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State Water Survey Division

SURFACE WATER SECTION

AT THE

UNIVERSITY OF ILLINOIS

Illinois Department of Energy and Natural Resources

SWS Contract Report 385

EXECUTIVE SUMMARY:
SEDIMENT MANAGEMENT FOR HORSESHOE LAKE AND ITS WATERSHED, ALEXANDER COUNTY, ILLINOIS

by

Ming T. Lee, Nani G. Bhowmik, Paul B. Makowski, Donald S. Blakley, Raman K. Raman, William C. Bogner, and William P. Fitzpatrick

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Introduction

The Illinois State Water Survey has conducted a diagnostic and feasibility study of sediment management for Horseshoe Lake, Alexander County, Illinois, for the Illinois Department of Conservation through a grant from the U.S. Fish and Wildlife Service. Horseshoe Lake is located near the Mississippi River as shown in figure 1.

Objectives of the Study

The objectives of this study are to:

- Determine the sedimentation rate at Horseshoe Lake,
- Analyze pertinent lake water quality parameters,
- Develop a lake hydrologic budget,
- Identify major sources of sediment by utilizing sediment budget analysis techniques, and
- Develop and evaluate a sediment management plan based on the gathered data and existing information.

Data Collection

An 18-month data collection and evaluation program was conducted. Three stream gaging stations and two raingages were established to measure rainfall, runoff, and suspended sediment loads in the watershed. The lake water quality was monitored monthly at five locations. The water quality parameters that were monitored consist of dissolved oxygen, temperature, secchi disc transparencies, pH, alkalinity, turbidity, total solids, suspended solids, suspended volatile solids, total phosphorus, total dissolved phosphorus, ammonia-nitrogen, and nitrate-nitrogen. A lake sedimentation survey was performed to determine the sedimentation rate. Three ground-water monitoring wells were installed in May 1985. This effort will continue for another year.

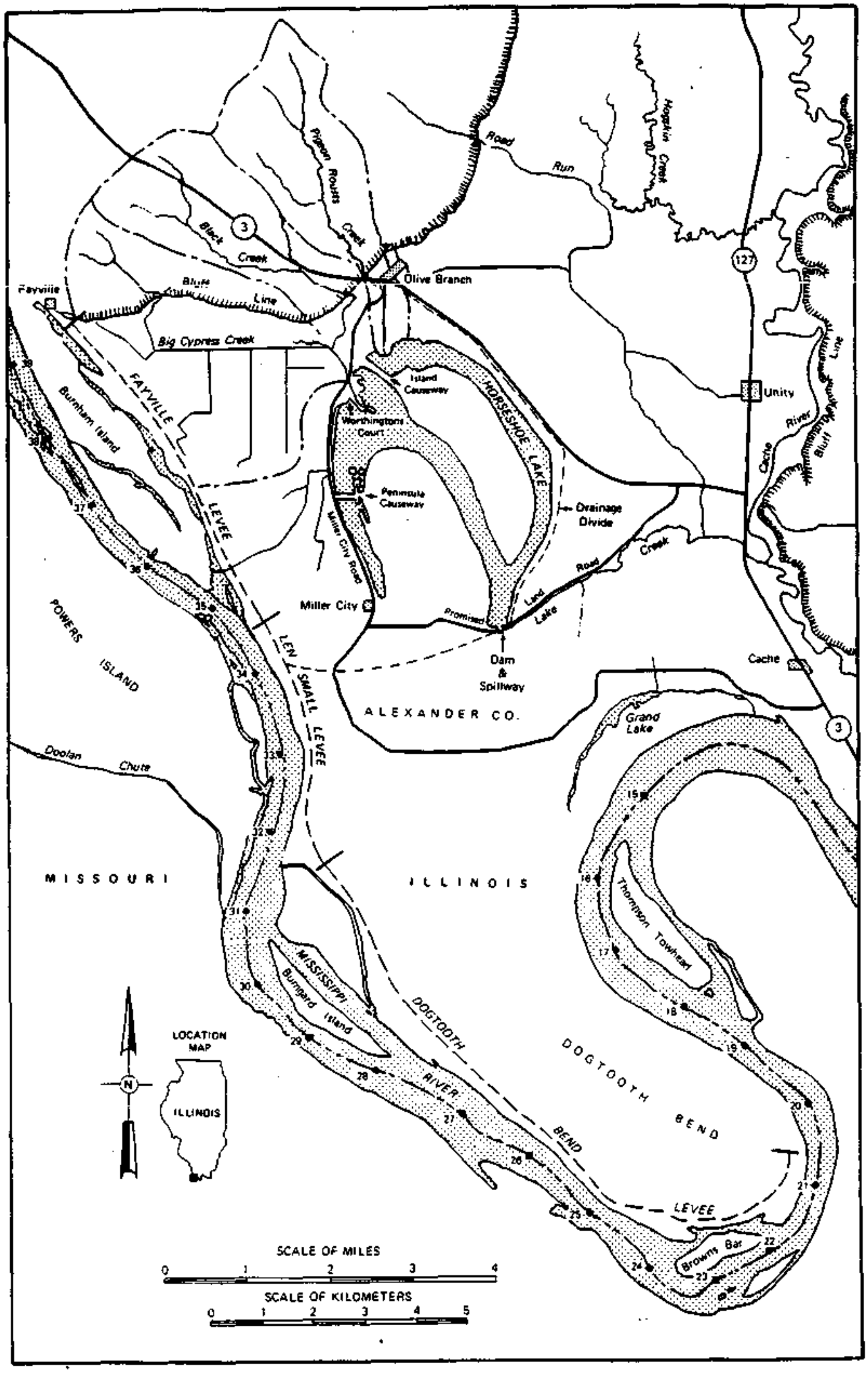

Figure 1. Location map for Horseshoe Lake, Alexander County, Illinois

Analysis

The results of the lake sedimentation survey indicated that a total of 2808 acre-feet of sediment accumulated in Horseshoe Lake from 1951 through 1984, which represents an annual sedimentation rate of 78.6 acre-feet. If this rate continues, 50 percent of the lake capacity will be lost to sedimentation by the year 2022, and the lake will be completely full of sediment by 2060. In terms of depletion of water depth, the sediment survey indicated that the lake is losing its depth at a rate of 0.47 inches per year. The results also showed that the sediment accumulation generally decreased from north to south, and that the east branch of the lake has a higher rate of sedimentation than the central branch (Figure 1). The main reason for the lower sedimentation rate at the middle branch may be the flushing action of Mississippi floodwaters which mainly passed through the middle branch of the lake prior to the closing of the river levee (Fayville Levee). In terms of sediment weight, 1,150,000 tons of sediment were deposited from 1951 to 1984, or 33,900 tons per year, or 2.58 tons per acre per year from the watershed. The organic content of Horseshoe Lake sediment ranges from 10.2 to 17.5 percent, which is considerably higher than that of man-made lakes in Illinois.

The lake water quality study indicated that temperatures were uniform through the water column at any given time. However, the dissolved oxygen concentrations tend to exhibit a significant gradient during summer months from supersaturated conditions near the surface to totally anoxic conditions near the bottom. The lake's sediment oxygen demand rates ranged from 4.04 to 6.58 mg per liter per day at 25.5 C. These results are indicative of a very high organic enrichment of the bottom sediments. The mean secchi disc values varied from 19 inches to 23 inches. The mean turbidity values for the lake ranged from 17 to 26 NTU. The suspended matter in the lake was predominantly volatile and consequently organic in nature. The mean phosphorus values ranged from 0.03 to 0.06 mg/l, which is much higher than the commorrreported critical level from the perspective of eutrophication. However, the inorganic nitrogen concentrations were below the critical level of 0.3 mg/1 for nitrogen. The lake experienced algal booms with densities greater than 500 counts/ml during late spring and summer months.

The 13-month hydrologic budget of Horseshoe Lake was established. The inflows consist of 64 inches of direct rainfall on the lake, 34 inches of runoff from the watersheds, and 8.4 inches of Mississippi River backwater. The outflows consist of 37 inches of lake evaporation, 1.2 inches of infiltration to the ground water, and 33 inches of flow over the spillway. There was a net gain of 35 inches of water at the end of April 1985.

Similarly, the sediment budget of the same period was also developed. The sediment yield which was delivered to Horseshoe Lake was assessed as 15,200 tons from its watersheds, 218 tons from the Mississippi River backwater, and 1,147 tons passed over the spillway. Consequently, it was estimated that 14,288 tons deposited in the lake. This value is below the long-term average inorganic sedimentation rate which was 30,400 tons based on the 1984 sediment survey. This deviation can be explained as follows:

The instream sediment data were collected for a period of 13 months only. This period may not be a representative period as far as the long term sediment inflow to the lake is concerned.

Feasibility Study and Alternative Solutions

In order to extend the useful life of Horseshoe Lake, a number of schemes for controlling sediment input and removing sediment were investigated. The intent of feasibility studies is to make comparisons among alternatives. For future implementation, much more detailed design and cost analyses will be required.

The unit prices for determining costs were obtained from local contractors, the Illinois Department of Transportation (IDOT), and the U.S. Corps of Engineers (USCOE). *The costs of land acquisition were not included.* It was assumed that, for comparable costs, the project had a 40-year life. All monetary figures are present worth. Future cash outlays were computed to present worth by using a 7.125 percent discount rate.

In-Stream Sediment Management

Instream sediment management techniques include the following alternatives:

I. Channel Diversion -- These alternatives would decrease future sediment delivery to Horseshoe Lake. This would be accomplished by diverting the major sources of sediment, Pigeon Roost and Black Creeks, during high flows. Four diversion schemes were investigated. These alternatives are shown in Figures 2 and 3.

1. Diversion to the Mississippi River

This alternative would route Pigeon Roost Creek through a diversion structure located in Black Creek. The flow of drainage through Big Cypress Swamp would be reversed to a point just before the levee. From this point a pump station would be used to get the water over the levee to the Mississippi River.

The initial cost of the pump station and appurtenant material is $11.8 million with a maintenance cost of $0.66 million. The initial cost of the channel is $1.56 million. The other costs including bridge replacement, diversion structure, and tree removal are estimated as $0.29 million. The total cost is $13.7 million.

2. Diversion along Route 3 to Lake Creek

This alternative would take the entire Black Creek flow to a control structure in Pigeon Roost Creek. The channel would then travel a path along the old channel of Pigeon Roost Creek to join Lake Creek just west of Route 3.

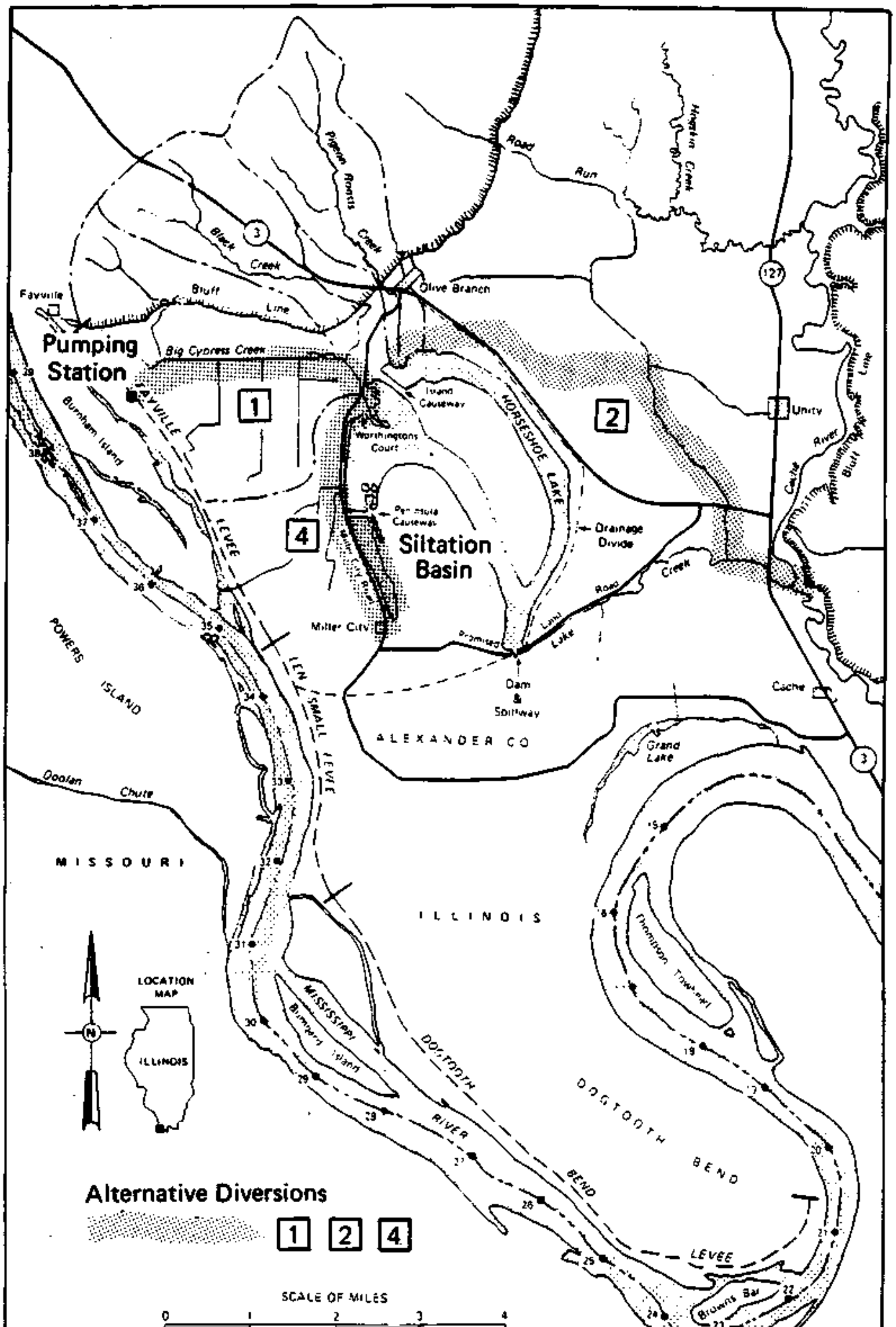

Figure 2. In-stream sediment management alternatives 1, 2, and 4

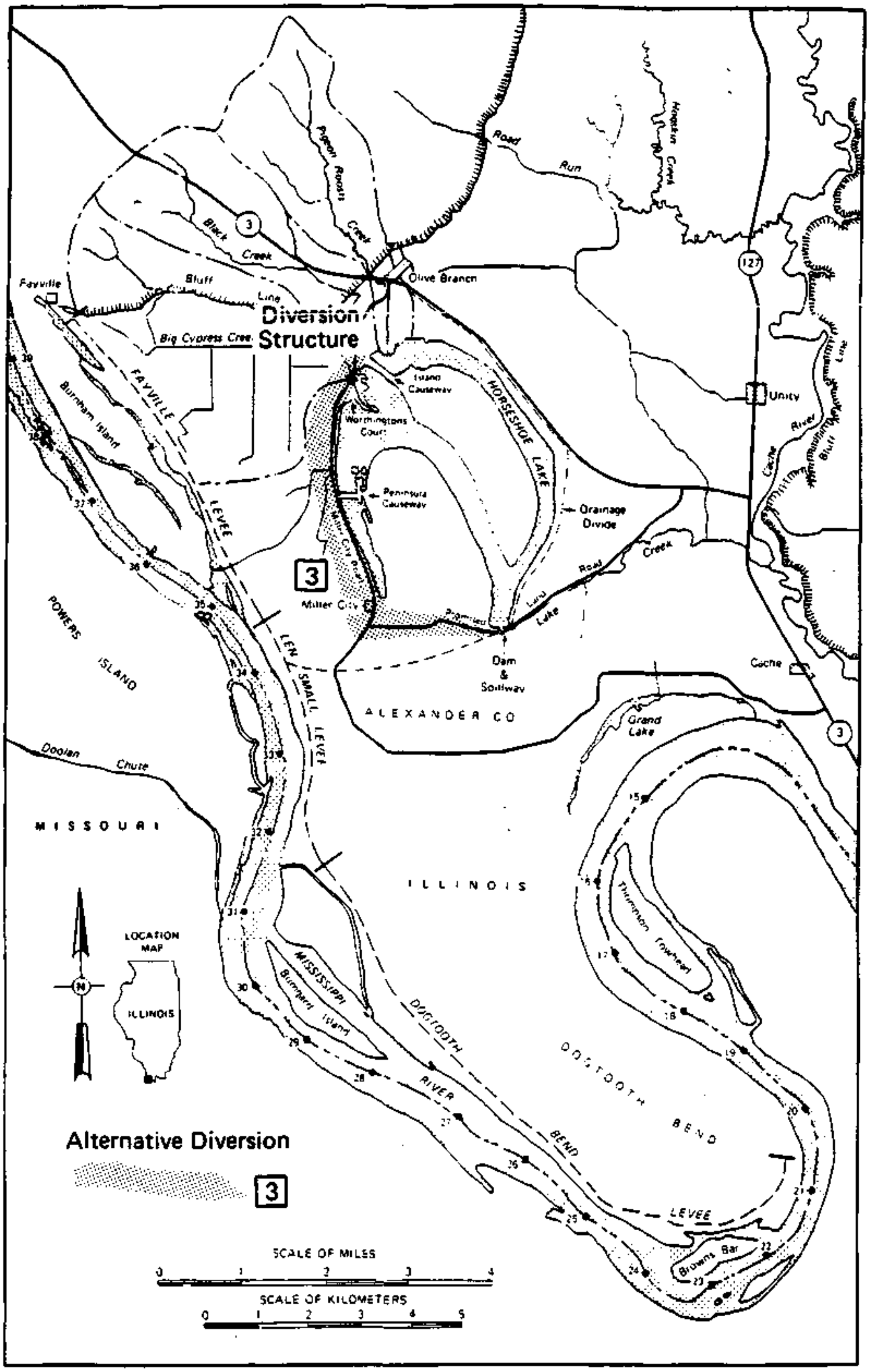

Figure 3. In-stream sediment management alternative 3

The cost of constructing the channel is estimated as $1.26 million. Approximately five bridges would have to be constructed. The cost of replacing bridges, constructing diversion structures, and removing trees is estimated as $1.29 million. The total cost is assessed as $2.55 million.

3. Diversion through Miller City Arm to Lake Creek

This alternative would take the flow from Pigeon Roost Creek to Black Creek. The combined flow would then be located within the lake just east of Miller City Road. The flow would then head east along the abandoned Missouri Pacific railroad to Lake Creek.

The cost of the channel diversion is $1.31 million. The other costs which include bridge construction, diversion structure, tree removal, and clearing Lake Creek are estimated as $0.58 million. The total cost is estimated as $1.89 million.

4. Diversion to Miller City Arm Sedimentation Basin

This alternative is similar to divers ion through the Miller City arm to Lake Creek except the flows would be diverted to the southern end of the Miller City arm. Once in the Miller City arm, the flow would continue north to join the lake above the peninsula causeway by an overflow spillway. The Miller City arm would become a sedimentation basin.

The diversion would cost $0.91 million. The overflow structure would cost $0.2 million. The other costs including diversion structure, restoration of drainage south of the Miller City arm, riprap, and tree removal are estimated as $0.49 million. Assuming a 40-year life, the lake would have to be dredged three times. The present cost of dredging is $3.72 million. The project would have a total cost of $5.14 million.

II. Stream Bank Protection -- A qualitative stream bank erosion assessment was conducted. The results indicated that stream bank erosion in Black Creek and Pigeon Roost Creek does not contribute a significant sediment load to the lake. However, it is recommended that stabilization techniques be applied for future channel maintenance. Techniques such as riprap, reinforced stone revetment, fencing, hardpoints, spurdikes, vanedikes, gabions, window revetment, steel sheet piles, in-situ concrete or concrete piling or timber piling, masonry brickwork, precast concrete, vegetation, synthetic materials, used rubber tires, breakwaters, and tree sausages can be used.

In-Lake Management

In-lake management techniques include raising the lake level, separating delta areas for sedimentation basins, constructing a segmental water level control system, and lake dredging.

I. Raising the Lake Level

The obvious alternative to gain depth in the lake is to raise the spillway. It was estimated that raising the spillway by one foot would increase the lake capacity approximately 60 percent.

The major cost of raising the spillway and the dam is estimated as $0.82 million. The cost of raising roads above the 2-year flood level, relocating utilities, and restoring drainage south of the Miller City arm would amount to $0.23 million. The total cost of this alternative is $1.05 million.

II. Separating Delta Areas for a Sedimentation Basin

This alternative would combine the sediment inflows of Pigeon Roost Creek and Black Creek into a sedimentation basin which would be located at the north end of the lake. The suspended sediment would then be allowed to drop out before the flow enters the lake. The sedimentation basin would then have to be dredged periodically. This is shown schematically in Figure 4.

Assuming a 40-year period, the lake would have to be dredged once and the cost would amount to $2.16 million. The spillway, dam, and riprap would cost $0.22 million. The total cost for this alternative amounts to $2.38 million.

III. Constructing a Segmental Water Level Control System

This alternative would involve the construction or modification of two water level control structures in the lake to allow surcharging and dewatering sections of the lake as separate units as shown in Figure 5. Major new construction would include reconstruction of the dam and spillway to complete dewatering of the lake. Also, an inflatable dam would be installed at the south end of the east arm of the lake.

Costs for this alternative include $0.82 million for constructing the dam and spillway, $4.00 million for installing the inflatable dam, and $50,000 each for modification of the two causeways. Total cost for this alternative is estimated as $4.87 million.

IV. Lake Dredging

Dredging implies the complete removal of the accumulated sediments from the lake. An initial increase in lake depth of 5 feet is recommended. From a dredging engineering perspective, open lake areas with no trees or stumps and at least 2 to 3 feet of water would be desirable. Spoil areas could be located on the Horseshoe Lake island, or on the peninsula east of the Miller City arm. Based on the unit weight measurement of sediment, dredging 100 acres or 5 percent of the lake to increase depth by 5 feet would require 170 acre-feet of wet sediment volume or 58 acre-feet of dewatered sediment.

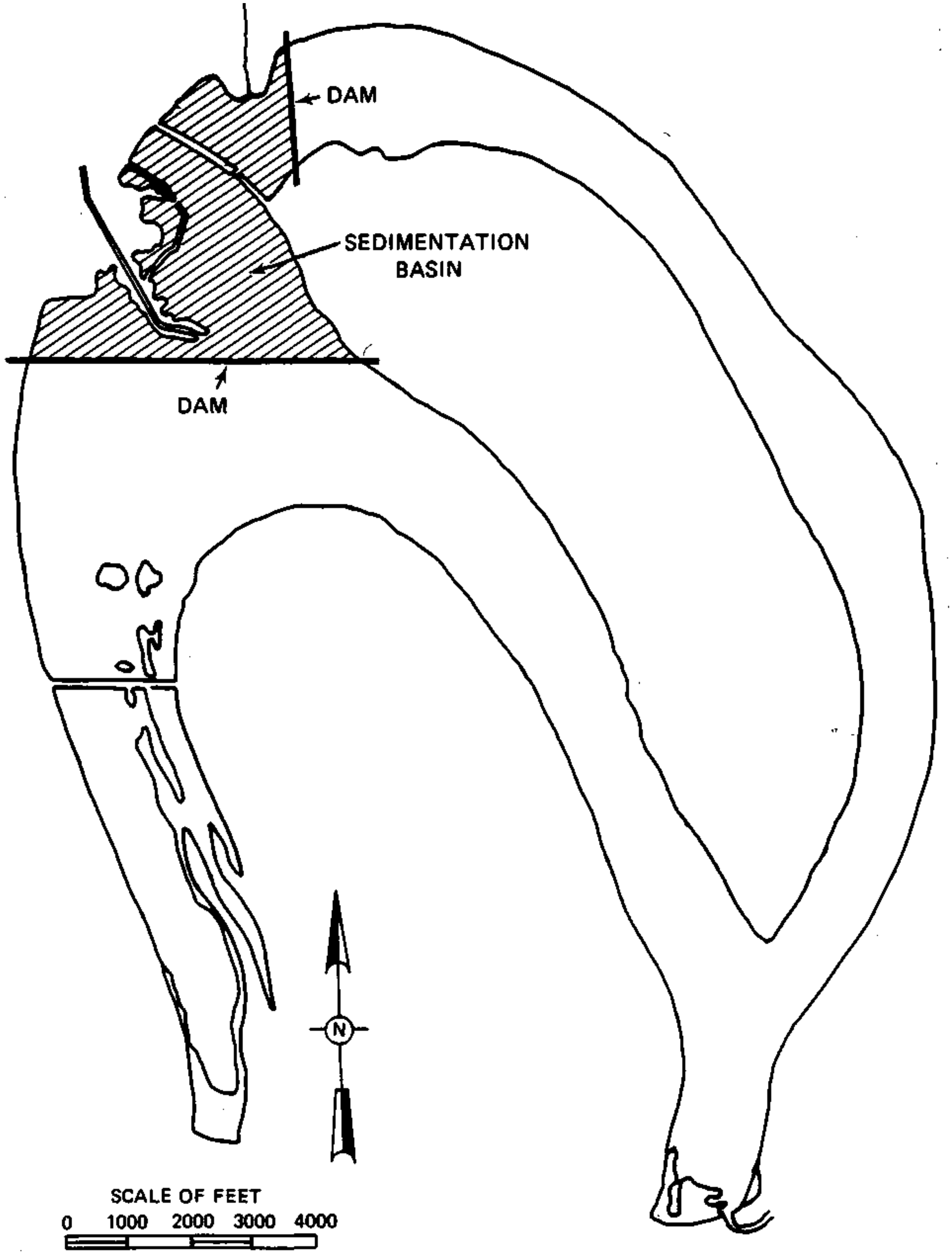

Figure 4. Separation of delta areas for sedimentation basins

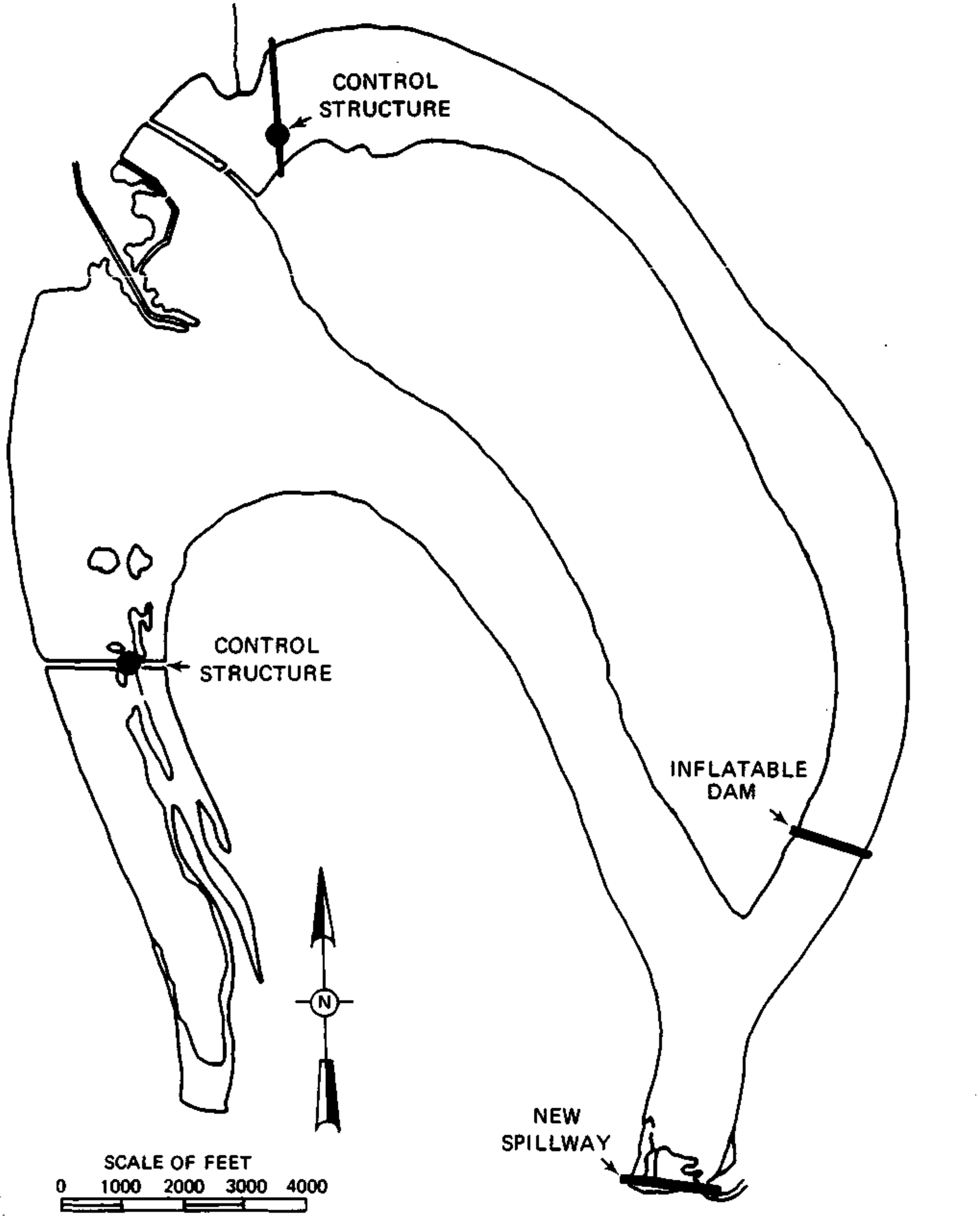

Figure 5. Segmental water level control

On the basis of the sediment survey, approximately 50 percent of the Horseshoe Lake area can be dredged. Using a unit cost of $10 per cubic yard of sediment removed, one year's dredging of 50 percent of the lake would cost $80 million.

Costs

The total costs of these alternatives are summarized in table 1. The cost data are intended for comparison of the alternatives. Detailed costs estimations will be required when any of the alternatives is implemented. In order to solve the immediate sedimentation problems, the least-cost alternative is to raise the spillway, which will cost $1.05 million. Channel diversion would cost at least $1.89 million. Watershed management is being studied by the Soil Conservation Service. The detailed cost is not available yet.

Table 1. Estimated Cost[1] of Alternative Solutions
(1985 Values in Millions of Dollars)

Alternatives	Channel	Dredging	Pump	Spillway and dam	Other[2]	Total cost
In-Stream Management						
Using Miller City arm as sed. basin	0.91	3.72	-	0.02	0.49	5.14
Diversion through Miller City arm	1.31	-	-	-	0.58	1.89
Diversion along Rt. 3 to Lake Creek	1.26	-	-	-	1.29	2.55
Diversion to Mississippi River	1.56	-	11.8	-	0.29	13.7
In-Lake Management						
Raising lake level with new dam	-	-	-	0.82	0.23	1.05
Separation of delta areas	-	2.16	-	0.208	0.011	2.38
Segmental water level control	-	-	-	0.82	4.65	4.87
Lake dredging	-	-	-	-	-	16-80

[1]40-yr life and 7.125% discount rate

[2]Other: raise roads, relocate utilities, riprap, bridges, block culverts, and restore drainage.

Recommendation

1. Watershed management has the potential to reduce the gross erosion to the level of 40 percent of the current. However, in order to achieve this, a long-range plan and full cooperation of the landowners in the watershed are absolutely necessary. The Illinois Department of Conservation is seeking technical assistance from the Soil Conservation Service to develop a detailed conservation plan to accomplish this alternative.

2. In-stream management could include both stream diversion and stream bank protection. From the preliminary cost estimate, the most economic alternative is to divert the flow through the Miller City arm, Figure 3. The cost estimation considers only engineering and construction aspects. Further information on the local landowner reaction and environmental impacts would need to be explored. The alternatives of diverting the streamflows west to the Mississippi River and to Lake Creek are considered costly due to high pumping costs and the long distance of the new proposed channels.

3. In-lake management could include both raising the lake level and increasing the water depth by removing the sediment. Raising the lake water level is the most economic alternative. This alternative would cost $1.05 million. However, the impacts on the cypress trees of additional water depth requires further evaluation.