INL/EXT-07-13057

INL Seismic Monitoring Annual Report: January 1, 2006 – December 31, 2006

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J. M. Hodges
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September 2007

Idaho National Laboratory

The INL is a U.S. Department of Energy National Laboratory
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SUMMARY

During 2006, the Idaho National Laboratory (INL) recorded 1998 independent triggers from earthquakes both within the local region and from around the world. Within the local region of southeastern Idaho, southwestern Montana, western Wyoming and northern Utah, fifteen small to moderate size earthquakes ranging in magnitude from 3.0 to 4.5 occurred within and outside the 161-km (100-mile) radius of INL. There were 357 earthquakes with magnitudes up to 4.5 that occurred within the 161-km radius of the INL. The majority of earthquakes occurred in the Basin and Range Province surrounding the eastern Snake River Plain (ESRP). The largest of these earthquakes had a body-wave magnitude (m_b) 4.5 and occurred on February 5, 2006. It was located northeast of Spencer, Idaho near the east-west trending Centennial fault along the Idaho-Montana border. The earthquake did not trigger SMAs located within INL buildings.

Three earthquakes occurred within the ESRP, two of which occurred within the INL boundaries. One earthquake of coda magnitude (M_c) 1.7 occurred on October 18, 2006 and was located southeast of Pocatello, Idaho. The two earthquakes within the INL boundaries included the local magnitude (M_L) 2.0 on July 31, 2006 located near the southern termination of the Lemhi fault and the M_c 0.4 on August 6, 2006 located near the center of INL. The M_L 2.0 earthquake was well recorded by most of the INL seismic stations and had a focal depth of 8.98 km. First motions were used to compute a focal mechanism, which indicated normal faulting along one of two possible fault planes that may strike S14ºE and dip 70±3ºSW or strike N55ºW and dip 20±13ºNE. Slip along a normal fault that strikes S14ºE and dips 70±3ºSW is consistent with slip along a possible segment of the NW-trending Lemhi normal fault.

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ACKNOWLEDGMENTS

We thank Austin Holland for his assistance with INL Seismic Monitoring Program for over a decade. We especially appreciate Alan Marley's (BEA) support of the seismic computer systems. We also thank staff at the University of Utah Seismograph Stations, U. S. Geological Survey, Montana Bureau of Mines and Geology, and BYU-Idaho for their earthworm data shares.

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ACRONYMS

ANL	Argonne National Laboratory
BLM	Bureau of Land Management
CFA	Central Facilities Area
DAAS	Data Acquisition/Analysis System
DOE	Department of Energy
DSL	Digital Subscriber Line
EFS	Experimental Field Station
ESRP	Eastern Snake River Plain
GPS	Global Positioning System
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
IRC	INL Research Center
LOFT	Loss of Fluid Test
MFC	Materials and Fuels Complex
NEIC	National Earthquake Information Center
NRF	Naval Reactor Facility
PBF	Power Burst Facility
P-wave	Compressional Wave
RTC	Reactor Technology Complex
RWMC	Radioactive and Waste Management Complex
S-wave	Shear Wave
SMC	Special Manufacturing Complex
SMA	Strong Motion Accelerograph
STC	Science and Technology Complex

TAN	Test Area North
TRA	Test Reactor Area
USGS	United States Geological Survey

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1. Introduction

The Idaho National Laboratory (INL) has accumulated 34 years of earthquake data (1972-2006). This report covers the earthquake activity from January 1, 2006 through December 31, 2006 within a 161-km (100-mile) radius from the center of the INL designated as 43° 39.00' N, 112° 47.00' W (Figure 1). The report briefly discusses earthquakes greater than magnitude 3.0 that have occurred around the local region, including two microearthquakes that occurred within the INL boundaries in 2006. It discusses the instrumentation used to record earthquake data and how the data were analyzed. It also includes a discussion of continuous GPS (Global Positioning System) stations co-located at INL seismic stations in support of crustal deformation studies. The report is a continuation of previous annual reports on earthquake activity surrounding the eastern Snake River Plain (ESRP) and within and near the INL.

1.1 History of INL Seismic Monitoring Program

1.1.1 Purpose

The purpose of the INL Seismic Monitoring Program is to provide the INL with earthquake data and staff expertise in support of seismic safety for ongoing reactor operations and waste management activities, seismic and volcanic hazards assessments for new and existing buildings, and acquisition of new major programs. The INL Seismic Monitoring Program supports the requirements for safety of workers and the public set by Nuclear Regulatory Commission regulations, Executive Orders, and Department of Energy (DOE) Directives, Orders, and Standards. For example, the earthquake data are used to assess seismic hazards and develop seismic design criteria for the INL as required by DOE Order 420.1A "Facility Safety" (DOE, 2003).

The INL Seismic Monitoring Program operates 27 permanent seismic stations for the purpose of determining the time, location, and size of earthquakes occurring in the vicinity of the INL. The seismic data are compiled to develop an historical database that defines the zones and frequency of earthquake activity. Seismic stations are located within and around the INL near potential earthquake sources that include major range-bounding normal faults and volcanic rift zones (Figure 1).

The INL Seismic Monitoring Program operates 24 strong-motion accelerographs (SMAs) for the purpose of recording strong ground motions from local moderate or major earthquakes. The SMAs are located within INL buildings to determine the response of these buildings to ground motions in the event of a large earthquake. Several SMAs are located at "free-field" sites (not within buildings) at INL facility areas and are used to determine the levels of earthquake ground motions at the ground (rock or soil) surface. SMAs are also co-located with INL seismic stations to record acceleration data and assess attenuation effects of small to large magnitude normal faulting earthquakes.

1.1.2 Seismic Stations

The INL seismic network has evolved from a single analog station to its current configuration of 27 digital seismic stations. The INL Seismic Monitoring Program also records data from seismic stations owned and operated by other seismic networks. The INL seismic network began with a single station in 1971 and expanded to three stations by October of 1972. In 1977, the INL began monitoring a station operated by BYU-Idaho in Rexburg, Idaho, and the INL installed two additional stations in 1979. From

1979 to 1985, the INL monitored earthquake activity using six seismic stations. In 1985, the INL installed a simulated Wood-Anderson system to improve the capabilities of measuring the magnitude of local earthquakes ($3.0 \leq M_L \leq 5.0$). During 1986, the INL began receiving seismic data from a station located in Pocatello, Idaho and operated by the University of Utah in Salt Lake City, Utah. Also, in 1986, the INL began receiving data from a station located near Palisades Reservoir, Idaho that is operated by BYU-Idaho. A seismic station within the INL boundaries was added to the INL seismic network in 1987. During 1990, four more seismic stations were installed within the INL boundaries. During 1991-1992, thirteen new stations were installed in support of construction and operation of the proposed New Production Reactor at INL. Monitoring of BYU-Idaho seismic station near Palisades Reservoir was terminated in 1991 to accommodate the addition of the new INL seismic stations. In 1994, two new INL seismic stations were installed near Gray's Lake, Idaho. During 1999, the INL Howe Scarp (HWSI) seismic station was relocated further east to a new location now referred to as HWFI because of a lawsuit filed against the Bureau of Land Management (BLM). With the implementation of the EARTHWORM computer software in 2000, up to 14 stations from several nearby networks were being recorded in real-time along with the INL seismic stations. During 2001-2003, analog seismic instruments at all INL seismic stations were replaced with digital instruments. In 2003, the University of Utah transferred ownership of the Pocatello, Idaho (PTI) seismic station to the INL Seismic Monitoring Program at which time a digital seismic station was installed. With addition of the PTI station, INL currently operates 27 seismic stations.

1.1.3 Strong Motion Accelerographs

The INL began an accelerograph network by installing SMAs in buildings at INL facility areas, and more recently at free-field sites for both rock and soil conditions. In 1973, the INL began an accelerograph network by installing eleven SMAs in critical INL facilities. Three were located within buildings at the Idaho Nuclear Technology and Engineering Center (INTEC) (formerly referred to as Idaho Chemical Processing Plant - ICPP), two within the Materials and Fuels Complex (MFC) facilities (formerly referred to as Argonne National Laboratory – ANL), three within the Power Burst Facility (PBF), two within buildings at the Reactor Technology Complex (RTC) (formerly referred to as Test Reactor Area – TRA), and one at the Old Fire Station (OFS). From 1978 to 1979, four SMAs were installed at Test Area North (TAN) within the Containment Test facility (formerly referred to as Loss of Fluid Test – LOFT facility). Just prior to the October 1983 M_s 7.3 Borah Peak, Idaho earthquake, one SMA was installed at the INL Research Center (IRC), which is now part of the Science and Technology Complex (STC) in Idaho Falls, Idaho. Following the 1983 earthquake, two SMAs were installed within buildings at the Naval Reactor Facility (NRF). In 1984, two additional SMAs were placed within buildings at INTEC. During 1990, one SMA was installed at the Central Facilities Area (CFA). A digital SMA was co-located with an analog SMA at MFC in 1993. In 1996, two free-field SMA sites were installed, one at NRF and the other at PBF. In 1997, one SMA was installed as a free-field site at the Radioactive Waste Management Complex (RWMC). In 2003, the SMAs were upgraded to digital NetDAS SMAs. At that time, one NetDAS digital SMA replaced two SMAs co-located at Building ANL-767 (Kinemetrics analog SMA-1 and digital SSA-2 accelerograhs). The SMA on the crane beam at PBF-620 was not upgraded, but removed due to decommissioning activities.

Over the years, several SMAs have been relocated because buildings have been decommissioned and demolished. In 1995, the SMA at OFS was moved to a storage building directly behind the fire station because the fire station was decommissioned. In 1997 when the storage building was demolished, this SMA was relocated to the Experimental Field Station (EFS). In 1996, the Containment Test facilities or LOFT facilities were decommissioned. Three of the SMAs from LOFT were moved to the TAN Hot Shop and one was placed at the TAN Air Monitoring building. In 1997, the SMA at CFA was relocated to CFA-1607 Refueling Building. In 2004, the TAN Air Monitoring building was demolished so the SMA was removed and was reinstalled in 2005 as a free-field site at TAN. In 2004, the PBF building was demolished and the three SMAs were removed. The SMAs were reinstalled in 2005 as free-field sites near PBF and RWMC. In 2006, the four SMAs at TAN were removed due demolition of the TAN Hot Shop. Three of the SMAs will be reinstalled in 2007 near TAN at proposed locations that include a free-field site, the TAN guardhouse, and the Special Manufacturing Complex (SMC). The fourth SMA will be reinstalled at the New Production Reactor, Idaho (NPRI) seismic station. One SMA at RTC was removed from the Experimental Test Reactor late in 2006 and will be reinstalled in the Advanced Test Reactor (ATR) in 2007.

Three-component accelerometers were added to some of the seismic stations. In 2002, accelerometers were added to four seismic stations: Gray's Range (GRRI), New Production Reactor (NPRI), HWFI, and Bear Canyon (BCYI). In 2003, accelerometers were added to seismic stations Telchick Spring, Idaho (TCSI), Split Crater (SPCI), and PTI. During 2006, the INL Accelerograph Network operated up to 24 SMAs within or near INL Site facility areas and 7 three-component accelerometers at seismic stations.

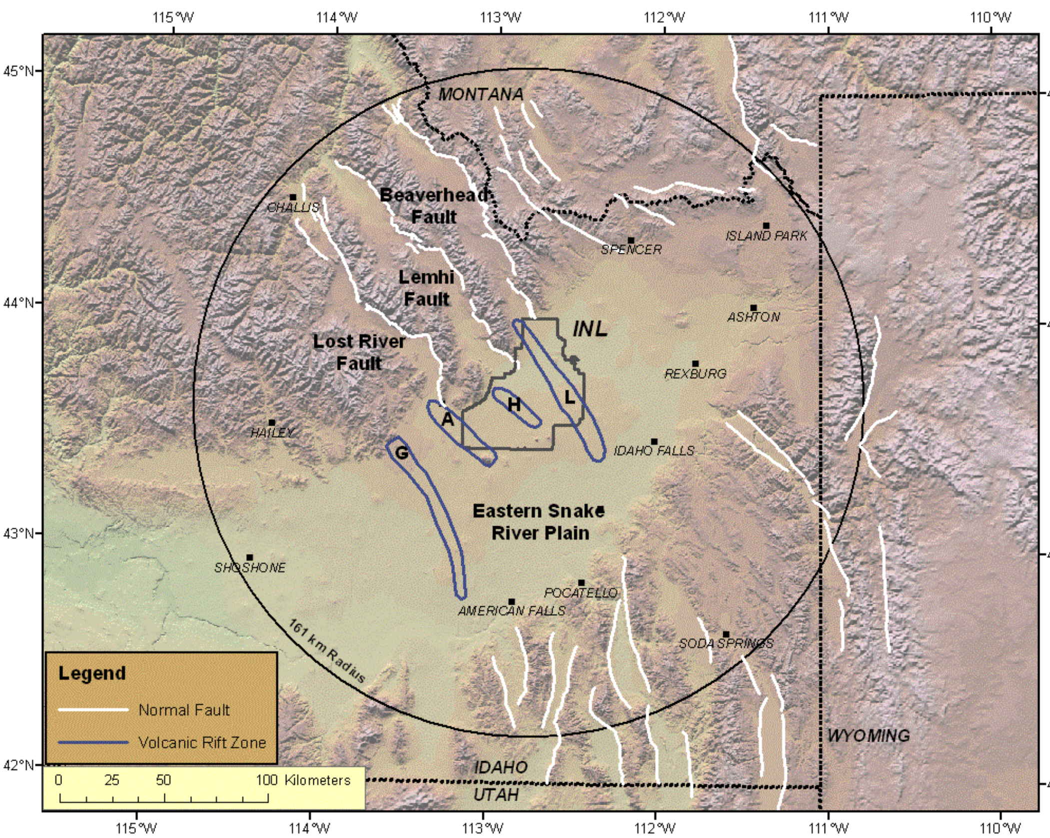

Figure 1. Map shows locations of the earthquake reporting area within the 161-km (100 mile) radius of the INL, Basin and Range normal faults, and volcanic rift zones: G – Great Rift, A – Arco, H – Howe-East Butte, and L – Lava Ridge-Hell's Half Acre.

2. Instrumentation

2.1 Seismic Station Network

During 2006, the INL Seismic Monitoring Program operated 27 permanent seismic stations and monitored 16 seismic stations from other nearby seismic networks (Figure 2). Table 1 lists the name, location, and date of installation for the seismic stations owned and operated by the INL Seismic Monitoring Program. Table 2 lists the name, location, and operation dates of seismic stations owned by other agencies. The INL records seismic data from these other seismic stations to improve the quality of earthquake locations within the 161-km radius of INL.

Instrumentation for INL seismic stations consists of digital recorders, one to three seismometers, and some accelerometers. The digital recorder is a DAQSystems NetDAS field unit, which is an embedded LINUX computer with a GPS clock and Symmetric Research 24 bit digitizer. The NetDAS units have nearly 22 bits of data resolution over ± 20 volts for a four-channel unit or ± 10 volts for an eight-channel unit. Four channel units (NetDAS-CH4) are located at seismic stations that have one or three sensors; eight channel units (NetDAS-CH8) are at seismic stations that have more than three sensors (such as three seismometers and three accelerometers). The seismic stations have pre-amplifiers that improve signal to noise ratios. The NetDAS digitizes data at the seismic station and time stamps the data with accuracies greater than 0.001 seconds. The seismic signals are transmitted by FreeWave Technologies DGR115 900 MHz Wireless Modem radios. These radios use standard IP (Internet Protocol) networking features that are included in the embedded LINUX.

Single-component seismic stations have vertically oriented velocity sensors that are a Mark Products model L-4C, Teledyne Geotech (TG) model S-13 or TG model S-13 Jr. seismometer buried within 3 m of the ground surface. All seismic stations located within the ESRP have a TG model S-13 J seismometer located at the bottom of 18 m or greater borehole to help dampen wind and cultural noise (Seismic, 1993). Seismic stations with horizontally oriented velocity sensors have two Teledyne Geotech model S-13 seismometers located within a concrete vault. Seismic stations with acceleration sensors have Applied MEMs Inc. model SF1500A, SF2500A, or SF3000L tri-axial accelerometers.

Where AC power is not available, seismic stations are powered by batteries, solar panels, and at some locations small wind generators. Radio frequency compatible antennas transmit and receive the seismic signals. Several seismic stations are used as relay stations to allow transmission of seismic signals to the IRC in Idaho Falls. The seismic data are relayed by digital radios or Internet Digital Subscriber Line (DSL) links (Appendix A). The data are acquired through EARTHWORM data shares on the Internet (discussed in Section 2.5). Digital seismograms are continuously displayed on three of four computer monitors referred to as “Webicorders.” The fourth monitor displays a map of current earthquakes located by the INL Seismic Monitoring Program.

2.2 Strong Motion Accelerographs

The INL accelerograph network has 24 strong-motion accelerographs at INL Site facilities; 23 are located at the INL Site and 1 is located in the IRC at the STC. Table 3 lists the location and date of installation for each of the SMAs in operation during 2006. There are 1 to 5 accelerographs at each INL Site facility area (Figure 3). Where possible, several SMAs are interconnected at a facility area so that if one instrument triggers to record data then others at that same area will also record data. Three SMAs are interconnected at TAN and two at INTEC. During 2006, earthquakes did not trigger SMAs located within INL facilities.

In October 2006, the four SMAs at TAN were removed due to demolition of the TAN Hot Shop (TAN-607). The SMAs will be reinstalled at new locations near TAN that will include a free-field site, the TAN guardhouse, and the Special Manufacturing Complex (SMC). The fourth SMA will be reinstalled at the New Production Reactor, Idaho (NPRI) seismic station since possible construction of a new power reactor is proposed for this region of INL. In December 2006, one SMA at RTC in the Experimental Test Reactor (TRA-642) was removed from the building prior to demolition activities. This SMA will be reinstalled in 2007 on the first floor of the ATR at RTC.

INL SMAs are DAQSystems NetDAS digital accelerographs that have Applied MEMS SiFlex SF2500 tri-axial accelerometers. Each SMA is set to trigger and record to compact flash when ground motions exceed 2500 counts, which is equivalent to about 0.005 g. The record lengths are set for 30 s of pre- and post-trigger thresholds. The triaxial accelerometers have two horizontal components oriented in an orthogonal manner, generally aligned in the north-south and east-west directions. Appendix B lists the accelerometer orientation and instrument response for the horizontal and vertical components of each SMA. SMAs at free-field sites have GPS clocks to synchronize the internal clocks to an absolute time system. For some SMAs at free-field sites and locations within buildings, acceleration data are transmitted to the IRC via digital radios or the Internet. Other SMAs record data on compact flash disks that are retrieved by INL seismic personnel using a laptop PC computer.

2.3 Continuous GPS Stations

The INL Seismic Monitoring Program has a geodetic network for the purpose of monitoring horizontal crustal deformation in support of INL seismic hazards assessments. GPS data are used to investigate active crustal deformation that is on the order of millimeters of movement per year within the ESRP, the surrounding Basin and Range, and Yellowstone Plateau. GPS data define regions of high velocity gradients having more frequent damaging earthquakes (e.g., Yellowstone – Hebgen Lake, Montana) than regions of low velocity gradients (e.g., eastern Snake River Plain). The spatial patterns of GPS data also constrain the fundamental geodynamic processes driving active continental deformation (e.g., Yellowstone hotspot). GPS data collected by INL also contribute to the larger scientific effort for the Plate Boundary Observatory operated under University NAVSTAR Consortium (UNAVCO) to understand western United States crustal deformation processes.

During 2006, six GPS receivers were co-located at INL seismic stations. Five GPS receivers are owned by the INL and one is owned by UNAVCO. There are three other continuous GPS stations owned by other agencies located within the 161-km radius of INL (Figure 4). Table 4 lists the name, ownership, location, and date of installation of the continuous GPS stations.

An INL GPS station consists of a Trimble NetRS GPS receiver connected to a L1/L2 dual frequency choke ring antenna. The antenna is attached to a 2.4 m steel rod that is drilled into a rock outcrop to a depth of about 1 m. Above ground the antenna is stabilized using a much larger PVC pipe filled with sand. This reduces the amount of wind noise within the GPS data, improving the accuracy. The NetRS receivers continuously collect GPS data. The data are relayed along with the seismic station data to DSL links, which are then accessed from the Internet at the IRC. Also, the data are downloaded daily from the Internet and archived by UNAVCO.

2.4 Seismic Data Acquisition and Analysis System

The INL records earthquake data on a computer Data Acquisition/Analysis System (DAAS) at the IRC. INL began recording earthquake data on the DAAS June 8, 1991 using the U. S. Geological Survey (USGS) CUSP processing software. Since 2001, significant upgrades have been made to the DAAS as a result of computer hardware and software advances. The USGS CUSP data acquisition and analysis software that supported use of the TIMIT program were replaced with the earthquake analysis program SEISAN (developed by the University of Bergen, Norway) in 2002 and the USGS EARTHWORM processing software in 2003. From June 1991 to November 2002, earthquake data were analyzed using the USGS TIMIT program. As of December 2002, earthquake data are now being analyzed using the SEISAN program. Use of the SEISAN and EARTHWORM programs facilitated the upgrades of seismic stations and SMAs to the NetDAS digital units, allowing concurrent waveform analyses of both velocity and acceleration data. Instrument responses of the NetDAS units at seismic stations and SMAs are now routinely performed and are integrated into the SEISAN database (see Appendices B and C). All digital earthquake data are also routinely archived to DVD media after analysis.

For acquisition of the earthquake data, the EARTHWORM program compares the digitized seismic data to the average noise or voltage level determined over a time interval of 1,000 s. The program determines that an earthquake has occurred when the amplitude of the voltage level over a 1-second time-interval for several stations within a subnet exceeds a threshold value of 2.5 times this average noise level. When an earthquake is detected, the seismograms for all stations within triggered subnets and the time codes are saved in a file on a disk. This file is labeled with a sequential number based on the date and time of the trigger for later reference to the earthquake in the SEISAN database. Each seismogram has 30 s of pre-event data and 20 s of post-event data stored within the file. In some instances, earthquakes have low-amplitude emergent P-waves with larger amplitude S-waves. When this occurs the DAAS may trigger on the S-waves instead of the P-waves, thus, saving 30 s of pre-event time allows recording of the P-waves also.

The earthquake detection software is set up to trigger on earthquakes detected by several stations within a subnet. Subnets contain several stations that are located in a small area and which are likely to detect the same local earthquake. All INL seismic stations usually detect earthquakes of magnitude 1.5. Subnets are specified for stations in close proximity to each other and their relationship to known seismic sources. For the ESRP though, a subnet was created for detection of small magnitude ($M < 0.5$) microearthquakes.

The EARTHWORM program also enables data sharing with other seismic networks in near real time over the Internet. The INL provides data from various seismic stations to the University of Utah, Montana Bureau of Mines and Geology, National Earthquake Information Center (NEIC), and BYU-Idaho, which in return provide data to INL (Table 2). EARTHWORM records seismic data from INL and these other agencies, which are analyzed using the SEISAN program.

Table 1. Seismic stations operated by INL.

Code	Station Name	Sensors Types	Latitude North (º)	Longitude West (º)	Elevation (m)	Date Installed (Month/Year)
ARNI	Argonne North, Idaho	Borehole Vertical Seismometer and GPS Reciever	43.6667	112.6235	1533	09/90
BCYI	Bear Canyon, Idaho	Vertical Seismometer, Three-component Accelerometers, and GPS Receiver	44.3108	113.4052	2194	05/92
CBTI	Cedar Butte, Idaho	Borehole Vertical Seismometer	43.3875	112.9115	1734	07/86
COMI	Craters of the Moon, Idaho	Vertical Seismometer	43.4618	113.5938	1890	03/92
CNCI	Crows Nest Canyon, Idaho	Vertical Seismometer	43.9283	113.4522	1914	05/92
CRBI	Circular Butte, Idaho	Borehole Vertical Seismometer	43.8303	112.6345	1520	11/87
ECRI	Eagle Creek, Idaho	Vertical Seismometer	43.0535	111.3705	2086	08/94
EMI	Eightmile Canyon, Idaho	Vertical Seismometer and GPS Receiver	44.0742	112.9262	1963	04/92
GBI	Big Grassy Butte, Idaho	Borehole Vertical Seismometer	43.9875	112.0633	1541	10/81
GRRI	Grays Range, Idaho	Vertical Seismometer and Three-component Accelerometers	42.9380	111.4217	2207	08/94
GTRI	Great Rift, Idaho	Borehole Vertical Seismometer and GPS Receiver	43.2440	113.2410	1522	05/92
HHAI	Hell's Half Acre, Idaho	Borehole Vertical Seismometer	43.2950	112.3795	1371	06/92
HPI	Howe Peak, Idaho	Vertical Seismometer and GPS Receiver	43.7113	113.0983	2597	10/72
HWFI	Howe Fault, Idaho	Three-component Seismometers and Accelerometers	43.9257	113.0973	1743	10/99

Table 1. Continued.

Code	Station Name	Sensors Types	Latitude North (º)	Longitude West (º)	Elevation (m)	Date Installed (Month/Year)
ICI	Italian Canyon, Idaho	Vertical Seismometer	44.3293	112.9412	2463	04/92
IRCI	INL Research Center, Idaho	Low-gain Three-component Seismometers	43.5153	112.0333	1442	11/88
JGI	Juniper Gulch, Idaho	Three-component Seismometers	44.0927	112.6768	1657	11/79
KBI	Kettle Butte, Idaho	Borehole Vertical Seismometer	43.5907	112.3767	1678	05/92
LJI	Lemhi Junction, Idaho	Vertical Seismometer	43.8208	112.8440	1643	05/90
LLRI	Little Lost River, Idaho	Three-component Seismometers and Accelerometers	43.7230	112.9330	1476	05/90
NPRI	New Production Reactor, Idaho	Three-component Seismometers and Accelerometers	43.5975	112.8272	1495	09/90
PZCI	Patelzick Creek, Idaho	Vertical Seismometer	44.3410	112.3172	2073	12/91
PTI	Pocatello, Idaho	Vertical Seismometer and Three-component Accelerometers	42.8703	112.3702	1670	10/84
SMBI	Sixmile Butte, Idaho	Borehole Vertical Seismometer	43.5022	113.2677	1716	05/92
SPCI	Split Crater, Idaho	Three-component Seismometers and Accelerometers	43.4500	112.6370	1553	06/92
TCSI	Telchick Spring, Idaho	Vertical Seismometer, Three-component Accelerometers, and GPS Receiver	43.6193	113.4783	1731	05/92
TMI	Taylor Mountain, Idaho	Three-component Seismometers	43.3057	111.9182	2179	10/72

Table 2. Stations monitored by the INL that are operated by other agencies.

Code	Station Name	Latitude North (º)	Longitude West (º)	Elevation (m)	Operating Dates (Month/Year)	
Brigham Young University – Idaho, Rexburg, Idaho						
CMI	Centennial Mountains, Idaho	44.6175	111.5165	2267	07/1980	Pres
IMW	Indian Meadows, Wyoming	43.8970	110.9392	2624	07/1980	Pres
RRI	Red Ridge, Idaho	43.3640	111.3190	2408	07/1985	Pres
U. S. National Seismic Network, Golden, Colorado						
AHID	Auburn, Idaho	42.7653	111.1003	1960	11/1997	Pres
BW06	Boulder, Wyoming	42.7667	109.5582	2224	05/1996	Pres
HLID	Hailey, Idaho	43.5625	114.4063	1498	08/1988	Pres
University of Utah, Salt Lake City, Utah						
BEI	Bear River Range, Idaho	42.1167	111.7823	1859	11/1984	Pres
BMUT	Black Mountain, Utah	41.9582	111.2342	2243	10/1979	Pres
MCID	Moose Creek, Idaho	44.1903	111.1827	2149	12/1995	Pres
MLI	Malad Range, Idaho	42.0268	112.1255	1896	10/1974	Pres
NPI	North Pocatello, Idaho	42.1473	112.5183	1640	04/1975	Pres
YMC	Maple Creek, Wyoming	44.7593	111.0062	2073	12/1983	Pres
YPP	Pitchstone Plateau, Wyoming	44.2710	110.8045	2707	08/1996	Pres
Montana Bureau of Mines and Geology, Butte, Montana						
MCMT	McKenzie Canyon, Montana	44.8277	112.8488	2323	09/1989	Pres
MOMT	Monida, Montana	44.5933	112.3943	2220	10/1995	Pres
TPMT	Teepee Creek, Montana	44.7298	111.6657	2518	10/1992	Pres

Table 3. Strong-motion accelerographs operated by INL.

INL Site Facility Area	Building Number	Location	SMA Code	Year Installed
MFC	ANL-767	Basement	EBR	1973
MFC	ANL-768	Basement	FCF	1973
CFA	CFA-1607	Free-field	CFAF	1996
CFA	EFS	Free-field	EFSF	1997
INTEC	CPP-668	Free-field	CPPF	1992
INTEC	CPP-601	First Floor	CPP1	1973
INTEC	CPP-601	Second Basement	CPP2	1973
INTEC	CPP-666	Second Floor	FAS1	1984
INTEC	CPP-666	Second Basement	FAS2	1984
NRF	NRF-768	Free-field	NRFF	1996
NRF	NRF-A1W	First Floor	A1W	1983
NRF	NRF-S1W	First Floor	S1W	1983
PBF	NA	Free-field	PBFF	2005
PBF	NA	Free-field	ARAF	2005
RTC	TRA-602	Free-field	TRAF	2003
RTC	TRA-642	Basement	TRA1	1973
RTC	TRA-670	Basement	TRA2	1996
RWMC	NA	Free-field	RWMC	1997
RWMC	NA	Free-field	RWME	2005
STC	IRC-602	First Floor	IRC	1983
TAN	NA	Free-field	TANA	2005
TAN	TAN-607	First Floor	TAN1	1996
TAN	TAN-607	Second Floor	TAN2	1996
TAN	TAN-607	Third Floor	TAN3	1996

NA – Not within a building.

Table 4. Location and ownership of continuous recording GPS stations.

Code	Station Name	Latitude North (º)	Longitude West (º)	Elevation (m)	Year Installed
Idaho National Laboratory					
ARNG	Argonne North, Idaho	43.6667	112.6235	1533	2005
BCYI	Bear Canyon, Idaho	44.3108	113.4052	2194	2003
EMIG	Eightmile Canyon, Idaho	44.0742	112.9262	1963	2005
HPIG	Howe Peak, Idaho	43.7113	113.0983	2597	2005
TCSG	Telchick Spring, Idaho	43.6193	113.4783	1731	2005
Yellowstone Hotspot GPS Network (UNAVCO)					
GTRG	Great Rift, Idaho	43.2440	113.2410	1522	1998
BBID	Big Bend Ridge, Idaho	44.1851	111.5261	1811	2001
AHID	Auburn, Idaho	42.7731	111.0637	1975	2000
HLID	Hailey, Idaho	43.5626	114.4144	1774	1999

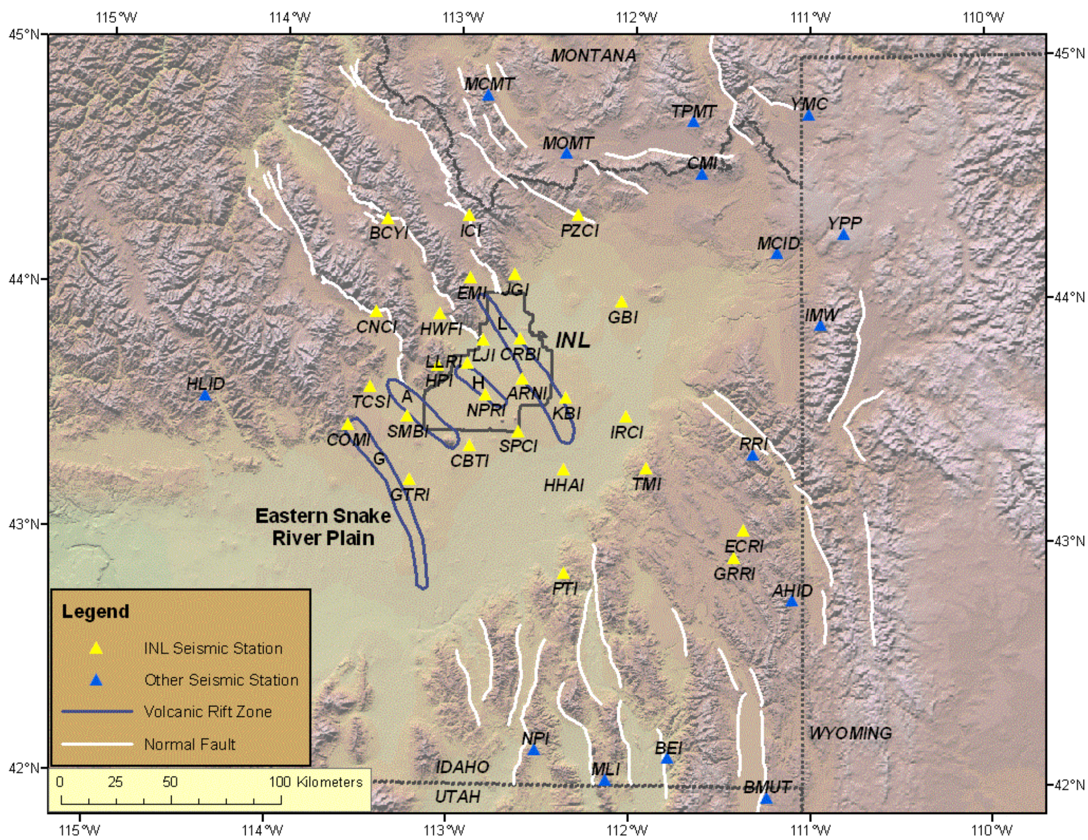

Figure 2. Locations of INL seismic stations and stations monitored by INL that are operated by other institutions. See Figure 1 for names of normal faults and volcanic rift zones.

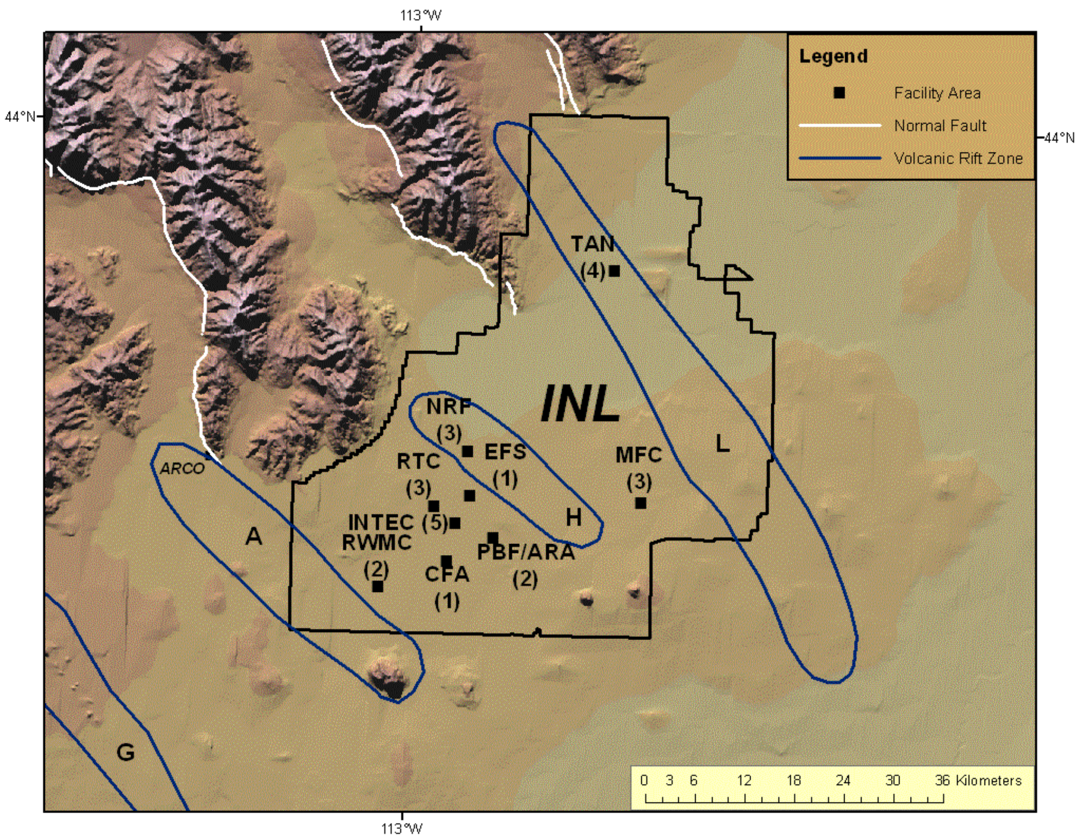

Figure 3. Numbers (in parentheses) of SMAs located at INL facility areas. See Figure 1 for names of normal faults and volcanic rift zones.

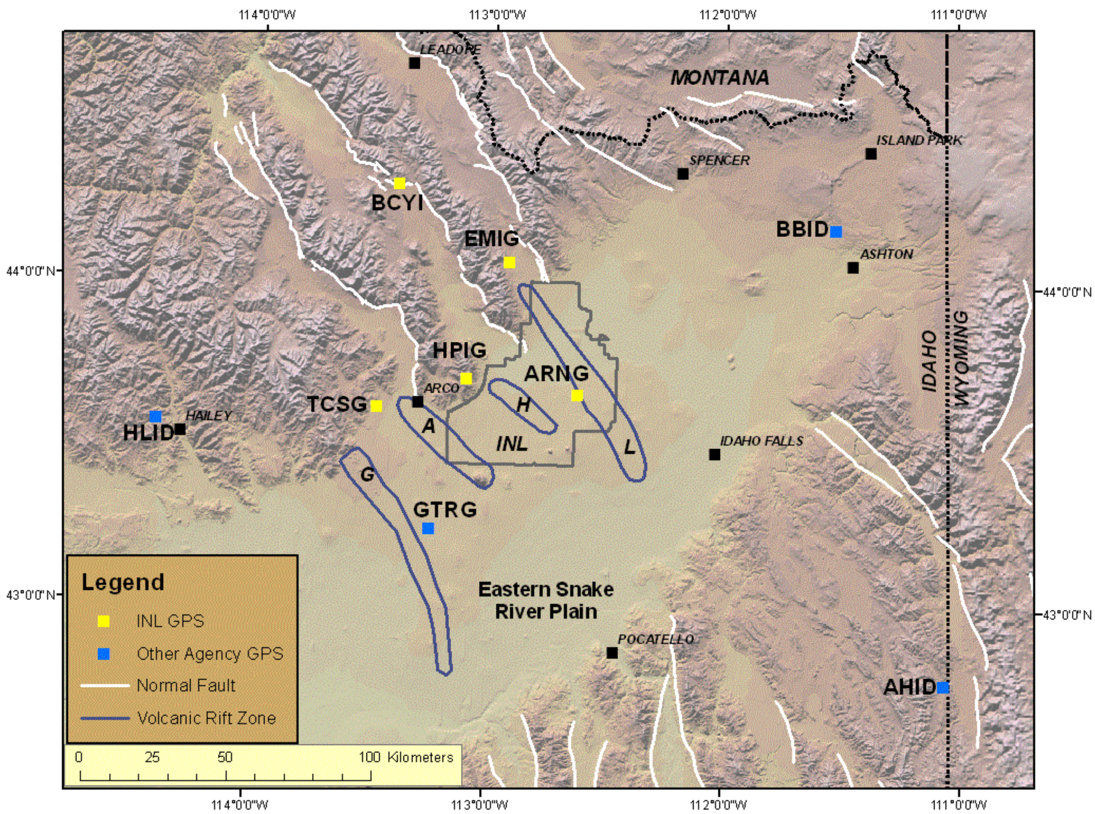

Figure 4. Locations of the continuous GPS stations co-located at INL seismic stations and operated by other agencies. See Figure 1 for names of normal faults and volcanic rift zones.

3. Data Analysis

Digital seismograms are analyzed using the SEISAN program to determine the location, magnitude, and peak ground accelerations. SEISAN displays multiple seismograms on a computer screen with corresponding times codes having accuracy of ± 0.001 s. P- and S- wave arrival times of the seismograms are recorded to a precision of 0.01 s. Duration and/or amplitude of a seismic signal is selected and then used to calculate the magnitude of an earthquake. The arrival times, durations, and amplitudes measured for an earthquake are saved in a computer file directly from the SEISAN program. A separate program then calculates the location (see below) and magnitude of an earthquake. The locations and magnitudes of the earthquakes are plotted on maps to assess seismically active regions near the INL. Amplitudes of the accelerograms are also measured using the SEISAN program, then processed using a separate program that outputs peak horizontal and vertical accelerations.

3.1 Location Method

The HYPOINVERSE computer program (Klein, 1989) is used to determine locations for all local earthquakes recorded. Phase data files (arrival times of the earthquake) from the output of SEISAN are input into the HYPOINVERSE location program. According to Zollweg and Sprenke (1995), stable locations are usually obtained from about seven to ten arrival times (P- and S-waves combined) for recorded events that are not surrounded by INL seismic stations. Within the INL network, stable locations can be obtained with a minimum of six arrival times. Because of the density and sensitivity of the INL seismic network, the majority (usually more than 90%) of earthquakes located within the 161-km radius have a minimum of six arrival times. However, some earthquakes are located with fewer than six arrival times and, thus, their locations have larger errors. Seismic stations from other agencies monitored by the INL provide coverage outside the INL network and phase arrivals from these stations supplement phase data from INL stations in an attempt to reduce location errors.

Four P-wave velocity models are used in the HYPOINVERSE location program depending on the location of the earthquakes (Table 5). The "ESRP" velocity model is used for locating earthquakes that occur within the ESRP including the mountainous terrain on the northern and eastern edge of the Plain (Olsen et al., 1979; Sparlin et al., 1979; Braile and Smith, 1979; and Ackerman, 1979). The "INL ESRP" velocity model is used to locate earthquakes that occur on the ESRP and are near or within the INL Site boundaries. This model was developed from Sparlin et al. (1982) and Braile et al. (1982) and checked with respect to a few microearthquakes located within the ESRP (Jackson et al., 1989). The "BPEAK" velocity model is used for locating earthquakes that occur in the Borah Peak aftershock area and the mountainous terrain northwest of the Plain (Richins et al., 1987). Finally, the "SMT" velocity model is used to locate earthquake in southwestern Montana (Stickney, 1997). For all velocity models, a P-wave velocity to S-wave velocity ratio of 1.75 is used (Bones, 1978; Greensfelder and Kovach, 1982; and Richins et al., 1987).

Other notable parameters used in the HYPOINVERSE location program are the starting focal depth, set to 5 km, and the distance cutoff for arrival weighting, set to 50 km. Zollweg and Sprenke (1995) evaluated the parameters chosen for the HYPOINVERSE program used by INL. They determined that the parameters chosen yield good location results despite the poor coverage in azimuth of earthquakes outside the network. An evaluation of the difference between the observed and computed latitude and longitude was less than 0.25 km.

3.2 Magnitude Calculations

Magnitudes are determined using two methods 1) coda magnitudes using signal duration of digital seismograms and 2) local magnitudes using amplitudes from digital seismograms. Coda magnitudes (M_c) are calculated for earthquakes of magnitudes less than 3.0 using signal durations of several earthquakes recorded on different seismic stations. Local magnitudes (M_L) are calculated using the largest peak-to-peak trace amplitude measured from digital waveforms and the Richter magnitude equation. If a magnitude cannot be determined for a local earthquake, then magnitudes determined by other seismic networks may be used. These include the University of Utah, Montana Bureau of Mines and Geology, NEIC, Boise State University, and the U.S. Bureau of Reclamation.

For the signal duration method, Tthe following expression is used to calculate coda magnitude at a station (Arabasz et al., 1979):

$$M_c = -3.13 + 2.74 \log \tau + 0.0012 \Delta \qquad [1]$$

Where:

τ = Total signal duration recorded at the station in seconds;

Δ = Epicentral distance from the station in km.

The duration is measured at the start of the earthquake signature (P-wave arrival) to the end of the coda, where the signal fades into the background noise of the trace. The final magnitude is determined by averaging the coda magnitude calculated for each seismogram. The SEISAN program automatically selects the duration of the earthquake when the P-wave arrival time is selected. Equation (1) is usually used to estimate magnitudes for events located by the HYPOINVERSE location program.

Local magnitudes calculated from the digital seismograms are based on the Richter magnitude scale. Richter (1958) defined the local magnitude scale from the following equation:

$$M_L = \text{Log } A - \text{Log } A_o \qquad [2]$$

Where:

A = Recorded maximum trace amplitude from the zero-line measured in millimeters on a standard seismogram;

A_o = Maximum trace amplitude from the zero-line in millimeters for a selected standard earthquake.

Dr. Richter developed the scale for a standard earthquake of magnitude 3.0 at 100 km for A_o = 0.001 mm and amplitude of 1.0 mm measured on the standard seismogram. He constructed a table of magnitudes based on distance and -Log A_o for maximum trace amplitudes recorded on the standard Wood-Anderson seismogram.

SEISAN has a program that uses equation [2] with amplitudes measured on a synthetic Wood-Anderson digital seismogram. The program allows the user to convert waveforms recorded on the horizontal channels of accelerometers and seismometers at INL seismic stations to synthetic Wood-Anderson seismograms. The SEISAN program uses the instrument response information contained in Appendix B for accelerograms and Appendix C for seismograms to calculate synthetic Wood-Anderson seismograms at a magnification of 2800. The user then selects the largest peak-to-peak amplitude (or A) in millimeters from the digital display of the synthetic Wood-Anderson seismogram. The SEISAN program then uses the distance of the simulated Wood-Anderson station to the earthquake's epicenter and one-half the peak-to-peak amplitude to determine local magnitude using Richter's table. The program determines the local magnitude for each amplitude selected.

3.3 Peak Accelerations

Peak horizontal and vertical accelerations are determined for accelerograms (or acceleration time histories) using the SEISAN program (Section 2.4). SEISAN displays the horizontal and vertical accelerograms for some free-field SMAs located at the INL and accelerometers co-located with the seismic stations. The SEISAN program allows the user to correct the accelerograms by removing the instrument responses listed in Appendices A and B. A separate program is used to measure the largest zero-to-peak acceleration amplitude from the corrected acceleration time history.

3.4 Location Quality

Comparisons between earthquake locations determined by the INL and locations determined by other temporary networks or NEIC have been used to approximate locations errors of earthquake epicenters (Jackson et al., 1993a). This method was very general and yielded an approximation of the quality of the INL earthquake locations. In 1995, the State of Idaho requested Zollweg and Sprenke (1995) to perform an independent assessment of the INL Seismic Monitoring Program. Zollweg and Sprenke (1995) evaluated the location accuracy of the INL seismic network by two methods: 1) directly comparing INL locations to well-located earthquakes; and 2) indirectly by evaluating the network bias or non-random error through varying independent permutations (or combinations) of recording stations.

For the first method, twenty-two earthquakes having high-quality locations determined from a temporary seismic network installed near Challis, Idaho from July 1, 1992 to July 12, 1992 (by Boise State University) were compared to INL locations for these earthquakes. The earthquakes were located about 120 km from the center of INL, had varying magnitudes ranging from 1.9 to 4.5, and had absolute errors less than 1 km. The epicenters determined by INL seismic stations for these events differed by 1.6 to 11.5 km with an average of 7.1 km. The differences in locations were dependent on magnitude, with the smaller magnitude earthquakes tending to have greater differences in locations (Zollweg and Sprenke, 1995). These results are similar to the earlier estimates of an error radius of 5 km for a comparison to high-quality locations of the aftershocks from the M_s 7.3 October 28, 1983 earthquake (Jackson et al., 1993a). However it is noted that this estimate for an error radius was based on having five stations in the INL seismic network at that time. The closest station to the aftershocks was at a distance of 50 km or more.

The second method used by Zollweg and Sprenke (1995) evaluates the network bias. Unless all earthquakes are located using exactly the same groups of stations and phases (P- and S-waves), the relative locations will be affected by a non-random error or network bias. The network bias is important for the smaller earthquakes that make up the majority of the events in a catalog since fewer stations usually record smaller earthquakes. Five earthquakes located northwest of the INL seismic network and ranging in magnitude from 1.8 to 3.8 were used in the analysis. Because INL operated 26 seismic stations at the time of the assessment, there were millions of possible combinations of recording stations. Zollweg and Sprenke (1995) chose to vary the combination of the ten most influential phase arrivals for the permutation analysis. The locations for most of the permutations clustered about radii ranging from 6.5 to 11 km. For the magnitude 3.8 earthquake, 8% of the permutations resulted in a linear band extending 100 km. Zollweg and Sprenke (1995) suggested that earthquakes located with fewer S-wave arrival times have less well-constrained locations. Some of the larger earthquakes, like the magnitude 3.8 earthquake, have fewer S-wave arrival times because the signals saturate the instrumentation and onset of the S- wave is indistinguishable from the P-waves. Earthquakes with more than three S-wave-arrival times resulted in better-constrained locations.

3.5 Depth Quality

The HYPOINVERSE location program also calculates depth to the hypocenter. Focal depths calculated by this program are not accurate for many of the earthquakes recorded by the INL seismic network for two reasons: 1) the station spacing is usually greater than twice the focal depth of the earthquake recorded; and 2) the earthquake usually occurs outside of the network. To calculate accurate focal depths, the earthquake must occur within the seismic network and at a distance equal to or less than its focal depth. Although focal depths are listed in Appendix D, they should be interpreted within the context of the limitations discussed in this section unless otherwise indicated.

3.6 Data Completeness

Local earthquakes are easily discriminated from other seismic data such as local mine blasts, air blasts (or sonic booms), and distant (worldwide) and regional earthquakes occurring far outside of the INL seismic network. For example, man-made blasts are easily discriminated from earthquakes on the basis of waveform characteristics, the time the event occurred, and the location of the event. The NEIC earthquake website listing is regularly inspected to confirm consistency with the INL earthquake catalog for magnitudes 2.5 and greater (the cutoff magnitude for NEIC earthquake locations).

Detection threshold can provide a measure of completeness for the INL earthquake catalog. It is defined as the magnitude level at which the seismic network will nearly always locate an earthquake. Zollweg and Sprenke (1995) evaluated the detection threshold by plotting the cumulative number of earthquakes as a function of magnitude to determine the lowest magnitude point that the curve begins to flatten. Zollweg and Sprenke (1995) determined the detection threshold to be a magnitude 1.3 anywhere within a 100-mile radius around INL. Their conclusion was based on a plot of 1360 earthquakes for an 18-month period. Since the seismic stations are all located within 90 km of the center of INL, they suggested that the detection threshold is magnitude 0.8 within the network on the ESRP. The analysis of Zollweg and Sprenke (1995) suggests that the INL earthquake catalog is complete for magnitudes above 1.3 within a 100-mile radius of INL and may be complete for magnitudes as low as 0.8 within the network. Hardware and software upgrades for the current DAAS have increased detection sensitivities on the order of magnitude 0.0 which allow recording of small magnitude microearthquakes within ESRP.

Table 5. P-wave velocity models used in location programs.

Velocity Model Code	Velocity (km/sec)	Depth to Top of Layer (km)	Layer Thickness (km)	References
ESRP	4.90	0.00	2.00	Olsen et al., 1979; Sparlin et al., 1979; Braile & Smith, 1979; Ackerman, 1979.
	6.00	2.00	15.00	
	6.70	17.00	23.00	
	7.90	40.00	Half-space	
INL ESRP	3.30	0.00	1.00	Sparlin et al., 1982; Braile et al., 1982; Jackson et al., 1989.
	4.90	1.00	2.00	
	5.30	3.00	2.00	
	6.15	5.00	2.00	
	6.53	7.00	10.00	
	6.80	17.00	23.00	
	8.00	40.00	Half-space	
BPEAK	4.75	0.00	1.64	Richins et al., 1987.
	5.59	1.64	5.31	
	6.16	6.95	11.05	
	6.80	18.00	22.00	
	8.00	40.00	Half-space	
SMT	5.52	0.00	5.86	Stickney, 1997.
	6.12	5.86	12.78	
	6.74	18.64	20.05	
	8.00	38.69	Half-space	

4. 2006 Earthquake Activity

During 2006, INL recorded 1,998 independent triggers from earthquakes both within the local region and from around the world. In the local region that includes southeastern Idaho, southwestern Montana, western Wyoming, and northern Utah, fifteen small to moderate size earthquakes ranging in magnitude from 3.0 to 4.5 occurred outside and within a 161-km (or 100-mile) radius of INL. The regional earthquake activity (1,051 events) occurred in areas that included central Idaho near Stanley and Challis, southwestern Montana along the Idaho border, Dillon Montana, Yellowstone National Park, Wyoming, Jackson, Wyoming, and southeastern Idaho. Of these events, 356 earthquakes were located within the 161-km radius of INL (see Appendix D for list of locations). Three of these earthquakes exceeded M_L 3.0, the largest earthquake had a M_L of 4.5. The majority of the earthquakes were located in areas that have been seismically active in the past, along the basin and range faults northwest of INL, southwestern Montana, and southeastern Idaho. Three earthquakes occurred within the ESRP, two of which were located within the INL boundaries.

4.1 Regional Earthquake Activity

Twelve earthquakes of magnitudes from 3.0 to 4.3 occurred in the region outside the 161-km radius of INL (Figure 5). Of these earthquakes, three occurred with M_L 3.2 (March), 3.8 (June), and 3.9 (January) and were located within the aftershock zone of the 2005 body wave magnitude (m_b) 5.7 Dillon, Montana earthquake. Residents in Dillon and nearby towns felt all of these earthquakes. Three earthquakes of M_L 3.2, 3.8 and 4.1 occurred northeast of Dillon, Montana in June and were also felt by local residents. Two earthquakes occurred east of Jackson, Wyoming; the first in April with an M_L 3.2 and the second in May with an M_L 3.9. Four events occurred in southeast Idaho as part of a sequence that began in June with a M_L 4.3 earthquake, which was followed by earthquakes of M_L 4.0 and 3.1 in July and M_L 3.6 in September. Residents in Pocatello, Soda Springs, Montpelier and other nearby Idaho towns, as well as several towns in northern Utah, felt these earthquakes.

4.2 Local Earthquake Activity

There were 356 earthquakes within the 161-km radius of INL that occurred within the ESRP and in the surrounding Basin and Range Province (Figure 6). Three of the earthquakes within 161-km radius of INL exceeded magnitude 3.0. The largest earthquake had an m_b 4.5, occurred on February 5, 2006, and was located northeast of Spencer, Idaho near the east-west trending Centennial fault along the Idaho-Montana border. Residents throughout southwestern Montana and along the border in Idaho felt the m_b 4.5 earthquake. On June 7, 2006, an earthquake of M_L 3.0 occurred near Palisades reservoir east of Idaho Falls, Idaho. Local residents in Swan Valley felt this event. An earthquake of M_L 3.5 occurred on August 2, 2006 at Challis, Idaho and was felt by local residents in Challis.

During 2006, three small earthquake swarms occurred in areas outside of the ESRP. The first swarm (~ 50 earthquakes) occurred in January northwest of Spencer, Idaho near the Idaho-Montana border. The second small swarm of earthquakes (< 10) occurred during June southeast of Ashton, Idaho. In August, a small swarm of earthquakes (15) occurred west of Challis, Idaho. Earthquakes occurred throughout the year in southeast Idaho along the Idaho-Wyoming border, near Yellowstone National Park, southwestern Montana along the Idaho-Montana border, and in the basin and range region northwest of the INL along the Lost River fault southeast of Challis (Figure 6).

4.3 Eastern Snake River Plain Earthquake Activity

Three earthquakes occurred within the ESRP during 2006. One earthquake of M_c 1.7 occurred southeast of Pocatello, Idaho on October 18, 2006 (Figure 6). The other two earthquakes occurred within the INL boundaries. The first was an earthquake of M_L 2.0 on July 31, 2006 (at 11:56 UTC) located near the southern termination of the Lemhi fault and the second an earthquake of M_c 0.4 on August 6, 2006 (at 11:01 UTC) located near the center of INL (Figure 7).

The M_L 2.0 earthquake was well recorded by most of the INL seismic stations resulting in 25 arrival times for both P- and S-waves. The earthquake had a focal depth of 8.98 km, which was evaluated using multiple runs of HYPOINVERSE with fixed focal depths to determine the minimum RMS. First motions were used to compute a focal mechanism, which is a method used by seismologists to determine fault type (i.e., normal, strike-slip, or thrust). The nodal planes of the focal mechanism computed for the July 31, 2006 earthquake using the program FPFIT (Reasenberg and Oppenheimer, 1985) indicate normal faulting with a small component of left-lateral slip along one of two possible fault planes: one with a strike of S14ºE and dip of 70±3ºSW or a second with a strike of N55ºW and dip of 20±13ºNE. The T-axis of N20ºE is consistent with the direction of extension indicated by the NW-trending normal faults northwest of the INL (Figure 7).

The M_L 2.0 epicenter is about 7 km from the mapped terminus of the southernmost NW-trending segment of the Lemhi fault (Kuntz et al., 1994). The focal depth of 8.98 km for the M_L 2.0 earthquake is consistent with the projected fault plane of the Lemhi fault assuming a dip of 50ºSW. Normal faulting along NW- and SE-striking nodal planes of the M_L 2.0 focal mechanism is consistent with the direction of slip along the Lemhi fault, whereas the nodal plane dip of 70ºSW is greater than the assumed Lemhi fault dip, and the nodal plane dip of 20±13ºNE is not consistent with the SW dip direction of the Lemhi fault. One possible interpretation is that the M_L 2.0 earthquake is associated with normal faulting along a plane that strikes S14ºE and dips 70±3ºSW. Slip along a normal fault of this orientation is consistent with normal faulting along a possible segment of the Lemhi fault, which is different from what is mapped at the surface (Figure 7).

5. 1972 – 2006 Earthquake Activity

Since earthquake monitoring began at INL in 1972, only small magnitude microearthquakes of $M_L \leq 2.0$ have occurred within the ESRP. Figure 8 shows the two 2006 earthquakes that occurred within the ESRP are located in areas of the ESRP that have been active in the past. Figure 8 also shows that the 2006 earthquakes located around the ESRP occurred in active regions of the surrounding Basin and Range Province. Even though microearthquakes ($M_L \leq 2.0$) have occurred within the ESRP, earthquake monitoring by the INL seismic network for the last 34 years indicates that the ESRP has been seismically inactive relative to the surrounding Basin and Range Province (Jackson et al., 1993b).

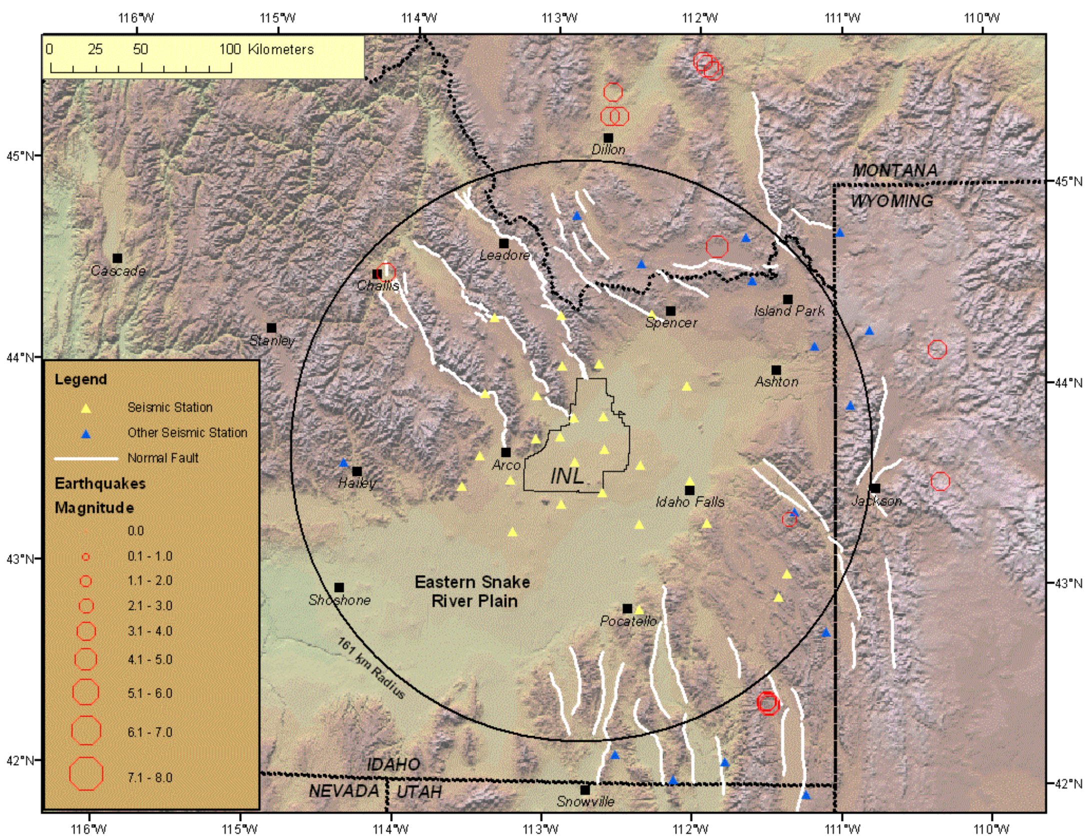

Figure 5. Map shows epicenters of earthquakes for magnitudes greater than 3.0 during 2006.

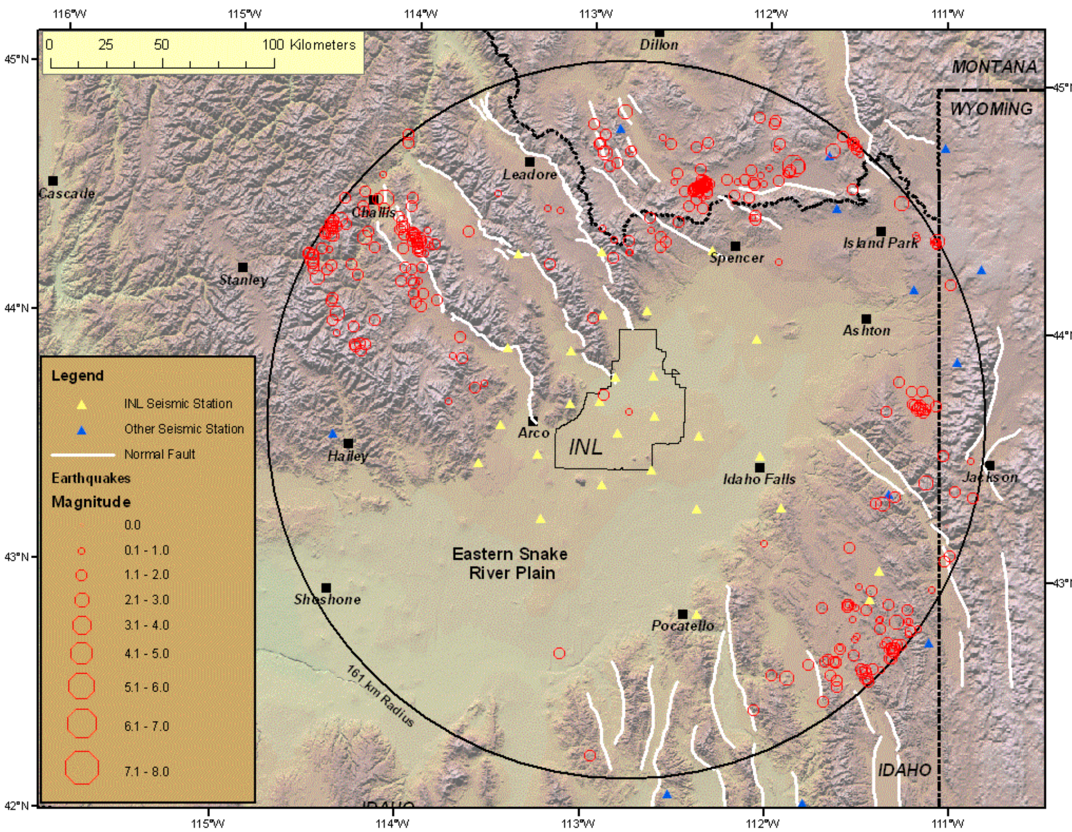

Figure 6. Map shows epicenters of earthquakes within the 161-km radius of INL from January 1, 2006 to December 31, 2006.

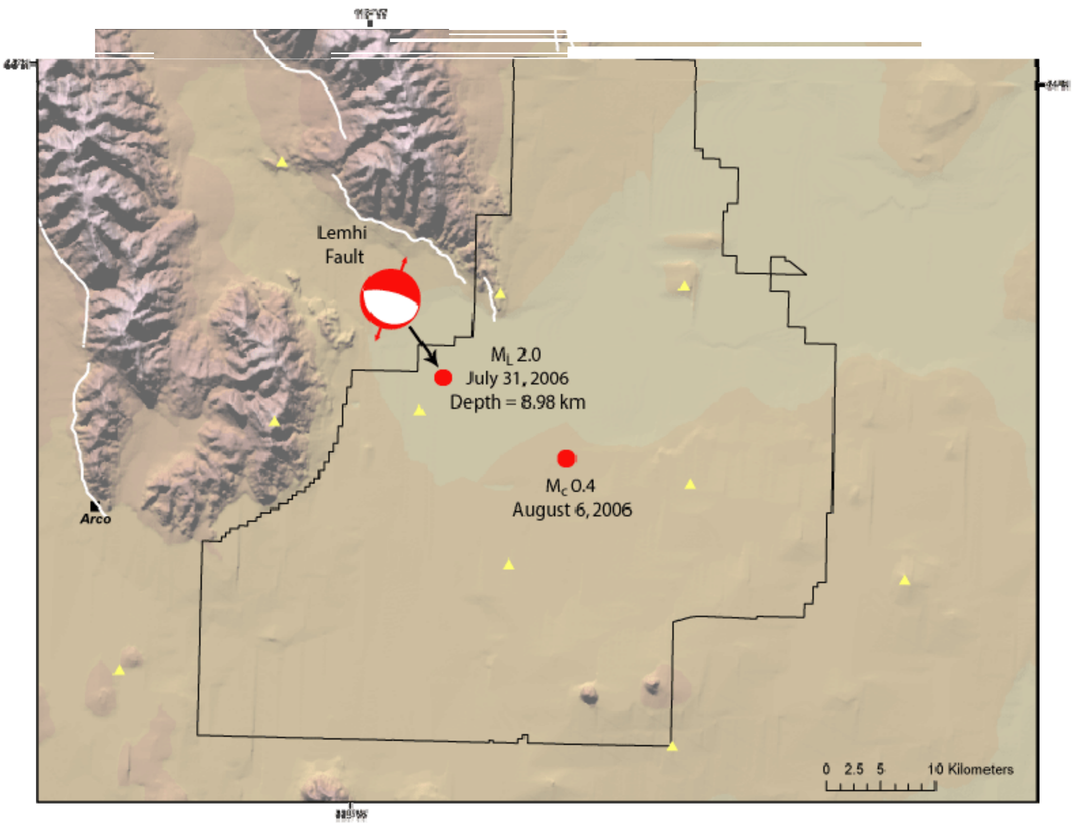

Figure 7. Map shows epicenters of the 2006 earthquakes (red dots) that occurred with the INL boundaries and the focal mechanism (red and white circle with arrows) of the July 31, 2006 earthquake.

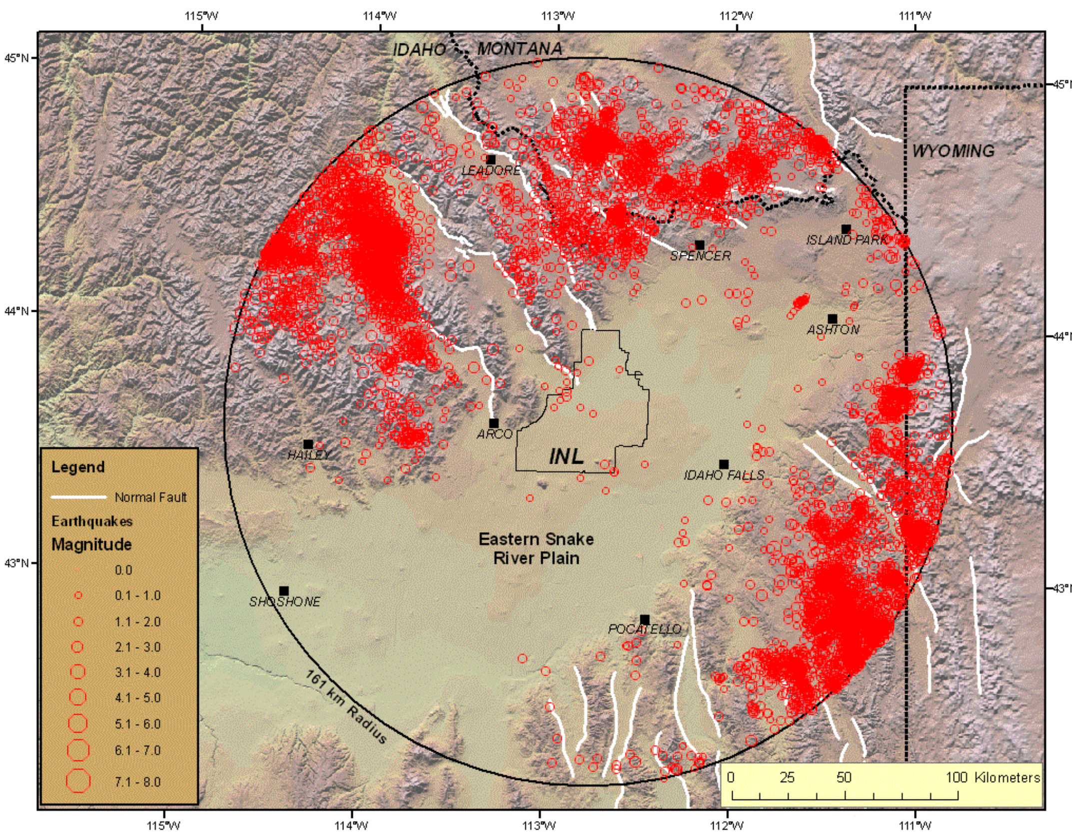

Figure 8. Map shows epicenters of earthquakes from 1972 to 2006 within the 161-km radius of INL.

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Appendix A

Seismic Station Telemetry

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Appendix A

Seismic Network Telemetry

Digital radios, Internet, or DSL links transmit seismic data from INL seismic stations and free-field SMAs to the IRC. Some seismic stations are used as relay links to transmit several seismic stations to a DSL drop point or directly to the IRC. Figure A-1 shows the telemetry configuration during 2006.

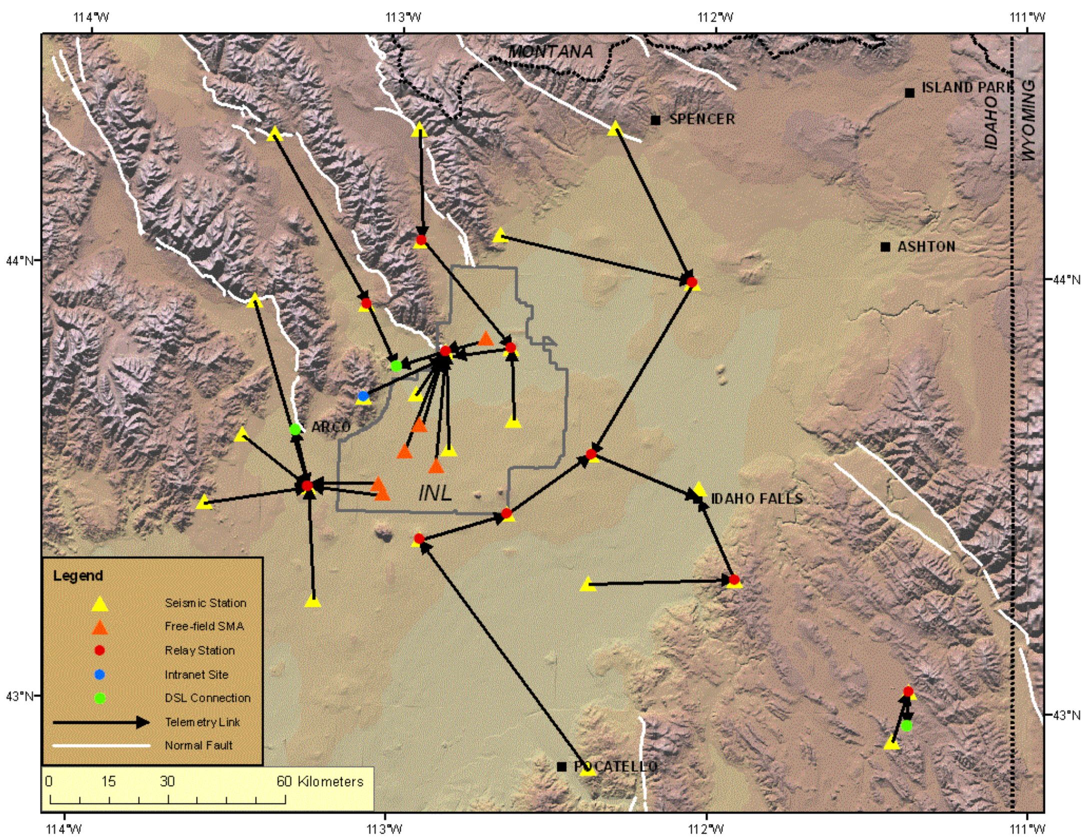

Figure A-1. Telemetry configuration of INL seismic stations and free-field SMAs during 2006.

Appendix B

Instrument Response of NetDAS SMAs

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Appendix B

Instrument Response of NetDAS SMAs

B.1 Method for Determining Amplitude Response

The instrument response of the NetDAS-SMA is used to convert the measured counts of ground motion amplitude to units of g. The NetDAS units that have accelerometers mounted within the unit are calibrated by conducting 1-g (acceleration of gravity) tilt tests. These tests are done on a leveled pad at the IRC seismic lab or on the actual leveled pad at their physical location listed in Table 3. These 1-g tilt tests provide a relationship between the number of digitizer counts and the 1-g offset. Equation B-1 provides the conversion from the measured count level to actual g level for the recorded motion. Trigger threshold accelerations and counts/g are listed for NetDAS units with SMAs in Table B-1 using equation:

$$\text{Acceleration (g)} = \text{Counts}_{\text{(Measured or target)}} / \text{(Counts/g)} \qquad \text{[B-1]}$$

For accelerographs without internally installed accelerometers within the NetDAS units, Equation B-1 does not apply; there is a frequency dependent amplitude response, which is discussed further in Appendix C. The frequency response information for the NetDAS-4CH should be applied to the acceleration data recorded by these external type accelerometers. Table B-2 lists the instrument response for these accelerometers using the methods discussed in Appendix C.

Tables B-1 and B-2 list the beginning and ending dates for the time periods that the instrument responses are applicable. If changes occurred to SMA or seismic station instrumentation (such as accelerometer or NetDAS unit) during the year, then more than one range of dates are listed for a location. Also, note that the building numbers and locations for the SMA codes are listed in Table 3.

Table B-1. Instrument responses for strong-motion accelerographs.

INL Site Facility Area	SMA Code	Instrument Response Begin Date	Instrument Response End Date	NetDAS Serial #	Accelerometer Model	Accelerometer Orientation	Positive Direction	Counts/g	Trigger Level (g)
MFC	EBR	6/2/2003	2/8/2006	1095	SF2500A	46	Vertical	547675	0.0046
							North	554219	0.0045
							East	547920	0.0046
	EBR	2/8/2006	12/31/2006	1095	SF2500A	46	Vertical	533228	0.0046
							North	555864	0.0045
							East	543393	0.0046
	FCF	6/2/2003	12/31/2006	1079	SF2500A	61	Vertical	549212	0.0046
							North	559404	0.0045
							East	558307	0.0045
CFA	CFAF	5/6/2004	2/8/2006	1097	SF2500A	37	Vertical	547045	0.0046
							North	551038	0.0045
							East	558177	0.0045
	CFAF	2/8/2006	12/31/2006	1097	SF2500A	37	Vertical	530620	0.0046
							North	547301	0.0045
							East	560906	0.0045
	EFSF	5/6/2004	12/31/2006	1096	SF2500A	49	Vertical	553390	0.0045
							North	526189	0.0048
							East	549747	0.0045

Table B-1. Continued.

INL Site Facility Area	SMA Code	Instrument Response Begin Date	Instrument Response End Date	NetDAS Serial #	Accelerometer Model	Accelerometer Orientation	Positive Direction	Counts/g	Trigger Level (g)
INTEC	CPPF	5/20/2004	2/2/2006	2000	SF2500A	42	Vertical	552940	0.0045
							North	569846	0.0044
							East	557651	0.0045
	CPPF	2/2/2006	12/31/2006	2000	SF2500A	42	Vertical	559216	0.0045
							North	569302	0.0044
							East	556137	0.0045
	CPP1	5/19/2004	12/31/2006	1099	SF2500A	43	Vertical	522025	0.0048
							North	563402	0.0044
							East	569090	0.0044
	CPP2	5/19/2004	12/31/2006	1078	SF2500A	NA	Vertical	615499	0.0041
							North	647203	0.0039
							East	628378	0.0040
	FAS1	5/19/2004	2/2/2006	1084	SF2500A	48	Vertical	568601	0.0044
							North	572126	0.0044
							East	549907	0.0045
	FAS1	2/2/2006	12/31/2006	1084	SF2500A	48	Vertical	573249	0.0044
							North	573389	0.0044
							East	546041	0.0045

Table B-1. Continued.

INL Site Facility Area	SMA Code	Instrument Response Begin Date	Instrument Response End Date	NetDAS Serial #	Accelerometer Model	Accelerometer Orientation	Positive Direction	Counts/g	Trigger Level (g)
INTEC	FAS2	5/19/2004	2/2/2006	1083	SF2500A	52	Vertical	545469	0.0046
							North	550078	0.0045
							East	562316	0.0044
	FAS2	2/2/2006	12/31/2006	1083	SF2500A	52	Vertical	544357	0.0046
							North	549370	0.0045
							East	565218	0.0044
NRF	NRFF	8/23/2005	12/31/2006	1098	SF2500A	55	Vertical	542167	0.0046
							North	552647	0.0045
							East	552261	0.0045
	A1W	1/31/2005	12/31/2006	1091	SF2500A	53	Vertical	541217	0.0045
							North	570002	0.0044
							East	564995	0.0044
	S1W	1/31/2005	12/31/2006	1088	SF2500A	45	Vertical	561125	0.0044
							North	558488	0.0045
							East	558473	0.0045
PBF	PBFF	6/7/2005	12/31/2006	1089	SF2500A	43	Vertical	559223	0.0047
							North	553304	0.0045
							East	557374	0.0045
	ARAF	6/8/2005	12/31/2006	1086	SF2500A	56	Vertical	530586	0.0045
							North	553243	0.0044
							East	550731	0.0042

Table B-1. Continued.

INL Site Facility Area	SMA Code	Instrument Response Begin Date	Instrument Response End Date	NetDAS Serial #	Accelerometer Model	Accelerometer Orientation	Positive Direction	Counts/g	Trigger Level (g)
RWMC	RWMC	11/9/2004	12/31/2006	1081	SF2500A	58	Vertical	556615	0.0045
							North	550661	0.0043
							East	572485	0.0048
	RWME	4/14/2005	12/31/2006	1077	SF2500A	58	Vertical	558903	0.0045
							North	564951	0.0043
							East	557551	0.0048
RTC	TRAF	9/1/2005	12/31/2006	1094	SF2500A	41	Vertical	526114	0.0048
							North	574035	0.0043
							East	549477	0.0045
	TRA1	5/6/2004	12/31/2006	1092	SF2500A	44	Vertical	539986	0.0046
							North	570784	0.0044
							East	549115	0.0046
	TRA2	5/6/2004	12/31/2006	1085	SF2500A	38	Vertical	543172	0.0046
							North	556212	0.0045
							East	568860	0.0044
STC	IRC	12/16/2002	8/21/2003	1086	SF2500A	52	Vertical	557263	0.0045
							North	572415	0.0044
							East	566145	0.0044

Table B-1. Continued.

INL Site Facility Area	SMA Code	Instrument Response Begin Date	Instrument Response End Date	NetDAS Serial #	Accelerometer Model	Accelerometer Orientation	Positive Direction	Counts/g	Trigger Level (g)
TAN	TANA	6/7/2005	12/31/2006	1090	SF2500A	40	Vertical	553849	0.0044
							North	564675	0.0044
							East	530791	0.0045
	TAN1	5/4/2004	12/31/2006	1093	SF2500A	47	Vertical	575282	0.0043
							North	576494	0.0043
							East	541081	0.0046
	TAN2	5/4/2004	12/31/2006	1087	SF2500A	39	Vertical	573037	0.0044
							North	598256	0.0042
							East	553210	0.0045
	TAN3	5/4/2004	12/31/2004	1080	SF2500A	51	Vertical	534052	0.0047
							North	543777	0.0046
							East	561958	0.0044

Table B-2. Instrument responses of accelerometers located at seismic stations.

Seismic Station	Instrument Response Begin Date	End Date	NetDAS Serial #	Accelerometer Model #	Serial #	Orientation	Datalogger Counts/Volt	Sensor Volt/g	Station Counts/g
BCYI	3/23/2005	12/31/2006	1071	SF3000L	185	Vertical	833601	1.220	1016993
						North	837596	1.200	1005115
						East	833104	1.220	1016387
GRRI	8/8/2005	12/31/2006	1013	SF2500A	57	Vertical	804275	1.396	1122768
						North	872679	1.345	1173753
						East	863351	1.412	1219052
HWFI	11/3/2005	12/31/2006	1069	SF2500A	62	Vertical	804003	1.378	1107916
						North	805254	1.371	1104003
						East	809573	1.352	1094542
NPRI	10/21/2005	12/31/2006	1065	SF2500A	36	Vertical	810927	1.427	1157193
						North	802533	1.376	1104286
						East	808520	1.371	1108481
PTI	11/2/2005	9/7/2006	1071	SF3000L	188	Vertical	805156	1.230	990341
						North	806126	1.194	962514
						East	805836	1.244	1002460
PTI	9/7/2006	12/31/2006	1071	SF3000L	188	Vertical	839813	1.230	990341
						North	833415	1.194	962514
						East	847947	1.244	1002460
SPCI	6/13/2005	12/31/2006	1070	SF3000L	186	Vertical	806336	1.216	980505
						North	806668	1.237	997848
						East	809144	1.215	983110
TCSI	6/9/2004	12/15/2006	1067	SF3000L	187	Vertical	806652	1.216	980889
						North	804646	1.237	995347
						East	804796	1.215	977827

Appendix C

Instrument Response of Seismic Stations

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Appendix C

Instrument Response of Seismic Stations

C.1 Method for Determining Amplitude Response

The INL determines instrument responses for both the four (4CH) and eight channel (8CH) NetDAS units. The INL establishes a DC counts/volt level by measuring a known voltage level for a specified duration of time for each channel on the NetDAS units and recording the mean and standard deviation in counts for this duration. The signal polarity is often reversed in order to obtain a greater measurement range. The mean provides the method to produce the DC counts/volt level (Equation C-1a and C-1b) and the standard deviation provides an idea of the measurement uncertainty and system noise.

Single ended:

$$\text{Counts/Volt} = \mu / v_i \qquad \text{[C-1a]}$$

Reversed Polarity:

$$\text{Counts/Volt} = (\mu^{+} - \mu^{-}) / (v_i^{+} - v_i^{-}) \qquad \text{[C-1b]}$$

Where:

μ is mean counts

v_i is input voltage

Subscript "+" is positive polarity

Subscript "– " is negative polarity

C.2 NetDAS-4CH Frequency Response

The response of the Symmetric Research PAR4CH (4CH) digitizer used in the NetDAS-4CH was calculated at the INL to establish the instrument response of NetDAS units and the methods incorporated vendor information. The DAQSystems, Inc., manufacturer of the NetDAS units, reviewed INL's frequency response results and methods, which is discussed in the following steps.

The NetDAS-4CH frequency response was determined empirically by measuring the output counts resulting from a known input signal. Trials were conducted using a constant-amplitude sine wave with frequencies varying between 0.1, 5, 10, 15, 20, 25, 30, and 35 Hz. The frequency sweep was performed twice for representative frequencies of 0.1, 5, 10, 15, 20, 25, 30, and 35 Hz. The averages of the measured counts at each frequency were then converted into decibel responses relative to the average response at 0.1 Hz, because the vendor data sheets list a gain of 1 at this frequency. A 2^{nd} order polynomial was then fit to the data creating a simple amplitude response in frequency. The perfectly matched response (R-squared of one) is shown here as described by Equations C-2 and C-3 (conversion to decibels).

$$Y_{dB} = -0.0045f^2 + 0.0074f - 0.014 \qquad \text{[C-2]}$$

$$\text{dB} = 20 \log (E_2/E_1) \qquad \text{[C-3]}$$

Where:

f – frequency (Hz)

E_1 – original signal level

E_2 - modified signal level

E_2/E_1 – commonly referred to as gain

This relationship was then used to calculate the gains out to the Nyquist frequency (1/2 the sample rate). The INL samples all data at 100 samples per second or 0.01 Hz. The information was then entered into MATLAB, which has a function to determine poles and zeros. Poles and zeros notations are the form that many seismic applications use to remove the instrument response. The NetDAS-4CH frequency response in dB and poles and zeros are shown in Figure C-1.

Equations C-2 and C-3 can be used in conjunction with the DC counts/volt measurement to generate a count based frequency response for short hand calculations or spectral deconvolution to remove the frequency response.

$$\text{Ycounts} = \text{Counts/Volt} \times 10\text{^}((-0.0045f^2 + 0.0074f - 0.014)/20) \qquad \text{[C-4]}$$

Where:

^ - Indicates 10 to the power of the number calculated in parentheses.

However, the preferred method for removing the frequency response from a recorded waveform is to use a seismic analysis package, such as SEISAN. This program recognizes the poles and zeros representation of instrument response, which quickly and accurately corrects recorded waveforms to actual ground motions.

C.3 NetDAS-8CH Frequency Response

The response of the Symmetric Research PAR24B (8CH) digitizer used in the NetDAS-8CH was based on vendor provided information, and calculated in the same method as described above for the PAR4CH. A 2nd order polynomial was fit to the data creating a simple amplitude response in frequency that matched the amplitude response (R-squared of 0.999). Equation C-5, listed below, is similar to Equation C-3 used for the response of the NetDAS-4CH. The NetDAS-8CH frequency response in dB and poles and zeros are shown in Figure C-2.

$$Y_{dB} = -0.0045f^2 + 0.0071f - 0.0158 \qquad \text{[C-5]}$$

C.4 Short-period high-gain seismic stations

In the fall of 2002, INL seismic personnel began tracking instrument response of the seismic stations. Table C-1 lists the measured responses and amplification information for the seismic stations that have been measured for instrument responses.

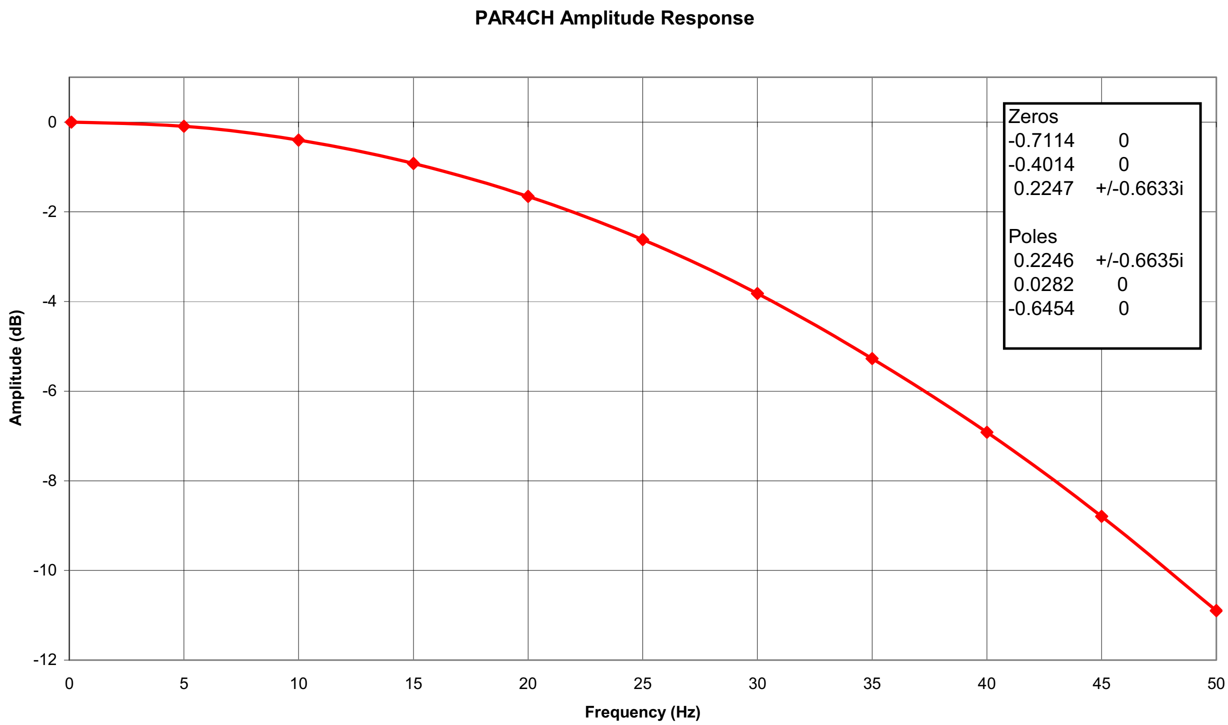

Figure C-1. Amplitude verses frequency system response of the Symmetric Research PAR4CH digitizer used in the NetDAS-4CH.

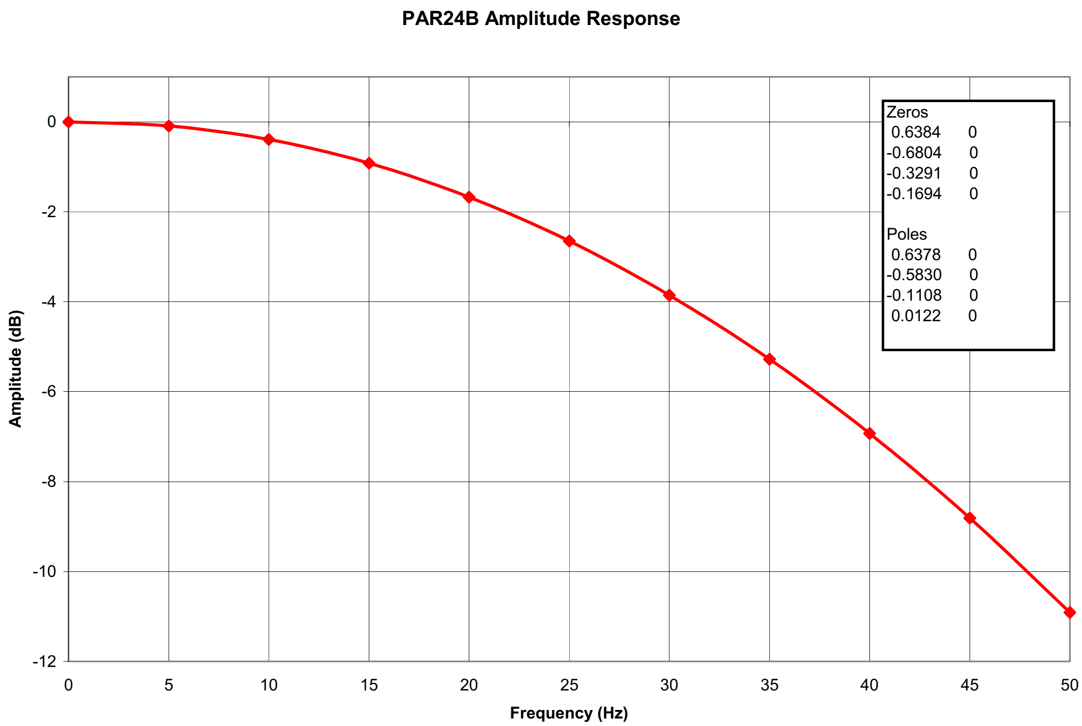

Figure C-2. Amplitude verses frequency system response of the Symmetric Research PAR24B digitizer used in the NetDAS-8CH.

Table C-1. Instrument responses of seismometers located at seismic stations.

Seismic Station	Instrument Response Begin Date	End Date	NetDAS Serial #	Digitizer Model	Orientation	Datalogger Counts/Volt[a]	Seismometer Model
Single-component seismic stations							
ARNI	8/29/2006	12/31/2006	1017	4CH	Vertical	488,042	S13J
BCYI	3/23/2005	12/31/2006	1068	8CH	Vertical	835,518	S13J
CBTI	10/6/2004	8/29/2006	1024	4CH	Vertical	480,777	S13J
CBTI	8/29/2006	12/31/2006	1024	4CH	Vertical	494794	S13J
CNCI	10/7/2004	8/30/2006	1066	4CH	Vertical	476,017	L4C
CNCI	8/30/2006	12/31/2006	1066	4CH	Vertical	492,673	L4C
COMI	10/6/2004	12/31/2006	2005	4CH	Vertical	387,088	S13
CRBI	10/27/2004	8/28/2006	1027	4CH	Vertical	443,124	S13J
CRBI	8/28/2006	12/31/2006	1027	4CH	Vertical	401,458	S13J
ECRI	11/11/2004	9/12/2006	1051	4CH	Vertical	434,299	S13
ECRI	9/12/2006	12/31/2006	1051	4CH	Vertical	324,557	S13
EMI	10/27/2004	8/28/2006	1019	4CH	Vertical	476,105	L4C
EMI	8/28/2006	12/31/2006	1019	4CH	Vertical	445,625	L4C
GBI	5/18/2005	12/31/2006	30802	24USB5V	Vertical	7,679,384	S13J
GRRI	1/20/2004	12/31/2006	1013	4CH	Vertical	NC	GRRI
GTRI	8/16/2006	12/31/2006	1021	4CH	Vertical	250,192	GTRI
HHAI	1/1/2006	12/31/2006	1014	4CH	Vertical	NC	S13J
HPI	8/31/2005	12/31/2006	1015	4CH	Vertical	474,874	L4C
ICI	10/27/2004	8/28/2006	1020	4CH	Vertical	477,973	L4C

Table C-1. Continued.

Seismic Station	Instrument Response Begin Date	End Date	NetDAS Serial #	Digitizer Model	Orientation	Datalogger Counts/Volt[a]	Seismometer Model
ICI	10/27/2004	12/31/2006	1020	4CH	Vertical	492,964	L4C
KBI	1/1/2006	12/31/2006	1018	4CH	Vertical	NC	KBI
LJI	2/24/2004	12/31/2006	1052	4CH	Vertical	477,522	LJI
PZCI	6/16/2004	12/31/2006	1023	4CH	Vertical	399,981	S13J
PTI	11/2/2005	9/12/2006	1071	8CH	Vertical	804,150	S13
PTI	9/12/2006	12/31/2006	1071	8CH	Vertical	833,485	S13
SMBI	8/24/2004	8/16/2006	1063	4CH	Vertical	447,541	S13J
SMBI	8/16/2006	12/31/2006	1063	4CH	Vertical	495,995	S13J
Three-component seismic stations							
HWFI	11/3/2005	12/31/2006	1069	8CH	Vertical	856,478	S13
					North	857,063	S13
					East	853,611	S13
IRCI	6/3/2005	12/31/2006	1012	4CH	Vertical	469,890	S13
					North	461,125	S13
					East	467,680	S13
JGI	5/10/2005	8/28/2006	30801	23USB5V	Vertical	2,722,002	S13
					North	2,730,140	S13
					East	2,738,391	S13
JGI	8/28/2006	12/31/2006	30801	23USB5V	Vertical	2,876,376	S13
					North	2,867,906	S13
					East	2,881,375	S13

Table C-1. Continued.

Seismic Station	Instrument Response Begin Date	End Date	NetDAS Serial #	Digitizer Model	Orientation	Datalogger Counts/Volt[a]	Seismometer Model
LLRI	10/7/2004	8/29/2006	1029	4CH	Vertical	479,710	S13J
					North	485,322	S13
					East	483,647	S13
LLRI	8/29/2006	12/31/2006	1029	4CH	Vertical	489,950	S13J
					North	493,268	S13
					East	483,647	S13
NPRI	10/21/2005	12/31/2006	1065	8CH	Vertical	836,486	S13J
					North	837,155	S13
					East	839,175	S13
SPCI	6/13/2005	12/31/2006	1070	8CH	Vertical	827,660	S13J
					North	827,077	S13
					East	829,743	S13
TCSI	8/16/2005	12/31/2006	1067	24USB5V	Vertical	2,642,927	S13
					North	2,642368	S13
					East	2,635,268	S13
TMI	8/1/2005	12/31/2006	2004	24USB5V	Vertical	2,226,262	S13
					North	2,198,172	S13
					East	2,194,452	S13

NC – Not Calibrated.

a. Gain not included.

Appendix D

2006 Earthquake List

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Appendix D

2006 Earthquake List

The summary list of earthquakes includes those located within a 161-km (100-mile) radius of the INL centered at 43.0° 39.00' N, 112° 47.00' W. Table D-1 provides an explanation of the headings listed in Table D-2 for the earthquake list. The format for this table has been modified from previous years. The earthquake identification number is no longer reported since the SEISAN analysis package identification number is simply the origin data and time. The listing also includes the distance of the earthquake epicenter from the center of INL.

Table D-1. Explanation of the earthquake summary table headings.

Heading	Example	Explanation
ORIGIN	1/1/2006 4:34	Date of the earthquake: month/day/year (1/1/2006); origin time of the earthquake: hour and minute in UTC (4:34)
LAT N	43.7055	Latitude of epicenter in degrees North
LONG W	113.7678	Longitude of epicenter in degrees West
MAG	1.0	Coda magnitude (M_c) of the earthquake as determined under Section 4.2 unless otherwise indicated by a B for BUT, N for NEIC, R for U.S. Bureau of Reclamation (USB), E for BSE, S for SLC, or I for INL, a measured local magnitude (M_L).
TYPE	Mc INL	Type of magnitude reported and reporting agency. Magnitude types: Coda magnitude (Mc); Local magnitude (ML); Moment magnitude (Mw); and Body wave magnitude (mb). Reporting agencies include: Idaho National Laboratory (INL); NEIC (US); University of Utah (UU); and Montana Bureau of Mines and Geology (MB).
DIST	79.6	Distance in km from center of INL at: 43° 39.00' N, 112° 47.00' W.
Z	0.03	Calculated focal depth in km. Some earthquakes have appropriate seismic station geometry for calculating a reliable focal depth.
NO	4	Number of station readings used in locating the earthquake with weights above 0.1. P- and S-wave arrival times for the same station are regarded as two readings.
GAP	293	Largest azimuthal separation in degrees between stations.
DMIN	25.2	Distance in km from the epicenter to the nearest station.
RMS	0.19	Root mean square error of time residuals in second using all weights as calculated by: $RMS=\sqrt{R_i^2/NO}$
		Where: R_i is the time residual for the i^{th} station.
ERH	7.3	Standard horizontal error of the epicenter in km.
ERZ	8.0	Standard vertical error of the focal depth in km.

Table D-2. Earthquakes located within 161-km radius of INL in 2006.

ORIGIN TIME	LAT N	LONG W	MAG-TYPE	DIST	Z	NO	GAP	DMIN	RMS	ERH	ERZ
1/1/2006 4:34	43.7055	113.7678	1.0 Mc INL	79.6	0.03	4	293	25.2	0.19	7.3	8.0
1/3/2006 17:19	44.2375	114.4542	1.4 Mc INL	149.2	0.08	5	310	84.1	0.09	2.6	2.8
1/3/2006 20:24	44.7918	112.6105	0.8 Mc INL	127.8	12.57	3	220	19.3	0.00	2.1	3.4
1/3/2006 22:39	44.3680	114.0083	1.3 Mc INL	126.6	6.67	7	220	85.2	0.29	1.7	4.2
1/5/2006 6:58	44.3272	112.7777	1.0 Mc INL	75.3	4.70	7	167	27.3	0.32	1.1	2.1
1/6/2006 12:11	44.5772	112.4013	1.2 Mc INL	107.6	5.60	7	140	1.9	0.09	1.5	0.9
1/6/2006 17:36	44.0127	114.3165	0.0 Mc INL	129.7	0.04	3	326	80.1	0.25	6.0	6.5
1/7/2006 10:39	44.7737	111.5170	1.0 Mc INL	160.8	12.12	7	204	12.7	0.09	0.6	1.4
1/8/2006 6:01	44.6000	112.3945	1.6 Mc INL	110.2	10.59	11	212	0.7	0.16	0.8	0.7
1/8/2006 6:11	44.6022	112.3785	0.0 NM	110.8	10.87	8	225	1.6	0.08	1.1	0.6
1/8/2006 6:16	44.6053	112.3770	1.0 Mc INL	111.1	10.70	8	215	1.9	0.11	0.7	0.6
1/8/2006 6:24	44.5875	112.4078	0.0 Mc INL	108.5	9.34	5	144	1.2	0.30	2.7	2.3
1/8/2006 6:27	44.5995	112.3755	0.6 Mc INL	110.6	9.46	8	214	1.6	0.27	1.0	0.9
1/8/2006 6:29	44.5182	112.4537	1.4 Mc INL	100.1	9.94	10	122	9.6	0.13	1.2	2.4
1/8/2006 6:38	44.5953	112.4082	1.1 Mc INL	109.4	9.25	11	154	1.1	0.13	0.6	0.6
1/8/2006 6:43	44.6672	112.3930	1.1 Mc INL	117.4	10.25	4	290	8.2	0.00	2.0	0.8
1/8/2006 6:45	44.5908	112.4028	1.5 Mc INL	109.0	9.22	14	120	0.7	0.24	0.6	0.8
1/8/2006 6:48	44.5785	112.4280	1.1 Mc INL	107.1	7.44	6	108	3.1	0.13	0.9	1.2
1/8/2006 6:51	44.5953	112.3997	1.6 Mc INL	109.5	10.36	17	133	0.5	0.17	0.4	0.6
1/8/2006 6:55	44.6012	112.3818	2.2 Mc INL	110.6	10.51	16	130	1.3	0.17	0.4	0.8
1/8/2006 6:58	44.5818	112.4600	0.0 Mc INL	106.8	4.43	4	124	5.4	0.22	14.4	17.1
1/8/2006 7:09	44.5772	112.4777	1.1 Mc INL	106.0	1.70	6	123	6.9	0.21	6.4	14.9
1/8/2006 7:11	44.5672	112.3948	0.5 Mc INL	106.7	2.54	8	157	2.9	0.19	1.3	1.8
1/8/2006 7:19	44.5908	112.3860	1.3 Mc INL	109.4	9.10	7	212	0.7	0.28	1.0	1.0
1/8/2006 7:33	44.5118	112.3725	1.7 Mc INL	101.4	3.13	9	217	9.2	0.15	1.7	2.2
1/8/2006 7:40	44.5922	112.4227	1.4 Mc INL	108.7	9.53	11	138	2.3	0.24	0.9	1.2
1/8/2006 8:05	44.5832	112.4315	1.2 Mc INL	107.6	7.89	7	118	3.2	0.21	1.1	1.3
1/8/2006 8:08	44.5953	112.4045	1.6 Mc INL	109.4	9.22	10	133	0.8	0.23	0.9	0.8
1/8/2006 8:37	44.5970	112.3763	1.2 Mc INL	110.3	10.98	6	259	1.5	0.06	2.5	0.9
1/8/2006 8:59	44.5953	112.3640	1.2 Mc INL	110.4	12.09	12	134	2.4	0.14	0.8	0.6
1/8/2006 9:18	44.5910	112.3955	0.5 Mc INL	109.2	8.92	6	160	0.3	0.19	2.4	1.4
1/8/2006 9:29	44.5872	112.4227	1.1 Mc INL	108.2	8.41	8	124	2.4	0.18	1.0	1.2
1/8/2006 9:34	44.5823	112.4270	0.0 Mc INL	107.6	8.94	7	114	2.9	0.07	0.7	0.8
1/8/2006 10:17	44.5993	112.5470	0.0 NM	107.3	2.46	5	136	12.1	0.10	6.2	13.1
1/8/2006 10:36	44.5855	112.4205	1.3 Mc INL	108.0	9.92	8	118	2.3	0.20	0.9	1.1
1/8/2006 11:29	44.5997	112.3647	1.1 Mc INL	110.8	11.07	13	131	2.5	0.13	0.4	0.7
1/8/2006 12:11	44.6002	112.4033	2.0 Mc INL	110.0	9.11	20	134	1.0	0.13	0.4	0.7
1/8/2006 13:15	44.6050	112.3753	1.7 Mc INL	111.1	10.78	10	131	2.0	0.17	0.4	0.6
1/8/2006 13:31	44.6120	112.3663	1.3 Mc INL	112.1	10.77	7	204	3.0	0.11	0.8	0.7
1/8/2006 14:17	44.6083	112.3833	0.7 Mc INL	111.3	9.94	7	191	1.9	0.18	1.0	0.6
1/8/2006 14:57	44.5527	112.3740	0.8 Mc INL	105.6	5.46	6	177	4.8	0.06	2.2	2.4
1/8/2006 17:26	44.6233	112.3812	1.9 Mc INL	113.0	10.86	13	189	3.5	0.13	0.6	0.5
1/8/2006 19:40	44.5692	112.3508	1.2 Mc INL	108.0	7.66	8	130	4.4	0.21	1.3	1.7
1/8/2006 21:19	44.5918	112.3817	1.7 Mc INL	109.6	9.78	13	128	1.0	0.29	0.7	0.9

Table D-2. Continued.

ORIGIN TIME	LAT N	LONG W	MAG-TYPE	DIST	Z	NO	GAP	DMIN	RMS	ERH	ERZ
1/8/2006 21:21	44.5870	112.4182	1.7 Mc INL	108.3	8.45	9	120	2.0	0.20	0.9	1.0
1/9/2006 6:06	44.5792	112.4262	0.8 Mc INL	107.2	10.13	8	107	3.0	0.09	0.6	0.7
1/9/2006 7:04	44.5825	112.4027	0.0 NM	108.1	7.95	9	129	1.4	0.32	0.9	1.4
1/9/2006 7:27	44.5913	112.4188	1.0 Mc INL	108.7	8.57	12	135	2.0	0.19	0.7	0.9
1/9/2006 7:45	44.6127	112.3753	2.2 Mc INL	112.0	11.50	21	133	2.6	0.19	0.4	0.6
1/9/2006 7:50	44.5907	112.4023	1.8 Mc INL	109.0	8.36	21	118	0.7	0.23	0.5	1.1
1/9/2006 8:02	44.6033	112.3777	1.4 Mc INL	110.9	11.38	10	131	1.7	0.13	0.5	0.6
1/9/2006 8:07	44.6040	112.3518	1.6 Mc INL	111.6	12.33	10	262	3.6	0.10	0.9	0.6
1/9/2006 11:46	44.6067	112.3412	1.2 Mc INL	112.2	12.62	7	263	4.5	0.10	1.7	0.5
1/10/2006 2:55	44.5785	112.3500	1.4 Mc INL	109.0	9.02	4	270	3.9	0.10	1.6	1.5
1/10/2006 4:54	44.6147	112.3585	1.3 Mc INL	112.6	11.24	8	262	3.7	0.07	0.7	1.4
1/10/2006 5:18	44.6065	112.3570	1.3 Mc INL	111.7	12.12	7	230	3.3	0.10	0.9	0.5
1/10/2006 6:12	44.6098	112.3707	1.4 Mc INL	111.8	10.16	11	137	2.6	0.16	0.8	1.0
1/10/2006 7:36	44.6067	112.3768	1.4 Mc INL	111.3	9.83	13	136	2.0	0.11	0.5	0.8
1/10/2006 15:20	44.5987	112.3748	1.4 Mc INL	110.5	11.45	10	135	1.7	0.09	0.5	0.5
1/20/2006 5:05	44.3600	113.9842	1.8 Mc INL	124.5	6.90	12	217	46.5	0.33	1.3	3.7
1/20/2006 21:14	44.3920	112.6062	1.1 Mc INL	83.8	0.02	5	124	23.7	0.11	0.4	2.2
1/23/2006 20:36	44.4262	114.0633	1.5 Mc INL	134.1	1.28	10	227	54.0	0.28	3.5	23.6
1/24/2006 0:26	44.6760	112.0040	0.9 Mc INL	130.0	4.05	4	152	27.5	0.02	1.3	2.9
1/24/2006 8:26	44.4668	112.6718	1.3 Mc INL	91.3	2.65	3	160	31.5	0.10	0.7	14.5
1/26/2006 1:29	43.1453	111.5377	1.5 Mc INL	115.4	11.98	9	287	35.7	0.09	0.9	0.5
1/30/2006 19:40	44.7762	114.0472	1.5 Mc INL	160.9	0.04	6	286	72.6	0.23	4.7	5.7
2/1/2006 2:42	44.7758	111.9440	1.4 Mc INL	142.1	12.29	11	176	22.6	0.17	1.0	1.8
2/2/2006 4:12	44.7523	111.9618	0.8 Mc INL	139.1	6.19	7	177	23.6	0.14	0.9	16.7
2/2/2006 7:09	43.3493	110.8518	1.2 Mc INL	159.7	3.15	18	125	68.0	0.12	0.5	1.2
2/3/2006 6:12	44.3165	114.0560	1.5 Mc INL	126.2	7.12	6	219	64.8	0.19	2.3	2.4
2/4/2006 7:58	44.6295	112.1370	1.5 Mc INL	120.6	11.97	14	141	20.8	0.11	0.6	1.4
2/4/2006 15:22	44.4823	112.0780	1.3 Mc INL	108.5	12.92	13	106	24.7	0.22	0.5	1.1
2/5/2006 3:25	44.6837	111.8627	4.5 mb US	136.5	12.51	30	149	16.4	0.18	0.5	1.2
2/5/2006 12:56	44.6820	111.8390	2.1 Mc INL	137.4	13.59	20	146	14.7	0.25	0.5	1.1
2/7/2006 3:38	44.6662	111.8820	1.4 Mc INL	134.1	9.61	13	143	18.6	0.19	0.5	2.6
2/7/2006 3:49	44.6617	111.8903	1.1 Mc INL	133.3	6.15	8	142	19.3	0.11	0.4	12.8
2/8/2006 1:25	44.1882	113.9975	1.8 Mc INL	114.4	7.26	14	205	49.2	0.15	1.4	6.6
2/8/2006 1:30	42.8468	111.2770	2.1 ML INL	151.4	2.79	23	208	17.1	0.06	1.0	12.1
2/8/2006 10:24	44.3273	113.9003	0.9 Mc INL	117.1	6.92	6	312	39.6	0.15	1.4	17.9
2/9/2006 18:28	44.7642	111.5185	0.7 Mc INL	159.9	12.32	9	175	12.3	0.10	0.5	0.7
2/10/2006 1:51	44.3237	113.9683	1.5 Mc INL	121.0	7.56	5	260	60.3	0.28	2.2	26.4
2/10/2006 17:42	44.6137	112.0917	1.2 Mc INL	120.6	6.18	10	146	24.1	0.15	0.8	16.2
2/11/2006 6:05	44.7578	111.5062	1.1 Mc INL	160.0	11.27	8	174	13.0	0.15	0.6	1.4
2/11/2006 21:57	44.3192	113.9700	1.6 Mc INL	120.8	7.36	7	214	45.1	0.23	1.1	22.2
2/12/2006 2:50	44.3707	114.0475	1.6 Mc INL	129.2	5.09	14	223	51.7	0.30	1.9	4.0
2/13/2006 4:08	44.3725	112.7892	1.2 Mc INL	80.4	13.89	9	92	13.0	0.25	0.6	1.8
2/13/2006 15:12	44.3430	113.9173	1.7 Mc INL	119.2	0.00	15	252	41.0	0.24	1.8	2.0
2/13/2006 18:12	44.0403	114.4098	2.5 Mc INL	137.8	0.31	21	280	77.8	0.22	2.4	2.7
2/13/2006 18:28	44.0157	114.4355	1.6 Mc INL	138.9	0.03	9	250	50.4	0.11	2.7	3.3

Table D-2. Continued.

ORIGIN TIME	LAT N	LONG W	MAG-TYPE	DIST	Z	NO	GAP	DMIN	RMS	ERH	ERZ
2/13/2006 22:33	42.9040	111.4977	0.1 Mc INL	133.3	0.03	4	160	7.3	0.31	7.5	8.2
2/14/2006 1:38	43.2335	111.0002	0.0 Mc INL	151.5	5.14	6	106	47.5	0.10	0.6	1.2
2/15/2006 7:53	42.9872	111.4798	0.8 Mc INL	128.8	7.28	10	149	7.2	0.27	1.0	1.9
2/15/2006 22:07	42.7758	111.5017	0.6 Mc INL	142.4	4.11	5	288	19.2	0.01	1.7	10.3
2/18/2006 2:20	44.0907	114.4412	1.6 Mc INL	142.0	5.12	7	239	58.7	0.07	1.3	3.0
2/18/2006 22:29	43.6947	111.3342	1.7 Mc INL	116.9	9.27	7	251	56.4	0.25	2.2	2.0
2/20/2006 6:15	44.3452	113.9775	0.5 Mc INL	123.1	2.37	6	216	45.8	0.14	1.2	1.7
2/23/2006 4:06	44.3787	113.9913	1.6 Mc INL	126.3	6.91	10	258	47.4	0.09	1.0	14.7
2/23/2006 9:41	44.3338	113.9737	1.2 Mc INL	122.1	6.15	8	250	45.4	0.22	1.8	5.3
2/24/2006 6:30	44.4955	113.2475	0.4 Mc INL	101.2	5.37	4	188	24.1	0.17	7.0	13.5
2/27/2006 22:43	42.8583	111.3665	0.2 Mc INL	144.8	2.43	5	119	9.9	0.31	1.7	25.8
3/2/2006 9:30	44.1828	114.0578	1.2 Mc INL	118.3	7.07	6	209	56.2	0.10	1.2	4.2
3/8/2006 2:17	44.7363	111.4890	0.6 Mc INL	159.0	5.03	3	178	14.0	0.15	8.8	11.2
3/8/2006 16:48	44.4740	114.1712	1.6 Mc INL	144.1	0.04	6	309	63.7	0.10	4.7	6.1
3/8/2006 17:01	44.5377	114.2792	1.3 Mc INL	155.2	0.16	8	247	74.0	0.30	5.7	13.5
3/8/2006 20:53	44.2788	114.5827	1.8 Mc INL	160.4	0.04	13	256	80.8	0.30	3.1	3.0
3/11/2006 2:13	44.2327	114.0043	1.1 Mc INL	117.5	6.89	6	209	48.6	0.28	1.3	5.3
3/11/2006 9:42	44.0832	113.9402	1.9 Mc INL	104.7	7.04	20	192	42.8	0.26	0.7	4.8
3/12/2006 11:07	44.3742	113.9997	1.6 Mc INL	126.5	6.87	11	219	47.9	0.26	1.3	4.7
3/13/2006 16:35	44.6258	111.9473	1.4 Mc INL	127.5	0.06	8	137	25.2	0.26	0.8	1.7
3/16/2006 22:13	42.8713	111.3448	0.0 Mc INL	145.4	2.50	4	125	9.7	0.21	1.7	19.1
3/18/2006 17:13	44.4428	114.0820	1.9 Mc INL	136.4	0.02	11	229	55.9	0.34	2.1	4.1
3/20/2006 9:49	43.9920	114.3167	1.4 Mc INL	129.1	0.04	7	291	69.8	0.29	4.4	6.0
3/22/2006 18:43	43.8802	113.7032	1.6 Mc INL	78.4	6.97	12	147	20.9	0.23	0.9	22.8
3/23/2006 3:11	44.4017	114.0663	1.8 Mc INL	132.5	4.38	13	226	53.7	0.31	1.8	3.5
3/24/2006 11:27	42.9415	111.3482	0.0 Mc INL	140.6	4.24	3	334	98.3	0.19	7.9	3.4
3/25/2006 21:14	44.3608	114.0100	1.0 Mc INL	126.2	7.45	5	220	48.6	0.26	1.3	24.7
3/26/2006 20:18	44.6073	112.0855	1.5 Mc INL	120.2	11.05	13	134	24.6	0.11	0.4	2.0
3/26/2006 23:33	44.4083	111.1740	0.7 Mc INL	154.1	5.01	5	99	24.2	0.12	0.6	11.5
3/27/2006 10:38	42.8095	111.1977	1.2 Mc INL	159.1	11.22	11	154	9.4	0.16	1.5	1.1
3/27/2006 21:07	44.3463	113.9547	1.9 Mc INL	121.8	6.90	9	215	44.0	0.17	1.1	2.8
3/28/2006 12:08	44.7415	114.0447	1.7 Mc INL	157.8	7.94	7	250	69.8	0.27	5.1	3.3
3/29/2006 4:25	44.3438	113.9778	2.0 Mc INL	123.0	5.29	8	216	45.8	0.29	1.4	3.9
3/29/2006 14:59	44.5425	112.4138	1.4 Mc INL	103.6	8.33	5	146	5.9	0.09	1.3	1.7
3/29/2006 16:33	44.3622	113.9588	1.4 Mc INL	123.1	4.82	5	309	44.5	0.31	10.1	20.2
3/30/2006 13:37	44.6437	112.0520	1.0 Mc INL	125.1	3.03	9	143	27.7	0.28	0.8	1.6
3/30/2006 21:54	42.7355	111.5842	1.2 Mc INL	140.8	5.03	4	301	26.1	0.00	2.5	11.4
4/1/2006 5:33	44.1358	113.9317	1.5 Mc INL	106.9	7.25	11	195	46.3	0.15	0.9	2.2
4/1/2006 10:48	44.0583	112.9790	1.1 Mc INL	48.1	9.11	14	135	4.6	0.05	0.4	0.6
4/1/2006 22:28	44.4753	112.0915	1.0 Mc INL	107.2	5.93	8	118	23.4	0.25	0.9	24.4
4/2/2006 5:32	44.1848	113.9557	0.8 Mc INL	111.4	6.86	7	202	46.1	0.23	1.8	4.4
4/4/2006 19:17	44.3918	113.6883	1.2 Mc INL	109.9	6.64	4	254	54.9	0.12	9.5	5.9
4/5/2006 14:27	44.3767	114.2538	1.2 Mc INL	142.9	6.95	8	237	68.1	0.29	1.8	2.6
4/6/2006 15:11	44.7722	111.5292	1.7 Mc INL	160.1	12.20	6	177	11.8	0.07	0.5	1.2
4/7/2006 19:39	43.7783	111.1972	1.8 Mc INL	128.5	0.02	14	183	45.8	0.24	0.7	1.9

Table D-2. Continued.

ORIGIN TIME	LAT N	LONG W	MAG-TYPE	DIST	Z	NO	GAP	DMIN	RMS	ERH	ERZ
4/7/2006 19:42	43.8153	111.2638	1.3 Mc INL	123.7	5.30	5	270	82.9	0.13	8.8	12.4
4/7/2006 23:17	42.7557	111.2513	1.9 Mc INL	159.3	12.87	12	127	12.4	0.05	7.7	9.7
4/8/2006 12:22	44.3668	114.0108	1.0 Mc INL	126.7	6.18	6	283	48.7	0.26	4.1	8.0
4/9/2006 3:22	42.8527	111.2113	0.0 NM	155.4	2.26	8	166	13.3	0.10	0.8	11.2
4/9/2006 3:35	43.7642	113.6277	1.4 Mc INL	69.2	3.76	12	125	23.1	0.18	0.5	1.0
4/12/2006 7:44	44.6088	114.1802	0.9 Mc INL	154.5	0.02	6	247	95.4	0.31	4.1	7.0
4/14/2006 10:30	44.5198	114.0117	1.5 Mc INL	138.0	0.06	9	276	53.6	0.20	5.1	8.4
4/14/2006 18:38	43.9220	114.2450	1.3 Mc INL	121.5	0.31	7	273	63.7	0.32	3.1	3.8
4/14/2006 19:04	43.9248	114.2747	1.2 Mc INL	123.8	1.35	10	276	66.1	0.32	3.8	3.9
4/15/2006 0:34	44.2840	114.5780	2.0 Mc INL	160.3	0.01	17	255	81.3	0.29	2.3	2.7
4/15/2006 0:45	43.9120	114.2993	1.2 Mc INL	125.4	7.03	6	255	39.8	0.07	1.2	13.9
4/15/2006 3:38	43.8990	114.2655	1.3 Mc INL	122.5	1.04	6	210	39.1	0.13	1.9	3.8
4/15/2006 4:43	43.9207	114.3063	1.3 Mc INL	126.2	5.38	12	226	40.6	0.14	0.7	1.9
4/15/2006 13:18	44.3935	113.9227	1.0 Mc INL	123.2	11.58	6	255	63.9	0.10	0.9	1.1
4/19/2006 16:23	42.7410	111.5833	0.8 Mc INL	140.5	3.56	9	156	25.6	0.07	0.6	10.4
4/19/2006 17:38	44.3800	114.0028	1.3 Mc INL	127.1	6.91	5	221	48.3	0.09	0.9	14.7
4/19/2006 22:11	44.3247	112.7880	0.6 Mc INL	75.1	7.04	4	189	50.8	0.14	1.8	16.8
4/23/2006 14:01	44.4068	114.0543	1.7 Mc INL	132.2	1.95	8	226	52.8	0.19	1.6	6.0
4/25/2006 6:17	44.3555	114.4603	1.7 Mc INL	155.7	1.86	8	250	84.3	0.09	1.1	3.7
4/26/2006 11:46	44.2440	113.9415	1.3 Mc INL	114.1	0.09	9	284	43.5	0.17	1.6	3.1
4/26/2006 19:56	42.7872	111.4933	1.0 Mc INL	142.1	0.02	5	284	17.7	0.13	10.8	12.2
4/27/2006 6:06	44.1110	113.8532	1.1 Mc INL	100.1	3.60	8	241	38.0	0.04	1.1	2.1
4/27/2006 16:53	42.8518	111.3695	1.0 Mc INL	145.1	2.13	5	134	10.5	0.12	1.1	15.7
4/27/2006 23:14	42.7478	111.2755	0.0 Mc INL	158.3	13.38	5	129	14.5	0.04	7.3	9.9
4/30/2006 0:32	44.8423	112.9975	1.6 Mc INL	133.8	1.34	9	248	11.9	0.10	4.1	6.6
5/4/2006 15:38	44.7563	111.4988	0.6 Mc INL	160.2	4.66	3	191	13.5	0.09	9.4	11.1
5/5/2006 0:24	44.3933	114.0753	1.3 Mc INL	132.5	1.58	8	226	54.2	0.13	1.4	1.0
5/5/2006 4:03	44.7742	112.3523	1.2 Mc INL	129.7	13.08	10	175	20.4	0.04	0.5	1.1
5/7/2006 10:15	44.3702	114.0480	1.3 Mc INL	129.2	3.90	5	223	51.7	0.19	1.8	4.8
5/8/2006 6:10	44.3177	114.2163	1.2 Mc INL	136.8	6.98	9	230	64.7	0.13	1.4	1.5
5/8/2006 23:13	42.7550	111.2720	1.3 Mc INL	158.1	12.83	6	126	14.1	0.03	7.5	10.1
5/11/2006 12:02	44.6560	111.9065	0.8 Mc INL	132.1	4.47	7	141	20.8	0.08	0.8	2.2
5/11/2006 14:18	43.7775	111.1340	1.4 Mc INL	133.6	5.51	8	169	46.0	0.04	0.6	2.1
5/12/2006 13:12	43.3528	111.2865	1.6 Mc INL	125.4	4.79	10	309	127.6	0.29	9.9	20.5
5/15/2006 2:54	44.4580	114.2792	1.1 Mc INL	149.8	4.94	4	331	71.5	0.06	6.0	12.0
5/15/2006 21:56	44.6483	112.5212	1.4 Mc INL	113.0	3.57	13	134	11.8	0.34	0.9	1.2
5/18/2006 3:44	44.5108	114.3902	1.8 Mc INL	160.4	4.15	11	252	99.0	0.14	2.0	3.1
5/19/2006 13:31	44.1835	114.5332	2.2 Mc INL	152.5	1.44	15	250	69.8	0.16	1.7	1.9
5/19/2006 19:25	42.6878	111.6198	1.2 Mc INL	142.8	2.64	9	154	43.4	0.13	0.8	15.9
5/23/2006 15:11	42.6467	111.4473	0.0 NM	155.7	5.03	8	128	31.3	0.08	0.8	11.8
5/23/2006 22:32	44.6148	112.5375	0.5 Mc INL	109.1	2.53	5	147	11.6	0.12	7.5	14.3
5/25/2006 4:50	43.3738	110.9545	1.6 Mc INL	150.9	0.30	6	294	137.7	0.24	6.1	6.0
5/25/2006 9:53	44.7545	112.4140	1.6 Mc INL	126.4	15.47	15	168	18.0	0.10	0.3	0.4
5/26/2006 15:48	42.7130	111.5063	1.2 Mc INL	147.1	3.31	6	141	25.9	0.04	0.7	11.3
5/27/2006 15:03	44.5232	112.2138	0.0 Mc INL	107.3	3.37	5	332	60.4	0.20	8.9	18.6

Table D-2. Continued.

ORIGIN TIME	LAT N	LONG W	MAG-TYPE	DIST	Z	NO	GAP	DMIN	RMS	ERH	ERZ
5/28/2006 2:04	44.4685	112.0770	1.7 Mc INL	107.2	5.91	17	126	23.8	0.12	0.4	15.6
5/29/2006 7:14	42.6362	111.4387	0.0 Mc INL	157.1	5.01	7	145	31.2	0.10	0.8	13.6
5/29/2006 7:18	42.6465	111.4598	1.6 Mc INL	155.0	2.52	18	131	32.3	0.14	0.7	16.8
5/31/2006 23:36	42.7745	111.3345	0.0 Mc INL	152.7	13.98	5	179	31.1	0.17	7.0	14.2
6/2/2006 4:44	44.5552	112.1117	1.9 Mc INL	114.1	11.36	29	123	22.8	0.19	0.4	1.1
6/5/2006 12:54	44.2095	110.9760	1.6 Mc INL	157.8	31.66	6	200	15.3	0.11	0.9	1.5
6/7/2006 4:04	43.3225	111.3552	3.0 ML US	121.1	14.17	30	198	29.9	0.09	0.6	0.7
6/7/2006 19:40	43.3262	111.3755	0.0 Mc INL	119.4	9.43	7	170	30.3	0.12	0.7	1.4
6/8/2006 15:12	42.6992	111.3128	1.2 Mc INL	159.6	10.01	5	156	18.9	0.33	3.7	6.8
6/8/2006 15:56	43.7070	111.1587	2.2 Mc INL	131.1	8.61	27	170	53.7	0.14	0.5	0.7
6/9/2006 11:34	44.4782	114.2860	1.4 Mc INL	151.6	6.47	9	272	72.6	0.33	2.9	5.2
6/9/2006 16:46	44.5952	111.5300	1.4 Mc INL	145.3	1.32	4	268	52.8	0.01	3.0	7.9
6/9/2006 20:15	43.6943	111.1295	1.6 Mc INL	133.4	10.89	6	242	55.3	0.06	1.2	2.3
6/10/2006 13:34	43.7227	111.1470	1.1 Mc INL	132.1	14.90	10	170	52.0	0.08	0.7	0.9
6/10/2006 14:46	43.7085	111.1495	1.7 Mc INL	131.8	11.69	15	171	53.6	0.06	0.6	0.8
6/11/2006 10:28	42.4883	112.0517	1.3 Mc INL	142.3	4.47	8	103	46.9	0.07	0.6	11.7
6/11/2006 17:16	43.7075	111.1583	1.2 ML INL	131.1	9.04	12	170	53.7	0.14	0.8	1.4
6/13/2006 9:23	43.7045	111.1345	1.6 Mc INL	133.0	13.39	13	173	54.1	0.08	0.6	0.9
6/13/2006 11:09	44.7608	111.5088	0.7 Mc INL	160.1	6.25	7	242	28.5	0.06	0.9	12.1
6/14/2006 17:27	44.7220	112.9337	2.3 Mc INL	119.9	0.03	6	224	106.9	0.13	2.3	3.7
6/14/2006 18:21	44.7317	112.9412	2.0 Mc INL	121.0	0.09	6	225	107.7	0.13	2.3	3.8
6/15/2006 6:21	44.7662	112.9587	2.0 Mc INL	125.0	0.16	5	227	110.0	0.06	1.9	3.1
6/15/2006 18:19	44.7803	111.5287	0.9 Mc INL	160.8	5.91	3	259	30.2	0.05	1.1	13.2
6/15/2006 21:32	42.5230	111.6720	1.6 Mc INL	154.6	8.13	6	204	46.0	0.13	0.9	8.1
6/16/2006 20:07	43.7068	111.1192	1.5 Mc INL	134.3	19.03	4	316	54.0	0.13	1.8	13.0
6/17/2006 22:39	43.6988	111.1143	1.0 Mc INL	134.6	5.06	3	334	54.9	0.09	1.8	14.5
6/18/2006 0:26	42.6780	111.4973	0.0 Mc INL	150.4	5.88	6	217	33.9	0.05	2.6	12.6
6/18/2006 6:40	42.6590	111.4703	1.7 Mc INL	153.4	5.18	10	191	32.5	0.10	2.0	12.8
6/19/2006 11:49	42.6287	111.9570	1.3 Mc INL	132.0	4.97	4	279	58.7	0.13	0.9	15.6
6/20/2006 2:19	42.6383	111.4410	1.1 Mc INL	156.8	12.24	10	147	31.3	0.08	0.6	3.0
6/20/2006 15:59	43.7812	113.5733	0.8 Mc INL	65.3	5.45	12	139	19.0	0.22	0.7	1.2
6/24/2006 16:16	44.7602	112.9663	1.1 Mc INL	124.4	6.63	6	260	47.9	0.09	1.8	5.2
6/25/2006 9:26	44.3753	112.8698	1.0 Mc INL	81.0	12.70	13	179	7.6	0.14	0.8	1.1
6/27/2006 22:59	42.7413	111.2913	1.6 Mc INL	157.8	4.96	7	128	15.9	0.32	1.1	8.5
6/28/2006 21:12	44.2778	114.5548	1.1 Mc INL	158.4	0.14	10	275	80.4	0.11	5.4	4.7
7/1/2006 5:46	44.2975	113.9303	0.6 Mc INL	116.9	4.00	5	326	56.1	0.05	5.2	11.5
7/1/2006 16:48	44.4213	112.9345	0.1 Mc INL	86.7	11.91	4	327	10.2	0.12	1.8	1.3
7/6/2006 7:20	42.9095	111.5468	1.2 Mc INL	129.8	2.16	13	190	10.7	0.03	0.8	11.9
7/6/2006 17:55	44.5493	113.5290	0.9 Mc INL	116.5	3.89	8	264	28.3	0.06	1.2	0.8
7/6/2006 21:55	42.8590	111.5135	0.9 Mc INL	135.5	11.51	6	277	24.6	0.10	4.2	3.7
7/7/2006 5:26	43.7253	111.1898	1.5 Mc INL	128.7	6.70	10	166	51.7	0.10	0.7	1.6
7/7/2006 11:15	42.9115	111.5177	0.5 Mc INL	131.5	2.26	8	152	8.4	0.13	0.7	13.1
7/7/2006 20:38	44.2980	111.9425	1.0 Mc INL	98.7	6.13	7	144	30.3	0.12	1.8	13.0
7/8/2006 14:33	42.9068	111.5450	1.6 Mc INL	130.1	2.02	24	154	10.7	0.08	0.5	13.9
7/8/2006 15:08	42.9165	111.5365	1.2 Mc INL	129.9	8.62	6	261	20.4	0.09	3.4	11.4

Table D-2. Continued.

ORIGIN TIME	LAT N	LONG W	MAG-TYPE	DIST	Z	NO	GAP	DMIN	RMS	ERH	ERZ
7/8/2006 22:20	42.9153	111.5403	0.8 Mc INL	129.8	0.07	9	188	10.0	0.06	0.7	0.9
7/9/2006 14:33	42.9153	111.5437	1.8 Mc INL	129.6	1.97	28	110	10.3	0.10	0.3	1.4
7/9/2006 21:17	43.1140	110.9830	1.1 Mc INL	157.5	5.69	5	266	32.3	0.08	2.9	1.4
7/12/2006 5:27	44.8002	112.9335	1.6 Mc INL	128.5	0.08	6	321	52.3	0.34	4.9	4.0
7/12/2006 19:52	44.3082	113.9712	1.5 Mc INL	120.2	7.09	12	243	45.2	0.20	1.0	11.7
7/13/2006 18:58	42.6302	111.6322	1.4 Mc INL	147.1	2.50	8	87	46.1	0.09	0.6	14.5
7/13/2006 21:34	42.6185	111.4323	1.3 Mc INL	158.9	8.68	9	109	31.7	0.10	0.5	2.3
7/14/2006 0:58	42.6112	111.6012	1.8 Mc INL	150.3	2.50	10	90	44.5	0.13	0.5	16.4
7/15/2006 2:54	42.6072	111.4262	1.8 Mc INL	160.1	4.97	14	111	32.0	0.11	0.6	11.7
7/18/2006 16:41	42.6083	111.5993	1.1 Mc INL	150.7	2.50	10	105	44.5	0.18	0.5	18.9
7/19/2006 1:46	42.5835	111.5980	1.9 Mc INL	152.9	7.92	9	235	45.5	0.09	0.9	4.2
7/19/2006 23:13	43.3268	111.3922	1.7 Mc INL	118.1	4.40	9	135	30.4	0.13	0.4	4.5
7/20/2006 23:15	44.2430	114.5500	1.9 Mc INL	156.4	4.68	8	284	76.5	0.05	1.1	2.2
7/21/2006 1:35	44.3730	112.5772	1.4 Mc INL	82.1	15.02	7	238	21.0	0.08	1.4	1.6
7/22/2006 11:59	44.3325	113.9620	0.7 Mc INL	121.3	7.44	9	246	60.7	0.12	1.1	15.9
7/22/2006 12:01	44.3333	113.9723	1.6 Mc INL	122.0	7.09	9	246	61.3	0.12	1.0	15.9
7/22/2006 14:45	44.6645	112.1048	1.6 Mc INL	125.2	9.19	13	230	39.7	0.12	1.3	4.3
7/23/2006 12:49	44.2187	114.4735	1.3 Mc INL	149.7	1.25	4	331	85.9	0.08	6.9	8.3
7/24/2006 7:11	44.7818	111.5280	1.1 Mc INL	160.9	6.33	3	259	30.3	0.08	1.2	13.2
7/24/2006 9:41	44.7865	111.5417	0.6 Mc INL	160.7	5.87	3	261	30.6	0.05	1.3	13.3
7/24/2006 17:58	42.8477	111.2038	0.4 Mc INL	156.2	11.79	5	175	12.5	0.09	3.6	2.4
7/24/2006 18:31	42.8485	111.2145	1.0 Mc INL	155.4	4.11	7	167	13.1	0.04	1.9	10.4
7/24/2006 23:06	42.7450	111.2860	1.6 Mc INL	157.9	9.37	9	130	15.4	0.07	1.0	2.6
7/25/2006 9:07	42.6595	111.4037	1.8 Mc INL	157.2	2.50	14	105	27.5	0.10	0.4	13.7
7/27/2006 13:33	44.3042	114.5108	1.5 Mc INL	156.5	0.02	11	316	88.2	0.24	3.3	4.0
7/27/2006 19:26	44.2983	114.4683	0.9 Mc INL	153.2	0.04	6	326	91.2	0.15	3.3	4.0
7/28/2006 14:59	44.3843	111.0543	2.2 ML INL	160.8	9.08	26	117	23.6	0.10	0.3	1.7
7/28/2006 15:13	44.3777	111.0470	0.6 Mc INL	161.0	12.00	4	117	22.7	0.07	0.5	2.8
7/28/2006 15:31	44.3813	111.0650	0.7 Mc INL	159.9	4.98	4	114	23.2	0.05	0.7	11.8
7/28/2006 21:58	44.3840	111.0555	0.6 Mc INL	160.7	4.99	4	117	23.6	0.10	0.7	10.6
7/29/2006 9:39	44.2188	114.5492	1.5 Mc INL	155.2	1.25	12	272	73.8	0.33	3.4	3.4
7/29/2006 10:29	42.7985	111.2112	0.8 Mc INL	158.9	4.44	6	206	31.2	0.09	0.6	1.5
7/29/2006 10:54	44.3370	113.8787	1.4 Mc INL	116.4	7.37	9	308	37.9	0.14	1.2	15.7
7/31/2006 8:25	44.8662	111.9713	1.8 Mc INL	150.0	6.34	13	225	47.9	0.16	0.7	3.7
7/31/2006 11:56	43.7512	112.9083	2.0 ML INL	14.8	8.98	25	44	3.7	0.10	0.3	0.8
7/31/2006 18:49	44.4890	113.1750	0.9 Mc INL	98.5	11.75	10	270	25.7	0.12	1.2	1.9
7/31/2006 23:06	42.7440	111.3028	1.7 Mc INL	156.9	9.63	9	129	16.7	0.05	0.5	1.7
8/2/2006 15:54	44.5103	114.1735	3.5 ML MB	146.8	0.16	23	257	65.1	0.25	2.0	2.8
8/2/2006 17:44	42.6870	111.6060	1.9 Mc INL	143.6	14.34	8	86	42.3	0.25	1.0	1.8
8/2/2006 21:45	44.5107	114.2087	1.8 Mc INL	149.0	0.08	12	259	67.7	0.24	3.0	2.4
8/4/2006 5:28	44.7667	112.5573	1.3 Mc INL	125.5	6.55	10	231	51.0	0.23	1.2	19.4
8/5/2006 6:39	44.3840	111.0537	0.3 Mc INL	160.9	4.95	5	117	23.5	0.07	0.9	10.5
8/5/2006 23:08	44.3398	113.9618	1.3 Mc INL	121.7	7.06	13	246	44.5	0.11	0.8	2.7
8/6/2006 6:43	44.4200	114.4490	1.5 Mc INL	158.6	0.04	9	330	84.1	0.26	6.4	6.5
8/6/2006 11:01	43.6842	112.7632	0.4 Mc INL	4.1	0.02	6	110	10.9	0.28	0.8	1.9

Table D-2. Continued.

ORIGIN TIME	LAT N	LONG W	MAG-TYPE	DIST	Z	NO	GAP	DMIN	RMS	ERH	ERZ
8/7/2006 2:18	44.2727	113.2287	1.1 Mc INL	78.0	1.79	6	228	23.8	0.08	1.2	14.1
8/8/2006 7:39	43.7218	111.1740	1.1 Mc INL	129.9	5.00	4	168	52.1	0.07	1.1	13.5
8/9/2006 9:24	44.8527	111.9762	1.7 Mc INL	148.5	9.58	11	214	47.0	0.11	0.7	1.9
8/10/2006 13:34	42.9757	111.0808	0.6 Mc INL	157.1	2.47	9	245	23.4	0.05	1.3	13.1
8/11/2006 1:53	44.3925	114.4542	1.7 Mc INL	157.4	0.05	7	275	92.3	0.22	3.4	3.6
8/11/2006 9:25	44.4160	114.4523	1.2 Mc INL	158.6	0.73	6	286	94.9	0.12	3.1	3.0
8/11/2006 11:20	44.3872	114.4525	1.1 Mc INL	156.9	0.07	5	285	91.7	0.08	3.3	3.0
8/14/2006 8:20	44.7428	112.7812	0.8 Mc INL	121.6	7.52	8	253	47.7	0.13	1.2	15.0
8/15/2006 9:14	44.5645	112.1998	1.5 Mc INL	111.9	17.98	6	314	26.5	0.12	1.6	1.3
8/20/2006 14:41	44.3945	114.4338	1.5 Mc INL	156.1	0.03	8	284	92.5	0.19	4.0	4.7
8/22/2006 5:48	44.6097	112.0317	1.0 Mc INL	122.5	6.73	8	238	34.5	0.08	1.0	11.5
8/22/2006 15:22	44.4043	114.3813	1.7 Mc INL	153.1	0.04	8	328	91.2	0.14	4.6	5.9
8/22/2006 18:16	44.4190	114.4170	2.6 ML INL	156.4	0.02	19	299	81.5	0.33	3.2	3.6
8/24/2006 15:45	44.4057	114.4677	2.0 Mc INL	159.0	1.34	17	275	85.4	0.32	2.7	2.9
8/24/2006 20:28	43.4968	110.8638	1.0 Mc INL	155.9	8.21	8	218	64.2	0.11	1.0	1.4
8/25/2006 11:34	44.0223	114.1998	1.3 Mc INL	121.2	0.04	6	246	53.7	0.13	7.8	6.1
8/25/2006 12:28	44.3685	114.4778	1.7 Mc INL	157.6	0.45	11	275	85.8	0.27	2.6	2.2
8/25/2006 16:08	44.3848	114.4665	1.7 Mc INL	157.8	4.81	8	279	85.0	0.23	2.0	3.8
8/25/2006 16:46	44.4065	114.4578	1.8 Mc INL	158.4	0.33	8	276	84.6	0.21	2.7	2.8
8/26/2006 1:28	42.8948	111.2125	1.2 Mc INL	152.6	3.22	6	183	17.1	0.11	1.8	10.8
8/26/2006 19:57	44.2558	114.5635	2.1 Mc INL	157.9	0.03	12	275	78.1	0.23	2.5	3.8
8/28/2006 7:21	43.9657	114.4058	0.7 Mc INL	135.2	4.60	6	243	44.8	0.00	2.6	4.1
8/28/2006 13:15	44.3565	114.4483	1.3 Mc INL	154.9	1.90	7	276	83.4	0.18	2.0	4.7
8/28/2006 13:22	44.3638	114.4927	1.3 Mc INL	158.4	4.28	8	286	89.3	0.21	1.7	3.1
8/29/2006 15:53	42.7547	111.3455	0.8 Mc INL	153.5	2.22	9	138	20.1	0.04	0.4	12.9
8/31/2006 9:39	44.3645	111.0585	0.8 Mc INL	159.5	4.96	4	112	21.7	0.09	0.7	12.2
9/1/2006 0:10	42.7313	111.2943	1.8 Mc INL	158.4	7.85	12	100	16.3	0.09	0.5	1.6
9/2/2006 18:46	42.7017	111.3025	1.2 Mc INL	160.0	4.93	7	242	18.0	0.12	2.1	12.7
9/4/2006 5:04	44.3722	114.4967	1.2 Mc INL	159.1	0.68	6	276	90.3	0.17	2.1	2.3
9/6/2006 19:14	44.3953	114.4628	1.2 Mc INL	158.1	0.02	7	275	92.7	0.28	4.5	4.5
9/6/2006 22:11	43.1583	112.0065	0.8 Mc INL	83.3	5.15	5	188	17.9	0.07	1.9	10.8
9/7/2006 9:09	44.1780	113.9895	1.2 Mc INL	113.3	8.61	5	231	51.2	0.09	1.3	14.3
9/7/2006 16:17	42.6932	111.6458	1.9 Mc INL	141.0	5.03	8	128	45.9	0.08	0.8	13.0
9/9/2006 4:15	42.6517	111.3568	1.0 Mc INL	160.6	4.50	7	136	24.5	0.10	0.7	10.9
9/9/2006 19:08	42.9033	111.6862	1.3 Mc INL	121.7	8.72	12	192	30.7	0.09	0.8	2.7
9/9/2006 22:53	42.7372	111.3148	1.8 Mc INL	156.7	4.61	8	131	17.8	0.05	0.4	2.9
9/14/2006 17:07	42.6718	111.7550	1.7 Mc INL	137.2	4.99	9	122	52.8	0.20	0.7	17.6
9/15/2006 20:35	42.6858	111.6645	1.5 Mc INL	140.6	4.99	5	159	47.4	0.29	1.8	22.6
9/16/2006 12:50	43.9670	113.7165	1.4 Mc INL	83.0	7.87	7	208	43.1	0.15	1.0	17.7
9/19/2006 15:44	43.0918	111.0100	1.3 Mc INL	156.5	2.61	10	195	37.0	0.04	0.9	12.7
9/22/2006 3:09	44.4152	112.6642	1.0 Mc INL	85.7	3.05	10	194	24.1	0.11	0.6	1.0
9/23/2006 20:49	42.9710	111.4098	1.5 Mc INL	134.6	9.16	10	179	34.1	0.08	1.4	1.9
9/29/2006 16:56	42.7320	111.2950	1.3 Mc INL	158.3	11.98	8	135	16.4	0.12	0.6	1.6
9/29/2006 23:27	42.7235	111.2882	1.4 Mc INL	159.3	7.89	9	139	16.1	0.14	0.4	1.1
10/2/2006 13:58	43.7172	111.0613	1.8 Mc INL	139.0	5.52	23	112	53.5	0.13	0.6	1.2

Table D-2. Continued.

ORIGIN TIME	LAT N	LONG W	MAG-TYPE	DIST	Z	NO	GAP	DMIN	RMS	ERH	ERZ
10/9/2006 1:13	44.8812	112.0628	1.4 Mc INL	148.5	7.02	7	239	84.7	0.23	1.5	4.3
10/9/2006 17:56	42.6805	111.6067	1.6 Mc INL	144.1	4.99	6	148	42.5	0.09	0.5	12.6
10/11/2006 0:57	44.3037	112.8757	1.1 Mc INL	73.1	0.07	7	302	28.3	0.24	5.8	6.4
10/11/2006 2:37	44.8907	112.8283	2.2 Mc INL	138.1	0.08	20	279	89.5	0.16	1.8	2.0
10/13/2006 6:01	42.6172	111.8768	2.3 Mc INL	136.5	3.75	8	103	56.1	0.10	0.5	5.7
10/13/2006 14:37	44.3515	112.6085	1.8 Mc INL	79.3	0.08	14	216	29.3	0.17	1.0	2.0
10/13/2006 19:18	42.8962	111.4382	1.5 Mc INL	137.6	2.18	5	249	31.2	0.12	1.8	15.8
10/14/2006 10:01	44.3935	111.1682	0.7 Mc INL	153.6	5.75	4	109	22.6	0.03	0.5	11.7
10/16/2006 4:11	42.6547	111.4467	1.6 Mc INL	155.1	10.42	7	112	30.9	0.09	1.4	3.8
10/17/2006 3:10	43.4073	111.1175	2.1 Mc INL	137.3	9.66	14	164	71.3	0.09	0.6	0.9
10/18/2006 16:44	42.7022	113.1182	1.7 Mc INL	108.9	10.69	19	172	61.0	0.14	0.8	0.7
10/19/2006 10:33	44.5343	111.2587	2.1 ML INL	156.7	6.38	12	131	28.6	0.09	0.5	13.9
10/19/2006 23:15	42.8205	111.3627	1.3 Mc INL	147.7	6.61	6	162	22.3	0.08	1.1	8.1
10/21/2006 7:07	42.8203	111.1592	0.6 Mc INL	160.9	9.30	7	202	7.8	0.03	1.5	1.4
10/21/2006 14:28	44.1345	113.9828	1.7 Mc INL	110.4	6.79	14	243	70.1	0.21	2.2	4.0
10/31/2006 8:01	43.7323	111.1123	2.1 Mc INL	134.9	8.10	20	252	80.6	0.11	1.1	0.9
11/1/2006 2:35	44.3042	113.9553	1.7 Mc INL	118.9	5.52	12	243	58.0	0.26	1.3	2.4
11/2/2006 8:19	44.6202	112.1807	1.0 Mc INL	118.2	6.86	7	240	32.9	0.10	1.4	12.2
11/3/2006 19:43	42.7628	111.3257	1.4 Mc INL	154.1	8.21	8	144	18.4	0.08	2.8	5.7
11/4/2006 8:58	42.9195	111.3215	1.8 ML INL	143.7	9.06	12	181	24.9	0.07	0.5	1.5
11/9/2006 11:52	44.3540	114.2752	2.6 ML INL	143.0	0.02	15	257	81.1	0.26	2.5	3.1
11/10/2006 3:43	44.1008	113.9713	1.4 Mc INL	107.8	7.35	5	240	45.8	0.11	2.0	15.6
11/10/2006 16:31	43.8888	113.7545	0.9 Mc INL	82.6	7.28	6	196	24.7	0.19	1.7	18.6
11/10/2006 21:11	42.6170	111.4463	1.1 Mc INL	158.2	3.08	8	107	32.8	0.08	0.8	13.0
11/17/2006 8:05	44.4867	114.0170	1.9 Mc INL	135.8	0.02	7	291	96.4	0.09	4.9	4.7
11/17/2006 11:08	44.7485	111.6433	2.1 Mc INL	152.4	0.08	9	273	25.9	0.15	2.6	2.2
11/20/2006 22:35	44.3838	111.0593	0.8 Mc INL	160.5	4.99	4	116	23.7	0.09	0.7	13.1
12/1/2006 22:10	44.2755	114.5598	1.5 Mc INL	158.6	0.04	5	276	80.2	0.27	4.3	5.2
12/3/2006 3:08	44.6712	112.9050	1.6 Mc INL	114.0	11.68	7	311	56.4	0.17	1.2	1.5
12/4/2006 13:39	44.6857	112.8600	1.4 Mc INL	115.4	0.04	6	273	60.1	0.26	4.8	5.8
12/5/2006 15:11	44.2035	114.3015	1.1 Mc INL	136.6	0.04	6	341	74.6	0.21	5.6	4.9
12/5/2006 18:57	44.1050	114.4412	1.6 ML INL	142.5	4.26	12	257	60.3	0.13	1.5	2.5
12/7/2006 10:34	44.3478	114.0010	1.2 Mc INL	124.7	0.08	7	253	47.7	0.16	4.0	5.1
12/7/2006 11:59	44.7333	112.7872	1.4 Mc INL	120.5	6.91	7	237	68.0	0.24	1.4	23.6
12/10/2006 23:02	44.2407	114.5605	1.2 Mc INL	157.0	0.09	8	274	76.4	0.32	4.4	5.5
12/14/2006 18:43	42.2927	112.9408	1.9 Mc INL	151.5	6.72	6	225	73.6	0.08	1.3	1.1
12/16/2006 3:43	44.8078	111.5860	2.0 Mc INL	160.4	12.97	13	230	46.2	0.05	0.8	2.2
12/22/2006 4:46	43.5165	111.0188	1.2 Mc INL	143.2	10.32	6	242	76.0	0.14	1.1	0.9
12/22/2006 7:55	44.6248	112.2402	1.6 Mc INL	116.8	15.05	6	268	32.1	0.08	1.8	1.1
12/22/2006 10:20	44.2443	114.3402	1.5 Mc INL	141.4	8.37	7	259	75.9	0.09	1.2	2.2
12/28/2006 1:26	44.2410	114.0353	1.3 Mc INL	120.1	7.61	8	272	58.2	0.18	1.4	18.7
12/31/2006 14:35	44.4532	112.5087	1.2 Mc INL	92.0	6.69	8	270	19.7	0.22	1.9	19.2