HANFORD SITE SEISMOLOGICAL NETWORK

REVIEW AND RECOMMENDATIONS FOR NETWORK RECONFIGURATION

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Executive Summary

Integrated Science Solutions, Inc. (ISSi) reviewed the Hanford seismic monitoring network and the use of seismic network data and information in order to develop recommendations regarding the reconfiguration of the network to meet Hanford specific needs. The evaluation considered the potential need for additional stations and/or the improvement of existing stations, as well as the removal of stations from the network, or the transfer of responsibility for station maintenance and operations to other organizations. Two highly qualified seismologists considered regulatory requirements, U.S. Department of Energy (DOE) and industry guidelines and practices, data and information needs of seismic data users at the Hanford Site, and the distribution of seismicity in the region. An important source of information regarding the use of seismic data is the ongoing Hanford Probabilistic Seismic Hazard Analysis (HPSHA), which is being performed in accordance with procedures defined by the Senior Seismic Hazard Analysis Committee (SSHAC). The primary users of seismic hazard data at Hanford are the scientists and engineers responsible for the design, operation and maintenance of critical facilities that treat or store hazardous and nuclear materials, and the staff responsible for emergency planning and response in the event of releases due to earthquakes.

The reviewers evaluated all of the stations in the current Hanford Seismic Network, including stations on the Hanford Site (i.e., Onsite stations) and stations operated by MSA located throughout eastern Washington and Oregon (i.e., Offsite stations). Reviewers also took into account other stations not operated by MSA in the area. The Offsite network includes a number of remote, primarily analog stations that do not contribute significantly to hazard assessments at Hanford, and the reviewers therefore recommended that MSA consider decommissioning or transferring responsibility for eleven of these stations to other agencies. Upgrades were recommended at three sites, and reviewers proposed upgrading or replacing one other site with an optional new station (WAT). No changes were recommended at eighteen Offsite stations. With regard to the Onsite network, the reviewers noted a lack of high-quality weak motion stations that could significantly improve data inputs for ground motion predictions. As a result, they recommended upgrades to eight Onsite stations, installation of two new Onsite stations, and installation of existing instruments at two other sites. We believe the recommended upgrades would improve the quality and reliability of data collected, while reducing the future level of effort and cost required to maintain the network. Specific recommendations are listed in Table 1 below. Station identification names and additional details are provided in the body of the report.

Table 1: Summary of Network Configuration Recommendations

Offsite Stations	Action
BRV, BVW, CCRK, CRF, DDRF, FHE, LNO, NAC, OD2, OT3, PHIN, PAT2, PRO, RED, TRW, VT2, WRD, YPT	No change
ELL, MOX, EPH, *WAT	Upgrade
*WAT - optional category	Install New
CBS, NEL, DY2, TWW, TBM, DPW, SAW, BLT, YA2, ET4, ETW, *WAT	Transfer
Onsite Stations	
LOC, MDW, MJ2, RSW, H20, BEN, H1K, H4A	No change
H2W, H2E, H3A, GBB, GBL, SNI, WA2, WIW	Upgrade
2 New Stations (XXX, XXX)	New Stations
Install Existing Basalt Equipment at 2 New Locations	Install Existing

1 Introduction

Integrated Science Solutions, Inc. (ISSi) was retained by Mission Support Alliance (MSA) to review the current Hanford seismic monitoring network and the use of seismic network data and information. The distribution and type of seismic monitoring stations and the historical seismicity were considered in developing recommendations regarding the possible reconfiguration of the network to meet Hanford specific needs. MSA requested that ISSi evaluate both the potential need for additional stations and/or the improvement of existing stations, as well as the potential removal or transfer of station support to other organizations. In order to accomplish the goals specified by MSA, ISSi retained the services of two highly qualified seismologists who currently manage or operate seismic monitoring networks for assessing the hazard and risk of seismic activity at sites that include radiological hazards. Dr. Ken Smith manages the ~200-station Nevada Regional Seismic Network which includes monitoring of the Nevada National Security Site (NNSA). Ms. Marcia McLaren manages seismic networks for Pacific Gas & Electric Company in the Diablo Canyon Nuclear Power Plant region, at the Humboldt Bay Independent Spent Fuel Storage Installation, and in the San Francisco Bay Area. Resumes for Dr. Smith and Ms. McLaren are provided in Attachment 1.

The review of the Hanford Seismic Network considered regulatory requirements, U.S. Department of Energy (DOE) and industry guidelines and practices, and the data and information needs of the users of seismic data at the Hanford Site. The references listed in Section 6 are the principle sources of information that provided the basis for this review and analysis of the Hanford Seismic Network, including both its Onsite and Offsite components. Specifically, the following subjects and topics were addressed:

- The locations of seismic stations required to meet DOE Order requirements (DOE O 420.1C, Section IV. *Seismic Detection;* DOE-STD-1020-2012, *Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities*) and standards for Hanford facilities with nuclear or hazardous materials.

- The type and number of monitoring instrumentation/equipment required at these seismic stations to detect and record the occurrence and severity of seismic events, and ensure that notification and monitoring data is available during and after a seismic event, and to meet other DOE Order requirements (DOE O 420.1C, Section IV, *Seismic Detection*; and DOE-STD-1020-2012, *Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities*).
- Near-term improvements (equipment upgrades such as transitioning from analog to digital equipment and upgrading from 3-channel to 6-channel data loggers) that could or should be made to the existing seismic stations.
- Which existing stations may be taken out of service, or ownership transferred to the Pacific Northwest Seismic Network (PNSN), the U.S. Geological Survey (USGS) or other organizations actively monitoring seismicity in Eastern Washington.

Reviewers also considered the interim results of the ongoing Hanford Probabilistic Seismic Hazard Analysis (HPSHA) being performed in accordance with procedures defined by the Senior Seismic Hazard Analysis Committee (SSHAC). The SSHAC was established by the DOE; the U.S. Nuclear Regulatory Commission (NRC), and the Electric Power Research Institute (EPRI) to provide methodological guidance on how to perform probabilistic seismic hazard analyses. The Hanford SSHAC studies are focused on the information important to assessing seismic hazard, which includes improving the Offsite station coverage for the Saddle Mountain and Umtanum Ridge faults with the objective to better understand earthquake sources that could affect Hanford facilities. The SSHAC review has indicated that adding weak motion (either broadband or short period) digital stations to the existing Onsite stations would result in an improved understanding of the ground motion scaling parameter ‘kappa’, which is critical for developing ground motion predictions at critical facilities. Reviewers also took into account the results of the SSHAC studies that conclude that the hazard is primarily driven by moderate magnitude earthquakes within 15 km of the site, and not necessarily by the regional Mmax or from earthquakes at greater distances (K. Coppersmith, personal communication, 2014). It is understood that to provide sufficient coverage within 15 km of the site, stations at greater distances are required.

The reviewers would like to emphasize that this review was limited in scope, and did not consider operational details or constraints that could affect some of the recommendations. These limitations include:

- The reviewers do not operate the network, and therefore are not familiar with the specifics of particular stations (the assessment was developed through photographs, station map locations, and station metadata provided by MSA and PNSN);
- Recommended locations for new stations are only an interpretation of potential monitoring needs. Reviewers are not familiar with site conditions or other station installation restrictions;
- Reviewers are not familiar with permitting or land use processes On- or Offsite;
- The recommendations for the reconfiguration of the network are an idealization based on the information provided and responses to general questions of network operators and data consumers;

- Recommendations were not based on funding criteria (i.e., budget constraints);
- The reviewers did not review or analyze potential telemetry limitations;

The following sections and tables summarize both specific and general recommendations for the modification of the network, including transfer or decommissioning of stations, modification or upgrades to stations, and installation of new stations. Attachment 2 to this report is a detailed table listing all of the current MSA managed seismic stations including specific recommendations on a station-by-station basis.

2 Assessment of Existing Seismograph Stations and Monitoring Capabilities

Effective seismic monitoring provides critical measurements of ground shaking, a catalog of seismic activity, and situational awareness for emergency managers in the event of a significant earthquake near a site of interest. The U.S. Geological Survey's Advanced National Seismic System (ANSS) under USGS Circular 1188, outlines the principles and objectives of professional seismic monitoring to address both immediate earthquake response and the need to develop an archive of high-quality data for reducing the uncertainties in Seismic Hazard Assessments. Many of the existing stations in the Eastern Washington Network are configured to transmit low-dynamic range single-channel analog velocity time-series data, utilizing technologies developed in the 1960-70s. Although these stations provide timing information for earthquake locations, magnitude estimates, and data for stress field assessments, they will not remain on scale for significant nearby earthquakes of interest. Also, a number of stations on the Hanford site record 3-channels of acceleration (i.e., strong motion) and will remain on scale for larger events, but are limited in their contribution to developing a local earthquake catalog and for weak motion 'kappa' estimates. In short, much of the instrumentation in and around the Hanford site is a generation behind current technologies, limiting data utility. The range of earthquake magnitude (potentially 6-7 orders of magnitude of ground motions) dictates the need for two types of sensors at a particular site to assure on-scale measurements for any potential event. Modern high-dynamic range high quality seismic stations are typically configured with 6-channel data loggers matched with a 3-channel broadband velocity sensor, and a 3-channel strong motion sensor. These systems, as with older technologies, operate at low power, typically with local solar powered systems. Modern data loggers provide 24-bit digitization and require digital communications (e.g., cell modem, digital radios, direct Internet, etc.) for real-time monitoring. Beyond the physical network, a staff of seismologists, record analysts, and field technicians are required to assure that immediate assessments of ground shaking within the network are communicated to the end user in order to effectively respond to a potentially damaging event. Therefore, in addition to quality data collection systems, earthquake monitoring is a 24/7 operation requiring reliable automated data management and event notification processes.

Seismic monitoring at the Hanford Site began in 1969 with the installation of short period seismic stations by the U.S. Geological Survey (USGS). Over the years, several different groups have assumed responsibility for maintenance and monitoring activities, including the University of Washington (UW) in 1975, the Basalt Waste Isolation Project (BWIP) in 1979, followed by

Rockwell Hanford Operations, and Westinghouse Hanford Company (WHC), who made major upgrades to the Eastern Washington Regional Seismic Network (EWRSN). As of October 1996, all seismic monitoring and regular reporting activities were transferred to the Pacific Northwest National Laboratory (PNNL). The Hanford Strong Motion Accelerometer (SMA) network was constructed during 1997 and, except for 1998 when it was off-line due to lack of funding, has operated continuously since 1999 (Bodin et al, 2012). During the third quarter of 2011, MSA assumed responsibility for the Hanford seismic network, with seismic operations conducted by the Pacific Northwest Seismic Network (PNSN) at the University of Washington.

For convenience, in this assessment of the Hanford area, MSA supported network stations are designated as either Onsite or Offsite depending whether they are operated within or outside the Hanford site boundary, respectively. The Onsite and Offsite stations that comprise the current MSA supported Hanford network, in and around the Hanford Site, are summarized in Tables 2 and 3, respectively. Table 4 lists additional stations that are operated and/or monitored by the PNSN in eastern Washington that are not supported by MSA. ISSi's overall assessment of seismic monitoring coverage and capabilities in the Hanford area considered all existing network coverage. In addition to the MSA/DOE supported seismic monitoring network in Eastern Washington, the PNSN, in recent years, has incorporated stations that were operated by the EarthScope USArray (http://www.earthscope.org), USGS installed National Network backbone stations, USGS National Strong Motion Program (NSMP) stations, and USGS supported NetQuakes strong motion instruments (http://earthquake.usgs.gov/monitoring/netquakes/). These additional stations are also listed in Table 4, and contribute to overall improved monitoring capabilities in eastern Washington. This assessment of the Hanford Seismic Network has considered these additional stations, historical seismicity (http://www.pnsn.org), and seismic source zones identified in the SSHAC process, relative to existing monitoring stations, in developing the recommendations described below.

Table 2: MSA Supported Onsite Stations, operated by PNSN

Station ID	Latitude	Longitude	Sensor Type	Elevation (m)	Station Name	Network Code
Strong Motion 3-Channel:						
H1K	46.6447	-119.5929	ETNA	152	100 K Area (SMA)	UW
H2E	46.5578	-119.5345	ETNA	210	200 East Area(SMA)	UW
H2W	46.5517	-119.6453	ETNA	201	200 West Area (SMA)	UW
H3A	46.3632	-119.2775	ETNA	119	300 Area (SMA)	UW
H4A	46.4377	-119.3557	ETNA	171	400 Area (SMA)	UW
3-Channel Analog Weak Motion:						
GBB	46.6081	-119.6290	S13	185	Gable Butte	UW
Single-Channel Analog Weak Motion:						
BEN	46.5200	-119.7217	S13	335	Benson Ranch	UW
GBL	46.5982	-119.4610	S13	330	Gable Mountain	UW
H2O	46.3956	-119.4241	Ranger	175	Water Station	UW
LOC	46.7169	-119.4320	SS1	210	Locke Island	UW
MDW	46.6130	-119.7621	S13	330	Midway	UW
MJ2	46.5573	-119.3601	SS1	146	May Junction Two	UW
RSW	46.3943	-119.5925	S13	1045	Rattlesnake Mountain	UW
SNI	46.4639	-119.6609	S13	323	Snively Ranch	UW
WA2	46.7552	-119.5668	L4	244	Wahluke Slope	UW
WIW	46.4292	-119.2888	S13	128	Wooded Island	UW

Table 3: MSA Supported Offsite Stations; Operated by PNSN

Station ID	Latitude	Longitude	Sensor Type	Elevation (m)	Station Name	Network Code
6-Channel Broadband/Strong Motion:						
CCRK	46.559	-119.855	G3T/ETNA	561	Cold Creek	UW
DDRF	46.491	-119.060	STS2/ETNA	233	Didier Farms	UW
PHIN	45.895	-119.928	GT3/ETNA	227	Phinney Hill	UW
3-Channel Weak Motion Analog (Short Period):						
FHE	46.952	-119.498	S13	455	Frenchman Hills East	UW
Single-Channel Analog (Short period):						
BLT	45.915	-120.177	SS1	659	Bickleton	UW
BRV	46.486	-119.992	L4	920	Black Rock Valley	UW
BVW	46.811	-119.883	SS1	670	Beverly	UW
CBS	47.805	-120.043	SS1	1067	Chelan Butte South	UW
CRF	46.825	-119.388	SS1	189	Corfu	UW
DPW	47.871	-118.204	S13	892	Davenport	UW
DY2	47.986	-119.773	SS1	890	Dyer Hill Two	UW
ELL	46.910	-120.568	SS1	789	Ellensburg	UW
EPH	47.356	-119.597	L4	661	Ephrata	UW
ET4	46.563	-118.945	S13	236	Ethiopia Four	UW
ETW	47.604	-120.334	S13	1477	Entiat	UW
LNO	45.872	-118.286	SS1	771	Lincton Mountain OR	UW
MOX	46.577	-120.299	SS1	501	Moxee City	UW
NAC	46.733	-120.825	S13	728	Naches	UW
NEL	48.070	-120.341	S13	1500	Nelson Butte	UW
OD2	47.388	-118.711	SS1	553	Odessa Two	UW
OT3	46.669	-119.234	S13	322	Othello Three	UW
PAT2	45.884	-119.757	SS1	262	Paterson Two	UW
PRO	46.213	-119.687	S13	553	Prosser	UW
RED	46.297	-119.439	S13	330	Red Mountain	UW
SAW	47.706	-119.402	SS1	701	St. Andrews	UW
TBM	47.170	-120.599	SS1	1006	Table Mountain	UW
TRW	46.292	-120.543	L4	723	Toppenish Ridge	UW
TWW	47.138	-120.870	L4	1027	Teanaway	UW
VT2	46.967	-120.000	S13	385	Vantage Two	UW
WAT	47.699	-119.955	SS1	821	Waterville	UW
WRD	46.970	-119.146	SS1	375	Warden	UW
YA2	46.527	-120.531	L4	652	Yakima Two	UW
YPT	46.049	-118.963	SS1	325	Yellepit	UW

ETNA:	3-component strong motion sensor	S13:	1-Hz short period sensor
G3T:	"Guralp" broadband sensor	SS1:	1-Hz short period sensor
L4:	1-Hz short period sensor	STS2:	'Streckheisen' broadband sensor

Table 4: Additional Stations; Operated or Monitored by PNSN

Station ID	Latitude	Longitude	Elevation	Type	Network
Broadband at least 3-Channel:					
PNT	49.3167	-119.6167	550	BB	UW
LTH	46.4617	-119.4176	157	BB	UW
BRAN	45.9734	-117.2277	1136	BB	UW
DAVN	47.8006	-118.2741	495	BB	UW
LTY	47.2545	-120.6663	807	BB	UW
MRBL	48.5183	-121.4845	75	BB	UW
OMAK	48.3584	-119.3332	696	BB	UW
WOLL	47.0573	-118.921	385	BB	UW
TUCA	46.5139	-118.1455	304	BB	UW
UMAT	45.2904	-118.9595	131	BB	UW
F05D	45.8852	-121.4597	472	BB	TA
HAWA	46.3925	-119.5327	364	BB	US
NEW	48.2642	-117.1227	760	BB	US
Short-Period (assumed analog - SP):					
WRW	47.85644	-120.8829	1189	SP	UW
GL2	45.95957	-120.8240	1000	SP	UW
GLDO	45.83878	-120.8147	610	SP	UW
GPW	48.11789	-121.1378	2354	SP	UW
SLF	47.76057	-120.5294	1750	SP	UW
VGB	45.51551	-120.77867	729	SP	UW
Strong Motion (SM):					
WWHS	46.0452	-118.3182	*	SM	UW
2123	47.7038	-117.4781	579	SM	NSMP
2161	47.9968	-119.6496	255	SM	NSMP
2222	46.5191	-116.3009	494	SM	NSMP
7009	46.249	-118.88	*	SM	NSMP
7036	46.064	-118.264	*	SM	NSMP
7206	48.1803	-116.998	639	SM	NSMP
USGS NetQuakes Strong Motion (SMNQ):					
QEWU	47.6695	-117.44224	573	SMNQ	UW
QGLD	46.6443	-120.58241	37	SMNQ	UW
QPID	47.6457	-117.36955	627	SMNQ	UW
QPJE	47.7104	-117.41313	630	SMNQ	UW
QSKF	47.6756	-117.43303	584	SMNQ	UW
QWER	47.6841	-117.41541	582	SMNQ	UW
QWSU	46.3322	-119.26478	114	SMNQ	UW
QZOE	47.7480	-117.49832	602	SMNQ	UW

Type		Network	
BB:	Broadband	NSMP:	National Strong Motion Program
SP:	Short-Period	TA:	EarthScope Transportable Array
SM:	Strong Motion	US:	US Geological Survey
SMNQ:	NetQuakes	UW:	University of Washington/PNSN

*Note - elevation information is not available at this time

3 Final Assessment and Recommendation Strategy

The approach for identifying potential improvements in the MSA supported seismic monitoring network included reviewing the number, type and locations of stations relative to active seismicity and particular fault zones that are important to hazard assessments. Qualitative considerations were given to source zones identified in the Hanford Probabilistic Seismic Hazard Assessment (HPSHA) investigations of the Hanford region (Hanford, 2012), and to Emergency Preparedness and Response needs in the event of a significant earthquake (Hanford Site Seismic Network Questionnaires). The current Offsite network includes a number of remote, primarily analog stations that do not contribute significantly to hazard assessments for the Hanford Site. The reviewers have therefore recommended that MSA consider offering to transfer responsibility for many of these stations to other agencies. Consideration should be given to upgrading a few remote analog sites to at least a 3-channel digital configuration to provide high quality data to constrain event and ground motion parameters near, but outside, the Hanford site area. The current Onsite network includes a number of single-channel vertical component short period instruments that essentially surround Hanford's critical facilities area. The reviewers recommend maintaining all of the sites in the existing Onsite network and recommend upgrading eight stations to modern high-dynamic range 6-channel weak-motion/strong-motion site configurations. It would be advantageous to maintain an existing framework of Onsite stations that have been in operation for many years in order to more effectively maintain a common history of ground motion measurements and to also address any potential magnitudes differences between a pre- and post-upgraded seismic network. Upgrading all stations to a modern 6-channel configuration could be considered ideal, but in the interest of cost and schedule, this may not be feasible – future upgrades should be developed under a long-term strategy to assure effective seismic monitoring for the site.

The proposed consolidation of Offsite stations would complement and supplement existing PNSN operated Eastern Washington stations, reduce operating costs for remote station operations, and improve overall data quality for events near the site, albeit from a fewer number of remote higher quality stations. '*Transfer*' of currently supported stations could refer to either passing operational responsibility to another agency (i.e., PNSN, USGS, etc.) or decommissioning the station in light of a potential network reconfiguration or funding constraints, although, in general, the reviewers prefer site transfer. If stations are decommissioned, components should be saved for potential reuse and/or replacement parts. Since the reviewers are not familiar with operational details of the eastern Washington network, input from the PNSN would be critical for any station reconfiguration strategy.

The reviewers also evaluated the quality of monitoring on the Hanford Site with respect to the needs identified by managers of critical facilities such as the Waste Treatment Plant (WTP), Tank Farm Operations, the Environmental Restoration and Disposal Facility (ERDF), and the Canister Storage Building (CSB) (Hanford Site Seismic Network Questionnaires). Although the existing network does meet the basic DOE requirement specified in DOE Order 420.1C (Facility Safety) for Seismic Detection (Chapter 4(3)(e), "*DOE sites with nuclear or hazardous materials must have instrumentation or other means to detect and record the occurrence and severity of seismic events*," the reviewers noted that the ongoing SSHAC review of HPSHA results has identified a lack of high-quality weak motion Onsite stations and data to provide additional constraints on the parameter ‘kappa’,to improve Ground Motion Prediction Equations (GMPE). As a result, the reviewers have suggested upgrades to current MSA Onsite stations an installation of additional Onsite stations. This potential vulnerability in the seismic program is compelling enough to consider future purchases of equipment upgrades for many of the seismic stations within the Hanford Network, to further improve Onsite monitoring.

3.1 Suggested Network Reconfiguration

The review of the seismological network supported by MSA and operated by PNSN identified a number of recommendations that could reduce network operating costs, and improve data quality. There are three categories of recommendations:

- Transfer or Decommission Seismic Network Stations. The current Offsite network includes a number of remote, primarily analog stations that provide data of limited utility to HPSHA analyses or Emergency Response for the Hanford Site. These stations could be transferred to other network operators such as PNSN, U.S. Geological Survey or another agency.
- Upgrade Existing Stations. The quality and utility of some existing stations could be significantly improved by upgrading a subset to more modern digital instruments. Recommendations include upgrading eight Onsite and four Offsite stations.
- Install New Stations. In some areas (particularly on the Hanford site), digital instrumentation would significantly improve the utility of the seismic data archive, address uncertainties in hazard assessments, and lead to improved ShakeMaps (and more effective earthquake response). Reviewers recommend installing two additional Onsite stations.

The results of the review are summarized briefly below, and are shown in Figures 1 through 4, which depict the current Onsite (Figure 1) and Offsite (Figure 3) networks, and the recommended reconfigured Onsite (Figure 2) and Offsite (Figure 4) networks. In addition, specific recommendations are summarized in Tables 5 and 6 and on a station-by-station basis in Attachment 2.

The reviewers recommend that MSA consider the following modifications to the network:

Offsite: The reviewers recommend leaving eighteen stations unchanged, upgrading three stations, and decommissioning (or transferring) eleven stations. One station (WAT) should either be upgraded (for a total of four upgraded stations) or replaced with an optional new station (in which case there would be twelve stations transferred or decommissioned).

Onsite: The reviewers recommend upgrading a number of currently supported MSA stations and installing new instruments near critical facilities. Implementing these recommendations would significantly improve station coverage and data quality, and address data needs for local seismic hazard assessments.

Specific recommendations include upgrading eight stations and leaving eight stations unchanged, with no stations transferred or decommissioned. The reviewers also recommend installing two new stations and installing two existing Basalt instruments at new locations.

Table 5: Offsite Station Assessment/Recommendations – Upgrades listed by priority

Station	Action	Comments
ELL, MOX	Upgrade	Upgrade to digital station BB/SM PNSN supported station. Stations are located within the faults of interest to Hanford.
EPH	Upgrade	Upgrade to digital (at least 3-channel velocity) to maintain adequate coverage. Consider 6-channel system if funding available
CBS, NEL, DY2, TWW, TBM, DPW, SAW, BLT	Transfer	Transfer distant from the Hanford Site, and known faults of interest to Hanford. BLT nearby PHIN and PAT2, recommend transferring.
YA2, ET4	Transfer	Transfer. YA2 close to MOX, which would be upgraded. ET4 is nearly DDRF, recommend transfer.
ETW, WAT	Transfer	Transfer ETW with optional upgrade for station WAT provides coverage for Chelan swarm area. See WAT below.
WAT - optional category	Install New Station	Install digital station approximately ~½ way between stations ETW and WAT as part of the offsite Hanford network (or upgrade the WAT site to digital) to supplement PNSN coverage near the Chelan swarm area. Reviewers want to consider scientific questions related to potential large earthquakes in the Chelan swarm area but recognize that the distance from the site may be a limitation (consider this site an optional upgrade/transfer).
BRV, BVW, CCRK, CRF, DDRF, FHE, LNO, NAC, OD2, OT3, PHIN, PAT2, PRO, RED, TRW, VT2, WRD, YPT	No change	No change, CCRK, DDRF, and PHIN are 3-component broadband strong motion stations. FHE is a 3-component short period station. Rest are vertical only analog; well-spaced for even coverage.

Table 6: Onsite Station Assessment/Recommendations – Upgrades listed by priority

Station	Action	Comments
H2W, H2E, H3A	Upgrade	Upgrade: Install new 3-component broadband seismometer, new 3-component accelerometer, and modern 6-channel datalogger (replace Etna). Broadband data will provide weak motion 'kappa' estimates, horizontal component S-waves will improve locations and depths, and increased bandwidth will improved moment tensor solutions for nearby events. Overall improvements in ShakeMaps.
GBB, GBL, SNI, WA2, WIW	Upgrade	Upgrade: Install new 3-component broadband seismometer, new 3-component accelerometer, and modern 6-channel datalogger (replace analog equipment). High dynamic range broadband data will provide weak motion 'kappa' estimates, horizontal component S-waves will improve locations and depths, and increased bandwidth will improve moment tensor solutions for nearby events. Accelerometers will remain on scale for large events. Overall improvement in ShakeMaps.
LOC, MDW, MJ2, RSW, H20, BEN	No change	Recommend continue to support analog site. Provides ability to '*calibrate*' duration magnitudes (legacy catalog magnitudes) and analog ground motions with magnitude estimates from upgraded stations (see Dashboard for additional comments).
H1K, H4A	No Change	Recommend maintaining two ETNA sites in order to corroborate recording from potential modernized stations with legacy ground motion archives.
New (XXX)	New Stations	Recommend installing additional 6-channel digital stations, 1) within the center of the critical facilities area, and 2) directly south of the facilities area (i.e., critical facilities provided in spreadsheet). Proposed additional station locations, 'XXX'; 46.5393N/119.5801W and 'XXX' 46.5050N /119.4713W. Improved locations and improved ShakeMaps in critical facilities area.
New (Existing Equipment)	Install Existing Instruments	Suggest installation of available Basalts in eastern 200 facility area, unless arrangements are in place for this equipment.

3.2 Reviewers Recommendations on Potential Station Upgrades

There are several possible strategies for upgrading or installing new seismograph stations. The existing MSA supported network has been in operation for many years and much of the instrumentation and technology used in the network is aging and dated. The reviewers recommend that MSA develop a plan to upgrade network components within the context of a long-term strategy. The plan should consider various alternative strategies, including the reuse of equipment as well as the purchase and installation of new equipment:

1. Reinstall velocity sensors (preferably S-13 weak motion sensors) removed from decommissioned sites or purchase new S-13s to upgrade existing vertical only analog stations to 3-component sites, both Onsite and Offsite.
2. Upgrade old or install new sites assuming 6-channel recording; i.e., broadband weak-motion and strong motion sensors. Broadband sensors would range in cost depending on the requirements for long period noise levels; less expensive broadband sensors would be sufficient to supplement existing PNSN coverage as well as be appropriate for the existing station spacing. Less costly modern broadband instruments are available that provide sufficient high-frequency response for microearthquake monitoring.

3.3 Rough Capital Cost Estimates (not a Quotation) for Information Purposes

Below is a list of the various instruments and components for consideration when upgrading or installing new stations, and ***rough*** capital cost estimates. Digital telemetry solutions must be addressed for station upgrades. Analog and digital telemetry have different requirements for data transmission. For example, analog telemetry generally works well with limited line-of-site (LOS), whereas digital communications may require shorter path links and direct LOS. New vaults would likely be required for 6-channel digital upgrades. Installation costs depend on site access, local site conditions, personnel costs, and travel requirements. The following are general estimates for guidance in evaluating potential costs for network reconfiguration and do not include long term operations costs:

Table 7: Approximate Cost of Seismic Equipment/Instrumentation

Equipment	Estimated Cost
6-channel Data-logger	$11,000
Broadband Sensor	$8,000-$13,000 (depending on quality required)
Short Period Sensor (S-13)	$4,300 (per component)
Strong Motion Sensor	$3,500
Solar/Batteries/Tower/Enclosures	$2,500
Charge Controllers	
Telemetry	Point-to-multipoint radio system ($500/end – variable; Cellular $50/mo)
Labor- highly variable	$5,000 per installation

4 Evaluation of Site Notification Procedures for Significant Earthquakes

The SOW also specified that reviewers perform an assessment to "*ensure that notification and monitoring data is available during and after a seismic event*." The following is a summary of the notification and reporting process from PNSN to the Hanford Richland Emergency Operations Center. Currently, only five Onsite strong motion stations are used to develop local ShakeMaps for the EOC. From reviewer discussions with the EOC, we understand that some additional stations are in the process of permitting and installation. We strongly support the installation of these additional stations and upgrades of existing stations within the Onsite region (Table 5) - they would provide important information for the EOC, and a more effective response following a significant event on or near the site. PNSN also operates additional strong motion stations Offsite that would contribute near real-time ground shaking information that would improve the ShakeMap/ShakeCast product. It is the reviewer's assessment that an adequate process is in place for notification to the Hanford Richland EOC.

Based on responses provided by both PNSN and MSA Hanford Site Seismic Network Questionnaires, a comprehensive notification mechanism is in place for reporting earthquake events and providing earthquake products to the EOC 24-hour shift personnel. PNSN reviews all events located on the site and has recently begun a process of scanning all waveforms for potentially missed events (i.e., small earthquakes missed by the automatic detection systems). The process would lead to a more complete catalog of Onsite earthquakes. PNSN distributes email notifications to the EOC for Onsite earthquakes of Magnitude >=2, and Magnitude >= 3 for Offsite events. For earthquakes of Magnitude >= 3 within the regional network (including Onsite) a site-specific ShakeMap (at a higher resolution than a routine PNSN regional ShakeMap) is provided to the EOC; all M >= 3 earthquakes are followed up with a phone call to the EOC within 30 minutes. It is our understanding that the USGS in Golden, Colorado, assisted in creating a ShakeCast system for Hanford that would incorporate high-resolution PNSN ShakeMaps. The ShakeCast system is designed to provide a more direct assessment of potential impacts to specific facilities following significant earthquakes. ShakeCast is operated directly by the EOC and they assume the responsibility to incorporate specific site and critical facility specifics into the system. Which critical facilities operate independent strong motion instrumentation (i.e., not integrated with routine network operations), or if information from these systems is integrated into incident response, is not known.

5 Maps of Existing and Proposed Station Configurations

The following figures show existing and recommended Onsite (Figures 1 and 2) and Offsite (Figures 3 and 4) seismic network station configurations. The proposed Onsite configuration (Figure 2) shows an optimized recommendation that could be implemented immediately. Ideally, upgrading all existing analog station (blue symbols) to a 6-component digital broadband/strong-motion configuration, over time, would best address hazard assessment and response performance. Figure 5 shows existing PNSN operated E. Washington network stations. Red lines are faults identified in the SSHAC process.

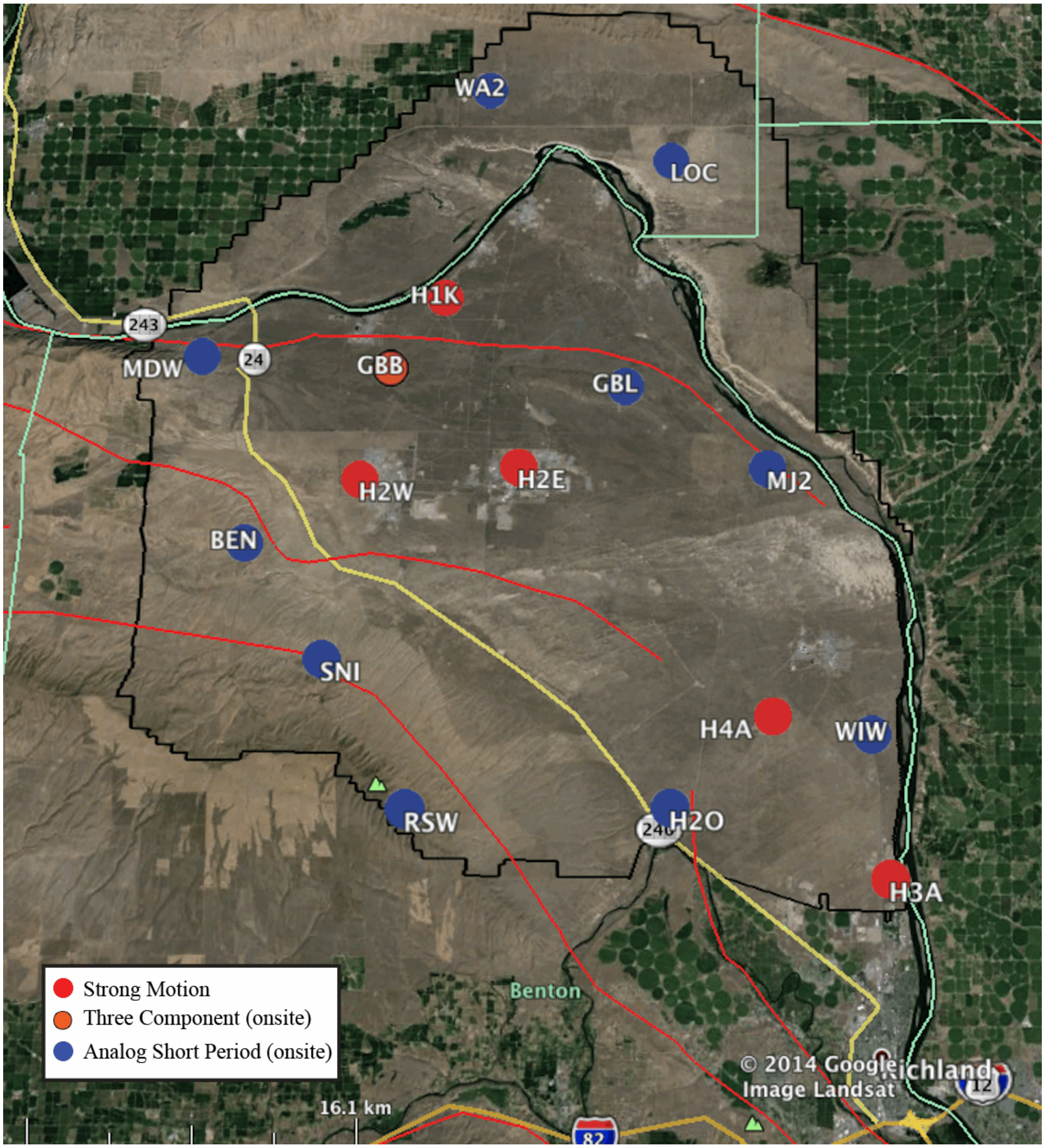

Figure 1: Existing MSA Supported Onsite Stations

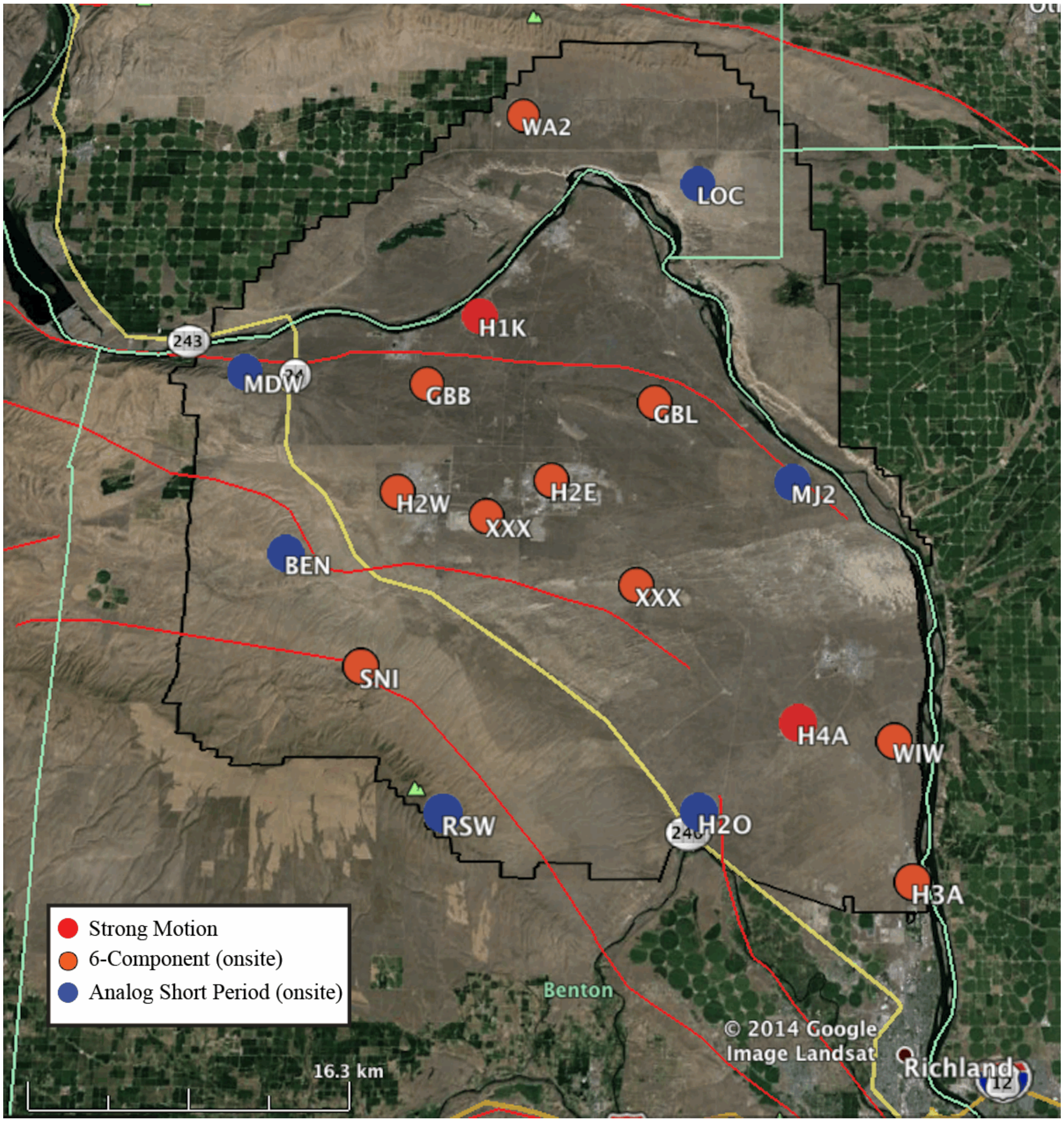

Figure 2: Proposed Configuration for Onsite Stations

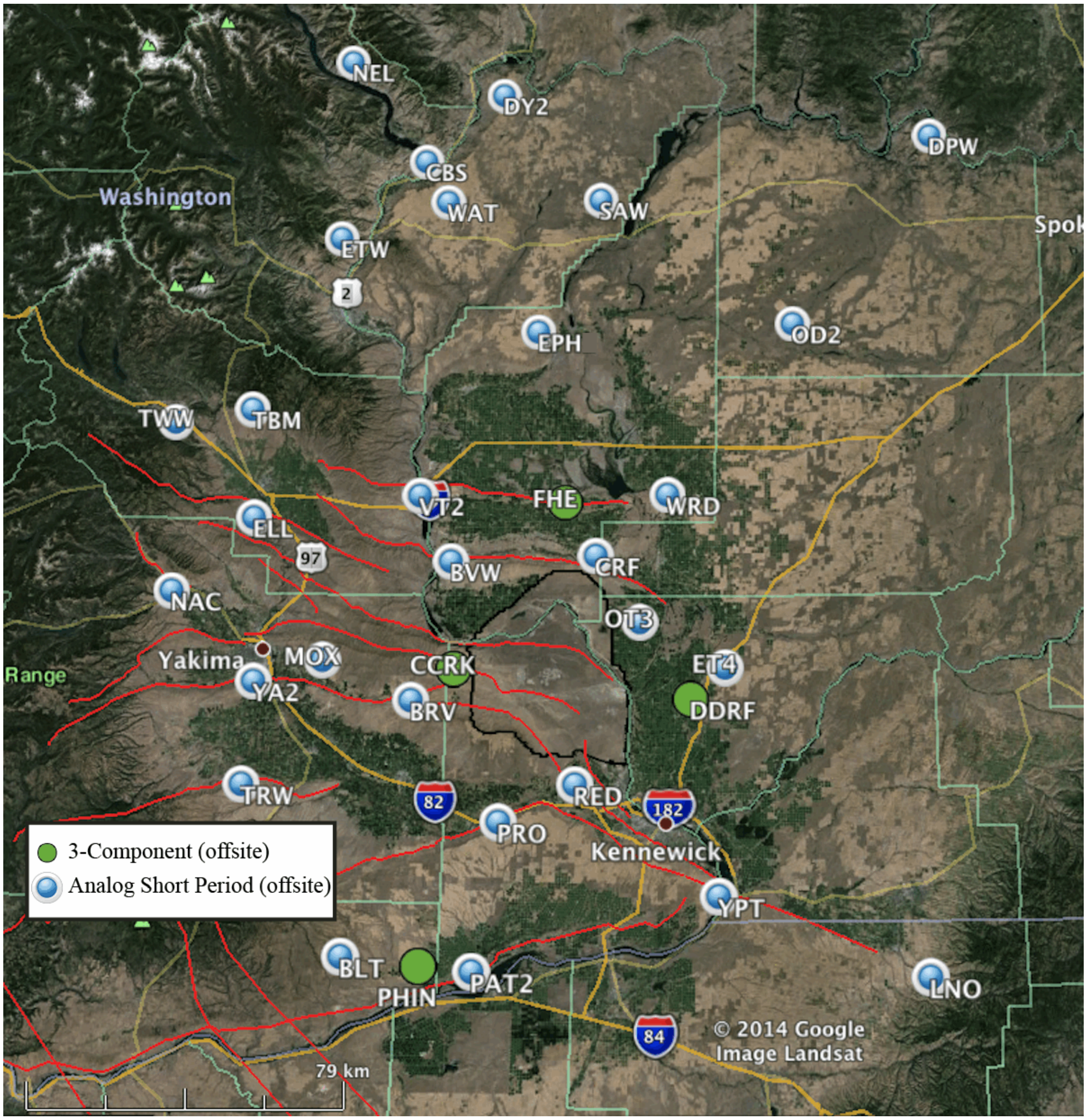

Figure 3: Existing MSA Supported Offsite Stations Configuration

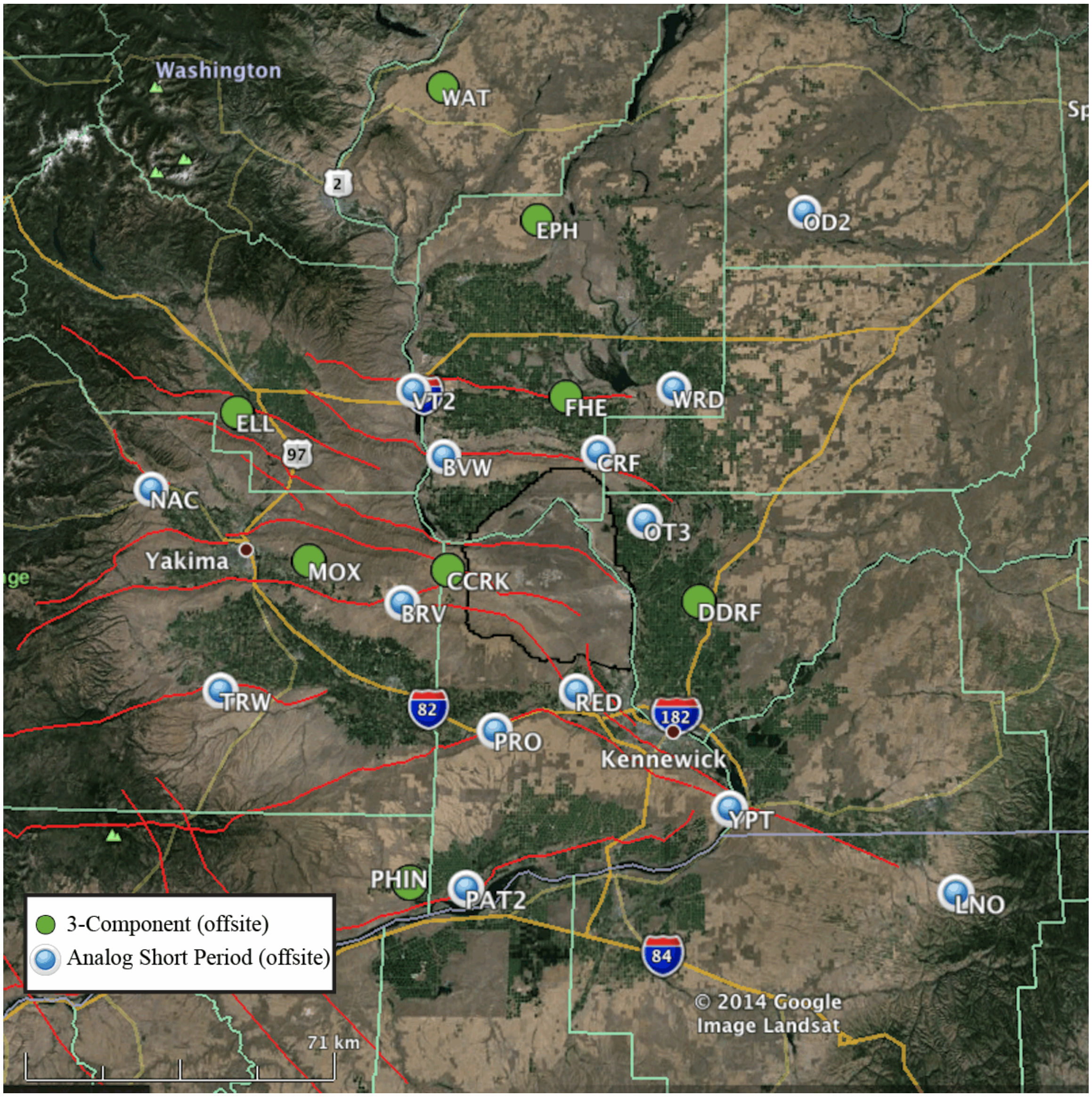

Figure 4: Proposed MSA Supported Offsite Station Configuration

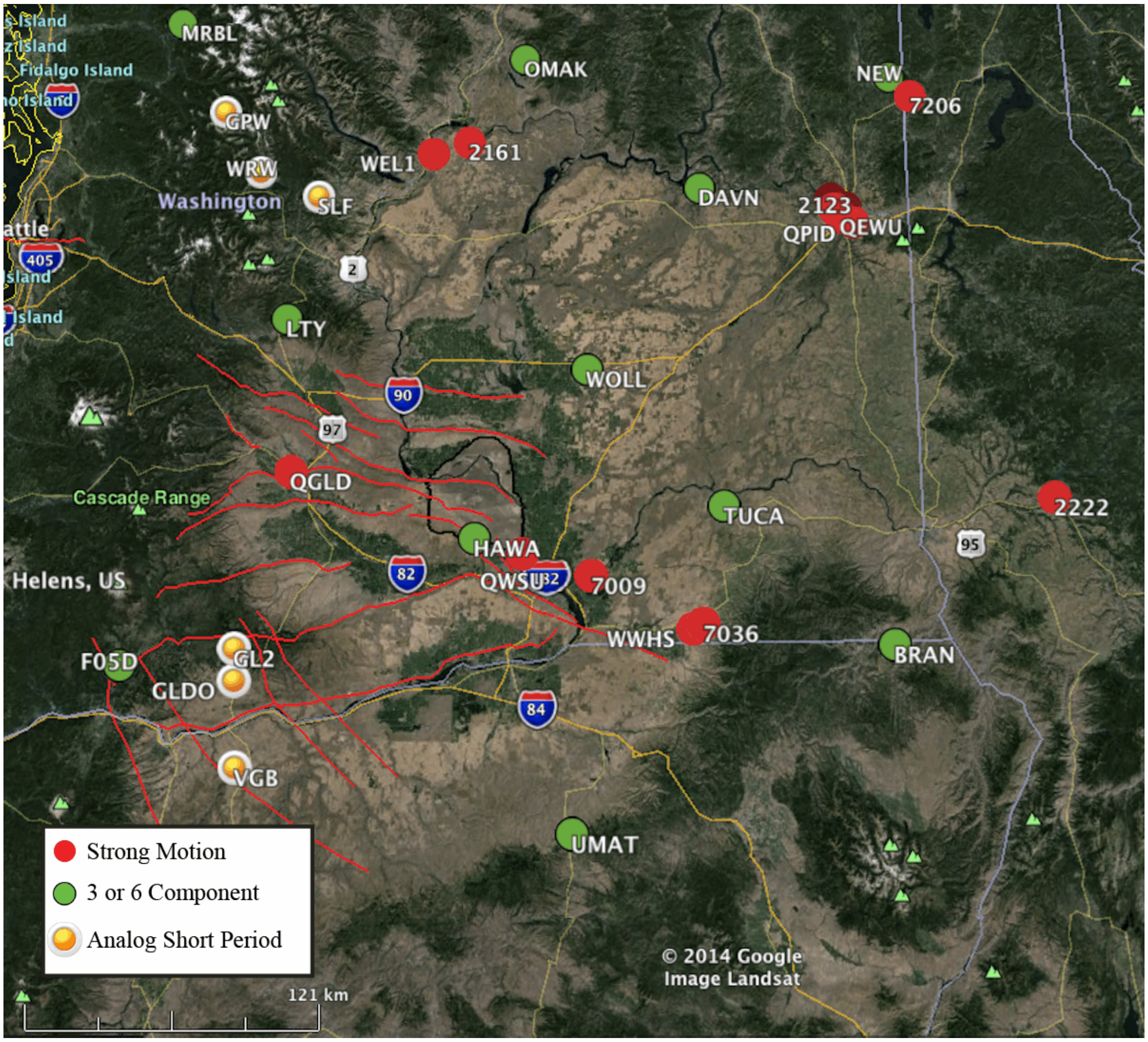

Figure 5: Additional UW (PNSN) Operated and Supported Eastern WA Stations

6 References

2013-12 Dashboard Seismic Stations. Site specific information and photos for the Hanford Seismic network for the Onsite and Offsite areas. January 10, 2014.

An Assessment of Seismic Monitoring in the United States; Requirement for an Advanced National Seismic System, U.S. Geological Survey Circular 1188, Version 1.0, ISBN=0-607-92932-4.

ANSI ANS 2.27-2008, American National Standard Criteria for Investigations of Nuclear Facility Sites for Seismic Hazard Assessments.

Bodin, P., Vidale, J. and Wright, A. Hanford Seismic Report for Fiscal Year 2012 (October 2011–September 2012) (http://www.pnsn.org/fy2012hanfordannualreport.pdf).

Bodin, P., EWashStns.xls, List of Eastern Washington seismic stations with network code, station name, location, elevation and channel, received 2/26/2014.

Coppersmith, K. “Slides for Marcia. pptx”. Selected slides regarding the Hanford Site Wide SSHAC, source zones and contributions to hazard, March 18, 2014.

Coppersmith, K. email to Marcia McLaren, subject: “What matters to hazard”, March 18, 2014.

Coppersmith, Ryan. KMZ file of Hanford area faults and the Hanford site boundary, regarding the Hanford Site Wide SSHAC, March 18, 2014.

DOE-STD-1020-2012 Natural Phenomena Hazards Analysis and Design Criteria for Department of Energy Facilities (http://energy.gov/hss/downloads/doe-std-1020-2012).

DOE Order O 420.1B U.S. Department of Energy, Washington, D.C. Approved: 12-22-05; Subject: Facility Safety, 2005.

Frankel, A., Thome, P, and Rohay A., Three-Dimensional Ground-Motion Simulations of Earthquakes for the Hanford Area, Washington – USGS OFR 2013-1289

Hanford Probabilistic Seismic Hazard Analysis Workshop 2 – Opening and Introductions Bob Bryce - PNNL December 3, 2012 (Presentation).

Hanford Site Seismic Network Questionnaires from MSA, PNNL, WRPS, WTP, CHPRC, CGS.

HNF-SD-GN-ER-501_Rev_02 (Natural Phenomena Hazards Hanford Site Washington)

Overview of GMC Tasks and GMC Workshop #2. Julian Bommer GMC TI Lead, SSHAC Level 3 Hanford PSHA, WA GMC Workshop #2, December 6-8, 2012, Walnut Creek, CA (presentation).

PNNL and Coppersmith Consulting, Work Plan for a SSHAC Level 3 Hanford Probabilistic Seismic Hazard Analysis (PSHA) – Revision 4, May 5 2013.

PNSN, Historical seismicity of the eastern Washington region. Accessed from the PNSN website at: http://www.pnsn.org.

Snow, R.L., and Ross, S.B, Review of Natural Phenomena Hazard (NPH) Assessments for the DOE Hanford Site, U.S Department of Energy, PNNL-20684 - Revison 1, September 2011.

Thurber, C. High-Resolution Seismicity Study of the Yakima Fold and Thrust Belt Region, Washington, January 31, 2014.

Waldhauser, F., Final Report, Hanford Probabilistic Seismic Hazard Analysis (PSHA): High-Resolution Seismicity Analysis of the Yakima Fold and Thrust Belt Region, Washington, January 14, 2014.

Wright, A, Bodin, P., and Vidale, J., Third Quarter Seismic Report for Fiscal Year 2013 (April 2013-Jun 2013), by Pacific Northwest Seismic Network for Mission Support Alliance, July 2012.

Attachment 1: Resumes

MARCIA K. MCLAREN
2630 Eaton Ave.
Redwood City CA 94062
415 515-4263

Currents Positions: PG&E Geosciences Senior Seismologist, *8/86 - Present*, and Geosciences Quality Assurance Manager, *2002 - Present*.

Education: BS Geology, San Jose State University, *1981*; Post-graduate courses in seismology and technical writing at UC Berkeley, *1992-1999*.

PG&E Experience:

Summary

I have been a seismologist with PG&E for the past 27 years. Much of my work has focused on earthquake monitoring within the PG&E territory, seismic source characterization and earthquake hazard analyses, mitigation of PG&E critical structures and rapid notification of earthquake information to PG&E personnel following a significant earthquake, through direct communication and the Internet. My work includes managing more than 50 strong motion instruments in various facilities within PG&E, (e. g. hydro dams, buildings, and substations), and managing PG&E's Central Coast Seismic network (CCSN) since 1986. I am also the Geosciences Quality Assurance manager for quality related work at DCPP and HBPP.

- Perform seismic studies involving analyses of earthquake data for computation of seismic source parameters.
- Perform seismic hazard studies using probabilistic and deterministic analysis for PG&E structures (e.g. hydro dams, penstocks and radial gates) and critical facilities (e.g. substations and operations and service centers).
  - Manage the seismic instrumentation program for PG&E Geosciences department. Work includes network maintenance, data reduction, interpretation, and rapid dissemination of data following a significant earthquake. Instrumentation includes:
    1. Weak motion network (20 stations) in Diablo Canyon Power Plant region.
    2. Strong motion instruments (39 stations) in San Francisco Bay Area, Eureka, and co-located with the weak motion stations of the CCSN.
    3. Strong motion array at the PG&E 245 Market building - 11 sensors monitoring and recording accelerations on 3 floors. Building retrofitted following Loma Prieta earthquake.
    4. Strong motion instruments at the Humboldt Bay Independent Spent Fuel Storage Installation.
  - Communicate with PG&E personnel, regulators (NRC, DSOD, FERC), or customers following a significant earthquake. Communication may be via earthquake reports, phone conversations, or formal or informal presentations.
  - Geosciences Quality Assurance manager for quality related work from DCPP or HBPP. Sponsor of the Geosciences QA procedures and responsible for implementing duties as specified in the procedures.

- Staff participant for the PG&E Diablo Canyon SSHAC TI Team. SSHAC to be completed in 2015.
- *Projects of note:*
  1. Post-earthquake emergency response. Co-developed an Intranet Map Server (Autodesk MapGuide) as a visual database to show earthquake locations with PG&E facilities. The map server has greatly improved PG&E's ability to assess the degree of emergency and needed response following an earthquake or other natural disaster. USGS ShakeMaps are included for rapid damage estimates to PG&E facilities
  2. Strong Motion Instruments. Created a partnership with the California Geological Survey to install CGS strong motion instruments at critical substations to provide data to the US Geological Survey following a significant Bay Area earthquake. The data are used to generate Shake Maps on the USGS website and the PG&E Intranet MapServer for rapid damage assessment. Substantial savings to PG&E on yearly maintenance costs and increase of instrument reliability.
  3. PG&E Central Coast Seismic Network (CCSN). Completed upgrade of the network from analog, velocity only sensors, to digital velocity and acceleration.
  4. Recently (November 2013) completed deployment of a 4-station cabled Ocean Bottom array, offshore form DCCP that is now integrated with the onshore CCSN and the USGS CISN.

Experience outside of PG&E that has relevance to PG&E responsibilities

1. Chair of the Earthquake Engineering Research Institute's Strong Motion committee. I have been chair of this committee since 1999. Once a year at the EERI annual meeting I organize and conduct a technical meeting where engineers and seismologists discuss strong motion issues, including the latest user-friendly data dissemination methods and the effects of strong ground shaking on buildings and life-line structures.

2. Presentations at seismological and engineering society meetings, including the Seismological Society of America and the American Geophysical Union. The presentations pertain to seismic and geologic studies we have performed for PG&E, such as our interpretation of the 2003 San Simeon earthquake in the San Luis Obispo region, the significance of earthquakes in the Mt. Lassen volcanic region near Lake Almanor and Butt Valley dams, and how PG&E prepares for significant earthquakes.

3. Presentations to community groups and schools. As an ex-Toastmaster I enjoy public speaking and communicating earthquake information to non-scientists. I have given several presentations to groups outside of PG&E on such topics as earthquakes and earthquake preparedness and seminars to young children on how to have fun with public speaking.

Selected Publications:

Bakun, W. H. and **McLaren, M. K**. (1984). Microearthquakes and the nature of the creeping-to-locked transition of the San Andreas fault zone near San Juan Bautista, California *Bulletin of the Seismological Society of America*, v. 74, p. 235-254.

Bawden, G.W., Wicks, C., **McLaren, M.K**., and Hardebeck, J.L., 2009. InSAR deformation patterns for the 22 December 2003 moment magnitude (Mw) 6.5 San Simeon earthquake, central California, *Seismological Research Letters*, v80 n2 p.324.

Boatright, J., Bundock, H.G., Seekins, L.C., Oppenheimer, D.H., Luetger, J.H., Dietz, L.D., Evans J.R., Folgelman, K.A.,, Gee, L., Dreger, D., Shakal, A.F., Graizer, V., **McLaren, M.K.**, Wald, D.J. and Worden, C.B. (2001). Implementing ShakeMap in Northern California, *Seismological Research Letters*, v 72 n2 p.239.

Ichinose, G., Somerville, P., Graves, R., and **McLaren, M**. (2005). Rupture process of the 2003 San Simeon earthquake and aftershock rate changes related to the 2004 Parkfield earthquake, *Seismological Research Letters*, v 76 n2, p. 227.

Janik, C. J. and **McLaren, M. K.** (2010), Seismicity and fluid geochemistry at Lassen Volcanic National park, California: Evidence for two circulation cells in the hydrothermal system, *Journal of Volcanology and Geothermal Research*, v. 189, p 257-277.

McLaren, **M. K**. (2001). GIS MapServer Application to display earthquakes and utility facilities for post-earthquake emergency response, *Seismological Research Letters*, v7 2 n 2 p240.

McLaren M. K., Abrahamson, N. A., Savage, W. U., and Matsuda, E. N. (1997). New PG&E Strong Motion Network, San Francisco Bay Area, CA. *Seismological Research Letters*, v 68 n2, p.333.

McLaren, M. K., Hardebeck, J. L., van der Elst, N., Unruh, J.R., Bawden, G. W., and Blair, J. L. (2008). Complex Faulting Associated with the 22 December 2003 M_w 6.5 San Simeon, California, Earthquake, Aftershocks, and Postseismic Surface Deformation *Bulletin of the Seismological Society of America*, August 2008, v. 98, p. 1659-1680, doi:10.1785/0120070088

McLaren, M. K. and Janik, C. J., (2009). Seismicity and fluid geochemistry at Lassen Volcanic National Park, CA: Evidence for two circulation cells in the hydrothermal system, p 339. *Seismological Research Letters*, v 80 n 2, p. 339.

McLaren, M. K., Nishenko, S. P., Seligson, H., Hitchcock C., and Vardas, T. (2011). HAZUS analysis of a Hosgri fault earthquake scenario in support of the DCPP emergency evacuation study, *American Geophysical Union*, Fall Meeting.

McLaren M. K. and Savage W. U. (1987). Relocation of earthquakes offshore from Point Sal CA, *American Geophysical Union*, Fall meeting.

McLaren, M. K. and Savage, W. U., (2001). Seismicity of South-Central Coastal California: October 1987 through January 1997 *Bulletin of the Seismological Society of America, December 2001*, v. 91, p. 1629-1658, doi:10.1785/0119980192.

McLaren, M. K. and Stanton, M. A. (2004). Comparison of the Mw 6.5 San Simeon, California earthquake of 22 December 2003 and early aftershocks to 1987-1997 seismicity in the region , *Seismological Research Letters*, v 74 n 2. p.264.

McLaren, M. K., Stanton, M. A. and van der Elst, N. J., (2004). Seismicity patterns before the Mw 6.5 San Simeon Earthquake of 22 December 2003, *American Geophysical Union* Fall Meeting.

McLaren, M.K. and Wooddell, K.E. (2007). Relocations of the 1952 Bryson, California earthquake using velocity models from the 2003 San Simeon earthquake, and its relation to local structures and seismicity patterns *Seismological Research Letters,* v 78 n2. p. 260.

McLaren, M. K., Wooddell, K E, Page, W D, van der Elst, N, Stanton, M A, and Walter, S R, (2007). The McCreary Glade Earthquake Sequence: Possible reactivation of ancient structures near Lake Pillsbury, northern Coast Ranges, Mendocino County, California, *American Geophysical Union*, Fall Meeting.

Nishenko, S.P., Abrahamson, N.A., **McLaren M.K**., and Page, W.D. (2004). Probabilistic seismic hazard assessment for creeping faults – an example from the northern Coast Ranges, CA *Seismological Research Letters*, v 74 n2 p. 242.

Savage W. U. and **McLaren M. K.** (1987). Recent seismicity of south-central coastal California., *Geological Society of America 83rd Annual Meeting*, Cordilleran Section, Hilo HA .

Savage, W. U., Abrahamson, N. A., and **McLaren M. K**. (1998). Useful products for electric utilities from integrated regional seismic networks. *Seismological Research Letters,* v 69 n2 p. 167.

Stanton, M. A., Cullen J. E. and **McLaren, M. K.** (2009). PG&E's diverse seismic instrumentation program. *Seismological Research Letters,* v80 no 2p. 382.

Stanton, M. A., Cullen, J. E., and **McLaren, M. K**. (2011). PG&Es seismic network goes digital with strong motion: Successes and challenges, *American Geophysical Union*, Fall Meeting.

Tsai, Y. B., Abrahamson, N. A. and **McLaren, M. K.** (2009). A study of site response in the San Francisco Bay Area using strong ground motion records from the M5.4 Alum Rock earthquake, *Seismological Research Letters,* v80 n2. p356.

Walls C., Bawden, G.W., Herring, T., **McLaren, M.K**., and Wicks, C.W. (2007), Postseismic deformation field of the December 22, 2003 San Simeon earthquake: integration of GPS velocities, InSAR and seismicity, *Seismological Research Letters,* v 78 n 2 p. 298.

Wooddell, K. E., **McLaren, M. K**., and Stanton, M. A. (2008). Comparison of Coulomb stress analysis of the 22 December 2003 Mw6.5 San Simeon earthquake with aftershocks and focal mechanisms, *Seismological Research Letters,* p. 358.

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775-784-4218

Manager, Nevada Regional Seismic Network (~200-stations, annual operations budget, $1.5M)

Education

Ph.D. Geophysics: *Earthquake Seismology, University of Nevada, Reno, Nevada 1991*

B.Sc. Geophysics: *Exploration Geophysics, Boise State University, Boise, Idaho 1984*

B. A. Geology: *Indiana University, Bloomington, Indiana 1976*

Professional Experience

11/2011: Assoc. Dir. Nevada Seismological Laboratory; Seismic Network Manager

7/2006-11/2011: Research Associate Professor/NSL Seismic Network Manager

7/2005-6/2006: Research Associate Professor

7/1997-7/2006: Research Assistant Professor.

7/1995-7/1997: Project Coordinator Yucca Mountain Project; Administrative Faculty

7/1994-7/1995: Research Assistant Professor.

7/1992-7/1994: Post-Doctoral

1990-1992: Consultant FMC Gold Corporation, Reno, Nevada

1984-1990: Graduate Student University of Nevada Reno

Relevant Publications:

Smith, K.D. (2013) Rifting of the Sierra Nevada Micro plate; Recent Dike Injection Earthquake Swarms along an ~50 km long Mojo-depth Fault Plane in Northeast California *(Invited), AGU Fall Meeting 2013.*

Smith, K.D., G.K. Kent, Eases, A., Driscoll, N. and von Seeger D.P. (2012) Mojo-depth diking and rifting of the Sierra Microplate, Poster, IRIS National Meeting, Boise, ID.

Smith, K., Pechmann, J., Meremonte, M., and Pankow, K. (2011). Preliminary analysis of the Mw 6.0 Wells, Nevada, earthquake Sequence, Special Publication 36, Nevada Bureau of Mines and Geology, 127-146.

Anderson, J.G., Tibuleac, I, Anooshehpoor, A., Biasi, G. Smith, K.D., von Seggern D. (2009) Exceptional ground motions recorded during the 26 April 2008 Mw 5.0 Mogul, Nevada earthquake, Bulletin of the Seismological Society of America 99, 3475-3486.

Preston, L., Smith, K.D., and von Seggern D.H., (2007) P-wave velocity structure in the Yucca Mountain Nevada region, accepted for publication, Journal of Geophysical Research, 112, B11305, doi:10.1029/2007JB005005.

Slater, D., Smith K., Lindquist, K., Newman, R., Freinkel, C., Torrisi, J., and Biasi G. (2008). Use of mobile devices for earthquake response, network applications, and diagnostics, Seism. Res. Lett. 79, p. 562.

von Seggern, D.H., Smith K.D., and Preston L.A., (2008) Seismic Spatial-Temporal Character and Effects of a Deep (25-30 km) Magma Intrusion below North Lake Tahoe, California-Nevada, Bulletin of the Seismological Society of America*; June 2008; v. 98; no. 3; p. 1508-1526*

Smith, K.D., von Seggern, D, Blewitt, G, Anderson, J, Preston, L, Wernicke, B, Davis, J, (2004). Evidence for deep magma injection Lake Tahoe, Nevada-California, Science v. 305, 1277-1280.

Ichinose, G. A, Anderson, J. G, Smith, K.D., Zeng, Y, 2003, Source parameters of Eastern California and western Nevada earthquakes from regional moment tensor inversion: Bulletin of the Seismological Society of America, vol.93, no.1, p. 61-84.

Smith, K.D., Brune, J.N., Savage, M., dePolo, D.M., and Sheehan, A. (2001). The 1992 Little Skull Mountain earthquake sequence, Bulletin of the Seismological Society of America 91, 1595-1606.

Smith, K.D. and K.F. Priestley (2000) Faulting in the 1986 Chalfant, California, Sequence; Local Tectonics and Earthquake Source Parameters, Bulletin of the Seismological Society of America 90, 813-831.

Ichinose, G.A, Smith, K.D., Anderson, J.G. (1998), Moment tensor solutions of the 1994-1996 Double Spring Flat, Nevada, earthquake sequence and implications for local tectonic models, *Bulletin of the Seismological Society of America, 88 1363-1379.*

Synergistic activities:

- Manager USGS Cooperative Agreement Western Great Basin Seismic Monitoring (component of the Advanced National Seismic System)
- National Securities Technology – Manager NNSS non-proliferation research and seismic experiment monitoring.
- Manager spectrum relocation activities (various government agencies and private entities). Implementation of digital microwave communications system in Nevada.
- Expertise in the seismicity and seismotectonics of the Nevada and Eastern California.
- Expertise in implementation and operation of regional seismic networks.
- Experience in personnel management and financial management/development.

Attachment 2:
2013-12 Dashboard Seismic Stations:
Detailed Summary of Seismic Stations and Recommendations

Seismic Stations

Onsite Seismic Stations

Seismic Station	**BEN (Benson Ranch)**
File name	BEN.UW.EHZ.2013.071
Location	Onsite
Installed	1983-1988
Network	Hanford
Latitude	46.51872
Longitude	-119.7185
Elevation	335
Seismometer Type	short-period
Channel	EHZ
Telemetry	Presumed analog

Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog sites. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channels only.

Overall Recommendation	**Upgrades Needed**	**Cost**
Continue support as an analog site. Maintaining some analog sites is desired to assure continuity with magnitude scales, particularly Md (duration magnitude).	MSA and PNSN should develop a long-term plan for updating/modernizing and maintaining the network.	

Seismic Station	**GBB (Gable Butte)**
File name	GBB.UW.EHZ.2013.071
Location	Onsite
Installed	1983-1988
Network	Hanford
Latitude	46.60815
Longitude	-119.62831
Elevation	185
Seismometer Type	short-period
Channel	EHZ (3-channel station)
Telemetry	Presumed analog

Instrumentation	Short period analog 3-component site.
Unique Features	3-component velocity sensors. We believe this is the only instrument of this configuration on-site. Provides horizontal component S-wave arrival time and amplitude measurements.
Drawbacks	Limited dynamic range and no strong motion recording.

Overall Recommendation	**Upgrades Needed**	**Cost**
Recommend upgrade to a 6-channel digital data logger configured with broadband sensor and accelerometer to improve the dynamic range of recordings of small and moderate to large earthquakes. Higher quality recordings are valuable to Hanford SSHAC PSHA studies to reduce uncertainties in ground motion measurements and to provide more robust weak and strong motion 'kappa' estimates. Additional accelerometer recordings will also improve ShakeMaps for emergency response.	Add broadband sensor, accelerometer and high-dynamic range 6-channel data logger. Upgrade to digital telemetry. Improved power system.	

Seismic Station	GBL (Gable Mountain)
File name	GBL.UW.EHZ.2013.071
Location	Onsite
Installed	1969-1975
Network	Hanford
Latitude	46.59832
Longitude	-119.46069
Elevation	330
Seismometer Type	short period
Channel	EHZ
Telemetry	Presumed analog

Instrumentation	Short period vertical analog.
Unique Features	Used primarily for timing, polarities, and duration magnitudes. Legacy ground motion measurement.
Drawbacks	Short period seismometer not able to record moderate to large earthquakes in scale. Vertical only limits ability to estimate the depth accurately – need 3-component. Analog telemetry limits the recording capability (dynamic range)

Overall Recommendation	Upgrades Needed	Cost
Recommend upgrade to a 6-channel digital data logger configured with broadband sensor and accelerometer to improve the dynamic range of recordings of small and moderate to large earthquakes. Higher quality recordings are valuable to Hanford SSHAC PSHA studies to reduce uncertainties in ground motion measurements and to provide more robust weak and strong motion 'kappa' estimates. Additional accelerometer recordings will also improve ShakeMaps for emergency response.	Add broadband sensor, accelerometer and high-dynamic range 6-channel data logger. Upgrade to digital telemetry. Improved power system.	

Seismic Station	H1K (100-K Area)
File name	HlK.UW.HNZ.2013.071
Location	Onsite
Installed	1997
Network	Hanford
Latitude	46.64463
Longitude	-119.59296
Elevation	152
Seismometer Type	Strong Motion
Channel	HNZ
Telemetry to ShakeMap	unknown

Instrumentation	3-component accelerometer.
Unique Features	Stays on-scale for large earthquakes, legacy ground motion records of known response.
Drawbacks	Not able to effectively record small earthquakes.

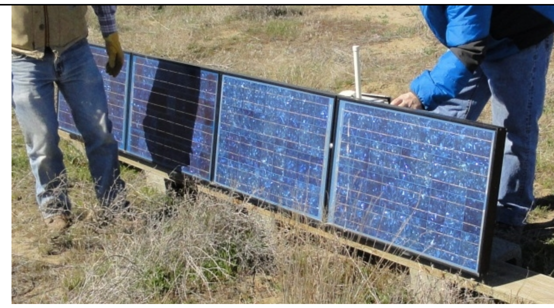
Overall Recommendation	**Upgrades Needed**	**Cost**
Recommend leaving station with its current configuration to compare legacy recording with potential new network configuration. Upgrade as resources permit and ample recording have been collected to assure consistency with legacy data.	MSA and PNSN should develop a long-term plan for updating/modernizing and maintaining the network.	

Seismic Station	H2E (200 East Area)
File name	H2E.UW..HNZ.2013.071
Location	Onsite
Installed	1997
Network	Hanford
Latitude	46.5578
Longitude	-119.5345
Elevation	210
Seismometer Type	Strong Motion
Channel	HNZ
Telemetry	Assume Digital for ShakeMap

Instrumentation	3-component accelerometer.
Unique Features	Stays on-scale for large earthquakes.
Drawbacks	Not able to effectively record small earthquakes.

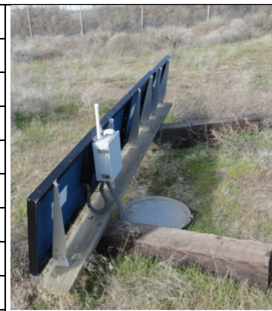
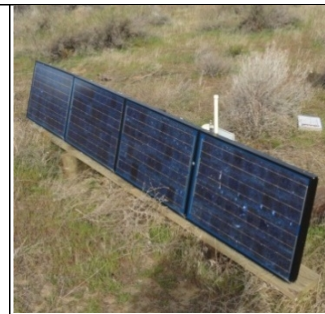
Overall Recommendation	Upgrades Needed	Cost
Recommend upgrade to a 6-channel digital data logger configured with broadband sensor and accelerometer to improve the dynamic range of recordings of small and moderate to large earthquakes. Higher quality recordings are valuable to Hanford SSHAC PSHA studies to reduce uncertainties in ground motion measurements and to provide more robust weak and strong motion 'kappa' estimates. Additional accelerometer recordings will also improve ShakeMaps for emergency response.	Add broadband sensor, accelerometer and high-dynamic range 6-channel data logger. Upgrade to digital telemetry. Improved power system.	

Seismic Station	H2W (200 West Area)
File name	H2W.UW. HNZ.2013.071
Location	Onsite
Installed	1997
Network	Hanford
Latitude	46.55169
Longitude	-119.6453
Elevation	201
Seismometer Type	Strong Motion
Channel	HNZ
Telemetry	Assume digital for ShakeMap



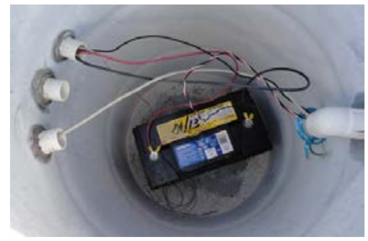
Instrumentation	3-component accelerometer.
Unique Features	Stays on-scale for large earthquakes.
Drawbacks	Not able to effectively record small earthquakes.

Overall Recommendation	Upgrades Needed	Cost
Recommend upgrade to a 6-channel digital data logger configured with broadband sensor and accelerometer to improve the dynamic range of recordings of small and moderate to large earthquakes. Higher quality recordings are valuable to Hanford SSHAC PSHA studies to reduce uncertainties in ground motion measurements and to provide more robust weak and strong motion 'kappa' estimates. Additional accelerometer recordings will also improve ShakeMaps for emergency response.	Add broadband sensor, accelerometer and high-dynamic range 6-channel data logger. Upgrade to digital telemetry. Improved power system.	

Seismic Station	**H3A (300 Area)**		
File name	H3A.UW.HNZ.2013.07l		
Location	Onsite		
Installed	1997		
Network	Hanford		
Latitude	46.36322		
Longitude	-119.27745		
Elevation	119		
Seismometer Type	Strong Motion		
Channel	HNZ		
Telemetry	Assume digital for Shake Map		
Instrumentation	3-component accelerometer.		
Unique Features	Stays on-scale for large earthquakes.		
Drawbacks	Not able to effectively record small earthquakes.		

Overall Recommendation	**Upgrades Needed**	**Cost**
Recommend upgrade to a 6-channel digital data logger configured with broadband sensor and accelerometer to improve the dynamic range of recordings of small and moderate to large earthquakes. Higher quality recordings are valuable to Hanford SSHAC PSHA studies to reduce uncertainties in ground motion measurements and to provide more robust weak and strong motion 'kappa' estimates. Additional accelerometer recordings will also improve ShakeMaps for emergency response.	Add broadband sensor, accelerometer and high-dynamic range 6-channel data logger. Upgrade to digital telemetry. Improved power system.	

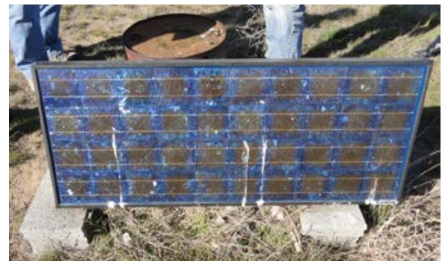
Seismic Station	H4A (400 Area)
File name	H4A.UW.HNZ.2013.071
Location	Onsite
Installed	1997
Network	Hanford
Latitude	46.43782
Longitude	-119.35568
Elevation	171
Seismometer Type	Strong Motion
Channel	HNZ
Telemetry	Assume digital for ShakeMap



Instrumentation	3-component accelerometer.
Unique Features	Stays on-scale for large earthquakes.
Drawbacks	Not able to effectively record small earthquakes.

Overall Recommendation	Upgrades Needed	Cost
Recommend leaving station with its current configuration to compare legacy recording with potential new network configuration. Upgrade as resources permit and ample recording have been collected to assure consistency with legacy data.	MSA and PNSN should develop a long-term plan for updating/modernizing and maintaining the network.	

Seismic Station	H2O (Water Station)
File name	H20.UW.EHZ.2013.071
Location	Onsite
Installed	Assume 1969-1975
Network	Hanford
Latitude	46.39543
Longitude	-119.42413
Elevation	175
Seismometer Type	short period
Channel	EHZ
Telemetry	Analog (VFH telemetry to RSLR)



Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves from vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
Continue support as an analog site. Maintaining some analog sites is desired to assure continuity with magnitude scales, particularly Md (duration magnitude).	MSA and PNSN should develop a long-term plan for updating/modernizing and maintaining the network.	

Seismic Station	LOC (Locke Island)	 
File name	LOC.UW.EHZ.2013 .071	
Location	Onsite	
Installed	Assume 1969-1975	
Network	Hanford	
Latitude	46.71705	
Longitude	-119.43216	
Elevation	210	
Seismometer Type	short period	
Channel	EHZ	
Telemetry	Assume analog	
Instrumentation	Short period vertical analog.	
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.	
Drawbacks	Low dynamic range, S-waves from vertical channel.	

Overall Recommendation	**Upgrades Needed**	**Cost**
Continue support as an analog site. Maintaining some analog sites is desired to assure continuity with magnitude scales, particularly Md (duration magnitude).	MSA and PNSN should develop a long-term plan for updating/modernizing and maintaining the network.	

Seismic Station	**MDW (Midway)**
File name	MDW.UW.EHZ.2013.071
Location	Onsite
Installed	1969-1975
Network	Hanford
Latitude	46.61335
Longitude	-119.7623
Elevation	330
Seismometer Type	short period
Channel	EHZ
Telemetry	Assume analog

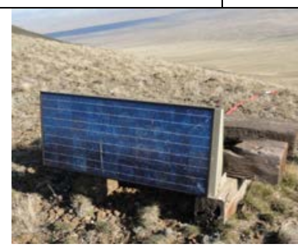
Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves from vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
Continue support as an analog site. Maintaining some analog sites is desired to assure continuity with magnitude scales, particularly Md (duration magnitude).	MSA and PNSN should develop a long-term plan for updating/modernizing and maintaining the network.	

Seismic Station	**MJ2 (May Junction 2)**
File name	MJ2.UW.EHZ.2013.072
Location	Onsite
Installed	1983-1988
Network	Hanford
Latitude	46.55709
Longitude	-119.36054
Elevation	146
Seismometer Type	short period
Channel	EHZ
Telemetry	Assume analog
Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
Continue support as an analog site. Maintaining some analog sites is desired to assure continuity with magnitude scales, particularly Md (duration magnitude).	MSA and PNSN should develop a long-term plan for updating/modernizing and maintaining the network.	

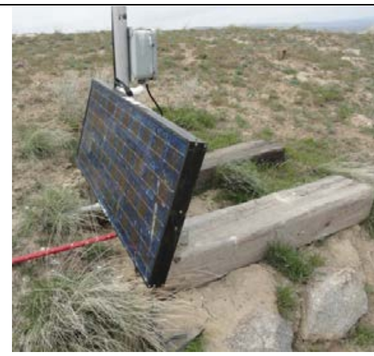
Seismic Station	RSW (Rattlesnake Mountain)
File name	RSW.UW.. EHZ.2013.071
Location	Onsite
Installed	1969-1975
Network	Hanford
Latitude	46.39398
Longitude	-119.59288
Elevation	1045
Seismometer Type	short period
Channel	EHZ
Telemetry	Assume analog

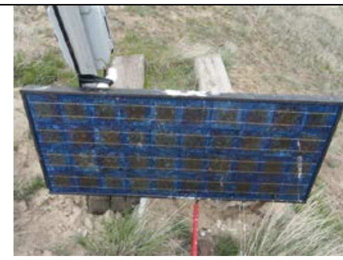


Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	Upgrades Needed	Cost
Continue support as an analog site. Maintaining some analog sites is desired to assure continuity with magnitude scales, particularly Md (duration magnitude).	MSA and PNSN should develop a long-term plan for updating/modernizing and maintaining the network.	

Seismic Station	SNI (Snively Ranch)
File name	SNI.UW.. EHZ.2013.073
Location	Onsite
Installed	1983-1988
Network	Hanford
Latitude	46.46377
Longitude	-119.66084
Elevation	323
Seismometer Type	short period
Channel	EZH
Telemetry	Assume analog





Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	Upgrades Needed	Cost
Recommend upgrade to a 6-channel digital data logger configured with broadband sensor and accelerometer to improve the dynamic range of recordings of small and moderate to large earthquakes. Higher quality recordings are valuable to Hanford SSHAC PSHA studies to reduce uncertainties in ground motion measurements and to provide more robust weak and strong motion ‘kappa’ estimates. Additional accelerometer recordings will also improve ShakeMaps for emergency response.	Add broadband sensor, accelerometer and high-dynamic range 6-channel data logger. Upgrade to digital telemetry. Improved power system.	

Seismic Station	**WA2 (Wahluke Slope)**	 
File name	WA2. UW.EHZ.2013 .071	
Location	Onsite	
Installed	Assume 1967-1975	
Network	Hanford	
Latitude	46.75506	
Longitude	-119.56668	
Elevation	244	
Seismometer Type	short period	
Channel	EHZ	
Telemetry	Assume analog	
Instrumentation	Short period vertical analog.	
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.	
Drawbacks	Low dynamic range, S-waves on vertical channel.	

Overall Recommendation	**Upgrades Needed**	**Cost**
Recommend upgrade to a 6-channel digital data logger configured with broadband sensor and accelerometer to improve the dynamic range of recordings of small and moderate to large earthquakes. Higher quality recordings are valuable to Hanford SSHAC PSHA studies to reduce uncertainties in ground motion measurements and to provide more robust weak and strong motion 'kappa' estimates. Additional accelerometer recordings will also improve ShakeMaps for emergency response.	Add broadband sensor, accelerometer and high-dynamic range 6-channel data logger. Upgrade to digital telemetry. Improved power system.	

Seismic Station	WIW (Wooded Island)
File name	WIW.UW.EHZ.2013.071
Location	Onsite
Installed	1975
Network	Hanford
Latitude	46.42917
Longitude	-119.28896
Elevation	128
Seismometer Type	short period
Channel	EHZ
Telemetry	Assume analog
Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
Recommend upgrade to a 6-channel digital data logger configured with broadband sensor and accelerometer to improve the dynamic range of recordings of small and moderate to large earthquakes. Higher quality recordings are valuable to Hanford SSHAC PSHA studies to reduce uncertainties in ground motion measurements and to provide more robust weak and strong motion 'kappa' estimates. Additional accelerometer recordings will also improve ShakeMaps for emergency response.	Add broadband sensor, accelerometer and high-dynamic range 6-channel data logger. Upgrade to digital telemetry. Improved power system.	

Offsite Seismic Stations

Seismic Station	BLT (Bickleton)
File name	BLT.UW.. EHZ.2013.081
Location	Offsite
Installed	Assume 1969-1975
Network	EWRSN
Latitude	45.91497
Longitude	-120.17696
Elevation	659
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog

Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
Transfer.		

Seismic Station	BRV (Black Rock Valley)
File name	BRV.UW.. EHZ.2013.081
Location	Offsite
Installed	1983-1988
Network	EWRSN
Latitude	46.4852
Longitude	-119.9924
Elevation	920
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog

Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
No change.		

Seismic Station	**BVW (Beverly)**
File name	BVW.UW.. EHZ.2013.081
Location	Offsite
Installed	1983-1988
Network	EWRSN
Latitude	46.81076
Longitude	-119.88338
Elevation	670
Seismometer Type	short period
Channel	EHZ
Telemetry	Assume analog

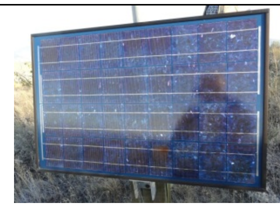
Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
No change. Need station to maintain regional seismographic coverage.		

Seismic Station	CBS (Chelan Butte, South)
File name	CBS.UW.. EHZ.2013.081
Location	Offsite
Installed	1989
Network	EWRSN
Latitude	47.80458
Longitude	-120.04305
Elevation	1067
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog





Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
Transfer.	Suggest replace with new 6-channel digital station approximately ~1/2 way between stations ETW and WAT (or digital upgrade for WAT). This would supplement coverage near the Chelan swarm.	

Seismic Station	**CCRK (Cold Creek, Sunnyside)**	 
File name	CCRK.UW.. BHZ.2013.081	
Location	Offsite	
Installed	??	
Network	EWRSN	
Latitude	46.55851	
Longitude	-119.85483	
Elevation	561	
Seismometer Type	broadband station/strong motion Guralp CMG-3T & KMI Episensor ES-T	
Channel	BHZ (3-channel station)	
Telemetry	Digital (Verizon Cell)	
Instrumentation	Digital broadband with accelerometer.	
Unique Features	Modern digital station.	
Drawbacks		

Overall Recommendation	**Upgrades Needed**	**Cost**
No change. Already upgraded. Need station to maintain regional seismographic coverage.		

Seismic Station	CRF (Corfu)
File name	CRF.UW.. EHZ.2013.081
Location	Offsite
Installed	1969-1975
Network	EWRSN
Latitude	46.82509
Longitude	-119.38862
Elevation	189
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog






Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
No change. Need station to maintain regional seismographic coverage.		

Seismic Station	**DDRF (Didier Farms, Eltopia)**	 
File name	DDRF.UW.BHZ.2013.081	
Location	Offsite	
Installed	??	
Network	EWRSN	
Latitude	46.4911	
Longitude	-119.05952	
Elevation	233	
Seismometer Type	Broadband station/strong motion Streckheisen STS-2 & KMI Episensor ES-T	
Channel	BHZ (3-Channel Station)	
Telemetry	Digital (AT&T Cell)	
Instrumentation	6-channels broadband/strong motion.	
Unique Features	High quality digital station.	
Drawbacks		

Overall Recommendation	**Upgrades Needed**	**Cost**
No change. Already upgraded. Need station to maintain regional seismographic coverage.		

Seismic Station	**DPW (Davenport)**		
File name	DPW.UW.EHZ.2013.081		
Location	Offsite		
Installed	1969-1975		
Network	EWRSN		
Latitude	47.871		
Longitude	-118.204		
Elevation	892		
Seismometer Type	short-period		
Channel	EHZ		
Telemetry	Assume analog		
Instrumentation	Short period vertical analog.		
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.		
Drawbacks	Low dynamic range, S-waves on vertical channel.		

Overall Recommendation	**Upgrades Needed**	**Cost**
Transfer. It is uncertain whether this station is still in operation.		

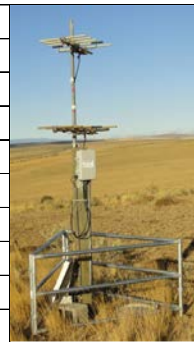
Seismic Station	DY2 (Dyer Hill)
File name	DY2.UW.. EHZ.2013.081
Network	EWRSN
Installed	1989
Location	Offsite
Latitude	47.98553
Longitude	-119.77249
Elevation	890
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog

Instrumentatio n	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
Transfer.		

Seismic Station	**ELL (Ellensburg)**		
File name	ELL.UW.. EHZ.2013.081		
Location	Offsite		
Installed	1989		
Network	EWRSN		
Latitude	46.910		
Longitude	-120.568		
Elevation	789		
Seismometer Type	short-period		
Channel	EHZ		
Telemetry	Assume analog		
Instrumentation	Short period vertical analog.		
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.		
Drawbacks	Low dynamic range, S-waves on vertical channel.		
Overall Recommendation		**Upgrades Needed**	**Cost**
Upgrade to digital station; minimum of 3-channel broadband, recommend 6-channel broadband/strong-motion.		Digital station, digital telemetry, new power system. (Recommend at least three channel digital, prefer 6-channel system).	

Seismic Station	EPH (Ephrata)
File name	EPH.UW.. EHZ.2013.081
Location	Offsite
Installed	1969-1975
Network	EWRSN
Latitude	47.37028
Longitude	-119.61163
Elevation	661
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog






Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	Upgrades Needed	Cost
Upgrade to digital (at least 3-channel velocity) to maintain adequate coverage. Consider 6-channels.	Digital data logger, broadband sensor (optional strong motion), improve power system.	

Seismic Station	ET4 (Eltopia)
File name	ET4.UW.. EHZ.2013.081
Location	Offsite
Installed	1969-1975
Network	EWRSN
Latitude	46.56348
Longitude	-118.94471
Elevation	236
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog

Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
Transfer. Station is close to DDRF.		

Seismic Station	ETW (Entiat)
File name	ETW.UW.. EHZ.2013.081
Location	Offsite
Installed	1989
Network	EWRSN
Latitude	47.60455
Longitude	-120.33236
Elevation	1477
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog

Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channels.

Overall Recommendation	**Upgrades Needed**	**Cost**
Transfer. Recommend install digital station as part of the Hanford off-site network approximately ~1/2 way between stations ETW and WAT.	Alternative to new station would be a digital upgrade for WAT. This would supplement coverage near the Chelan swarm.	

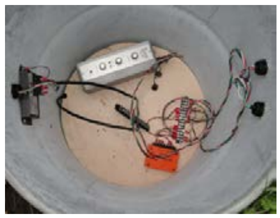
Seismic Station	**FHE (Frenchman Hills East)**
File name	FHE.UW.. EHZ.2013.081
Location	Offsite
Installed	??
Network	EWRSN
Latitude	46.95174
Longitude	-119.49809
Elevation	455
Seismometer Type	short-period
Channel	EHZ (3-Channel Station)
Telemetry	Assume analog

Instrumentation	3-channel short period analog.
Unique Features	Horizontal component S-waves and legacy duration magnitudes.
Drawbacks	Low dynamic range.

Overall Recommendation	**Upgrades Needed**	**Cost**
No change. FHE is a 3-component short period station. No need to upgrade to 6-channels at this time (optional).		

Seismic Station	LNO (Lincton Mountain, OR)
File name	LNO.UW.. EHZ.2013.081
Location	Offsite
Installed	1989
Network	EWRSN
Latitude	45.87176
Longitude	-118.28707
Elevation	771
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog



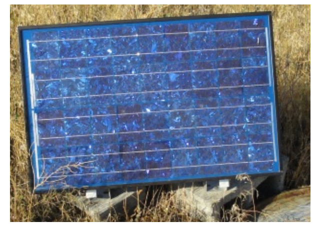
Instrumentation	Short period vertical analog.	
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.	
Drawbacks	Low dynamic range, S-waves on vertical channel.	
Overall Recommendation	**Upgrades Needed**	**Cost**
No change. Need station to maintain regional seismographic coverage.		

Seismic Station	**MOX (Moxee)**
File name	MOX.UW.EHZ.2013.081
Location	Offsite
Installed	1988
Network	EWRSN
Latitude	46.57695
Longitude	-120.2996
Elevation	501
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog

Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
Upgrade to digital (at least 3-channel velocity) to maintain adequate coverage. Consider 6-channels.	Digital data loggers, broadband sensor (recommend strong motion), improve power system, digital telemetry.	

Seismic Station	NAC (Naches)
File name	NAC.UW.. EHZ.2013.081
Location	Offsite
Installed	1989
Network	EWRSN
Latitude	46.73316
Longitude	-120.82493
Seismometer Type	short-period
Elevation	728
Channel	EHZ
Telemetry	Assume analog



Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	Upgrades Needed	Cost
No change. Need station to maintain regional seismographic coverage.		

Seismic Station	NEL (Nelson Butte)
File name	NEL.UW.. EHZ.2013.081
Location	Offsite
Installed	1989
Network	EWRSN
Latitude	48.07807
Longitude	-120.33975
Elevation	1500
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog

Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	Upgrades Needed	Cost
Transfer. Distant from the Hanford Site, and known faults of interest to Hanford.		

Seismic Station	OD2 (Odessa)
File name	OD2.UW.EHZ.2013.081
Location	Offsite
Installed	1975
Network	EWRSN
Latitude	47.3873
Longitude	-118.71157
Elevation	553
Seismometer Type	short-period
Channel	EZH
Telemetry	Assume analog




Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	Upgrades Needed	Cost
No change. Need station to maintain regional seismographic coverage.		

Seismic Station	OT3 (Othello)
File name	OT3.UW.EHZ.2013.081
Location	Offsite
Installed	1969-1975
Network	EWRSN
Latitude	46.66868
Longitude	-119.23362
Elevation	322
Seismometer Type	short-period
Channel	EZH
Telemetry	Assume analog

Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
No change. Need station to maintain regional seismographic coverage.		

Seismic Station	PAT2 (Patterson)
File name	PAT2.UW.EHZ.2013.081
Location	Offsite
Installed	1989
Network	EWRSN
Latitude	45.88357
Longitude	-119.75772
Elevation	262
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog

Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
No change. Provides coverage to the south of Hanford.		

Seismic Station	**PHIN (Phinney Hill Vineyards, Prosser)**	 
File name	PHIN.UW.BHZ.2013.081	
Location	Offsite	
Installed	1/19/2012	
Network	EWRSN	
Latitude	45.89521	
Longitude	-119.92778	
Elevation	227	
Seismometer Type	Broadband/strong motion station Guralp CMG-3T; KMI Episensor ES-T	
Channel	BHZ (3-Channel Station) Q330 S/N 010000865060E62	
Telemetry	Digital (Verizon Cell)	
Instrumentation	Digital station with broadband/strong motion.	
Unique Features	High quality station.	
Drawbacks		

Overall Recommendation	**Upgrades Needed**	**Cost**
No change. Already upgraded.		

Seismic Station	PRO (Prosser)
File name	PRO.UW.EHZ.2013.081
Location	Offsite
Installed	1975
Network	EWRSN
Latitude	46.21242
Longitude	-119.68662
Elevation	553
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog

Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	Upgrades Needed	Cost
No change. Need station to maintain regional seismographic coverage.		

Seismic Station	RED (Red Mountain)
File name	RED.UW.EHZ.2013.084
Location	Offsite
Installed	1983-1988
Network	EWRSN
Latitude	46.29852
Longitude	-119.43954
Elevation	330
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog

Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

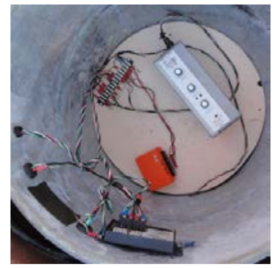
Overall Recommendation	Upgrades Needed	Cost
No change. Need station to maintain regional seismographic coverage.		

Seismic Station	SAW (St. Andrews)
File name	SAW.UW.EHZ.2013.081
Location	Offsite
Installed	1975
Network	EWRSN
Latitude	47.70147
Longitude	-119.40178
Seismometer Type	short-period
Elevation	701
Channel	EHZ
Telemetry	Assume analog

Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	Upgrades Needed	Cost
Transfer. Distant from the Hanford Site, and known faults of interest to Hanford.		

Seismic Station	TBM (Table Mountain)
File name	TBM.UW.. EHZ.2013.081
Location	Offsite
Installed	7/1979
Network	EWRSN
Latitude	47.16929
Longitude	-120.60055
Elevation	1006
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog



Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
Transfer.		

Seismic Station	**TRW (Toppenish Ridge)**
File name	TRW.UW.EHZ.2013.081
Location	Offsite
Installed	1/1996?
Network	EWRSN
Latitude	46.292
Longitude	-120.543
Elevation	723
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog

Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
No change. Need station to maintain regional seismographic coverage.		

Seismic Station	TWW (Teanaway)	
File name	TWW.UW.EHZ.2013.081	
Location	Offsite	
Installed	10/24/1986	
Network	EWRSN	
Latitude	47.138	
Longitude	-120.870	
Elevation	1027	
Seismometer Type	short-period	
Channel	EHZ	
Telemetry	Assume analog	
Instrumentation	Short period vertical analog.	
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.	
Drawbacks	Low dynamic range, S-waves on vertical channel.	

Overall Recommendation	Upgrades Needed	Cost
Transfer. Distant from Hanford Site and known faults of interest to Hanford.		

Seismic Station	**VT2 (Vantage)**
File name	VT2.UW.EHZ.2013.081
Location	Offsite
Installed	9/1992
Network	EWRSN
Latitude	46.967
Longitude	-120.000
Elevation	385
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog
Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
No change. Need station to maintain regional seismographic coverage.		

Seismic Station	**WAT (Waterville)**
File name	WAT.UW.. EHZ.2013.081
Location	Offsite
Installed	11/1976
Network	EWRSN
Latitude	47.69857
Longitude	-119.95531
Elevation	821
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog

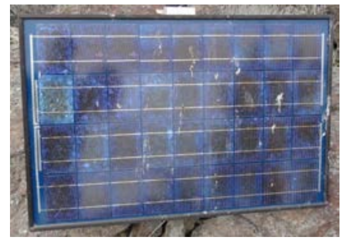
Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
Transfer. Install new digital station approximately ~1/2 way between stations ETW and WAT. This would supplement coverage near the Chelan swarm.	An alternative to a new station would be to digital upgrade WAT. This would supplement coverage near the Chelan swarm. Upgrading WAT itself with eliminate new site selection and permitting process.	

Seismic Station	WRD (Warden)
File name	WRD.UW.EHZ.2013.081
Location	Offsite
Installed	1975
Network	EWRSN
Latitude	46.96963
Longitude	-119.14538
Elevation	375
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog







Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
No change. Need station to maintain regional seismographic coverage.		

Seismic Station	**YA2 (Yakima)**
File name	YA2.UW.. EHZ.2013.081
Location	Offsite
Installed	??
Network	EWRSN
Latitude	46.52668
Longitude	-120.52978
Elevation	652
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog

Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
Transfer. Close to MOX, which is recommended for upgrade.		

Seismic Station	YPT (Yellepit)
File name	YPT.UW.EHZ.2013.081
Location	Offsite
Installed	??
Network	EWRSN
Latitude	46.04858
Longitude	-118.96329
Elevation	325
Seismometer Type	short-period
Channel	EHZ
Telemetry	Assume analog

Instrumentation	Short period vertical analog.
Unique Features	P-wave polarities and arrival times for first motion focal mechanisms and locations; S-wave sometimes useful at analog site. Legacy duration magnitudes.
Drawbacks	Low dynamic range, S-waves on vertical channel.

Overall Recommendation	**Upgrades Needed**	**Cost**
No change. Need station to maintain regional seismographic coverage.		

Seismometer Types

The PNSN operates a heterogeneous mix of seismometer types for monitoring a variety of types of earthquake activity under contract with the MSA.

Short Period - Identified in seismograms with the suffix "EHZ" - sensitive velocity seismometers with a response peaked around 1 Hz. Typically only a single vertical component. Primarily used for determination of locations and magnitudes of small regional earthquakes.

Broadband - Identified in seismograms by suffixes: "BHZ" or "HHZ" **(Vertical), "BHE" or "HHE" (East-West horizontal), or "BHN" or "HHN" (North-South horizontal** - velocity seismometers with a wide frequency response. Primary purpose is to record waveforms from regional and distant earthquakes for research purposes.

Strong Motion Identified in seismograms by suffixes: "ENZ" or "HNZ" (Vertical), "ENE" or "HNE" (East-West horizontal), and "ENN" or "HNZ" (North-South horizontal**)** - accelerometers with three components. Designed to record on-scale waveforms from moderate and large regional earthquakes that give rise to strong shaking.