FINAL REPORT

REND LAKE
UPPER MISSISSIPPI RIVER BASIN

BIG MUDDY RIVER, ILLINOIS

REPORT OF SEDIMENTATION
2009 RESURVEY

U.S. Army Engineer District, St. Louis
Corps of Engineers
St. Louis, Missouri

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REPORT ON RESURVEY OF SEDIMENTATION
REND LAKE
BIG MUDDY RIVER, ILLINOIS

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PERTINENT DATA SUMMARY
REND LAKE

Item	**Unit**	
DRAINAGE AREA		
Upstream from dam site	sq. mi.	488
Upstream from mouth	sq. mi.	2,360
INACTIVE STORAGE POOL		
Elevation	NGVD	391.3
Area	acres	5,039
Storage	acre-feet	21,372
Storage (runoff)	inches	0.82
JOINT USE POOL		
Elevation	NGVD	391.3-405.0
Area	acres	19,151
Storage	acre-feet	154,165
Storage (runoff)	inches	5.92
Regulated outflow	cfs	30
FLOOD CONTROL POOL		
Elevation	NGVD	405.0-410.0
Area	acres	25,070
Storage	acre-feet	116,027
Storage (runoff)	inches	4.46
Unregulated outflow (min.)	cfs	30
Unregulated outflow (max.)	cfs	1,030
SURCHARGE POOL (Standard Project Flood)		
Elevation	NGVD	410.0-416.1
Area	acres	30,994
Storage	acre-feet	153,401
Storage (runoff)	inches	5.89
Unregulated outflow (min.)	cfs	1,030
Unregulated outflow (max.)	cfs	30,500

PERTINENT DATA SUMMARY (continued)

SURCHARGE POOL (Maximum Possible)

Elevation	NGVD	410.0-419.7
Area	acres	40,700
Storage	acre-feet	263,130
Storage (runoff)	inches	10.11
Unregulated outflow (min.)	cfs	1,030
Unregulated outflow (max.)	cfs	87,250

FREEBOARD

Elevation	NGVD	419.7-424.0
Area	acres	50,000
Storage	acre-feet	147,094
Storage (runoff)	inches	5.65
Height	feet	4.3

STANDARD PROJECT FLOOD

Peak inflow	cfs	150,960
Peak outflow	cfs	30,500
Design storm	inches	14.71
Runoff (includes baseflow)	acre-feet	283,423
Runoff (includes baseflow)	inches	10.89

DAM

Elevation, top of dam	NGVD	424
Height above streambed	feet	54
Length of crest	feet	8,035

MAIN SPILLWAY (Ungated)

Width at crest	feet	435[1/]
Elevation of crest	NGVD	410
Capacity at elevation 419.7	cfs	58,000
Capacity of notch at elevation 410	cfs	1,000

AUXILIARY SPILLWAY (Ungated)

Width at crest	feet	800
Elevation of crest	NGVD	415
Capacity at elevation 419.7	cfs	29,250

[1/] Includes 31-foot-wide notch with crest at elevation 405

PERTINENT DATA SUMMARY
Subimpoundment Dams

Big Muddy

Type	Earthfill dam with ungated overflow section
Total length, feet	3,740
Overflow length, feet	2,435
Non-overflow section, NGVD	416.0
Overflow section, NGVD	412.0
Outlet conduit, feet	6x6 reinforced concrete box
Flowline of conduit, NGVD	396.2

Casey Fork

Type	Earthfill dam with ungated overflow section
Total length, feet	7,650
Overflow length, feet	4,485
Non-overflow section, NGVD	416.0
Overflow section, NGVD	412.0
Outlet conduit, feet	6x6 reinforced concrete box
Flowline of conduit, NGVD	396.2

CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	25.4	millimeters
feet	0.3048	meters
miles (U.S. statute)	1.609344	kilometers
square miles	3.589988	square kilometers
cubic yards	0.7645549	cubic meters
acre-feet	1,233.482	cubic meters
feet per second	0.3048	meters per second
cubic feet per second	0.02831685	cubic meters per second

REPORT ON RESURVEY OF SEDIMENTAITON
REND LAKE
BIG MUDDY RIVER, ILLINOIS

1. INTRODUCTION.

This report is prepared according to instructions in EM 1110-2-4000, dated November 15, 1961, and compares the original 1970 survey with the 2009 resurveys of the upstream sediment ranges and downstream retrogression ranges for Rend Lake, including the subimpoundment dams on the Big Muddy River and Casey Fork.

The purpose of the investigation is to analyze the 2009 resurvey data to determine the distribution of sediment, the depletion of storage in the reservoir, and the trap efficiency of the reservoir. Construction of the subimpoundment dams was completed in April 1966. Main dam construction was finished in December 1971. Operation of the reservoir was initialized in February 1971 when an interim elevation of 395.0[1/] was reached.

2. LOCATION OF RESERVOIR.

Rend Lake is located in Franklin and Jefferson Counties, Illinois, on the Big Muddy River. The dam is approximately 104 miles[2/] above the confluence of the Big Muddy and the Mississippi Rivers, and approximately 3 miles northwest of the town of Benton, Illinois. The watershed contributing to the reservoir is 488 square miles or about 21 percent of the total river basin. The Big Muddy River basin is shown on Plate 1.

3. PURPOSE OF RESERVOIR.

Rend Lake provides for the following project purposes: flood control, downstream water-quality control, water supply, recreation, fish and wildlife management, and area redevelopment. The Big Muddy River and Casey Fork subimpoundment dams are operated by the state of Illinois and are reserved for intensive waterfowl management.

4. RESERVOIR PERTINENT DATA – DAM AND APPURTENANT STRUCTURES.

The Pertinent Data Summary, shown on pages iv and v, contains data concerning the dam, outlet, and spillway structures and the elevations, areas, and capacities of the inactive, joint-use, flood control, and surcharge pools. Page vi shows pertinent data concerning the Big Muddy River and Casey Fork subimpoundment dams.

[1/] All elevations (el) cited herein are in feet referred to National Geodetic Vertical Datum.
[2/] A table of factors for converting U.S. customary units of measurement to metric (SI) units is presented on page vii.

5. WATERSHED CHARACTERISTICS.

The watershed has a total area of 488 square miles. The reservoir occupies approximately 39 square miles of this area at flood-control pool (el. 410.0). The watershed has a median length of 32 miles, a maximum width of 20 miles, and an average width of about 15 miles. The topography of the basin is characterized by hilly uplands and broad, almost flat lowlands along principal streams. Most of the floodplain area upstream of the dam site is timbered. A few farms are located in the cleared areas of the valley. The principal industries in the watershed are mining of bituminous coal, oil production, and farming.

6. SUBIMPOUNDMENTS.

Two subimpoundment dams were constructed on the Big Muddy River and Casey Fork tributaries in the upper reaches of the lake (see Plate 2). These subimpoundment dams consist of compacted earth embankments with crest elevations at 412.0. Both have gravity outlets with gates which enable the pool level above the dams to be regulated for the benefit of fish and wildlife. At elevation 412.0, the Big Muddy River subimpoundment occupies approximately 1,960 acres and the Casey Fork subimpoundment occupies approximately 2,125 acres.

7. CLIMATE.

The climate of the area is relatively moderate. The summers are usually mild with occasional temperatures of 100°F or slightly higher. The winters are usually moderate, although temperatures below 0°F are occasionally experienced. The minimum and maximum temperatures of record are -22°F during the winter and 114°F during the summer. The average annual temperature for the area is about 65°F.

8. RESERVOIR OPERATION.

The general plan for operation of the reservoir provides for a regulated release of 30 cubic feet per second (cfs) when the reservoir is in the joint-use pool range (el 391.3 to 405.0). In the flood-control range (el 405.0 to 410.0), the outflow is unregulated and will vary from 30 to 1,030 cfs (the approximate downstream capacity). At elevations above 410.0, uncontrolled outflow will be over the main (ungated) spillway. Above elevation 415.0, the auxiliary (ungated) spillway will go into service.

9. RESERVOIR INFLOW.

Summaries of the monthly and annual precipitation and runoff data for the watershed are given in Tables 1 and 2. One inch of runoff equals 26,027 acre-feet. Average annual precipitation and inflow for the sediment survey period are tabulated in Items 34 and 35 of Plate 39, a data summary of reservoir sediment, ENG Form 1787. The average monthly inflow hydrograph for the period of 1971 through 2009 is shown on Plate 3. The average monthly pool elevations for the same period are shown on Plate 4.

10. ORIGINAL RESERVOIR SURVEY.

Reservoir area and volume were determined from U.S. Geological Survey (USGS) 15 minute quadrangle sheets. A tabulation of the original capacity at 5-foot intervals is shown in Table 3a. Item 46 of Plate 40 gives area and storage (capacity) tabulation at 5-foot intervals for the original survey. Area and capacity curves are shown on Plate 5.

11. TYPE AND SCOPE OF THE INITIAL SEDIMENT SURVEY.

There are 23 sediment ranges that were established and surveyed by direct leveling during the period of May 1969 through January 1971 for the purpose of observing sediment distribution and the approximate rate of reservoir storage depletion. Plate 2 shows the locations of the pool sediment ranges. The cross sections of the ranges for the original, 1974, 1980, 1986, and 2009 resurveys are shown on Plates 6 through 28. Appendix A shows detailed location of the end points for the 23 sediment ranges.

12. TYPE AND SCOPE OF SEDIMENT RESURVEY.

Detailed sediment resurveys were made in 1974, 1980, 1986, and 2009. For the 2009 survey, the dry land topographic portions of the sedimentation resurveys were completed utilizing a total station and prism rod. Hydrographic surveying was completed using an Odum Hydrographic Hydrotrac Echo Sounder. Hydrographic data was collected, edited, and processed using Hypack 2009 software. The shoreline was marked at the ends of each range line. These points were used to create planned run lines within Hypack and/or were used visually by the boat operator to maintain proper alignment.

The horizontal project datum is the North American Datum of 1983 (NAD83), US State Plane Illinois East Zone, FIPS 1201. Horizontal positioning of topographic features was determined by handheld GPS observations or Real Time Kinematic (RTK) observations on range line control points and should be considered approximate. Horizontal positioning of hydrographic data was established by Differential GPS (DGPS) observations made with a Trimble AG132 DGPS unit with antenna mounted to the survey boat.

Range line control points with known elevations were held when completing topographic surveys of sedimentation ranges. For all retrogression ranges and for sedimentation ranges where existing control was unreliable, RTK observations were used to establish control point elevations.

To process sedimentation range hydrographic data, water surface elevations were based on the Rend Lake Pool, Big Muddy Subimpoundment or Casey Fork Subimpoundment gage readings. To process retrogression range hydrographic data, water surface elevations were established by leveling to the water surface from known control points prior to sounding.

The survey was conducted in NGVD29. All topographic and hydrographic data were transformed from NGVD29 to NAVD88 using the datum conversion at the project

benchmark (OPUS-DB PID: BBBS61, Designation: Rend Visitors East). The NGVD29 to NAVD88 datum conversion at this station is -0.510 feet and is based on the difference between the NGVD29 elevation provided by the USACE and the OPUS-DB NAVD88 solution (NGVD29 El. = 424.328, NAVD88 El. = 423.818).

The 1974 resurvey data and results of analysis were not included in the 1980 Report of Sedimentation and are also not presented herein. The 1980 report stated that it was possible the contractor's equipment for the 1974 resurvey produced erroneous results.

Sections of missing data in the 2009 resurvey were supplemented with 1986 resurvey data for sedimentation ranges 7B (station 1752.54 to 2246), 16A (station 5444.78 to 6337), and 20A (station 2098.55 to 2304.51 and station 3752.66 to 4012.24). Missing data for the 2009 resurvey of sedimentation range 15A (station 869 to 1527.54 and station 3223.05 to 4201.64) was supplemented with data from the 1980 resurvey. Sedimentation range 15A was not resurveyed in 1986.

13. METHODS OF SEDIMENT COMPUTATIONS.

The procedure based on the prismoidal formula for computing reservoir capacities and developed by the U.S. Soil Conservation Service (SCS) was used in the 1980 and 1986 studies and also in this study. The procedure was published by H.M. Eakin of the SCS as USDA Technical Bulletin No. 524, "Silting of Reservoirs," July 1936 (rev. C.B. Brown, August 1939). Eakin describes a range-end formula given by

$$V = \frac{A'}{3}\left(\frac{E_1 + E_2}{W_1 + W_2}\right) + \frac{A}{3}\left(\frac{E_1}{W_1} + \frac{E_2}{W_2}\right) + \frac{h_3E_3 + h_4E_4}{3(43{,}560)}$$

where V = capacity, acre-feet

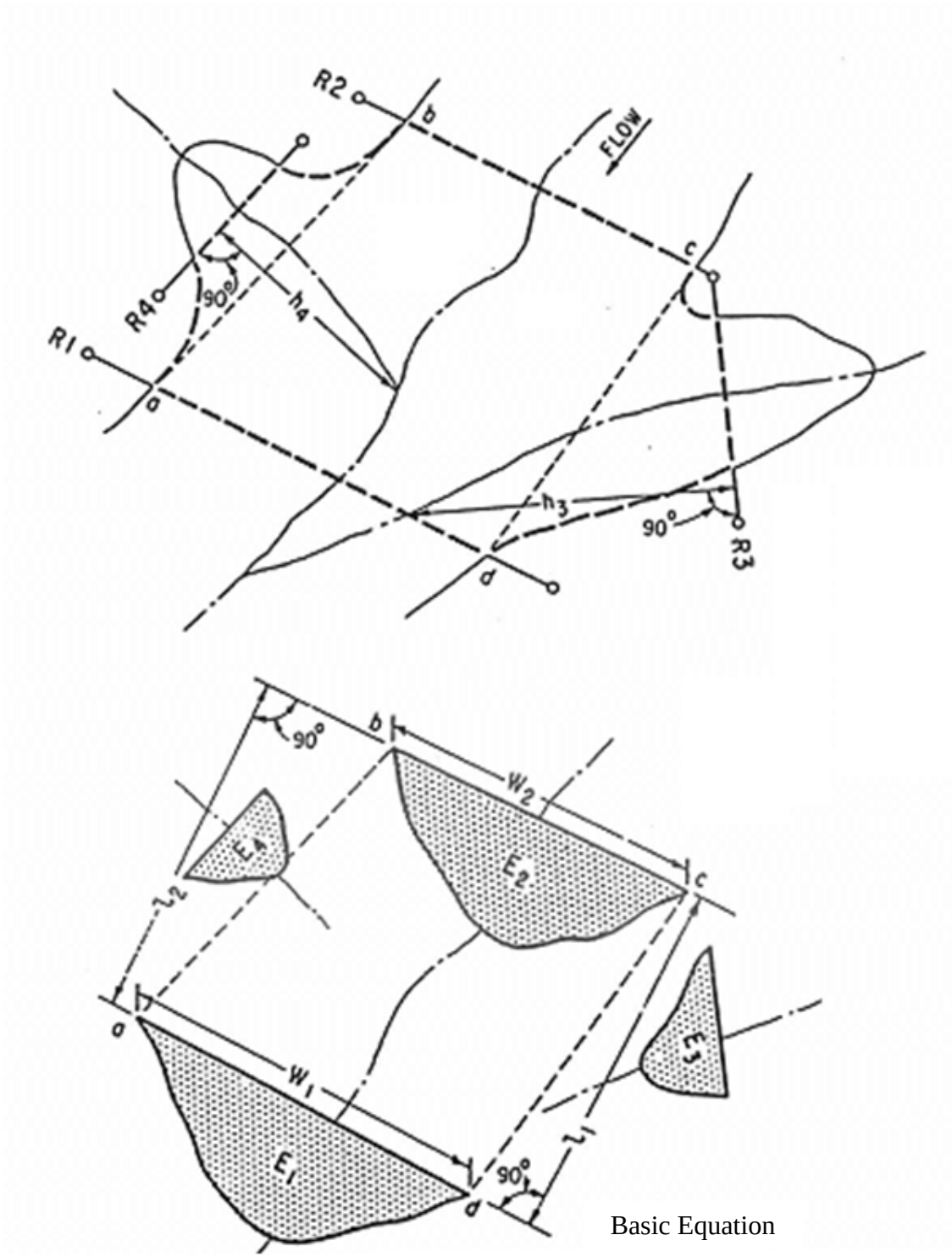
A' = area of the quadrilateral formed by connecting the points of intersection of the ranges with a given contour, acres

E = Range cross-section area, square feet

W = Width of the main stream range at a given elevation, feet

A = Total surface area of the segment bounded by the ranges, acres

h = Perpendicular distance from a range on a tributary to the junction of the tributary with the main stream; or if this junction is outside the segment, to the intersection of the thalweg of the tributary with the downstream range, feet



Basic Equation

$$V = \frac{A'}{3}\left(\frac{E_1+E_2}{W_1+W_2}\right) + \frac{A}{3}\left(\frac{E_1}{W_1} + \frac{E_2}{W_2}\right) + \frac{h_3E_3+h_4E_4}{3(43{,}560)}$$

Figure 1. Terms of range-end formula for determining the capacity of a reservoir. (Taken from ASCE N&R No. 54 “Sedimentation Engineering”, V.A. Vanoni, Editor, 1975, pp. 378-379).

This formula is illustrated in Figure 1 with a reservoir segment that includes two tributary arms, and is thus bounded by four ranges. The formula is applicable for all reservoir segments except for the one between the most downstream range and the dam. The reservoir volume in this section is given by

$$V = A\left(\frac{E}{W}\right) - \frac{L\left(2B - \frac{E}{W}S\right)\frac{E}{W}}{3(43{,}560)}$$

where V, A, and W are the same as defined above, and

L = length of the dam, feet

B = base width of the dam, feet

S = slope of the upstream face of the dam

The length L and base width B refer to distances on the dam describing the volume of water displaced by the upstream face of the dam. Therefore, L and B almost always vary with reservoir stage.

In the study, the quadrilateral area A' and surface area A were computed from USGS 7.5 minute topographic maps of the reservoir in GIS. HEC-RAS was used to obtain the values for E and W from the surveyed cross-sectional data.

Values for A', A, E, and W were computed at four reservoir elevations: 390.0, 400.0, 405.0, and 410.0 feet. These elevations correspond closely or exactly to the tops of the inactive pool (391.3 feet), the joint-use pool (405.0 feet), and the flood-control pool (410.0 feet); and were also contour elevations on the USGS topographic maps. Remaining reservoir volumes were interpolated from these results. Volumes for the two subimpoundments were also calculated at a stage of 412.0 feet, the elevation of the flood-control pools for the subimpoundments.

Table 3a lists the original reservoir capacities as listed in the 1980 Report on Sedimentation. Table 3b lists the 1980 and 1986 reservoir capacities as shown in the 1986 Report on Sedimentation, as well as the 2009 reservoir capacities for Rend Lake and the two subimpoundments. Table 3c provides the computed changes in reservoir capacity for the periods 1970-1980, 1970-1986, and 1970-2009.

In reporting reservoir volumes, or sediment volumes, values were given to the nearest acre-foot. Due to inaccuracies in the survey data and in the application of the prismoidal formula, volumes can be accurate to three significant digits, at best. However, in order to be precise relative to previous work and in comparison of one value to another within this analysis, precision to the nearest acre-foot was maintained.

Table 4 lists quadrilateral and total surface areas between ranges and approximate distances between ranges at flood-control pool. The quadrilateral areas are generally smaller than the total surface areas because the quadrilateral areas do not reflect inlets and coves along the reservoir shoreline, which are included in the surface area.

Range cross-sectional areas measured in the 1970, 1980, 1986 and 2009 surveys are listed in Table 5. Cross-sectional areas shown in the table correspond to the crest elevation (410.0 for Rend Lake and 412.0 for the two subimpoundments). Table 6 describes the surveyed cross-sectional area changes for the 1970-1980, 1970-1986, and 1970-2009 periods.

The cross-sectional areas of certain ranges increased since the original survey. Increased cross sectional area is possibly due to subsidence of the ground surface caused by historic coal mining in the vicinity. Ranges showing significant changes in the area are 6B, 7B, 17AB, 20A, and 23AB. Note the significant increase in area from 1970 to 2009 at Range 20A (over 10,000 square feet at el 410.0, a 54% increase). Plate 25 shows the change in ground profile in 2009 for Range 20A, extending approximately from stations 1+00 to 44+00. The decrease in elevation was measured to be as great as 7 feet, at about station 44+60.

Item 46 of Plate 40, ENG Form 1787, also lists elevation versus reservoir surface area for original conditions, 1986, and 2009. In solving for 2009 reservoir areas, the reservoir volumes computed from the 2009 resurvey were used, taking advantage of the average end area method to relate volume with surface areas. The average end area formula is

$$V = \frac{h}{2}(A_1 + A_2)$$

where V = volume between given reservoir elevations, acre-feet

h = distance between reservoir elevations, feet

A = surface area of the reservoir at a given elevation, acres

A normalized form of this relationship was derived to provide an expression for 2009 reservoir areas as a function of the original reservoir volumes and areas and the 2009 reservoir volumes computed with the prismoidal method. This relationship is given by

$$\frac{V_{1970} - V_{2009}}{V_{1970}} = \frac{h}{2}\,\frac{(A_1 + A_2)_{1970} - (A_1 + A_2)_{2009}}{(A_1 + A_2)_{1970}}$$

It may be assumed that the surface area does not change over time at elevations above the maximum pool elevation. Therefore, using the above expression and starting the calculations at the maximum pool elevation, the 2009 area at the lower end of the elevation interval $(A_2)_{2009}$ is computed.

The calculation proceeds step-wise toward the reservoir bottom in this manner. Area-elevation computations were performed at 5-foot intervals and are listed in Item 46 of Plate 40 and plotted on Plate 4. The computed surface areas reflect the increase in reservoir volume found between all ranges, except at elevation 385. The increase in volume is possibly due to ground subsidence resulting from historic coal mining.

14. SEDIMENT QUANTITIES

Capacities for 1970 and 2009 are listed by reach for the flood-control pool, joint-use pool, and inactive pool in Tables 7. A summary of the volume changes which have occurred in each reach of Rend Lake over the 1970-1980, 1970-1986, and 1970-2009 periods is presented in Tables 8a, 8b, and 8c. These tables describe the changes below elevations 410.0, 405.0, and 390.0, respectively. More reaches experienced a larger increase in volume below elevation 410.0 than below elevations 405.0 and 390.0, indicating that a large portion of the volume increase has occurred between 405.0 and 410.0. In addition, the reaches which have increased in volume tend to be on the western (Big Muddy River side) side of Rend Lake. It should be noted that for the prismoidal formula as described above, volume changes are a function of both changes in cross-sectional area and top width. Volume change and top width are inversely related. Therefore, an increase in volume can be computed when cross-sectional area decreases if the surveyed top width decreases at a greater rate than the cross-sectional area.

The following table summarizes the change in storage from 1970 to 2009 for the various pools, the main reservoir, and the subimpoundments based on the 2009 resurvey. A period of 38.8 years (see Item 28, ENG Form 1787, Plate 39) was used in the calculations.

	Amount of Sediment Deposited (acre-feet)	Rate of Deposition (acre-feet/yr)	Percent of Storage Lost
Inactive Pool	3,693	95	14.7%
Joint-Use Pool	5,445	140	3.4%
Flood-Control Pool	-6,552*	-169	-6.0%
Total Reservoir	-7,917	-204	-2.6%
Main Reservoir	-1,820	-47	-0.6%
Casey Fork SI	22	1	3.2%
Big Muddy SI	-1,427	-37	-13.6%

*Negative values indicate an increase in storage.
Note: Capacities for the total reservoir and main reservoir are at elevation 410.0.
Capacities for the subimpoundments are at elevation 412.0.

The table indicates that sediment accumulation has had the greatest impact in the inactive and joint-use pools and in the Casey Fork subimpoundment. Conversely, the Big Muddy subimpoundment and the flood-control pool have been most affected by apparent ground subsidence.

15. TRAP EFFICIENCY OF THE RESERVOIR

For the period of operation, the entire reservoir has a trap efficiency of 99 percent. This computation was based on the method of Gunner Brune, where percentage of sediment trapped is a function of the ratio of reservoir capacity to mean annual inflow, both in the same volume units (Item 33, Plate 39), presented in a transaction of the American Geophysical Union, Volume 34, Number 3, Figure 6, June 1953, pages 407-414.

The trap efficiencies of the subimpoundments were not computed because the inflows into each subimpoundment were not known. Table 9 is a tabulation of sieve analysis of sediment samples taken in 1980. Sediment samples were not collected in 2009. As seen in Table 9, the majority of the samples indicate the bed of the reservoir is composed of sand sized and smaller sediment.

16. DOWNSTREAM CHANNEL AND RESERVOIR OPERATION

A series of eight retrogression ranges cover the reach which extends from river mile 103.5 to 98.3 (see Plate 29). The Big Muddy River through this reach averages about 100 feet in top width and 653 square feet in cross-sectional area at bankfull stage. A thalweg profile, including the initial 1970 survey and the 1974, 1980, 1986, and 2009 resurveys, is shown on Plate 30. The plotted downstream cross sections are shown as Plates 31 through 38. 1970 and 2009 capacities for the retrogression ranges are listed in Table 10. Table 11 shows a tabulation of volume changes for reaches downstream of the dam. The average end area method of volume computations was used for the downstream channel since the width of the channel is fairly uniform and the prismoidal method requires accurate elevation verse area curves which were not readily available. The volumes were computed at approximately bankfull stage for both the 1970 and 2009 resurveys. The 1986 Report on Sedimentation estimated the bankfull volume of the Big Muddy River for retrogression ranges 1C through 8C to be 245.3 acre-feet. However, the 1986 report does not document the river stage used to obtain the 1970 or 1986 result or provide the capacities for each reach. The 1970 volumes were recalculated in order to determine the 1970-2009 volume changes by reach. At bankfull, the recalculated 1970 volume of the Big Muddy River from retrogression ranges 1C through 8C was estimated to be 256.3 acre-feet, a 4 percent difference. For 2009, the volume was 358 acre-feet, an increase of approximately 39.7 percent.

Range 8C showed maximum scouring of the bed, approximately 4 feet in the 1974 and 1980 resurveys. The maximum scour at Range 8C increased to 6 feet since 1986. Range 3C soured about 3 feet. Overall, the channel has widened. The 2009 resurvey data show the channel of Range 2C widened approximately 30 feet. The thalweg of the channel at Range 7C shifted about 25 feet toward the right bank. Since 1970, there has been about a 40 percent increase in volume. In general, degradation or aggradation downstream of Rend Lake Dam has not been significant. However, extensive widening of the channel through bank erosion has caused a significant increase in channel capacity downstream of Rend Lake to Range 8C. Currently, a tailwater rating curve is unavailable. Appendix B shows detailed location of the end points for the eight retrogression ranges.

17. SUMMARY

Numerous coal mines and oil and gas wells have been developed in the vicinity of the project. Many tunnels are known to be located beneath the bottom of the lake. The possibility exists that the mine shafts and wells are causing a large area to subside, resulting in an increase in the capacity of the Big Muddy subimpoundment and other segments of the reservoir, as was calculated using the prismoidal formula.

Due to the computed increase in volume in certain reaches of the reservoir caused by apparent ground subsidence, it is impossible to accurately ascertain the actual amount of sediment accumulation that has occurred. For the entire reservoir, the 2009 resurvey indicates a rate of increase in storage volume of 204 acre-feet per year, while the predicted rate of sediment deposition (loss of storage) is 244 acre-feet per year. For the Casey Fork subimpoundment, the computed sedimentation rate of 1 acre-foot per year is less than the expected rate of 49 acre-feet per year. For the Big Muddy subimpoundment, the 2009 resurvey showed an increase in capacity of 1,427 acre-feet per year, while the expected rate of sedimentation is 86 acre-feet per year. Predicted rates, defined in the 1986 Report of Sedimentation, were based on analyses of other Illinois reservoirs, since there are no sedimentation stations in the Big Muddy River basin, presented in the Journal of the American Water Resources Association, Volume 16, Issue 5, October 1980, pages 874-880.

At the computed sedimentation rate of 95 acre-feet per year, the inactive storage will have lost 4,750 acre-feet of capacity after 50 years of operation. It should be noted that the inactive pool was designed for 100 years of sedimentation. At the computed rate of 140 acre-feet per year, the joint-use pool will have lost 7,000 acre-feet of storage after 50 years of operation. At the computed deposition and subsidence rate of -204 acre-feet per year, about 10,200 acre-feet of storage will be gained after 50 years of operation.

The 2009 survey, supported by previous surveys, indicates the overall increasing trend in storage is continuing to rise. Subsidence may stabilize as the reservoir ages, resulting in the expected overall deposition process. However, until that time no significant overall sedimentation problems are anticipated. Localized areas of deposition may cause isolated concerns, but a study of this scope is not intended to study isolated areas.

18. RECOMMENDATION

Current budgeting guidance limits potential funding for future sediment surveys. Funding will be requested to conduct another resurvey in the next five to ten years. However, until such time that the sediment deposition is anticipated to have significant impact on project operations, funding will be unlikely. At the current rate of sedimentation, and the apparent subsidence of adjacent land due to coal mining and gas and oil well production operations, funding for a resurvey could be possible in 10 to 15 years. The decision to do so should be based on an evaluation of future flood events and their estimated contribution to loss of available storage. Also, any noted increase in land subsidence or mining-related ground movements may warrant either a complete or partial resurvey.

Table 1. Monthly Precipitation and Runoff for the Big Muddy River at Rend Lake (1971-2009)

Month	Maximum Precipitation (inches)	Minimum Precipitation (inches)	Average Precipitation (inches)	Average Runoff (inches)	Runoff (percent)
Jan	6.88	0.41	2.25	1.42	63.10
Feb	7.11	1.11	2.74	1.70	60.00
Mar	7.82	1.35	4.50	2.54	56.40
Apr	9.20	1.72	4.21	2.12	50.40
May	9.00	0.91	4.67	1.59	34.00
Jun	6.82	1.39	3.49	0.63	18.10
Jul	9.58	0.97	3.50	0.40	11.40
Aug	6.93	0.42	3.60	0.23	6.40
Sep	6.12	7.76	2.43	0.21	8.60
Oct	8.51	0.92	3.20	0.30	9.40
Nov	10.97	0.65	4.58	0.90	19.70
Dec	13.60	0.68	3.74	1.36	36.40

Table 2. Annual Precipitation and Runoff for the Big Muddy River at Rend Lake (1971-2009)

Year	Rainfall (inches)	Runoff (inches)	Runoff (percent)	Average Daily Runoff (cfs)
1971	30.19	8.94	29.60	321.00
1972	44.58	12.16	27.30	437.00
1973	52.18	18.11	34.70	651.00
1974	42.56	12.90	30.30	464.00
1975	47.04	15.72	33.40	565.00
1976	26.36	1.38	5.10	49.00
1977	41.43	7.67	18.50	276.00
1978	37.13	8.93	24.10	321.00
1979	43.36	15.25	35.20	548.00
1980	31.33	4.18	13.30	450.00
1981	43.71	5.99	13.70	215.00
1982	54.63	18.28	33.50	657.00
1983	53.90	16.32	30.30	587.00
1984	49.08	23.67	48.20	851.00
1985	47.40	23.66	49.90	851.00
1986	29.16	7.46	25.60	268.29
1987	15.03	6.70	44.60	240.95
1988	16.51	12.03	72.90	432.42
1989	26.68	17.03	63.80	612.27
1990	36.37	17.03	46.80	612.05
1991	23.42	12.49	53.30	448.96
1992	21.63	7.49	34.60	269.15
1993	31.06	24.60	79.20	884.20
1994	19.7	13.78	70.0	495.51
1995	32.75	19.91	60.80	715.77
1996	44.3	15.94	40.00	572.93
1997	41.42	12.11	29.20	435.43
1998	43.19	13.48	31.20	484.61
1999	33.05	13.98	42.30	502.56
2000	36.39	7.69	21.10	276.53
2001	38.08	12.27	32.20	441.21
2002	32.91	14.84	45.10	533.49
2003	28.78	11.20	38.90	402.73
2004	35.48	13.33	37.60	479.12
2005	30.75	9.62	31.90	345.86
2006	47.55	18.75	39.40	673.92
2007	28.86	8.57	29.70	308.25
2008	50.81	18.88	37.20	678.74
2009	59.67	22.55	37.80	810.58
Maximum	59.67	24.60	79.20	884.20
Minimum	15.03	1.38	5.10	49.00
Average	36.54	13.51	38.58	494.16

Table 3a. Tabulation of Capacity for Rend Lake

	Big Muddy Subimpoundment		Casey Fork Subimpoundment		Main Reservoir		Total Reservoir	
Elevation (NGVD)	Original Capacity[1/] (ac-ft)	1980 Capacity[2/] (ac-ft)	Original Capacity[1/] (ac-ft)	1980 Capacity[2/] (ac-ft)	Original Capacity[1/] (ac-ft)	1980 Capacity[2/] (ac-ft)	Original Capacity[1/] (ac-ft)	1980 Capacity[2/] (ac-ft)
385					3,650	2,498	3,650	2,498
390					18,525	15,241	18,525	15,241
395					50,550	45,869	50,550	45,869
400	102	130	4	1	104,344	99,385	104,450	99,516
405	1,759	1,818	650	650	182,266	175,006	184,675	177,084
410	6,647	6,746	3,759	3,759	283,744	276,107	294,150	286,472
415	18,178	18,200	14,558	14,558	403,939	396,299	436,675	428,997
420	38,662	38,764	34,779	34,779	546,559	538,919	620,000	612,322

[1/] As listed in Report of Sedimentation, 1980 Resurvey, Rend Lake.
[2/] Based upon results of prismoidal method

Table 3b. Capacity for Rend Lake Reservoir (2009)

	Big Muddy Subimpoundment			Casey Fork Subimpoundment			Main Reservoir			Total Reservoir		
Elevation (NGVD)	Adjusted 1980 Capacity[1/] (ac-ft)	1986 Capacity[1/] (ac-ft)	2009 Capacity (ac-ft)	Adjusted 1980 Capacity[1/] (ac-ft)	1986 Capacity[1/] (ac-ft)	2009 Capacity (ac-ft)	Adjusted 1980 Capacity[1/] (ac-ft)	1986 Capacity[1/] (ac-ft)	2009 Capacity (ac-ft)	Adjusted 1980 Capacity[1/] (ac-ft)	1986 Capacity[1/] (ac-ft)	2009 Capacity (ac-ft)
385							3,000	2,900	2,000	3,000	2,900	2,000
390							16,074	16,474	22,062	16,074	16,474	22,062
395							46,675	45,100	47,733	46,675	45,100	47,733
400	75	50	33	1	0	0	94,324	92,050	104,681	94,400	92,100	104,714
405	1,729	1,456	2,100	322	161	28	173,863	173,442	175,537	175,914	175,059	177,665
410	6,986	7,889	6,878	3,553	3,131	3,625	281,551	280,928	291,564	292,090	291,948	302,067
415	18,340	19,300	19,600	41,300	13,790	10,250	401,975	401,485	413,876	434,615	434,575	443,726
420	38,825	39,790	34,250	34,530	34,000	23,450	544,585	544,010	564,390	617,940	617,800	622,090

[1/] As listed in Report of Sedimentation, 1986 Resurvey, Rend Lake

Table 3c. Computed Change in Capacity for Rend Lake Reservoir

	Big Muddy Subimpoundment			Casey Fork Subimpoundment			Main Reservoir			Total Reservoir		
Elevation (NGVD)	Capacity Change 1970-1980 (ac-ft)	Capacity Change 1970-1986 (ac-ft)	Capacity Change 1970-2009 (ac-ft)	Capacity Change 1970-1980 (ac-ft)	Capacity Change 1970-1986 (ac-ft)	Capacity Change 1970-2009 (ac-ft)	Capacity Change 1970-1980 (ac-ft)	Capacity Change 1970-1986 (ac-ft)	Capacity Change 1970-2009 (ac-ft)	Capacity Change 1970-1980 (ac-ft)	Capacity Change 1970-1986 (ac-ft)	Capacity Change 1970-2009 (ac-ft)
390							2,451	2,051	-3,537	2,451	2,051	-3,537
405	30	303	-341	328	692	622	8,403	8,537	6,729	8,761	9,616	7,010
410	-339[1/]	-1,242	-231	206	628	134	2,193	2,816	-7,820	2,060	2,202	-7,917
412	-163	-1,126	-1,427	253	764	22						

[1/] A negative value indicates an increase in storage

Table 4. Range Data – Rend Lake

Reach	Water-Surface Elevation (NGVD)	Distance Between Ranges (ft)	Quadrilateral Area - A' [1/] (acres)	Measured Surface Area A (acres)
Dam-1A	410	750	--	153
1A-3A	410	4,800	944	1,167
2B	410	9,100	94	250
3A-8AB	410	14,100	2,967	4,107
4B	410	9,000	245	347
5AB-6B	410	13,500	1,296	1,439
6B-7B	410	9,800	544	676
7B	410	6,900	160	94
8AB-10A	410	7,600	1,907	2,058
9B	410	2,700	43	64
10A(W1/2)-17AB	410	10,900	1,956	2,132
17AB-18A	410	7,800	1,370	1,680
18A-19A	410	9,900	1,084	1,350
19A-20A	412	5,700	531	719
20A-21A	412	5,400	485	492
21A-23AB	412	3,800	170	187
22AB	412	2,800	3	24
23AB	412	7,800	9	55
10A(E1/2)-11AB	410	10,300	1,191	1,685
11AB-12A	410	12,000	2,450	2,866
12A-14A	410	9,050	1,650	1,793
13B	410	7,700	260	185
14A-15A	412	3,000	402	387
15A-16A	412	3,600	433	469
14A-16A	412	6,600	825	856
16A	412	12,300	707	553

[1/] Area formed by connecting the points of intersection of the ranges with the crest elevation

Table 5. Cross-Sectional Area Data – Rend Lake

Range Number	Elevation (NGVD)	1970[1/] Area (ft^2)	1980[2/] Area (ft^2)	1986[2/] Area (ft^2)	2009 Area (ft^2)
1A	410	201,417	200,901	196,162	210,378
2B	410	26,166	25,425	28,135	29,528
3A	410	161,343	157,309	159,153	179,577
4B	410	35,314	39,683	39,300	39,721
5AB	410	67,157	64,431	64,817	69,812
6B	410	23,458	21,215	20,314	20,019
7B	410	1,755	1,655	1,629	3,074
8AB	410	189,207	181,042	181,798	194,653
9B	410	10,573	10,738	10,999	9,852
10A	410	203,313	200,310	200,449	213,637
11AB	410	105,634	102,482	104,863	117,812
12A	410	73,013	73,977	74,581	73,226
13B	410	16,607	16,118	15,566	15,254
14A	412	37,646	36,282	34,299	37,385
15A	412	31,100	31,690	- - [3/]	31,963
16A	412	16,544	16,117	14,688	15,255
17AB	410	109,331	108,525	108,990	126,692
18A	410	72,063	71,733	72,472	65,743
19A	412	24,569	26,304	26,466	26,236
20A	412	19,501	17,973	26,055	30,030
21A	412	9,041	8,011	8,730	9,547
22AB	412	1,136	760	882	1,176
23AB	412	1,288	1,464	1,553	929

[1/]Recalculated for Report of Sedimentation, 2009 Resurvey, Rend Lake
[2/]As listed in 1986 Report of Sedimentation, Rend Lake
[3/]Not resurveyed in 1986

Table 6. Range Cross-Sectional Changes in Rend Lake.

Range Cross Section	Elevation (NGVD)	Area Change 1970-1980[1/] (sq. ft.)	Area Change 1970-1986[1/] (sq. ft.)	Area Change 1970-2009[2/] (sq. ft.)
1A	410	491	5,230	-8,961
2B	410	737	-1973*	-3,362
3A	410	4,031	2,187	-18,234
4B	410	-4,369	-3,986	-4,407
5AB	410	2,726	2,340	-2,655
6B	410	1,735	2,636	3,439
7B	410	166	192	-1,319
8AB	410	8,162	7,406	-5,446
9B	410	-165	-426	721
10A	410	2,873	2,734	-10,324
11AB	410	3,334	953	-12,178
12A	410	-964	-1,568	-213
13B	410	489	1,041	1,353
14A	412	1,489	3,472	261
15A	412	-590	- - [3/]	-863
16A	412	774	2,203	1,289
17AB	410	821	356	-17,361
18A	410	282	-457	6,320
19A	412	-1,650	-1,812	-1,667
20A	412	1,703	-6,329	-10,529
21A	412	1,085	365	-506
22AB	412	396	274	-40
23AB	412	-176	-265	359

[1/]As listed in the Report of Sedimentation, 1986 Resurvey, Rend Lake
[2/]Based on recalculated 1970 capacities
[3/]Not resurveyed in 1986

Table 7. Reservoir Capacities by Reach Below Elevations 390, 405, and 410.

	Elevation 390		Elevation 405		Elevation 410	
Reach	1970[1/] (ac-ft)	2009 (ac-ft)	1970[1/] (ac-ft)	2009 (ac-ft)	1970[1/] (ac-ft)	2009 (ac-ft)
Dam-1A	712	769	2,213	2,295	3,089	3,206
1A-3A	4,563	5,591	17,874	19,283	24,133	25,899
2B	5	2	963	595	1,635	1,342
3A-8AB	10,324	14,364	54,008	57,948	73,252	79,889
4B	--	--	1,396	1,603	2,600	2,880
5AB-6B	74	25	7,591	7,154	14,774	22,287
6B-7B			1,141	911	2,971	2,730
7B	--	--	5	4	105	113
8AB-10A	968	1,199	25,151	24,305	33,042	34,714
9B	--	--	131	104	287	268
10A(E1/2)-11AB	715	271	13,461	12,150	17,126	18,524
11AB-12A	85	32	13,128	13,144	27,478	29,533
12A-14A	--	--	1,373	979	10,463	10,401
13B	--	--	21	6	774	707
14A-16A	--	--	--	--	1,911	1,668
16A	--	--	--	--	92	53
10A(W1/2)-17AB	80	80	20,019	21,800	32,662	34,722
17AB-18A	96	0	8,717	9,348	16,393	17,033
18A-19A	20	0	2,250	2,045	8,915	8,528
19A-20A	--	--	--	--	1,846	1,432
20A-21A	--	--	--	--	411	761
21A-23AB	--	--	--	--	47	104
22AB	--	--	--	--	9	19
23AB	--	--	--	--	27	80

[1/]Recalculated for Report of Sedimentation, 2009 Resurvey, Rend Lake

Table 8a. Reservoir Sediment Distribution Below Elevation 410.0

Reach	1970 - 1980[1/] (ac-ft)	1970 - 1986[1/] (ac-ft)	1970-2009[2/] (ac-ft)
Dam-1A	-3 [3/]	94	-117
1A-3A	263	419	-1,766
2B	97	337	293
3A-8AB	704	-428	-6,637
4B	-298	-292	-280
5AB-6B	401	484	-7,513
6B-7B	36	168	241
7B	6	8	-8
8AB-10A	320	43	-1,672
9B	-1	-9	19
10A(E1/2)-11AB	1,081	1,251	-1,398
11AB-12A	476	311	-2,055
12A-14A	129	570	62
13B	33	71	67
14A-16A	129	378	243
16A	8	23	39
10A(W1/2)-17AB	-134	17	-2,110
17AB-18A	-450	74	-640
18A-19A	-587	-263	387
19A-20A	-102	-566	414
20A-21A	28	-380	-350
21A-23AB	-50	-73	-57
22AB	-6	-10	-10
23AB	-20	-25	-53
	2,063	2,202	-22,901

[1/] As listed in Report of Sedimentation, 1986 Resurvey, Rend Lake
[2/] Volume changed based on recalculated 1970 capacities
[3/] Negative value indicates an increase in storage.

Table 8b. Reservoir Sediment Distribution Below Elevation 405.0

Reach	1970 - 1980[1/] (ac-ft)	1970 - 1986[1/] (ac-ft)	1970 - 2009[2/] (ac-ft)
Dam-1A	24	95	-82
1A-3A	385	540	-1,409
2B	43	214	368
3A-8AB	2,566	1,986	-3,940
4B	-268 [3/]	-236	-207
5AB-6B	406	426	437
6B-7B	81	-41	230
7B	3	-2	1
8AB-10A	1,583	1,440	846
9B	2	4	28
10A(E1/2)-11AB	923	1,010	1,311
11AB-12A	1,098	1,112	-16
12A-14A	715	1,605	394
13B	-4	2	15
14A-16A	184	322	--
16A	25	27	--
10A(W1/2)-17AB	754	639	-1,781
17AB-18A	182	136	-631
18A-19A	-298	-218	205
19A-20A	180	376	--
20A-21A	92	142	--
21A-23AB	81	43	--
22AB	-1	-2	--
23AB	5	-4	--
	8,761	9,616	-4,231

[1/] As listed in Report of Sedimentation, 1986 Resurvey, Rend Lake
[2/] Volume changed based on recalculated 1970 capacities
[3/] Negative value indicates an increase in storage.

Table 8c. Reservoir Sediment Distribution Below Elevation 390.0

Reach	1970 - 1980[1/] (ac-ft)	1970 - 1986[1/] (ac-ft)	1970 - 2009[2/] (ac-ft)
Dam-1A	46	94	-57
1A-3A	454	435	-1,028
2B	3	-1	3
3A-8AB	1,576	1,170	-4,040
4B	--	--	--
5AB-6B	-16 [3/]	6	49
6B-7B	--	--	--
7B	--	--	--
8AB-10A	272	294	-231
9B	--	--	--
10A(E1/2)-11AB	69	82	--
11AB-12A	--	--	53
12A-14A	--	--	--
13B	--	--	--
14A-16A	--	--	--
16A	--	--	--
10A(W1/2)-17AB	47	-29	--
17AB-18A	--	--	96
18A-19A	--	--	6
19A-20A	--	--	--
20A-21A	--	--	--
21A-23AB	--	--	--
22AB	--	--	--
23AB	--	--	--
	2,451	2,051	-5149

[1/] As listed in Report of Sedimentation, 1986 Resurvey, Rend Lake
[2/] Volume changed based on recalculated 1970 capacities
[3/] Negative value indicates an increase in storage.

Table 9. Sieve Analysis Summary for Sedimentation Samples at Rend Lake (1980).

Sampled (Range)	Sieve Size		Percent Retained	Percent Passing
1A-1 [1/]	# 60		0.3	99.7
	#100		0.5	99.5
	#200		0.7	99.3
	0.044	mm	17.0	83.0
	0.0045	mm	59.3	40.7
1A-2	# 60		1.2	98.8
	#100		2.4	97.6
	#200		4.8	95.2
	0.044	mm	18.3	81.0
	0.0048	mm	40.7	36.5
2B	# 60		0.5	99.5
	#100		1.1	98.9
	#200		2.8	97.2
	0.042	mm	18.6	81.4
	0.0048	mm	76.7	23.3
3A-1	# 40		19.2	80.8
	# 60		24.2	75.8
	#100		28.7	71.3
	#200		32.0	68.0
	0.049	mm	59.6	40.4
	0.005	mm	96.1	3.9
3A-2	# 40		0.2	99.8
	# 60		0.3	99.7
	#100		0.5	99.5
	#200		0.9	99.1
	0.042	mm	9.9	90.1
	0.0048	mm	78.0	22.0
4B	# 40		22.0	48.0
	# 60		29.8	70.2
	#100		38.2	61.8
	#200		44.8	55.2
	0.050	mm	64.5	35.5
	0.005	mm	93.5	6.5

[1/] Some ranges had two samples taken (i.e., 1A-1 and 1A-2)

Table 9. Sieve Analysis Summary for Sedimentation Samples at Rend Lake (1980). (Continued)

Sampled (Range)	Sieve Size		Percent Retained	Percent Passing
5B	# 40		0.9	99.1
	# 60		1.1	98.9
	#100		1.4	98.6
	#200		1.8	98.2
	0.040	mm	6.7	93.3
	0.0046	mm	63.8	36.2
6B	# 40		0.3	99.7
	# 60		0.5	99.5
	#100		1.0	99.0
	#200		1.7	98.3
	0.042	mm	16.7	83.3
	0.0046	mm	62.2	37.8
7B	# 40		11.5	88.5
	# 60		15.5	84.5
	#100		17.7	82.3
	#200		19.6	80.4
	0.045	mm	28.6	71.4
	0.0047	mm	73.2	26.8
8AB-1	# 40		4.3	95.7
	# 60		5.8	94.2
	#100		7.0	93.0
	#200		9.2	90.8
	0.043	mm	52.4	47.6
	0.0046	mm	77.4	22.6
9B	#100		--	--
	#200		0.4	99.6
	0.043	mm	18.3	81.7
	0.0048	mm	77.6	22.3
10A-1	# 40		2.0	98.0
	# 60		3.1	96.9
	#100		3.8	96.2
	#200		409.0	95.1
	0.039	mm	10.8	89.2
	0.0044	mm	61.8	38.2

Table 9. Sieve Analysis Summary for Sedimentation Samples at Rend Lake (1980). (Continued)

Sampled (Range)	Sieve Size		Percent Retained	Percent Passing
10A-2	# 40		0.3	99.7
	# 60		0.5	99.5
	#100		0.7	99.3
	#200		1.1	98.9
	0.040	mm	13.0	87.0
	0.0043	mm	56.7	43.3
11AB	# 40		0.6	99.4
	# 60		0.9	99.1
	#100		1.2	98.8
	#200		1.5	98.5
	0.040	mm	14.0	86.0
	0.0043	mm	62.1	37.9
12A	# 40		0.6	99.4
	# 60		0.9	99.1
	#100		1.1	98.9
	#200		1.6	98.4
	0.042	mm	22.6	77.4
	0.0046	mm	74.3	25.7
13B	# 40		0.5	99.5
	# 60		0.8	99.2
	#100		1.2	98.8
	#200		3.0	97.0
	0.042	mm	23.3	76.7
	0.0046	mm	77.2	22.8
15AB	# 40		0.2	99.8
	# 60		0.4	99.6
	#100		0.8	99.2
	#200		2.2	97.8
	0.043	mm	32.3	67.7
	0.0047	mm	81.4	18.6

Table 9. Sieve Analysis Summary for Sedimentation Samples at Rend Lake (1980). (Continued)

Sampled (Range)	Sieve Size		Percent Retained	Percent Passing
17AB	# 40		0.8	99.2
	# 60		1.8	98.2
	#100		2.0	98.0
	#200		3.6	96.4
	0.039	mm	10.2	89.8
	0.0046	mm	76.1	23.9
18A	# 40		7.6	92.4
	# 60		9.6	90.4
	#100		11.2	88.8
	#200		13.6	86.4
	0.042	mm	23.1	76.9
	0.0046	mm	74.8	25.2
21A	# 40		0.8	99.2
	# 60		0.9	99.1
	#100		1.0	99.0
	#200		1.2	98.8
	0.039	mm	10.4	89.6
	0.004	mm	58.3	41.7
23AB	3/4 in.		4.0	96.0
	1/2 in.		6.4	93.6
	3/8 in.		7.2	92.7
	# 4		15.4	84.6
	# 10		42.4	57.6
	# 40		77.4	22.6
	# 70		82.9	17.1
	#100		83.9	16.1
	#200		85.1	14.9

Table 10. Capacities for Retrogression Ranges – Big Muddy River

Reach	1970[1/, 2/] Volume (acre-feet)	2009[1/] Volume (acre-feet)
1C-2C	24	41
2C-3C	8	18
3C-4C	29	58
4C-5C	30	65
5C-6C	64	87
6C-7C	78	67
7C-8C	22	23
	256	358

[1/] Calculated using average end area method
[2/] Recalculated for 2009 Report on Sedimentation, Rend Lake

Table 11. Volume Changes Downstream of Rend Lake Dam – Big Muddy River

Reach	1970 - 1980 Volume Change (ac-ft)	1970 - 1986 Volume Change (ac-ft)	1970 - 2009 Volume Change[1/] (ac-ft)
1C-2C	-5.9 [2/]	-10.6	-17.0
2C-3C	-1.1	-1.7	-10.5
3C-4C	-2.1	-11.9	-28.4
4C-5C	-0.9	-14.1	-34.2
5C-6C	-9.3	-19.7	-22.5
6C-7C	-0.1	-12.2	11.4
7C-8C	-4.1	-7.6	-0.4
TOTAL	-23.5	-77.8	-101.6

Percent Changes

1970 - 1980 $\left(\frac{23.5}{245.3}\right) \times 100 = 9.6\%$ increase in volume

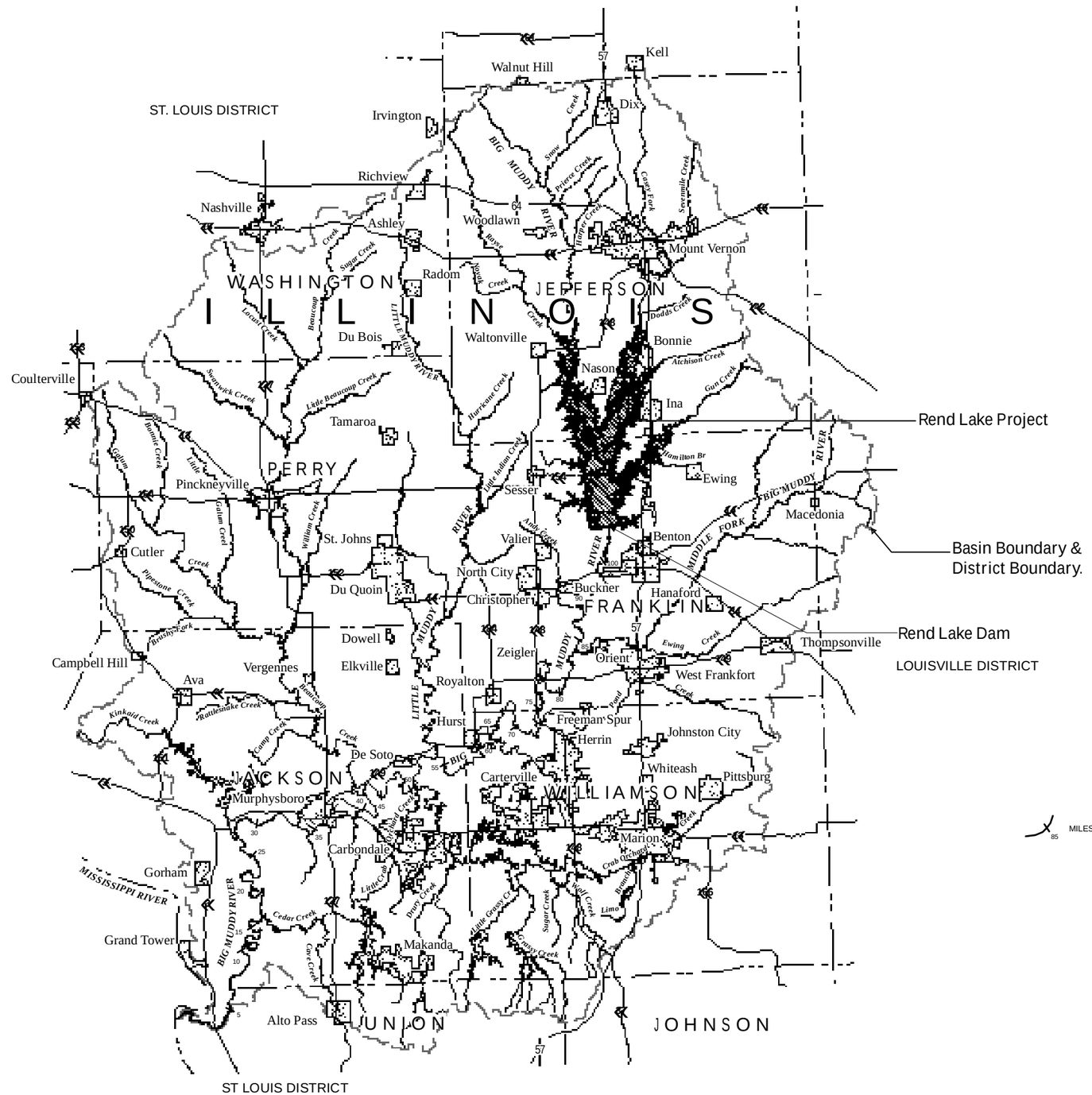
1970 - 1986 $\left(\frac{77.8}{245.3}\right) \times 100 = 31.7\%$ increase in volume

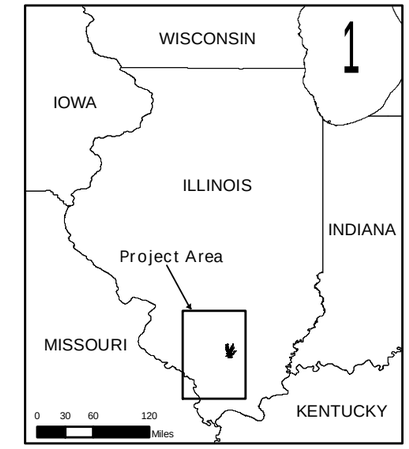
1970 - 2009 $\left(\frac{102}{256}\right) \times 100 = 39.7\%$ increase in volume

[1/] Based on 1970 recalculated values
[2/] Negative value indicates an increase in volume.

APPENDIX A

3





VICINITY MAP

LEGEND

MILES ABOVE MOUTH OF RIVER MEASURED ALONG PRESENT CHANNEL

REND LAKE
BIG MUDDY RIVER, ILLINOIS
FOURTH RESURVEY OF
SEDIMENTATION 2009

BIG MUDDY RIVER
DRAINAGE BASIN MAP

U.S. ARMY ENGINEER DISTRICT
ST. LOUIS, CORPS OF ENGINEERS

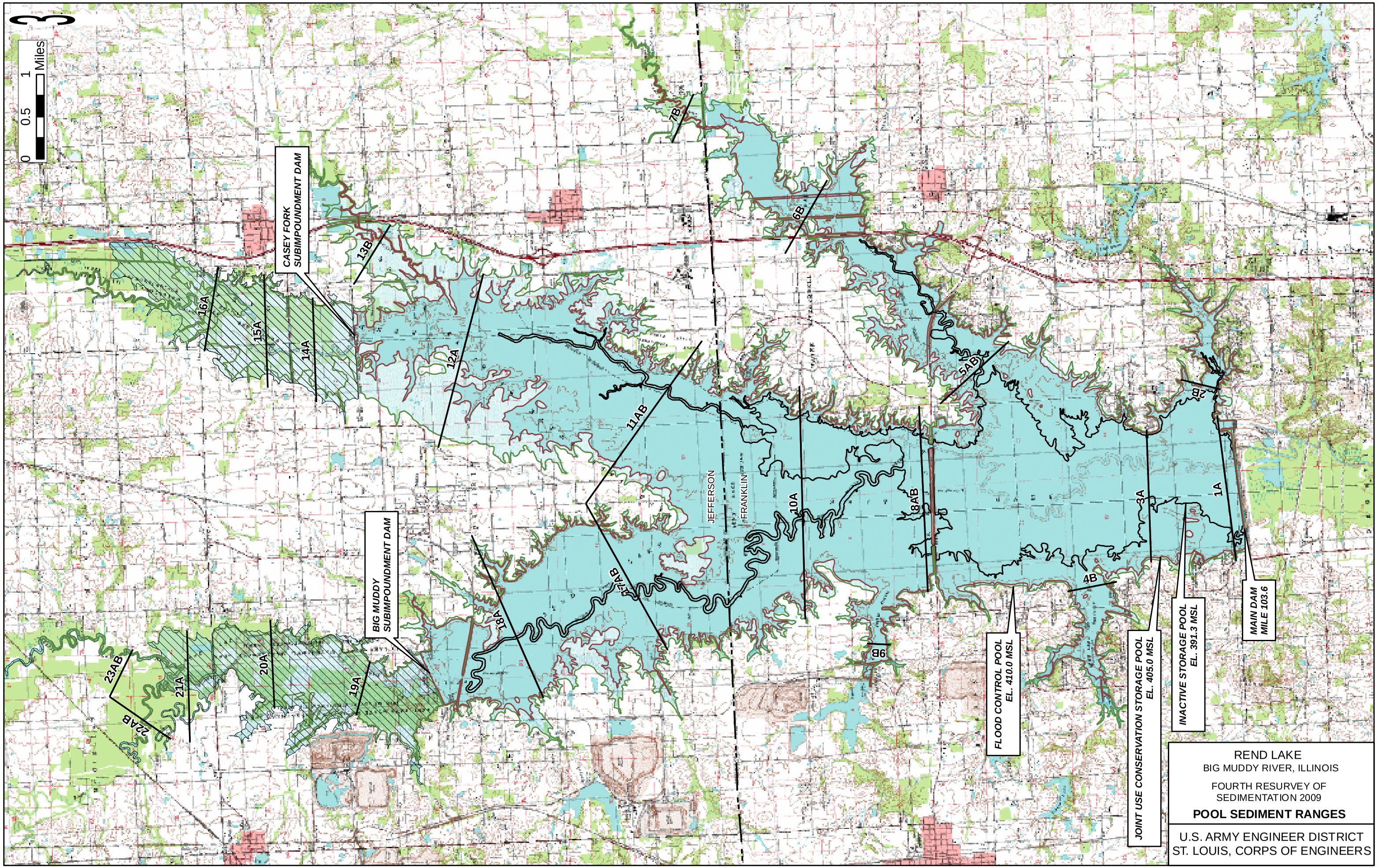
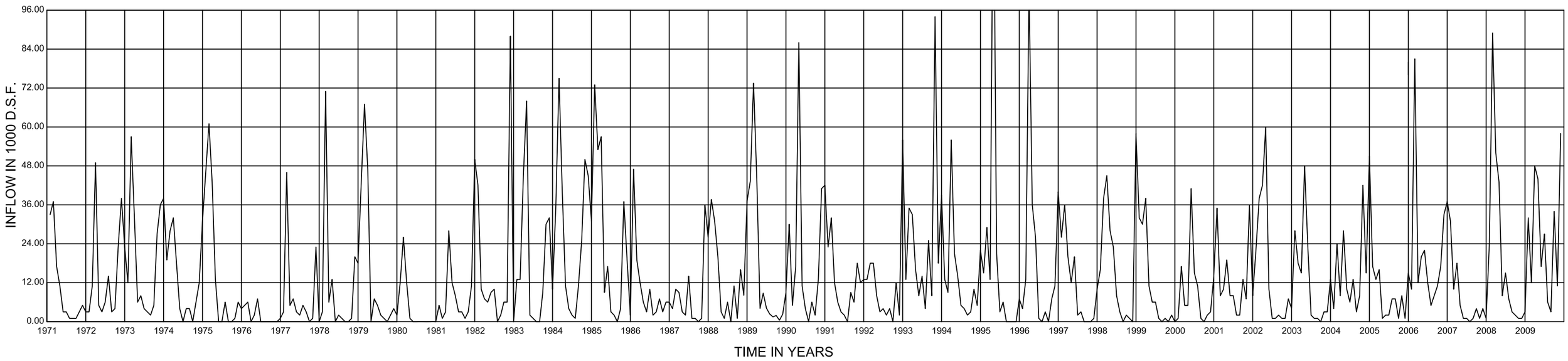
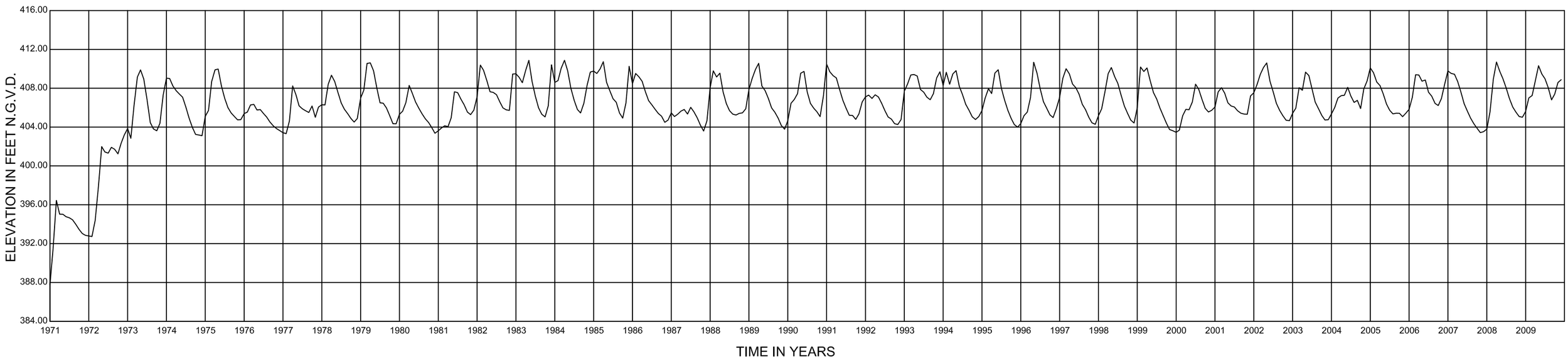

0
0.5
1
Miles
CASEY FORK
SUBIMPOUNDMENT DAM
BIG MUDDY
SUBIMPOUNDMENT DAM
16A
15A
14A
13B
12A
11AB
10A
9B
8AB
7B
6B
5AB
4B
3A
2B
1A
17AB
18A
19A
20A
21A
22AB
23AB
JEFFERSON
FRANKLIN
FLOOD CONTROL POOL
EL. 410.0 MSL
JOINT USE CONSERVATION STORAGE POOL
EL. 405.0 MSL
INACTIVE STORAGE POOL
EL. 391.3 MSL
MAIN DAM
MILE 103.6
REND LAKE
BIG MUDDY RIVER, ILLINOIS
FOURTH RESURVEY OF
SEDIMENTATION 2009
POOL SEDIMENT RANGES
U.S. ARMY ENGINEER DISTRICT
ST. LOUIS, CORPS OF ENGINEERS

PLATE 2



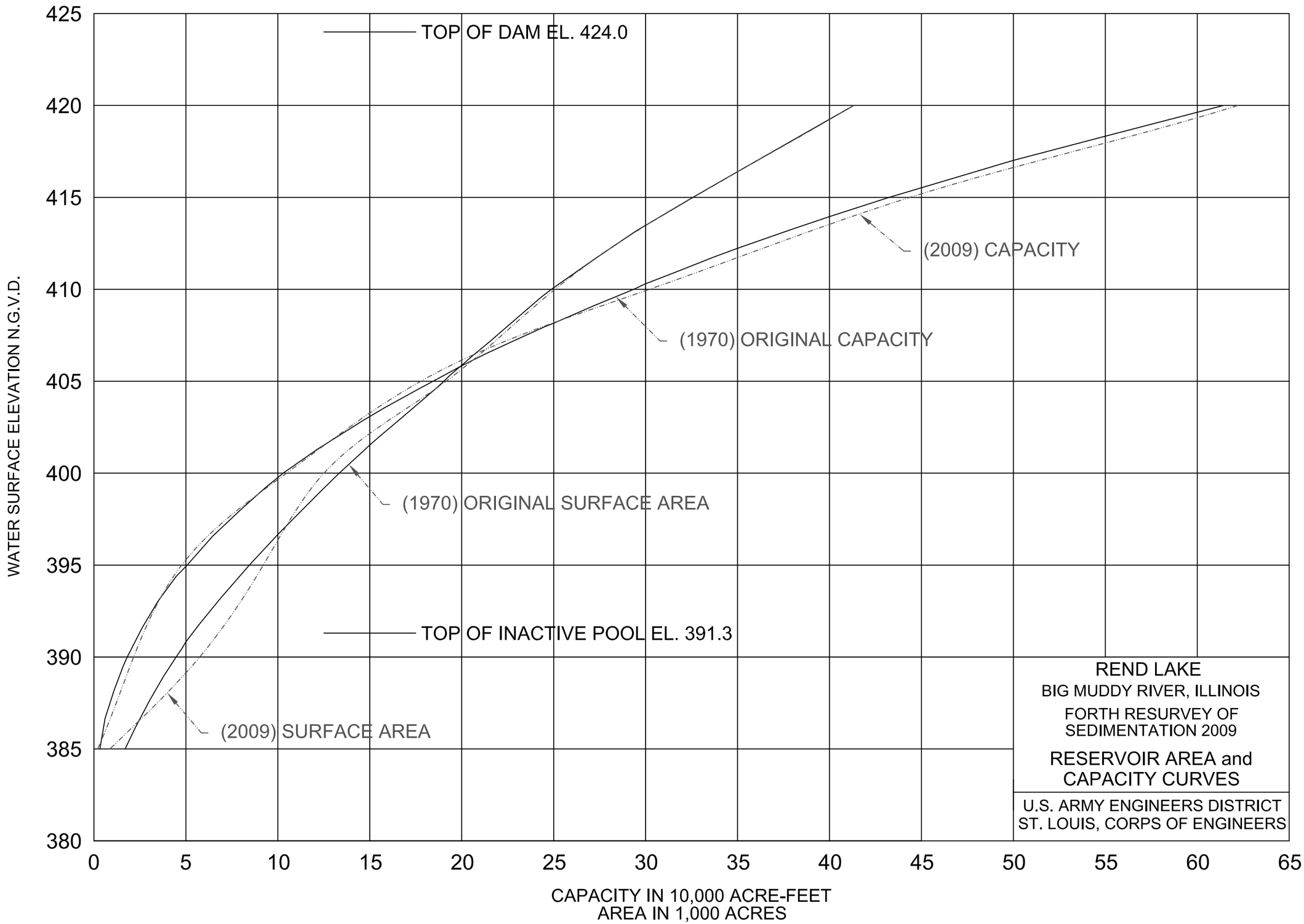
REND LAKE
BIG MUDDY RIVER, ILLINOIS
FORTH RESURVEY OF
SEDIMENTATION 2009
AVERAGE MONTHLY INFLOW
HYDROGRAPH (1971-2009)
U.S. ARMY ENGINEERS DISTRICT
ST. LOUIS, CORPS OF ENGINEERS



REND LAKE
BIG MUDDY RIVER, ILLINOIS
FORTH RESURVEY OF
SEDIMENTATION 2009
AVERAGE MONTHLY
POOL ELEVATIONS

U.S. ARMY ENGINEERS DISTRICT
ST. LOUIS, CORPS OF ENGINEERS

PLATE 4


TOP OF DAM EL. 424.0
TOP OF INACTIVE POOL EL. 391.3
(2009) CAPACITY
(1970) ORIGINAL CAPACITY
(1970) ORIGINAL SURFACE AREA
(2009) SURFACE AREA
WATER SURFACE ELEVATION N.G.V.D.
425
420
415
410
405
400
395
390
385
380
0
5
10
15
20
25
30
35
40
45
50
55
60
65
CAPACITY IN 10,000 ACRE-FEET
AREA IN 1,000 ACRES
REND LAKE
BIG MUDDY RIVER, ILLINOIS
FORTH RESURVEY OF
SEDIMENTATION 2009
RESERVOIR AREA and
CAPACITY CURVES
U.S. ARMY ENGINEERS DISTRICT
ST. LOUIS, CORPS OF ENGINEERS

REND LAKE
SEDIMENTATION RANGE: 1A

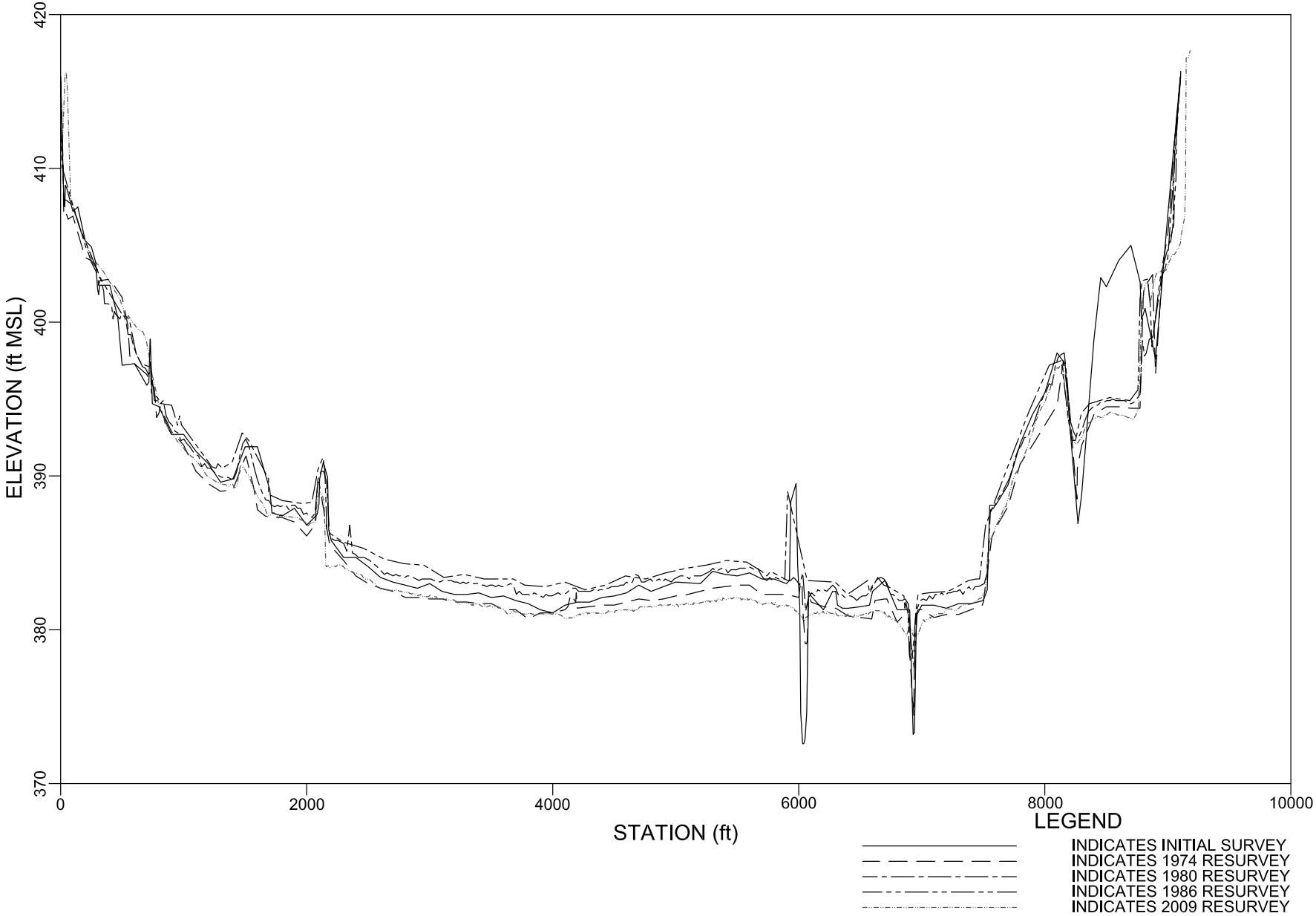


PLATE 6

REND LAKE
SEDIMENTATION RANGE: 2B

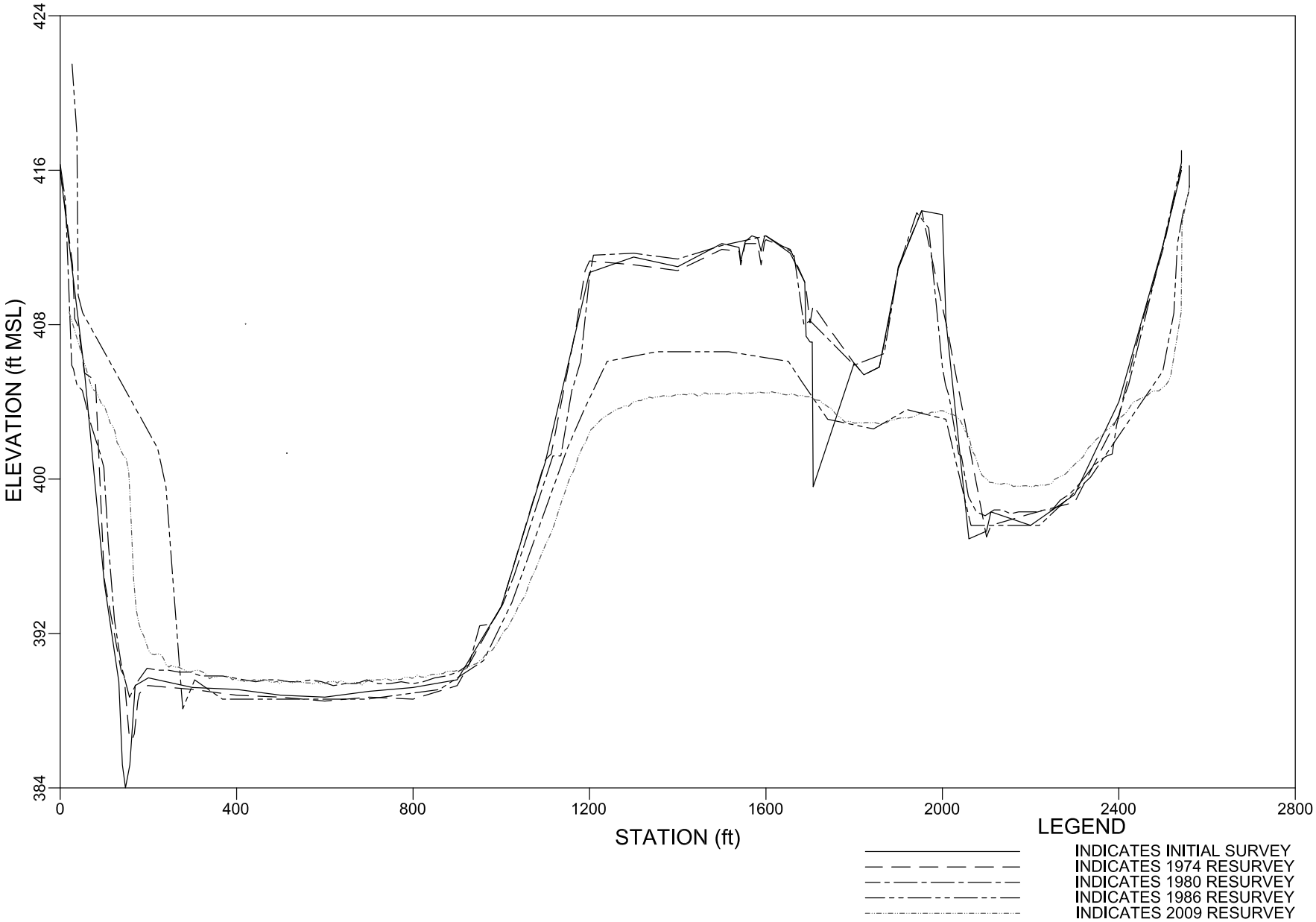


PLATE 7

REND LAKE
SEDIMENTATION RANGE: 3A

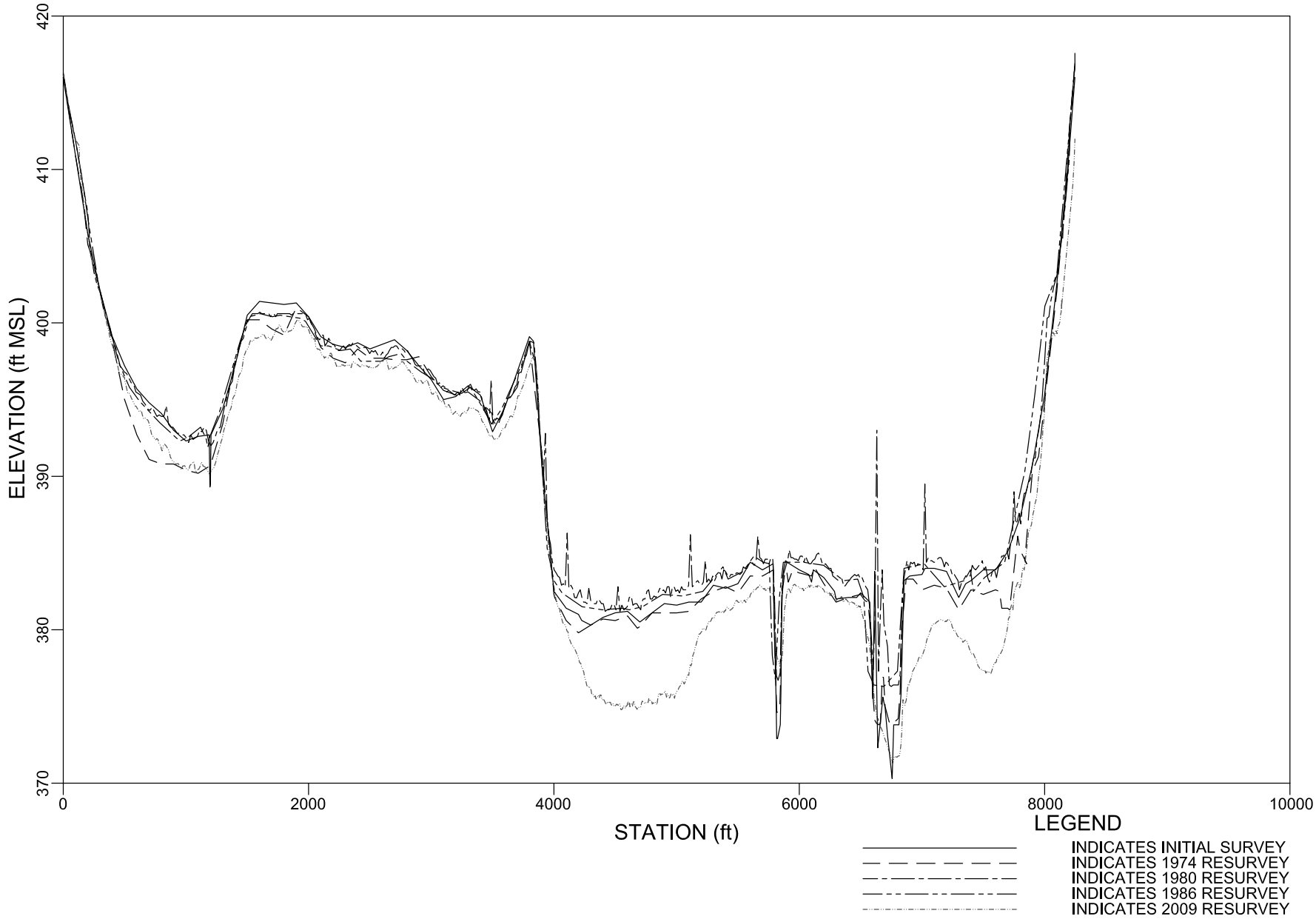


PLATE 8

REND LAKE
SEDIMENTATION RANGE: 4B

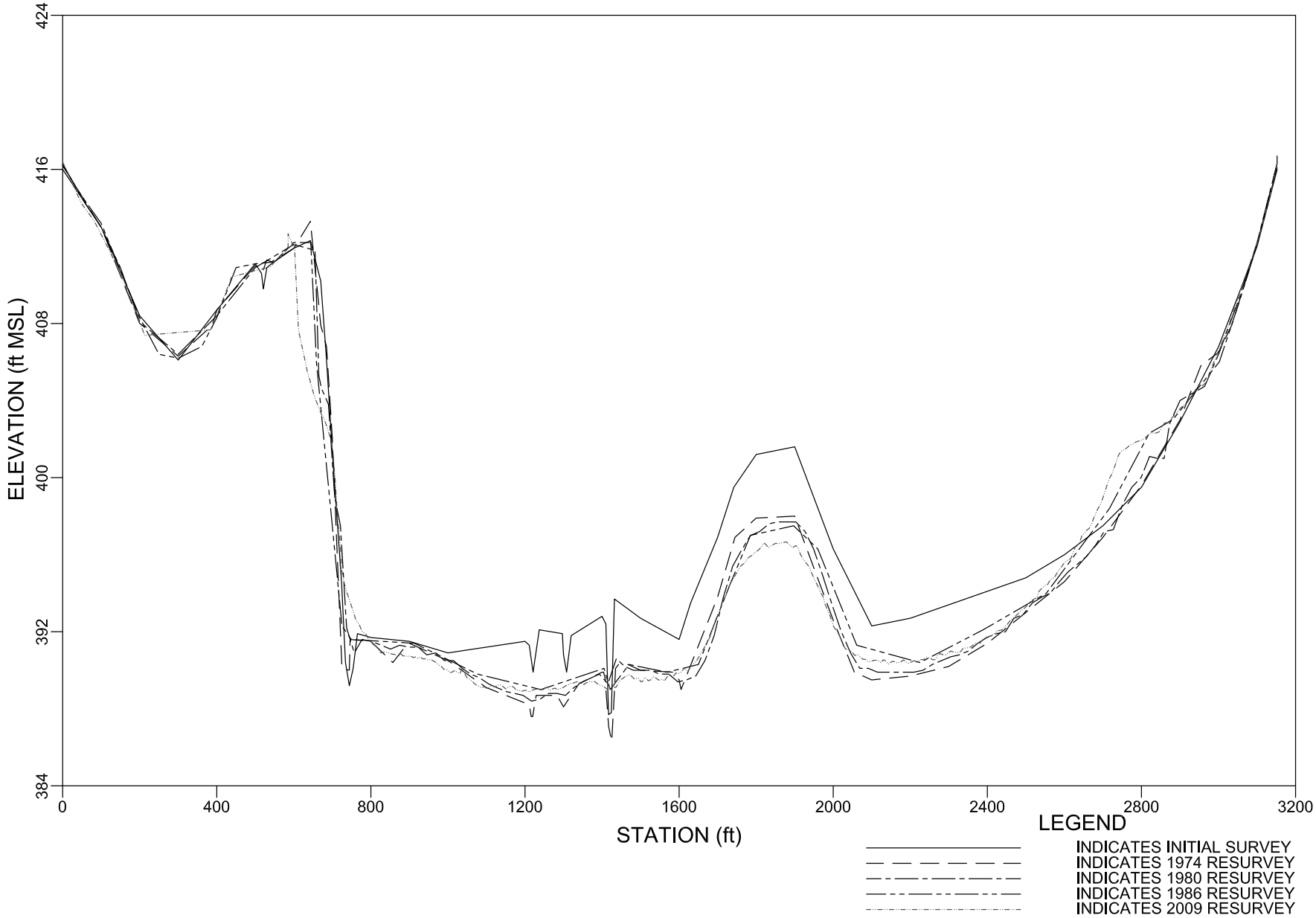


PLATE 9

REND LAKE
SEDIMENTATION RANGE: 5AB

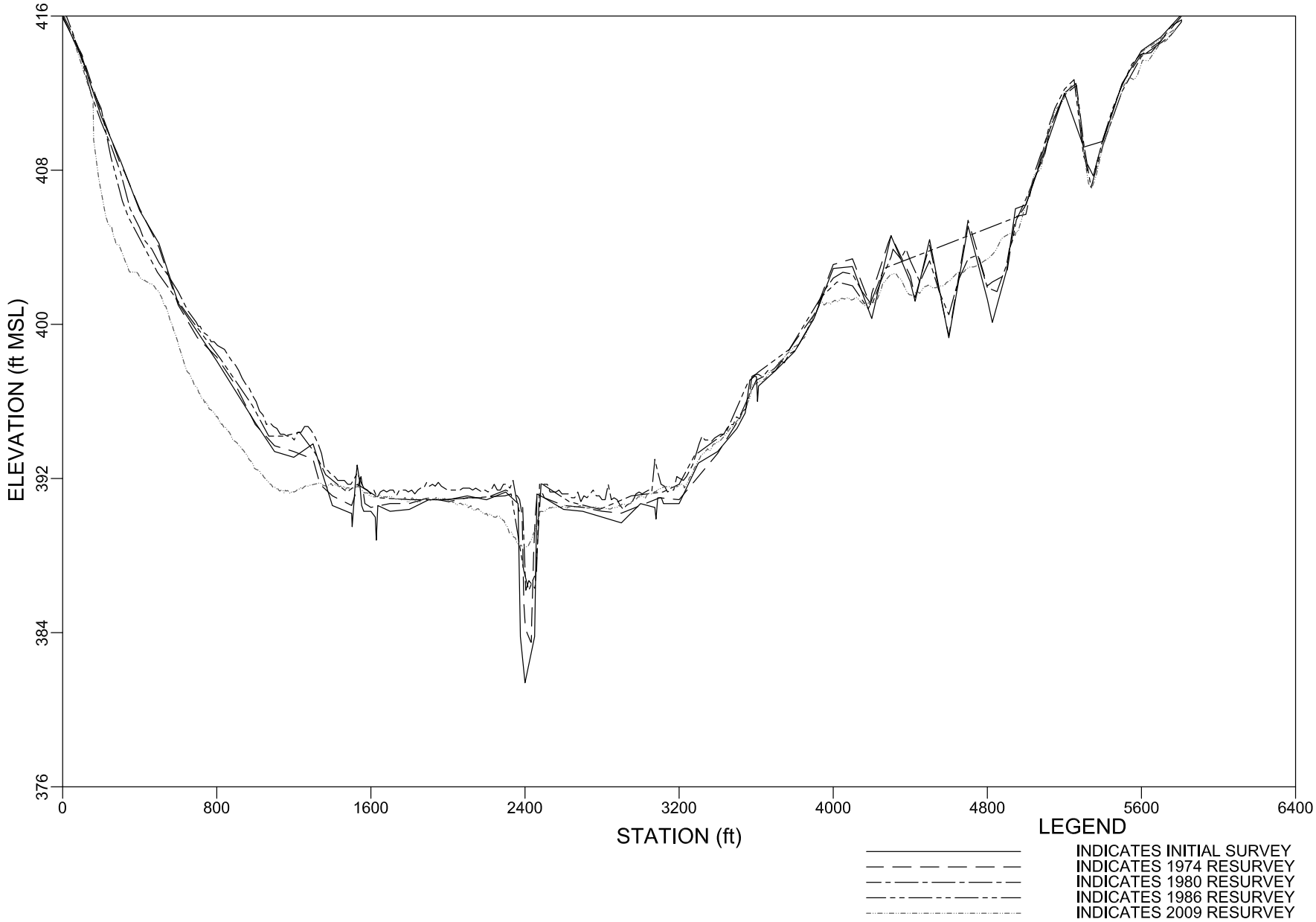


PLATE 10

REND LAKE
SEDIMENTATION RANGE: 6B

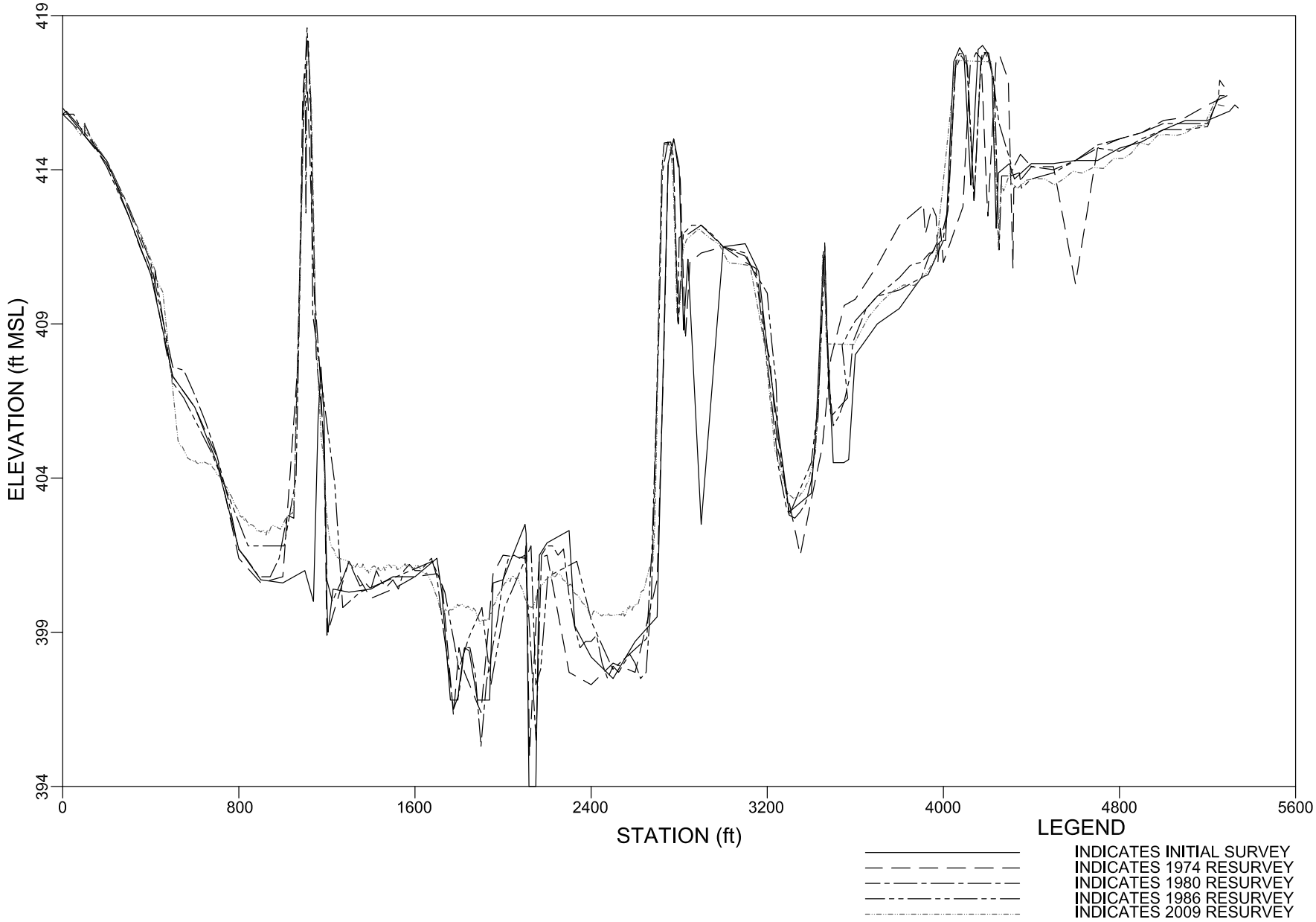
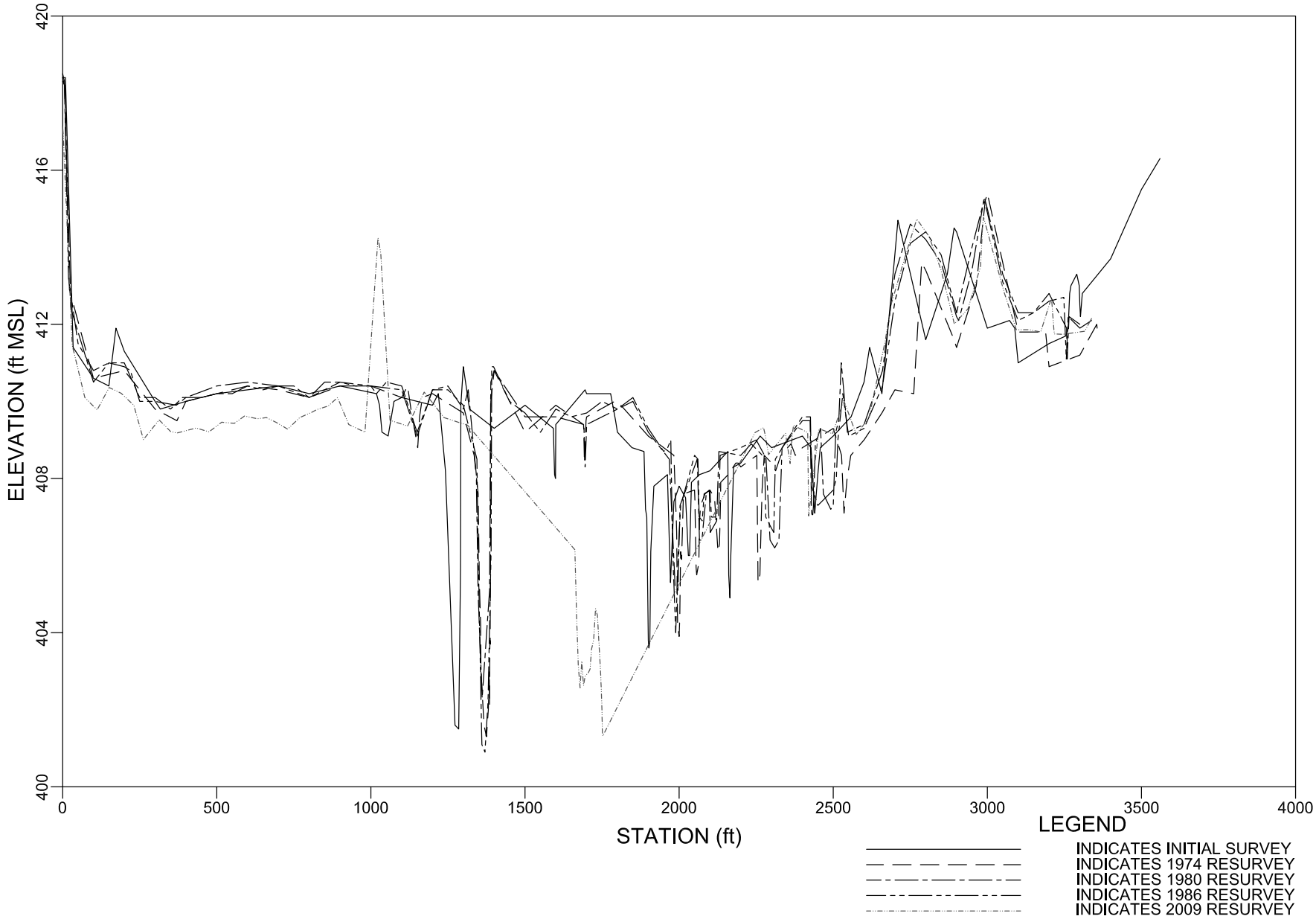
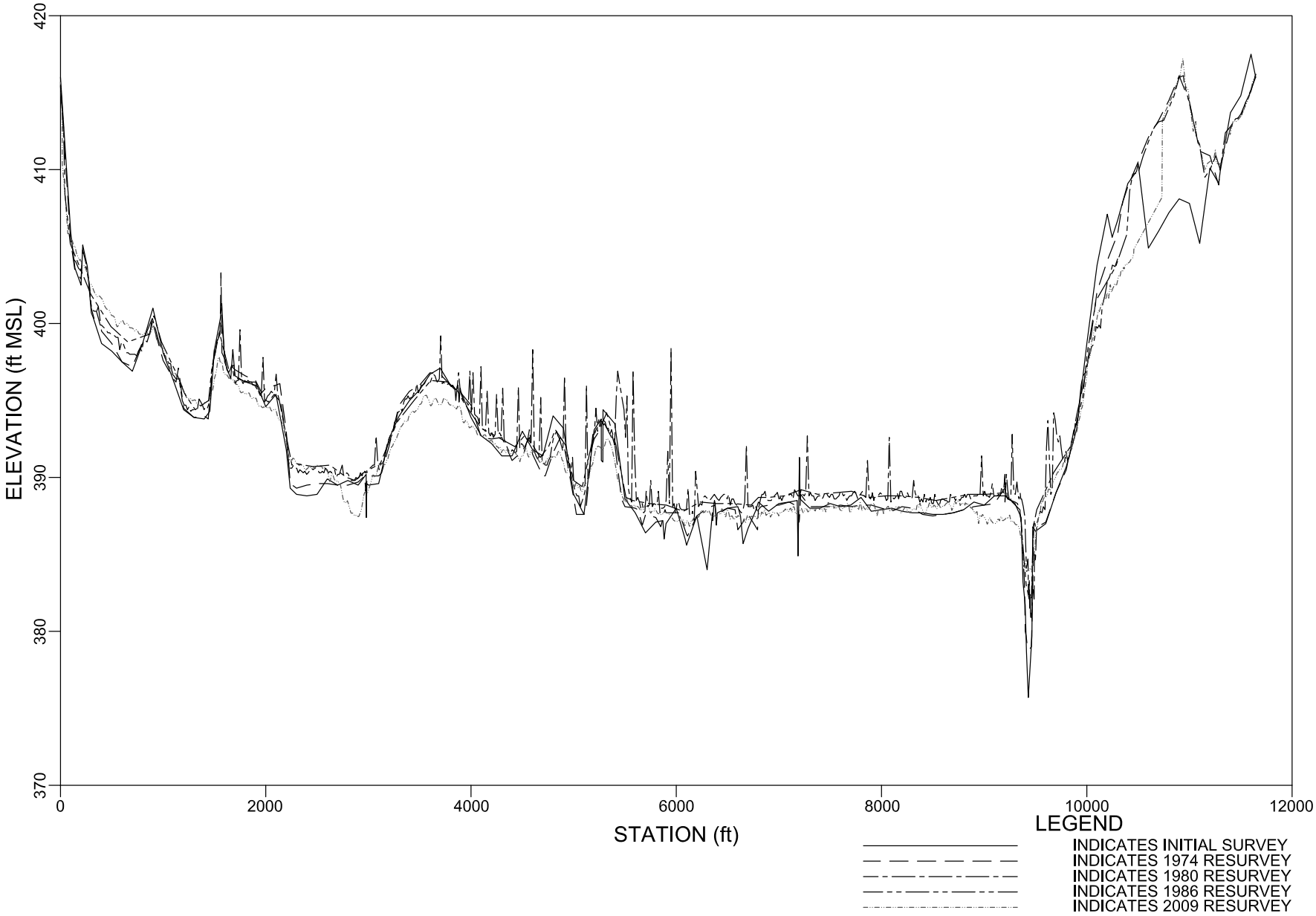


PLATE 11

REND LAKE
SEDIMENTATION RANGE: 7B



REND LAKE
SEDIMENTATION RANGE: 8AB



REND LAKE
SEDIMENTATION RANGE: 9B

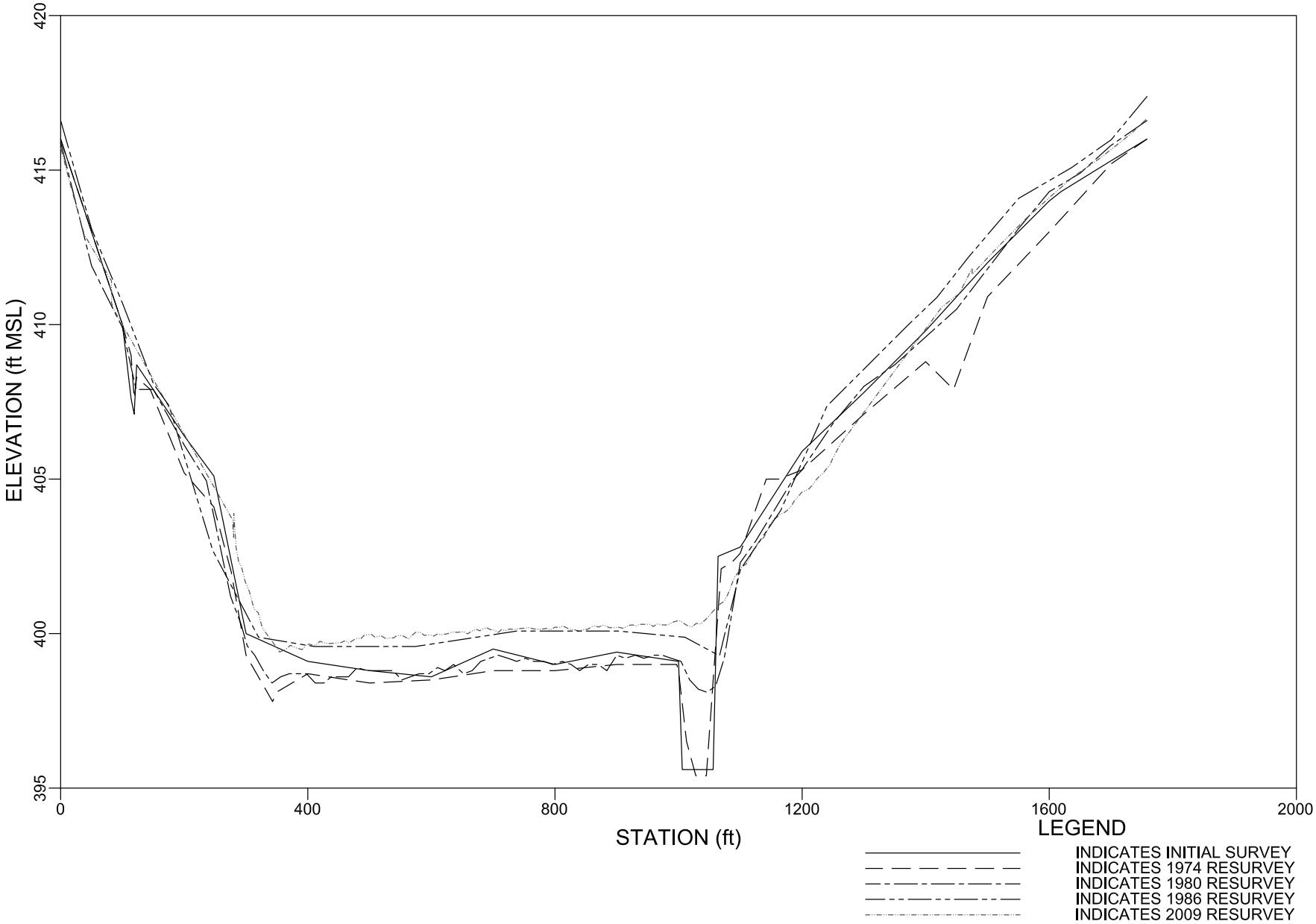
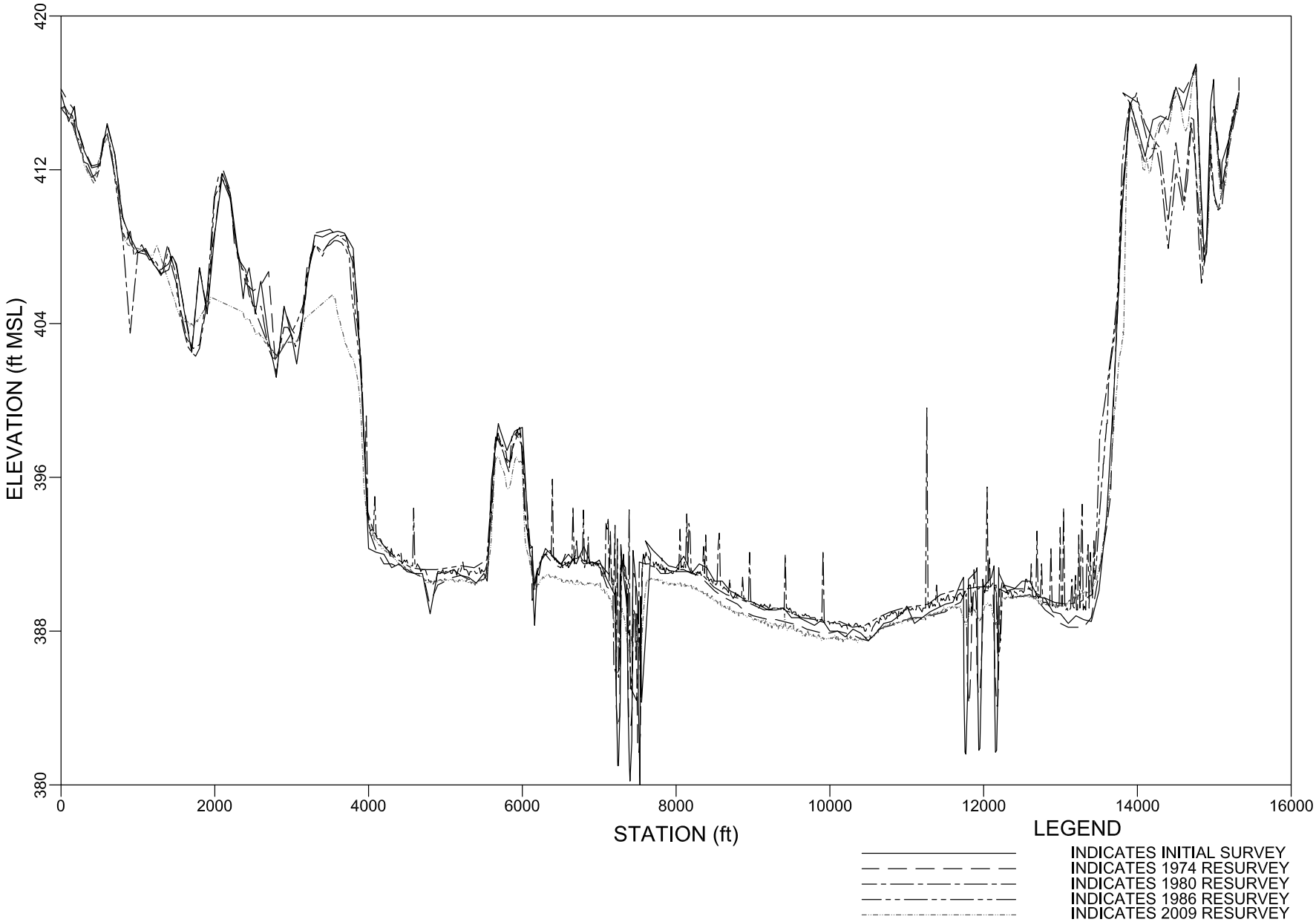


PLATE 14

REND LAKE
SEDIMENTATION RANGE: 10A



REND LAKE
SEDIMENTATION RANGE: 11AB

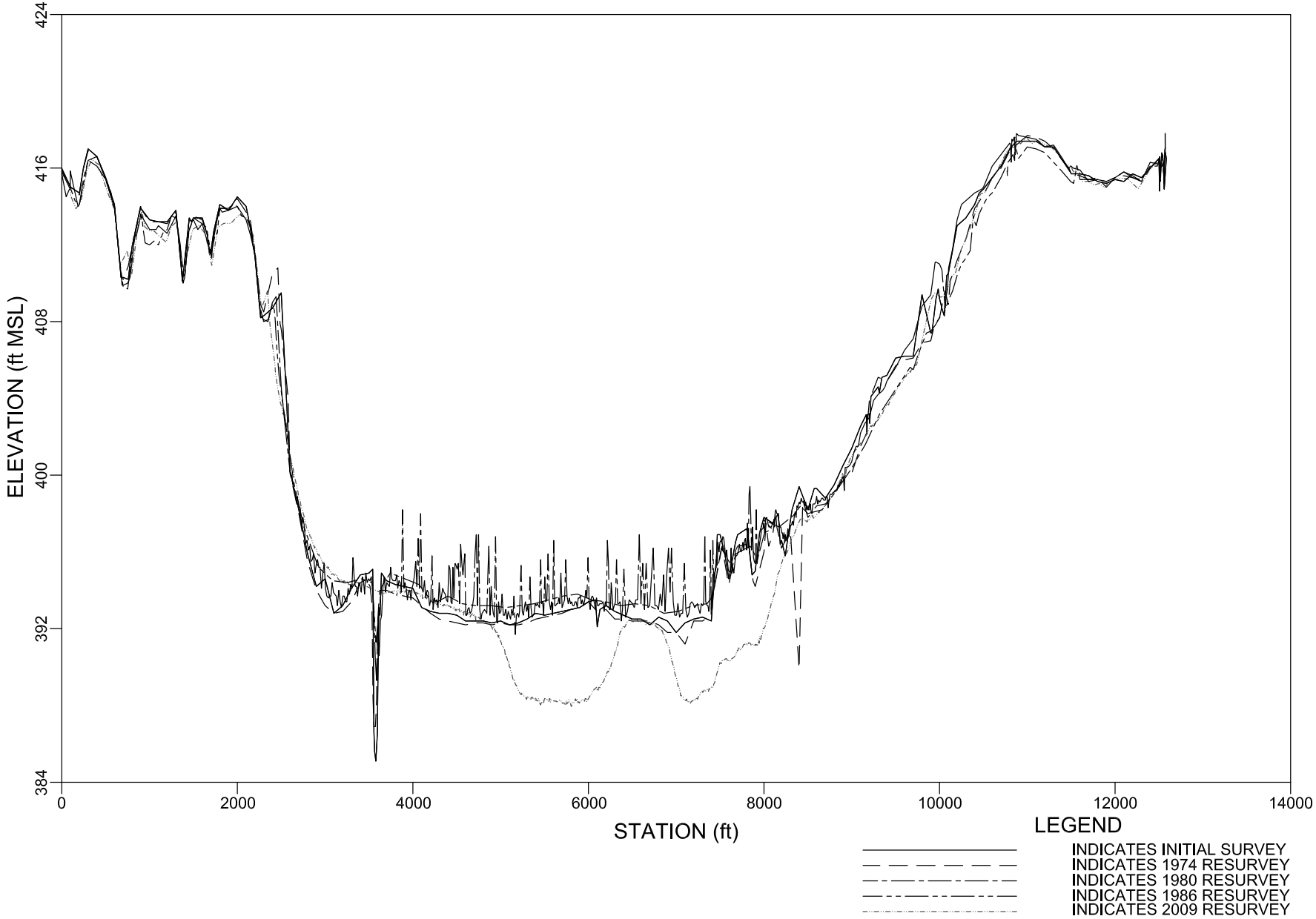


PLATE 16

REND LAKE
SEDIMENTATION RANGE: 12A

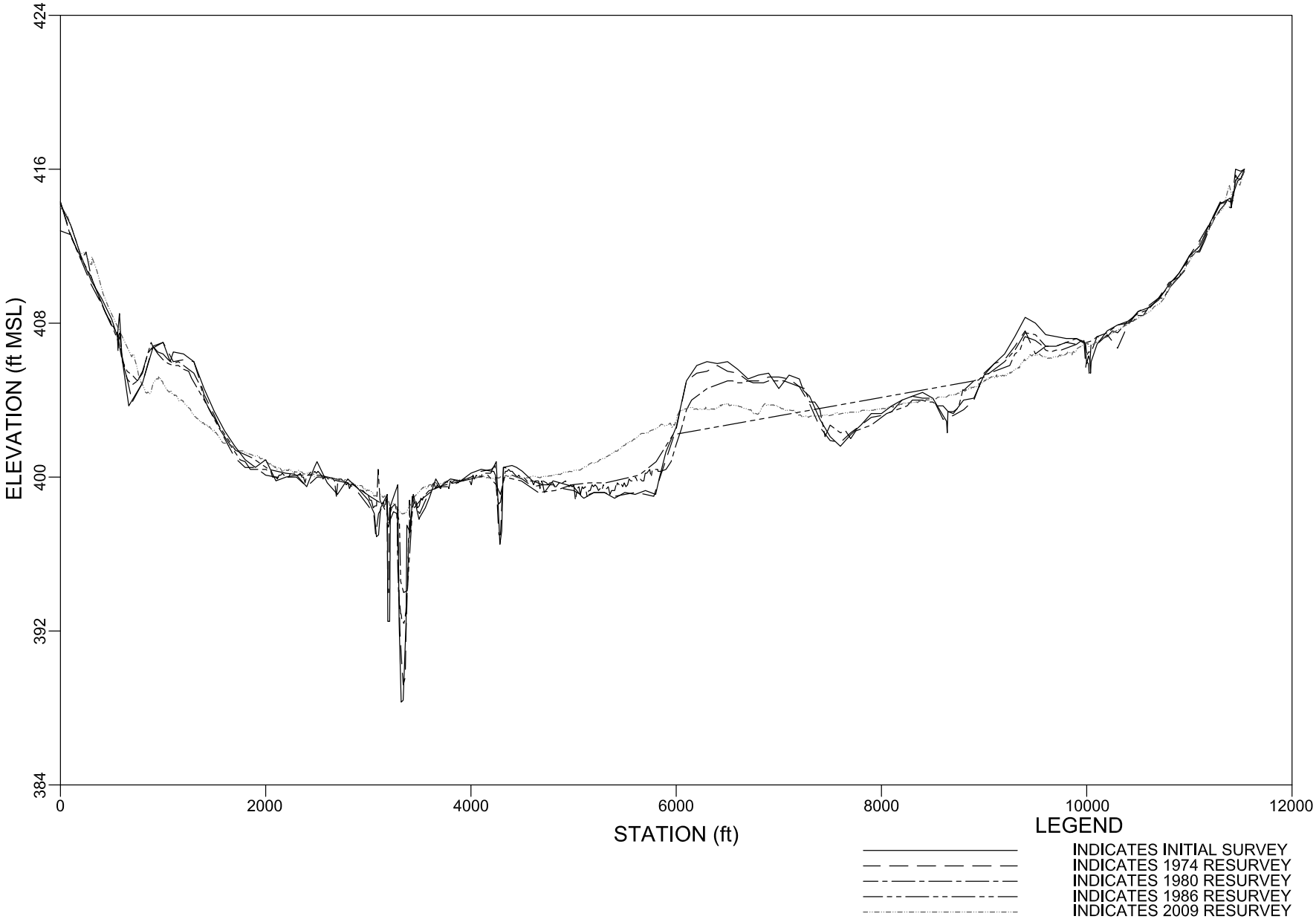
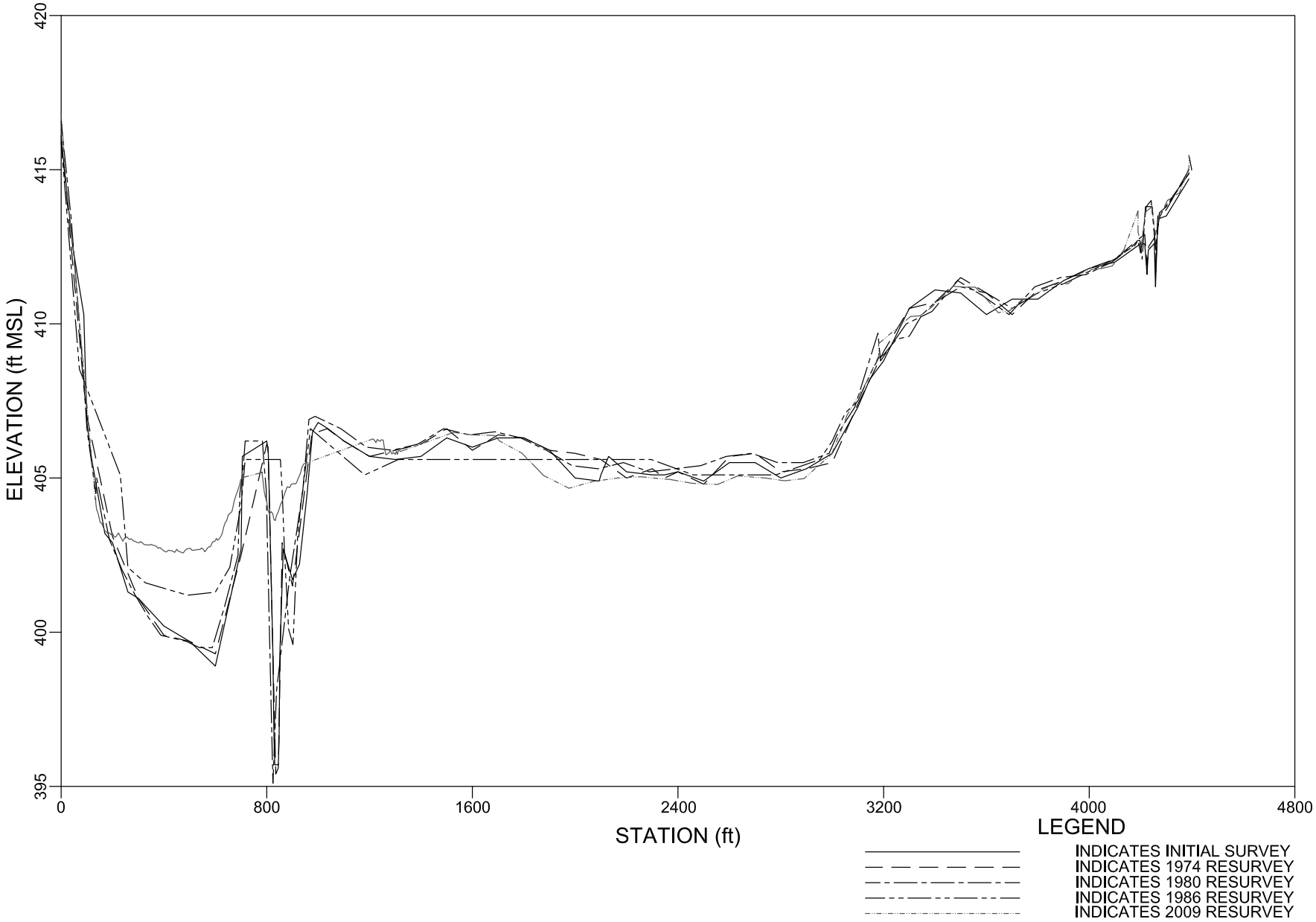
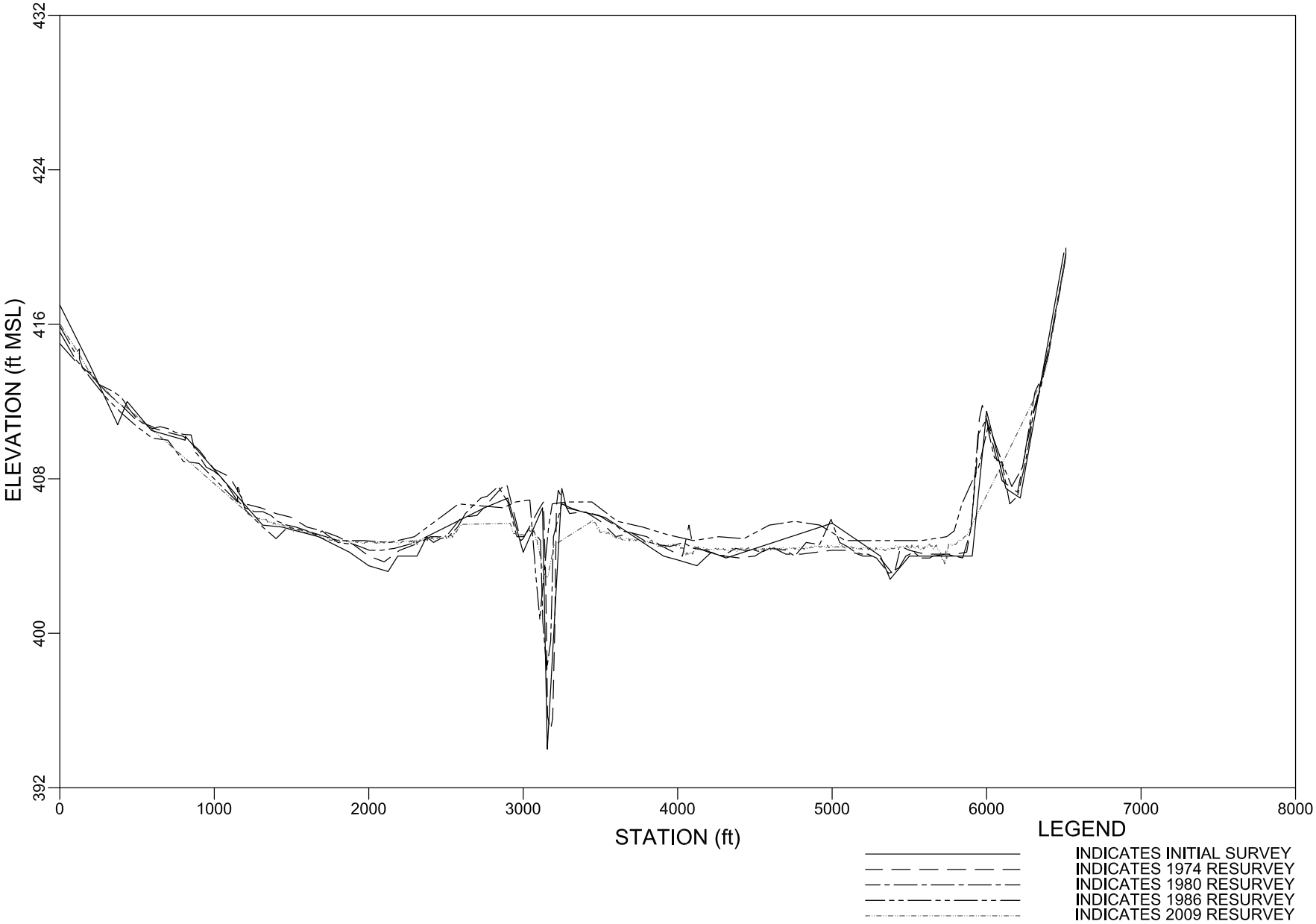


PLATE 17

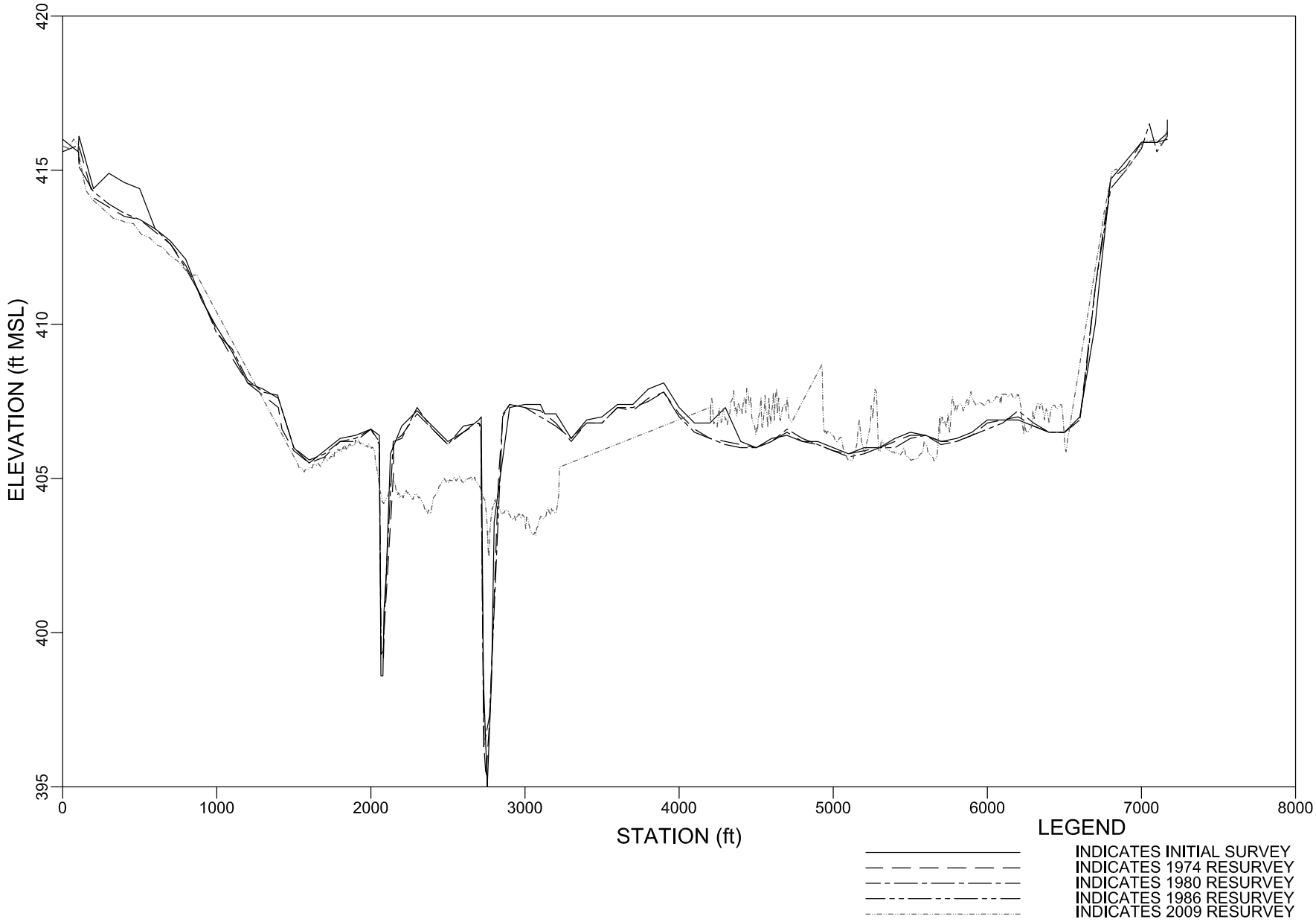
REND LAKE
SEDIMENTATION RANGE: 13B



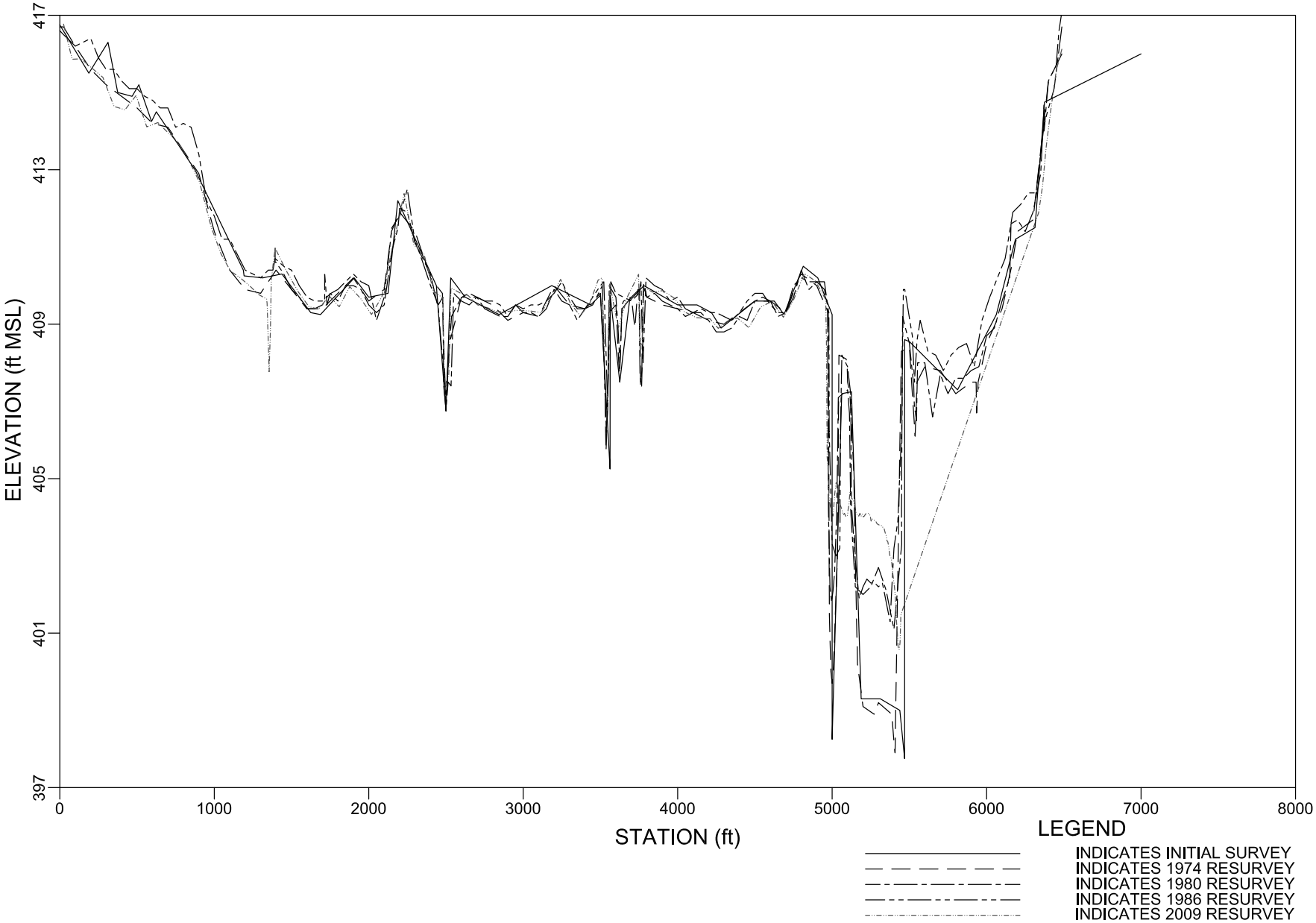
REND LAKE
SEDIMENTATION RANGE: 14A



REND LAKE
SEDIMENTATION RANGE: 15A



REND LAKE
SEDIMENTATION RANGE: 16A



REND LAKE
SEDIMENTATION RANGE: 17AB

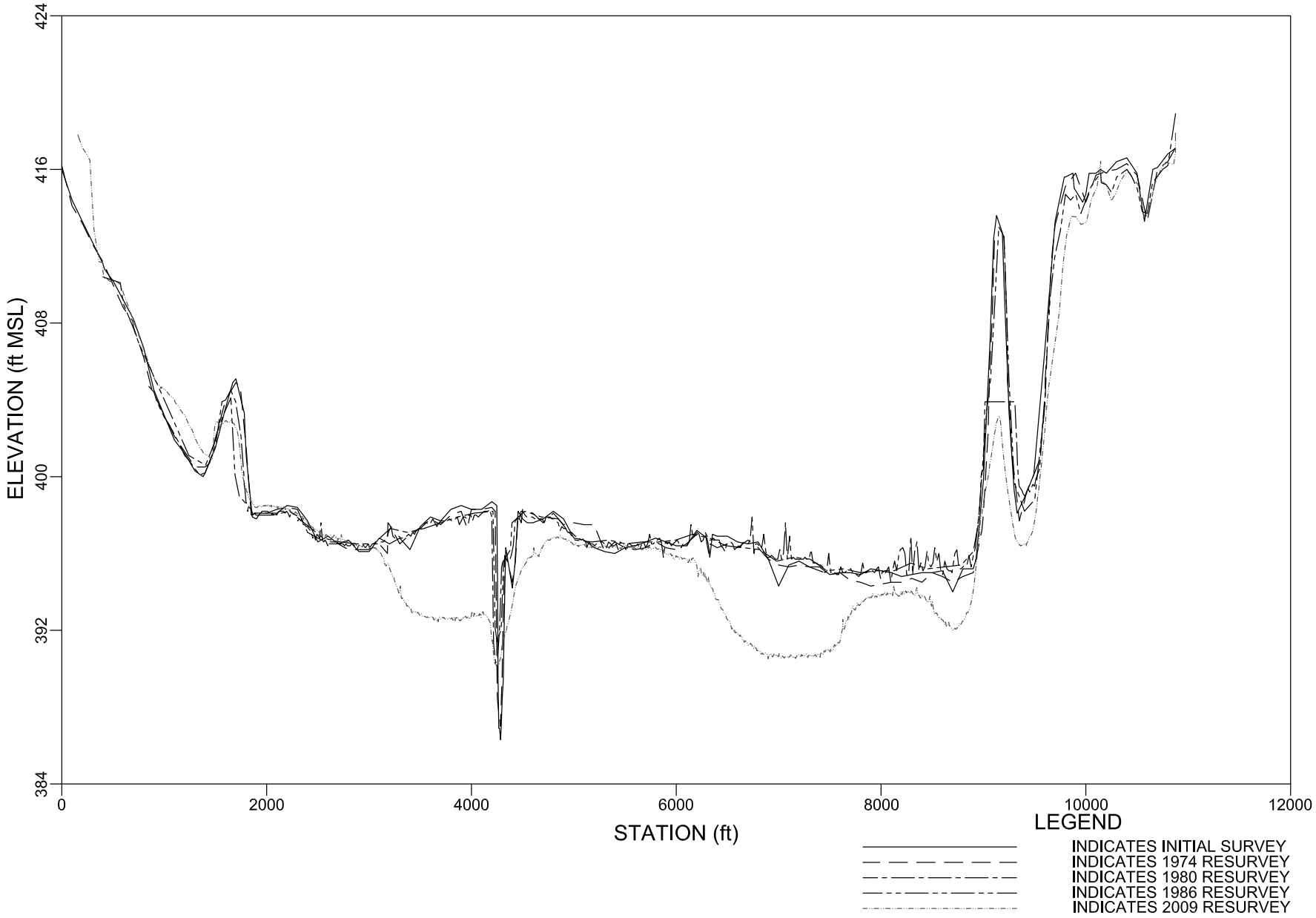
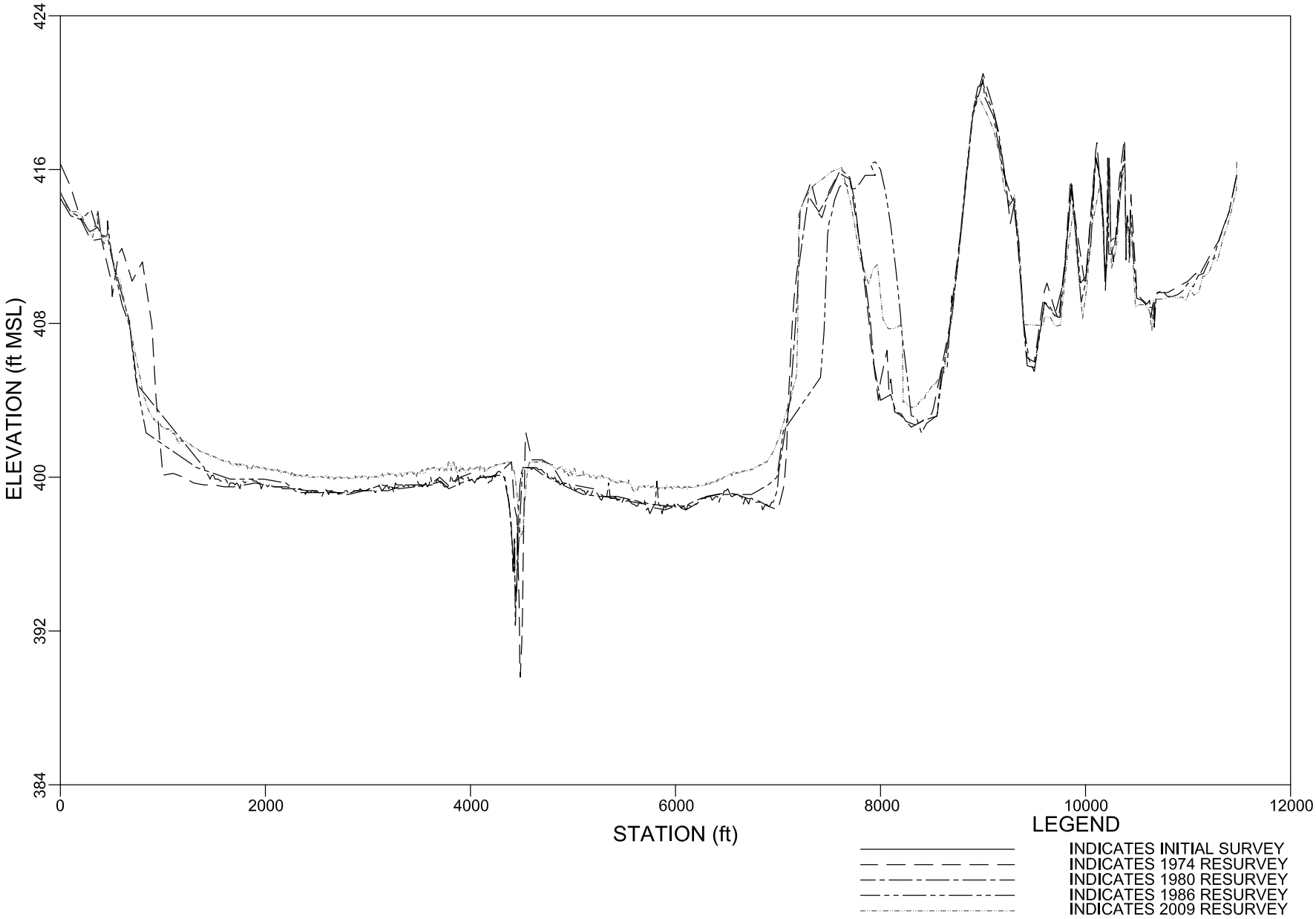
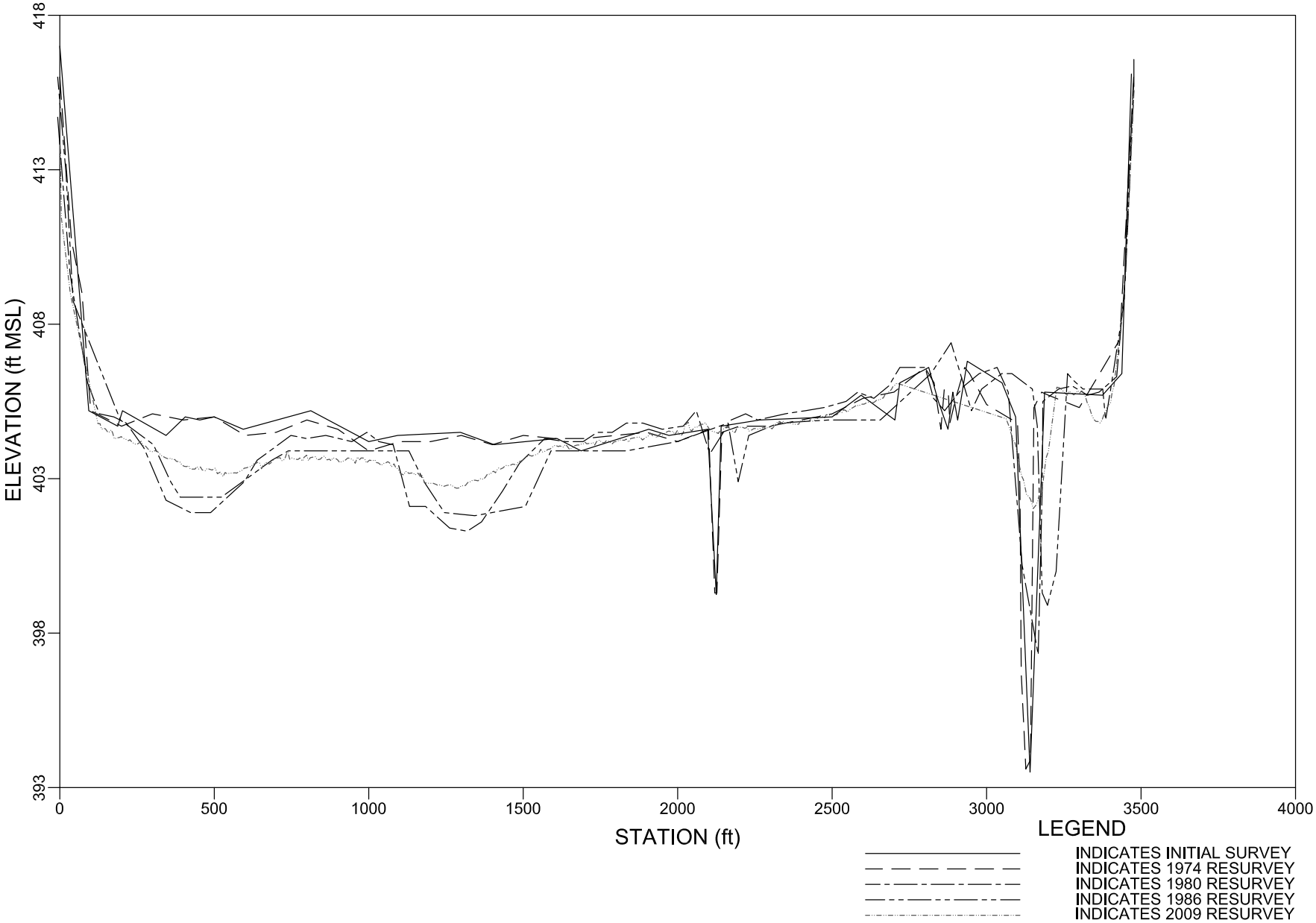


PLATE 22

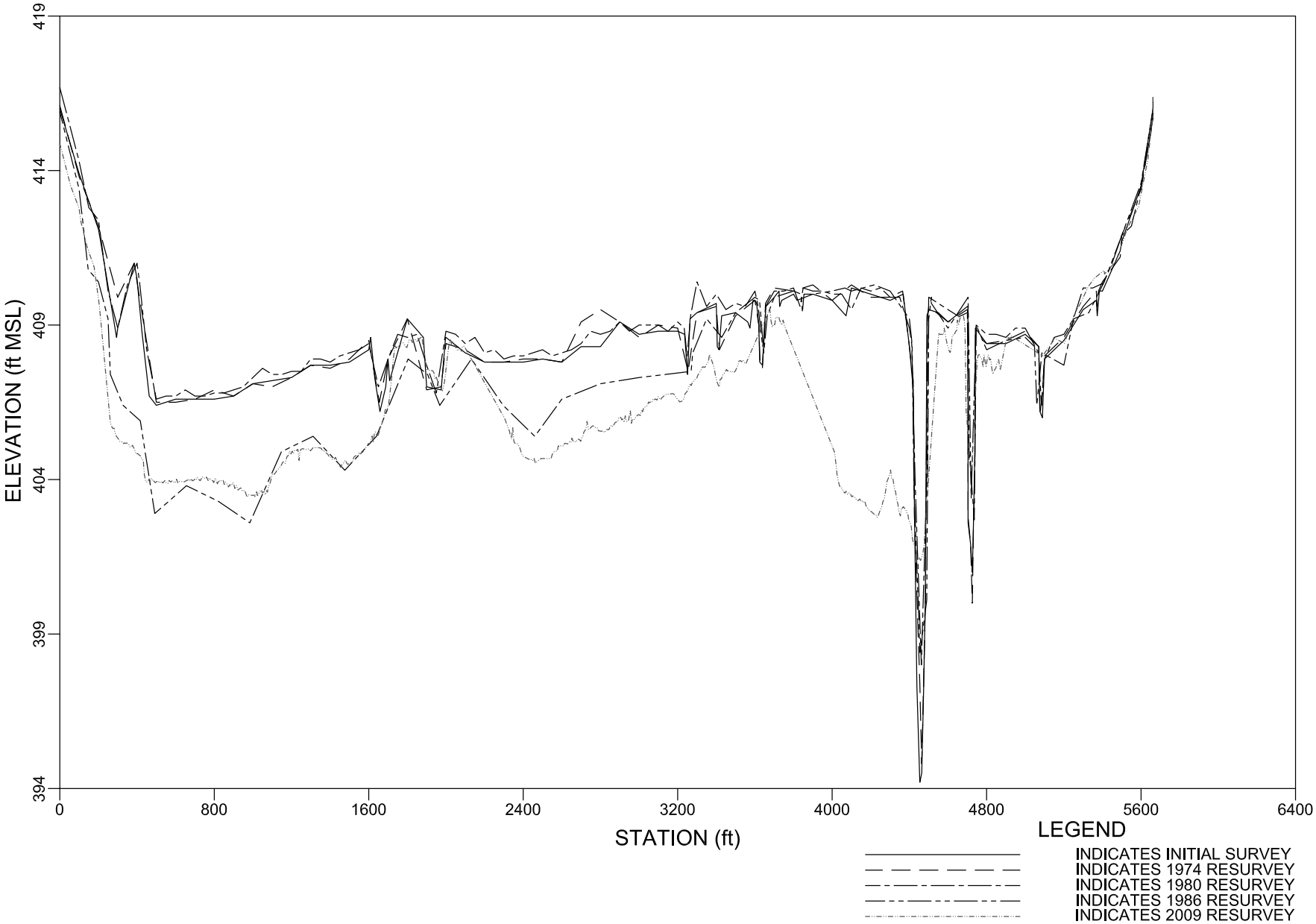
REND LAKE
SEDIMENTATION RANGE: 18A



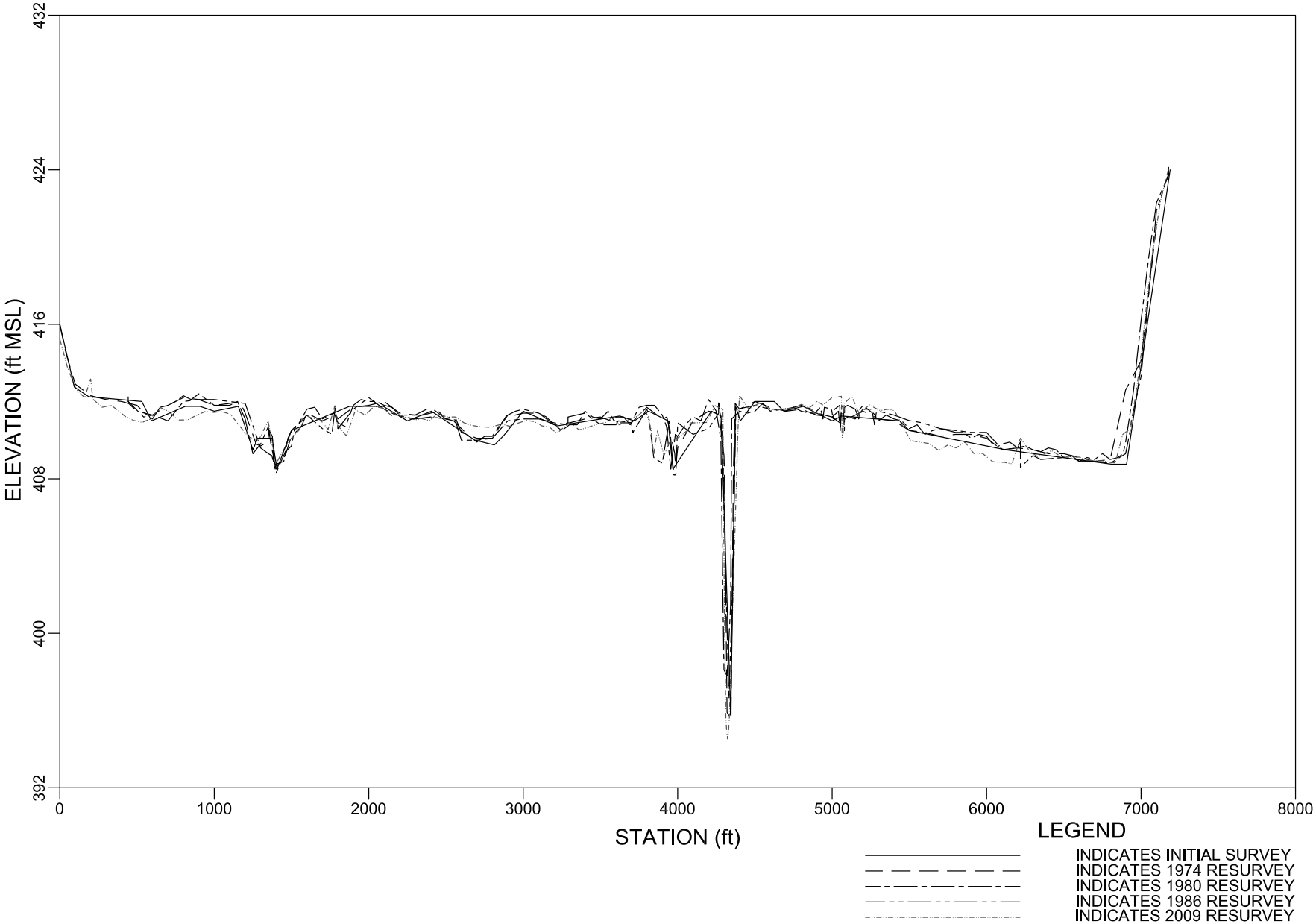
REND LAKE
SEDIMENTATION RANGE: 19A



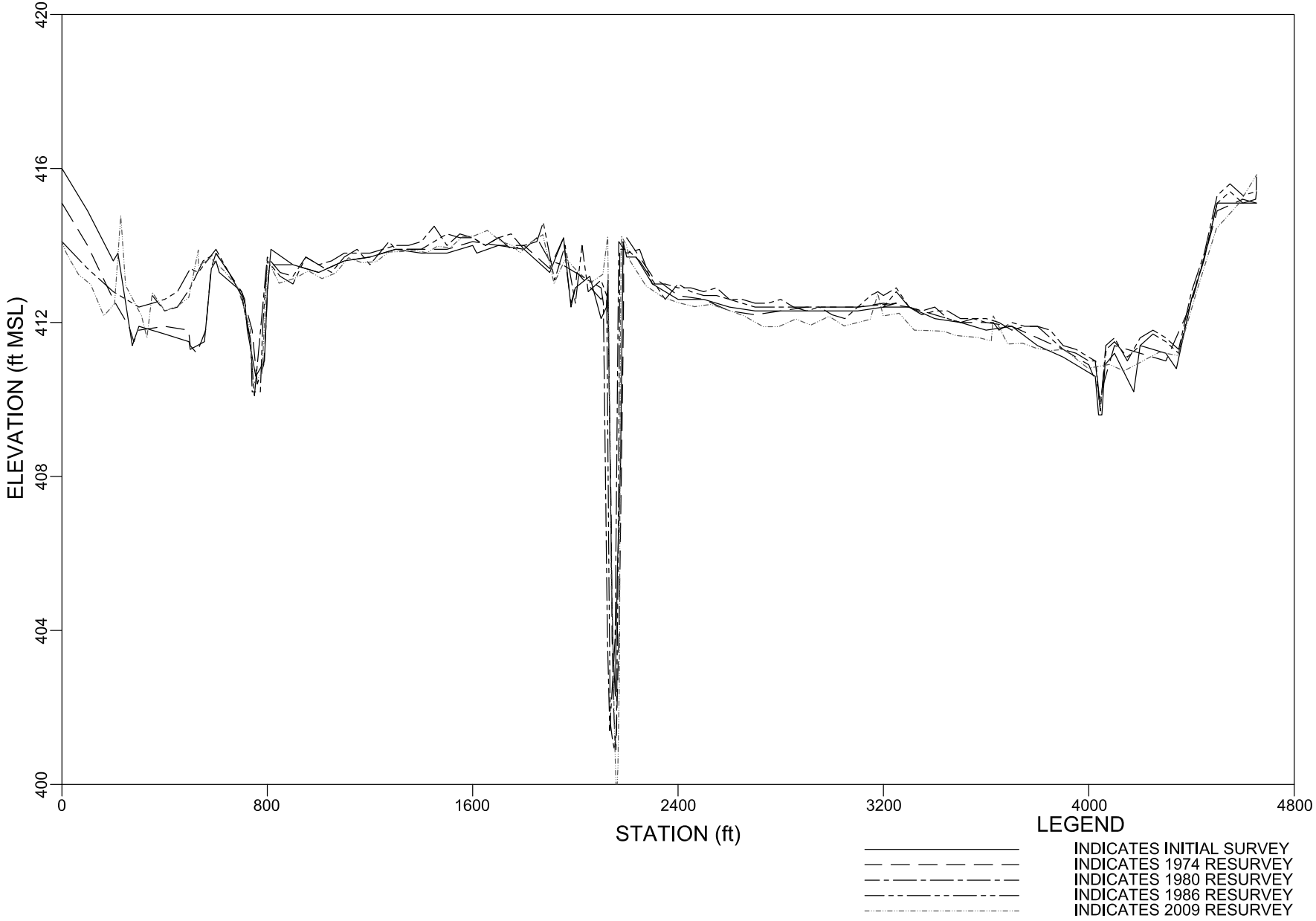
REND LAKE
SEDIMENTATION RANGE: 20A



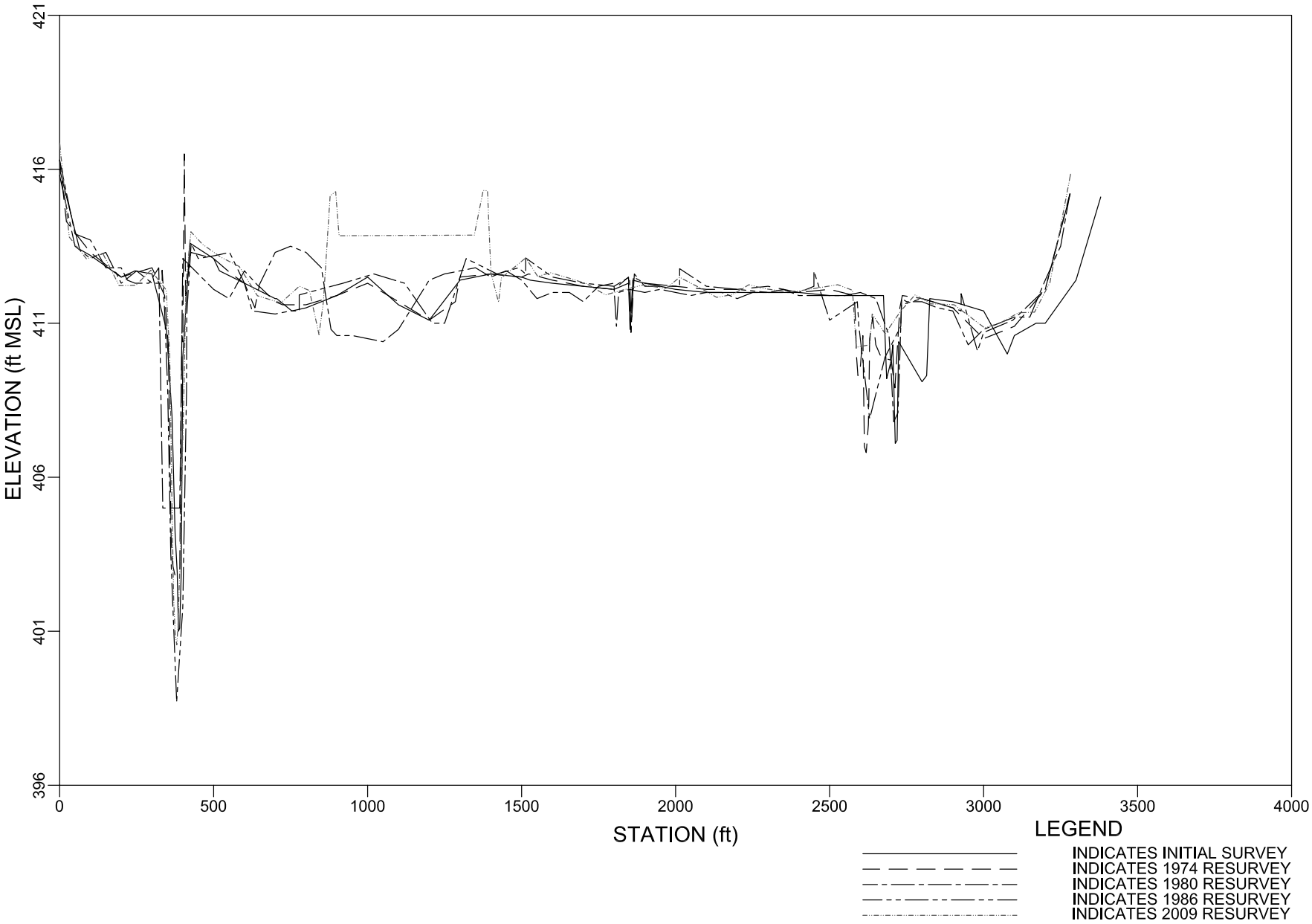
REND LAKE
SEDIMENTATION RANGE: 21A



REND LAKE
SEDIMENTATION RANGE: 22AB



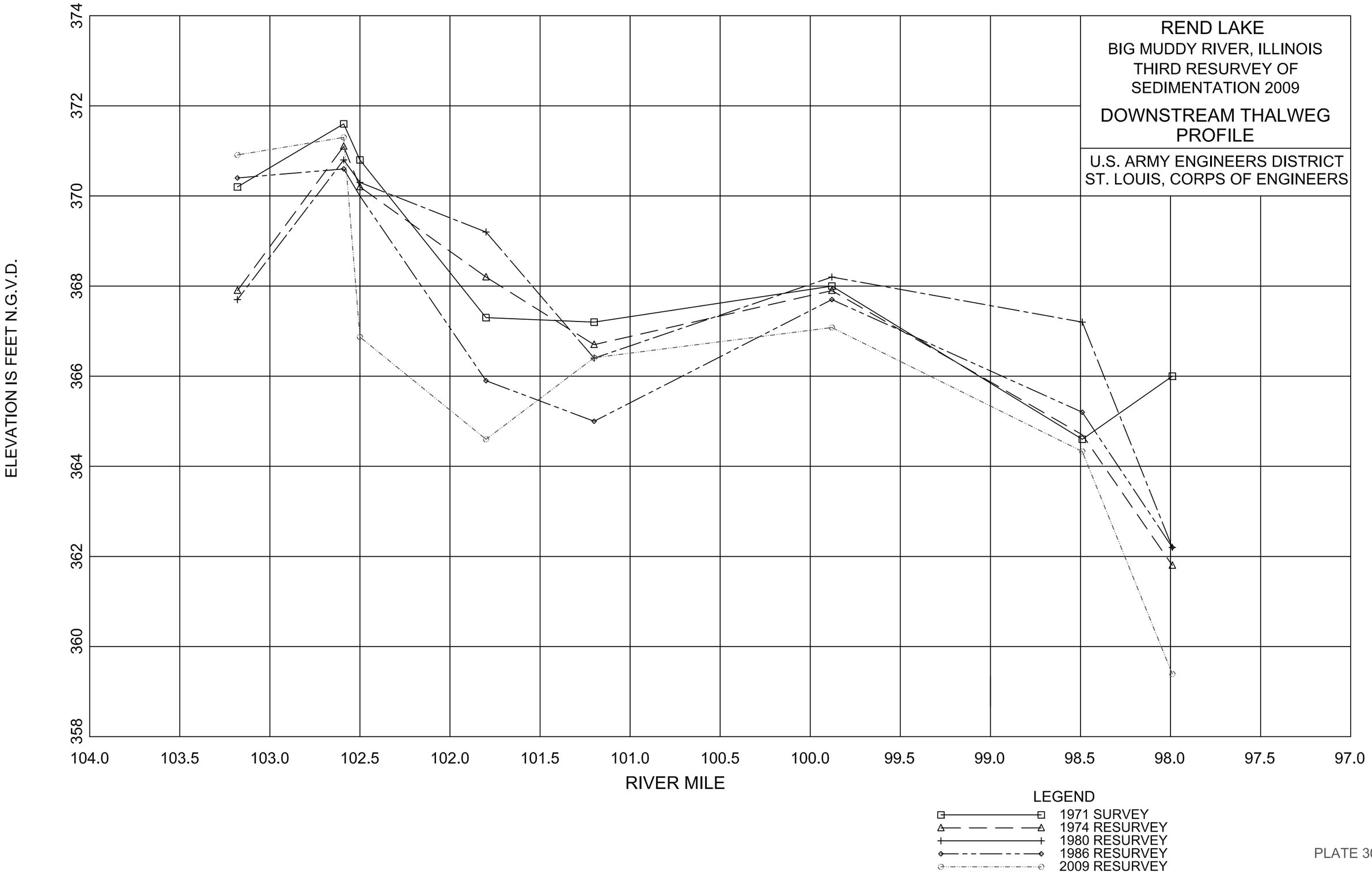
REND LAKE
SEDIMENTATION RANGE: 23AB



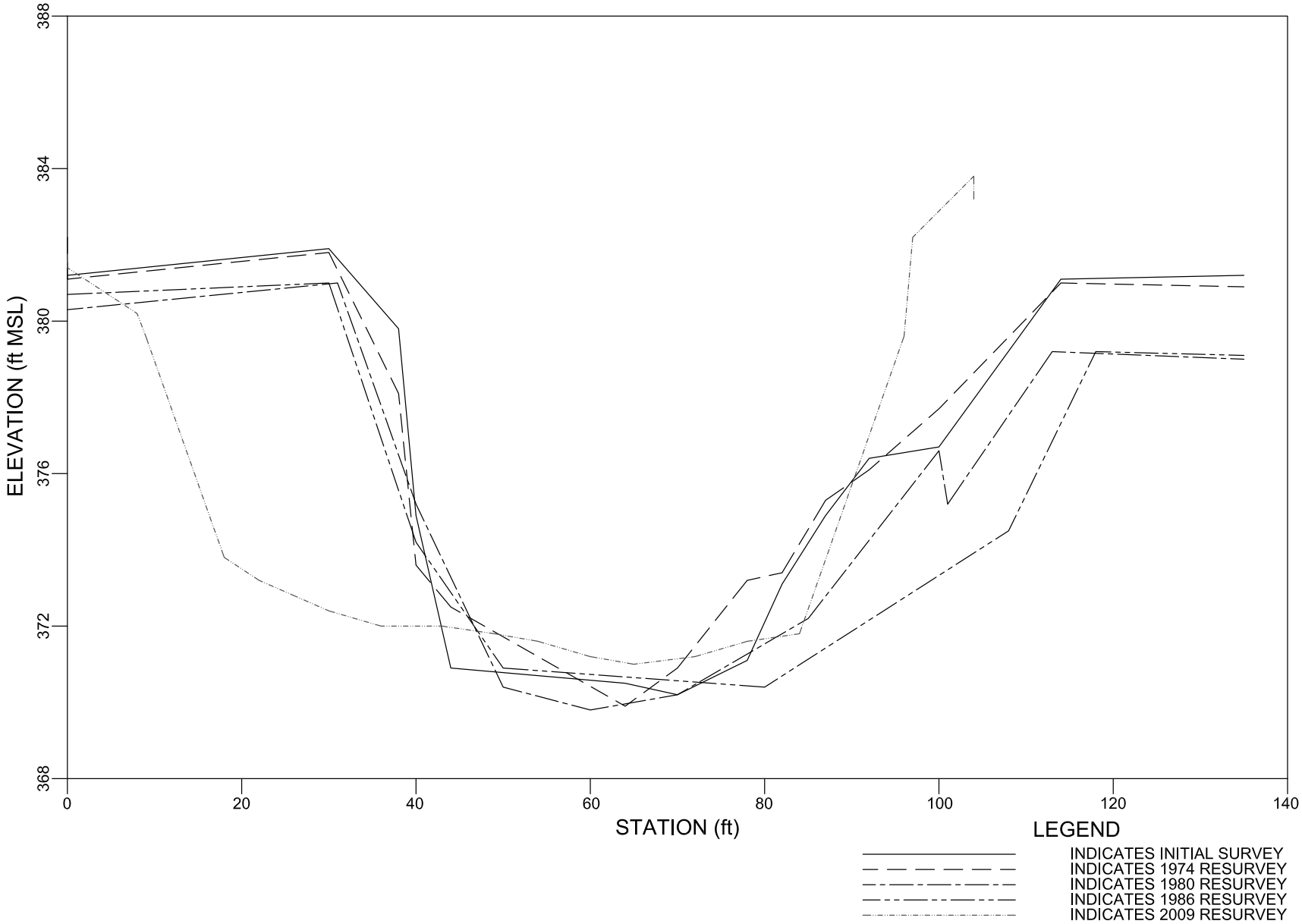
REND LAKE
BIG MUDDY RIVER, ILLINOIS

FOURTH RESURVEY OF SEDIMENTATION 2009
DOWNSTREAM RETROGRESSION RANGES

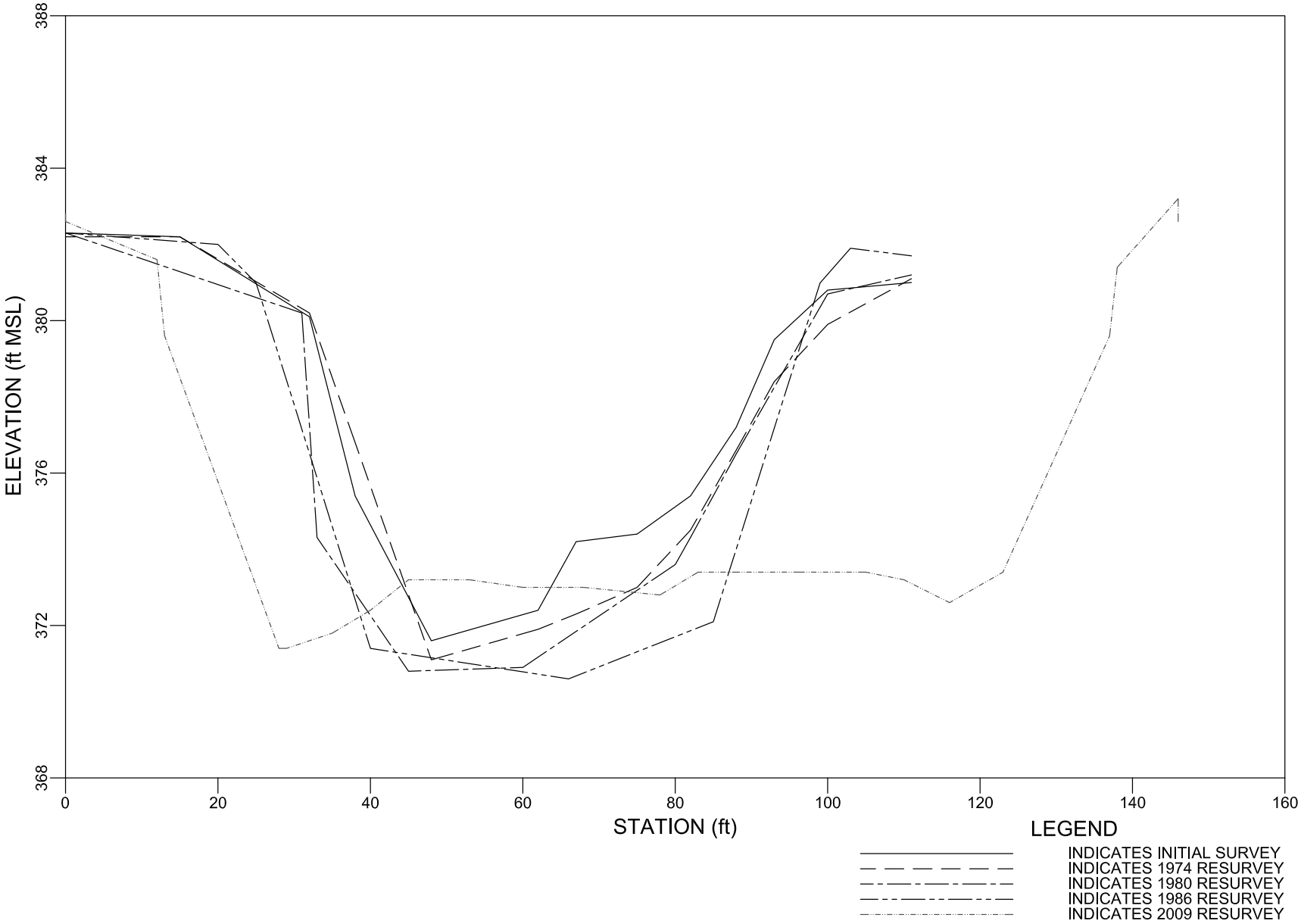
U.S. ARMY ENGINEER DISTRICT
ST. LOUIS, CORPS OF ENGINEERS


REND LAKE
BIG MUDDY RIVER, ILLINOIS
THIRD RESURVEY OF
SEDIMENTATION 2009
DOWNSTREAM THALWEG
PROFILE
U.S. ARMY ENGINEERS DISTRICT
ST. LOUIS, CORPS OF ENGINEERS
ELEVATION IS FEET N.G.V.D.
374
372
370
368
366
364
362
360
358
104.0
103.5
103.0
102.5
102.0
101.5
101.0
100.5
100.0
99.5
99.0
98.5
98.0
97.5
97.0
RIVER MILE
LEGEND
1971 SURVEY
1974 RESURVEY
1980 RESURVEY
1986 RESURVEY
2009 RESURVEY

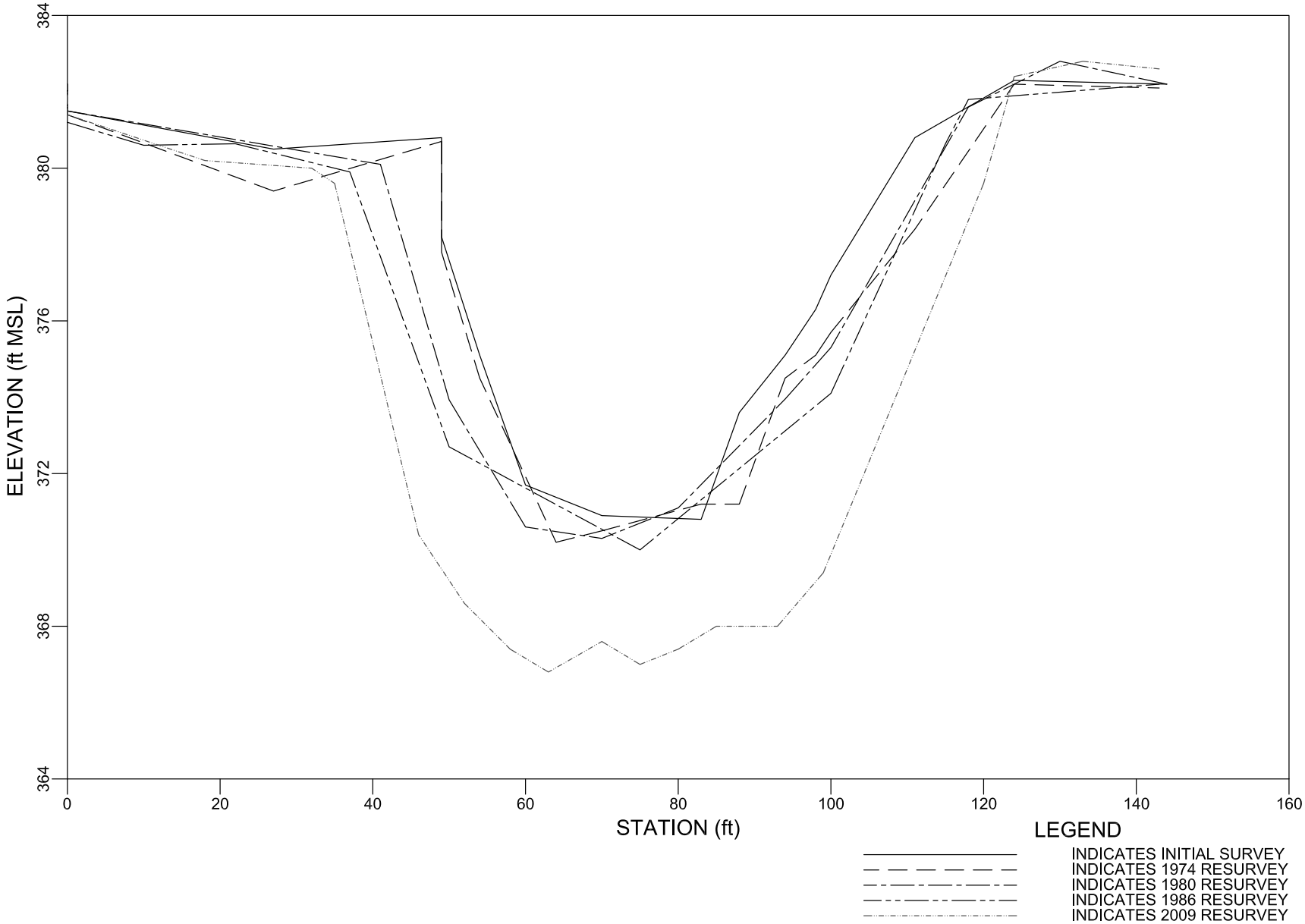
REND LAKE
RETROGRESSION RANGE: 1C



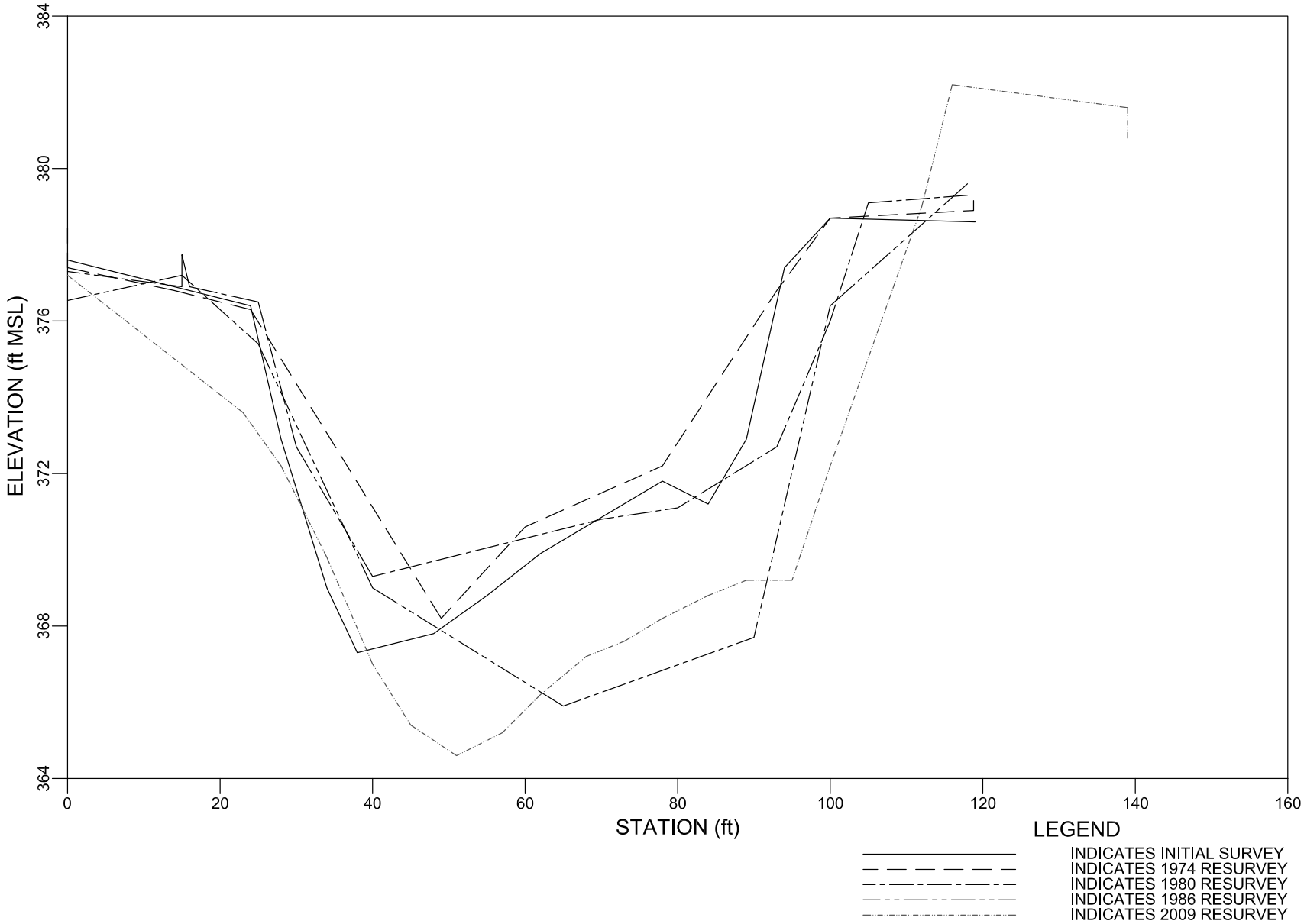
REND LAKE
RETROGRESSION RANGE: 2C



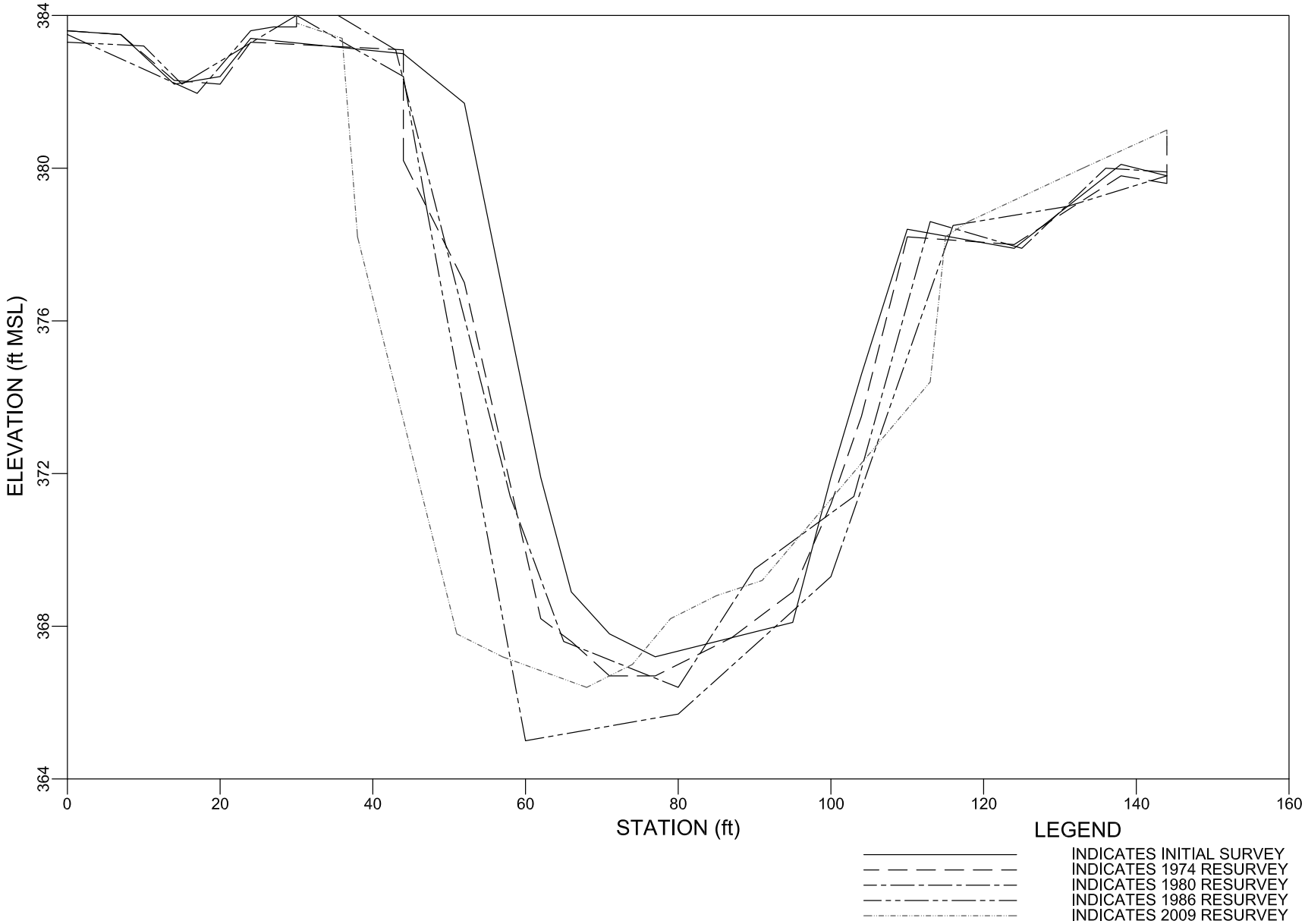
REND LAKE
RETROGRESSION RANGE: 3C



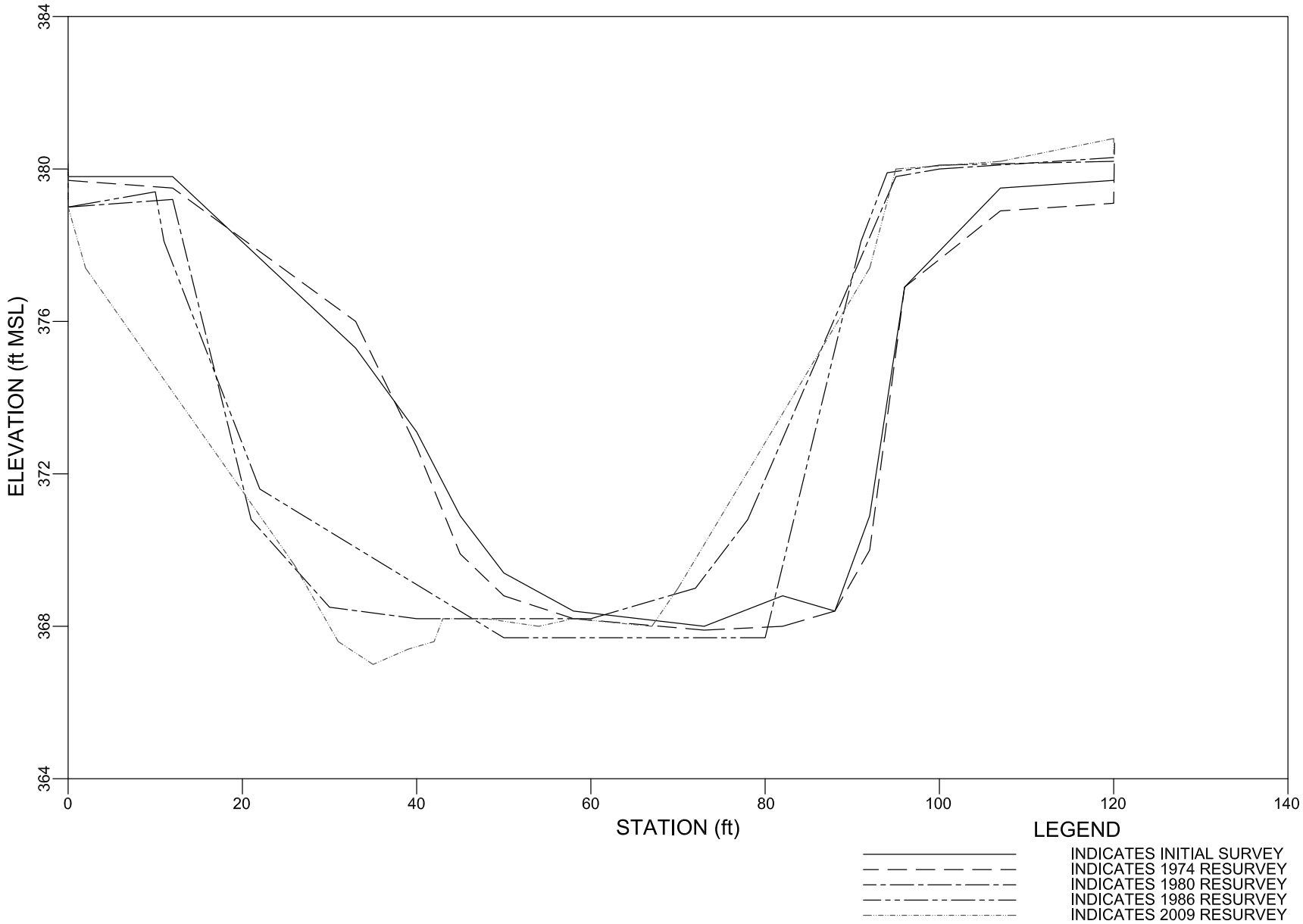
REND LAKE
RETROGRESSION RANGE: 4C



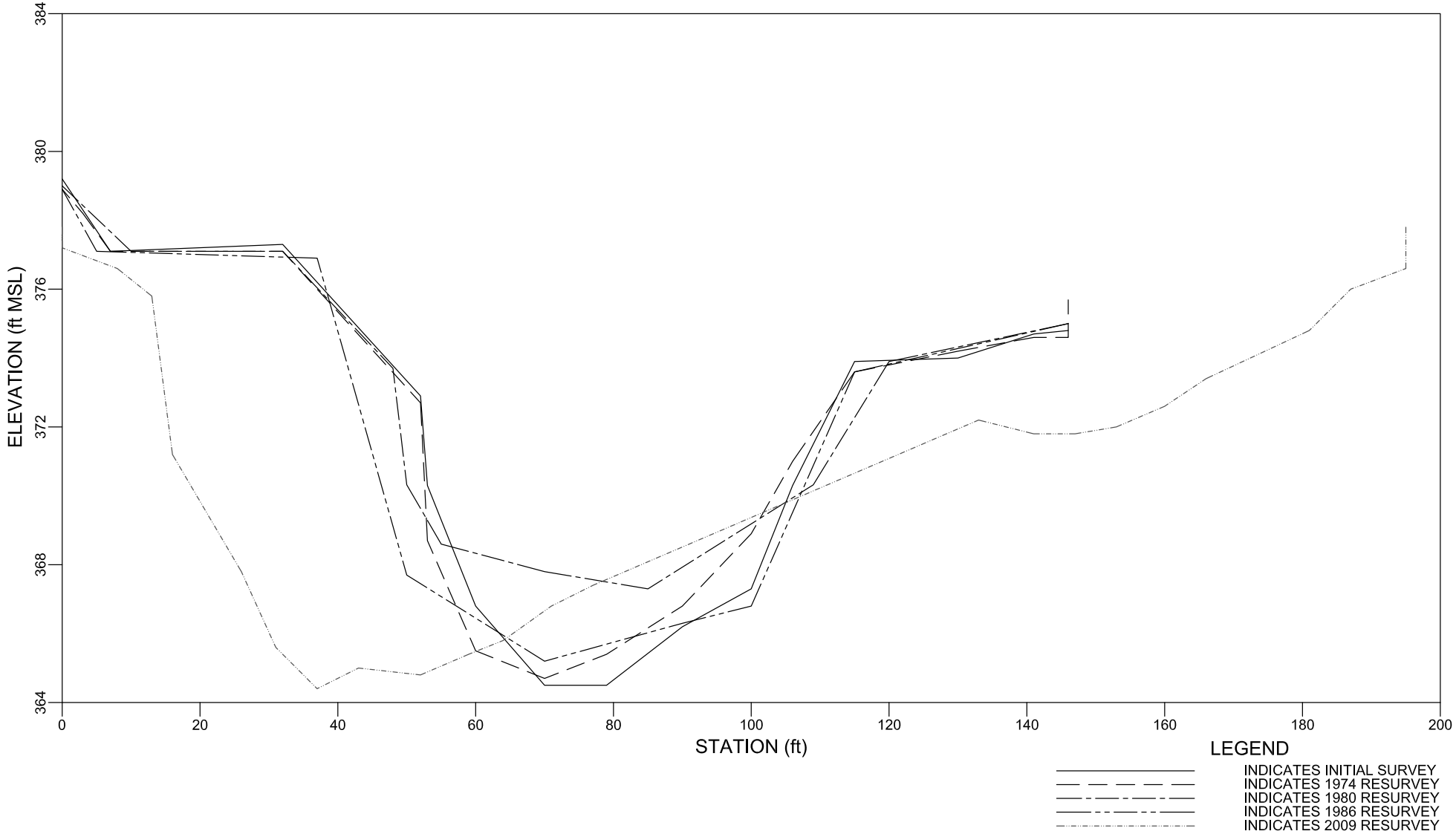
REND LAKE
RETROGRESSION RANGE: 5C



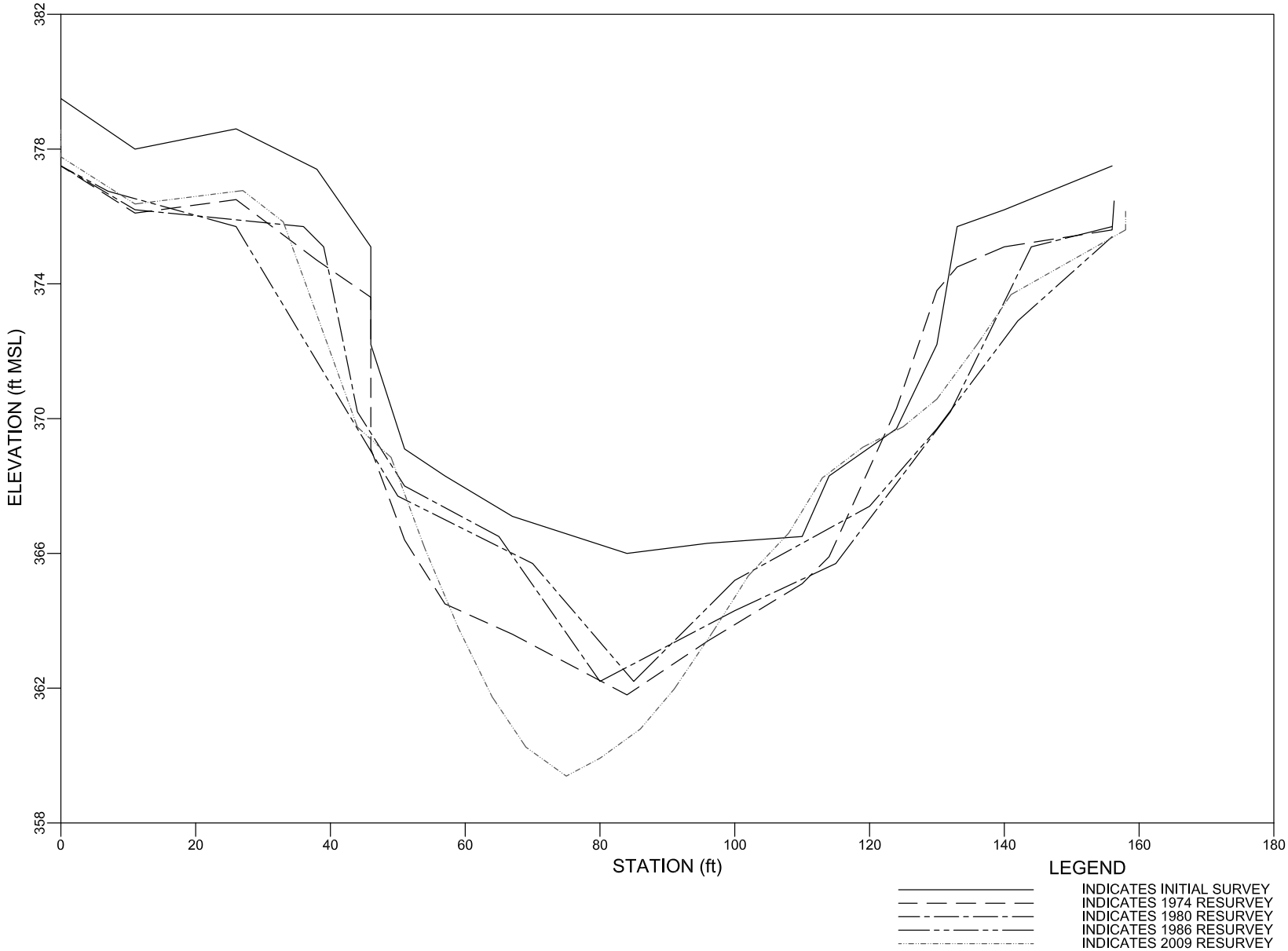
REND LAKE
RETROGRESSION RANGE: 6C



REND LAKE
RETROGRESSION RANGE: 7C



REND LAKE
RETROGRESSION RANGE: 8C



RESERVOIR SEDIMENT
DATA SUMMARY

REND LAKE
NAME OF RESERVOIR

DATA SHEET NO.

DAM

1. OWNER Dept. of Army, Corps of Engineers	2. STREAM Big Muddy River	3. STATE Illinois
4. SEC. 2 - 3 TWP. 6S RANGE 2E	5. NEAREST P.O. Benton, Illinois 3NW	6. COUNTY Franklin - Jefferson
7. LAT. 38° 02' 16" LONG. 88° 57' 24"	8. TOP OF DAM ELEVATION 424.0	9. SPILLWAY CREST ELEV. 410.0[1]

RESERVOIR

10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. ORIGINAL SURFACE AREA, ACRES	13. ORIGINAL CAPACITY, ACRE-FEET	14. GROSS STORAGE, ACRE-FEET	15. DATE STORAGE BEGAN
a. FLOOD CONTROL	410.0	24,800	109,475	294,150	24 October 1970
b. MULTIPLE USE [2]	405.0	18,950	159,675	184,675	
c. POWER					
d. WATER SUPPLY					16. DATE NORMAL OPER. BEGAN
e. IRRIGATION					23 February 1971
f. CONSERVATION					
g. INACTIVE	391.3	5,400	25,000	25,000	

17. LENGTH OF RESERVOIR 25.4[3] MILES AV. WIDTH OF RESERVOIR 1.5 MILES

WATERSHED

18. TOTAL DRAINAGE AREA 488 SQ. MI.		22. MEAN ANNUAL PRECIPITATION 36.5 INCHES	
19. NET SEDIMENT CONTRIBUTING AREA 449.2 SQ. MI.		23. MEAN ANNUAL RUNOFF 13.5 INCHES	
20. LENGTH 32 MILES	AV. WIDTH 15.3 MILES	24. MEAN ANNUAL RUNOFF 351,338 AC. FT.	
21. MAX. ELEV. 620	MIN. ELEV. 380	25. ANNUAL TEMP: MEAN 52.7° F	RANGE 30.3° - 72.8° F

SURVEY DATA

26. DATE OF SURVEY	27. PERIOD YEARS	28. ACCL. YEARS	29. TYPE OF SURVEY	30. NO. OF RANGES OR CONTOUR INT.	31. SURFACE AREA, ACRES	32. CAPACITY, ACRE-FEET	33. C/I. RATIO, AC.-FT. PER AC.-FT.
October 1970			Range	31	24,800	294,150	0.88
March 1974[4]							
September 1980	9.9	9.9	Range	31	24,800	292,090[7]	0.87
March 1986[5]	5.5	15.4	Range	30[6]	24,800	291,948	0.87
April 2010[8]	24	38.8	Range (D)	31	25,070	302,067	0.86

26. DATE OF SURVEY	34. PERIOD ANNUAL PRECIPITATION	35. PERIOD WATER INFLOW. ACRE-FEET			36. WATER INFL. TO DATE, AC.-FT.	
		a. MEAN ANNUAL	b. MAX. ANNUAL	c. PERIOD TOTAL	a. MEAN ANNUAL	b. TOTAL TO DATE
October 1970						
September 1980	39.96	273,800	471,400	2,738,040	273,800	2,738,040
March 1986	48.82	439,760	616,050	2,418,660	334,850	5,156,700
April 2010	33.48	359,780	640,139	8,634,708	377,907	13,791,408

26. DATE OF SURVEY	37. PERIOD CAPACITY LOSS, ACRE-FEET			38. TOTAL SED. DEPOSITS TO DATE, ACRE-FEET		
	a. PERIOD TOTAL	b. AV. ANNUAL	c. PER SQ. MI.-YEAR	a. TOTAL TO DATE	b. AV. ANNUAL	c. PER SQ. MI.-YEAR
October 1970						
September 1980	2,060	213	0.47	2,060	213	0.47
March 1986	142	26	0.06	2,202	143	0.32
April 2010	-10,119	-422	-0.94	-7,917	-204	-0.45

26. DATE OF SURVEY	39. AV. DRY WGT. LBS. PER CU. FT.	40. SED. DEP. TONS PER SQ. MI.-YR.		41. STORAGE LOSS PCT.		42. SED. INFLOW PPM	
		a. PERIOD	b. TOTAL TO DATE	a. AV. ANN.	b. TOTAL TO DATE	a. PERIOD	b. TOTAL TO DATE
October 1970	[9]						
September 1980	43.2 (22)	446	446	0.07	0.70	521	521
March 1986	[9]	54	300	0.05	0.75	41	296
April 2010	[9]	-883	-423	-0.07	-2.69	-8,112	-397

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26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE IN FEET BELOW, AND ABOVE, CREST ELEVATION											
	30-25	25-20	20-15	15-10	10-5	5-0	0-+5	+5-+10				
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION											
September 1980	31.6	87.4	69.1	299.8	-62.6	-325.3 10/	0.0	0.0				
March 1986	34.1	59.1	154.5	313.6	-124.3	-337.0 10/	0.0	0.0				
April 2010	20.8	-65.5	80.3	38.9	91.9	-188.5 10/	0.0	0.0				

26. DATE OF SURVEY	44. REACH DESIGNATION PERCENT OF TOTAL ORIGINAL LENGTH OF RESERVOIR														
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	-105	-110	-115	-120	-125
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN REACH DESIGNATION														
September 1980	23.3	22.8	20.4	25.7	22.3	-2.4	-13.1	-0.5	2.4	-0.9					
March 1986	37.7	-1.4	0.0	24.1	36.3	10.4	10.4	-9.5	-7.7	-0.3					
April 2010	-2.5	-60.1	-16.8	-8.1	-6.9	-5.6	-2.3	1.4	2.3	-1.5					

45. RANGE IN RESERVOIR OPERATION

WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AC.-FT.	WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AC.-FT.
1971	396.99	389.60	232,600	1997	410.25	404.22	315,242
1972	404.00	392.56	316,480	1998	410.76	404.18	350,849
1973	411.36	401.85	471,400	1999	411.27	403.40	363,839
1974	410.21	402.85	335,860	2000	408.76	403.32	200,205
1975	411.46	403.69	409,080	2001	408.78	404.89	319,423
1976	406.69	403.47	35,830	2002	412.04	404.34	386,237
1977	411.41	403.28	199,620	2003	410.62	404.40	291,565
1978	410.47	404.85	232,530	2004	409.25	404.78	346,874
1979	412.12	404.27	396,980	2005	411.49	404.83	250,398
1980	408.56	403.23	108,720	2006	412.15	405.35	487,901
1981	407.98	403.22	126,750	2007	410.88	403.14	223,164
1982	409.25	405.95	305,030	2008	412.06	403.64	491,392
1983	412.89	404.93	482,270	2009	410.93	405.50	586,838
1984	411.48	405.26	525,740				
1985	412.53	404.65	727,970				
1986	410.16	404.32	194,234				
1987	407.56	403.37	174,439				
1988	410.59	404.81	313,958				
1989	412.72	403.64	443,273				
1990	411.81	403.90	443,110				
1991	410.99	404.44	325,040				
1992	407.63	403.70	194,859				
1993	412.31	404.96	640,139				
1994	411.05	404.54	358,736				
1995	413.83	403.85	518,203				
1996	412.72	403.92	414,790				

46. ELEVATION-AREA-CAPACITY DATA

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
ORIGINAL - 1970			1986 Resurvey			2009 Resurvey		
385	1,700	3,650	385	1,670	2,900	385	868	2,000
390	4,450	18,525	390	4,260	16,474	390	5,752	22,062
395	8,500	50,550	395	8,140	45,100	395	9,211	47,733
400	13,200	104,450	400	12,450	92,100	400	12,511	104,714
405	18,950	184,675	405	20,140	175,059	405	19,151	177,665
410	24,800	294,150	410	24,800	291,948	410	25,070	302,067
415	32,450	436,675	415	32,450	434,575	415	32,549	443,726
420	41,300	620,000	420	41,300	617,800	420	41,300	622,090

47. REMARKS AND REFERENCES

1/ Spillway has length of 435 ft at el 410.0 plus a 31 ft notch at el 405.0

2/ Includes 109,000 acre-feet water supply and 51,000 acre-feet for downstream release for stream flow regulation including water quality

3/ 13.0 miles Big Muddy River and 12.4 miles Casey Fork

4/ March 1974 resurvey data not shown

5/ Resurvey conducted Sep-Oct 1985 and Feb-Mar 1986

6/ Range 15A not surveyed in 1986

7/ Items 32, 33, 37, 38, 40-43 for the 1980 resurvey were recalculated in 1986. Results for the 1980 resurvey are those presented in the 1986 report, which do not agree with those presented in the 1980 report.

8/ Resurvey conducted August 2009 through April 2010

9/ Sediment samples not collected. Results of 1980 sample used in calculations

10/ Large negative number possibly due to settling of the ground surface

48. AGENCY MAKING SURVEY U.S. Army Engineer District

49. AGENCY SUPPLYING DATA St. Louis, Missouri

50. DATE August 2010

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APPENDIX A

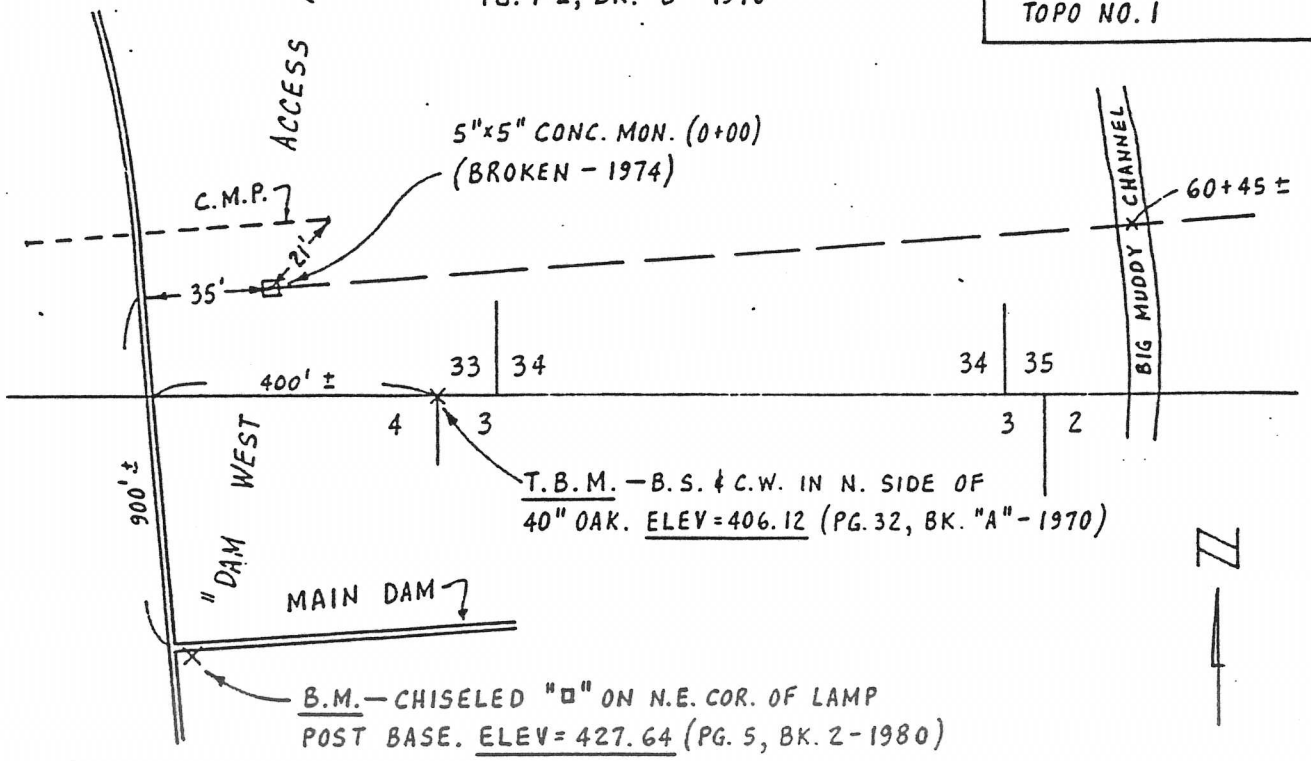
COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 1 OF 23	COMPUTED BY WCM	DATE 12-18-80
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

RANGE 1-A

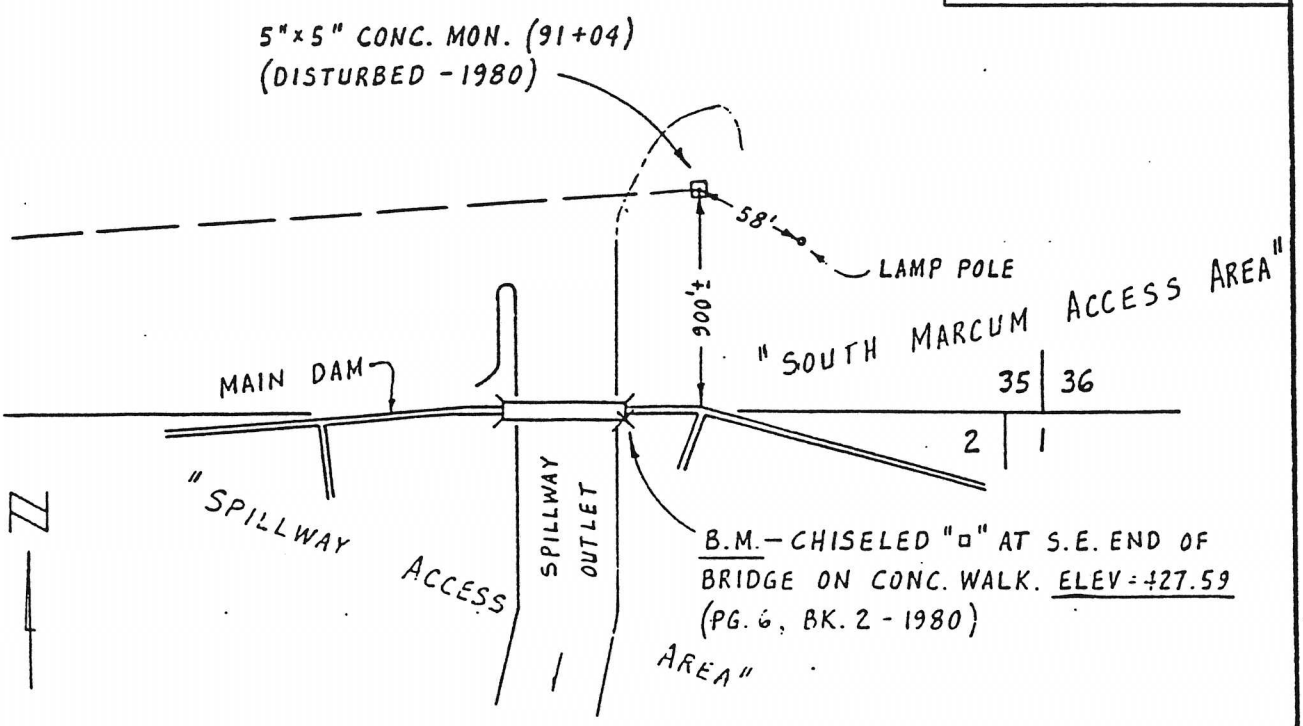
LAYOUT — PG. 1, BK. "C" - 1970
PG. 1-2, BK. "B" - 1970

N 500,000
E 312,040
TOPO NO. 1
0+00 APPR.



LAYOUT — PG. 2, BK. "C" - 1970
PG. 1-2, BK. "B" - 1970

N 500,580
E 321,120
TOPO NO. 1
91+04 APPR.

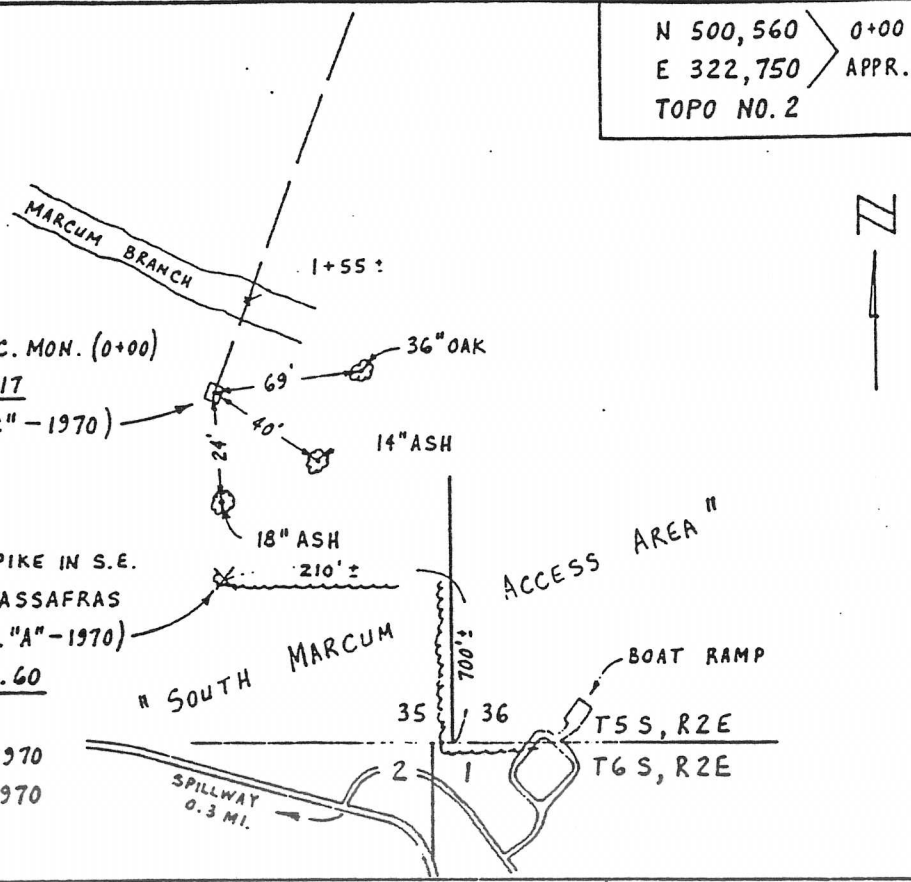


COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 2 OF 23	COMPUTED BY WSM	DATE 12-22-80
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

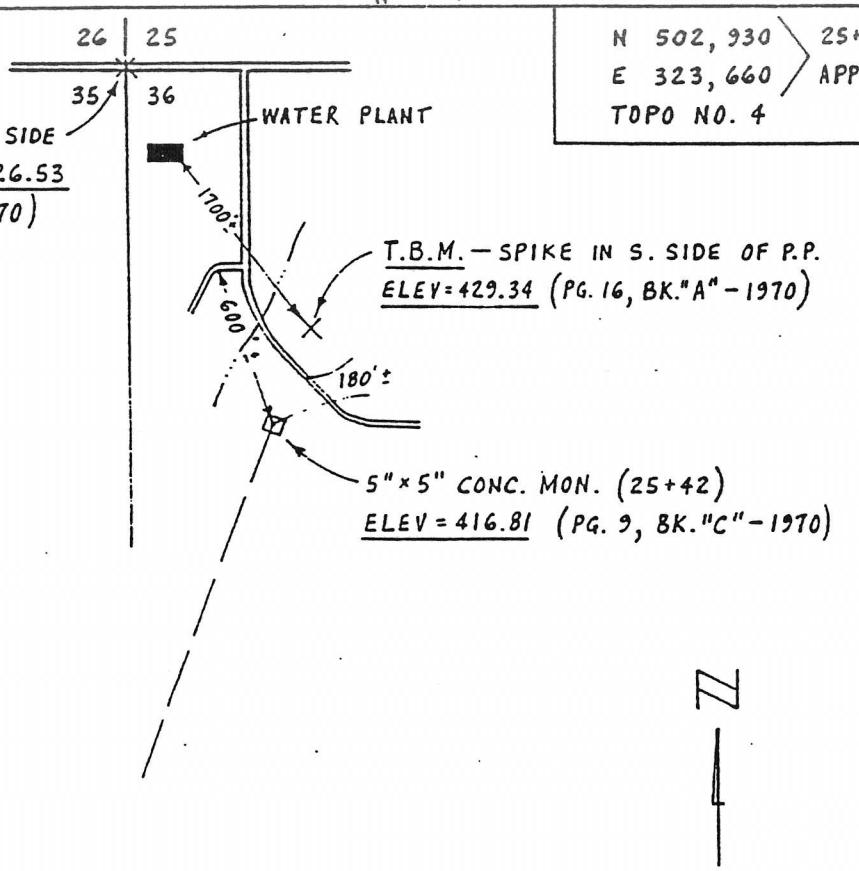
RANGE 2-B

N 500,560
E 322,750
TOPO NO. 2
0+00 APPR.



LAYOUT – PG. 3, BK. "C" – 1970
PG. 11, BK. "B" – 1970

N 502,930
E 323,660
TOPO NO. 4
25+42 APPR.



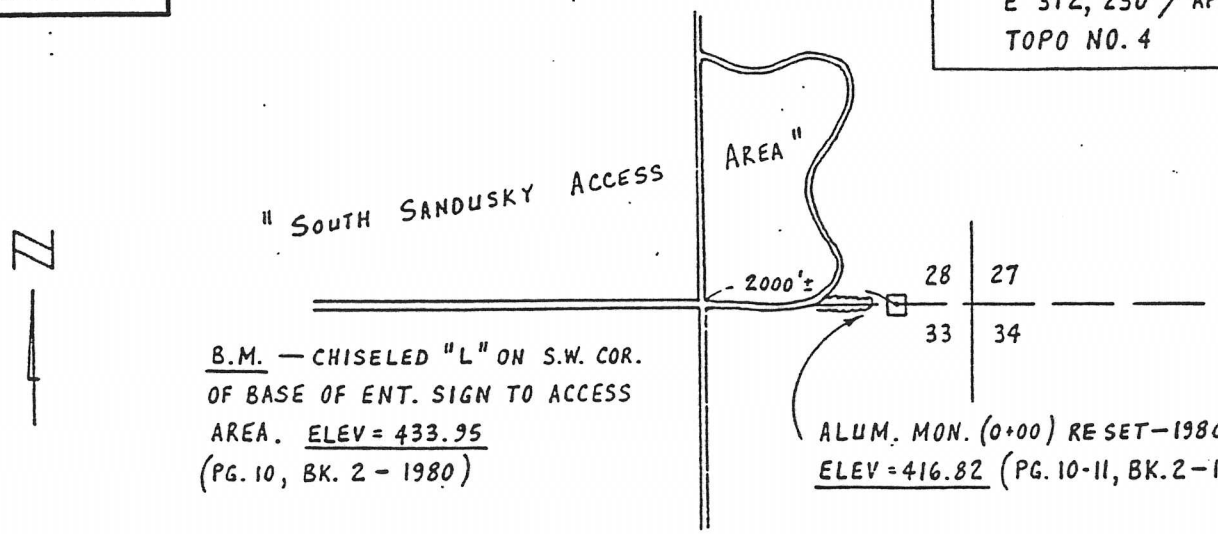
LAYOUT – PG. 9, BK. "C" – 1970
PG. 11, BK. "B" – 1970

COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 3 OF 23	COMPUTED BY W&M	DATE 12-22-80
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

RANGE 3-A

N 505,330 / E 312,230 — 0+00 APPR.
TOPO NO. 4

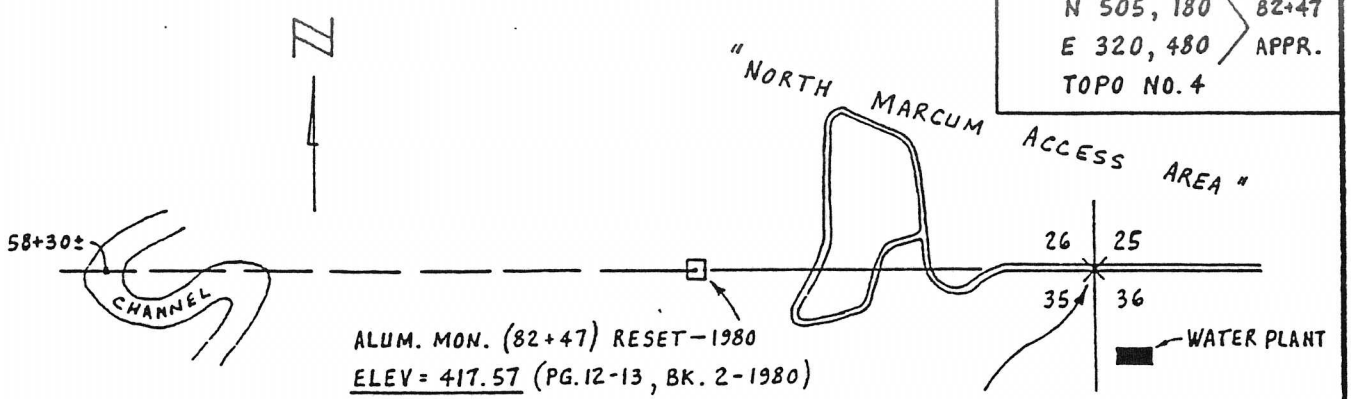


B.M. — CHISELED "L" ON S.W. COR. OF BASE OF ENT. SIGN TO ACCESS AREA. ELEV = 433.95 (PG. 10, BK. 2 - 1980)

ALUM. MON. (0+00) RESET-1980 ELEV = 416.82 (PG. 10-11, BK. 2-1980)

LAYOUT — PG. 11, BK. "C" - 1970
PG. 16, BK. "B" - 1970

N 505,180 / E 320,480 — 82+47 APPR.
TOPO NO. 4



ALUM. MON. (82+47) RESET-1980 ELEV = 417.57 (PG. 12-13, BK. 2-1980)

B.M. — R.R. SPIKE IN N. SIDE OF P.P. ELEV. = 426.53 (PG. 16, BK. "A" - 1970)

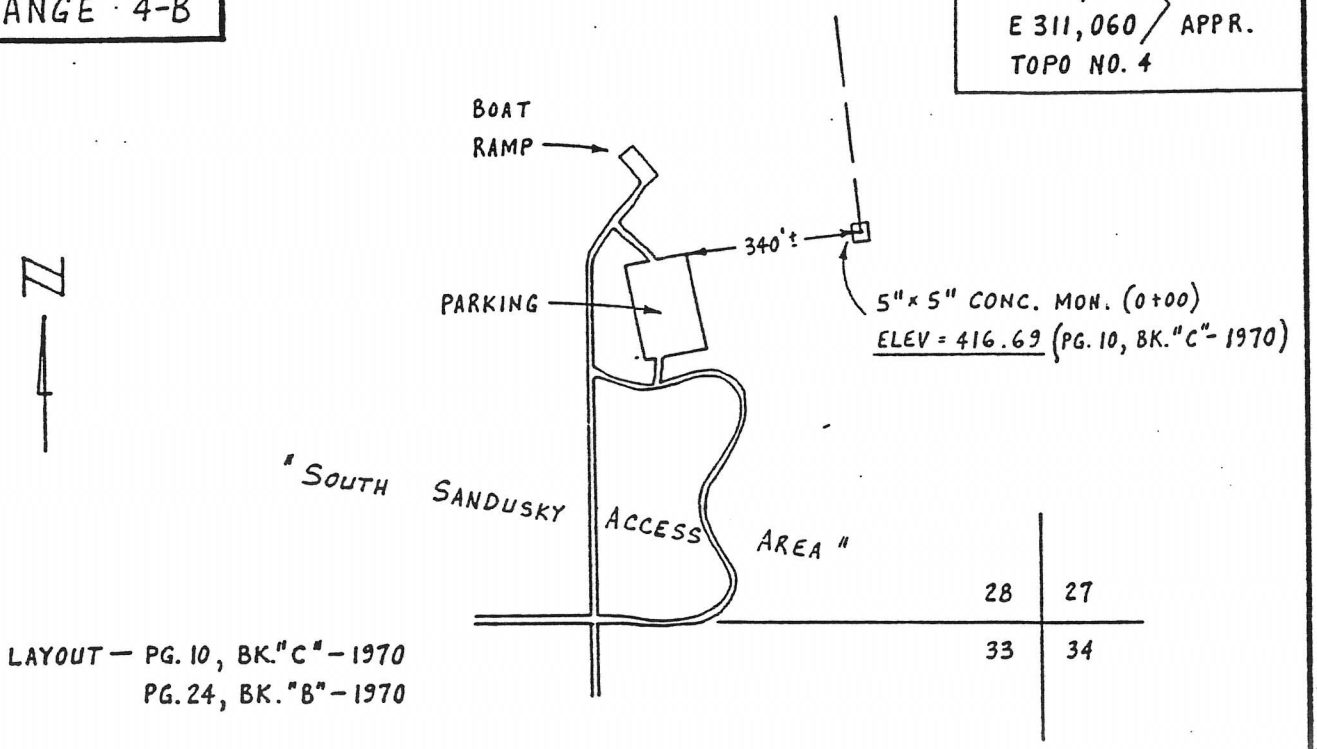
LAYOUT — PG. 13, BK. "C" - 1970
PG. 16, BK. "B" - 1970

COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 4 OF 23	COMPUTED BY WJM	DATE 12-23-80
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

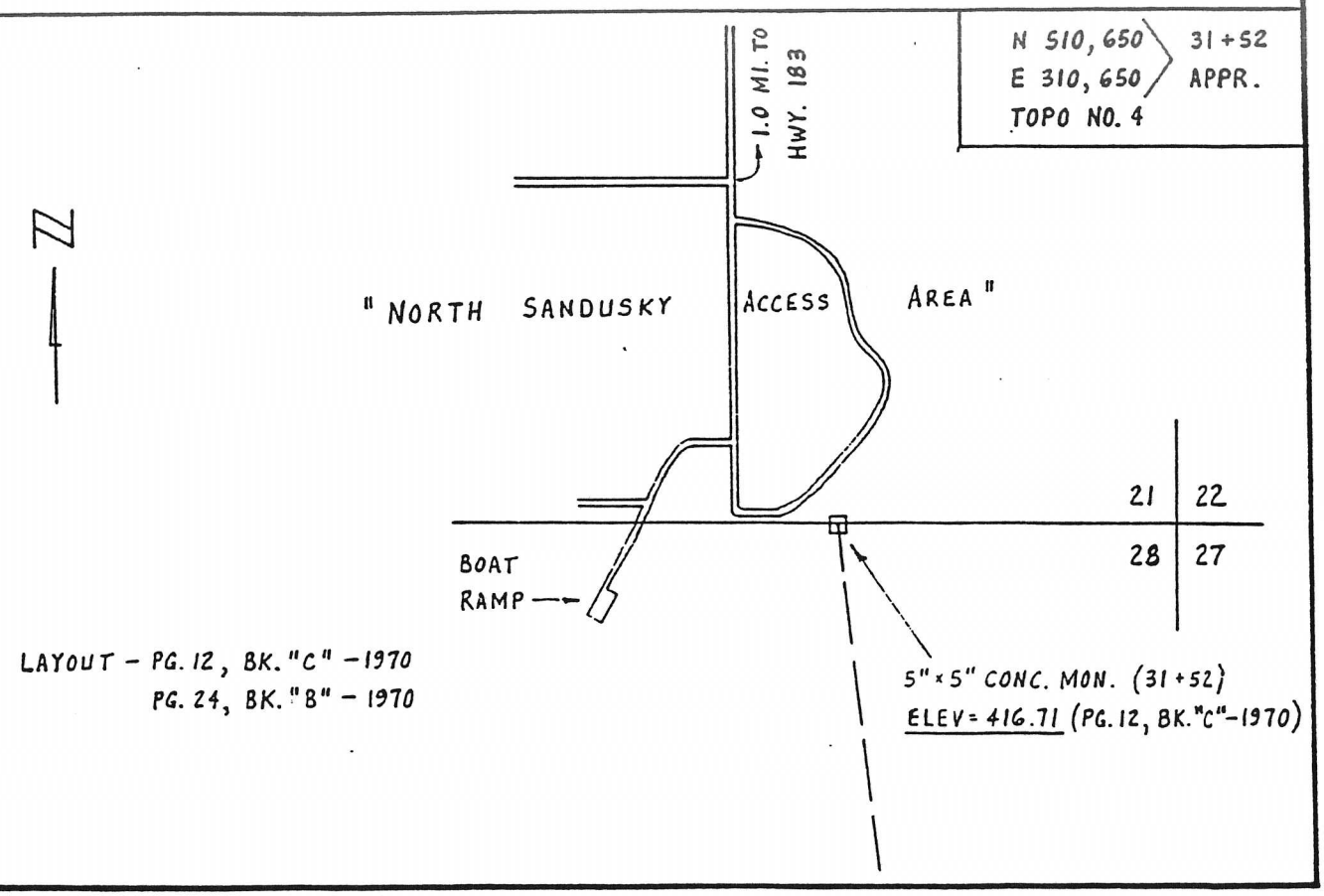
RANGE 4-B

N 507,520 / E 311,060 — 0+00 APPR. TOPO NO. 4



LAYOUT — PG. 10, BK."C"-1970
PG. 24, BK."B"-1970

N 510,650 / E 310,650 — 31+52 APPR. TOPO NO. 4



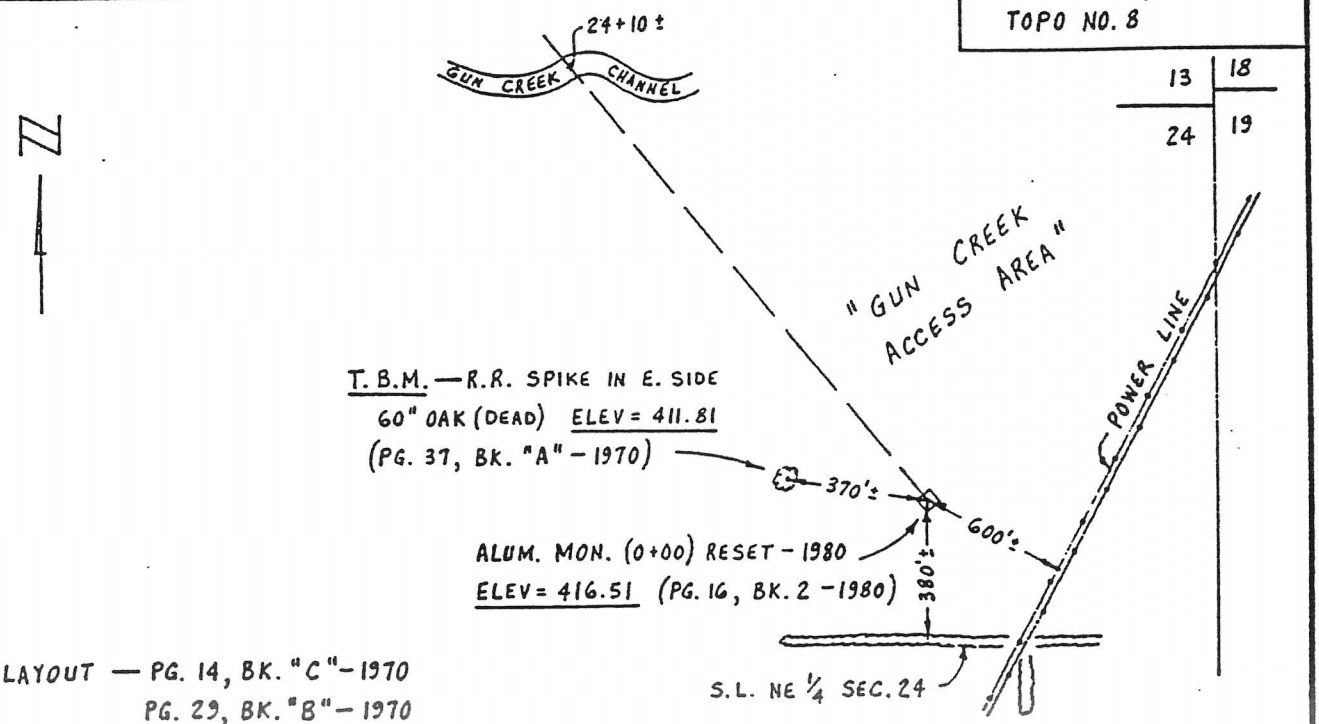
LAYOUT - PG. 12, BK."C"-1970
PG. 24, BK."B"-1970

COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 5 OF 23	COMPUTED BY W&M	DATE 12-23-80
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

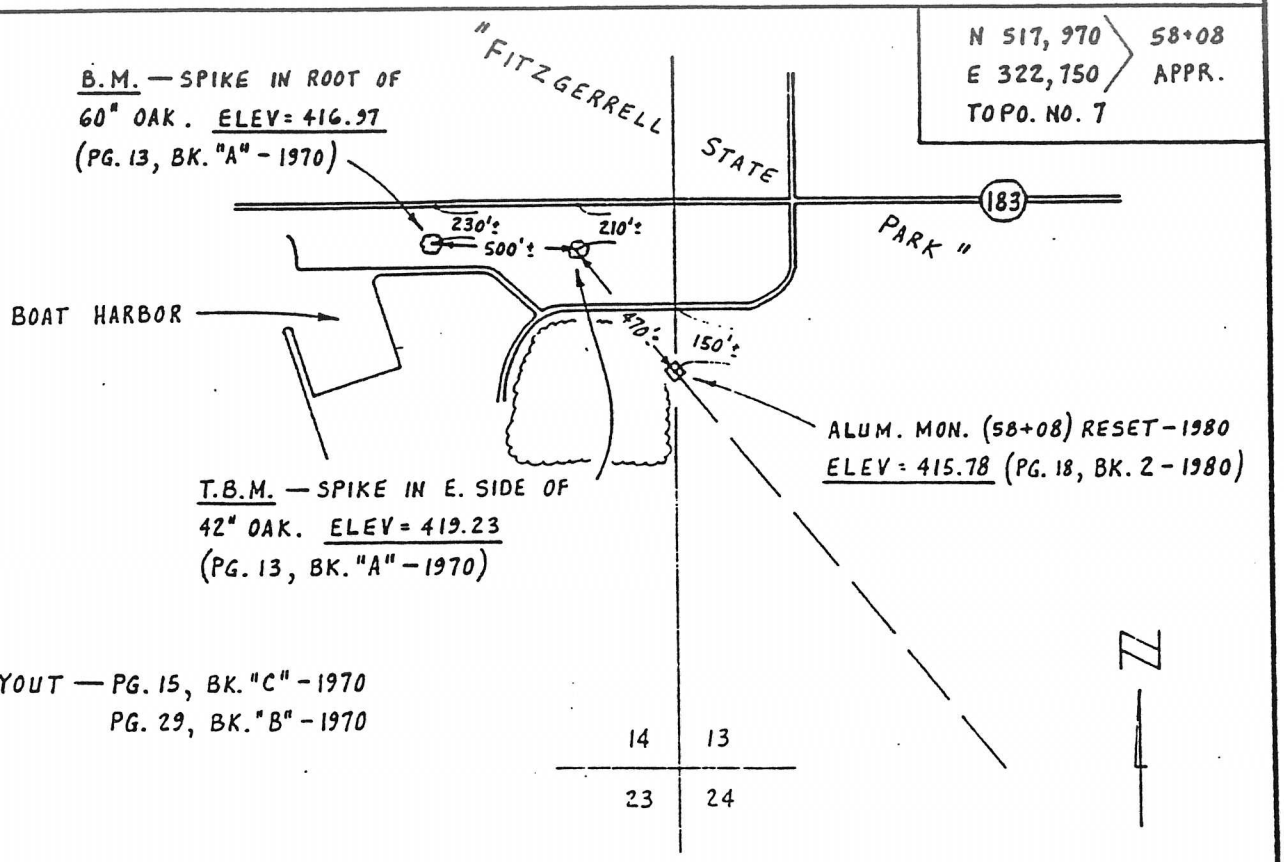
RANGE 5-AB

N 513,480 / E 326,430 / TOPO NO. 8 — 0+00 APPR.



LAYOUT — PG. 14, BK. "C" - 1970
PG. 29, BK. "B" - 1970

N 517,970 / E 322,750 / TOPO. NO. 7 — 58+08 APPR.



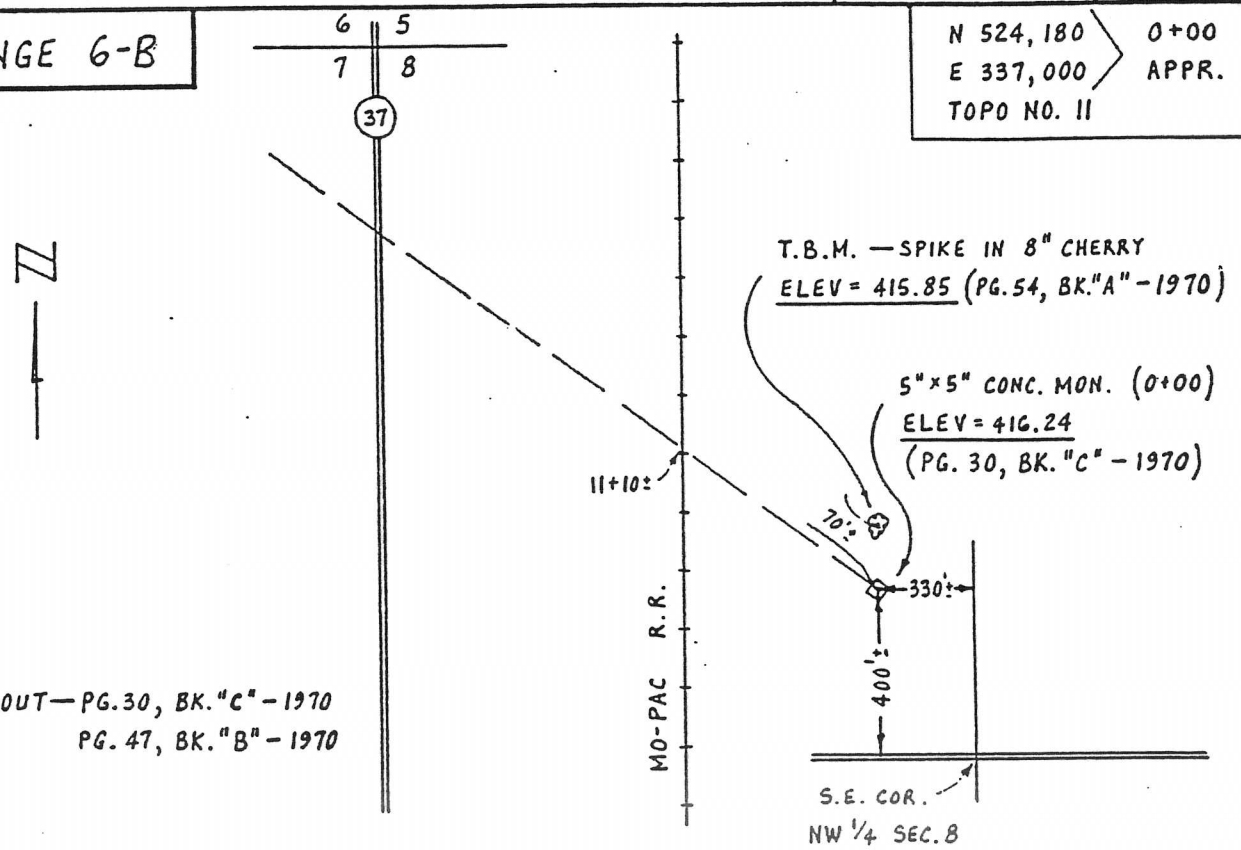
LAYOUT — PG. 15, BK. "C" - 1970
PG. 29, BK. "B" - 1970

COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 6 OF 23	COMPUTED BY WJM	DATE 12-30-80
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

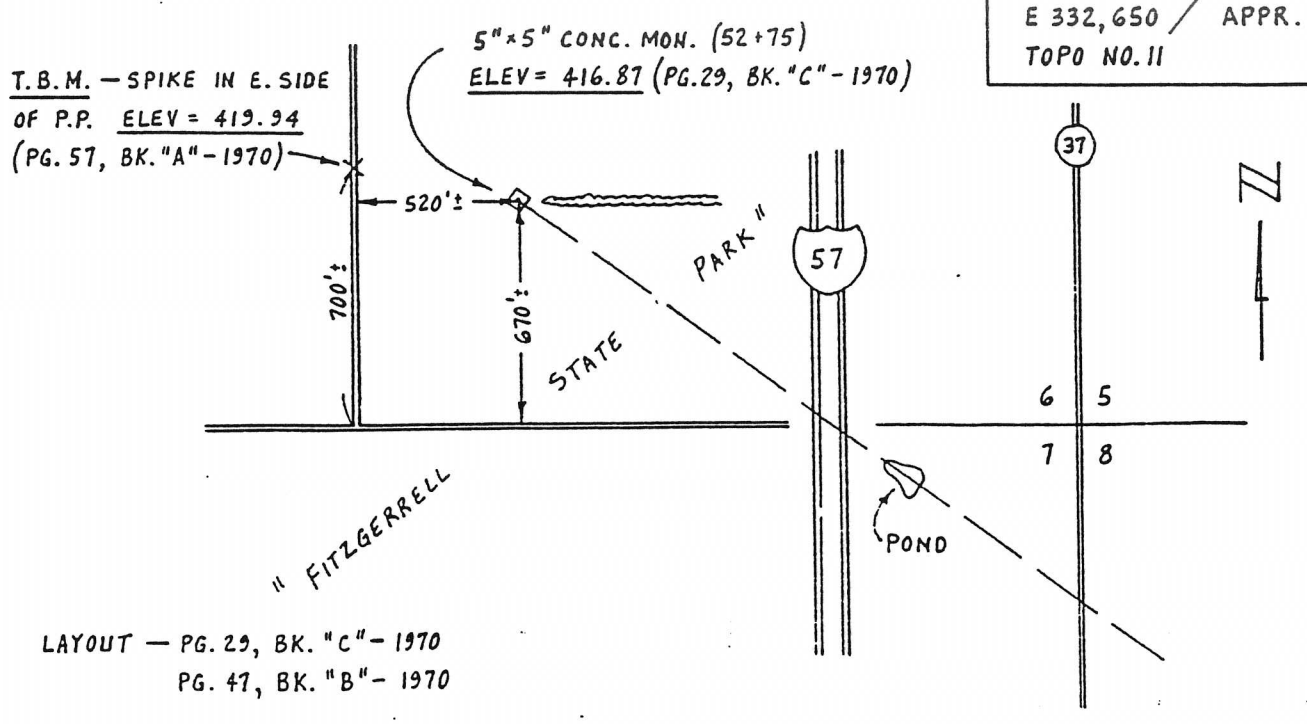
RANGE 6-B

N 524,180
E 337,000
TOPO NO. 11
0+00 APPR.



LAYOUT — PG. 30, BK."C" - 1970
PG. 47, BK."B" - 1970

N 527,170
E 332,650
TOPO NO. 11
52+75 APPR.



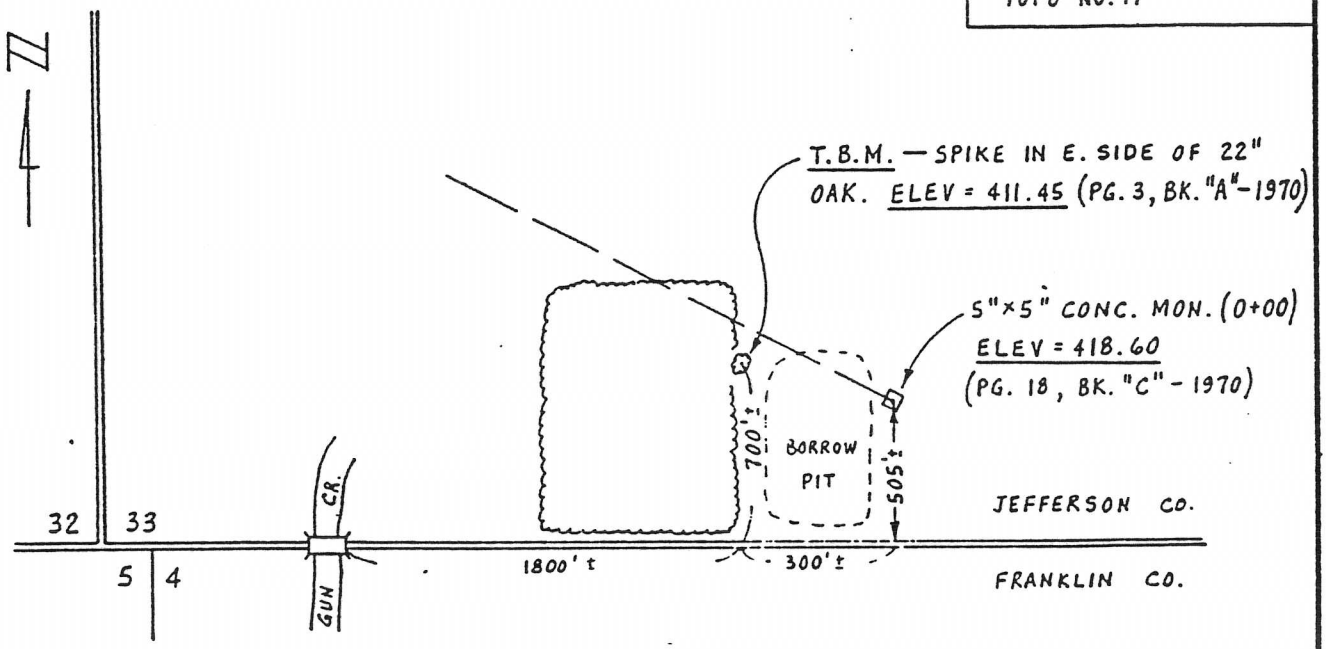
LAYOUT — PG. 29, BK."C" - 1970
PG. 47, BK."B" - 1970

COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 7 OF 23	COMPUTED BY W&M	DATE 1-02-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

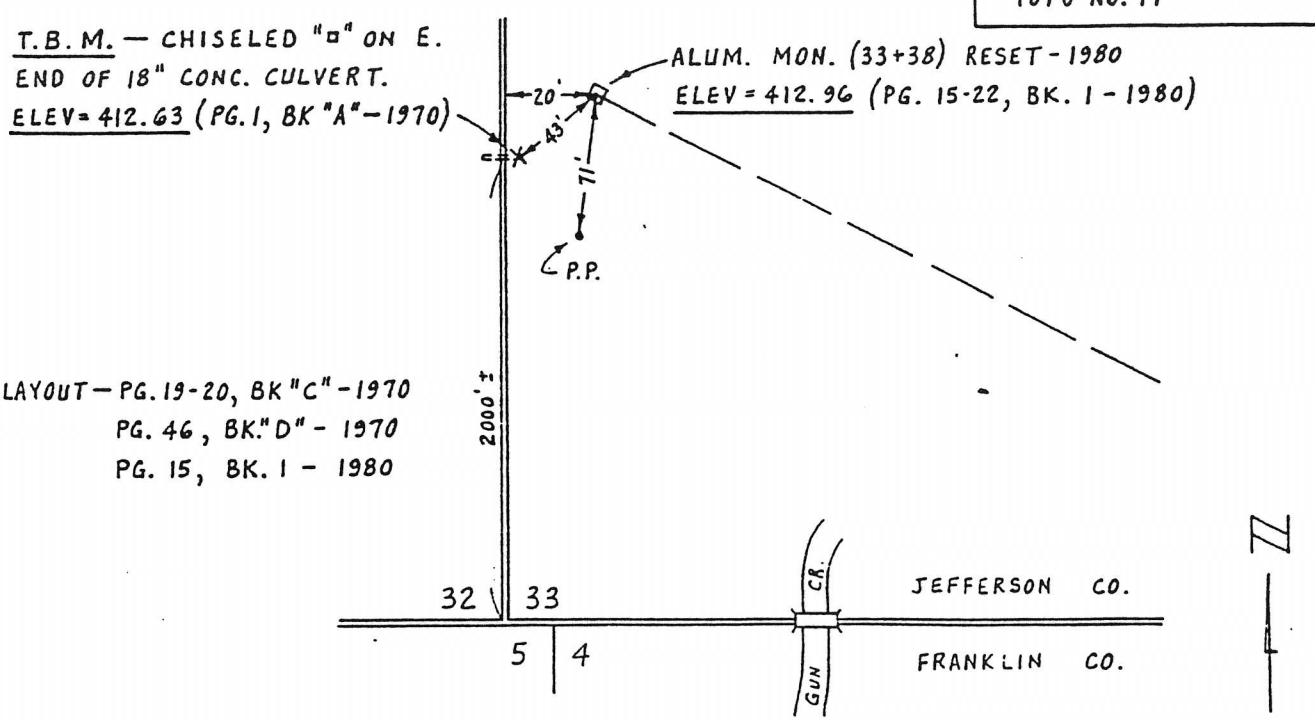
RANGE 7-B

N 532,380
E 342,850
TOPO NO. 17
0+00 APPR.



LAYOUT — PG. 18, BK. "C" - 1970
PG. 46, BK. "D" - 1970

N 533,870
E 339,860
TOPO NO. 17
33+38 APPR.



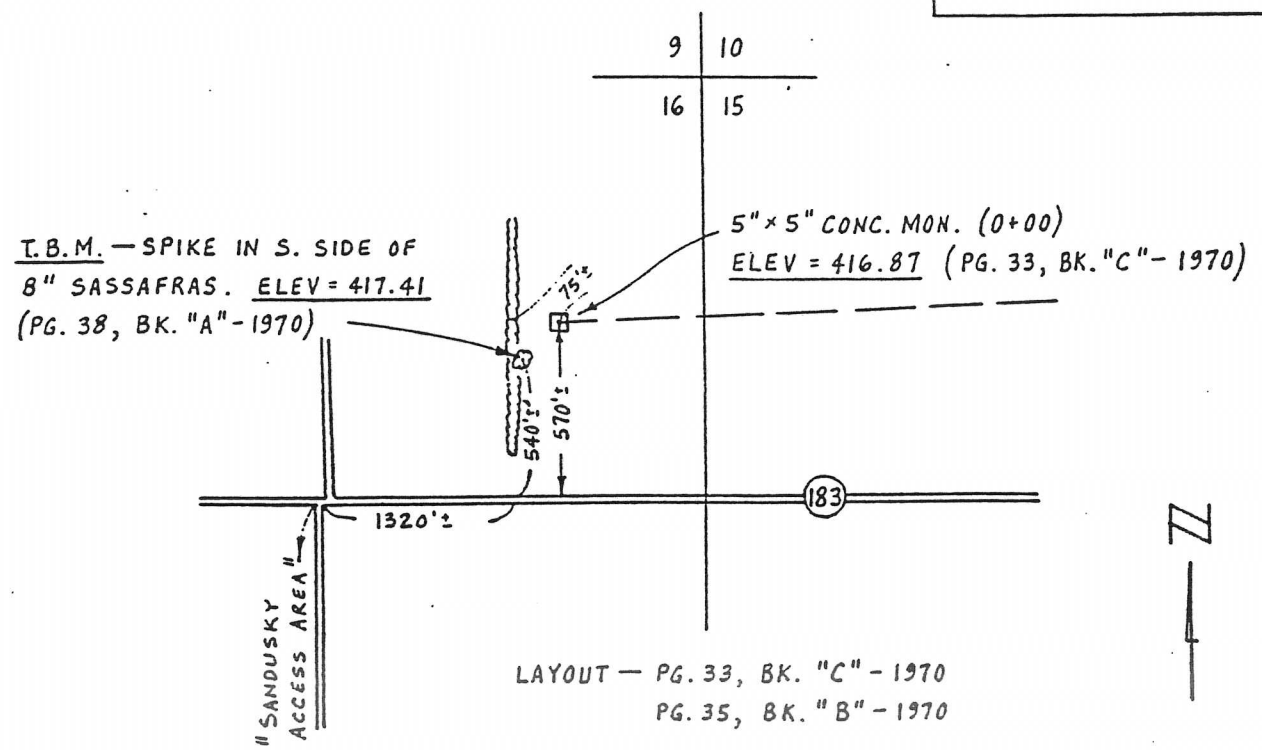
LAYOUT — PG. 19-20, BK "C" - 1970
PG. 46, BK. "D" - 1970
PG. 15, BK. 1 - 1980

COMPUTATION SHEET

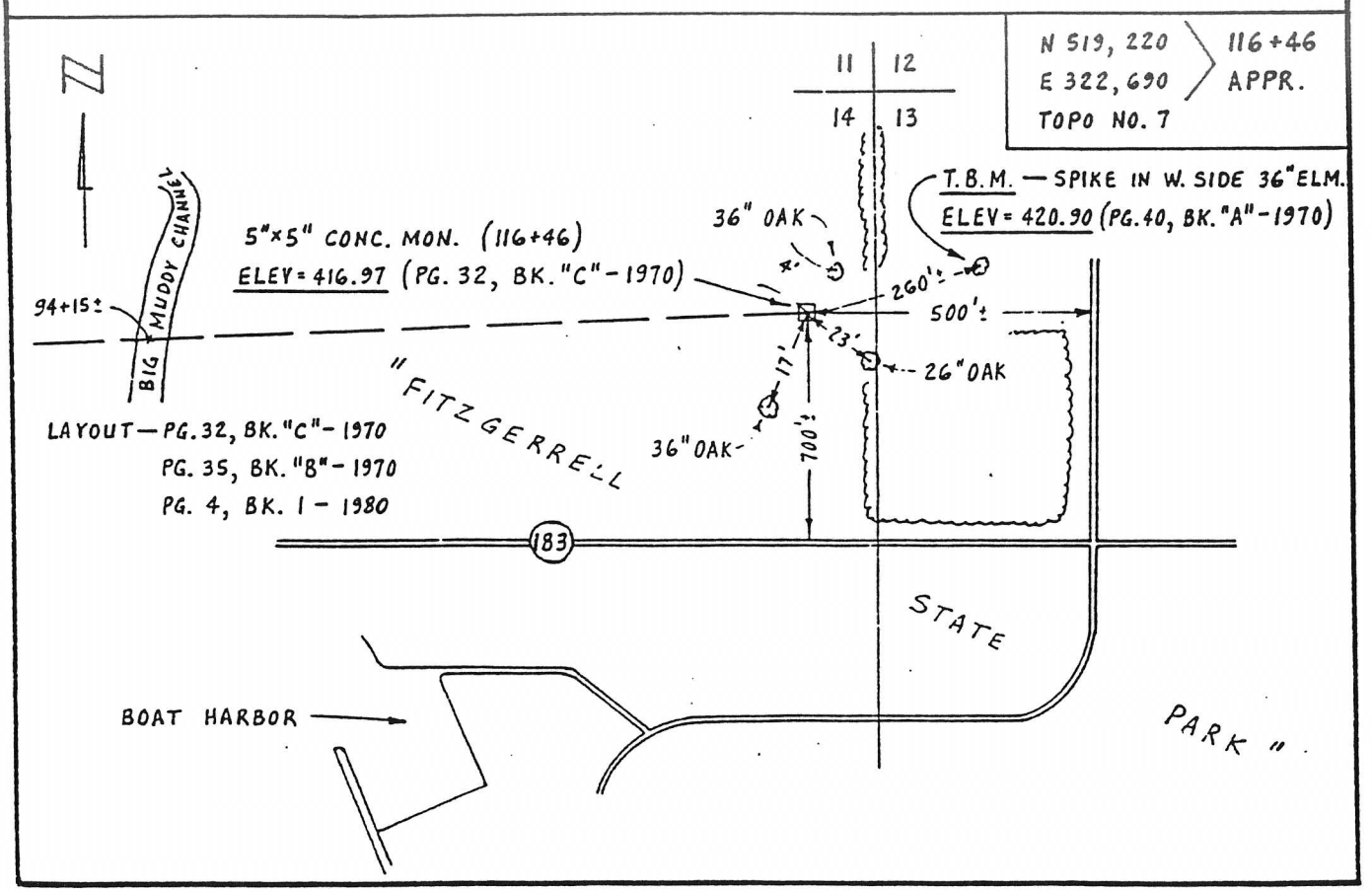
PROJECT	REND LAKE	PAGE 8 OF 23	COMPUTED BY WJM	DATE 1-02-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

RANGE 8-AB

N 519380
E 311040
TOPO NO.7
0+00 APPR.



N 519,220
E 322,690
TOPO NO. 7
116+46 APPR.



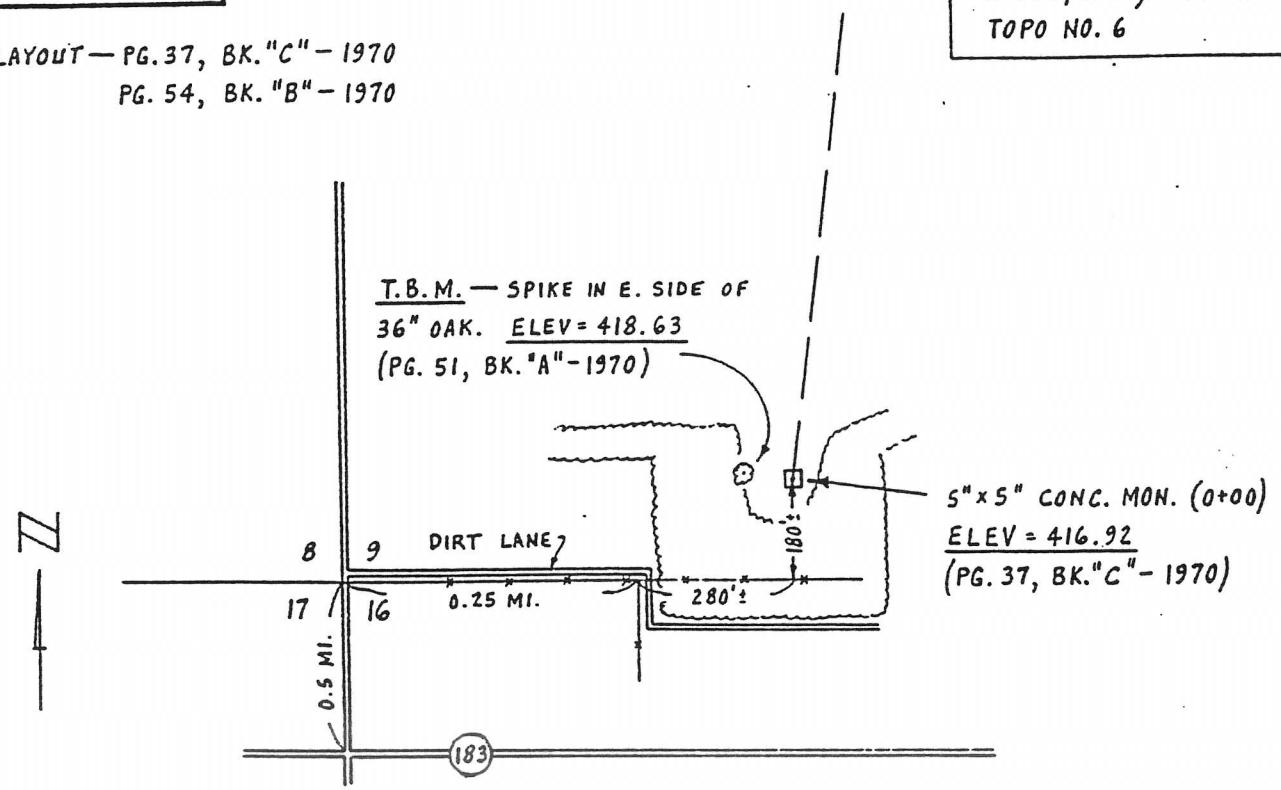
COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 9 OF 23	COMPUTED BY WSM	DATE 1-05-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

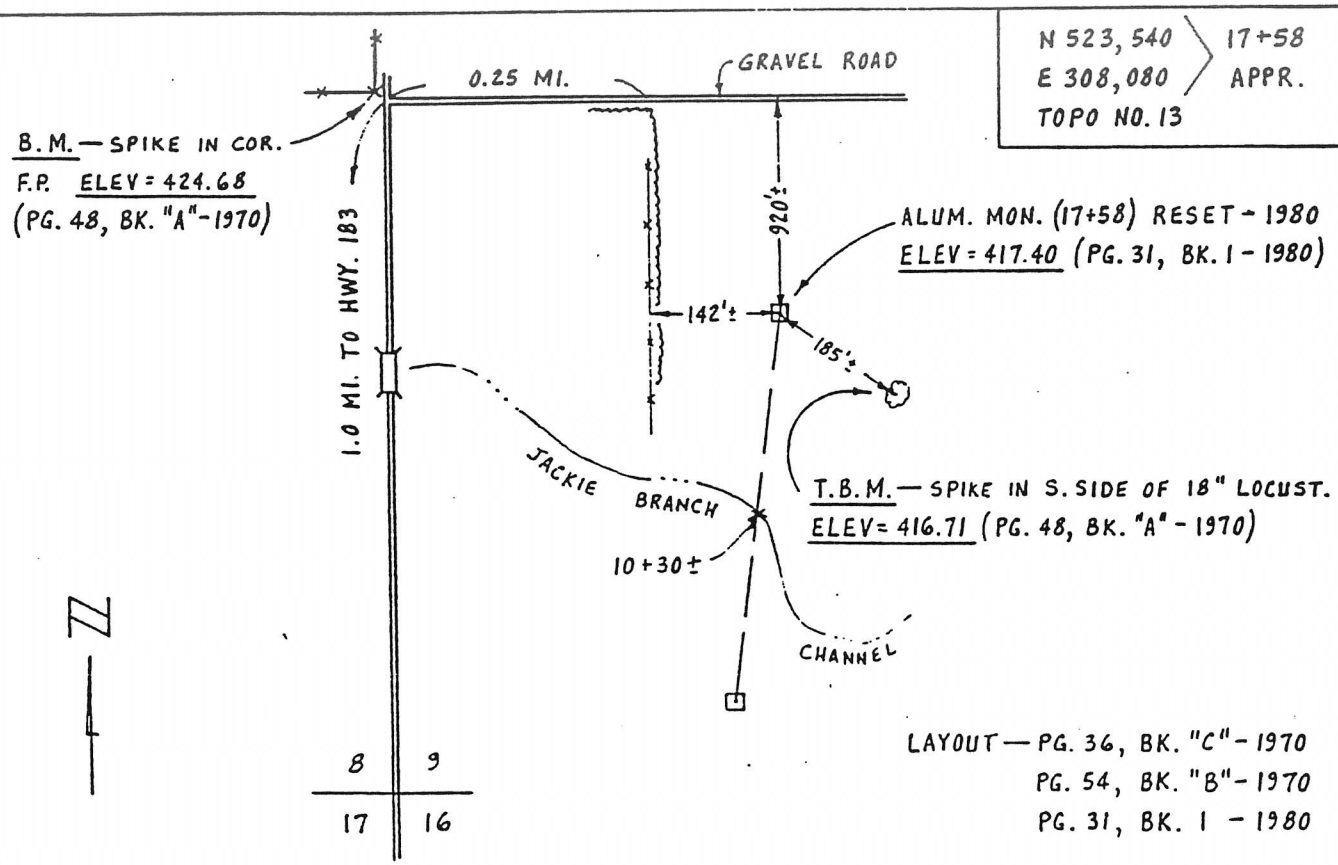
RANGE 9-B

N 521,790
E 307,880
TOPO NO. 6
0+00 APPR.

LAYOUT — PG. 37, BK. "C" – 1970
PG. 54, BK. "B" – 1970



N 523,540
E 308,080
TOPO NO. 13
17+58 APPR.



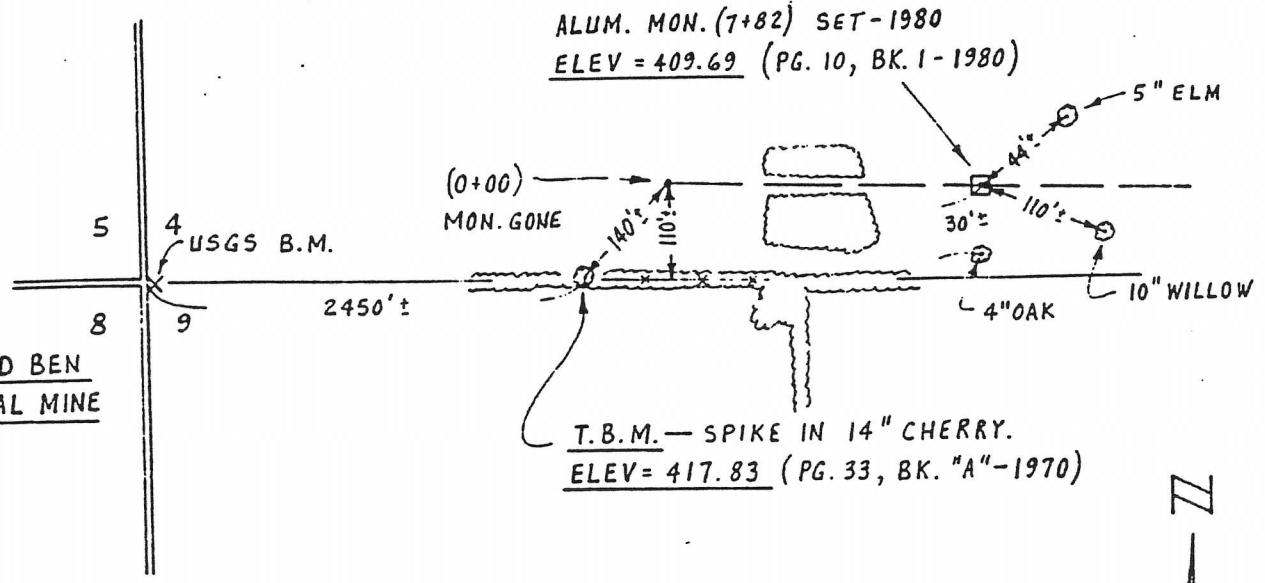
LAYOUT — PG. 36, BK. "C" – 1970
PG. 54, BK. "B" – 1970
PG. 31, BK. 1 – 1980

COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 10 OF 23	COMPUTED BY WDM	DATE 1-06-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

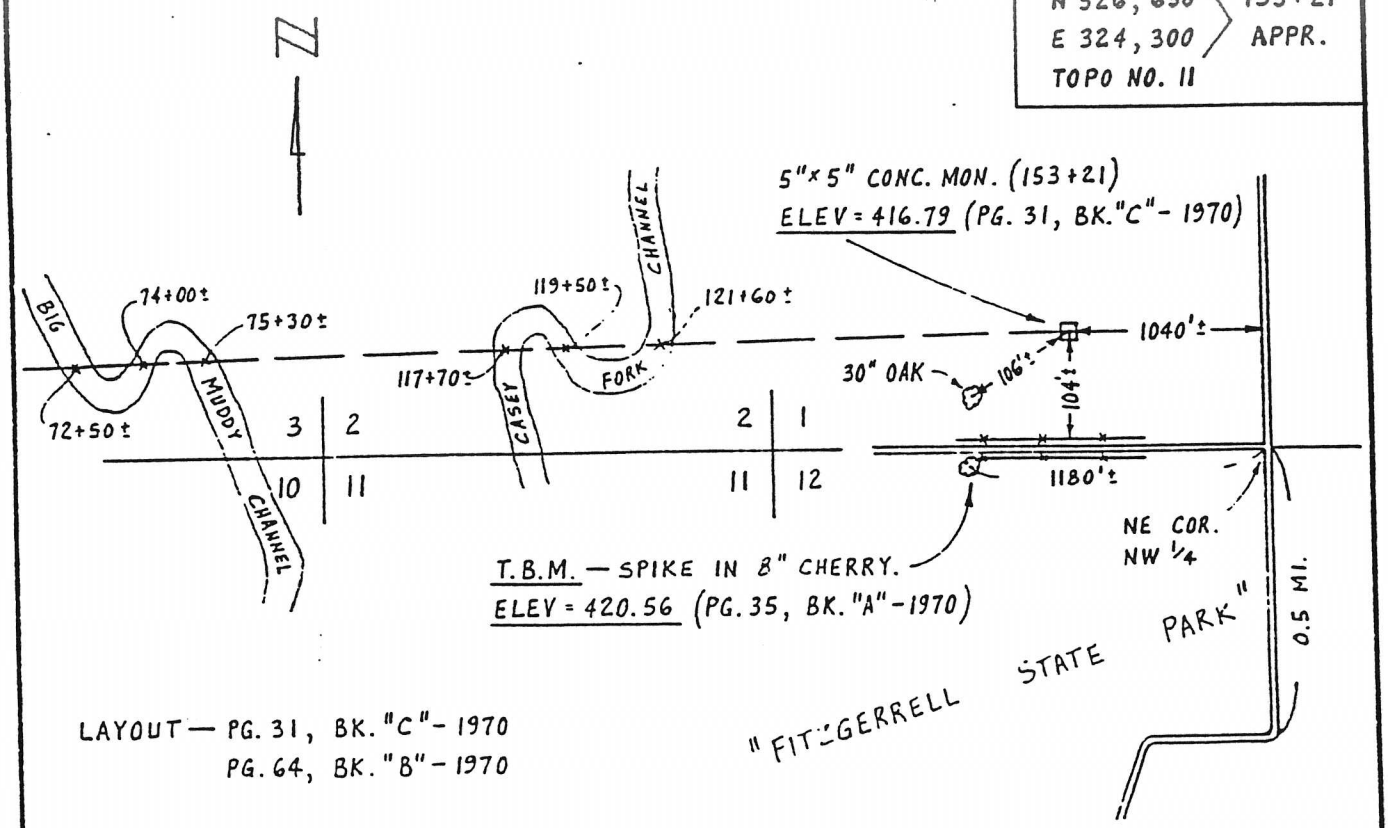
RANGE 10-A

N 527,050
E 309,760
TOPO NO 13
7+82 APPR.



LAYOUT — PG. 35, BK. "C"-1970
PG. 64, BK. "B"-1970
PG. 10, BK. 1 - 1980

N 526,650
E 324,300
TOPO NO. 11
153+21 APPR.



LAYOUT — PG. 31, BK."C"-1970
PG. 64, BK."B"-1970

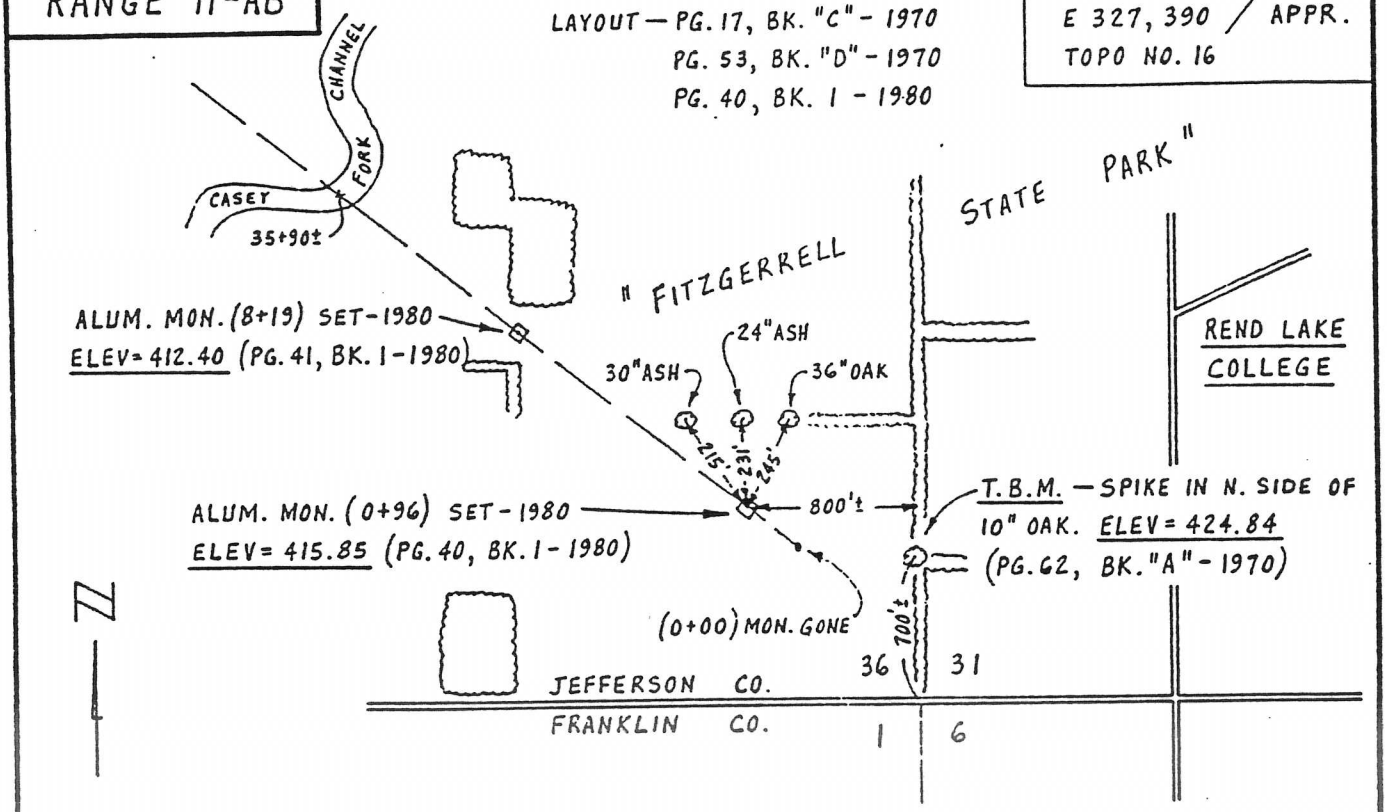
COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 11 OF 23	COMPUTED BY WJM	DATE 1-07-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

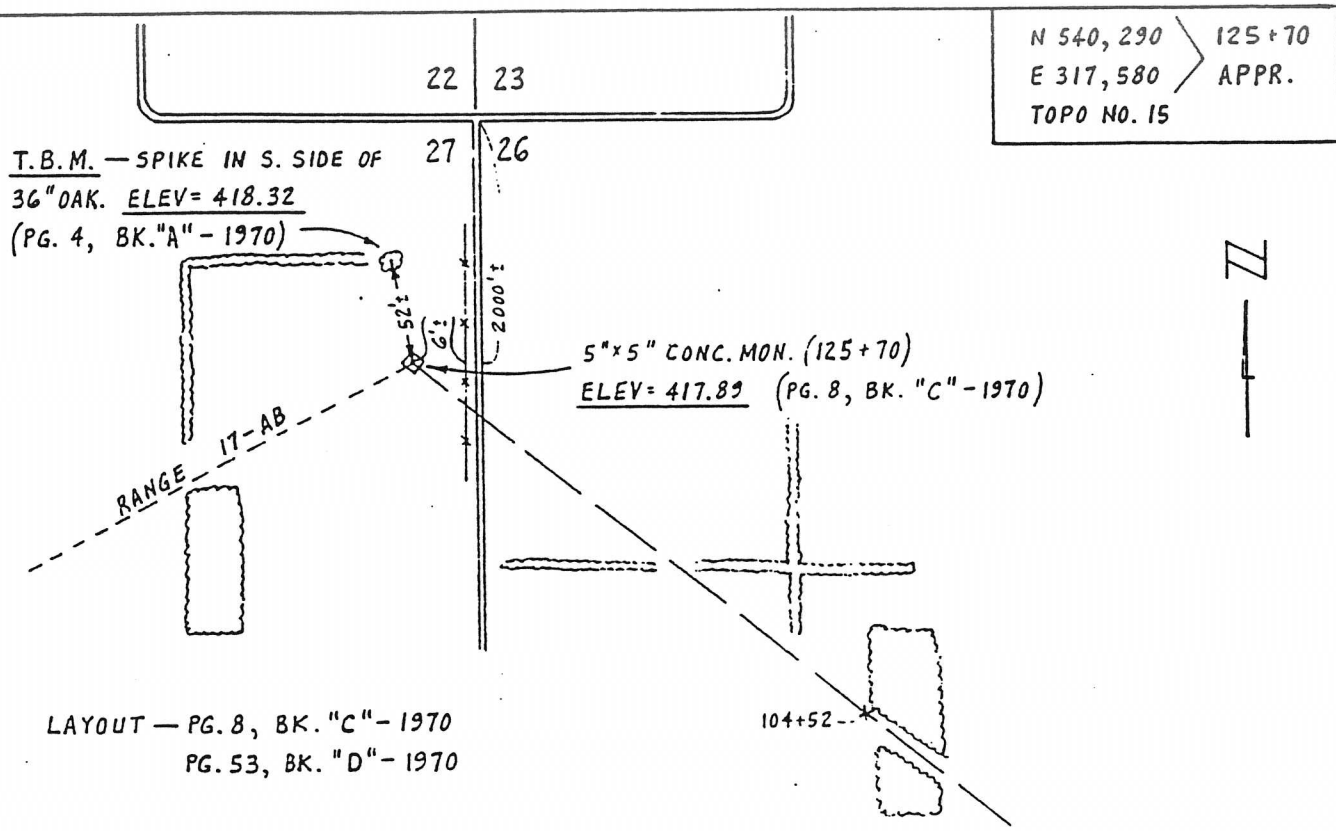
RANGE 11-AB

N 532,600 / E 327,390 / TOPO NO. 16 — 0+96 APPR.

LAYOUT — PG. 17, BK. "C" - 1970
PG. 53, BK. "D" - 1970
PG. 40, BK. 1 - 1980



N 540,290 / E 317,580 / TOPO NO. 15 — 125+70 APPR.



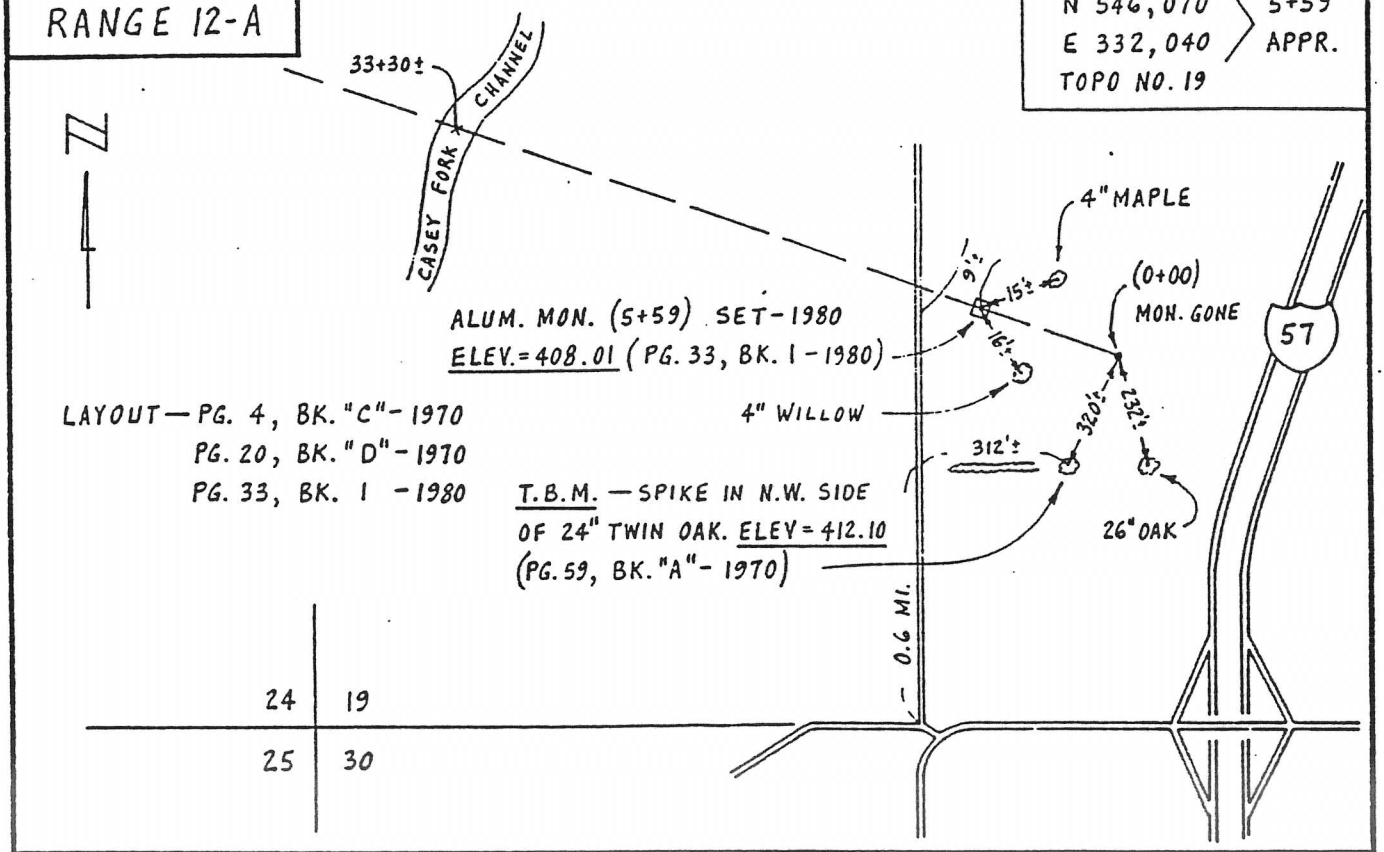
LAYOUT — PG. 8, BK. "C" - 1970
PG. 53, BK. "D" - 1970

COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 12 OF 23	COMPUTED BY WJM	DATE 1-08-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

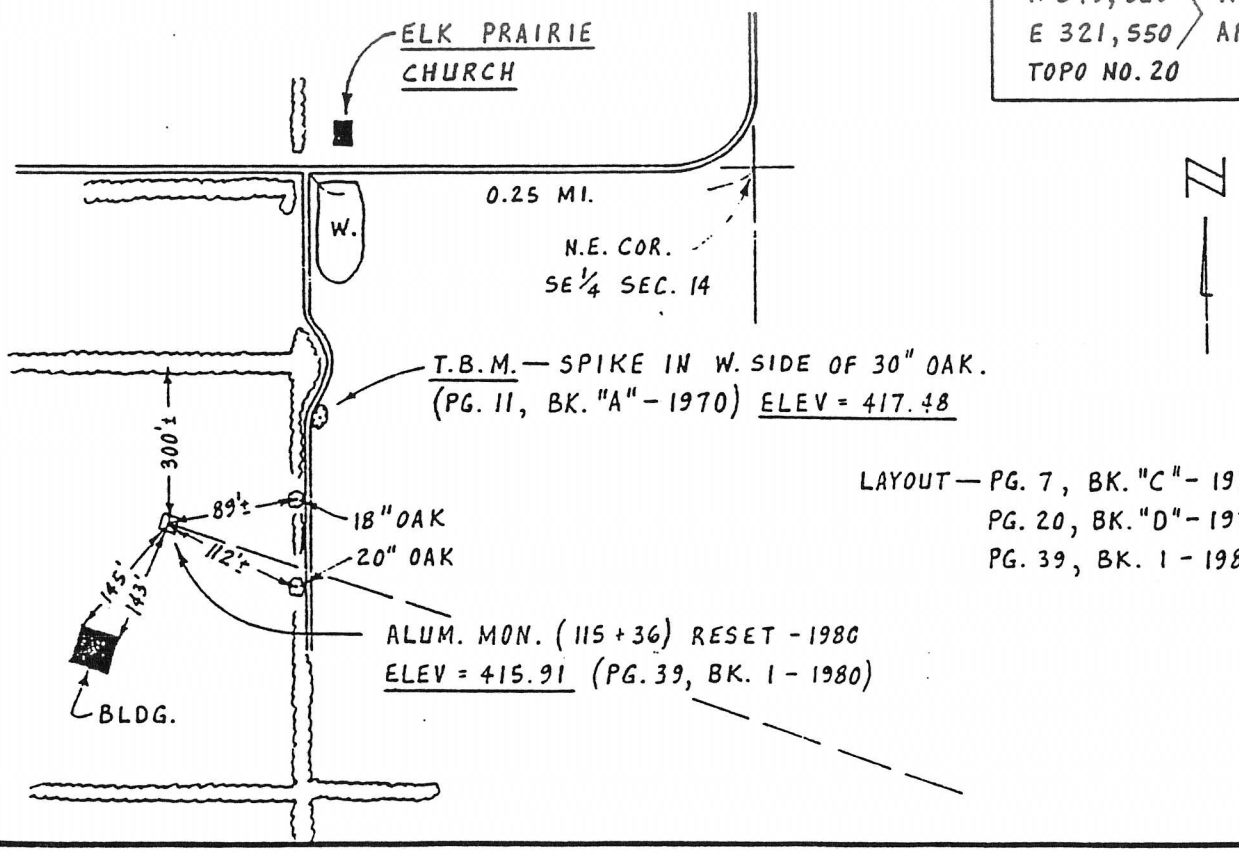
RANGE 12-A

N 546,070
E 332,040
TOPO NO. 19
5+59 APPR.



LAYOUT — PG. 4, BK. "C"-1970
PG. 20, BK. "D"-1970
PG. 33, BK. 1 -1980

N 549,320
E 321,550
TOPO NO. 20
115+36 APPR.



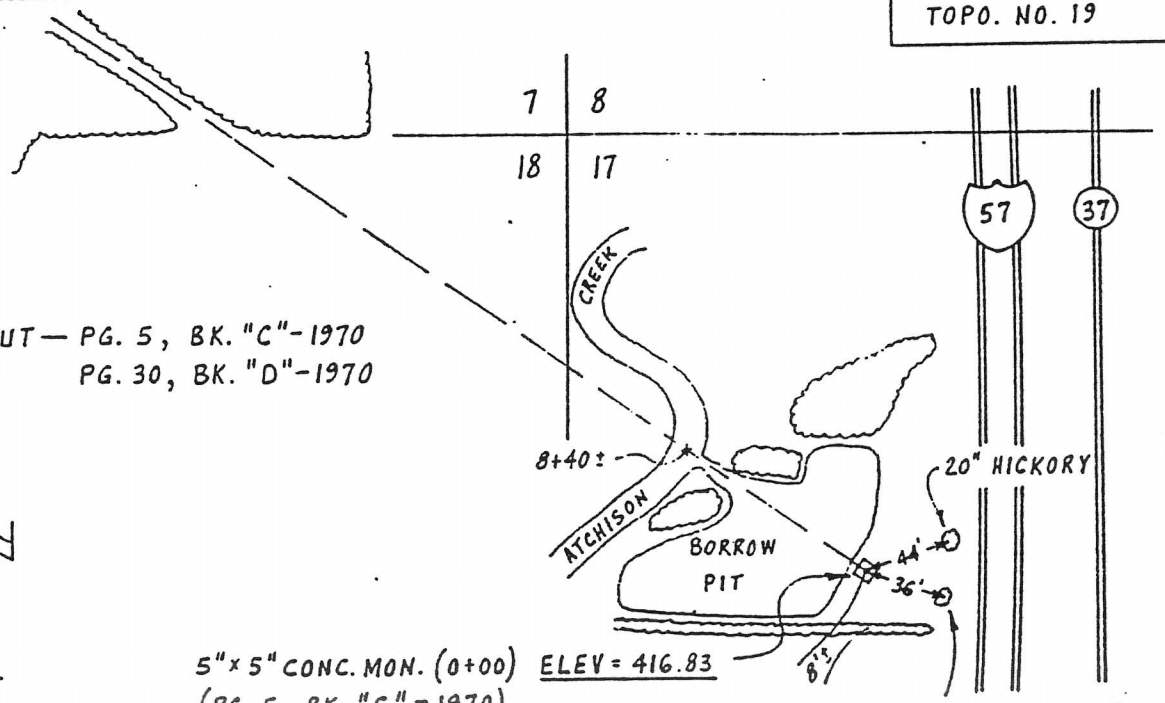
LAYOUT — PG. 7, BK. "C"-1970
PG. 20, BK. "D"-1970
PG. 39, BK. 1-1980

COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 13 OF 23	COMPUTED BY WSM	DATE 1-08-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

RANGE 13-B

N 551,670 / E 335,670 — 0+00 APPR.
TOPO. NO. 19

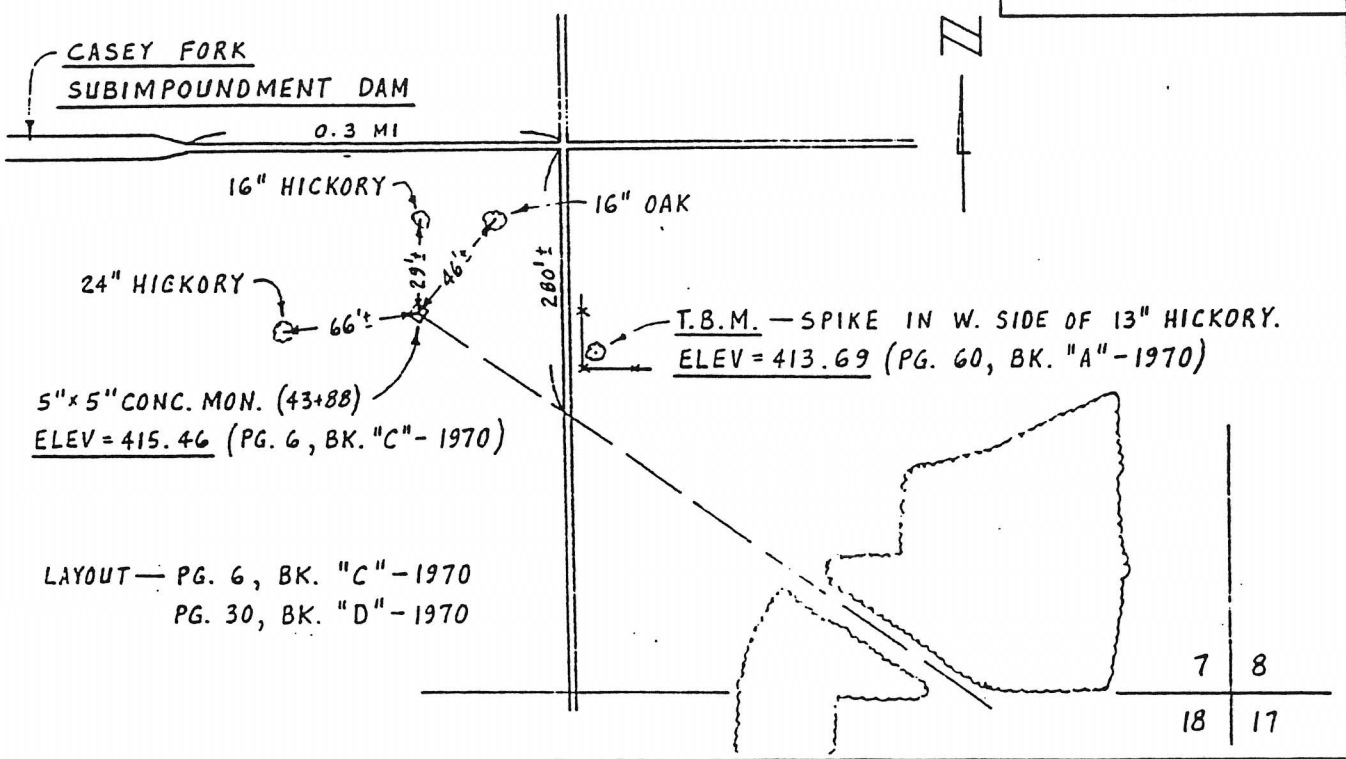


LAYOUT — PG. 5, BK. "C"-1970
PG. 30, BK. "D"-1970

5"x5" CONC. MON. (0+00) ELEV = 416.83
(PG. 5, BK. "C"-1970)

T.B.M. — SPIKE IN W. SIDE OF 14" HICKORY.
ELEV = 417.77 (PG. 61, BK. "A"-1970)

N 554,110 / E 332,020 — 43+88 APPR.
TOPO NO. 27



T.B.M. — SPIKE IN W. SIDE OF 13" HICKORY.
ELEV = 413.69 (PG. 60, BK. "A"-1970)

5"x5" CONC. MON. (43+88)
ELEV = 415.46 (PG. 6, BK. "C"-1970)

LAYOUT — PG. 6, BK. "C"-1970
PG. 30, BK. "D"-1970

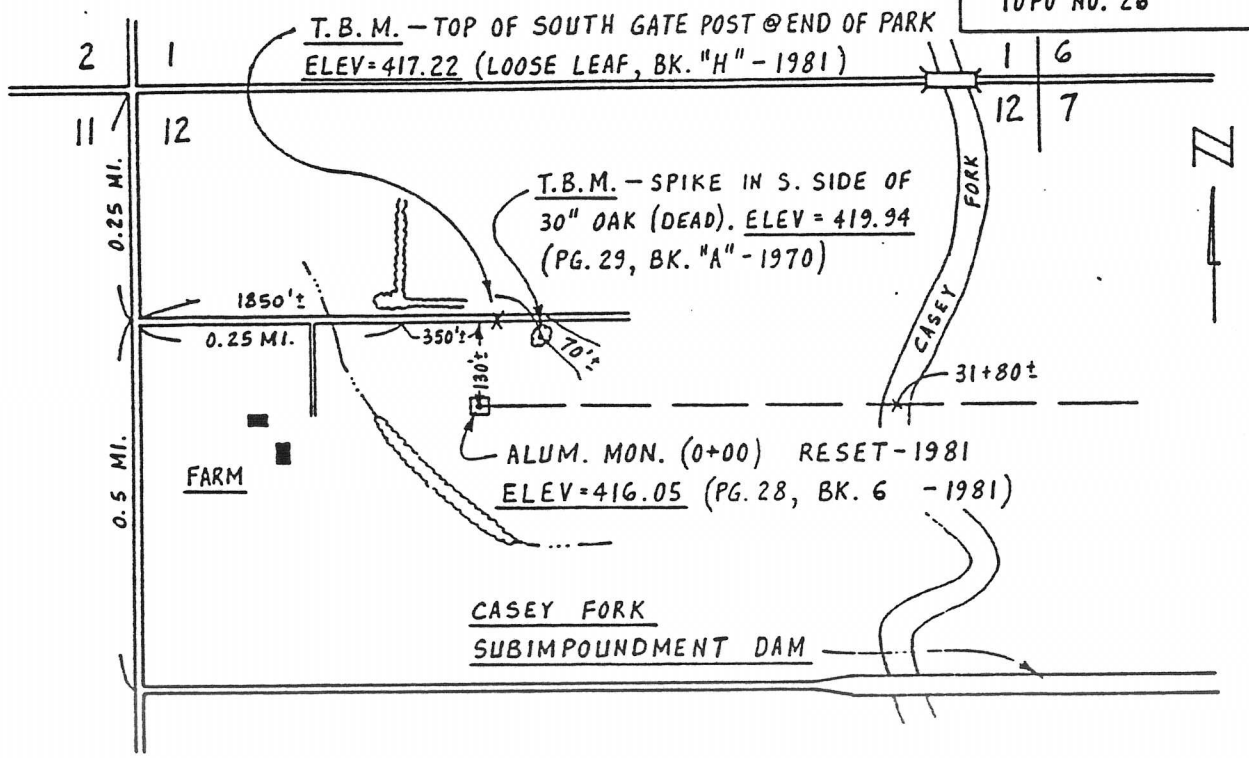
COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 14 OF 23	COMPUTED BY WJM	DATE 1-09-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

RANGE 14-A

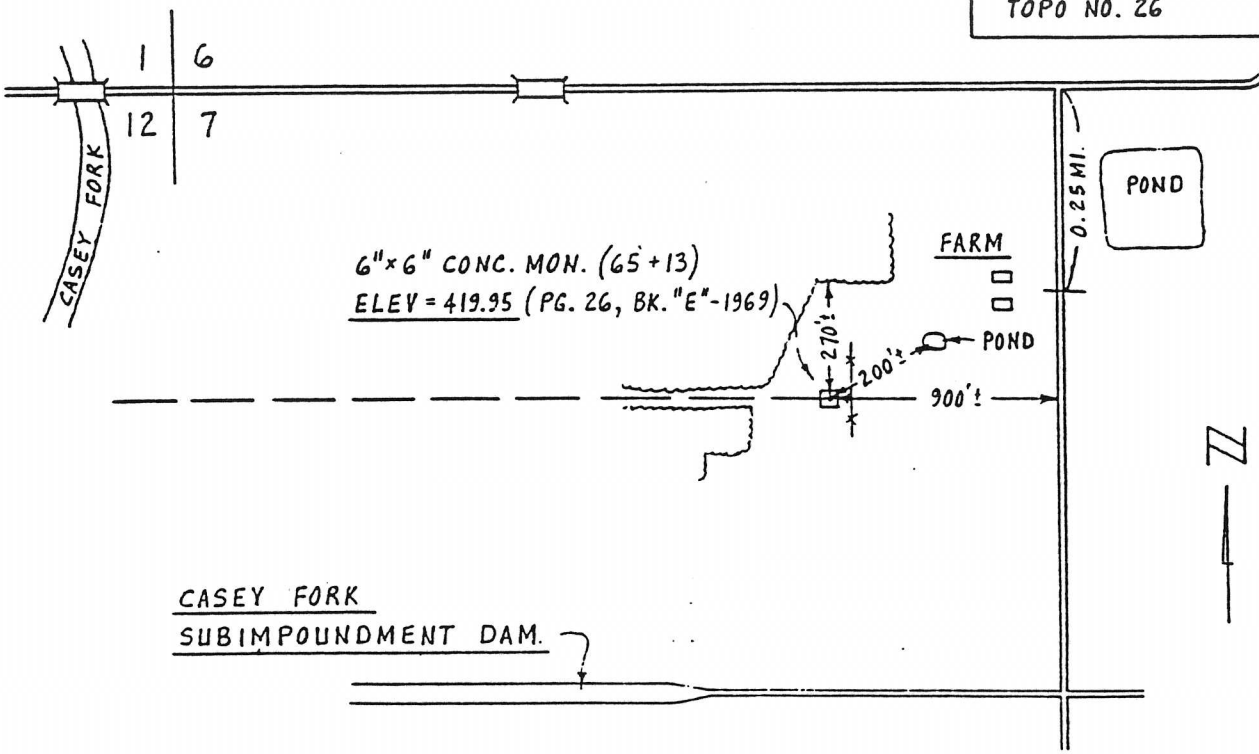
N 556,830
E 324,790
TOPO NO. 26
0+00 APPR.

LAYOUT — PG. 21, BK. "E" - 1969



N 556,810
E 331,300
TOPO NO. 26
65+13 APPR.

LAYOUT — PG. 21, BK. "E" - 1969



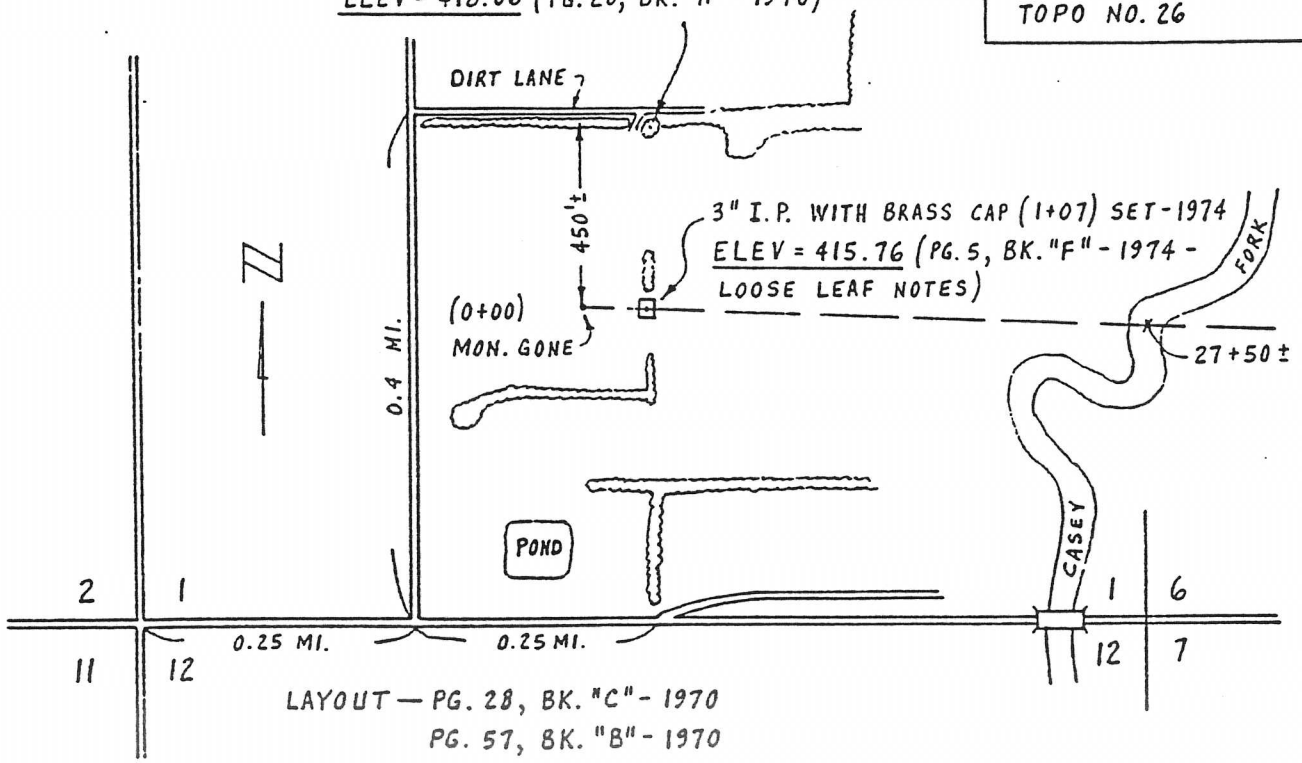
COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 15 OF 23	COMPUTED BY W&M	DATE 1-09-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

RANGE 15-A

N 559,810 / E 325,850 / TOPO NO. 26 — 1+07 APPR.

T.B.M. — SPIKE IN W. SIDE OF 14" OAK.
ELEV = 418.06 (PG. 28, BK. "A" - 1970)

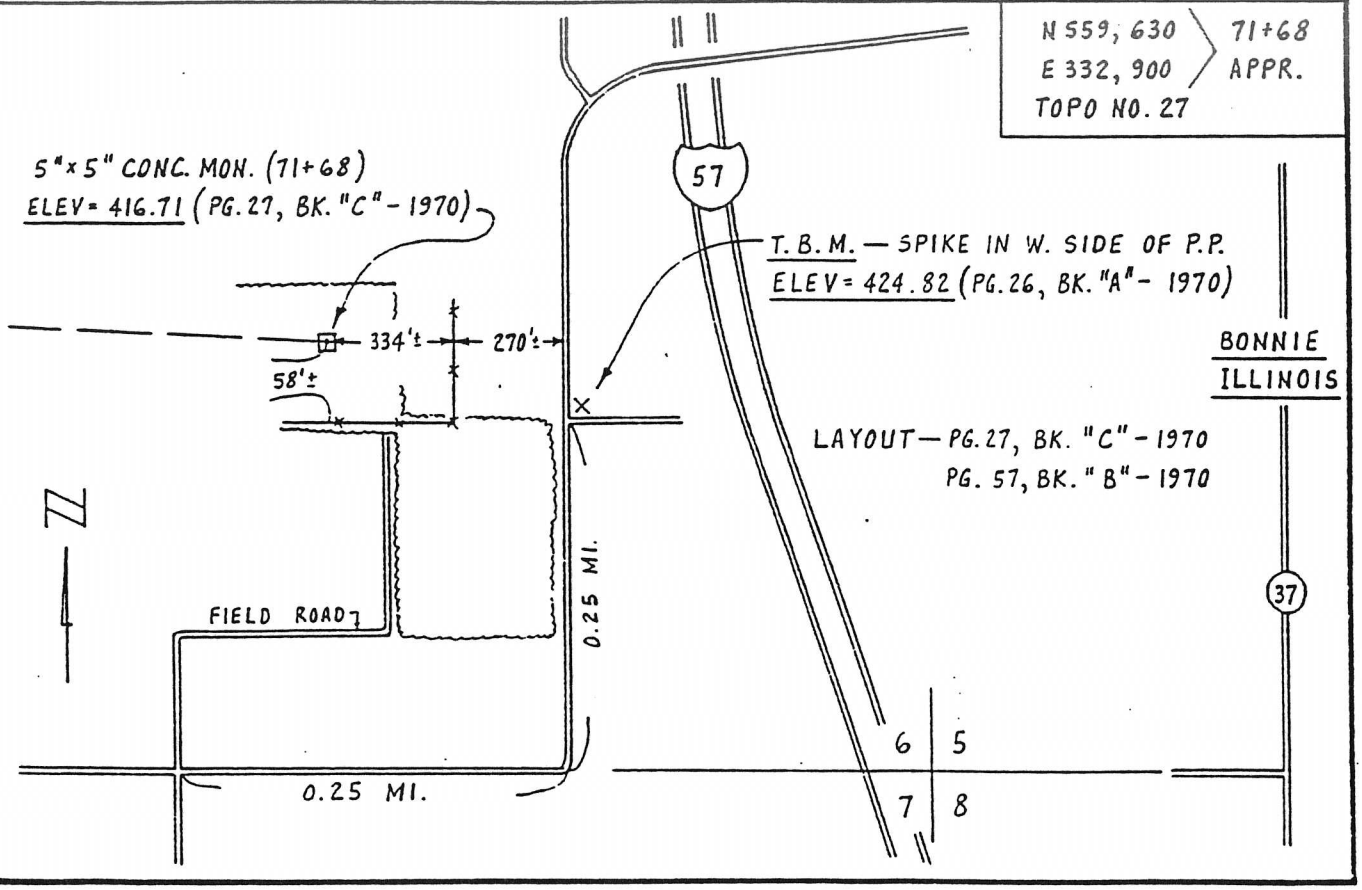


LAYOUT — PG. 28, BK. "C" - 1970
PG. 57, BK. "B" - 1970

N 559,630 / E 332,900 / TOPO NO. 27 — 71+68 APPR.

5"x5" CONC. MON. (71+68)
ELEV = 416.71 (PG. 27, BK. "C" - 1970)

T.B.M. — SPIKE IN W. SIDE OF P.P.
ELEV = 424.82 (PG. 26, BK. "A" - 1970)



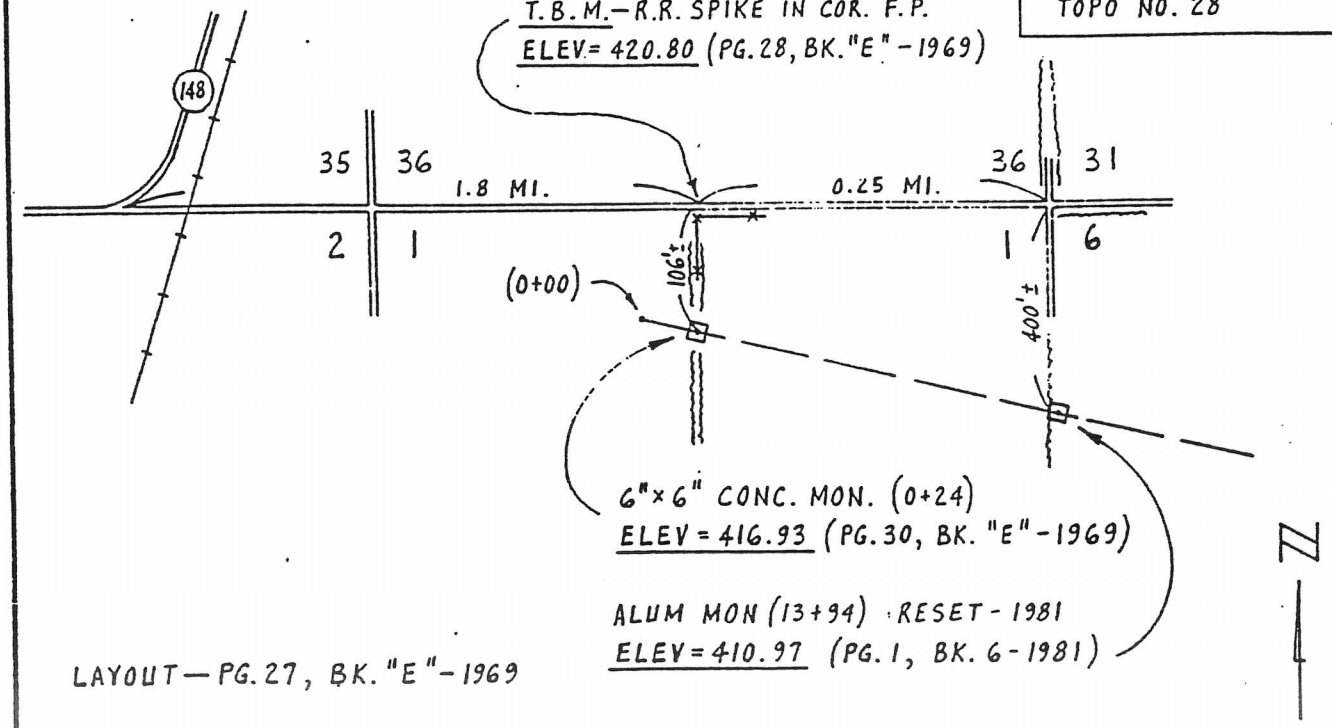
LAYOUT — PG. 27, BK. "C" - 1970
PG. 57, BK. "B" - 1970

COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 16 OF 23	COMPUTED BY WJM	DATE 1-12-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

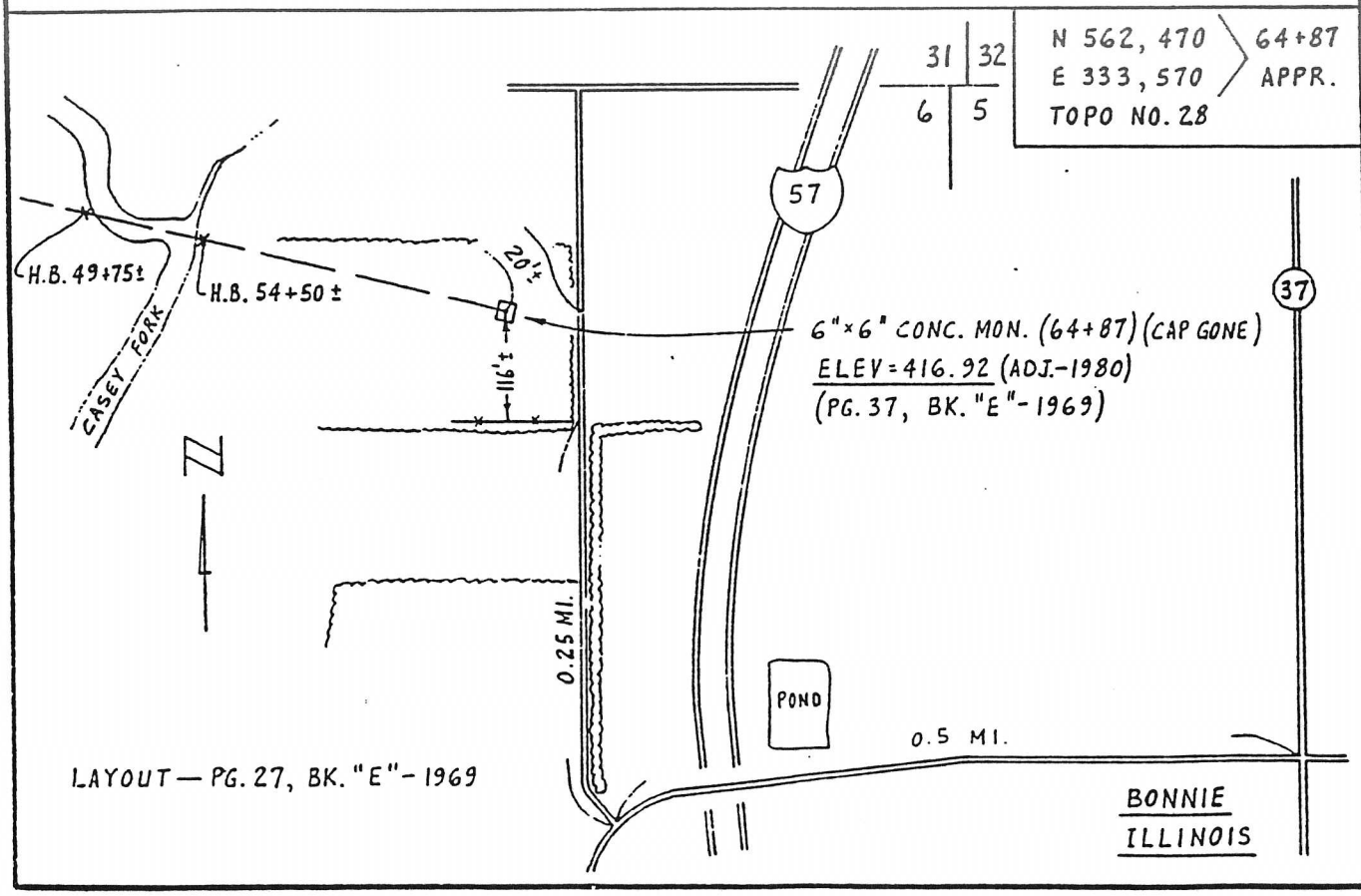
RANGE 16-A

N 563,870
E 327,260
TOPO NO. 28
0+24 APPR.



LAYOUT—PG.27, BK."E"-1969

N 562,470
E 333,570
TOPO NO. 28
64+87 APPR.



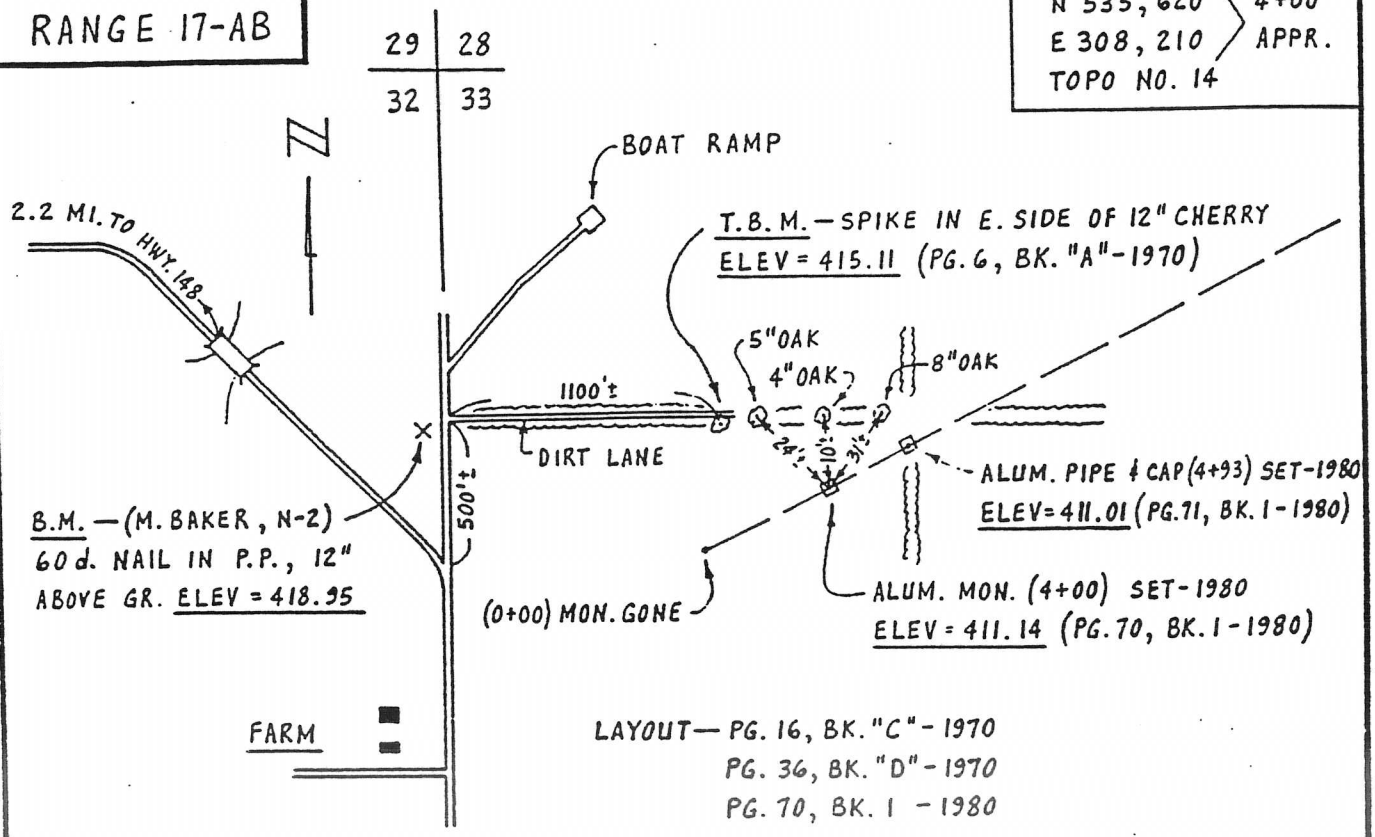
LAYOUT—PG.27, BK."E"-1969

COMPUTATION SHEET

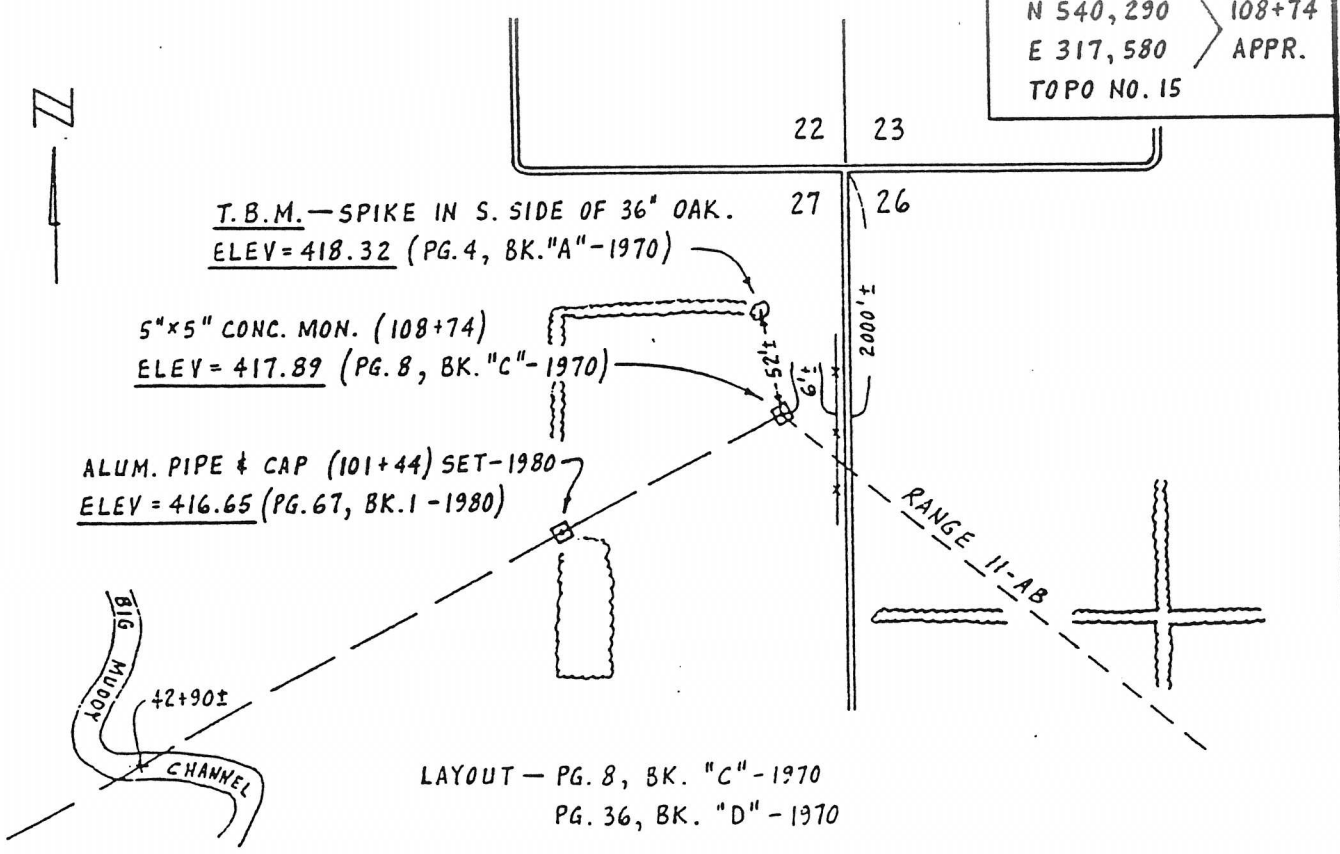
PROJECT	REND LAKE	PAGE 17 OF 23	COMPUTED BY WJM	DATE 1-13-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

RANGE 17-AB

N 535,620
E 308,210
TOPO NO. 14
4+00 APPR.



N 540,290
E 317,580
TOPO NO. 15
108+74 APPR.



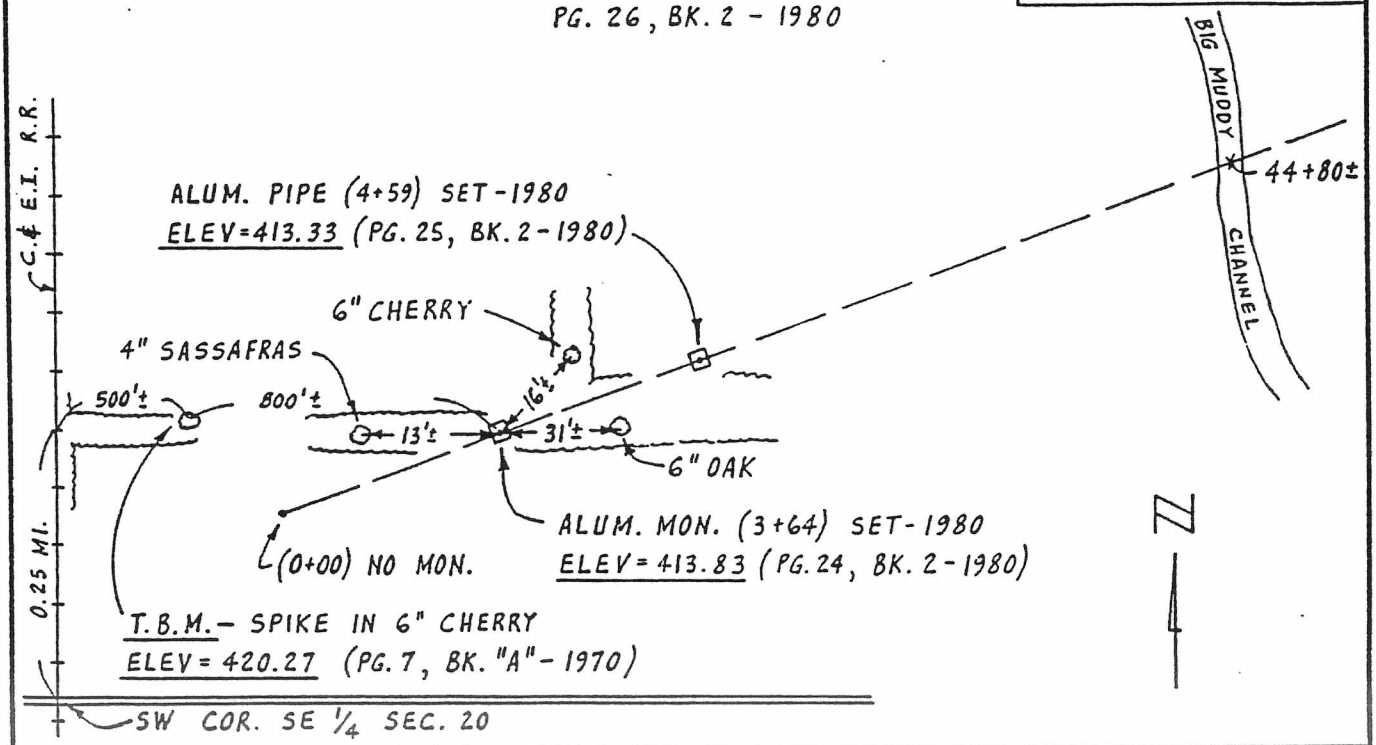
COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 18 OF 23	COMPUTED BY WJM	DATE 1-14-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

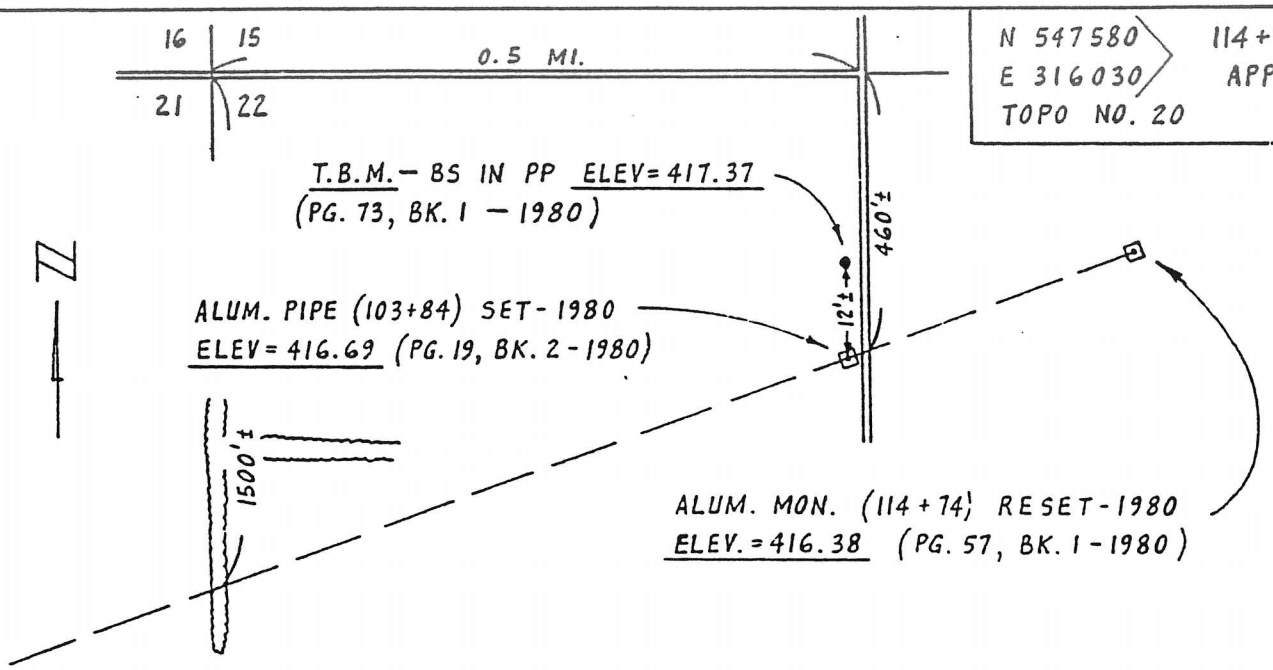
RANGE 18-A

N 543540 / E 305300 / TOPO NO. 21 — 0+00 APPR.

LAYOUT – PG. 65, BK. "D" - 1970
PG. 21 & 38, BK. "C" - 1970
PG. 26, BK. 2 - 1980



N 547580 / E 316030 / TOPO NO. 20 — 114+74 APPR.



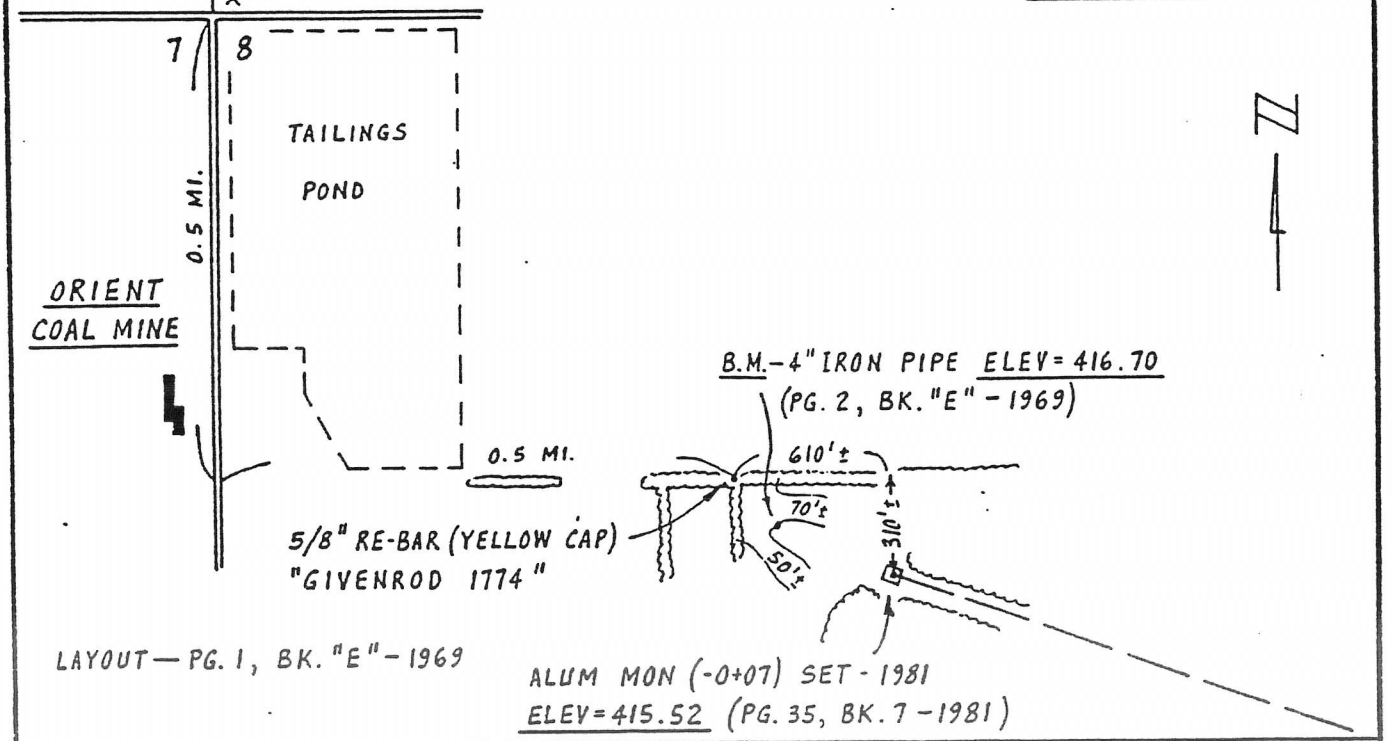
LAYOUT – PG. 65, BK. "D" - 1970
PG. 22, BK. "C" - 1970

COMPUTATION SHEET

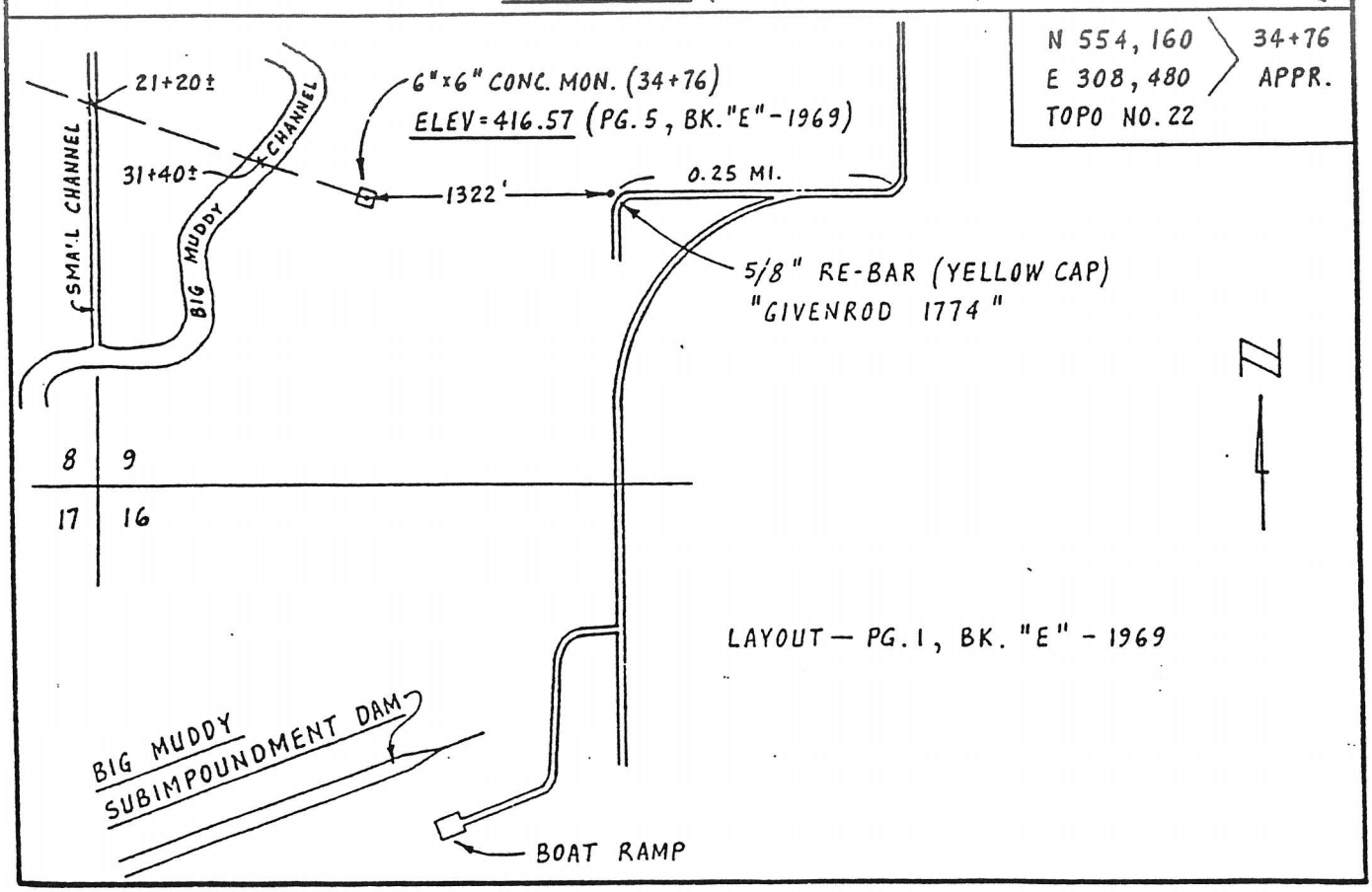
PROJECT	REND LAKE	PAGE 19 OF 23	COMPUTED BY WJM	DATE 1-16-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

RANGE 19-A

N 555,320
E 305,200
TOPO NO. 22
0+00 APPR.



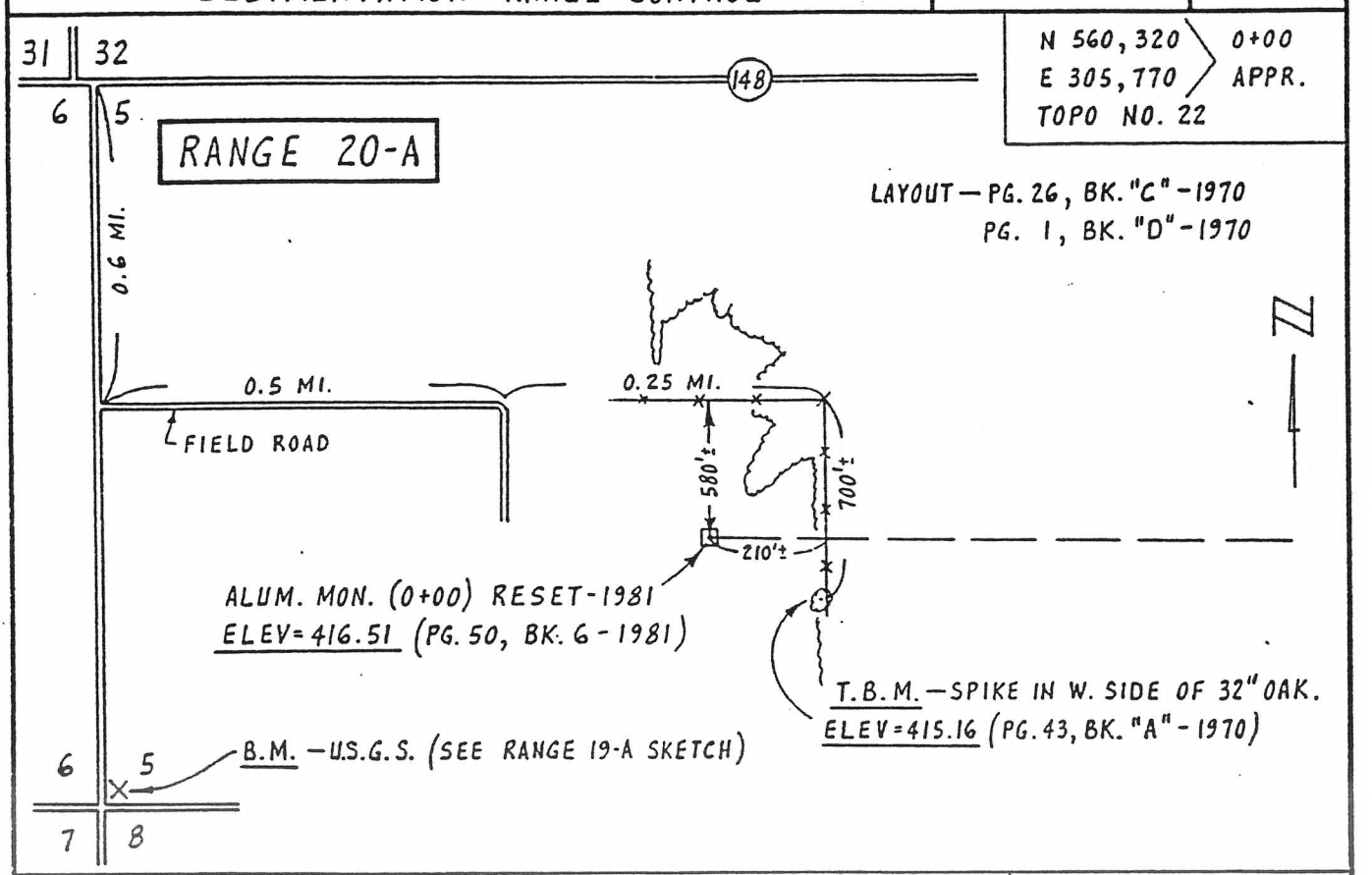
N 554,160
E 308,480
TOPO NO. 22
34+76 APPR.



COMPUTATION SHEET

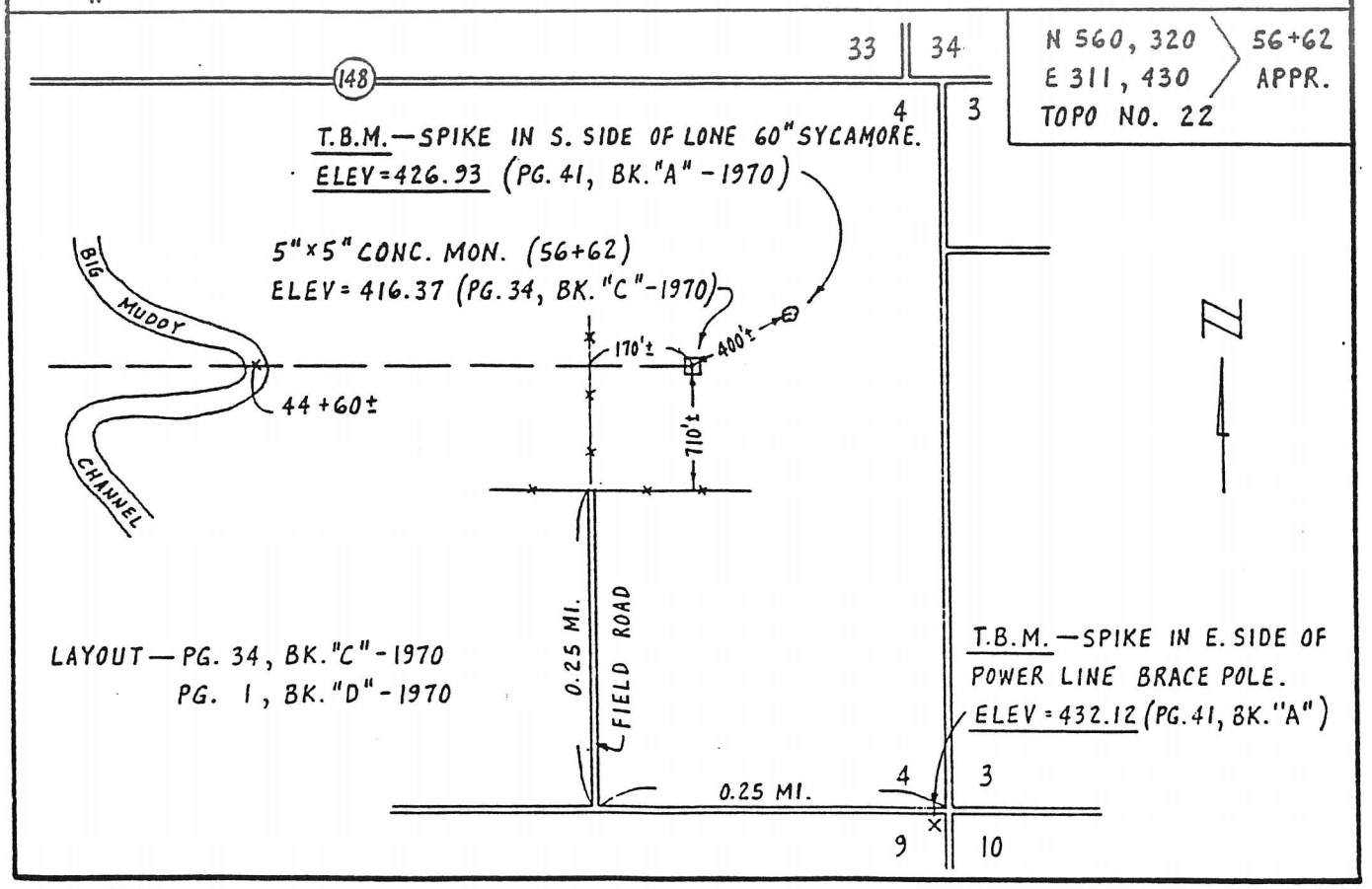
PROJECT	REND LAKE	PAGE 20 OF 23	COMPUTED BY: WJM	DATE 1-19-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

N 560,320
E 305,770
TOPO NO. 22
0+00 APPR.



LAYOUT—PG. 26, BK. "C"-1970
PG. 1, BK. "D"-1970

N 560,320
E 311,430
TOPO NO. 22
56+62 APPR.



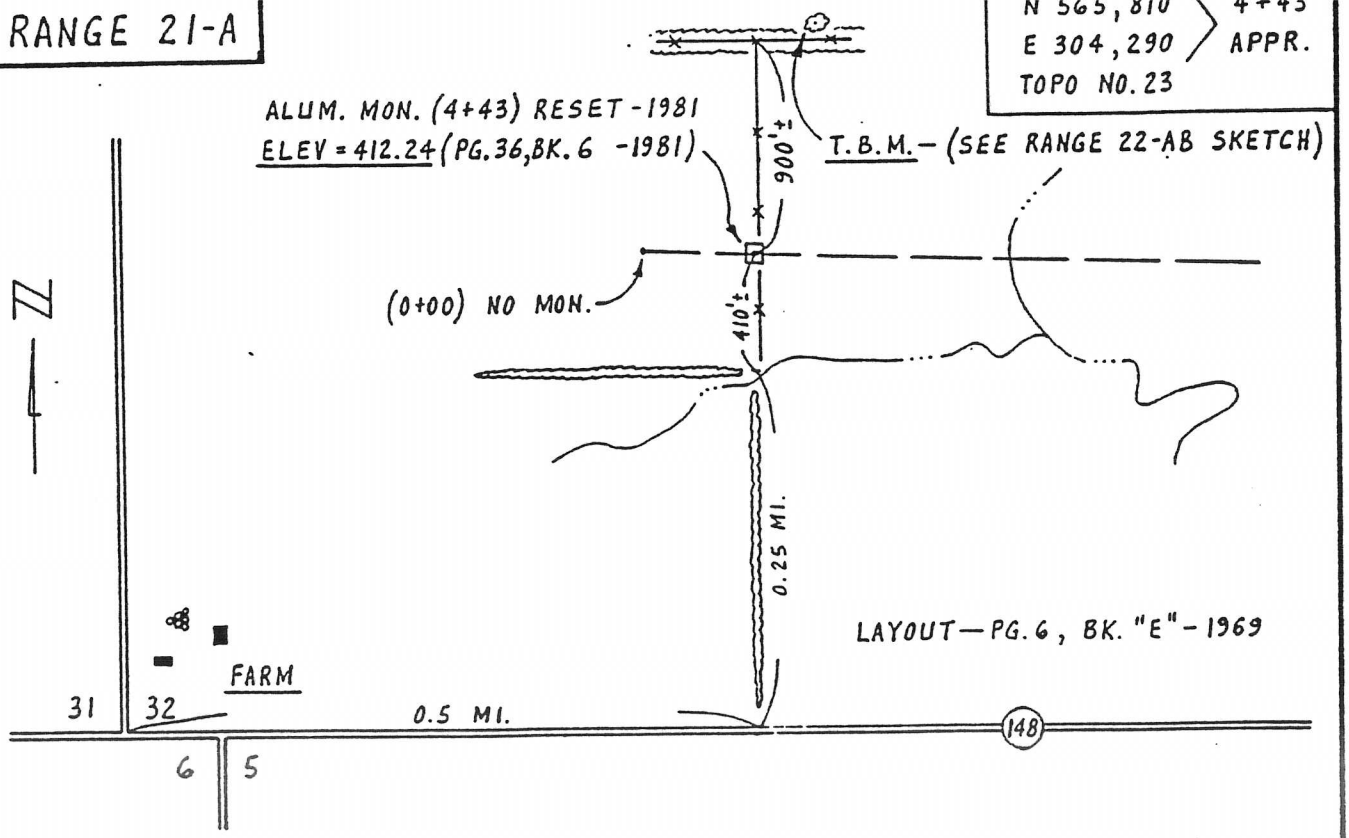
LAYOUT—PG. 34, BK. "C"-1970
PG. 1, BK. "D"-1970

COMPUTATION SHEET

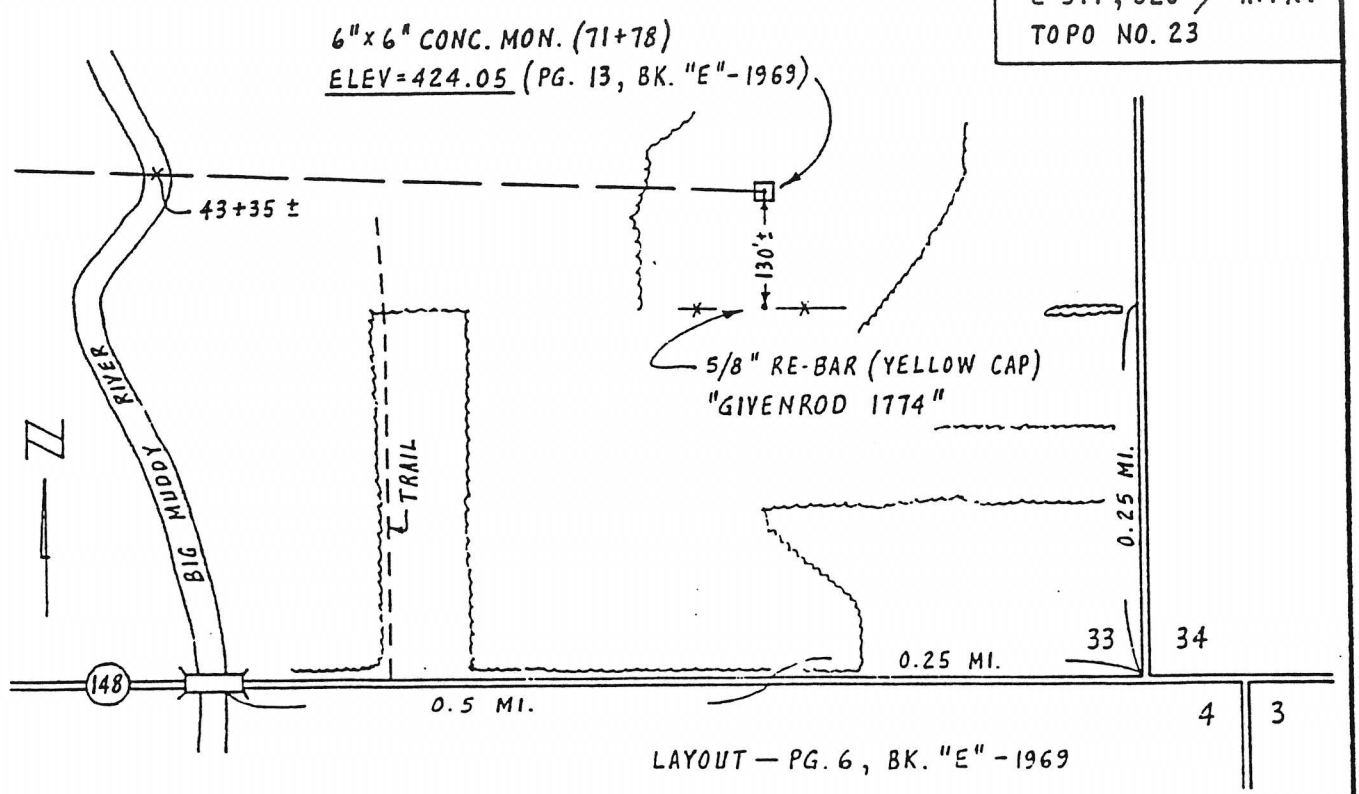
PROJECT	RENO LAKE	PAGE 21 OF 23	COMPUTED BY W&M	DATE 1-20-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

RANGE 21-A

N 565,810
E 304,290
TOPO NO. 23
4+43 APPR.



N 565,660
E 311,020
TOPO NO. 23
71+78 APPR.



LMV FORM 107e

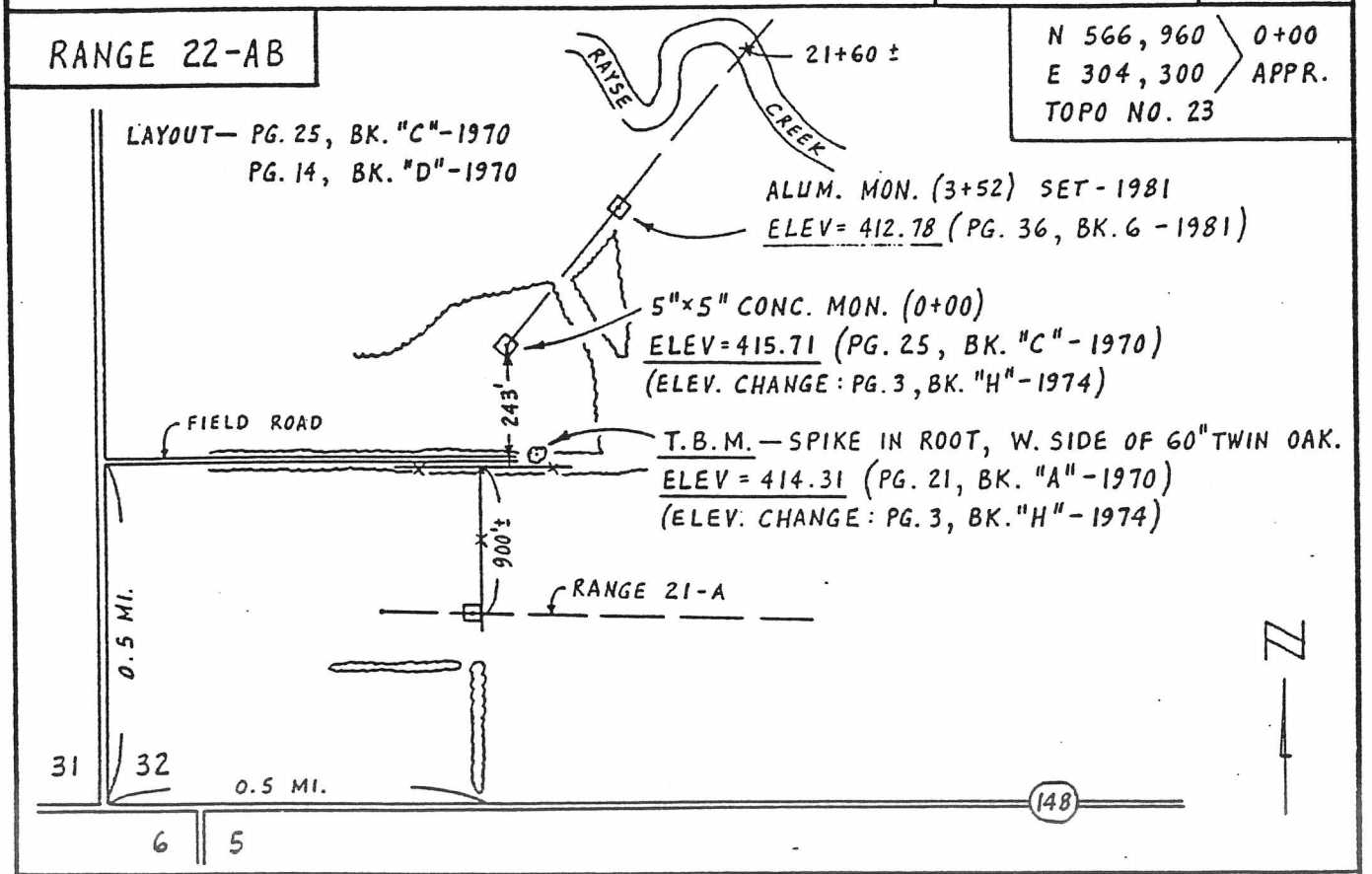
ORIGINAL

COMPUTATION SHEET

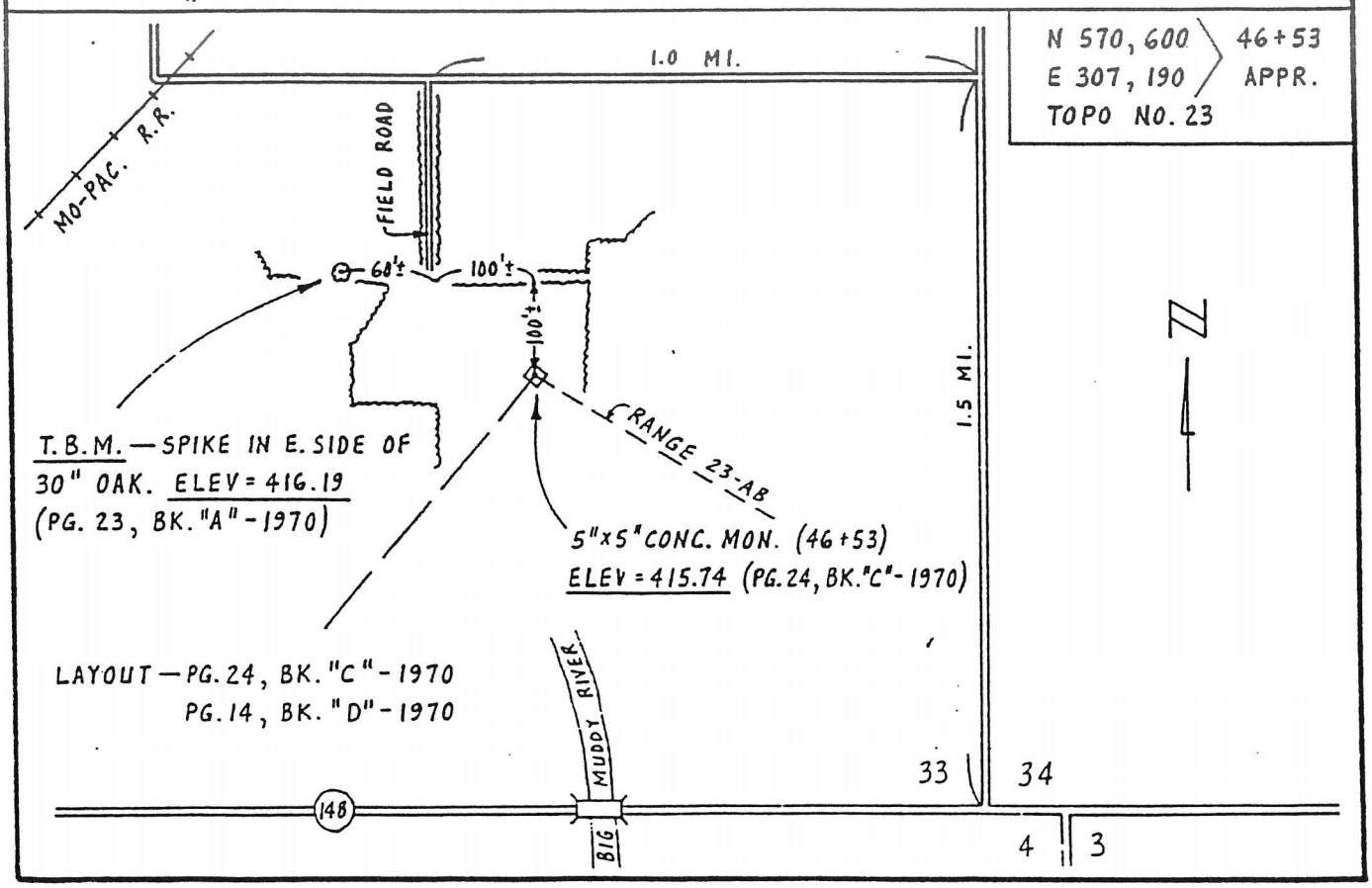
PROJECT	REND LAKE	PAGE 22 OF 23	COMPUTED BY WJM	DATE 1-21-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

RANGE 22-AB

N 566,960 / E 304,300 — 0+00 APPR.
TOPO NO. 23



N 570,600 / E 307,190 — 46+53 APPR.
TOPO NO. 23

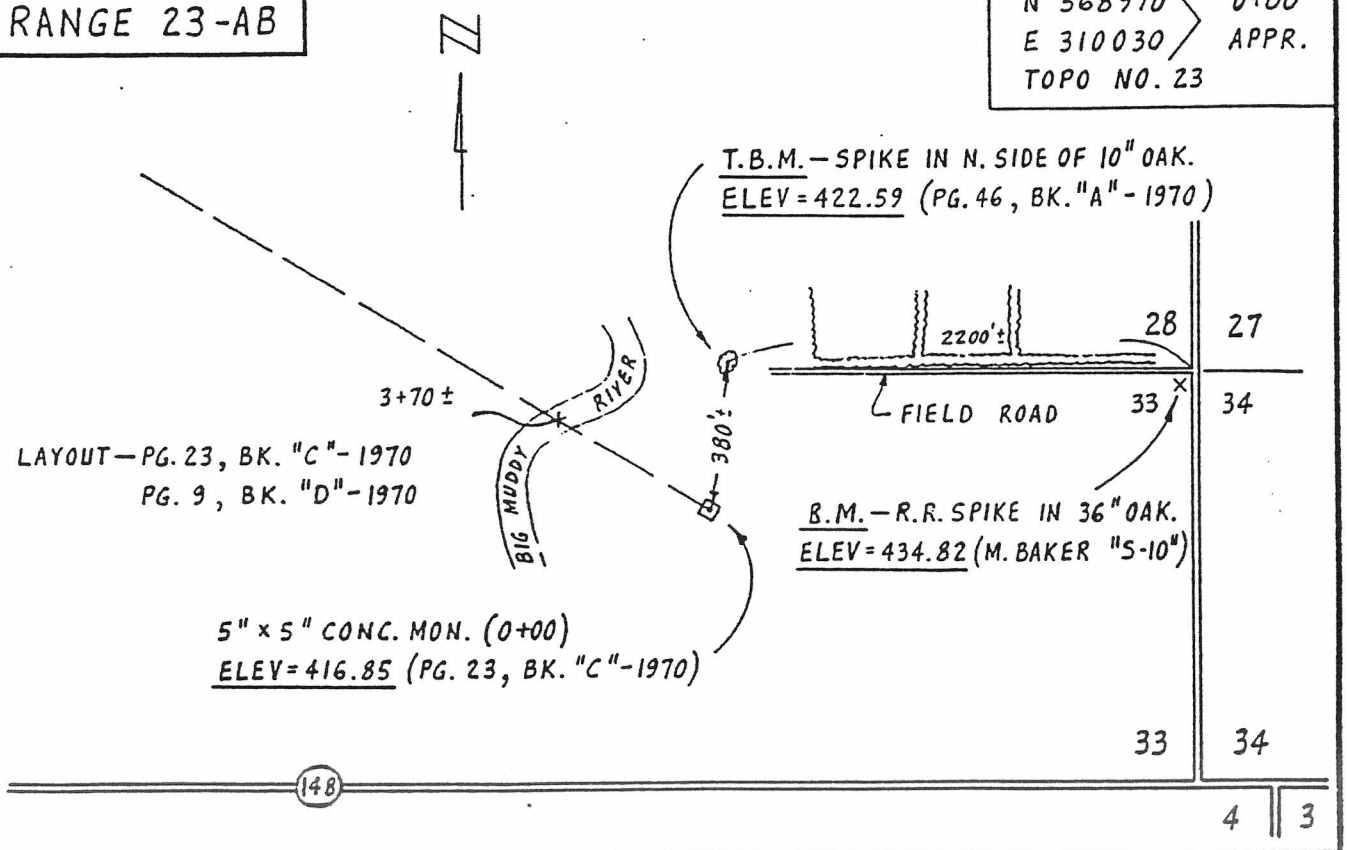


COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 23 OF 23	COMPUTED BY WJM	DATE 1-22-81
SUBJECT	SEDIMENTATION RANGE CONTROL		CHECKED BY	DATE

RANGE 23-AB

N 568970
E 310030
TOPO NO. 23
0+00 APPR.



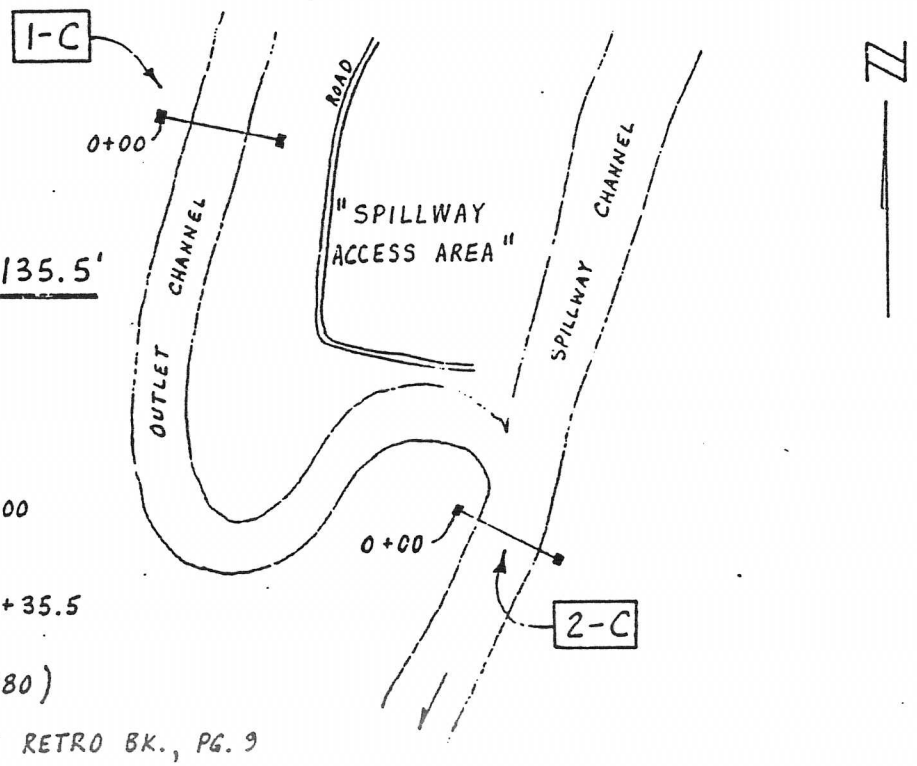
N 570,600
E 307,190
TOPO NO. 23
32+80 APPR.

SAME MON. AS 46+53 OF RANGE 22-AB

APPENDIX B

COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 1 OF 4	COMPUTED BY WSM	DATE 12-10-80
SUBJECT	RETROGRESSION RANGES		CHECKED BY	DATE



RANGE 1-C

S 77° 45' E (TRUE) 135.5'

5" x 5" CONC. MON. @ 0+00
ELEV = 380.98

5" x 5" CONC. MON @ 1+35.5
ELEV = 379.48
(BOTH RE-LEVELED 1980)

ORIG. LAYOUT — 1971 RETRO BK., PG. 9
ORIG. LEVELS — 1971 RETRO BK., PG. 2

RANGE 2-C

S 59° 59' E (TRUE) 111.0'

SEE SKETCH ABOVE

5" x 5" CONC. MON. @ 0+00
ELEV = 383.00

5" x 5" CONC. MON. @ 1+11.0
ELEV = 381.60

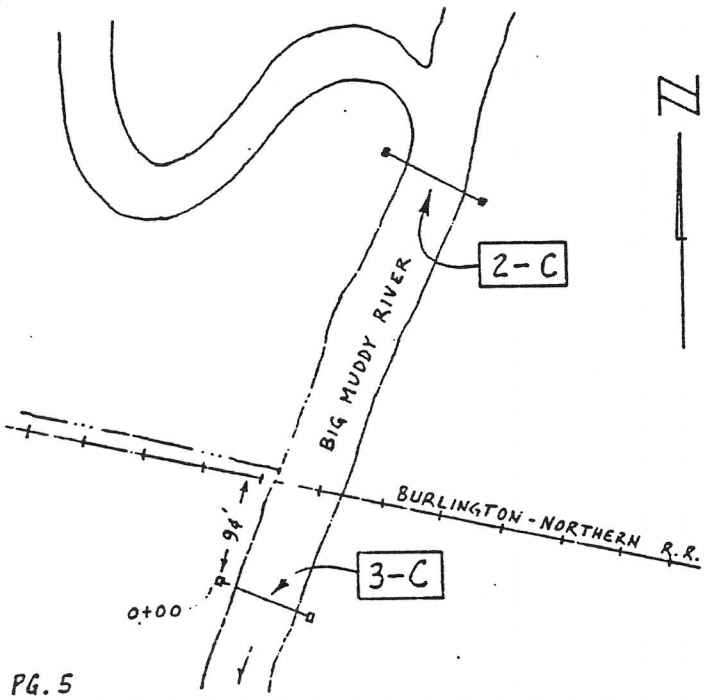
ORIG. LAYOUT — 1971 RETRO BK., PG. 7
ORIG. LEVELS — 1971 RETRO BK., PG. 2

COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 2 OF 4	COMPUTED BY W&M	DATE 12-10-80
SUBJECT	RETROGRESSION RANGES		CHECKED BY	DATE

RANGE 3-C

S 67° 30' E (TRUE) 143.5'



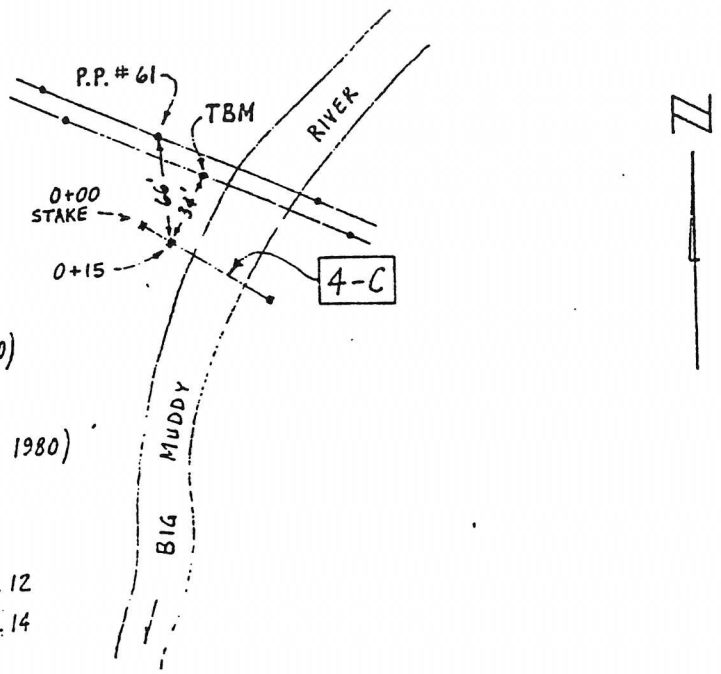
5"x5" CONC. MON. @ 0+00
DISTURBED - 1980

5"x5" CONC. MON. @ 1+43.5
ELEV = 382.55

ORIG. LAYOUT — 1971 RETRO BK., PG. 5
ORIG. LEVELS — 1971 RETRO BK., PG. 2

RANGE 4-C

S 57° 30' E (TRUE) 118.8'



TBM — RR SPIKE IN P.P.
ELEV = 379.29

ALUM. MON. @ 0+15 (RESET 1980)
ELEV = 377.74

ALUM MON. @ 1+18.8 (RESET 1980)
ELEV = 380.24

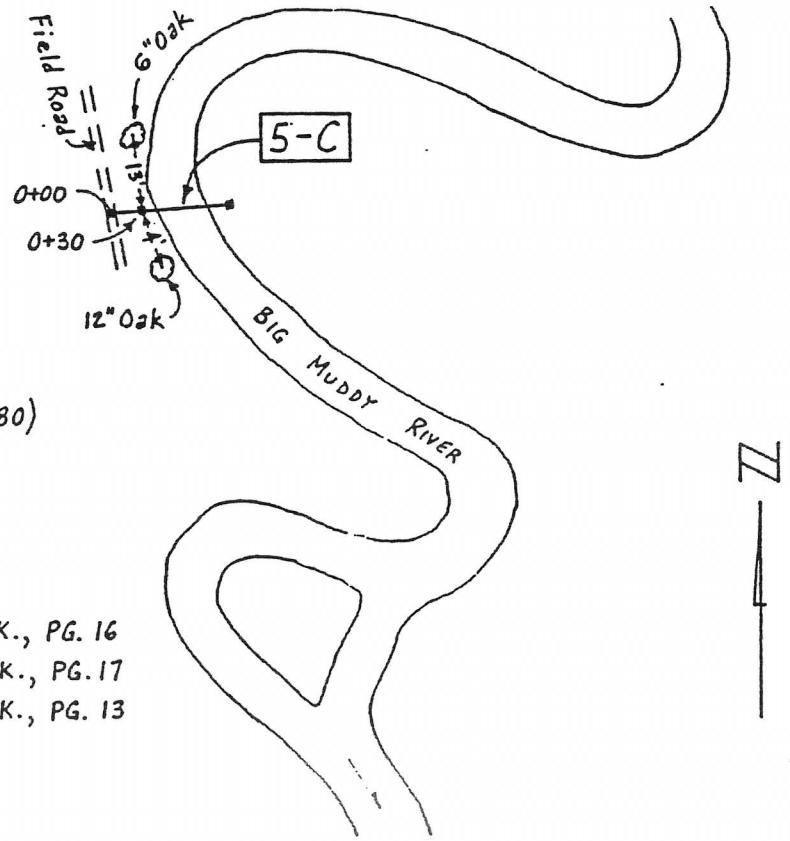
ORIG. LAYOUT -- 1971 RETRO BK., PG. 12
M-G LAYOUT — 1980 RETRO BK., PG. 14

COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 3 OF 4	COMPUTED BY W&M	DATE 12-11-80
SUBJECT	RETROGRESSION RANGES		CHECKED BY	DATE

RANGE 5-C

N 86°00'E (TRUE) 144.0'



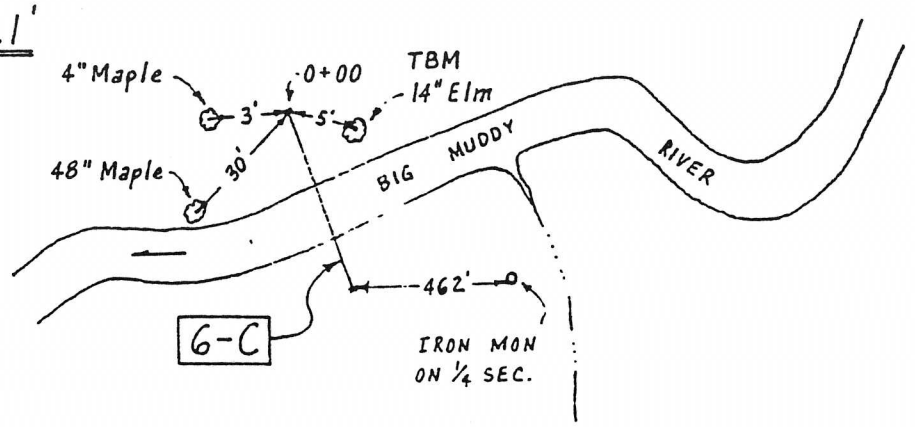
ALUM. MON. @ 0+30 (RESET 1980)
ELEV = 384.65

5" x 5" CONC. MON. @ 1+44
ELEV = 380.84

ORIG. LAYOUT — 1971 RETRO BK., PG. 16
M-G LAYOUT — 1980 RETRO BK., PG. 17
ORIG. LEVELS — 1971 RETRO BK., PG. 13

RANGE 6-C

S 20° E (TRUE) 120.1'



TBM — RR SPIKE IN 14" ELM
ELEV = 380.87

ALUM. MON. @ 0+00 (RESET 1980)
ELEV = 380.13

ALUM. MON. @ 1+20.1 (RESET 1980)
ELEV = 381.40

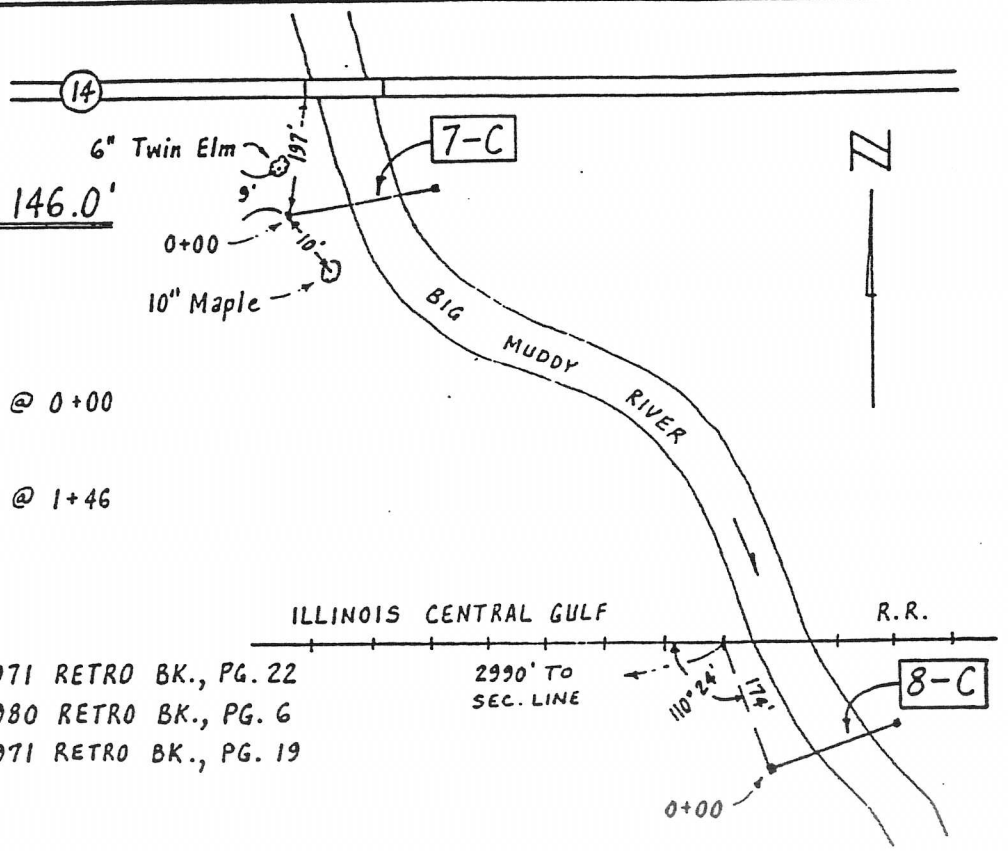
ORIG. LAYOUT — 1971 RETRO BK., PG. 18
M-G LAYOUT — 1980 RETRO BK., PG. 20

COMPUTATION SHEET

PROJECT	REND LAKE	PAGE 4 OF 4	COMPUTED BY WJM	DATE 12-11-80
SUBJECT	RETROGRESSION RANGES		CHECKED BY	DATE

RANGE 7-C

N 80°30'E (TRUE) 146.0'



5"x5" CONC. MON. @ 0+00
ELEV = 379.83

5"x5" CONC. MON. @ 1+46
ELEV = 375.69

ORIG. LAYOUT – 1971 RETRO BK., PG. 22
M-G LAYOUT – 1980 RETRO BK., PG. 6
ORIG. LEVELS – 1971 RETRO BK., PG. 19

RANGE 8-C

N 72°15'E (TRUE) 156.3'

SEE SKETCH ABOVE

5"x5" CONC. MON. @ 0+00
ELEV = 378.45

5"x5" CONC. MON. @ 1+56.3
ELEV = 376.40
(BOTH RE-LEVELED 1980)

ORIG. LAYOUT – 1971 RETRO BK., PG. 24