Final Technical Report

Submitted to the
U.S. GEOLOGICAL SURVEY

By the Seismological Laboratory
CALIFORNIA INSTITUTE OF TECHNOLOGY

Cooperative Agreement No.: Award No. 07HQAG0007

Name of Contractor: California Institute of Technology

Principal Investigators: Robert Clayton
Professor of Geophysics
clay@gps.caltech.edu

Egill Hauksson
Senior Research
Associate of Geophysics
hauksson@gps.caltech.edu

Government Technical Officer: Elizabeth Lemersal
External Research Support Manager
Earthquake Hazards Program, USGS

Title of Work: Partial Support of the Joint USGS/ Caltech Southern California Seismographic Network

Project Web Sites: www.scsn.org
www.data.scec.org

Period Covered by Report: 1 Feb. 2007 – 31 Jan. 2010

Date: 16 April 2010

This work is sponsored by the U.S. Geological Survey under Contract Award No. 07HQAG0007. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessary representing the official policies, either expressed or implied of the U.S. Government.

Partial Support of Joint USGS-CALTECH Southern California Seismographic Network

USGS Award No. 07HQAG0007

INVESTIGATIONS

This Cooperative Agreement provides partial support for the joint USGS-Caltech Southern California Seismic Network (SCSN) and the Southern California Earthquake Data Center (SCEDC). The purpose is to record and analyze data from more than 43,628 events (including local and regional earthquakes and quarry blasts) during the reporting period (1 February 2007 through 31 January 2010). We also generated a database of parametric data and digital seismograms. The primary product derived from the database is a joint USGS-Caltech catalog of earthquakes in the southern California region and the associated waveforms. We maintain the SCSN and SCEDC infrastructures. We also provide rapid response to emergency services, the media, and public inquiries about earthquakes and data for seismological research.

RESULTS

Network Operations

The SCSN operation of network infrastructure consists of: 1) operating computer and communications hardware/software and other instrumentation for data acquisition at the central site; 2) installation and field maintenance of new and existing digital stations; and 3) population and maintenance of earthquake databases. Caltech and USGS personnel share these operations responsibilities. Because the SCSN is a cooperative project of Caltech and USGS, all the facilities listed below are jointly operated and contribute to the overall project mission.

At present we operate ~170 broadband and strong motion stations and record data from 16 Anza network broadband and strong motion stations. These stations provide flat instrument response from 50 Hz to 60 seconds or greater. Approximately 75% of the broadband sensors have low frequency response to 120 sec (8 stations have bandwidth out to 360 sec). These stations are free field sites that are located away from structures of two or more stories, and preferentially in places with low ambient ground noise (Figure 1).

We also operate reference stations that differ from traditional free field sites. They are sited close to structures of two or more stories or are located near major facilities or near groups of significant structures. All of these stations have local recording. At present we receive real-time data from ~15 SCSN, ~8 CGS, and ~15 NSMP strong motion reference stations equipped with K2 dataloggers. We also record data from three University of California borehole strong motion stations located on UC campuses, and 4 SCEC borehole strong motion stations. The sharing of strong motion data facilitates dual use of the data, for both ground motion measurements and earthquake locations.

Digital Station Response Characteristics

The implementation of the Station Information System (SIS) has been completed and the SCSN and SCEDC are using this new database in routine operations. We have migrated all legacy metadata from broadband and short-period stations to the SIS database. New updates to metadata are done through SIS GUI (graphical user interface). Dataless SEED volumes are now being generated from the SIS database within two hours of station fieldwork being entered in

SIS. In addition to the SEED volumes for broadband stations, the SIS now stores the metadata to generate SEED volumes for USGS short period telemetered stations. We have also developed stored procedures for SIS as an API between applications and the data model. Stored procedures include writing SEED volumes, inserting and modifying logger, sensor, power and telemetry system information into the database. Dataless SEED volumes are available for all digital (Quanterra and K2 dataloggers) stations back to 1987. We also provide Cosmos Standard V0 for all stations to facilitate engineering use of the data. Nominal gains are available for short period stations, extending back to the 1980s.

We validate instrument responses by analyzing the waveform data. For instance, routine picking by data analysts sometimes leads to discovery of data timing errors. Both ShakeMap and moment tensor processing software packages report exceptional outliers. We operate a set of scripts that allow easy plotting of 8 hr time windows to find problems with the long period response. We are in the process of installing PQLX to provide routine noise probability density plots for all of the SCSN broadband stations.

Dataless SEED Volumes

These are made available through an ftp site (located at www.data.scec.org). This ftp site is queried daily by the metadata server at the USGS in Golden Colorado. An email notification is also sent to partners in IRIS and NCEDC when a dataless SEED is updated.

Vs30 Values

Measured Vs30 values are available for some sites. In most cases the Vs30 values are derived from California Geological Survey (CGS) surface velocity maps for California.

State of Health

The SCSN state of health is monitored using SeisNetWatch. SeisNetWatch can be operated remotely using a regular web browser and field engineers can be notified via paging or email in case problems develop. SeisNetWatch is a good example of how the seismic network community has benefited from SCSN/TriNet development. Initially, it was developed as TriNetWatch and was made available to the community as SeisNetWatch at the request of the USGS/ANSS earthworm group in Golden Colorado.

Metadata

Full metadata are available for all digital SCSN stations. These will be updated within one day of any instrument change. The full metadata are available now from www.data.scec.org or www.iris.edu for a subset of stations. Only partial metadata are available for short-period analog stations.

Completed Special Operational Objectives

The milestones listed below were completed during the contract period:

1) Implementation of firewall hardware
2) Reconfiguration of waveform import servers
3) Implementation of the new station response database (SIS) into real-time operations
4) Transferred wavepools from the real-time processing systems to independent servers
5) Upgrade of database to Oracle 10i including new hardware (SCEDC)
6) Configuration of all Quanterra dataloggers to report their data to import servers
7) Recalculation of ML station corrections to match true station gains and to enable statewide calibration of CISN
8) Implementation of noise tracking tool, probability density functions of noise spectra (PDF)
9) Moved equipment inventory control from Excel spreadsheets to SIS
10) Developed a draft of a continuity of operations plan for SCSN and SCEDC

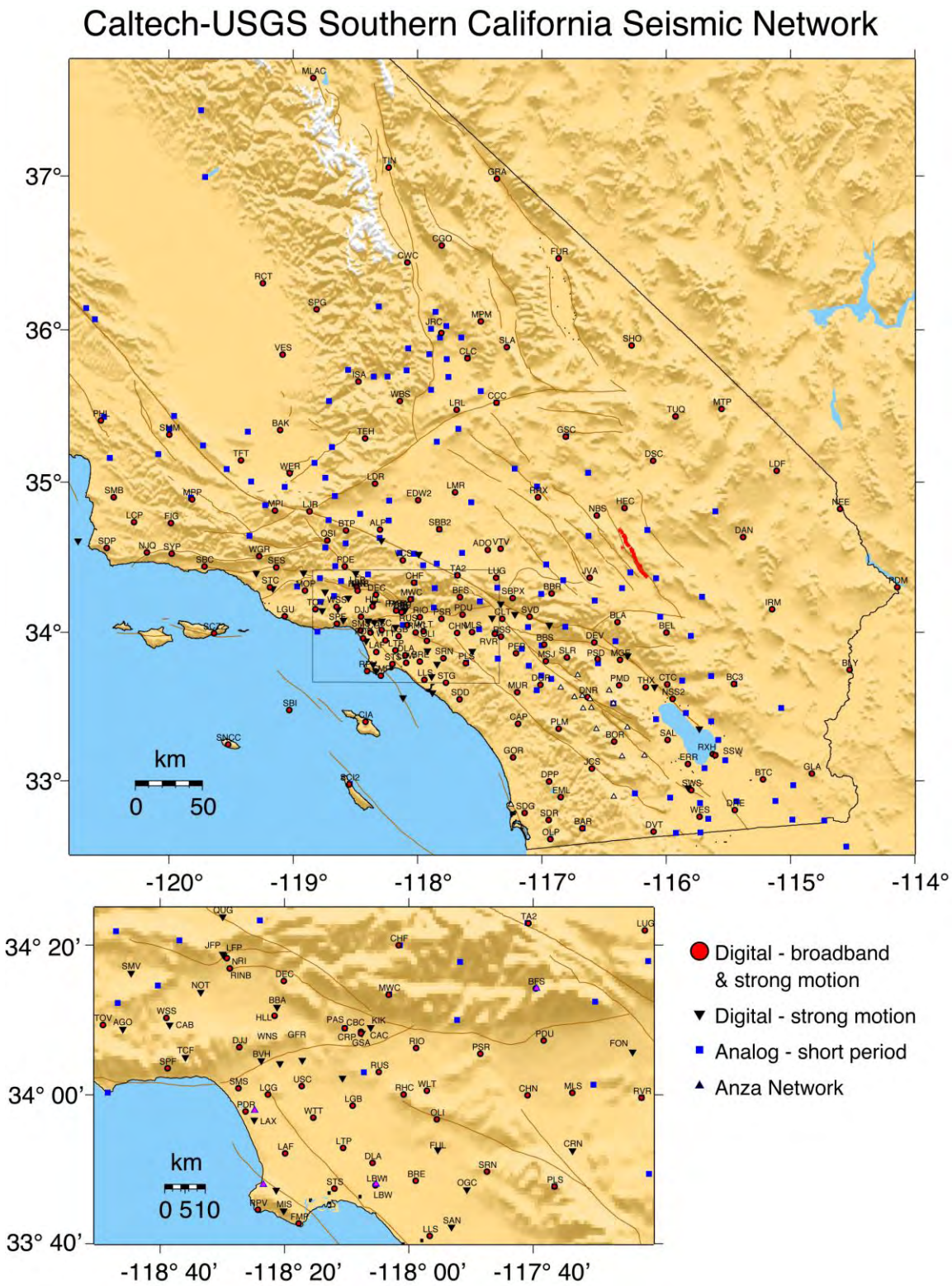

Figure 1. Southern California seismic stations recorded and operated by the SCSN. Not shown are an additional 50 stations recorded by SCSN but operated by other agencies.

New Stations

(Includes stations installed by SCSN and stations operated by other networks, but for which data recording by the SCSN commenced).

NEW STATIONS						
NET	**STA.**	**CHA LOC STANAME**	**LAT.**	**LON.**	**ELEV.**	**ONDATE - OFFDATE**
ZY	SHF2	Superstition Hills Fault, portable 2	32.93328	-115.70393	17	2007/04/19 - 2008/07/16
ZY	SHF7	Superstition Hills Fault, portable 7	32.94397	-115.718	4	2007/04/19 - 2008/07/16
PG	DCD	Diablo Creek digital	35.21217	-120.84084	238	2007/04/24 - 3000/01/01
CI	TOR	Toro Canyon	33.57526	-116.22584	4	2007/04/30 - 3000/01/01
TA	214A	Organ Pipe Natnl Mon., Ajo, AZ	31.9559	-112.8115	543	2007/05/07 - 3000/01/01
CE	35110	California Valley - Painted Rock	35.263	-119.815	695	2007/07/24 - 3000/01/01
CI	CTD	Catalina Thompson Dam	33.35486	-118.44436	190	2007/07/26 - 3000/01/01
PB	B900	blacka900bcn2007, Parkfield, CA	35.63	-120.015	245	2007/08/22 - 3000/01/01
CE	35342	California Valley - Elkhorn Rd	35.261	-119.82	-999	2007/08/28 - 3000/01/01
AZ	MONP2	Monument Peak TA Vault, Anza, CA	32.892	-116.4223	1000	2007/09/15 - 3000/01/01
PB	B093	trippf093bcs2007, Anza, CA,	33.59369	-116.7641	1229	2007/09/20 - 3000/01/01
PB	B901	indspr901bcn2007, Parkfield, CA	35.69	-120.142	275	2007/09/26 - 3000/01/01
EN	ELM	Elmore	33.1772	-115.6134	-64	2007/12/01 - 3000/01/01
EN	ENG	English	33.1477	-115.5438	-64	2007/12/01 - 3000/01/01
EN	HAT	Hatfield	33.1705	-115.5883	-64	2007/12/01 - 3000/01/01
EN	LIN	Lindsey	33.1473	-115.6387	-64	2007/12/01 - 3000/01/01
EN	OBS	Obsidian Butte	33.1752	-115.6379	-64	2007/12/01 - 3000/01/01
EN	RED	Red Hill Marina	33.1996	-115.6088	-64	2007/12/01 - 3000/01/01
EN	SIM	Simpson	33.1913	-115.545	-64	2007/12/01 - 3000/01/01
EN	YOU	Young	33.133	-115.606	-64	2007/12/01 -3000/01/01
CE	25902	Oxnard Offshore - MMS OBS Grace	34.179	-119.47	0	2008/01/01 - 3000/01/01
PB	B916	marips916bcs2008, China Lake, CA	36.1925	-117.6685	1860	2008/03/13 - 3000/01/01
CI	BCW	Bitter Creek Wildlife	34.94009	-119.41313	1101	2008/04/08 - 3000/01/01
CI	JEM	Julian Eagle Mine	33.08098	-116.59755	1308	2008/05/01 - 3000/01/01
CI	SMR	Santa Margarita Ranch	35.37699	-120.61247	341	2008/05/22 - 3000/01/01
PB	B921	randsb921bcs2008, China Lake, CA	35.5865	-117.4622	695	2008/06/03 - 3000/01/01
PB	B918	mtsprn918bcs2008, China Lake, CA	35.93724	-117.5906	1043	2008/06/21 - 3000/01/01
CI	GATR	Ground to Air Transmit & Receive C.	34.55266	-120.50235	590	2008/07/02 - 3000/01/01
PB	B917	tonyso917bcs2008, China Lake, CA	35.3892	-117.2587	1126	2008/07/14 - 3000/01/01
PG	NPD	Nipomo	35.086334	-120.4725	452	2008/08/09 - 3000/01/01
CI	MIKB	Millikan Library Basement(rotation)	34.13688	-118.12601	231	2008/08/25 - 3000/01/01
SB	GVA08	Garner Valley	33.6689	-116.6738	1341	2008/09/13 - 3000/01/01
NC	MDPB	Devils Postpile (new)	37.632267	-119.07935	2360	2008/09/25 - 3000/01/01
ZY	WWS2	WWS2	33.94597	-116.64457	511	2008/10/09 - 2008/11/30
ZY	WWS5	WWS5	33.94425	-116.64505	505	2008/10/09 - 2008/12/06
CI	SNO	Snow Peak	34.03515	-116.80778	2339	2008/12/03 - 3000/01/01
CI	SMW	Santa Maria Wineman	35.01108	-120.40997	169	2008/12/09 - 3000/01/01
CI	SLB	Salton Beach	33.48519	-115.86643	0	2009/02/06 - 3000/01/01
CI	BOM	Bombay Beach	33.36465	-115.72963	-54	2009/02/10 - 3000/01/01
CI	THM	Thermal Canyon	33.65066	-116.07734	60	2009/03/10 - 3000/01/01
CI	WWC	West Wide Canyon	33.94068	-116.40876	619	2009/04/01 - 3000/01/01
CI	MSC	Mission Creek	34.03852	-116.64795	938	2009/04/22 - 3000/01/01
CI	BHP	Baldwin Hills Oil	33.99053	-118.36171	81	2009/05/20 - 3000/01/01
CI	LPC	Lone Pine Canyon	34.31478	-117.54642	1351	2009/05/28 - 3000/01/01
CI	FHO	Forest Home - SOSAF Station	34.09355	-116.93588	1614	2009/08/04 - 3000/01/01
CI	BLA2	Black Rock Canyon Campground 2	34.06931	-116.38993	1247	2009/08/05 - 3000/01/01
PG	BUD	former name of VPD PG	35.2399	-120.869	435	2009/08/12 - 2009/09/14
ZY	OWL1	Owens Lake	36.38562	-117.85973	1168	2009/10/07 - 2009/11/18

Discontinued Stations

(Includes both CI stations and stations operated by other networks, which the SCSN stopped recording)

DISCONTINUED STATIONS						
NET	**STA**	**STA. NAME**	**LAT.**	**LONG.**	**ELEV.**	**ONDATE - OFFDATE**
CI	SBB	Saddleback Butte	34.68817	-117.82501	796	1974/01/03 - 2007/11/28
CI	PNM	Pinto Mtns	33.97738	-115.80161	1101	1974/04/30 - 2008/12/10
CI	GRP	Granite Pass	34.80481	-115.60705	978	1974/12/30 - 2009/08/05
CI	RAY	Raywood Flat	34.03749	-116.81306	2369	1975/11/25 - 2009/01/13
CI	MIR	Martinez Indian Rese	33.41621	-116.08171	30	1981/04/30 - 2007/02/28
NC	MDP	Devils Postpile	37.63246	-119.07972	2315	1984/10/20 - 2008/09/18
PG	DP	Davis Peak	35.23300	-120.78167	488	1986/06/12 - 2008/05/08
PG	NP	Nipomo	35.08633	-120.4725	452	1987/07/13 - 2008/11/20
PG	DC	Diablo Creek	35.21216	-120.84084	238	1987/10/01 - 2007/06/11
CI	TAB	Table Mountain	34.38245	-117.68191	2274	1989/11/30 - 2008/05/07
CI	EW2	East Wide Canyon	33.94059	-116.40839	639	1996/02/16 - 2009/01/13
CI	TOV	Thousand Oaks Ventura	34.15607	-118.82039	298	1997/10/03 - 2007/03/09
CI	JCS	Julian Camp Stevens	33.08590	-116.5959	1264	1998/09/17 - 2007/09/16
CI	THX	Thermal Airport	33.63495	-116.16402	-31	1999/01/27 - 2007/04/16
CI	BLA	Blackrock Canyon Campground	34.06948	-116.38896	1243	2000/04/11 - 2009/01/06
CI	CAP	Capra Ranch	33.38822	-117.19495	285	2000/04/13 - 2007/10/25
CI	DVT	Desert View Tower	32.65915	-116.10061	881	2001/06/22 - 2010/01/14
NC	MTC	Tac Room Lo Gain	37.63155	-118.96606	2371	2002/11/18 - 2007/10/05
CI	CRP	Caltech Robinson Pit	34.13624	-118.12705	233	2003/01/31 - 2008/11/04
TA	109C	Camp Elliot, Miramar, CA,	32.8889	-117.1051	150	2004/05/04 - 2008/09/12
TA	V04C	Ramage Ranch, Paso Robles, CA	35.636	-120.8699	431	2004/06/07 - 2007/09/01
NP	5398	5398, Burbank Airport, CA	34.19551	-118.3534	182	2004/07/15 - 2008/08/29
CE	14901	MMS OBS Eureka, Newport Beach	33.562	-118.117	0	2004/10/12 - 2008/07/16
TA	U05C	Westside ANR, Five Points, CA	36.3356	-120.1205	92	2004/12/06 - 2007/12/06
NP	5445	5445, Wheeler Ridge, CA,	35.0613	-119.02794	128	2005/01/26 - 2008/08/29
TA	HELL	Mitchell Peak, Miramonte, CA,	36.6801	-119.0228	1145	2005/02/11 - 2007/10/14
TA	V05C	Boulder Hill, Kettleman City, CA	35.8667	-119.9028	118	2005/04/11 - 2007/12/07
TA	S08C	White Mtn Res Sta-C. Creek, CA	37.4993	-118.1711	3087	2005/08/02 - 2007/10/03
TA	Y13A	Salome, AZ,	33.8142	-113.8287	357	2006/03/16 - 2008/10/09
TA	W12A	Cal Nev Ari, NV,	35.301	-114.8701	775	2006/03/25 - 2008/10/22
ZY	SHF2	Superstition Hills Fault, portable 2	32.9332	-115.70393	17	2007/04/19 - 2008/07/16
ZY	SHF7	Superstition Hills Fault, portable 7	32.9440	-115.718	4	2007/04/19 - 2008/07/16
ZY	WWS2	WWS2	33.94597	-116.64457	511	2008/10/09 - 2008/11/30
ZY	WWS5	WWS5	33.94425	-116.64505	505	2008/10/09 - 2008/12/06
PG	BUD	former name of VPD PG	35.2398	-120.869	435	2009/08/12 - 2009/09/14
ZY	OWL1	Owens Lake	36.3856	-117.85973	1168	2009/10/07 - 2009/11/18

Data Management Practices

The SCSN works with other CISN partners, USGS, and the ANSS NIC to develop and implement system-wide rules necessary to avoid problems and possible confusion resulting from posting and distributing multiple locations and magnitudes for the same earthquake. The SCSN coordinates earthquake response and reporting by adhering to system-wide ANSS rules for authoritative reporting of earthquake location and magnitude. The SCSN earthquake reporting includes appropriate attribution and identification of earthquake data and information providers.

To avoid duplication of effort and reporting, we have an agreement with the Anza network about data sharing and reporting. The Anza network transmits all waveforms real-time to the SCSN

and the SCSN determines the catalog parameters. In turn, the SCSN distributes products using the SCSN, Anza, and data from other partners. This agreement was reached many years ago to avoid having more than one source of authoritative earthquake information in southern California.

As an example of how the SCSN contributes to product generation elsewhere, the SCSN provides continuous data feeds from 8 broadband stations to the NOAA Tsunami Warning Centers (TWCs) for analysis and production of tsunami warnings.

Earthquake Information Distribution

The SCSN provides earthquake locations and magnitudes to the USGS Earthquake Hazards Program web site, earthquake.usgs.gov. When approved by NEIC in Golden, the SCSN plans to migrate to using Earthquake Information Distribution System (EIDS) as a standard exchange utility. SCSN uses earthworm software for real-time notification. Magnitudes are determined using real-time recursive filters that provide real-time Wood-Anderson amplitudes and long period amplitudes, which only need a distance correction to determine the final magnitude. The real-time moment tensors and Mw are calculated from waveforms using software developed by D. Dreger of UC Berkeley. It is worth pointing out that SCSN has generated a catalog of earthquakes with consistent local magnitudes (ML) for more than 77 years.

Coordinate Public Response

For all significant earthquakes (either felt or larger than a regionally adopted threshold magnitude), the SCSN coordinates public response with USGS Pasadena Office, USGS Menlo Park, NEIC, SCEC, and CISN partners as quickly as possible.

Continuity of Operations Plan

The SCSN and SCEDC have established plans and agreements to ensure the continuity of earthquake reporting in the event of a significant network disruption (fire, natural disaster, long-term power disruption, etc.).

The SCSN and SCEDC continuity of operations plan is available from:

http://scsnwiki.gps.caltech.edu/lib/exe/fetch.php?id=continuity_of_operations_draft&cache=cache&media=datacenter:sc_coo.pdf

Updates will be provided with each year's Annual Progress Report.

We also save copies of the SCEDC data offsite at ASL. After the SCSN/ARRA upgrade all digital BB/SM stations will have a baler onsite (disk storage) for backup.

We have put a substantial effort into making the SCSN data telemetry diverse and robust. We use different technologies, frame relay, dedicated T1, microwave, spread spectrum, and the Internet. The three T1 frame relay lines are brought into two different buildings and we have the capability of doing a failover from one T1 to another. Some high bandwidth stations transmit data via two T1 lines into the South Mudd and 525 Wilson buildings. We have station data being transported on microwave links independently operated by So Cal Gas, So Cal Edison, and LA DWP and we provide the last mile links into Caltech. We have data being transmitted on the new USGS digital microwave backbone. We also acquire data via the Internet, the CISN backbone, the dedicated T1 from Edwards Air Force Base, and on spread spectrum from nearby stations. Further, the 12 stations with dual data feeds (one to UC Berkeley and one to Pasadena) provide additional robustness.

NEIC, ATWC, and USGS MP submit their solutions to the QDDS and thus provide an automated backup. The CISN has three sites that generate ShakeMap, Bay Area, Pasadena, and Sacramento.

Data and Information Products

The SCSN abides by ANSS Data Policy. Both raw data and derived products are archived at the SCEDC in accordance with ANSS performance standards and available in standard formats to support earthquake hazard reduction research and development.

ANSS Catalog

The SCSN and SCEC compile and maintain the authoritative Caltech/USGS seismicity catalog for southern California. Updates to the catalog are uploaded daily to the ANSS composite catalog (http://www.ncedc.org/anss/). Since the beginning of the SCSN, or for 77 years of catalog production, procedures are clearly documented in a manuscript just published in BSSA, *Hutton et al*. (2010).

Seismicity Summary for Southern California

Events processed and distributed by the Southern California Seismic Network during the reporting period (1 February 2007 through 31 January 2010) (Figure 2):

43,628 earthquakes (inside & just outside of our region) & quarry blasts, of which
5,945 were magnitude 2.0 or larger, of which
809 were magnitude 3.0 or larger, of which
94 were magnitude 4.0 or larger, of which
11 were magnitude 5.0 or larger.

The magnitude 4.5+ quakes are listed below:

Magnitude 4.5+ Quakes 2007 - 2009						
Mag.	Local date	Local time	Latitude	Longitude	Depth	Descriptive location
4.7	2007/08/09	00:58:49	34 18.0 N	-118 37.2 W	7.6	5 km (3 mi) NNW of Chatsworth
4.7	2007/09/02	10:29:14	33 43.9 N	-117 28.6 W	12.6	15 km (10 mi) WNW of Lake Elsinore
5.1	2008/02/08	23:12:04	32 21.6 N	-115 16.6 W	6.0	40 km (25 mi) SSE of Calexico
5.1	2008/02/11	10:29:30	32 19.6 N	-115 15.4 W	6.0	44 km (27 mi) SSE of Calexico
5.0	2008/02/11	20:32:39	32 26.8 N	-115 19.0 W	6.0	30 km (18 mi) SE of Calexico
4.5	2008/02/12	01:27:19	32 27.8 N	-115 18.3 W	6.0	29 km (18 mi) SE of Calexico
5.0	2008/02/19	14:41:29	32 25.9 N	-115 18.8 W	6.0	31 km (19 mi) SSE of Calexico
4.8	2008/02/19	17:28:55	32 25.6 N	-115 18.4 W	6.0	32 km (20 mi) SSE of Calexico
4.8	2008/02/22	11:31:18	32 25.3 N	-115 17.1 W	6.0	34 km (21 mi) SE of Calexico
4.6	2008/02/22	11:33:52	32 23.4 N	-115 16.2 W	6.0	37 km (23 mi) SE of Calexico
5.4	2008/07/29	11:42:15	33 57.2 N	-117 45.7 W	14.7	7 km (4 mi) SE of Diamond Bar
4.6	2008/09/05	14:54:33	32 20.8 N	-115 13.8 W	15.0	44 km (27 mi) SE of Calexico
5.0	2008/11/20	11:23:00	32 19.7 N	-115 19.9 W	6.0	41 km (25 mi) SSE of Calexico
5.1	2008/12/05	20:18:42	34 48.8 N	-116 25.1 W	7.3	56 km (35 mi) E of Barstow
4.5	2008/12/27	21:17:07	32 34.1 N	-115 32.6 W	10.0	12 km (7 mi) SSW of Calexico
4.5	2009/01/08	19:49:46	34 6.4 N	-117 18.3 W	14.2	1 km (0 mi) W of San Bernardino
4.8	2009/03/24	04:55:43	33 19.0 N	-115 43.7 W	6.0	4 km (2 mi) S of Bombay Beach
4.7	2009/05/17	20:39:36	33 56.3 N	-118 20.1 W	13.9	3 km (2 mi) NNE of Hawthorne
4.7	2009/05/23	15:58:32	36 23.8 N	-117 50.3 W	1.1	20 km (12 mi) NE of Olancha
5.1	2009/09/19	15:55:17	32 22.2 N	-115 15.7 W	10.0	40 km (25 mi) SSE of Calexico

Continued Magnitude 4.5+ Quakes 2007 – 2009						
Mag.	Local date	Local time	Latitude	Longitude	Depth	Descriptive location
5.0	2009/10/01	03:01:24	36 23.3 N	-117 51.5 W	5.6	18 km (11 mi) NE of Olancha
4.7	2009/10/02	18:09:19	36 23.5 N	-117 51.8 W	2.5	18 km (11 mi) NE of Olancha
4.9	2009/10/02	18:10:26	36 23.2 N	-117 52.1 W	3.6	17 km (11 mi) NE of Olancha
5.2	2009/10/02	18:16:00	36 23.5 N	-117 51.6 W	0.0	18 km (11 mi) NE of Olancha
4.7	2009/10/02	22:31:57	36 23.4 N	-117 51.8 W	1.9	18 km (11 mi) NE of Olancha
4.6	2009/11/16	13:21:30	35 32.9 N	-117 16.5 W	2.2	26 km (16 mi) SSE of Trona
5.8	2009/12/30	10:48:57	32 27.8 N	-115 11.4 W	6.0	37 km (23 mi) SE of Calexico
4.8	2009/12/30	10:53:23	32 31.9 N	-115 12.5 W	6.0	31 km (19 mi) ESE of Calexico

Half of the earthquakes in the table (14 out of 28), including the largest one Mw5.8, occurred in Baja California, Mexico, a very active area. All of the large events listed were felt in Imperial Valley, CA, however, and some in San Diego. For example, the Mw5.8 earthquake in December 2009 generated 8,630 DYFI ("Did You Feel It?") responses, most of them in California and Arizona, as far away as Orange County and the Phoenix area. The peak intensity was MMI VI in the Holtville CA zip code.

The largest earthquake during the reporting period that was inside our seismic network was the Mw5.4 event in July 2008, generally known as the Chino Hills earthquake (listed in the above table as southeast of Diamond Bar) (Figure 3). 41,123 people reported this event to DYFI, a few from as far away as Needles and Paso Robles. The peak intensity was MMI VI in a wide area centered on the epicenter of the earthquake. The aftershock sequence was rather sparse for an earthquake of this size, including less than 300 events.

The Mw4.7 earthquake north-northeast of Hawthorne, near the Los Angeles International Airport, got even more public attention. It has been omitted somehow from the DYFI archives, but a snapshot at the time reveals 46,341 reports, with a maximum intensity of MMI V over much of the South Bay area. One of the nodal planes indicates a fault near and parallel to the Newport-Inglewood fault.

The Lake Elsinore earthquake ML4.7 in September 2007 also generated quite a bit of public interest: 17,201 DYFI reports, with a peak intensity of IV in the epicentral area.

Another widely felt earthquake was the one in August 2007, north-northwest of Chatsworth. 15,366 people reported it to DYFI, from as far as Santa Barbara and Apple Valley. Peak intensity was MMI V in Simi Valley, Chatsworth, and Porter Ranch.

The Mw5.1 east of Barstow, in December 2008 was widely felt (from Los Angeles to Arizona), although the total DYFI numbers were lower due to the sparse population. There were 4,560 reports, showing a peak intensity of MMI IV. This Mw5.1 quake was classified as an aftershock of the 1999 Hector Mine Mw7.1 earthquake.

The ML4.8 earthquake in March 2009 under the Salton Sea was not widely felt, due again to the low population density, but it did pique seismological and some public interest due to its location near hypothetical epicenter used in the ShakeOut earthquake drill scenario. Peak intensity was IV on the east side of the Salton Sea, including Bombay Beach and Niland. The ML4.8 and a ML4.0 aftershock probably occurred on northeast trending faults perpendicular to the Brawley Seismic Zone, which are common under the Salton Sea and in the northern Imperial Valley.

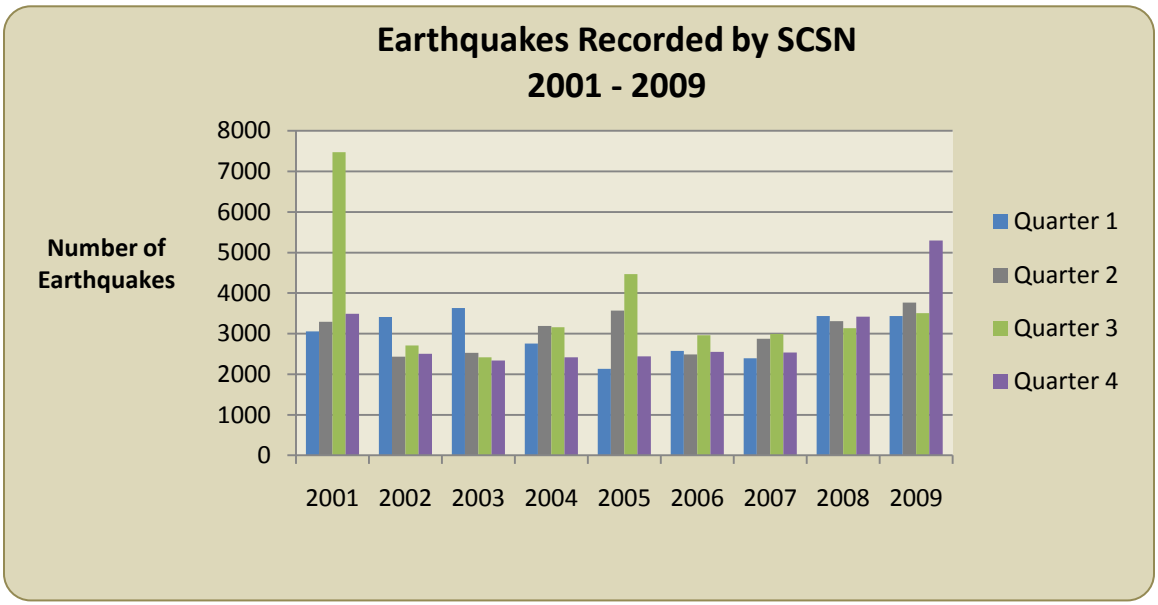

Figure 2. Number of local earthquakes recorded and processed during each quarter since 2001.

The sequence of earthquakes northeast of Olancha in October 2009 also piqued seismological interest, because the events happened in a slightly unusual location, at the northern edge of where we normally see Coso Range seismicity. Population density is very low in that area, so DYFI only shows 351 reports for the Mw5.0 and 723 for the Mw5.2. The earthquakes occurred on the southeastern shore of Owens Lake. 3D relocations showed the sequence members to have occurred on two northwest trending and one northeast trending strike-slip fault. Cracking in the sediments was observed in the field, indicating some liquefaction. The aftershock sequence was a robust one, including approximately 900 events so far.

Processing of Backlog of SCSN Data

We have completed the processing of earlier backlogs. Events from 1932 through 1976 now have computerized locations and magnitudes consistent with our current calibrations. All data from 1932 onward has been written to the Oracle database, and all previous backlogs such as from 1977 to 1981 have been completely processed. All of the CEDAR system data (1977 through 1980) that are readable from the tapes of that period have been translated from CEDAR format to CUSP and have been converted into the Oracle database.

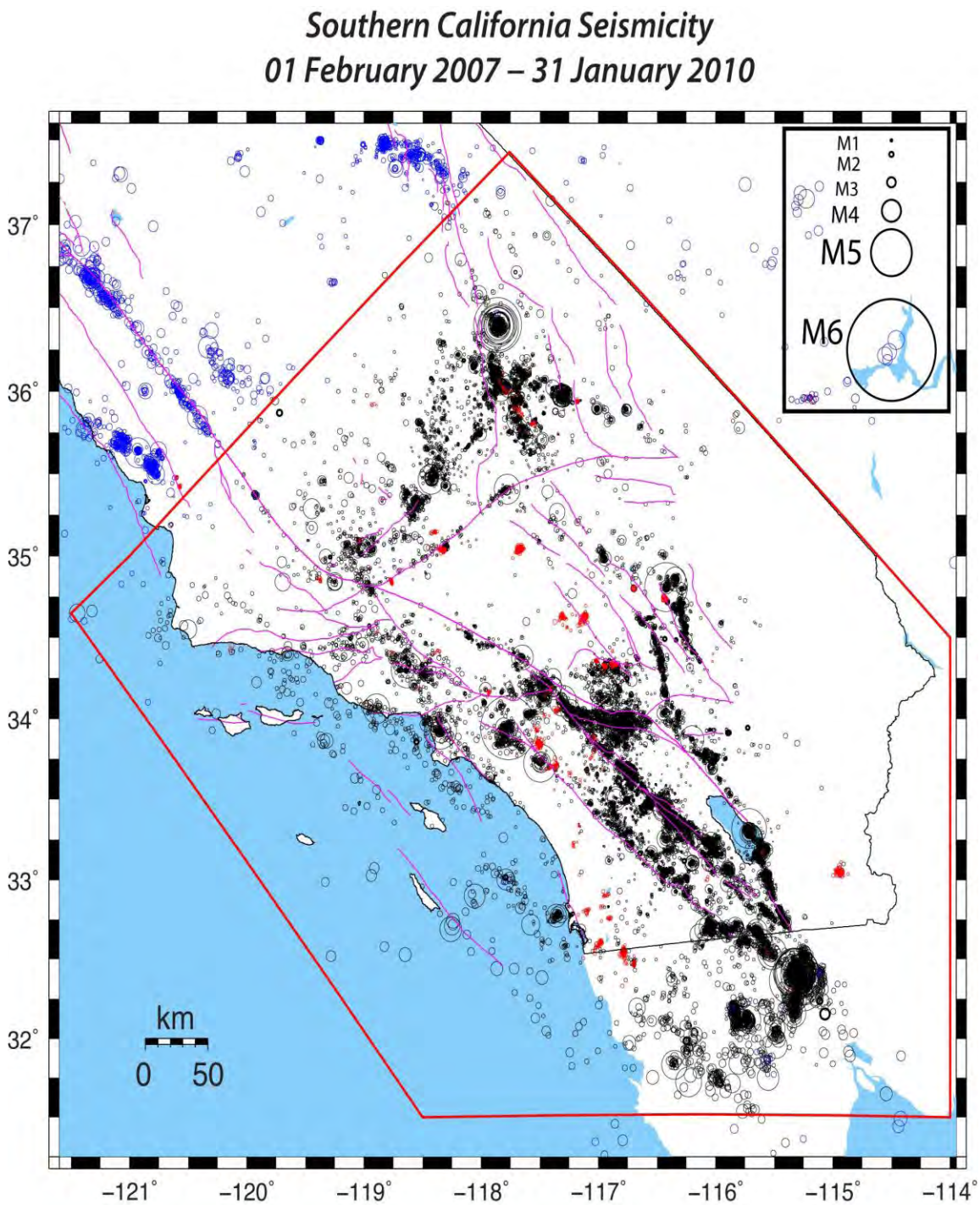

Figure 3. Southern California seismicity recorded by SCSN and archived by SCEDC: February 1, 2007 to January 31, 2010. The black circles are earthquakes, red circles are quarry blasts, and blue circles are earthquakes recorded but occurred outside the SCSN reporting region. The SCSN reporting area is within the red polygon.

Data Processing and Production of Earthquake Information

Between February 1, 2007 to January 31, 2010, the SCEDC:

- archived 47,509 new events (including teleseisms, sonics, and other sources)
- archived 54,668,767 seismograms.

The diagram below illustrates the website requests for SCEDC archived data (Figure 4).

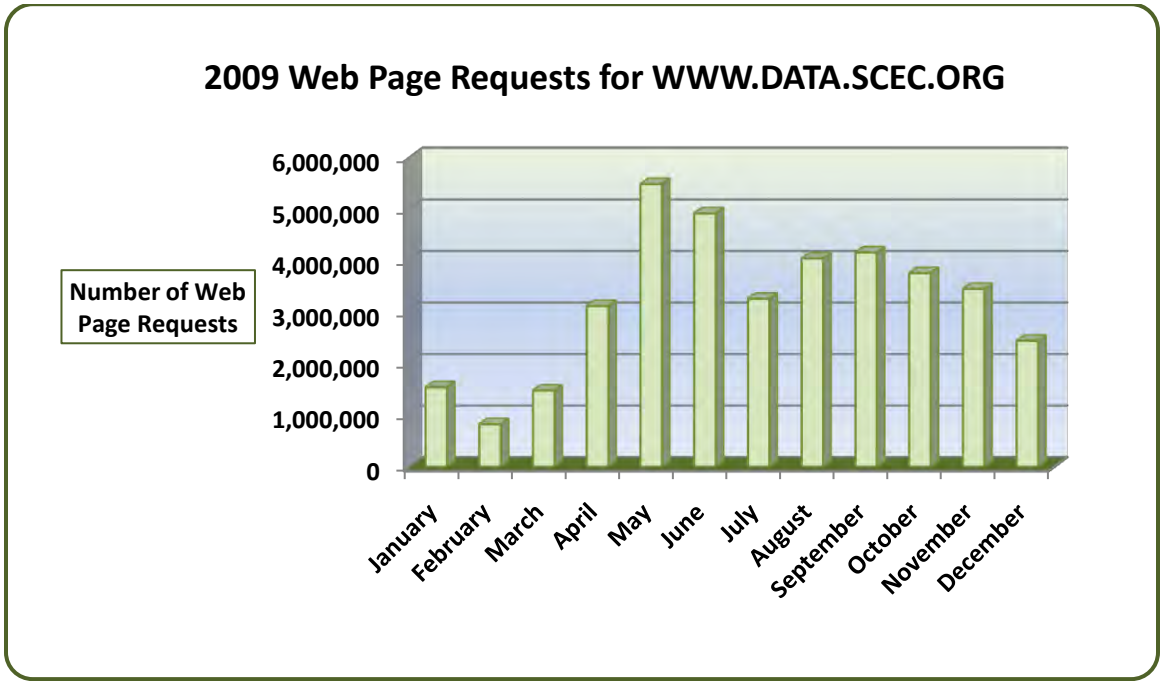

Figure 4. SCEDC Website statistics for 2009.

Statewide Network Integration

We continue to make progress in exchanging data with CISN partners.

- Our current system automatically checks for changes in station response. When one is detected, an updated dataless SEED volume is automatically generated and an email is sent to partners at NCEDC and IRIS.
- We continue development, implementation and documentation for the CISN to use stationXML as a method of station metadata exchange. StationXML is documented at: http://www.data.scec.org/xml/station/station_schema.html.
- Both SCEDC and NCEDC are now using the same set of stored procedures for accessing waveform and parametric data. This code is version controlled in a common repository. This practice enforces standard methods of access and use of data, which is essential to data exchange between CISN data centers.
- We also continue efforts to keep parts of our database schemas the same as our CISN counterparts so that the same applications can be used at each center.

Servers

The SCEDC has made every effort to ensure each mission critical component has a redundant node between its two server locations, 267 S. Mudd and 525 S. Wilson. In each location we have installed a database server, 2 application servers, and a web server. The databases are replicated and serve as real time back ups to one another and to balance user load. Both databases are Oracle 10.2.0.4 and run on Red Hat Linux. One application server is used for waveform archival and alarming, and QDDS, and the other will be used to host SIS and stp servers. The web servers both resolve to the SCEDC website, http://www.data.scec.org by round robin. This system of 2 parallel "stove pipes" is compatible with SCSN postprocessing and RT server topology.

Seismic Transfer Program (STP)

STP is our main tool used to distribute earthquake data to researchers. STP now delivers complete SEED volumes. We put in production a version of STP that can access both the NCEDC and SCEDC waveform archives. STP can now output mseed data with no gap filling. While many users prefer to have gaps padded with the value 0, in some there are some use cases in archive quality control where it is beneficial to see the data unpadded.

Data Handling Interface (DHI)

We have put development efforts into making Data Handling Interface, distributed by IRIS, more stable. Our DHI server is now running on two application servers to provide redundancy. We have also added additional logging features which we believe will be helpful to both SCEDC and IRIS.

Station Information System (SIS)

The SIS is an Oracle database that stores all the SCSN station metadata. We have continually made improvements to the SIS User Interface to promote SIS as the central repository of station metadata. Two key developments are the SIS "Channel Manager", which allows an analyst to edit historical metadata, and the storing power system and telemetry equipment. SIS is now fully integrated with SCSN operations and available to researchers via the www.data.scec.org web pages.

Data Archival

All SCSN BH channels have been upgraded from 20 sps to 40 sps to conform to the ANSS standard. To comply with SEED naming conventions, the SCEDC has worked with the SCSN real time group to rename all channels using the "L" instrument code to use the "N" instrument code. Starting January 1, 2008, the SCEDC began archiving EH, SH, and HH channels continuously. In October 2009, the SCEDC began archiving HN borehole channels continuously.

Catalogs

We have finished archiving all events from 1932 to present. All solutions are now in the database, searchable and accessible to the public from the data center website. For more information about the catalog and its history, see Hutton, Woessner, and Hauksson, 2010, *BSSA*. We continue to work with analysts to resolve any issues with the catalog.

Reference

L. K. Hutton, J. Woessner, and E. Hauksson, Seventy-Seven Years (1932 – 2009) of Earthquake Monitoring in Southern California, (2010), *Bull. Seismol. Soc. Am*, v. 100; no. 2; p. 423-446; DOI: 10.1785/0120090130