TECHNICAL REPORT 91-2

SEISMIC ACTIVITY NEAR THE V.C. SUMMER NUCLEAR STATION

FOR THE PERIOD

APRIL-JUNE 1991

BY

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INTRODUCTION

Analysis of the seismic activity near the V.C. Summer Nuclear Station in South Carolina between April 1 and June 30, 1991 is presented in this report. During this period, 38 events were recorded in the vicinity of Monticello Reservoir, 31 of which were located. The largest shock was of magnitude M_L=2.0 which occurred on April 29 (18:41:07.72 UTC).

SEISMIC NETWORK

Earthquakes during this period were recorded on stations of Monticello Reservoir and South Carolina Seismic Networks. The configuration of 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 have been determined using the computer program HYPO71(Lee and Lahr, 1972). The velocity model used in the earthquake locations is given in Appendix III. The format of the output is given in Appendix IV. 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):

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

OBSERVED SEISMICITY DURING APRIL-JUNE 1991

During this period 38 earthquakes were recorded, of which 31 were located (Figure 2a). Most of the events occurred during April- May (Figures 2b, 2c) and were located in the central part of the reservoir. During June the activity was of low level (Figure 2d).

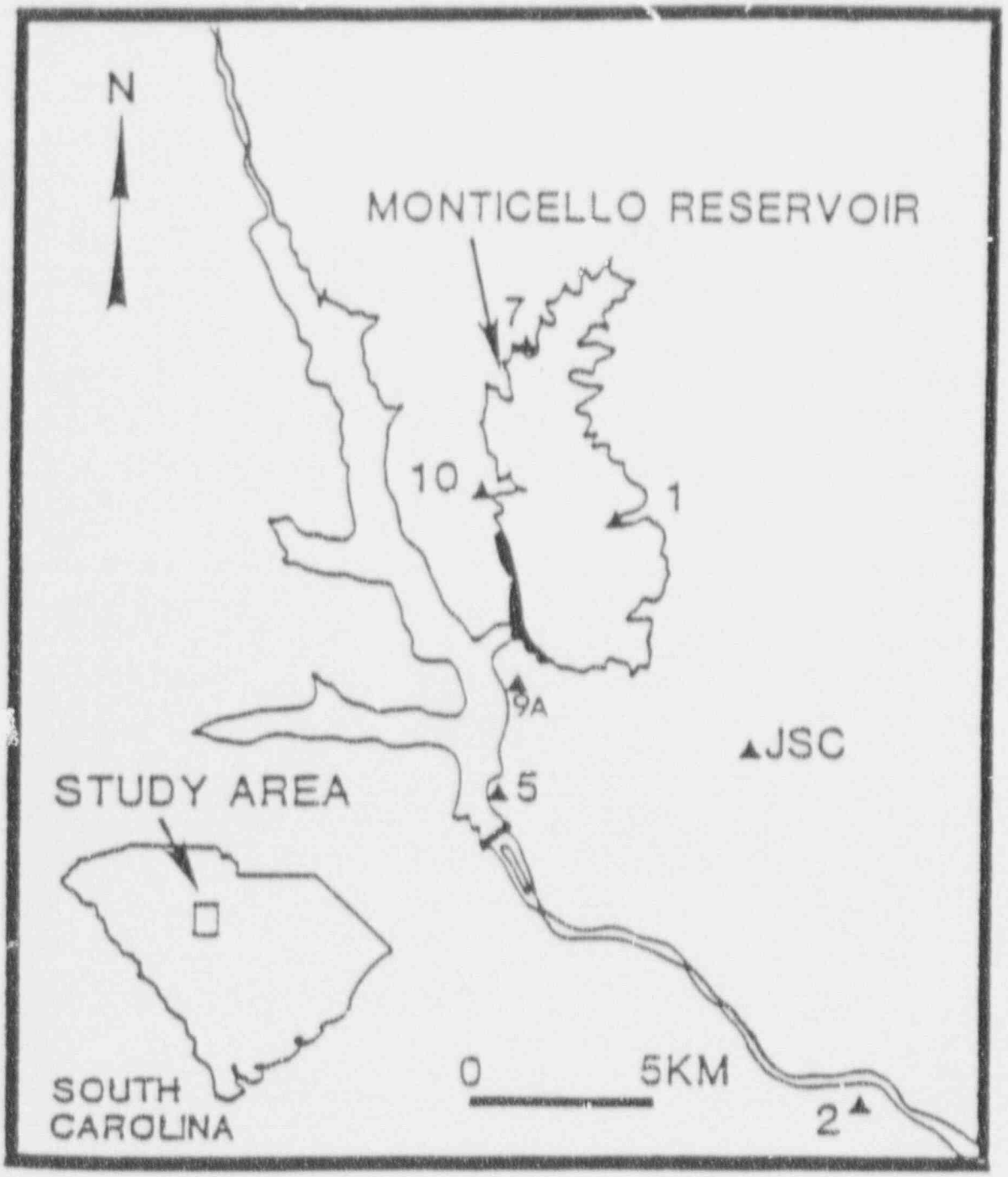

Figure 1. Location of Monticello Reservoir area showing seismic stations used in locating seismicity.

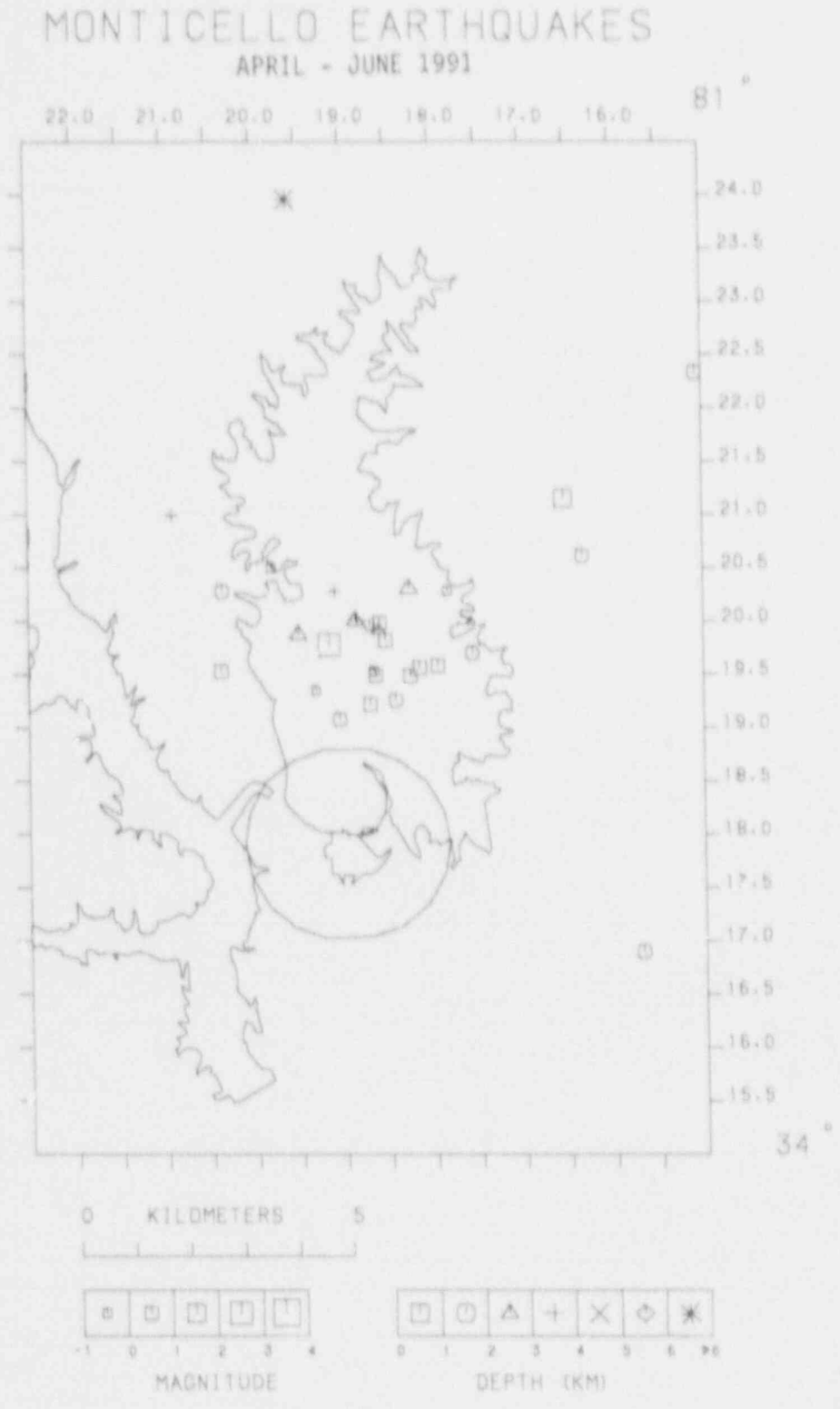

Figure 2a. Earthquakes located near Monticello Reservoir during April - June, 1991.

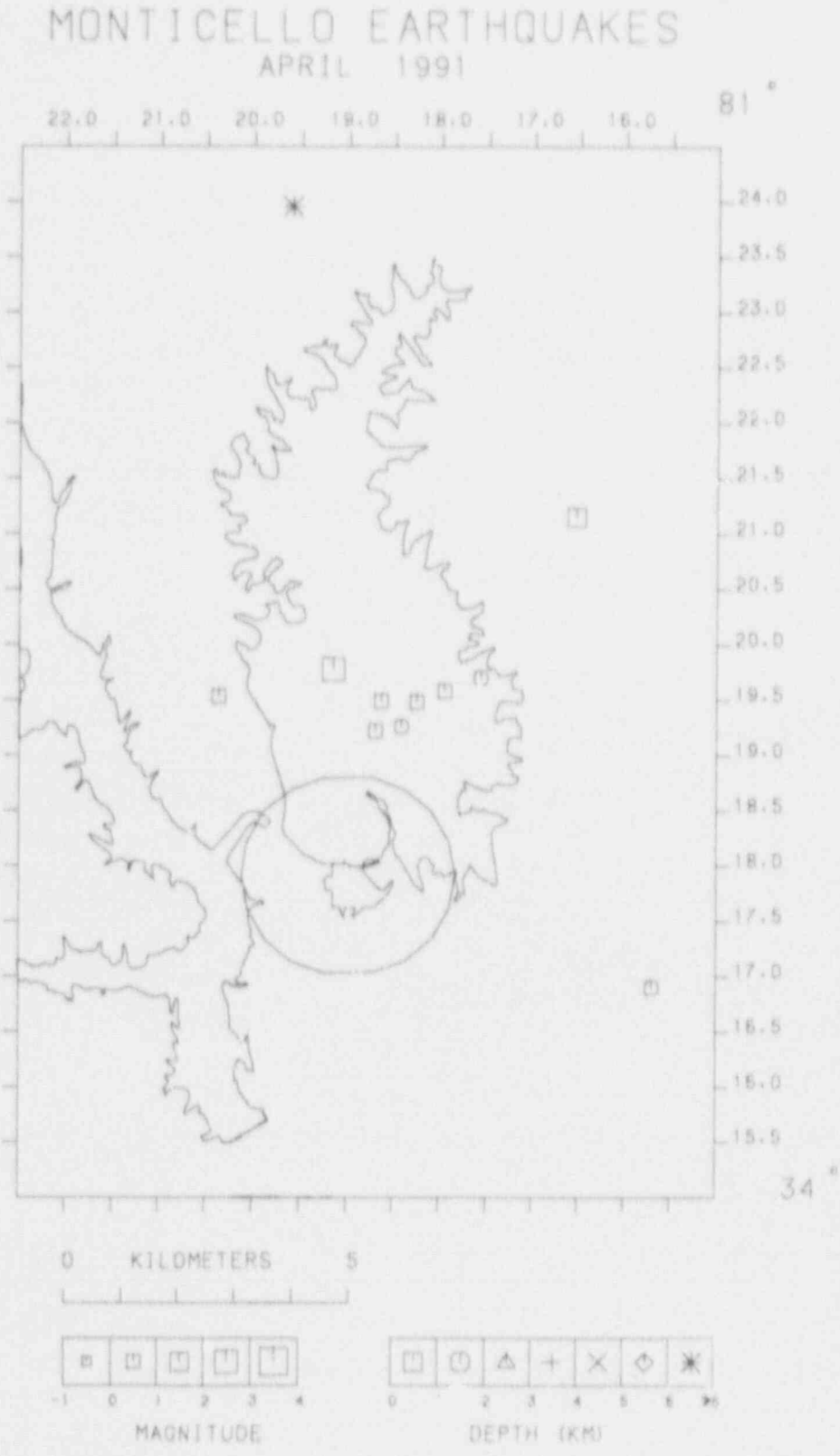

Figure 2b. Earthquakes located near Monticello Reservoir during April 1991.

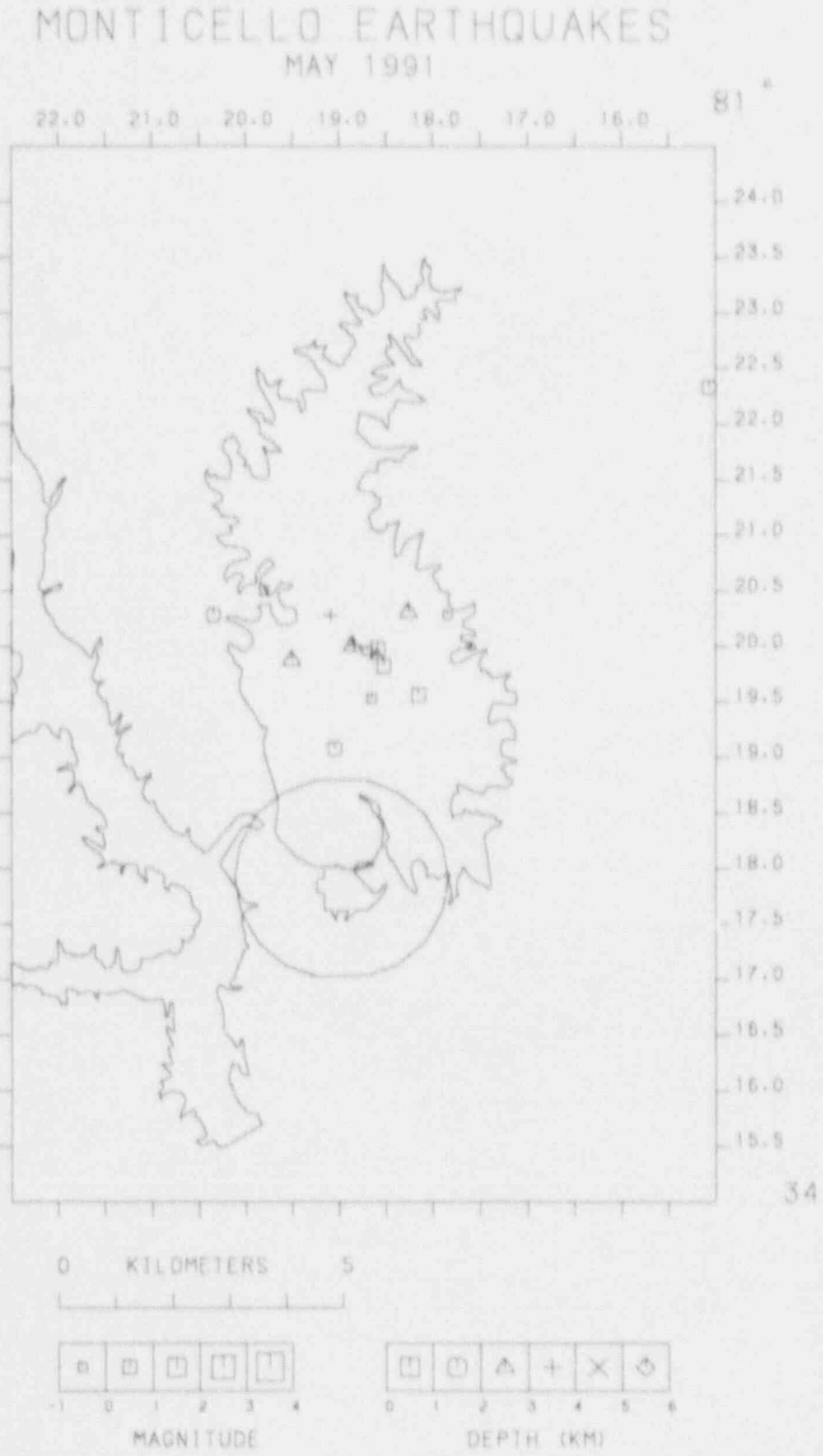

Figure 2c. Earthquakes located near Monticello Reservoir during May 1991.

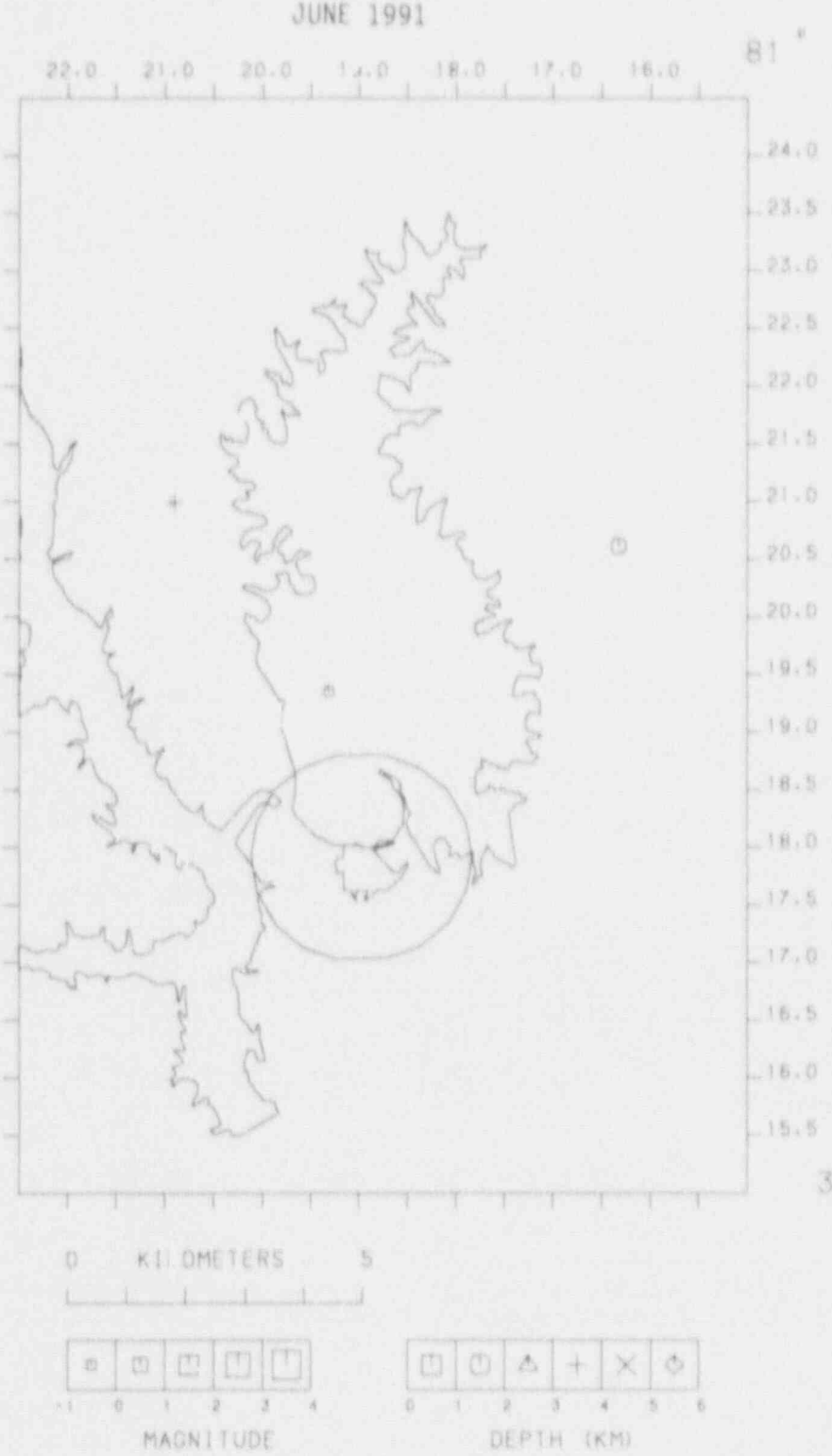

Figure 2d. Earthquakes located near Monticello Reservoir during June 1991.

Most of the located events were of poor quality. Only six events were of B quality and the rest were of C and D quality. Most of the unlocated events were of low magnitude ($M_L \leq 0.6$) with the exception of one event on May 06 (M_L=1.2; 18:52:24.80) which was recorded at stations JSC and 007 (Appendix VI).

The largest event of this quarter was of magnitude M_L = 2.0 which occurred on April 29 (18:41:07.72 UTC) . There were six other events of magnitude ≥ 1.0; 21 events of magnitude ≥ 0.0 and the rest of the events were of magnitude < 0.0. The long term decline in seismicity observed at Monticello is continuing (Figure 3). However, the observed seismicity during this quarter was relatively higher (larger number of events) compared to the previous quarter (Figure 3).

The seismicity during this quarter occurred primarily in one sequence during April 29- May 03. Most of the events during this swarm occurred in the center of the lake (Figures 2 b and 2c). The largest event during this quarter was a part of this sequence (April 29, M_L=2.0). This event was followed by several aftershocks, five of which were of magnitude ≥1.0.

CORRELATION OF WATER LEVEL WITH SEISMICITY

Monticello Reservoir is a pumped storage facility. Any decrease in the reservoir level associated with power generation is recovered when water is pumped back into the reservoir. There can be normal variations up to five feet per day between 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 levels are 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 water level from day to day. The number of events per day and the log of energy released are shown in the lower histograms. These charts include all reported earthquakes listed in Appendix 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 reservoir level fluctuations.

CONCLUSIONS

The level of seismicity during the second quarter was higher, compared to the

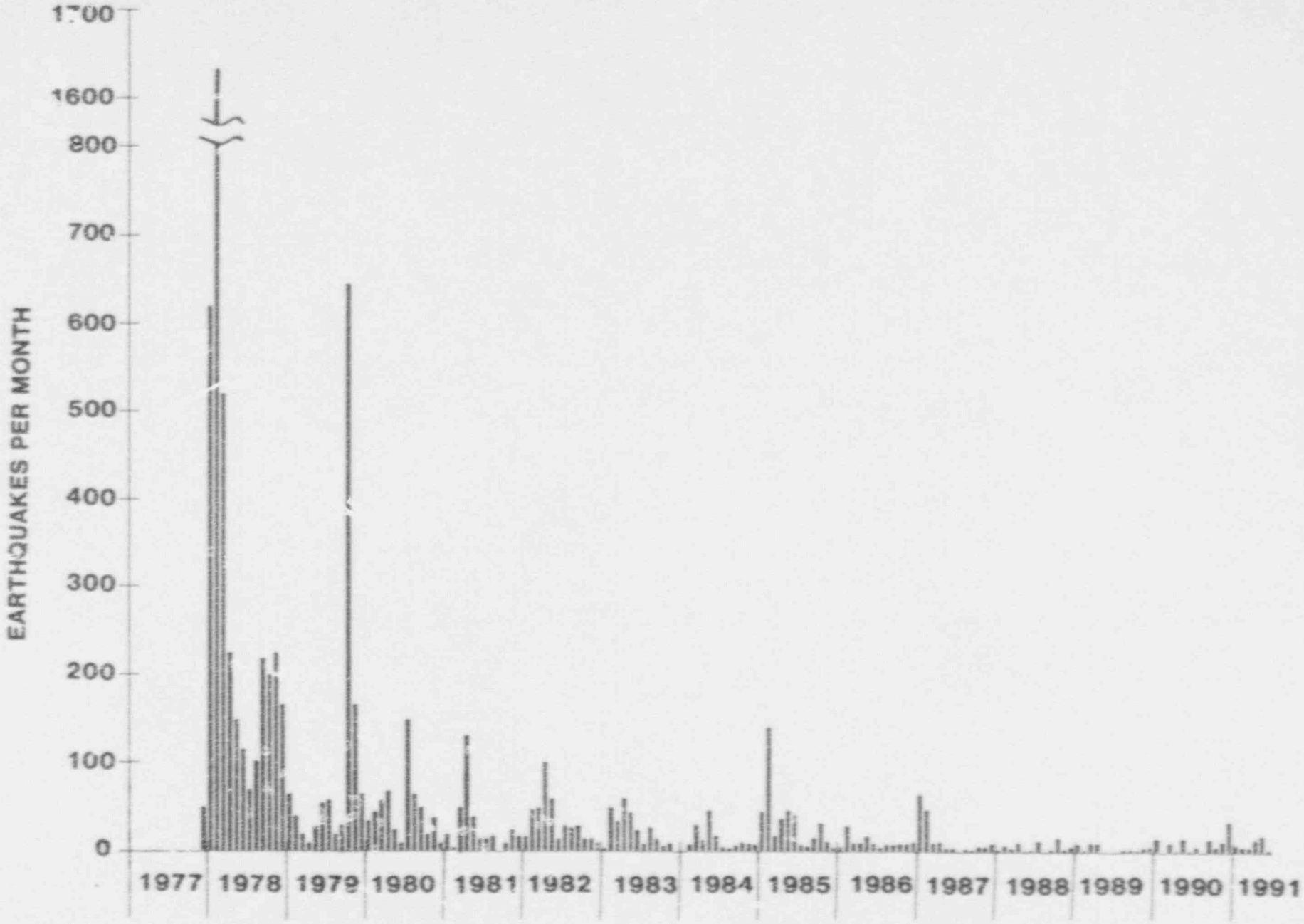

Figure 3. Earthquakes per month between impoundment and June, 1991.

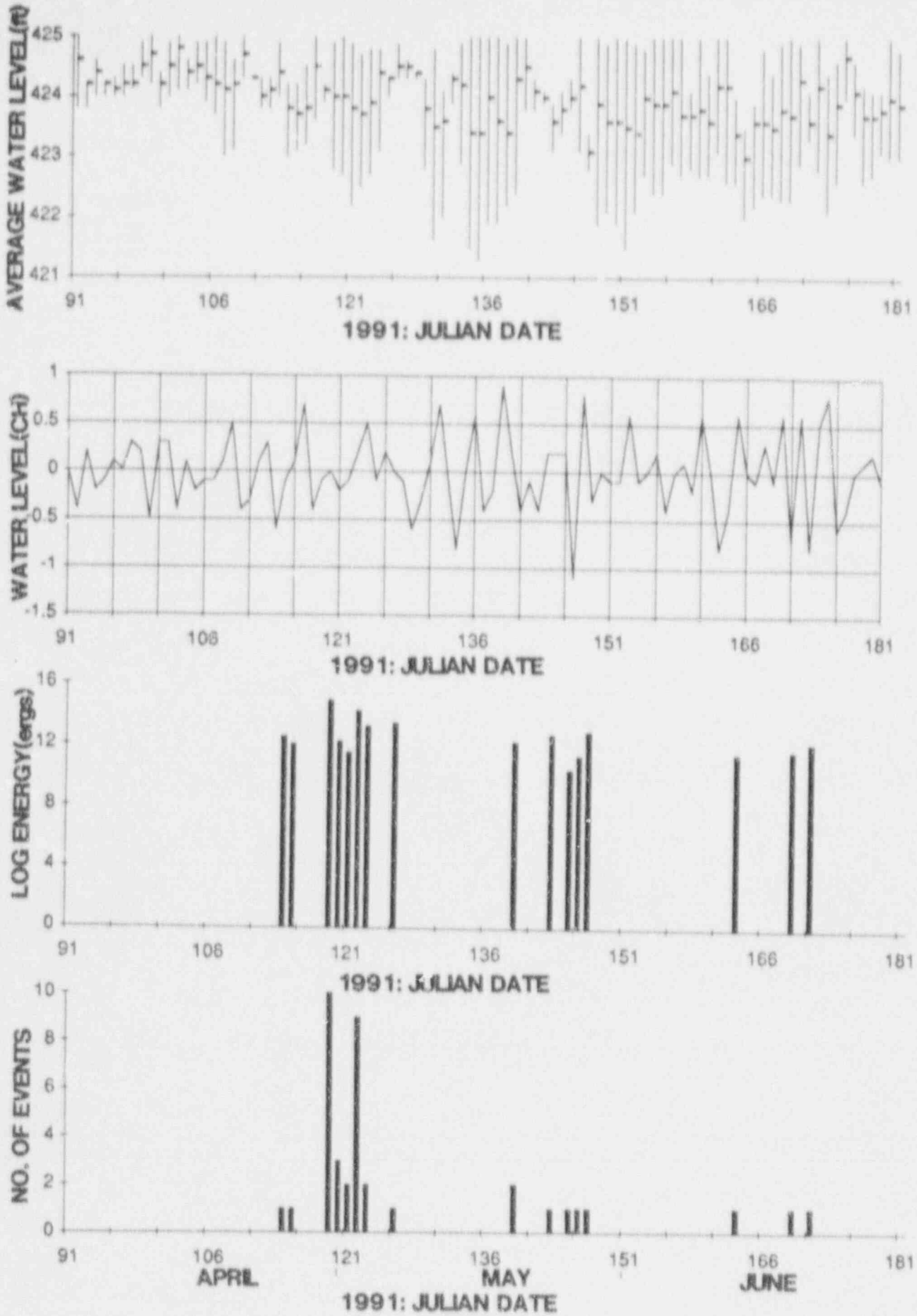

Figure 4. Comparison of daily lake level, variation in lake level, number of earthquakes and log of energy release (ergs per day) at Monicello Reservoir. Error bars in the top panel indicate daily fluctuations in lake level.

previous quarter. The largest event was of magnitude $M_L = 2.0$ which occurred on April 29 (18:41:07.72 UTC). There were six other events of magnitude ≥ 1.0. The seismicity during this quarter was primarily confined to the central part of the reservoir as in the previous quarter (Talwani *et al.*, 1991). No systematic correlation was observed between 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.

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APPENDIX I

STATION LOCATIONS

STATION	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
APRIL 01-JUNE 30,1991

STATION	PERCENT DOWNTIME
JSC	6
001	7
002	8
005	12
007	6
010	8
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 EARTHQUAKES
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.

* 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.

APPENDIX V

MONTICELLO EARTHQUAKES

APRIL-JUNE 1991

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM
0425	1416 41.31	34-19.53	81-20.37	0.23	0.21	5	244	1.2	0.06	0.1	0.1	C1
429	1113 54.77	34-21.15	81-16.53	0.69	1.72	4	233	5.0	0.21			C1
429	1251 50.15	34-19.70	81-17.57	1.93	0.82	7	183	4.2	0.07	0.5	2.2	C1
429	14 3 31.91	34-19.58	81-17.95	0.23	0.44	8	171	3.7	0.10	0.7	2.7	C1
0429	1423 42.66	34-16.90	81-15.70	1.00	0.21	5	172	0.2	0.16	0.8	0.7	C1
910429	16 3 13.10	34-19.22	81-18.70	0.55	0.82	6	154	3.0	0.09	1.2	6.2	C1
910429	1614 51.45	34-19.26	81-18.42	1.11	0.57	9	153	3.3	0.12	0.8	5.0	C1
910429	1841 7.72	34-19.78	81-19.16	0.96	2.00	5	142	1.8	0.05	1.2	4.5	C1
910429	2012 19.31	34-19.49	81-18.64	0.81	0.82	7	151	2.8	0.10	1.1	2.1	C1
910429	2025 56.74	34-23.96	81-19.60	6.84	1.02	5	327	3.2	0.16	16.0	14.1	D1
910430	332 0.77	34-19.48	81-18.25	0.85	0.21	6	161	3.3	0.10	2.0	39.7	C1
910501	4 4 6.91	34-20.00	81-17.58	2.88	-0.24	6	188	4.1	0.10	1.7	2.7	C1
910501	13 5 55.63	34-19.53	81-18.66	0.63	-0.40	6	152	2.7	0.14	3.8	18.0	C1
910502	1035 18.94	34-19.88	81-19.51	2.94	1.18	10	110	1.3	0.10	0.6	0.7	B1
910502	1040 31.25	34-19.82	81-18.53	0.92	0.12	8	160	2.7	0.09	0.6	4.6	C1
910502	1222 55.71	34-20.01	81-18.86	2.60	1.02	12	110	1.7	0.09	0.5	0.6	B1
910502	1321 58.12	34-19.96	81-18.70	0.73	-0.60	7	157	2.4	0.12	1.5	3.2	C1
910502	1750 58.13	34-19.98	81-18.59	0.02	0.82	4	161	2.6	0.03			C1
910502	2339 52.38	34-20.31	81-18.26	2.84	1.54	11	161	1.1	0.19	1.3	1.7	C1
910502	2351 19.12	34-20.28	81-19.09	3.80	0.21	12	118	1.8	0.13	0.8	0.8	B1
910502	2351 35.81	34-20.28	81-17.84	1.00	-0.40	8	187	0.7	0.13	1.0	1.3	C1
910503	0 3 5.87	34-20.01	81-18.84	3.27	0.82	11	110	1.7	0.10	0.6	0.7	B1
910503	110 38.96	34-19.92	81-18.60	2.22	0.82	12	108	1.3	0.08	0.4	0.6	B1
910519	5 8 2.82	34-19.56	81-18.15	0.87	0.12	6	165	3.4	0.07	0.6	9.0	C1
910519	511 8.19	34-19.08	81-19.05	1.93	0.21	7	168	2.7	0.07	0.9	1.4	B1
910523	1546 16.35	34-22.33	81-15.07	1.85	0.68	5	266	6.8	0.11	4.7	15.9	D1
910526	23 3 46.60	34-20.50	81-19.81	0.28	-0.24	6	139	0.9	0.05	1.0	2.5	C1
910527	419 28.32	34-20.28	81-20.35	1.00	0.82	12	203	0.2	0.16	1.0	0.8	C1
910612	2332 26.38	34-19.35	81-19.32	1.52	-0.11	5	188	2.1	0.12	4.2	4.4	D1
910618	17 6 12.33	34-20.61	81-16.33	1.83	0.01	6	229	2.5	0.13	3.0	3.7	D1
910620	1919 23.33	34-20.99	81-20.90	3.35	0.37	9	231	1.8	0.11	1.0	0.8	C1

APPENDIX VI

LIST OF EVENTS WITH S-P ≤ 2.5 SEC RECORDED AROUND MONTICELLO RESERVOIR DURING 1 APRIL 1991 - 30 JUNE 1991

DATE	STATION	P-ARRIVAL TIME H MIN SEC	S-P SEC	EP.DIST s-p·8.5km	DUR SEC	MAG
91 04 24	JSC	18 25 35.10	1.9	16.2	15.0	0.6
91 04 29	007	11 25 39.30	*	*	5.0	0.4
	JSC	39.80	0.6	05.1	-	-
91 04 30	JSC	01 54 28.00	*	*	10.0	0.2
91 04 30	JSC	19 02 26.80	*	*	3.0	-0.9
91 05 02	JSC	22 00 47.90	0.5	04.7	5.0	-0.4
91 05 06	007	18 52 24.80	1.2	10.2	30.0	1.2
	JSC	26.50	1.5	12.8	-	-
91 05 25	JSC	21 55 36.10	0.6	05.1	3.0	-0.9

* 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 April 1 - June 30, 1991.

	A	B	C	D	E	F	G
1	DATE	WL(max)	WL(min)	WL(avg)	CHANGE	No.Eqs	ENERGY
2	91	425	423.8	424.6	0	0	0
3	92	424.2	423.8	424.2	-0.4	0	0
4	93	424.6	424	424.4	0.2	0	0
5	94	424.2	424	424.2	-0.2	0	0
6	95	424.3	424	424.1	-0.1	0	0
7	96	424.5	424	424.2	0.1	0	0
8	97	424.5	424.1	424.2	0	0	0
9	98	424.9	424.3	424.5	0.3	0	0
10	99	425	424.2	424.7	0.2	0	0
11	100	424.4	423.8	424.2	-0.5	0	0
12	101	424.9	424	424.5	0.3	0	0
13	102	425	424.1	424.8	0.3	0	0
14	103	424.6	424.1	424.4	-0.4	0	0
15	104	424.9	424.2	424.5	0.1	0	0
16	105	424.9	423.9	424.3	-0.2	0	0
17	106	425	423.7	424.2	-0.1	0	0
18	107	424.9	423	424.1	-0.1	0	0
19	108	424.6	423.1	424.2	0.1	0	0
20	109	425	424.3	424.7	0.5	0	0
21	110	424.3	424.3	424.3	-0.4	0	0
22	111	424.3	423.8	424	-0.3	0	0
23	112	424.3	423.8	424.1	0.1	0	0
24	113	424.9	424	424.4	0.3	0	0
25	114	424.2	423	423.8	-0.6	1	12.6
26	115	424.2	423.1	423.7	-0.1	1	12.1
27	116	424.5	423.2	423.8	0.1	0	0
28	117	425	423.6	424.5	0.7	0	0
29	118	424.2	423.9	424.1	-0.4	0	0
30	119	424.9	422.8	424	-0.1	10	15
31	120	425	422.7	424	0	3	12.3
32	121	424.9	422.2	423.8	-0.2	2	11.6
33	122	424.7	422.5	423.7	-0.1	9	14.3
34	123	424.8	422.7	423.9	0.2	2	13.3
35	124	424.8	423.1	424.4	0.5	0	0
36	125	424.3	424	424.3	-0.1	0	0
37	126	424.9	424.3	424.5	0.2	1	13.5
38	127	424.6	424.3	424.5	0	0	0
39	128	424.4	424.3	424.4	-0.1	0	0
40	129	424.3	422.8	423.8	-0.6	0	0
41	130	424.8	421.6	423.5	-0.3	0	0
42	131	424.1	422	423.6	0.1	0	0
43	132	424.4	423.9	424.3	0.7	0	0
44	133	424.9	422.9	424.2	-0.1	0	0
45	134	425	421.5	423.4	-0.8	0	0
46	135	425	421.3	423.4	0	0	0
47	136	425	421.9	424	0.6	0	0
48	137	425	421.9	423.6	-0.4	0	0

	A	B	C	D	E	F	G
49	138	424.9	422.2	423.4	-0.2	0	0
50	139	425	422.4	424.3	0.9	2	12.3
51	140	425	423.8	424.5	0.2	0	0
52	141	424.3	423.8	424.1	-0.4	0	0
53	142	424.1	423.9	424	-0.1	0	0
54	143	423.9	423.1	423.6	-0.4	1	12.8
55	144	424.1	423.4	423.8	0.2	0	0
56	145	424.3	423.8	424	0.2	1	10.5
57	146	425	423.1	424.2	0.2	1	11.4
58	147	423.4	422.8	423.1	-1.1	1	13
59	148	425	421.9	423.9	0.8	0	0
60	149	424.9	422.1	423.6	-0.3	0	0
61	150	425	421.9	423.6	0	0	0
62	151	425	421.5	423.5	-0.1	0	0
63	152	424.9	422.1	423.4	-0.1	0	0
64	153	424.8	422.7	424	0.6	0	0
65	154	425	422.4	423.9	-0.1	0	0
66	155	425	422.4	423.9	0	0	0
67	156	425	422.9	424.1	0.2	0	0
68	157	425	422.7	423.7	-0.4	0	0
69	158	424.1	422.8	423.7	0	0	0
70	159	425	422.7	423.8	0.1	0	0
71	160	424.4	422.7	423.6	-0.2	0	0
72	161	425	423.1	424.2	0.6	0	0
73	162	425	422.6	424.2	0	0	0
74	163	424	422.6	423.4	-0.8	1	11.6
75	164	423.5	422	423	-0.4	0	0
76	165	423.9	422.2	423.6	0.6	0	0
77	166	424.8	422.4	423.6	0	0	0
78	167	424.4	422.4	423.5	-0.1	0	0
79	168	424.9	422.3	423.8	0.3	0	0
80	169	425	422.3	423.7	-0.1	1	11.8
81	170	424.9	422.9	424.3	0.6	0	0
82	171	424.1	423.3	423.6	-0.7	1	12.3
83	172	425	422.8	424.2	0.6	0	0
84	173	424.4	422.1	423.4	-0.8	0	0
85	174	424.6	422.6	423.9	0.5	0	0
86	175	425	424	424.7	0.8	0	0
87	176	424.6	423.4	424.1	-0.6	0	0
88	177	424.2	422.6	423.7	-0.4	0	0
89	178	424.1	422.7	423.7	0	0	0
90	179	424.1	423.1	423.8	0.1	0	0
91	180	425	423	424	0.2	0	0
92	181	424.8	423	423.9	-0.1	0	0