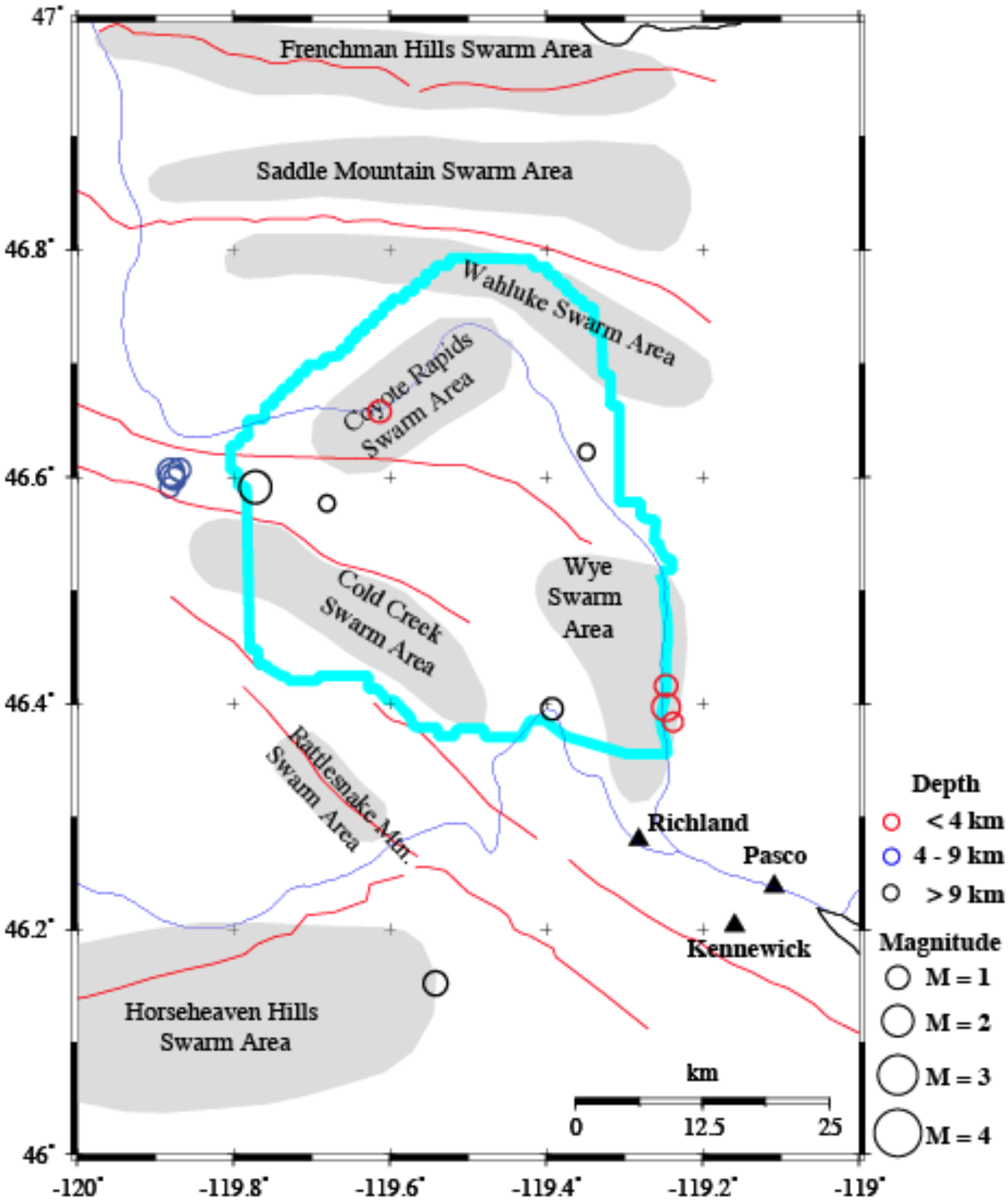

*Figure 4.2 Epicenters of earthquakes occurring during the 2nd Quarter of FY2013 in the vicinity of the Hanford site (blue outline), and their relationship to known structures (red lines), swarm areas (shaded regions), and cultural features and cities (black triangles). Circles are earthquake epicenters, with size scaled by magnitude [radius (in inches) = 0.05*M + 0.1]. Representative symbols for magnitudes 1-4 are shown in the legend. Epicenter symbols are colored by depth, as shown in legend.*

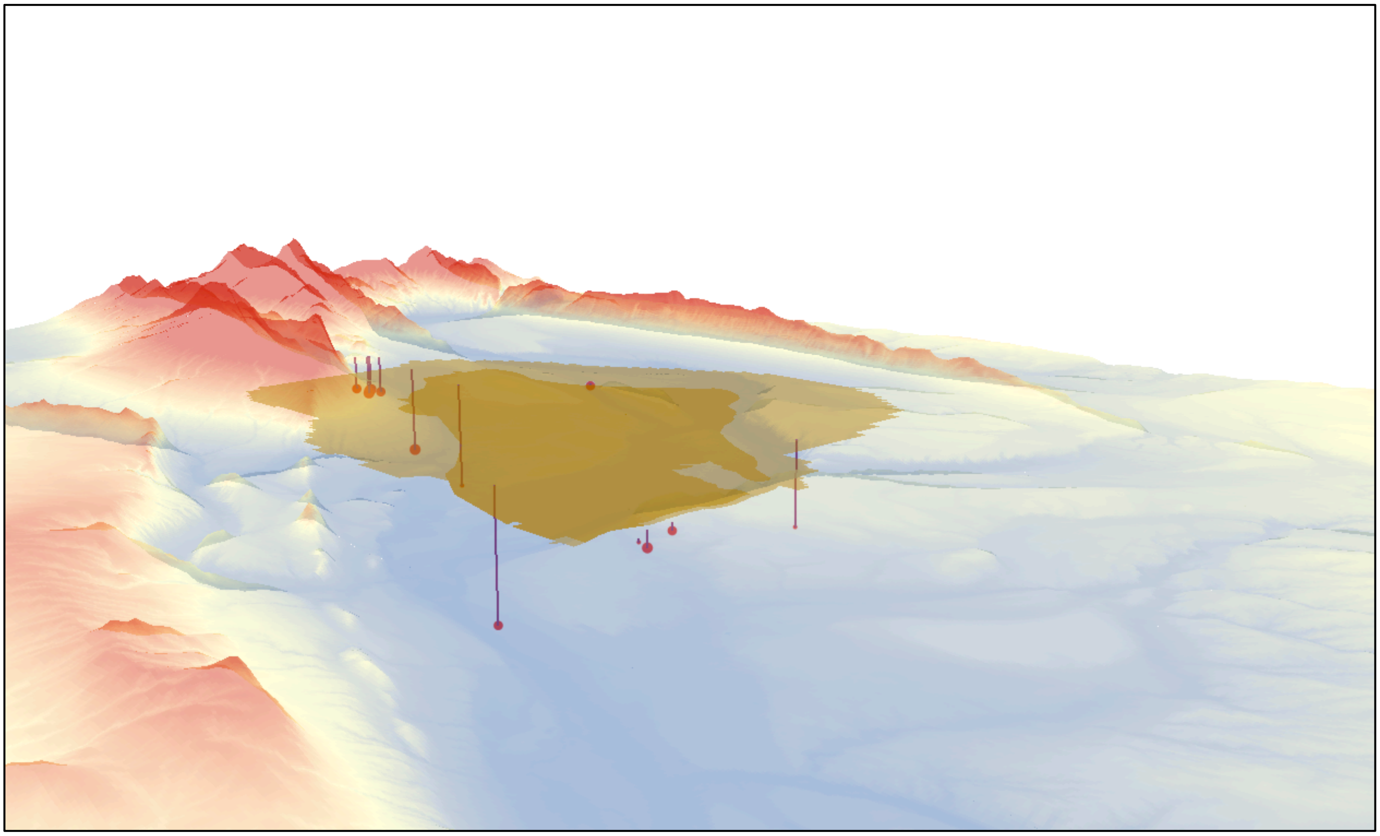

Figure 4.3 Perspective plot showing topography (exaggerated) and hypocenters (red dots, connected to epicenter with fine vertical line) of earthquakes occurring during the 2nd Quarter of FY2013 in the vicinity of the Hanford site, both overall (lightly shaded region), and inner (darker shading). Probable blasts are not shown in this figure.

Table 4.2 Summary Table of the Distribution of Earthquakes for 2nd Quarter, FY 2013

Event Category		2nd Quarter Hanford	2nd Quarter Region
Depth of Earthquakes	< 4 km	4	15
	4-9 km	5	16
	>9 km	5	5
Sub-total		14	36
Total		50	
Geographic Area	FHS	0	0
	SMS	0	0
	WAHS	0	0
	CRS	1	0
	CCS	0	0
	WYES	3	0
	RMS	0	0
	Horse Heaven Hills	1	0
	Structure	0	0
Random Earthquake		9	0
Sub-total		14	0
Total		14	0
Felt Earthquake		0	1
Probable Blast		5	14

5.0 Significant or Notable Seismic Events

5.1 Significant Earthquakes

We consider earthquakes that were felt widely, generated public interest, or produced notable shaking on the Hanford site to be significant earthquake events. We generally include any earthquake exceeding M3.0 to fall into this category. There were no $M \geq 3.0$ earthquakes in the 2nd quarter of FY2013. The largest earthquake of the quarter was a M_L=2.9, but was not located on the Hanford site nor widely felt.

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Prepared for the Mission Support Alliance, LLC under award 44955 by the
Pacific Northwest Seismic Network,
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Seattle, WA 98195-1310
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http://www.pnsn.org/