TECHNICAL REPORT 91-1

SEISMIC ACTIVITY NEAR

THE V.C. SUMMER NUCLEAR STATION

FOR THE PERIOD

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BY

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INTRODUCTION

Analysis of the seismic activity near the V.C. Summer Nuclear Station in South Carolina between January 1 and March 31, 1991, is presented in this report. During this period, 22 events were recorded in the vicinity of Monticello Reservoir, twelve of which were located. The largest shock was of magnitude (M_L)=1.2 which occurred on February 26 (17:35:31.97 UTC).

SEISMIC NETWORK

Earthquakes during this period were recorded on stations of Monticello Reservoir and South Carolina networks. The configuration of the stations utilized to locate Monticello events is shown in Figure 1 and station coordinates are listed in Appendix I. The operational status of the network is given in Appendix II.

DATA ANALYSIS

Hypocentral locations of the events have been determined using the computer program HYPO71. The velocity model used in earthquake locations is given in Appendix III. The format of the output of HYPO71 is given in Appendix IV (Lee and Lahr, 1972). The event magnitude was determined from the signal duration at JSC, using the following relation:

$$M_L = -1.83 + 2.04 \text{ Log } D,$$

where D is the signal duration (seconds).

An estimate of daily energy release was determined using a simplified magnitude (M_L) - energy (E) relation by Gutenberg and Richter (1956):

$$\text{Log}_{10} E = 11.8 + 1.5 M_L.$$

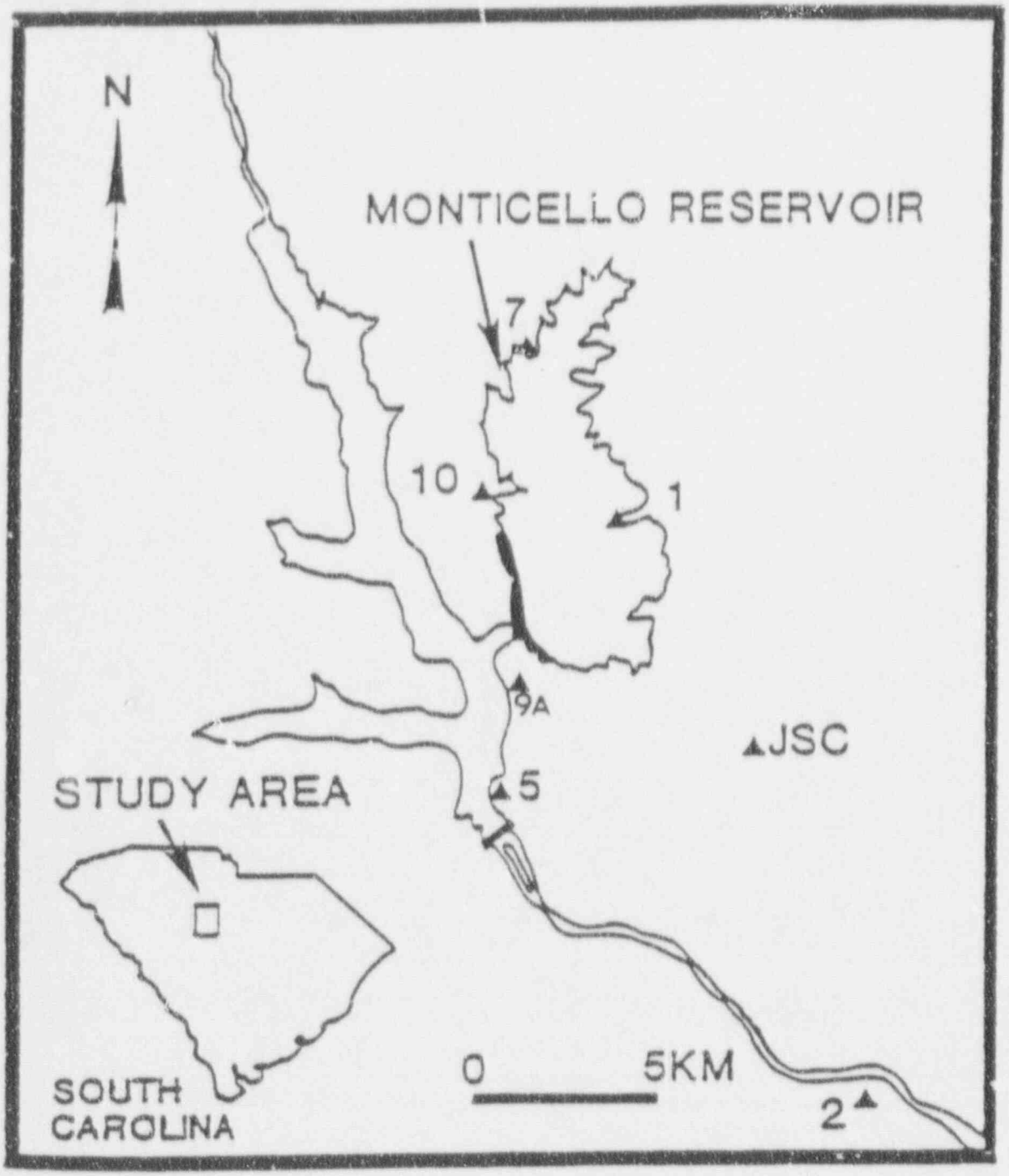

Figure 1. Location of Monticello Reservoir area showing seismic stations used in locating seismicity.

OBSERVED SEISMICITY FOR THE PERIOD JANUARY - MARCH 1991

During this period 22 earthquakes were recorded, of which twelve were located (Appendix V ; Figure 2). Most of these were located in the central part of the reservoir. However, the locations were of poor quality. Only two were of B quality and the rest were of C and D. Most of the nonlocated events were of small magnitude (< 1.0). Seven of the nonlocated events occurred close to station 007 and had S-P $\leq$ 1.0 sec. (Appendix VI).

The largest event of this quarter was of magnitude M_L = 1.2, which occurred on February 26 (17:35:31.97 UTC). There were two other events of magnitude > 1.0; eleven events of magnitude $\geq$ 0.0 and the rest of the events were of magnitude < 0.0. (Appendices V and VI). The seismicity in this period is comparable to that of the previous quarters. The long term decline in seismicity observed is continuing (Figure 3).

CORRELATION OF RESERVOIR WATER LEVEL WITH SEISMICITY

Monticello Reservoir is a pumped storage facility. Any decrease in reservoir level associated with power generation is recovered when water is pumped back into the reservoir. There can be normal variations up to approximately five feet per day between the maximum and minimum water levels. The water level has been monitored to see if there is any correlation between the daily or seasonal changes in the reservoir level and the local seismicity. Water level is compared with seismicity in Figure 4. The top panel shows the average water level; the error bars show the maximum and minimum water levels each day. The second panel shows the change in average water level from day to day. The

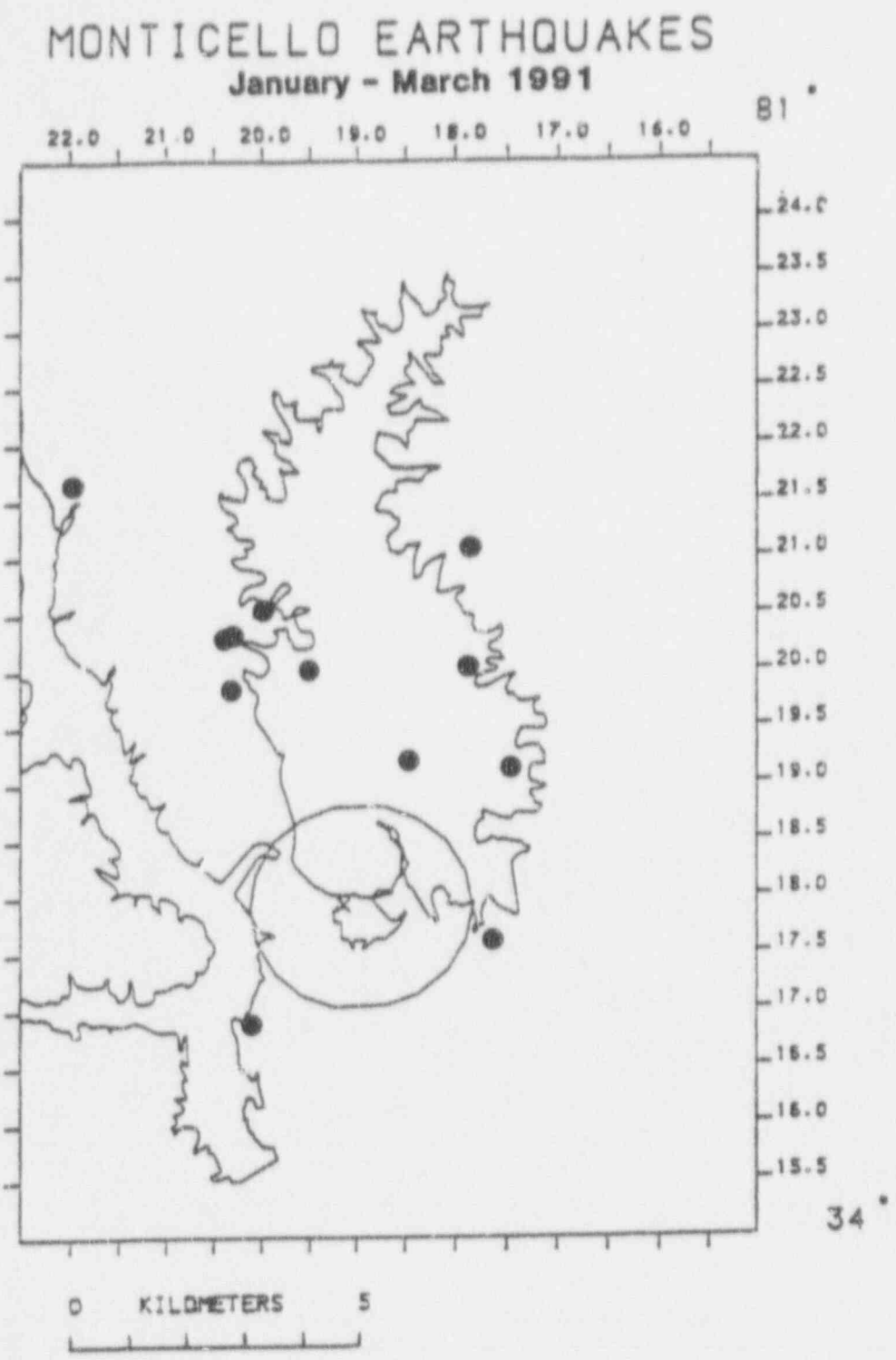

Figure 2. Earthquakes located near Monticello Resevoir during January - March, 1991.

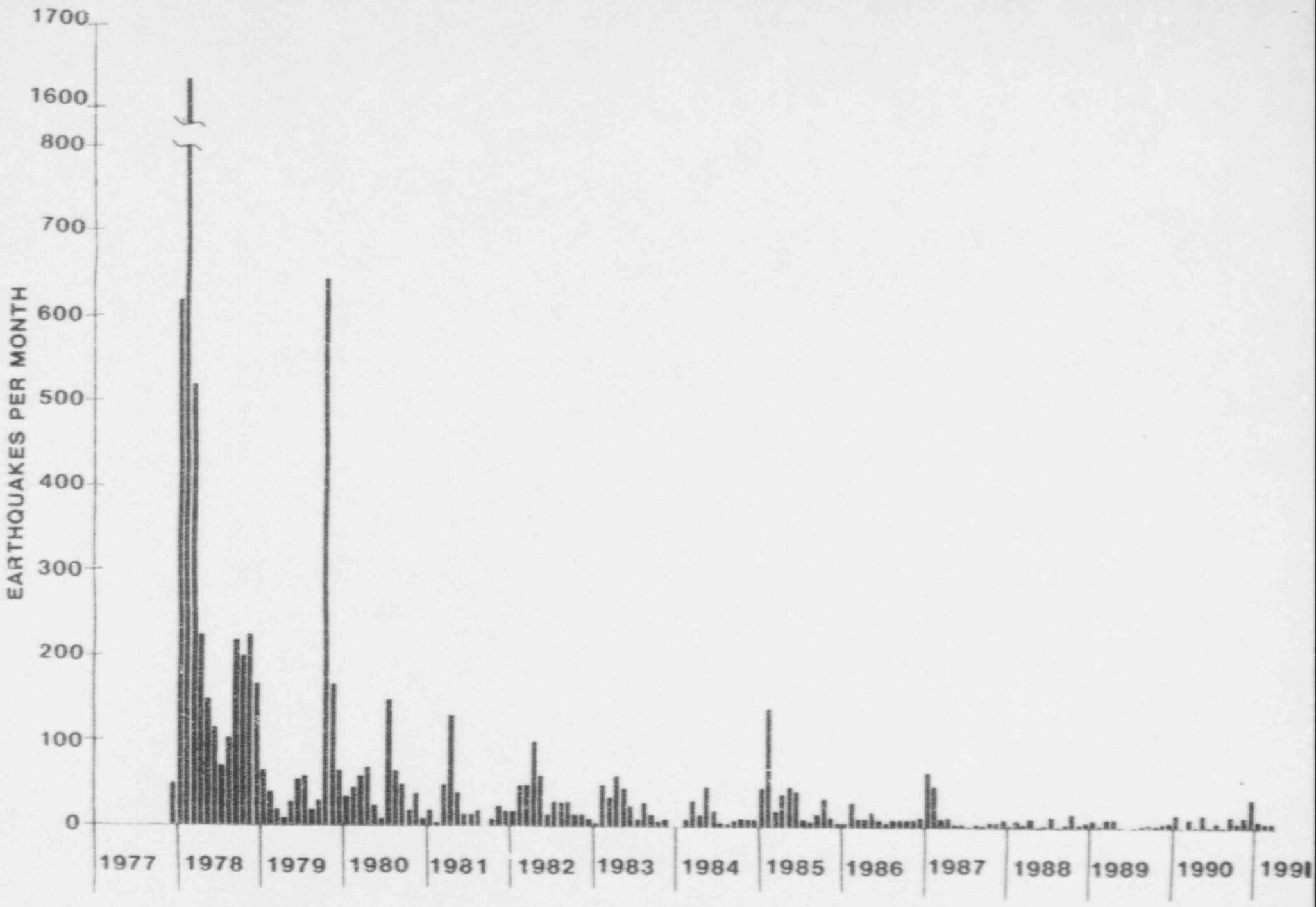

Figure 3. Earthquakes per month between impoundment and March 1991.

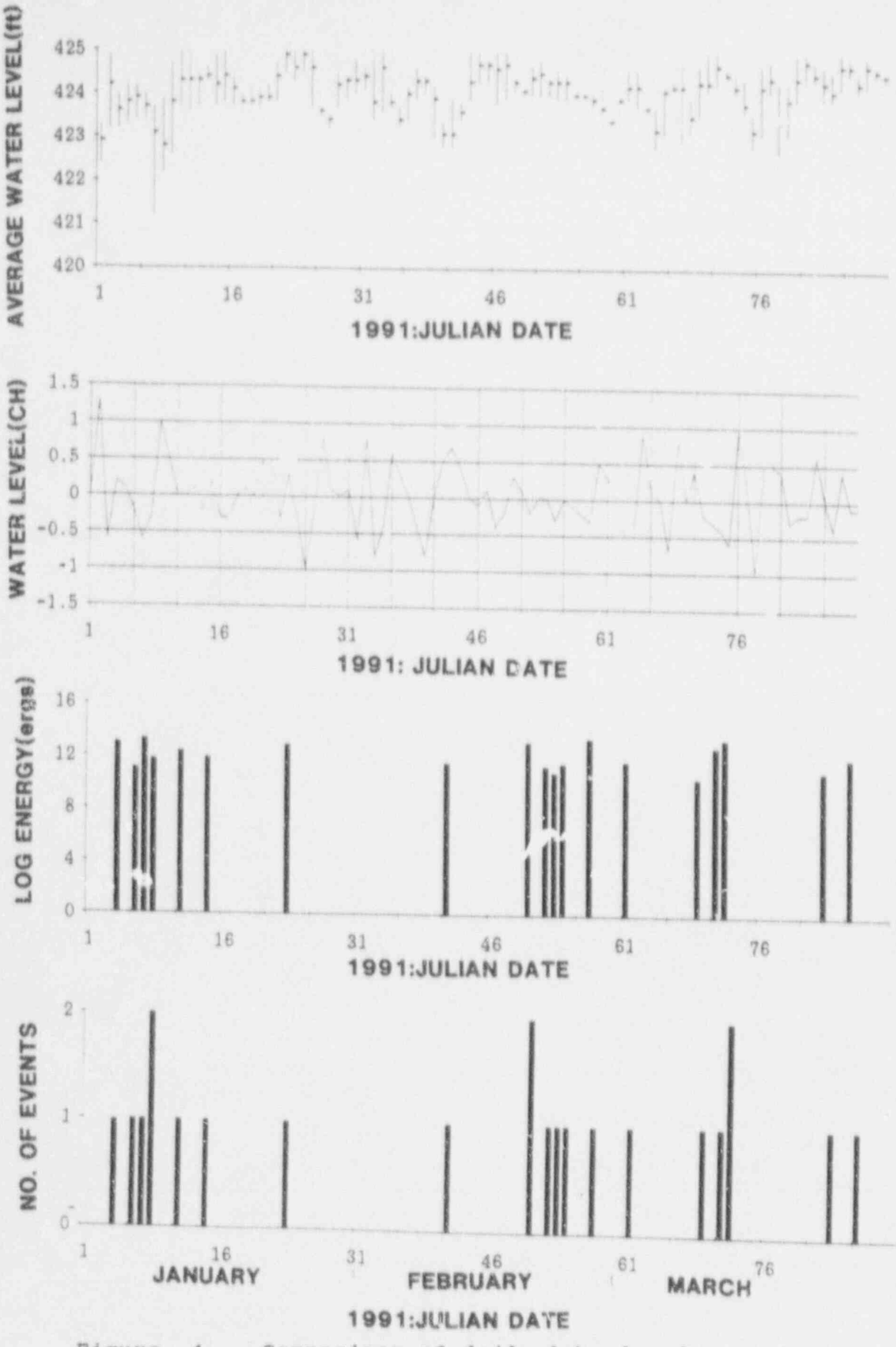

Figure 4. Comparison of daily lake level, variation in lake level, number of earthquakes and log of energy release (ergs per day) at Monicello Reservoir. Error bars in the top panel indicate daily fluctuations in lake level.

number of events per day and the log of the energy released per day are shown in the lower two histograms. These charts include all reported earthquakes listed in Appendices V and VI. The average water level, daily changes in water level, number of earthquakes and energy release are given in Appendix VII. No systematic correlation was observed between the seismicity and the reservoir level fluctuations.

CONCLUSIONS

The level of seismic activity during the first quarter of 1991 was low and comparable to that of the previous quarter. The largest event was of magnitude (M_L) = 1.2, which occurred on February 26 (17:35:31.97 UTC). There were two other events of magnitude (M_L) > 1.0. While the seismicity during the last quarter was confined to the northern part of the reservoir, the events during the current quarter occurred mostly within the center of the reservoir. No systematic correlation was observed betweeen the reservoir level fluctuations and the seismicity.

REFERENCES

Gutenberg, B. and Richter, C.F. (1956). Magnitude and energy of earthquakes, Ann. Geof. **9**, 1-15.

Lee, W.H.K. and Lahr, J.C.(1972). A computer program for determining hypocenter, magnitude and first motion pattern of local earthquakes, revisions of HYPO71, U.S. Geological Survey, Open-File Report, 100 pp.

APPENDIX I

STATION LOCATIONS

STN.	LAT. N	LONG. W
JSC	34° 16.80′	81° 15.60′
001	34° 19.91′	81° 17.74′
002	34° 11.58′	81° 13.81′
005	34° 16.05′	81° 20.05′
007	34° 22.23′	81° 19.50′
010	34° 20.18′	81° 20.25′
09A	34° 17.24′	81° 19.75′

APPENDIX II

SEISMIC STATION OPERATIONAL STATUS
JANUARY 01-MARCH 31, 1991

STATION	PERCENT DOWNTIME
JSC	3%
001	4%
002	62%
005	4%
007	4%
010	31%
09A	100%

APPENDIX III

MONTICELLO RESERVOIR

VELOCITY MODEL

Velocity km/sec	Depth to top km
1.00	0.00
5.40	0.03
5.90	0.18
6.10	0.46
6.30	0.82
8.10	30.00

APPENDIX IV

MONTICELLO EARTHQUAKE

HYPO71 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 = R_i^2/NO, where R_i 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.

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

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

APPENDIX V

MONTICELLO EARTHQUAKES
JANUARY 01-MARCH 31, 1991

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM
910104	2115 7.80	34-16.83	81-20.14	0.15	0.99	4	192	1.4	0.07			C1
910106	2132 37.41	34-20.01	81-17.84	2.78	-0.40	6	173	0.2	0.08	1.2	1.3	C1
910107	2053 27.74	34-19.16	81-18.43	0.95	1.02	10	101	1.7	0.09	0.4	2.4	B1
910108	326 9.76	34-19.13	81-17.48	0.10	0.01	4	186	5.2	0.08			C1
910219	10 0 29.17	34-19.94	81-19.54	1.15	0.73	9	106	1.2	0.07	0.4	0.9	B1
910219	10 2 45.46	34-20.28	81-20.35	2.60	0.82	9	203	0.2	0.09	0.6	1.0	C1
910223	315 4.79	34-21.03	81-17.84	1.00	-0.11	3	225	2.1	0.08			C1
910226	1735 31.97	34-21.59	81-21.98	1.68	1.15	8	269	3.7	0.08	0.9	2.1	C1
910312	1121 5.19	34-19.73	81-20.35	1.75	0.78	9	194	0.9	0.08	0.4	1.0	C1
910313	9 3 13.01	34-20.28	81-20.35	1.00	0.95	8	203	0.2	0.08	0.5	0.8	C1
910313	2259 34.17	34-17.58	81-17.55	0.87	1.02	8	203	3.3	0.03	0.7	14.5	D1
910327	1646 32.66	34-20.46	81-19.97	2.78	0.21	10	153	0.7	0.09	0.6	0.6	B1

APPENDIX VI

LIST OF EVENTS WITH S-P ≤ 2.5 SEC RECORDED AROUND MONTICELLO RESERVOIR DURING 1 JANUARY 1991 - 31 MARCH 1991

DATE	STATION	P-ARRIVAL TIME H MIN SEC	S-P SEC	EP.DIST s-p*8.5km	DUR SEC	MAG
91 01 08	007	03 33 59.40	*	-	1.0	-1.8
"	JSC	59.50				
91 01 11	007	06 47 52.00	*	-	13.0	0.4
	JSC	54.70	0.3	2.6		
91 01 14	007	17 27 21.90	*	-	9.0	0.1
91 01 23	007	09 44 10.00	*	-	18.0	0.7
"	JSC	11.60	0.6	5.1		
91 02 10	010	21 57 02.60	1.6	13.6	7.0	-0.1
91 02 21	007	09 27 15.30	0.7	6.0	6.0	-0.2
91 02 22	010	18 15 35.50	1.1	9.4	4.0	-6.0
91 03 02	JSC	04 06 09.70	*	-	8.0	0.0
91 03 10	007	06 43 27.10	*	-	3.0	-0.9
91 03 24	007	04 35 24 80	1.0	8.5	5.0	-0.4

*Event is very close to the station; (S-P) not clear.

Appendix VII

Maximum and minimum water levels (ft), change in water level, number of earthquakes and log energy release (ergs per day) at Monticello Reservoir during January 1 - March 31, 1991.

	A	B	C	D	E	F	G
1	DATE	WL(max)	WL(min)	WL(avg)	CHANGE	No.Eqs	ENERGY
2	1	423.3	422.4	422.9	0	0	0
3	2	424.9	423.2	424.2	1.3	0	0
4	3	424	423.2	423.6	-0.6	0	0
5	4	424.2	423.3	423.8	0.2	2	13.6
6	5	424.2	423.4	423.9	0.1	0	0
7	6	424	423.4	423.7	-0.2	1	11.1
8	7	423.7	421.2	423.1	-0.6	1	13.3
9	8	423.9	422.2	422.8	-0.3	2	11.8
10	9	424.7	422.6	423.8	1	0	0
11	10	425	423.7	424.3	0.5	0	0
12	11	425	423.6	424.3	0	1	12.4
13	12	424.5	423.7	424.3	0	0	0
14	13	424.6	424.3	424.4	0.1	0	0
15	14	424.9	423.7	424.2	-0.2	1	11.9
16	15	425	423.8	424.4	0.2	0	0
17	16	424.4	423.7	424.1	-0.3	0	0
18	17	424	423.7	423.8	-0.3	0	0
19	18	424.2	423.6	423.8	0	0	0
20	19	424.1	423.7	423.9	0.1	0	0
21	20	424.2	423.8	423.9	0	0	0
22	21	424.7	423.8	424.4	0.5	0	0
23	22	425	424.5	424.9	0.5	0	0
24	23	425	424.3	424.6	-0.3	1	12.9
25	24	425	424.5	424.9	0.3	0	0
26	25	425	423.7	424.6	-0.3	0	0
27	26	423.7	423.5	423.6	-1	0	0
28	27	423.5	423.2	423.4	-0.2	0	0
29	28	424.5	423.7	424.2	0.8	0	0
30	29	424.4	423.9	424.3	0.1	0	0
31	30	424.8	424	424.3	0	0	0
32	31	424.6	424.1	424.4	0.1	0	0
33	32	424.8	423.4	423.8	-0.6	0	0
34	33	425	423.6	424.6	0.8	0	0
35	34	424	423.7	423.8	-0.8	0	0
36	35	423.7	423.3	423.4	-0.4	0	0
37	36	424.2	423.4	424	0.6	0	0
38	37	424.6	423.9	424.3	0.3	0	0
39	38	424.4	424	424.3	0	0	0
40	39	424.2	423	423.9	-0.4	0	0

	A	B	C	D	E	F	G
41	40	423.4	422.8	423.1	-0.8	0	0
42	41	423.9	422.8	423.1	0	1	11.6
43	42	423.8	423.4	423.6	0.5	0	0
44	43	425	423.9	424.3	0.7	0	0
45	44	425	424.3	424.7	0.4	0	0
46	45	424.8	424.3	424.7	0	0	0
47	46	425	423.8	424.6	-0.1	0	0
48	47	425	423.9	424.7	0.1	0	0
49	48	424.4	424.1	424.3	-0.4	0	0
50	49	424.1	424.1	424.1	-0.2	0	0
51	50	424.7	424	424.4	0.3	2	13.2
52	51	424.8	424	424.5	0.1	0	0
53	52	424.4	424	424.3	-0.2	1	11.4
54	53	424.6	423.9	424.3	0	1	10.9
55	54	424.5	423.9	424.3	0	1	11.6
56	55	424	424	424	-0.3	0	0
57	56	424	424	424	0	0	0
58	57	424.1	423.7	423.9	-0.1	1	13.5
59	58	424.3	423.3	423.7	-0.2	0	0
60	59	424	423.3	423.4	-0.3	0	0
61	60	424.1	423.5	423.9	0.5	0	0
62	61	424.6	423.9	424.2	0.3	1	11.8
63	62	424.6	423.7	424.2	0	0	0
64	63	423.7	423.7	423.7	-0.5	0	0
65	64	423.7	422.8	423.2	-0.5	0	0
66	65	424.2	423.1	424.1	0.9	0	0
67	66	424.4	424.1	424.2	0.1	0	0
68	67	424.9	422.9	424.2	0	0	0
69	68	424	423.1	423.5	-0.7	0	0
70	69	424.7	423.5	424.3	0.8	1	10.5
71	70	425	424.1	424.3	0	0	0
72	71	425	424.3	424.7	0.4	1	12.9
73	72	424.6	424.5	424.5	-0.2	2	13.5
74	73	424.5	424.1	424.2	-0.3	0	0
75	74	424.4	423.6	423.8	-0.4	0	0
76	75	423.6	422.8	423.2	-0.6	0	0
77	76	424.7	423.1	424.2	1	0	0
78	77	424.8	424.1	424.4	0.2	0	0
79	78	424.3	422.7	423.4	-1	0	0
80	79	424.3	423.1	423.9	0.5	0	0

	A	B	C	D	E	F	G
81	80	425	423.9	424.4	0.5	0	0
82	81	425	424.3	424.8	0.4	0	0
83	82	424.8	424.4	424.5	-0.3	0	0
84	83	424.7	423.9	424.3	-0.2	1	11.1
85	84	424.6	423.9	424.1	-0.2	0	0
86	85	425	424.2	424.7	0.6	0	0
87	86	424.9	424.5	424.7	0	1	12.1
88	87	424.5	424.1	424.3	-0.4	0	0
89	88	424.9	424.2	424.7	0.4	0	0
90	89	424.7	424.5	424.6	-0.1	0	0
91	90	424.5	424.5	424.5	-0.1	0	0