Contract Report 643

Sedimentation Survey of Lake Vermilion, Vermilion County, Illinois

by
William C. Bogner and K. Erin Hessler

Prepared for the Consumers Illinois Water Company

May 1999

Illinois State Water Survey
Watershed Science Section
Champaign, Illinois

A Division of the Illinois Department of Natural Resources

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Sedimentation Survey of Lake Vermilion, Vermilion County, Illinois

Introduction

The Illinois State Water Survey (ISWS), in cooperation with the Consumers Illinois Water Company (CIWC), conducted a sedimentation survey of Lake Vermilion during the summer of 1998. The survey was undertaken to provide information on the storage and sedimentation conditions of the lake following a 1991 increase in the operational lake level. Lake Vermilion is owned and operated by the CIWC. The CIWC withdraws water from Lake Vermilion as the sole raw water source for direct distribution of finished water to Danville and Tilton, Illinois. The CIWC also provides finished water to the Catlin and Westville public water supplies.

Sedimentation detracts from the use of any water supply lake by reducing depth and volume, with a reduction of reserve water supply capacity and burying of intake structures.

Sedimentation of a reservoir is a natural process that can be either accelerated or slowed by human activities in the watershed. In general, sedimentation of a lake is presumed to be unintentionally accelerated as a secondary impact of other developments within the watershed. For example, construction and agricultural activities in a lake watershed generally are presumed to increase sediment delivery to the lake due to increased exposure of soil material to erosive forces.

Reductions of the sedimentation rate in a lake due to human impacts almost always are the result of programs intentionally designed to reduce soil and streambank erosion, and they are often the result of implementing lake remediation programs. These programs might include, but are not limited to, the implementation of watershed erosion control practices, streambank and lakeshore stabilization, stream energy dissipaters, and lake dredging.

Sedimentation of a reservoir is the final stage of a three-step sediment transport process. The three steps are watershed erosion by sheet, rill, gully, and/or streambank erosion; sediment transport in a defined stream system; and deposition of the sediment, in which stream energy is reduced such that the sediment can no longer be transported either in suspension or as bedload. Sediment deposition can occur throughout the stream system.

Lake sedimentation occurs when sediment-laden water in a stream enters the reduced flow velocity regime of a lake. As water velocity is reduced, suspended sediment is deposited in patterns related to the size and fall velocity of each particle. During this process, soil particles are partially sorted by size along the longitudinal axis of the lake. Larger and heavier sand and coarse silt particles are deposited in the upper end of the lake; finer silts and clay particles tend to be carried further into the lake.

Several empirical methods have been developed for estimating sedimentation rates in Illinois (ISWS, 1967; Upper Mississippi River Basin Commission, 1970; Singh and Durgunoglu, 1990). These methods use regionalized relationships between watershed size and lake sedimentation rates. As estimates, they serve well within limits. A more precise measure of the sedimentation rate is provided by conducting a sedimentation survey of the reservoir. The sedimentation survey provides detailed information on distribution patterns within the lake as well as defining temporal changes in overall sedimentation rates.

Acknowledgments

The project was funded by the Consumers Illinois Water Company. John Waite and Jerry Connolly were project managers.

Views expressed in this report are those of the authors and do not necessarily reflect the views of the sponsor or the Illinois State Water Survey.

This project was conducted by the authors as part of their regular duties at the Illinois State Water Survey under the administrative guidance of Derek Winstanley, Chief, and Nani G. Bhowmik, Head of the Watershed Science Section. Susan Shaw assisted with the field data collection. Yi Han analyzed the sediment samples. Richard Allgire, Sally McConkey, and H. Vernon Knapp provided technical review. Eva Kingston and Agnes Dillon edited the report. Linda Hascall reviewed the graphics.

Lake Information

Lake Vermilion (figure 1) is located in Vermilion County, one mile northwest of Danville, Illinois. The location of the dam is 40° 9’ 24” north latitude and 87° 39’8” west longitude in Section 31, T.20N., R.11W., Vermilion County, Illinois. The dam impounds the North Fork of the Vermilion River, a tributary of the Vermilion River in the Wabash River Basin. The watershed is a portion of Hydrologic Unit 05120109 as defined by the U.S. Geological Survey (U.S. Geological Survey, 1974).

Reservoir and Water Supply History

The first public water supply system for Danville was placed in service by the Danville Water Company in 1883. This system was constructed under a franchise granted by the Danville City Council. The source of water for this system was the available flow from the North Fork of the Vermilion River. The original waterworks are described in Water Survey file notes as “a single brick building, divided into a boiler and an engine room.” There are no indications of any water purification facilities.

With this initial supply system, the water taken directly from the river was unreliable in terms of quantity and quality. Water supply was limited during periods of low stream flow, and at other times water quality was affected by high turbidity. By 1902 several improvements to the system had been made: in-stream storage was increased by a small channel dam, a small excavated settling pond was added, turbidity was reduced with the installation of a rapid sand filtration plant, and the pumping capacity was increased. In 1912, the treatment plant was expanded to include a laboratory and hypochlorite treatment of the water.

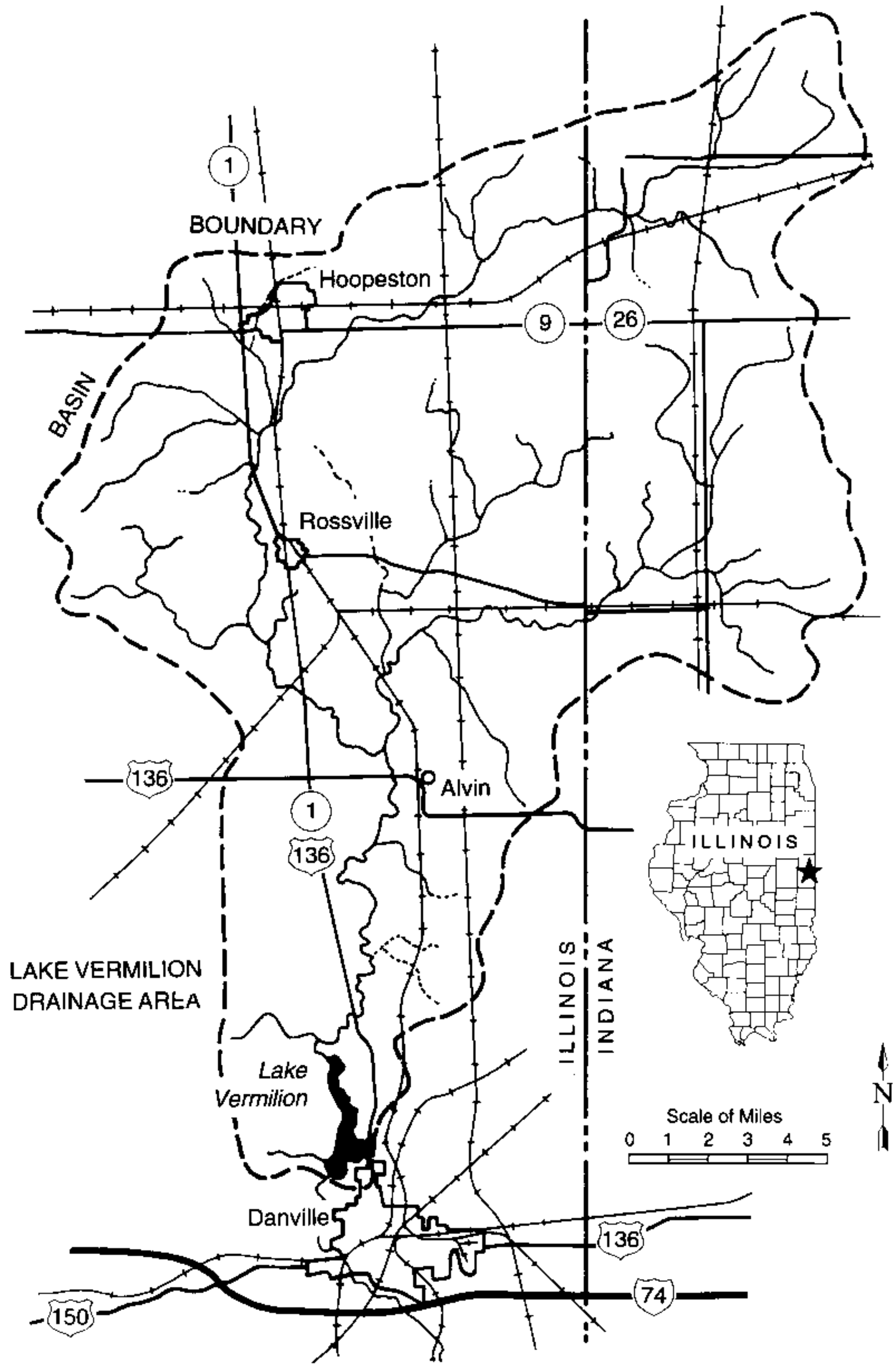


Figure 1. Location and watershed delineation for Lake Vermilion

Efforts to augment the surface water supply with a ground-water system periodically have been initiated since at least 1913. At that time, six wells were bored to a depth of 90 feet. According to Water Survey file reports, "these wells flowed and furnished a very large yield." However, the high iron content and mineralization of the well water made it less desirable than the surface water supply.

The old dam was constructed in 1914 to augment flow to the pre-existing channel dam adjacent to the treatment plant. The present dam and spillway were constructed in 1925, with an initial storage capacity of 8,514 acre-feet (ac-ft) or 2,784 million gallons. The initial construction and filling of the new reservoir submerged the 1914 dam structure to just below the surface of the new water level. The gates of the 1925 spillway structure were modified in 1991 to accommodate an increase in the operating pool elevation.

A water shortage in 1976 prompted a search for additional sources of raw water. This search effort led a Water Survey report *Water Supply Alternatives for the City of Danville, Illinois* (Singh, 1978). Options considered in this study were raising the lake level, lake dredging, water transfers from the Vermilion or Wabash Rivers, and ground-water development either locally, in the Wabash River valley, or regionally, in northern Vermilion County.

Subsequent to additional water shortages in 1988 and 1989, the following actions were taken related to alternatives presented in the 1978 study. In October 1991, an increase in the operating spillway level for Lake Vermilion was approved. The pool level was increased from 576 feet National Geodetic Vertical Datum (NGVD) to 582.2 feet NGVD, using extensions that had been added to the original spillway gates. The available storage in the reservoir was increased by approximately 4,600 ac-ft or 1,500 million gallons.

Several exploratory wells have been drilled both locally and in northern Vermilion County. At least one well near the lake was drilled, logged, and tested. In northern Vermilion County, several exploratory wells were drilled, but there have been no reported efforts to develop or run pumping tests on these wells.

Watershed

The Lake Vermilion watershed consists of the 298-square-mile area drained by the North Fork of the Vermilion River above the dam site (figure 1). The highest point in the watershed is at an elevation of 820 feet NGVD and the normal pool elevation of the lake is 582.2 feet NGVD.

Land use in the watershed of the lake is mainly agricultural. Average annual precipitation in the area is 39.02 inches as measured at Danville (1925 to 1998), and the average runoff (1928 to 1996) is approximately 11.7 inches (Vermilion River at Danville). Average annual lake evaporation rates are 10.5 inches per year at Urbana, Illinois (Roberts and Stall, 1967).

The upland soils in the watershed are dark, prairie soils formed in glacial till deposits. Valley wall soils, formed under forest conditions, are lighter in color. Each of these soil types is generally underlain by a poorly drained subsoil that causes them to be highly susceptible to erosion (Wascher et al., 1938; USDA-SCS, 1982).

Lake Sedimentation Surveys

The ISWS conducted sedimentation surveys of Lake Vermilion in 1963 (Neibel and Stall, 1964) and 1976 (Bogner and Gibb, 1977). The 1998 sedimentation survey of Lake Vermilion (figure 2) repeated as closely as possible a series of survey lines established during the 1963 survey. In 1963, cross sections were laid out at 18 lines across the lake, surveyed, and monumented by installing 4-inch by 4-inch concrete posts to mark the transect ends. During the 1976 and 1998 surveys, these survey lines were resurveyed to define temporal changes in lakebed topography.

For the 1963 and 1976 sedimentation surveys, horizontal distances along the cross-sectional transects were measured by stretching a marked polyethylene cable between corresponding range end monuments. Water depth (vertical control) was referenced to the water surface, and all depths were adjusted to the spillway crest elevation. Depth measurements were made using an aluminum sounding pole lowered to the top of the sediment surface to measure the existing water depth. The pole was then used to probe to the original bottom as determined by the initial point of resistance to the sediment probe.

The 1998 survey was conducted using an Odom Hydrographic Systems MK II fathometer for depth measurement and a differentially corrected Geodetic Position Systems (GPS) for horizontal control across the transect. The GPS system units used were either a Trimble Pathfinder GPS or a Leica 9600 System. All navigation and data logging functions were controlled using Hypack, a hydrographic survey software. The GPS positions were differentially corrected using RTCM correction signals broadcast by the U.S. Coast Guard from St. Louis, Missouri, or Rock Island, Illinois.

The fathometer was calibrated daily prior to initiating measurements. Calibration checks at the end of most work days showed daily variations of 0.1-0.2 feet in a profile at one-foot depth intervals. For each main lake cross section, three to five physical measurements of the water depth and sediment thickness were made with an aluminum sounding pole.

Plots of all surveyed cross sections from 1963, 1976, and 1998 are presented in appendix I. For comparison, the 1998 pole measurements also are plotted in appendix I as point data. These water-depth measurements with the pole show a close correspondence with the 1998 depth sounder readings. Comparison of the original lake depth for the 1998 pole readings to the full cross-section data collected for the 1963 and 1976 surveys shows a good match in the deeper areas of the lake (R1-R2 through R9-R10). In shallower water areas, the sediments have become more consolidated and difficult to penetrate due to the occasional exposure events prior to 1991.

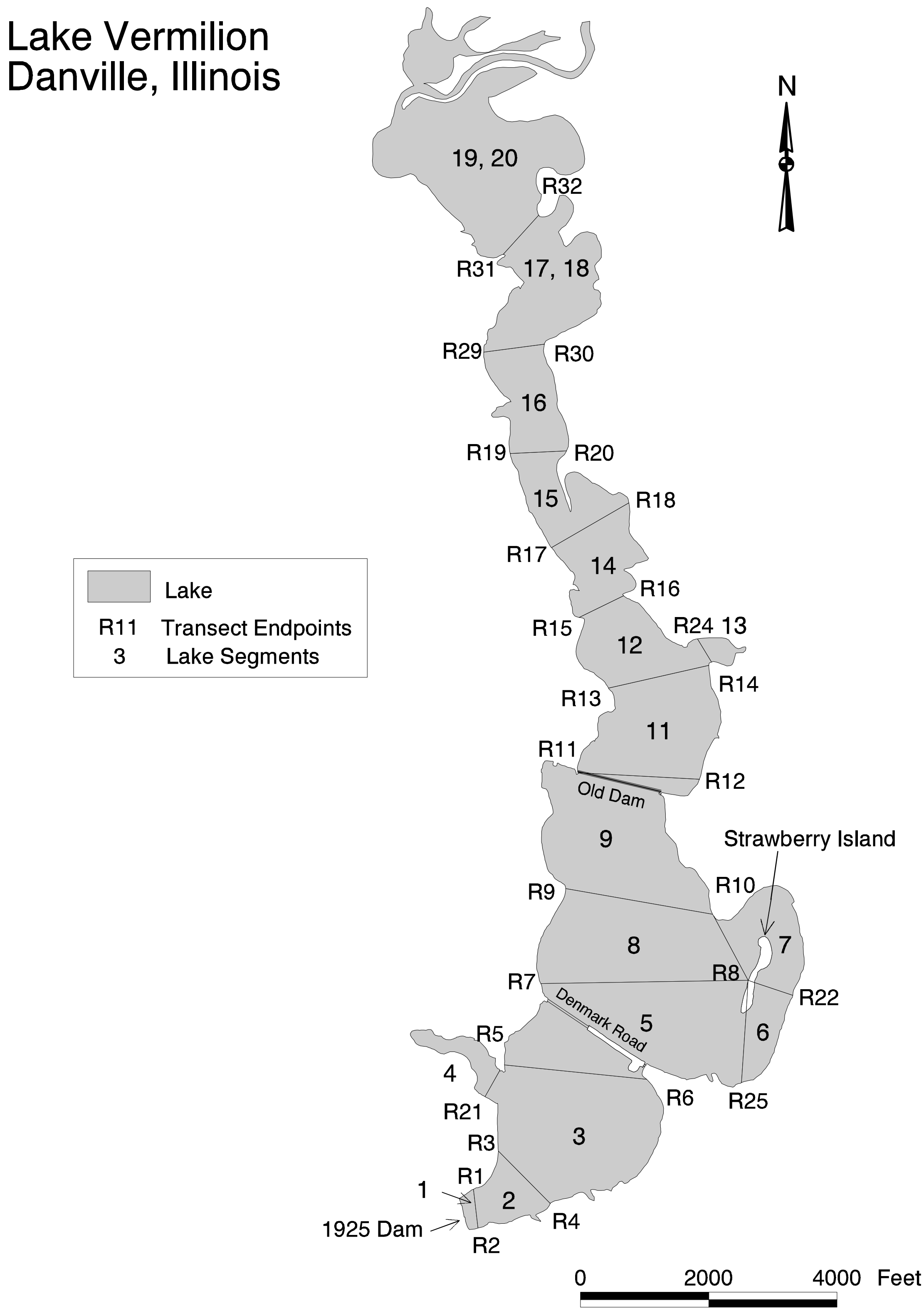


Figure 2. Survey plan for Lake Vermilion, 1998

Lake Basin Volumes

Calculations of the lake capacities were made using methods described in *the National Engineering Handbook* of the U.S. Soil Conservation Service (USDA-SCS, 1968). This method requires the surface area of the lake segments, the cross-sectional area and widths of their bounding segments, and a shape factor to determine the original and present volume of each segment. These volumes are then summed to determine the total lake volume. The reference elevation used for the lake was the top of the spillway gates, 582.2 feet NGVD.

The volume calculation results of the three surveys are presented in table 1. Given the 1991 change in lake elevation, the analysis of sedimentation rates required the use of a potential capacity for the pre-1991 lake volumes. For consistency, the volumes discussed in the remainder of this report are relative to the capacity of the valley basin below the reference spillway elevation of 582.2 feet NGVD. This potential capacity corresponds to the volume of lake storage that would have been achieved if the original 1925 lake had been constructed in the valley at the 1991 spillway elevation. Prior to 1991, it was physically impossible to maintain the pool level at this elevation, so the capacity discussed is defined as the potential capacity.

Table 1. Reservoir Capacity and Capacity Loss Analysis

Period	*Capacity*	*Capacity loss for period*	*Cumulative capacity loss*	*Period annual capacity loss rate*	*Cumulative annual capacity loss rate*
a) Analysis in units of ac-ft					
1925	13,209				
1925-1963	9,810	3,399	3,399	89.5	89.5
1963-1976	9,157	653	4,052	50.2	79.5
1976-1998	7,971	1,186	5,238	53.9	71.8
b) Analysis in units of million gallons					
1925	4,304				
1925-1963	3,196	1,108	1,108	29.1	29.1
1963-1976	2,984	213	1,320	16.4	25.9
1976-1998	2,597	386	1,707	17.6	23.4

Note: Lake surface area is 878 acres for 1998.
Capacity shown is for the sedimentation survey conducted at the end of the period.

Sedimentation has reduced the basin capacity from 13,209 ac-ft in 1925 to 7,971 ac-ft in 1998. The 1998 basin capacity was 60.3 percent of the 1925 potential basin capacity. For water supply purposes, these volumes convert to capacities of 4,304 million gallons in 1925 and 2,597 million gallons in 1998. The potential capacity of the lake in 1963 was 9,810 ac-ft (3,196 million gallons), and in 1976 it was 9,157 ac-ft (2,984 million gallons).

The 1998 water depths for the lake were used to generate the bathymetric map in figure 3 and the volume distribution curve data in figure 4. Figure 4 can be used to determine the capacity of the reservoir below a given stage elevation. For example, the water volume below the 4-foot depth contour (shown by the dashed line in figure 4) is 4,543 ac-ft. With time and continued sedimentation, the relationships shown in figure 4 will become obsolete. Alteration of the spillway elevation, or the implementation of a dredging program would likewise alter these relationships.

During the 1998 survey, much of the area flooded because the 1991 spillway level increase was found to have a depth of 4 to 5 feet. Much of the inundated area had been part of the original lake. Earlier sedimentation surveys found that 165 acres of the original surface area of the lake had become terrestrial. Analyses of aerial photography verify that, in 1936 11 years after construction of the present dam and 23 years after construction of the old dam) the lake covered an area approximately equal to the present extent of the lake. By 1976, sediment had filled most of this 165-acre area and had formed exposed land above the then existing lake pool level.

Sedimentation Rates

Analysis of the sedimentation rates for Lake Vermilion was made in terms of delivery rates from the watershed and from accumulation rates in the reservoir. The in-lake accumulation rate provides a means of extrapolating future lake conditions from past and present lake conditions in order to evaluate the integrity of the lake as a water supply source as well as a recreational resource. The watershed delivery rates are the link between soil erosion processes in the watershed, sediment transport processes, and water supply quantity impacts in the reservoir. These delivery rates measure the actual sediment yield from the watershed, including reduced sediment transport due field and in-stream redeposition.

The sedimentation rates for Lake Vermilion and its watershed are given in table 2 and table 3 for the periods 1925-1963, 1963-1976, 1976-1998, and 1925-1998. These rates indicate a steady decline in net sediment yield from the watershed from 89.5 ac-ft from 1925-1963 to 53.9 ac-ft annually from 1976-1998. The long-term average annual sediment yield from 1925-1998 was 71.8 ac-ft. These delivery rates show the need for continuing efforts to control watershed erosion, thereby reducing reservoir sedimentation rates.

Factors Impacting Lake Sedimentation Rates

Sedimentation rates in a lake can vary over time due to changes in either watershed or in-lake conditions. Changes in watershed conditions, such as altered precipitation patterns, land-use patterns, and streamflow variability, also affect the sediment delivery rates to the lake.

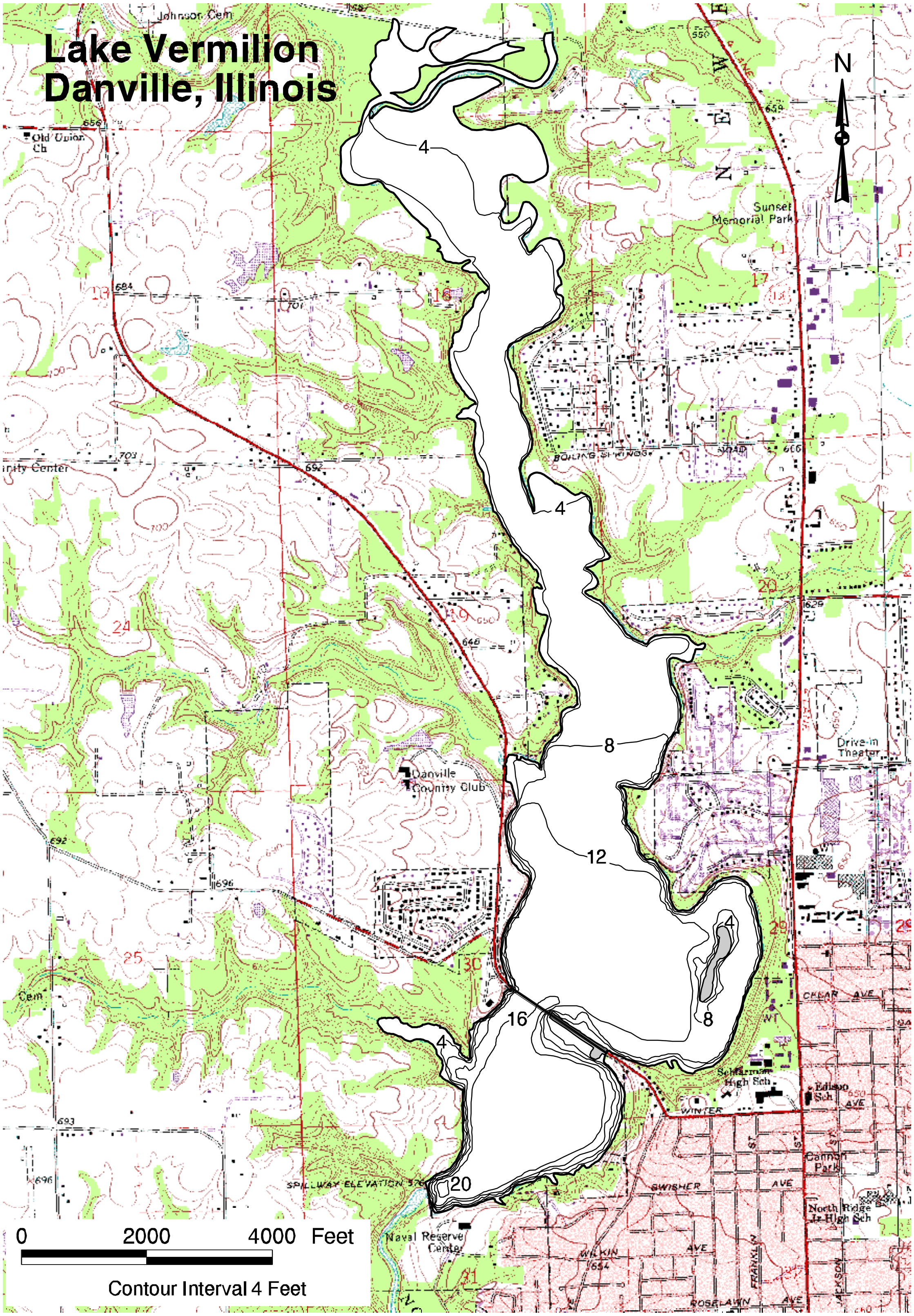


Figure 3. Bathymetric map of Lake Vermilion

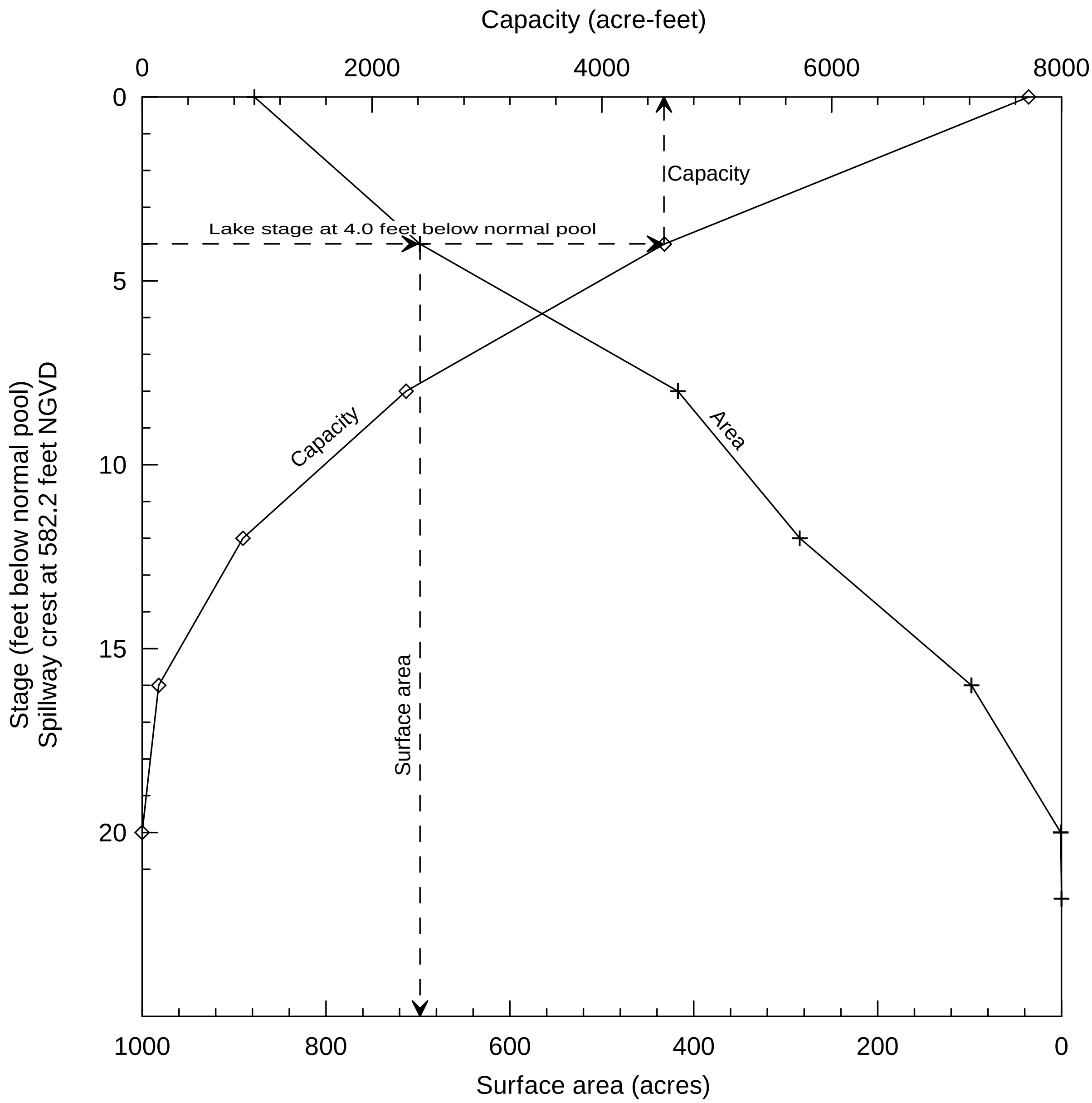


Figure 4. Stage vs. volume vs. area relationship for Lake Vermilion, 1998

In-lake conditions that also impact sedimentation rates involve the variation of trap efficiency (due to reduced storage capacity) and sediment consolidation. Sedimentation conditions for Lake Vermilion are further complicated by the old dam that predated the present dam. This structure would have accumulated sediment in the upper end of Lake Vermilion prior to 1925. The annual rate of sedimentation of the lake prior to 1925 cannot be determined today. Due to the old lake's smaller size, it would have had a lower trap efficiency than the larger 1925 structure, and, therefore a lower accumulation rate.

As a rough estimate of the impact of the sedimentation of the old lake on the 1925-1963 sedimentation rates for Lake Vermilion, the 1963 sediment accumulation can be averaged over the 49 years from 1914 instead of the 38 years from 1925. The 49-year sedimentation rate is 69.4 ac-ft per year in contrast to the 89.5 ac-ft in table 2. In reality, the sedimentation rate for the 1925-1963 period probably lies between these values.

Representative streamflow values for the Vermilion River at Danville from October 1928-September 1996 are shown in figure 5. The most important of these plots for analysis of lake

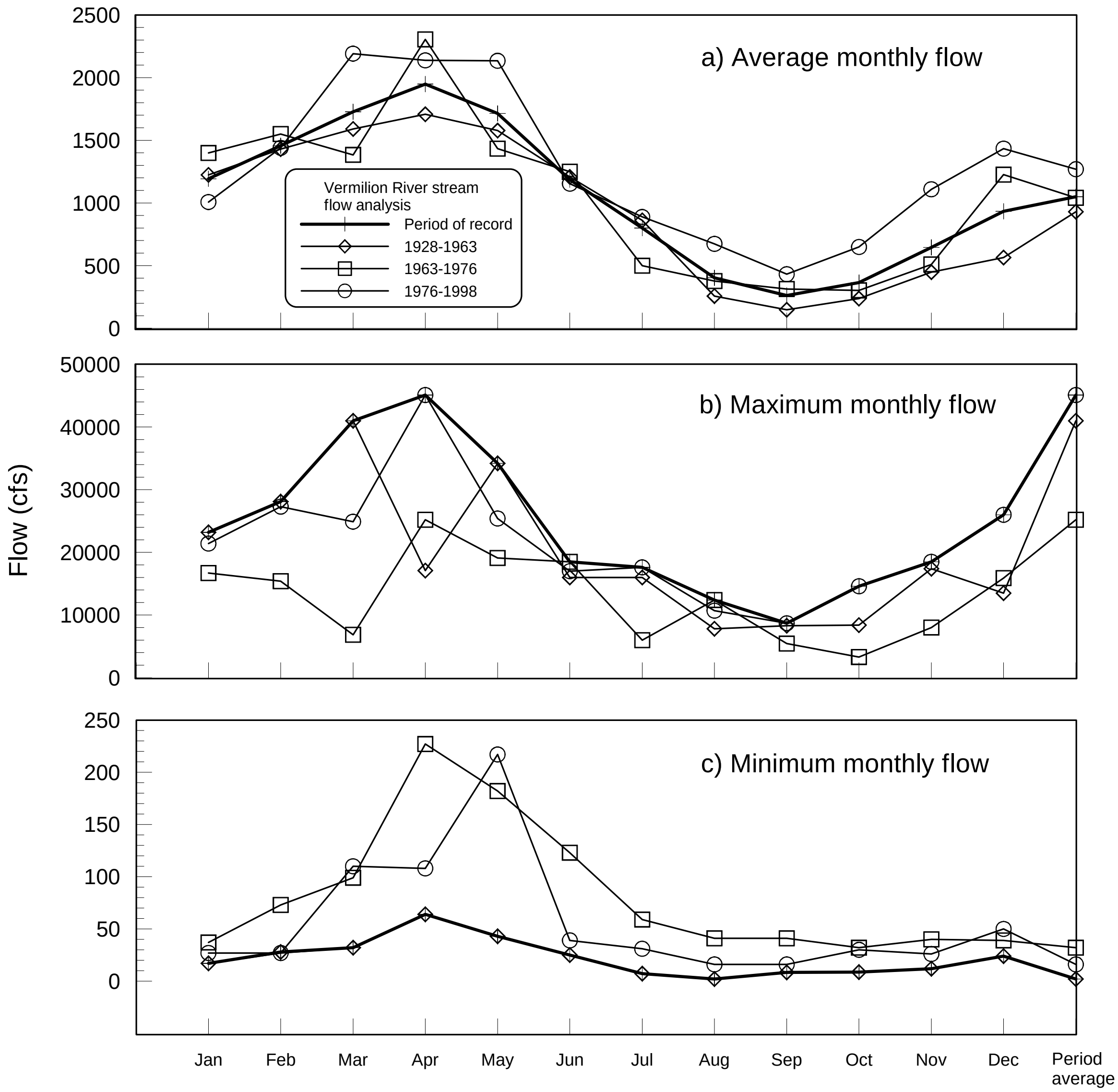
Table 2. Computed Sediment Delivery Rates from the Watershed for Each Sedimentation Period

	Annual deposition rates			
Period	*acre-feet*	*acre-feet per square mile*	*cubic feet per acre*	*tons per acre*
1925-1963	89.5	0.30	20.4	0.52
1963-1976	50.2	0.17	11.5	0.28
1976-1998	53.9	0.18	12.3	0.28
1925-1998	71.8	0.24	16.4	0.40

Note: Total watershed area is 298 square miles.

Table 3. Capacity Loss Rates (percent) Relative to the Original Lake Capacity

Period	*Per period*	*Cumulative*	*Period annual loss*	*Cumulative annual loss*
1925-1963	25.7	25.7	0.68	
1963-1976	4.9	30.7	0.38	
1976-1998	9.0	39.7	0.41	0.54



Note: Maximum and minimum lines and symbols for sub-periods are hidden when they are coincident with the period of record (heavier line) in the figure.

Figure 5. Comparison of a) average monthly flow, b) maximum monthly flow, c) minimum monthly flow for the Vermilion River near Danville for the three sedimentation periods (1928-1963, 1963-1976, and 1976-1998) and the full record of the station

sedimentation are the maximum flows and the average flows. High sediment transport rates are closely related to peak water discharge periods (Demissie et al., 1983; Bhowmik et al., 1993). The plots in figure 5 indicate that average flows for most months have been higher during the most recent (1976-1998) sedimentation study period for Lake Vermilion. This observation is consistent with statistical analyses of streamflow records presented in IDNR (1999), which indicate that average streamflow since 1965 has been 20 percent higher than in previous years. This increase in flow was observed to coincide with an increase in annual precipitation. This suggests that sediment delivery to the lake should be somewhat higher during the latter two survey periods. Instead, the latter two survey periods show lower sedimentation relative to the 1925-1963 period. This suggests that other watershed conditions have been larger factors in determining Lake Vermilion sedimentation rates.

The trap efficiency (percentage portion of sediment captured by the reservoir) of the lake was determined using a predictive equation developed by Dendy (1974) based on the relationship between the annual capacity to inflow ratio and sediment-holding capacity. The trap efficiency of Lake Vermilion was 75 percent in 1925, meaning that 75 percent of all sediment entering the lake was trapped in the lake basin. In the following years, as sediment accumulation reduced the volume of the basin, the holding time for water entering the lake was reduced. This reduction in holding time meant that there was less time for sediment to drop out of suspension and the trap efficiency was reduced. By 1963 and 1976, the trap efficiency was reduced to 67 and 65 percent, respectively. The 1991 increase in spillway elevation meant that the lake basin volume was again increased thereby increasing trap efficiency to 74 percent.

Gradual consolidation of lake sediments affects the calculated sedimentation rate of the lake by reducing the volume of accumulated sediments. Sediments accumulate on the bottom of the lake in a very loose, fluid mass. As these sediments are covered by continued sedimentation or are exposed by occasional lake drawdown, they are subject to compaction. This process reduces the volume of the sediments while increasing the weight per unit volume. Thus, the tonnage of the sediments accumulated during a period of time will not change, but the volume of the sediments may be reduced over time by up to 50 percent. This is also consistent with a reduced volumetric sedimentation rate over time. Consolidation of sediments would be most pronounced in the north end of Lake Vermilion. The exposure of sediment in the terrestrial deposits previously mentioned and the shallow water deposits that are subject to frequent exposure due to lake level drawdown would be consolidated on an annual basis.

Overall, sedimentation rates for Lake Vermilion were high for the initial period (1925-1963) with a possible range of 69 to 89 ac-ft per year. Sedimentation rates for subsequent periods (1963-1976 and 1976-1998) have been considerably lower with slight variations that may reflect variations in streamflow conditions.

Sediment Distribution

The distribution of sediment in the lake is shown in table 4. This table lists the average sediment thickness and mass distribution for the lake and for each lake calculation segment as shown in figure 2. Sediment thickness ranges from 2.3 to 9.3 feet. The most significant accumulation by either measure, depth or mass, is in the segments north of Denmark Road and north beyond the old dam.

Density analyses of the sediment samples (appendix II) indicate that sediment north of the old dam has greater unit weight than sediment south of the old dam. In general, coarser sediments are expected to be deposited in the upstream portion of a lake where the entrainment velocity of the stream is reduced to the much slower velocities of a lake environment. These coarser sediments tend to be denser when settled and are subject to drying and higher compaction rates as a result of more frequent drawdown exposure in the shallow water environment. As the remaining sediment load of the stream is transported through the lake, increasingly finer particle sizes and decreasing unit weight are observed.

Sediment Particle Size Distribution

A total of 16 lakebed sediment samples were collected for particle size distribution analysis. The laboratory analyses for these samples are presented in figure 6. The analyses shown in figure 6a and 6b are particle size distribution plots for samples collected from the top surface of the accumulated sediments. These samples show extremely uniform characteristics south of the old dam area (figure 6a). Surface sediment samples collected north of the old dam show a tendency to become slightly finer from upstream to downstream. This reduction in deposited sediment particle sizes is consistent with all other Illinois impoundment lakes for which particle size distribution data are available. This trend in particle-size distribution is a result of the natural sorting of suspended sediments in the lake environment. Coarser sediments are deposited as the inflowing stream water is first slowed upon entering the lake. As water moves through the lake, the suspended sediments become finer as the coarser-sized fractions fall out of suspension. At the dam, the suspended sediments are predominantly composed of colloidal and organic materials.

Field examination of two samples indicated sand size material (figure 6c). Both samples were collected in the near-channel areas of the north end of the lake. All other samples were composed of clay and fine silt size sediment materials. This would be consistent with general observations concerning sediment distribution in Illinois lakes (Fitzpatrick et al., 1987; Bogner, 1986). These and other sources indicate that the occurrences of sand exceeding 10 percent are unusual for samples collected from lake sediments. In this case the sand was associated with the redevelopment of the stream channel since 1991.

Three sets of samples (figure 6d) were collected to analyze vertical variations in particle size distribution. These samples show a temporal trend toward finer sediments in the surface layer at each sample site. This observation is counter to the usual trend in lake sediments. Surficial sediment, the most recently deposited sediment, tends to be coarser with time at a given point. This is due to the downlake shift in the initial depositional environment of the lake due to the loss of trap efficiency of the upper end of the lake. With time, the initial depositional zone in the lake will move further down the lake because of water volume loss to sedimentation. For Lake Vermilion, this tendency was interrupted by the 1991 spillway increase, which re-established upstream sediment storage capacity.

Table 4. Sediment Distribution in Lake Vermilion

Segment from figure 2	*Sediment accumulation (ac-ft)*	*Sediment weight (tons)*	*Sediment thickness (feet)*	*Sediment per segment acre (tons)*
1	19	13,769	7.1	5,296
2	137	110,387	7.9	6,344
3	560	464,383	5.6	4,648
4	66	54,647	6.1	5,060
5	692	609,088	6.2	5,497
6	125	120,385	2.6	2,498
8	671	648,726	8.1	7,844
9	876	770,804	9.2	8,071
11	598	836,437	9.3	13,069
12	267	368,044	6.7	9,224
13	22	29,223	4.9	6,641
14	154	207,648	4.8	6,469
15	195	267,294	6.3	8,622
16	233	320,873	6.8	9,382
17	283	381,766	4.9	6,548
19	341	420,928	2.3	2,879
Totals	5,238	5,624,404	6.0	6,406

Note: Several lake segments have been combined in this analysis. The segment number listed is the lower numbered segment.

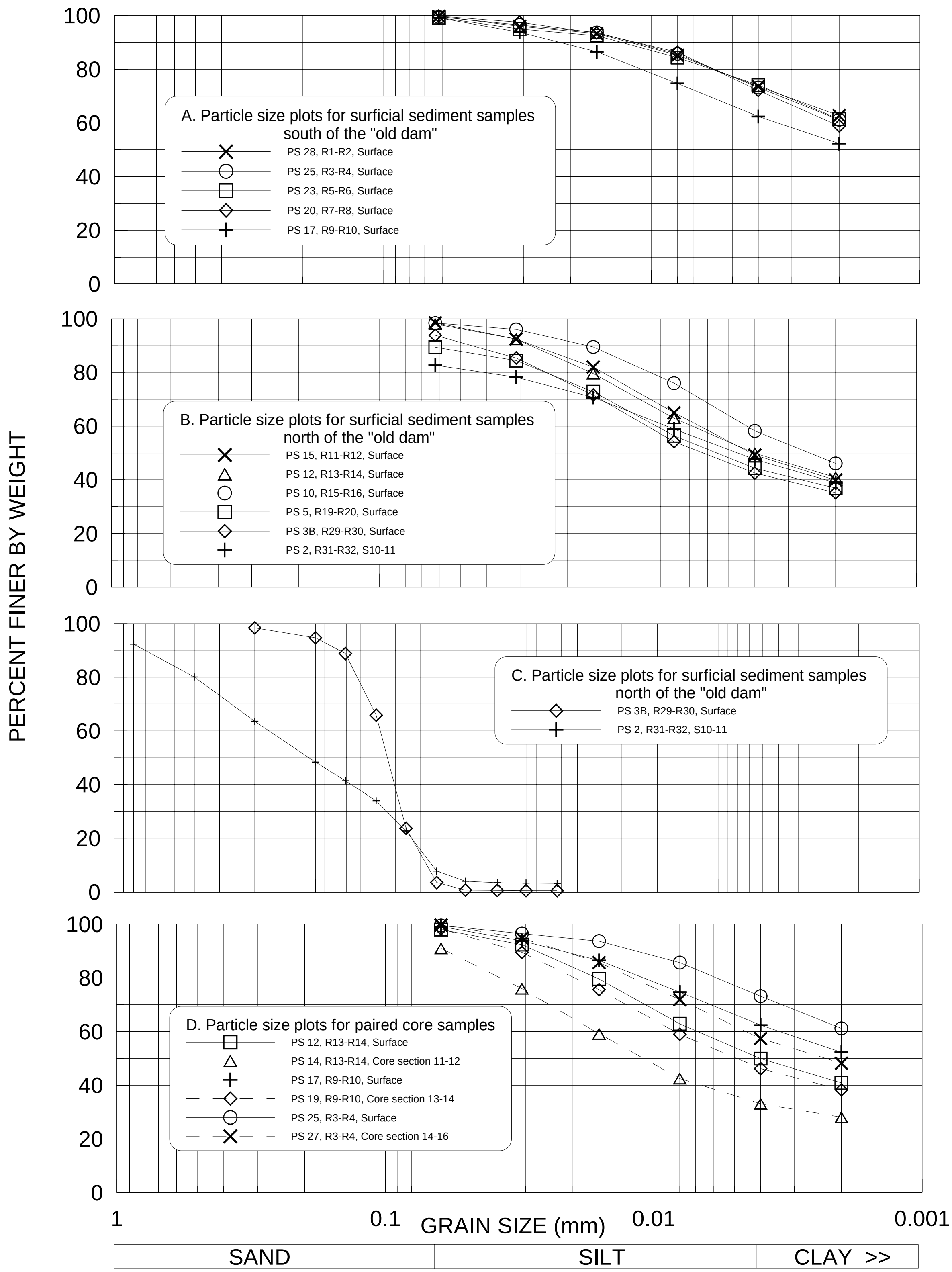


Figure 6. Particle size (ps) distributions for Lake Vermilion sediment samples

Evaluation

Maintaining the water supply storage capacity of Lake Vermilion is essential for the maintenance of an adequate water supply for Danville. In addition to water supply, Lake Vermilion also provides a much needed water-based recreational resource for the Vermilion County area.

Capacity loss rate (0.54 percent per year) and watershed sediment yield rate (0.40 tons per acre) of the lake and its watershed over the 1925-1998 period are about average for Illinois impoundment lakes.

To avoid potential confusion, the sedimentation rates presented by the 1963 and 1976 sedimentation studies have not been included in this report. Values presented in the earlier reports reflect only water volume displacement at the then existing operational pool level. Values in this report include deposits that were above water level in the earlier surveys.

The capacity loss rate of 0.54 percent per year determined by this study is considerably lower than the values in the 1963 (0.98 percent per year) and 1977 (0.88 percent per year) reports. The values in this report were calculated in reference to the 1925 potential lake basin capacity at the present spillway level. If the 1998 sediment volume were referenced to the 1976 determination of the 1925 basin volume, the capacity loss rate would have been 0.84 percent per year.

Summary

The Illinois State Water Survey has conducted a sedimentation survey of Lake Vermilion in Danville, Illinois. The lake, originally constructed in 1925, is the raw water source Danville public water supply. Previous lake sedimentation surveys were conducted in 1963 and 1976.

The operating elevation for the reservoir was increased from 576 feet NGVD to 582.2 feet NGVD in 1991. This modification increased storage capacity of the lake by approximately 4,600 ac-ft. Analysis of sedimentation rates for this larger storage capacity required the introduction of the term potential capacity for the reservoir for 1925-1991. The potential reservoir capacity was defined as the capacity of the reservoir if the basin formed by the valley had been filled to the level of the 1991 spillway.

Sedimentation has reduced the potential capacity of Lake Vermilion from 13,209 ac-ft (4,304 million gallons) in 1925 to 7,971 ac-ft (2,597 million gallons) in 1998. The sediment accumulation rates in the lake have averaged 71.8 ac-ft per year from 1925-1998. Annual sedimentation rates for three separate periods, 1925-1963, 1963-1976, and 1976-1998 were 89.5, 50.2, and 53.9 ac-ft, respectively.

Earlier lake structures affect the lake as it exists in 1999. These early structures also affected the ability to analyze the present sedimentation rate.

The 1914 structure (the old dam) impounded water in what is now the upstream, northern half (lengthwise) of the present lake. This structure caused an undocumented amount of sedimentation in the affected lake segments. This sedimentation is included in the calculated sedimentation volume for the 1925-1963 survey period. On the basis of a 38-year (1925-1963) or a 49-year sedimentation period (1914-1963), the average annual sedimentation rate for the lake would be 89.5 and 69.4 ac-ft per year, respectively. Either rate is considerably higher than subsequent rates. The adjustment of the earlier volumes included an accounting of above water-level deposits for the 1963 and 1976 survey calculations and slightly increased the reported sediment volumes for those surveys. The change in reference capacity also significantly altered the presented sedimentation rates in percent of original volume.

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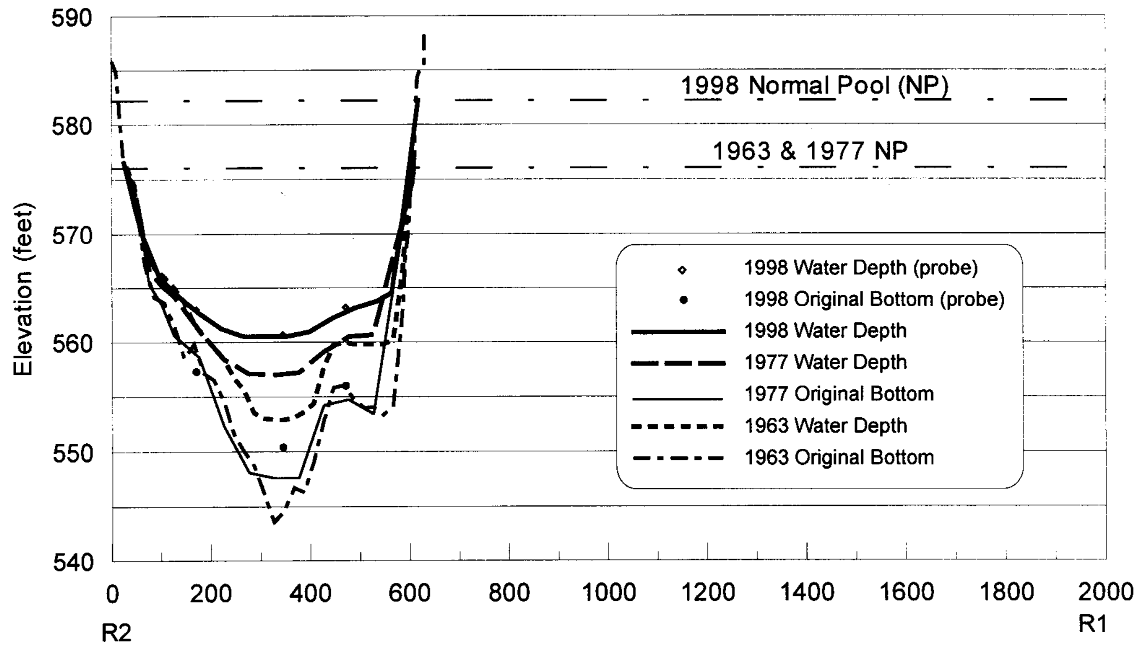
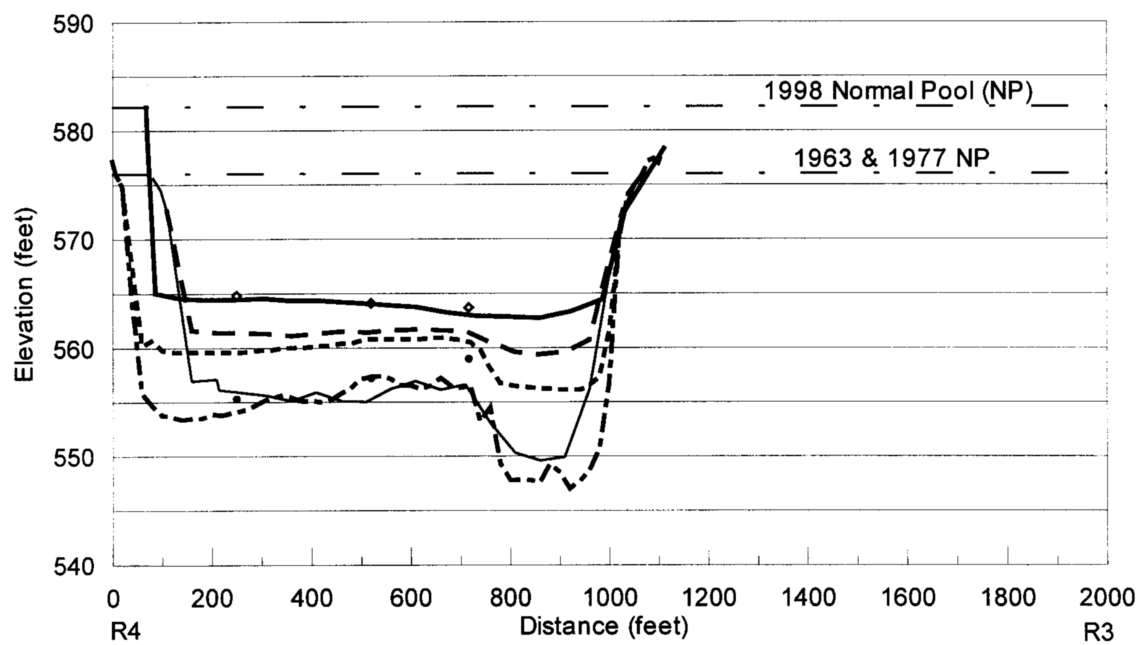
Appendix I. Cross-Section Plots of the Lake Vermilion Transects

R2-R1



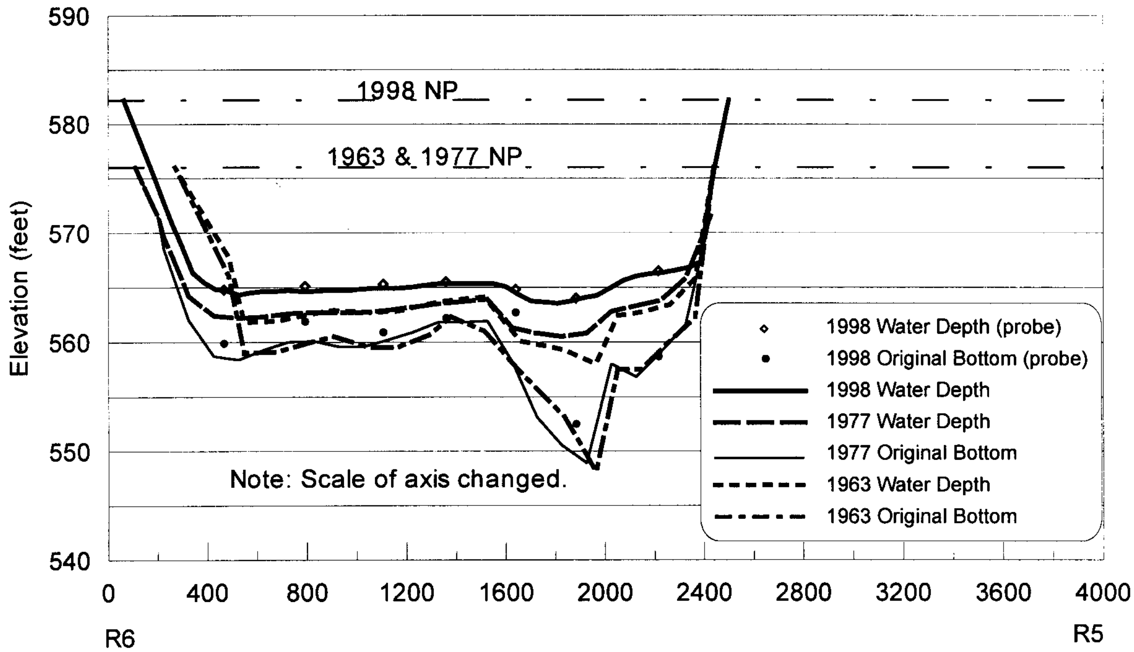
590
580
570
560
550
540
Elevation (feet)
1998 Normal Pool (NP)
1963 & 1977 NP
1998 Water Depth (probe)
1998 Original Bottom (probe)
1998 Water Depth
1977 Water Depth
1977 Original Bottom
1963 Water Depth
1963 Original Bottom
0 200 400 600 800 1000 1200 1400 1600 1800 2000
R2
R1

R4-R3

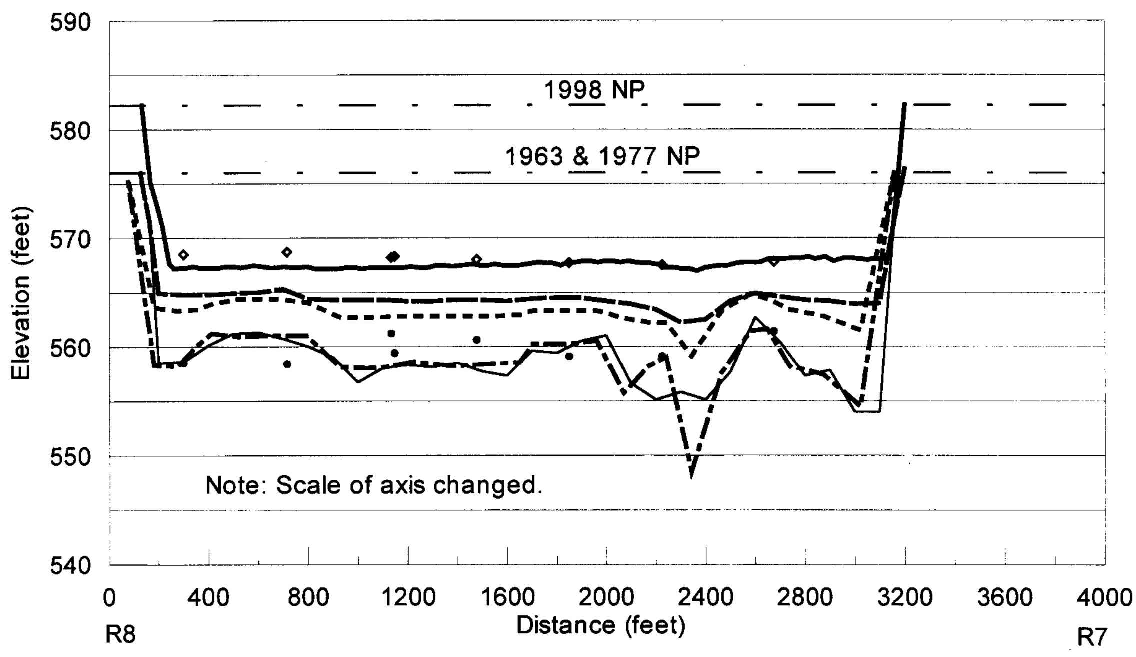


590
580
570
560
550
540
Elevation (feet)
1998 Normal Pool (NP)
1963 & 1977 NP
0 200 400 600 800 1000 1200 1400 1600 1800 2000
R4
Distance (feet)
R3

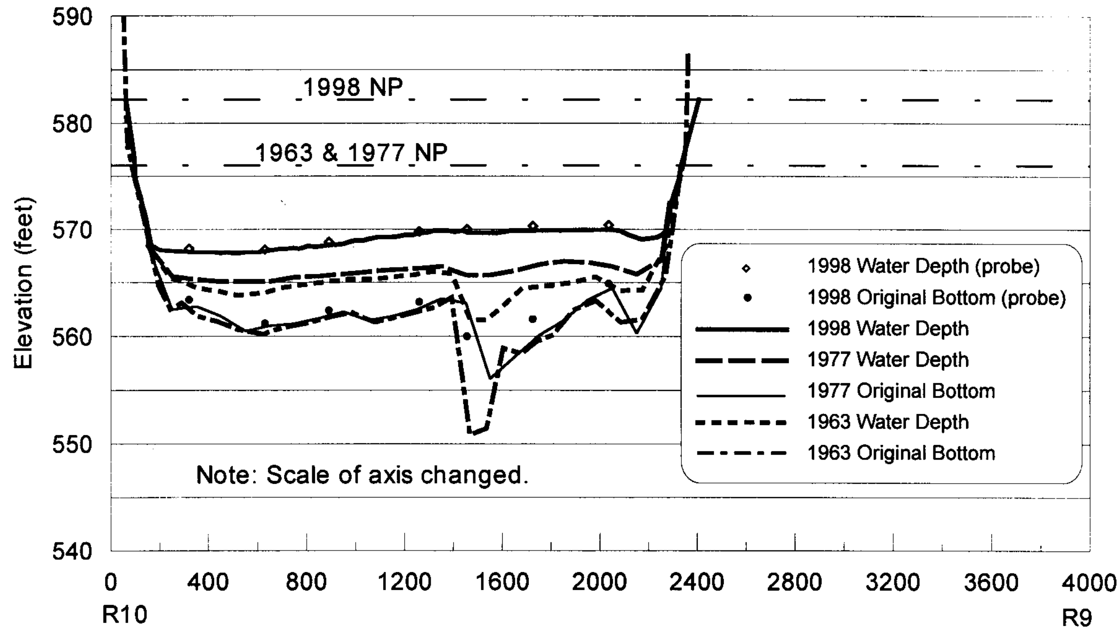
R6-R5


590
580
570
560
550
540
Elevation (feet)
1998 NP
1963 & 1977 NP
Note: Scale of axis changed.
1998 Water Depth (probe)
1998 Original Bottom (probe)
1998 Water Depth
1977 Water Depth
1977 Original Bottom
1963 Water Depth
1963 Original Bottom
0
400
800
1200
1600
2000
2400
2800
3200
3600
4000
R6
R5

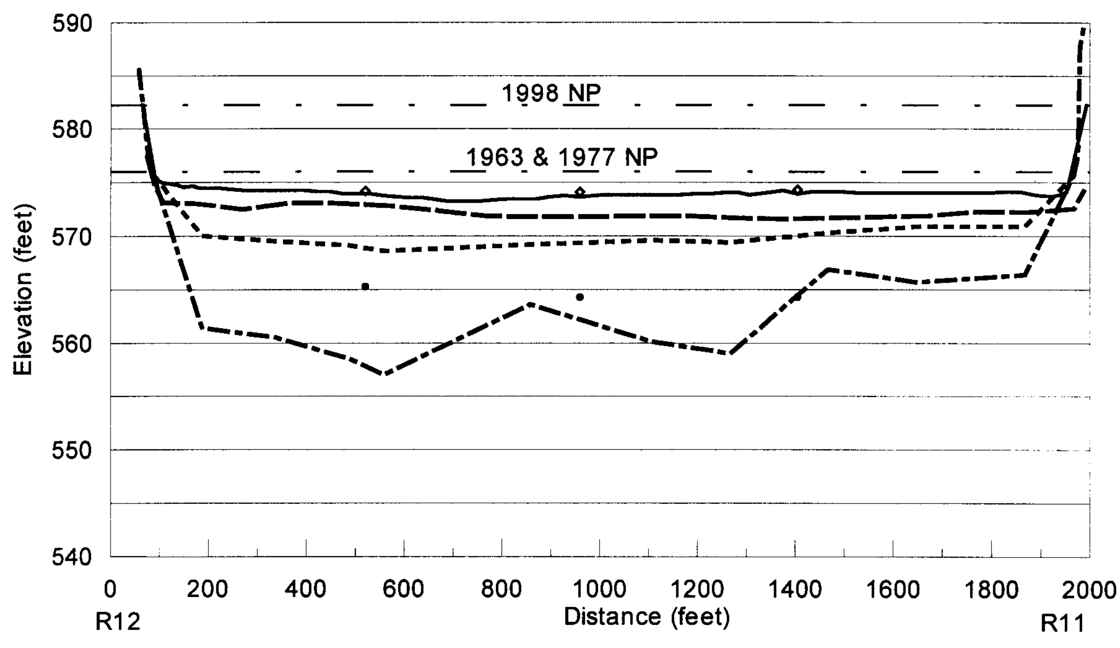
R8-R7

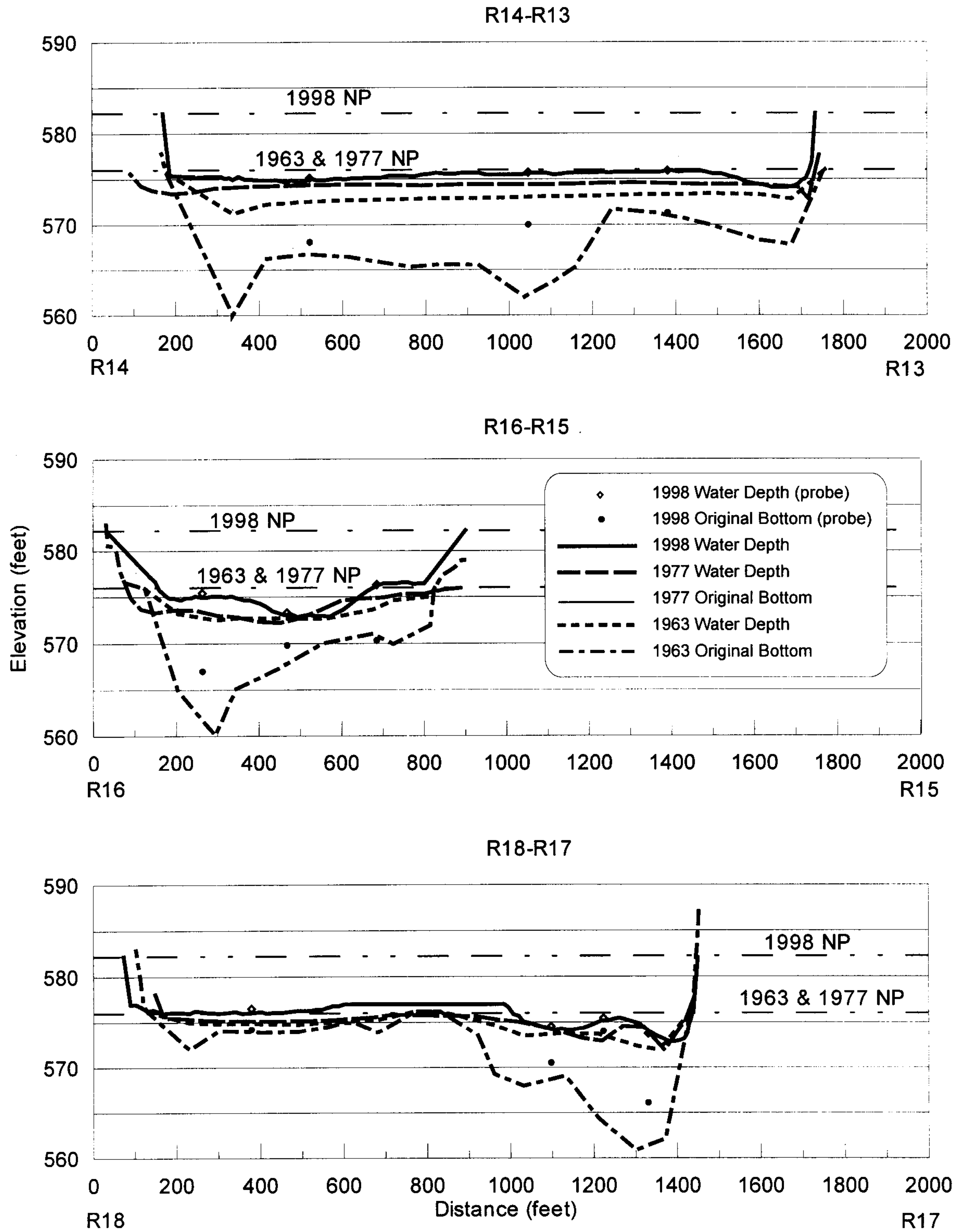

590
580
570
560
550
540
Elevation (feet)
1998 NP
1963 & 1977 NP
Note: Scale of axis changed.
0
400
800
1200
1600
2000
2400
2800
3200
3600
4000
R8
Distance (feet)
R7

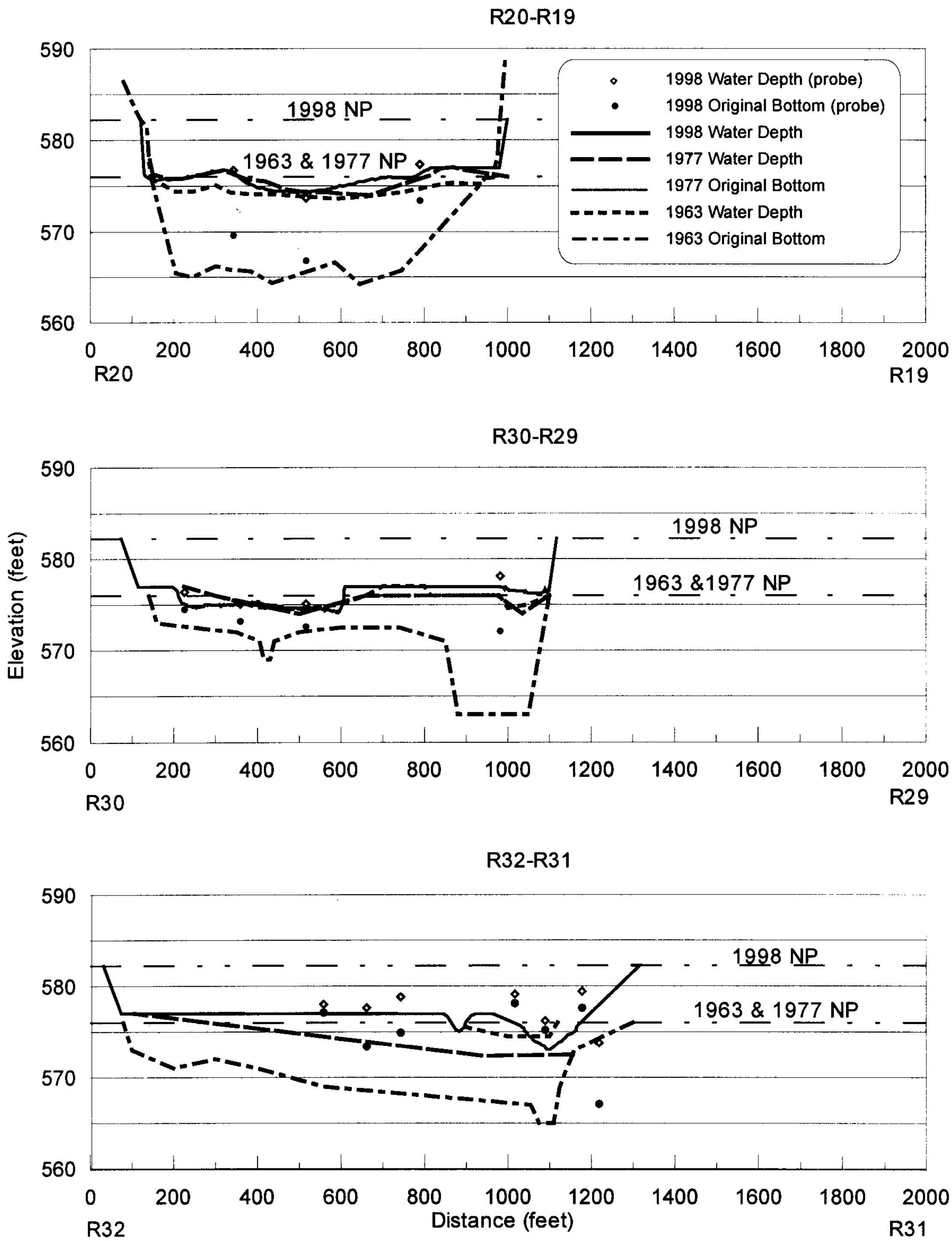
R10-R9

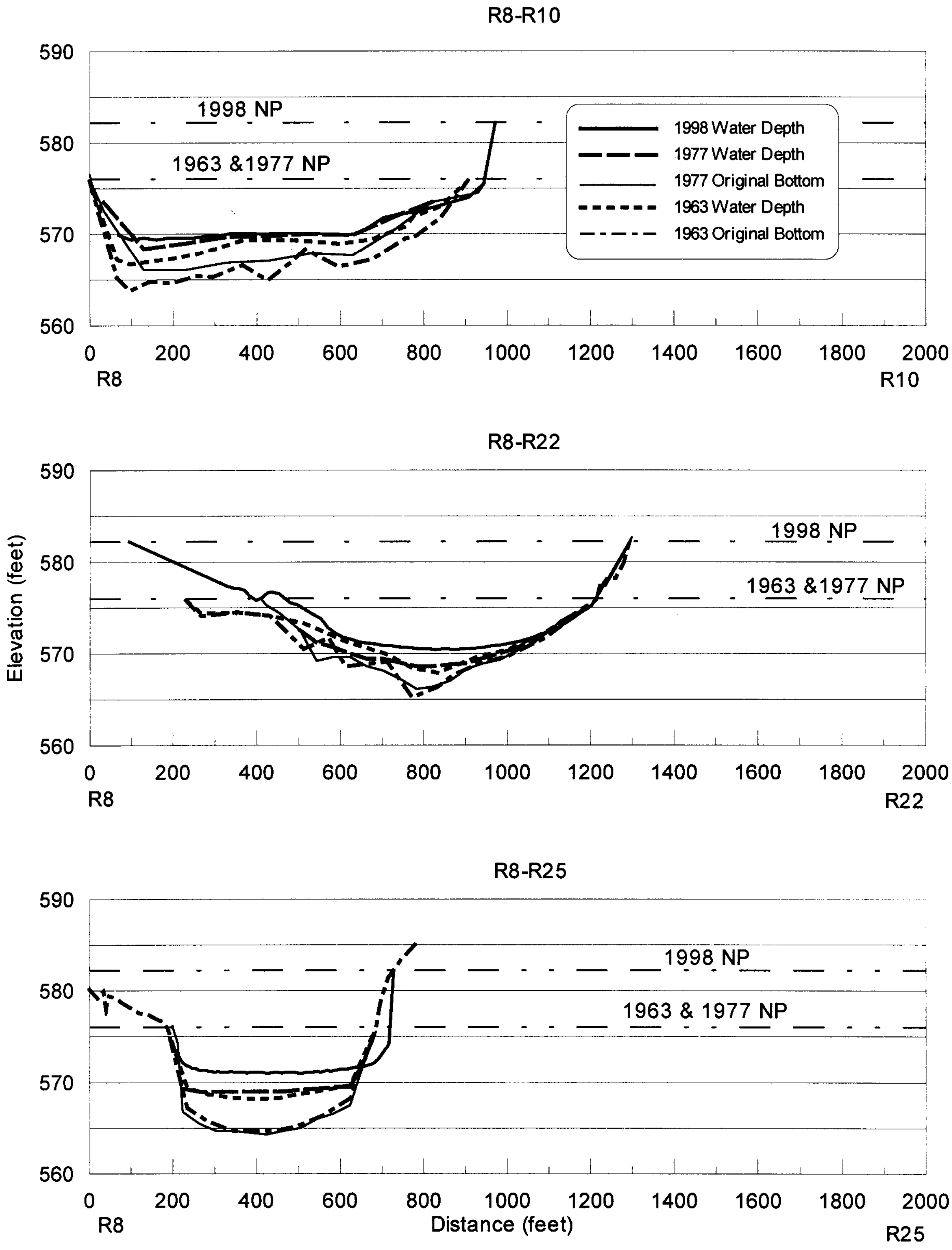


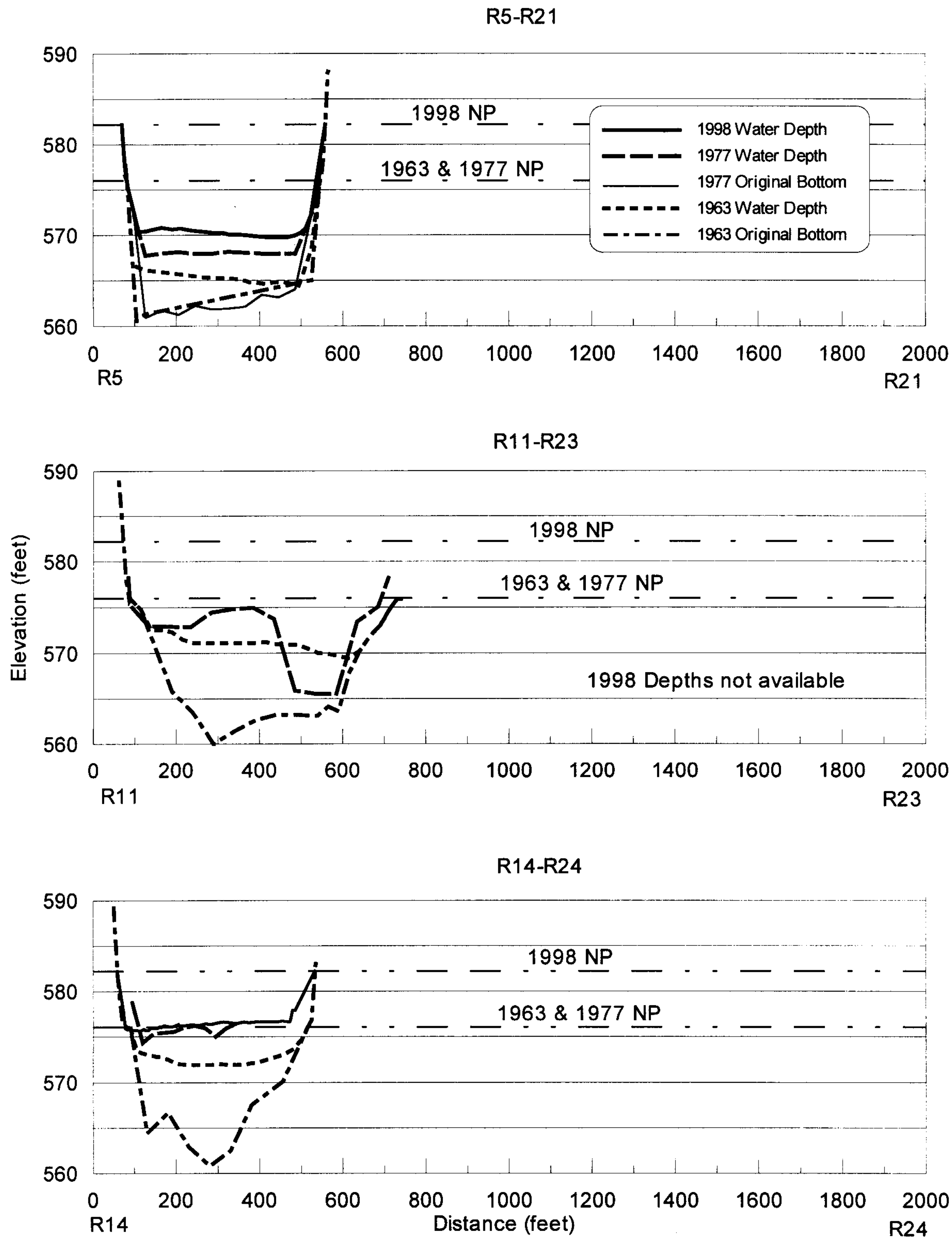
R12-R11




R14-R13
590
580
570
560
0
200
400
600
800
1000
1200
1400
1600
1800
2000
R14
R13
1998 NP
1963 & 1977 NP
R16-R15
Elevation (feet)
590
580
570
560
0
200
400
600
800
1000
1200
1400
1600
1800
2000
R16
R15
1998 NP
1963 & 1977 NP
1998 Water Depth (probe)
1998 Original Bottom (probe)
1998 Water Depth
1977 Water Depth
1977 Original Bottom
1963 Water Depth
1963 Original Bottom
R18-R17
590
580
570
560
0
200
400
600
800
1000
1200
1400
1600
1800
2000
R18
Distance (feet)
R17
1998 NP
1963 & 1977 NP


R20-R19
590
580
570
560
0
200
400
600
800
1000
1200
1400
1600
1800
2000
R20
R19
1998 NP
1963 & 1977 NP
1998 Water Depth (probe)
1998 Original Bottom (probe)
1998 Water Depth
1977 Water Depth
1977 Original Bottom
1963 Water Depth
1963 Original Bottom
R30-R29
R30
R29
1998 NP
1963 &1977 NP
Elevation (feet)
R32-R31
R32
R31
1998 NP
1963 & 1977 NP
Distance (feet)


R8-R10
1998 NP
1963 &1977 NP
1998 Water Depth
1977 Water Depth
1977 Original Bottom
1963 Water Depth
1963 Original Bottom
R8
R10
R8-R22
1998 NP
1963 &1977 NP
R8
R22
R8-R25
1998 NP
1963 & 1977 NP
R8
R25
Elevation (feet)
Distance (feet)
590
580
570
560
0
200
400
600
800
1000
1200
1400
1600
1800
2000


R5-R21
1998 NP
1963 & 1977 NP
1998 Water Depth
1977 Water Depth
1977 Original Bottom
1963 Water Depth
1963 Original Bottom
R5
R21
R11-R23
1998 NP
1963 & 1977 NP
1998 Depths not available
Elevation (feet)
R11
R23
R14-R24
1998 NP
1963 & 1977 NP
R14
Distance (feet)
R24

Appendix II. Sediment Core Sample Unit Weight Results

Sample number	*Location*	*Sediment layers*	*Unit weight (pounds per cubic foot)*
1	R31-R32	7-10	65.1
4	R29-R30	4-7	41.4
6	R19-R20	2-5	40.3
7	R19-R20	13-16	56.9
9	R17-R18	15-18	85.2
11	R15-R16	5-8	47.7
13	R13-R14	8-11	65.5
16	R11-R12	7-10	61.1
18	R9-R10	10-13	48.4
21	R7-R8	3-6	42.2
22	R7-R8	15-18	42.5
24	R5-R6	9-12	36.5
26	R3-R4	11-14	39.7
29	R1-R2	10-13	34.1

Appendix III. Sediment Particle Size Distribution Sample Results

Particle size (millimeters)	*Sample number* PS 2 R31-R32	PS 3B R29-R30	PS 5 R19-R20	PS 10 R15-R16	PS 12 R13-R14	PS 14 R13-R14 section 11-12
0.062	83	94	89	98	98	91
0.031	78	85	84	96	92	76
0.016	71	72	73	90	80	59
0.008	59	54	56	76	63	43
0.004	48	43	44	58	50	33
0.002	39	35	37	46	41	28

Particle size (millimeters)	*Sample number* PS 15 R11-R12	PS 17 R9-R10 Section 13-14	PS 19 R9-R10	PS 20 R7-R8	PS 23 R5-R6	PS 25 R3-R4 Section 14-16
0.062	99	99	98	100	99	100
0.031	92	94	90	98	95	97
0.016	82	87	76	94	93	94
0.008	65	75	59	86	84	86
0.004	49	62	46	72	74	73
0.002	40	52	38	59	61	61

Particle size (millimeter)	*Sample number* PS 27 R3-R4	PS 28 R1-R2
0.062	100	100
0.031	95	96
0.016	86	93
0.008	72	85
0.004	57	74
0.002	48	63

Appendix III. Concluded

	Sample number	
Particle size (millimeter)	*PS 3 R31-R32*	*PS 8 R17- R18* Section 0-6
8	92	
4	80	
2	64	98
1	48	95
0.71	41	89
0.5	34	66
0.355	23	24
0.25	8	4
0.18	4	1
0.125	3	1
0.09	3	1
0.063	3	1

Illinois State WATER Survey (1895)

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