ANNUAL PROGRESS REPORT

AWARD NUMBER: 01HQGR0157

HIGH–RESOLUTION MONITORING OF THE HAYWARD FAULT

T. V. McEvilly, P.I. and Robert A. Uhrhammer, Co–P.I.
Berkeley Seismological Laboratory, Berkeley, CA 94720–4760
(510 642–8504, 643–5811 (Fax), bob@seismo.berkeley.edu

PROGRAM ELEMENTS : I & II

KEY WORDS: Source Characteristics, Fault Dynamics,
Fault Segmentation, Earthquake Forecasting

NON–TECHNICAL SUMMARY

A network of borehole–installed wide dynamic range telemetered seismographic stations is being developed cooperatively among UCB, USGS, CALTRANS, LLNL, and EPRI along the Hayward Fault. This grant initiated and remains the cornerstone of the network, providing the instruments, their installation, operation and maintenance, data acquisition and supporting infrastructure for the other participants. The focus of the new network and associated research is to increase substantially the numbers of well–recorded small earthquakes along the Hayward fault zone in order to improve our working models of this very hazardous but poorly understood fault zone, to integrate the data into the REDI real–time monitoring and alert system for northern California, and to provide bedrock ground motions in strong–motion response calculations for bridges and other critical facilities within the network.

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INVESTIGATIONS UNDERTAKEN

A network of borehole–installed wide dynamic range telemetered seismographic stations is being developed cooperatively among UCB, USGS, CALTRANS, LLNL, and EPRI along the Hayward Fault in the East San Francisco Bay Region. The NEHRP grant initiated and remains the cornerstone of the network, providing the instruments, their installation, operation and maintenance, data acquisition and supporting infrastructure for the other participants. The focus of the new network and associated research is to increase substantially the numbers of well–recorded small earthquakes along the Hayward fault zone in order to improve our working models of this very hazardous but poorly understood fault zone, to integrate the data into the REDI real–time monitoring and alert system for northern California, and to provide bedrock ground motions in strong–motion response calculations for bridges and other critical facilities within the network.

After initial operation with event recorders, 24–bit data acquisition and frame–relay telemetry platforms have been installed at nine stations. The frame–relay telemetry, made possible under a cooperative program with Pacific Bell, allows centralized network control so that the incessant noise triggers at individual stations do not overwhelm the system with spurious 500 sps data streams. The network has improved by almost two orders of magnitude the microearthquake detection threshold over previous capabilities using existing surface stations in the culturally noisy East Bay, triggering at multiple stations and recording sharp signals from local earthquakes as small as M=–1. The data can now accumulate at a rate of a local event every few days, allowing high–resolution studies of the Hayward fault to proceed aggressively despite relatively low rate of seismicity. Data streams flow smoothly into the northern California archive at UCB and USGS and are input in parallel to REDI, the real–time detection and notification system. The Bridge Safety Project of CALTRANS and a grant from UC statewide with LLNL have provided boreholes and maintenance support so that there are bedrock sensor packages in 12 boreholes at the five Bay bridges.

RESULTS

Introduction

Complementary to the regional broadband network, a deployment of borehole–installed, wide–dynamic range seismographic stations is being established along the Hayward Fault and throughout the San Francisco Bay toll bridges network. This project is a cooperative development of the BSL and the USGS, with support from USGS, Caltrans, EPRI, the University of California Campus/Laboratory Collaboration (CLC) program, LLNL, and LBNL (Figure 1 and Table 1).

The purpose of the network is twofold: to lower substantially the threshold of microearthquake detection and increase the recorded bandwidth for events along the Hayward fault; and to obtain bedrock ground motion signals at the bridges from small earthquakes for investigating bridge responses to stronger ground motions. Lower detection threshold will increase the resolution of fault–zone structural features and define spatio–temporal characteristics in the seismicity at M > ~0, where occurrence rates are dramatically higher than those captured by the surface sites of the NCSN. This new data collection will contribute to improved working models for the Hayward fault. The bedrock ground motion recordings are being used to provide input for estimating the likely responses of the bridges to large, potentially damaging earthquakes. Combined with the improved Hayward fault models, source–specific response calculations can be made.

The Hayward Fault Network (HFN) consists of two parts. The Northern Hayward Fault Network (NHFN) is operated by the BSL and currently consists of 20 stations, including those located on the Bay bridges. This network is considered part of the BDSN and uses the network code BK. The Southern Hayward Fault Network (SHFN) is operated by the USGS and currently consists of 5 stations. This network is considered part of the NCSN and uses the network code NC. This report is primarily focused on the NHFN and activities associated with the BSL operations.

Sensors, Recording, and Telemetry Systems

All sites of the HFN have six–component borehole sensor packages which were designed and fabricated at LBNL's Geophysical Measurement Facility by Don Lippert and Ray Solbau, with the exception of site SFAB. Three channels of acceleration are provided by Wilcoxon 731A piezoelectric accelerometers and three channels of velocity are provided by Oyo HS–1 4.5 Hz geophones (Table 2). Sensors are installed at depths of 100–300 m and provide signals to the on–site data loggers (Quanterra Q4120 and Q730, Nanometrics HRD24, or RefTek 72A–07 systems).

The 0.1–400 Hz Wilcoxon accelerometers have lower self–noise than the geophones above about 25–30 Hz, and remain on scale and linear to 0.5 g. Figure 2 compares the noise level of the Wilcoxon accelerometer with other sensors used in the BDSN. In tests performed in the Byerly vault at UC Berkeley, the Wilcoxon is considerably quieter than the FBA–23 at all periods, and is almost as quiet as the STS–2 between 1 and 50 Hz.

Figure 1. Map showing the locations of the HFN stations operated by the BSL (NHFN – squares) and the USGS (SHFN – circles) in the San Francisco Bay Area. Operational sites are filled, while sites in progress are gray. Other instrumented boreholes are indicated as open symbols.

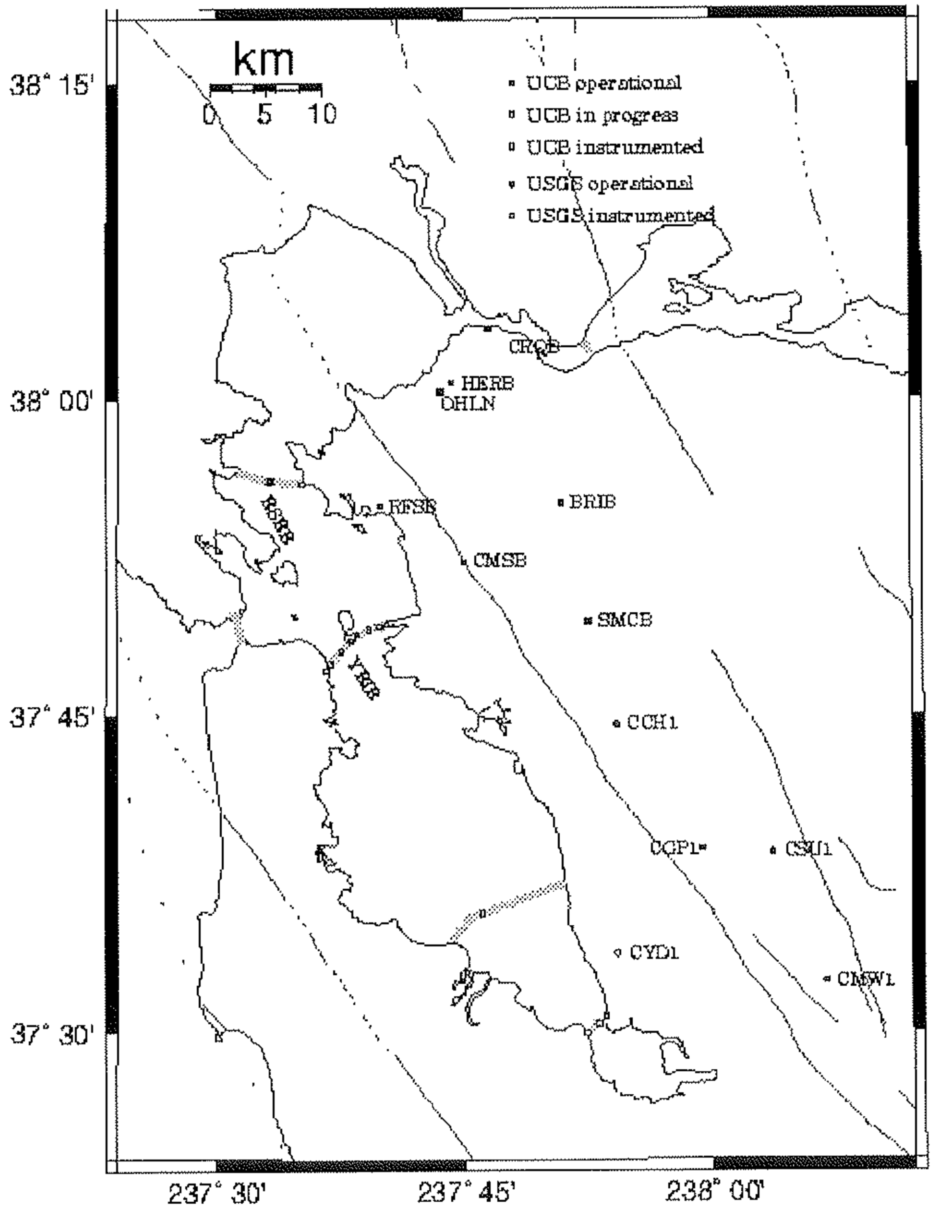


Table 1. Stations of the Hayward Fault Network. Each HFN station is listed with its station code, network id, location, operational dates, and site description. The latitude and longitude (in degrees) are given in the WGS84 reference frame. The elevation of the well head (in meters) is relative to the WGS84 reference ellipsoid. The overburden is given in meters. The date indicates either the upgrade or installation time. The abbreviations are: BB – Bay Bridge; BR – Briones Reserve; CMS – Cal Memorial Stadium; CB – Carquinez Bridge; DB – Dumbarton Bridge; RFS – Richmond Field Station; RSRB – Richmond–San Rafael Bridge; SF – San Francisco; SMB – San Mateo Bridge; SMC – St. Mary's College; and, YB – Yerba Buena. The * for YBIB, RSRB and BB sites (as described in text) indicates that the stations are not currently operational at this time. RSRB is shut down while Caltrans is retrofitting the Richmond–San Rafael bridge (as of April 19, 2001) and YBIB has been off–line since August 24, 2000 when power cables to the site where shut down.

Code	*Net*	*Lat*	*Lon*	*Elev*	*Over*	*Date*	*Location*
BRIB	BK	37.91866	–122.15179	219.7	108.8	95/07–	BR, Orinda
CMSB	BK	37.87195	–122.25168	94.7	167.6	94/12–	CMS, Berkeley
CRQB	BK	38.05578	–122.22487	–25	38.4	96/07–	CB
RFSB	BK	37.91608	–122.33610	–27.3	91.4	96/01–	RFS, Richmond
RSRB	BK	37.93575	–122.44648	–48	109	97/06–*	RSRB, Pier 34
SMCB	BK	37.83881	–122.11159	180.9	3.4	97/12–	SMC, Moraga
YBIB	BK	37.81420	–122.35923	–27	61	97/12–*	BB, Pier E2
HERB	BK	38.01250	–122.26222	–25	217.9	00/05–	CMY, Hercules
SFAB	BK	37.78610	–122.38930		0	98/06–*	BB, SF Anchor
W02B	BK	37.79120	–122.38525		57.6	96/04–*	BB, Pier W2
W05B	BK	37.80100	–122.37370		36.3	97/10–*	BB, Pier W5
YBAB	BK	37.80940	–122.36450		3	98/06–*	BB, YB Anchor
E07B	BK	37.81847	–122.34688		134	96/02–*	BB, Pier E7
E17B	BK	37.82086	–122.33534		160	95/08–*	BB, Pier E17
BBEB	BK	37.82167	–122.32867		150	94/03–95/10	BB, Pier E23
DB1B	BK	37.49947	–122.12755		0	94/07–94/09	DB, Pier 1
					1.5	94/09–94/09	
					71.6	94/09–94/09	
					228	93/08–	
DB2B	BK	37.50687	–122.11566		?	94/07–	DB, Pier 27
					189.2	92/07–92/11	
DB3B	BK	37.51295	–122.10857		1.5	94/09–94/11	DB, Pier 44
					62.5	94/09–94/09	

					157.9	94/07–	
SM1B	BK	37.54903	–122.23242		298	not recorded	SMB, Pier 343
RB2B	BK	37.93372	–122.41313		44	97/06–	RSRB, Pier 58
CCH1	NC	37.74334	–122.09685	145		92/08–	Chabot
CGP1	NC	37.64539	–122.01144	337		92/01–	Garin Park
CMW1	NC	37.54054	–121.88733	113		92/09–	Mill Creek
CSU1	NC	37.64297	–121.94023	409		92/09–	Sunol
CYD1	NC	37.56289	–122.09670	–127		92/10–	Coyote
OHLN	BK	38.00625	–122.27299	–197.2	196.7	01/10––	Ohlone

Figure 2. Background noise PSD comparison of co–located vertical seismic sensors in the BKS vault. Shown are the Kinemetrics FBA–23 and Wilcoxon 731A force balance accelerometers and the Streckeisen STS–1 and STS–2 broadband seismometers. The high– and low–noise models are also plotted for reference.

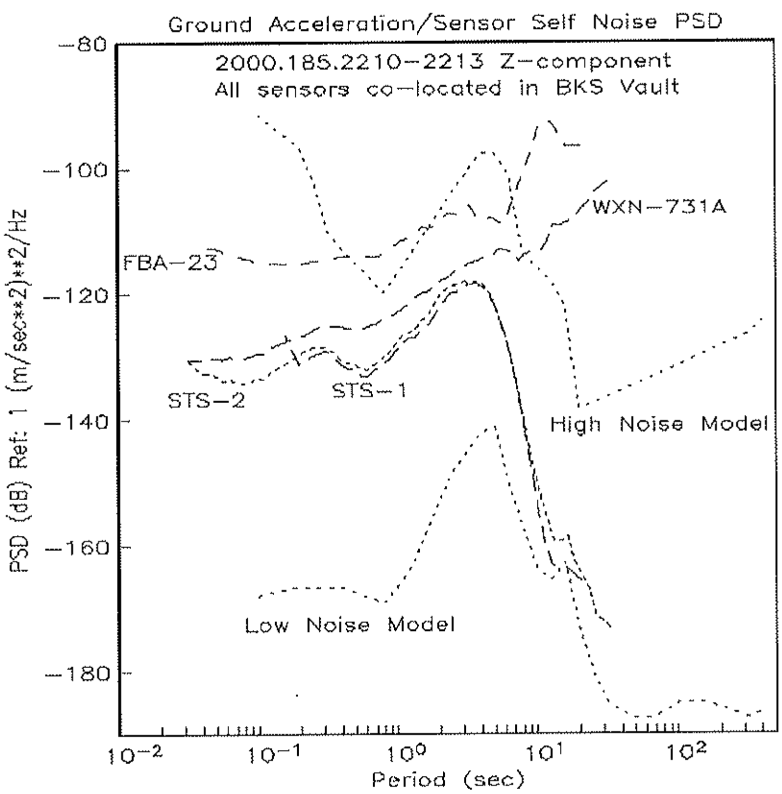


Table 2. Instrumentation of the HFN as of 06/30/2001. Every HFN downhole package consists of co–located geophones and accelerometers, with the exception of SFAB. Eight NHFN sites have Quanterra data loggers with continuous telemetry to the BSL. The remaining sites have used RefTek data loggers for on–site recording but they are not currently operating (see text for details). Four SHFN sites have Nanometrics data loggers with radio telemetry to the USGS. The fifth SHFN site (CYD1) currently has no telemetry. The orientation of the sensors (vertical – Z, horizontals – H1 and H2) are indicated where known or identified as "to be determined" (TBD).

Stn	*Geoph*	*Accel*	*Z*	*H1*	*H2*	*Logger*	*Tele*	*Note*
BRIB	HS–1	731A	–90	79	349	Q4120	FR	1 Acc. failed
CMSB	HS–1	731A	–90	19	109	Q4120	FR	
CRQB	HS–1	731A	–90	251	341	Q4120	FR	
HERB	HS–1	731A	–90	222	312	Q4120	FR	
RFSB	HS–1	731A	–90	256	346	Q4120	FR	
RSRB	HS–1	731A	–90	50	140	Q4120	FR	3 Acc. failed
SMCB	HS–1	731A	–90	76	166	Q4120	FR	Posthole
YBIB	HS–1	731A	–90	257	347	Q4120	Radio	Z Geo. failed
SFAB	None	S6000	TBD	TBD	TBD	72A–07		
WB02	HS–1	731A	TBD	TBD	TBD	72A–07		
WB05	HS–1	731A	TBD	TBD	TBD	72A–07		
YBAB	HS–1	731A	TBD	TBD	TBD	72A–07		
E07B	HS–1	731A	TBD	TBD	TBD	72A–07		
E17B	HS–1	731A	TBD	TBD	TBD	72A–07		
BBEB	HS–1	731A	TBD	TBD	TBD	None		Not recorded
DB1B	HS–1	731A	TBD	TBD	TBD	72A–07		
DB2B	HS–1	731A	TBD	TBD	TBD	72A–07		
DB3B	HS–1	731A	TBD	TBD	TBD	72A–07		Acc. failed
SM1B	HS–1	731A	TBD	TBD	TBD	None		
RB2B	HS–1	731A	TBD	TBD	TBD	72A–07		
CCH1	HS–1	731A	TBD	TBD	TBD	HRD24	Radio	
CGP1	HS–1	731A	TBD	TBD	TBD	HRD24	Radio	
CMW1	HS–1	731A	TBD	TBD	TBD	HRD24	Radio	
CSU1	HS–1	731A	TBD	TBD	TBD	HRD24	Radio	
CYD1	HS–1	731A	TBD	TBD	TBD	None		
OHLN	HS–1	None	TBD	TBD	TBD	Q4120	FR	

Eight of the NHFN sites have Quanterra data loggers with continuous telemetry to the BSL. Similar to BDSN sites, these stations are capable of on–site recording and local storage of all data for more than one day and have batteries to provide backup power. Signals from these stations are digitized at a variety of data rates up to 500 Hz at 24–bit resolution (Table 3). In contrast to the BDSN implementation, the NHFN data loggers employ casual FIR filters at high data rates and acasual FIR filters at lower data rates. Because of limitations in telemetry bandwidth and disk storage, these 7 sites transmit triggered data at 500 sps, using the Murdock, Hutt, and Halbert (MHH) event detection algorithm (Murdock and Hutt, 1983), and continuous data at reduced rates (100, 20 and 1 sps) to the BSL.

Table 3. Typical data streams acquired at each NHFN site, with channel name, sampling rate, sampling mode and FIR filter type. C indicates continuous; T triggered; Ca causal; and Ac acausal. The 100 sps channels (EP & HL) are only archived when the 500 sps channels are not available.

Sensor	*Channel*	*Rate (sps)*	*Mode*	*FIR*
Accelerometer	CL?	500	T	Ca
Accelerometer	HL?	100	C	Ca
Accelerometer	BL?	20	C	Ac
Accelerometer	LL?	1	C	Ac
Geophone	DP?	500	T	Ca
Geophone	EP?	100	C	Ca
Geophone	BP?	20	C	Ac
Geophone	LP?	1	C	Ac

The remaining 13 sites of the NHFN have recorded data using RefTek data loggers. These sites do not have continuous telemetry for acquisition and require visits from BSL staff for data recovery. Owing to a hiatus in funding from Caltrans, we decided to stop servicing the RefTek equipped stations in April 2000. The accelerometer sites continued to collect data until the accelerometer batteries ran down (approximately two months after the February 2000 service visit) and the sites collecting velocity data continued to run until April 2001 when the sites were visited and the RefTek data loggers were removed. They will be reinstalled when funding is available.

Seven of the sites located on the Bay Bridge have had the requisite infrastructure installed (spread spectrum radios and antennas, GPS antenna, batteries, chargers, power distribution system, and weather resistant enclosures) and they are scheduled to be upgraded with Quanterra data loggers and continuous telemetry in the summer of 2002. Due to the power cut at the Yerba Buena (YBIB) station, the collection node for the east span of the Bay Bridge has been moved to the east side of east span. The Bay Bridge component of the NHFN has been delayed in the past year, primarily due to the major effort required to upgrade the HRSN.

Signals from four of the five SHFN stations (CCH1, CGP1, CMW1, and CSU1) are digitized at 200 sps and telemetered to Menlo Park. The digital data streams are processed by the Earthworm system with the NCSN data and waveforms are saved when the Earthworm detects an event. One site of the SHFN (CYD1) does not have telemetry and no data logger is on site at this time.

Station Maintenance

Data Acquisition Systems

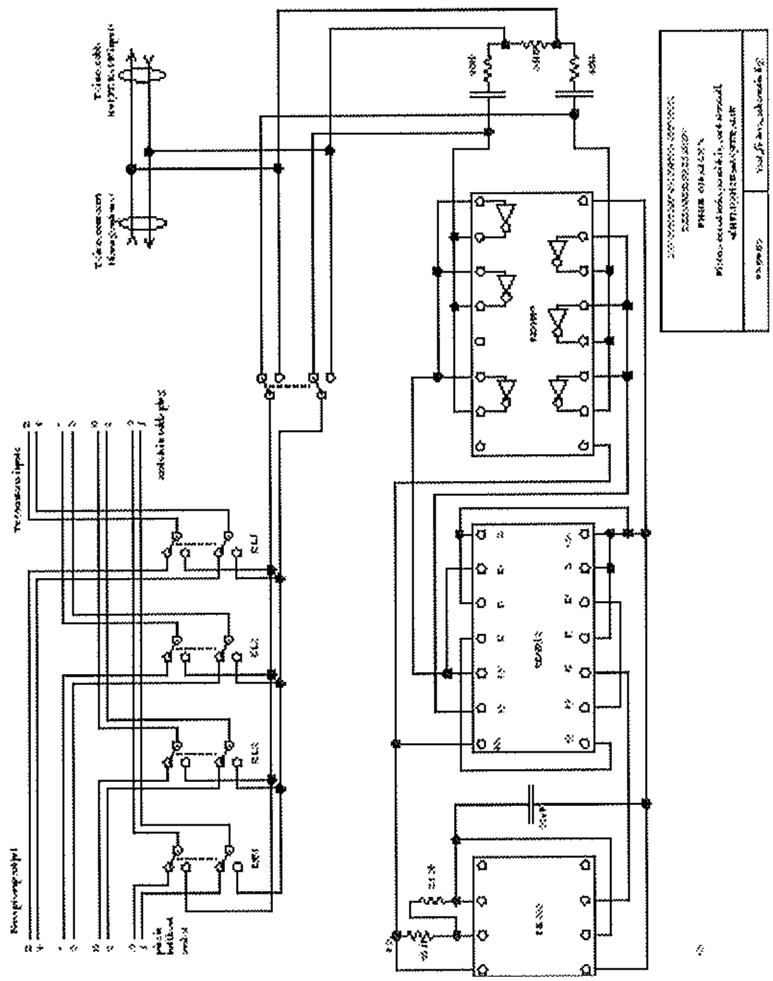
Similar to BDSN sites, NHFN Quanterra data loggers are capable of continuous on–site recording and local storage at full resolution for more than one day and have batteries to provide backup power. On–site detectors can monitor critical conditions and preset changes in operating mode can be invoked. The UltraSHEAR communication software developed for the NHFN allowed control and change of parameters from the central site. Last year, this was replaced with MultiSHEAR, which provides for multi–station nodes using up to three Q730 satellite acquisition platforms around a Q4120, with a single 4 station telemetry link to the central site.

The MultiSHEAR software upgrade also enabled central site triggering of the Quanterra data loggers. Initially, the 100 Hz HFN EP1 data streams from the vertical component geophones were continuously telemetered to Berkeley for use by the central site detector/associator. However, we quickly determined that the 40 Hz bandwidth of the EP1 data streams severely limited the ability to resolve the smallest events which have considerable energy at frequencies of 70 Hz and above. We thus decided to telemeter the HFN DP1 (500 Hz sampling with a 200 Hz bandwidth) data streams continuously for use by the central site detection algorithm. Testing of the central site detector/associator using the 500 Hz DP1 data showed that there is a large diurnal variation in the ambient cultural noise levels observed at the borehole stations. Setting the Murdock–Hutt (1983) parameters to detect the smallest events (M~–1) resulted in a large number of coincident noise detections (95+ percent, say, of the total number of detections) during noisy times. Pre–detector filtration, tuned for the noise characteristics at each station individually, only marginally reduced the percentage of coincident noise detections. We expect that the fraction of coincident noise detections will reduce significantly when the Bay Bridge borehole stations come on–line this summer because a couple of the deeper Bay Bridge sites are among the quietest of all the borehole stations.

Calibration and Testing

A test instrument (Figure 3) and associated termination plugs and cabling was designed and built to facilitate calibration and background noise testing of NHFN equipment. The test instrument is designed for in situ testing of the sensors (impulse voltage to geophones), the preamp (gain), the data logger (sensitivity), and also to aid in determining the noise floor and noise characteristics of the data logger and the preamp using resistance terminations. Whenever a NHFN station is visited, the engineer at the site and a seismologist at the BSL work together to expedite the testing process, especially when attempting to identify and correct ground–loop faults which generally

Figure 3. Schematic of NHFN calibration and testing equipment. The lower half of the circuitry is a square–wave generator for supplying a calibration signal at two drive levels to the preamp and the data logger. The upper left part of the circuitry is a switching network to allow supplying the calibration signal in various combinations to preamp and simultaneously directly to the data logger for checking the preamp channel gains, the data logger channel sensitivities, and also cross–talk. The upper right part of the circuitry is for supplying a calibration signal to the geophone while it is in–line.

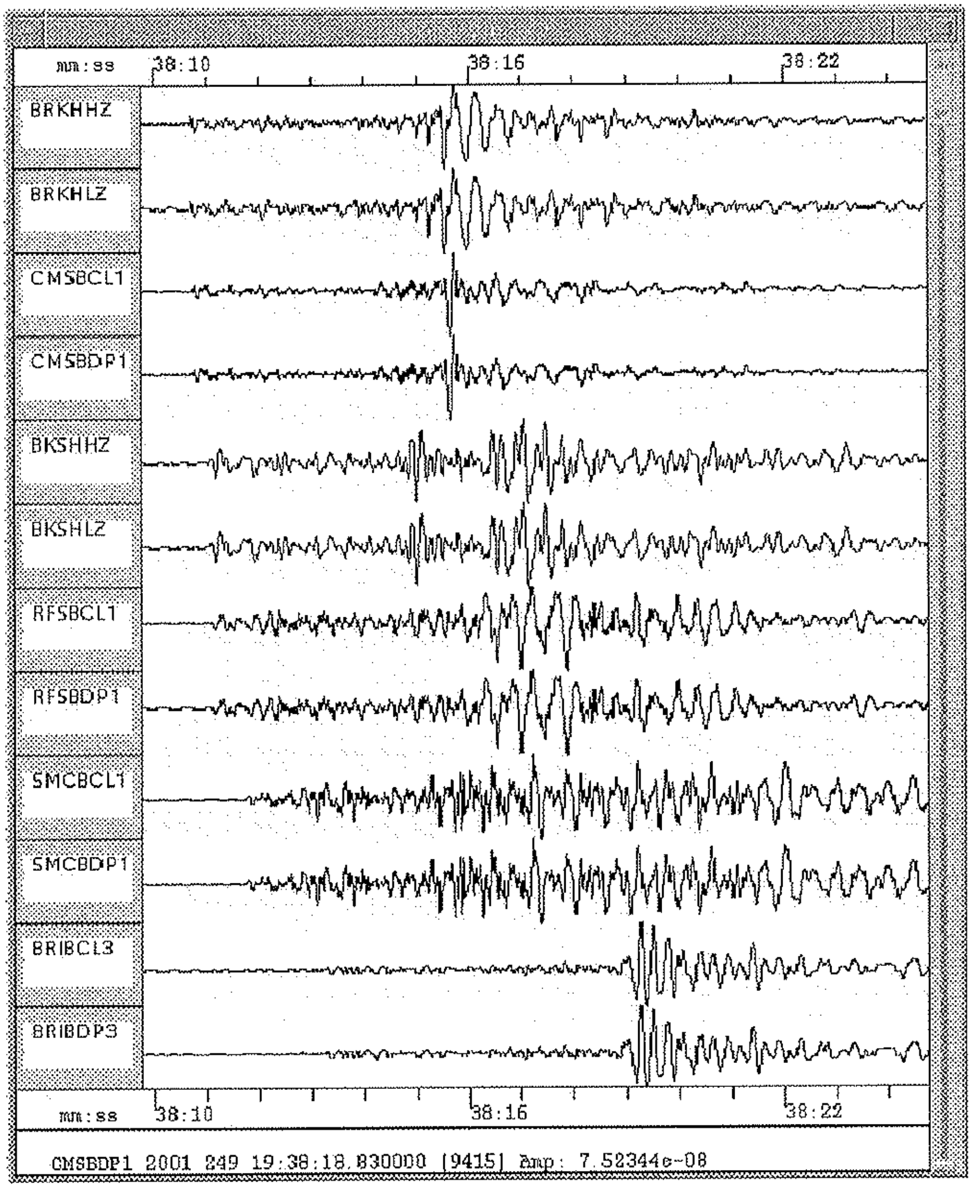


induce significant 60, 120, 180, and 240 Hz seismic signal contamination due to stray power line signal pickup, generally inductively coupled and aggravated by the presence of ground loops.

The geophones can be pulsed in situ with a calibration signal to check their response characteristics. However, the accelerometers can not be tested in situ and we must evaluate their response to seismic signals and their background noise PSD level to determine whether or not they are operating within their specifications.

As a check on the calibration and an example of the capabilities of borehole installed network, we compare the high–pass (HP) filtered (2 Hz) ground displacements, as

Figure 4. Ground displacement waveforms, inferred from accelerometer and velocity sensors at four NHFN and two BDSN stations in the vicinity of UCB, for the Sept. 6, 2001 M 3.0 Pacifica earthquake. The waveforms have been HP filtered at 2 Hz to reduce the low–frequency noise level. That the pairs of waveforms are visually nearly identical is conformation that the instruments at each station are operating normally and that the transfer functions are correct. The two BDSN stations (BKS and BRK) are shown for comparison. Horizontal components are compared at BRIB because the BRIB vertical component accelerometer is not operational.



inferred from the vertical component accelerometer 500 Hz (CL1) and from the vertical component geophone 500 Hz (DP1) data streams recorded at BRIB, CMSB, RFSB, and SMCB, for a M 3.0 earthquake that occurred in Pacifica, 34 km SW of UCB, in Figure 4.

An example of the seismic background noise PSD, inferred from the accelerometer and from the geophone sensors at CMSB are shown in Figure 5. The broad background noise peak, centered at 10 Hz is attributed to organ pipe mode resonances of the steel casing and the water column in the open borehole.

Figure 5. Background noise PSD observed on the 500 Hz (DP1) geophone channel (dots) and on the 500 Hz (CL1) accelerometer channel (crosses) at CMSB. The accelerometer has a lower self–noise than the geophone at frequencies above 70 Hz while the geophone has the lowest noise level in the vicinity of its 2 Hz natural frequency.

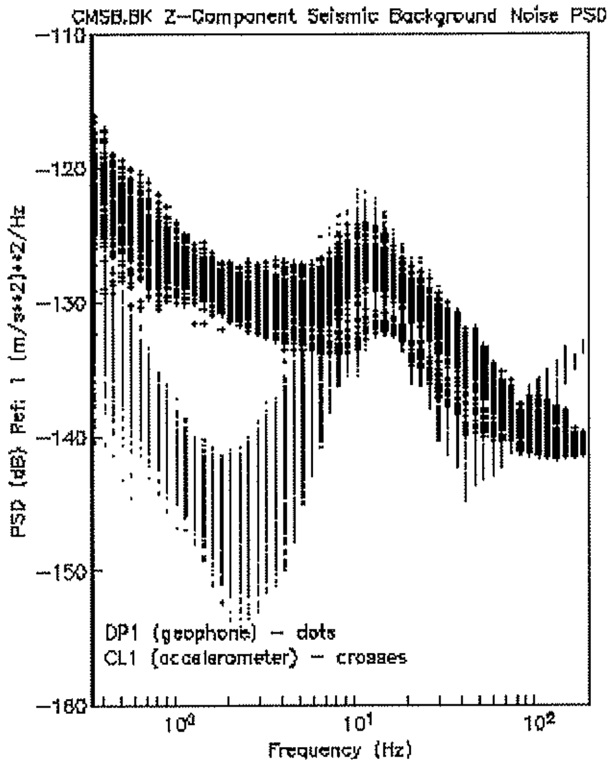
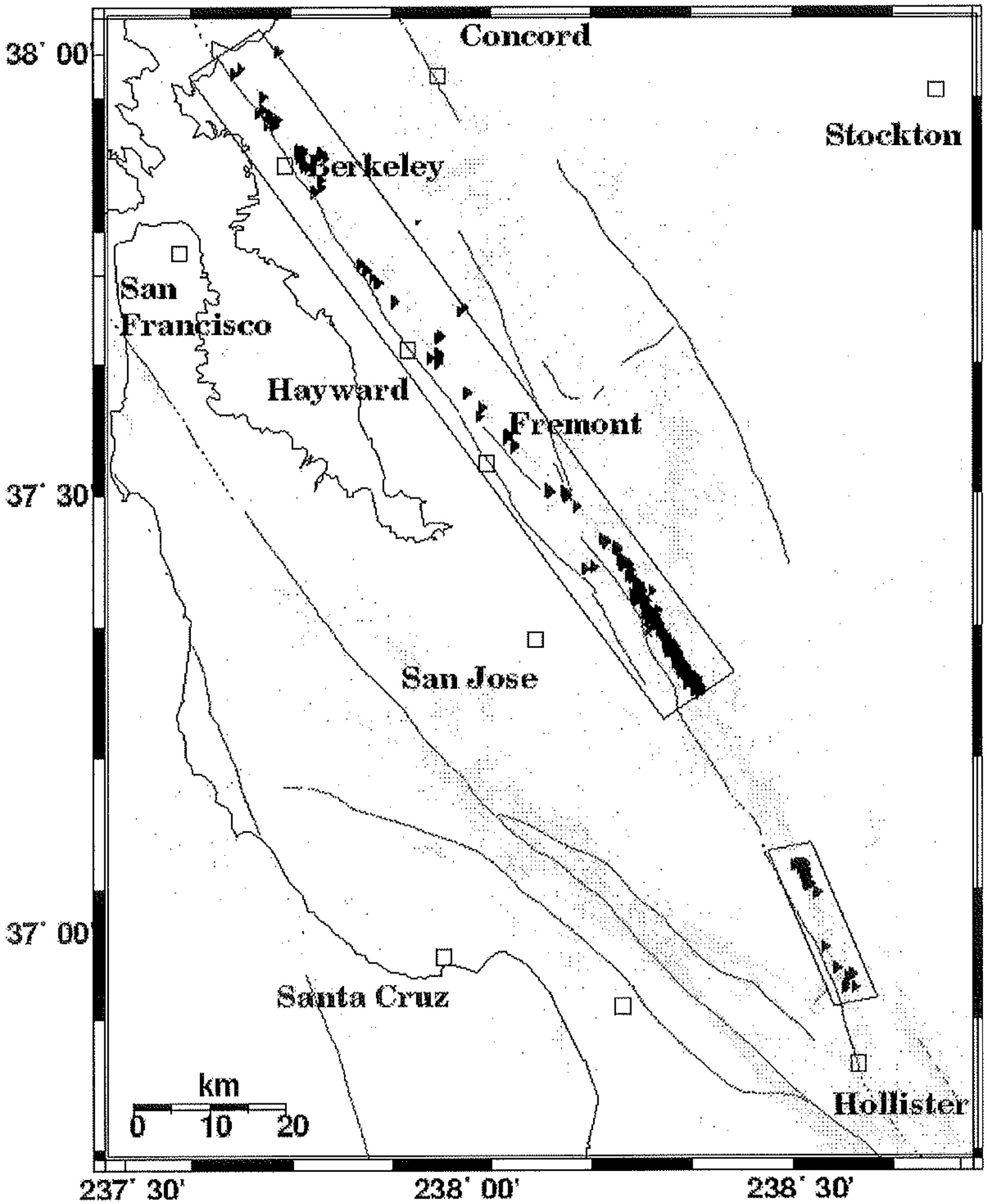


Figure 6 shows characteristically repeating and highly similar events that have been identified in the region. The NHFN borehole installed sensors are designed with the goal, in part, of obtaining temporally stable waveform recordings of microearthquakes, with a magnitude threshold lower than is observable with surface installed stations, to facilitate the search for highly similar and repeating earthquakes.

An example of seismic waveform complexity generated by near vertical wave propagation through the three–dimensional complex structural of the upper crust in the vicinity of the Hayward fault zone is shown in Figure 7. The earthquake is a M 1.7 event (2002.091.1306) which occurred along the Hayward Fault at a depth of ~8300 m under the Berkeley campus. The station epicental distances and azimuths from the REDI event location are: BKS: 1900 m N59E; CMSB: 550 m N22E, and: BRK: 700 m N41W.

Figure 6. Characteristically repeating and highly similar events along the Hayward, Calaveras and Mission crossover faults. Gray dots are background seismicity. Black triangles are locations of earthquakes either identified as members of repeating earthquake sequences (about 200 quakes) or having similar waveforms with cross–correlation coefficients greater than 0.98 at multiple stations (over 1800 quakes–potential repeaters yet to be confirmed and grouped into repeating earthquake sequences). Polygons show approximate areas of similarity searches completed so far.



Hardware Maintenance

Q4120 Equipped Stations

The most pervasive problem at the Q4120 equipped stations is power line noise (60 Hz and its harmonics at 120, 180, and 240 Hz). This noise reduces the sensitivity of the MHH detectors. The data loggers were upgraded to MSHEAR 001122 during February 2001 to enable near–real–time central site triggering. During the past year, the following stations required site visits:

BRIB: Facilities Management accidentally cut the conduit and cables, which carry power from the power supply in the observatory down the hill to the vault, in two places while doing road work near the observatory. This caused the fuse in the power supply to blow and the Q4120 to hang in an endless bootup loop. After cable and conduit was repaired, the fuse was replaced and the Q4120 power cycled to restore normal operation.

CMSB: Repaired power supply and replaced batteries. Repaired area of signal cable that was damaged by rats.

CRQB: Replaced faulty battery. Revamped power supply.

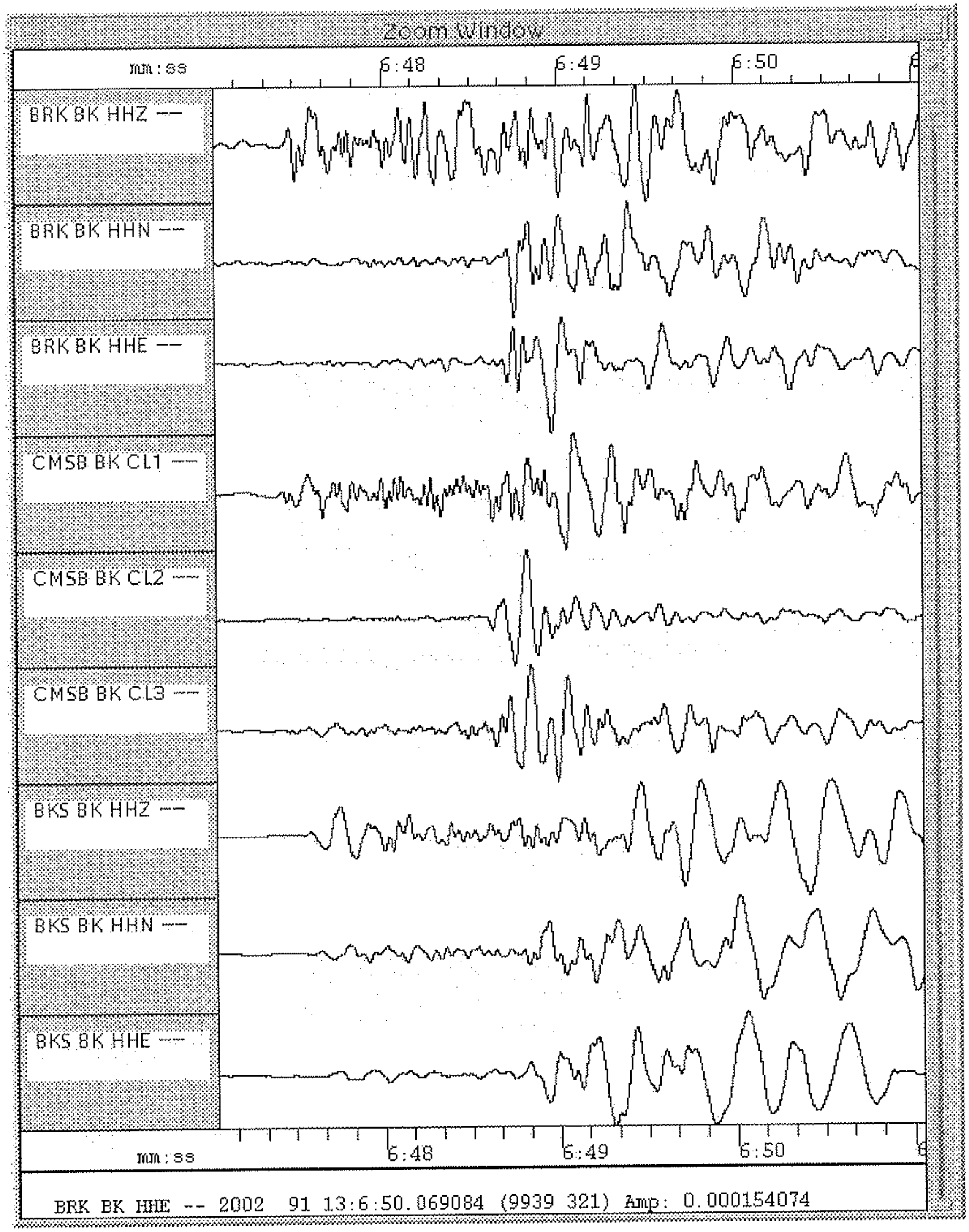
HERB: Replaced suspected faulty FRAD.

RFSB: Reconfigured equipment and installed hardware into new equipment enclosure. Spent considerable time systematically reducing 60 Hz (and harmonics) signals on seismic channels and eliminating ground loops. Removed downhole sensor package in June 2001 and brought back to lab for repair and installation of ferrite beads for noise suppression and reinstalled it two days later. Added 4 bags of sand to securely couple the sensor package in the bottom of the borehole and eliminate resonance of the suspension cable.

RSRB: Shut down on April 19, 2001 because Caltrans is retrofitting the bridge. Caltrans will eventually install an HFN package at the toll plaza as a replacement for for the sites shut down. This is unscheduled, as it depends upon the Caltrans drill crew having sufficient slack time to drill the hole. A site has been picked and we have a sensor package ready to go and Caltrans is currently installing the infrastructure (trenching power and phone lines, and installing the equipment housing).

SMCB: The telemetry circuit was randomly going down due to the FRAD rebooting and the FRAD logged alarms indicate that the FRAD power was interrupted. Upgraded power system to mitigate the power interruption problem.

Figure 7. Filtered (2–30 Hz) ground displacement waveforms, from a local M 1.7 earthquake which occurred at a depth of 8.3 km under Berkeley, recorded at the borehole station CMSB sited in the Hayward fault zone and at two surface broadband stations, BRK on the southwest (fast) side of the fault and BKS on the northeast (slow) side of the fault. The striking differences in the waveforms are attributed to the near vertical propagation path through the complex three–dimensional upper–crustal structure in the vicinity of the Hayward fault.



New Station Installations

HERB:

The newest NHFN station (HERB) is sited at the Caltrans Hercules maintenance yard. The site is 5 km NE of the Hayward Fault and it is the farthest north of the NHFN on–land stations. Starting on April 17, 2000, a Caltrans crew drilled a 5–5/8 inch borehole to a depth of 218 m in five days (the deepest of any of the NHFN stations). The hole was mud–logged during the drilling and the primary material is siltstone and shale, with units of sandstone and clay. It is a very competent hole and no casing was required. Caltrans HFN_2001_Annual_Progress_Report.sdw

Borehole Geophysical Logging Services also provided geophysical testing using a P–S logger, a Caliper, a Gamma logger, and a resistance logger. The instrument sonde is a "standard HFN" package. After the sonde was installed the hole was back–filled with cement slurry with approximately the same density as the surrounding material. A 10m hole was drilled 5 m north of the main hole and cased with PVC for the future installation of a surface instrument.

After a few months delay waiting for the frame–relay connection to HERB to be established and for Caltrans to provide "24–hour" power (during the past year, AC power was available only during normal working hours), the station was installed and it became operational on September 18, 2001.

OHLN:

A modified HFN instrumentation sonde containing three HS–1 geophones and no accelerometers was installed at a depth of 196.7 m in the mini–PBO borehole at Ohlone Park in Hercules (OHLN). The station became operational and began telemetering data to Berkeley on October 5, 2001.

DATA AVAILABILITY

Data archival and Distribution

The Northern California Earthquake Data Center, a joint project of the Berkeley Seismological Laboratory and the U.S. Geological Survey at Menlo Park, serves as an "on–line" archive for various types of digital data relating to earthquakes in central and northern California. The NCEDC is located at the Berkeley Seismological Laboratory, and has been accessible to users via the Internet since mid–1992.

The primary goal of the NCEDC is to provide a stable and permanent archival and distribution center of digital geophysical data for northern and central California such as seismic waveforms, electromagnetic data, GPS data, and earthquake parametric data. The principal networks contributing seismic data to the data center are the Berkeley Digital Seismic Network (BDSN) operated by the Seismological Laboratory, the Northern California Seismic Network (NCSN) operated by the USGS, and the Bay Area

Regional Deformation (BARD) GPS network.

The NCEDC continues to use the World Wide Web as a principal interface for users to request, search, and receive data from the NCEDC. The NCEDC has implemented a number of useful and original mechanisms of data search and retrieval using the World Wide Web, which are available to anyone on the Internet. All of the documentation about the NCEDC, including the research users' guide, is available via the Web. Users can perform catalog searches and retrieve hypocentral information and phase readings from the various earthquake catalogs at the NCEDC via easy–to–use forms on the Web. In addition, users can peruse the index of available broadband data at the NCEDC, and can request and retrieve broadband data in standard SEED format via the Web. Access to all datasets is available via research accounts at the NCEDC. The NCEDC's home page address is http://quake.geo.berkeley.edu/

The archival of current NHFN seismic data is an ongoing task. NHFN data are telemetered from the seismic data loggers in real–time to the BSL, where they are written to disk files. Each day, an extraction process creates a daily archive by retrieving all continuous and event-triggered data for the previous day. The daily archive is run through quality control procedures to correct any timing errors, triggered data is reselected based on the REDI, NCSN, and UCB earthquake catalogs, and the resulting daily collection of data is archived at the NCEDC.

All of the data acquired from the BDSN and NHFN Quanterra data loggers are archived at the NCEDC. Most of the 16–bit BDSN digital broadband data from 1987–1991 have been converted to MiniSEED (Halbert et al., 1996) and are now online. Data acquired by portable 24–bit RefTek recorders before the installation of Quanterra data loggers at NHFN sites is currently in the process of being converted to MiniSEED and archived at the NCEDC. Working backward in time, we started with the mid–1999 RefTek recorded data and we are currently processing 1996 data.

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