DIAGNOSTIC\FEASIBILITY STUDY REPORT

RAVINE LAKE

BEADLE COUNTY, SOUTH DAKOTA

SOUTH DAKOTA CLEAN LAKES PROGRAM

DIVISION OF WATER RESOURCES MANAGEMENT

SOUTH DAKOTA DEPARTMENT OF WATER AND NATURAL RESOURCES

JULY, 1990

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RAVINE LAKE DIAGNOSTIC / FEASIBILITY STUDY REPORT

INTRODUCTION

The purpose of this report is to provide information gathered from a Diagnostic/Feasibility Study of Ravine Lake. The study was conducted from June, 1988 through September, 1989 and involved the cooperation of the South Dakota Department of Water and Natural Resources, and the City of Huron, South Dakota.

Excessive nutrient inflow and poor water quality have plagued Ravine Lake for many years and have resulted in declining recreational use. The study was initiated at local request to identify and assess the current status of the lake, determine water quality problems and pollution sources, and develop specific restoration alternatives. This report presents the results of data analyses, identification of significant lake impairments, and recommendations for restoration.

STUDY SITE DESCRIPTION

Ravine Lake has a surface area of 83 acres, a mean depth of approximately 7 feet and a maximum depth of 13 feet. The lake has been assigned the South Dakota beneficial uses of: warm water semipermanent fish life propagation, immersion recreation, limited contact recreation, and wildlife propagation and stock watering.

The Ravine Lake watershed contains 85,560 acres of the Northern Great Plains ecosystem of east central South Dakota. Figure 1 is a map of the Ravine Lake watershed. The watershed occurs entirely in Beadle County, South Dakota. The Ravine Lake watershed is approximately 24 miles long and 6 miles wide with its long axis on a northwest to southeast orientation. The principal receiving water body is Ravine Lake, a city-owned impoundment of Broadland Creek. The discharge from Ravine Lake drains to the James River. Huron, South Dakota, the primary user of the lake, lies directly west of Ravine Lake. In 1981 the estimated population within a 65 mile radius of the lake was 130,160.

The Ravine Lake watershed consists of flat to gently undulating glaciated uplands in the James Basin of the Central Lowlands Physiographic Province. Local topographic relief is generally less than 20 feet. Pierre shale of Cretaceous age forms the bedrock of the area and is mantled by an average of 75 feet of

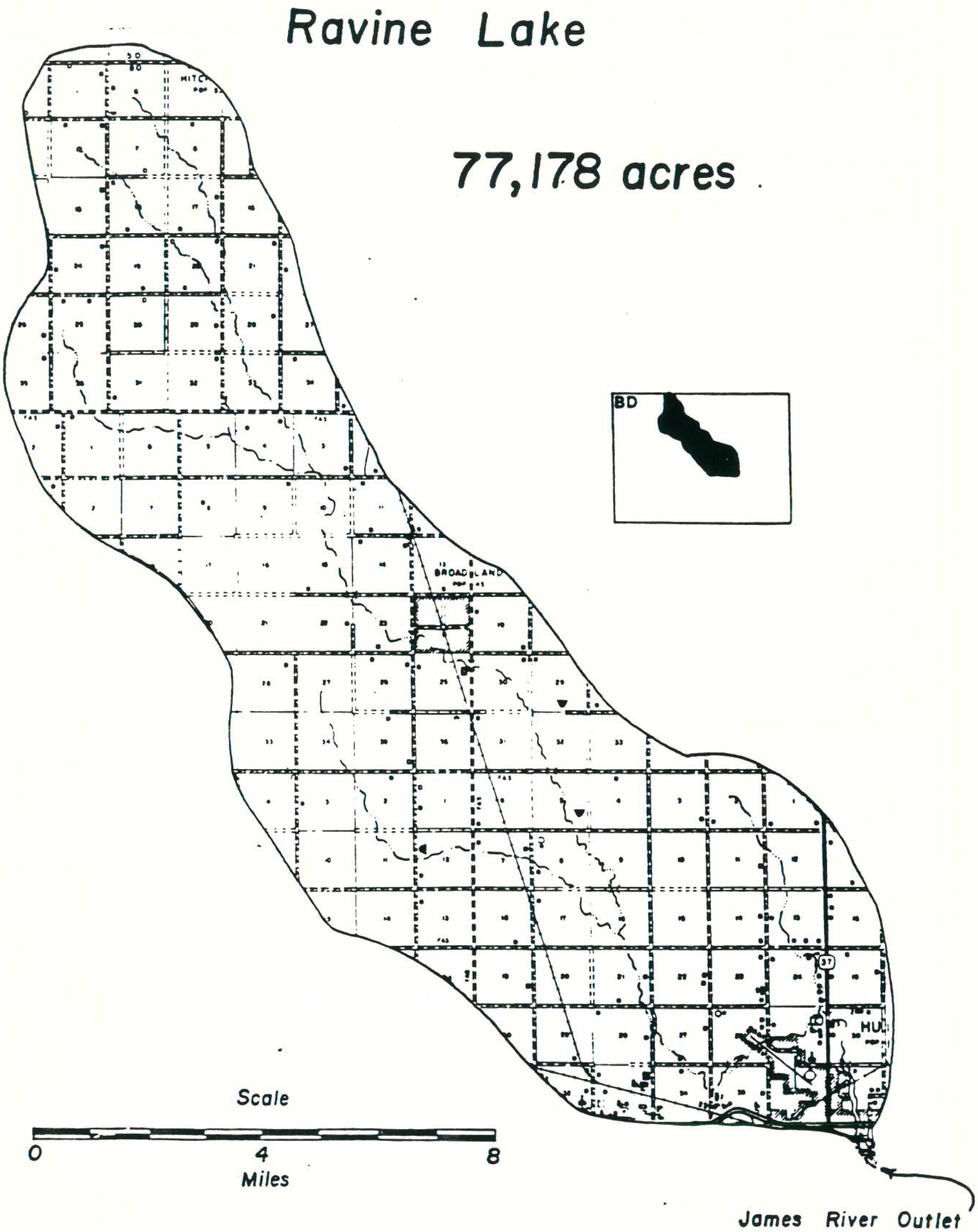

Figure 1 Ravine Lake Watershed

Pleistocene glacial till. The till contains a mix of clay, silt, sand, gravel, and boulders. Soils are generally deep, well-drained loamy soils formed in glacial drift.

The Ravine Lake watershed has a continental climate with extremes of hot and cold, and rapid fluctuations of temperature. The average annual temperature is 45^{o}F and the average annual precipitation is approximately 20 inches. Agriculture is the primary enterprise of the watershed. Land use is estimated to be 51 percent cropland and 49 percent rangeland or pasture.

WATER QUALITY STANDARDS

The water quality standards for the State of South Dakota are based on the highest ranking beneficial use assigned to a body of water. The highest beneficial use assigned to Ravine Lake is warmwater semipermanent fish life propagation waters. Other beneficial uses assigned to Ravine Lake include immersion recreation, limited contact recreation, and wildlife propagation and stock watering. The water quality standards for Ravine Lake are listed in Table 1.

Table 1.-Ravine Lake Water Quality Standards

Parameter	Standard
Total Chlorine Residual	<0.02 mg/l
Un-Ionized Ammonia Nitrogen	<0.04 mg/l
Total Cyanide	<0.02 mg/l
Free Cyanide	<0.005 mg/l
Dissolved Oxygen	>5.0 mg/l
Undissassociated Hydrogen Sulfide	<0.002 mg/l
pH	>6.5 units and <8.3 units
Suspended Solids	<90 mg/l
Temperature	<90^{o} F
Polychlorinated Biphenyls	<0.000001 mg/l
Fecal Coliform Organisms	<200 per 100 ml*

*Based on geometric mean based on a minimum of 5 samples obtained during separate 24-hour periods for any 30-day period, and they may not exceed this value in more than 20 percent of the samples examined in this 30-day period. A sample may not exceed 400 per 100 ml in any one sample from May 1 to September 30.

METHODS AND MATERIALS

Water samples were collected at 10 individual sampling sites in the Ravine lake Study Area. Figure 2 is a map of the sampling sites for the study. Site 1 was the outlet near the spillway of the dam. Sites 2 - 5 were tributary sites in the watershed of Ravine Lake. Sites 6 and 7 were in-lake sites. Sites SD1, SD2, and SD5 were storm sewer discharge outlets which drain directly into Ravine Lake. The Location of each of the sampling sites is as follows:

Site 1 - Located at the outlet structure near the spillway on the east side of the dam. Latitude: 44° 22' 03"N. Longitude: 98° 12' 04". Site 1 samples are representative of the water quality of the outflow of Ravine Lake.

Site 2 - Located 3/4 mile east of Highway 37 on the section line road forming the south boundary of Section 31 at the confluence of the northeast tributary and the section line road. Latitude: 44° 23' 07"N. Longitude: 98° 11' 59". Site 2 samples are representative of water quality for the portion of the watershed drained by the northeast tributary.

Site 3 - Located approximately 4/5 mile north of the Huron City Limits on Highway 37 at the confluence of the main tributary and Highway 37. Latitude 44° 23' 50"N. Longitude: 98° 12' 50". This site was selected to collect data from the major tributary leading to Ravine Lake.

Site 4 - Located 2,560 feet west of Highway 37 on the section line road forming the north boundary of Section 25 at the confluence of the North Branch of the main tributary and the Section line road. Latitude: 44° 23' 59"N. Longitude: 98° 12' 53". This site provided loading data for an arm of the main tributary which flows through an area of concentrated animal feeding operations.

Site 5 - Located approximately 1/3 mile east of Highway 37 on the section line road forming the north boundary of Section 30 at the confluence of the north tributary and the section line road. Latitude: 44° 23' 58"N. Longitude 98° 12' 26". This site provided data for the portion of the watershed drained by the north tributary.

Site 6 - Located near the Burlington Northern railroad

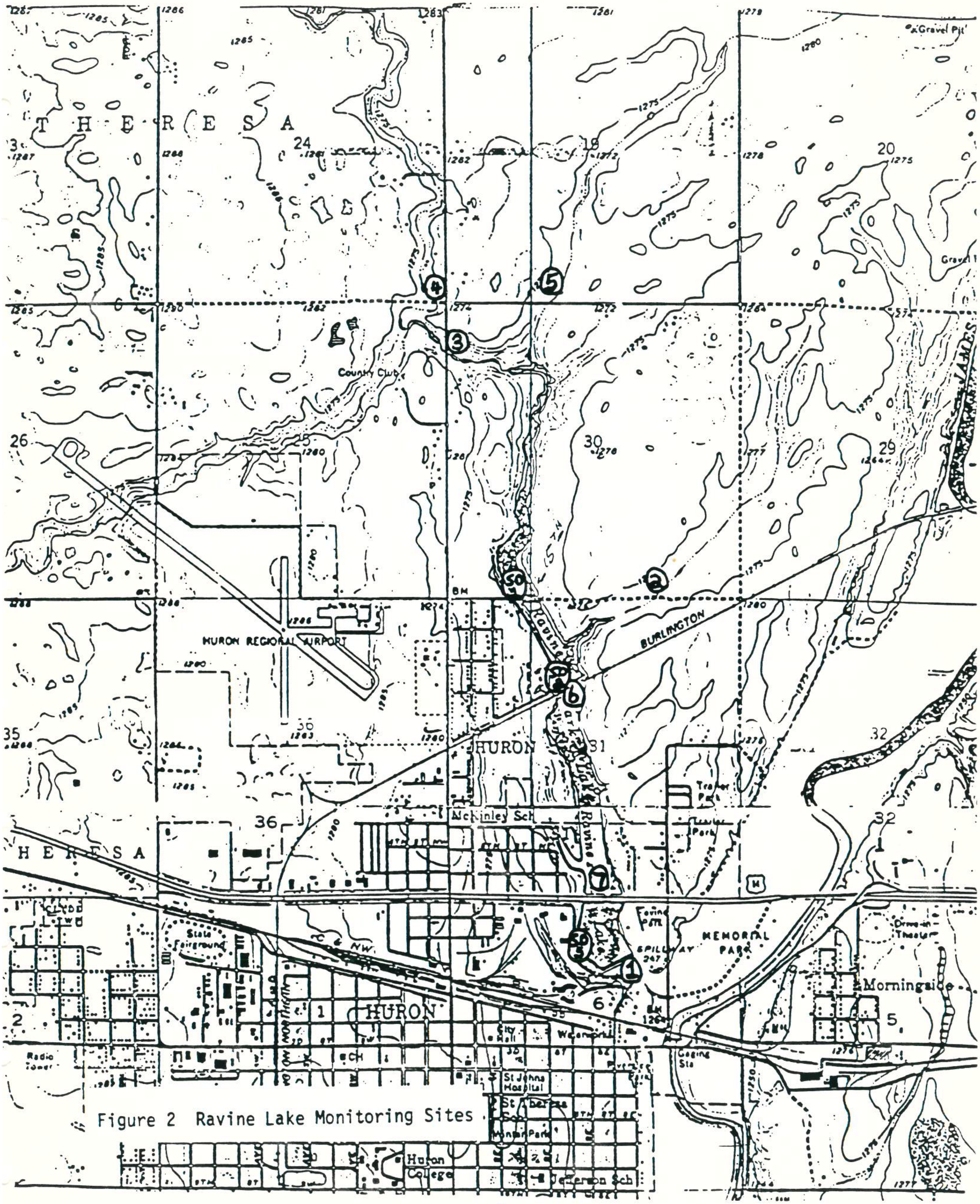

Figure 2 Ravine Lake Monitoring Sites

trestle on Ravine Lake. Latitude 44° 23' 01"N, Longitude 98° 12' 21". This site provided in-lake data for the northern portion of Ravine Lake.

Site 7 - Located approximately near the north side of the bridge where Highway 14 crosses Ravine Lake. Latitude 44° 22' 15"N, Longitude 98° 12' 11". This site provided in-lake data for the southern portion of Ravine Lake.

Site SD1- Located approximately 1\4 mile east of highway 37 on the section line road along the northern border of section 31, near the west shore of Ravine Lake. Latitude 44° 23' 07"N, Longitude 98° 12' 33". This site provided data for storm drain #1.

Site SD2- Located on the west shore of Ravine Lake near the Burlington Northern railroad trestle. Latitude 44° 22' 50"N, Longitude 98° 12' 23". This site provided data for storm drain #2.

Site SD5- Located approximately on the west shore of Ravine Lake, east of the corner of Second St. and East Center St. in Huron, South Dakota. Latitude 44° 22' 07"N, Longitude 98° 12' 18". This site provided data for storm drain #5.

As listed in the following table (Table 2), the sampling period for this study extended from March 19, 1988, through July 10, 1989. During that period, a total of 173 samples were collected from the ten sites.

TABLE 2.-SAMPLING PERIOD AND NUMBER OF SAMPLES

SITE #	SAMPLE TIME PERIOD FROM:		TO:	# OF SAMPLES
1	3/19/88	-	7/10/89	33
2	4/15/88	-	5/23/89	12
3	4/15/88	-	7/10/89	29
4	4/15/88	-	5/1/89	9
5	4/4/88	-	5/16/89	12
6	4/12/88	-	6/14/89	19
7	4/12/88	-	6/21/89	28
SD1	3/14/89	-	4/19/89	6
SD2	3/20/88	-	7/10/89	9
SD5	7/26/89	-	7/10/89	16
			Total Samples:	173

The schedule for the collection of water quality samples at the three in-lake sites was comparable to that used at other D/F Study projects. At each of the sites two samples were collected per month from April through September, and one sample was collected per month from October through March except during unsafe ice periods. This sampling schedule was adhered to as nearly as possible throughout the project period. Occasionally, due to drought conditions in the watershed, there was no flow at some of the tributary sites. Under average conditions, samples are collected at the surface and bottom at each site. However, because of the relatively shallow depth of Ravine Lake - average depth approximately 7 feet - only surface samples were collected. The "surface" sample is actually a grab sample collected approximately 6" below the water surface.

The laboratory analyses were conducted by the South Dakota State Health Laboratory in Pierre, South Dakota. Field sample collection and analyses were done by Floyd Kallenburger, a local resident.

The raw water quality data was compiled by the Water Resources Management Division of the Department of Water and Natural Resources. Water quality data was loaded onto computer files and was analyzed for trends. A minimum, mean, and maximum were calculated for each of the parameters.

The water quality parameters that were sampled for at each of the three in-lake sites are shown in Table 3. A description of each of the parameters may be found in Appendix A.

Table 3.-Water Quality Parameters

Parameter	
Water Temperature	Total Solids
Air Temperature	Total Dissolved Solids
Secchi Disk	Total Suspended Solids
Dissolved Oxygen	Ammonia
Field pH	Nitrates + Nitrites
Fecal Coliform Bacteria	Total Kjeldahl Nitrogen
Specific Conductance	Total Phosphorus
Laboratory pH	Orthophosphate
Total Alkalinity	Unionized Ammonia

A sediment survey was completed for Ravine Lake during February of 1986. Cross sections of the lake depicting water depth and sediment depth were taken at 100 ft. intervals for a distance of 700 feet north of the dam. Points for each cross section were taken at 100 foot intervals. The cross sections may be found in Appendix B.

Two elutriate samples were collected in the spring of 1988 and sent to the U.S. Army Corps of Engineers Laboratory in Omaha, Nebraska, for analysis. One sample was from the northern portion of the lake and one sample was from the southern portion of the lake. An elutriate sample is a sediment sample which is analyzed for toxic chemicals and/or metals. Results of the elutriate samples may be seen in Appendix C.

RESULTS AND DISCUSSION

A review of the water quality samples from the two in-lake sites produced somewhat predictable results. Most of the sample concentrations of the parameters tested were within the legal limits set by the Surface Water Quality Standards of the State of South Dakota (Table 1). However, factors such as Secchi Disk for determining water clarity and total phosphorus concentrations are not subject to standards limitations. Therefore, a simple review of standards violations is somewhat misleading.

Generally, the established standards for the concentrations of selected parameters are based upon the results of a 24-hour representative, composited sample. The numerical value of a parameter found in any one grab sample collected during the period may not exceed 1.75 times the applicable criterion. As an example, any single grab sample that yields a suspended solids number in excess of 157.5 mg/l is in violation of the standards (90 mg/l x 1.75). Also, the standard for pH states that the applicable criterion is to be maintained at all times, without exception. For Ravine Lake, the pH should not be below 6.5 units or above 8.3 units. All of the water quality samples collected for this project were individual grab samples. For a summary of the results of the sample analysis for each site please refer to Table 4. The results of the water quality sampling analyses for the Ravine Lake Diagnostic/Feasibility are in table form in Appendix C.

Based on the results of the data evaluation, the parameters of concern for Ravine Lake are dissolved oxygen, fecal coliform bacteria, pH, unionized ammonia, and phosphorus. Each one of these parameters exhibits either violations of existing standards and/or may be responsible for limitations on beneficial uses. The following discussion details the rationale for focusing on each parameter.

Dissolved Oxygen

The dissolved oxygen standard was exceeded on at least one occasion during the sampling period at site 3 on June 6, 1989. As noted above, the standard for dissolved oxygen is 5 mg/l. The concentration on June 6, was 1.1 mg/l. Low concentrations of dissolved oxygen are responsible for fish kills. During summer, water containing less that 3.5 mg/l of dissolved oxygen is lethal to most northern fishes. Decreases in dissolved oxygen can be attributed to the respiration of plants, animals, and the aerobic bacteria of decay (Cole, 1983).

Fecal Coliform Bacteria

Fecal coliform organisms are the bacteria which inhabit the digestive systems of warm-blooded animals. The presence of these bacteria in water is indicative of human or animal waste. The water quality standards for fecal coliform bacteria state that a

Table 4 Ravine Lake Sample Concentration Summary 1988 - 1989

SITE	# OF SAMPLES		WTEMP	ATEMP	SECCHI	DISOX	FECAL	COND	LABPH	TALKAL	TSOL	TDSOL	TSSOL	AMMON	NITRO	TKN_N	TPO4	OPO4	UNIAM
SD-1	6	MINIMUM	27	16	2.00	9.90	0	356	7.71	69	299	250	2	0.02	0.10	0.32	0.058	0.025	0.0001
		MAXIMUM	41	63	2.00	12.60	900	1500	8.04	444	1255	1191	516	0.60	0.90	1.94	0.461	0.256	0.0042
		MEAN	36	40	2.00	11.23	157	744	7.85	173	647	532	105	0.21	0.47	1.00	0.234	0.121	0.0012
SD-2	9	MINIMUM	26	34	1.80	7.50	10	371	7.79	83	784	270	1	0.02	0.60	0.54	0.098	0.021	0.0009
		MAXIMUM	74	86	2.30	10.90	310	3100	8.44	316	2886	2760	540	0.98	18.00	2.83	0.996	0.754	0.0171
		MEAN	48	60	2.03	8.88	76	2020	8.21	214	1945	1750	103	0.31	3.55	1.25	0.421	0.199	0.0068
SD-5	16	MINIMUM	34	40	1.80	7.50	10	280	7.46	6	287	242	1	0.02	0.60	0.28	0.041	0.008	0.0006
		MAXIMUM	73	86	2.90	13.60	2700	4235	8.30	405	4081	3722	296	3.64	14.20	3.77	0.508	0.300	0.0493
		MEAN	51	63	2.14	10.12	339	2788	8.09	307	2892	2662	69	0.87	8.17	1.42	0.107	0.049	0.0123
SITE 1	33	MINIMUM	27	16	1.45	7.50	0	470	7.12	65	390	289	0	0.02	0.01	0.22	0.024	0.005	0.0003
		MAXIMUM	80	86	2.90	13.50	115000	2646	9.00	600	2474	2305	236	0.89	1.30	4.60	1.010	0.881	0.0207
		MEAN	50	55	2.05	10.30	3833	1438	8.03	207	1144	1063	60	0.28	0.39	1.67	0.484	0.280	0.0050
SITE 2	12	MINIMUM	28	18	1.90	9.60	0	816	6.79	34	503	278	2	0.02	1.00	0.32	0.047	0.012	0.0004
		MAXIMUM	57	84	2.10	9.70	2200	4120	8.37	506	3913	3561	357	1.50	4.10	2.98	1.780	1.240	0.0096
		MEAN	48	59	1.98	9.65	594	2402	8.00	250	2298	2069	167	0.20	2.84	1.05	0.282	0.166	0.0024
SITE 3	29	MINIMUM	27	16	1.20	1.10	0	265	6.90	40	237	206	1	0.02	0.10	0.91	0.220	0.011	0.0002
		MAXIMUM	78	86	2.90	13.60	720	4028	9.00	949	8178	5206	2972	6.10	1.10	9.50	7.100	6.180	0.1377
		MEAN	50	55	1.97	9.41	51	1543	8.09	242	1518	1313	182	0.43	0.22	2.73	1.262	0.772	0.0093
SITE 4	9	MINIMUM	28	17	1.80	9.90	10	525	7.07	55	408	363	1	0.02	0.00	0.56	0.054	0.009	.0000
		MAXIMUM	50	59	2.45	13.60	190	3068	8.31	1169	2914	2706	208	0.36	0.70	1.87	0.519	0.371	0.0005
		MEAN	41	44	2.07	11.13	33	1560	7.89	253	1347	1251	41	0.09	0.21	1.08	0.220	0.109	0.0003
SITE 5	12	MINIMUM	34	34	1.90	11.20	10	110	7.32	33	116	104	2	0.04	0.10	0.82	0.037	0.015	0.0003
		MAXIMUM	55	76	2.20	11.20	42000	3914	8.15	438	3969	3637	364	1.62	9.50	2.33	0.916	0.754	0.0269
		MEAN	44	54	2.02	11.20	6030	2418	7.95	276	2407	2203	131	0.77	3.62	1.48	0.230	0.158	0.0113
SITE 6	19	MINIMUM	33	22	1.45	9.20	10	410	7.49	60	323	281	0	0.02	0.01	1.18	0.376	0.104	0.0018
		MAXIMUM	73	84	13.00	12.50	200	1566	9.11	277	1282	1170	157	0.78	0.80	2.73	1.390	0.648	0.0154
		MEAN	50	57	2.74	10.17	33	1201	8.65	198	954	876	66	0.11	0.13	1.76	0.686	0.408	0.0044
SITE 7	28	MINIMUM	29	1	0.67	7.50	10	371	7.50	66	305	114	4	0.02	0.10	1.03	0.288	0.018	0.0000
		MAXIMUM	84	83	2.40	12.60	320	1552	9.10	272	1270	1136	1103	0.92	0.40	3.10	1.210	0.695	0.0194
		MEAN	51	53	1.84	9.89	37	1260	8.67	214	1002	879	114	0.13	0.12	1.94	0.748	0.470	0.0062

sample may not exceed a count of 400 per 100 ml in any one grab sample from May 1 to September 30. A total of 18 samples had counts of equal to or greater than 400 colonies per 100 ml of sample. SD-1 had 1 sample, SD-5 had 3 samples, site 1 had 6 samples, site 2 had 4 samples, site 3 had 1 sample and site 5 had 2 samples out of compliance with the standard for fecal coliform bacteria. Possible sources of this bacteria in Ravine Lake include wild mammals or birds, domestic animals or livestock, or a malfunctioning sewer system for homes near the lake or a leak of a sewer line to the storm sewer system.

pH

As noted above, the water quality standard for pH states that the pH must fall in a range between 6.5 and 8.3 units. The laboratory pH measurements were not below the minimum standard at any of the sites. The maximum pH standard was exceeded during the sampling period at 5 of the sampling sites. SD-2 had 3 samples, site 1 had 7 samples, site 3 had 10 samples, site 6 had 16 samples, and site 7 had 24 samples greater than 8.3 units of pH. The maximum pH measurement obtained at any site was 9.11. Limited evidence indicates that pH in excess of 8.3 units may cause minor eye irritation in swimmers. The high pH values may be the result of soil composition in the watershed. Vegetation (algae or macrophytes) can also cause elevated pH. The photosynthetic processes of plants can result in a rise in pH (Cole, 1983).

Total Suspended Solids

The Water Quality Standard for suspended solids at Ravine Lake is 90 mg/l. As noted earlier, when dealing with individual grab samples the standard concentration may be multiplied by 1.75 for an allowable concentration of 157.5 mg/l. Approximately 18 percent of the samples during the study were in excess of 157.5 mg/l. The mean concentration of all of the in-lake samples (site 5 and site 6) was 95 mg/l. Concentrations of suspended solids at this level impair recreation by giving the water a muddy appearance and subsequent reduced appeal. High concentrations of suspended solids may also adversely effect sight feeding species of fish, reduce oxygen intake by clogging gills and inhibit the growth of desirable aquatic plants by reducing light transmission.

Un-ionized Ammonia

The un-ionized ammonia standard for Ravine Lake is 0.04 mg/l. The standard concentration of un-ionized ammonia was exceeded in one sample at site SD-5 and one sample at site 3. Un-ionized ammonia is the fraction of total ammonia that is highly toxic to fish. The level of un-ionized ammonia is directly related to temperature and pH.

Phosphorus

The State of South Dakota does not include phosphorus in the water quality standards. In spite of this fact, the concentration of total phosphorus in Ravine Lake is extremely high. The average in-lake concentration of total phosphorus is approximately .7 mg/l. When phosphorus concentrations exceed .025 mg/l, nuisance growths of aquatic vegetation may occur (EPA 1976). Sources of phosphorus in a lake may be human or animal waste, fertilizer, detergent, run off from the land, and point source pollution. Total phosphorus concentrations in Broadland Creek ranged from 1.320 mg/l to a high of 7.100 mg/l during a period from April to July of 1988. These high concentrations coincided with a discharge from drain tile into Broadland Creek. The material discharging from the drain tile is believed to have been effluent from the wastewater treatment facility belonging to Huron Dressed Beef. Corrective measures have been taken to ensure that this discharge will not occur in the future. Huron Dressed Beef has constructed a zero discharge treatment facility so that all effluent will be disposed of on their own property.

Oil and Grease

Of the two elutriate samples collected in Ravine Lake, the elutriate water sample collected in the south end of the lake contained 8.6 mg/l of oil and grease. The South Dakota Standard for oil and grease is 10 mg/l. The source of the material may be from storm sewer discharge, an auto salvage business on the lake shore, a point source, or a spill.

CONCLUSIONS

The water quality of Ravine Lake is generally poorer than most eastern South Dakota prairie lakes. Nutrient concentrations are high both in the lake and the tributaries which feed the lake. Suspended solid concentrations are excessive and may indicate sedimentation of the lake basin.

The primary source of water to Ravine Lake is Broadland Creek. Broadland Creek is also the source of the majority of the nutrient and sediment pollution to the lake. Huron Dressed Beef was a point source to the lake at least during the spring of 1988 (EPA 1989). The problem has been corrected and no further discharge from Huron Dressed Beef is anticipated. Both an urban and agricultural nonpoint pollution problem is suspected in the lake and its watershed. The City of Huron has 5 discharge points from the storm sewer system which contribute nutrient and sediment to Ravine lake. Storm drain #5 seems to have a constant discharge even during extended dry periods. The source of this water was not determined during the course of the study. The storm sewer concentration while significant, does not account for the major loading of pollution to the lake.

Due to the size of the Broadland Creek watershed and the concentrations of nutrients in the samples, it is apparent that most of the loadings enter the lake from Broadland Creek. Some potential sources of nutrients to the lake in the Broadland Creek watershed include runoff from agricultural land, runoff from the golf course, feedlot runoff, and airport runoff. The only point source identified in the watershed was Huron Dressed Beef. Huron Dressed Beef is not expected to be a source of pollution in the future due to the construction of the new waste water treatment facility.

RESTORATION ALTERNATIVES

The alternatives considered for restoration of Ravine Lake include the following:

1. No action
2. Broadland Creek hydrologic unit plan
3. Reroute storm drain discharge
4. Selective dredging
5. Dewatering of reservoir
6. Land based removal of sediment

No Action

If the no action alternative is selected, the lake will not improve. The large concentration of nutrients currently in the lake will continue to cycle through the system. The lake will continue to degrade and algae or emergent macrophytes may take over the lake. Odor problems may develop due to decaying organic material. Recreation will be increasingly impaired.

Broadland Creek Hydrologic Unit Plan

If the Broadland Creek hydrologic unit plan alternative is selected, the pollution problems in the watershed will be identified and an implementation strategy will be developed. The City of Huron may contact the Beadle County Conservation District and request a hydrologic unit plan be completed for the Broadland Creek watershed and Ravine Lake. With the help of the Department of Agriculture, Soil Conservation Service, a series of public hearings will be held to get input from the landowners, and other interested parties. A strategy for the implementation of corrective measures will be the final product of this process. This is one of the requirements for eligibility for Section 319, Nonpoint Source, and federal assistance from the Environmental Protection Agency.

Reroute Storm Drain Discharge

If the Reroute Storm Drain Discharge alternative is selected, engineering plans and specifications will need to be developed. This alternative will eliminate the effect of the nutrients from the storm drains. The source of the continual discharge to storm drain number 5 is unknown. This alternative may not have an acceptable cost to benefit ratio. This alternative needs further study before implementation.

Selective Dredging

If selective areas in the lake basin are dredged, there will be several improvements. Fish habitat will be enhanced and the threat of summer and winter fishkill will be reduced. There will be better control of macrophytes in the dredged areas. Selective dredging is less expensive and less time-consuming than whole lake dredging. Fewer sediment disposal ponds would need to be constructed. Suspended solids may remain a problem, depending on how much sediment is removed, due to resuspension of the remaining sediment by wind or recreation activities. If dredging is concentrated in areas with greatest sediment accumulation that is prone to wind and wave action, improvements would be most noticeable. In addition, dredging thick layers of sediment would improve dredging efficiency. Hydraulic residence time may be increased with dredging. This will result in slower flushing time. The cost of operation for an eight inch dredge is estimated to be approximately $175,000 per year.

Dewatering of Reservoir

If the Dewatering the Reservoir alternative is selected, the removal of water from the lake basin would probably be accomplished by the use of a pump. The volume of Ravine Lake is approximately 556.1 acre-feet. This volume of water could feasibly be removed by the use of a high capacity pump. Pumps are available for lease that will pump up to 10,000 gallons per minute. The cost of leasing a pump will depend on the size of the pump. For a 12 inch diesel pump the rental cost is approximately $5,000 to $7,000 per month. Shipping cost for a pump of this size will be approximately $4,000. It would take a pump of this size approximately 1.5 months to dewater Ravine Lake. Ideally, the lake basin should remain dry for one summer and one freeze - thaw cycle.

Several potential benefits will occur by the use of this alternative. By exposing the bottom of the lake, the sediment will consolidate and lake volume will increase slightly. The consolidation of sediment is considered to be permanent and the material will not rise back up. The rich organic surface of the sediment will be oxidized and this may reduce release of nutrients to the water from the sediments. Aquatic macrophytes may be controlled using this method. Any subsurface pollution sources may be detected and corrected during the period that the lake is dewatered. Total removal of the rough fish population could be accomplished during the drawdown, however, rough fish would eventually return to the lake. After the lake basin is allowed to refill, the lake may be restocked with more desirable species of game fish. Some rip-rap is needed on the north end of the lake. This alternative would make the riprapping easier to accomplish and therefore cheaper. The lake is currently extremely eutrophic and high in nutrient concentration. This alternative will allow for the rapid removal of the nutrient rich water all at once. Higher quality water will replace the existing water in the reservoir (Cooke, 1986 and Wisconsin DNR, 1975).

There are several potential negative factors involved with this alternative. Potential failure of the reservoir to promptly refill is one of the risks of dewatering the reservoir. Drought is always a potential problem in South Dakota. Blooms of algae have been reported after reflooding of lakes which have been dewatered. Care must be used in game fish salvage operations during drawdown to avoid a fishkill. The lake basin may be taken over by noxious weeds during drawdown but the weeds would be drowned out during reflooding. Also chemical weed control may be used if necessary. The soft, flocculent sediment may crust over creating a hazard to people attempting to walk across the lake basin.

Land Based Removal of Sediment

If the Dewatering of the Reservoir is selected, land based removal of the sediment is a possibility. Rather than attempting to remove all of the soft sediment from the lake, a series of deep pools may be constructed. These pools would increase recreation potential in the lake and provide fish habitat. The advantage of land based removal of sediment is that it can be accomplished with conventional equipment such as draglines, bulldozers or scrapers. The dry sediment may be transported and disposed of immediately by trucks. The sediment may be removed after it dries or in the winter. The City may remove as much sediment as it desires or can afford and locate the pools in the lake basin at whatever location they desire. In addition, fish habitat structure may be constructed, such as rock piles, ditches, or walls.

RECOMMENDATIONS

Based on the information collected in the course of this study and an evaluation of historical baseline data, the Water Resources Management Division of the Department of Water and Natural Resources recommends that restoration activities of Ravine Lake be accomplished using the following restorative alternatives.

1. Broadland Creek Hydrologic Unit Plan
2. Dewatering of the Reservoir
3. Land Based Removal of Sediment

The reason for the selection of the Broadland Creek Hydrologic Unit Plan alternative is to address the pollution entering the lake from the watershed. This alternative is the most cost effective and practical method of dealing with the problem. This method will allow the landowners to have a voice in the implementation of management practices to reduce the sediment and nutrient load to the creek and ultimately to the lake. The inflow of nutrients and sediment from Broadland Creek is by far larger than the input from the City storm drains due to the amount of land drained by Broadland Creek. The City may also wish to consider urban best management practices (BMP's) to control the water quality in the storm runoff to the lake. Urban BMP's may be incorporated into the hydrologic unit planning process for the watershed. Some urban BMP's include sediment traps for areas which contribute large amounts of sediment to the storm sewer runoff, an aggressive street sweeping program, and an inspection of the sanitary sewer system to insure that the system is not leaking into the storm sewer system.

There are several reasons for choosing the Dewatering the Reservoir alternative. This method is much more cost effective for Ravine Lake than a dredging project. This alternative will improve the recreation potential of the lake faster than the hydrologic unit alternative alone. The water in the lake has extremely high concentrations of nutrients and it will take a much longer period of time to clean itself by natural flushing. The riprap installation will be easier on the north end of the lake if the lake is dewatered. The loss of availability of lake water for irrigation on the golf course is a local problem which should be considered by the City. The primary goals of this alternative are to remove the nutrient rich water from the lake, consolidate the sediment and increase lake volume, and to oxidize the organic material on the surface of the sediment layer. Other goals may include rough fish removal and game fish restocking, macrophyte control, construction activities such as riprap of eroded shoreline areas or possibly swimming beach construction.

The Land Based Removal of Sediment alternatives was selected to improve the fish habitat in the lake and to reduce the threat of fishkill in Ravine Lake. The addition of structure to the lake will improve the fishing in the lake. The sediment removal may be conducted by the City to the extent that the City wishes. The State recommends a series of deep pools at intervals along the length of the reservoir. This will increase the area which fish may winter in and increase area for recreational fishing.

The City may select any of the restoration alternatives listed and described in this report or choose to take another plan of action. The restoration alternatives are presented to the City as a group of options based on the watershed and water quality information available.

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Cole, Gerald A. Textbook of Limnology. C.V. Mosby Co., 1983.

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APPENDIX A. DESCRIPTIONS OF WATER QUALITY PARAMETERS

WATER QUALITY PARAMETERS

1. **Laboratory Analysis:**

   a. Fecal coliform (organisms/100ml) can indicate fecal contamination and thus potential human health hazards.
   Fecal coliform bacteria are bacteria which live in the digestive tract of warm-blooded animals. These bacteria are considered to be an indicator of sewage pollution or livestock manure. Fecal coliform bacteria are not found in the digestive tract of cold-blooded animals such as fish, amphibians or reptiles. Some fecal coliform will exist in nature from the fecal material of wild animals or birds.

   b. Biochemical oxygen demand (BOD) (mg/l) is used to measure the organic content in polluted waters. BOD is a measurement of the potential for oxygen removal from the water and an indicator of organic pollution. As organisms die, the process of decomposition by bacteria removes dissolved oxygen from the water. The more nutrient rich the environment, the more potential for growth of aquatic organisms; hence, there will be more bacterial decomposition.

   c. Laboratory pH (su) is a measurement of the hydrogen ion activity which directly affects the toxicity (solubility) of heavy metals in water, among other items. The pH scale is a number range between 1 and 14, with 7 being neutral. Any value less than 7 is considered acidic and any value greater than 7 is considered basic.

   d. Suspended solids (mg/l) can indicate the sediment load into a body of water and possible problems to the biological community. Suspended solids does not include a measure of larger particles that are moved along the stream bed during high flows.

   e. Total solids (mg/l) are used to determine dissolved solids by subtracting suspended solids from total solids. Dissolved solids may have a detrimental affect on the biological community.

   f. Ammonia-nitrogen (mg/l) is a product of the first oxidative step in degrading organic material. It is directly available to plants as a nutrient for growth. Ammonia can be used as evidence of organic pollution and the unionized fraction of ammonia is toxic to fish.

g. Nitrate-nitrogen (mg/l) constitutes the inorganic nitrogen fraction which is used by phytoplankton. Nitrate-nitrogen also indicates pollution from animal wastes, fertilizers or nitrogenous organic matter which are used by algae. It gives an indication as to what may be causing pollution in a lake (i.e., fertilizers, animal wastes, nitrogenous organic matter).

h. Total Kjeldahl Nitrogen (mg/l) is used to measure both ammonia and organic nitrogen. Ammonia is subtracted from TKN and results in the organic nitrogen fraction which can be broken down to nitrogen compounds which are utilized by phytoplankton.

i. Total phosphorus (mg/l) represents all of the phosphorus found in the water sample. Not all of the phosphorus is immediately available to aquatic plants and algae. Phosphorus is an element which is essential to all life and is the least available to living organisms. For this reason, phosphorus is commonly the limiting factor for biological productivity. When phosphorus concentrations are high, nuisance growth of aquatic plants or algae may result.

j. Ortho-phosphorus (mg/l) is analyzed because it is phosphorus which is immediately available to algae.

2. Field Analysis:

a. Water temperature (F or C) is taken since it has considerable effect on the chemical processes in a lake. Also, temperature is important to fish life and other aquatic species.

b. Field pH (su) measures the hydrogen ion activity which can affect the toxicity of heavy metals in the water, as well as other factors.

c. Dissolved oxygen (mg/l) is an indicator of the overall health of the lake and it is needed to sustain most aquatic animal life.

d. Climatic conditions - wind, precipitation, air temperature (F or C).

e. Visual observations - septic conditions, odor, water color, turbidity or anything unusual (e.g. dead fish).

f. Tributary flow depth (ft.) to calculate flows entering the lake.

g. The following additional measurements are taken for in-lake analysis: water depth, oxygen profiles, composite sampling at various lake depths (surface, mid-depth, and bottom), chlorophyll a, secchi disc (visibiliity) and phytoplankton identification.

3. **In-lake Sediment Sampling**

a. Corps of Engineers elutriate test for some of the above mentioned paramenters plus selected pesticides: such as endrin, DDT, parathion, etc., is used to determine what is in the sediments.

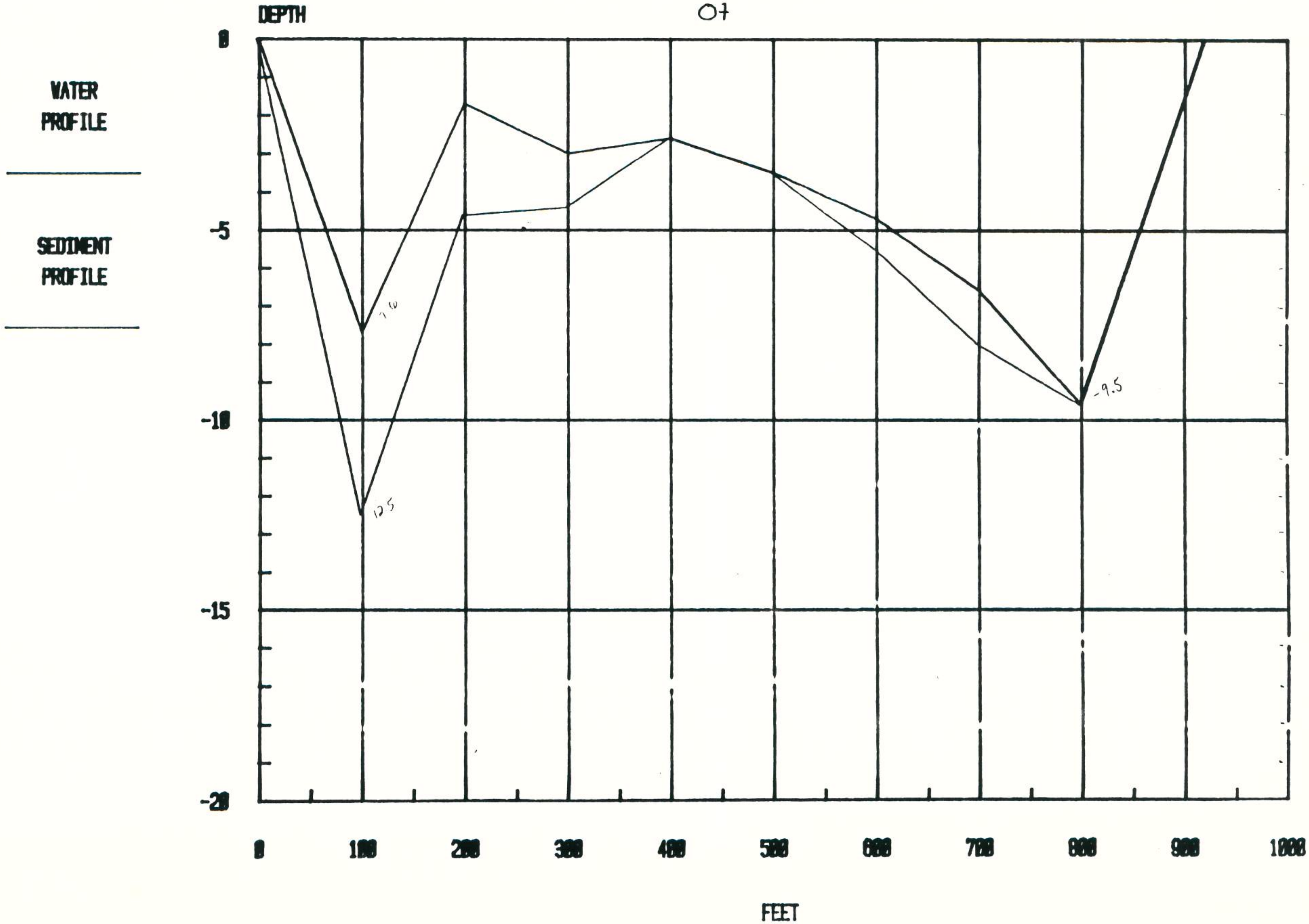
b. Sediment topographic surveys and sediment depth measurements are used to determine sediment volumes in the lake.

APPENDIX B. CROSS SECTIONS OF RAVINE LAKE

RAVINE LAKE CROSS-SECTIONS

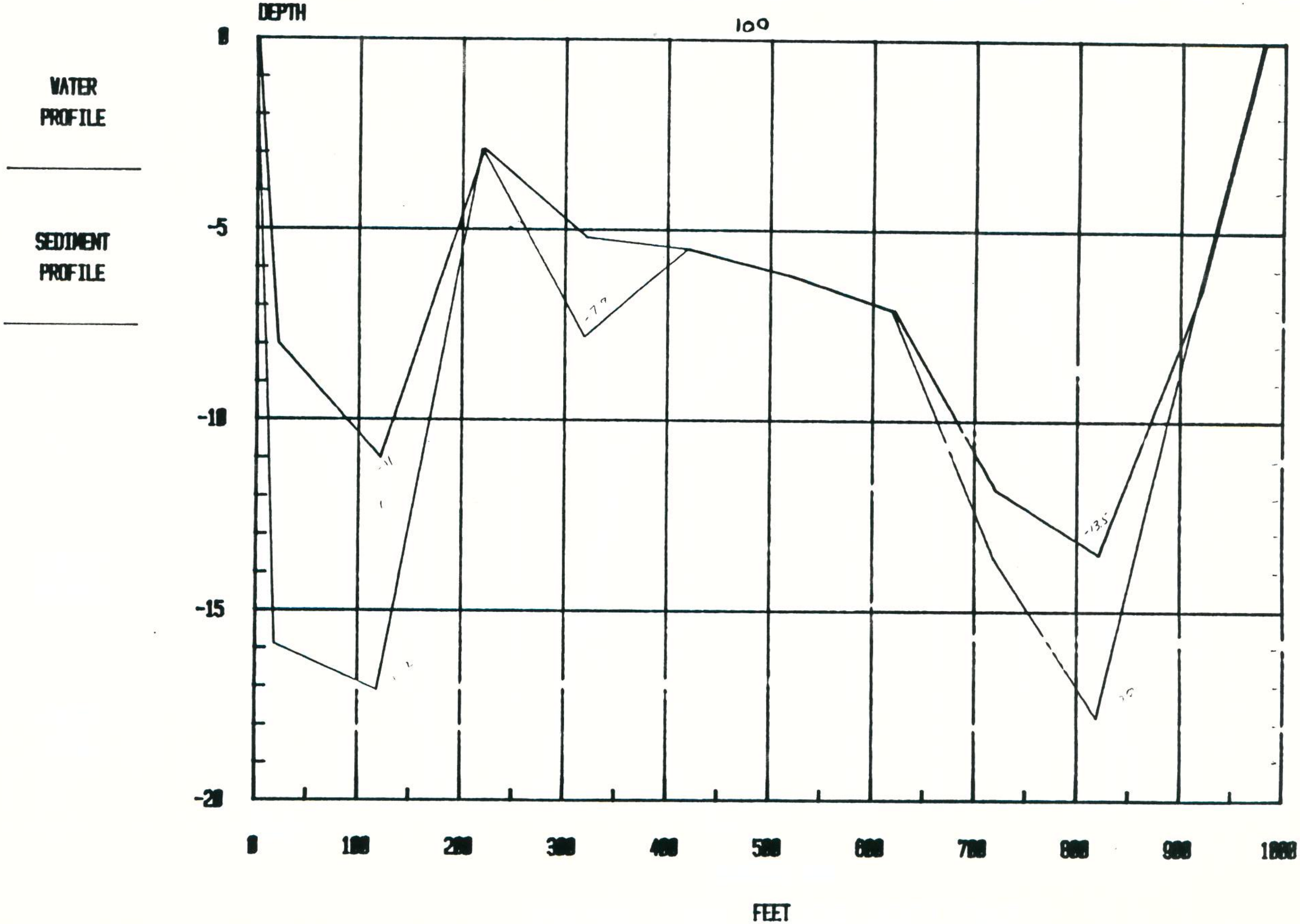
FEBRUARY 1986

07



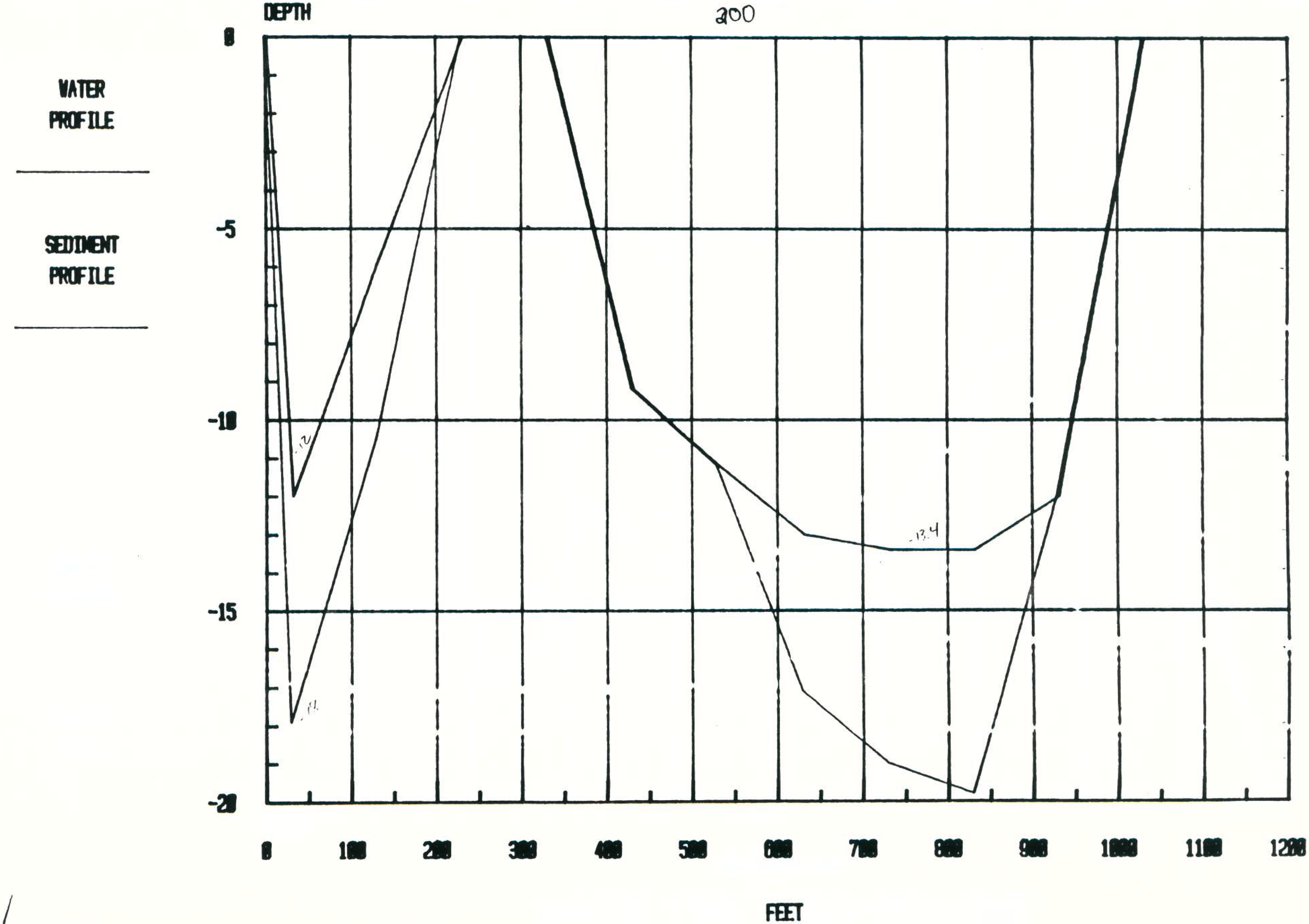
RAVINE LAKE CROSS-SECTIONS

FEBRUARY 1986



RAVINE LAKE CROSS-SECTIONS

FEBRUARY 1986



RAVINE LAKE CROSS-SECTIONS

FEBRUARY 1986

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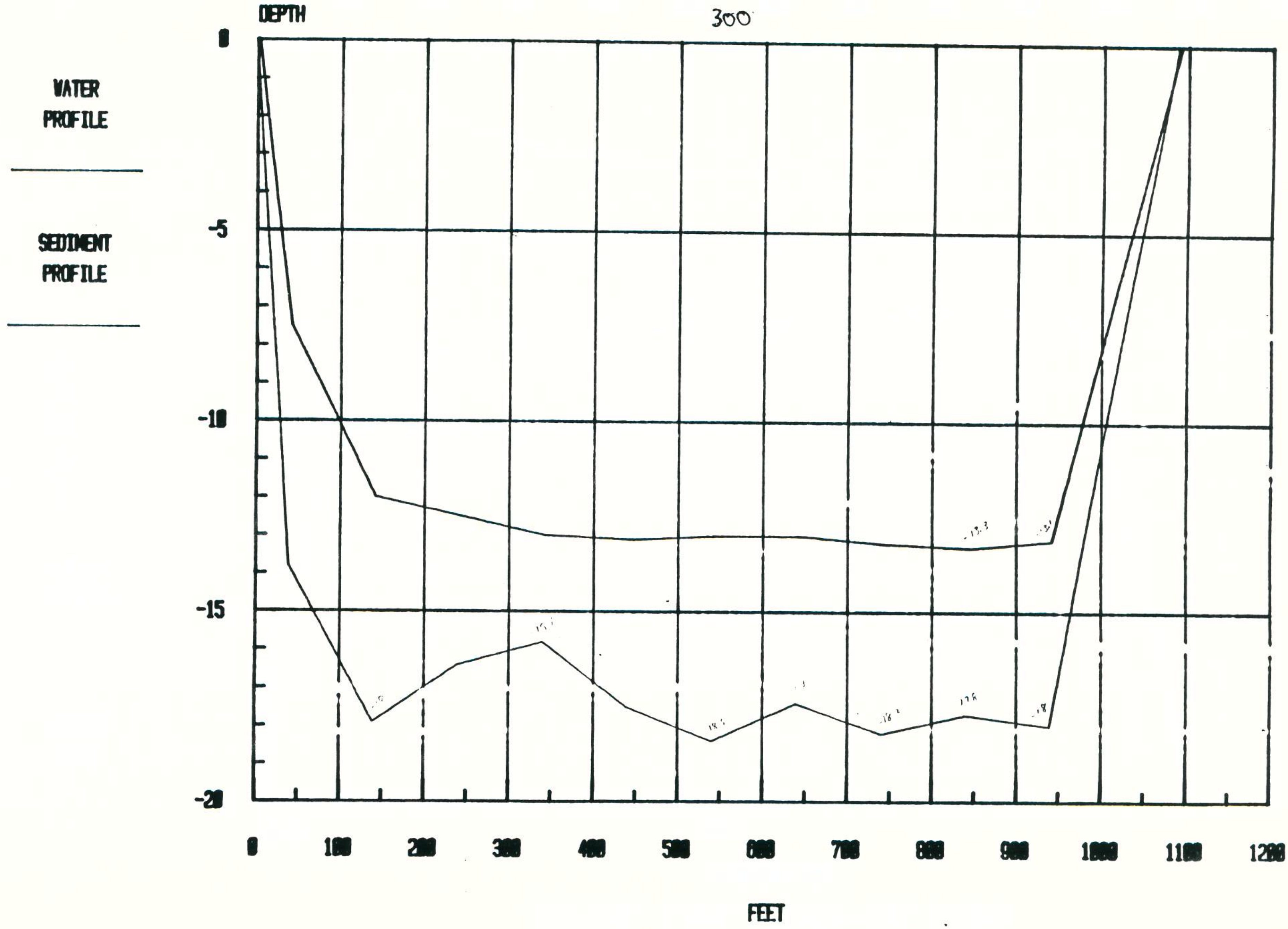
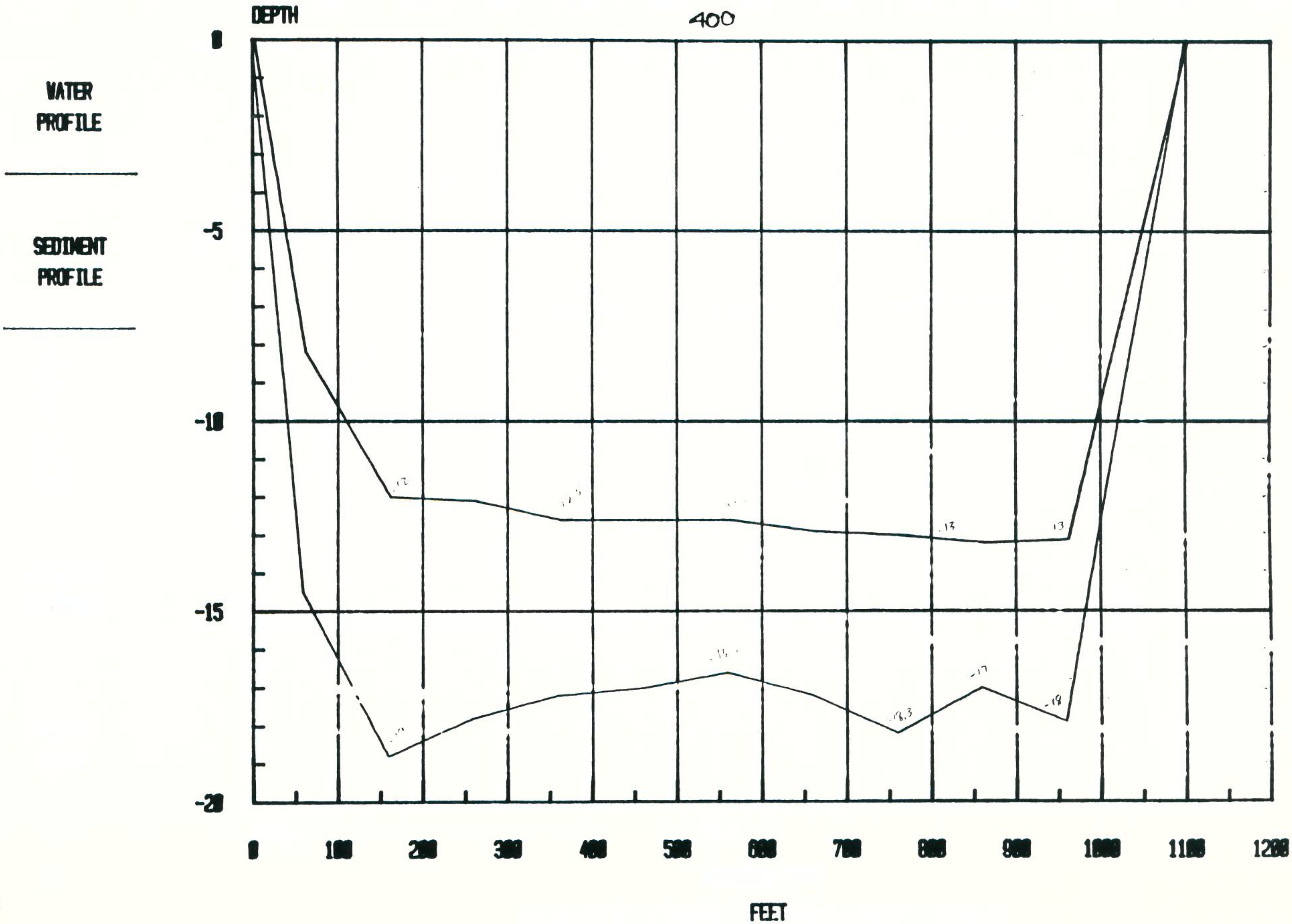


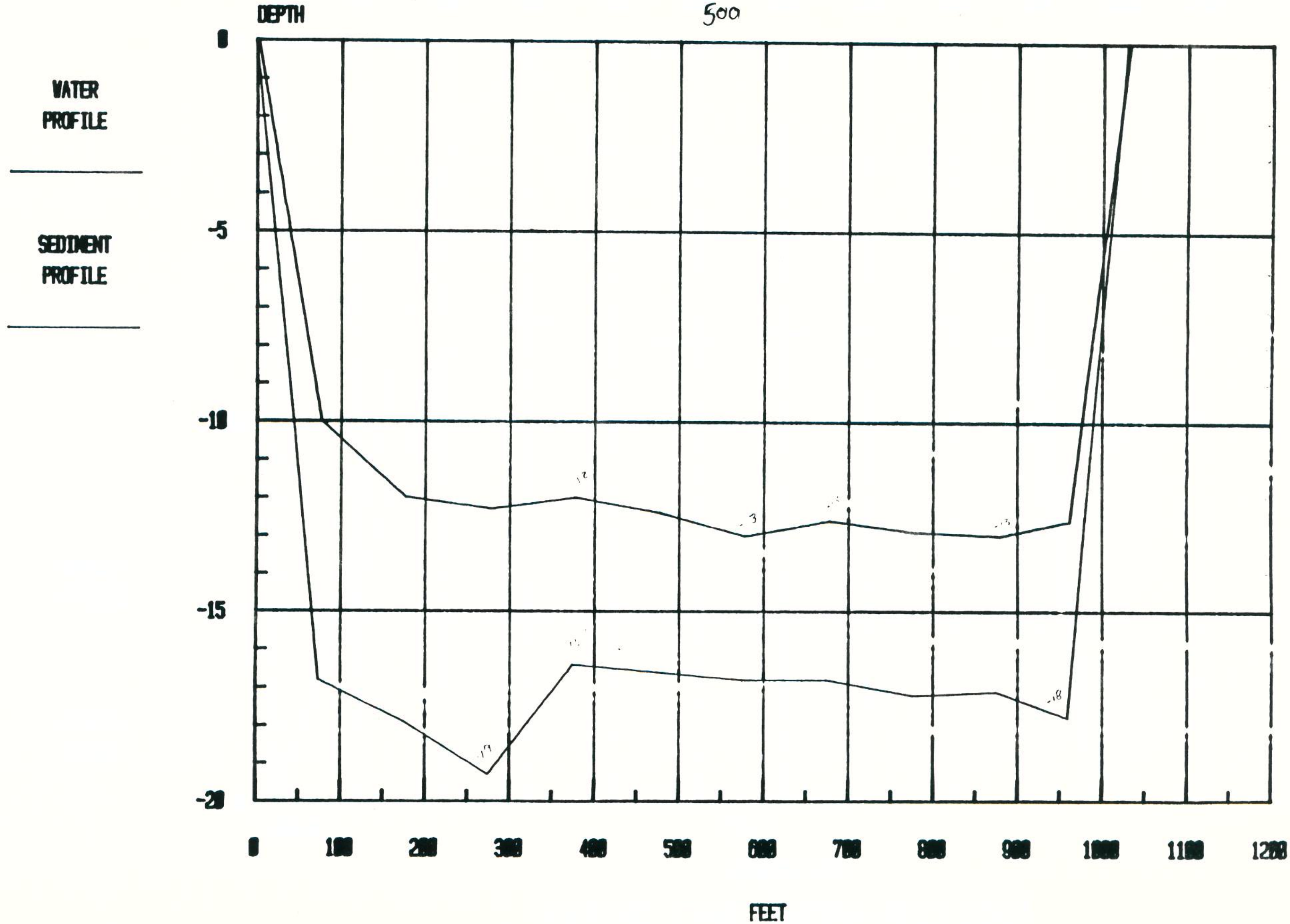
RAVINE LAKE CROSS-SECTIONS

FEBRUARY 1986



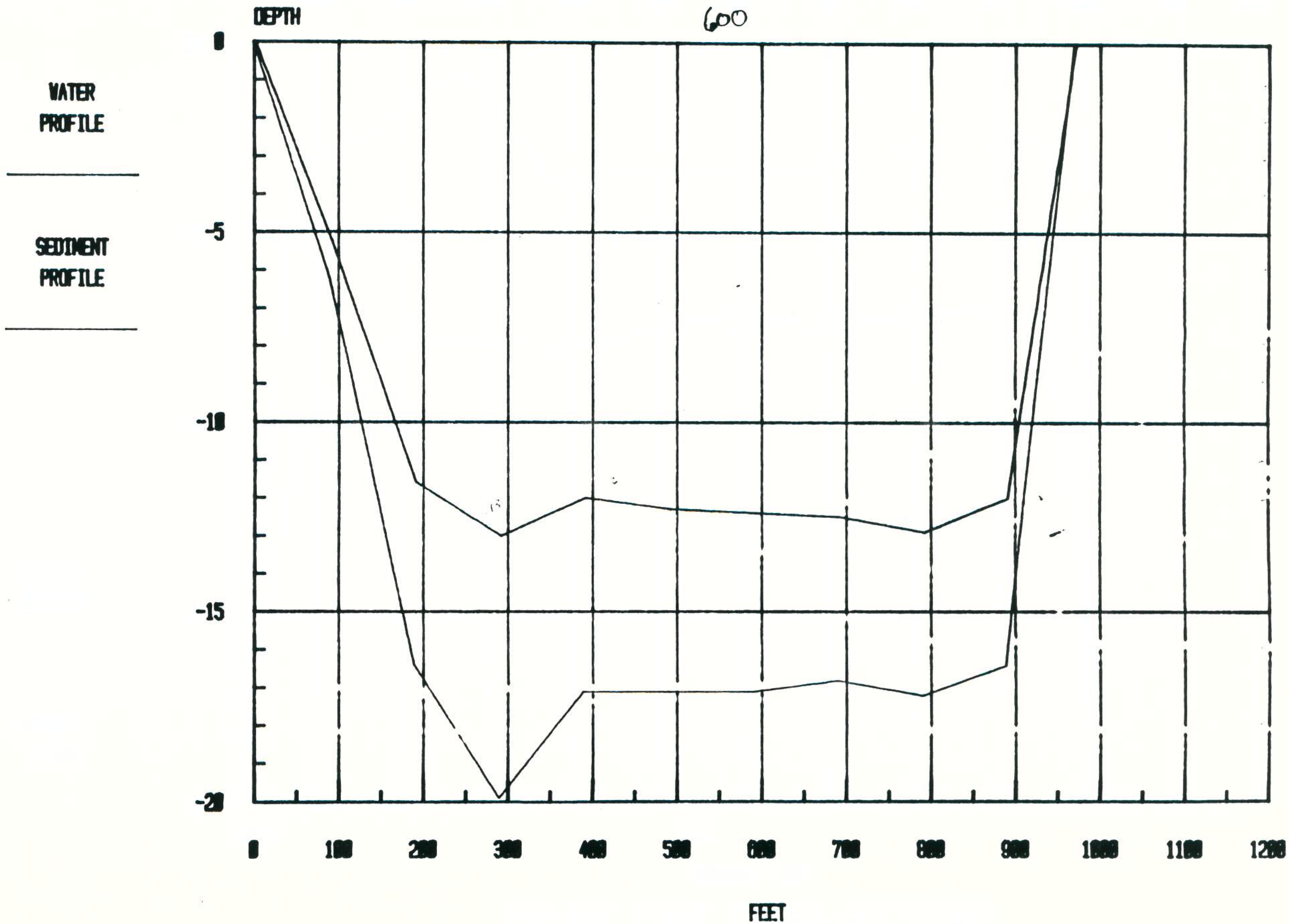
RAVINE LAKE CROSS-SECTIONS

FEBRUARY 1988



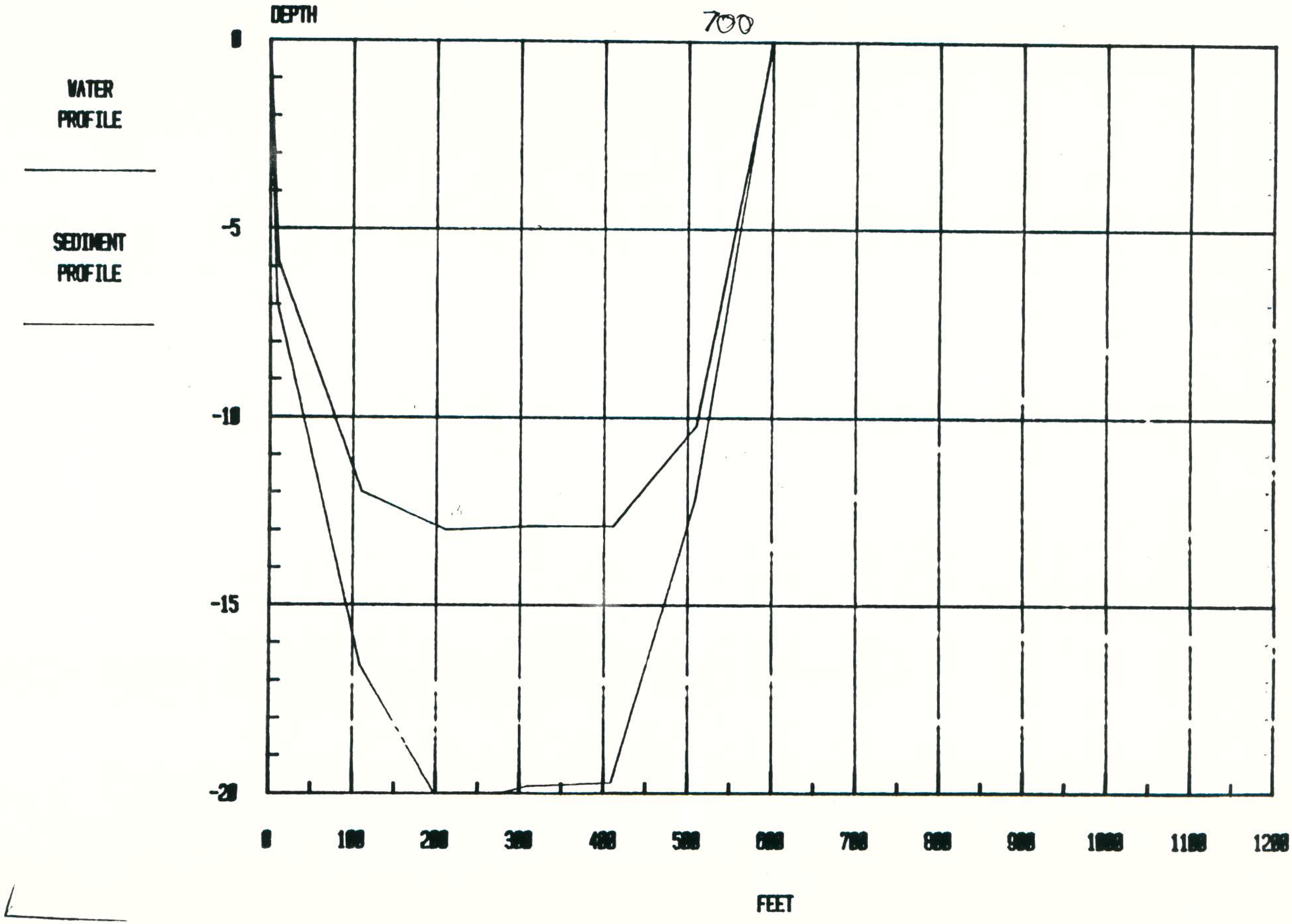
RAVINE LAKE CROSS-SECTIONS

FEBRUARY 1986



RAVINE LAKE CROSS-SECTIONS

FEBRUARY 1986



APPENDIX C. WATER QUALITY DATA AND ELUTRIATE RESULTS

RAVINE LAKE SAMPLE CONCENTRATIONS 1988 - 1989

LAKE NAME	DATE	TIME	SITE	SAMP	DEPTH	WTEMP	ATEMP	SECCHI	DISOX	FECAL	COND	LABPH	TALKAL	TSOL	TDSOL	TSSOL	AMMON	NITRO	TKN_N	TPO4	OPO4	UNIAM
RAVINE LAKE	14-Mar-89	1025	SD-1	GRAB	SURFACE	35	34	2.00		900	356	7.87	69	299	250	52	0.60	0.90	1.94	0.461	0.256	0.0042
RAVINE LAKE	20-Mar-89	1040	SD-1	GRAB	SURFACE	27	16			10	749	7.76	85	921	443	516	0.40	0.70	1.53	0.397	0.140	
RAVINE LAKE	27-Mar-89	1030	SD-1	GRAB	SURFACE	34	43	2.00	11.20	10	447	7.87	114	339	309	8	0.03	0.40	1.02	0.203	0.106	0.0002
RAVINE LAKE	04-Apr-89	1425	SD-1	GRAB	SURFACE	41	48		9.90	10	510	7.71	120	340	331	32	0.16	0.60	0.75	0.207	0.140	0.0010
RAVINE LAKE	11-Apr-89	940	SD-1	GRAB	SURFACE	35	36	2.00	12.60	10	901	7.87	205	725	667	2	0.02	0.10	0.32	0.075	0.057	0.0001
RAVINE LAKE	19-Apr-89	1145	SD-1	GRAB	SURFACE	41	63	2.00		0	1500	8.04	444	1255	1191	18	0.04	0.10	0.41	0.058	0.025	0.0005
RAVINE LAKE	20-Mar-88	1140	SD-2	GRAB	SURFACE																	
RAVINE LAKE	14-Mar-89	1015	SD-2	GRAB	SURFACE	35	34	2.00		130	1060	7.79	83	842	646	184	0.96	1.30	2.83	0.980	0.513	0.0056
RAVINE LAKE	22-Mar-89	1515	SD-2	GRAB	SURFACE	26	34			80	371	8.08	144	845	270	540	0.34	0.60	1.57	0.881	0.110	
RAVINE LAKE	19-Apr-89	1135	SD-2	GRAB	SURFACE	37	62	2.00		10	3100	8.23	316	2886	2760	32	0.40	1.90	0.88	0.112	0.047	0.0070
RAVINE LAKE	25-Apr-89	925	SD-2	GRAB	SURFACE	41	50	2.10	10.90	10	3050	8.30	303	2879	2737	1	0.51	2.20	1.52	0.996	0.754	0.0124
RAVINE LAKE	14-Jun-89	1430	SD-2	GRAB	SURFACE	52	63	2.10	9.40	10	2619	8.34	258	2549	2420	22	0.02	2.00	0.54	0.108	0.058	0.0009
RAVINE LAKE	21-Jun-89	1410	SD-2	GRAB	SURFACE	52	66	1.80	7.50	44	941	8.17	121	784	717	2	0.03	0.90	0.75	0.098	0.047	0.0009
RAVINE LAKE	27-Jun-89	1455	SD-2	GRAB	SURFACE	68	85	1.90	7.70	310	2318	8.29	295	2150	2023	18	0.05	18.00	0.56	0.115	0.038	0.0036
RAVINE LAKE	10-Jul-89	1450	SD-2	GRAB	SURFACE	74	86	2.30		10	2703	8.44	191	2626	2430	24	0.14	1.50	1.31	0.108	0.021	0.0171
RAVINE LAKE	26-Jul-88	945	SD-5	GRAB	SURFACE	65	74			150	2546	8.26	281	2597	2301	296	0.02	8.10	0.48	0.108	0.075	0.0012
RAVINE LAKE	09-Aug-88	1100	SD-5	GRAB	SURFACE	73	78			400	3264	8.16	351	3238	3005	233	0.03	13.20	0.44	0.061	0.048	0.0020
RAVINE LAKE	04-Oct-88		SD-5	GRAB	SURFACE	43	40			320	3348	8.17	370	3278	2988	290	0.03	14.20	0.65	0.081	0.008	0.0006
RAVINE LAKE	27-Mar-89	1008	SD-5	GRAB	SURFACE	34	46	2.00	11.20	10	389	7.46	6	287	242	12	0.39	0.60	1.50	0.508	0.300	0.0010
RAVINE LAKE	03-Apr-89	1415	SD-5	GRAB	SURFACE																	
RAVINE LAKE	03-Apr-89	1415	SD-5	GRAB	SURFACE	40	54			10	3744	8.06	381	3721	3382	18	3.64	7.90	3.78	0.075	0.015	0.0493
RAVINE LAKE	04-Apr-89	1350	SD-5	GRAB	SURFACE	37	48	2.45	9.90	10	288	8.08	279	2596	2373	24	2.02	6.20	2.18	0.108	0.029	0.0212
RAVINE LAKE	10-Apr-89	1405	SD-5	GRAB	SURFACE	36	44	2.20	9.90	10	4235	8.06	405	4081	3722	20	3.40	9.40	3.77	0.041	0.014	0.0384
RAVINE LAKE	18-Apr-89	1400	SD-5	GRAB	SURFACE	41	57	1.80	13.60	10	3900	8.04	391	3800	3552	96	1.60	9.70	2.22	0.061	0.018	0.0216
RAVINE LAKE	25-Apr-89	950	SD-5	GRAB	SURFACE	41	50	2.10	10.90	10	3088	8.11	389	3884	3568	2	1.26	10.00	1.72	0.061	0.024	0.0200
RAVINE LAKE	23-May-89	1410	SS-5	GRAB	SURFACE	56	79	1.90	9.70	800	2750	8.15	312	2707	2555	1	0.02	7.60	0.25	0.054	0.013	0.0007
RAVINE LAKE	06-Jun-89	1400	SD-5	GRAB	SURFACE	55	82	2.90	11.40	60	2808	8.29	316	2830	2614	8	0.02	6.10	0.98	0.078	0.046	0.0009
RAVINE LAKE	14-Jun-89	1415	SD-5	GRAB	SURFACE	52	63	2.10	9.40	2700	2183	8.11	244	2108	2048	12	0.04	5.20	0.82	0.129	0.025	0.0010
RAVINE LAKE	21-Jun-89	1340	SD-5	GRAB	SURFACE	55	65	1.80	7.50	90	2064	8.14	227	2029	1889	2	0.04	5.30	0.76	0.061	0.033	0.0012
RAVINE LAKE	27-Jun-89	1435	SD-5	GRAB	SURFACE	66	85	1.90	7.70	400	3213	8.10	333	3018	2845	12	0.50	10.30	0.98	0.081	0.034	0.0220
RAVINE LAKE	10-Jul-89	1525	SD-5	GRAB	SURFACE	71	86	2.40		100	3213	8.30	318	3210	2839	14	0.05	8.80	0.81	0.092	0.051	0.0041
RAVINE LAKE	19-Mar-88	945	1	GRAB	SURFACE	33				115000	756	7.80	143	596	562	34	0.05	0.40	0.68	0.153	0.077	0.0003
RAVINE LAKE	15-Apr-88	1000	1	GRAB	SURFACE	47	55			0	1494	8.50	246	1157	1065	92	0.02	0.10	1.60	0.465	0.264	0.0010
RAVINE LAKE	19-Apr-88	1040	1	GRAB	SURFACE	40	53			30	2273	7.90	331	1947	1795	152	0.09	0.10	0.86	0.244	0.084	0.0008
RAVINE LAKE	21-Apr-88	1150	1	GRAB	SURFACE	34	36			60	470	8.10	65	390	289	101	0.63	1.00	1.31	0.214	0.096	0.0071
RAVINE LAKE	21-Apr-88	1045	1	GRAB	SURFACE	34	41			200	1728	7.90	203	1401	1265	136	0.24	0.40	0.94	0.186	0.064	0.0017
RAVINE LAKE	27-Apr-88	1035	1	GRAB	SURFACE	39	39			1	1455	8.60	239	1149	1083	66	0.04	0.10	1.40	0.319	0.152	0.0017
RAVINE LAKE	28-Apr-88	1045	1	GRAB	SURFACE	47	52			10	2522	8.00	305	2474	2305	236	0.02	0.01	0.29	0.024	0.008	0.0003
RAVINE LAKE	28-Apr-88	925	1	GRAB	SURFACE	44	48			0	1515	8.50	240	1142	1092	50	0.03	0.01	1.30	0.288	0.145	0.0013
RAVINE LAKE	03-May-88	1315	1	GRAB	SURFACE	50	55			10	1375	9.00	233	1085	1085	0	0.06	0.10	1.41	0.322	0.130	0.0094
RAVINE LAKE	06-May-88	1010	1	GRAB	SURFACE	56	66			0	1595	8.10	251	1260	1186	74	0.13	0.10	1.41	0.298	0.147	0.0038
RAVINE LAKE	18-May-88	1030	1	GRAB	SURFACE	75	58				2052	7.60	600	1752	1611	141	0.21	0.01	1.68	0.970	0.203	0.0043
RAVINE LAKE	19-May-88	950	1	GRAB	SURFACE	56	60			1600	1998	7.70	259	1672	1539	133	0.27	0.10	1.21	0.620	0.181	0.0032
RAVINE LAKE	07-Jun-88	845	1	GRAB	SURFACE	59	65			1100	1632	7.90	231	1288	1195	93	0.48	0.60	1.34	0.281	0.223	0.0102
RAVINE LAKE	26-Jul-88	900	1	GRAB	SURFACE	64	66			130	2288	7.83	219	1546	1459	87	0.13	1.30	0.45	0.488	0.347	0.0029
RAVINE LAKE	04-Oct-88		1	GRAB	SURFACE	43	40	1.45		60	2646	7.96	309	2210	2044	166	0.07	0.10	0.62	0.149	0.057	0.0009
RAVINE LAKE	14-Mar-89	1110	1	GRAB	SURFACE	35	34	2.00		160	1015	8.03	156	744	706	28	0.84	0.60	2.31	0.760	0.622	0.0085
RAVINE LAKE	16-Mar-89	1040	1	GRAB	SURFACE	28	18			120	864	8.03	137	649	606	1	0.70	0.50	2.65	0.970	0.750	
RAVINE LAKE	20-Mar-89	1100	1	GRAB	SURFACE	27	16			10	541	7.51	80	411	365	72	0.53	0.80	2.65	0.824	0.630	
RAVINE LAKE	27-Mar-89	945	1	GRAB	SURFACE	34	42	2.00	11.20	10	683	7.63	110	483	452	10	0.59	0.40	2.29	0.848	0.729	0.0023
RAVINE LAKE	04-Apr-89	1335	1	GRAB	SURFACE	41	48	2.45	9.90	20	945	8.01	163	662	632	28	0.89	0.10	2.35	1.010	0.881	0.0112
RAVINE LAKE	10-Apr-89	1350	1	GRAB	SURFACE	38	43	2.20	9.90	10	869	8.13	149	682	597	12	0.60	0.10	2.20	0.909	0.732	0.0087
RAVINE LAKE	18-Apr-89	1430	1	GRAB	SURFACE	48	57	1.80	13.50	10	828	8.89	143	660	603	84	0.02	0.10	1.94	0.814	0.448	0.0023
RAVINE LAKE	25-Apr-89	1015	1	GRAB	SURFACE	46	50	2.10	10.90	10	880	7.97	153	655	590	4	0.32	0.10	2.19	0.640	0.345	0.0046
RAVINE LAKE	01-May-89	1440	1	GRAB	SURFACE	49	52	1.90		50	1705	8.11	242	1559	1451	19	0.02	0.10	0.22	0.078	0.032	0.0004
RAVINE LAKE	01-May-89	1350	1	GRAB	SURFACE	49	53	1.90		60	788	8.49	139	587	522	48	0.19	0.10	1.74	0.610	0.400	0.0099
RAVINE LAKE	08-May-89	1350	1	GRAB	SURFACE	55	62	2.10	9.60	180	860	8.43	147	640	597	4	0.06	0.10	1.33	0.464	0.259	0.0035
RAVINE LAKE	16-May-89	1350	1	GRAB	SURFACE	60	76	2.00		220	2496	7.12	191	2161	1972	40	0.43	0.40	2.19	0.414	0.005	0.0016
RAVINE LAKE	23-May-89	1350	1	GRAB	SURFACE	70	79	1.90	9.70	850	1948	7.63	272	1741	1618	4	0.56	0.20	1.59	0.502	0.219	0.0101
RAVINE LAKE	06-Jun-89	1345	1	GRAB	SURFACE	67	80	2.90	11.40	550	1284	7.93	146	839	784	8	0.03	1.00	1.56	0.451	0.134	0.0009
RAVINE LAKE	14-Jun-89	1400	1	GRAB	SURFACE	59	63	2.10	9.40	70	1488	7.91	168	979	928	14	0.05	1.10	0.78	0.387	0.168	0.0011
RAVINE LAKE	21-Jun-89	1320	1	GRAB	SURFACE	62	66	1.80	7.50	250	1425	7.92	181	1025	968	4	0.24	1.20	4.60	0.441	0.260	0.0060
RAVINE LAKE	27-Jun-89	1415	1	GRAB	SURFACE	78	85	1.90		1600	1560	7.94	196	1168	1114	20	0.30	0.90	3.66	0.376	0.171	0.0147
RAVINE LAKE	10-Jul-89	1400	1	GRAB	SURFACE	80	86	2.30		262	1479	7.82	181	1049	985	24	0.51	0.80	2.48	0.440	0.284	0.0207
RAVINE LAKE	15-Apr-88	1130	2	GRAB	SURFACE	48	56				4120	8.20	347	3913	3561	352	0.06	4.00	1.12	0.132	0.012	0.0016
RAVINE LAKE	21-Apr-88	1130	2	GRAB	SURFACE	34	34			2200	519	7.85	65	503	331	172	1.50	3.40	2.09	0.546	0.156	0.0096
RAVINE LAKE	28-Apr-88	1015	2	GRAB	SURFACE	44	51			10	3840	8.10	340	3567	3334	233	0.02	3.90	0.33	0.047	0.046	0.0004
RAVINE LAKE	06-May-88	1110	2	GRAB	SURFACE	56	65			0	4070	8.30	506	3857	3500	357	0.04	4.10	0.33	0.047	0.020	0.0018
RAVINE LAKE	19-May-88	930	2	GRAB	SURFACE	53	60			1270	1853	8.10	174	1670	1458	212	0.04	3.80	0.70	0.142	0.091	0.0010
RAVINE LAKE	26-May-88	1435	2	GRAB	SURFACE	57	84			700	2805	8.10	303	2626	2453	173	0.06	2.70	0.51	0.136	0.099	0.0018
RAVINE LAKE	07-Jun-88	955	2	GRAB	SURFACE	56	74			20							0.04	4.00	0.32	0.047		
RAVINE LAKE	16-Mar-89	1035	2	GRAB	SURFACE	28	18			2100	316	6.79	34	781	278	204	0.30	1.00	2.98	1.780	1.240	

LAKE NAME	DATE	TIME	SITE	SAMP	DEPTH	WTEMP	ATEMP	SECCHI	DISOX	FECAL	COND	LABPH	TALKAL	TSOL	TDSOL	TSSOL	AMMON	NITRO	TKN_N	TPO4	OPO4	UNIAM
RAVINE LAKE	01-May-89	1430	2	GRAB	SURFACE	41	52	1.90		10	2544	8.37	302	2455	2308	20	0.07	2.00	0.84	0.108	0.078	0.0020
RAVINE LAKE	08-May-89	1420	2	GRAB	SURFACE	53	62	2.10	9.60	10	1500	7.99	167	1294	1196	102	0.02	1.90	0.92	0.156	0.034	0.0004
RAVINE LAKE	16-May-89	1430	2	GRAB	SURFACE	49	75	2.00		10	3150	8.25	304	3056	2894	13	0.06	1.70	0.80	0.105	0.019	0.0018
RAVINE LAKE	23-May-89	1400	2	GRAB	SURFACE	51	80	1.90	9.70	200	1710	8.00	205	1552	1445	2	0.17	1.60	1.96	0.139	0.036	0.0032
RAVINE LAKE	15-Apr-88	1055	3	GRAB	SURFACE	46	54			0	3120	9.00	337	2533	2311	222	0.07	0.10	4.10	2.020	0.988	0.0095
RAVINE LAKE	21-Apr-88	1210	3	GRAB	SURFACE	34	37			10	3183	9.00	460	2603	2392	211	0.09	0.10	5.59	2.740	1.030	0.0075
RAVINE LAKE	28-Apr-88	1055	3	GRAB	SURFACE	48	60	1.20		10	3312	8.30	541	2650	2481	169	0.08	0.10	5.56	3.080	1.660	0.0026
RAVINE LAKE	06-May-88	1130	3	GRAB	SURFACE					0	3575	8.70	661	2984	2748	236	0.07	0.10	4.70	2.380	1.280	
RAVINE LAKE	18-May-88	1000	3	GRAB	SURFACE	59	77			10	4028	8.20	949	3196	3011	185	3.31	0.10	7.92	4.360	3.340	0.1377
RAVINE LAKE	21-May-88	1520	3	GRAB	SURFACE							6.90		8178	5206	2972	6.10	0.10	9.50	7.100	6.180	
RAVINE LAKE	07-Jun-88	925	3	GRAB	SURFACE	66	74			40	1803	8.80	316	1405	1303	102	0.03	0.10	2.47	1.740	1.460	0.0058
RAVINE LAKE	26-Jul-88	1010	3	GRAB	SURFACE	72	75			50	1892	8.49	270	1515	1380	135	0.05	0.10	3.39	1.320	0.428	0.0063
RAVINE LAKE	23-Aug-88	1015	3	GRAB	SURFACE	65	69	1.80		40	890	8.59	266	1441	1350	91	0.02	0.10	2.18	0.460	0.126	0.0024
RAVINE LAKE	06-Sep-88		3	GRAB	SURFACE	59	64	1.50		20	1819	8.35	262	1476	1334	142	0.02	0.10	2.27	0.593	0.091	0.0012
RAVINE LAKE	04-Oct-88	1050	3	GRAB	SURFACE	43	40	1.60		10	1782	8.48	211	1437	1344	93	0.02	0.10	1.19	0.220	0.011	0.0008
RAVINE LAKE	14-Mar-89	1000	3	GRAB	SURFACE	35	34	2.00		210	265	7.42	40	237	206	24	0.83	1.10	2.93	0.806	0.684	0.0021
RAVINE LAKE	16-Mar-89	925	3	GRAB	SURFACE	28	18			70	375	7.28	49	315	282	1	0.50	0.90	2.46	0.780	0.609	
RAVINE LAKE	20-Mar-89	930	3	GRAB	SURFACE	27	16			10	458	7.36	69	363	331	48	0.22	0.70	1.80	0.797	0.692	
RAVINE LAKE	20-Mar-89	940	3	GRAB	SURFACE	27	16			10	1196	7.50	112	940	888	30	0.21	0.50	1.45	0.305	0.208	
RAVINE LAKE	22-Mar-89	1535	3	GRAB	SURFACE	28	34		12.30	10	337	7.12	54	294	254	12	0.06	0.70	1.58	0.780	0.609	
RAVINE LAKE	28-Mar-89	845	3	GRAB	SURFACE	31	34	1.85		10	315	7.63	58	267	216	20	0.29	0.20	1.53	0.454	0.372	
RAVINE LAKE	03-Apr-89	1445	3	GRAB	SURFACE	46	54			10	390	7.78	74	305	283	24	0.02	0.10	1.18	0.349	0.239	0.0002
RAVINE LAKE	04-Apr-89	1430	3	GRAB	SURFACE	44	49	2.45	9.90	10	428	7.85	127	337	290	28	0.02	0.10	1.04	0.359	0.240	0.0002
RAVINE LAKE	10-Apr-89	1420	3	GRAB	SURFACE	37	44	2.20	9.90	10	620	7.91	102	521	475	2	0.02	0.10	0.91	0.302	0.261	0.0002
RAVINE LAKE	18-Apr-89	1425	3	GRAB	SURFACE	47	58	1.80	13.60	10	1040	8.24	148	802	763	60	0.02	0.10	1.24	0.393	0.272	0.0006
RAVINE LAKE	25-Apr-89	910	3	GRAB	SURFACE	48	50	2.10	10.90	10	1404	8.26	192	1105	1031	4	0.02	0.10	1.38	0.376	0.176	0.0006
RAVINE LAKE	01-May-89	1445	3	GRAB	SURFACE	45	51	1.90		30	1820	8.12	229	1516	1408	36	0.03	0.10	1.19	0.508	0.363	0.0006
RAVINE LAKE	08-May-89	1435	3	GRAB	SURFACE	55	62	2.10	9.60	10	1350	8.28	207	1105	1036	69	0.02	0.10	1.48	0.376	0.222	0.0008
RAVINE LAKE	16-May-89	1455	3	GRAB	SURFACE	67	77	2.00		10	1716	8.02	221	1368	1253	32	0.02	0.10	1.32	0.295	0.063	0.0008
RAVINE LAKE	23-May-89	1500	3	GRAB	SURFACE	71	80	1.90	9.70	10	2043	7.99	235	1732	1625	12	0.02	0.10	1.36	0.414	0.185	0.0008
RAVINE LAKE	06-Jun-89	1445	3	GRAB	SURFACE	75	82	2.90	1.10	10	1552	8.28	206	1209	1065	20	0.04	0.10	2.33	0.675	0.177	0.0036
RAVINE LAKE	27-Jun-89	1500	3	GRAB	SURFACE	76	85	1.90	7.70	720	1173	8.50	149	939	835	76	0.07	0.10	1.68	0.879	0.231	0.0103
RAVINE LAKE	10-Jul-89	1515	3	GRAB	SURFACE	78	86	2.30		90	1326	8.30	243	1235	977	224	0.09	0.10	3.49	1.740	0.188	0.0095
RAVINE LAKE	15-Apr-88	1100	4	GRAB	SURFACE	46	55				3068	7.90	188	2914	2706	208	0.02	0.10	0.56	0.054	0.009	0.0002
RAVINE LAKE	14-Mar-89	1015	4	GRAB	SURFACE	35	34	2.00		190							0.36	0.70	1.78	0.464		.0000
RAVINE LAKE	16-Mar-89	940	4	GRAB	SURFACE	28	17			10	566	7.07	55	465	430	1	0.24	0.60	1.87	0.519	0.371	
RAVINE LAKE	28-Mar-89	900	4	GRAB	SURFACE	32	35			10	525	7.48	66	408	363	14	0.11	0.10	1.27	0.329	0.192	
RAVINE LAKE	03-Apr-89	1430	4	GRAB	SURFACE	46	54			10	915	8.00	101	684	650	4	0.02	0.10	1.06	0.166	0.089	0.0003
RAVINE LAKE	04-Apr-89	1445	4	GRAB	SURFACE	44	49	2.45	9.90	10	965	8.19	104	767	703	20	0.02	0.10	0.91	0.142	0.078	0.0004
RAVINE LAKE	10-Apr-89	1440	4	GRAB	SURFACE	40	44	2.20	9.90	10	1320	8.31	121	1081	976	1	0.02	0.00	0.68	0.064	0.044	0.0005
RAVINE LAKE	18-Apr-89	1445	4	GRAB	SURFACE	50	59	1.80	13.60	10	2205	8.07	1169	1824	1732	82	0.02	0.10	0.81	0.146	0.048	0.0004
RAVINE LAKE	01-May-89	1500	4	GRAB	SURFACE	47	50	1.90		10	2912	8.06	224	2636	2450	26	0.02	0.10	0.76	0.098	0.040	0.0004
RAVINE LAKE	04-Apr-88	1105	5	GRAB	SURFACE	34	36			12000	601	7.80	67	539	390	149	1.45	3.30	1.98	0.212	0.154	0.0083
RAVINE LAKE	15-Apr-88	1030	5	GRAB	SURFACE	46	55				3914	8.10	438	3969	3605	364	1.34	1.51	1.47	0.085	0.024	0.0259
RAVINE LAKE	28-Apr-88	1010	5	GRAB	SURFACE	44	50				3871	8.10	433	3927	3637	290	1.52	1.53	1.60	0.054	0.032	0.0269
RAVINE LAKE	03-May-88	1345	5	GRAB	SURFACE	45	46			10	3850	8.10	431	3781	3563	218	0.87	1.78	1.30	0.037	0.024	0.0161
RAVINE LAKE	06-May-88	1040	5	GRAB	SURFACE	50	65				3740	8.10	425	3967	3618	349	0.78	1.76	1.21	0.058	0.015	0.0179
RAVINE LAKE	19-May-88	915	5	GRAB	SURFACE	55	60			42000	1572	8.00	189	1501	1360	141	0.04	5.40	0.82	0.210	0.123	0.0009
RAVINE LAKE	14-Mar-89	1015	5	GRAB	SURFACE	35	34	2.00		100	110	7.32	33	116	104	8	0.63	0.90	2.33	0.515	0.374	0.0012
RAVINE LAKE	27-Mar-89	1045	5	GRAB	SURFACE	35	44	2.00	11.20	10	121	7.52	44	140	104	4	0.10	0.30	1.43	0.400	0.284	0.0003
RAVINE LAKE	03-Apr-89	1400	5	GRAB	SURFACE	40	54			10	788	8.01	138	562	548	32	0.69	0.10	2.20	0.916	0.754	0.0083
RAVINE LAKE	01-May-89	1410	5	GRAB	SURFACE	41	53	1.90		50	3675	8.11	368	3502	3200	18	1.62	8.60	1.83	0.105	0.029	0.0257
RAVINE LAKE	09-May-89	1330	5	GRAB	SURFACE	48	76	2.20		20	3445	8.15	379	3588	3259	2	0.13	9.50	0.62	0.088	0.045	0.0031
RAVINE LAKE	16-May-89	1415	5	GRAB	SURFACE	50	76	2.00		70	3328	8.14	361	3290	3052	2	0.04	8.70	0.94	0.085	0.032	0.0010
RAVINE LAKE	12-Apr-88	2355	6	GRAB	1.0	52	72	13.00	12.00	10	1400	8.90	229	1089	1077	12	0.04	0.10	1.85	0.660	0.343	0.0056
RAVINE LAKE	12-Apr-88	1155	6	GRAB	10.0	52	72			10	1300	8.90	227	1001	989	12	0.04	0.10	1.82	0.720	0.358	0.0056
RAVINE LAKE	17-Apr-88	1045	6	GRAB	0.0	46	40	1.50		10	1407	8.80	226	1136	1040	96	0.04	0.01	1.33	0.386	0.104	0.0036
RAVINE LAKE	17-Apr-88	1045	6	GRAB	0.0	46	42	1.50		10	1416	8.80	226	1033	1033	0	0.03	0.10	1.59	0.397	0.106	0.0027
RAVINE LAKE	16-May-88	1405	6	GRAB	3.5	56	84			40	1407	8.60	216	1154	1025	129	0.06	0.10	1.73	0.471	0.233	0.0053
RAVINE LAKE	26-May-88	1405	6	GRAB	0.1	55	83			10	1372	8.60	217	1139	1029	110	0.04	0.10	1.55	0.390	0.210	0.0034
RAVINE LAKE	09-Aug-88	1015	6	GRAB	SURFACE	73	74	1.85		10	1428	9.11	251	1196	1072	124	0.04	0.10	2.55	0.890	0.506	0.0154
RAVINE LAKE	23-Aug-88	950	6	GRAB	2.25					10	1485	9.10	259	1195	1112	83	0.03	0.10	1.94	0.898	0.648	
RAVINE LAKE	06-Sep-88		6	GRAB	1	58	64	1.45		10	1552	8.98	267	1282	1146	136	0.04	0.10	1.67	1.390	0.568	0.0080
RAVINE LAKE	21-Sep-88	1015	6	GRAB	SURFACE	52	50			200	1485	8.85	137	1192	1089	103	0.03	0.10	1.98	0.770	0.553	0.0038
RAVINE LAKE	12-Oct-88	1030	6	GRAB	1.45	49	48	1.80	9.50	10	1504	8.88	268	1243	1086	157	0.04	0.10	1.58	0.915	0.612	0.0048
RAVINE LAKE	15-Nov-88	940	6	GRAB	SURFACE	35	34	2.40	9.20	10	1545	8.92	266	1195	1097	98	0.03	0.02	2.08	0.830	0.543	0.0022
RAVINE LAKE	07-Dec-88	1030	6	GRAB	SURFACE	35	22	1.90	9.80	10	1566	8.93	277	1253	1170	83	0.03	0.10	2.02	0.862	0.609	0.0022
RAVINE LAKE	14-Mar-89	1035	6	GRAB	SURFACE	35	34	2.00		170	410	7.49	60	323	281	20	0.78	0.80	2.73	0.706	0.573	0.0023
RAVINE LAKE	04-Apr-89	1415	6	GRAB	SURFACE	42	48	2.45	9.90	10	599	8.02	111	453	407	36	0.51	0.10	1.82	0.806	0.571	0.0069
RAVINE LAKE	11-Apr-89	955	6	GRAB	1.5	33	37	2.00	12.50	10	616	7.96	107	480	413	14	0.31	0.10	1.64	0.678	0.575	0.0024
RAVINE LAKE	09-May-89	1415	6	GRAB	SURFACE	60	75	2.21	9.60	10	749	8.64	131	550	498	4	0.02	0.10	1.30	0.376	0.185	0.0022
RAVINE LAKE	09-May-89	1410	6	GRAB	SURFACE	60	75	2.20	9.60	10	749	8.57	133	576	502	8	0.02	0.10	1.16	0.403	0.190	0.0019
RAVINE LAKE	14-Jun-89	1440	6	GRAB	0.5	58	63	2.10	9.40	60	826	8.38	151	632	574	34	0.03	0.10	1.17	0.488	0.269	0.0018
RAVINE LAKE	12-Apr-88	1315	7	GRAB	0.0	52	75	1.80		10	1310	9.10	233	1069	962	107	0.03	0.10	1.62	0.651	0.353	0.0061

LAKE NAME	DATE	TIME	SITE	SAMP	DEPTH	WTEMP	ATEMP	SECCHI	DISOX	FECAL	COND	LABPH	TALKAL	TSOL	TDSOL	TSSOL	AMMON	NITRO	TKN_N	TPO4	OPO4	UNIAM
RAVINE LAKE	27-Apr-88	1020	7	GRAB	11.4	44	48	1.80		10	1400	8.90	227	1103	1022	81	0.03	0.10	1.40	0.393	0.101	0.0031
RAVINE LAKE	27-Apr-88	1005	7	GRAB	0.0	44	48	1.80		10	1425	8.90	226	1105	1027	78	0.04	0.10	1.41	0.346	0.102	0.0041
RAVINE LAKE	16-May-88	1400	7	GRAB	0.1	56	83			90	1378	8.60	216	1111	1015	96	0.03	0.10	1.57	0.288	0.109	0.0026
RAVINE LAKE	26-May-88	1400	7	GRAB	7.5					100	1425	8.60	220	1124	1017	107	0.03	0.10	1.51	0.312	0.118	
RAVINE LAKE	07-Jun-88	930	7	GRAB	0.0						1377	8.60	215	1020	1005	15					0.399	
RAVINE LAKE	07-Jun-88	1045	7	GRAB	5.0	84	78				1377	8.50	215	1113	998	115					0.401	0.0000
RAVINE LAKE	09-Aug-88	1035	7	GRAB	SURFACE	73	74			10	1428	8.91	250	1235	1081	154	0.03	0.10	3.10	1.130	0.558	0.0085
RAVINE LAKE	09-Aug-88	1035	7	GRAB	7.25	73	74	1.50		10	1479	8.70	238	1182	1074	108	0.03	0.10	2.35	0.848	0.537	0.0059
RAVINE LAKE	23-Aug-88	925	7	GRAB	6	70	68	1.80		10	1484	9.07	259	1201	1110	91	0.02	0.10	2.73	1.000	0.695	0.0067
RAVINE LAKE	23-Aug-88	915	7	GRAB	SURFACE	70	68	1.80		10	1498	9.08	260	1217	114	1103	0.02	0.10	2.10	0.975	0.679	0.0068
RAVINE LAKE	06-Sep-88	920	7	GRAB	SURFACE	59	64	1.45		10	1498	8.95	257	1245	1135	110	0.02	0.10	2.49	0.958	0.550	0.0039
RAVINE LAKE	06-Sep-88	920	7	GRAB	7.5	57	64			10	1484	8.94	262	1270	1119	151	0.03	0.10	2.36	0.965	0.567	0.0054
RAVINE LAKE	21-Sep-88	945	7	GRAB	SURFACE	52	52	1.80		320	1365	8.91	235	1103	1005	98	0.07	0.10	1.97	0.660	0.444	0.0099
RAVINE LAKE	21-Sep-88	950	7	GRAB	7.5	54	52	1.85		100	1530	8.90	260	1191	1099	92	0.13	0.10	1.96	0.830	0.624	0.0194
RAVINE LAKE	12-Oct-88	1000	7	GRAB	SURFACE	48	48	1.80	9.50	10	1510	8.80	264	1172	1063	109	0.04	0.10	1.95	0.915	0.654	0.0039
RAVINE LAKE	12-Oct-88	1010	7	GRAB	7.25	48	48	1.85	9.50	10	1495	8.78	265	1168	1071	97	0.04	0.10	2.25	0.915	0.668	0.0037
RAVINE LAKE	15-Nov-88	910	7	GRAB	7.25	37	35	2.40	9.20	10	1494	8.84	265	1179	1092	87	0.10	0.10	1.82	0.822	0.604	0.0067
RAVINE LAKE	15-Nov-88	855	7	GRAB	SURFACE	37	35	2.40	9.20	10	1494	8.84	265	1176	1093	83	0.11	0.10	1.81	0.805	0.601	0.0074
RAVINE LAKE	07-Dec-88	1000	7	GRAB	SURFACE	34	22	1.90	9.80	10	1525	8.78	269	1206	1136	70	0.18	0.10	1.98	0.890	0.661	0.0093
RAVINE LAKE	07-Dec-88	1000	7	GRAB	7.25	35	22	1.90	9.80	10	1552	8.78	272	1216	1135	81	0.23	0.10	2.06	0.982	0.661	0.0122
RAVINE LAKE	15-Mar-89	1125	7	GRAB	SURFACE	29	1	0.67		120	639	7.78	98	498	453	45	0.92	0.40	3.09	1.210	0.678	
RAVINE LAKE	28-Mar-89	1000	7	GRAB	SURFACE	31	35	1.85		10	371	7.50	66	305	253	18	0.44	0.30	1.69	0.684	0.530	
RAVINE LAKE	11-Apr-89	1005	7	GRAB	SURFACE	35	37	2.00	12.50	10	693	8.18	121	554	473	12	0.40	0.10	1.70	0.753	0.598	0.0087
RAVINE LAKE	11-Apr-89	1015	7	GRAB	6.5	36	38	2.00	12.60	10	693	8.27	122	544	483	4	0.39	0.10	1.71	0.746	0.614	0.0071
RAVINE LAKE	08-May-89	1400	7	GRAB	SURFACE	55	62	2.10	9.60	10	770	8.52	134	580	523	57	0.02	0.10	1.44	0.437	0.247	0.0014
RAVINE LAKE	09-May-89	1345	7	GRAB	7	55	75	2.20	9.60	10	749	8.58	131	552	495	4	0.02	0.10	1.03	0.363	0.018	0.0016
RAVINE LAKE	21-Jun-89	1350	7	GRAB	0.5	61	66	1.80	7.50	30	834	8.35	155	625	570	18	0.11	0.10	1.38	0.562	0.378	0.0069