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PLAN

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Hanford Site Seismic Monitoring Instrumentation Plan

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Westinghouse Hanford Company, Richland, WA 99352

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Abstract: This document provides a plan to comply with the seismic monitoring provisions of U.S. DOE Order 5480.28, Natural Phenomena Hazards.

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HANFORD SITE SEISMIC MONITORING INSTRUMENTATION PLAN

Carleton Moore and Stephen Reidel

January 1996

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EXECUTIVE SUMMARY

Requirements for Natural Phenomena Hazard (NPH) Detection contained in paragraph 10.d(1) of U.S. Department of Energy (DOE) Order 5480.28 state that facilities or sites that have structures, systems, or components (SSCs) in Performance Category (PC) 2 with hazardous material, PC-3, or PC-4 shall have instrumentation or other means to detect and record the occurrence and severity of seismic events. This plan defines a cost-effective detection system for Westinghouse Hanford Company (WHC) facilities that meets those requirements.

The existing Hanford seismic monitoring network is designed to detect, locate, and determine earthquakes with magnitudes as low as 1.5 or less. Although the network has only operated for less than 30 years, the largest earthquake recorded at Hanford in that time is less than a magnitude of 4.0 with most seismic events less than magnitude 3.0. These events have been demonstrated to be of no consequence to life, safety, or the safe function of PC-2, PC-3, and PC-4 SSCs. The Hanford seismic monitoring network is made up of primarily vertical sensors that cannot characterize seismic time histories for use in future evaluations of SSCs.

The geologic record indicates that the Hanford Site has had seismic events as large as magnitude 7.0. Since July 8, 1982, the Hanford Site has recorded approximate 650 earthquakes between the magnitudes of 0 and 3.8. The response from an event of magnitude 5.0 and larger, which could compromise the safety of Hanford SSCs, would exceed the scale of the current seismic instruments. Therefore, the strategy to achieve compliance with DOE Order 5480.28 and be able to evaluate Site structures following a seismic event is to augment the existing seismic monitoring network and team at Hanford with a proposed free-field network of strong motion accelerometers (SMA).

This approach provides WHC with real-time seismic response of strategic buildings to be used in conjunction with an emergency response plan along with seismic records to evaluate all other WHC buildings following a seismic event.

After a seismic event, the Seismic Monitoring Center would provide Hanford facility managers with key emergency response data so that they could implement the rest of the Emergency Response Plan to stabilize the systems and redeploy the facility staff.

Therefore, we propose the following:

1. Complement the existing seismic monitoring team and instrumentation and integrate with a minimum free-field SMA network. That will provide the most cost-effective method to install and maintain equipment, analyze data, and provide semi-real-time input to plant managers.
2. Install or upgrade to a digital recording, free-field SMA in each of the following areas: 100-K, 200 East, 200 West, 300, and 400.

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HANFORD SITE SEISMIC MONITORING INSTRUMENTATION PLAN

1.0 INTRODUCTION

During fiscal year 1993, the U.S. Department of Energy, Richland Operations Office (RL) transmitted U.S. Department of Energy (DOE) Order 5480.28, *Natural Phenomena Hazards Mitigation*, to Westinghouse Hanford Company (WHC) for compliance. This order became effective on TBD.

Requirements for Natural Phenomena Hazard (NPH) Detection, the subject of this plan, are contained in paragraph 10.d(1) of DOE Order 5480.28:

***NPH Detection.** Facilities or sites which have Structures, Systems or Components (SSCs) in Performance Category (PC) 2 with hazardous material, PC-3 or PC-4 shall have instrumentation or other means to detect and record the occurrence and severity of seismic events.*

DOE Order 420.1, *Facility Safety*, was issued 10-13-95, but will not become effective until it is incorporated in the WHC contract. At that time it will supersede DOE Order 5480.28. However, both DOE orders contains the same requirements for NPH detection.

1.1 OBJECTIVE

The objective of this plan is to define a cost-effective detection system for WHC facilities that meets the requirements in DOE Orders 5480.28 and 420.1. Recommendations include the locations for instrumentation, type of instruments, and a data-handling system. These recommendations take advantage, where possible, of current seismic instrumentation located throughout the Site.

1.2 SCOPE

The scope of this plan encompasses all strong-motion seismic instrumentation installed or recommended to be installed by WHC at the Hanford Site. Procurement, installation, and design procedures for Performance Class 4 instruments will be provided under separate cover.

1.3 STATUS OF EARTHQUAKE MONITORING AT HANFORD

Since 1969 the DOE has required contractors to collect seismic data from networks of seismic instruments located both on and near the Hanford Site. These instruments are used to locate and identify the source of seismic activity as well as the magnitude of the seismic

event. They measure ground motion in the direction of the accelerometer and transmit this automatically to the Hanford Seismic Recording Center. These data are used by Hanford Emergency Site Services to evaluate the seismic hazards for the Hanford Site and to monitor changes in the historical pattern of seismic activity on site.

Seismometers used in the network are extremely sensitive so that small-magnitude events can be located at the Hanford Site. Seismic Monitoring presently locates all seismic events of magnitude 2.5 and larger for most of eastern Washington and all magnitude 1.5 and larger on or near the Hanford Site. Earthquakes of less than magnitude 1.0 are regularly detected and located at Hanford. Because of the instruments' sensitivity, the network must be regional for large-magnitude events. If a magnitude-3.0 earthquake occurs at Hanford, the closer instruments would be saturated and only the regional network could be used to locate the event and determine its magnitude.

Since July 1982, approximately 650 earthquakes between magnitude 0 and 3.8 have been recorded on and around the Hanford Site. The pattern of earthquakes between 1900 and 1995 is shown in Figure 1. The figure shows that the greatest seismic activity is in the low-magnitude range, with only 5 events exceeding a magnitude of 3.0.

1.4 NEED FOR STRONG MOTION ACCELEROMETERS

The present seismic monitoring capability at the Hanford Site does not fulfill the requirements of DOE Orders 5480.28 and 420.1. The DOE orders require that the seismic monitoring be designed to obtain local site ground accelerations during a seismic event to the degree it can be used to subsequently evaluate structures. Present seismic monitoring capabilities cannot determine the impact of an earthquake on a structure or facility at the Hanford Site. The design and intended use of the present seismic monitoring instruments is too sensitive to serve this purpose and engineers cannot characterize the ground motions with just the vertical component. All sites except two are vertical component stations. The two exceptions are three-component stations consisting of one vertical, one north-south horizontal, and one east-west horizontal data channel.

Details of records from the present seismographic instruments normally are of limited use for large seismic events. This is the case because seismographs go off scale in the near field; they are on scale only when the motion is weak, and usually too dispersed to be greatly informative about strong shaking. Also, the natural frequency of the transducers of most seismographs are so low that recovery of the high-frequency ground acceleration from records is a difficult, inaccurate process.

Strong motion accelerometer (SMA) information will be needed after a large seismic event to allow the engineering staff to relate the potential earthquake damage to the site specifications and the facilities seismic design bases. The present seismic monitoring network can only be used to determine magnitude, location, and direction of seismic waves.

Figure 1. Earthquakes Recorded on or Near the Hanford Site Between 1990 and 1995.

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Seismic studies conducted by structural engineers concentrate on ground acceleration rather than velocity or displacement. Structural engineers also need to know the magnitude and the direction of the event. Strong ground motion from earthquakes of magnitude 5 and greater are of main interest because they have the potential to damage structures and internal systems and components. In addition, with only few exceptions, potentially damaging effects are confined to within several tens of kilometers of the causative fault, even in great earthquakes. For these reasons, engineers developed special instrumentation for recording strong ground shaking and structural response. Strong motion instruments are accelerometers with relatively high (25-50 Hz) frequency transducers. This type of instrumentation was chosen because acceleration is the fundamental quantity of interest and because accelerometers with the desired frequency range are practically feasible.

2.0 INSTRUMENTATION

2.1 INSTRUMENTATION STRATEGY

The DOE Orders 5480.28 and 420.1 require that facilities or sites that have structures, or components in Performance Category 2 with hazardous material, PC-3, or PC-4 shall have instrumentation or other means to detect and record the occurrence and severity of seismic events.

The existing seismic monitoring instrumentation included in the Hanford seismic array is designed to detect, locate, and determine earthquakes with magnitudes as low as 1.5 or less. Although the network has operated for only less than 30 years, the largest earthquake recorded at Hanford in that time is less than a magnitude of 4.0, with most seismic events less than magnitude 3.0. These events have been demonstrated to be of no consequence to life, safety, or the safe function of PC-2, PC-3, and PC-4 structures, systems and components (SSC).

The response from relatively large events that can compromise the safety of Hanford SSCs would exceed the scale of the seismic instruments currently on Site. Therefore, the strategy for compliance with DOE Order 5480.28 and 420.1 is to combine the existing seismic monitoring network (WHC-CM-7-8, Procedures 3.1 and 3.2)¹ at Hanford with a proposed free-field network of SMAs in the 100, 200 East, 200 West, 300, and 400 Areas.

This approach to the deployment of seismic instrumentation provides WHC with real-time seismic response for strategic buildings to be used in conjunction with an emergency response plan and seismic records to evaluate all other WHC buildings following a seismic event.

¹WHC-CM-7-8, *Environmental Activities*, Procedure 3.1, "Installation and Maintenance of Seismic Array," and Procedure 3.2, "Seismic Data Analysis and Record Processing," Westinghouse Hanford Company, Richland, Washington.

2.2 STRATEGY FOR NUMBER AND PLACEMENT OF FREE-FIELD INSTRUMENTS

Information on attenuation and other related soil properties from the Hanford Site are generally lacking. The scarcity of this type of information has hampered determining actual spectral response curves for facilities from any large seismic event postulated for the Hanford Site. Similarly, the absence of these data does not permit a direct approach for determining the number and best placement for a network of free-field accelerometers or SMAs for buildings/facilities.

An alternative approach for placement of free-field instruments at Hanford is to evaluate existing SMA networks elsewhere and apply data on how sediment types and distances between instrumented sites can affect the wave form and peak accelerations. If a systematic relationship between soil types and distances between sites appears to exist, some maximum distance between sites may be applied to locating free-field SMA sites at Hanford.

The best instrumented area in the world is the Los Angeles Basin in southern California—The Southern California Seismographic Network (SCSN) and the Strong Motion Instrumentation Program (SMIP) operated by the California Division of Mines and Geology. The SCSN is jointly operated by the U.S. Geological Survey and Seismological Laboratory of the California Institute of Technology. Both networks provide very dense coverage of the Los Angeles Basin for determining both the location and magnitude of earthquakes and the peak accelerations measured at selected sites.

Free-field accelerometer data from the January 17, 1994, Northridge, California earthquake provided an extensive set of strong-motion records over the Los Angeles Basin. These records suggests that, in spite of heterogeneities in the sediments of the basin and the complex geology of the Los Angeles Basin, strong motion instruments within a radius of about 5 kilometers recorded similar peak accelerations and had similar wave forms (Appendix C). This information suggests that one free-field accelerometer can provide representative ground acceleration records for a limited area.

A comparison of the Pasco Basin and Los Angeles Basin show that the Hanford Site is an area with a uniform stratigraphy lacking the complexities of the Los Angeles Basin. The Pasco Basin has fewer geologic structural complexities, which should permit application of the free-field spacing interval knowledge gained in the Los Angeles Basin.

We propose that one free-field instrument be placed in each of the following areas: 200 West Area, 200 East Area, 100K Area, 300 Area, and 400 Area. Each of these areas requires a free-field instrument because no two areas are close enough together for one instrument to service both areas (Figure 2, Table 1). However, each area contains less than 25 km² (Figures 3 through 7). The buildings and facilities are located within these areas so that no building is more than 3 km from the center of the area. Placing one instrument in each area will provide a conservative area of coverage based on the SCSN and SMIP experience.

Table 1. Distances Between Areas on the Hanford Site.

AREA	Distance in kilometers to					
	100 K	100 N	200 East	200 West	300	400
100 K		5	11	10	40	30
100 N	5		15	12	45	30
200 East	11	12		7	32	18
200 West	10	12	7		32	23
300	40	45	32	32		10
400	30	30	18	23	10	

2.3 STRONG MOTION ACCELEROMETER DESIGN

A strong motion accelerometer has three accelerometers arranged in orthogonal configuration: two aligned to the base of the instrument and the third vertical. The instrument is triggered by an adjustable vertical starter and typically runs from 20 seconds after the last motion of triggering level. There is an internal timing circuit that generates half-second marks on the record. The timing system is typically tied to the National Bureau of Standards (WWVB) time code and is recorded in universal time. The system is connected to a recording system that records each accelerometer separately. Originally film records were used but now magnetic tape cartridges and digital accelerographs are available. Digital accelerographs have the advantage that the required digitization of the analog signal is part of the recording process and subsequent data processing is more cost effective and convenient than for magnetic tape cartridges. In addition, a buffer memory allows the automatic retention of the pre-event memory so that, on triggering, the entire record, starting before the P wave arrival, can be recorded. The P wave is the compressional wave and the first seismic wave to arrive. Details of the instrumentation design are described in Appendix B.

2.4 INSTRUMENTATION AND MONITORING SERVICES

We propose to utilize the existing Hanford Seismic monitoring system and organization to install and have responsibility for the proposed Hanford network of free-field devices as well as the building/facility SMAs. This combined network would be linked as is the current network via radio communications or cellular telephone systems with independent power sources (battery and solar panel). All maintenance and data logging would be provided by the Seismic Monitoring team. The instrumentation, data, and maintenance would be provided as a Hanford Site service. The present Seismic Monitoring office (Room 176, 337 BLDG) would house data-logging facilities and would provide an area and point of contact for facility Emergency Response and Safety Personnel to receive information from the network.

Figure 2. Location of Areas within the Hanford Site.

Figure 3. Location of Free-Field SMA for 100K Area.

Figure 4. Location of Free-Field SMA for 200 East Area.

Figure 5. Location of Free-Field SMA for 200 West Area.

* Proposed Location of Strong Motion Accelerometer

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Figure 6. Location of Free-Field SMA for 300 Area.

Figure 7. Location of Free-Field SMA for 400 Area.

After a large-magnitude seismic event, the Seismic Monitoring Center would provide Hanford facility managers with key emergency response data so that they could implement the rest of the Emergency Response Plan to stabilize the systems and restaff the facility.

2.5 NUMBER AND LOCATION OF INSTRUMENTS

Based on information from the California Bureau of Mines and Geology (Appendix C), the minimum SMA instrumentation proposed for the Hanford Site will include five free-field instruments.

2.5.1 Instrumentation Schedule

It is recommended that the five free-field instruments be installed to support submittal of the instrumentation plan. The priority for the free-field SMA instrumentation installation should be 100K Area, 200 East Area, 200 West Area, 300 Area, and upgrade the 400 Area.

2.5.2 Locations for Free-Field Instruments

The proposed locations for the free-field instruments include those recommended in Table 2 and discussed in Appendix B.

Table 2. Proposed Free-Field SMA Sites.

Site	Location	Design
100 K Area	Near K Basins	One free-field SMA housed in a ground vault
200 East Area	Between Canister Storage Building and B Plant	One free-field SMA housed in ground vault
200 West Area	Near PFP	One free-field SMA housed in ground vault
300 Area	Near 337 Building	One free-field SMA housed in ground vault
400 Area	Use existing SMA site	Upgrade instrument to be compatible with SMA network

3.0 COST ESTIMATES

Table 3 is based on the best available information at the time of the issuance of this report.

Table 3. Cost Estimate for Installation and First-Year Operation of SMA.

<i>Expense</i>	<i>Amount (\$)</i>
Material	
<i>Instruments:</i>	
<i>Strong Motion Accelerograph including accessories</i>	<i>8,700</i>
<i>Global Positioning Satellite system</i>	<i>900</i>
<i>Modem</i>	<i>400</i>
<i>Cellular telephone data link system:</i>	
<i>Cellular telephone</i>	<i>300</i>
<i>Solar sub-system</i>	<i>600</i>
<i>Electronic and hardware</i>	<i>500</i>
<i>Subtotal (per site)</i>	<i>11,400</i>
<i>Subtotal for five sites.</i>	<i>57,000</i>
<i>Computer system</i>	
<i>Pentium PC to handle software</i>	<i>2,600</i>
<i>Notebook (remote access)</i>	<i>2,600</i>
<i>Replacement parts</i>	<i>8,000</i>
<i>Software</i>	<i>8,000</i>
<i>Material Subtotal</i>	<i>78,000</i>
LABOR	
<i>Installation of SMA sites at 3 person months</i>	
<i>Set up and integrate system at 3 person months</i>	
<i>Subtotal</i>	<i>50,000</i>
<i>Yearly operation and Maintenance—Allow 0.5 FTE each year after year 1</i>	
<i>Total cost for installation and first-year operation</i>	<i>128,000</i>

¹The software systems are designed for a Pentium PC. The present system uses a SUN workstation and a 486 PC. The Pentium PC would be located at the Office of Seismic Monitoring and the notebook would be used for off

4.0 RECOMMENDATIONS

The following recommendations are made with respect to bringing the Hanford Site into compliance with DOE Orders 5480.28 and 420.1.

1. Use the existing seismic monitoring team and facilities and integrate with the free-field, SMA network. That will provide the most cost-effective method to install, maintain, analyze, and provide semi-real-time data to plant managers.
2. Install or upgrade to a digital recording, free-field SMA in each of the following areas: 100-K, 200 East, 200 West, 300, and 400.

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APPENDIX A
GEOLOGIC SETTING OF THE HANFORD SITE AND REGION

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APPENDIX A

GEOLOGIC SETTING OF THE HANFORD SITE AND REGION

The Hanford Site is located in the south-central part of the Columbia Basin of eastern Washington State. The Columbia Basin is an intermontane basin between the Cascade Range and the Rocky Mountains filled with Cenozoic volcanic rocks of the Columbia River Basalt Group (CRBG) and sediments.

The Columbia Basin has two structural subdivisions: the Yakima Fold Belt and the Palouse Slope. The Yakima Fold Belt includes the western and central parts of the Columbia Basin and is a series of anticlinal ridges and synclinal valleys. The Palouse Slope is the eastern part of the basin and is the least deformed subprovince with only a few faults and folds on an otherwise gently westward dipping paleoslope.

The Hanford Site lies within the Yakima Fold Belt of the Columbia Basin. The Yakima Fold Belt consists of basalt flows and sediments that have been folded and faulted over the past 17 million years, creating broad structural and topographic valleys and basins separated by asymmetrical anticlinal ridges. Sediments up to 518 m thick have accumulated in some of these basins. Basalt flows are exposed along the anticlinal ridges where they have been uplifted as much as 1,097 m above the surrounding area.

Overlying the CRBG in the synclinal valleys are sediments of the late Miocene, Pliocene, and Pleistocene age. The Hanford Site lies within one of the larger basins, the Pasco Basin. The Pasco Basin is bounded on the north by the Saddle Mountains and on the south by Rattlesnake Mountain and the Rattlesnake Hills (Figure A-1). Yakima Ridge and Umtanum Ridge trend into the basin and subdivide it into a series of anticlinal ridges and synclinal basins. The largest syncline, the Cold Creek syncline, lies between Umtanum Ridge and Yakima Ridge and is the principal structure containing the U.S. Department of Energy (DOE) waste management areas.

A.1 STRATIGRAPHY OF THE HANFORD SITE

The stratigraphy of the Hanford Site consists of four layers that are important for seismic consideration. The uppermost layer, the suprabasalt sediments, consists of a series of consolidated and unconsolidated sediments extending from the surface to about 750 feet deep. From the base of the suprabasalt sediments to about 5 km deep is the Columbia River Basalt Group. From the base of the Columbia River Basalt Group to about 10 km deep is a series of consolidated sediments called the prebasalt sediments. Below the prebasalt sediments

Figure A-1. Structural Configuration of the Columbia Basin.

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through to the base of the seismogenic crust is the crystalline basement. This stratigraphy forms the basic velocity model for interpreting seismic data.

For Strong Motion Accelerometer (SMA) data considerations, the suprabasalt sediments and the Columbia River Basalt Group rocks are the most important units. The Columbia River Basalt Group rock forms the solid bedrock and structural framework of the Hanford Site. The suprabasalt sediments are the Hanford "soils" in which the foundations of all the facilities are anchored. The suprabasalt sediments are the largest unknown factor in determining how earthquakes from a seismic source will affect a facility. Their attenuation properties have been poorly determined for the Hanford Site.

A.1.1 Suprabasalt Sediments

The suprabasalt sedimentary sequence at the Hanford Site is up to approximately 230 m thick in the west central Cold Creek syncline, and pinches out against the anticlinal ridges surrounding the Site. The suprabasalt sediments are dominated by laterally extensive deposits of the late Miocene- to Pliocene-aged Ringold Formation and the Pleistocene Hanford formation. Locally occurring strata of the informal Plio-Pleistocene unit, early "Palouse" soil, and pre-Missoula gravels compose the remainder of the sequence.

Ringold Formation. The Ringold Formation forms the lower part of the suprabasalt sequence. It is up to 185 m thick in the deepest part of the Cold Creek syncline south of the 200 West Area. The Ringold Formation pinches out against the anticlines surrounding the Site.

The Ringold Formation consists of semi-indurated clay, silt, pedified mud, fine- to coarse-grained sand, and granule to cobble gravel. The lower half of the Ringold Formation contains five separate stratigraphic intervals dominated by fluvial gravels. These gravels are separated by intervals containing deposits typical of the overbank and lacustrine facies associations. The uppermost gravel grades upward into interbedded fluvial sand and overbank deposits, which are in turn overlain by a second lacustrine interval.

Post-Ringold Pre-Hanford Deposits. Thin alluvial deposits occur between the Ringold Formation and the Hanford formation on the Hanford Site. These deposits are referred to informally as the Plio-Pleistocene unit, pre-Missoula gravels, and early "Palouse" soil.

Plio-Pleistocene Unit. Unconformably overlying the Ringold Formation in the western Cold Creek syncline in the vicinity of the 200 West Area is the laterally discontinuous Plio-Pleistocene unit. The unit is up to 25 m thick and separated into two facies: basaltic detritus and pedogenic calcrete. Depending on location one or both facies may be present. The calcrete facies generally consists of interfingering carbonate-cemented silt, sand, and gravel and carbonate-poor silt and sand. The basaltic detritus facies consists of weathered and unweathered basaltic gravels deposited as locally derived slope wash, colluvium, and sidestream alluvium.

Pre-Missoula Gravels. Quartzose to gneissic clast-supported pebble to cobble gravel with a quartzo-feldspathic sand matrix underlies the Hanford formation in the east-central Cold Creek syncline and south of the 200 East Area. These gravels, called the pre-Missoula gravels, are up to 25 m thick.

Early "Palouse" Soil. The early "Palouse" soil consists of up to 20 m of silt and fine-grained sand that overlies the Plio-Pleistocene unit in the western Cold Creek syncline around the 200 West Area. Deposits composing the early "Palouse" soil are massive, brown yellow, and compact. These deposits are very loess-like in character.

Hanford Formation. The Hanford formation (an informal name) consists of pebble to boulder gravel, fine- to coarse-grained sand, and silt. The gravel deposits range from well to poorly sorted. The fine-grained deposits, which make up the most extensive and voluminous part of the Hanford formation, are divided into two facies: plane-laminated sand and normally graded rhythmites, also referred to as "Touchet Beds." The Hanford formation is commonly divided into two informal members: the Pasco gravels and the Touchet Beds. The Pasco gravels generally correspond to the gravelly facies, and the Touchet Beds to the sandy to silty facies. The Hanford formation is thickest in the Cold Creek bar in the vicinity of the 200 West and 200 East Areas where it is up to 65 m thick.

The gravel-dominated deposits (or facies) consist of coarse-grained sand and boulder gravel that display massive bedding planes. Matrix commonly is lacking in these gravels, giving them an open framework appearance. Gravels dominate the Hanford formation in the 100 Areas north of Gable Mountain the northern part of 200 East Area and the eastern part of the Site including the 300 Area. In the 200 East and 200 West Areas the gravels generally fine to the south. The gravel-dominated facies were deposited by high-energy flood waters in or immediately adjacent to the main cataclysmic flood channelways.

The laminated sand facies consists of fine- to coarse-grained sand displaying plane lamination and bedding and less commonly plane and trough cross-bedding in outcrop. The laminated sand facies is most common in the central Cold Creek Syncline in the area of the 200 East and 200 West Areas and is transitional between the gravel-dominated facies to the north and the rhythmite facies to the south.

The rhythmite facies consists of silt and fine- to coarse-grained sand that commonly display normally graded rhythmites a few centimeters to several tens of centimeters thick in outcrop. This facies is found throughout the central, southern, and western Cold Creek syncline within and south of the 200 East and West Areas.

A.2 STRUCTURE OF THE HANFORD SITE.

The Hanford Site is located in the Pasco Basin, one of the largest structural basins in the Yakima Fold Belt. The Yakima Fold Belt is a series of anticlinal ridges and synclinal valleys that covers about 14,000 km² of the western Columbia Plateau. The fold belt formed

as basalt flows of the Columbia River Basalt Group, and intercalated sediments of the Ellensburg Formation were folded and faulted under north-south directed compression.

The Pasco Basin is bounded on the north by the Saddle Mountains anticline, on the west by the Umtanum Ridge, Yakima Ridge, and Rattlesnake Hills anticlines, and on the south by the Rattlesnake Mountain anticline (Figure A-1). The Palouse slope, a west-dipping monocline, bounds the Pasco Basin on the east. The Pasco Basin is divided into the Wahluke and Cold Creek synclines by the Gable Mountain anticline, the easternmost extension of the Umtanum Ridge anticline.

The Cold Creek syncline lies between the Umtanum Ridge-Gable Mountain uplift and the Yakima Ridge uplift, and is the main structural unit that encloses the 200 Areas. The 200 Areas lie on the northern flank of the syncline with the bedrock gently (approximately 5°) dipping to the south. The 300 Area lies at the eastern end of the Cold Creek syncline where it merges with the Pasco syncline.

The Wahluke syncline is the principal structural unit that contains the 100 Areas. The Wahluke syncline is an asymmetrical structure similar to the Cold Creek syncline. The northern limb dips gently (approximately 5°) to the south. The steepest limb is adjacent to the Umtanum-Gable Mountain structure.

The Umtanum Ridge-Gable Mountain structural trend lies north of the 200 and 300 Areas and south of the 100 Areas. From the west, the Umtanum Ridge plunges eastward and joins Gable Mountain and Gable Butte just east of the western boundary of the Hanford Site. The easternmost segment, the Southeast anticline, trends southeast off the eastern boundary of the Gable Mountain.

Umtanum Ridge is an asymmetrical, north-vergent-to-locally overturned anticline with a major thrust to a high-angle reverse fault on the north side that dies out eastward toward Gable Mountain. Gable Mountain and Gable Butte are two topographically isolated, anticlinal ridges that are composed of a series of northwest trending, doubly plunging, en echelon anticlines, synclines, and associated faults. Capable faulting has been identified on Gable Mountain.

The Yakima Ridge uplift extends from west of Yakima, Washington, to the center of the Pasco Basin, where it forms the southern boundary of the Cold Creek syncline. The easternmost surface expression of the Yakima Ridge uplift is represented by an anticline that plunges eastward into the Pasco Basin. The eastern extension of Yakima Ridge is mostly buried beneath late Cenozoic sediments.

The 200 and 300 Areas are situated on the south flank of the Umtanum-Gable Mountain anticline where the Miocene-aged basalt bedrock dips to the southwest into the Cold Creek syncline. The 100 Area lies north of the Umtanum-Gable Mountain anticline in the Wahluke syncline. The deepest parts of the Cold Creek syncline, the Wye Barricade depression and the Cold Creek depression, are approximately 7.5 mi southeast of the 200 Areas and under the 200 West Area, respectively.

A.3 GEOLOGIC DOMAINS IN THE 100, 200, AND 300 AREAS

The 200 and 300 Areas lie within the Cold Creek syncline and the 100 Areas lie within the Wahluke syncline. The Wahluke and Cold Creek synclines form the largest individual structural units in the Hanford Site. The Wahluke and Cold Creek synclines are first order geologic domains. Because of different distances to the various seismic sources (Table A-1) different areas within each syncline will probably respond differently to an earthquake nearby. Thus, the Wahluke and Cold Creek synclines cannot function as single geologic domains but must be subdivided.

100 Area. The 100K Area lies near the axis of the Wahluke syncline. The suprabasalt sediments are mainly the Ringold Formation with a thin veneer of the Hanford formation. Figure A-2 shows that the sediments tend to be relatively uniform across the area. No known faults or secondary folds underlie the area, but the site is in the Coyote Rapids earthquake swarm area. Thus, the 100K Area is considered one geologic domain.

200 Areas. Previous studies have shown that the stratigraphy and structure of the 200 East and West Areas are very similar. Figures A-3, A-4, and A-5 are diagrams representing the sediments that lie above the basalt. In general, the entire suprabasalt sedimentary package thins from west to east and from south to north. Figure A-5 shows that the primary difference between the 200 East and 200 West Areas is the thickness of the Ringold Formation and Hanford formation. In the 200 West Area, the Ringold is thicker and the Hanford is thinner. In both the 200 East and 200 West Areas, the suprabasalt units tend not to vary greatly across the sites.

No faults or secondary folds are currently known to underlie either the 200 East or 200 West Area. Both sites lie on the north flank of the Cold Creek syncline with shallow dips to the south. This suggests that no geologic features in the immediate vicinity of the sites could be earthquake sources.

The 200 East and West Areas are separated by over 5 km. Overall the differences between them are in the thickness of the suprabasalt sediments. Each individual area is relatively uniform. Thus, 200 East Area and 200 West Area are each considered to be individual geologic domains.

Figure A-2. Stratigraphic Cross Section through 100 K Area.

H95110336.5b

Figure A-3. Stratigraphic Cross Section through 200 East Area.

H95110336.3

Figure A-4. Stratigraphic Cross Section through 200 West Area.

H95110336.1

Figure A-5. Stratigraphic Cross Section through 200 West and 200 East Areas.

M95110336.4

300 Area. The 300 Area also lies on the north flank of the Cold Creek syncline but is over 25 km from the 200 East Area and 10 km from the 400 Area. It lies on the southeast edge of the Wye Barricade depression where the Cold Creek syncline joins with the Pasco syncline. The suprabasalt sediments are dominated by the Ringold Formation with a thin layer of the Hanford formation overlying it. Figure A-6 shows that the sediments tend to be relatively uniform across the area. In addition, no faults or secondary folds underlie the site. The 300 Area is considered to be an individual geologic domain.

400 Area. The 400 Area lies on the southern boundary of the Cold Creek syncline and Wye Barricade depression. The suprabasalt sediments are dominated by the Ringold Formation with a thin veneer of Hanford formation. No faults or folds are known to underlie this area. This area is considered to be a geologic domain.

A.4 SEISMIC SOURCES AND SEISMICITY AT HANFORD

Past studies at the Hanford Site have concluded that Hanford and the Columbia Basin of eastern Washington contain six different types of tectonic environments where earthquakes can occur.

1. Reverse/thrust faults in the CRBG associated with major anticlinal ridges such as Rattlesnake Mountain, Yakima Ridge and Umtanum Ridge could produce the largest earthquakes at the Site. This source is probably the most realistic seismic source at the Hanford Site.
2. Secondary faults associated with the major anticlinal ridges. This source is tectonically tied to the first source and, for all practical purposes, will be the same distance as the first source.
3. Earthquake activity occurring in small geographic areas (swarms) usually in the CRBG in synclinal valleys. Three major swarm areas are known on the Hanford Site. One is the Wooded Island Swarm Area along the Columbia near the 300 Area. The second area, the Coyote Rapids Swarm, extends from the vicinity of the 100K Area north-northeast along the Columbia River Horn to the vicinity of 100N Area. The third major swarm is along the Saddle Mountains north of the Hanford Site.
4. The fourth tectonic environment is the entire Columbia Basin, including the Hanford Site, which would produce a "floating" earthquake. A floating earthquake is one that can happen anywhere in a tectonic province and need not be associated with any known geologic structure. It is considered a random event.

Figure A-6. Stratigraphic Cross Section through the 300 Area.

H95110336.2

5. **Basement Sources** are the fifth tectonic environment. Past studies suggest that major earthquakes can originate in tectonic structures in the crystalline basement. Because very little is known about geologic structures beneath the Hanford Site, earthquakes cannot be directly tied to a fault in the crystalline basement. Earthquakes occurring in the crystalline basement without known sources are treated as random events.
6. The sixth source structure is the **Cascadia Subduction Zone**. This source recently has been postulated to be capable of producing a 9 Coda Amplitude Magnitude earthquake. Because this source is along the western boundary of Washington State and outside of the Hanford Array, the Cascadia Subduction Zone is not an earthquake source that is monitored at the Hanford Site. Because any earthquake along the Cascadia Subduction zone can have a significant impact on the Site, the University of Washington monitors and reports on this earthquake source.

Depth of Earthquakes. Past studies of seismicity at the Hanford Site have shown that the seismicity is related to crustal stratigraphy (layers of rock types). These are the Columbia River Basalt Group (approximately 0-5 kilometer deep), the prebasalt sediments (approximately 5-10 km deep), and the crystalline basement (greater than approximately 10 km). Since records have been kept, about 75 percent of the earthquakes at Hanford originate in the Columbia River Basalt Group (CRBG) layer. The prebasalt sediments has had about 7 percent of the events and the crystalline basement has had 18 percent.

Distance to Seismic Sources. Table A-1 lists the distance from selected areas to the seismic sources considered above. The closest seismic sources are the Gable Mountain-Umtanum Ridge source, and the Yakima Ridge source.

Number of Earthquakes. Since July 1982, approximately 650 earthquakes have been recorded on or near the Hanford Site. Most earthquakes are in the low-magnitude range with the largest instrumentally recorded earthquake having a magnitude of less than 4.

Table A-1. Distance to Seismic Sources at the Hanford Site.

Seismic Source	Distance to source (km)				
	100-K	200 East	200 West	300	400
1. Yakima Folds-main fault and secondary structures	Measured to closest anticlines.				
Gable Mountain-Umtanum Ridge	3.0	5.0	6.0	20.0	12.0
Yakima Ridge	16.0	7.0	6.0	NA	14.0
Rattlesnake Mountain	19.0	14.0	11.0	10.0 RAW ²	14.0
Saddle Mountains	21.0	26.0	28.0	40.0	40.0
2. Swarms	in Coyote Rapids	10.0+	10.0+	in Wooded Island	8.0 - Wooded Island
3. Floating	NA	NA	NA	NA	NA
4. Basement	10.0+	10.0+	10.0+	10.0+	10.0+
5. Cascadia Subduction Zone	> 400	> 400	> 400	> 400	> 400

NA - Not Applicable

A.5 SEISMIC HAZARDS

Geomatrix (1993) completed a seismic hazards evaluation for selected sites on the Hanford Site. The study concluded that the Site is in an area of moderate seismic hazard, dominated by earthquakes of magnitude 5 to 6 (approximately two-thirds of the total exposure at the Hanford Site) at distances less than 20 km. The soil properties across the site are relatively uniform with no known dominating characteristic such as liquefaction potential to give large side effects. However, experimental data suggest strong ground motion can be affected by soil structure interaction, by very soft soil deposits, by topography, and by the presence of surface waves.

The three-dimensional geometry of the Hanford Site may result in greater differences among individual sites than a more distant, larger source. Table A-1 shows the distances

Rattlesnake Wallula alignment

from various areas at the Hanford Site to seismic sources. Only the closest anticlinal ridges with large reverse/thrust faults are included. Gable Mountain-Umtanum Ridge and Yakima Ridge are the closest structures to the 200 Areas and 100K. These distances are less than 10 km, except for the distance from 100K to Yakima Ridge, but 100K Area lies in the Coyote Rapids earthquake swarm. Further, except for the Saddle Mountains, the anticlinal ridges at or near the Hanford Site are considered to have 0.25 or less probability of activity. The Saddle Mountains on the north boundary of the Hanford Site has the highest activity, 0.50 probability. This structure has evidence of large earthquakes in the recent past.

Major reverse/thrust fault zones on the anticlinal ridges appear to attenuate seismic waves passing through the site. For example, the Wallula Gap site, located on the south side of the Horse Heaven Hills fault zone, receives seismic waves best from the south. Seismic waves coming from the north must pass through the Horse Heaven Hills fault zone and are always attenuated. A similar pattern has been observed for waves passing through Gable Mountain.

Thus, the three-dimensional geometry of the Hanford Site is one of the greatest constraints on establishing a SMA network. This geometry precludes using one free-field instrument for the entire site or one free-field instrument for each syncline area. A series of free-field sites will produce the most representative method of measuring peak accelerations in critical areas. Appendix C describes the experience gained as a result of the Northridge earthquake to determine the free-field network for the Hanford Site.

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APPENDIX B
INSTRUMENTATION

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APPENDIX B

INSTRUMENTATION

B.1. STATUS OF EARTHQUAKE MONITORING AT HANFORD

Since 1969 the U.S. Department of Energy (DOE) has required contractors to collect seismic data from monitoring networks at and near the Hanford Site. Since 1969 the Hanford Site has operated an instrumental network. This instrumental network is used to locate and identify the source of seismic activity as well as the magnitude of the seismic event. Hanford Emergency Services uses these data to evaluate seismic hazards for the Hanford Site, and to monitor changes in the historic pattern of seismicity at the Site.

B.1.1 History of Seismic Monitoring at Hanford

The earthquake monitoring in the Columbia Basin began around 1850 when people started to settle in eastern Washington State and earthquakes were felt. Records of earthquakes were seldom kept except in diaries and in newspaper accounts. The actual instrumental location of earthquakes in eastern Washington started in about 1957. Location and magnitudes were based on seismograph stations in western Washington, other states and Canada. Moderate-size earthquakes (magnitude 5.0 and larger) were necessary for the distant seismograph stations to record useable location data.

Hanford's instrumental seismic monitoring network began when the U.S. Geological Survey (USGS) installed a small array of seismograph stations around the Hanford Site in the summer of 1969. This array was able to locate earthquakes of magnitude 1.5 and larger. In 1975 the University of Washington Geophysics Program (UW) assumed operation of the USGS array and installed a regional network of seismograph stations throughout eastern Washington that could locate earthquakes of magnitude 2.0 and larger. These seismic networks were sponsored by the Atomic Energy Commission.

In 1982 a closely spaced seismic network was installed at the Hanford Site to characterize the microseismicity on Hanford for a possible high-level waste repository as part of the Basalt Waste Isolation Project (BWIP). This network operated until 1989. During this time the Eastern Washington Regional Network array was expanded, improving sensitivity. Earthquakes of magnitude 1.0 and larger were able to be located at and near Hanford. Both the Hanford network and the eastern Washington network were funded by the Civilian Nuclear Waste Fund through the DOE.

When the BWIP ended in late 1988, the number of stations in the eastern Washington regional network and the local Hanford Site network were reduced. Funding for both networks was then provided by the DOE as part of the Hanford RCRA Operational Monitoring Program (ROM). Earthquakes of magnitudes 0.0 and larger are currently being

located at the Hanford Site and earthquakes of magnitude 2.5 and larger are located throughout most of eastern Washington State.

Seismic monitoring has been performed by the Westinghouse Hanford Company Geosciences organizations since May 1989. In 1995, seismic monitoring, along with other ROM program functions, was moved to Liquid Effluents Services where it remains today.

Seismic monitoring operates, maintains, and analyzes data from the Hanford Seismic Network (HSN), extending the historical Site seismic database and fulfilling DOE requirements and orders. Seismic Monitoring also provides regional seismic data necessary to assess seismic hazards at the Hanford Site.

B.1.2 Seismic Networks, Equipment, and Data Processing at the Hanford Site

The DOE seismic monitoring for the Hanford Site consists of a network of 40 stations. The Site has 21 stations (Figure B-1); the remaining stations are spread throughout eastern Washington. The design and distribution of the seismic monitoring stations ensure detailed coverage for the Hanford Site and regional coverage for the Yakima Fold Belt, the geologic/tectonic province where the Site is located. (See Appendix A for information about Hanford Site geology).

All sites are vertical component stations except Royal City and Gable Butte, which are three-component stations consisting of one vertical, one north-south horizontal, and one east-west horizontal data channel.

Seismic stations consist of seismometers, electronic signal conditioning units, solar power subsystem, and radio transmitters. The radio relay stations consists of solar power subsystem, signal conditioning units, and radio transmitters and receivers.

Data from seismic stations are transmitted by radio to the Hanford Recording Center. Continuous recording averages over the last 4 years are better than 99 percent. Seismic events are automatically recorded on a computer system. Data are processed initially by an automated preliminary processing system that calculates a preliminary hypocenter location and magnitude for those seismic events originating on or very near the Hanford Site. All seismic events detected at or near the Hanford Site are recorded on magnetic tape and stored; this system is currently being changed so that data are stored on optical disks. These data are used to make an earthquake catalog that is sent to DOE annually or as requested. The catalog consists of the local earthquake locations and magnitudes with maps and a geologic and tectonic interpretation of the seismic events.

Figure B-1. Location of Seismic Monitoring Stations at Hanford.

B.1.3 Seismic Monitoring Capabilities

Seismic monitoring is designed to locate earthquakes on and near the Hanford Site and determine their magnitude and hypocenter location. The system is designed to determine magnitudes and locate earthquakes as precisely as possible so that the geologic source of the earthquake can be identified and characterized. This information is then used to determine the seismic hazard of the Site.

Seismometers used in the network are extremely sensitive so that small-magnitude events can be located at the Hanford Site. Seismic monitoring presently locates seismic events of magnitude 2.5 and larger for most of eastern Washington and magnitude 1.5 and larger for all earthquakes originating on or near the Hanford Site. Earthquakes with magnitudes of less than 1.0 are regularly detected and located at Hanford. Because of the instrument sensitivity, the network must be regional to locate larger events and determine their magnitudes at or near the Hanford Site. If a magnitude 3.0 event occurs at Hanford, the closer instruments become saturated and the regional network is used to precisely locate the event and determine its magnitude.

B.2 NEED FOR STRONG MOTION ACCELEROMETERS

Seismic structural evaluations require three-dimensional data on ground acceleration rather than velocity or displacement. Strong ground motion from earthquakes of magnitude 5 and greater are of main interest because they have the potential to damage structures. In addition, with only few exceptions, potentially damaging effects are confined to within several tens of kilometers of the causative fault, even in great earthquakes.

The present seismic monitoring system cannot record the ground motion from such events so that it can be used to evaluate structures. The system is designed to record normal seismic events at the Hanford Site, which are typically of magnitudes less than 4.0. The present seismic monitoring capabilities cannot determine the impact of an earthquake on a structure or facility at the Hanford Site. However, it does provide the magnitude, location, and recurrence of earthquakes. This information is used in the seismic design of structures and facilities. The design and intended use of the present seismic monitoring instruments is too sensitive to serve this purpose. Details of records from seismographic instruments, such as those used in the Hanford Seismic Monitoring, normally are of limited use. This is the case, first because seismographs go off scale in the near field; they are on scale only when the motion is weak, and usually too dispersed to be greatly informative about strong shaking. A second reason is that the natural frequency of the transducers of most seismographs are so low that recovery of the high-frequency ground acceleration from records is a difficult, inaccurate process.

For those reasons, engineers developed special instrumentation for the recording of strong ground shaking and structural response. Strong motion instruments are accelerographs with relatively high-frequency (25-50 Hz) transducers. This type of instrumentation was

chosen because three-dimensional acceleration is required by engineers because accelerometers with the desired frequency range are practically feasible to evaluate the structural response caused by ground shaking.

B.2.1 Strong Motion Accelerometer Status

In 1972, the DOE convened a blue ribbon panel to evaluate the seismic risk of Hanford facilities. As a result of this evaluation, a number of SMAs were purchased and deployed in various Hanford facilities (e.g., N Reactor, tank farms, the Plutonium-Uranium Extraction Plant). These were battery operated and required periodic changing of film. Also, no clear authority or guidance was provided for how the data were to be used in any emergency.

The present status of strong-motion instrumentation at Hanford is summarized in Table B-1. In the course of inspecting existing Hanford Site strong-motion accelerometers, this seismic equipment was found to be in disrepair or had been removed. This has resulted in minimal instrumentation on the Hanford Site (Table B-1).

Our inspections of existing equipment have lead to the following observation that facility budget cuts have resulted in SMA's being shut down and not maintained.

B.3 PROPOSED INSTRUMENTATION

The minimum strong-motion instrumentation proposed for the Hanford Site will included six free-field instruments.

B.3.1 Locations for Free-Field Instruments

The proposed locations for the free-field instruments include those recommended in Table B-2.

Table B-1. Status of Strong Motion Accelerometers at Hanford.

Facility	Device	Status	Contact
100 K	No device	NA	NA
100 N	3 Terra Tech	Nonoperational; located in high rad. area.	Jack Moffitt
300 Area	1 Kinemetric (DSA-1) SMA and tape reader	Operational in seismic monitoring office, 337 Building.	Steve Reidel
Wesf-B Plant	None	Excessed	Joe Thrasher
FFTF	Terra Techs 1) DCA300 2) SWR102 3) SWP300	Shut down in reactor area in Feb. 1995; Fuel Storage Facility has one seismic switch and 2 peak accelerometers.	George Taylor
PFP	Terra Tech 2 DCA333	Operational but horizontal components only	Dan Connors
PUREX	None	Excessed	
Tank Farms	None	Excessed	

Table B-2. Proposed Free-Field SMA Sites.

Site	Location	Design
100 K Area	Near K Basins	One free-field SMA housed in ground vault
200 East Area	Between Canister Storage Building and B-Plant	One free-field SMA housed in ground vault
200 West Area	Near PFP	One free-field SMA housed in ground vault
300 Area (optional)	Near 337 Building	One free-field SMA housed in ground vault
400 Area	Use existing SMA site	Upgrade instrument

B.3.3 Design of Instrumentation

The basic design of the instrumentation system is to collect SMA data at free-field sites and facilities, and then transmit the data via radio links to the Hanford Office of Seismic Monitoring (337 Building/Rm 176) where the data will be recorded in digital form on a computer before processing and interpreted before being forwarded to plant managers.

All SMA sites will be three-component stations consisting of one vertical, one north-south horizontal and one east-west horizontal data channels. SMA stations will consist of strong-motion accelerometers, electronic signal conditioning units, solar power subsystems for free-field sites, and radio transmitters. The radio relay stations will consist of solar power subsystems, signal conditioning units, and radio transmitters and receivers.

Free-field sites will consist of a poured concrete base with an inserted J bolt to securely attach a SMA to the concrete pad. Depending on exact conditions of the site, the free-field SMAs will be housed in either a buried or a surface vault. A buried vault is preferred because it provides security and ensures the SMA is protected from the elements in a ground insulated environment. All sites will be case hardened against the weather to ensure high-quality operating conditions and minimal maintenance costs. All free-field stations and relay sites will be solar-powered subsystems and battery powered to ensure a power source free of interruption in the event of a major seismic event.

The present seismic monitoring network uses radio transmitter-receiver pairs coupled with telephone lines. The SMA monitoring system is proposed to use either radio pairs or cellular telephone connections to provide an independent data link free of possible disruptions caused by an earthquake at the Hanford Site. Radio data links or cellular telephones would provide the most cost-efficient data transmittal system on Site.

B.3.3 Personal Requirements

Currently one full-time and one half-time person are assigned to seismic monitoring on the Hanford Site. Their duties include assessing channel operation, performing analysis, and maintaining the network. Personnel are only present during a normal 40-hour work week except when major outage conditions or major projects require an extended day or week. In the case of a Richter magnitude 3.0 or greater event on the Hanford Site, Seismic Monitoring personnel respond to an Emergency Services request to analyze the event and provide interpretations as necessary.

It is proposed that the SMA monitoring network will use the existing personnel, but the added duties of the SMA network will increase the staffing requirements to 2 FTEs. During the initial phase of establishing the SMA network, an additional 0.5 FTE will be required. Two FTEs can maintain or oversee maintenance and operate the seismic monitoring network and the SMA network.

B.3.4 Instruments

The first strong motion accelerometer was developed by the Coast and Geodetic Survey and the National Bureau of Standards in the 1930's. A strong-motion accelerograph has three accelerometers arranged in orthogonal configuration: two aligned to the base of the instrument and the third vertical. The instrument is triggered by an adjustable vertical starter and typically runs from 20 seconds after the last motion of triggering level. An internal timing circuit generates half-second marks on the record. The timing system is typically tied to the National Bureau of Standards (WWVB) time code and is recorded in universal time. The system is connected to a recording system that records each accelerometer separately. Originally film records were used, but now magnetic tape cartridges and digital accelerographs are available. Digital accelerographs have the advantage that the required digitization of the analog signal is part of the recording process and subsequent data processing is more convenient. In addition, a buffer memory allows the automatic retention of the pre-event memory, so that on triggering, the entire record, starting before the P-wave arrival, can be recorded.

Currently the SMAs on Site are all Terra Tech instruments with data recorded on a tape mounted in the SMA. The only exception is the Kinemetrics instrument in the Office of Seismic Monitoring, but this too is designed to record information on a tape. The Supply System currently uses Kinemetric SMAs similar to the one in the office of Seismic Monitoring in WNP-2. Hanford Site experience with the Terra Tech tape units has found them to be unreliable and have high maintenance costs. In addition, this type of system requires a technician to physically go to the site, retrieve the tape, and return to a central facility to recover the information. In the event of a significant earthquake, sites might end up being located in areas where access cannot be obtained for a period of time.

We propose that the SMA network for the Hanford Site use instruments with the capability of electronically transmitting the data to a central recording station in the Office of Seismic Monitoring. This has two advantages. First, this system would save considerable time in the case of a significant earthquake by eliminating the need to have a technician go to the various sites and retrieve data tapes. Second, all data could be processed at one location immediately and facility managers would be able to get information from a central point remote from the areas affected. In addition, the status of all instruments could be queried at any time from the central recording facility.

Several instruments are available that meet these requirements. To maintain a system that is reliable and has minimum down time, we recommend only one model of instrument be used from one manufacturer. This will minimize the number of replacement parts to be purchased and stocked and it will allow the Seismic Monitoring team to reduce training requirements by concentrating all resources on only one model of instrument. It will result in an overall cost savings.

For the Hanford SMA network, we recommend that an instrument be used that has a digital signal process with a minimum of three channels (vertical and 2 horizontal) per site. Table B-3 summarizes the recommended requirements for the SMA.

Table B-3. Recommended Instrument Specifications.

Parameter	Recommended value or range
SENSOR	
Type	Triaxial Force Balance Accelerometer, orthogonally oriented with internal standard.
Full-Scale Range	Minimum 2g with options up to 4g
Natural Frequency	Minimum 50 Hz
Damping	70% critical
Dynamic Range	Greater than 135 db
DATA ACQUISITION	
Number of Channels	3
Dynamic Range	> 110 db @ 200 sps
Frequency Response	DC to 80 Hz @ 200 sps
Resolution	19-bit resolution @ 200sps
RMS Noise	3.5 μ V RMS @ 200 sps
Sampling Rate	100, 200, 250 sps
Output data format	24 bit signed (3 bytes)
Digital Output	Real-time, RS-232 Output Stream
TRIGGER	
Type	IIR Bandwidth filter
Trigger Bandwidth	0.1-12.5 Hz
Alarm Threshold	Selectable from 0.01% to 100%
Pre-event Memory	Minimum 60 sec
Post-event Time	Up to 65,000 sec

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APPENDIX C
THE NORTHRIDGE EXPERIENCE

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APPENDIX C

THE NORTHRIDGE EXPERIENCE

On January 17, 1994, a 6.7 Mw occurred 32 km northwest of Los Angeles, California near Northridge, California. This earthquake occurred on a south-dipping (35-45°) thrust fault. No surface rupture was observed.

Strong-motion records were obtained from 193 stations of the California Strong Motion Instrumentation Program (CSMIP). Of these stations, 116 stations were ground-response stations (free-field stations) and 77 were from extensively instrumented structures.

C.1 FREE-FIELD INSTRUMENTS

The Los Angeles Basin is a structural basin (in the geologic sense) that has developed along a major plate tectonic boundary between the North American Plate and the Pacific Plate. The extensive plate interaction over millions of years has resulted in a long and complex geologic history for the area. The two plates currently form a transform boundary and slide past each other at a long-term rate of 5 cm per year.

Because of the long history of plate interaction in the Southern California area, the Los Angeles basin presently is a down-dropped basin filled with consolidated sedimentary rocks and unconsolidated alluvial fill, surrounded by bedrock hills and mountains. The area is an active tectonic zone that has prompted California State and the US Geological Survey, in cooperation with local universities, to install an extensive seismic monitoring network and an extensive strong-motion network.

The Los Angeles Basin provides an excellent area to evaluate and estimate how dense an array of strong motion instruments is necessary to obtain adequate coverage for free-field instrumentation for the Pasco Basin and the area of the Hanford Site. Both areas are in sedimentary basins with a foundation of solid bedrock. Both basins have extensive fills of both consolidated and unconsolidated sediments. The consolidated sediments are in the deeper parts of the basins and the unconsolidated material is at the surface.

The Los Angeles Basin differs from the Pasco Basin, which encloses the Hanford Site, in that the Pasco Basin is over 400 km from an active plate margin and thus is expected to experience less seismic activity, smaller earthquakes, and much longer times between large earthquakes (Geomatrix 1994). Through time the Pasco Basin has experienced less deformation than the Los Angeles Basin and, unlike the Los Angeles Basin, which has undergone extensive deformation of the sediments, the Pasco Basin's sediment fill has undergone only mild deformation consisting of mainly low-amplitude folds and minor faulting. In addition, the rate of deformation for the Pasco Basin is estimated to be only hundredths of a mm per year as compared to 5 cm per year for the Los Angeles Basin.

Further, the sediments of the Pasco Basin are more continuous throughout the basin; in the Los Angeles Basin many local sediments interfinger with other local sediments.

C.1.1 Strong Motion Records

Records from the California Strong Motion Instrumentation Program showed the greatest accelerations near the epicenter with accelerations dropping off with distance. Two examples are shown in Figure C-1 where the peak ground accelerations obtained from a series of SMAs in an southeast line (A) and a north-northwest line (B) are plotted versus distance. As might be expected, recorded peak accelerations are variable near the source but become more uniform with distance. The primary factors that probably affect this pattern are caused by local geology differences, both stratigraphic variations and structural (in the geologic sense) differences.

The following questions need to be addressed.

- In spite of the variability, how similar will readings be from accelerometers that are closely spaced in an area or geologic domain; how close must accelerometers be to achieve similar records; how similar are SMA records for closely spaced instruments near or at the source?
- Variations from a uniform acceleration over an area appear to depend on the uniformity of the soil properties and structural complexities (three-dimensional geometry) of the geology. Growth of the hills surrounding the Los Angeles Basin and periodic inundation of the basin by the Pacific Ocean has resulted in considerable variability in sediment types, soil properties, and three-dimensional geometry of the basin.

The Los Angeles basin overlies an active plate margin where two major crustal plates slide past each other at an average rate of 5 cm/yr. Plate Tectonic activity over the past 20 million years has deformed the sediments filling the basin resulting in a complex stratigraphy that shows units with limited extent and little uniformity of sediment layers.

A geologic domain is defined here as an unit of area that has similar stratigraphic and structural properties. It is difficult to determine how big a geologic domain must be to have similar properties in the Los Angeles Basin, but the geologic history of the basin suggests that a representative unit area size is probably highly variable. Hanford geologic domains are on the whole probably much larger (Appendix A).

Without a good idea of how big a geologic domain in the Los Angeles Basin might be, SMA records were examined from a series of closely spaced free-field stations. Five sets of records are shown in Figures C-2 to C-5. These records were drawn from distances of between 10 and 40 km from the epicenter and distances separating the SMAs of between 2 and 10 km. Unfortunately, no closely spaced stations were within 10 km of the epicenter so

no evaluations can be made for those distances. Table C-1 provides the pertinent information for the sites.

An examination of the acceleration records for east-west, north-south, and vertical directions for these examples suggests that in spite of differences in soil types, if the SMAs are within several kilometers of each other and 10 km from the source, the peak accelerations and records are similar. The absence of information from stations closer than 10 km does not permit extrapolating this observation for distances closer than 10 km, but also does not indicate that it is not possible.

The data in Table C-1 suggest that a single free-field SMA can provide a record that is representative of a limited area. Although records shown here from SMAs up to 10 km apart can give similar records, most stations within 5 km are typically similar. We suggest that a single free-field instrument properly located in an area of uniform geology (a single geologic domain) can provide a representative record for a radius of 5 km.

Figure C-1. Peak Ground Accelerations Obtained from a Series of SMAs in an SE Line (A) and a NNW Line (B) versus Distance from the Northridge Earthquake.

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Figure C-2a. Arleta-Northhoff Ave. F.S., C-2b. Pacoima-Kagel Canyon.

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Figure C-3a. Newhall-LA County F.S., C-3b. Sylmar-County Hospital.

Figure C-4a. LA-Pico and Sentous, C-4b. LA-Temple and Hope.

H95110224.5

Figure C-5a. LA-City Terrace, C-5b. LA-Obregon Park.

H95110224.4

Figure C-6a. Alhambra-Fremont School, C-6b. San Marino-Southwestern Academy.

Table C-1. Strong Motion Accelerometer Records from the Northridge Earthquake.

Figure	Site Names	Soil Type	Distance from epicenter	Distance between SMAs
C-2	Arieta-Northoff Ave. F.S. (24087)	Alluvium	10 km	8 km
	Pacoima-Kagel Canyon (24088)	Sedimentary Rock	18 km	
C-3	Newhall-LA County F.S. (24279)	Alluvium	20 km	10 km
	Symar-County Hospital Parking Lot (24514)	Alluvium	16 km	
C-4	LA-Pico & Sentous (24612)	Alluvium	31 km	3 km
	LA-Temple & Hope (24611)	Sedimentary Rock	32 km	
C-5	LA-City Terrace (24592)	Sedimentary Rock	38 km	2 km
	LA-Obregon Park (24400)	Alluvium	39 km	
C-6	Alhambra-Fremont School (924461)	Alluvium	39 km	5.5 km
	San Marino-Southwestern Academy (24401)	Deep Alluvium	39 km	

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