THE GEOLOGY AND HYDROGEOLOGY OF UNIVERSITY BAY, MADISON, WISCONSIN

BY

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Abstract

A geologic-hydrogeologic field study was made of University Bay on the University of Wisconsin, Madison campus between November, 1972 to January, 1974. This study was performed under the auspices of the University Bay Committee for the purpose obtaining base line data on the geology, groundwater quality of the University Bay and lands surrounding the Bay. These data were gathered from literature reviews and a detailed field analysis of the groundwater and surficial geology of the Bay area. The groundwater/surface water relationships in and around the Bay, and the affects of road salting and municipal pumpage on groundwater were determined. Areas which are not suited for construction due either to soils having poor bearing capacities, or poor drainage, or thin soils over bedrock or a high water table were delineated. Data and conclusions derived will hopefully be useful to campus planners in formulating management and rehabilitation alternatives for the University Bay and west campus area.

Acknowledgments

Financial support for this project was derived from a Class of 1922 grant to the University of Wisconsin. The University Bay Committee administrating the program, under the guidance of Professor Elizabeth McCoy, aided greatly in advice and patience. A special thanks goes to Richard McCabe and Stephanie Carpenter of the University Bay Project for invaluable help and understanding.

This study was conducted under the supervision of Dr. D. A. Stephenson, Associate Professor of Geology, who provided valuable suggestions and guidance throughout the study. Professord D. Mickelson and R. Gates of the Department of Geology and Geophysics also provided critical reviews of text and acted as degree committee members.

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Introduction

It is intended that this report be used as a tool for both campus and city planners. Hopefully, knowledge gained from this report will help those responsible in managing the campus.

University Bay and the contiguous land areas (Figure 1) have provided the university community with recreational and aesthetic benefits since the campus was first developed. Presently these amenities are being seriously jeopardized as a result of increased urbanization. Lake Mendota, as well as other Madison area lakes, reflects this urban pressure through increased sediment loads, increased nutrients, and increased inputs of other noxious wastes.

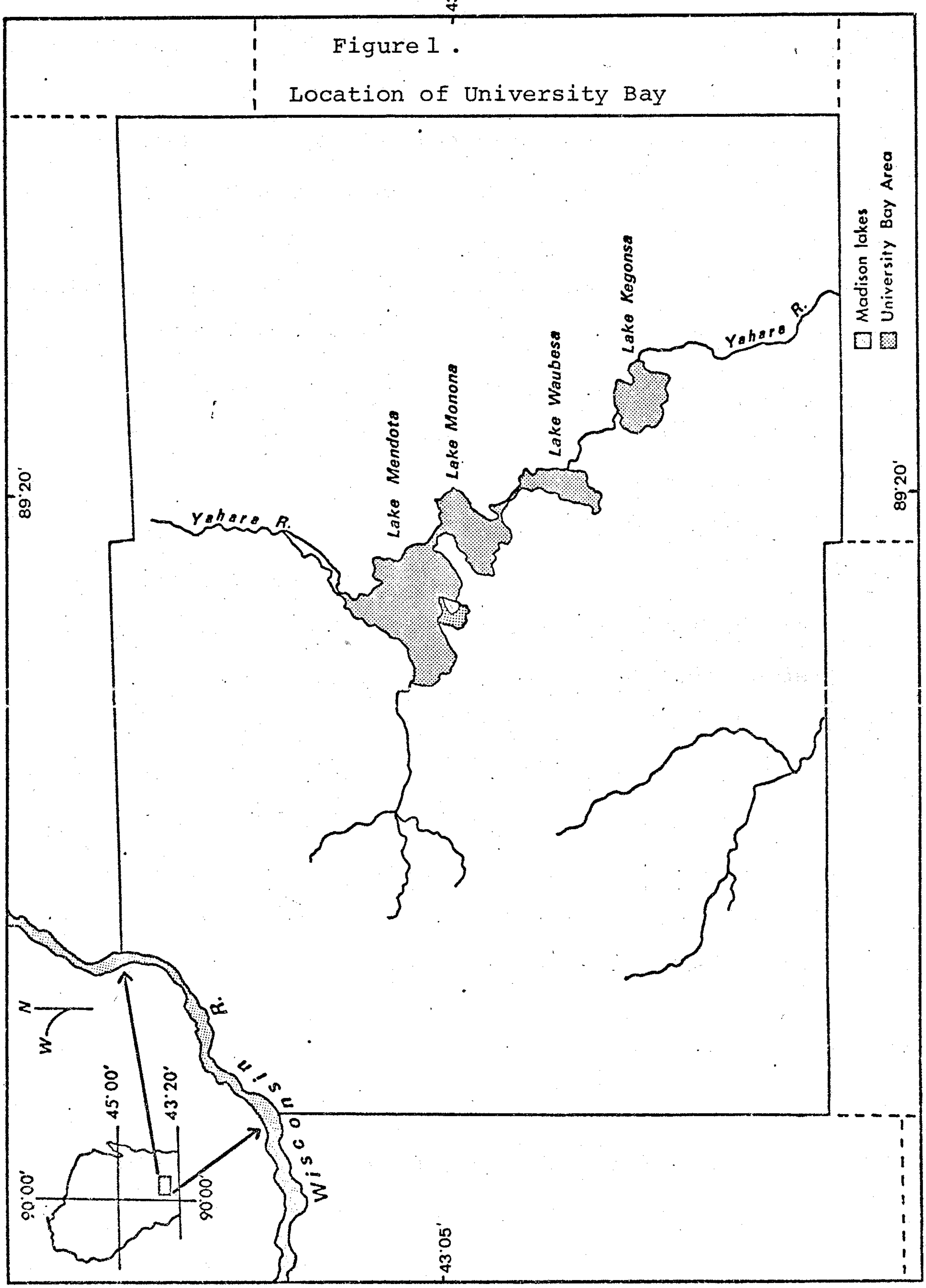
Today, the complex relationships which contribute to the degradation of lakes are better understood, and the scientific and technical expertise is available to be used in formulating lake management programs. Such programs should aim at controlling and directing both natural and man-made activities such that the amenities derived from our water resources can be sustained and expanded.

Purpose and Scope

Through the generosity of the UW Alumni Class of 1922 in their 50-year gift to the university, funds were supplied with which to develop and maintain programs designed to study the natural environment of University Bay and the

Figure 1.

Location of University Bay



(drawn by: S. Carpenter)

Dane County, Wisconsin

surrounding lands. The University Bay Project was organized in 1971, under the auspices of the Graduate School, as a mission-oriented, multi-disciplinary effort to meet certain objectives. Two objectives are to preserve and enhance the environment of University Bay. A thirteen-member Advisory Committee was selected. The Advisory Committee determined that the first efforts of the project would have to be directed at accumulating an accurate and inclusive survey of University Bay's natural condition. The geological and hydrogeological parameters of the Bay area were essentially unrecorded; therefore, these parameters were deemed to have a high investigative priority.

Part of the information generated by this study is useful to planners, who should now be better able to delineate areas which would be unsuitable for the construction of buildings. These areas may be unsuitable due to poor soil conditions, soils having low bearing capacities, or a high groundwater table. Also, the planner could use this information in determining what effects certain activities may have on the Bay and ultimately on Lake Mendota. These activities may include construction, the disposal of wastes, stockpiling of snow or soil, the salting of roads, or landscaping.

A second part of the study was concerned with a survey of the Bay. Areas of investigation included: bathymetry (lake depth) analysis, soft sediment thickness, and delineation of the delta. This information will be useful in future Bay rehabilitation activities. If dredging or recontouring of parts of the Bay bottom are deemed an essential part of the rehabilitation plan, then it is of the utmost importance to determine how much sediment will have to be moved. This part of the study will also be useful in determining what areas of the Bay are experiencing deposition of sediments and what areas are eroding.

In summary, the specific goals of this project were the following:

1. Delineate soil thicknesses and areas where bedrock may impede construction.
2. Delineation of the shallow groundwater system contiguous to the Bay and to ascertain the inter-relationships between surface water.
3. Determine depths to groundwater and areas which may have construction problems due to a high water table.
4. Construct bathymetry and soft sediment isopach maps of the Bay.
5. Determine what the present water quality is and how road salting or other Bay area activities may affect this quality.
6. Make a determination of groundwater gradients related to the Bay; compute volume of groundwater outflow from the Bay and an assessment of how Madison municipal water-supply pumpage may influence the groundwater gradients.

Brief History of Bay Use

The first people to have a physical impact on the University Bay-Lake Mendota areas were the Indians. The presence of these early inhabitants is marked by ceremonial mounds which are found around the lake perimeter. One such mound is located between University Bay and the University of Wisconsin Natatorium. These mounds and other nonconspicuous artifacts are the only remains of the Indians. These people did not have a detrimental effect on the Lake or Bay.

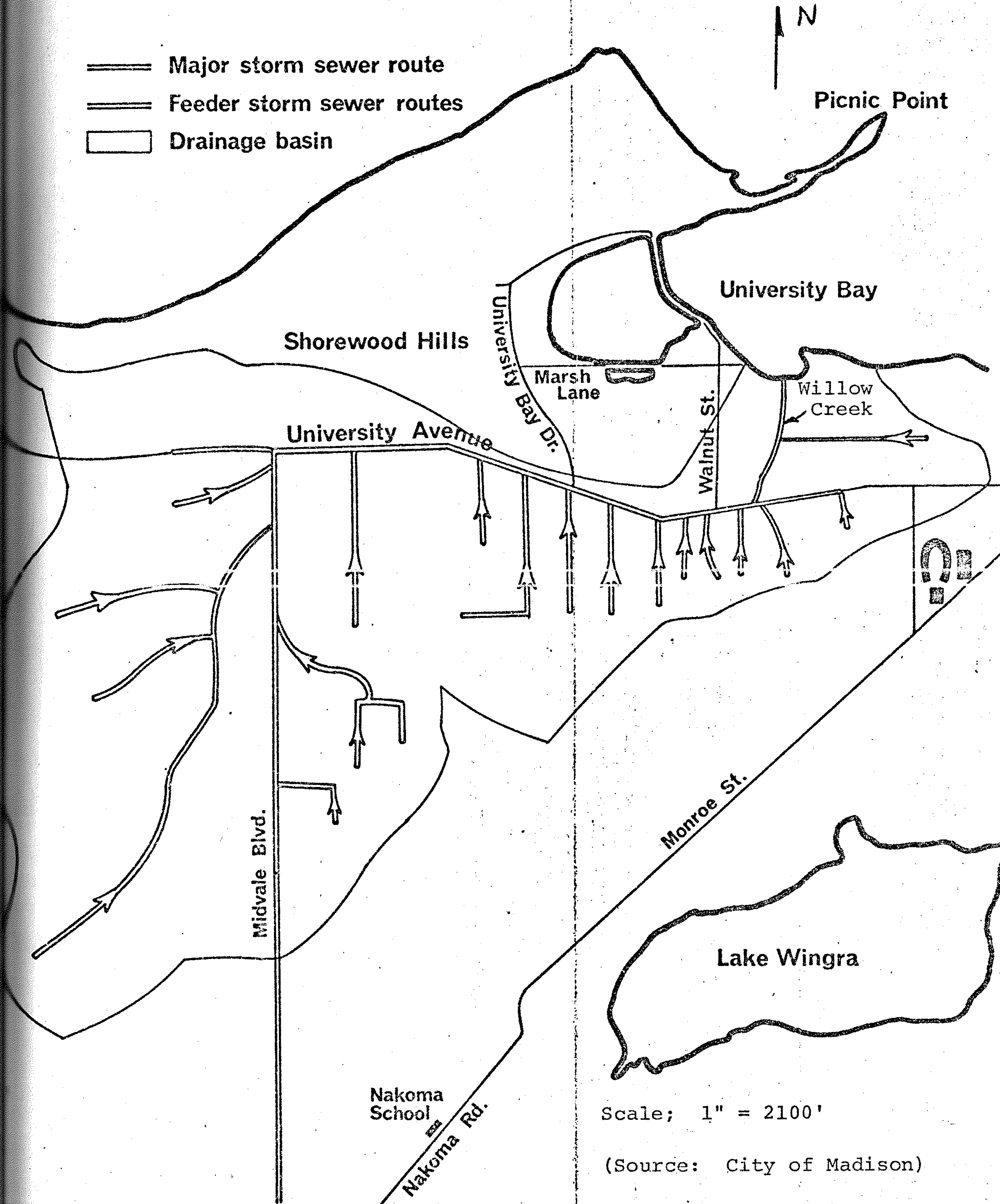
The pristine conditions of the lake which the Indians enjoyed was not to last forever. The coming of white settlers was accompanied by the cutting of forested areas and the tilling of the prairie region in the Lake Mendota drainage basin to establish farms. The cutting of forests and the plowing of the prairie lands accelerated erosion and increased the sediment loads flowing to the lake (Bortleson & Lee, 1972). In 1847, a dam was constructed where the Yahara River exited from Lake Mendota. This action marked the beginning of what was to be a continuous interference by man in the natural aging process of the lake.

However, the manipulation of lake levels was only a small part of man's past and present total impact on the lake. Other significant actions which have adversely affected the lake are: farming the highlands, developing the lakeshore, draining the wetlands, and discharging wastes into the lake.

One classical example of this type of impact has been the development of the Hilldale area of Madison. In 1948, Willow Creek, a small stream which empties into University Bay, was channelized and a storm sewer outfall was placed at the head of the stream. This storm sewer system services the Hilldale area. During the mid 1950's and early 1960's, Hilldale's sewer drainage basin expanded in size from less than three square miles to greater than six square miles (Figure 2). Along with this expansion in area, the density of housing also increased. To keep pace with this expansion, the sewer service also broadened. This urban growth caused increased runoff flows and sediment yields to the sewers.

As previously stated, the discharge point for this sewer system is eventually University Bay. The impacts of urban runoff are substantial. Fertilizers used on lawns, leaves, and grass clippings are swept into the Bay, thus helping to make the waters fertile for aquatic weed and algae growth (Born & Yanggen, 1972). Sediments washed off of construction sites and deposited into the Bay are infilling the Bay and Lake; the result being that once deep, clean waters are being converted into bogs at a greater than normal rate. Other substances included in urban runoff are: cigarette filters, gasoline, oils, greases, plastics, paper, and a whole host of other noxious elements.

Figure 2.
WILLOW CREEK DRAINAGE AREA



The ultimate result of this urban input will be that our lakes will become the recepticles of our affluent and careless society's wastes.

Another adverse man-made impact on the lake has been the development of the groundwater resource. In 1882, the first groundwater pumping station was built to service the City of Madison (Water Utility Records). Since that time, 23 wells have been constructed and an additional four are proposed or are currently under construction (Figure 3).

Extensive groundwater pumping has resulted in a decline of groundwater levels; however, the water levels do recover after pumping ceases. Because of communication between the shallow and deep aquifers, this extensive groundwater withdrawal has disrupted the normal flow of springs on the western end of Lake Mendota during operations.

Perhaps the most significant adverse impact brought on by man is the exponential rise in the influx of nutrients to the lake (Frey, 1963).

The exact loading of nutrients to the lake by urban sources or septic tanks or by farms cannot be ascertained; however, an estimate computed from the studies of Sonzogni and Lee, 1972, would be 139,000 lbs./year of total phosphorus and 1,251,000 lbs./year of total nitrogen enter Lake Mendota.

While the City of Madison at no time expelled treated sewage into Lake Mendota, until 1971 communities north of Madison, such as Waunakee and DeForest, dumped their

MADISON WATER UTILITY FIELD FACILITIES

SUPPLY HDQTS.
NICHOLS STA. 311 N. HANCOCK
DISTRIBUTION HDQTS.
SERVICE BLDG. 115 S. PATERSON
WELLS / PUMPING STATIONS:
NICHOLS STA. 311 N. HANCOCK ST.
DAYTON WELL 726 E. DAYTON ST.
EAST WELL 18 S. PATERSON ST.
No. 1 - 817 KNICKERBOCKER ST.
No. 2 - 845 VILAS AVE.
No. 3 - 212 N. FIRST ST.
No. 4 - 5 N. RANDALL AVE.
No. 5 - NINE SPRINGS
No. 6 - 2757 UNIVERSITY AVE.
No. 7 - 1709 N. SHERMAN AVE.
No. 8 - 3206 LAKELAND AVE.
No. 9 - 3140 SPAANUM AVE.
No. 10 - 4251 MOHAWK DR.
No. 11 - 102 DEMPSEY RD.
No. 12 - 801 S. WHITNEY WAY
No. 13 - 1201 KEARNEY RD.
No. 14 - GOLDSMITH STA.
No. 15 - 3900 E. WASHINGTON AVE.
No. 16 - 6706 MINERAL POINT RD.
No. 17 - CROWLEY STA.
No. 18 - ROHLICH STA.
No. 19 - GORDER STA.
No. 20 - SMITH STA.
No. 21 - 5705 ARBOR VITAE RD.
No. 22 - 1109 PFLAUM RD.
No. 23 - 4502 LEO DR.
LOW SERVICE WELL 622 E. DAYTON

RESERVOIRS:

LOW SERVICE	2.500 M.G.
HIGH SERVICE	6.000 " "
LAKEVIEW	0.055 " "
L.A. SMITH	4.200 " "
ALLIS HEIGHTS	3.000 " "
E.L. NORDNESS	3.000 " "
Z.A. GORDER	3.000 " "
NICHOLS (1974)	4.000 " "

● IN SERVICE
◍ - UNDER CONSTRUCTION
◍ - PLANNING
▲ - RESERVOIR

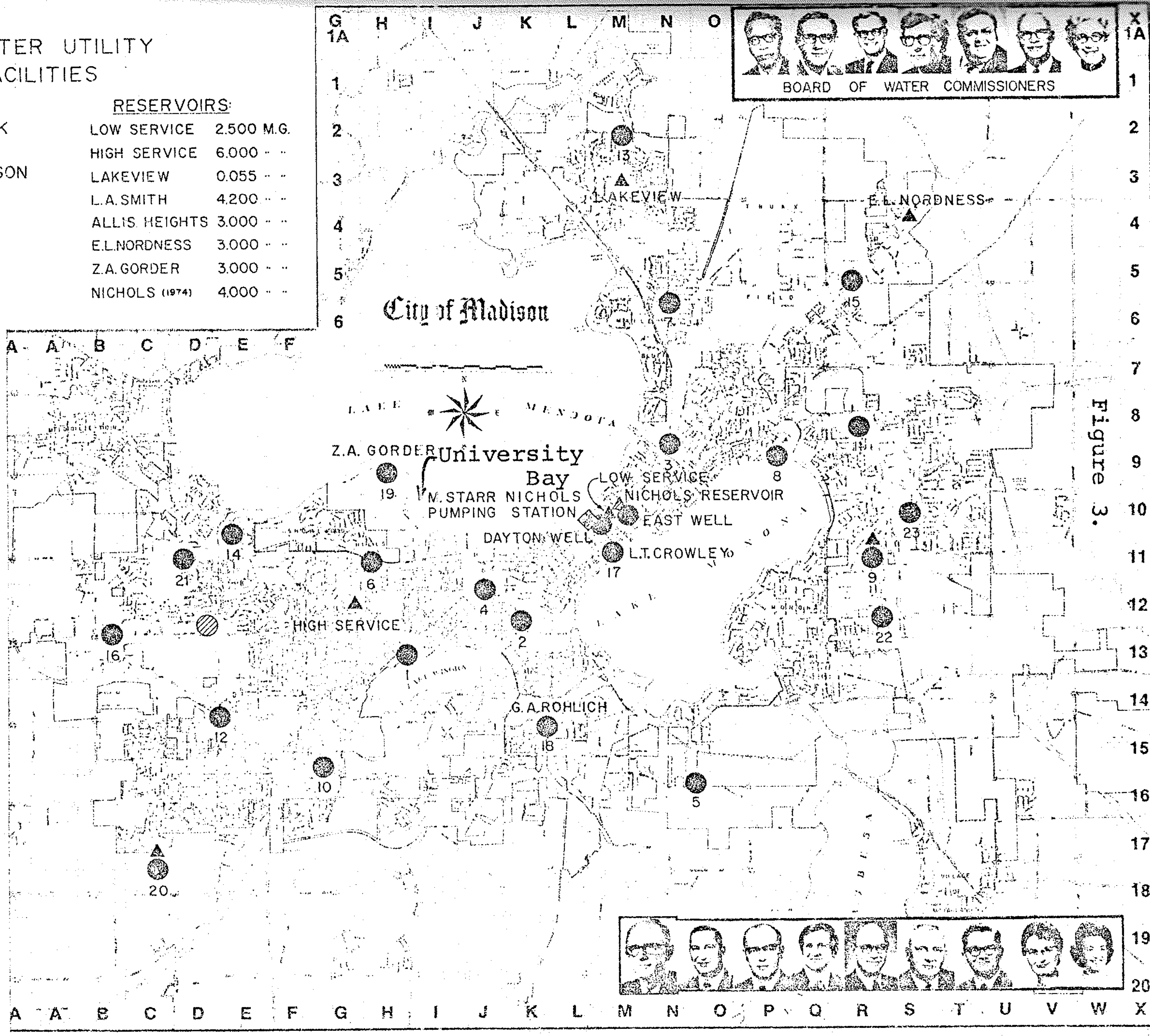


Figure 3.

treated sewage into the Yahara River, a major inflow stream to Lake Mendota (personal communication, City Sanitation Department). This treated sewage has supplied nutrients to the lakes in such abundance that algae and other aquatic weeds have grown prolifically.

Site Conditions

Location

University Bay is located within the city limits of Madison, Wisconsin (Township 7 North, Range 9 East, Sections 9, 15, and 16). The Bay is situated approximately two miles west of the state capitol building. The study area comprises a region which extends from Babcock Drive on the east to University Bay Drive on the west and from Second Point on the north to University Avenue on the south, a total of about 570 acres (Figure 4).

Climate

The climate of southern Wisconsin is continental in nature. The mean January temperature for the period 1941-1970 was 16.8°F, and the mean July temperature for the same 30-year period was 70.1°F. The average mean temperature is 46.2°F (Cline, 1965).

The total annual precipitation averages about 31.2 inches (1940-1970) (Cline, 1965). There are generally three to four inches of precipitation per month during May

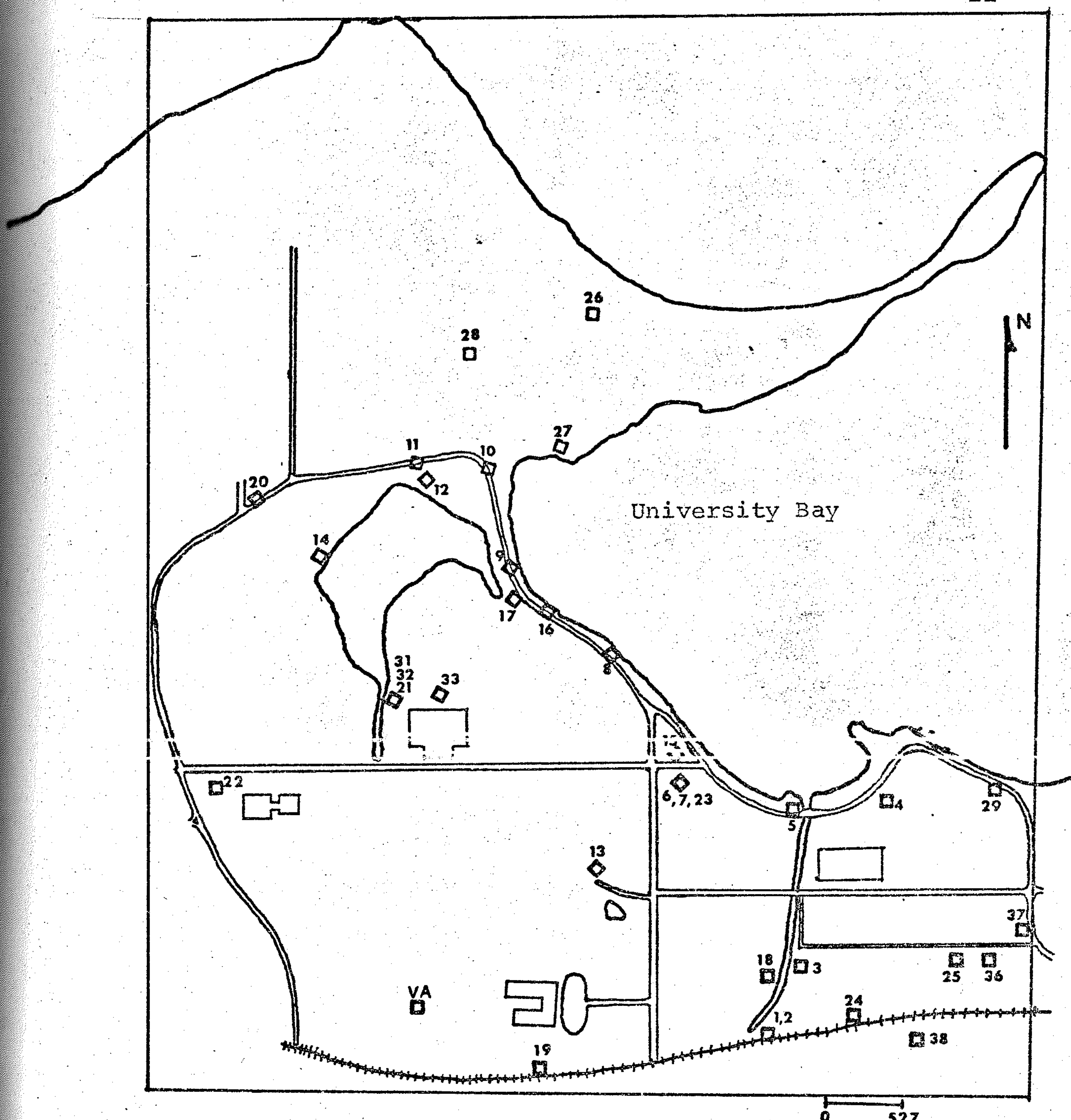


Figure 4. Map showing University Bay study area

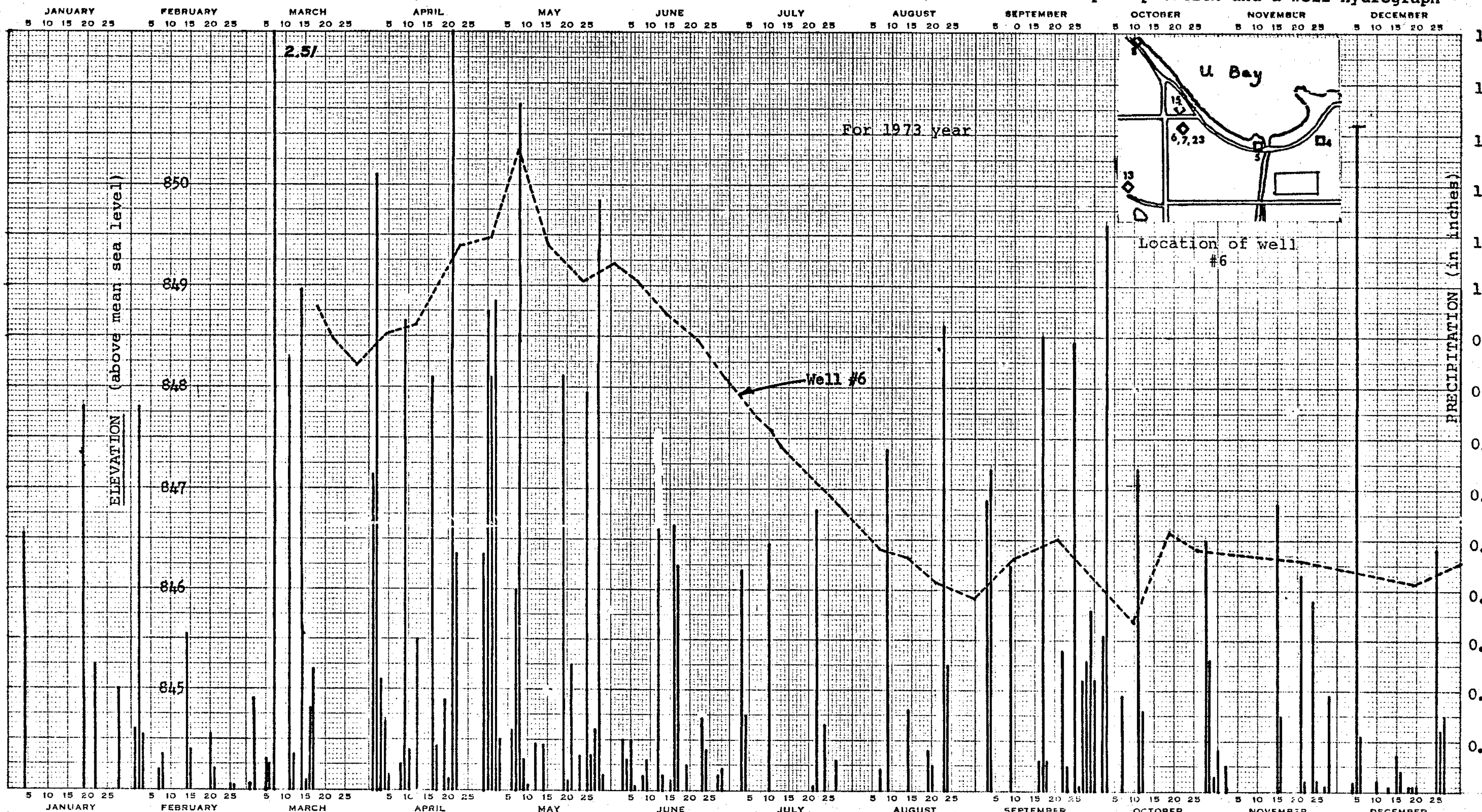
through September. During the study period between January 1, 1973, to January 1, 1974, the total precipitation was 42.73 inches (Figure 5). An average evaporation estimate for the land surface for this same period was 16 inches. The lake surfaces experienced about 29 inches of evaporation.

Topography and Drainage

The Yahara River Valley, in which Madison is located, has an irregular topography which ranges from hilly to flat. This topography is a direct result of continental glaciation which ended about 12,000 years ago. The Yahara River and its tributaries drain glacial-drift soils. The eastern part of the watershed has poor drainage due both to the clay soils and poorly developed stream net patterns. This poor drainage is exemplified by the many marshes and wetlands which are found in the area. The hills which are seen in the Yahara River drainage basin are generally physiographic features left by the glaciers. These hills are commonly drumlins (which are teardrop-shaped hills of unconsolidated material). Drainage in this hilly region is good. Also bedrock ridges form many hills in the basin.

The University Bay lands consist of a 14-acre marsh in a central lowland surrounded by a ring of hills which rise about 70 feet on the south side and about 100 feet on the north side above the lowland (Figure 6, in folder). As might be expected, drainage is good on the high areas but poor in the marsh area. The water level in the marsh is artificially

Figure 5. Plot of precipitation and a well hydrograph



controlled by a pumping station which is situated near Willow Drive. This pumphouse was installed in 1912 with a manual pump for the purpose of keeping the lowlands drained when this area was converted from marsh to farmland. The present marsh was reinstated from this farmland in 1965.

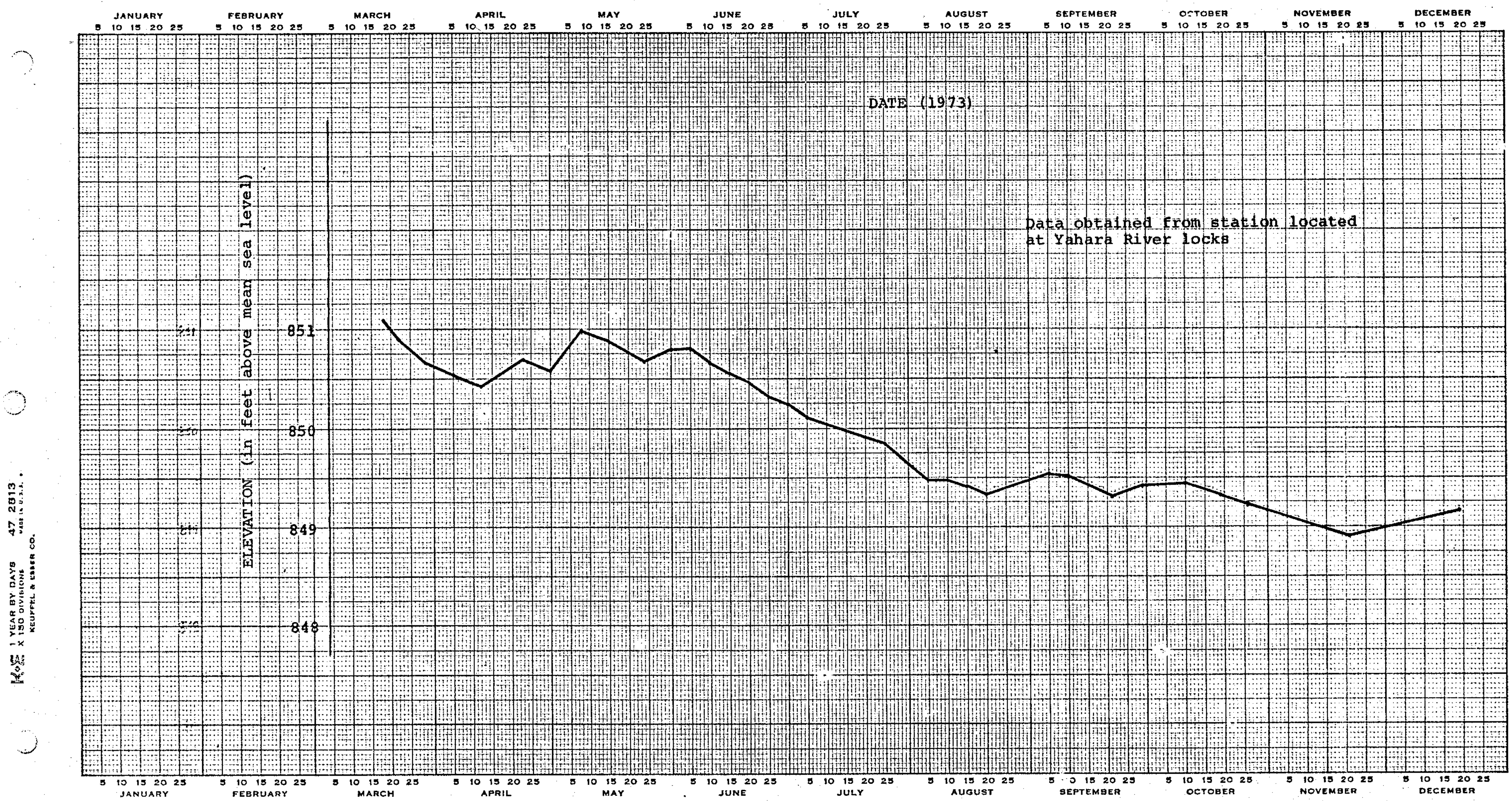
There are three sources of inflow into the Bay from the study area in addition to overland surface flow. One inflow is an open ditch which is between the lanes of University Bay Drive on the north side of the marsh. This ditch flows into the northwest corner of the Bay. Due to its small drainage area and ephemeral character, the volume of water and quality of water contributed by this source was considered inconsequential. The drainage basin for this ditch includes part of Picnic Point and a part of Eagle Heights. In terms of nutrients or other chemicals, this ditch probably does not have a significant effect upon the lake. A second point of discharge into the Bay is from the pumphouse which was built to control the marsh levels. This drainage basin is entirely made up of the marsh and the playing fields. Again, because of its intermittent and low flow (0.7% of inflow into Lake Mendota, Frey, 1963) detailed studies of this outfall were not collected. It was felt that the impacts of these two outfalls, whether in terms of flow quantities, chemical loads, or sediment loads into the Bay were so minor that they did not warrant detailed study. The last major outfall to University Bay is Willow Creek. Its impact on the Bay is considerable, as may be inferred from the sizable delta which is being built up at the mouth of the stream due to the incoming sediments.

According to Eid and Olsen (1950) the normal flow of the stream was less than 0.25 cfs. However, due to the storm sewer at the stream head, high flash flows following rains resulted. These flows ranged from 0.25 cfs to greater than 5 cfs. As previously mentioned, in 1950 the drainage area served by these storm sewers was less than three square miles. With the expansion of the Hilldale area, it is expected that these flows have increased in magnitude both in volume and intensity above the 1950 flows. The exact flow characteristics of this stream are being monitored through a joint effort of the University Bay Project and the United States Geological Survey. A wier and a gaging station equipped with digital recording devices were installed in the fall of 1973, and data collection began in the spring of 1974. These data are not included in this report due to the fact that they were unavailable during the implementation of this project.

Lake Levels

Since 1847 when the first dam was constructed, Lake Mendota's water levels have been manipulated by man (Figure 7). As a general rule, in the winter the lake level is dropped approximately one and one-half feet below summer levels. This procedure accomplished two objectives: 1) it allows for flood protection in the spring; and 2) it prevents

Figure 7. Lake Mendota lake elevations



ice damage to docks and beaches in the winter.

Ice generally covers the lake from mid-December to mid-April. During the study period, the lake froze the third week of November in 1972, and thawed by March 19, 1973, one of the earliest documented times for this to occur.

Lake Circulation

Circulation patterns in Lake Mendota and in University Bay have been studies extensively by Bryson and Ragotzkie (1955). They established a line of observation points across the mouth of University Bay at which they measured current profiles at various times in order to determine the rate at which the waters of University Bay were replaced by waters from the rest of Lake Mendota. They found that the complete replacement rate varies from less than one to several days. They also found that University Bay was normally occupied by a clockwise gyre, the rotation rate of which was nearly constant and independent of the current velocity (Figure 8).

It was also observed that a high velocity jet extended into the lake along the south side of Picnic Point. This jet plays an important role in sediment distribution in the Bay which will subsequently be discussed. The exact velocity of this jet varies considerably due to many circumstances such as wind speed and direction.

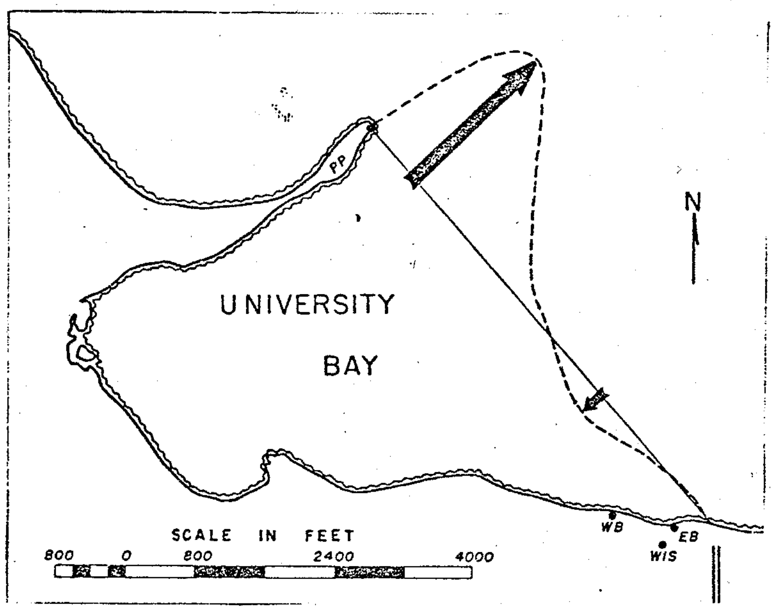


Figure 8. Major velocity vectors in University Bay

(after Bryson and Ragotskie 1955)

Surficial Geology and Soils

The surficial geology of University Bay is dominated by glacial sediments and landforms. Buckley (1895), Bean (1936), and Cline (1965) all addressed themselves to the surficial geology of Dane County; however, only Buckley's work addressed itself specifically to the Pleistocene geology around Madison. The surficial geology of the area is a result of deposition during the Woodfordian (Cary) Substage of the Wisconsin Glacial Stage about 13,500 years ago.

The furthest advance of the glacier during this time was to a point about eight miles west of the Bay. As the glacier melted and the ice margin receded back to the north-east, it formed the dominant glacial feature in the Bay area. That feature is the Wingra Recessional Moraine. This moraine constitutes the high area which wraps around the lowlands (Figure 9). Based on surface exposures and auger drilling around the VA Hospital this moraine was determined to be a kame* deposit of fluvial or stream origins in the Bay area. The best surface exposures of this kame are near the medical complex construction site.

It is of little importance to the planner, however, it only the depositional history of the near surface is known. The planner must know what type of buildings can or cannot

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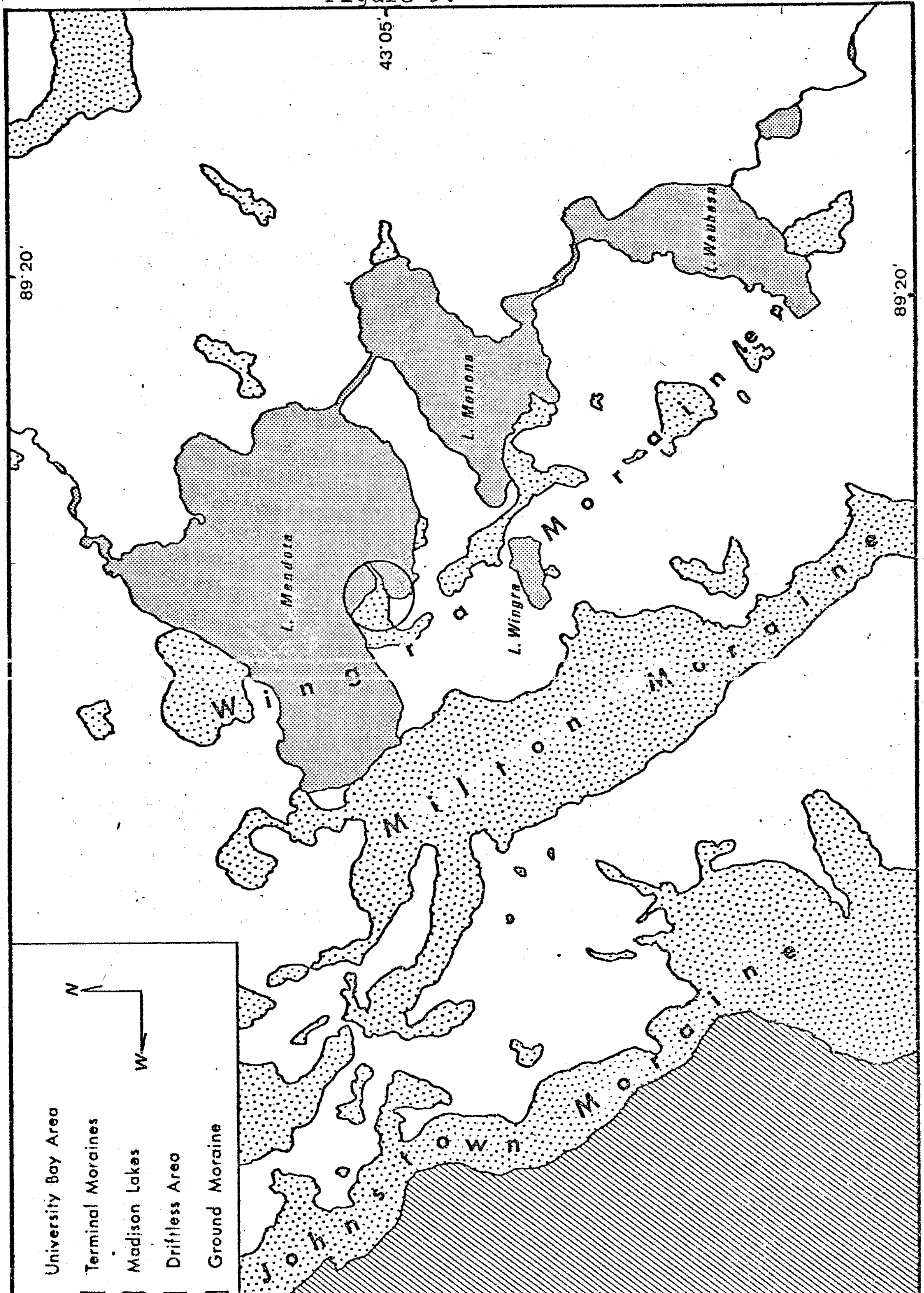
*AGI Definition: A short irregular ridge of gravel or sand deposited in contact with glacier ice.

Figure 9.



Terminal and Recessional Moraines of the Madison Area be built on the soils found throughout the Bay area.

Soil scientists have classified the soils of the Bay into fifteen categories; in soil terminology these categories are called types. These types are seen in Figure 10. The Soil Conservation Service soil survey interpretations for the soils are found in Appendix A.

Instead of all of these classes, this study has consolidated all of the soils of the Bay area into four groups. This classification is based upon depositional mechanisms and lithology. These four groups are (Figure 11):

Stratified ice contact drift (kame)

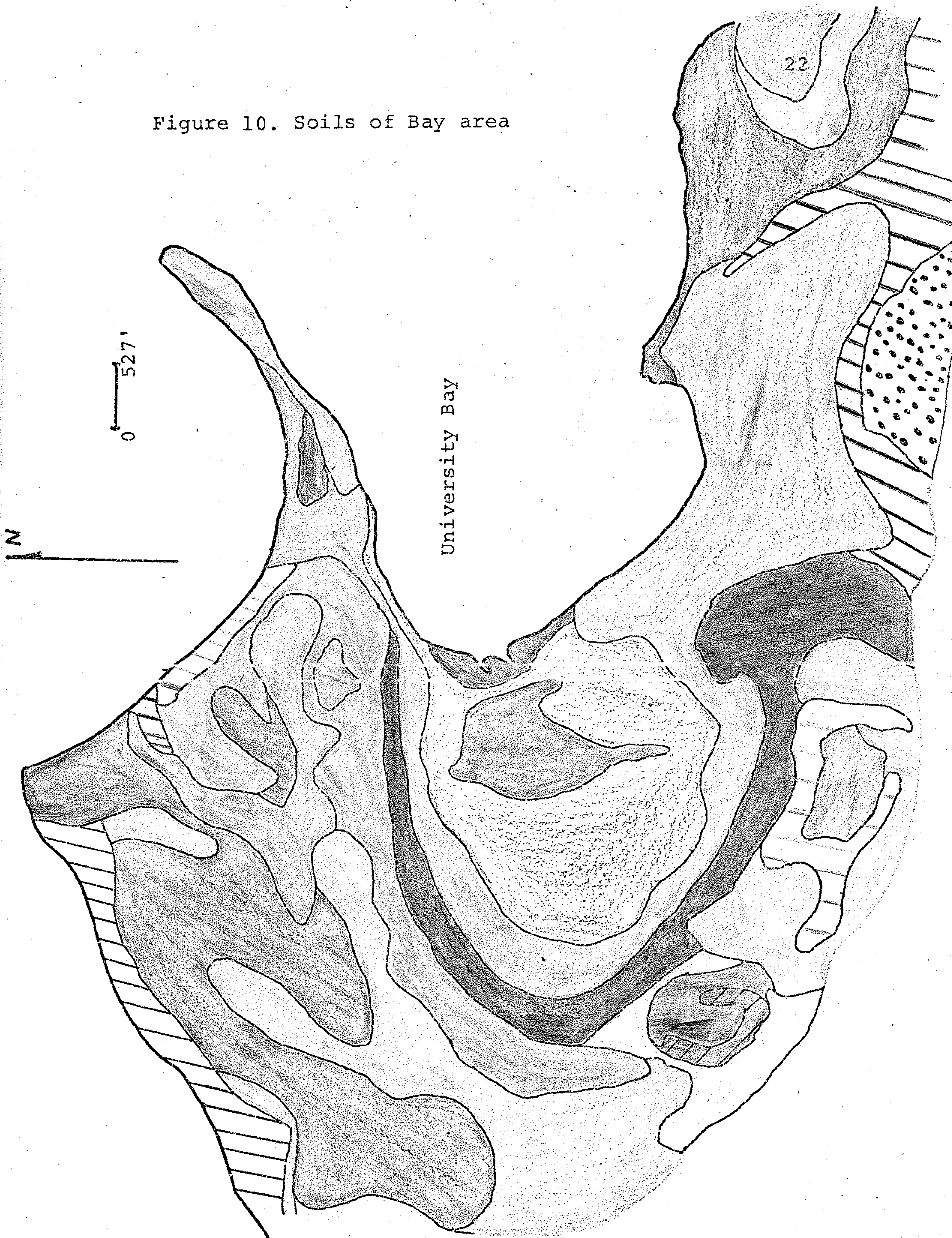
Lacustrine deposits

Till

Stream deposited sands and gravels

The stratified ice contact drift composes the kame morainic deposits which constitute the uplands surrounding the Bay. When the glacier receded to the northeast and east, it experienced a period of stagnation. During this period of stagnation the stratified moraine was deposited. These sediments directly overlie the bedrock core, and their thicknesses vary from zero to greater than 50 feet. The thinnest areas are around the Forest Products Laboratory, and the thickest deposits are west of the University's recreation fields. The kame sediments are characterized by interbedded and interfingered coarse sands and gravels. Grain size analysis of selected samples was performed in the Twenhofel Geological Laboratory and the

Figure 10. Soils of Bay area



Key to Figure 10
SOILS OF THE UNIVERSITY BAY REGION

COLOR	SOIL TYPE
	McHenry Silt Loam
	Nippersink
	Colwood Silt Loam
	St. Charles Silt Loam
	Kidder Loam
	Houghton
	Standing Water or Marsh
	Kegonsa Silt Loam
	Virgil Loam Gravel Substrate
	Arland Loam
	Weyland Loam
	Robin Sandy Loam
	Glacial till or Drift
	Fox Silt Loam
	Batavia Silt Loam Gravelly Substrate
	Fox Loam

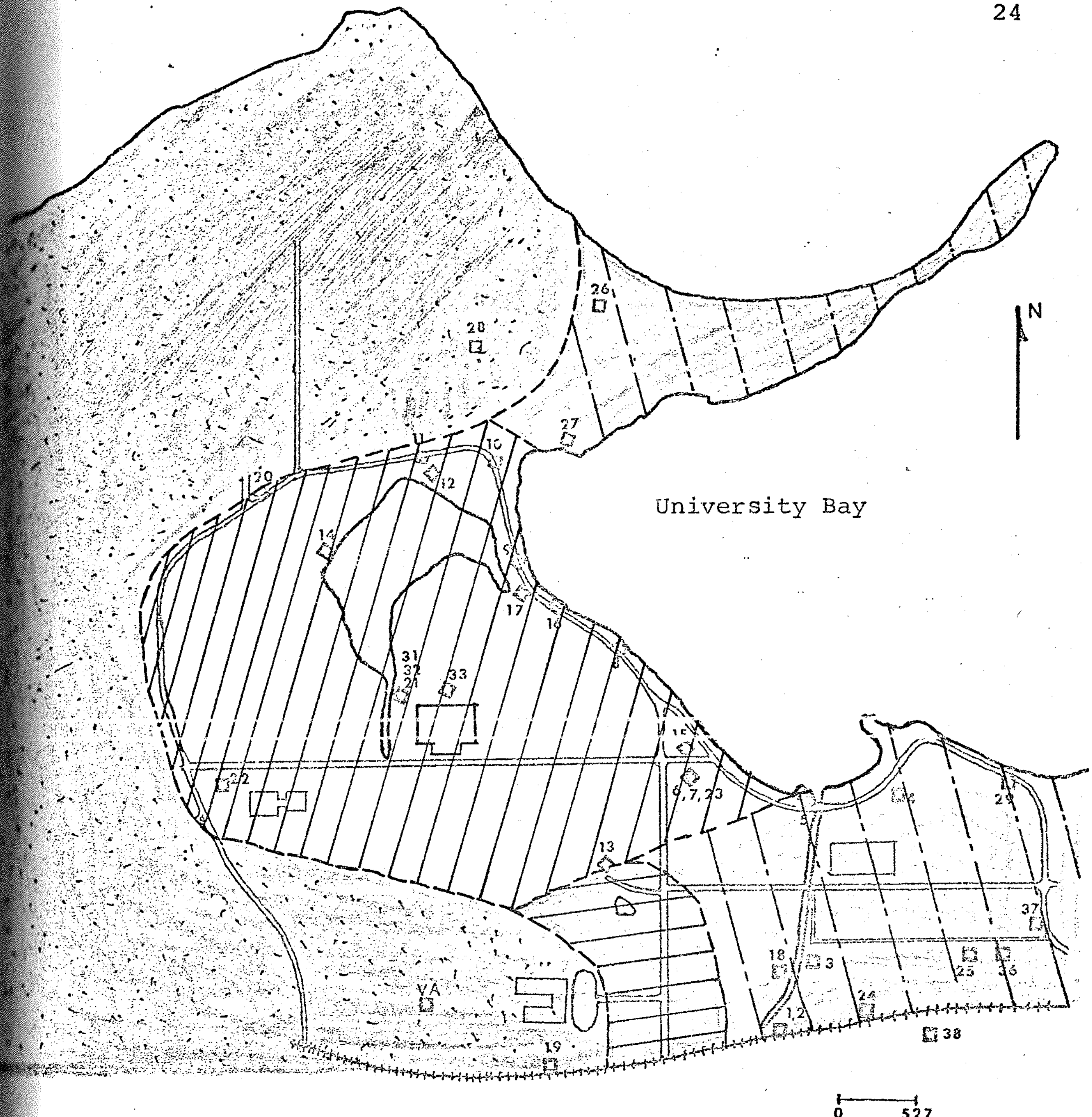


Figure 11. Soils of University Bay

Key

Stratified ice contact drift

Till

Lacustrine deposits

Stream deposited sands and gravels

results appear in Appendix B. Thicknesses of unconsolidated sediments were determined from bore holes drilled by Warzyn Engineering Company or by myself.

Because these soils are predominantly silts, sands, and gravels, and because they are distributed on the uplands, they are generally well-drained and well suited construction foundations. However, construction on hills of this material may result in erosion and slope stability problems, especially where an unsupported earth face is exposed.

After the glacier receded from the Bay area, the waters of Lake Mendota extended to the base of the moraine. During this period of occupation, lake marls were deposited in the area which is presently the marsh and playing fields. A borehole near the northwest corner of Nielsen Tennis Stadium revealed that these lake marls are about 50 feet thick. The marly are gray colored silty clays of very low permeabilities. These marls probably represent deeper water deposition. Because of their organic content and a high water table, this location is unsuited for construction.

In addition to the lacustrine marls and silts, other shallow-water deposited sediments are found on the lower fringes of the topographically high areas. These sediments are characterized by sandy silts. Excavations for the new medical center and boreholes on the north side of the marsh provided field evidence for these shallow-water lacustrine deposits. Because of their moderate drainage capacity, shallow slopes and suitability for foundations, these soils make acceptable building site locations. It is important to remember though that only their physical properties make them suitable for foundations. Possible problems with the areas in which these sediments are located could be a high groundwater table or aesthetic and land ownership characteristics that may prevent or retard substantial development.

Areas to the south of the WARF building, east of the Forest Products Laboratory, and west of the new heating plant are underlain by glacial till overlying bedrock. This till is approximately nine feet thick, and it is a blend of sand, clay, and boulders. There is no stratification or any orderly arrangement of the sediments. No borings were taken to determine the characteristics of these sediments, since excellent cross-sectional exposures were provided in the trenches dug for steam line placement to the new medical center.

The final group of soils in the aforementioned classification is the stream deposited sands and gravels. Soils of this nature are found on Picnic Point and the area east of Walnut Drive. Logs of boreholes, drilled either by myself or by Warzyn Engineering, appear in Appendix A.

Drill hole data was not sufficient in order to construct an accurate isopach map. However, a generalized map was drawn (Figure 12) which shows the thickness of the unconsolidated sediments.

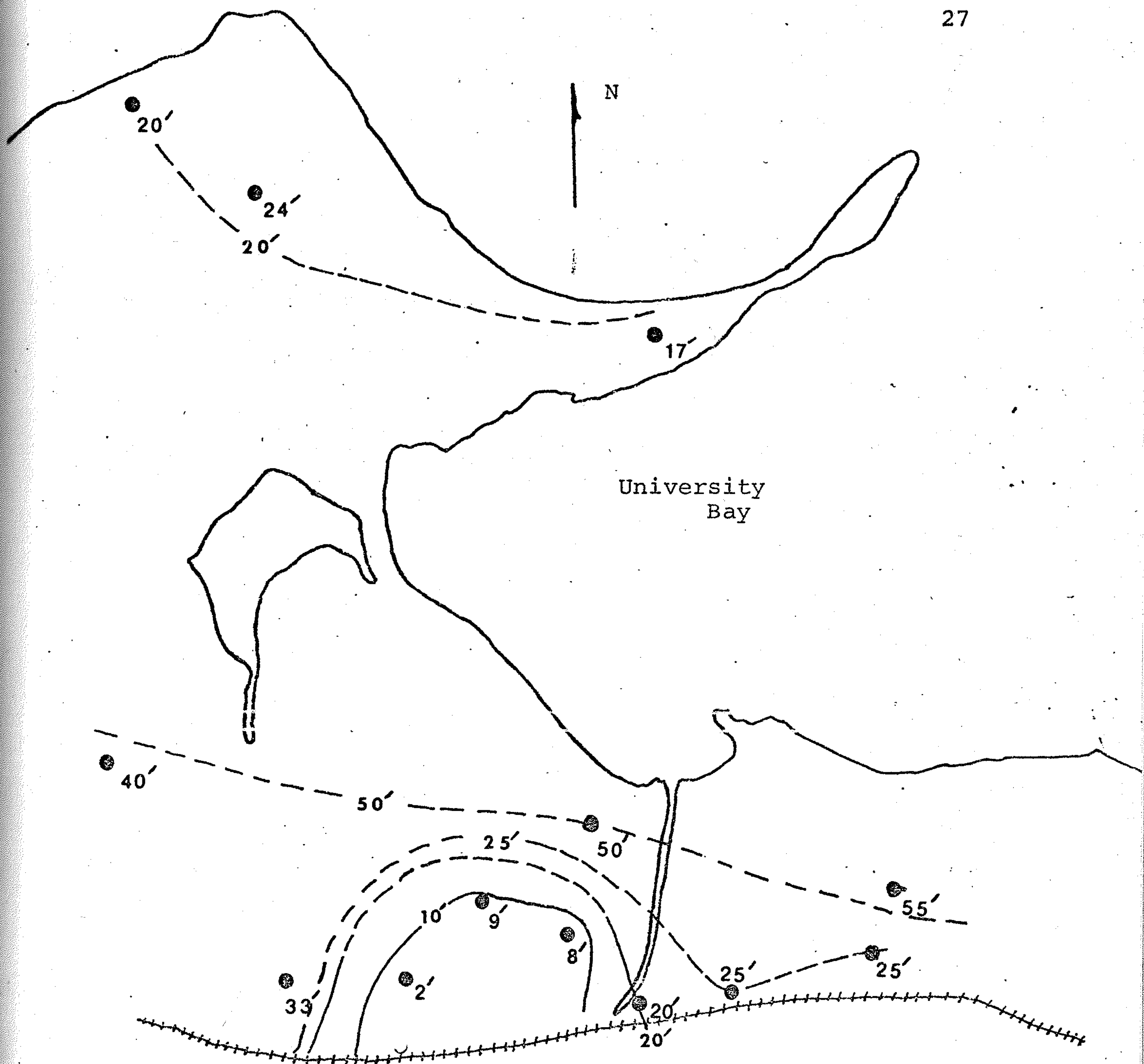


Figure 12. Thicknesses of unconsolidated sediments.

Bedrock Geology and Geologic History

Knowledge of the bedrock geology of the University Bay area may not appear to be essential to the campus planner; however, the bedrock does impose limitations on where and how construction can be pursued. A case in point it the topographic high referred to as Eagle Heights. Unconsolidated sediments at this location are approximately twenty feet thick. Below these sediments is bedrock. Construction which would involve deep foundations may experience unexpected higher costs in excavation for these foundations if there is no knowledge of where the bedrock will be encountered; however, the bedrock has excellent bearing capacities.

The bedrock geology of the University Bay area consists of Upper Cambrian sandstones and sandy dolomites (Figure 13). Oven seven hundred feet of sedimentary units overlie the pre-Cambrian crystalline basement rocks.

To gain a perspective of the relation of these rocks to each other, Figure 14 is a geologic cross section of the lake. The sedimentary rock units are inclined to the southwest at a dip of fifteen feet to the mile.

The following are brief explanations of each formation beneath the study area, from crystalline basement rocks to the surface.

The Mount Simon Formation, an upper Cambrian sandstone,

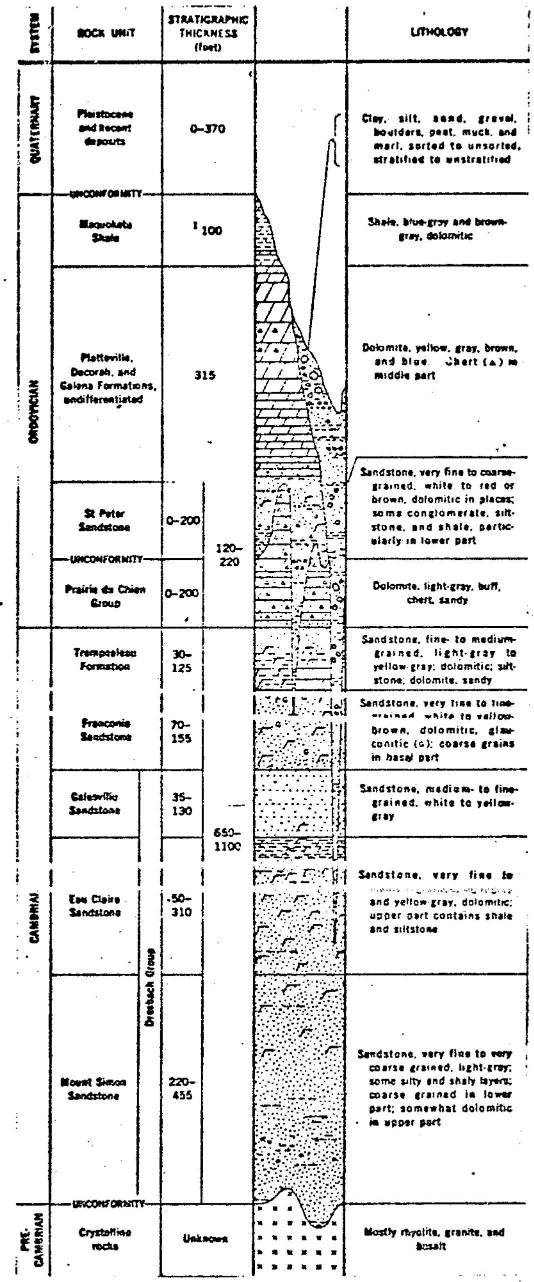
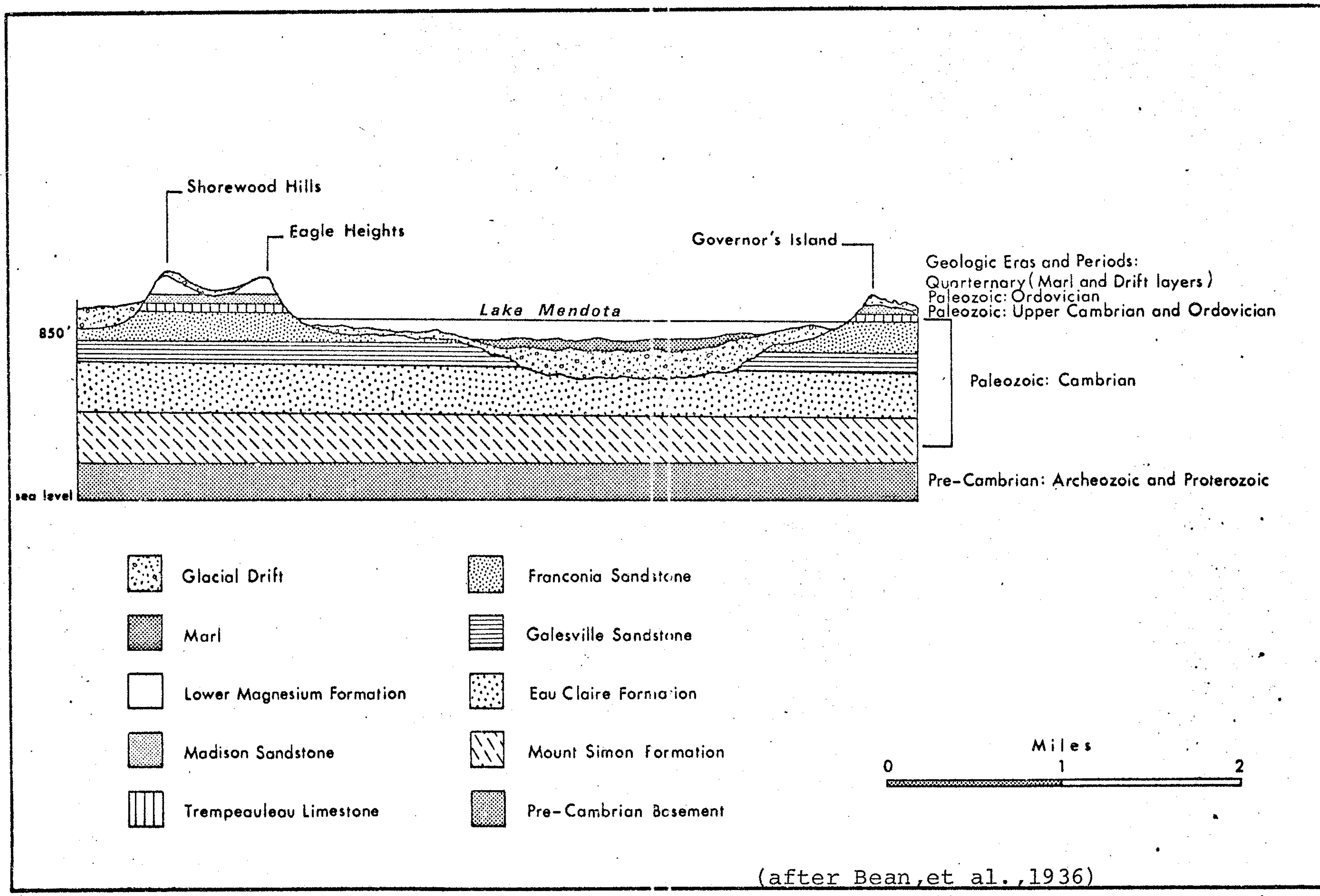


Figure 13. Geologic column of Dane County (after Cline, 1965).

Figure 14.



(after Bean, et al., 1936)

(Drawn by S. Carpenter)

Bedrock Column of Lake Mendota

unconformibly* overlies the pre-Cambrian rocks. It is predominantly a well-cemented medium-grained sandstone that contains very fine to very coarse sand (Cline, 1965). The City of Madison draws its municipal water supplies from this formation.

Above the Mount Simon is the Eau Claire Sandstone which is fine to medium-grained and dolomitic; this means it contains the calcium-magnesium mineral, dolomite. This formation is distinguished from the Mount Simon in that it contains more fine-graned clasts and more dolomite.

The next unit overlying the Eau Claire Formation is the Galesville Sandstone. It is predominantly a medium to fine-grained sandstone that has an approximate thickness in the Madison area of about 130 feet (Cline, 1965). However, pre-glacial erosion has removed much of this formation. The preceding three formations do not crop out (exposed at the surface) in the University Bay area; however, the Galesville in many areas is directly overlain by glacial till.

Above the Galesville is the Franconia Sandstone. This rock unit forms much of the bedrock surface in the University Bay area. Exposures of this formation can be seen at the edge of the lake in two areas; one point is west of Second Point and the other exposure is along the south

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*Unconformity - AGI Definition: A surface of erosion or nondeposition, usually the former, that separates younger strata from older rocks. Unconformable means having the relation of unconformity to the underlying rocks; not succeeding the underlying strata in immediate order of age and in parallel position.

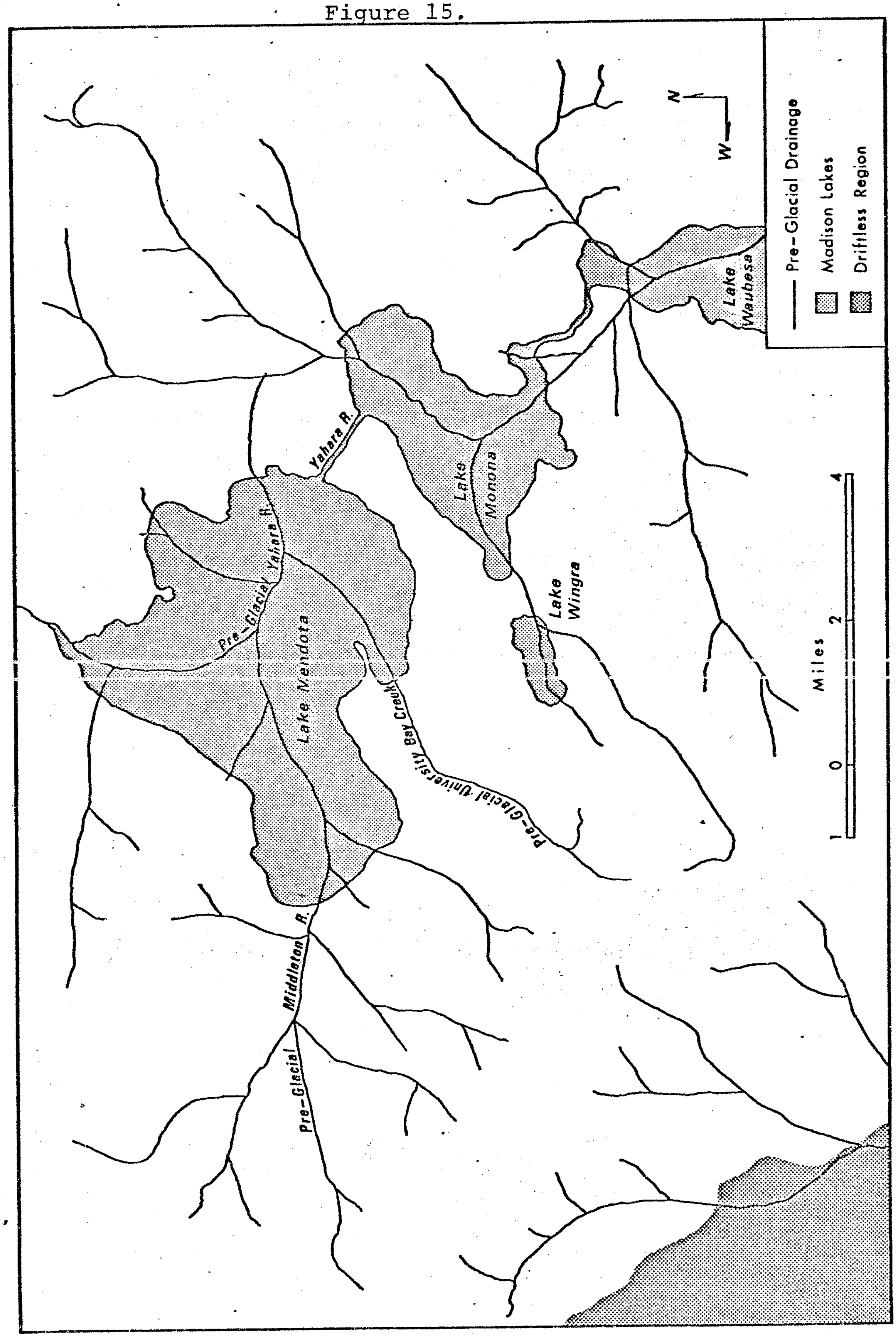
shore of Picnic Point. The formation is divided into upper and lower parts on the basis of lithology. The upper parts contain a high percentage of the green clay mineral, glauconite. Cementation of the clasts on the very top few feet of this unit is very poor due to pre-glacial erosion. The exposure of this formation west of Second Point along the lake exemplifies this "green-sand" feature beautifully. The lower part of the formation is a fine to coarse-grained sandstone which is only locally dolomitic and glauconitic (Cline, 1965).

Pre and Post Glacial History

Before the arrival of the glaciers, the study area topographically resembled the region of southwest Wisconsin, which is typified by V-shaped and steep-walled valleys. Picnic Point was a bedrock ridge between the valleys of the pre-glacial University Bay Creek and the pre-glacial Middletion River (Figure 15). From the top of Picnic Point to the bottom of the pre-glacial University Bay Creek Valley was a drop of almost 250 feet.

During the last stage of continental glaciation, referred to as the Wisconsin Stage, the ice advanced into the Madison area from the northeast. As the glacier moved forward, bedrock material was incorporated into the ice. This advance halted near the present community of Cross Plains. The material incorporated into the glacier was deposited at the front as the glacier melted. The hill

Figure 15.



Pre-Glacial Drainage near Madison

(after Bean et al. 1936, Drawn by S. Carpenter) which was formed from this material is referred to as the Johnstown terminal moraine*.

As the world-wide temperature increased, the continental glaciers melted and retreated. The retreat of the glaciers was not uniform in time, but rather it was an interrupted series of pauses. Accompanying these halts, unconsolidated material was deposited in ridges from the melting glaciers. These ridges are called recessional moraines. Two recessional moraines directly east of the Johnstown terminal moraine are called the Milton and Wingra recessional moraines (Figure 9).

As the ice moved out of the University Bay, it is believed that melt water was trapped between the retreating ice and the Wingra moraine. This water probably exited from the Bay in a southeast and northeast direction. Sediments deposited by these streams are found on Picnic Point on the north side of the Bay between Walnut Drive and Observatory Hill. A physical description of these sediments can be found in the Surficial Geology section.

After the glaciers had retreated completely from the area, the entire landscape was drastically altered from that before the arrival of the glacier. Within the study area, the affects of the glacier are pronounced. The valleys of the pre-glacial streams were filled with 150 to

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*AGI Definition: Drift, deposited chiefly by direct glacial action, and having constructional topography independent of control by the surface on which the drift lies.

200 feet of glacial till, and the bedrock ridge of Picnic Point was leveled and covered with a thin layer of glacial deposits. The result of the glacier was that the general topography was changed from deep valleys and sharp ridges, which are characteristic of the driftless area west of Madison today, to a rolling topography.

The post glacial drainage was characterized by numerous swamps and lakes. In fact, the Madison lakes themselves are due to the blockage of stream valleys by glacial drift. Originally, Lake Mendota occupied a more extensive area than it does today. University Bay was also larger.

Lake Aging

Analogous to a living organism, once a lake is born, it is bound to die. Due to wave erosion of the shoreline, sediment influx by inflowing streams, and in-lake biological activity, sediments were deposited in the lake. This sedimentation gradually infills the lake. This sequence of lake aging can be exemplified in University Bay. At the start, the Bay extended to the base of the present Shorewood Hills. Erosion of the hills and deposition in the Bay gradually decreased its depth. As the water depths became shallower more aquatic vegetation appeared. When this vegetation dies, the remains were added to the sediments on the bottom of the Bay. This organic sedimentation drastically accelerated the infilling process of the Bay. The result of all of these processes has been that the lake and Bay are decreasing in size due to the conversion of lake to land.

Physical Aspects of University Bay

By field measurements, it was determined that University Bay is approximately 3,400 feet long from west to east, and 2,500 feet from north to south. It has a maximum depth of 50 feet and the average depth is about 15 feet.

Bathmetry studies were preformed in the winter and summer of 1973. In the winter, holes were drilled through the ice and a secchi disk was dropped until it settled on the bottom. The depths of water were read from a calibrated rope attached to the disk. It is unknown how much compaction of the sediments took place under the weight of the disk; however, it is felt that such accuracy was unwarranted in this study. The bathymetry study could not be completed in the winter months, so it was finished in late July and early August. It was discovered though that performing the study from a boat was much more tedious than working on ice. Difficulties were encountered in surveying the location of the sample point due to the instability of the boat.

In spite of these difficulties, seventy-five sampling points were made at random in the lake. Also, a detailed study of the delta at the mouth of Willow Creek was conducted in August of 1973.

The procedure followed in making the delta study involved setting up a grid system over the delta area and a sample was taken at each node of the grid. Seventy-three sample points were made of the area.

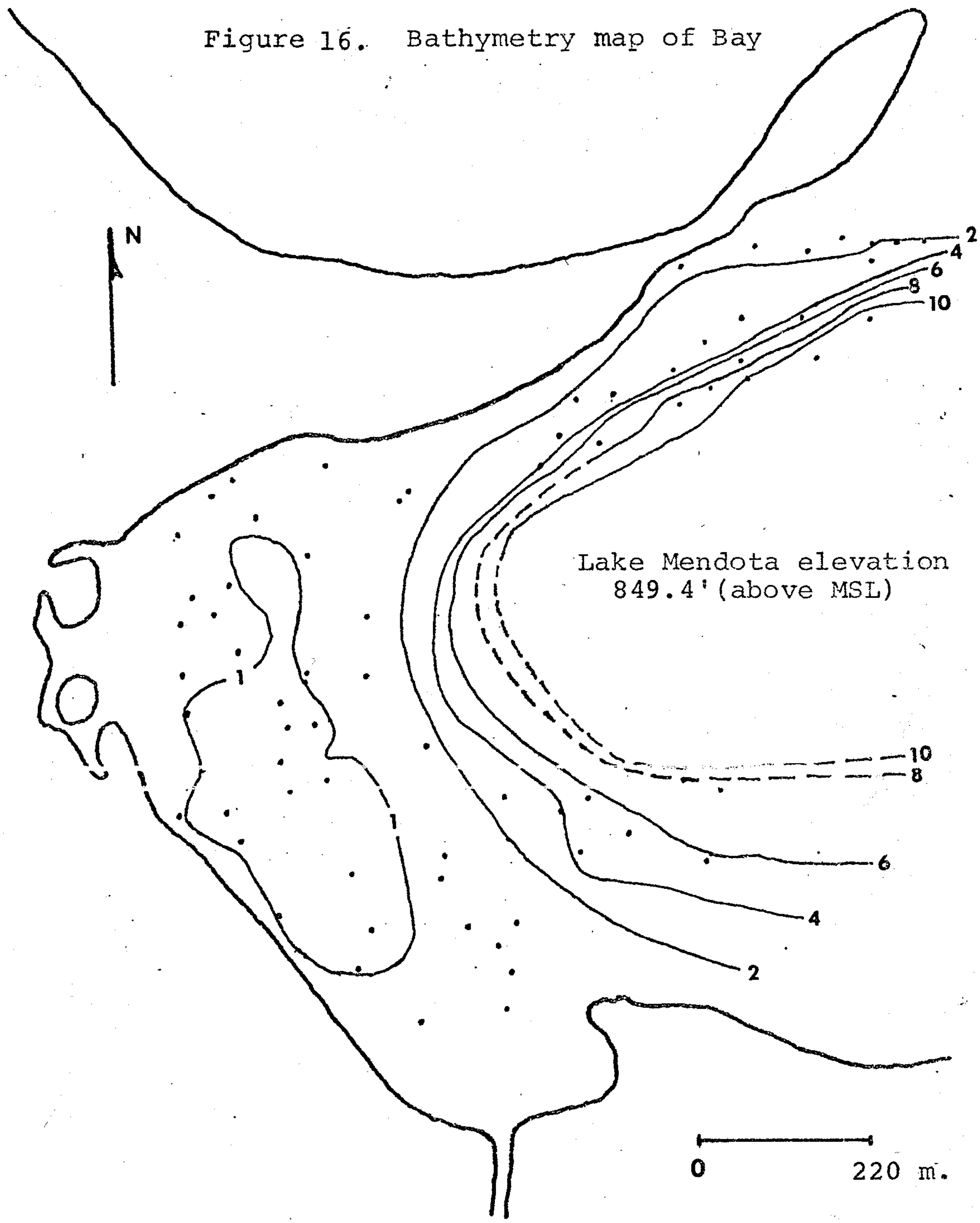
Bathymetry maps of both the Bay and the delta appear in Figures 16 and 17. The Department of Civil and Environmental Engineering in the spring of 1973 performed a bathymetric study of the Bay by means of a sounder, a more sophisticated model of the popular fish sounder (Figure 18, in folder). These maps agree closely. Both show that on the north side of the Bay there is a narrow shallow water shelf and then a very sharp, narrow drop off into the deeper parts of the Bay. On the south side this is generally not the case. Instead there is a gentle slope from the shallow waters into the deeper waters. West of the sand bar both maps show three to five feet of water.

Because of the Bay's and lake's depth, thermal stratification does occur. This stratification is well developed by early summer and when this occurs, the lower stratified section of the lake, called the hypolimnion, is soon depleted of its oxygen. The thermocline, that section of the lake in which temperatures rapidly change, generally develops at a depth of 20 to 25 feet. By the time the autumnal overturn occurs, the thermocline is suppressed to a depth of 45 feet (Murray, 1956).

Sediments of the Bay

There are three dominant sediment distribution areas in the Bay (Figure 19). The first area is located west of

Figure 16. Bathymetry map of Bay



Note: all measurements are in meters

Figure 17. Bathymetry map of delta area

Lake level on day of sampling = 849.45 feet above mean sea level

Note: All measurements are in centimeters

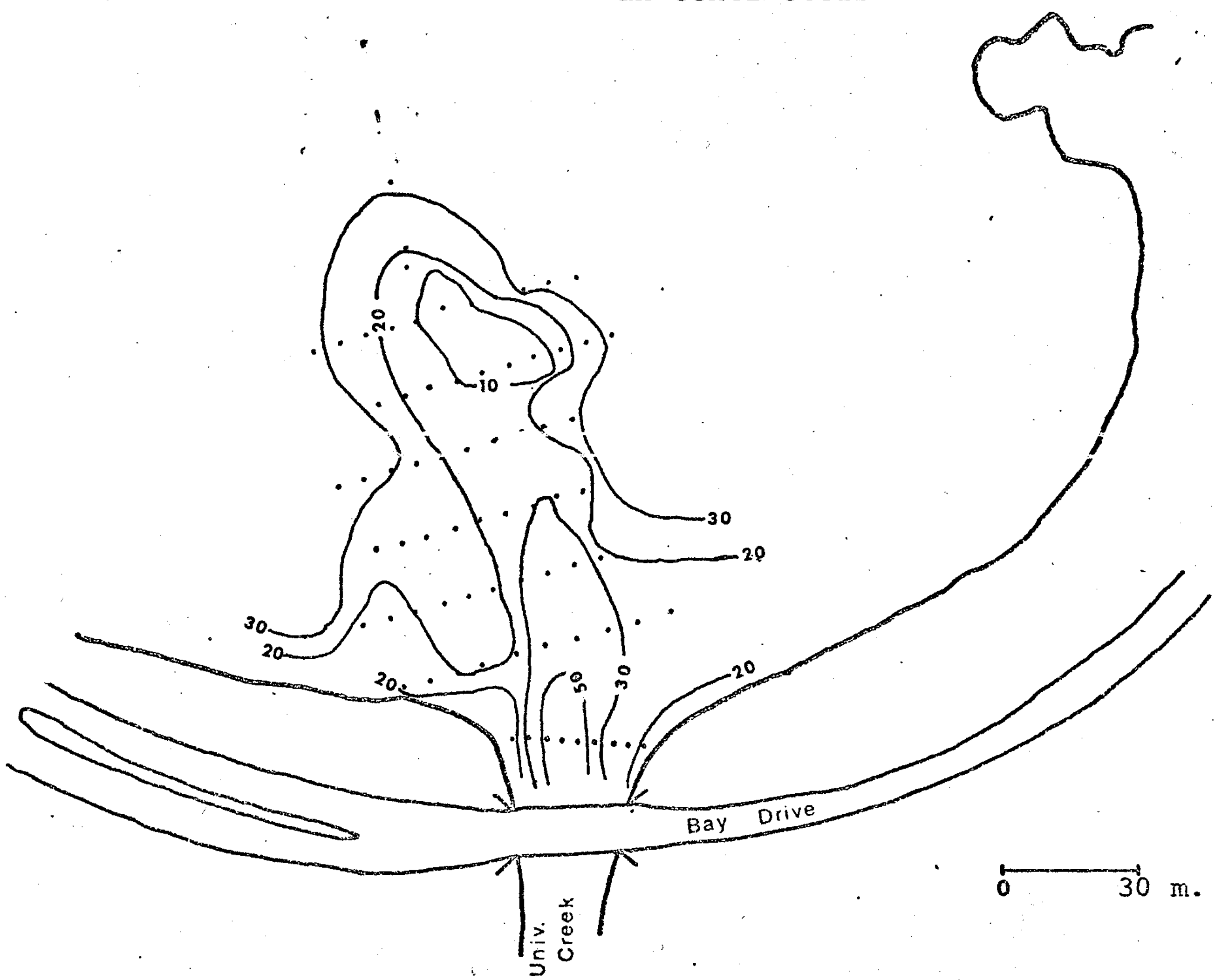
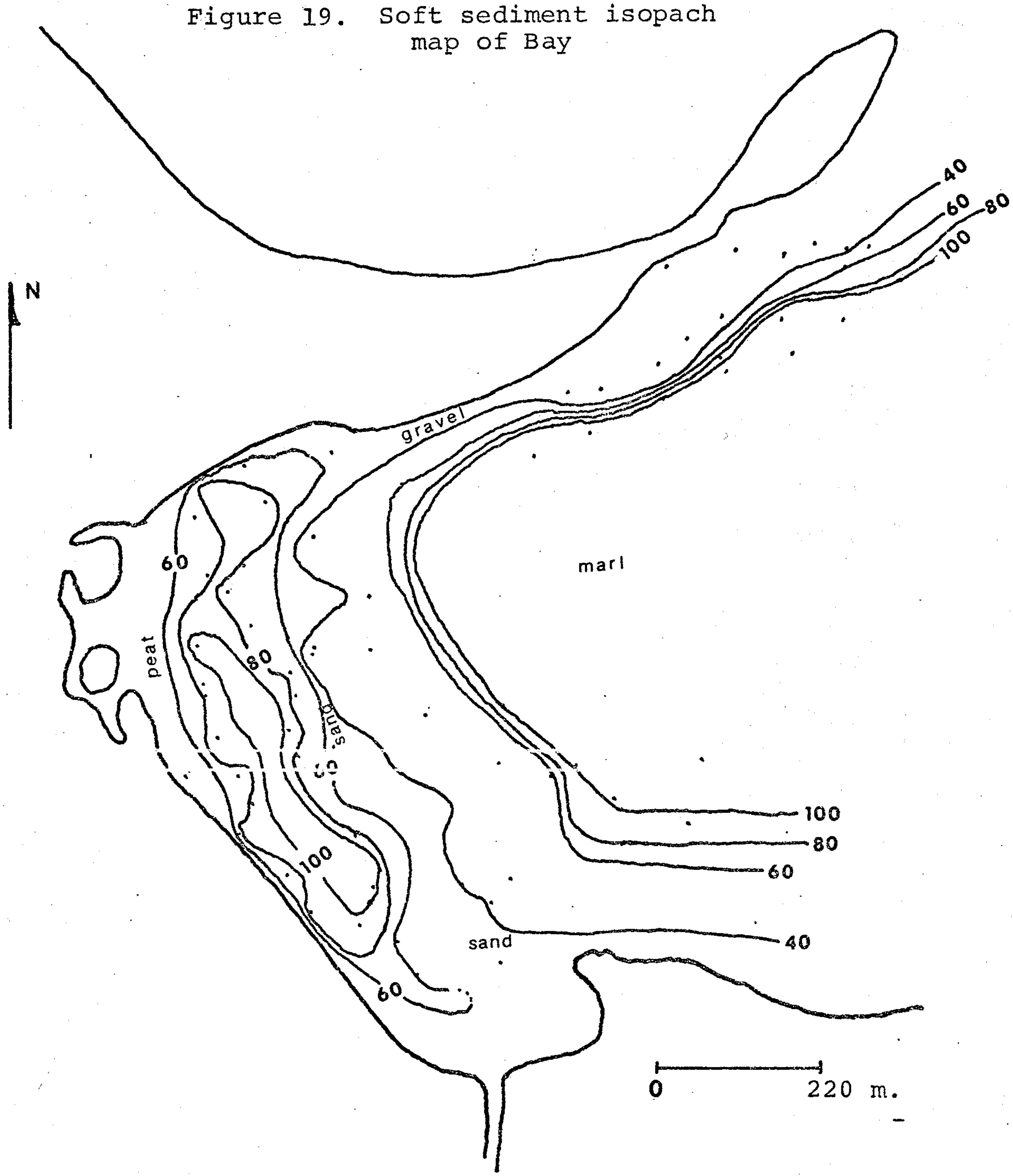


Figure 19. Soft sediment isopach map of Bay



Note: all measurements are in centimeters the sand bar. As one approaches the sand bar from the west, the sediments, of course, become more sandy; however, the general characteristics of these sediments are that they have a high organic or peat content. From the one core that I did manage to obtain in this area, lake marls were covered by 40 centimeters of peat.

The second area of distinct sediment deposition is the sand bar and delta complex. This area is made up of fine to medium-grained sands. These sands grade gradually into the peats to the west, and into the deeper water sediments to the east.

The deeper water sediment class covers more area in the Bay. These sediments are generally found in water greater than 20 feet in depth, and they are typified by a black sludge, or gyttja, overlying a buff or gray colored marl. This black sludge ranges from 0 to 14 inches, and much of it is a floculand of colloidal sized particles. In the sludge layer, biological activity is very profuse; many worms and calcareous shells were observed. Below this gyttja is the buff or gray marl. According to Twenhofel (1935), Hansen (1952) and Murray (1956), the interface between the marl and sludge is a knife sharp contact; on the other hand, Bortleson and Lee (1972) contend that there is rather a gradual transition between the marl and the sludge. The latter believe that this knife sharp contact reported earlier may be due in part to the sampling methods, rather than what really occurs in nature. In my sampling I observed a gradual transition.

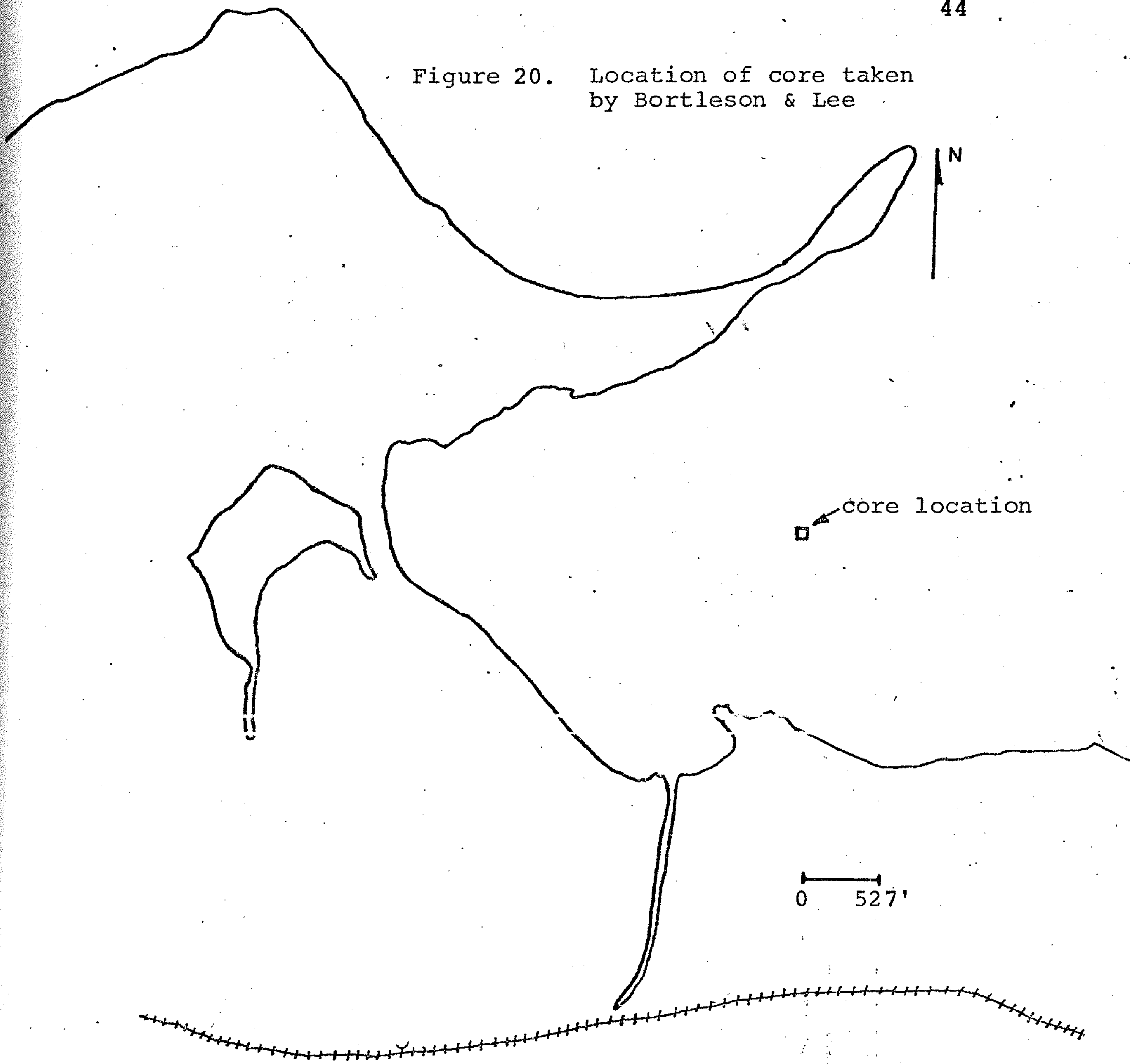
Origins of the sludge and marl have been sources of controversy through time. Twenhofel (1933) theorized that the marl was the diagenetic result of the sludge. He envisioned an almost total destruction of the organic matter in the sludge to form the marl. Hanson (1952) also made observations on the sediments of Lake Mendota, especially in University Bay. Hanson concurred with Twenhofel that the marl was formed from the gyttja; however, he believed that there was not total destruction of the organic matter. In 1956, Murray contended that gyttja was a separate and distinct sedimentary unit overlying the marl. He based his conclusions on the fact that he found the gyttja overlying not only the marl but also other units as well, such as sands and clays. Bortleson and Lee (1972) as stated before, did not see this knife sharp break between the marl and gytjja; instead they identified four units in their deep core samples. Their Zone I was buff marl which occupied the bottom 22c. of a 100 cm. core. By pollen analysis, they determined that this zone was laid down prior to any major disturbance by white settlers in the Lake Mendota drainage basin. The sediments of Zone II consisted of gray colored gyttja-marl, and this unit represents the transition zone between the buff marl and black gyttja. They concluded that this 30 cm. unit was deposited during the time period of 1820 to 1880. The next 30 to 35 cm. of sediment, Zone III, is a black gyttja which represents rapid expansion of agriculture in the basin between 1880 and 1940. Zone IV, the top 15 cm. of sediment, is also a black gyttja and it was deposited, according to the authors, from 1940 to the present. This gyttja is different from Zone IV in that the concentrations of phosphorous and nitrogen drastically increase. The authors referred to this time period as the "Detergent Era". They concluded that the marls and sludge represented different depositional units, but that these units graded into each other.

An area of coarse sand, gravel, and boulders was encountered on the north side of the Bay immediately adjacent to Picnic Point. It is believed that the coarse clasts were eroded from the glacial drift capping Picnic Point by wave action. The reason few fine sediments were encountered is due to the fact that the bottom is swept clean by the jetting current which occurs along Picnic Point. West of the sand bar these coarse sediments are also encountered, but they are accompanied by organic sediments and fine sands and clays.

Sedimentation Rates and Sediment Thicknesses

Bortleson and Lee (1972) obtained sedimentation rates for two of their cores, one of these cores was taken from University Bay (Figure 20). They calculated a mean sedimentation rate of 5.6 millimeters per year for the last 100 years in the black gyttja zones.

Figure 20. Location of core taken by Bortleson & Lee



An attempt was made to determine the sedimentation rates of the delta by means of a core, but this attempt was not successful. However, from an investigation of aerial photographs of the Bay, it is my opinion that the bulk of the delta has formed since Willow Creek was channelized and connected with storm sewer drainage in 1948.

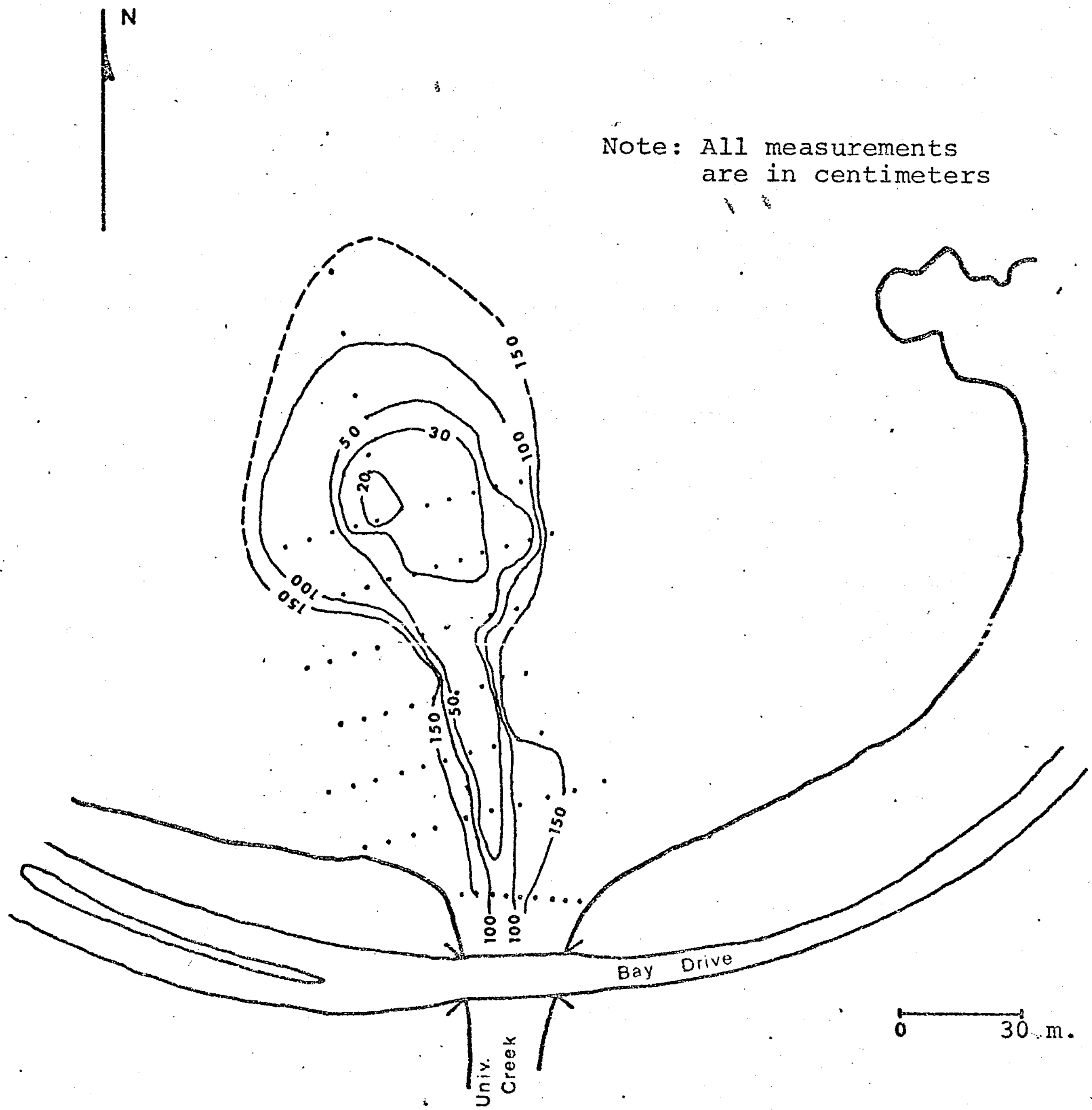
Soft sediment thickness studies were also conducted by myself in conjunction with the bathymetric study. After the depth of water was measured a 1/2 inch I.D. (inside diameter) pipe was pushed into the sediments until hard resistance was encountered. This usually occurred when the probing rod encountered sand or highly compacted marl. The depth of penetration of the rod was recorded and soft sediment isopach maps were drawn from the data (Figures 19 and 21). It was found that probing by this method was limited to water depths of 15 feet because of depths greater than this the probing rods would bend considerably when pressure was exerted on them. As it can be seen from Figure 19, the area west of the sand bar has a thick sequence of soft, highly organic sediments.

Physical and Chemical Analysis of Cores

Chemical and physical analyses were performed on the tip 20 cm. of a core which was taken west of the sand bar and on another core which was taken in deeper water east of the sand bar. The chemical analysis was performed by the Soil and Plant Analysis Laboratory and the results appear

Figure 21. Soft sediment isopach map of delta area

Note: All measurements are in centimeters



in Appendix C. According to Dr. James O. Peterson, water chemist, the chemical composition of these cores is not radically different than other bottom sediments taken from eutrophic lakes in Wisconsin. Since only two cores were taken and due to collecting methods, conclusions concerning the true chemical character of the bottom sediments of University Bay cannot be made using this data. If further information is needed, the reader is referred to the Bortleson and Lee 1972 article.

The permeabilities* of both cores were determined by a "Soil Test" permeameter. The bottom 14 centimeters of a 34 centimeter core taken west of the sand bar was extruded and placed into the permeameter. Two test runs were made on the core and an average permeability for the two runs was 13.9 gallons/day/ft^2, a low value and one characteristic of clays to silty clays. The material being tested was a peaty, organic silt; therefore, it is expected to have a very low permeability. It should be noted that this permeability is for a sample that has been removed from its natural surroundings and thus it may <u>not</u> reflect the true permeability of the material. The value may be higher or lower at the true permeability depending on testing techniques.

A core was taken west of the sand bar. The silty clay material was tested for permeability in a fashion

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*Permeability is a measure of the ability of a rock or soil to transmit water.

similar to the aforementioned procedures. For this silty clay material an average permeability of two runs was 0.17 gallons/day/ft^2. This very low permeability indicates that these sediments are acting as retarding strata for groundwater movement both into and out of the lake. No core was taken on the sand bar because I did not have the equipment necessary to obtain a core in sands.

Hydrogeology

Methodology

The last portion of the project consisted of a detailed examination of the groundwater flow systems around the University Bay. In order to gain adequate groundwater elevation and chemical data, a system of 36 observation wells, or piezometers, including three "nests"*, were incorporated into the project area (Figure 22). Five of the wells were installed by the United States Geological Survey for the purpose of studying water quality around the University feed lots. These wells consisted of 1 1/4-inch diameter black steel casing with 18-inch long sand points at the lower end. Two piezometers were installed by the Highway Soils Laboratory for studying groundwater in the medical complex construction site. The remaining 29 piezometers

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*A "nest" is a group of closely spaced observation wells, each one of which is at a different depth. With information obtained from a "nest" the hydrogeologist can tell if groundwater has an upward or downward component to its flow.

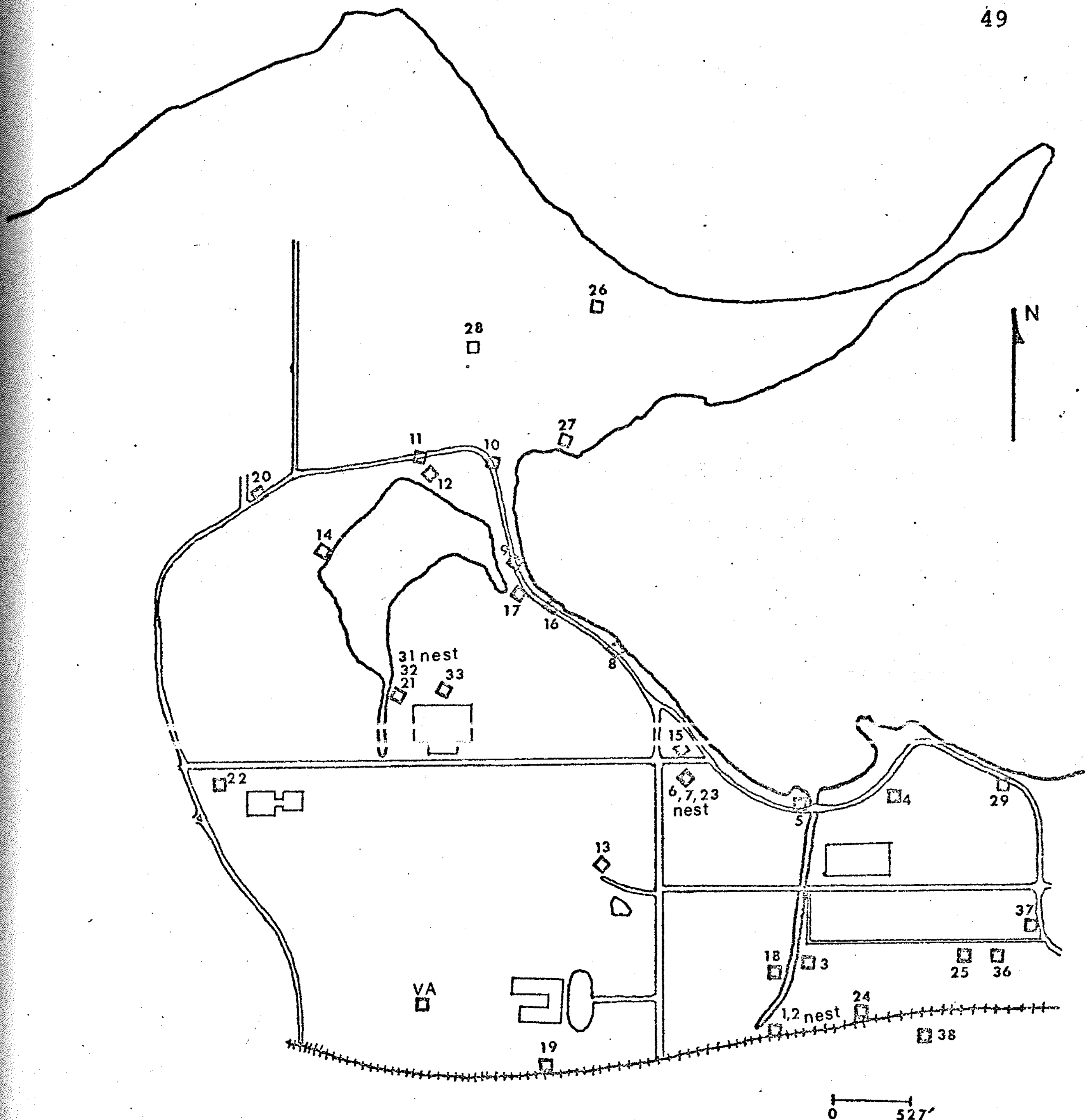


Figure 22. Location of observation wells

were installed by myself using 1 1/4-inch galvanized steel casing and an 18-inch screened well point. These last wells were installed either by drilling a hole with a rotary auger and then inserting the casing and well point into the augered hole, or by manually driving the point into the ground by means of an 85 pound hammer.

In the beginning of the study bimonthly well potentials were measured, but then these measurements were conducted on a monthly basis from September 1973 to January 1974 because water level trends had been established. Water samples for water quality were collected on a random basis and as trends were seen in certain areas, the number of wells sampled was expanded. All of these samples were collected by means of bailing. Bailing is a technique of water samples by which a closed-end tube is inserted into the well and lowered past the water level in the well by a rope.

A suite of chemical constituents were tested on the well water samples by the University of Wisconsin Soils and Plant Analysis Laboratory. Random samples were also taken from Willow Creek and these were tested for the same suite of chemicals as the observation wells. The results of these tests will be discussed later.

Permeabilities for the unconsolidated sediments were obtained from permeameter tests and pump tests. The permeameter tests were conducted in the University of Wisconsin Department of Geology and Geophysics Twenhofel

Laboratory by various students (Appendix D). The sediments used in the permeameter tests were well cuttings collected from a four-inch diameter auger drill.

General Theory and Considerations of Groundwater Flow

The following is a brief discussion of the general concepts which are used by hydrogeologists. It is believed necessary to present this information so that a total perception and evaluation of the conclusions concerning the Bay's hydrogeology can be made.

Saturated Flow

Groundwater is that part of subsurface water which occurs in the zone of saturation. The saturated zone is that portion of the rock or soil column in which all of the pore spaces are completely filled by water. The upper boundary of this zone of saturation is generally defined as being the water table. The lower boundary is the zone of plasticity or where rock flowage occurs. Precipitation is the sole source for groundwater. Not all precipitation reaches the groundwater table, some evaporates, some falls on surface water, some runs off the land surface as overland flow, and the rest is transpired by plants.

Once water reaches the water table by means of percolation it becomes part of the basic groundwater flow system. This flow system was ideally modelled by Hubbert (1940). His theory presented movement of water under the influence of gravity from areas of high elevation (recharge) to areas of lower elevation (discharge) (Figure 23). The flow path and velocity of groundwater are subject to other influences such as local topography, geology, water quality variations (density), temperature, and the horizontal and vertical dimensions of the flow system.

The basic rule of groundwater flow is described by Darcy's Law:

$$Q = KiA \quad (1)$$

Where Q = discharge (gallons/day)

K = hydraulic conductivity (gallons/day/ft^2)

i = hydraulic gradient (ft/ft)

A = cross-sectional area (feet^2)

In a similar manner, the velocity of groundwater movement may be calculated by:

$$V = Ki/7.48\ N_e \quad (2)$$

Where 7.48 = number of gallons per cubic foot of water, a conversion factor

V = velocity of water flow (feet/day)

N_e = effective porosity of the sediments (percentage)

Permeabilities for the land sediments ranged from less than 0.4 to 868 gpd/ft^2. The lowest permeabilities were obtained from the lake marls found in the marsh-playing fields area, and the sands on the south side of the Bay had the highest. It was found that not only did the permeabilities vary widely between different lithologies, but they also had a wide range within the same unit. It should be

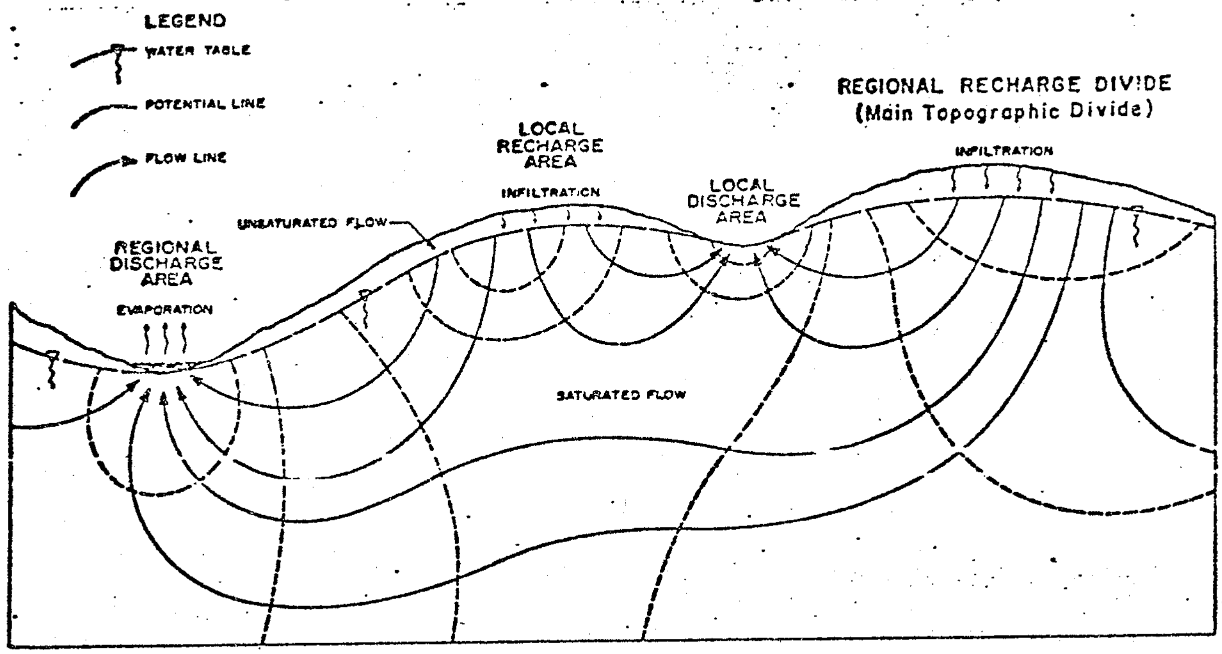


Figure 23. Idealized local and regional groundwater flow systems, homogeneous conditions (after Born & Stephenson, 1969).

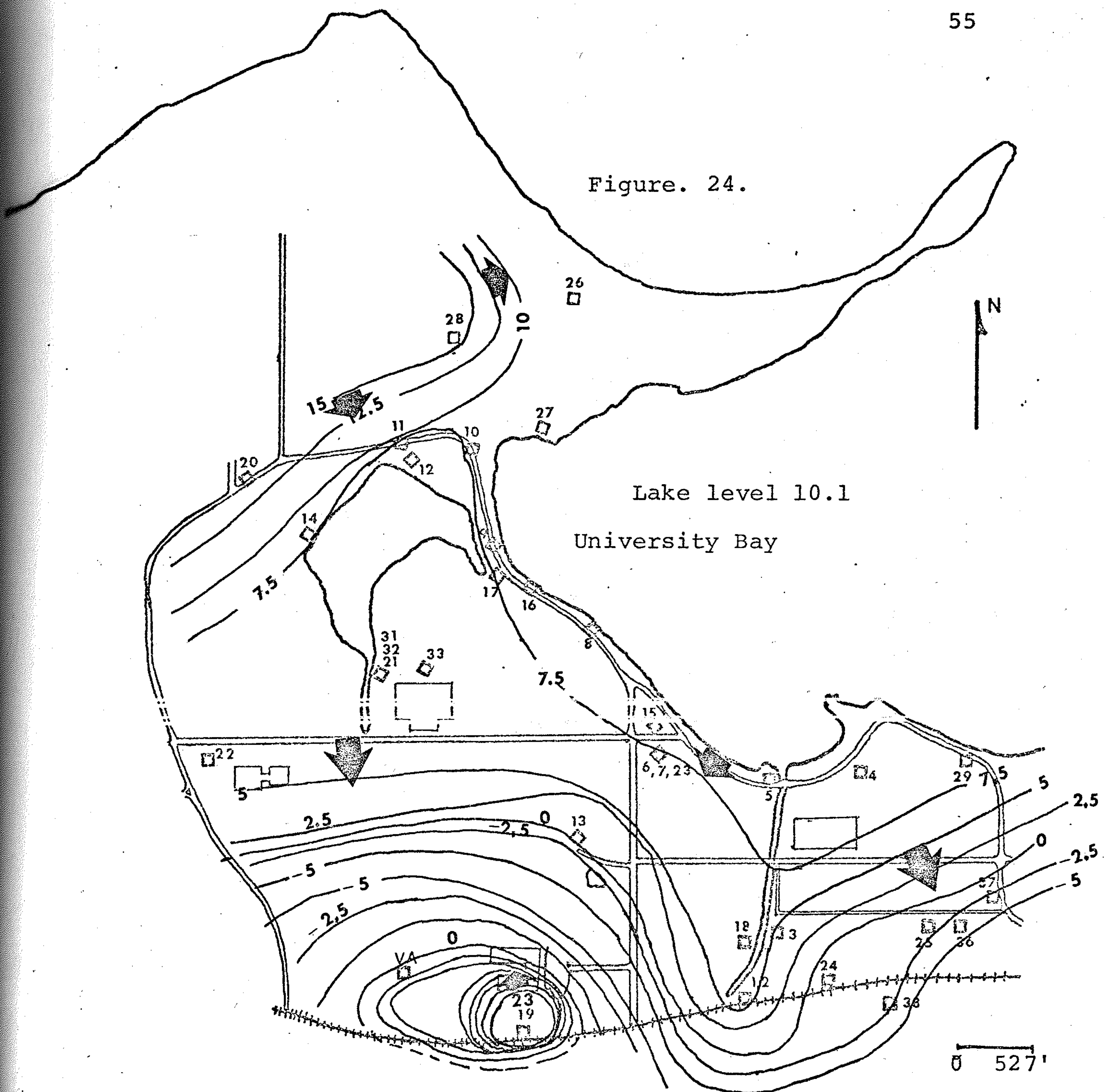
noted that since some of the permeabilities were obtained in laboratory apparatus the samples were disturbed, thus the values obtained probably will not be the same as those found insitu. These laboratory values may be higher or lower than true field values.

Groundwater moves under the influence of gravity, at any point in the system the water possesses a certain level of total energy or head. Total head is composed of two components, elevation and pressure head. As groundwater moves through the open interstices of the rock or soil it loses energy through friction. As a consequence of this, the potential energy of groundwater at a high elevation is equal to the potential energy at a lower elevation plus the energy loss between the two points.

The water levels observed in the piezometers measure the potential of the water at the given depth of the well point. Groundwater will move according to Darcy's Law from areas of high potential (recharge areas) to areas of lower potential (discharge areas). The "i" of equations (1) and (2) is the slope of the water table (dh/dl). In areas of groundwater recharge the potential decreases with depth; the opposite is true in discharge areas.

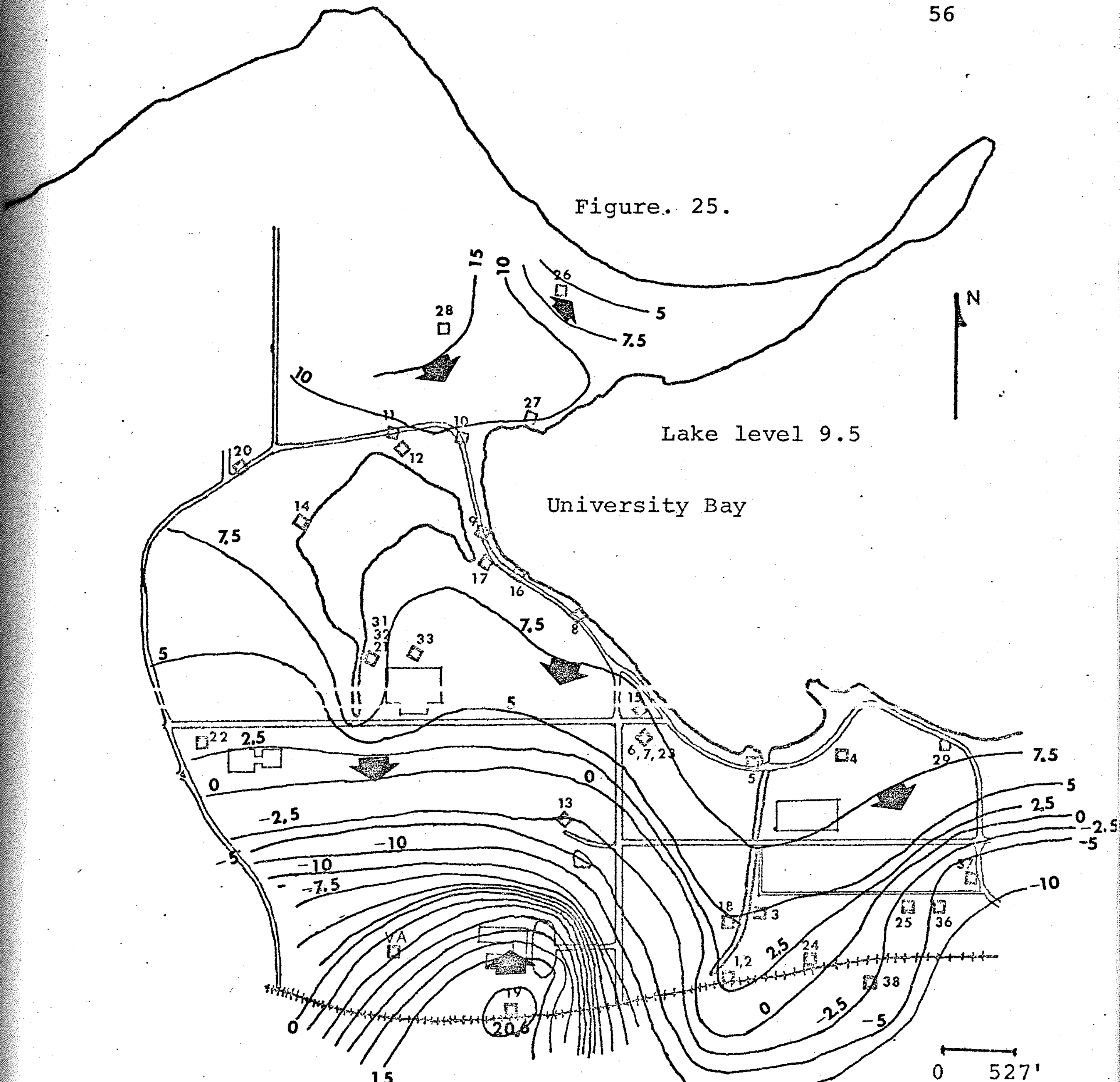
If shallow observation well potentials are plotted on a map, lines of equal potential (equipotential lines) may be drawn. The potentials are measured in feet above mean sea level (MSL). Figures 24 to 28 are examples of these types of maps; however, the interpretation of this data will

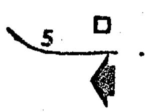
Figure. 24.



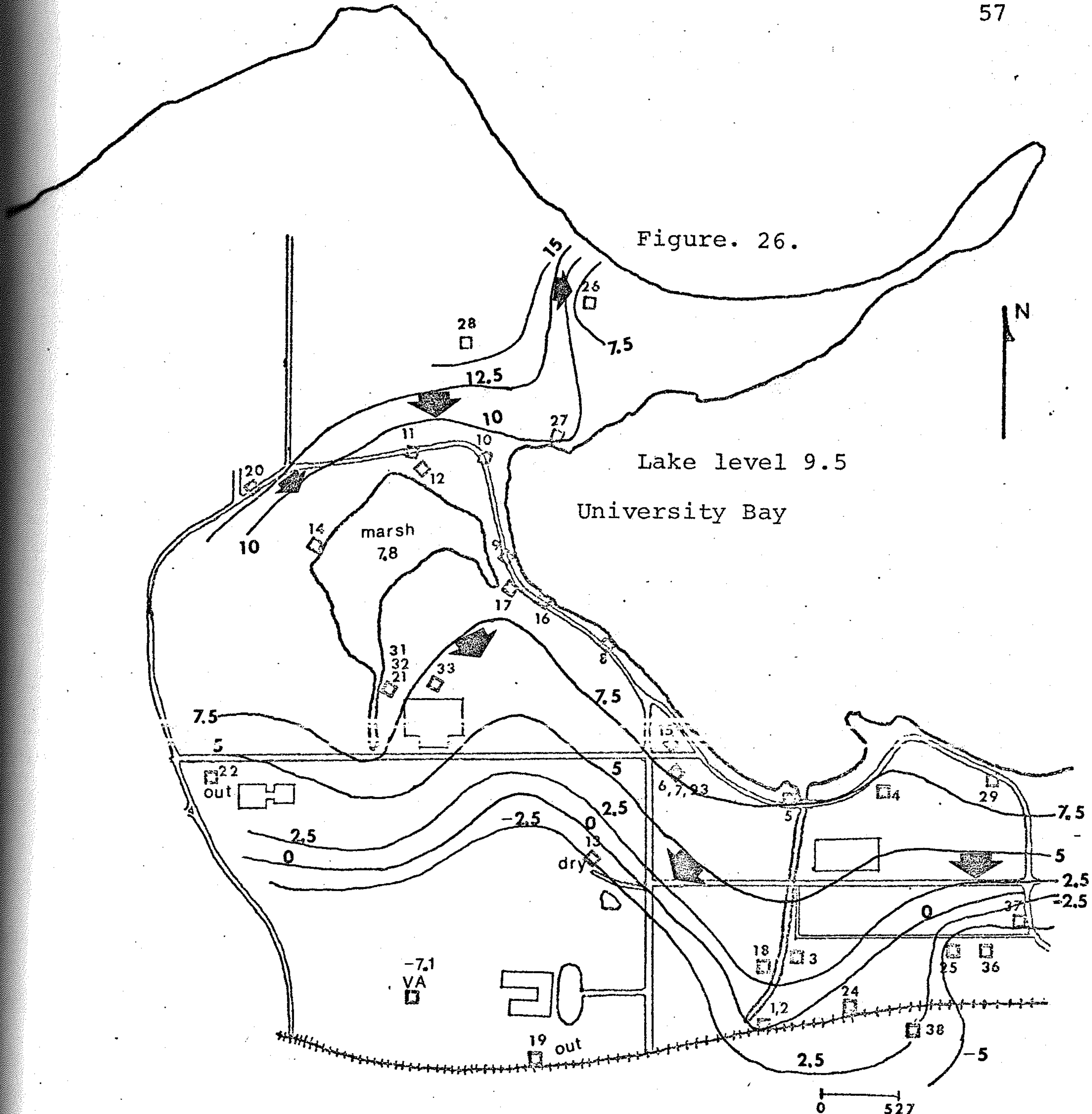
Potentiometric surface, July 12, 1973
5 □ Observation well
Equipotential line (feet above datum 840'MSL)
Direction of groundwater flow

Figure. 25.



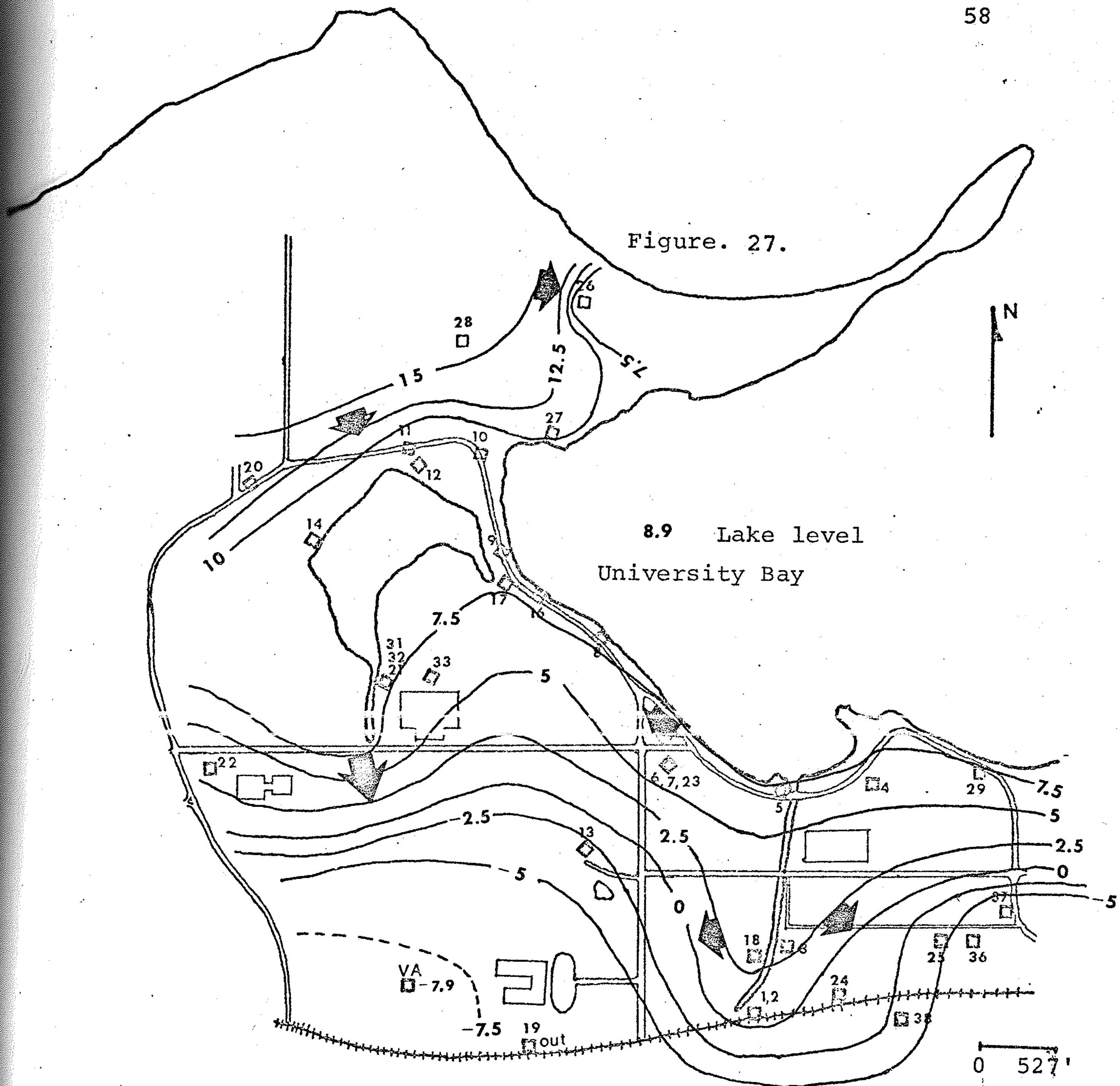


Potentiometric surface, September 5, 1973
Observation well
Equipotential line (feet above datum 840'MSL)
Direction of groundwater flow



Potentiometric surface, October 10, 1973
Observation well
Equipotential line (feet above datum 840'MSL)
Direction of groundwater flow

Figure. 27.

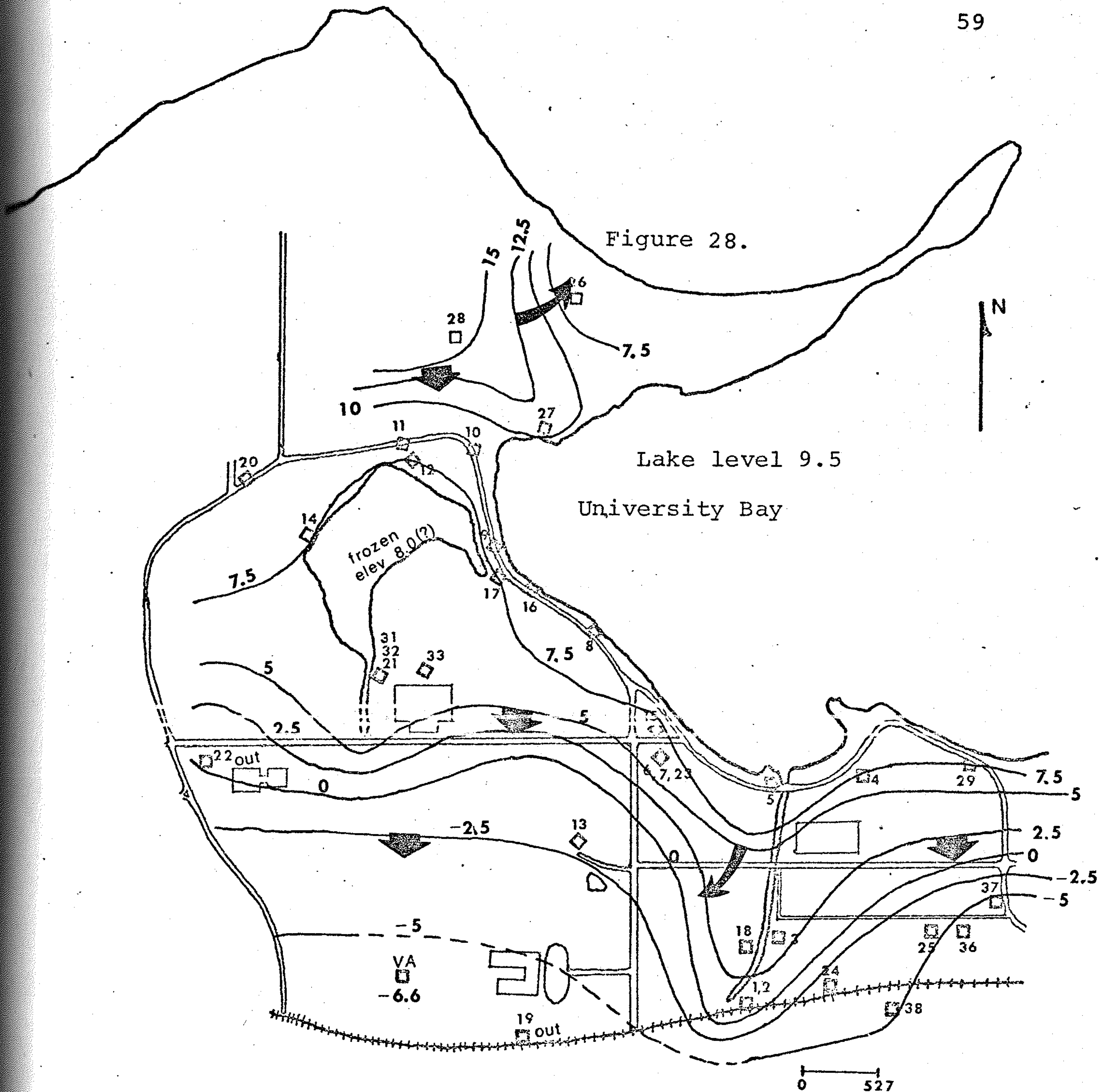


Potentiometric surface, November 21, 1973

□ Observation well

5 —— Equipotential line (feet above datum 840' MSL)

Direction of groundwater flow



Potentiometric surface, January 24, 1974

Observation well

Equipotential line (feet above datum 840'MSL)

Direction of groundwater flow

be presented in the Flow Net Analysis section. It can be stated that groundwater flow takes place perpendicular to equipotential lines in the direction of decreasing potential.

Water Table Fluctuations

In the "Humid East", that region of the U.S. which is east of the Mississippi River, the elevation of the water table fluctuates over a calendar year in response to changes of precipitation and evapotranspiration. The elevation of the water table rises very sharply in the spring due to recharge by snow melt and heavy spring rains. During the summer there is a decline in the water because of an increase in evaporation. There is a gradual increase of the water table in the fall as evapotranspiration decreases and the precipitation increases. Because of the ground being frozen and precipitation being in the form of snow, the water table in the winter experiences a steady decline. Figures 29 to 34 show the responses of various wells to these influences.

The hydrograph of Well 6 plotted with the yearly precipitation shows the general trend of the water table with rainfall (Figure 5). Comparison of this hydrograph with others (Figures 29 to 34) shows that water table variations throughout the seasons are not uniform.

There are several reasons for the wells to show non-uniform variations in the water levels. One reason is that vegetation cover varies throughout the study area. Trees

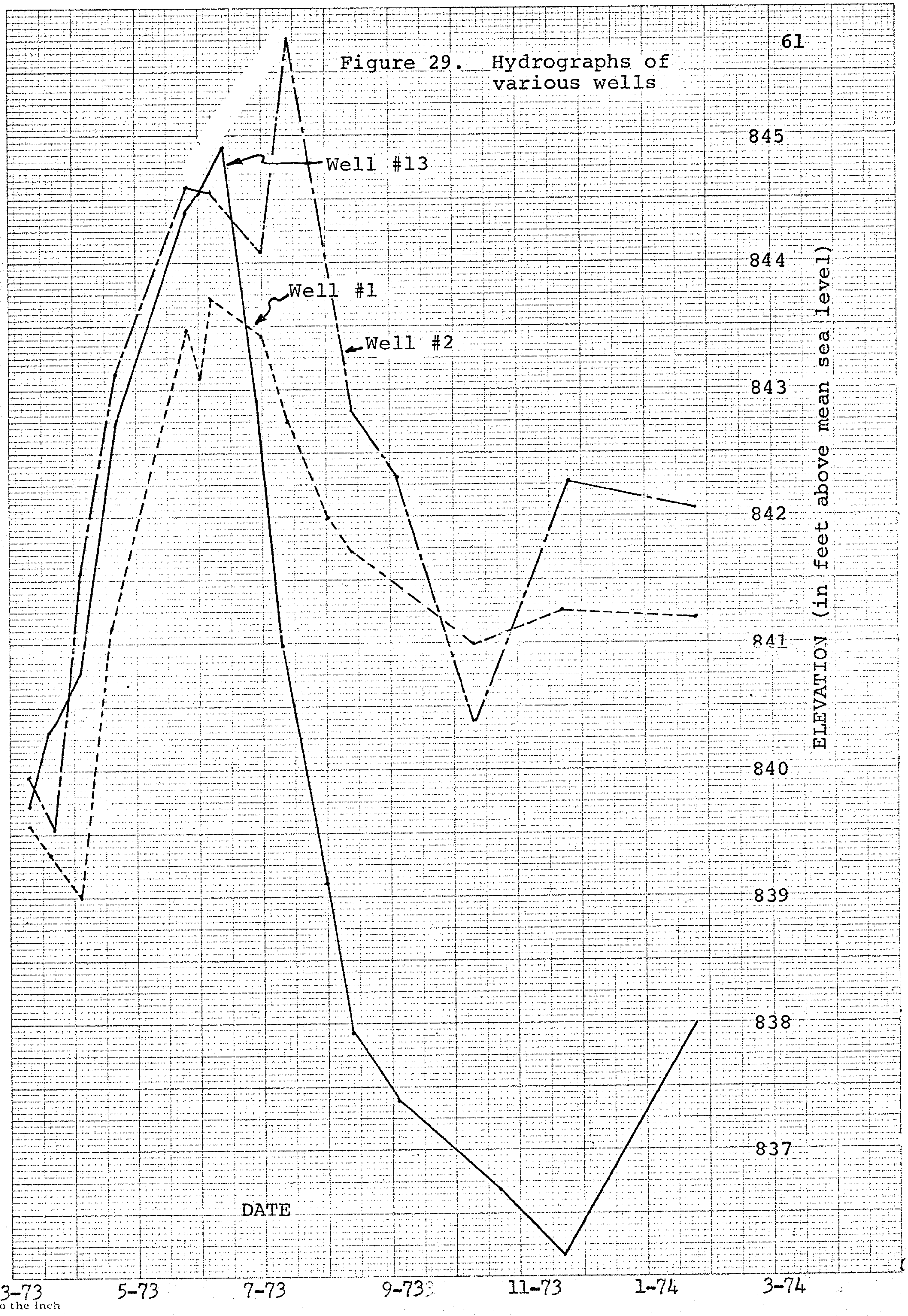
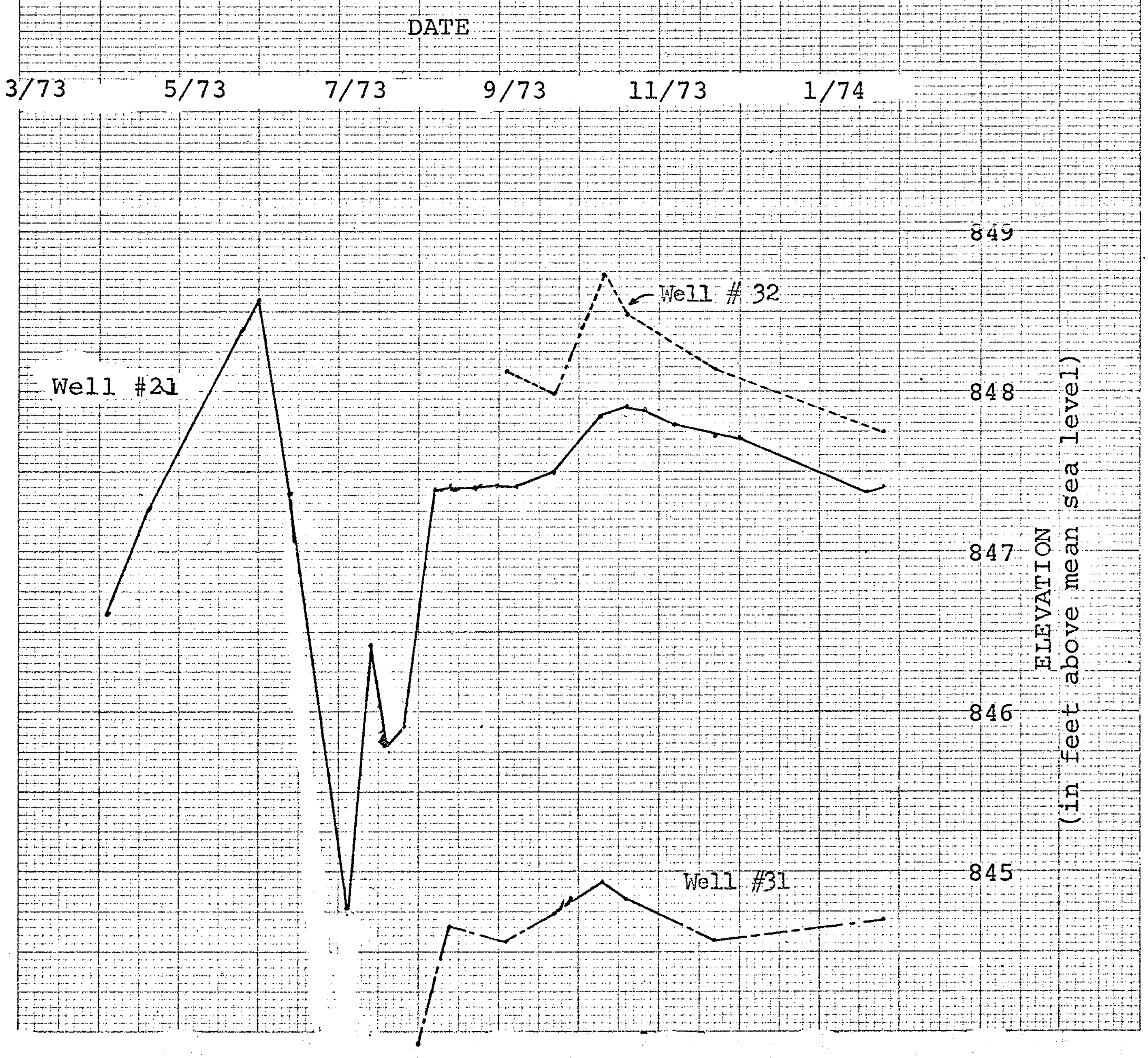


Figure 29. Hydrographs of various wells

Figure 30.

Hydrographs of marsh nest



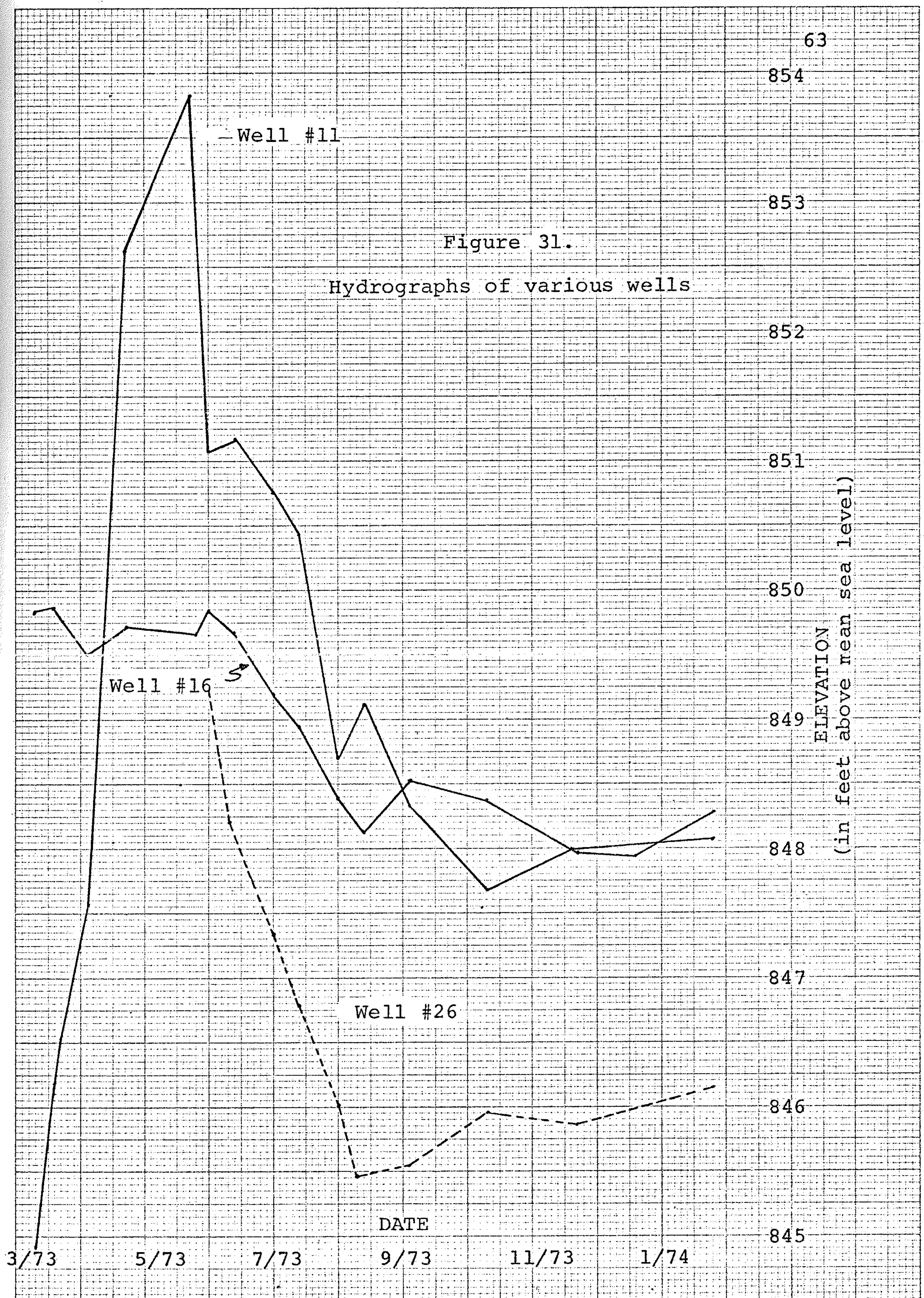


Figure 31.

Hydrographs of various wells

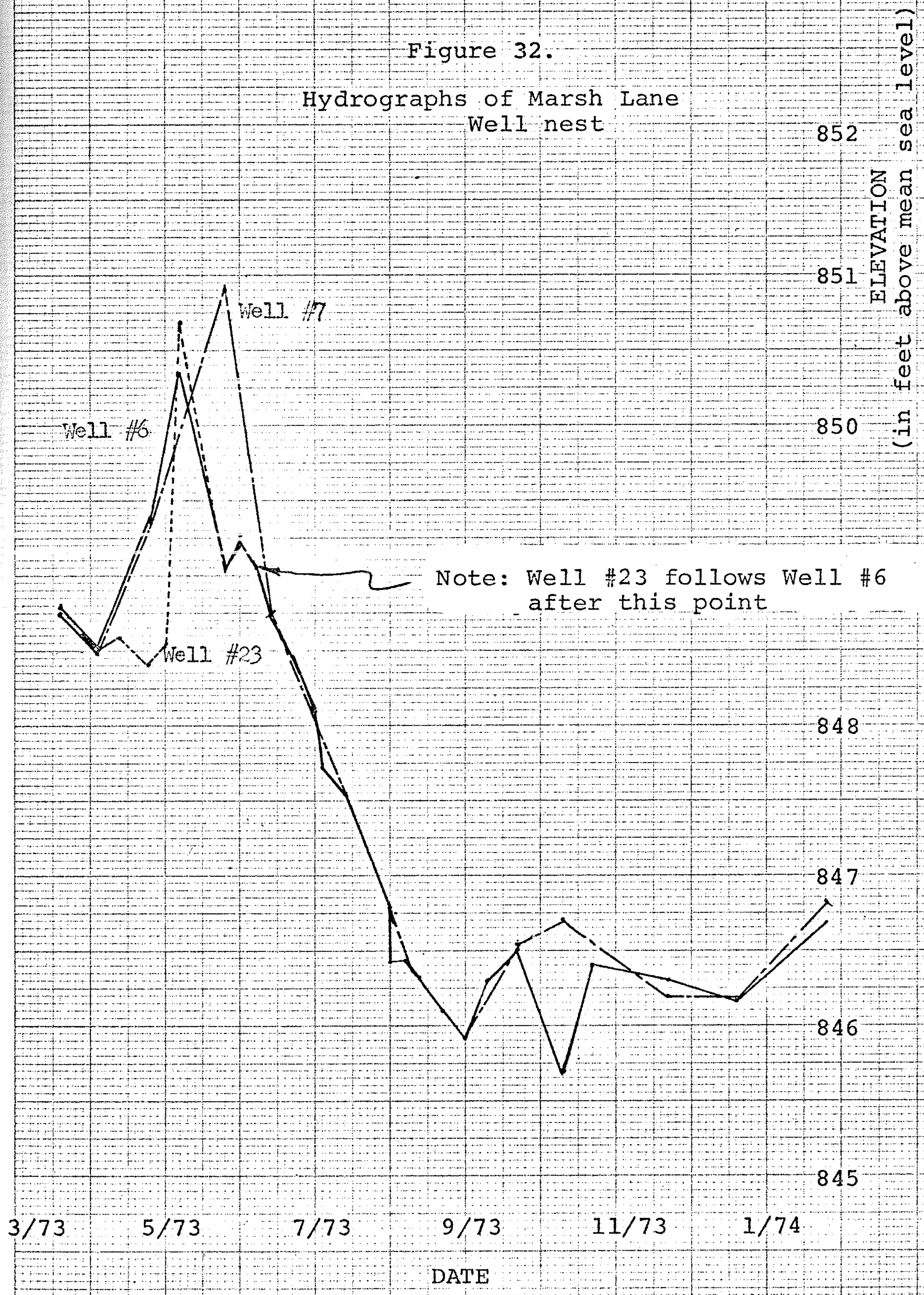


Figure 32.
Hydrographs of Marsh Lane
Well nest
Well #7
Well #6
Well #23
Note: Well #23 follows Well #6
after this point
852
851
850
848
847
846
845
ELEVATION
(in feet above mean sea level)
3/73
5/73
7/73
9/73
11/73
1/74
DATE

Figure 33.
Hydrographs of various wells

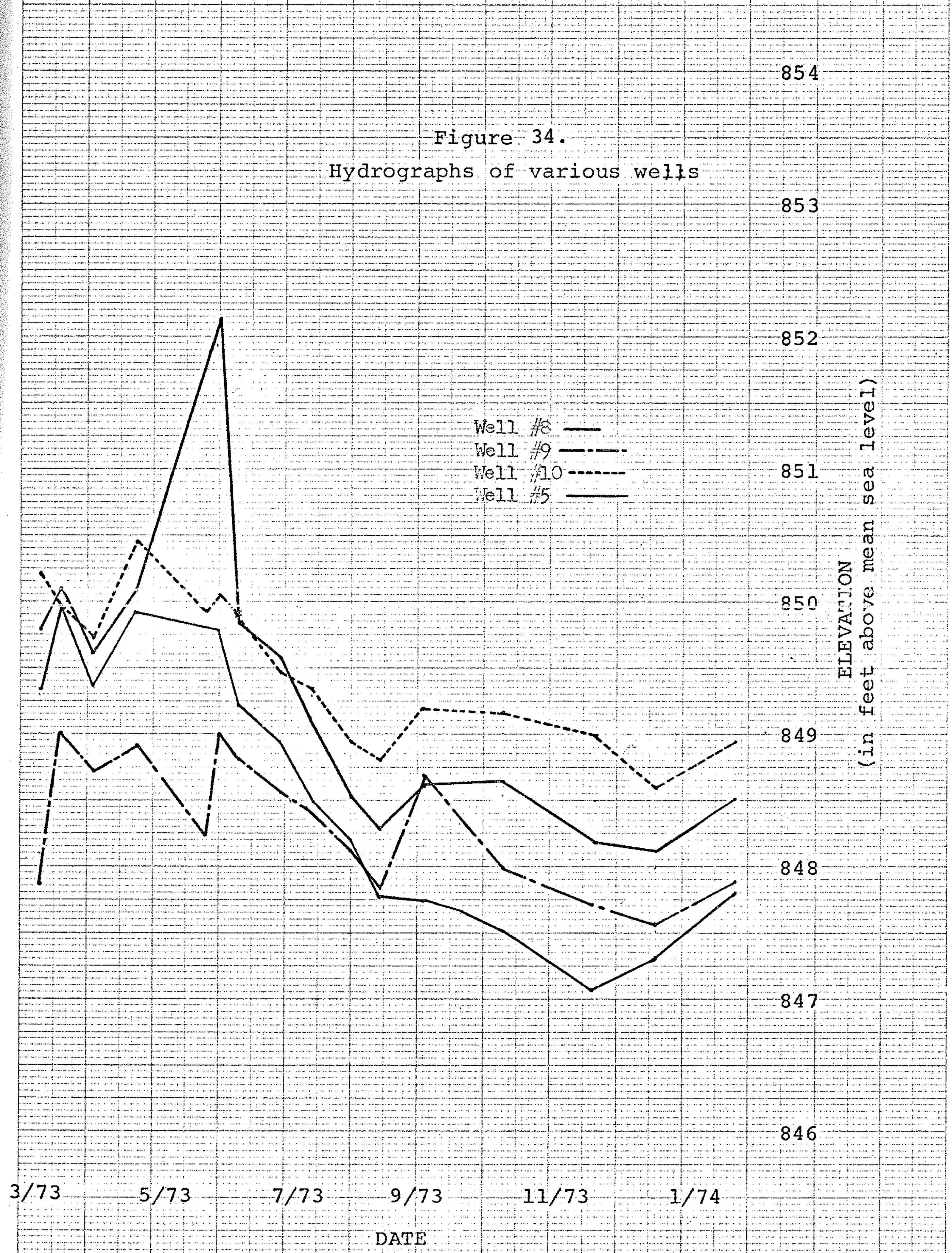


Figure 34.
Hydrographs of various wells

and large shrubs during the growing season act as "pumps" in that their root systems extract water from the ground. As a consequence of this the water table will tend to decline. Thus, a well near trees could show water table fluctuations due to the growing behavior of the trees. Another reason for varying fluctuations is the difference in soil permeabilities. Low permeability soils will dampen the effects of precipitation because it will take a longer time for the water to reach and affect the water table.

Analyzing Figure 29, one will see that Well Number 33 (a well north of the WARF building) has a water table fluctuation of almost eight feet over the study period. This fluctuation is substantially greater than the other wells except Number 11. Also, there appears to be a sudden rise in late November in the water level. It is believed that both the sizable fluctuations and the late November water rise can be attributed to the dewatering pump activity around the medical center complex construction. This construction site is approximately 1,000 feet from Well 13. The dewatering pumps were started in July, 1973, and the last pump was shut off at the end of November of that same year.

Well Number 11 on Figure 31 also shows a substantial fluctuation in its water levels. This fluctuation cannot be accounted for. However, this well is in a clayey silt soil and as a consequence this fluctuation may not be representative of the true water table fluctuations.

Sometines these fine grained sediments will plug the well, thus making it inoperative.

Figure 34 shows hydrographs of wells which border the Bay. All of these wells are in an organic silty sand. As it can be seen all the wells generally respond in the same manner throughout the year except for Well Number 8. This well shows a very large jump in the water level on June 1, 1973. At this time no satisfactory reason can be given as to why this jump occurred. Perhaps someone tampered with the well, but this is only a guess.

Flow Net Analysis

Five piezometric surface maps have been drawn for the time between July, 1973 to January, 1974 (Figures 24 to 28). These maps seem to indicate that the water table is related to the topography. That is to say that in those areas where there are hills the water table is also higher in elevation. In more precise terms, it appears that groundwater divides parallel surface water divides. Wells on the north side of the study area indicate that Eagle Heights is a recharge area. A recharge area is where water, after it reaches the water table by percolating through the soil, will move down away from the water table. From this particular recharge area water can move in several directions and this type of situation is what is called a groundwater divide. There is a groundwater divide in Eagle Heights running parallel to the hill. North of this divide groundwater moves toward

Lake Mendota, and south of this divide groundwater moves toward the Bay area.

The regional groundwater flow for the area (Figure 35) indicates flow from the north to the south, this general trend is also seen in the local flow system of University Bay, but with some modifications.

One such modification is the topographic high on the south side of the study area. This area too is a recharge mound; however, water flowing north from this mound is not discharged at the surface, but rather, it is believed that the water curves under and joins the regional flow system (Figure 36).

From the piezometric surface maps (Figures 24 to 28), it can be seen that the configuration of the water table surface does not vary significantly through the year. This means that groundwater flow direction reversals did not occur.

The marsh located in the middle of the study area was found to have both recharge and discharge characteristics. From Figures 24 to 28 it can be seen that groundwater enters the marsh on the north and east sides and moves from the marsh into the ground on the west and south sides. A well nest on the south side of the marsh indicates recharge conditions. It was consistently found that the shallower well of the nest had higher water elevations than the deep well. This indicates that groundwater has a downward vertical flow. This recharge condition may be induced by

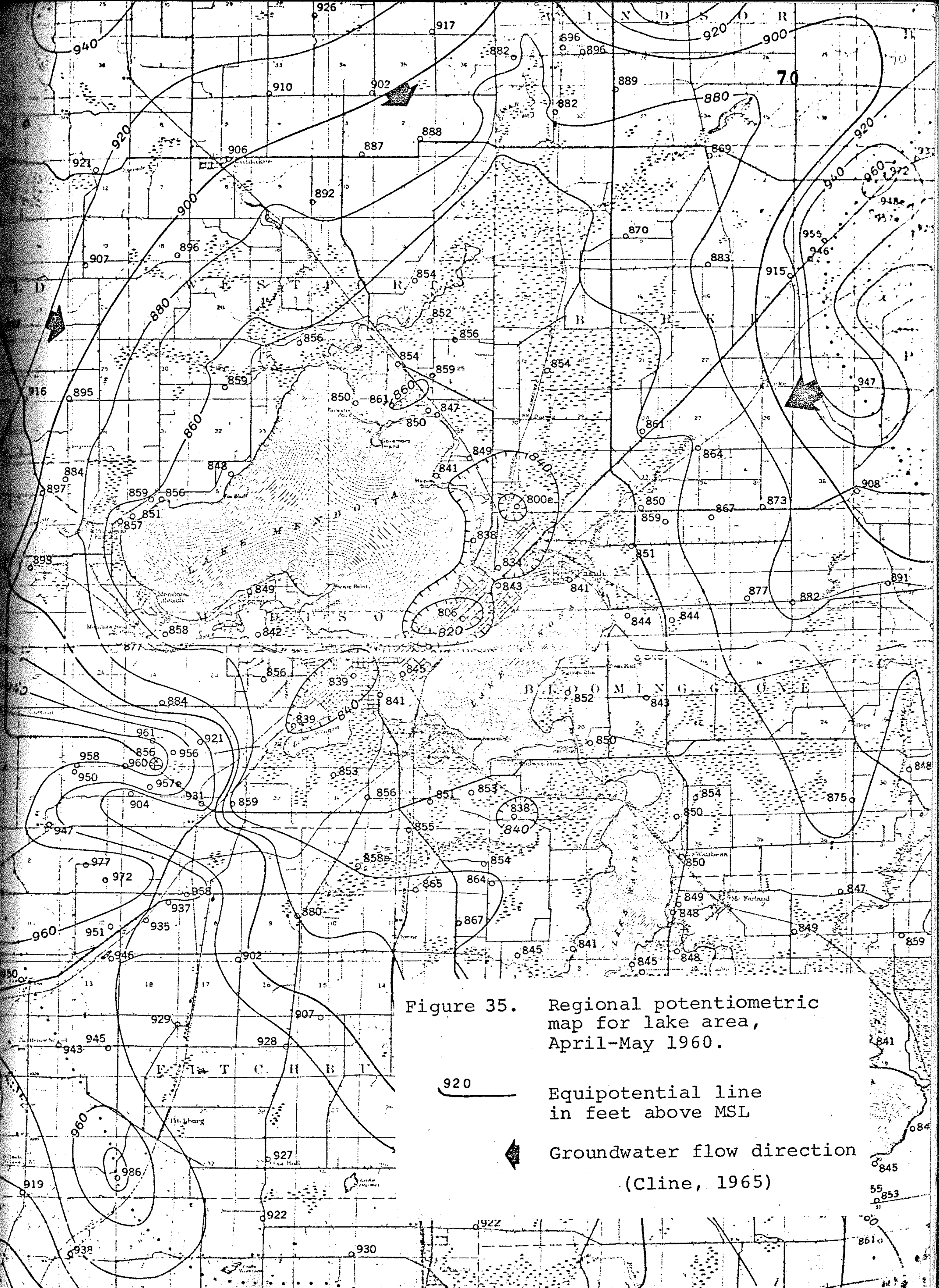


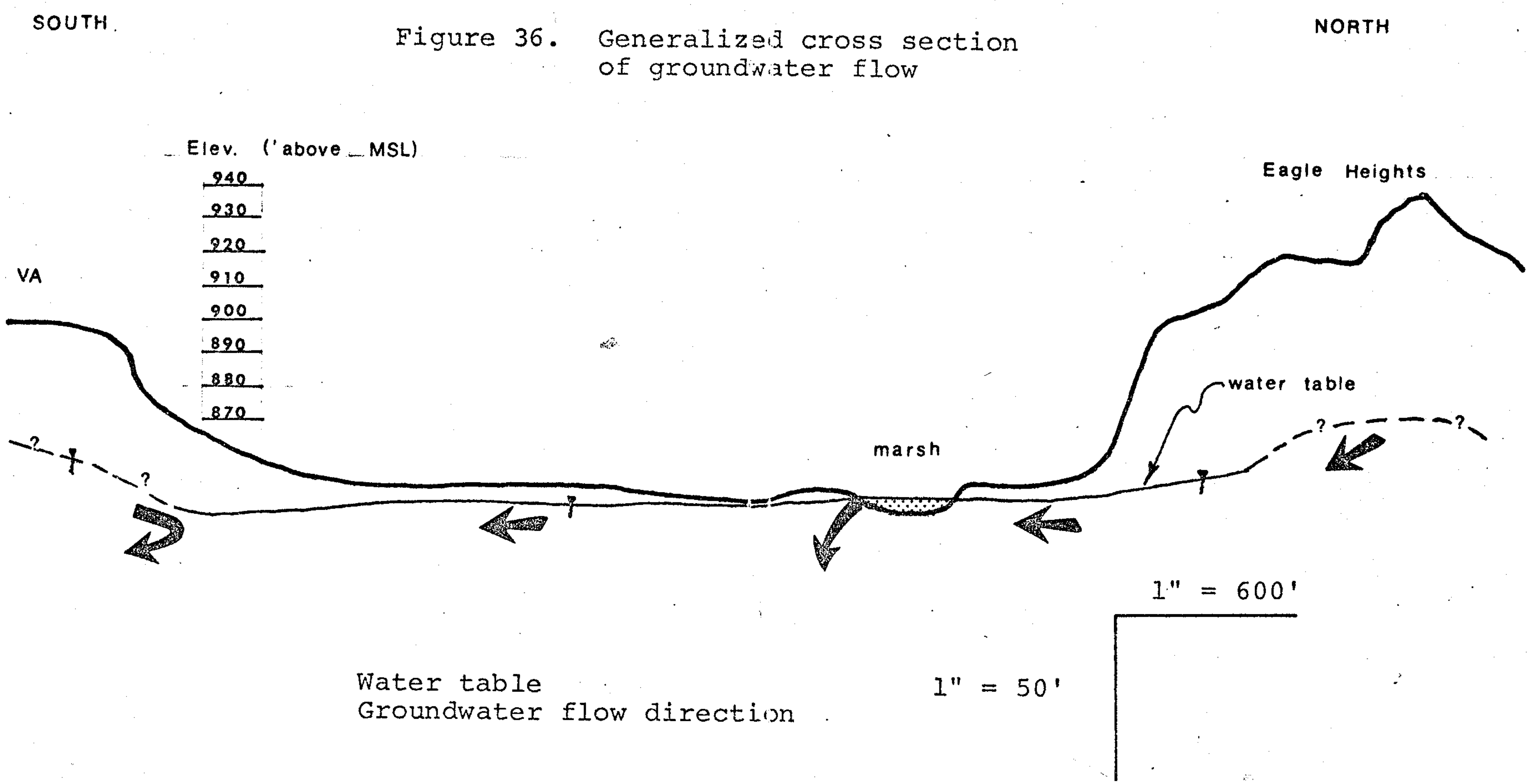
Figure 35. Regional potentiometric map for lake area, April-May 1960.

920 — Equipotential line in feet above MSL

Groundwater flow direction

(Cline, 1965)

Figure 36. Generalized cross section of groundwater flow



Note: Groundwater elevations are for October 10, 1975 city pumping of municipal Well Number 6 which is located on University Avenue and Franklin Street, southwest of the Veteran's Hospital. It is felt that municipal Well Number 4 on the corner of Regent and Randall Streets may have some influence on the area, but because of a closer proximity, Well Number 6 probably has the most influence on the Bay. It was not documented that Well Number 6 actually influenced the water levels in the marsh. The well "nest" was completed in mid-July, 1973 and since that time the Number 6 well has been pumping fairly continuously. From November, 1972 to July, 1973 the municipal well was not in operation. During this time it is not known what vertical gradients existed in the marsh area.

An estimation was made of groundwater flows in the marsh area. The marsh itself displays "flow through conditions". This means that water enters one side of the marsh and leaves the other side. This type of flow is unusual for a marsh. Most marshes experience groundwater seepage from all sides and water leaves the marsh through evaporation and transpiration of plants. Due to the low permeability of the sediments found within the marsh (less than 0.4 gals/day/ft^2), seepage from the marsh is estimated to be 15 gallons/day (Appendix E). This seepage takes place along the south side of the marsh. As can be seen, this amount is almost negligible.

As it can be seen from Figures 24 to 28, a majority of the study area receives water from the Bay into the groundwater system. From various calculations and assumptions it is estimated that flow from the Bay into the land is 23,200 gallons/day (Appendix E).

Also in viewing Figure 24 one can see that the water table contours bend downgradient. This seems to indicate that Willow Creek is an influent stream*. Also, it should be noted that this type of flow is a reversal of what appears to be the norm. Figure 35 shows the groundwater and the surface water moving in the same direction. This situation does not hold true for Willow Creek. Willow Creek flows to the north while the groundwater flows to the south. This stream also appears to be a groundwater divide in that water flows either to the southeast or southwest from the stream. Initially it was thought the this divide was caused by pumping of city Wells Numbers 6 and 4; however, this configuration of the water table occurs in January, 1974 even though Well Number 4 had been shut off for a period of tow and a half months (Appendix F).

Some caution must be taken when interpreting the data of the wells around the marsh area because of the fine grained sediments. Sometines the well points become plugges with sediment and as a consequence the well did not have good communication with the groundwater system. For example, Well Number 12 shows little variation of water levels

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*An influent stream is a stream which recharges the groundwater system. In other terms, water moves from the stream into the ground.

throughout the year and the water levels in it sometimes show a flow system which probably cannot exist, thus the readings should be discarded. This well is located in fine grained marls.

Effects of Municipal Well Pumping

Effects on the shallow aquifer by pumping of the Number 6 city well are best illustrated in Figure 37. Observation wells were installed by the Highway Soils Laboratory in order to observe groundwater fluctuations in and around the new medical center construction site. Because of a very high water table in the spring of 1973, two pumps were installed so that the area could be dewatered and building foundations poured. It can be seen in Figure 36 that when the city well was shut off, a rise of almost two feet occurred in the VA observation well.

Model of Shallow Aquifer

Because of a high water table around the construction site for the new medical center, it was decided by the construction engineers in cooperation with the state to dewater the site by pumps so that the footings for the building could be emplaced. In order to do this two pumps and various observation wells were installed in the construction site (Figure 38). Water level and pumping rate data were collected by the State Highway Soils Laboratory. A major goal of this study was to ascertain the

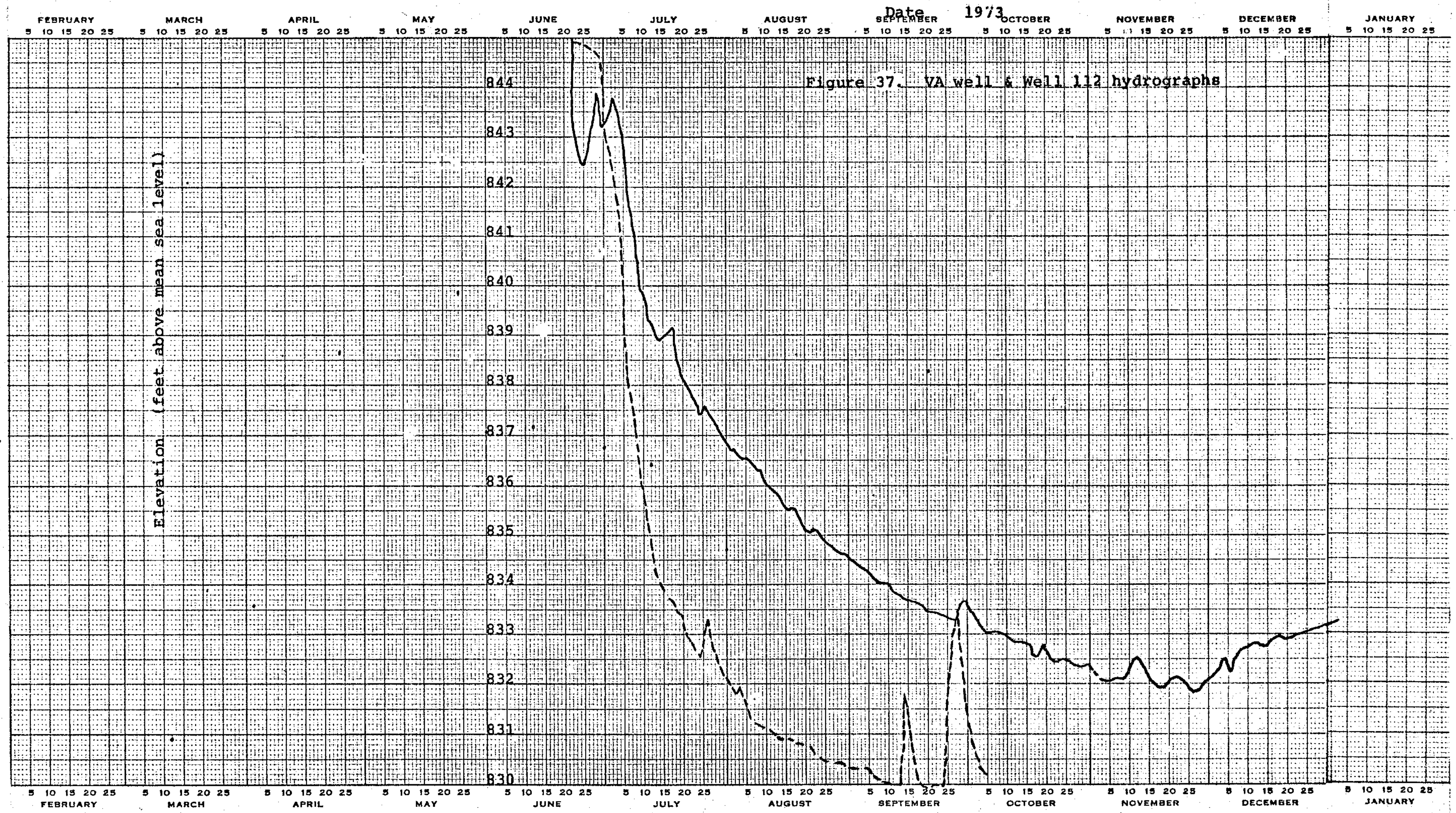

Figure 37. VA well & Well 112 hydrographs

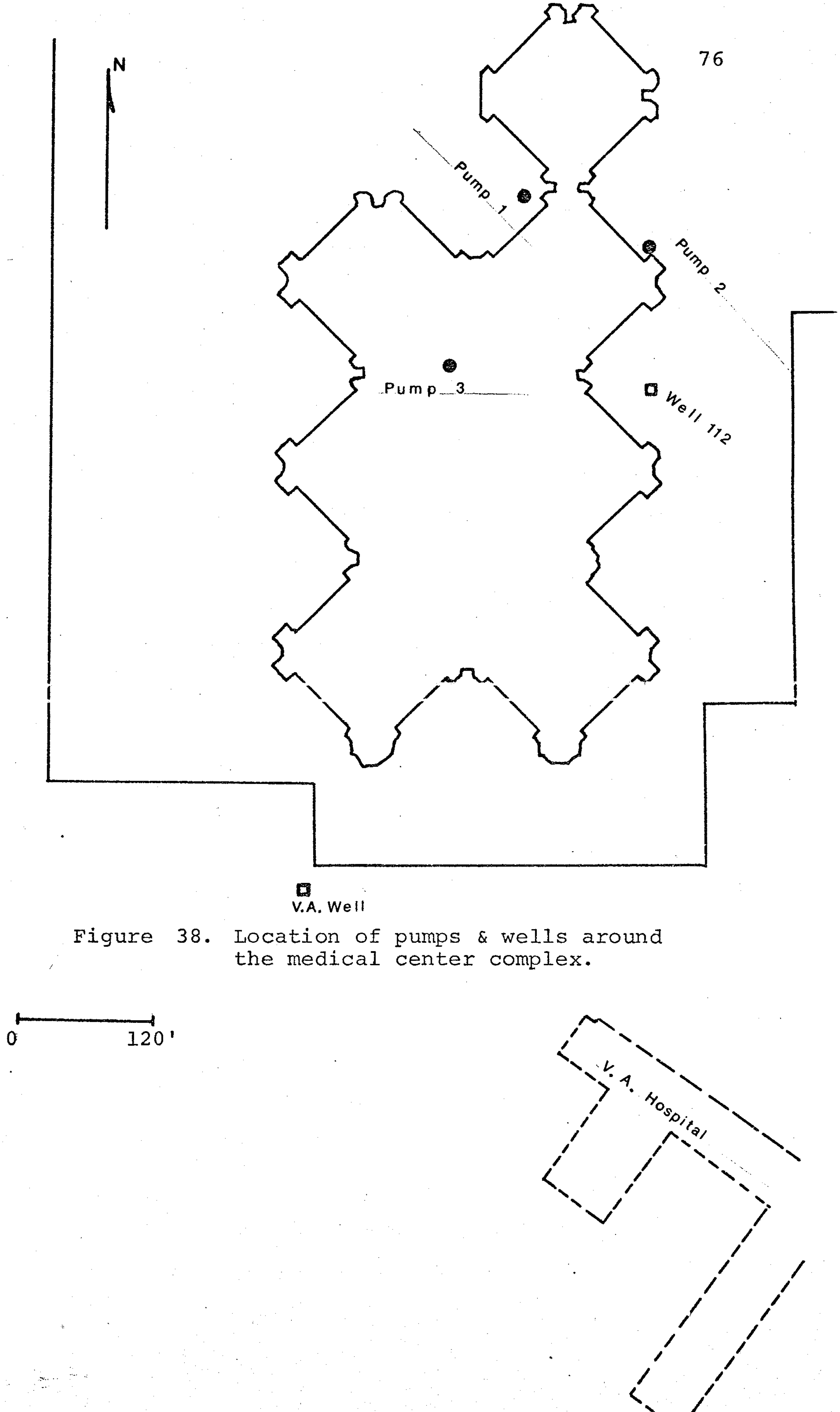

Figure 38. Location of pumps & wells around the medical center complex.

effectiveness of the dewatering pumps in drawing the water table down. After this data was collected it would be used in the construction plans for locating sump pumps in the new medical building so that the foundations would not be flooded.

In order to evaluate the effectiveness of the pumps certain aquifer properties must be determined. The major aquifer property which can be determined from this type of test is transmissivity. The transmissivity of an aquifer is the thickness of the aquifer multiplied by the permeability of the aquifer.

Another important aquifer property to be determined is the storage coefficient. This dimensionless number represents the volume of water released from the aquifer per unit surface area of aquifer per unit change in head.

The transmissivity and storage coefficient are extremely useful to the foundation engineer. Transmissivity affects the size and shape of the cone of depression around a pumping well. Figure 39 displays this point quite well. In picture A the transmissibility is ten times less than that in B. As it can be seen in A when the pump is turned on the drawdown around the well is much greater than in B. This is very important in designing the size and location of sump pumps and/or municipal water wells. The engineer is interested in how much drawdown will occur when a given pump is turned on. Transmissivity and storage coefficient can also be used to determine how much water can

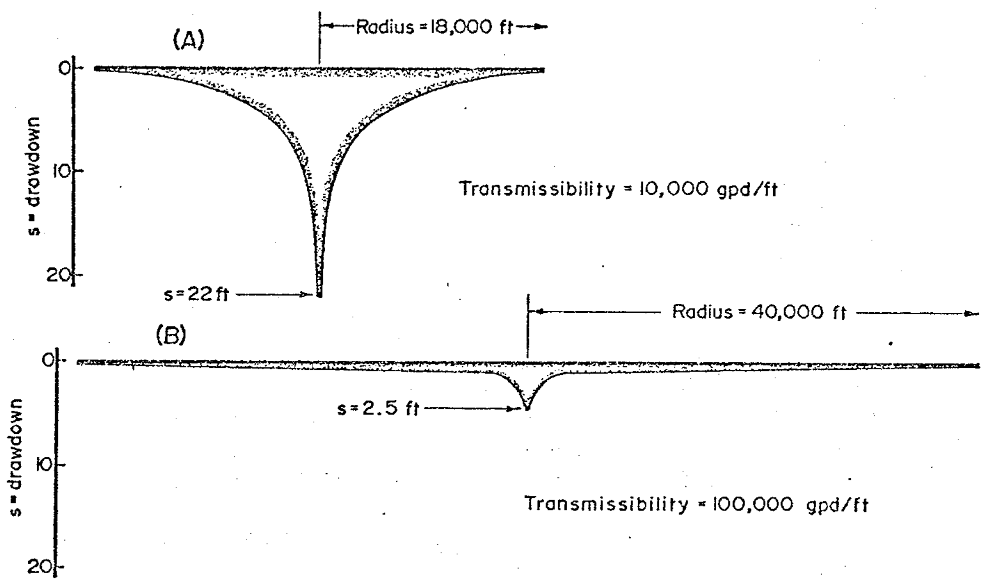

Figure 39. Effect of differing coefficients of transmissibility upon the shape, depth and extent of the cone of depression, pumping rate and other factors being the same in both cases. (after Johnson, 1972).

be obtained from an aquifer. A value for permeability can be obtained from the transmissivity. And with such a value calculations can be made to determine groundwater velocities and groundwater flow quantities.

The thickness of the aquifer was determined by drilling. The permeability of the soil was determined by pump-test analysis. Figure 40 shows the drawdown curve for the VA well. From various calculations (Appendix G) it was determined that the permeability of the sandy-gravely soil in the construction was 430 gallons/day/ft^2. This value is in agreement with the permeameter tests which indicated a permeability range of 200 to 530 gpd/ft^2.

After obtaining the above data it was decided to model the shallow aquifer by digital computer methods. With such a model, efficiences of drawing down the water table can be evaluated by varying the size and position of the pumping wells.

The proposed digital computer model which was selected was developed by Messrs. Thomas A. Prickett and Carl G. Lonnquist. The model is described in detail in their publication "Selected Digital Computer Techniques for Groundwater Resource Evaluation", Illinois State Water Survey Bulletin 55, 1971. For assumptions and model see Appendix H.

The model for the Bay project was set up on the University of Illinois' IBM Model 360 computer. Two trial runs were made in Illinois; however, it became clear that certain assumptions were erroneous. Some of these assumptions

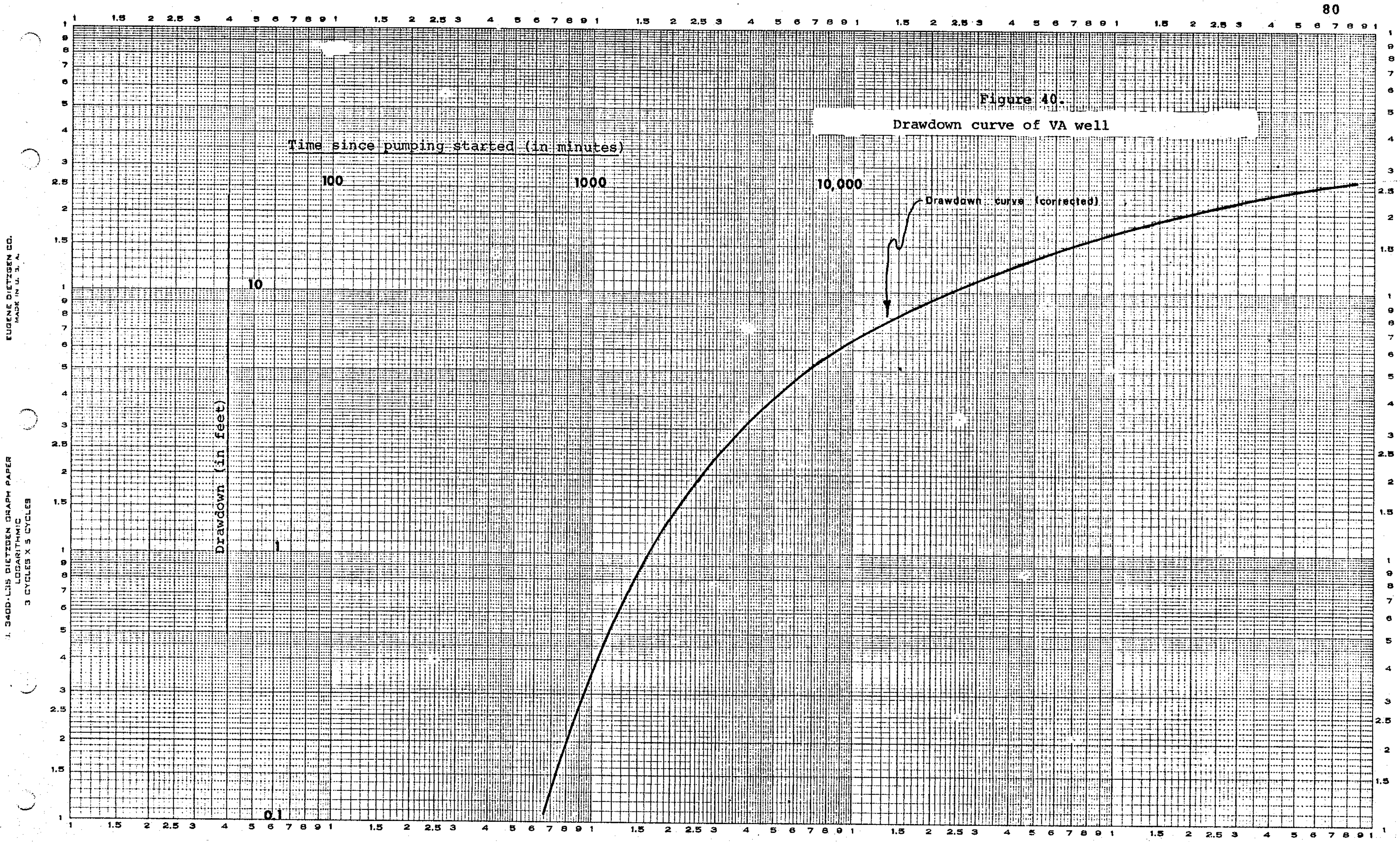

Figure 40.

Drawdown curve of VA well

concerned the thickness of the aquifer and boundary conditions. Time did not permit further runs in Illinois.

In Madison, an attempt was made to transfer the computer program from the IBM 360 to the Engineering Laboratory Datacraft 3600. Immense conversion problems resulted. These problems were not only in procedural matters but also in storage. Due to lack of time and money the digital modelling of the Bay was abandoned. Because the model was abandoned, the goal of ascertaining the effectiveness of dewatering pumps was not achieved. In locating the sump pumps, the engineers did use the permeabilities which were obtained for the aquifer.

Hydrogeochemistry

The purpose of groundwater chemical analysis was not to define flow systems but merely to obtain some idea of water quality in the Bay area. Constituents tested and wells sampled appear in Appendix I.

Well Number 8 shows the affects of road salting. Chloride levels fluctuate from a high of 479 parts per million (ppm) in March to 53.7 ppm in June.

The generally poor water quality of Well Number 32, the shallow well of the marsh nest, is attributed to the decaying of material which was placed there when the area was a landfill. The water quality of the deeper wells in the nest is improved. This is due to the fact that these waters are below the landfill; thus dilution by groundwater has occurred.

Well Numbers 25 and 38 show high Ca, Mg, S04-S, and Cl concentrations. This poorer water quality may be explained by the fact that both wells are cased for at least 15 feet into the bedrock. Waters from the calcareous cemented sandstone bedrock have been in the flow system longer thus they are probably saturated with various dissolved solids.

Because of sampling techniques, further conclusions would be tenuous. The sampling method was by bailing. According to Dr. James O. Peterson of the University Extension, this method is inherently wrought with errors. Bailing was the only feasible means of obtaining water samples because none of the wells could be pumped. The reason for this is either the sediments around the wells were of such low permeability that water could not enter the well when pumping started, or the pumping levels were too great for the available small pitcher type sampling pump.

Discussion

It was the stated purpose of this report that it be used as a tool for the campus planner in helping to formulate management plans for the west campus area. This discussion is to summarize the work which has been completed for this report.

Figure 41 is a development suitability map based on the results of this study. Basically, the areas which are designated unsuitable for development are delineated on the

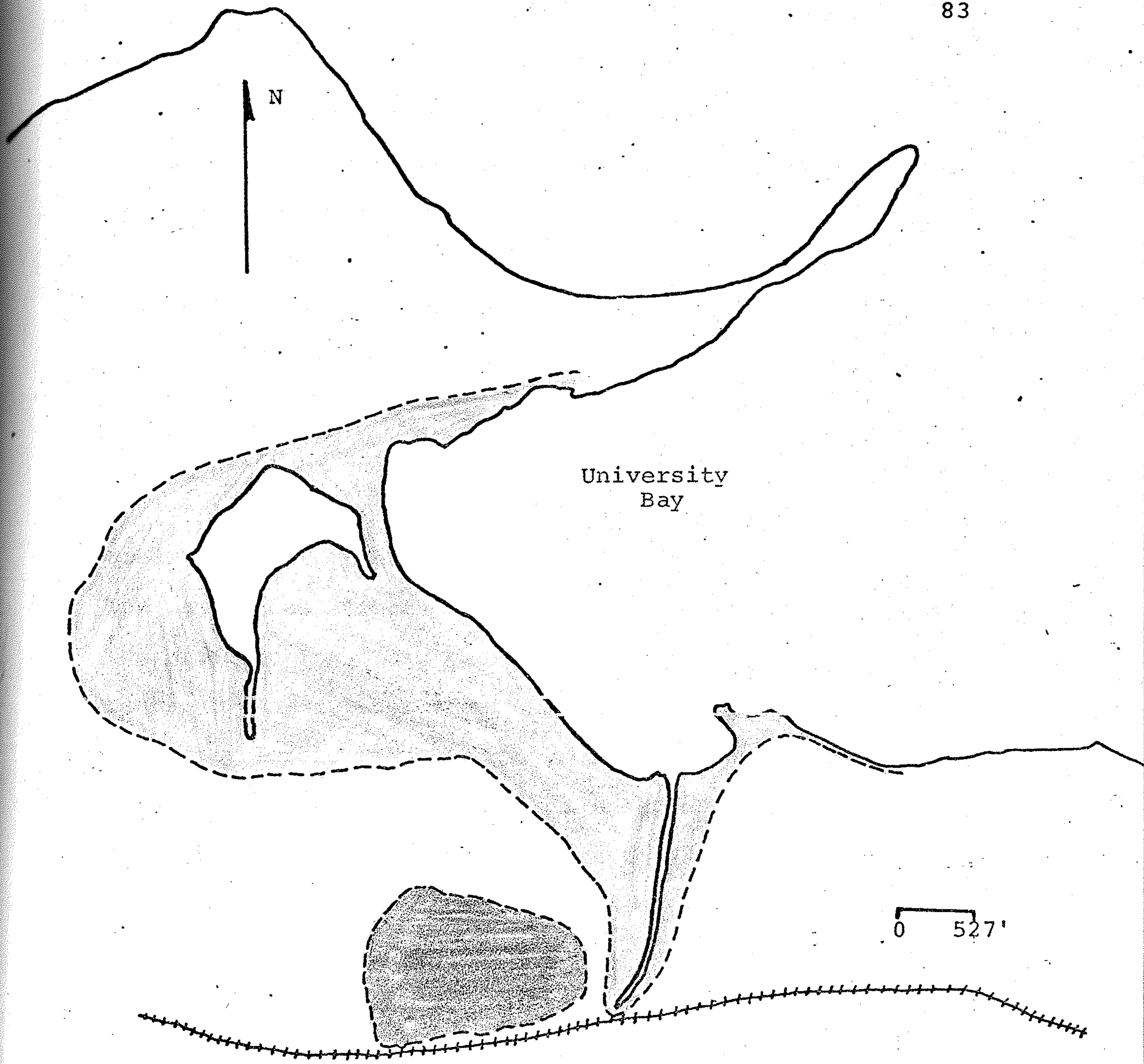

Figure 41. Areas unsuitable for construction
less than 10 feet to bedrock
less than 10 feet to water table

basis of either a high water table, poor soil conditions or bedrock near the surface. In each case construction involving excavation could take place with proper designing; however, the expense of construction may be prohibitively high. Outside of the areas unsuitable for construction, the only remaining open spaces are the fields west and south of the Natatorium, Picnic Point and the field southwest of the Biotron.

It must be noted, however, that each one of these areas does serve a role in the University community. These open areas are being used either for recreation or natural studies. The campus has already utilized much of its open spaces and the aforementioned are the only areas left for outdoor recreation. Any further reduction of these open spaces will seriously impair the outdoor recreational benefits available to the University community. In essence, no further construction can take place on the west end of campus without exceedingly high construction costs or a substantial reduction in recreational benefits.

In the first part of this report six specific goals were enumerated. These goals were accomplished and the results are the following:

1. Soil thicknesses vary from 1 foot to greater than 150 feet. Figure 41 denotes those areas where bedrock is close to the surface.
2. The shallow groundwater flow system shows that most of the Bay recharges the groundwater

system. Picnic Point is the only land area which recharges the Bay. Groundwater does not discharge into Willow Creek. On the contrary, water levels around the Creek seem to indicate that water moves from the Creek into the ground.

3. The water table in the study area varies from 3 to greater than 40 feet below the ground surface. The land occupied by the marsh and playing fields is where the water table is closest to the land surface and as a consequence this area should be avoided where construction will involve the emplacement of deep foundations.

4. Bathymetric and soft sediment isopach maps were constructed for the Bay. These maps delineate the location of the sand bar and the delta. However, sedimentation rates for the delta were not obtained.

5. Water samples were collected from various observation wells. Because of sampling techniques conclusions cannot be drawn with regard to the overall quality of the groundwater in the Bay study area. The affects of road salting were seen in several wells located near roads.

6. It was calculated that approximately 23,000

gallons of water move from the Bay into the ground. Both horizontal and vertical gradients were calculated for various areas around the Bay area. It was seen that Madison municipal water-supply pumpage did influence the water table. Around the medical center construction complex it was discovered that shallow aquifer levels varied approximately two feet with municipal pumpage.

Conclusions

Some of these conclusions are repetitions of points which were made in the discussion section; however, there is a need to repeat them in this section.

University Bay field and laboratory investigations lead to the following conclusions:

1. Picnic Point and Eagle Heights are a recharge area. Activity such as the disposal of wastes either in landfills or seepage pits could affect the groundwater quality in the rest of the Bay. These areas are upgradient and polluted groundwater can move from them to the marsh or Bay.
2. University Bay serves as a recharge source to most of the Bay lands. Feedlots and/or landfills on any land besides Picnic Point will not impact the water quality of the Bay proper

by means of groundwater. However, storm sewer drainage can empty into the Bay and this drainage can contribute nutrients to the Bay and Lake Mendota.

3. The 1918 Marsh experiences "flow-through" conditions. Salting the roads north of the marsh will contribute chlorides to the marsh via groundwater. However, because of the fact that the marsh soils are fine grained and thus of low permeability, the amount of groundwater entering the marsh is very small, about 11 gallons/day.

4. The water table in the marsh area is between five and eight feet below the surface. Because of this fact it is recommended that large structures should not be built in this area. If construction does take place, dewatering pumps will most likely have to be used.

5. Salting the roads in this area does have an impact on the groundwater quality. It was observed that this road salting increases the chloride content of the groundwater. Chlorides are not absorbed by soil particles and as a consequence they do have the ability to travel through the groundwater system.

6. Municipal well pumping does have an effect on

groundwater levels. When the city well number 6 is on, the water levels in the southwest corner of the study area dropped. Knowledge of this hydraulic connection between the shallow and deep aquifers is valuable in building construction and waste disposal. In building construction foundation design must take this knowledge into account in order to prevent flooding if the municipal wells are shut off. This knowledge is also useful to know when locating disposal sites for refuse. Leachate may enter the groundwater system and contaminate the municipal well. If hazardous materials are spilled in the area, say by a rail car derailment, it is imperative to retrieve as much of the material as possible so that it does not get into the groundwater system and eventually pollute the municipal water wells.

7. The University feedlots do not have an impact on the Bay by means of groundwater because the feedlots are down gradient of the Bay. They may have an effect on the Bay due to sheet runoff and eventual discharge to the Bay by either storm sewers or Willow Creek.

Recommendations

At the completion of this study it is suggested that the following additional data be obtained at sometime in the future.

1. Better soil thickness maps should be constructed. There are few boreholes in the Bay area which encountered bedrock. In order to construct these maps more drilling will have to take place.
2. Observation wells will be left and they should be periodically measured for groundwater levels and water quality.
3. When the USGS has compiled its surface water data for Willow Creek, this data should be incorporated with previous studies into a new report.

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MRTSC Trial Form
File Code Soils-12
Rev. 7-1-71

APPENDIX A.

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL SURVEY INTERPRETATIONS

SERIES Kegonsa
STATE Wisconsin
MLRA 91K, 95L

Well drained soils with subsoils of silty clay loam over sandy clay loam underlain by sand and gravel at 26 to 40 inches. These are nearly level to steep soils with moderate permeability in the subsoil and rapid permeability in the substratum. They have medium available water capacity.

ESTIMATED SOIL PROPERTIES SIGNIFICANT TO ENGINEERING

Major Soil Horizons (inches)	Classification			Coarse Fract. >3 in. %	Percentage less than 3 inches Passing Sieve No.--				LL	PI	Permea-bility in./hr.	Avail. Water Capac. in./in.	Soil Reac-tion pH	Shrink Swell Poten-tial
	USDA Texture	Unified	AASHO		4	10	40	200						
0-12	sil	ML	A-4	-	100	95-100	90-100	80-90	15-20	2-4	0.6-2.0	.22-.24	6.1-7.3	Low
12-29	sicl	CL	A-7	-	100	95-100	90-100	85-95	30-40	15-20	0.6-2.0	.18-.20	5.1-5.5	Mod.
29-34	scl	SC	A-6	-	100	85-95	85-95	40-50	25-35	10-15	0.6-2.0	.15-.17	5.1-5.5	Low
34-60	s&g	GP-GM	A-1	-	40-50	30-40	10-15	1-5	NP	NP	6.0-20	.02-.04	7.9-8.4	Low

Flooding: None
Hydrologic group: B
Depth to water table: >5 feet
Depth to bedrock: >5 feet
Corrosivity - uncoated steel: Low
Corrosivity - concrete: Low

SUITABILITY OF SOIL AS SOURCE OF SELECTED MATERIAL AND FEATURES AFFECTING USE

Roadfill	GOOD
Sand	FAIR - high gravel content.
Gravel	FAIR - high sand content.
Topsoil	FAIR - thin layer.

DEGREE AND KIND OF LIMITATIONS

Septic Tank Filter Fields - SLIGHT for 0 to 6% slopes; MODERATE for steeper soils. 1/

Sewage Lagoons
SEVERE - rapidly permeable substratum.

Shallow Excavations- MODERATE - substratum sloughs easily.

Dwellings:
With Basements SLIGHT on 0 to 6% slopes; MODERATE on steeper soils.
Without Basements: SLIGHT on 0 to 6% slopes; MODERATE on steeper soils.

Sanitary Landfill
SEVERE - little amelioration of leachate.

Local Roads and Streets
SLIGHT

Frost Hazard: Moderate - strong capillarity.

MAJOR SOIL FEATURES AFFECTING SELECTED USE

Pond Reservoir Areas - Rapidly permeable substratum; moderately permeable soils.

Embankments, Dikes, and Levees - Pervious; high stability.

Drainage of Cropland and Pasture - Natural drainage adequate.

Irrigation - Medium available water capacity; moderate permeability.

Terraces and Diversions - Moderately deep to sand and gravel.

Grassed Waterways - Moderately deep to sand and gravel.

Golf Course Fairways - Favorable.

1/ Danger of ground water contamination.

Series Kegonsa

DEGREE OF SOIL LIMITATION AND MAJOR FEATURES AFFECTING RECREATION USES

Camp Areas	SLIGHT for 0 to 6%; MODERATE for steeper soils.
Picnic Areas	SLIGHT on 0 to 6% slopes; MODERATE on 6 to 12% slopes; SEVERE on steeper soils.
Playgrounds	SLIGHT for 0 to 2%; MODERATE for 2 to 6%; SEVERE for steeper soils.
Paths and Trails	SLIGHT.

CAPABILITY, SOIL LOSS FACTORS, AND POTENTIAL YIELDS--(High level management)

Phases of Series	Capability	Soil Loss K	Soil Loss T	Corn grain(bu)	Corn silage(T)	Oats (bu)	
0-2%	IIs1	.37	3	95	15	65	
2-6%	IIe2			95	15	65	
6-12%	IIIe2			95	15	65	

PASTURELAND AND HAYLAND

Phases of Series	Group	Species, Yield in AUMs for Dryland (Irrigated) Forage Production
0-12%	Ao1	Alfalfa-brome hay - 3 T/A; bluegrass pasture - 120 AUD.

WILDLIFE HABITAT SUITABILITY

Phases of Series	Potential for -- Grain and Seed Crops	Grasses, Legumes	Wild Herbaceous Plants	Hardwood Trees and Shrubs	Coniferous Plants	Wetland Food and Cover	Shallow Water Devel.	Potential for-- Openland Wildlife	Woodland Wildlife	Wetland Wildlife
0-6%	Good	Good	Good	Good	Good	Very Poor	Very Poor	Good	Good	Very Poor
6-12%	Fair	Good	Good	Good	Good	Very Poor	Very Poor			Very Poor

WOODLAND SUITABILITY

Phases of Series	Ordination	Potential Productivity: Important Trees	Site Index	Woodland Management Hazards: Erosion Hazard	Equipment Limitations	Seeding Mortality	Plant Competition	Suitable Species: To Favor	To Plant	Other
0-12%	2d3	hickory elm white oak red oak	MH	Slight	Slight	Slight	Slight	red oak white oak	red pine white pine	

RANGE

Phases of Series	Range Site Name	Climax Vegetation and Productivity of Air-Dry Herbage (lb./ac.)

WINDBREAK

Group	Adapted Trees to Plant	Tree Height Prediction at 20 Years Age	Relative Vigor

OTHER

APPENDIX A. (Contd.)

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U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL SURVEY INTERPRETATIONS

SERIES Colwood
STATE Wisconsin
MLRA 95 L

Poorly drained soils with silty clay loam or silt loam subsoils underlain at 20 to 40 inches by stratified very fine sand and silt. These are moderately permeable soils with high available water capacity.

ESTIMATED SOIL PROPERTIES SIGNIFICANT TO ENGINEERING

Major Soil Horizons (inches)	Classification			Coarse Fract. >3 in. %	Percentage less than 3 inches Passing Sieve No.--				LL	PI	Permea-bility in./hr.	Avail. Water Capac. in./in.	Soil Reac-tion pH	Shrink Swell Poten-tial
	USDA Texture	Unified	AASHO		4	10	40	200						
0-12	sil	ML	A-4	-	100	100	80-100	85-95	20-30	0-4	0.6-2.0	.22-.24	6.6-7.3	Low
12-18	Hvy. l	CL	A-6	-	100	100	80-100	80-90	30-40	15-20	0.6-2.0	.20-.22	6.6-7.3	Low
18-36	lt.sicl	CL	A-6	-	100	100	80-100	85-95	30-40	15-20	0.6-2.0	.18-.20	7.4-7.8	Moderate
36-60	si-fs vfs	ML-CL	A-4	-	100	100	80-90	75-95	10-20	2-6	0.6-2.0	.11-.13	7.9-8.4	Low

Flooding: Frequent flooding for brief periods.
Hydrologic group: B/D
Depth to water table: Seasonal high water table, 0 to 1 foot
Depth to bedrock: More than 6 feet
Corrosivity - uncoated steel: High
Corrosivity - concrete: Low

SUITABILITY OF SOIL AS SOURCE OF SELECTED MATERIAL AND FEATURES AFFECTING USE

Roadfill	Poor - high frost action; poorly drained.
Sand	Unsuited - stratified very fine sand and silt.
Gravel	Unsuited - little or no gravel.
Topsoil	Poor - seasonal high water table.

DEGREE AND KIND OF SOIL LIMITATION FOR SELECTED USES

Septic Tank Filter Fields	Very severe - seasonal high water table; frequent flooding.
Sewage Lagoons	Severe - seasonal high water table; moderate permeability.
Shallow Excavations	Very severe - seasonal high water table; frequent flooding.
Dwellings: With Basements	Very severe - seasonal high water table; frequent flooding.
Dwellings: Without Basements	Severe - seasonal high water table; frequent flooding.
Sanitary Landfill	Severe - seasonal high water table; frequent flooding.
Local Roads and Streets	Very Severe - frequent flooding; high frost action.
Potential Frost Action	High

MAJOR SOIL FEATURES AFFECTING SELECTED USES

Pond Reservoir Areas	Moderate permeability; seasonal high water table.
Embankments, Dikes, and Levees	Medium shear strength and compressibility; high to medium piping.
Drainage of Cropland and Pasture	Moderate permeability; frequent brief flooding.
Irrigation	Not applicable.
Terraces and Diversions	Not applicable.
Grassed Waterways	Poorly drained; moderately permeable.
Golf Course Fairways	seasonal high water table; poor trafficability.

Series Colwood

DEGREE OF SOIL LIMITATION AND MAJOR FEATURES AFFECTING RECREATION USES

Camp Areas	Severe - poorly drained; frequent flooding.
Picnic Areas	Severe - poorly drained; frequent flooding.
Playgrounds	Severe - poorly drained; frequent flooding.
Paths and Trails	Severe - poorly drained; frequent flooding.

CAPABILITY, SOIL LOSS FACTORS, AND POTENTIAL YIELDS--(High level management)

Phases of Series	Capability	Soil Loss K	Soil Loss T	Corn grain (bu)	Corn silage (T)	Oats (bu)	
0-2%	IIw1	-	-	100	15	60	

PASTURELAND AND HAYLAND

Phases of Series	Group	Species, Yield in AUMs for Dryland (Irrigated) Forage Production
0-2%	Bw3	Alfalfa-brome hay - 4.0 T/A; pasture (bluegrass) - 145 AUD

WILDLIFE HABITAT SUITABILITY

Phases of Series	Potential for-- Grain and Seed Crops	Grasses, Legumes	Wild Herbaceous Plants	Hardwood Trees and Shrubs	Coniferous Plants	Wetland Food and Cover	Shallow Water Devel.	Potential for-- Openland Wildlife	Woodland Wildlife	Wetland Wildlife
0-2%	Poor undrained Fair drained	Fair undrained Good drained	Fair	Fair	Fair	Good	Good	Fair	Fair	Good

WOODLAND SUITABILITY

Phases of Series	Ordination	Potential Productivity: Important Trees	Site Index	Woodland Management Hazards: Erosion Hazard	Equipment Limitations	Seeding Mortality	Plant Competition	Suitable Species: To Favor	To Plant	Other
0-2%	1w5	silver maple red maple white ash red oak	red maple 75+	Slight	Slight	Moderate	Moderate	silver maple white ash	soft maple cottonwood wh. ash	

RANGE

Phases of Series	Range Site Name	Climax Vegetation and Productivity of Air-Dry Herbage (lb./ac.)

WINDBREAK

Group	Adapted Trees to Plant	Tree Height Prediction at 20 Years Age	Relative Vigor

OTHER

Appendix A. (Contd.) #01 #04

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U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL SURVEY INTERPRETATIONS 1/

SERIES Houghton
STATE Wisconsin
MLRA 91, 95, 105

Deep, very poorly drained organic soil in wet depressions and bottomlands, and along rivers and streams. These soils have moderately rapid permeability and very high available water capacity.

ESTIMATED SOIL PROPERTIES SIGNIFICANT TO ENGINEERING

Major Soil Horizons (inches)	Classification			Coarse Fract. >3 in. %	Percentage less than 3 inches Passing Sieve No.--				LL	PI	Permeability in./hr.	Avail. Water Capac. in./in.	Soil Reaction pH	Shrink Swell Potential
	USDA Texture	Unified	AASHO		4	10	40	200						
0-60	muck	Pt	-	-	-	-	-	-	-	-	2.0-6.0	.25-.35	6.0-7.0	Low

Flooding Frequent flooding for very long periods. Hydrologic group: A/D

Depth to water table: Seasonal high water table, 0 to 1 foot. Depth to bedrock: More than 6 feet

Corrosivity - uncoated steel: High. Corrosivity - concrete: Low

SUITABILITY OF SOIL AS SOURCE OF SELECTED MATERIAL AND FEATURES AFFECTING USE

Roadfill	Very poor - seasonal high water table; high compressibility; unstable.
Sand	Unsuitable - no sand present.
Gravel	Unsuitable - no gravel present.
Topsoil	Poor - organic material oxidizes rapidly; erosive.

DEGREE AND KIND OF SOIL LIMITATION FOR SELECTED USES

Septic Tank Filter Fields	Very severe - seasonal high water table; organic material.
Sewage Lagoons	Very severe - seasonal high water table; organic material.
Shallow Excavations	Very severe - seasonal high water table; frequent flooding.
Dwellings: With Basements / Without Basements	Very severe - seasonal high water table; frequent flooding; low strength.
Sanitary Landfill	Very severe - seasonal high water table; frequent flooding.
Local Roads and Streets	Very severe - seasonal high water table; frequent flooding; low strength.
Potential Frost Action	Moderate - wet soil.

MAJOR SOIL FEATURES AFFECTING SELECTED USES

Pond Reservoir Areas	Seasonal high water table; moderately rapid permeability; nearly level.
Embankments, Dikes, and Levees	Low shear strength; high compressibility.
Drainage of Cropland and Pasture	Moderately rapid permeability; organic muck.
Irrigation	Not applicable.
Terraces and Diversions	Not applicable.
Grassed Waterways	Very poorly drained; nearly level.
Golf Course Fairways:	Seasonal high water table; high compressibility; poor trafficability.

1/ Use in conjunction with Guide to Soil Survey Interpretation Sheets.

Series Houghton

Appendix A. (Contd.)

DEGREE OF SOIL LIMITATION AND MAJOR FEATURES AFFECTING RECREATION USES

Camp Areas	Very severe - very poorly drained; frequent flooding.
Picnic Areas	Very severe - very poorly drained; frequent flooding.
Playgrounds	Very severe - very poorly drained; frequent flooding.
Paths and Trails	Very severe - very poorly drained; frequent flooding.

CAPABILITY, SOIL LOSS FACTORS, AND POTENTIAL YIELDS--(High level management)

Phases of Series	Capability	Soil Loss K	Soil Loss T	Corn grain (bu)	Corn silage (T)	Oats (bu)	
0-2%	IIIw9	-	-	120	20	60	

PASTURELAND AND HAYLAND 2/

Phases of Series	Group	Species, Yield in AUMs for Dryland (Irrigated) Forage Production
0-2%	Bw6	

WILDLIFE HABITAT SUITABILITY

Phases of Series	Potential for--							Potential for--		
	Grain and Seed Crops	Grasses, Legumes	Wild Herbaceous Plants	Hardwood Trees and Shrubs	Coniferous Plants	Wetland Food and Cover	Shallow Water Devel.	Openland Wildlife	Woodland Wildlife	Wetland Wildlife
0-2%	V. poor undrained Fair drained	Poor undrained Fair - drained	Poor	Poor	Poor	Good	Good	Poor	Poor	Good

WOODLAND SUITABILITY

Phases of Series	Ordination	Potential Productivity		Woodland Management Hazards				Suitable Species		Other
		Important Trees	Site Index	Erosion Hazard	Equipment Limitations	Seeding Mortality	Plant Competition	To Favor	To Plant	
0-2%	5w6	northern wh. cedar tamarack	northern wh. cedar 30-36	Slight	Severe	Severe	Severe	northern wh. cedar tamarack	Not suitable for planting	

RANGE

Phases of Series	Range Site Name	Climax Vegetation and Productivity of Air-Dry Herbage (lb./ac.)

WINDBREAK

Group	Adapted Trees to Plant	Tree Height Prediction at 20 Years Age	Relative Vigor

OTHER

2/ Use of this soil for hay or pasture will result in severe damage to the soil because of low bearing capacity and stability.

USDA-SCS-LINCOLN, NEBR. 1974

Appendix A.
(Contd.)

#766

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL SURVEY INTERPRETATIONS 1/

SERIES Batavia silt loam, gravelly substratum
STATE Wisconsin
MLRA L 95

Well drained silty soils over 40 inches thick, developed in 36 to 50 inches silt over stratified sand and gravel. These are nearly level to sloping, moderately permeable soils with high available water capacity.

ESTIMATED SOIL PROPERTIES SIGNIFICANT TO ENGINEERING

Major Soil Horizons (inches)	Classification			Coarse Fract. >3 in. %	Percentage less than 3 inches Passing Sieve No.--				LL	PI	Permea-bility in./hr.	Avail. Water Capac. in./in.	Soil Reac-tion pH	Shrink Swell Poten-tial
	USDA Texture	Unified	AASHO		4	10	40	200						
0-10	Sil	ML	A-4	-	100	95-100	90-100	85-95	20-30	1-5	0.6-2.0	.22-.24	6.6-7.3	Low
10-44	Sicl	CL	A-7	-	100	95-100	90-100	85-95	40-50	20-30	0.6-2.0	.18-.20	5.6-6.0	Mod.
44-50	Cl	CL	A-6	0-1	90-100	80-90	70-80	60-70	25-35	10-20	0.6-2.0	.15-.19	6.1-7.8	Mod.
50-60	S&G	GP-GW	A-1	1-5	40-50	30-40	15-25	1-5	-	NP	6.0-20.	.02-.04	8.4	Very Low

Flooding: None

Hydrologic group: B

Depth to water table: (seasonal) 3 to 5 ft. or more

Depth to bedrock: 10 ft. or more

Corrosivity - uncoated steel: Low

Corrosivity - concrete: Low

SUITABILITY OF SOIL AS SOURCE OF SELECTED MATERIAL AND FEATURES AFFECTING USE

Roadfill	Subsoil - POOR: moderate shrink-swell potential & low bearing value; unstable when wet.
Sand	FAIR - substratum is poorly graded sand; thick overburden.
Gravel	FAIR - substratum is poorly graded gravel; thick overburden.
Topsoil	Fair - thin layer.

DEGREE AND KIND OF SOIL LIMITATION FOR SELECTED USES

Septic Tank Filter Fields	MODERATE on 0 to 6%; SEVERE on steeper slopes; silty material shortens life of filter fields.
Sewage Lagoons	SEVERE - substratum has rapid permeability.
Shallow Excavations	SLIGHT - 0 - 6%; MODERATE 6 - 12%
Dwellings: With Basements / Without Basements	SLIGHT - 0 - 6%; MODERATE 6 - 12%
Sanitary Landfill	SLIGHT
Local Roads and Streets	SEVERE - high potential frost action - low bearing value
Potential Frost Action	MODERATE - strong capillary action.

MAJOR SOIL FEATURES AFFECTING SELECTED USES

Pond Reservoir Areas	Moderate permeability through subsoil; rapid permeability in sand and gravel substratum.
Embankments, Dikes, and Levees	Subsoil-fair to good stability and compaction characteristics; semi-pervious. Substratum-fair stability & fair to good compaction characteristics; very pervious.
Drainage of Cropland and Pasture	Well and moderately well drained; artificial drainage not needed.
Irrigation	High available water capacity; moderate water intake rate.
Terraces and Diversions	Moderate permeability.
Grassed Waterways	Moderate permeability.
Golf Course Fairways	Erosive on slopes. Moderate permeability.

1/ Use in conjunction with Guide to Soil Survey Interpretation Sheets.

Batavia silt loam, gravelly substratum

Appendix A. (Contd.)

DEGREE OF SOIL LIMITATION AND MAJOR FEATURES AFFECTING RECREATION USES

Camp Areas	MODERATE - sites remain wet and soft for short periods; surface compacts easily.
Picnic Areas	SLIGHT on 0 to 6%; MODERATE on 6 to 12%; SEVERE on steeper slopes; erosive on slopes; compacts easily when wet.
Playgrounds	MODERATE on 0 to 6%; SEVERE on steeper slopes; erosive on slopes; compacts easily when wet.
Paths and Trails	MODERATE - erosive on slopes; muddy and slippery when wet.

CAPABILITY, SOIL LOSS FACTORS, AND POTENTIAL YIELDS--(High level management)

Phases of Series	Capability	Soil Loss K	Soil Loss T	Corn Grain (bu)	Corn Silage (T)	Oats (bu)	
0 - 2%	I-3	.32	3	140	18	80	
2 - 6%	IIe-1	.32	3	130	16	80	
6 -12%	IIIe-1	.32	3	120	14	70	

PASTURELAND AND HAYLAND

Phases of Series	Group	Species, Yield in AUMs for Dryland (Irrigated) Forage Production
0 - 2%	Ao1	Alfalfa - brome (hay) 6.5 T/A; pasture (bluegrass) 160 AUD.
2 - 6%		" 5.5 T/A; " 140 AUD.
6 -12%		" 5.0 T/A; " 120 AUD.

WILDLIFE HABITAT SUITABILITY

Phases of Series	Potential for-- Grain and Seed Crops	Grasses, Legumes	Wild Herbaceous Plants	Hardwood Trees and Shrubs	Coniferous Plants	Wetland Food and Cover	Shallow Water Devel.	Potential for-- Openland Wildlife	Woodland Wildlife	Wetland Wildlife
0-12%	Good	Good	Good	Good	Good	Poor	V. Poor	Good	Good	V. Poor

WOODLAND SUITABILITY

Phases of Series	Ordination	Potential Productivity: Important Trees	Site Index	Woodland Management Hazards: Erosion Hazard	Equipment Limitations	Seeding Mortality	Plant Competition	Suitable Species: To Favor	To Plant	Other
0 - 2% 2 - 6% 6 -12%	2o1	Red oak Sugar maple Wh. ash Cherry	MH	Slight	Slight	Slight	Moderate	Redoak Sugar Maple	Red pine Wh. pine Wh.spruce	

RANGE

Phases of Series	Range Site Name	Climax Vegetation and Productivity of Air-Dry Herbage (lb./ac.)

WINDBREAK

Group	Adapted Trees to Plant	Tree Height Prediction at 20 Years Age	Relative Vigor

OTHER

#758

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

#758

SOIL SURVEY INTERPRETATIONS [1]

SERIES Arland
STATE Wisconsin
MLRA 90 K

Well drained, gently sloping to moderately steep, loamy soils of glacial deposits underlain by sandstone residuum at 20 to 40 inches. There are moderately permeable soils with medium available water capacity.

ESTIMATED SOIL PROPERTIES SIGNIFICANT TO ENGINEERING

Major Soil Horizons (inches)	Classification: USDA Texture	Classification: Unified	Classification: AASHO	Coarse Fract. >3 in. %	Percentage less than 3 inches Passing Sieve No.-- 4	10	40	200	LL	PI	Permeability in./hr.	Avail. Water Capac. in./in.	Soil Reaction pH	Shrink Swell Potential
0-10	sl	ML	A-4	-	90-100	80-90	60-70	30-40	10-20	1-4	2.0-6.0	.13-.15	5.6-6.0	Low
10-29	h. scl	CL CL-ML	A-4,A-6	-	90-100	70-80	80-90	35-45	20-30	5-15	0.6-2.0	.15-.19	5.1-6.0	Low
24-37	ls	SM	A-2	-	90-100	70-80	60-70	15-25	5-10	NP	2.0-6.0	.09-.11	5.1-5.5	Low
37-60	weakly cemented sandstone bedrock					-	-	-	-	-	-	-	-	-

Flooding : None

Hydrologic group: B

Depth to water table: More than 6 ft.

Depth to bedrock: More than 6 ft.

Corrosivity - uncoated steel: Low

Corrosivity - concrete: Moderate

SUITABILITY OF SOIL AS SOURCE OF SELECTED MATERIAL AND FEATURES AFFECTING USE

Roadfill	Good.
Sand	Good.
Gravel	Poor - sandy.
Topsoil	Fair - 10 inches sandy loam surface.

DEGREE AND KIND OF SOIL LIMITATION FOR SELECTED USES

Septic Tank Filter Fields:	Moderate for 2 to 12% slopes, weakly cemented sandstone bedrock less than 40 inches; severe for steeper soils.
Sewage Lagoons:	Moderate for 2 to 12% slopes, weakly cemented sandstone bedrock less than 40 inches; severe for steeper soils.
Shallow Excavations:	Moderate for 2 to 12% slopes, weakly sandstone bedrock less than 40 inches; severe for steeper soils.
Dwellings: With Basements -	Moderate for 2 to 12% slopes, weakly cemented sandstone bedrock less than 40 inches; severe for steeper soils.
Without Basements -	Slight for 2 to 6% slopes, weakly cemented sandstone bedrock at less than 40 inches; moderate for 6 to 12% slopes; severe for steeper soils.
Sanitary Landfill:	Moderate for 2 to 20% slopes,less than 40 inches to weakly cemented sandstone bedrock; severe for steeper soils.
Local Roads and Streets:	Slight for 2 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Potential Frost Action:	Low

MAJOR SOIL FEATURES AFFECTING SELECTED USES

Pond Reservoir Areas:	Well drained; moderate permeability.
Embankments, Dikes, and Levees:	Medium to low shear strength and compressibility; moderate permeability.
Drainage of Cropland and Pasture:	Well drained; moderate permeability; loamy soil.
Irrigation:	Well drained, medium available water capacity; less than 40 inches to sandstone bedrock.
Terraces and Diversions:	Less than 40 inches to sandstone bedrock; loamy sil; moderate permeability.
Grassed Waterways:	Loamy soil 20 to 40 inches over sandstone bedrock; well drained.
Golf Course Fairways:	Well drained, moderate permeability; loamy soil; some soils too steep.

1/ Use in conjunction with Guide to Soil Survey Interpretation Sheets.

Appendix A. (Contd.)

Arland

DEGREE OF SOIL LIMITATION AND MAJOR FEATURES AFFECTING RECREATION USES

Camp Areas	Slight for 2 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Picnic Areas	Slight for 2 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Playgrounds	Moderate for 2 to 6% slopes; severe for steeper soils.
Paths and Trails	Slight for 2 to 12% slopes; moderate for steeper soils.

CAPABILITY, SOIL LOSS FACTORS, AND POTENTIAL YIELDS--(High level management)

Phases of Series	Capability	Soil Loss K	Soil Loss T	Corn Grain(bu)	Corn Silage(T)	Oats (bu)	
2-6%	IIe2	.32	3	80	13	65	
6-12%	IIIe2			75	12	60	
12-20%	IVe2			70	11	50	

PASTURELAND AND HAYLAND

Phases of Series	Group	Species, Yield in AUMs for Dryland (Irrigated) Forage Production
2-6%	Aol	Alfalfa-brome (hay) 3.5T/A;-pasture (bluegrass)- 90 AUD.
6-12%	Aol	Alfalfa-brome (hay) 3.0T/A;-pasture (bluegrass)- 80 AUD.
12-20%	Aol	Alfalfa-brome (hay) 2.5T/A;-pasture (bluegrass)- 70 AUD.

WILDLIFE HABITAT SUITABILITY

Phases of Series	Potential for-- Grain and Seed Crops	Grasses, Legumes	Wild Herbaceous Plants	Hardwood Trees and Shrubs	Coniferous Plants	Wetland Food and Cover	Shallow Water Devel.	Potential for-- Openland Wildlife	Woodland Wildlife	Wetland Wildlife
2-6%	Good	Good	Good	Good	Good	Poor	V. Poor	Good	Good	V. Poor
6-12%	Fair	Fair	Good	Good	Good	V. Poor	V. Poor	Fair	Good	V. Poor
12-20%	Poor	Fair	Good	Good	Good	V.Poor	V. Poor	Fair	Good	V. Poor

WOODLAND SUITABILITY

Phases of Series	Ordination	Potential Productivity: Important Trees	Site Index	Woodland Management Hazards: Erosion Hazard	Equipment Limitations	Seeding Mortality	Plant Competition	Suitable Species: To Favor	To Plant	Other
2-12%	2d1	sugar maple, red oak, bass-wood, white pine	MH	Slight	Slight	Slight	Slight	sugar maple, red oak, white pine	red pine white pine	
12-20%	2d2	red pine		Moderate	Moderate	Slight on N&E slopes. Mod. on S&W slopes.		red pine		

RANGE

Phases of Series	Range Site Name	Climax Vegetation and Productivity of Air-Dry Herbage (lb./ac.)

WINDBREAK

Group	Adapted Trees to Plant	Tree Height Prediction at 20 Years Age	Relative Vigor

OTHER

USDA-SCS-LINCOLN, NEBR. 1974

Appendix A. (Contd.)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL SURVEY INTERPRETATIONS

SERIES Kidder
STATE Wisconsin
MLRA L-95

Loamy soil, 20 to 40 inches thick, over calcareous sandy loam till. These are well drained, gently sloping to steep, moderately permeable soils with medium available water capacity.

ESTIMATED SOIL PROPERTIES SIGNIFICANT TO ENGINEERING

Major Soil Horizons (inches)	Classification			Coarse Fract. >3 in. %	Percentage less than 3 inches Passing Sieve No.--				LL	PI	Permea-bility in./hr.	Avail. Water Capac. in./in.	Soil Reaction pH	Shrink Swell Potential
	USDA Texture	Unified	AASHO		4	10	40	200						
0-11	l	CL-ML,CL	A-4	-	95-100	85-95	75-85	55-65	20-30	5-10	0.6-2.0	.16-.20	6.6-7.3	Low
11-28	scl	SC	A-6	-	95-100	90-100	65-75	35-45	25-35	10-15	0.6 2.0	.14-.18	6.6-7.3	Mod.
28-60	sl	SM,SM-SC	A-2,A-4	10	85-95	80-90	60-70	30-40	10-20	2-6	2.0-6.0	.08-.12	7.4-8.4	Low

Flooding: None
Hydrologic group: B
Depth to water table: >5 feet
Depth to bedrock: >5 feet
Corrosivity - uncoated steel: Low
Corrosivity - concrete: Low

SUITABILITY OF SOIL AS SOURCE OF SELECTED MATERIAL AND FEATURES AFFECTING USE

Roadfill	Subsoil - fair; moderate shrink-swell potential, stability and bearing value. Substratum - good; moderately stable.
Sand	Poor - pockets of poorly graded sand in substratum in some places.
Gravel	Poor - pockets of poorly graded gravel in substratum in some places.
Topsoil	Surface - good; thin. Subsoil - fair; sand; stony in places.

DEGREE AND KIND OF LIMITATIONS

Septic Tank Filter Fields - Slight on 0 to 6% slopes; moderate on 6 to 12% slopes; severe on steeper soils.

Sewage Lagoons - Severe - substratum is moderately rapidly permeable; stony in places.

Shallow Excavations Slight for 0 to 6% slopes; moderate for 6 to 20% slopes; severe for steeper soils.

Dwellings:
With Basements
Without Basements } Slight for 0 to 6% slopes; moderate for 6 to 20% slopes; severe for steeper soils.

Sanitary Landfill Slight on 0 to 6% slopes; moderate on 6 to 12% slopes; severe on steeper soils.

Local Roads and Streets Slight for 0 to 6% slopes; moderate for 6 to 20% slopes; severe for steeper soils.

Potential Frost Action: Low

MAJOR SOIL FEATURES AFFECTING SELECTED USE

Pond Reservoir Areas Moderate permeability through subsoil; moderately rapid permeability in substratum.

Embankments, Dikes, and Levees - Subsoil - fair stability and compaction; semipervious. Substratum - fair stability and compaction; pervious; piping hazard.

Drainage of Cropland and Pasture - Drainage is adequate.

Irrigation Medium available water capacity; deep soil; moderate water intake rate; sloping.

Terraces and Diversions Sandy loam substratum.

Grassed Waterways - Sandy loam usbstratum.

Golf Course Fairways - Favorable up to 12% slopes: other soils too steep.

DEGREE OF SOIL LIMITATION AND MAJOR FEATURES AFFECTING RECREATION USES

Camp Areas	Slight on 0 to 6% slopes; moderate on 6 to 12% slopes; severe on steeper soils; erosive on slopes; stony in places.
Picnic Areas	Slight on 0 to 6% slopes; moderate on 6 to 12% slopes; severe on steeper soils; slightly drouthy; erosive on slopes; stony in places.
Playgrounds	Moderate on 2 to 6% slopes; severe on steeper soils; erosive on slopes; slightly drouthy; may be erosive.
Paths and Trails	Slight on 0 to 12% slopes; moderate on 12 to 20% slopes; severe on steeper soils; erosive on slopes; stony in places.

CAPABILITY, SOIL LOSS FACTORS, AND POTENTIAL YIELDS--(High level management) 1/

Phases of Series	Capability	Soil Loss K	Soil Loss T	Corn grain(bu)	Corn silage(T)	Oats (bu)	
A 0-2%	IIsl	.32	3	100	13	70	
B 2-6%	IIel			100	13	70	
C 6-12%	IIIel			85	11	65	
D 12-20%	IVel			75	9	60	
E 20-30%	VIel			-	-	-	

PASTURELAND AND HAYLAND

Phases of Series	Group	Species, Yield in AUMs for Dryland (Irrigated) Forage Production
A,B,C 0-12%	Aol	Alfalfa-brome hay - 4 T/A; pasture (bluegrass) - 150 AUD
D 12-20%	Aol	Alfalfa-brome hay - 3 T/A; pasture (bluegrass) - 120 AUD
E 20-30%	Arl	Alfalfa-brome hay - 2.5 T/A; pasture (bluegrass - 100 AUD

WILDLIFE HABITAT SUITABILITY

Phases of Series	Potential for--							Potential for--		
	Grain and Seed Crops	Grasses, Legumes	Wild Herbaceous Plants	Hardwood Trees and Shrubs	Coniferous Plants	Wetland Food and Cover	Shallow Water Devel.	Openland Wildlife	Woodland Wildlife	Wetland Wildlife
A,B 0-6%	Good	Good	Good	Good	Good	V. poor	V. poor	Good	Good	V. poor
C 6-12%	Fair	Good								
D 12-20%	Poor	Fair								
E 20-30%	V. poor	Poor								

WOODLAND SUITABILITY

Phases of Series	Ordination	Potential Productivity		Woodland Management Hazards				Suitable Species		Other
		Important Trees	Site Index	Erosion Hazard	Equipment Limitations	Seeding Mortality	Plant Competition	To Favor	To Plant	
A,B,C 0-12%	3o1	red oak bl. oak	M	Slight	Slight	Slight	Slight	red oak wh. ash	wh. pine red pine	
D,E 12-30%		wh. ash wh. oak hickory		Moderate	Moderate	Mod. S&W Sl. N&E	Slight			

RANGE

Phases of Series	Range Site Name	Climax Vegetation and Productivity of Air-Dry Herbage (lb./ac.)

WINDBREAK

Group	Adapted Trees to Plant	Tree Height Prediction at 20 Years Age	Relative Vigor

OTHER

USDA-SCS-LINCOLN, NEBR. 1974

1/ Yields of fine sandy loam are lower than those given

Appendix A. (Contd.)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL SURVEY INTERPRETATIONS 1/

SERIES McHenry
STATE Wisconsin
MLRA 95

Well drained, nearly level to moderately steep soil, 30 to 40 inches thick, over calcareous sandy loam glacial till. The surface 15 to 30 inches is silty. These soils are moderately permeable and have high available water capacity.

ESTIMATED SOIL PROPERTIES SIGNIFICANT TO ENGINEERING

Major Soil Horizons (inches)	Classification			Coarse Fract. >3 in. %	Percentage less than 3 inches Passing Sieve No.--				LL	PI	Permeability in./hr.	Avail. Water Capac. in./in.	Soil Reaction pH	Shrink Swell Potential
	USDA Texture	Unified	AASHO		4	10	40	200						
0-13	sil	ML	A-4	-	100	100	85-95	70-80	25-35	1-4	0.6-2.0	.22-.24	6.6-7.3	Low
13-30	cl	CL	A-6	-	100	95-100	90-100	75-85	30-40	15-25	0.6-2.0	.16-.18	5.1-5.5	Moderate
30-60	sl	SM	A-2	1-5	80-90	70-80	60-70	25-35	10-20	1-4	0.6-2.0	.11-.13	7.9-8.4	Low

Flooding None

Hydrologic group: B

Depth to water table: More than 5 feet

Depth to bedrock: More than 5 feet

Corrosivity - uncoated steel: Low

Corrosivity - concrete: Low

SUITABILITY OF SOIL AS SOURCE OF SELECTED MATERIAL AND FEATURES AFFECTING USE

Roadfill	Good
Sand	Poor - pockets of poorly graded sand and gravel in substratum.
Gravel	Poor - pockets of poorly graded sand and gravel in substratum.
Topsoil	Fair - thin.

DEGREE AND KIND OF SOIL LIMITATION FOR SELECTED USES

Septic Tank Filter Fields	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Sewage Lagoons	Moderate - moderately permeable substratum.
Shallow Excavations	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Dwellings: With Basements) Without Basements)	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Sanitary Landfill	Slight for 0 to 12% slopes; severe for steeper soils.
Local Roads and Streets	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Potential Frost Action	Low

MAJOR SOIL FEATURES AFFECTING SELECTED USES

Pond Reservoir Areas	Moderate permeability; well drained.
Embankments, Dikes, and Levees	Medium to low shear strength, compressibility, and compacted permeability; substratum - fair to good compaction.
Drainage of Cropland and Pasture	Drainage adequate.
Irrigation	High available water capacity; moderate permeability.
Terraces and Diversions	Nearly level to moderately steep; loamy; moderate permeability.
Grassed Waterways	Loamy; high available water capacity.
Golf Course Fairways:	Moderate permeability; silt loam surface; nearly level to steep soils.

1/ Use in conjunction with Guide to Soil Survey Interpretation Sheets.

DEGREE OF SOIL LIMITATION AND MAJOR FEATURES AFFECTING RECREATION USES

Camp Areas	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Picnic Areas	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Playgrounds	Slight for 0 to 2% slopes; moderate for 2 to 6% slopes; severe for steeper soils.
Paths and Trails	Slight for 0 to 12% slopes; moderate for steeper soils.

CAPABILITY, SOIL LOSS FACTORS, AND POTENTIAL YIELDS--(High level management)

Phases of Series	Capability	Soil Loss K	Soil Loss T	Corn grain (bu)	Corn silage (T)	Oats (bu)	
0-2%	I-4	.37	4	105	18	75	
2-6%	IIe1			100	17	70	
6-12%	IIIe1			90	15	70	
12-20%	IVe1			80	13	65	

PASTURELAND AND HAYLAND

Phases of Series	Group	Species, Yield in AUMs for Dryland (Irrigated) Forage Production
0-6%	Ao1	Alfalfa-brome hay - 4.5 T/A; bluegrass pasture - 150 AUD.
6-12%	Ao1	Alfalfa-brome hay - 4.0 T/A; bluegrass pasture - 130 AUD.
12-20%	Ao1	Alfalfa-brome hay - 3.5 T/A; bluegrass pasture - 120 AUD.

WILDLIFE HABITAT SUITABILITY

Phases of Series	Potential for-- Grain and Seed Crops	Grasses, Legumes	Wild Herbaceous Plants	Hardwood Trees and Shrubs	Coniferous Plants	Wetland Food and Cover	Shallow Water Devel.	Potential for-- Openland Wildlife	Woodland Wildlife	Wetland Wildlife
0-6%	Good	Good	Good	Good	Good	V. poor	V. poor	Good	Good	V. poor
6-12%	Fair	Good	Good	Good	Good	V. poor	V. poor	Good	Good	V. poor
12-20%	Poor	Fair	Good	Good	Good	V. poor	V. poor	Fair	Good	V. poor

WOODLAND SUITABILITY

Phases of Series	Ordination	Potential Productivity: Important Trees	Site Index	Woodland Management Hazards: Erosion Hazard	Equipment Limitations	Seeding Mortality	Plant Competition	Suitable Species: To Favor	To Plant	Other
0-6%	2o1	red oak	68	Slight	Slight	Slight	Moderate for	red oak	r. pine	
6-12%	2o1	white oak		Slight	Slight	Slight	hardwoods	wh. ash	wh. pine	
12-20%	2r1	bl. cherry		Moderate	Moderate	Sl. N&E	Severe for	bl.cherry	wh.spruce	
		hickory				Mod. S&W	conifers			

RANGE

Phases of Series	Range Site Name	Climax Vegetation and Productivity of Air-Dry Herbage (lb./ac.)

WINDBREAK

Group	Adapted Trees to Plant	Tree Height Prediction at 20 Years Age	Relative Vigor

OTHER

Appendix A. (Contd.)

#354

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL SURVEY INTERPRETATIONS

SERIES Nippersink
STATE Wisconsin
MLRA 95 L

106

Well drained, nearly level to sloping soils underlain at 30 to 40 inches by calcareous sandy loam till. These are medium and moderately fine textured soils with medium available water capacity and moderate permeability.

ESTIMATED SOIL PROPERTIES SIGNIFICANT TO ENGINEERING

Major Soil Horizons (inches)	Classification			Coarse Fract. >3 in. %	Percentage less than 3 inches Passing Sieve No.--				LL	PI	Permea-bility in./hr.	Avail. Water Capac. in./in.	Soil Reac-tion pH	Shrink Swell Poten-tial
	USDA Texture	Unified	AASHO		4	10	40	200						
0-10	sil	ML	A-4	-	90-100	90-100	90-100	85-95	30-40	6-10	0.6-2.0	.22-.24	6.1-6.5	Low
10-34	cl	CL	A-6	-	90-100	90-100	90-100	85-95	30-40	13-22	0.6-2.0	.18-.20	6.1-6.5	Moderate
34-60	sl	SM-SC	A-2	1-5	80-90	70-80	60-70	25-35	10-19	2-6	2.0-6.0	.11-.13	7.9-8.4	Low

Flooding None

Hydrologic group: B

Depth to water table: More than 6 ft.

Depth to bedrock: More than 6 feet

Corrosivity - uncoated steel: Low

Corrosivity - concrete: Low

SUITABILITY OF SOIL AS SOURCE OF SELECTED MATERIAL AND FEATURES AFFECTING USE

Roadfill	Good
Sand	Poor - pockets of poorly graded sand in substratum.
Gravel	Poor - pockets of gravel in substratum.
Topsoil	Fair - thin surface layer.

DEGREE AND KIND OF SOIL LIMITATION FOR SELECTED USES

Septic Tank Filter Fields	Slight for 0 to 6% slopes; moderate on steeper soils.
Sewage Lagoons	Severe - moderately rapid permeability in substratum.
Shallow Excavations	Slight for 0 to 6% slopes; moderate for steeper soils.
Dwellings: With Basements) Without Basements)	Slight for 0 to 6% slopes; moderate for steeper soils.
Sanitary Landfill	Slight
Local Roads and Streets	Slight for 0 to 6% slopes; moderate for steeper soils.
Potential Frost Action	Low

MAJOR SOIL FEATURES AFFECTING SELECTED USES

Pond Reservoir Areas	Moderately rapid permeability in substratum.
Embankments, Dikes, and Levees	Medium to low shear strength and compressibility.
Drainage of Cropland and Pasture	Not applicable.
Irrigation	Medium available water capacity; moderate permeability.
Terraces and Diversions	Moderate permeability.
Grassed Waterways	Well drained; medium available water capacity.
Golf Course Fairways - Well drained; moderately permeable.	

SERIES Nippersink

Appendix A. (Contd.)

DEGREE OF SOIL LIMITATION AND MAJOR FEATURES AFFECTING RECREATION USES

Camp Areas	Slight for 0 to 6% slopes; moderate for steeper soils.
Picnic Areas	Slight for 0 to 6% slopes; moderate for steeper soils.
Playgrounds	Slight for 0 to 2% slopes; moderate for 2 to 6% slopes; severe for steeper soils.
Paths and Trails	Slight.

CAPABILITY, SOIL LOSS FACTORS, AND POTENTIAL YIELDS--(High level management)

Phases of Series	Capability	Soil Loss K	Soil Loss T	Corn grain (b)	Corn silage (T)	Oats (bu)	
0-2%	I-4	.32	4	105	18	75	
2-6%	IIe1			100	17	70	
6-12%	IIIe1			90	15	65	

PASTURELAND AND HAYLAND

Phases of Series	Group	Species, Yield in AUMs for Dryland (Irrigated) Forage Production
0-6%	Ao1	Alfalfa-brome hay - 4.5 T/A; pasture (bluegrss) - 150 AUD.
6-12%	Ao1	Alfalfa-brome hay - 4.0 T/A; pasture (bluegrass) - 120 AUD.

WILDLIFE HABITAT SUITABILITY

Phases of Series	Potential for--							Potential for--		
	Grain and Seed Crops	Grasses, Legumes	Wild Herbaceous Plants	Hardwood Trees and Shrubs	Coniferous Plants	Wetland Food and Cover	Shallow Water Devel.	Openland Wildlife	Woodland Wildlife	Wetland Wildlife
0-6%	Good	Good	Good	Good	Good	V. poor	V. poor	Good	Good	V. poor
6-12%	Good	Good	Good	Good	Good	V. poor	V. poor	Good	Good	V. poor

WOODLAND SUITABILITY

Phases of Series	Ordination	Potential Productivity		Woodland Management Hazards				Suitable Species		Other
		Important Trees	Site Index	Erosion Hazard	Equipment Limitations	Seeding Mortality	Plant Competition	To Favor	To Plant	
0-12%	2o1	red oak sugar maple basswood white ash	red oak 60-70	Slight	Slight	Slight	Slight	red oak sugar maple	red pine wh. pine	

RANGE

Phases of Series	Range Site Name	Climax Vegetation and Productivity of Air-Dry Herbage (lb./ac.)

WINDBREAK

Group	Adapted Trees to Plant	Tree Height Prediction at 20 Years Age	Relative Vigor

OTHER

#61d

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL SURVEY INTERPRETATIONS

SERIES St. Charles
STATE Wisconsin
MLRA 95 L

Well drained, deep silty soil, 40 to 60 inches thick, over calcareous sandy loam till. These soils are nearly level to steep, moderately permeable, and have a high available water capacity.

ESTIMATED SOIL PROPERTIES SIGNIFICANT TO ENGINEERING

Major Soil Horizons (inches)	Classification			Coarse Fract. >3 in. %	Percentage less than 3 inches Passing Sieve No.--				LL	PI	Permea-bility in./hr.	Avail. Water Capac. in./in.	Soil Reac-tion pH	Shrink Swell Poten-tial
	USDA Texture	Unified	AASHO		4	10	40	200						
0-13	sil	ML	A-4	-	100	95-100	90-100	85-95	20-30	2-4	0.6-2.0	.18-.22	5.6-6.5	Low
13-52	sicl	CL	A-6	-	100	95-100	90-100	85-95	30-40	15-20	0.6-2.0	.18-.20	5.6-6.0	Moderate
52-62	1	CL,CL-ML	A-4	0-1	90-100	80-90	70-80	60-70	20-30	5-10	0.6-2.0	.16-.20	6.6-7.3	Low
62-70	sl	SM	A-2	1-5	90-100	80-90	60-70	30-40	10-20	2-4	0.6-2.0	.10-.13	7.9-8.4	Low

Flooding None

Hydrologic group: B

Depth to water table: More than 5 feet

Depth to bedrock: More than 5 feet

Corrosivity - uncoated steel: Low

Corrosivity - concrete: Low

SUITABILITY OF SOIL AS SOURCE OF SELECTED MATERIAL AND FEATURES AFFECTING USE

Roadfill	Fair - low strength; medium compressibility.
Sand	Poor - pockets of poorly graded sand in the substratum.
Gravel	Poor - pockets of graded gravel in the substratum.
Topsoil	Fair - thin surface layer.

DEGREE AND KIND OF SOIL LIMITATION FOR SELECTED USES

Septic Tank Filter Fields	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Sewage Lagoons	Moderate - subsoil has moderate permeability; substratum has moderately rapid permeability. severe for steeper soils.
Shallow Excavations	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Dwellings: With Basements) Without Basements)	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Sanitary Landfill	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Local Roads and Streets	Moderate for 0 to 12% slopes; severe for steeper soils; low strength; subsoil has moderate shrink-swell potential.
Potential Frost Action	Moderate - strong capillary action.

MAJOR SOIL FEATURES AFFECTING SELECTED USES

Pond Reservoir Areas	Moderate permeability.
Embankments, Dikes, and Levees	Medium to low shear strenth and compressibility; moderate permeability.
Drainage of Cropland and Pasture	Not applicable.
Irrigation	High available water capacity; moderate permeability.
Terraces and Diversions	Slopes range from 0 to 30%; moderate prmeability.
Grassed Waterways	Well drained.
Golf Course Fairways - Slopes range from 0 to 30%; moderately permeable.	

Series St. Charles

DEGREE OF SOIL LIMITATION AND MAJOR FEATURES AFFECTING RECREATION USES

Camp Areas	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Picnic Areas	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Playgrounds	Slight for 0 to 2% slopes; moderate for 2 to 6% slopes; severe for steeper soils.
Paths and Trails	Slight for 0 to 20% slopes; severe for steeper soils.

CAPABILITY, SOIL LOSS FACTORS, AND POTENTIAL YIELDS--(High level management)

Phases of Series	Capability	Soil Loss K	Soil Loss T	Corn grain (bu)	Corn silage (T)	Oats (bu)	
0-2%	I-3	.37	4	135	21	90	
2-6%	IIe1			125	19	80	
6-12%	IIIe1			110	17	75	
12-20%	IVe1			95	13	70	
20-30%	VIe1			-	-	-	

PASTURELAND AND HAYLAND

Phases of Series	Group	Species, Yield in AUMs for Dryland (Irrigated) Forage Production
0-6%	Ao1	Alfalfa-brome hay - 5.0 T/A; pasture (bluegrass) - 150 AUD.
6-20%	Ao1	Alfalfa-brome hay - 4.0 T/A; pasture (bluegrass) - 100 AUD.
20-30%	Ar1	Alfalfa-brome hay - 3.0 T/A; pasture (bluegrass) - 100 AUD.

WILDLIFE HABITAT SUITABILITY

Phases of Series	Potential for-- Grain and Seed Crops	Grasses, Legumes	Wild Herbaceous Plants	Hardwood Trees and Shrubs	Coniferous Plants	Wetland Food and Cover	Shallow Water Devel.	Potential for-- Openland Wildlife	Woodland Wildlife	Wetland Wildlife
0-6%	Good	Good	Good	Good	Good	V. poor	V. poor	Good	Good	V. poor
6-20%	Fair	Good	Good	Good	Good	V. poor	V. poor	Good	Good	V. poor
20-30%	Poor	Poor	Fair	Fair	Fair	V. poor	V. poor	Good	Good	V. poor

WOODLAND SUITABILITY

Phases of Series	Ordination	Potential Productivity: Important Trees	Potential Productivity: Site Index	Woodland Management Hazards: Erosion Hazard	Equipment Limitations	Seeding Mortality	Plant Competition	Suitable Species: To Favor	Suitable Species: To Plant	Other
0-12%	1s1	red oak	red oak	Slight	Slight	Slight	Slight	red oak	red pine	
12-30%		sugar maple	70+	Moderate	Moderate	Sl. N&E	Slight	sugar maple	wh. pine	
		blk. cherry				Mod. S&W			wh. spruce	

RANGE

Phases of Series	Range Site Name	Climax Vegetation and Productivity of Air-Dry Herbage (lb./ac.)

WINDBREAK

Group	Adapted Trees to Plant	Tree Height Prediction at 20 Years Age	Relative Vigor

OTHER

Appendix A. (Contd.)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL SURVEY INTERPRETATIONS 1/

SERIES Marsh
STATE Wisconsin
MLRA All

Miscellaneous land areas that are inundated most of the year and includes flowage margins, sloughs and very shallow lakes.

ESTIMATED SOIL PROPERTIES SIGNIFICANT TO ENGINEERING

Major Soil Horizons (inches)	Classification			Coarse Fract. >3 in. %	Percentage less than 3 inches Passing Sieve No.--				LL	PI	Permea-bility in./hr.	Avail. Water Capac. in./in.	Soil Reac-tion pH	Shrink Swell Poten-tial
	USDA Texture	Unified	AASHO		4	10	40	200						
	-	-	-	VARIABLE			-	-	-					

Flooding Standing water most of year

Hydrologic group: -

Depth to water table: Surface

Depth to bedrock: Over 5 feet

Corrosivity - uncoated steel: Variable

Corrosivity - concrete: Variable

SUITABILITY OF SOIL AS SOURCE OF SELECTED MATERIAL AND FEATURES AFFECTING USE

Roadfill	Unsuitable - Ponded most of year; low stability and bearing capacity.
Sand	Unsuitable - No sand.
Gravel	Unsuitable - No gravel.
Topsoil	Unsuitable - Ponded most of year.

DEGREE AND KIND OF SOIL LIMITATION FOR SELECTED USES

Septic Tank Filter Fields	Very Severe - nearly continuous high water table - usually flooded.
Sewage Lagoons	Very Severe - nearly continuous high water table - usually flooded.
Shallow Excavations	Very Severe - nearly continuous high water table - usually flooded.
Dwellings: With Basements	Very Severe - nearly continuous high water table - usually flooded.
Without Basements	Very Severe - nearly continuous high water table - usually flooded.
Sanitary Landfill	Very Severe - nearly continuous high water table - usually flooded.
Local Roads and Streets	Very Severe - nearly continuous high water table - usually flooded.
Potential Frost Action	High

MAJOR SOIL FEATURES AFFECTING SELECTED USES

Pond Reservoir Areas	Flooded most of year.
Embankments, Dikes, and Levees	Variable characteristics; flooded most of year.
Drainage of Cropland and Pasture	Not feasible or applicable.
Irrigation	Not feasible or applicable.
Terraces and Diversions	Not feasible or applicable.
Grassed Waterways	Not feasible or applicable.

1/ Use in conjunction with Guide to Soil Survey Interpretation Sheets.

Series Marsh

DEGREE OF SOIL LIMITATION AND MAJOR FEATURES AFFECTING RECREATION USES

Camp Areas	Very Severe - flooded most of the year.
Picnic Areas	Very Severe - flooded most of the year.
Playgrounds	Very Severe - flooded most of the year.
Paths and Trails	Very Severe - flooded most of the year.

CAPABILITY, SOIL LOSS FACTORS, AND POTENTIAL YIELDS--(High level management)

Phases of Series	Capability	Soil Loss K	Soil Loss T				
A - 0-2%	VIIIw15	-	-	Not suitable for crop production.			

PASTURELAND AND HAYLAND

Phases of Series	Group	Species, Yield in AUMs for Dryland (Irrigated) Forage Production
A - 0-2%		Not suitable.

WILDLIFE HABITAT SUITABILITY

Phases of Series	Potential for--							Potential for--		
	Grain and Seed Crops	Grasses, Legumes	Wild Herbaceous Plants	Hardwood Trees and Shrubs	Coniferous Plants	Wetland Food and Cover	Shallow Water Devel.	Openland Wildlife	Woodland Wildlife	Wetland Wildlife
A - 0-2%	Very poor	Very poor	Very poor	Very poor	Very poor	Good	Good	Poor	Poor	Good

WOODLAND SUITABILITY

Phases of Series	Ordination	Potential Productivity		Woodland Management Hazards				Suitable Species		Other
		Important Trees	Site Index	Erosion Hazard	Equipment Limitations	Seeding Mortality	Plant Competition	To Favor	To Plant	
A - 0-2%	6w5	None	-	None	-	-	-	None	Not suitable	

RANGE

Phases of Series	Range Site Name	Climax Vegetation and Productivity of Air-Dry Herbage (lb./ac.)

WINDBREAK

Group	Adapted Trees to Plant	Tree Height Prediction at 20 Years Age	Relative Vigor

OTHER

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL SURVEY INTERPRETATIONS

SERIES Fox
STATE Wisconsin
MLRA 95L

Well drained loamy soils underlain by calcareous sand and gravel at 20 to 40 inches. These are nearly level to steep moderately permeable soils with medium available water capacity.

ESTIMATED SOIL PROPERTIES SIGNIFICANT TO ENGINEERING

Major Soil Horizons (inches)	Classification			Coarse Fract. >3 in. %	Percentage less than 3 inches Passing Sieve No.--				LL	PI	Permeability in./hr.	Avail. Water Capac. in./in.	Soil Reaction pH	Shrink Swell Potential
	USDA Texture	Unified	AASHO		4	10	40	200						
0-11	sil	ML, CL-ML	A-4, A-6	-	95-100	95-100	85-95	80-90	25-35	5-10	0.6-2.0	.20-.22	5.6-6.5	low
8-34	scl	SC	A-6	-	90-100	85-95	70-80	40-50	30-39	13-22	0.6-2.0	.16-.18	5.6-7.8	Moderate
34-60	s&g	GW-GM	A-1	0-5	70-80	50-70	30-40	5-10	-	NP	6.0-20	.02-.04	7.8-8.4	Low

Flooding None

Hydrologic group: B

Depth to water table: More than 6 feet

Depth to bedrock: More than 6 feet

Corrosivity - uncoated steel: Low

Corrosivity - concrete: Low

SUITABILITY OF SOIL AS SOURCE OF SELECTED MATERIAL AND FEATURES AFFECTING USE

Roadfill	Fair - subsoil; substratum good.
Sand	Fair - large amount of gravel.
Gravel	Fair - large amounts of sand
Topsoil	Fair - silt loam surface 11 inches thick.

DEGREE AND KIND OF SOIL LIMITATION FOR SELECTED USES

Septic Tank Filter Fields	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils; danger of ground water contamination.
Sewage Lagoons	Severe - rapid permeability in substratum.
Shallow Excavations	Moderate for 0 to 12% slopes; severe for steeper soils; substratum soughs easily.
Dwellings: With Basements	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Dwellings: Without Basements	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Sanitary Landfill	Severe - sand and gravel at 20 to 40 inches; danger of ground water contamination.
Local Roads and Streets	Moderate for 0 to 12% slopes; severe for steeper soils; moderate shrink-swell potential.
Potential Frost Action	Low

MAJOR SOIL FEATURES AFFECTING SELECTED USES

Pond Reservoir Areas	Rapid permeability in substratum.
Embankments, Dikes, and Levees	Medium shear strength and compressibility in subsoils; high shear strength and low compressibility in substratum.
Drainage of Cropland and Pasture	Not applicable.
Irrigation	Medium available water capacity; 20 to 40 inch sola.
Terraces and Diversions	Sand and gravel at 20 to 40 inches.
Grassed Waterways	Sand and gravel at 20 to 40 inches.
Golf Course Fairways.	Up to 30% slopes; well drained; moderate permeability.

DEGREE OF SOIL LIMITATION AND MAJOR FEATURES AFFECTING RECREATION USES

Camp Areas	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Picnic Areas	Slight for 0 to 6% slopes; moderate for 6 to 12% slopes; severe for steeper soils.
Playgrounds	Slight for 0 to 2% slopes; moderate for 2 to 6% slopes; severe for steeper soils.
Paths and Trails	Slight for 0 to 20% slopes; moderate for steeper soils.

CAPABILITY, SOIL LOSS FACTORS, AND POTENTIAL YIELDS--(High level management)

Phases of Series	Capability	Soil Loss K	Soil Loss T	Corn grain (bu)	Corn silage (T)	Oats (bu)	
0-2%	IIs1	.37	3	90	13	75	
2-6%	IIe2			85	13	70	
6-12%	IIIe2			80	11	65	
12-20	IVe2			70	9	60	
20-30%	VIe2			-	-	45	

PASTURELAND AND HAYLAND

Phases of Series	Group	Species, Yield in AUMs for Dryland (Irrigated) Forage Production
0-20%	Ao1	Alfalfa-brome hay - 3.0 T/A; pasture (bluegrass) - 105 AUD.
20-30%	Ar1	Alfalfa-brome hay - 2.0 T/A; pasture (bluegrass) - 80 AUD.

WILDLIFE HABITAT SUITABILITY

Phases of Series	Potential for-- Grain and Seed Crops	Grasses, Legumes	Wild Herbaceous Plants	Hardwood Trees and Shrubs	Coniferous Plants	Wetland Food and Cover	Shallow Water Devel.	Potential for-- Openland Wildlife	Woodland Wildlife	Wetland Wildlife
0-6%	Good	Good	Good	Good	Good	V. poor	V. poor	Good	Good	V. poor
6-20%	Fair	Fair	Good	Good	Good	V. poor	V. poor	Fair	Good	V. poor
20-30%	Poor	Poor	Fair	Good	Good	V. poor	V. poor	Fair	Good	V. poor

WOODLAND SUITABILITY

Phases of Series	Ordination	Potential Productivity: Important Trees	Site Index	Woodland Management Hazards: Erosion Hazard	Equipment Limitations	Seeding Mortality	Plant Competition	Suitable Species: To Favor	To Plant	Other
0-12%	2d1	red oak white oak sugar maple	red oak 60-70	Slight	Slight	Slight	Slight	red oak sugar maple	red pine white pine	
12-30%	2d2			Moderate	Moderate	Sl. N&E Mod - S&W	Slight			

RANGE

Phases of Series	Range Site Name	Climax Vegetation and Productivity of Air-Dry Herbage (lb./ac.)

WINDBREAK

Group	Adapted Trees to Plant	Tree Height Prediction at 20 Years Age	Relative Vigor

OTHER

USDA-SCS-LINCOLN, NEBR. 1973

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL SURVEY INTERPRETATIONS 1/

SERIES Virgil silt loam gravelly substratum
STATE Wisconsin
MLRA L 95

Deep, silty nearly level and gently sloping soils 36 to 60 inches thick over calcareous sand and gravel. Somewhat poorly drained. Moderately slowly permeable with high available water capacity.

ESTIMATED SOIL PROPERTIES SIGNIFICANT TO ENGINEERING

Major Soil Horizons (inches)	Classification			Coarse Fract. >3 in. %	Percentage less than 3 inches Passing Sieve No.--				LL	PI	Permeability in./hr.	Avail. Water Capac. in./in.	Soil Reaction pH	Shrink Swell Potential
	USDA Texture	Unified	AASHO		4	10	40	200						
0-13	Sil	CL or ML	A-4	-	100	100	90-100	80-90	20-30	1-5	0.6-2.0	.18-.22	5.1-7.3	Low
13-49	Sicl	CL	A-6	-	100	95-100	90-100	85-95	30-40	15-20	0.2-0.6	.16-.20	5.1-6.0	Moderate
49-60	S&G	SP	A-1	1-5	95-100	85-95	20-30	1-5	-	NP	6.0-20.	.11-.13	7.9-8.4	Low

Flooding: Rare
Hydrologic group: B
Depth to water table: (seasonal) 1 to 3 ft.
Depth to bedrock: more than 5 ft.
Corrosivity - uncoated steel: High
Corrosivity - concrete: Low

SUITABILITY OF SOIL AS SOURCE OF SELECTED MATERIAL AND FEATURES AFFECTING USE

Roadfill	Subsoil - Poor; mod. shrink-swell potential and low bearing value; unstable when wet. Substratum - fair; low stability unless confined.
Sand	Poor - substratum is poorly graded sands with some fines; thick overburden.
Gravel	Unsuitable - substratum contains little gravel of commercial value.
Topsoil	Surface - good; dark; thick; medium texture. Subsoil - fair; mod. fine texture; seasonal high water table.

DEGREE AND KIND OF SOIL LIMITATION FOR SELECTED USES

Septic Tank Filter Fields	SEVERE - seasonal high water table.
Sewage Lagoons	MODERATE on 0 to 6%; SEVERE on steeper slopes; moderately slow permeability.
Shallow Excavations	SEVERE - seasonal high water table, 1 to 3 ft.
Dwellings: With Basements	SEVERE - seasonal high water table 1 to 3 ft.
Dwellings: Without Basements	MODERATE - seasonal high water table 1 to 3 ft.
Sanitary Landfill	SEVERE - seasonal high water table; difficult to work in wet seasons; partial amelioration of leachate.
Local Roads and Streets	SEVERE - high frost action.
Potential Frost Action	HIGH - seasonal high water table, 1 to 3 ft.; strong capillarity

MAJOR SOIL FEATURES AFFECTING SELECTED USES

Pond Reservoir Areas	Moderately slow permeability through subsoil; sand and gravel substratum; seasonal high water table; dugout ponds may be feasible.
Embankments, Dikes, and Levees	SLIGHT - subsoil - fair to good stability and compaction characteristics semipervious. Substratum-fair stability & fair to good compaction characteristics; very pervious.
Drainage of Cropland and Pasture	Moderately slow permeability; seasonal high water table; subsurface or surface drainage feasible.
Irrigation	High available water capacity; moderately deep soil; moderate water intake rate; somewhat poorly drained.
Terraces and Diversions	Sand and gravel at 20 to 40 inch depth.
Grassed Waterways	Wetness may hinder construction; use water tolerant grasses.
Golf Course Fairways	Seasonal high water table; very low relief; turf easily damaged when wet.

1/ Use in conjunction with Guide to Soil Survey Interpretation Sheets.

Virgil silt loam, gravelly substratum

DEGREE OF SOIL LIMITATION AND MAJOR FEATURES AFFECTING RECREATION USES

Camp Areas	MODERATE - sites remain wet for moderate periods; surface compacts easily.
Picnic Areas	MODERATE - seasonal high water table; heavy foot traffic may damage sod during wet seasons.
Playgrounds	MODERATE - seasonal high water table; compactseasily when wet.
Paths and Trails	MODERATE - wet for moderate periods; muddy and slippery when wet; erosive on slopes.

CAPABILITY, SOIL LOSS FACTORS, AND POTENTIAL YIELDS--(High level management)

Phases of Series	Capability	Soil Loss K	Soil Loss T	Corn Grain(bu)	Corn Silage(T)	Oats (bu)	
0 - 2%	IIw-2	.35	4	130	21		
2 - 6%	IIw-2	.35	4	125	20		

PASTURELAND AND HAYLAND

Phases of Series	Group	Species, Yield in AUMs for Dryland (Irrigated) Forage Production
0 - 2%	Bwl	Alfalfa - brome (hay) 5.2 T/A; pasture (bluegrass) 170 AUD.
2 - 6%		" 5.8 T/A; " 165 AUD.

WILDLIFE HABITAT SUITABILITY

Phases of Series	Potential for-- Grain and Seed Crops	Grasses, Legumes	Wild Herbaceous Plants	Hardwood Trees and Shrubs	Coniferous Plants	Wetland Food and Cover	Shallow Water Devel.	Potential for-- Openland Wildlife	Woodland Wildlife	Wetland Wildlife
0 - 6%	Fair	Good	Good	Good	Good	Fair	Fair	Good	Good	Fair

WOODLAND SUITABILITY

Phases of Series	Ordination	Potential Productivity: Important Trees	Site Index	Woodland Management Hazards: Erosion Hazard	Equipment Limitations	Seeding Mortality	Plant Competition	Suitable Species: To Favor	To Plant	Other
2 - 6%	3o1	Red oaks Wh. oak	M	Slight	Slight	Slight	Moderate	Red and Silver Maple	Wh.pine Wh.spruce Soft maples	
6 - 12%		Aspen Cherry Soft maples	M	Slight	Slight	Slight	Moderate			

RANGE

Phases of Series	Range Site Name	Climax Vegetation and Productivity of Air-Dry Herbage (lb./ac.)

WINDBREAK

Group	Adapted Trees to Plant	Tree Height Prediction at 20 Years Age	Relative Vigor

OTHER

USDA-SCS-LINCOLN, NEBR. 1974

Appendix A. (contd.)

Sample Descriptions--Well Logs

#1 - 5 feet	Gray-black, sandy, clayey soil with large pebbles. High organic content.
#1 - 10 feet	Tan-brown, clayey sand. Fine to very fine sand. angular, fair sorting. Some black organic clayeys are found within the sample.
#1 - 15 feet	Poorly sorted sand. Sub-angular, various sized sand grains are found. Black organic clays bind sediment together. Some sand grains are well rounded, others are not. 90% of grains appear to be quartz. Some pebbles are found in the sample.
#1 - 20 feet	Mottled, clayey silt. Tan-brown color. Grey mottled clays found dispersed in material.
#1 - 25 feet	Tan-brown, unconsolidated sand. Little clay, good sorting, very rounding, good sphericity, excellent rounding. Medium size sand.
#1 - 30 feet	Yellow-brown sand. Brown-black clay pellets, almost 100% quartz except for the clay. Good sorting, good sphericity, excellent rounding. Medium size sand.
#1 - 37 feet	Gray-brown, clayey sand. Good rounding, good sphericity, good sorting. Organic clays found within material. Binds clays together.
#4 - 10 feet	Sub-rounded, medium sand. Some clay is within - binds some particles. Brown color. Fairly good sorting.
#4 - 15 feet	Dark brown, clayey sand. Very fine sand. Everything else is the same as #29 - 27 feet.
#4 - 20 feet	Brown sand. Fair amount of clay. Good sorting, good sphericity, good rounding, almost 100% quartz. Few grains of black minerals.

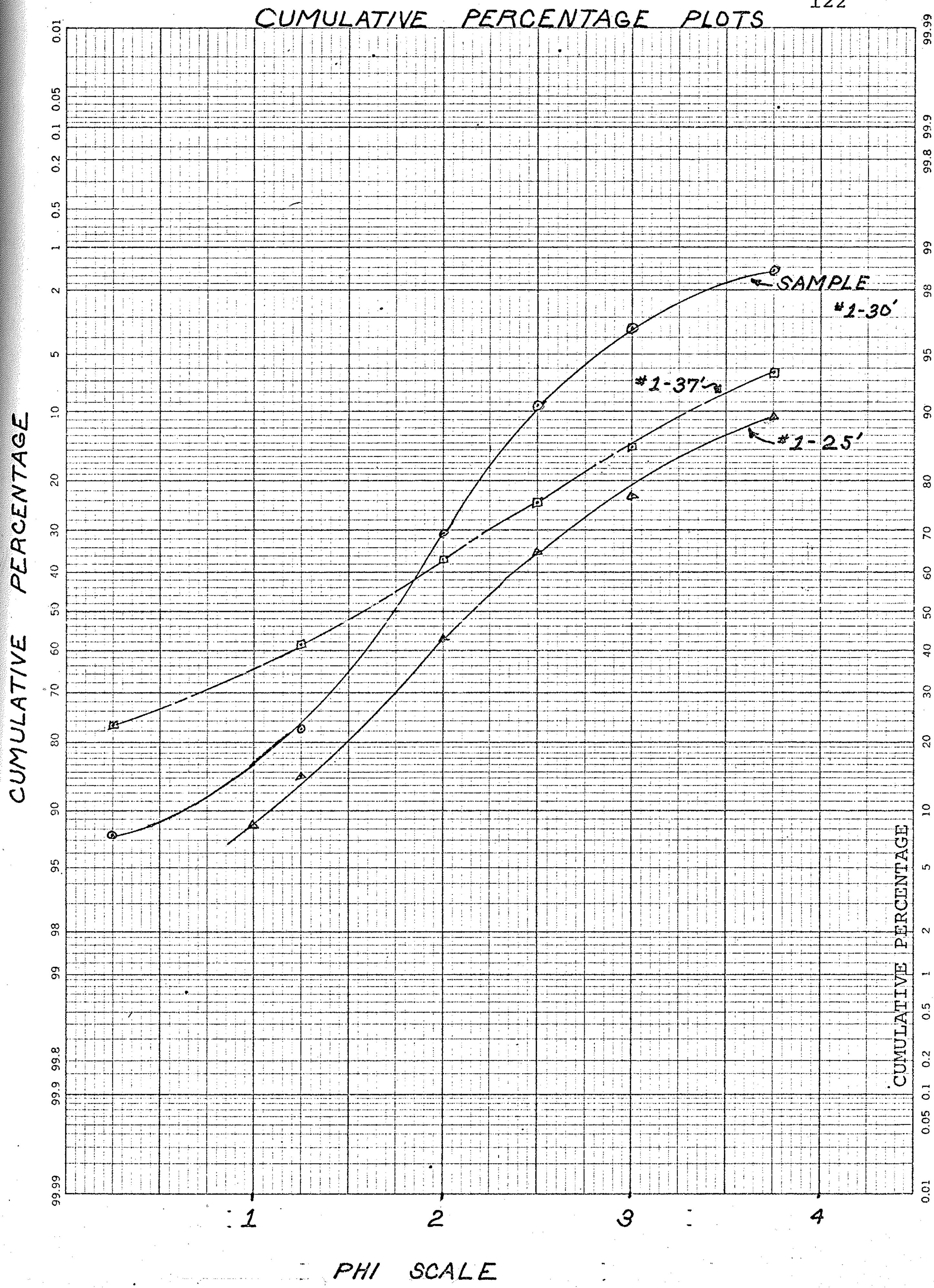
#5 - 10 feet	Same as #5 - 15 feet, but the sample has more pebbles in it.
#5 - 15 feet	Poorly sorted sand. Sub-angular, various sand grains are found. Black organic clays bind sediment together. Some sand grains are well rounded, others are not. 90% of grains appear to be quartz. Some pebbles are found in the sample.
#5 - 20 feet	Same as #5 - 15 feet.
#5 - 25 feet	Black, organic, sandy clay. Sand grains are medium fine size, constitutes about 20% (quartz is major const.). Shell fragments and gastropods are seen. Large pebbles are also interspersed.
#8 - 10 feet	Same as #8 - 15 feet.
#8 - 15 feet	Same as #8 - 20 feet, except higher clay content.
#8 - 20 feet	Blackish-gray quartz sand. Poorly sorted. Some chert content. Some $CaCO_3$. Fine sand, subrounded. Organic clays.
#11 - 7 feet	Silty clay. Gray-brown color. No $CaCO_3$.
#11 - 10 feet	Pebbly-sandy, brown clay.
#11 - 15 feet	Tan, sandy clay.
#11 - 20 feet	Pebbly-silty, tan clay.
#11 - 25 feet	Gray-brown, silty clay. Less silt than #11 - 7 feet.
#11 - 30 feet	Greenish-yellow, brown color. Clayey. Fine sand, fair sorting, good rounding, fair sphericity, some $CaCO_3$, appears to be glauconite.
#11 - 35 feet	Silty clay. Has $CaCO_3$ in it. Tan-brown color. Some black organic material, but very little.
#13 - 6 feet	Chocolate brown, clayey sand. Fine to very fine sand. Sub to well rounded grains. No $CaCO_3$.
#13 - 9 feet	Same as #13 - 6 feet, but higher sand content. No clay.

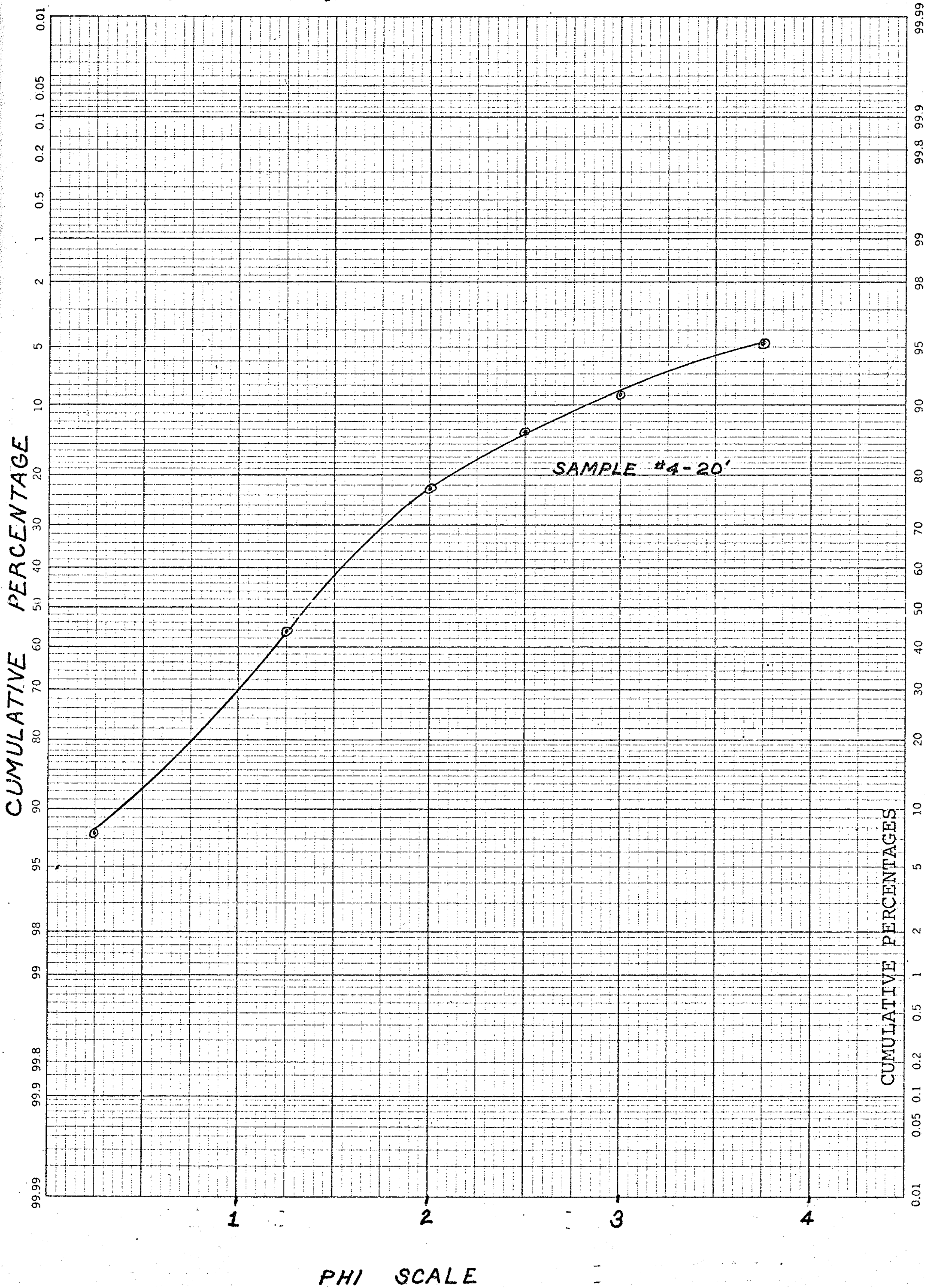
#13 - 21 feet	Light brown quartz sand. Sub to well rounded grains. Little clay content. Fair sorting. Some $CaCO_3$.
#13 - 24 feet	Brownish-yellow, unconsolidated sand, some clay. Poor sorting, good rounding, fair sphericity. 90% quartz, black minerals, and other opaque light colored minerals. Medium fine sand. Small gravel pebbles. Glauconite pebbles and grains are found. High $CaCO_3$ content.
#13 - 30 feet	Brownish-yellow, unconsolidated sand-clay. Poor sorting, good rounding, fair sphericity. 70% quartz, mixed mineralogy. Fine sand. Pebbles found in the material include: 1 pebble, well rounded chert; 1 pebble, blocky well cement quartzarenite, Fe minerals are found within.
#18 - 6 feet	Black-gray organic clay. Little or no sand or silt.
#18 - 12 feet	Fine to very fine quartz sand. Sub-rounded to well rounded grains. Good sorting. Small amount of blackish clay in spaces.
#18 - 24 feet	Tan-brown quartz sand. Sub-rounded to sub-angular. 90% quartz. Little clay content. Medium to fine sand.
#19 - 5 feet	Medium sand. Brown color. No clay, gravel also found in this level. Excellent rounding and sphericity. Poor sorting. Most material is medium sand. $CaCO_3$ has very good effervence. 90% quartz.
#19 - 10 feet	Gravel and sand at almost even percentage by weight. Large gravel pieces.
#19 - 15 feet	Very clean medium sand. 100% quartz. Excellent rounding, sphericity, etc.
#19 - 20 feet	Sand like other #19 - medium size.
#19 - 25 feet	Tan-brown pumpkin color, unconsolidated sand. Clay in material. Good sorting, good rounding, good sphericity. 90% quartz. 10% black minerals (hornblende?). Very fine sand.

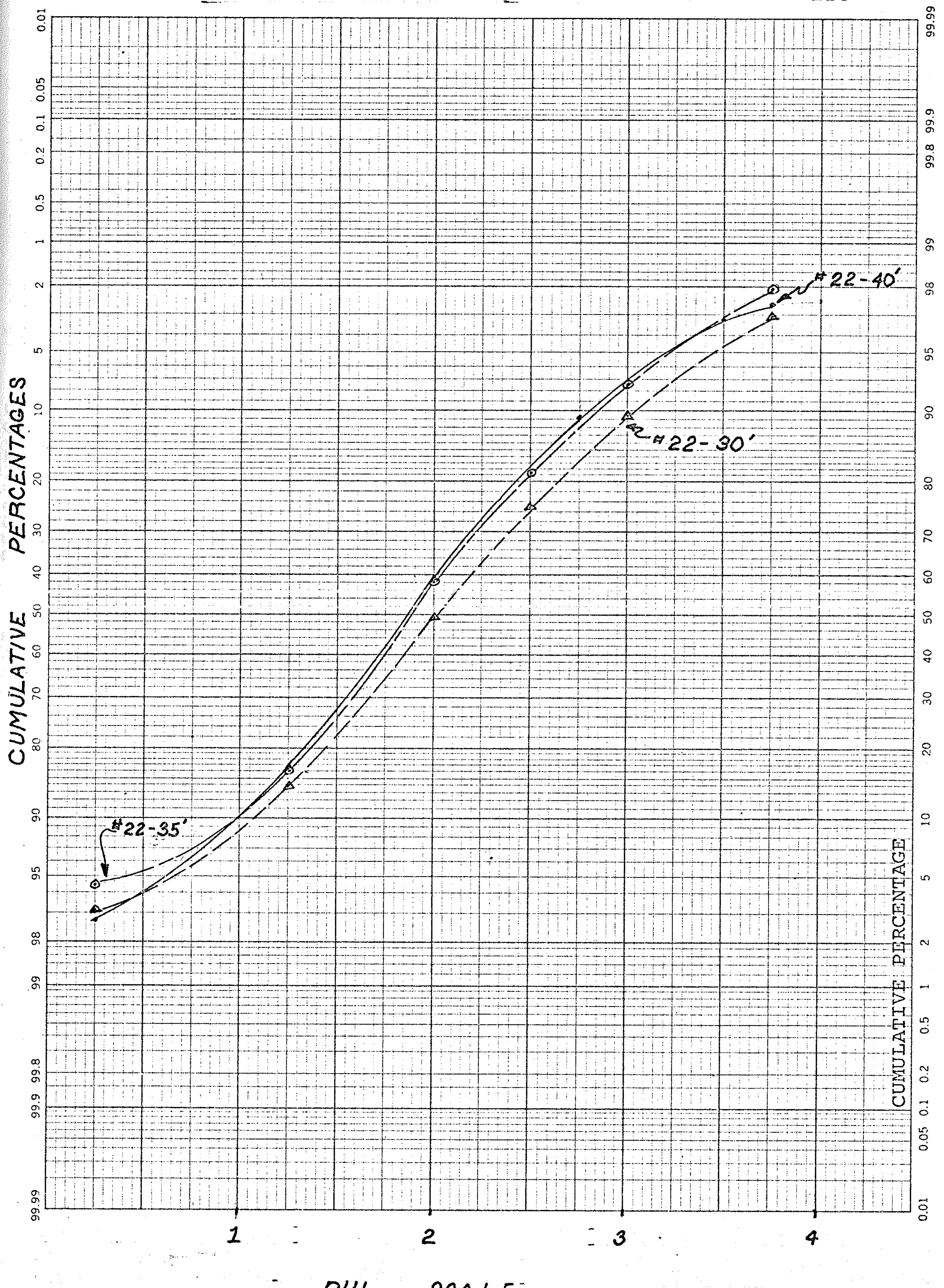
#19 - 35 feet	Fine to very fine sand. Same as #19 - 40 feet. Some $CaCO_3$.
#19 - 40 feet	Greenish, yellow-brown color. Very little. Fine sand, some clay pellets, 95% quartz. Good rounding, good sorting, good sphericity. Some glauconite may be present.
#20 - 10 feet	Organic clay. Tan-brown color, perhaps mottled. No $CaCO_3$. Some silt, but it makes up a small percentage.
#20 - 15 feet	Light tan silty clay. High in $CaCO_3$.
#20 - 20 feet	Same as #20 - 15 feet.
#21 - 10 feet	Black, organic, pebbly, sandy clay.
#21 - 15 feet	Black, sandy, organic clay. Much higher organic content than #21 - 10 feet.
#21 - 20 feet	Black, highly organic clay. Sand grains interspersed within material.
#22 - 10 feet	Same as #22 - 15 feet, but higher clay pebble content.
#22 - 15 feet	Yellow, almost pure quartz sand. Angular to subrounded. Some clay pellets, but these may be contamination. Medium size. Larger grains are well rounded. Sand is poorly sorted. No cementing of grains.
#22 - 20 feet	Medium to fine sand. Same as #22 - 15 feet, but no clay, some large pebbles are found.
#22 - 25 feet	Brownish-yellow, unconsolidated sand. No clay, good sorting, good sphericity, very good rounding. The sand is about 95% quartz, nondescript black minerals make up the rest. Medium size sand. Other remarks-appears to be some cement sand in the material.
#22 - 40 feet	Light brown color, unconsolidated sand. Very little clay, good sorting, good rounding, excellent sphericity. 97% quartz sand. Medium coarse sand.
#24 - 10 feet	Light brown, silty clay. Silt is quartz.

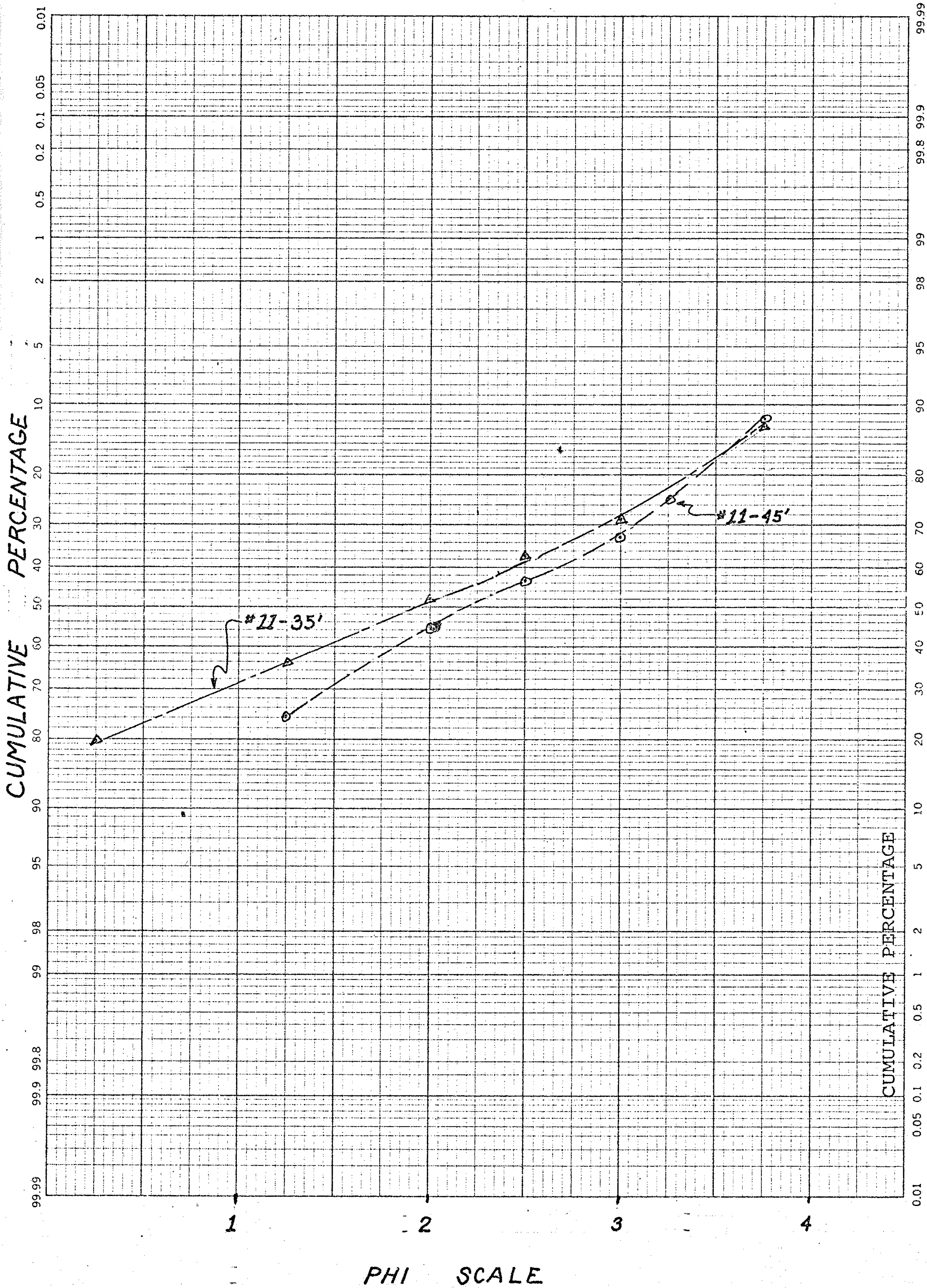
#24 - 15 feet	Light brown clayey fine sand. Angular. Good sorting of sand. Some $CaCO_3$.
#24 - 17 feet	Fine quartz sand. Yellow-tan color. Sub rounded, fair sorting. Some gravel is in the material. High in $CaCO_3$.
#25 - 10 feet	Sub rounded to round tan-brown quartz sand. Fine sand, good sorting.
#25 - 15 feet	Tan-brown very fine sand. Poorly sorted, some well rounded grains, but most grains are sub-angular.
#25 - 18 feet	Brownish-green quartz sand. 25 to 35% glauconite. No other clays found. Sub-angular, fine sand.
$\#25^2$ - 17 feet	Dark brown, quartz sand, some clay. Very little $CaCO_3$ content.
$\#25^2$ - 20 feet	Tannish-brown quartz sand. Glauconite pellets found in high percentage. Some $CaCO_3$.
#26 - 5 feet	Brown silty clay. No $CaCO_3$.
#26 - 10 feet	Same as #26 - 5 feet, but higher silt content.
#26 - 15 feet	Tan, clayey quartz sand, same sand, has a large percentage of pebbles. Little $CaCO_3$ in it.
#27 - 5 feet	Dark tan-brown clayey sand. Fine sand size, some gravel. Sand is bound into balls by the clay. Very little $CaCO_3$.
#27 - 10 feet	Light tan quartz sand. Medium size. Good sorting, no clay. Some hornblende in sand, about 5%. Contains some $CaCO_3$.
#27 - 15 feet	Light tan quartz sand, little clay. Medium size, sub-angular, some clay pellets. High amount of $CaCO_3$.
#28 - 5 feet	Brown-black silty clay, with some brown mottling.
#28 - 10 feet	Brown silty clay. Higher and coarser silt content.
#28 - 15 feet	Dark brown silty clay. Mottling is found.

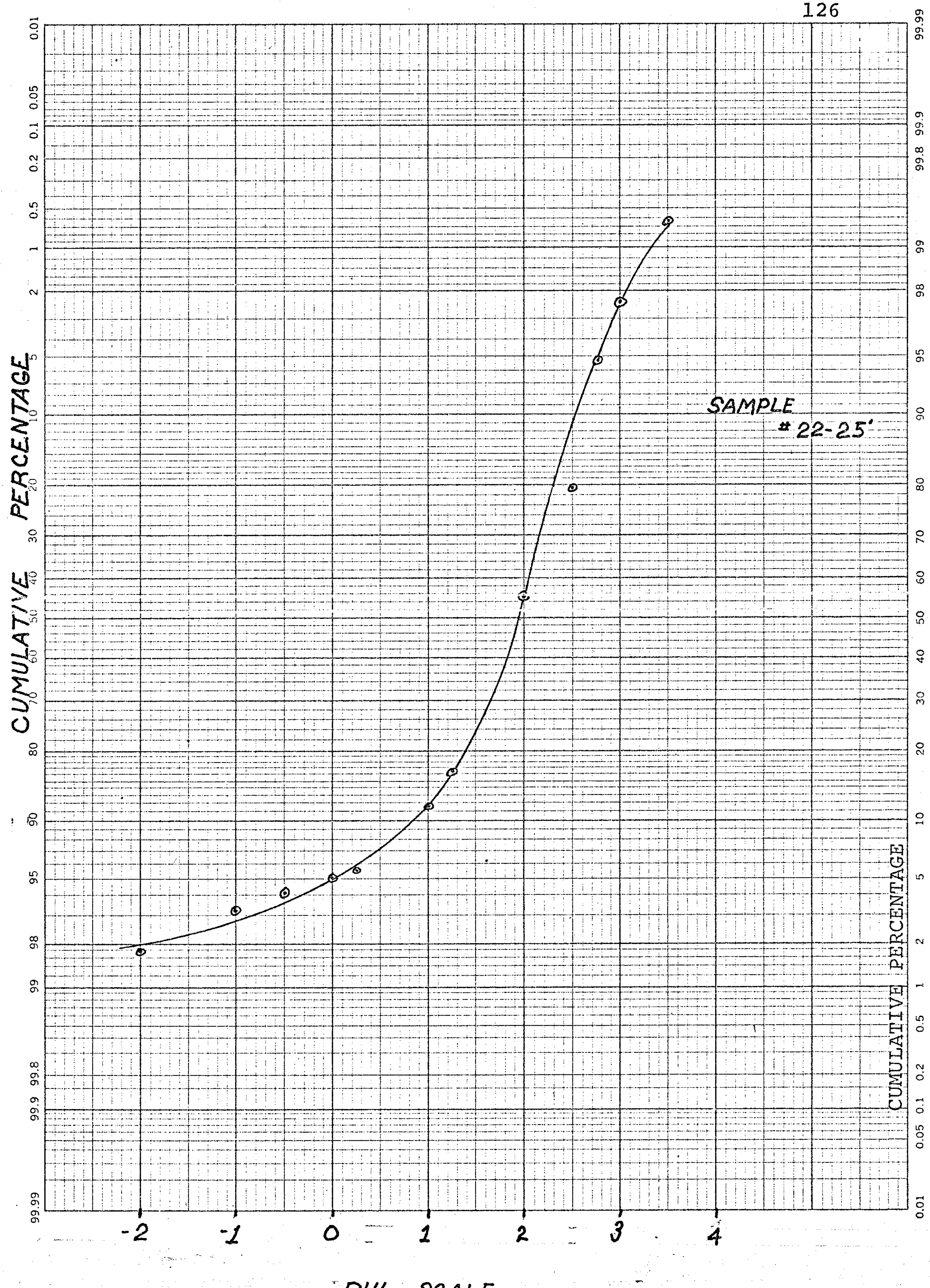
#28 - 20 feet	Brown, silty clay. Binds into balls.
#28 - 25 feet	Tan silt.
#28 - 30 feet	Same as #28 - 35 feet.
#28 - 35 feet	Light tan silt. Very fine grains. About 100% quartz. High in $CaCO_3$.
#28 - 40 feet	Tan quartz silt. Angular, good sorting. No clay. 95% quartz.
#28 - 45 feet	Some silt.
#29 - 5 feet	Dark brown sandy clay. Forms into balls. Black organics are found within.
#29 - 10 feet	Medium to dark brown color. Fine to medium sand. Sub-rounded, poorly sorted quartz sand. Fine material tends to bind the coarse particles into a very tight rock.
#29 - 13 feet	Fine sand, sub-rounded. Poor sorting. Clay material in sample binds sand grains. About 95% or greater quartz grains. Light brown color.
#29 - 15 feet	Dark brown clayey sand. Very fine sand. Everything else is the same as #29 - 27 feet.
#29 - 20 feet	Very fine sand. Everything else is the same as #29 - 27 feet.
#29 - 27 feet	Fine grained. Sub-angular to sub-rounded. Fairly good sorting. 90 to 95% quartz. The other is nondescript black minerals. Tan color. Appears to be no cementing of grains.
Greenhouse 6 feet	Brown-black, mottled silty clay. No $CaCO_3$.
NE Corner of Lot 62 - 5 feet	Light yellow-greenish tan. Fine to very fine sand. Angular to sub-angular. Quartz sand. High content of $CaCO_3$. Some cementing of grains.
NE Corner of Lot 62	Tan clayey quartz sand. Some pebbles are found. Fine to very fine sand. Sub-angular, poor sorting. About 90% quartz, other 19% is nondescript.

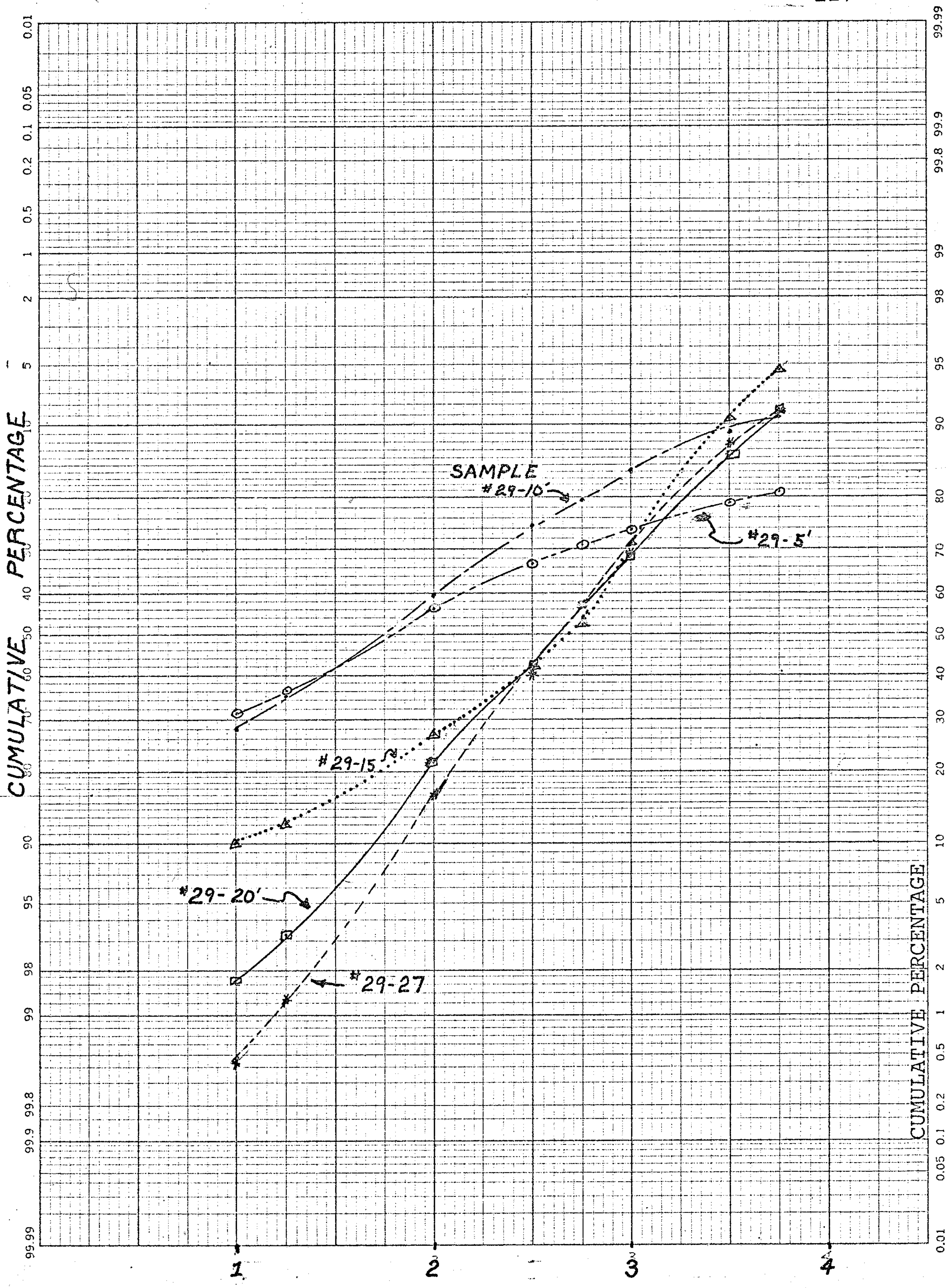

CUMULATIVE PERCENTAGE PLOTS
CUMULATIVE PERCENTAGE
SAMPLE #1-30'
#1-37'
#1-25'
1
2
3
4
PHI SCALE
CUMULATIVE PERCENTAGE

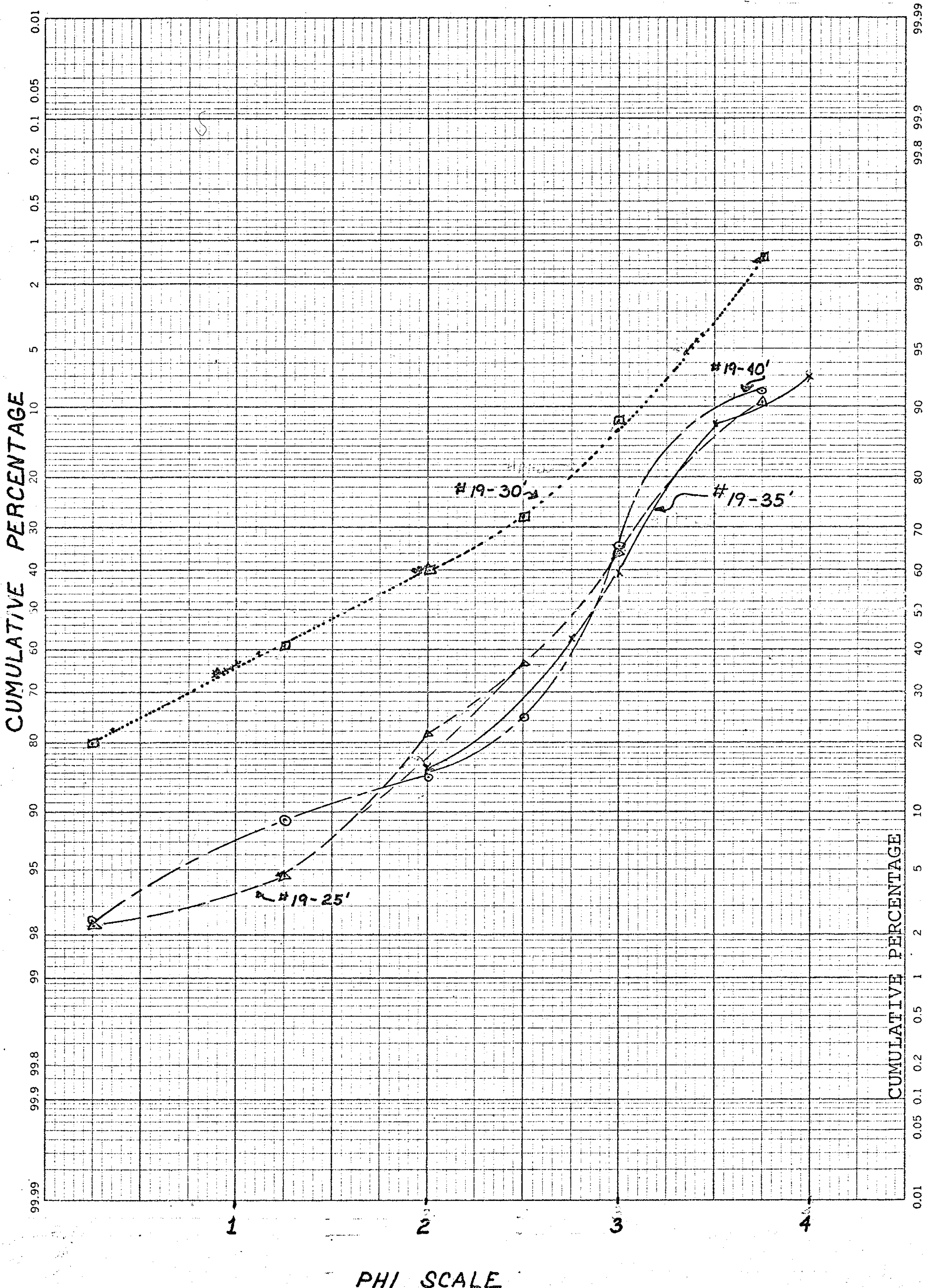

SAMPLE #4-20'
CUMULATIVE PERCENTAGE
CUMULATIVE PERCENTAGES
PHI SCALE
1
2
3
4
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99

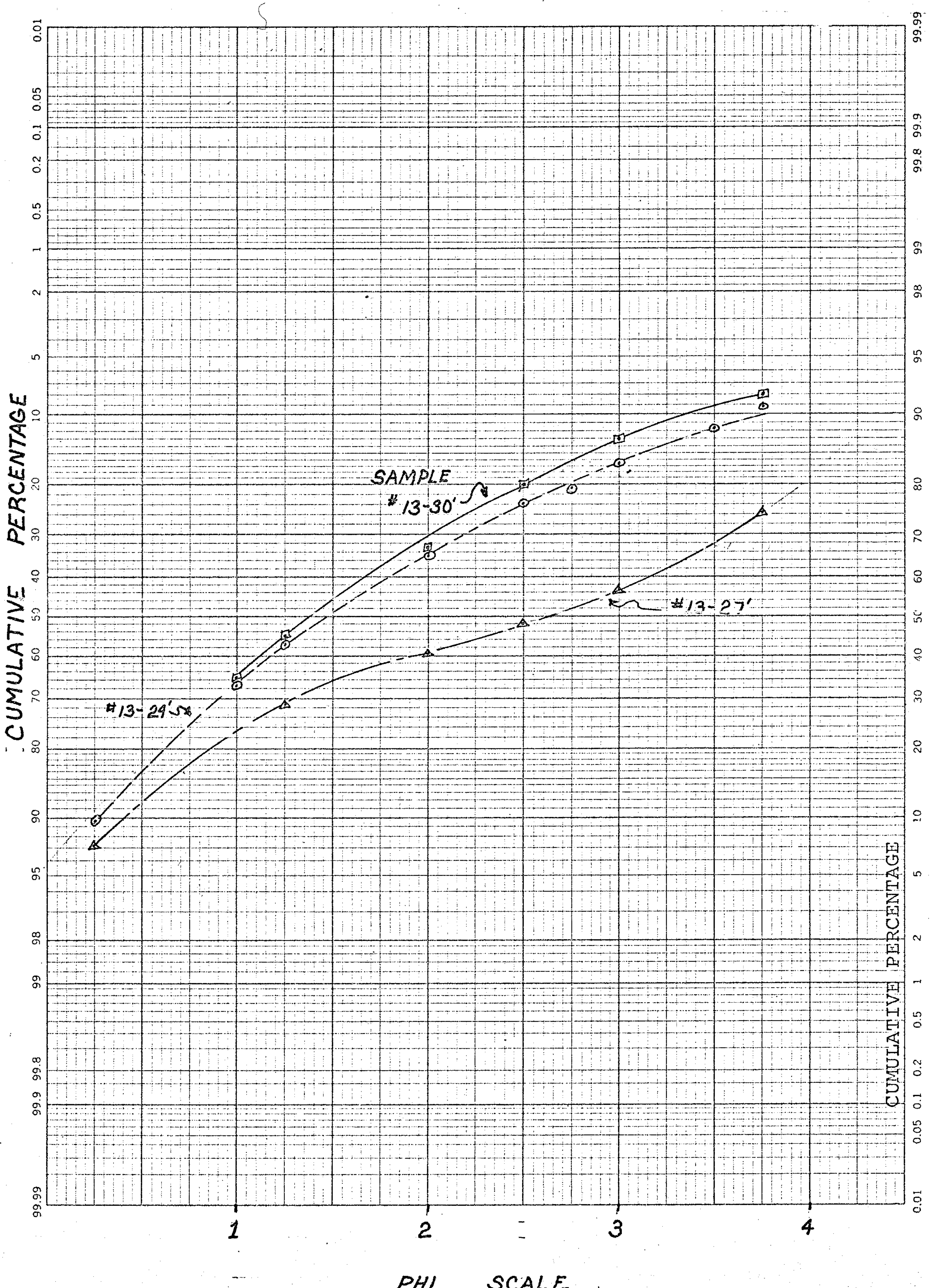

CUMULATIVE PERCENTAGES
CUMULATIVE PERCENTAGE
#22-40'
#22-30'
#22-35'
1
2
3
4
PHI SCALE


CUMULATIVE PERCENTAGE
CUMULATIVE PERCENTAGE
#11-35'
#11-45'
1
2
3
4
PHI SCALE


CUMULATIVE PERCENTAGE
SAMPLE
22-25'
CUMULATIVE PERCENTAGE
-2
-1
0
1
2
3
4
PHI SCALE


CUMULATIVE PERCENTAGE
SAMPLE
#29-10'
#29-5'
#29-15'
#29-20'
#29-27
1
2
3
4
CUMULATIVE PERCENTAGE


CUMULATIVE PERCENTAGE
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
#19-40'
#19-30'
#19-35'
#19-25'
1
2
3
4
PHI SCALE


CUMULATIVE PERCENTAGE
SAMPLE
#13-30'
#13-27'
#13-29'5"
1
2
3
4
PHI SCALE

Appendix C
UNIVERSITY BAY CORE ANALYSIS

Constituent in ppm.	U. Bay Shallow Core	U. Bay Deep Core
Solids	29.48	31.92
P	0.97	1.00
K	1.32	1.74
Ca	3.86	14.00
Mg	1.87	1.64
Na	0.13	0.23
Al	4210	4320
Ba	78.6	86.9
Fe	9500	8120
Sr	25.9	56.0
B	80.0	77.0
Cu	42.0	32.3
Zn	73.7	67.1
Mn	348	541
Cr	53.3	76.2
NH_4-N	14.9	4.4
NO_3-N	33.1	16.2

Available

Ca	4500	4200
Mg	1100	625
B	0.25	0.15
Mn	7.5	10.0
Zn	0.5	0.5
SO_4-S	356	412

Appendix D.
Laboratory determination of permeability

Well #	Depth of sample	Permeability (gallons/day/ft^2)
1	25	15
1	30	441
4	20	no results
8	10	5.4
11	35	no results
13	24	132
13	30	868
21	20	no results
22	25	43
22	30	540
22	35	225
29	27	49

Appendix E.

Calculations of flow quantities

Seepage from the marsh:

Using the equation derived from Darcy's Law:

$$Q = KiA$$

where
- Q is the volume of water in gallons per day
- K is the permeability of the soil in gallons per day per square foot
- "i" is the gradient of the water table in feet per foot
- A is the cross sectional area through which the groundwater flows, in square feet

For seepage form the marsh the following values were taken from laboratory experiments, potentiometric maps, and maps:

$$\text{"i"} = 0.002 \text{ ft/ft}$$

$$K = 0.4 \text{ gals/day/ft}^2$$

$$A = 1845 \text{ feet} \times 10 \text{ feet} = 18450 \text{ ft}^2$$

$$Q \text{ gals/day} = 0.4 \text{ gpd/ft}^2 \times 0.002 \text{ ft/ft} \times 18450 \text{ ft}^2$$

$$Q = 15 \text{ gals/day}$$

Seepage from the lake involves using the same equation. The following values were used for the calculations:

$$K = 20 \text{ gpd/ft}^2$$

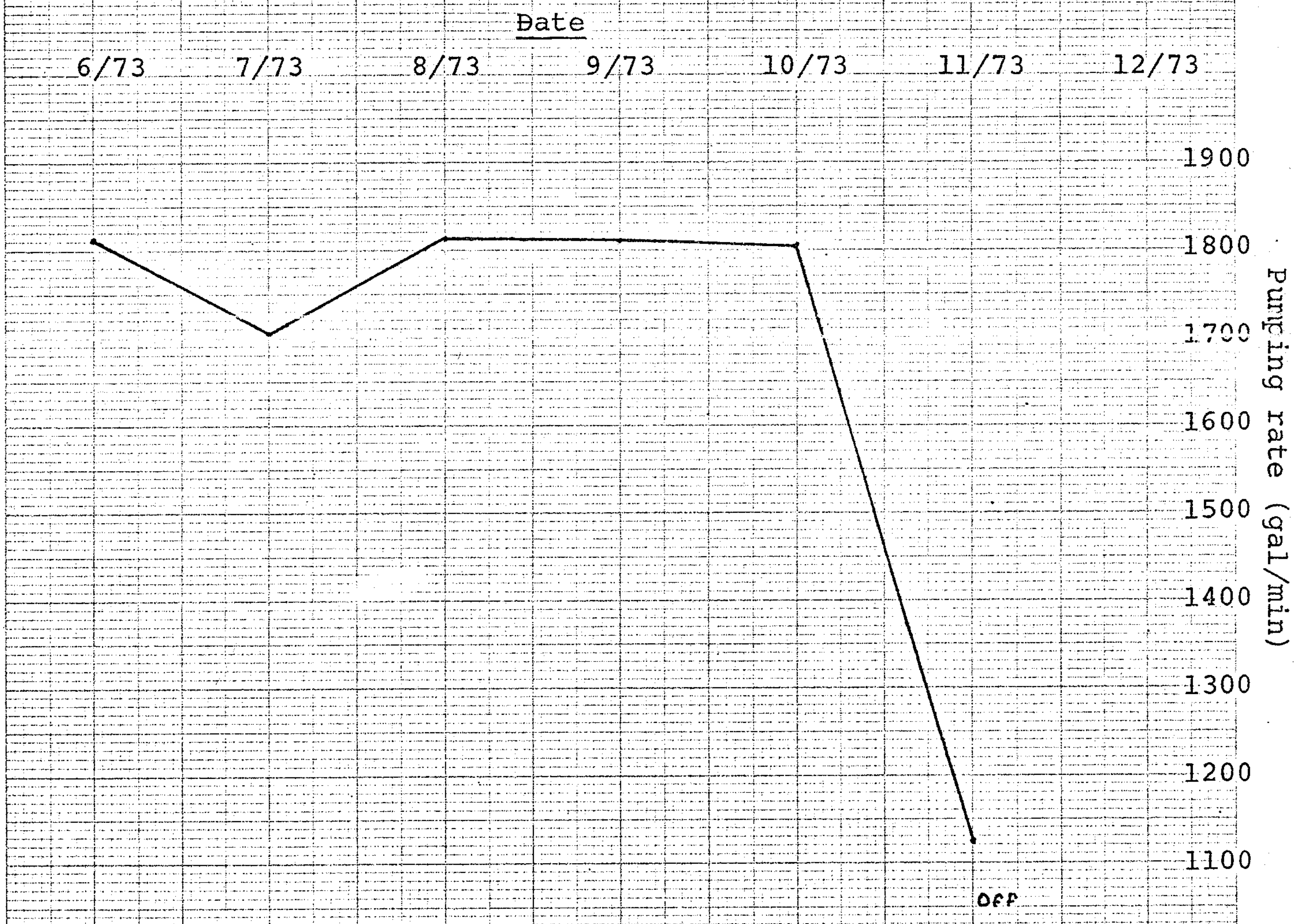
$$\text{"i"} = 0.01 \text{ ft/ft}$$

$$A = 116033 \text{ ft}^2$$

$$Q \text{ gals/day} = 20 \text{ gpd/ft}^2 \times 0.01 \text{ ft/ft} \times 116033 \text{ ft}^2$$

$$Q = 23200 \text{ gals/day}$$

Appendix F. Pumping schedule for municipal well #4.



APPENDIX G.

Pump Test Analysis

In this particular pump-test case, the VA observation well (Figure 38) was used. The purpose of analyzing the time-drawdown data measured in the VA well due to pumpage from #1 pump was to determine the storage coefficient* and permeability of the aquifer.

The pump test occurred from July 3rd to July 12, 1973. This pump test is under water-table conditions which makes the evaluation of the data a little more difficult because the transmissibility of the aquifer changes through time with pumping. In this case study, two well readings were taken before the pumping began. These two wells show that the water table is rising. This rise in water table must be taken into account when evaluating the pump test data.

Table 1 displays the various data which were used in the compilation of the storage coefficient* and transmissibility factors.

Since this pump test was performed without my supervision, certain assumptions had to be made about the performance of the test. It was assumed that pump #1 was turned on at 8:00 a.m., July 3rd. The time column in Table 1 records the time in minutes since the start of the pumping.

---

*Storage coefficient--is the volume of water released from storage, or taken into storage, per unit of surface area of the aquifer per unit change in head. In a water table aquifer, which is this case, is the same as the specific yield or effective porosity of the aquifer.

The water level column records the measurement of the water level in the observation well in relation to the city datum of 845.90 feet above mean sea level. The zero elevation is 845.90 feet.

Uncorrected drawdowns are the difference between the water level of July 2nd, and the date of observation. An example would be on July 9th the water level was -5.7. The uncorrected drawdown is -5.7 minus -1.8 equals -3.9. The term uncorrected drawdown means that the trend of the rising water table has not been taken into account

The trend of the water table can be seen on the following page. Since only two dates were recorded before the pump was turned on, it is assumed that the water table would experience a linear rise during the test period. A more accurate analysis would have been to have monitored the water levels in the observation well longer before pumping. The resulting trend would have probably been in the form of a curve rather than a straight line.

The final column is the corrected drawdown. This is the sum of columns 4 and 5, the uncorrected drawdowns and the trend. The trend curve illustrates the process of obtaining a corrected drawdown.

After the values of the corrected drawdown are calculated, one must then determine the values of transmissibility (T) and storage coefficient (S). The method used in this case is named after the geohydrologist C. V. Theis. Theis, in 1935, developed a series of equations to describe the

Table 1.

Time (minutes	Date	Water Level (in feet from city datum)	Drawdown uncorrected (raw data) in feet	Trend (see graph)	Corrected Drawdown (in feet)
	6/30/73	-2.4			
	7/2/73	-1.8			
391	7/3/73	-3.4	1.6	+0.3	1.9
3980	7/6/73	-3.7	1.9	+1.2	3.1
8350	7/9/73	-5.7	3.9	+2.0	5.9
9790	7/10/73	-5.8	4.0	+2.4	6.4
11100	7/11/73	-6.3	4.5	+2.6	7.1
12600	7/12/73	-6.4	4.6	+3.0	7.6
14200	7/13/73	-6.7	4.9	+3.3	8.2

non-equilibrium drawdown condition around a pumping well. A non-equilibrium pumping condition means that the maximum drawdown by the pump has not been attained or that a water table condition exists. In its simplest form, the Theis formula is:

$$s = \frac{114 \cdot Q\, W(\mu)}{T}$$

where

s = drawdown, in ft. at any point in the vicinity of a well discharging at a constant rate

Q = pumping rate, in gallons per minute

T = coefficient of transmissibility of the aquifer, in gallons per day per foot

W(μ) = the "well function of μ"

W(μ) is a short form for the following integral:

$$\int_{1.87r^2S/T}^{\infty} \frac{e^{-\mu}}{u}\, d\mu = W(\mu) = -0.5772 - \log_e \mu + \mu - \frac{\mu^2}{2 \cdot 2!} + \frac{\mu^3}{3 \cdot 3!} \ldots$$

In the above equation, $\mu = 1.87r^2s/Tt$

where

r = distance, in feet, from the center of the pumped well to the point where drawdown is measured

S = coefficient of storage, this is dimensionless

T = coefficient of transmissibility, in gpd per ft.

t = time since pumping started, in days

In order to determine the T and s of an aquifer, Theis developed a graphical method of solution if values of the other terms are known, which in this case they are.

This method involves matching a curve plotted from specific pumping test data with what is called a type curve. The type curve is prepared by plotting calculated values of $W(\mu)$ against $1/\mu$ on graph paper with logarithmic scales. Data which were generated from the pumping test were plotted on similar graph paper with logarithmic scales and cycles identical to those of the type curve.

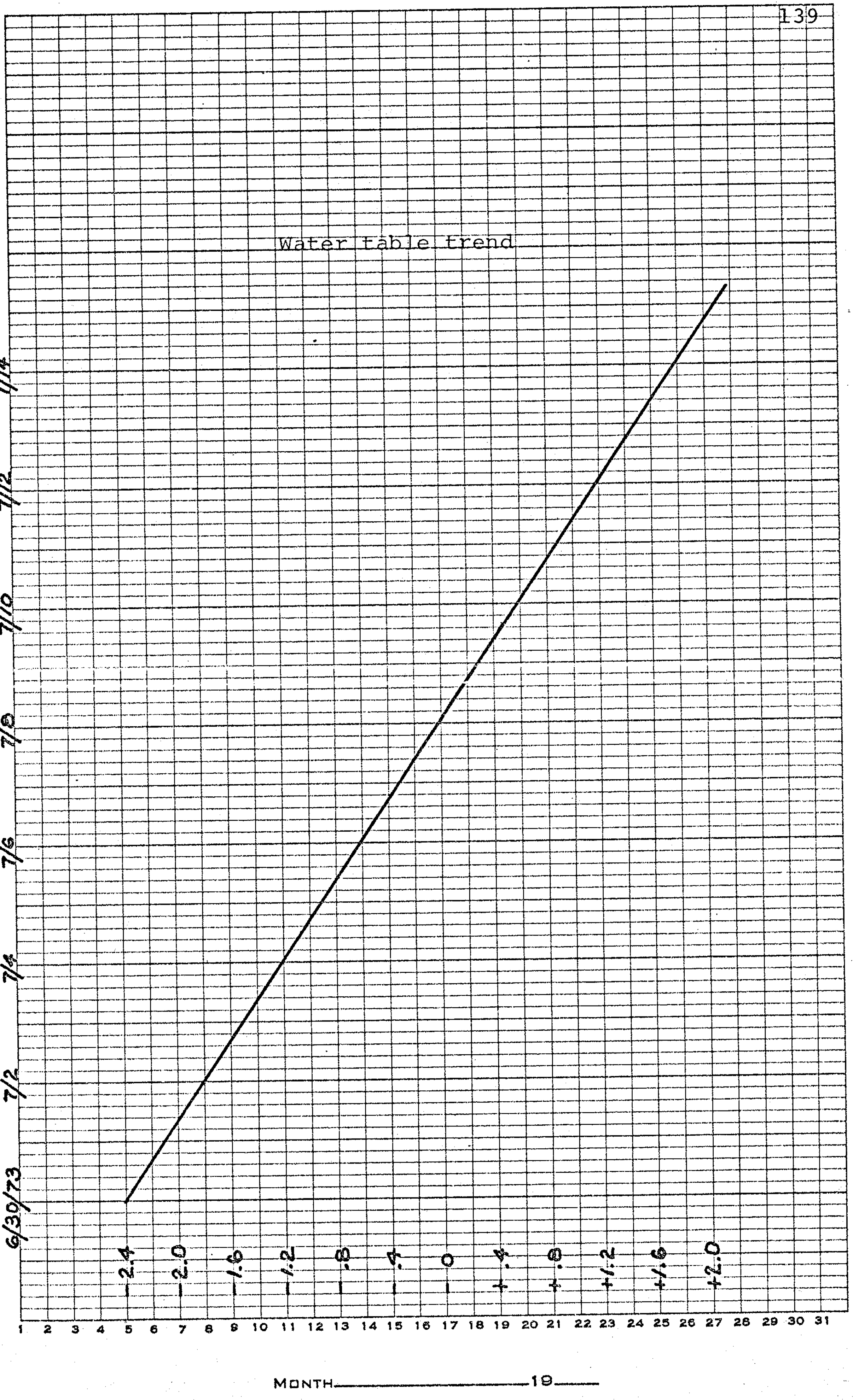
The test data in this case were plotted on a graph with the vertical axis representing the drawdown and the horizontal axis representing the time since pumping started. The curve of the data which then results is superimposed on the type curve so that the data curve matches a portion of the type curve. Once this alignment takes place, a match point is selected. The values of the match point on both curves are recorded. In this case, values for s, t, $W(\mu)$ and $1/\mu$ were found.

With these values of s, t, $W(\mu)$ and μ, and knowing Q and the distance of the observation well and thickness of the aquifer, the values of S and T can be determined by simultaneous solution of the following equations:

$$T = \frac{114.6\ Q\ W(\mu)}{s}$$

$$S = T\mu t/2693r^2$$

Appendix G. (Contd.)



Appendix G. (Contd.)

From the match points, the equations become:

$$T = \frac{1.14 \times 10^{2} \times 4.5 \times 10^{2} \times 1}{4.7}$$

$$T = 10{,}960 \text{ gpd/ft.}$$

$$S = \frac{1.096 \times 10^{4} \times 10^{-1} \times 1.7 \times 10^{-1}}{2.693 \times 10^{3} \times 6.6 \times 6.6 \times 10^{4}}$$

$$S = .0162$$

K = permeability = T/m   m = aquifer thickness

$$K = 10{,}960/25 = 438 \text{ gpd/ft.}^{2}$$

Appendix H.

Digital Computer Model

As stated before, an attempt was made to model, by digital computer techniques, the shallow aquifer around the medical complex construction site. The model was formulated by T. A. Prickett and C. G. Lonnquist and explained in Illinois State Water Survey Bulletin 55.

In this appendix is the computer format for the model which was used. This model is set up to investigate the following situation: variable pumping, water table condition.

At this point, if an individual would desire an in-depth analysis of the model, they are referred to the previously mentioned bulletin. The basic flow equation which is modified and massaged for these purposes is the partial differential equation governing the non-steady state, two-dimensional flow of groundwater in an artesian, non-homogeneous, and isotropic aquifer. That equation is:

$$\partial/\partial x\ (T\partial h/\partial x) + \partial/\partial y\ (T\partial h/\partial y) = S\partial h/\partial t + Q$$

where

T = aquifer transmissibility

h = head

t = time

S = aquifer storage coefficient

Q = net groundwater withdrawal rate per unit area

x,y = rectangular coordinates

The above equation has no general solution; however, a numerical solution of that equation can be obtained through a finite difference approach.

Basically, what is done is that the aquifer under consideration is divided into cells by laying a grid system over the aquifer. The flow equations for each cell can be solved by finite difference methods. By solving the finite difference equations many times for each cell of the grid, a final solution for the entire system can be achieved.

The computer is an excellent tool for solving such a problem. It can solve the many equations involved in just a matter of minutes.

On this grid system, the pumping wells can be located and then their effects on the water table can be seen at the nodes of the grid system. If this model could have been set up properly, then it would have been possible to see how the proposed sump pumps for the medical complex would have impacted the water table on the west end of the study area.

Appendix H. Program Output for Computer Model.

```
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$LIBASGN FORGO
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      C
      C
      C
      C    BASIC AQUIFER SIMULATION PROGRAM                               0001
      C    WITH WATER-TABLE CONDITIONS                                    0002
      C    AND ALSO MODIFIED FOR VARIABLE PUMPAGE AND
      C    AND LEAKY ARTESIAND CONDITIONS
      C                                                                   0003
      C                                                                   0004
      C    DEFINITION OF VARIABLES                                        0005
      C                                                                   0006
      C    HH(I,J)-----HEADS AT START OF TIME                             0007
      C                INCREMENT (I,J)                                    0008
      C    H(I,J)------HEADS AT END OF TIME                               0009
      C                INCREMENT (FT)                                     0010
      C    SF1(I,J)----STORAGE FACTOR FOR WATER-                          0011
      C                TABLE CONDITIONS (GAL/FT)                          0012
      C    Q(I,J)------CONSTANT WITHDRAWAL                                0013
      C                RATES (GPD)                                        0014
      C    T(I,J,1)----AQUIFER TRANSMISSIVITY                             0015
      C                BETWEEN I,J AND I,J+1                              0016
      C                (GAL/DAY/FT)                                       0017
      C    T(I,J,2)----AQUIFER TRANSMISSIVITY                             0018
      C                BETWEEN I,J AND I+1,J                              0019
      C                (GAL/DAY/FT)                                       0020
      C    AA,BB,CC,DD-COEFFICIENTS IN WATER                              0021
      C                BALANCE EQUATIONS                                  0022
      C    NR-----------NO. OF ROWS IN MODEL                              0023
      C    NC-----------NO. OF COLUMNS IN MODEL                           0024
      C    NSTEPS-------NO. OF TIME INCREMENTS                            0025
      C    DELTA--------TIME INCREMENTS (DAYS)                            0026
      C    HH,S2,Q2,TT-DEFAULT VALUES                                     0027
      C    I------------MODEL COLUMN NUMBER                               0028
      C    J------------MODEL ROW NUMBER                                  0029
      C    PERM(I,J,1)-AQUIFER PERMEABILITY                               0030
      C                BETWEEN I, J AND I, J+1                            0031
      C                (GAL/DAY/SQ FT)                                    0032
      C    PERM(I,J,2)-AQUIFER PERMEABILITY                               0033
      C                BETWEEN I, J AND I+1, J                            0034
      C                (GAL/DAY/SQ FT)                                    0035
      C    BOT(I,J)----ELEVATION OF BOTTOM OF                             0036
      C                AQUIFER (FT)                                       0037
      C    R(I,J)------RECHARGE FACTOR                                    0022
      C                (GAL/DAY/FT)                                       0023
      C    RH(I,J)-----ELEVATION OF WATER                                 0024
      C                LEVEL IN SOURCE                                    0025
      C                BED (FT)                                           0026
      C    IP-----------I COORDINATE OF PUMP                              0035
      C    JP-----------J COORDINATE OF PUMP                              0036
      C    P(I,KC)------PUMPING RATE AT WELL                              0037
      C                I AT RATE KC (GPD)                                 0038
      C    NP-----------NUMBER OF PUMPS                                   0039
      C    NS-----------NUMBER OF TIME INCREMENTS                         0040
      C                PER PUMPAGE CHANGE                                 0041
```

Appendix H. (Contd.)


```
C       NRT----------NUMBER OF RATES IN                              0042
C                    PUMPING SCHEDULE                                0043
C                                                                    0038
C                                                                    0039
C                                                                    0040
C                                                                    0041
        INTEGER OUT                                                  0054
        DIMENSION H(25,25),HO(25,25),
       1SF2(25,25),Q(25,25),T(25,25,2),
       2B(25),S(25),DL(25,25),R(25,25),
       3RH(25,25),IP(100),JP(100),P(100,12)
       3,PERM(25,25,2),BOT(25,25)
C                                                                    0046
C       TURN OFF UNDERFLOW TRAP                                      0047
C                                                                    0048
C                                                                    0050
C       DEFINE INPUT AND OUTPUT DEVICE NUMBERS                       0051
C                                                                    0052
        IN=5                                                         0055
        OUT=6                                                        0056
C                                                                    0057
C       READ PARAMETER CARD AND                                      0058
C       DEFAULT VALUE CARD                                           0059
C                                                                    0060
        READ(IN,10)NSTEPS,DELTA,ERROR,                               0061
       1NC,NR,TT,HH,QQ,RR,RRH,S2,PP,BUTT
 10     FORMAT(I6,2F6.0/2I6,1F6.0,6X,5F6.0,6X,2F6.0)
C       READ PUMP PARAMETER CARD                                     0070
C                                                                    0071
        READ(IN,11) NP,NSP,NRT                                       0072
 11     FORMAT(3I6)                                                  0073
C                                                                    0074
C       READ PUMPING SCHEDULES                                       0075
C                                                                    0076
        DO 12 I=1,NP                                                 0077
 12     READ(IN,13) IP(I),JP(I),                                     0078
       1(P(I,K),K=1,NRT)                                             0079
 13     FORMAT(2I3,12F6.0)                                           0080
C                                                                    0065
C       FILL ARRAYS WITH DEFAULT VALUES                              0066
C                                                                    0067
        DO 20 I=1,NC                                                 0068
        DO 20 J=1,NR                                                 0069
        SF2(I,J)=S2                                                  0070
        PERM(I,J,1)=PP                                               0071
        PERM(I,J,2)=PP                                               0072
        BOT(I,J)=BUTT                                                0073
        R(I,J)=RR
        RH(I,J)=RRH
        T(I,J,1)=TT                                                  0074
        T(I,J,2)=TT                                                  0075
        H(I,J)=HH                                                    0076
        HO(I,J)=HH                                                   0077
 20     Q(I,J)=QQ                                                    0078
C                                                                    0079
C       READ NODE CARDS                                              0080
C                                                                    0081
 30     READ(5,40,END=50)I,J,T(I,J,1),                               0082
       1T(I,J,2),H(I,J),Q(I,J),R(I,J),RH(I,J),SF2(I,J),
```

```
          2PERM(I,J,1),PERM(I,J,2),BOT(I,J)
   40     FORMAT(2I3,2F6.0,4X,1F4.0,3F6.0,
         *6X,1F6.0,6X,3F6.0)
          GO TO 30                                       0086
    C                                                    0087
    C     START OF SIMULATION                            0088
    C                                                    0089
   50     TIME=0                                         0090
          DEL=DELTA                                      0103
          KC=1                                           0104
          DO 320 ISTEP=1,NSTEPS                          0091
    C                                                    0106
    C     ENTER PUMPAGE SCHEDULES                        0107
    C                                                    0108
          Z= ISTEP-1.0)/NSP+1.0                          0109
*****                 $                                  WARNING -- DATA TYPES MIXED
*****                                                    WARNING -- DATA TYPES MIXED
          IF(Z-KC)53,51,53                               0110
*****           $                                        WARNING -- DATA TYPES MIXED
   51     DO 52 K=1,NP                                   0111
          I=IP(K)                                        0112
          J=JP(K)                                        0113
   52     Q(I,J)=P(K,KC)                                 0114
          DELTA=DEL                                      0115
          KC=KC+1                                        0116
    C                                                    0093
    C     PREDICT HEADS FOR NEXT                         0094
    C     TIME INCREMENT                                 0095
    C                                                    0096
   53     DO 70 I=1,NC
          DO 70 J=1,NR
          D=H(I,J)-HO(I,J)                               0099
          HO(I,J)=H(I,J)                                 0100
          F=1.0                                          0101
          IF(DL(I,J).EQ.0.0)GO TO 60                     0102
*****                  $                                 WARNING -- CHECKING EQUALITY BETWEEN NON-INTEGERS
          IF(ISTEP.GT.2)F=D/DL(I,J)                      0103
          IF(F.GT.5)F=5.0                                0104
          IF(F.LT.0.0)F=0.0                              0105
   60     DL(I,J)=D                                      0106
          H(I,J)=H(I,J)+D*F                              0107
   70     IF(H(I,J).LE.BOT(I,J))H(I,J)=BOT(I,J)+0.01     0108
    C                                                    0109
    C     REFINE ESTIMATES OF HEADS BY IADI METHOD       0110
    C                                                    0111
          TIME=TIME+DELTA                                0092
          ITER=0                                         0112
   80     E=0.0                                          0113
          ITER=ITER+1                                    0114
    C                                                    0115
    C     TRANSMISSIVITY CONTROL                         0116
    C                                                    0117
          DO 83 I=1,NC                                   0118
          DO 83 J=1,NR                                   0119
          IF(I.LT.NC)T(I,J,2)=PERM(I,J,2)*SQRT((H(I,J)-  0120
         1BOT(I,J))*(H(I+1,J)-BOT(I+1,J)))               0121
   83     IF(J.LT.NR)T(I,J,1)=PERM(I,J,1)*SQRT((H(I,J)-  0122
         1BOT(I,J))*(H(I,J+1)-BOT(I,J+1)))               0123
```

```
FORGO      VERSION: NOVEMBER 1972                    DATE: 03/19/74     IDEN: 2795      PAGE: 004
C
C     COLUMN CALCULATIONS
C
      DO 190 II=1,NC
      I=II
      IF (MOD(ISTEP+ITER,2).EQ.1) I=NC-I+1
      DO 170 J=1,NR
C
C     CALCULATE B AND G ARRAYS
C
      BB=SF2(I,J)/DELTA
      DD=HO(I,J)*SF2(I,J)/DELTA-Q(I,J)+
     1RH(I,J)*P(I,J)
      AA=0.0
      CC=0.0
      IF(J-1)90,100,90
90    AA=-T(I,J-1,1)
      BB=BB+T(I,J-1,1)
100   IF(J-NR)110,120,110
110   CC=-T(I,J,1)
      BB=BB+T(I,J,1)
120   IF(I-1)130,140,130
130   BB=BB+T(I-1,J,2)
      DD=DD+H(I-1,J)*T(I-1,J,2)
140   IF(I-NC)150,160,150
150   BB=BB+T(I,J,2)
      DD=DD+H(I+1,J)*T(I,J,2)
160   W=BB-AA*B(J-1)
      B(J)=CC/W
170   G(J)=(DD-AA*G(J-1))/W
C
C     RE-ESTIMATE HEADS
C
      E=E+ABS(H(I,NR)-G(NR))
      H(I,NR)=G(NR)
      N=NR-1
180   HA=G(N)-B(N)*H(I,N+1)
      E=E+ABS(HA-H(I,N))
      H(I,N)=HA
      N=N-1
      IF(N.GT.0)GO TO 180
      DO 190 N=1,NR
      IF(H(I,N).G .BOT(I,N))GO TO 190
      E=E+BOT(I,N)+0.01-H(I,N)
      H(I,N)=BOT(I,N)+0.01
190   CONTINUE
C
C     TRANSMISSIVITY CONTROL
C
      DO 193 J=1,NR
      DO 193 I=1,NC
      IF (I.LT.NC) T(I,J,2)=PERM(I,J,2)*SQRT((H(I,J)-
     1BOT(I,J))*(H(I+1,J)-BOT(I+1,J)))
193   IF (J.LT.NR)T(I,J,1)=PERM(I,J,1)*SQRT((H(I,J)-
     1BOT(I,J))*(H(I,J+1)-BOT(I,J+1)))
C
C     RB CALCULATIONS
```

```
C
      DO 300 J=1,NR
      J=JJ
      IF(MOD(ISTEP+ITER,2).EQ.1) J=NR-J+1
      DO 280 I=1,NC
      BB=SF2(I,J)/DELTA
      DD=H(I,J)*SF2(I,J)/DELTA-Q(I,J)+
     1R(I,J)*R(I,J)
      AA=0.0
      CC=0.0
      IF(J-1)200,210,200
  200 BB=BB+T(I,J-1,1)
      DD=DD+H(I,J-1)*T(I,J-1,1)
  210 IF(J-NR)220,230,220
  220 DD=DD+H(I,J+1)*T(I,J,1)
      BB=BB+T(I,J,1)
  230 IF(I-1)240,250,240
  240 BB=BB+T(I-1,J,2)
      AA=-T(I-1,J,2)
  250 IF(I-NC)260,270,260
  260 BB=BB+T(I,J,2)
      CC=-T(I,J,2)
  270 W=BB-AA*B(I-1)
      B(I)=CC/W
  280 G(I)=(DD-AA*G(I-1))/W
C
C     RE-ESTIMATE HEADS
C
      E=E+ABS(H(NC,J)-G(NC))
      H(NC,J)=G(NC)
      N=NC-1
  290 HA=G(N)-B(N)*H(N+1,J)
      E=E+ABS(H(N,J)-HA)
      H(N,J)=HA
      N=N-1
      IF(N.GT.0)GO TO 290
      DO 300 N=1,NC
      IF(H(N,J).GT.BOT(N,J))GO TO 300
      E=E+BOT(N,J)+0.01-H(N,J)
      H(N,J)=BOT(N,J)+0.01
  300 CONTINUE
C
C     PRINT RESULTS
      IF(E.GT.ERROR) GO TO 80
C
      WRITE(OUT,310)TIME,E,ITER
  310 FORMAT(6H2TIME=,F6.2///,E20.7,I5)
      DELTA=DELTA*1.2
      DO 320 J=1,NR
  320 WRITE(OUT,330)J,(H(I,J),I=1,NC)
  330 FORMAT(I5,5X,10F10.4/(12X10F10.4))
C
      STOP
      END
```

Appendix I. Chemical Analysis of Groundwater Samples.

WELL # 31

DATE

	3/10/73	6/1/73	6/22/73	7/18/73	8/11/73	9/21/73	11/21/73	12/31/73	1/24/74
K				41.7	11.6	10.0			6.5
Na				59.0	24.3	24			22.4
Ca				84.4	32.0	23.2			12.9
Mg				70.4	32.9	24.7			22.3
NH_4-N				12.03	3.95	3.30			2.70
NO_3-N				1.14	0.01	0.01			0.15
Org. N				3.59	1.09	0.72			0.68
PO_4-P				0.01	0.01	0.01			0.02
SO_4S				67.5	25.8	21.6			20.0
Cl^-				45.8	17.4	17.1			11.5

** All measurements in ppm.

WELL # 38

DATE

	3/10/73	6/1/73	6/22/73	7/18/73	8/14/73	9/21/73	11/21/73	12/31/73	1/24/74
K							6.7	3.4	3.0
Na							18.6	14.2	12.7
Ca							100.0	160.4	153.8
Mg							60.0	63.1	63.1
NH_4-N							0.04	0.01	0.09
NO_3-N							0.01	0.01	0.01
Org. N							0.16	0.36	0.17
PO_4-P							0.02	0.02	0.02
SO_4S							121.0	104.0	109.0
Cl^-							133.5	98.2	67.2

** All measurements in ppm.

WELL #25

	DATE								
	3/10/73	6/1/73	6/22/73	7/18/73	8/14/73	9/21/73	11/21/73	12/31/73	1/24/74
K							15.7	5.9	
Na							79.5	46.5	
Ca							71.8	87.8	
Mg							100.0	102.3	
NH_4-N							6.06	1.55	
NO_3-N							0.41	0.13	
Org. N							1.18	0.81	
PO_4-P							0.02	0.02	
SO_4S							197.0	112.0	
Cl^-							249.5	206.0	

** All measurements in ppm.

Appendix I. (Contd.)

WELL #29

	DATE								
	3/10/73	6/1/73	6/22/73	7/18/73	8/14/73	9/21/73	11/21/73	12/31/73	1/24/74
K							5.2	3.9	3.2
Na							11.6	11.1	10.1
Ca							17.0	24.8	26.0
Mg							14.7	22.3	20.0
NH_4-N							1.13	0.84	0.71
NO_3-N							0.32	0.02	0.01
Org. N							0.33	0.56	0.49
PO_4-P							0.02	0.02	0.02
SO_4S							12.4	10.6	8.3
Cl^-							17.5	17.2	15.5

** All measurements in ppm.

Appendix I. (Contd.)

WELL # 20

	DATE								
	3/10/73	6/1/73	6/22/73	7/18/73	8/14/73	9/21/73	11/21/73	12/31/73	1/24/74
K							2.7		2.5
Na							15.3		14.9
Ca							12.0		10.8
Mg							32.6		34.9
NH_4-N							0.21		0.01
NO_3-N							0.01		0.01
Org. N							0.57		1.34
PO_4-P							0.02		0.02
SO_4S							21.2		20.0
Cl^-							44.6		43.1

** All measurements in ppm.

Appendix I. (Contd.)

WELL # 15

DATE

	3/10/73	6/1/73	6/22/73	7/18/73	8/14/73	9/21/73	11/21/73	12/31/73	1/24/74
K							3.0	3.4	3.4
Na							89.0	83.0	77.6
Ca							12.0	13.5	14.3
Mg							14.7	20.9	22.3
NH_4-N							1.17	0.87	0.66
NO_3-N							0.12	0.04	0.01
Org. N							0.53	0.57	0.68
PO_4-P							0.02	0.02	0.02
SO_4S							5.9	3.2	5.0
Cl^-							31.9	39.3	44.7

** All measurements in ppm.

Appendix I. (Contd.)

WELL # 14

	DATE								
	3/10/73	6/1/73	6/22/73	7/18/73	8/14/73	9/21/73	11/21/73	12/31/73	1/24/74
K							3.9		3.4
Na							17.9		17.9
Ca							14.3		13.4
Mg							17.3		11.1
NH_4-N							7.95		7.95
NO_3-N							0.52		0.61
Org. N							0.89		1.41
PO_4-P							0.02		0.02
SO_4S							7.2		7.2
Cl^-							3.7		3.5

** All measurements in ppm.

WELL #10

	DATE									
	3/10/73	6/1/73	6/22/73	7/18/73	8/14/73	9/21/73	11/21/73	12/31/73	1/24/74
K							1.3	1.3	1.5
Na							6.3	7.0	7.3
Ca							41.4	44.8	49.0
Mg							25.7	31.0	31.0
NH_4-N							0.39	0.01	0.01
NO_3-N							0.01	0.01	0.01
Org. N							0.31	0.52	0.56
PO_4-P							0.02	0.02	0.02
SO_4 S							7.4	2.5	1.7
Cl^-							19.7	20.5	16.6

** All measurements in ppm.

WELL # 28

DATE

	3/10/73	6/1/73	6/22/73	7/18/73	8/14/73	9/21/73	11/21/73	12/31/73	1/24/74
K					1.6		1.3	1.3	1.3
Na					9.9		10.8	11.1	10.1
Ca					33.0		12.0	8.6	9.2
Mg					32.9		24.6	23.4	27.8
NH_4-N					0.01		0.01	0.01	0.01
NO_3-N					0.01		0.01	0.01	0.01
Org. N					0.22		0.26	0.22	0.36
PO_4-P					0.01		0.02	0.02	0.02
SO_4S					21.4		13.6	8.0	10.4
Cl^-					9.5		13.7	1.7	2.2

** All measurements in ppm.

WELL # 26

	DATE								
	3/10/73	6/1/73	6/22/73	7/18/73	8/14/73	9/21/73	11/21/73	12/31/73	1/24/74
K		1.8	2.2			1.8			
Na		19.6	15.0			13.6			
Ca		40.0	30.9			10.3			
Mg		52.2	46.3			17.0			
NH_4-N		0.05	0.05			0.15			
NO_3-N		0.01	0.01			0.02			
Org. N		1.00	1.59			0.01			
PO_4-P		0.01	0.01			0.01			
SO_4S		43.0	29.0			13.1			
Cl^-		27.5	19.6			13.0			

** All measurements in ppm.

WELL # 2

	DATE								
	3/10/73	6/1/73	6/22/73	7/18/73	8/14/73	9/21/73	11/21/73	12/31/73	1/24/74
K	8.0	2.2	2.2	2.6	3.1	2.6	2.5	3.0	2.3
Na	63.8	95.8	93.5	112.0	110.0	114.9	100.0	105.0	107.3
Ca	49.1	42.0	44.4	44.2	49.9	41.6	36.0	30.2	31.2
Mg	26.6	36.2	47.1	38.0	40.0	42.2	38.8	34.2	38.7
NH_4-N	0.06	0.21	0.41	0.35	0.41	0.43	0.65	0.99	0.66
NO_3-N	0.04	0.01	0.01	0.01	0.01	0.01	0.05	0.01	0.01
Org. N	0.42	1.37	0.95	0.95	1.01	0.71	0.45	0.50	0.48
PO_4-P	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
SO_4-S	13.7	8.7	11.5	13.5	20.2	18.7	16.3	11.1	14.2
Cl^-	74	64.8	87.3	90.6	81.2	89.6	100.0	96.6	89.6

** All measurements in ppm.

Appendix I. (Contd.)

WELL # 8

DATE

	3/10/73	6/1/73	6/22/73	7/18/73	8/14/73	9/21/73	11/21/73	12/31/73	1/24/74
K	7.8	7.6	7.6	7.4	8.0	8.0	6.7	6.7	6.3
Na	24.0	25.0	24.1	20.0	21.4	21.7	21.7	27.0	29.3
Ca	39.7	29.0	38.7	43.7	46.1	46.0	45.6	47.8	48.7
Mg	25.0	33.1	36.3	28.8	29.6	30.4	30.0	28.9	30.9
NH_4-N	0.20	3.88	3.60	3.54	3.70	3.43	3.38	3.19	3.02
NO_3-N	0.09	0.02	0.02	0.01	0.18	0.01	0.26	0.27	0.24
Org. N	3.82	6.10	1.52	1.26	0.71	0.01	0.60	0.79	0.80
PO_4-P	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
SO_4S	2.4	0.6	0.6	1.8	4.2	3.8	4.0	1.1	5.2
Cl^-	479	53.7	75.2	87.4	95.0	96.6	103.3	95.4	84.8

** All measurements in ppm.

Appendix I. (Contd.)

WELL #22

	DATE								
	3/10/73	6/1/73	6/22/73	7/18/73	8/14/73	9/21/73	11/21/73	12/31/73	1/24/74
K	6.4	3.9	5.1	4.2	3.7				
Na	18.6	13.0	13.0	13.0	11.8				
Ca	75.0	52.3	51.4	75.5	73.5				
Mg	47.1	52.2	50.2	45.3	45.1				
NH_4-N	0.01	0.01	0.01	0.01	0.01				
NO_3-N	1.63	0.01	0.01	0.01	0.01				
Org. N	0.74	0.82	1.60	1.08	0.62				
PO_4-P	0.01	0.01	0.01	0.01	0.01				
SO_4S	71.5	52.0	51.0	48.0	51.6				
Cl^-	293	23.2	25.5	24.3	24.0				

** All measurements in ppm.

WELL # 32

	DATE								
	3/10/73	6/1/73	6/22/73	7/18/73	8/14/73	9/21/73	11/21/73	12/31/73	1/24/74
K						37.6		46.4	
Na						57.5		61.5	
Ca						134.2		168.0	
Mg						72.0		89.8	
NH_4-N						26.37		39.02	
NO_3-N						1.19		4.09	
Org. N						4.01		5.50	
PO_4-P						0.01		0.02	
SO_4S						---		----	
Cl^-						168.0		149.0	

** All measurements in ppm.

Appendix I. (Contd.)

WELL # 21

DATE

	3/10/73	6/1/73	6/22/73	7/18/73	8/14/73	9/21/73	11/21/73	12/31/73	1/24/74
K	17.5	6.3	5.1	28.4					
Na	41.4	26.7	23.0	45.5					
Ca	46.1	21.5	23.4	51.8					
Mg	38.2	23.7	23.5	53.2					
NH_4-N	3.95	5.96	5.61	14.00					
NO_3-N	0.64	0.70	0.53	0.71					
Org. N	6.95	1.36	1.19	3.78					
PO_4-P	0.01	0.01	0.01	0.01					
SO_4-S	5.1	9.0	6.3	6.8					
Cl^-	295	25.3	18.7	43.2					

** All measurements in ppm.

THE GEOLOGY AND HYDROGEOLOGY

OF

UNIVERSITY BAY

MADISON, WISCONSIN

Approved:

David A. Stephenson 7-25-75

David A. Stephenson Date