Illinois State Water Survey Division
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SWS Contract Report 432

RELATIONSHIP BETWEEN LAKE STAGES AND LOCAL GROUND-WATER LEVELS AT HORSESHOE LAKE, ALEXANDER COUNTY, ILLINOIS

by Donald S. Blakley and Ming T. Lee

**Prepared for the
Illinois Department of Conservation**

Champaign, Illinois
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INTRODUCTION

Since 1984 the Illinois State Water Survey (ISWS) has been conducting an investigation of lake management at Horseshoe Lake, Alexander County, for the Illinois Department of Conservation through a grant from the U.S. Fish and Wildlife Service. Previous reports provided information on lake sedimentation (Bogner et al., 1985) and on hydrologic and sediment budgets and lake management alternatives (Lee et al., 1986). Lake-stage manipulation is one of the proposed lake management schemes. The current research project focuses on the relationship between lake stage and local ground-water levels. The following objectives were set:

1. Determine if additional water stored in the lake through an increase in the spillway elevation would experience significant losses to the ground-water system.
2. Determine if a higher lake pool elevation would cause a rise in ground-water elevations beneath the Horseshoe Lake Island Nature Preserve.

Acknowledgements

This report was prepared under the general direction of Richard G. Semonin, Chief of the Illinois State Water Survey; Richard J. Schicht, Assistant Chief; Michael L. Terstriep, Surface Water Section Head; and Nani G. Bhowmik, Surface Water Section Assistant Head. Special thanks are given to Ellis Sanderson, Adrian Visocky, and Stephen Burch of the Ground-Water Section for their suggestions, criticisms, and assistance with analysis. The Mississippi River stages were provided by the U.S. Army Corps of Engineers, St. Louis District. Grateful acknowledgement is also given to the Illinois Department of Conservation personnel at Horseshoe Lake who assisted with data collection and well installation and to Gary Pulley of the Illinois Department of Transportation's District 9 Laboratory and his drill crew for extracting and analyzing the core data. Finally, a personal

thanks to K. Andrew West, Illinois Department of Conservation Natural Heritage Biologist, for many useful discussions and for information about the island nature preserve.

Many staff members at the Illinois State Water Survey contributed to this report. The figures were prepared by John W. Brother, Jr., and Linda Riggin, and the report was edited by Gail Taylor. The draft and camera-ready copies of the report were typed by Kathleen Brown, Becky Howard, and Patricia Odencrantz.

Study Area

Horseshoe Lake and its associated island lie within the Horseshoe Lake State Fish and Wildlife Management Area, two miles south of Olive Branch, Illinois, and 15 miles northwest of Cairo, Illinois, in Alexander County. Figure 1 shows the regional location.

The Horseshoe Lake State Fish and Wildlife Management Area is a floodplain wetland. The area occupies 9570 acres, which includes the 2007-acre Horseshoe Lake and the approximately 1300-acre Horseshoe Lake island. The area exhibits wetland characteristics common to more southern environments. A detailed description of the characteristics of the area may be found in the Illinois Department of Conservation Water Management Plan for Horseshoe Lake (IDOC, 1972) and a previous Illinois State Water Survey report (Lee et al., 1986).

DATA COLLECTION

To accomplish the objectives at Horseshoe Lake, precipitation, lake stage, Mississippi River stage, and island ground-water data were collected or were supplied by the U.S. Army Corps of Engineers. Geologic data were retrieved from existing information and on-site evaluations of core samples. The following sections describe the methods used.

Ground-Water Data

Ground-water elevation data were collected from the Horseshoe Lake island from May 1985 to July 1986. Data collected during the first four months of this period were used to determine if an extended ground-water evaluation was needed for the development of lake management strategies.

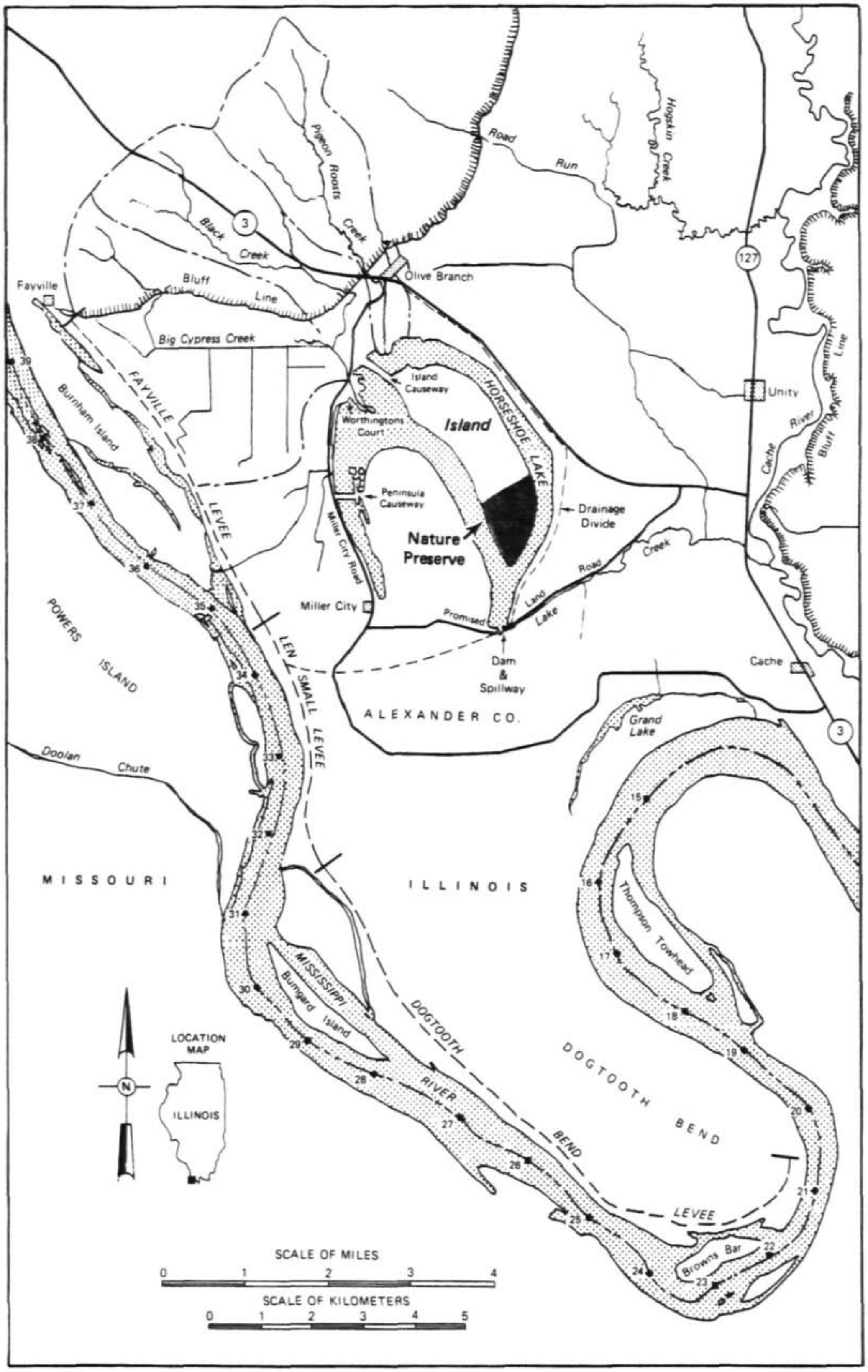

Figure 1. Location map for Horseshoe Lake, Alexander County, Illinois (After Lee et al.} 1986)

Although data collection during this period was limited, the data did indicate a downward trend in ground-water elevations, which is common during the summer season. On the basis of this preliminary investigation and the needs of the Illinois Department of Conservation, it was determined that a further analysis of ground water - lake relationships was needed. To meet these needs, the ground-water investigation was extended through July 1986.

Well Location, Design, and Construction

Many criteria are used in designing wells, and no standardized design criteria are acceptable to all those concerned with water wells (Walton, 1970). The location, design, and construction of a well depend upon economic considerations, local hydrologic conditions, and the purpose of the well (Walton, 1970). Our purpose at Horseshoe Lake was simply to monitor ground-water fluctuations beneath the Horseshoe Lake island, primarily in the vicinity of the Horseshoe Lake Island Nature Preserve at the south end of the island (see figure 1).

In May 1985, six observation wells (numbered 1, 1A, 2, 2A, 3, and 3A) were installed along an east-west transect of the island bordering the northern boundary of the nature preserve. (See figure 2.) The wells were located on low ridges between swales in an attempt to improve accessibility during wet periods of the year. The relatively straight-line transect allowed development of a two-dimensional water level profile beneath the island.

The island wells were constructed from 5-foot sections of 1-1/2-inch-diameter galvanized steel pipe fitted with 36-inch-long stainless steel sandpoints with 60-gauze screens. The small pipe diameter was chosen because the wells were to be hand-driven. As indicated by Davis and DeWiest (1966), driven wells are usually limited to less than 3 inches in diameter and to less than 40 feet in depth because of increasing friction with progressively deeper depths and larger well diameters. A local well-point distributor indicated that most local production wells were fitted with 60-gauze screens, which influenced our choice of screen size. Figure 3 is a diagram of a typical well used.

The six observation wells were placed at three low ridgetop locations. At each location, one well was driven to a depth of 16 feet

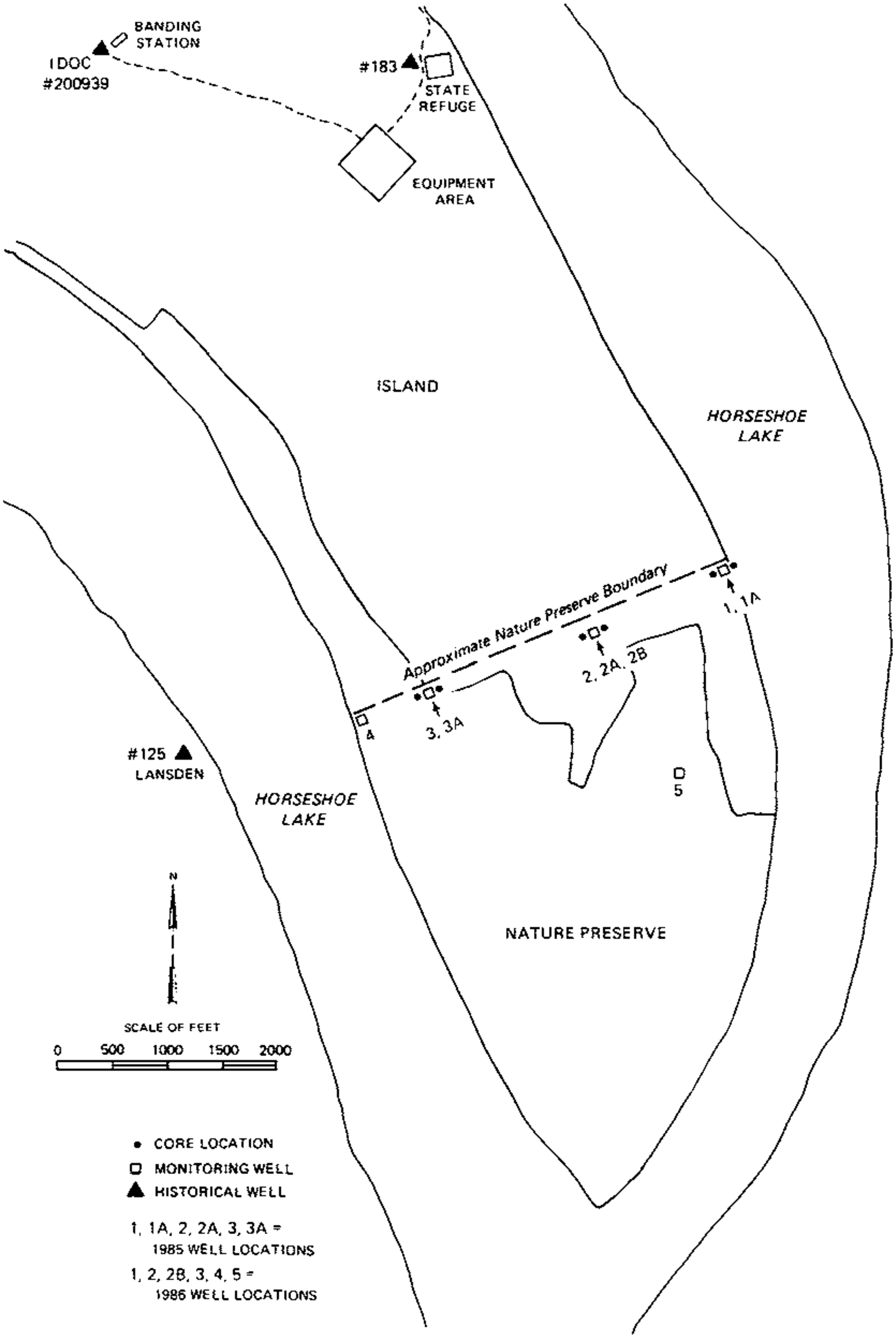

Figure 2. Positions of original and relocated monitoring wells

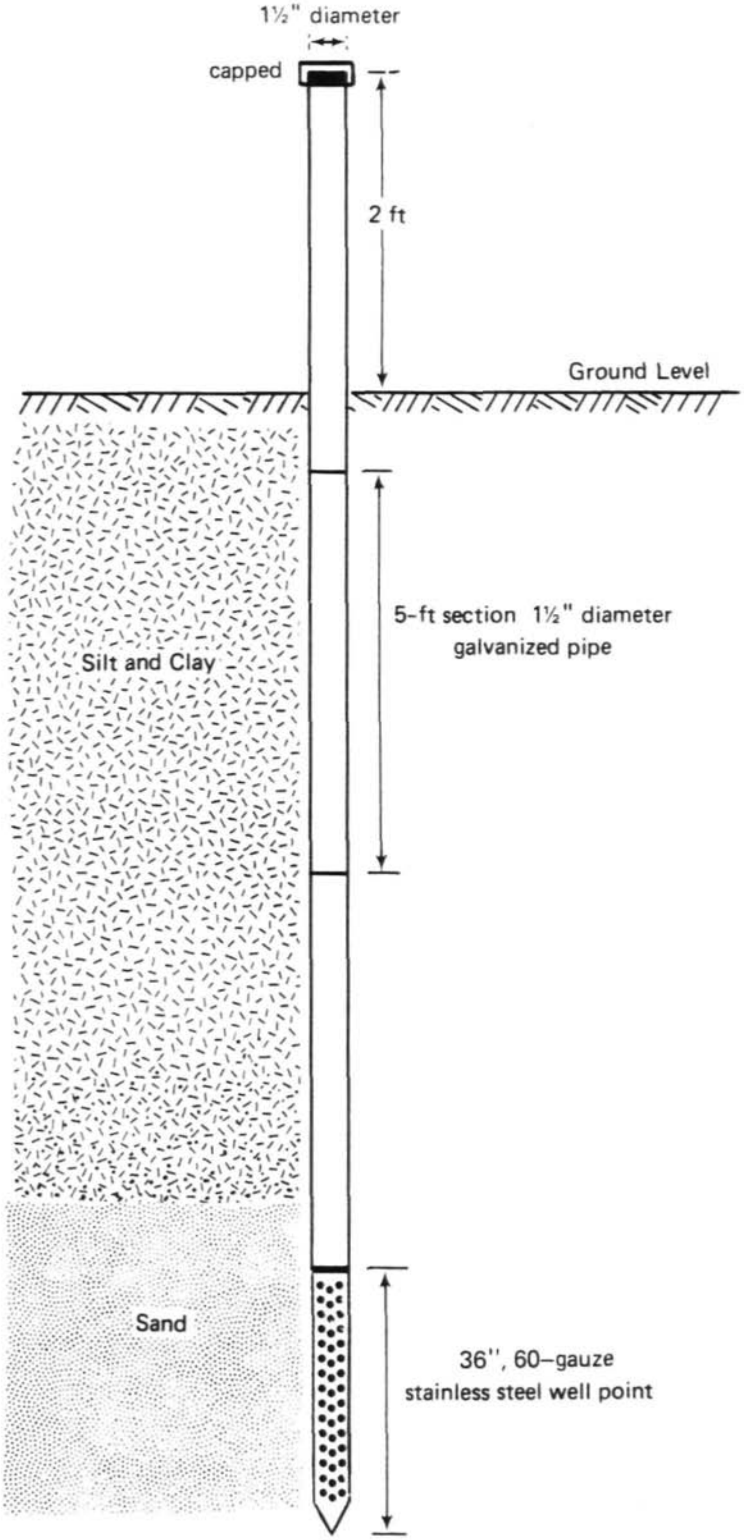

Figure 3. Typical monitoring well

(wells 1, 2, and 3) and one to a depth of 10 or 11 feet (wells 1A, 2A, and 3A). Well depths were chosen on the basis of available well log information of the region and advice from Ground-Water Section personnel of the Illinois State Water Survey. An examination of the log of an existing well on the island (figure 4) indicated a static water level of 10 feet and a fine brown sand at this depth. As indicated by Davis and DeWiest (1966), driven wells are economical and rapid to construct in soft alluvium with a water table at a depth of less than 20 feet; in addition, saturated sand and coarse silt cannot be penetrated by an ordinary hand auger. Such was the case on the Horseshoe Lake island.

In early 1986, the three 10- and 11-foot wells were relocated. Figure 2 shows the original and new positions of these wells. Wells 1A and 3A were increased to the 16-foot depth by adding one 5-foot section of pipe to each. In February 1986 one of these wells was moved to the west end of the island transect and was renamed well 4, and the other well was placed south of the transect mid-point on an undisturbed ridge within the nature preserve, where it was renamed well 5. The purpose of this relocation was to obtain water-level data from beneath the swampy area and to provide a third dimension to the water-level profile. This was critical in determining the local hydraulic gradient of the ground water in the study area. The third relocated well (well 2A) was merely shortened, and in April 1986 it was redriven to a depth of 6 feet at its initial location on the transect mid-point. It was then called well 2B. The shallow depth placed the well point above the sand aquifer and within the silt and clay materials. The purpose of this relocation was to assist in determining if saturation of the silts and clays occurred during upward movement of the ground water.

Data Collection Schedule

Well data were collected from 1 to 3 times per week beginning in May 1985. At times the wells were inaccessible because of wet conditions, although an attempt to avoid this situation was made when choosing the well locations. The data record for the period June 1985 through October 1985 is incomplete, although enough data were gathered to show a generally dropping trend in ground-water elevations during the summer months. Upon tentative agreement to continue the ground-water investigation, data

Date Drilled: January 6, 1976
Water Well No.: 1
Test Hole No.:
Static Level: 10'
Depth of Drilled Hole: 125'
Bottom of Screen Set at: 117'

Owner: Horseshoe Lake Conserv. Area
Address: Alexander County
Location of Well: Goose Trap
Size of Drilled Hole: 24"
Final Casing Elevation above grade: 18"

Well Casing:
- Material: steel-black-plain end
- Diameter: 8" I.D.
- Length: 108"
- Wall Thickness: 0.322" standard

Well Screen:
- Material: 10.5' stainless steel
- Diameter: 8" PS
- Slot Size: 150
- Type Make: U0P Johnson Water Mark

Gravel Filter:
- Tons Used: 14.5
- Wall Thickness: 8"

Gravel Filter:
- Feet above screen: 37'
- Gradation:#2 Roessler Gravel Filter

LOG OF STRATA

From	To	DESCRIPTION
0	5	Clay, yellow, silty
5	20	Sand, brown, fine
20	45	Sand, brown, fine to medium
45	50	Sand, brown, medium to coarse
50	65	Sand, gray, coarse with gravel to 2"
65	70	Sand, gray, coarse, with gravel to 1"
70	75	Sand, gray, coarse, with gravel to 1/2"
75	80	Sand, gray, medium to coarse
80	85	Sand, gray, fine to medium
85	95	Sand, gray, medium to coarse
95	105	Sand, gray, fine to coarse
105	110	Sand, gray, very coarse, w/gravel to 2"
110	117	Sand, gray, coarse w/gravel to 1"
117	125	Sand, gray, fine to medium

Supt.: Eugene Linker

Driller: Robert Kennedy
Clinton Trankle Jr.

L0HR BROS., INC.
Columbia, Illinois

Figure 4. Well drilling record

collection was performed on a more regular basis beginning in November 1985.

From November 1985 through April 1986, wells were measured twice weekly. From April 1986 through July 1986, data collection was increased to 3 times per week because the spring season generally produces the greatest fluctuations in ground-water levels. Appendices A through C contain all the pertinent well data.

Measurement Methods

Various methods are available for collecting water-level data from wells and are discussed by Davis and DeWiest (1966). For our purposes, a combination of sonic and steel tape methods was used. A steel surveyor's tape may be used to measure water levels in wells by applying chalk to the lower portion of the tape and lowering it into the well. A reading is then made at the top of the well. The depth to water is equal to the reading at the measuring point minus the length of wetted tape. This method is accurate to about 0.01 feet. On the other hand, sonic methods are very inaccurate and are highly dependent upon air temperature and the velocity of sound at a given temperature. In deep wells, this can produce inaccuracies of 10 feet or more (Davis and DeWiest, 1966).

Because the wells on the Horseshoe Lake island were shallow (16 feet deep or less), the effect of air temperature on sound velocities was assumed to have an insignificant effect on the accuracy of our method. By using a steel 25-foot tape with a small foot attached on the zero end, we were able to sound the well water and read the depth to water at the measuring point (well head).

The measurements were recorded in inches and converted to feet. By subtracting the depth to water from the well-head elevation we were able to compute the mean sea level elevations of the ground water at each location. These data are compiled in Appendix C.

To test the accuracy of our method, the same steel tape coated with chalk was used to measure water levels after sounding measurements had been taken. The largest discrepancy observed was 0.08 feet. We believe this error is acceptable for the purposes of this investigation.

Lake Stage

The stage or water level in Horseshoe Lake was monitored from 3 to 5 times weekly by IDOC and ISWS personnel from February 1984 through July 1986. Readings were recorded from a 10-foot staff gage designated HL-1 and located at the Horseshoe Lake spillway (figure 5). Stage readings were converted to mean sea level elevations on the basis of the spillway elevation of 321.41 feet mean sea level. The lake-stage hydrograph was computed by using the recorded data and was then compared to island ground-water hydrographs so that hydraulic relationships could be analyzed through graph comparisons, used in conjunction with regression analyses. This method was documented by Mikels (1952) and has been used by Walton (1962). The compiled lake-stage data for the period from May 1985 through July 1986 may be found in Appendix D.

Precipitation

On-site precipitation data collection has been ongoing since February 1984 at two locations. Two Belfort 3777 Universal Raingages located at the Horseshoe Lake main office (designated RG-1) and west of the island near the spillway equipment shed (designated RG-2) were monitored on a weekly basis. The data were used to estimate the influence of precipitation on the hydrologic budget at Horseshoe Lake. Schicht and Walton (1961) have used this information in similar ground-water budget investigations. Figure 5 shows the raingage locations.

Mississippi River Stages

Mississippi River stages were monitored daily by the U.S. Army Corps of Engineers at Price Landing, Missouri (river mile 28.2) and at Commerce, Missouri (river mile 39.5). The data were supplied to the Illinois State Water Survey on request.

River stage data were used to develop hydrographs for the same time frame as our lake stage and ground-water monitoring activities. These graphs helped to determine if the river stage fluctuations have a hydraulic relationship with the island ground-water and lake systems. The comparison method mentioned in the section on lake stage was used in conjunction with regression analysis techniques.

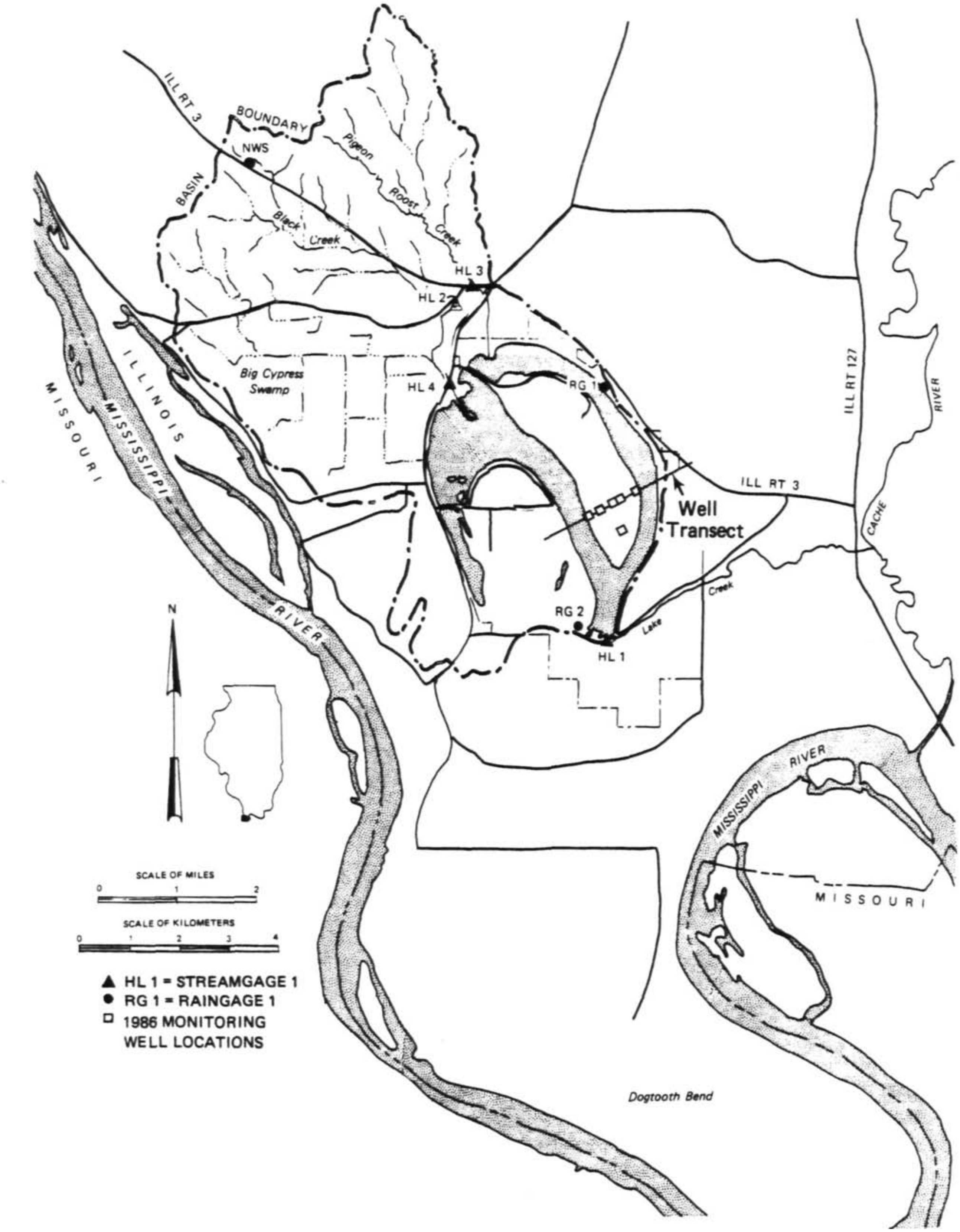

Figure 5. Locations of monitoring stations (After Lee et al., 1986)

Illinois Department of Transportation (IDOT) Data

After the initial installation of six wells on the island, it was determined that drill cores were needed along the well transect to determine the stratigraphic sequence beneath the well transect, to determine soil characteristics that would aid in determining infiltration and percolation rates, and to ensure that our wells were reaching the sand aquifer beneath the island. Drilling and core analysis were performed by the Illinois Department of Transportation.

At each of the three original monitoring locations, two cores were taken by using a hydraulic rotary drilling rig mounted with a 2-inch split spoon sampler. Core samples bracketed each of the three well locations and were taken on the transect line, as indicated in figure 2. Five of the bore holes reached a depth of 22.5 feet, and the one on the east end of the transect extended to a depth of 32.5 feet. The cores were analyzed to determine grain size and graduation, sand-silt-clay contents, liquid limit, and plasticity. During drilling, water content and unconfined compressive strength of the materials were examined. A standard penetration test was also performed during drilling. From the core data, a detailed stratigraphic profile was constructed as shown in figure 6.

HYDROGEOLOGICAL ASSESSMENT

Horseshoe Lake Region

Horseshoe Lake and its associated island lie at the boundary between the Salem Plateau Section of the broad Ozark Plateau and the Mississippi River Alluvial Section of the Gulf Coastal Plain Province (Hunt, 1974). The lake and island are part of the Mississippi River floodplain and, as indicated by Pryor (1956), are underlain by two major geologic units.

Pleistocene alluvium grading from fine silts and clays near the surface to coarse sands and gravels at depth underlies most of the floodplain region. The upper silts and clays reach depths of 20 feet or more in some locations, and gravel lenses occur in the lower 100 feet of alluvium.

The deposits at depth are highly permeable and extensive, holding large amounts of water. They are considered an excellent aquifer (Pryor, 1956).

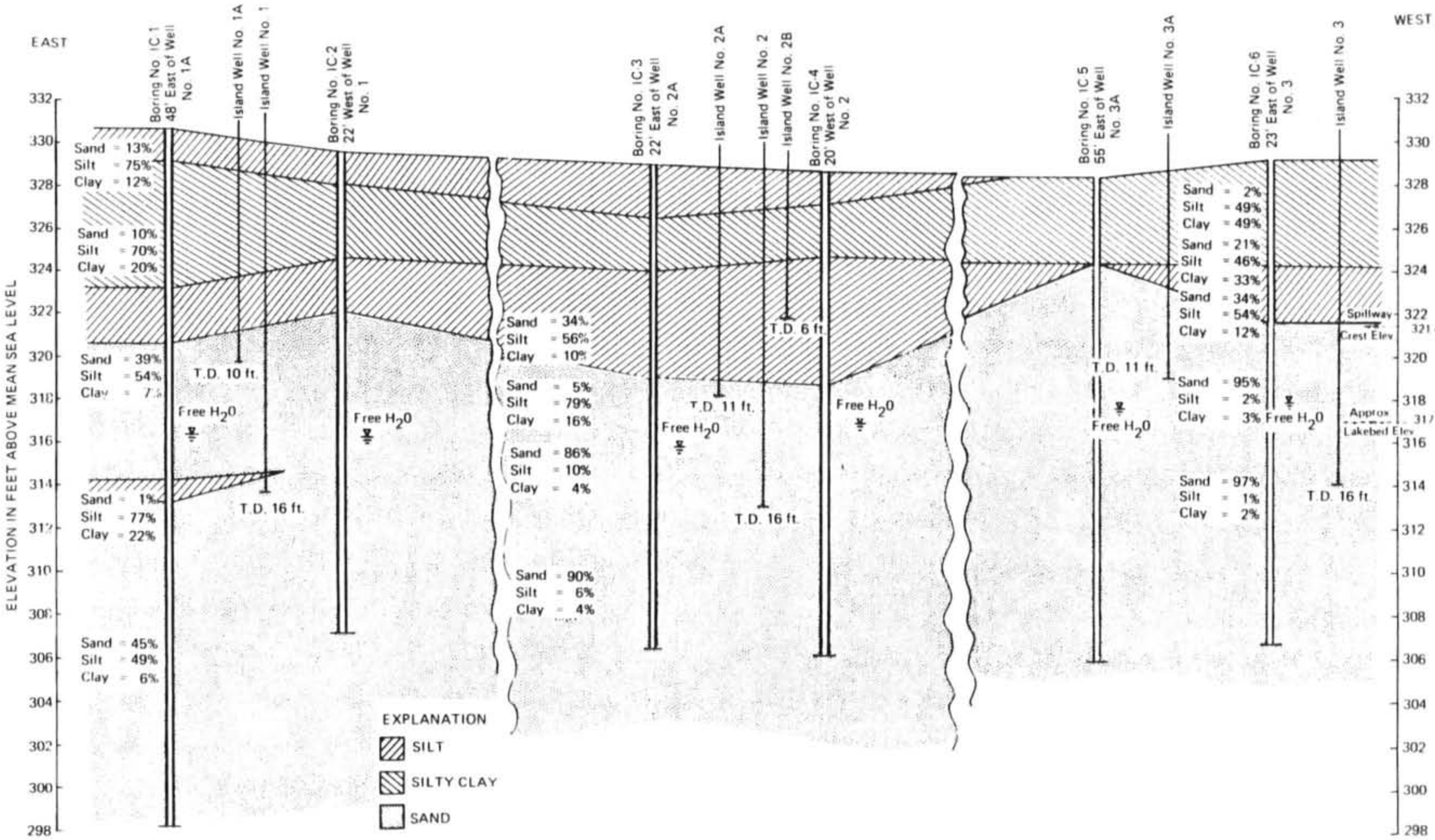

Figure 6. Stratigraphy of monitoring wells

Depths to bedrock range from 50 feet near Olive Branch to more than 200 feet south of the lake. The bedrock is chert-rich Paleozoic carbonates ranging in age from Devonian to older southward from Olive Branch (Pryor, 1956). The carbonate rocks may also produce usable quantities of water.

North of Olive Branch, the upper Horseshoe Lake watershed is composed of Devonian carbonates at depth, overlain by Cretaceous and Tertiary clays and gravels. The hills are generally topped by 10 to 15 feet of Quaternary loess (Pryor, 1957).

An ISWS report (Lee et al., 1986) indicates that the regional ground-water gradient is from the bluff northwest of Olive Branch to the southeast and presumably beneath Horseshoe Lake. As shown in the same report, the average ground-water elevation in the area of the lake was 314.3 feet MSL, approximately 4 feet below the average lake bottom elevation of 318.4 feet MSL.

Horseshoe Lake

Horseshoe Lake is a topographic feature characteristic of most large river valleys, commonly termed an oxbow lake. An oxbow lake may be created as a river migrates through its floodplain, leaving a series of concentric ridges and swales in its path. This is known as meander scroll topography. At a point determined by the river hydraulics and stream channel geometry, the meander loop is abandoned and lakes such as Horseshoe Lake are formed. An ISWS report prepared by Bogner et al. (1985) describes and provides a geomorphic interpretation of the creation of Horseshoe Lake. The report estimates that the lake is approximately 6000 years old.

After a meander loop is abandoned, overbank deposition of fine-grained sediments tends to fill floodplain depressions through a process of vertical accretion of floodplain deposits. Abandoned channels represented by oxbow lakes are subject to this deposition and may gradually fill with silt and clay, which form a "clay plug" in the lake bottom (Davis and DeWiest, 1966; Ritter, 1978). Shallow cores taken from the bed of Horseshoe Lake to a depth of 2 to 3 feet indicate that the lakebed exhibits this clay-plug characteristic (Bogner et al., 1985), although the total thickness of the plug has not been determined. It may be assumed that the plug continues to greater depths.

Lee et al. (1986) assumed that the clay plug is at least 30 feet thick and extends to an elevation on the lake shores at least equal to the current spillway elevation. Using this clay thickness and Darcy's equation

$$q = k \bullet i \bullet a$$

(where q = discharge, gpd; k = hydraulic conductivity, gpd/ft^2; i = hydraulic gradient, ft/ft; and q = discharge, gpd), Lee et al. estimated that the discharge from the lake to ground water is 168,675 gallons per day (gpd) or 0.0031 inches per day. This is based on a k value (hydraulic conductivity) of 0.005 gallons per day per square foot (gpd/ft^2) for clays of this type, as estimated by Walton (1965). If the assumption of 30 feet of clay is correct, this computation indicates that the clay plug beneath the lake forms an aquitard and that little interaction occurs between the two systems.

Horseshoe Lake Island

The island in Horseshoe Lake is probably a remnant of point bar construction and vertical floodplain accretion that occurred during the river's meandering process. Ideally, both types of deposition accumulate more or less evenly across the valley bottom (Ritter, 1978). If a somewhat even accumulation occurs, elevations across the floodplain and island should be similar. Point bars tend to increase in height until they attain the elevation of the older floodplain. Elevations on the Horseshoe Lake island and the surrounding floodplain are similar, most being in the range of 328 to 332 feet mean sea level. The crescentic ridge and swale topography support the probability of a point bar origin.

The 1300-acre island surface is about 40 percent forested, primarily on its southern tip, which has been designated the Horseshoe Lake Island Nature Preserve (IDOC, 1972). The northern two-thirds of the island is used for wildlife management and related agricultural activities. During this investigation, our interest has been primarily in the forested nature preserve area.

The slope of the island surface is gently south-southwest in the study area, and most drainage is directed southward into the nature preserve via the swale topography. The ridge and swale sequences continue through the preserve to their truncation at the southern end of the island. The nature preserve is densely vegetated with various species of phreatophytes, and soil conditions are less disturbed than in the more northern agriculturally impacted land. A permanent swamp exists within the preserve, and to date has been known to completely dry up only once (Russell Garrison, IDOC, personal communication, 1986). The preserve is characteristically wet with several intermittent swamps occupying the swale depressions.

Island Stratigraphy

Both recent and historical stratigraphic data indicate that a typical sequence of alluvial deposits exists beneath the Horseshoe Lake island. Soil test data from IDOT core samples taken in June 1985 indicate that an upper unit of soft to stiff grey and brown silts and clays overlies a lower unit of very wet, loose, fine-grained brown sand. The contact between the units is gradational for a short depth, but is pronounced. The lower sand unit, as mentioned by Pryor (1956), is the shallow aquifer under the island.

The silts and clays exist to depths from 4 to 10 feet along the well transect, although the east end of the transect at island core 1 shows silt and clay to a depth of 17.5 feet. Figure 7 shows the combined silt/clay contents at selected depths for island cores 1, 3, and 6 beneath the well transect. Figure 8 shows the general boundary between the upper and lower units, and the free water surface encountered during coring. Below 17.5 feet, island core 1 exhibits a sand-silt mixture with very little clay.

The upper unit exhibits clay contents ranging from 10 to 22 percent in the east and central island alluvium, increasing to nearly 50 percent on the west end of the transect. Silt content ranges from near 80 percent in the east to near 50 percent on the west side. These percentages vary between depths of 0 to 10 feet at each core location (excluding core 1), but below 10 feet silt and clay contents drop dramatically as the sand content increases to 90 percent or more as seen in figure 7. Well logs from existing wells in the region provide similar stratigraphic descriptions (see appendix A), although unit thickness varies and constituent percentages are not mentioned.

Although no cores were taken from the nature preserve, we are assuming on the basis of the regional well log description that the stratigraphic profile at the preserve is similar to that at the boring

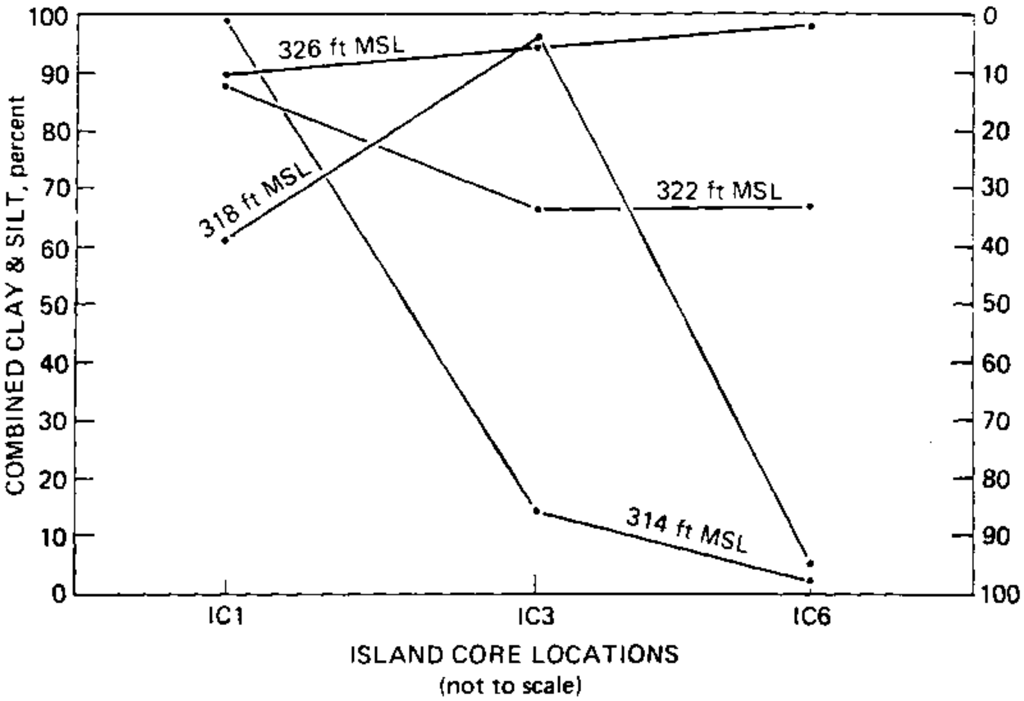

Figure 7. Clay/silt percentages at selected depths for island cores 1, 3, and 6 beneath the well transect (See figure 6 for coring locations)

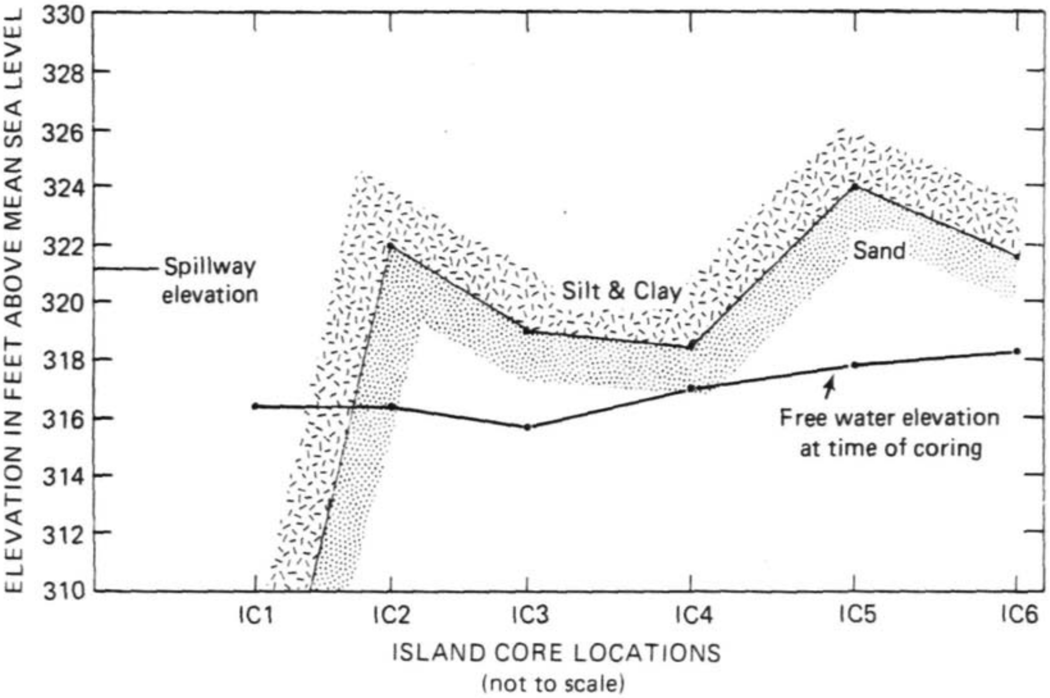

Figure 8. Contact area between silt/clay and sand units, and free water elevation encountered during coring (See figure 6 for coring locations)

locations, and that percentages of sand-silt-clay in the upper and lower units are also similar. Floodplain alluvium is not homogeneous and lateral variations in stratigraphy do exist, but if the hypothesis of point bar origin and thereby the same mode and time of deposition of these materials is accepted, it may be assumed that no major variations exist in the near-surface materials in the immediate study location.

Porosity, Permeabilities, and Infiltration

The porosity and permeability of the upper unit silts and clays in the study area have a predictable effect on infiltration of surface water. As clay and fine silt content increases, permeability generally decreases. With clay and silt contents ranging to near 100 percent in the upper unit, permeability values may be expected to be low. Davis and DeWiest (1966) indicate that porosity values of fine silts and clays are less than 10 percent.

The permeability of silt and clay deposits is also extremely low. As shown by Walton (1970), a range of 0.001 to 2.0 gallons per day per square foot (gpd/ft^2) may be expected. For comparison, well-sorted fine sand may exhibit permeabilities of 100-3000 gpd/ft^2 (Walton, 1970) and porosity up to 90 percent (Davis and DeWiest, 1966). These clay and silt values indicate that these types of materials are pervious, but that infiltration and percolation of water through them is extremely slow. If the silts and clays which make up the island alluvium are of the same type as those forming the plug in the lake bottom (on the assumption that they have the same source area and the same time and mode of deposition), then they should have a permeability near 0.005 gpd/ft^2, which is the value estimated by Lee et al. (1986) for the clay plug in the lake bottom.

"Pans" are another important influence on the permeability and infiltration of surface water on the island. A pan is a layer of soil on the surface or at depth which has been compacted or cemented to the degree that it forms a relatively hard horizon within the soil profile which is relatively impervious to water. Soil pans may be natural or anthropic and include several different types. For a discussion of the different types, see Donahue et al. (1971).

IDOT data and the agricultural history of the study area point to the existence of both natural and anthropic pans on the Horseshoe Lake island.

The island surface north of the nature preserve has been subjected to tillage for over 30 years (R. Garrison, IDOC, personal communication, 1986). As indicated by Donahue et al. (1971), continuous tillage reduces permeability, and the bottom of a plow sliding along a fine-textured soil at the same depth year after year soon compacts the soil into a tillage pan. Continued compaction caused by heavy farm machinery also may create the same condition. It is believed that both conditions exist on the island as retardants of surface water infiltration. In addition, clay pans or fragipans formed from a natural accumulation of clay and/or silt in the soil profile may also affect infiltration. In a study by Donahue et al. (1971) of the effect of a tillage pan on infiltration rates in the southern Great Plains, 35 years of cropping were found to reduce the infiltration rate to 0.2 inches of water per hour, whereas below the pan the infiltration was 9 inches per hour, or 45 times faster. Ponding of water in the island swales during wet periods of the year is indicative of the low infiltration rates.

As part of the IDOT boring procedure, a standard penetration test was performed at each of the boring locations. The standard penetration test (N value) is the number of blows per foot needed to drive a 2-inch split-spoon sampler 1 foot with a 140-pound hammer falling 30 inches (IDOT, 1985). N values from the bore logs (see Appendix A) indicate a significant increase in the N values between the 2- and 5-foot depths along the transect. The soil descriptions associated with this depth range indicate that a stiff to very stiff clay layer exists along the transect in this depth range, which is probably the near-surface hardpan which acts as a major retardant to infiltration.

During light-intensity rainfall, most of the precipitation reaching this portion of the study area is probably stored or lost to evapotranspiration. However, when the rainfall intensity exceeds the availability of depression storage and the infiltration capacity of the island soils, runoff begins. On the island, the existence of a hardpan at shallow depths will retard the infiltration and provide a horizon where interflow can occur, whereby this infiltrated water will reach the main surface runoff channels or depression storage areas such as the island nature preserve.

The opposite of this situation exists within the island nature preserve. Soils within the nature preserve are relatively undisturbed.

The over 400-acre tract has never been farmed and no tillage or plowpan exists, although a natural claypan may possibly exist at shallow depths. The permeability of the nature preserve soils is considerably higher than that of the agricultural land, and infiltration rates should be higher. Although no bore data exist to show this, the general character of the preserve and the analysis of well measurements point to higher infiltration rates in this area.

The nature preserve soils contain a high percentage of cumulose materials near the surface, especially in the low, swampy areas. Although percentages are not known, they probably range from fibric to sapric with the majority falling in the folic to hemic classes. This material is highly organic, and as indicated by Donahue et al. (1971), the more organic matter is and the coarser it is, the greater the infiltration rate of surface water. In addition, the growth of deep-rooted plants increases the permeability of these soils. Plant roots tend to break soil aggregates apart and provide avenues for surface water infiltration and percolation.

During an on-site evaluation of water and drainage conditions in the nature preserve in September 1986, the drainage of the swamp areas was observed to be restricted by both natural debris and elevation of the drainage channels. At an undetermined water stage in the swamps, surface discharge via the drainage network ceases as a result of continued accumulation of vegetative litter in the drainage network. At this time, the swamp water becomes ponded. Any reduction in water elevation after this time seems to be caused either by evapotranspiration or by infiltration and percolation to the ground water. The existence of a ground-water mound under the nature preserve during the study period as indicated by our well data, and the normal hydraulics associated with swampy areas as discussed in the literature, indicate that a significant portion of the ponded water is lost to infiltration to the ground-water system.

REGRESSION ANALYSES

Regression analysis was used to define the relationships between ground-water levels at the island and nature preserve region and lake water levels. The main reason for defining this relationship is to provide the information needed for future lake management through control of lake water levels. Knowing the fluctuation of ground-water levels due to the lake levels is vital to determining possible effects on the vegetation in the nature preserve area that might result from raising the lake water level. The following analyses were performed (well numbers are those used after the well relocations in February 1986, as shown in figure 2):

1. The correlation between water levels at well 1 (located at the east side of the island) and lake stages
2. The correlation between water levels at well 2 (located in the middle of the island) and lake stages
3. The correlation between water levels at well 2 and well 5 (located in the nature preserve)
4. The correlation between water levels at well 5 and lake stages
5. A time series analysis of ground-water levels at well 5, lake stages, and rainfall from late February 1986 through July 31, 1986

The results of the correlation between water levels at well 1 and lake water levels are as follows:

Wl - -401.19 + 2.25 WL, R^2 = 0.58

where W1 is the water level at well 1 in feet above msl, WL is the lake stage in feet above msl, and R is the correlation coefficient. The data are also plotted in figure 9. Ground-water-level fluctuations appeared to follow the same trend as the lake water levels. Most of the time, especially in the hot summer months, the ground-water level was lower than the lake level. When rainfall events occurred, the ground-water level increased more rapidly than the lake water level. As a result, on some occasions the ground-water level exceeded the lake water level. This indicates that the ground water actually flowed into the lake. The square of the correlation coefficient is 0.58.

The second regression analysis was conducted to correlate water levels at well 2 with lake water levels. Well 2 is located at the middle of the island. The results of this correlation, which are plotted in figure 10, are as follows:

W2 - -557.75 + 2.73 WL, R^2 = 0.40

where W2 is the water level at well 2 in feet above msl, and the other terms are as defined previously.

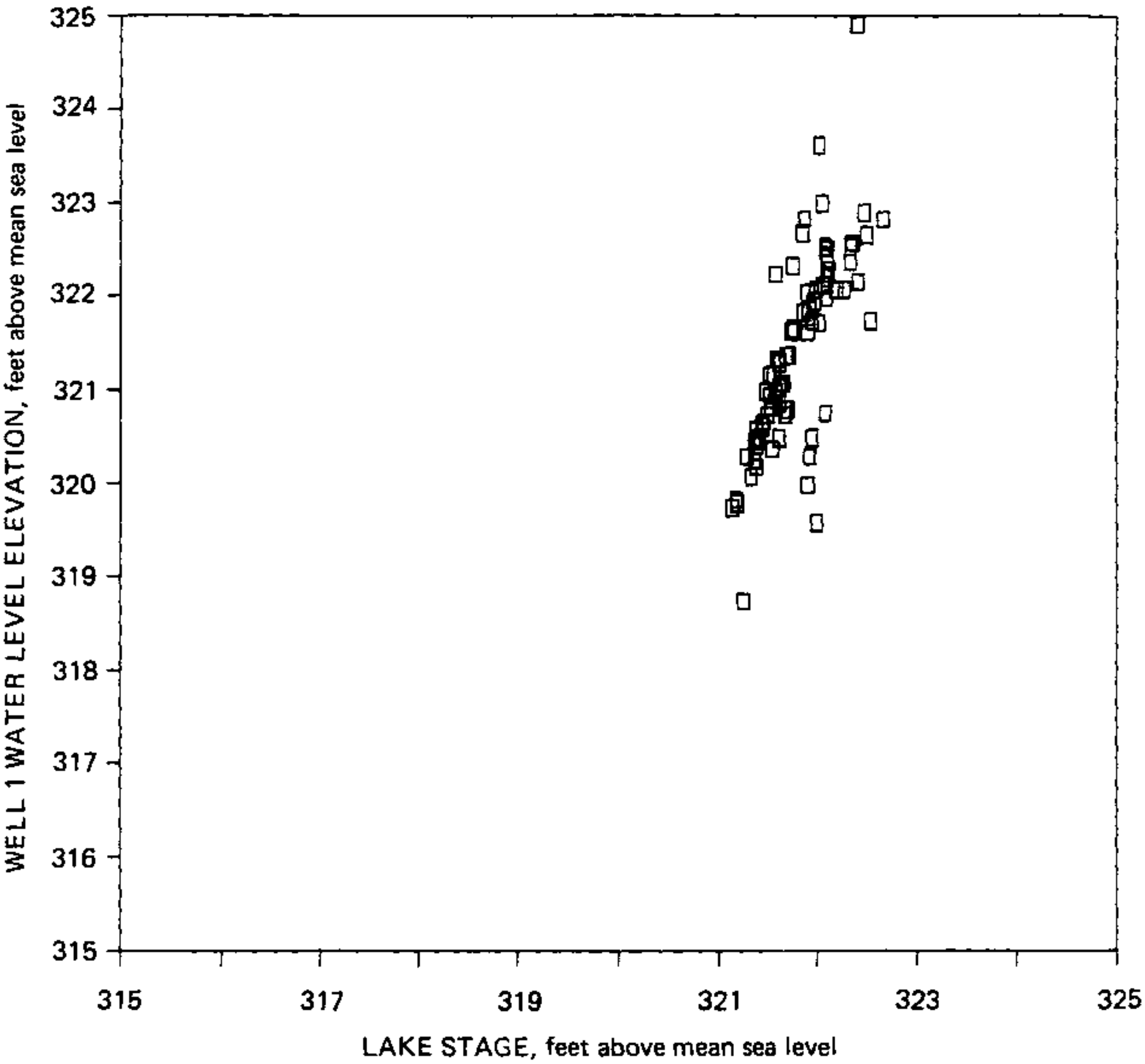

Figure 9. Correlation between water levels at well 1 and lake levels

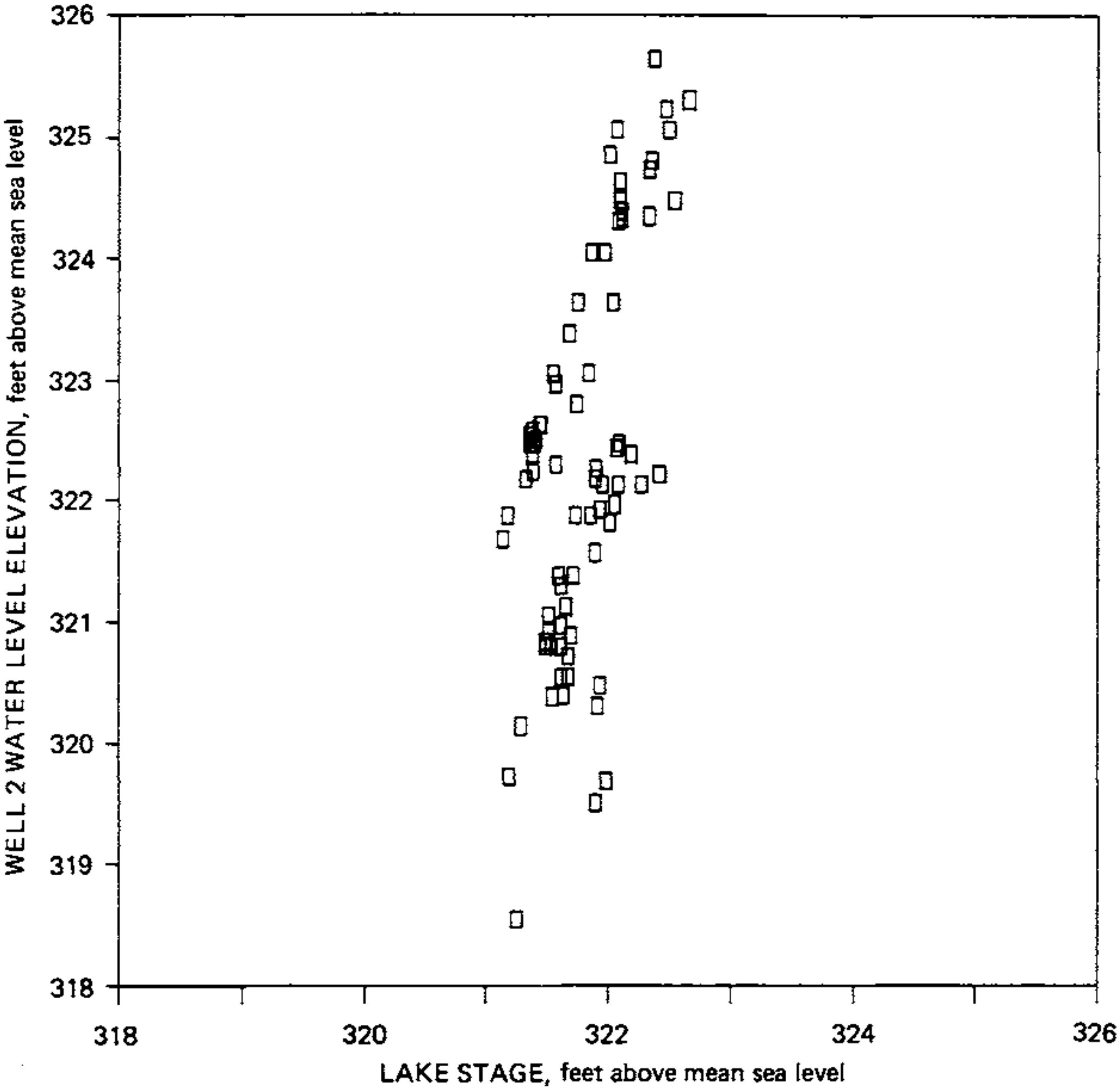

Figure 10. Correlation between water levels at well 2 and lake levels

The general trend is approximately the same as that for the correlation between well 1 and the lake level. However, the correlation is not as good as that between well 1 and the lake water level because well 2 is farther from the lake than well 1.

The third regression analysis was conducted to relate levels at well 2 (located in the middle of the transect) and well 5 (located in the nature preserve area). The regression equation is as follows (also see figure 11):

$$W5 = 84.37 + 0.74\ W2, \quad R^2 = 0.30$$

where W5 is the water level at well 5 in feet above msl, and the other terms are as defined previously.

The results indicate that levels at the ground-water well in the middle of the island (W2) showed similar trends to levels at well 5, located in the nature preserve area. Most of the observation data indicated that water levels at well 5 are higher than those at well 2. As a result, the ground-water gradient forced water to flow in a northerly direction during the data collection period. The square of the correlation coefficient is 0.30. This indicates that the ground-water flow pattern between well 2 and well 5 is influenced by many other factors in addition to the ground-water gradient.

The fourth regression analysis was conducted to define the relationship between water levels at well 5 and lake stages. The result is as follows:

$$W5 = -779.76 + 3.43\ WL, \quad R^2 = 0.48$$

where the terms are as defined previously.

The results indicate that the nature preserve ground-water levels have the same trend as the lake stages. Most of the observations showed that the nature preserve ground-water table was higher than the lake water level. The data are plotted in figure 12.

To illustrate the time distribution of rainfall, lake stage, and ground-water levels at well 5 (located in the nature preserve area), time series data were plotted (figure 13). The results clearly indicate that the ground-water table is driven by the rainfall events. The lake stage responds to the rainfall much faster than does the ground-water level. This is expected because water reaches the lake faster than the ground-

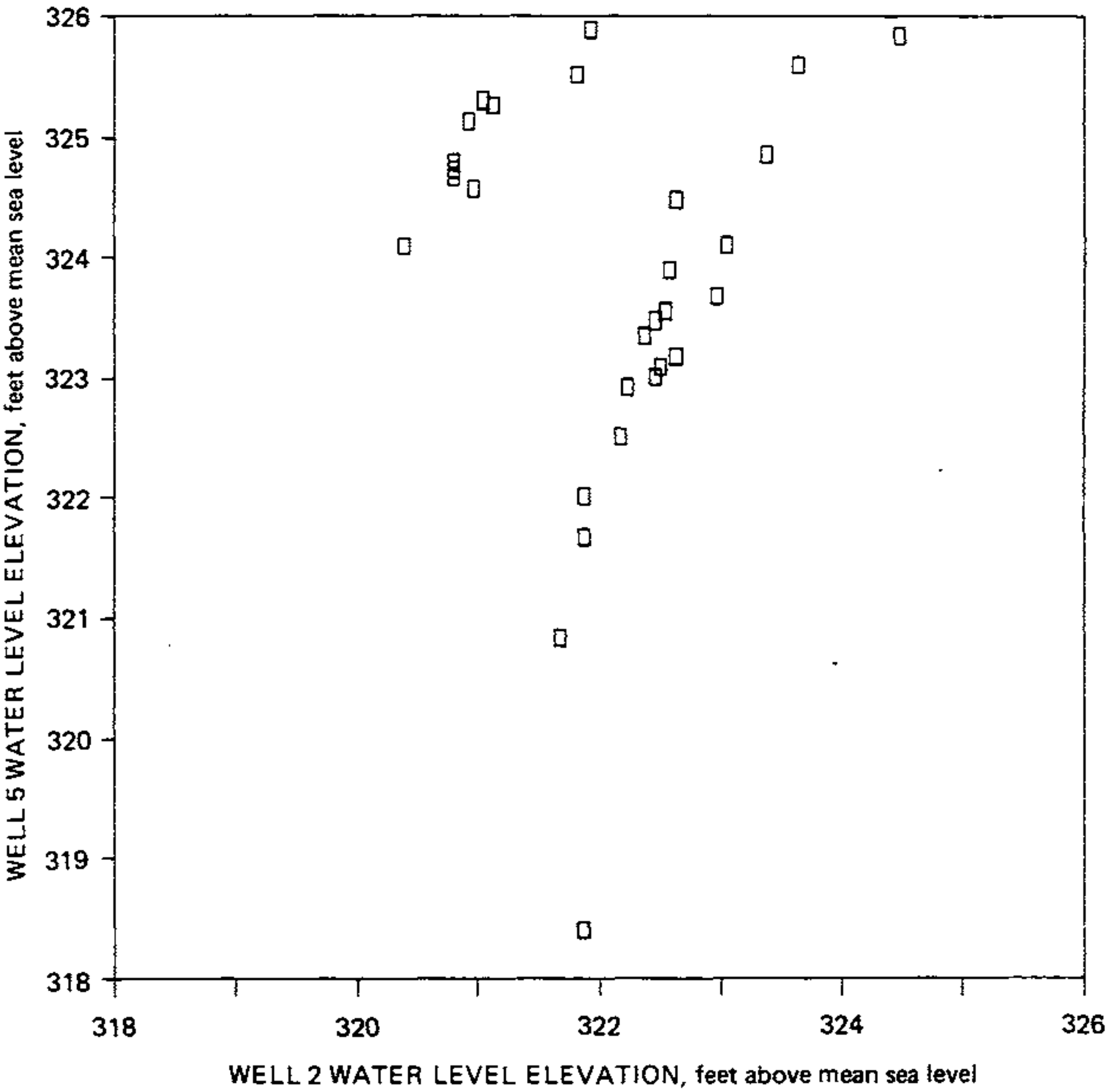

Figure 11. Correlation between water levels at wells 2 and 5

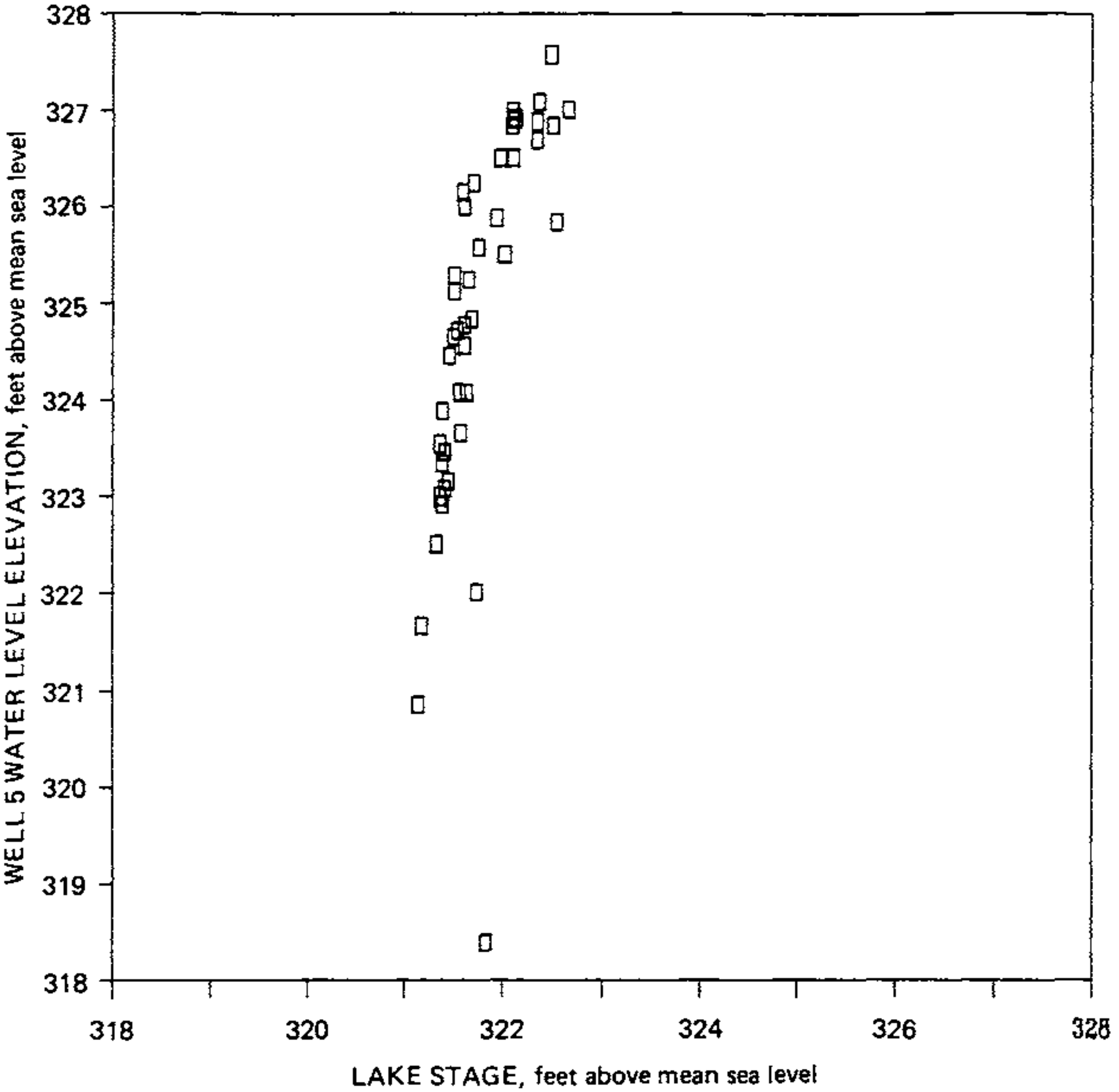

Figure 12. Correlation between water levels at well 5 and lake levels

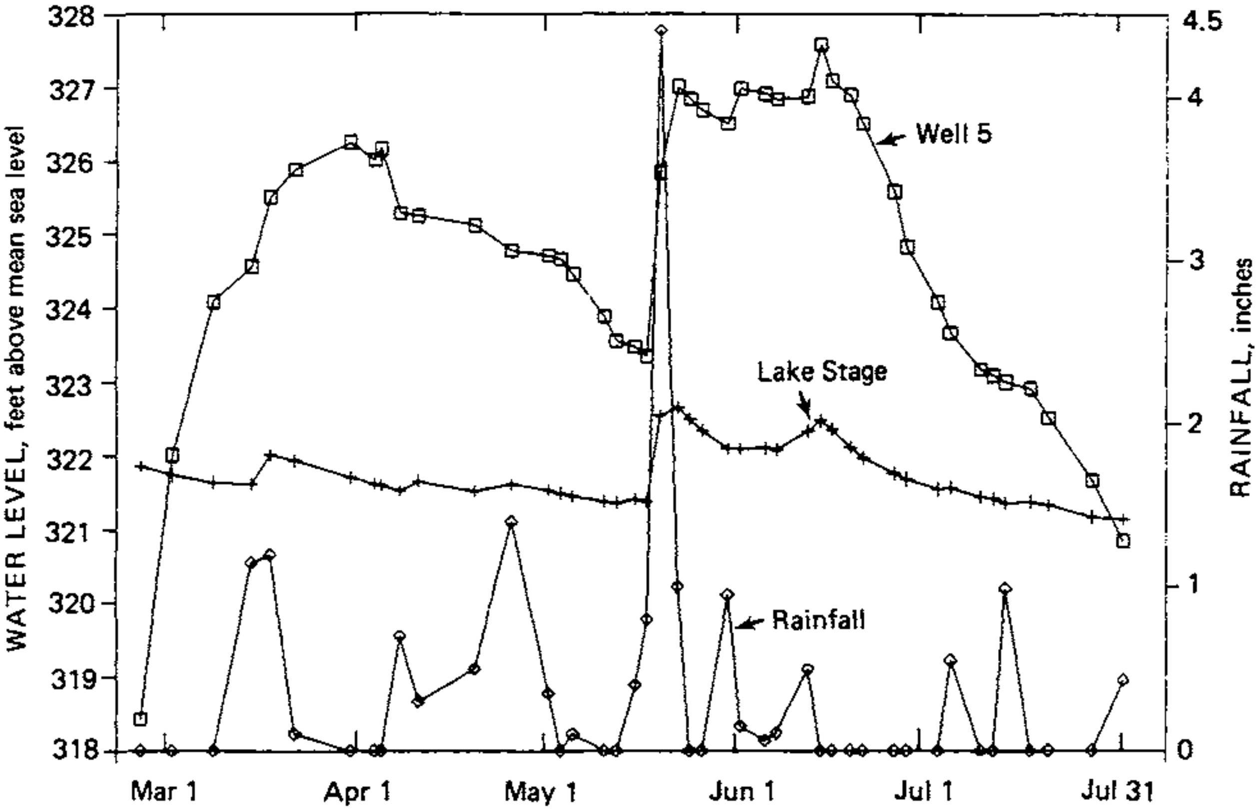

Figure 13. Time distribution of water levels at well 5 lake levels, and rainfall

water table. Figure 13 also shows that the ground-water levels at well 5 at the nature preserve area were higher than the lake levels except in February 1986 and on July 31, 1986, when the ground-water level dropped faster than the lake level because of the hot summer weather.

According to this regression analysis, the rate of rise of ground-water levels is 2 to 3 times that of the lake levels. The highest ground-water elevation observed at all the wells was 327.6 feet MSL, which is 2 to 3 feet below the ground surface and 6 feet above the spillway elevation. The correlation of lake and well-water elevations is slightly better on the island perimeter than at the middle of the island, as is expected due to some bank storage of water.

SUMMARY AND CONCLUSIONS

As indicated by Walton (1970), the water level in shallow, 10- to 30-foot-deep wells fluctuates through a wide range in response to precipitation. Such is the case on the Horseshoe Lake island. Precipitation on the island surface infiltrates and percolates downward to recharge the local ground-water system. Although the agricultural nature of the northern part of the study area retards the rates and amounts of infiltration, small amounts of infiltration do occur. The majority of the rainfall becomes surface and interflow runoff, a major portion of which drains into the nature preserve. Water reaching the nature preserve swamps from direct precipitation and drainage from the north continues to drain from the preserve via one prominent ditch on the southwest end of the island. Once water levels in the swamps recede to an elevation lower than the bed elevation of the drainage ditch, the swamp water becomes ponded and is lost, primarily to evapotranspiration and infiltration. The loose, organic, undisturbed soil characteristics in the preserve and the dense vegetation with its associated root systems create a greater soil permeability and therefore higher infiltration rates. During wet periods of the year, a ground-water mound exists beneath the nature preserve.

Since the water table in the nature preserve is almost always at a higher elevation than the lake stage and is higher than measured water levels north of the preserve, a gradient exists away from the island nature preserve. During prolonged dry periods, however, the water table elevation could fall below the lake level and the gradient could reverse to a flow from the lake to the ground-water system. At this time, as estimated by Lee et al. (1986), the loss to ground water would be approximately 0.0031 inches per day. For the period from March 1984 through April 1985, the total loss to ground water was estimated to be 1.32 inches. By comparison, the total evaporation for this period was estimated as 35.19 inches or approximately 27 times the amount of the ground-water loss. This indicates that the lake does not experience a significant loss to the ground-water system.

If an additional storage quantity of 2000 acre-feet were added to the lake by raising the spillway elevation 1 foot to 322.41 MSL, no significant rise in island ground-water levels should occur under the nature preserve as the water table under the preserve is higher than this elevation 90 percent of the time. Under these conditions, the hydraulic gradient would still be toward the lake.

However, it can be expected that additional lake storage would cause higher ground-water levels within the immediate lake bank on the island because of some bank storage of water.

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APPENDIX A

IDOT BORING LOGS AND SOIL TEST DATA

Appendix A.

FORM NO. B D 137 REV. 9-66

Sh. 1 of 1 Sh.

BRIDGE FOUNDATION BORING LOG

BRIDGE ____

Date JULY, 1985

ROUTE HORSESHOE LAKE

Bored By JOHN R. HAYDEN

SEC. SURFACE WATER SECTION

STA. ISLAND BORING

Checked By GARY L. PULLEY

COUNTY ALEXANDER

Boring No. IC-1

Station 48' E. WELL #1A

Offset ____

Surface Water El. NONE

Groundwater El. at Completion -

After - Hours -

	Elevation	N	Qu t/s.f.	w (%)
Ground Surface 330.7	0			
MEDIUM MOIST DK. BROWN SILT LOAM A-4(2) 329.2		3	0.5S	14
STIFF TO VERY STIFF MOIST BRN. SILTY CLAY LOAM TO SILT LOAM A-6(14)		4	2.0S	22
		5	1.0S	21
	-5	8	1.1S	22
		4	0.6S	29
323.2		8	0.5S	26
SOFT TO MEDIUM WET SILT LOAM A-4(5)		3	0.5S	31
320.7	-10	4	0.4S	30
VERY LOOSE WET BROWN SILT LOAM A-4(0)		2	-	-
		2	-	-
		2	-	-
315.7	-15	2	-	-
VERY SOFT V. MOIST BROWN SILT LOAM A-4 314.2		2	0.1B	32
SOFT V.MOIST GREY ST.BRN. SILTY CLAY LOAM A-6(19) 313.2		3	0.3B	37
LOOSE TO V. LOOSE WET GREY LOAM A-4(0)		3	-	-
	-20	9	-	-
		6	-	-
		11	-	-
SEE NEXT COLUMN				

	Elevation	N	Qu t/s.f.	w (%)
SEE PREVIOUS COLUMN				
		2	-	-
	-25	2	-	-
	-30			
		2	-	-
298.2		7	-	-
BOTTOM OF HOLE = 32.5 FEET.				
	-35			
	-40			
	-45			

BOTTOM OF HOLE = 32.5 FEET.

DURING DRILLING OPERATIONS IT APPEARED THAT FREE WATER WAS ENCOUNTERED AT 14.0 FEET.

DURING DRILLING OPERATIONS WASHOUT PROCEDURE WAS USED FROM 18.0 FEET TO 30.0 FEET. ELEV. TAKEN FROM TOP OF PIPE WELL #1. ELEV. 331.65.

N – Standard Penetration Test – Blows per foot to drive 2" O.D. Split Spoon Sampler 12" with 140# hammer falling 30".

Qu – Unconfined Compressive Strength – t/sf

w – Water Content – percentage of oven dry weight – %.

Type failure:
B – Bulge Failure
S – Shear Failure
E – Estimated Value
P – Penetrometer

FORM NO. B. D. 137 REV. 9-60

sh. 1 of 1 sh.

BRIDGE FOUNDATION BORING LOG

BRIDGE ____

Date JULY, 1985

ROUTE HORSESHOE LAKE

Bored By JOHN R. HAYDEN

SEC. SURFACE WATER SECTION

STA. ISLAND BORING

Checked By GARY L. PULLEY

COUNTY ALEXANDER

Boring No. IC-2

Station 22' W. WELL #1

Offset ____

Surface Water El. NONE

Groundwater El. at Completion -

After - Hours -

	Elevation	N	Qu t/s.f.	w (%)
Ground Surface 329.6	0			
VERY STIFF DAMP BROWN SILT LOAM A-4		6	3.5S	19
328.1				
MEDIUM MOIST TO V. MOIST BRN. SILTY CLAY LOAM TO SILT LOAM A-6		8	0.8S	20
		5	1.1S	22
324.6	5	9	1.1S	25
SOFT V. MOIST BROWN SILT LOAM A-4		3	0.4B	31
322.1		4	0.4B	34
LOOSE TO V. LOOSE V. MOIST BROWN FINE GRAINED SAND		2	-	-
	10	6	-	-
		5	-	-
		8	-	-
		6	-	-
314.6	15	8	-	-
MEDIUM TO VERY LOOSE V. MOIST BROWN FINE GRAINED SAND		16	-	-
		23	-	-
		12	-	-
	20	16	-	-
		4	-	-
307.1		10	-	-

(SEE NEXT COLUMN)

BOTTOM OF HOLE = 22.5 FEET.

DURING DRILLING OPERATIONS IT APPEARED THAT FREE WATER WAS ENCOUNTERED AT 13.0 FEET.

DURING DRILLING OPERATIONS WASHOUT PROCEDURES WAS USED FROM 12.5 FEET TO 20.0 FEET.

ELEV. TAKEN FROM TOP PIPE WELL #1 - ELEV. 331.65.

Elevation	N	Qu t/s.f.	w (%)
25			
30			
35			
40			
45			

N - Standard Penetration Test - Blows per foot to drive 2" O.D. Split Spoon Sampler 12" with 140# hammer falling 30".

Qu - Unconfined Compressive Strength - t/sf

w - Water Content - percentage of oven dry weight - %.

Type failure:
B - Bulge Failure
S - Shear Failure
E - Estimated Value
P - Penetrometer

FORM NO. B. D 137 REV. 9-66

Sh. 1 of 1 Sh.

BRIDGE FOUNDATION BORING LOG

BRIDGE

Date JULY, 1985

ROUTE HORSESHOE LAKE

Bored By JOHN R. HAYDEN

SEC. SURFACE WATER SECTION

STA. ISLAND BORING

Checked By GARY L. PULLEY

COUNTY ALEXANDER

Boring No. IC-3

Station 24' E. WELL #2A

Offset

Surface Water El. NONE

Groundwater El. at Completion -

After - **Hours** -

		Elevation	N	Qu t/s.f.	w (%)
Ground Surface	328.8	0			
MEDIUM TO SOFT DAMP BROWN SILT LOAM A-4			2	0.4S	15
	326.3		7	0.6S	21
STIFF V. MOIST GREY & BROWN SILTY CLAY LOAM A-6			5	1.2S	42
	323.8	-5	8	1.9S	34
SOFT TO MEDIUM V. MOIST BROWN SILT LOAM A-4(0)			5	0.5 B	33
	321.3		5	0.4S	29
SOFT V. MOIST BROWN SILT LOAM A-4(10)			3	0.4B	35
	318.8	-10	4	0.3B	33
LOOSE TO V. LOOSE WET BROWN SAND A-2-4(0)			10	-	-
			16	-	-
			9	-	-
		-15	8	-	-
			2	-	-
	311.3		3	-	-
LOOSE TO V. LOOSE WET BROWN SAND A-3(0)			3	-	-
		-20	5	-	-
			7	-	-
	306.3		9	-	-
(SEE NEXT COLUMN)					

BOTTOM OF HOLE = 22.5 FEET.

DURING DRILLING OPERATIONS IT APPEARED THAT FREE WATER WAS ENCOUNTERED AT 13.0 FEET.

DURING DRILLING OPERATIONS WASHOUT PROCEDURES USED FROM 12.5 FEET TO 20.0 FEET.

ELEV. TAKEN FROM TOP OF PIPE WELL #2A

ELEV. 330.91.

Elevation	N	Qu t/s.f.	w (%)
-25			
-30			
-35			
-40			
-45			

N – Standard Penetration Test – Blows per foot to drive 2" O.D. Split Spoon Sampler 12" with 140# hammer falling 30".

Qu – Unconfined Compressive Strength – t/sf

w – Water Content – percentage of oven dry weight – %.

Type failure:
B – Bulge Failure
S – Shear Failure
E – Estimated Value
P – Penetrometer

FORM NO. B. O. 137 REV. 9-60

Sh. 1 of 1 Sh.

BRIDGE FOUNDATION BORING LOG

ROUTE HORSESHOE LAKE
SEC. SURFACE WATER SECTION
COUNTY ALEXANDER
BRIDGE
STA. ISLAND BORING
Date JULY, 1985
Bored By JOHN R. HAYDEN
Checked By GARY L. PULLEY

Boring No. IC-4
Station 23' WEST WELL #2
Offset -

Surface Water El. NONE
Groundwater El. at Completion -
After - **Hours** -

	Elevation	N	Qu t/s.f.	w (%)
Ground Surface 328.5	0			
MEDIUM DAMP BROWN SILT LOAM A-4		4	0.7S	-
327.0				
STIFF V. MOIST GREY & BROWN CLAY A-7-6		7	1.7B	30
324.5		5	1.4B	39
SOFT TO MEDIUM V. MOIST BROWN SILT LOAM A-4	-5	10	0.6S	26
		4	0.3B	31
		6	0.8B	32
319.5		4	0.6B	34
STIFF V. MOIST SILT LOAM A-4 318.5	-10	6	1.1B	31
LOOSE TO VERY LOOSE WET SAND		10	-	-
		7	-	-
		5	-	-
	-15	6	-	-
		2	-	-
311.0		2	-	-
LOOSE TO V. LOOSE WET GREY SAND		1	-	-
	-20	5	-	-
		6	-	-
306.0		7	-	-
(SEE NEXT COLUMN)				

BOTTOM OF HOLE = 22.5 FEET.

DURING DRILLING OPERATIONS IT APPEARED THAT FREE WATER WAS ENCOUNTERED AT 11.5 FEET.

DURING DRILLING OPERATIONS WASHOUT PROCEDURE WAS USED FROM 13.0 FEET TO 20.0 FEET.

ELEV. TAKEN FROM TOP OF PIPE WELL #2A

ELEV. 330.91.

	Elevation	N	Qu t/s.f.	w (%)
	-25			
	-30			
	-35			
	-40			
	-45			

N – Standard Penetration Test – Blows per foot to drive 2" O.D. Split Spoon Sampler 12" with 140# hammer falling 30".

Qu – Unconfined Compressive Strength – t/sf

w – Water Content – percentage of oven dry weight – %.

Type failure:
B – Bulge Failure
S – Shear Failure
E – Estimated Value
P – Penetrometer

FORM NO. B. D 137 REV. [illegible]

Sh. 1 of 1 Sh.

BRIDGE FOUNDATION BORING LOG

BRIDGE

ROUTE HORSESHOE LAKE

SEC. SURFACE WATER SECTION

STA. ISLAND BORING

COUNTY ALEXANDER

Date JULY, 1985

Bored By JOHN R. HAYDEN

Checked By GARY L. PULLEY

Boring No. IC-5

Station 55' E. WELL #3A

Offset

Surface Water El. NONE

Groundwater El. at Completion -

After - **Hours** -

	Elevation	N	Qu t/s.f.	w (%)
Ground Surface 328.4	0			
STIFF V. MOIST DK. BROWN MOT. GREY CLAY A-7-6		6	1.3B	33
325.9		9	1.5B	28
STIFF V. MOIST BROWN CLAY A-7-6				
324.4		8	1.5B	22
MEDIUM V. MOIST BROWN FINE GRAINED SAND	-5	20	-	-
		13	-	-
320.9		15	-	-
LOOSE V. MOIST TO WET BROWN SAND		9	-	-
	-10	9	-	-
316.9		8	-	-
MEDIUM TO LOOSE WET BROWN SAND		12	-	-
		14	-	-
	-15	25	-	-
		7	-	-
		14	-	-
		9	-	-
	-20	17	-	-
		9	-	-
305.9		14	-	-

(SEE NEXT COLUMN)

BOTTOM OF HOLE = 22.5 FEET.

DURING DRILLING OPERATIONS IT APPEARED THAT FREE WATER WAS ENCOUNTERED AT 10.5 FEET.

DURING DRILLING OPERATIONS WASHOUT PROCEDURES USED FROM 12.5 FEET TO 20.0 FEET.

ELEV. TAKEN FROM TOP PIPE WELL #3.

ELEV. 332.08.

Elevation	N	Qu t/s.f.	w (%)
-25			
-30			
-35			
-40			
-45			

~~N – Standard Penetration Test –~~ Blows per foot to drive 2" O.D. Split Spoon Sampler 12" with 140# hammer falling 30".

Qu – Unconfined Compressive Strength – t/sf

w – Water Content – percentage of oven dry weight – %.

Type failure:
B – Bulge Failure
S – Shear Failure
E – Estimated Value
P – Penetrometer

FORM NO. B. D 137 REV. 9-60

Sh. 1 of 1 Sh.

BRIDGE FOUNDATION BORING LOG

ROUTE HORSESHOE LAKE

SEC. SURFACE WATER SECTION

COUNTY ALEXANDER

BRIDGE

STA. ISLAND BORING

Date JULY, 1985

Bored By JOHN R. HAYDEN

Checked By GARY L. PULLEY

Boring No. IC-6

Station 23' E. WELL #3

Offset

Surface Water El. NONE

Groundwater El. at Completion -

After - **Hours** -

			Elevation	N	Qu t/s.f.	w (%)
Ground Surface	329.2	0				
V. STIFF MOIST BROWN SILT LOAM A-4	328.7			6	3.1B	24
V.STIFF TO STIFF MOIST CLAY A-7-6(44)	326.7			12	1.8S	21
STIFF TO MED. V.MOIST BROWN CLAY A-7-6(17)				7	1.5S	20
	324.2		-5	8	0.7S	18
SOFT V. MOIST SILT LOAM A-4(0)				4	0.4S	29
	321.7			5	0.4S	27
LOOSE TO V. LOOSE MOIST TO WET BROWN SAND A-3(0)				4	-	-
			-10	6	-	-
				2	-	-
	316.7			3	-	-
MEDIUM WET BROWN SAND A-3(0)				14	-	-
			-15	23	-	-
				14	-	-
				23	-	-
				8	-	-
			-20	23	-	-
				7	-	-
	306.7			19	-	-
~~(SEE NEXT COLUMN)~~						

BOTTOM OF HOLE = 22.5 FEET.

DURING DRILLING OPERATIONS IT APPEARED THAT FREE WATER WAS ENCOUNTERED AT 11.0 FEET.

DURING DRILLING OPERATIONS WASHOUT PROCEDURES USED FROM 10.5 FEET TO 20.5 FEET.

ELEV. TAKEN FROM TOP PIPE WELL #3.

ELEV. 332.08.

Elevation	N	Qu t/s.f.	w (%)
-25			
-30			
-35			
-40			
-45			

N – Standard Penetration Test – Blows per foot to drive 2" O.D. Split Spoon Sampler 12" with 140# hammer falling 30".

Qu – Unconfined Compressive Strength – t/sf

w – Water Content – percentage of oven dry weight – %.

Type failure:
B – Bulge Failure
S – Shear Failure
E – Estimated Value
P – Penetrometer

B0-508A
REV 2-65

STATE OF ILLINOIS
Department of Public Works and Buildings
Division of Highways

SOIL TEST DATA

STATE JOB NUMBER - ROUTE ISLAND BORINGS PROJECT HORSESHOE LAKE

SECTION - ~~CITY~~ OR COUNTY ALEXANDER

LAB. NO.	85(S)-117	85(S)-118	85(S)-119	85(S)-120	85(S)-121
STATION	IC-1	-	-	-	-
LOCATION	48' E. WELL #1A		-	-	-
DEPTH	0.0'-1.5'	1.5'-7.5'	7.5'-10.0'	10.0'-15.0'	16.5'-17.5'
HRB CLASSIFICATION & GROUP INDEX	A-4(2)	A-6(14)	A-4(5)	A-4(0)	A-6(19)
GRAIN SIZE CLASSIFICATION	SIL	SICL-SIL	SIL	SIL	SICL
GRADUATION - PASSING 1" SIEVE %					
" 3/4" " %					
" 1/2" " %					
" NO. 4 " %	100	100	100	100	100
" NO. 10 " %	100	100	100	100	100
" NO. 40 " %					
" NO. 100 " %					
" NO. 200 " %	87	90	88	61	99
SAND %	13	10	12	39	1
SILT %	75	70	74	54	77
CLAY %	12	20	14	7	22
LIQUID LIMIT %	22.9	35.5	27.6	24.4	39.7
PLASTICITY INDEX %	3.8	15.9	6.8	0.6	18.2
BEARING RATIO %					
STANDARD DRY DENSITY AASHO T99 %					
OPTIMUM MOISTURE %					

REMARKS:

HOLE CONTINUED ON NEXT SHEET.

BD-508A
REV 2-65

STATE OF ILLINOIS
Department of Public Works and Buildings
Division of Highways

SOIL TEST DATA

STATE JOB NUMBER -
ROUTE ISLAND BORINGS
PROJECT HORSESHOE LAKE
SECTION -
~~CITY OR~~ COUNTY ALEXANDER

LAB. NO.	85(S)-122				
STATION	IC-1				
LOCATION	48'E. WELL #1A				
DEPTH	17.5'-25.0'				
HRB CLASSIFICATION & GROUP INDEX	A-4(0)				
GRAIN SIZE CLASSIFICATION	LOAM				
GRADUATION-PASSING 1" SIEVE %					
" 3/4" " %					
" 1/2" " %					
" NO. 4 " %	100				
" NO. 10 " %	100				
" NO. 40 " %					
" NO. 100 " %					
" NO. 200 " %	55				
SAND %	45				
SILT %	49				
CLAY %	6				
LIQUID LIMIT %	N.P.				
PLASTICITY INDEX %	N.P.				
BEARING RATIO %					
STANDARD DRY DENSITY AASHO T99 %					
OPTIMUM MOISTURE %					

REMARKS: XXX

XXX DENOTES BOTTOM OF HOLE.

BD-508A
REV 2-65

STATE OF ILLINOIS
Department of Public Works and Buildings
Division of Highways

SOIL TEST DATA

STATE JOB NUMBER -
ROUTE ISLAND BORINGS
PROJECT HORSESHOE LAKE
SECTION -
XXXXXXX ~~CITY OR~~ COUNTY ALEXANDER

LAB. NO.	85(S)-123	85(S)-124	85(S)-125	85(S)-126	
STATION	IC-3	-	-	-	
LOCATION	24' E. WELL #2A				
DEPTH	5.0'-7.5'	7.5'-10.0'	10.0'-17.5'	17.5'-22.5'	
HRB CLASSIFICATION & GROUP INDEX	A-4(0)	A-4(10)	A-2-4(0)	A-3(0)	
GRAIN SIZE CLASSIFICATION	SIL	SIL	SAND	SAND	
GRADUATION - PASSING 1" SIEVE %					
" 3/4" " %					
" 1/2" " %					
" NO. 4 " %	100	100	100	100	
" NO. 10 " %	100	100	100	100	
" NO. 40 " %					
" NO. 100 " %					
" NO. 200 " %	66	95	14	10	
SAND %	34	5	86	90	
SILT %	56	79	10	6	
CLAY %	10	16	4	4	
LIQUID LIMIT %	25.4	31.4	N.P.	N.P.	
PLASTICITY INDEX %	3.4	10.1	N.P.	N.P.	
BEARING RATIO %					
STANDARD DRY DENSITY AASHO T99 %					
OPTIMUM MOISTURE %					

REMARKS:

XXX

XXX DENOTES BOTTOM OF HOLE.

B0-508A
REV 2-65

STATE OF ILLINOIS
Department of Public Works and Buildings
Division of Highways

SOIL TEST DATA

STATE JOB NUMBER -

ROUTE ISLAND BORINGS

PROJECT HORSESHOE LAKE

SECTION -

~~CITY~~ OR COUNTY ALEXANDER

LAB. NO.	85(S)-127	85(S)-128	85(S)-129	85(S)-130	85(S)-131
STATION	IC-6	-	-	-	-
LOCATION	23' E. WELL #3		-	-	-
DEPTH	0.5'-2.5'	2.5'-5.0'	5.0'-7.5'	7.5'-12.5'	12.5'-22.5'
HRB CLASSIFICATION & GROUP INDEX	A-7-6(44)	A-7-6(17)	A-4(0)	A-3(0)	A-3(0)
GRAIN SIZE CLASSIFICATION	CLAY	CLAY	SIL	SAND	SAND
GRADUATION - PASSING 1" SIEVE %					
" 3/4" " %					
" 1/2" " %					
" NO. 4 " %	100	100	100	100	100
" NO. 10 " %	100	100	100	100	100
" NO. 40 " %					
" NO. 100 " %					
" NO. 200 " %	98	79	66	5	3
SAND %	2	21	34	95	97
SILT %	49	46	54	2	1
CLAY %	49	33	12	3	2
LIQUID LIMIT %	62.9	41.8	22.5	N.P.	N.P.
PLASTICITY INDEX %	39.3	23.3	2.5	N.P.	N.P.
BEARING RATIO %					
STANDARD DRY DENSITY AASHO T99 %					
OPTIMUM MOISTURE %					

REMARKS:

XXX

XXX DENOTES BOTTOM OF HOLE.

APPENDIX B

CHARACTERISTICS OF MONITORING WELLS, AND WELL INSTALLATION AND RELOCATION DATES

Appendix B-1. Characteristics of Monitoring Wells

Well no.	Total depth	Head elevation	Bottom elevation	Finished in
1A	10'	331.77	319.77	SAND
2A	11'	330.91	317.91	SAND
3A	11'	332.00	319.00	SAND
1	16'	331.65	313.65	SAND
2	16'	330.80	312.80	SAND
3	16'	332.08	314.08	SAND
4	16'	331.43	313.43	SAND
5	16'	332.84	314.84	SAND
2B	6'	331.95	323.95	SANDY SILT

Note: All wells use 60-gauze, 1.5-inch pipe

Appendix B-2. Well Installation and Relocation Dates

Well no.	Date installed	Date removed
1A	4/29/85	12/10/86
1	4/30/85	
2A	4/30/85	12/10/86
2	4/29/85	
3A	6/9/85	12/10/86
3	4/30/85	
4	2/19/86	
5	2/19/86	
2B	4/10/86	

APPENDIX C

WATER-LEVEL ELEVATIONS (MSL) IN MONITORING WELLS, MAY 1985 THROUGH JULY 1986

Appendix C. Water-Level Elevations (MSL) in Monitoring Wells, May 1985 through July 1986

MAY 1985

Date	#1	#1A	#2	#2A	#3	#3A
5/3	324.90	320.44	325.63	319.99	325.42	N/A
5/8	320.75	323.99	325.05	321.37	324..08	N/A
5/10	323.61	321.35	324.84	321.58	323.,81	N/A
5/16	322.82	321.85	324.05	321.91	323..16	N/A
5/23	322.99	322.15	323.63	322.33	323.,66	N/A
5/28	322.67	322.35	323.05	322.56	322.,91	N/A
5/31	322.32	322.40	322.80	322.58	322..66	N/A

JUNE 1985

6/13	322.23	322.06	322.30	322.41	322..42	322.75
6/24	N/A	N/A	N/A	N/A	322,.16	322.63

JULY 1985

7/9	320.98	322.19	320.84	321.91	321 .28	321.67
7/18	320.28	322.02	320.14	321.45	320,.54	320.92

AUGUST 1985

8/2	319.78	321.73	319.72	319.99	320 .00	320.92

SEPTEMBER 1985

9/5	319.57	321.31	319.68	319.66	319..58	319.92

OCTOBER 1985

Date	#1	#1A	#2	#2A	#3	#3A	#4	#5
10/10	318.73	N/A	318.55	N/A	318.75	N/A	N/A	N/A

NOVEMBER 1985

11/19	319.98	321.85	N/A	N/A	320.04	320.00	N/A	N/A
11/22	320.28	321.85	320.30	320.08	320.16	320.21	N/A	N/A
11/25	320.48	321.85	320.47	320,08	320.37	320.33	N/A	N/A

Appendix C. Continued

DECEMBER 1985

Date	#1	#1A	#2	#2A	#3	#3A	#4	#5
12/2	322.15.	322.10	322.22	320.83	322.00	322.17	N/A	N/A
12/4	322.07	322.27	322.13	320.91	322.25	322.29	N/A	N/A
12/9	322.11	322.19	321.97	321.16	322.16	322.38	N/A	N/A
12/11	322.40	N/A	322.47	N/A	322.41	N/A	N/A	N/A
12/16	322.53	N/A	322.43	N/A	322.66	N/A	N/A	N/A
12/19	321.94	N/A	322.13	N/A	322.37	N/A	N/A	N/A

JANUARY 1986

1/9	320.78	320.88	321.21	N/A	N/A	N/A	N/A	N/A
1/13	320.78	320.72	321.08	N/A	N/A	N/A	N/A	N/A
1/15	320.73	320.55	321.16	N/A	N/A	N/A	N/A	N/A
1/23	320.48	320.55	320.87	N/A	N/A	N/A	N/A	N/A
1/31	320.36	320.38	320.83	N/A	N/A	N/A	N/A	N/A

FEBRUARY 1986

2/7	322.07		322.38		322.41	N/A	N/A	N/A
2/10	321.98		322.13		322.37	N/A	N/A	N/A
2/17	321.86		322.26		322.37	N/A	N/A	N/A
2/19	322.03		322.18		322.33	N/A	N/A	N/A
2/21	321.82		321.88		322.08	N/A	315.76	318.42
2/26	321.61		321.88		322.12	N/A	318.18	322.01

MARCH 1986

Date	#1	#1	#3	#4	#5	#2B
3/5	321.07	320.39	321.46	319.72	324..09	N/A
3/11	321.03	320.97	321.23	320.51	324..57	N/A
3/14	321.71	321.82	322.16	320.85	325.51	N/A
3/18	321.73	321.93	322.16	321.18	N/A	N/A
3/27	321.36	321.38	321.66	321.60	326.26	N/A
3/31	321.28	321.30	321.58	321.51	326.01	N/A

Appendix C. Continued

APRIL 1986

Date	#1	#2	#3	#4	#5	#2B
4/1	321.32	321.38	321.58	321.60	326.17	N/A
4/4	321.15	321.05	321.46	321.51	325.30	N/A
4/7	321.07	321.13	321.42	321.43	325.26	N/A
4/16	320.94	320.93	321.25	321.45	325.13	DRY
4/22	320.86	320.80	321.21	321.35	324.78	DRY
4/28	320.82	320.80	321.21	321.35	324.72	DRY
4/30	320.73	320.80	321.16	321.31	324.67	DRY

MAY 1986

5/2	320.65	322.63	321.00	321.22	324.47	DRY
5/7	320.57	322.58	320.92	321.14	323.89	DRY
5/9	320.44	322.55	320.87	321.01	323.55	DRY
5/12	320.47	322.47	320.79	320.93	323.47	DRY
5/14	320.40	322.38	320.75	320.85	323.34	DRY
5/16	321.73	324.47	322.04	322.10	325.84	DRY
5/19	322.82	325.30	323.91	323.18	327.01	323.78
5/21	322.65	325.05	323.00	322.97	326.84	323.78
5/23	322.53	324.72	322.83	322.93	326.69	323.70
5/27	322.44	324.47	322.66	322.85	326.51	DRY
5/29	322.50	324.63	322.91	323.01	326.99	DRY

JUNE 1986

6/2	322.23	324.32	322.62	322.76	326.92	DRY
6/4	322.19	324.30	322.58	322.70	326.84	DRY
6/9	322.36	324.34	322.96	322.93	326.88	DRY
6/11	322.90	325.22	323.50	323.35	327.58	324.03
6/13	322.57	324.80	323.04	323.10	327.09	323.99
6/16	322.28	324.38	322.79	322.81	326.90	323.78
6/18	322.07	324.05	322.50	322.60	326.51	DRY
6/23	321.65	323.63	322.00	322.56	325.59	DRY
6/25	321.36	323.38	321.75	322.43	324.84	DRY
6/30	321.15	323.05	321.50	322.26	324.09	DRY

Appendix C. Concluded

JULY 1986

Date	#1	#2	#3	#4	#5	#2B
7/2	320.98	322.97	321.33	322.18	323.67	DRY
7/7	320.61	322.63	320.87	321.93	323.17	DRY
7/9	320.48	322.51	320.87	321.81	323.09	DRY
7/11	320.23	322.47	320.75	N/A	N/A	DRY
7/15	320.17	322.24	320.54	321.60	322.92	DRY
7/18	320.07	322.18	320.44	321.47	322.51	DRY
7/25	319.82	321.88	320.16	321.31	321.67	DRY
7/30	319.73	321.68	320.04	N/A	320.84	DRY

APPENDIX D

LAKE STAGES, MAY 1985 THROUGH JULY 1986

Appendix 0. Lake Stages,
May 1985 through July 1986

				1985								1986			
DAY	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY
1												321.60			
2				321.19				322.42				321.60	321.46	322.12	321.58
3	322.41							322.34			321.64	321.56			
4								322.28			321.64	321.52		322.09	
5					321.99			322.24			321.64	321.56	321.42		
6								322.18			321.62	321.66	321.36		
7							321.81			322.20	321.62	321.66	321.39		321.45
8	322.08											321.64	321.38		
9			321.49					322.06	321.70			321.64	321.37	322.34	321.42
10	322.02					321.25		322.08		322.09	321.62	321.60			
11								322.10			321.62	321.60		322.48	321.37
12								322.14			321.92	321.58	321.41		
13		321.58							321.68			321.56	321.39	322.36	
14											322.02	321.54	321.39		
15									321.68			321.54	321.62		321.39
16	321.87							322.08			321.94	321.52	322.54	322.12	
17								322.02		321.91		321.50			
18			321.29					ICE			321.94	321.50		321.98	321.33
19							321.90	321.96		321.90	321.94	321.54	322.66		
20							322.06				321.90	321.58			
21										321.86	321.84	321.62	322.50		
22							321.92					321.62			
23	322.05								321.62			321.60	322.34	321.76	
24		321.90										321.56	322.26		
25							321.94					321.56		321.69	321.18
26										321.74		321.54			
27											321.72	321.52	322.10		
28	321.85											321.54			
29					321.45								322.10		
30													322.00	321.56	321.14
31	321.75								321.55		321.62				

NOTE: As of 11/25/85, spillway (HL1) gage changed. Datum 5.67 - 321.41 msl