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PREFACE

Volume XIV of the South Carolina Seismic Network (SCSN) Bulletin describes the seismicity in the state in 2004. The largest event with a magnitude M_L 3.1 occurred on July 20, 2004 near Summerville. Seismicity continued at a low level near Monticello Reservoir where eight events were located. Seismicity was recorded in the Middleton Place Summerville Seismic Zone (MPSSZ) where a total of twelve events were located. Four events were located ~10 - 20 km west, northeast, and northwest of Monticello Reservoir.

The South Carolina Seismic Network website lists historical and instrumental seismicity in South Carolina and details of the location of the current seismicity. The website address is http://scsn.seis.sc.edu.

In 2004, the SCSN continued routine digital recording of seismicity in the state. The data from Coastal Plain stations surrounding MPSSZ are recorded in an event triggered format at Charleston Southern University (CSU) near Summerville, and accessed via the Internet from the University of South Carolina (USC), where other digital data are recorded.

Successful operation of the SCSN is due in part to the support from the U.S. Geological Survey and Westinghouse Savannah River Company. This bulletin is the result of the efforts of the staff and students at USC.

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I. INTRODUCTION

Volume XIV of the South Carolina Seismic Network (SCSN) Bulletin covers the period from January to December, 2004. This issue presents the details concerning the observed seismicity and network operation in the state during 2004.

We observed a lower level of seismicity in the Middleton Place Summerville Seismic Zone (MPSSZ) during the year compared to 2003. Twelve earthquakes were located in 2004 compared to twenty-three earthquakes in 2003. The largest event during 2004 was a M_L 3.1 that occurred on July 20, 2004. Among the earthquakes located in 2004, ten were of $M_L \geq 2.0$, and one event was of $M_L \geq 3.0$ (Table 2).

Seismicity at Monticello Reservoir was slightly lower in 2004 compared to twelve events in 2003. A total of eight events were located in 2004 among which five events with $1.0 \leq M_L \leq 2.5$ were located. The largest event in the Monticello Reservoir area had a M_L 2.5 (Table 4).

Four events with magnitudes from M_L 0.3 to 1.6 were located in areas outside the MPSSZ, and Monticello Reservoir. These events were located about 20 km west and northeast, and ~10 km northwest of the Monticello Reservoir (Table 3).

In 1987 the SCSN began digital recording of seismicity in the state, but only for the stations telemetered to USC. The digitizing of data from Coastal Plain stations surrounding MPSSZ started in 1995 and are recorded in an event triggered format at Charleston Southern University (CSU) near Summerville, and accessed via the Internet from the University of South Carolina (USC), where other digital data are recorded in triggered mode and continuously.

The bulletin is arranged in four sections. The next section deals with the network operations, current methods of data acquisition, retrieval and processing. An analysis of the seismicity of the state in 2004 is presented in the third section. Future plans of the SCSN, (http://scsn.seis.sc.edu), are presented in the last section.

II. SOUTH CAROLINA SEISMIC NETWORK OPERATION - 2004

II.1. Station Locations

In 2004, the SCSN consisted of sixteen stations. These included three stations in the "main net", eight stations in the Coastal Plain network and five stations in the Monticello Reservoir sub-network. The present configuration of the seismic network is shown in Figure 1. The stations of the "main" SCSN (JSC, LHS) cover the area in the lower Piedmont and (COW) covers the upper Coastal Plain. Data from these stations are telemetered and recorded at the USC. The Coastal Plain Seismic Network consists of three bore-hole stations, CSB, RGR, and HBF, and six surface stations, CSU, DRC, MGS, SVS, TWB and WAS. These cover the meizoseismal area of the 1886 Charleston earthquake (Figure 2). Data from these stations are telemetered and recorded at Charleston Southern University and also transmitted to USC.

The configuration of stations in the vicinity of Monticello Reservoir area is shown in Figure 3. Data from the Monticello Reservoir sub-network (Figure 3) are telemetered and recorded at the USC Seismic Laboratory in Columbia.

II.2. Recording Facilities

Digital data are recorded continuously at USC on PC-based system at 50 samples/second. To facilitate easier storage of the continuous data being recorded at USC, a DAT tape drive was installed on our PCSUDS analysis workstation. This tape drive can store approximately 2 gigabytes of data on a single tape. Accumulating data at the rate of 288 Mb per day, the new tape drive has given us the ability to mass dump data each morning from hard disk to tape. A backlog of 60 days data is maintained at the present time.

At USC data are also recorded on two Helicorders. Of these, one is used to record data from stations in the Coastal Plain, and one is dedicated to data from the induced seismicity sub-network.

In October of 1998, the USGS initiated a new phase of cooperative seismic monitoring. The recording operations of both the Charleston Southern University and USC facilities were augmented with the installation of “Earthworm”. Earthworm is a PC-based, event triggered and short term continuous data recording system that utilized the Internet for data transfer and sharing. This allows data from the SCSN to be shared with networks at CERI (Memphis) and the USGS in Golden, Colorado as part of the Advanced National Seismic System (ANSS) for the Central and Southeast US region. It also gives the main data analysis group at USC the ability to import data from stations throughout the southeast, thereby enhancing our event detection and location capabilities.

II.3. Operational Status

Yearly operational status of the stations of the main SCSN in 2004 is shown in Figure 5. Most of the stations were completely operational throughout the year. The downtime ranges from 0% to ~12%.

The yearly operational status of the sub-net at Monticello Reservoir is shown in Figure 6. The Monticello sub-net’s downtime ranges from 0% to 7% in general in 2004 except station MR05 which has been inoperational since 2003 due to the utility company not taking corrective measures after reconfiguration of telemetry for the station.

II.4. Data Analyses

Data are analyzed at the USC’s seismological laboratory. Identification of blasting activity, documentation of regional and teleseismic events, location and analyses of local earthquakes form a part of the routine analyses. The present configuration of triggering operators consists of six separate triggering parameters encompassing the several sub-networks and the main network and some combinations. This increased triggering capability has allowed for the recording and locating of events of $M_L \leq 1.0$. Examples of the system digital playbacks are shown in Figures 7a and b. These include the M_L 3.1 event in MPSSZ on July 20, 2004 (Figure 7a), and the M_L 0.7 Monticello Reservoir event on March 29, 2004 (Figure 7b).

The ability to store data on 8 mm digital tapes is an added advantage of using a digital recording system. The data are processed using the Seismic Analyses Code (SAC program on the Sun workstations. Hypocentral locations are obtained using HYPO71 and HYPOELLIPSE programs with an appropriate velocity model for each region. Format of the HYPO71/HYPOELLIPSE output is given in Table 1. Event magnitudes are determined using the following relation:

$$M_L = -1.83 + 2.04 \log D$$

where D is the signal duration in seconds.

The results of seismic monitoring in the state during 2004 are presented in the next section.

III. SOUTH CAROLINA SEISMICITY: 2004

Seismic activity continued in the MPSSZ (12 located events) and Monticello Reservoir (9 located events) (Figures 2 and 3). Seismicity in the different regions (Figure 8) is discussed below, first tectonic seismicity is presented (Sections III.1 and III.2) and then the induced seismicity (Section III.3).

III.1. Middleton Place Summerville Seismic Zone

The MPSSZ continued to be the most active (non reservoir induced) seismic source zone in the Coastal Plain in 2004 (Figures 2 and 9). Seismic activity was lower in MPSSZ during 2004 compared to that in 2003 when 23 events were located. Twelve events were located during 2004 with magnitudes ranging between M_L = 1.9 and M_L = 3.1 at depths between 5 and 13 km (Table 2, Figure 2). Five events were located in a cluster in MPSSZ and six events were located about 15 – 20 km north and northwest of the cluster. Four of these six events were located north of Summerville (Figure 2). Temporally, the seismicity was distributed throughout the year with the exception of March, April, June, September, and October (Figure 10).

III.2. Other Tectonic Activity

Four events of M_L 0.3 – 1.6 were located outside the MPSSZ, and Monticello Reservoir in 2004 (Table 3, Figure 4). Three of the events were located about 20 km west and northeast of Monticello Reservoir whereas one event was located ~10 km northwest of the reservoir.

III.3. Reservoir Induced Seismicity – Monticello Reservoir

The seismic activity near Monticello Reservoir was slightly lower during 2004 compared to that in 2003. Eight earthquakes were located near Monticello Reservoir area during 2004 (Table 4, Figure 3) compared to twelve earthquakes in 2003. Except two earthquakes all the others in 2004 had M_L < 1.5. The largest earthquake had a M_L = 2.5 and occurred on April 4, 2004 at a depth of ~8.8 km. The focal depths of the other earthquakes were shallower than 2.5 km. The monthly distribution of the earthquakes around Monticello Reservoir is given in Figure 11.

IV. RECORDING FACILITIES AND UPGRADE AT THE SCSN

The location of stations of the SCSN in 2004 are shown in Figure 1. Data from stations of the Monticello Reservoir network are now telemetered to the USC via a dedicated phone line (Figure 12). Data from the stations in the MPSSZ are telemetered and recorded at CSU (Figure 13). We continue to record analog data on two Helicorders at USC. The instrument acquisition and deployment history is given in earlier bulletins of the SCSN.

This section addresses some of the comments of the seismic network proposal review panel (that met last year) and other input from other components of Mid America Integrated Seismic Network (MAISN). It was recommended that SCSN "must make better progress in moving towards the Advanced National Seismic System (ANSS) model"… But it also recognized that .. "ultimately the advancement of the SCSN under the ANSS umbrella depends upon close cooperation with the MAISN **and upon technical assistance from the University of Memphis/CERI. To that end, the panel had recommended that the USGS makes a commitment to coordinate with CERI in improving the quality and effectiveness of data acquisition in South Carolina and in improving the integration of data for local, regional, and national use. In addition, the USGS made a commitment to the panel that it would provide technical help to SCSN, in coordination with and through CERI, aimed at helping achieve the basic ANSS performance goals."**

In view of the above, the following progress has been made.

1. During 2004, the South Carolina Seismic Network started a plan to reconfigure key stations of the network. This will consist of replacing ancient electronics components at key sites in the state. The SCSN Network Manager visited CERI in June 2004, where it was agreed that newer equipment would be supplied to USC in the coming year. Four sets of PANDA II instrumentations, including replacements for radio transmitters, receivers, and antennas were received in September 2004. The new equipment is not compatible with existing transmitters and receivers. Antennas at both ends of the radio links will also have to be changed as well as the coaxial cables. (Funds for the purchase of the coaxial cables are being sought in the second year budget). Our systems manager is not familiar with the new equipment and anticipates having to carry out some testing.

2. SCSN implemented quick earthquake submission to NEIC in 2004 by installing and configuring QDDS (Quick Data Distribution System) on the UNIX side of the Earthworm System at USC. For the next year there are plans to enhance the PC system hosting Earthworm by adding more memory and hard disk capacity to the machine. Due to its age, the present system has reached the limits of its ability to upgrade versions of any further releases of acquisition software. If funding permits, it is desirable to replace the PC with a new computer. This would allow us to run a newer operating system and use the latest releases of the Earthworm software.
3. Improving communication and data sharing with CERI – Currently we send only earthquake location to CERI with the QDDS. We are awaiting CERI to configure their machines so that the import/export protocol between SCSN and Memphis is established and will allow us to forward waveforms in real time. The ball is in the CERI court.
4. Our network manager underwent a major shoulder surgery this Fall thus delaying the deployment of the new equipment. We anticipate beginning to install the new equipment in the Spring of 2005.
5. We <u>do</u> collaborate with Prof. Thomas Owens and the South Carolina Earth Physics Project (SCEPP). Data from SCEPP provide information from areas where no SCSN stations are present. Because of the low sampling rate (SCEPP stations are geared to study teleseisms), it is not possible to pick arrival phases for local events with the desired accuracy. Hence SCEPP provides marginal help to the goals of SCSN.
6. Although SCSN has been slow in the integration with ANSS, it continues to provide an up-to-the-minute information to the public and the seismological community on any felt earthquake in South Carolina. The seismological data have been very carefully analyzed to determine the seismogenic faults in the Middleton Place Summerville Seismic Zone. These structures are essential elements in the developments of seismic hazard maps.

In summary, in spite of the greatly decreased funding, SCSN continues to make progress towards integration with ANSS.

IV.1. Future Plans

We hope to bring the bore hole stations at TWB online in 2005 and plan to begin installing the new equipment in the Spring of 2005.

V. SCSN Web Page

The SCSN Web Page can be accessed at http://scsn.seis.sc.edu. The historical and instrumental data are displayed on the web site. We also maintain an updated list, and locations of current seismicity.

TABLE 1
HYPO71/HYPOELLIPSE FORMAT

Column	1	Date
Column	2	Origin time (UTC) h.m.sec.
Column	3	Latitude (N) degrees, min.
Column	4	Longitude (W) degrees, min.
Column	5	Depth (km)
Column	6	Local duration magnitude.
Column	7	No. of station readings used to locate event. P and S arrivals from same stations are regarded as 2 readings.
Column	8	Largest azimuthal separation in degrees between stations.
Column	9	Epicentral distance in km to nearest station.
Column	10	Root mean square error of time residuals in sec. RMS = Ri2/No, where Ri is the time residual for the ith station.
Column	11	Standard error of the epicenter in km*.
Column	12	Standard error of the focal depth in km*
Column	13	Quality of the epicentral location.

* Statistical interpretation of standard errors involves assumptions which may not be met in earthquake locations. Therefore standard errors may not represent actual error limits.

Note: If ERH or ERZ is blank, this means that it cannot be computed, because of insufficient data.

Table 2: List of Earthquakes located in the MPSSZ during 2004													
#	**DATE (YYYYMMDD)**	**ORIGIN (HR:MN:SEC)**	**LAT (N)**	**LONG (W)**	**DEPTH (KM)**	**MAG**	**NO.**	**GAP**	**DMIN (KM)**	**RMS (SEC)**	**ERH (KM)**	**ERZ (KM)**	**Q**
1	20040113	18:19:26.87	33-01.03	80-13.15	7.47	2.2	12	103	6	0.05	0.2	0.7	A
2	20040212	11:03:35.20	32-54.47	80-09.39	9.09	2.0	10	133	2	0.05	0.9	0.5	A
3	20040229	12:40:05.26	32-56.13	80-10.08	7.69	2.0	10	152	4	0.03	0.7	0.7	A
4	20040501	04:16:28.27	32-59.71	80-00.16	10.66	2.7	14	265	6	0.12	0.6	0.5	A
5	20040508	11:25:21.68	32-55.37	80-10.52	5.75	1.9	12	108	2	0.04	0.3	0.6	A
6	20040720	09:13:14.45	32-58.42	80-14.78	9.90	3.1	14	127	1	0.09	0.5	0.5	A
7	20040813	04:11:05.09	32-58.94	80-16.57	7.04	2.2	12	174	3	0.09	0.4	0.5	A
8	20040818	03:43:42.36	33-01.35	80-10.28	7.71	2.5	13	151	9	0.05	0.3	0.8	A
9	20040820	01:56:21.34	32-56.00	80-09.11	6.92	1.9	10	119	4	0.04	0.3	0.7	A
10	20041125	22:58:45.89	33-03.20	80-11.39	12.88	2.7	12	122	11	0.06	0.5	1.2	A
11	20041207	22:23:50.80	32-55.22	80-09.77	6.95	2.2	12	106	3	0.09	0.4	0.6	A
12	20041210	07:13:00.87	33-04.50	80-10.31	10.32	2.4	8	321	1	0.05	1.0	1.3	B

Table 3: List of Earthquakes located outside of MPSSZ and Monticello Reservoir during 2004

#	DATE (YYYYMMDD)	ORIGIN (HR:MN:SEC)	LAT (N)	LONG (W)	DEPTH (KM)	MAG	NO.	GAP	DMIN (KM)	RMS (SEC)	ERH (KM)	ERZ (KM)	Q
1	20040112	01:55:16.90	34-27.13	81-09.82	2.52	1.4	17	313	10	0.02	2.2	19.3	C
2	20040202	17:13:38.56	34-26.16	81-23.77	2.77	0.3	10	343	1	0.03	1.5	2.6	B
3	20040325	03:03:11.44	34-19.24	81-33.33	3.24	1.2	10	320	20	0.05	2.5	17.4	C
4	20040329	23:15:40.74	34-27.06	81-09.85	1.75	1.6	10	313	17	0.05	2.0	29.0	C

Table 4: List of Earthquakes located near Monticello Reservoir during 2004

#	DATE (YYYYMMDD)	ORIGIN (HR:MN:SEC)	LAT (N)	LONG (W)	DEPTH (KM)	MAG	NO.	GAP	DMIN (KM)	RMS (SEC)	ERH (KM)	ERZ (KM)	Q
1	20040120	05:45:27.64	34-21.07	81-19.21	1.11	1.0	10	144	2	0.04	0.4	1.1	A
2	20040120	16:57:51.31	34-20.72	81-19.33	1.47	1.0	10	127	1	0.03	0.4	0.7	A
3	20040130	17:42:30.85	34-21.47	81-20.27	0.26	0.5	8	217	1	0.03	1.1	2.1	B
4	20040202	15:45:52.18	34-20.99	81-20.62	1.72	1.7	7	235	1	0.06	0.7	0.8	A
5	20040202	15:46:40.78	34-21.10	81-20.53	2.01	0.1	10	229	2	0.07	0.7	0.8	A
6	20040311	08:54:47.33	34-21.43	81-20.76	0.92	1.0	10	248	2	0.05	0.6	1.3	A
7	20040329	10:09:16.46	34-20.71	81-20.13	1.71	0.7	10	187	1	0.03	0.5	0.6	A
8	20040404	09:18:55.52	34-19.62	81-20.29	8.78	2.5	10	218	1	0.03	1.1	0.7	A

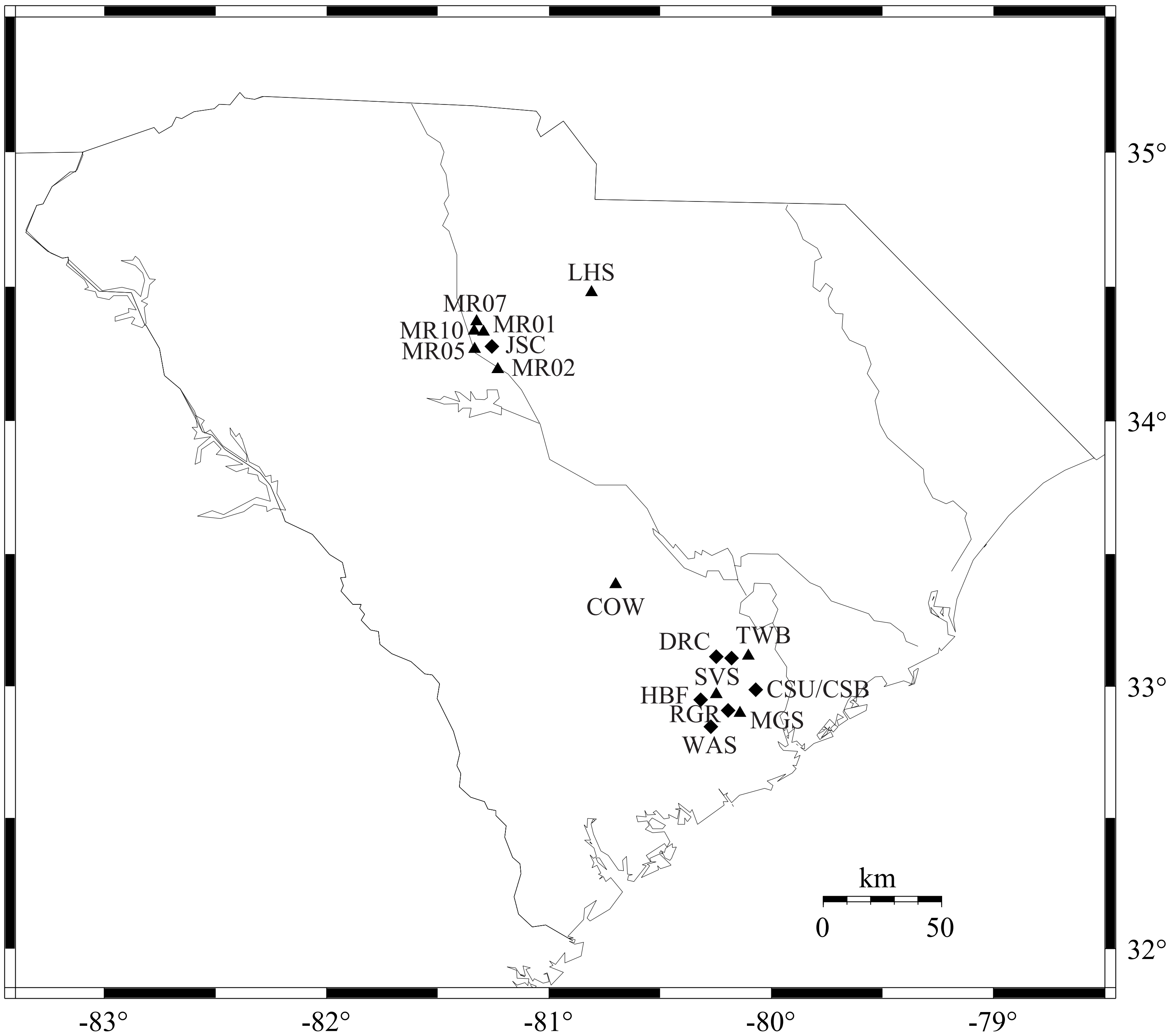

Figure 1: Distribution of stations/subnets of the South Carolina Seismic Network during 2004. Triangles (▲) and diamonds (◆) represent single and three-component stations respectively.

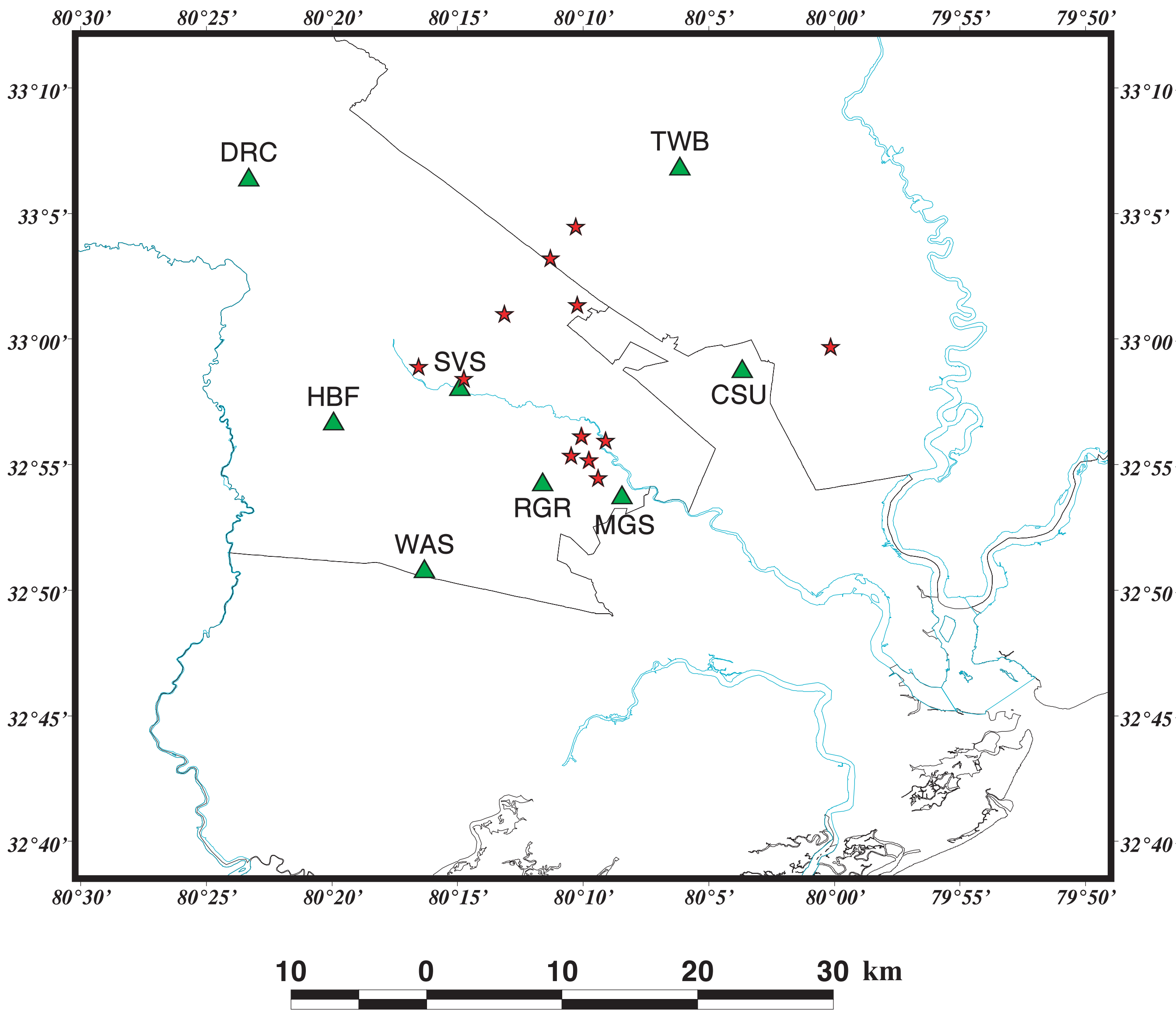

Figure 2: All earthquakes located in the MPSSZ during 2004 (★). Solid green triangles (▲) show the locations of SCSN stations in MPSSZ.

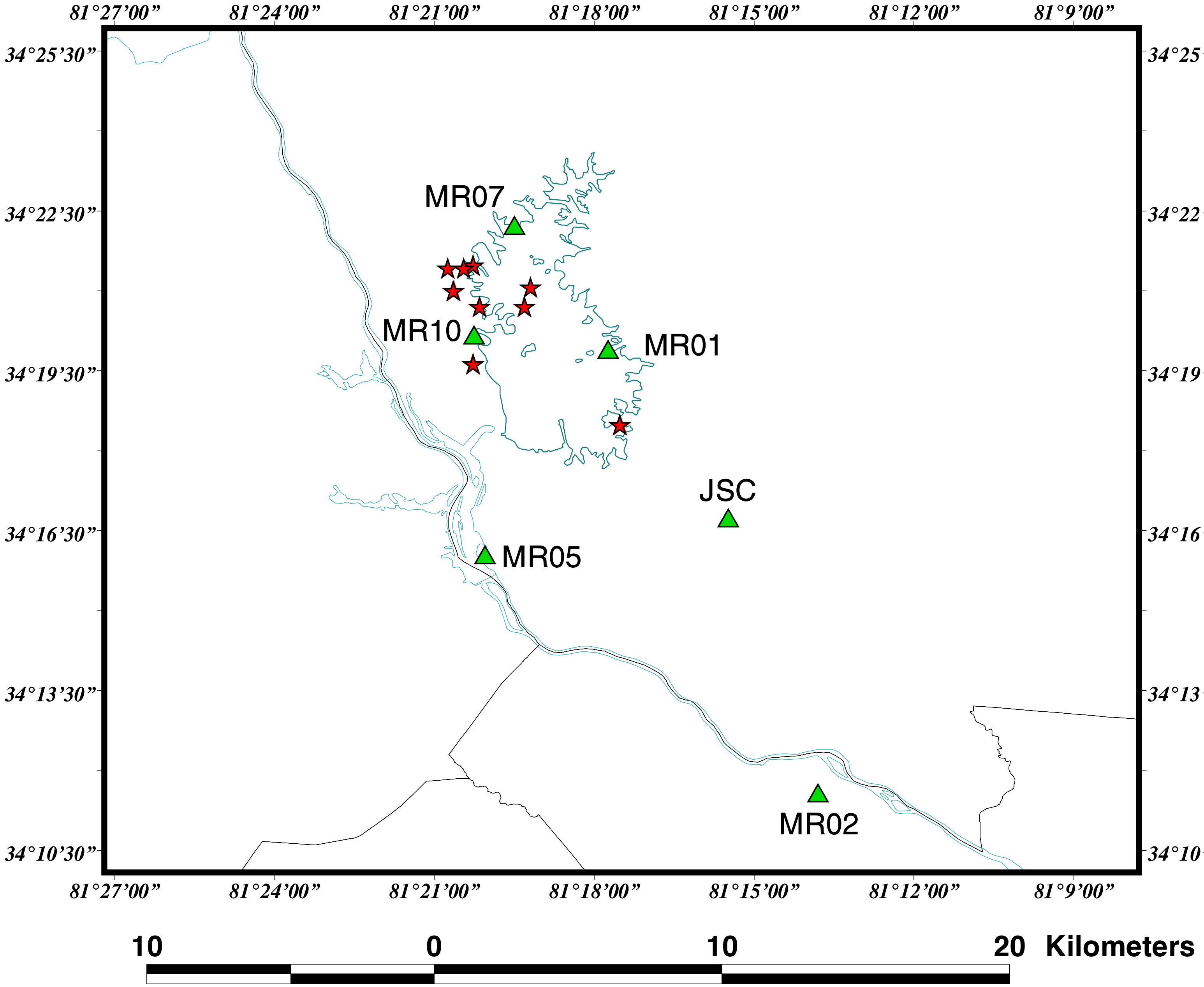

Figure 3: All events located near the Monticello Reservoir during 2004 (★). Solid green triangles (▲) show the station locations of the Monticello sub-network.

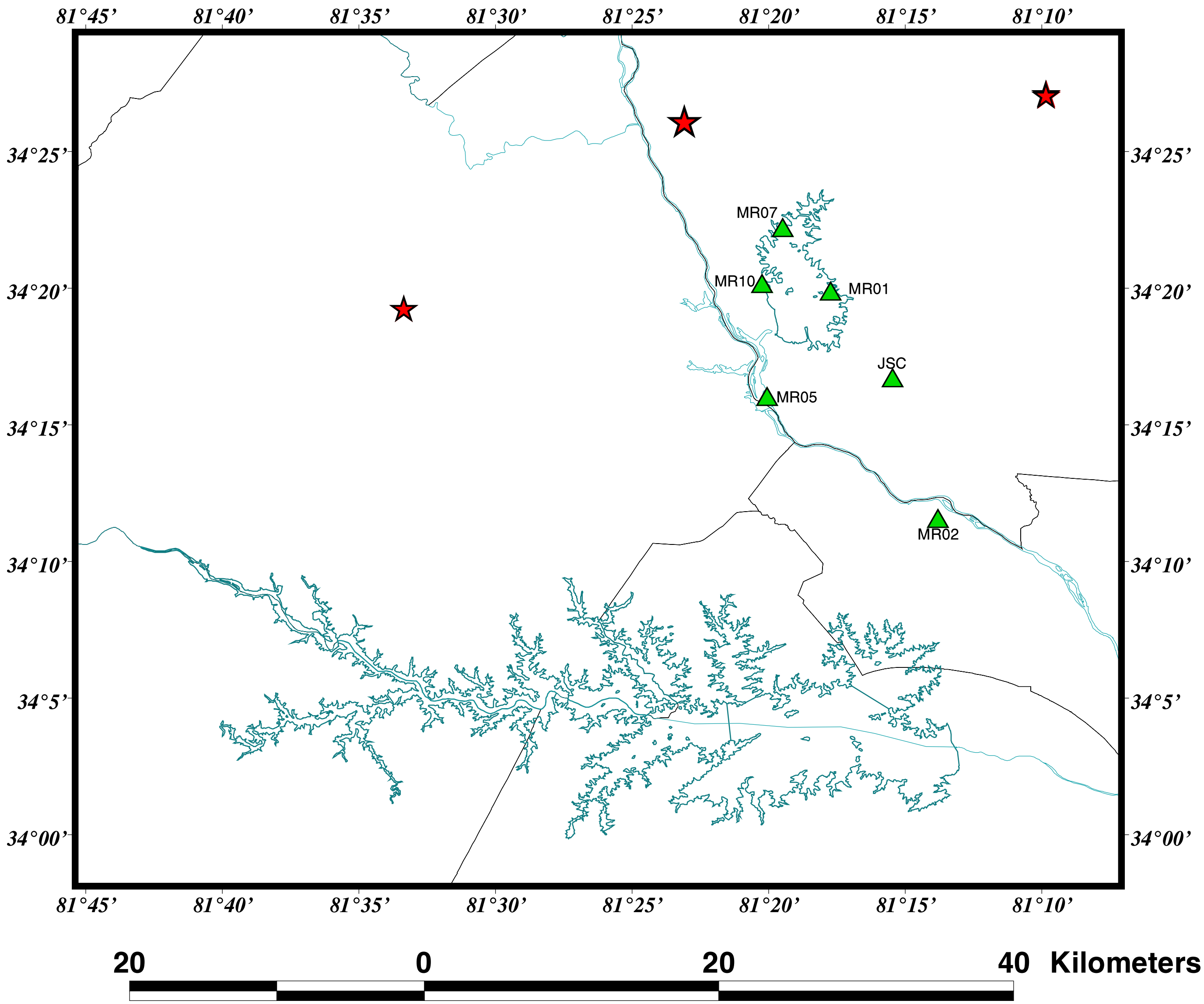

Figure 4: All events located outside of MPSSZ and Monticello Reservoir during 2004 (★). Solid green triangles (▲) show the station locations of the Monticello sub-network.

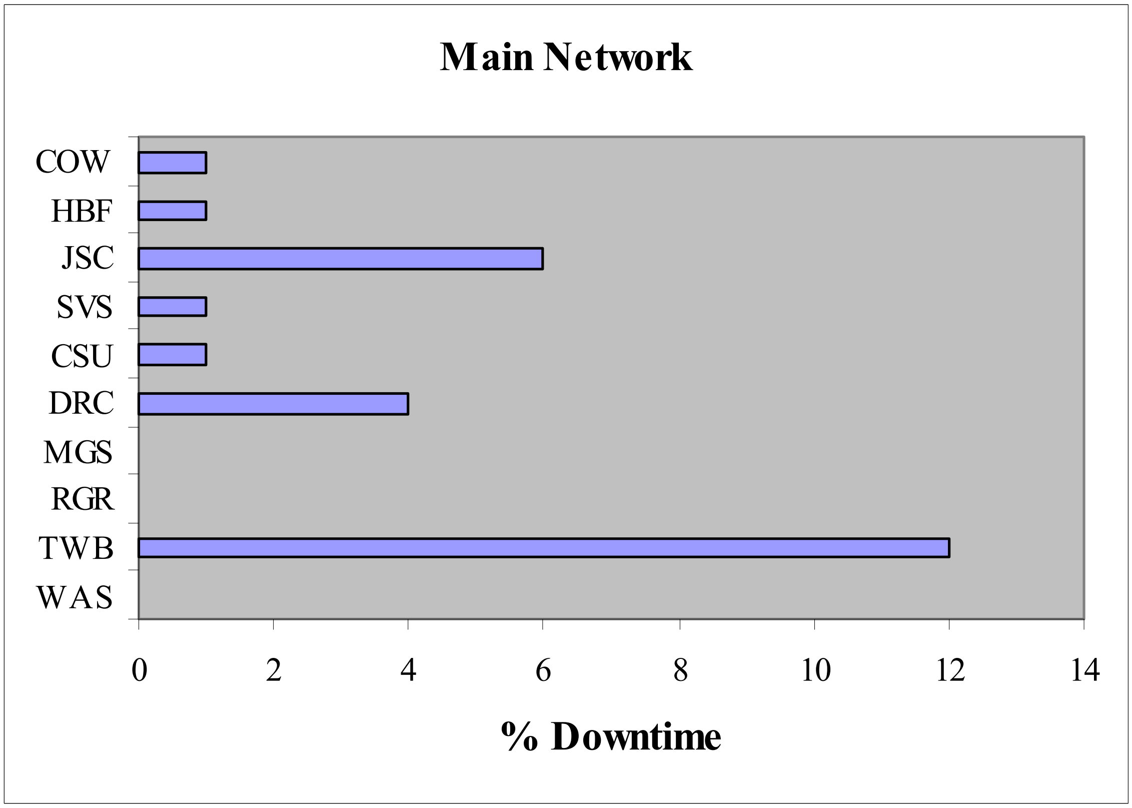

Figure 5: Operational status of the main network of the SCSN during 2004.

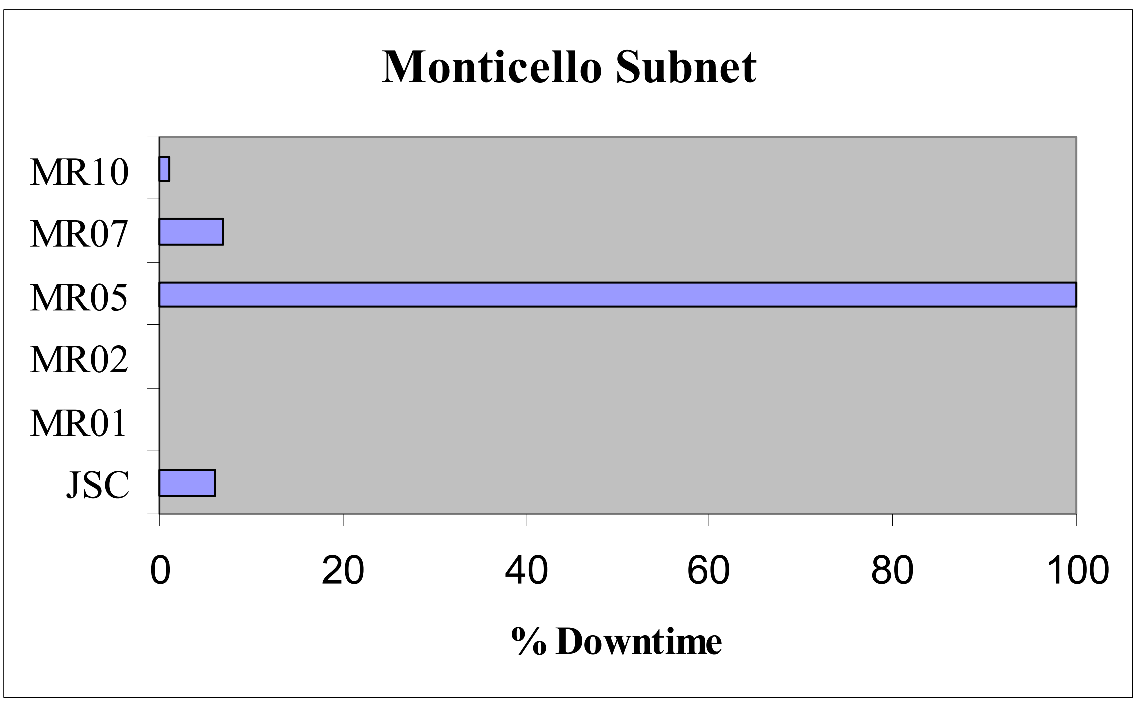

Figure 6: Yearly operational status of the Monticello Reservoir subnetwork during 2004.

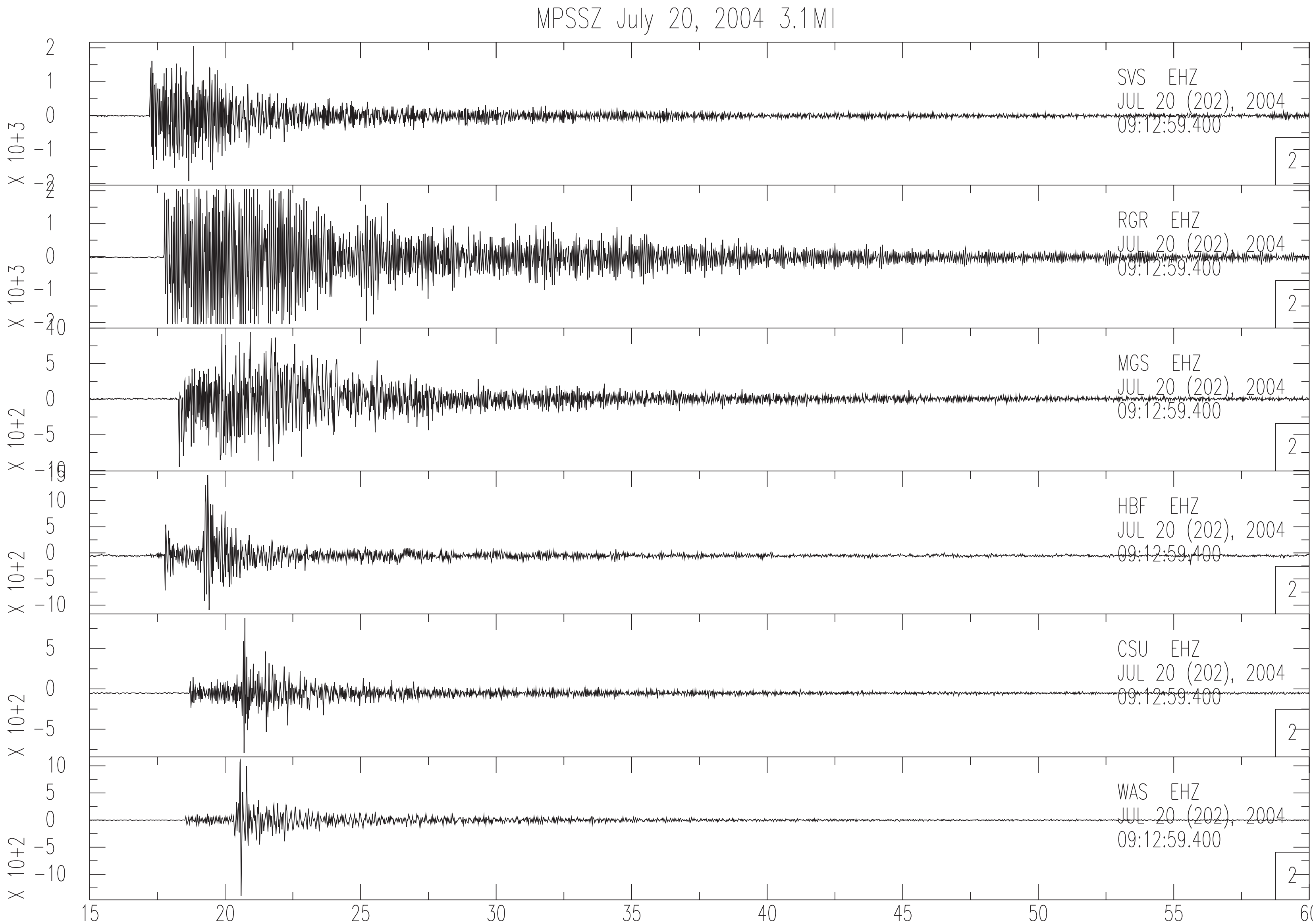

Figure 7a: Digital playback of a M_L 3.1 event in MPSSZ on July 20, 2004.

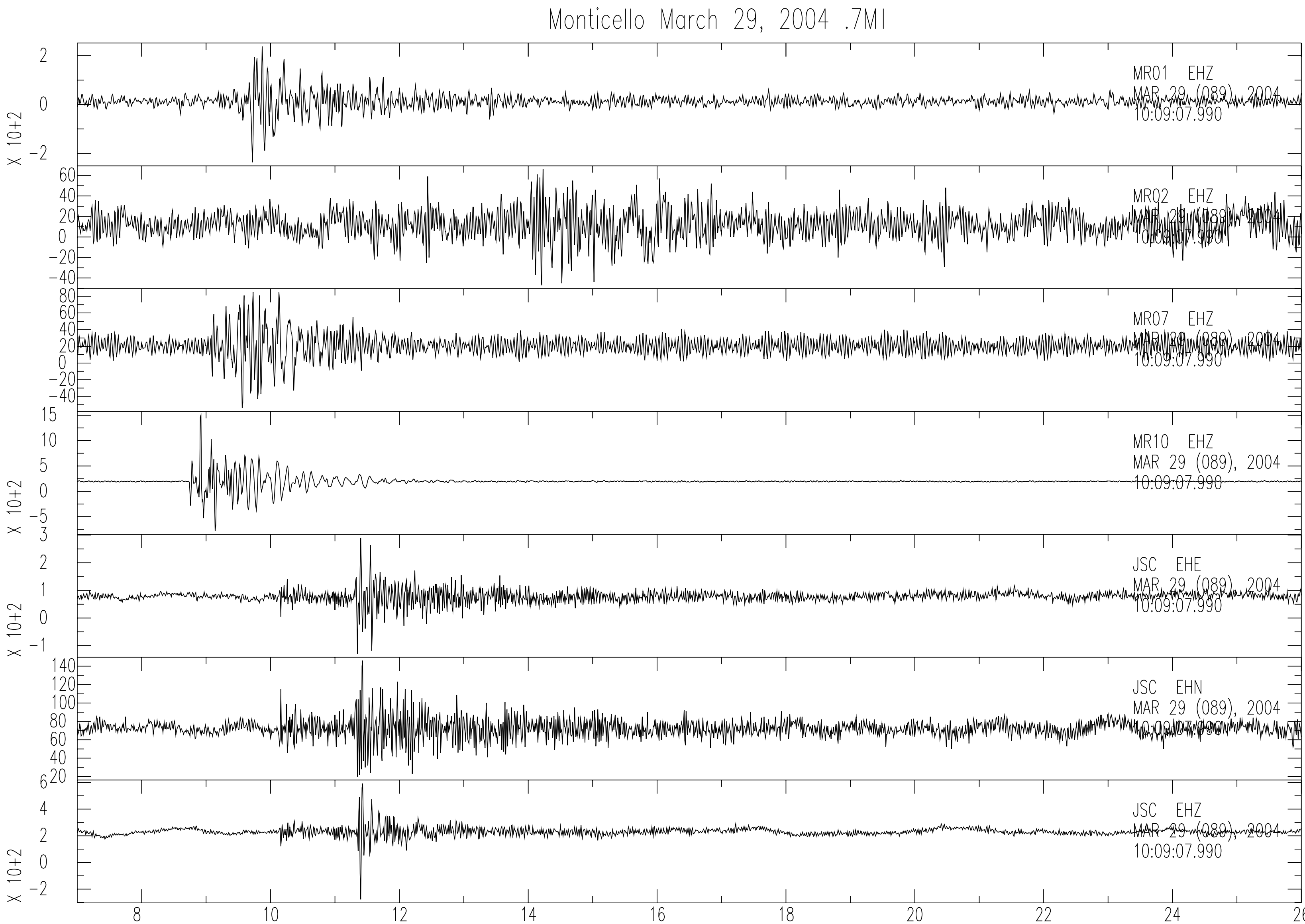

Figure 7b: Digital playback of a M_L 0.7 event in Monticello Reservoir on March 29, 2004.

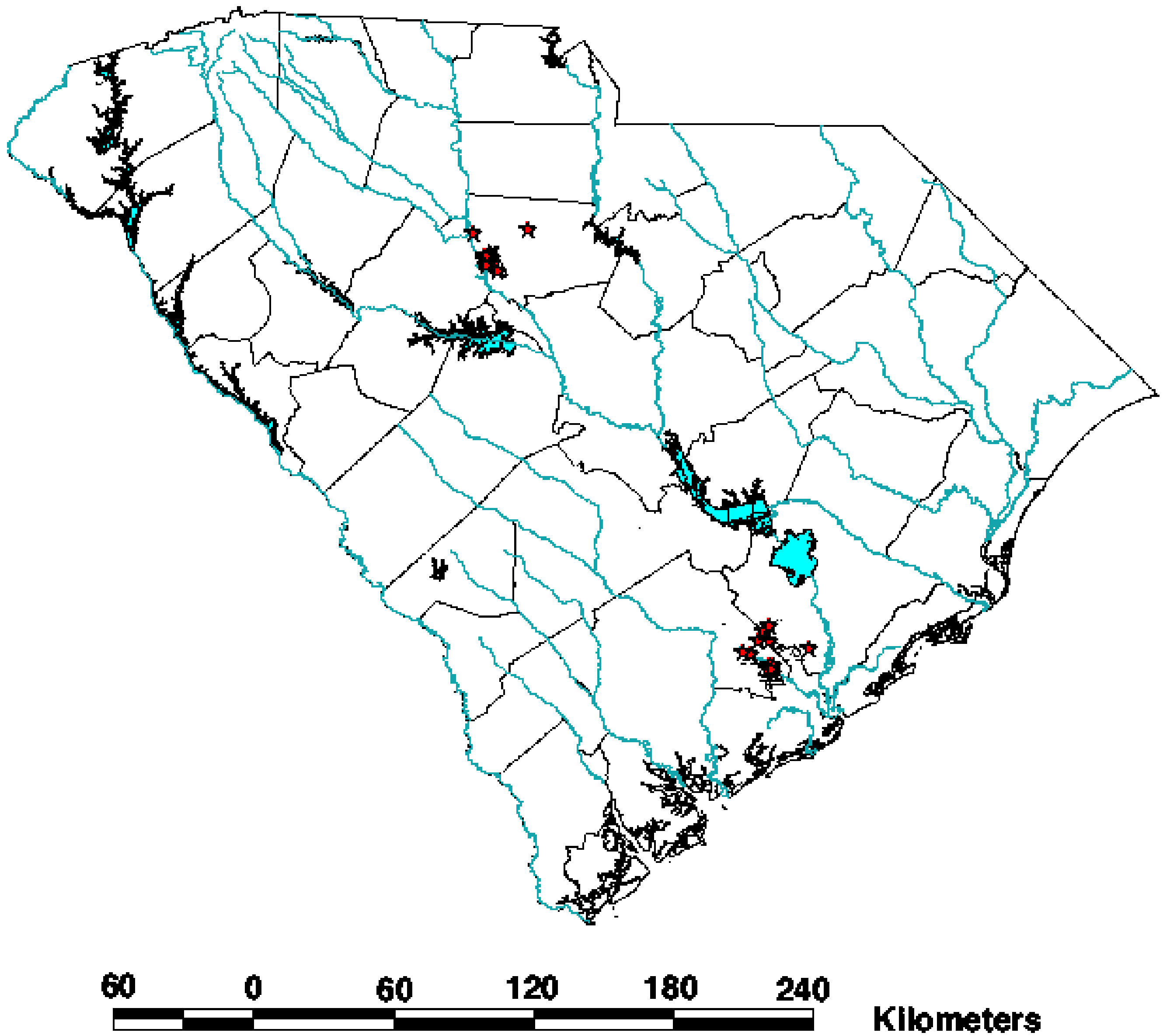

Figure 8: Cumulative seismicity in South Carolina during 2004 (*).

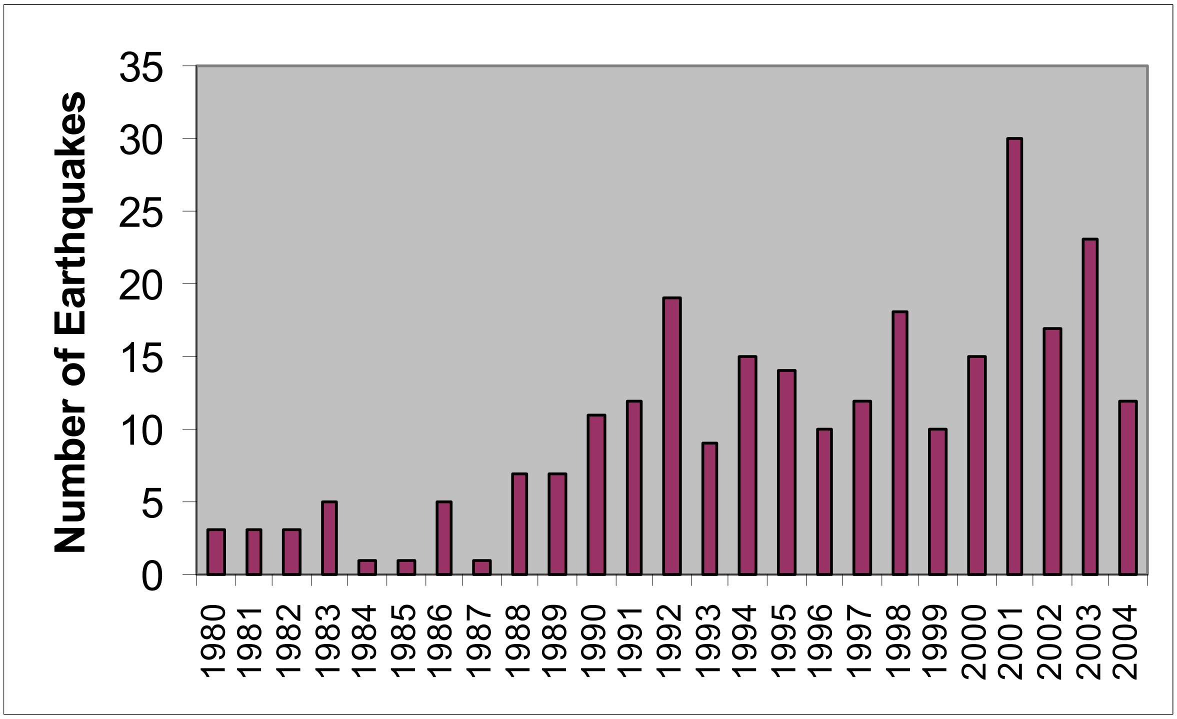

Figure 9: Number of located earthquakes in MPSSZ with magnitudes >0.6 for the period 1980-2004.

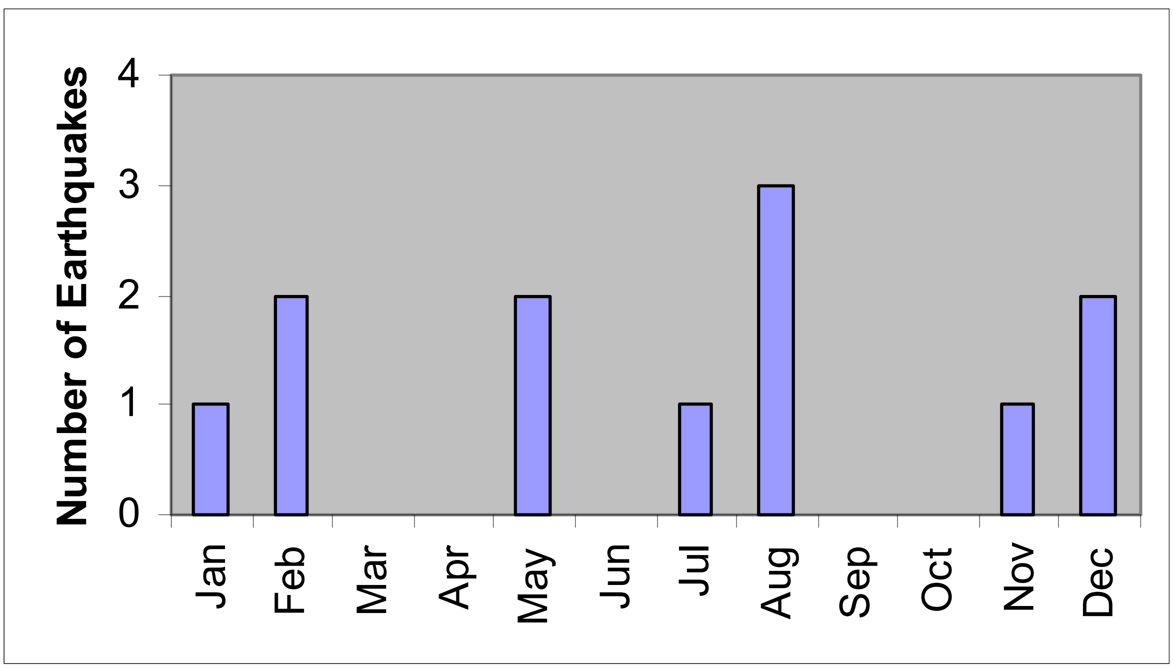

Figure 10: Monthly distribution of earthquakes located in MPSSZ during 2004.

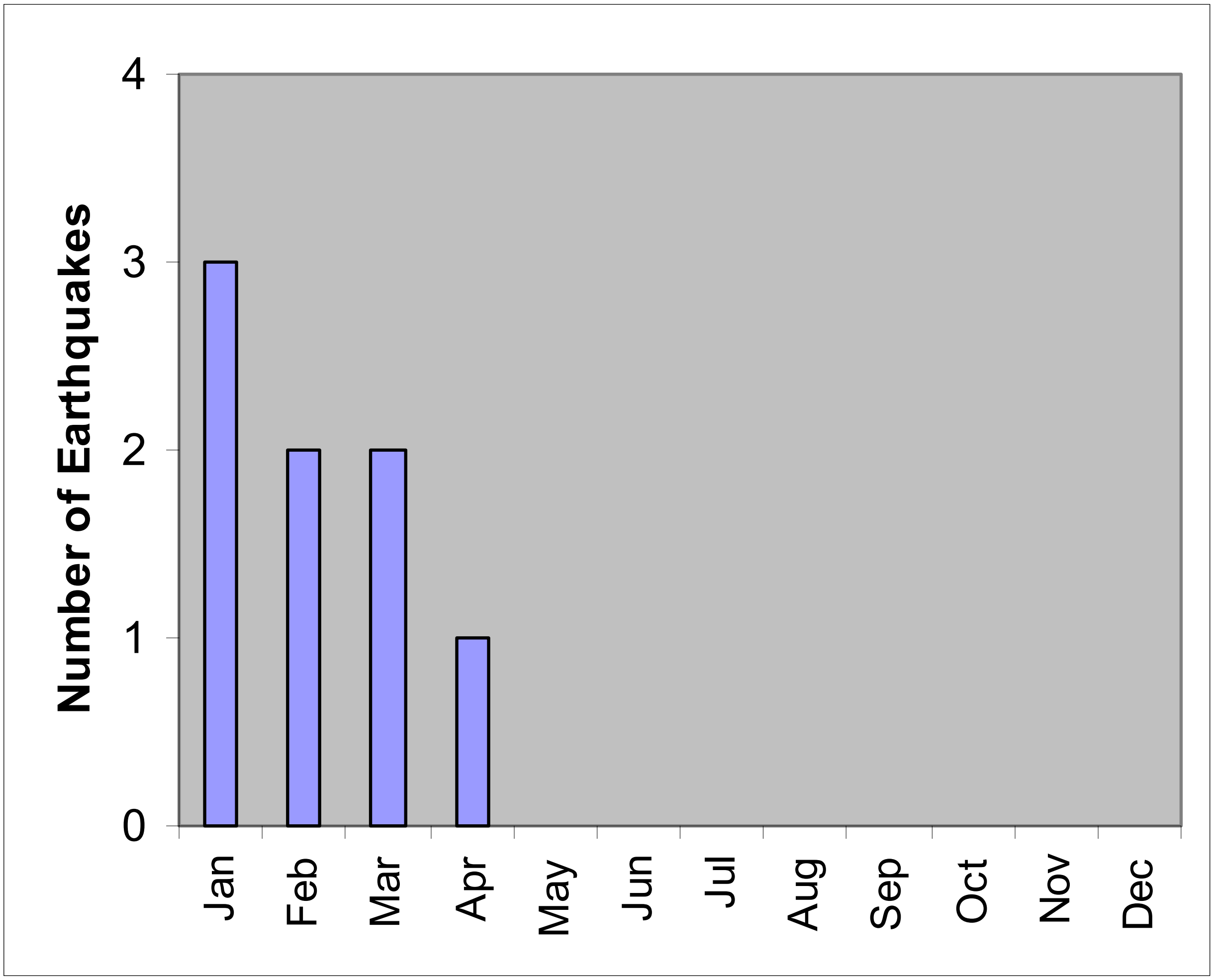

Figure 11: Monthly distribution of located earthquakes near Monticello Reservoir during 2004.

South Carolina Seismic Network

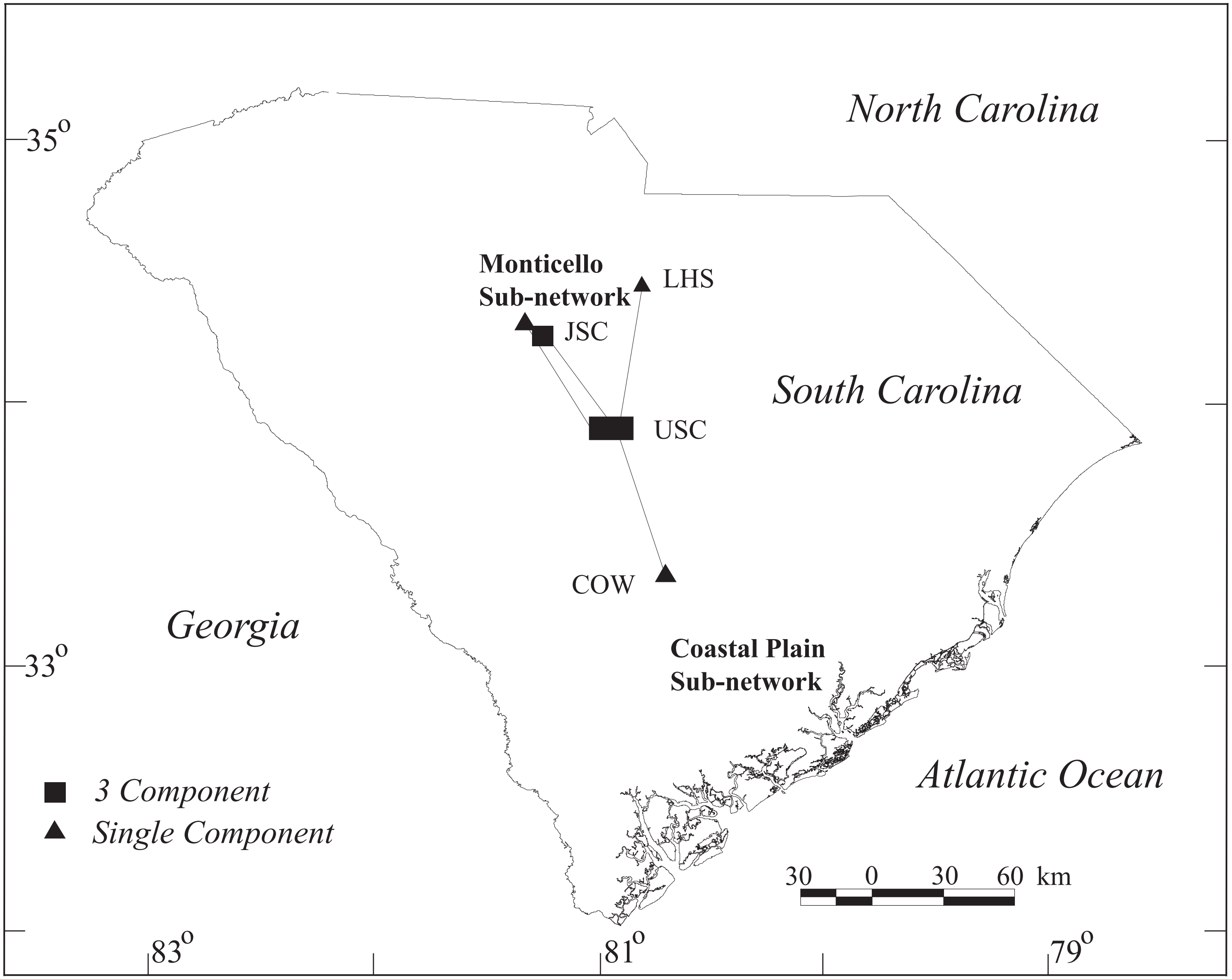

Figure 12: Telemetry routes for seismic data transmitted to USC.

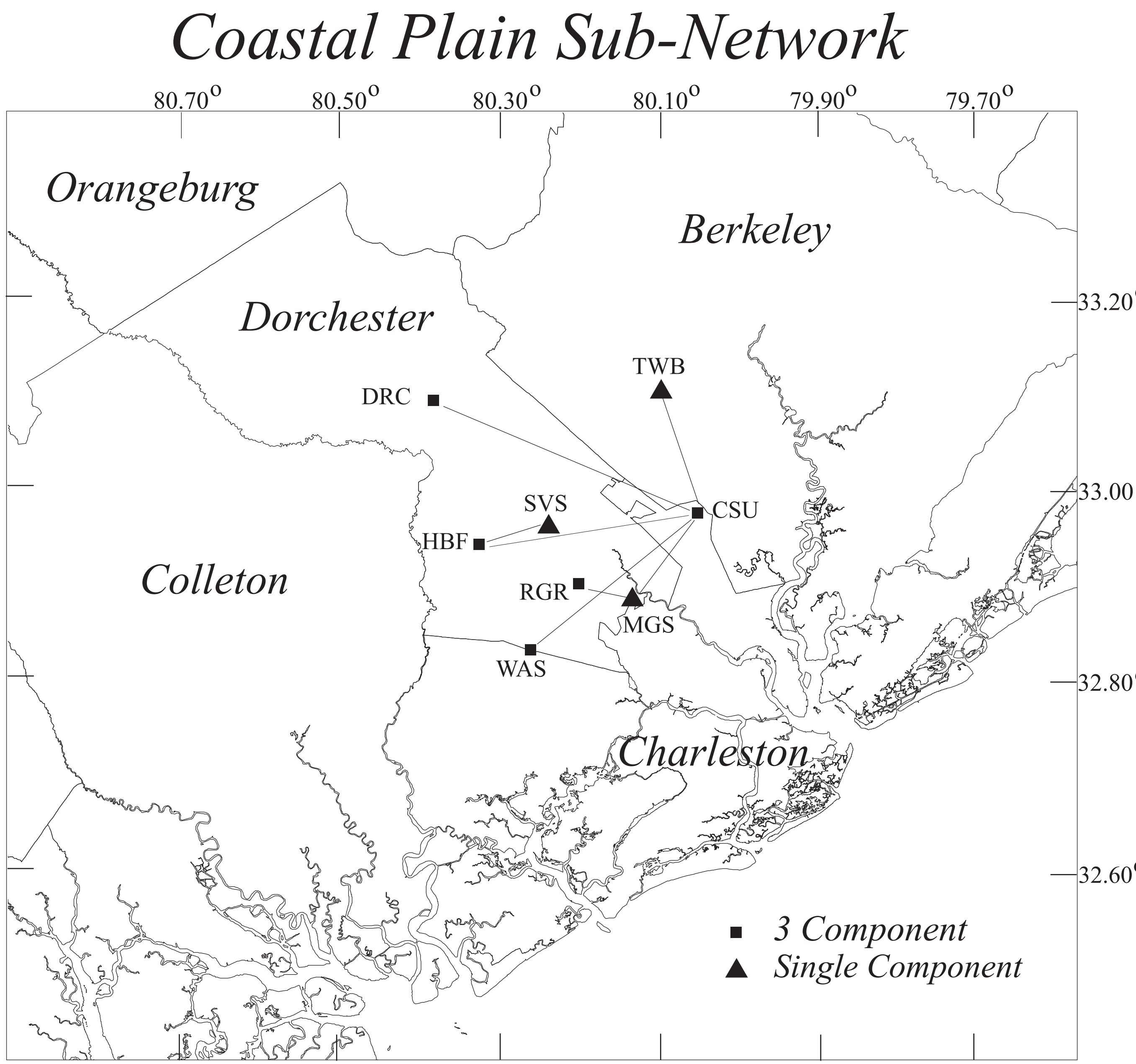

Figure 13: Telemetry routes for seismic data to Charleston Southern University.