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WATER-LEVEL FLUCTUATIONS OF LAKES IN FLORIDA

by G.H. Hughes

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INTRODUCTION

The fresh-water lakes of Florida are of importance not only because they constitute sources of water supply but also because they provide countless and diverse opportunities for camping, fishing, boating, swimming, and other types of outdoor recreation.

Unfortunately, the various recreational uses of lakes are not entirely compatible and, also, they may conflict with other established lake uses. Furthermore, intensive use of lakes for any purpose generally leads to deterioration. Thus, protection of public and private interests alike requires some degree of control and management of the water quality and level of lakes.

Wise and effective management of lakes in turn requires knowledge of lake hydrology. The purpose of this report is to promote the under standing of lake hydrology, particularly as it pertains to the nature and causes of lake-level fluctuations. The chemical and biological condition of lakes is closely related to the hydrology of lakes, but for the sake of brevity is not discussed.

DISTRIBUTION OF LAKES AND LAKE-LEVEL MEASUREMENT STATIONS

The fresh-water lakes of Florida are plentiful and generally well distributed within the State. A recent tabulation (Florida Board of Conservation, 1969) lists 7,712 fresh-water lakes in Florida, including all lakes named on topographic maps of the U.S. Geological Survey and unnamed lakes having surface areas of 10 acres or more. Most of the lakes cover less than 100 acres, about half of these less than 20 acres; 930 lakes have surface areas greater than 100 acres and 115 have surface areas greater than 1,000 acres. The largest, Lake Okeechobee, covers 436,000 acres. Although about 35 percent of the lakes are in 4 counties–Osceola, Orange, Lake, and Polk–12 counties each have more than 200 lakes and only 15 counties have less than 30 lakes. The number of lakes listed for each county of Florida is shown on the State map.

The U.S. Geological Survey has recorded lake-level fluctuations at some of the important lakes in Florida for many years, in cooperation with State, local, and other Federal governmental agencies. As of 1972 lake-level records were being collected at 160 lakes. Included in this total are both meandered and non-meandered lakes. A meandered lake is one whose approximate shoreline was established by a series of survey lines in the original land survey of Florida. All navigable lakes were supposed to be included in the survey but only about 200 of the many lakes considered navigable were surveyed. Responsibility for managing the bottom lands of the meandered lakes rests with the Trustees of the Internal Improvement Trust Fund. Through a cooperative agreement between that agency and the U.S. Geological Survey, lake-level records as of 1972 were being obtained at 72 meandered lakes including most of the large ones.

Records for some lakes in central Florida begin in the late 20's and early 30's; for example, that for Lake Kissimmee begins in 1929 and for Lake Okeechobee in 1931. Records spanning 20 years or more are available for several lakes throughout the State. Continuous water- level recorders are operated at some of the lakes; daily, weekly, or less frequent observations are made at others. Over the years lake- level records have been discontinued at about 100 lakes.

MAGNITUDE OF OBSERVED LAKE-LEVEL FLUCTUATIONS

Between significant wet and dry spells, the range of fluctuation in level varies greatly among lakes: as small as 2 feet for some lakes, more than 30 feet for others. About 80 percent fluctuate 5 feet or more as indicated in figure 1.

Levels of lakes connected by a throughgoing stream tend to fluctuate together but the range of fluctuation may differ significantly. Since 1935 the fluctuation in level of a group of large lakes on the Oklawaha River has ranged from 4 feet at Lake Griffin to 6 feet at Lake Eustis. Since 1942 the maximum fluctuation in level of lakes on the main stem of the Kissimmee River has ranged from 9.2 feet at Lake Cypress to 12.4 feet at Lake Kissimmee. Several other lakes connected to the Kissimmee River by lateral streams or canals fluctuate in levels less than 5 feet. The difference in the magnitude of lake-level fluctuations is marked in a chain of lakes on a small creek in Clay County where since 1957 the fluctuation in level has ranged from only 2 feet at Sand Hill Lake to 10.2 feet at Brooklyn Lake.

Levels of lakes in the same general area often fluctuate together, even though they are not connected by a throughgoing stream, but again the range of fluctuation may differ significantly. Pebble Lake and Kingsley Lake in Clay County are only about 10 miles apart in what appears to be similar terrane. Yet since 1945 the range of fluctuation in level of Pebble Lake is about 10 times greater than the range for Kingsley Lake, as indicated in figure 2.

CAUSES OF LAKE-LEVEL FLUCTUATIONS

An understanding of lake-level fluctuations, and of why they may differ in magnitude so greatly for nearby lakes, is best obtained from consideration of the hydrologic system of a lake. The elements of such a system are portrayed by the diagram in figure 3 for two types of lakes that are common in Florida.

The hydrologic system of a lake involves rainfall, evaporation, runoff, and the interchange of water between the lake and one or more aquifers. In Florida two types of aquifers generally are involved: an unconfined aquifer and a confined aquifer. The confined aquifer is recharged by downward leakage from the unconfined aquifer and from lakes and streams, and directly from rainfall in instances where part of the aquifer is exposed at the land surface. A confining bed of relatively impermeable material maintains the water of the confined aquifer under pressure generated by the level of water in areas where the aquifer is recharged. The water of the confined aquifer is discharged in areas where the confining bed is breached or fractured and where the static head of water in the confined aquifer is above land surface. The static head of water in an aquifer is represented by the potentiometric surface, which is defined by the levels to which water will rise in tightly cased wells penetrating the aquifer. The water table is the potentiometric surface of an unconfined aquifer.

The distinguishing features of the two types of lakes shown in figure 3 are as follows: Lake A represents a landlocked lake in an area where recharge of the confined aquifer occurs. The level of lake A is above the potentiometric surface of the confined aquifer. Thus, given the required opening in the confining beds, water moves downward from lake A into the confined aquifer. On the other hand, lake B represents a lake with a surface outlet in an area where discharge from the confined aquifer occurs. The level of lake B is below the potentiometric surface of the confined aquifer. Thus, given the required opening in the confining bed, water moves upward into lake B from the confined aquifer.

Lake-level fluctuations are the net effect of factors that cause the lake level to rise and factors that cause the lake level to decline. Factors that cause the lake level to rise are related to rainfall, the source of water for all fresh-water lakes in Florida. Part of the lake water comes directly from rainfall on the lake and part comes from surface- and ground-water inflow derived from rainfall on the drainage basin of the lake. The extent of the lake-level rise varies with the size of the lake and the magnitude of the inflow.

The magnitude of surface-water inflow varies with the quantity and intensity of rainfall, with the size and slope of the contributing land surface, and with the permeability of the materials beneath the contributing land surface. The magnitude of ground-water inflow varies with the difference in levels of water in the lake and water in the contributing aquifer, and with the hydraulic conductivity of the materials along the path of flow. Ground water may enter the lake from one or more aquifers.

Factors that cause the lake level to decline are evaporation from the lake surface, transpiration by aquatic plants growing in the lake, transpiration by peripheral vegetation that draws part or all its water from the lake, discharge of water through or over the rim of the lake basin, and leakage of water through the lake bottom. The decline in level is more gradual and generally longer lasting than the rise in level.

Lake evaporation occurs continuously but it varies diurnally and seasonally following a cyclic pattern set by solar radiation. Transpiration varies similarly because solar radiation is the source of driving energy for both processes; however, plants do impose some differences. If the plants die or become dormant, as occurs with some species in the winter, transpiration ceases while in Florida evaporation from a water surface continues.

Discharge of water through or over the rim of the lake basin varies with the height of the lake level above the spill level of the outlet and with the size and shape of the outlet. Discharge through the outlet in some instances may be restricted by a control structure. Where the altitude of the banks of the downstream receiving channel is the same as that of the lake rim, discharge of water from the lake can be restricted by the capacity of the receiving channel.

Leakage of water through the lake bottom varies with the difference in levels of water in the lake and water in the receiving aquifer, and with the hydraulic conductivity of materials along the path of flow. Water may leak from the lake to one or more aquifers.

The diagram in figure 3 essentially represents a steady-state condition. In reality such a condition never occurs because the water levels are continually changing and they change at different rates. Rainfall is the source of water for the aquifers as well as for the lakes, as previously stated. Hence, ground-water levels fluctuate in much the same way that lake levels fluctuate. The hydraulic gradients between the water in the lake and water in the different aquifers vary substantially between wet and dry spells and even may reverse. For example, figure 4 shows that at Lake Sherwood in Orange County the lake level remains above the potentiometric surface of the underlying confined aquifer but that the water table near the lake is sometimes above the lake level and sometimes below the lake level. In areas where the difference between the lake level and the potentiometric surface of a confined aquifer is small relative to their ranges of fluctuation, the potentiometric surface may rise from below the lake level during dry periods to above the lake level during wet periods. This condition is portrayed by the graphs in figure 5 for Bay Lake in Orange County. At Bay Lake the water table near the lake generally is slightly above the lake level when the potentiometric surface of the confined aquifer is above the lake level and is slightly below the lake level when the potentiometric surface is below the lake level. The relation between lake and ground-water levels is not always the same on all sides of the lake. At large lakes the potentiometric surface of an underlying confined aquifer may be simultaneously above the lake level on one side of the lake and below the lake level on the other side. A lake also may gain water from the unconfined aquifer on one side of the lake while losing water to the same aquifer on the other side.

WHY LAKE-LEVEL FLUCTUATIONS DIFFER IN MAGNITUDE

The elements that affect lake-level fluctuations–rainfall, evaporation, runoff, for example–may occur uniformly over large areas of Florida, or they may vary locally. It is the spatial variability of the elements that causes lake-level fluctuations to differ in magnitude.

Given similar lake basins in the same hydrologic and geologic setting, differences in the magnitude of lake-level fluctuations owing to the variability of rainfall are generally short term rather than long term. Much of the rainfall in Florida comes from thunderstorms and tropical depressions. The quantity of rainfall from any one storm may differ greatly over a distance of a few miles but the total rainfall from the many such storms that occur over a number of months or years is about evenly distributed. Thus, over the short term the rise in level due to rainfall on the lake–and, also, due to surface- and ground-water inflow generated by the rainfall–may differ substantially for lakes in the same general area; but over the long term the net effect of rainfall is about the same.

Differences in the magnitude of lake-level fluctuations due to variations in evaporation generally are small. The energy available for natural evaporation of water is about uniformly distributed over large parts of Florida. Factors that regulate evaporation–such as wind speed, air temperature, and humidity–and, hence, determine the proportion of the available energy that is dissipated by processes of conduction, radiation, and evaporation, are also nearly uniform over large areas. Thus, the decline in lake levels due to evaporation tends to be about the same for lakes in the same general area. This is especially true for large lakes because their surfaces are exposed to wind movement to about the same degree. For small lakes, however, the degree of exposure to wind movement may differ greatly; hence, evaporation from small lakes may differ appreciably. For example, evaporation from a small lake in a large, flat, and open area would be about the same as evaporation from a large lake in the same general area. However, if the small lake is shielded from wind because it sits low in a sinkhole depression or is surrounded by tall and dense vegetation, evaporation from it might be markedly less than from the large lake.

One of the chief causes of differences in the magnitude of lake- level fluctuations is the variability in permeability of materials beneath the land surface. In combination with the slope of the land surface, the permeability of materials determines the extent to which rainfall runs off the land surface or percolates down to the water table. Other things being equal, a lake that receives water primarily from surface-water inflow will have a greater range of fluctuation than one that receives water primarily from ground-water inflow. The permeability of materials beneath the land surface also determines the extent to which water can leak downward from the lake. In general, the rate of leakage varies directly with the permeability of the materials, and the range of lake-level fluctuations increases with increasing leakage.

Another factor that contributes greatly to differences in the magnitude of lake-level fluctuations is the relation between the lake level and the potentiometric surface of the confined aquifer. Lakes in recharge areas generally fluctuate more widely than do lakes in discharge areas. In hilly terrane, the relation between the lake level and the potentiometric surface can vary greatly over a relatively short distance.

Although the size of a drainage basin is an important factor in determining how much water a lake receives, size alone does not cause differences in the magnitude of lake level fluctuations of different lakes. Given uniform rainfall over similarly shaped lakes and drainage basins in the same hydrologic and geologic setting, areas of lakes would adjust in proportion to drainage areas and the magnitude of lake-level fluctuations would be the same for all lakes regardless of size of the drainage basins. The same conclusion would apply to the size of natural surface outlets because, under the assumed conditions, the flow into and out of the lakes would be proportional to the size of the drainage basins; hence, the size of the surface outlets would adjust by erosion to the outflow from the lakes.

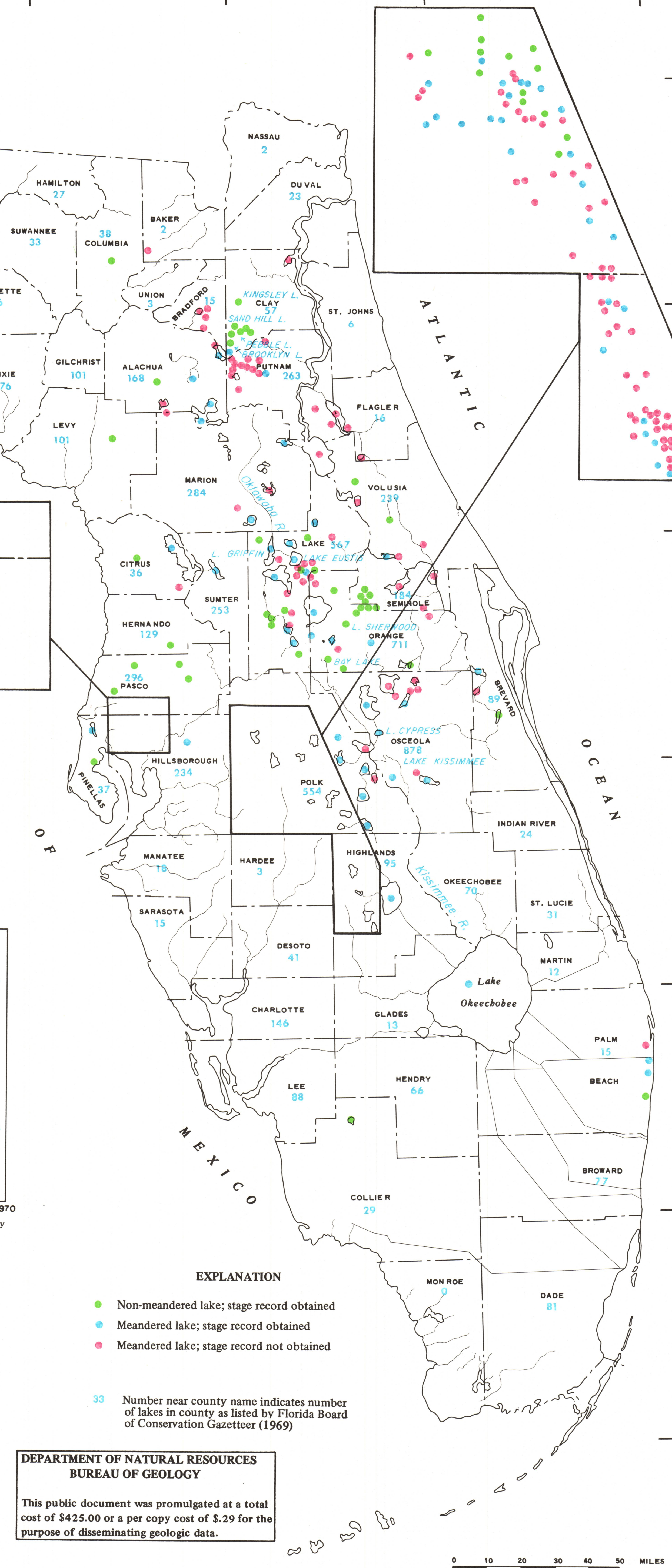
On the other hand, if the size of the natural surface outlet of a lake is increased or decreased, the range of lake-level fluctuations will decrease or increase accordingly. For example, if the surface outlet is decreased in size, the maximum attainable lake level will be higher than before. The minimum lake level attainable is also higher than before, but the increase will be less than for the maximum level because of compensating factors. If the aquifers that contribute water to and receive water from a lake are presumed to be extensive relative to the lake, as they usually are, an independent change in the lake level will not affect the level of water in the aquifers except locally. If the lake level is raised as a result of a change in the lake outlet, therefore, the hydraulic gradient between the lake and the contributing aquifer is decreased, and the hydraulic gradient between the lake and the receiving aquifer is increased. Ground-water inflow to the lake is thereby decreased and ground-water outflow from the lake is thereby increased. Depending on the relative importance of ground-water inflow and outflow in the hydrologic system of the lake, the minimum lake level attained at the end of a drought may or may not be appreciably higher than would have resulted naturally had the lake outlet not been changed.

For any change in the hydrologic system of a lake, a reaction must take place somewhere in the system. Because of the relations and inter-relations that exist between rainfall, runoff, lake levels, and ground-water levels, the hydrologic system of a lake must be adequately defined before effects of changes can be fully evaluated.

SELECTED REFERENCES

U.S. Geological Survey,
Water Resources Data for Florida: Part 1, Vol. 3, Surface water records–lakes 1961-1970.

Florida Board of Conservation,
1969 *Florida lakes, Part 3, Gazetteer:* 145 p.

EXPLANATION

- Non-meandered lake; stage record obtained
- Meandered lake; stage record obtained
- Meandered lake; stage record not obtained

33 Number near county name indicates number of lakes in county as listed by Florida Board of Conservation Gazetteer (1969)

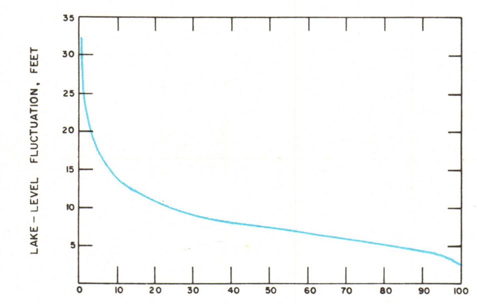


Figure 1.–Cumulative frequency distribution of maximum fluctuation in level of Florida lakes based on records spanning 10 years or more for 110 lakes.

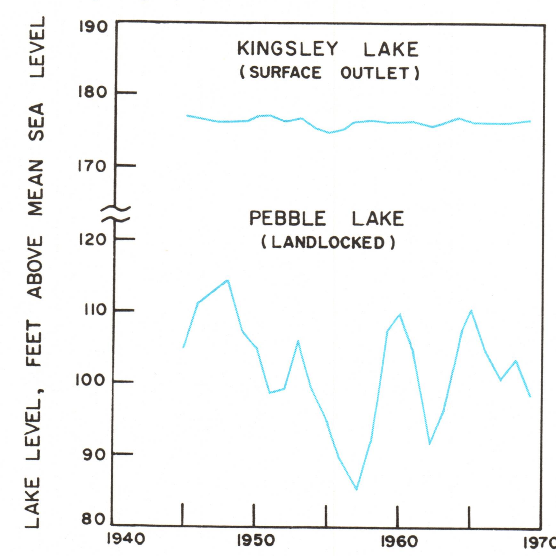


Figure 2.–Contrasting hydrographs of two lakes in Clay County, Florida.

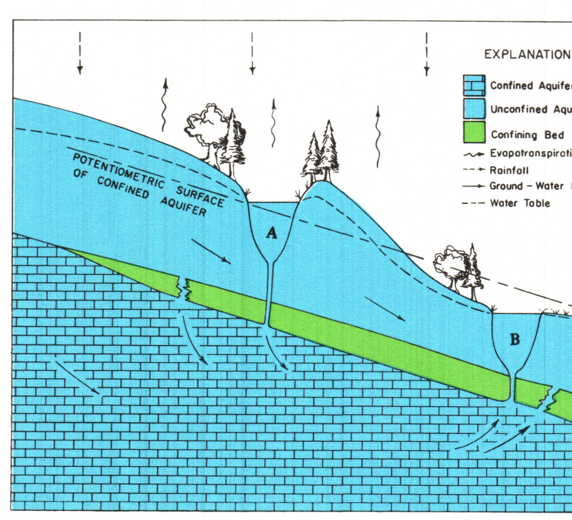


Figure 3.–Diagrammatic section showing elements that affect lake-level fluctuations of lakes A and B.

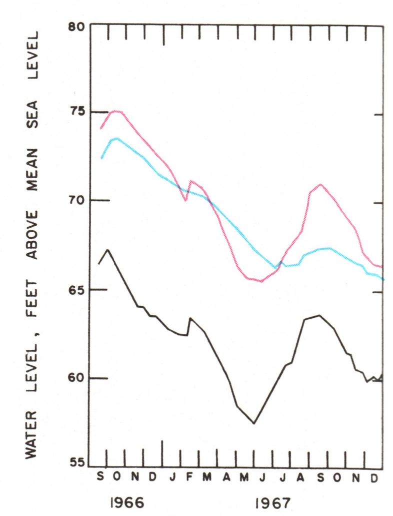


Figure 4.–Seasonal fluctuation of level of Lake Sherwood (blue), water-table aquifer (red), and potentiometric surface of confined aquifer (black).

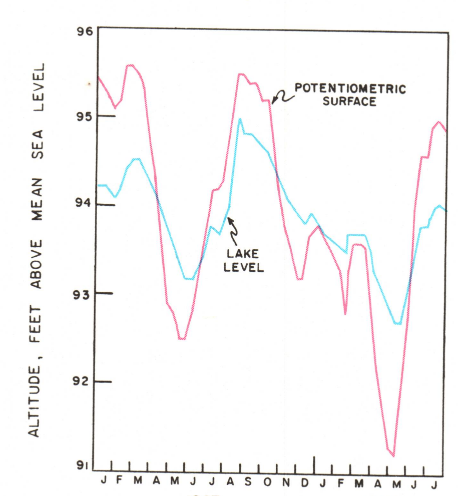


Figure 5.–Seasonal fluctuation in levels of Bay Lake, Orange County, Florida, and potentiometric surface of confined aquifer (Floridan) underlying Bay Lake, January 1967 to August 1968.

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