RISING GROUND-WATER LEVEL IN DOWNTOWN LOUISVILLE, KENTUCKY, 1972-1977

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 77-92

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Vincent E. McKelvey, Director

For additional information write to:

U.S. Geological Survey
Room 572 Federal Building
600 Federal Place
Louisville, Kentucky 40202

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CONVERSION FACTORS

The following are factors used for converting English units to metric units:

English	Multiply by	Metric
feet (ft)	0.3048	meters (m)
gallons (gal)	3.785	liters (L)
square miles (mi^2)	2.590	square kilometers (km^2)
cubic feet per second (ft^3/s)	.02832	cubic meters per second (m^3/s)
gallons per minute (gal/min)	.06309	liters per second (L/s)
million gallons per day (Mgal/d)	.04381	cubic meters per second (m^3/s)

RISING GROUND-WATER LEVEL IN DOWNTOWN LOUISVILLE, KENTUCKY, 1972-1977

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ABSTRACT

Ground-water levels in the alluvial aquifer in Louisville, Jefferson County, Kentucky, are rising at a rate which could cause wet basements and possible structural damage to buildings in the downtown area by 1982. The predicted water level for 1982 is based on the nearly linear increase which has been observed from 1972 to 1977, during which period a rise of as much as 32 feet was recorded in water-level observation wells. Foremost among the possible causes of the rise is a decrease in withdrawal of ground water.

INTRODUCTION

Ground-water levels are rising in the alluvial aquifer beneath Louisville, Ky. The area of the largest and potentially most damaging rise has been beneath downtown Louisville where the increase has been as much as 32 feet from 1972 to 1977 and 4.35 ft for the 11 months preceding March 1977. The present water-level elevation is approximately 420 ft above mean sea level, or 35 to 40 ft below land surface, depending on the surface topography.

At the present rate of increase, ground-water levels may rise to within 20 ft of land surface by 1982. There is a potential for water damage as basements and subbasements in the downtown area are commonly 20 to 25 ft below land surface, and some utility service lines are as much as 40 ft below land surface.

Many other areas of the country have recently experienced structural damage to buildings, flooded basements and damage to underground utility services as a direct result of rising water levels. Among these areas are St. Louis, Mo., and Brooklyn, N. Y. (Soren, 1976).

The purpose of this report is to call attention to the possibility of property damage in downtown Louisville should ground-water levels continue to rise. As opposed to the other areas listed previously, no property losses due to high water levels are known to be occurring in Louisville at present. However, in view of the data which are available, and assuming that there is no change in current water-level trends, existing structures in downtown Louisville could be jeopardized by rising ground-water levels in 1982.

The data on ground-water levels which are presented in this report were collected as a part of the basic network of ground-water level observations in Kentucky. Funding to maintain this network is provided in part by the University of Kentucky, Kentucky Geological Survey in cooperation with the U.S. Geological Survey.

HYDROGEOLOGY

The majority of Louisville and a large part of Jefferson County, Kentucky, (see figs. 1 and 2) is situated on glacial outwash which partly fills the valley of the Ohio River. The outwash, generally consisting of unconsolidated sand and gravel and thin layers of silt, clay or organic material, is as thick as 130 ft at some locations. A zone of boulders is common at the base of the outwash where the channel of the ancestral Ohio River cut deepest into bedrock shale and limestone.

Blanketing the top of the sand and gravel is a layer of fine silt and clay which averages 20 ft in thickness. This layer thickens at the bank of the river and thins again as it extends beneath the present channel of the Ohio River. Figure 3 is a generalized lithologic cross-section of the alluvial aquifer from the Ohio River southward through the downtown area. The line along which the section is drawn is shown on figure 2.

Open spaces between the individual grains of sand and gravel in the aquifer are water filled below the water table. These spaces account for about 20 percent of the total volume of the aquifer (about 1.5 gallons of water would drain from a cube of the aquifer 1 foot on each side). The spaces are interconnected and allow water to flow from areas of high water levels to areas of low water levels. Wells which are constructed in the aquifer obtain water by draining the intergranular spaces thus lowering the water level and inducing flow through the spaces toward the well. When withdrawal of water from the well ceases, water will continue to flow toward the area of low water

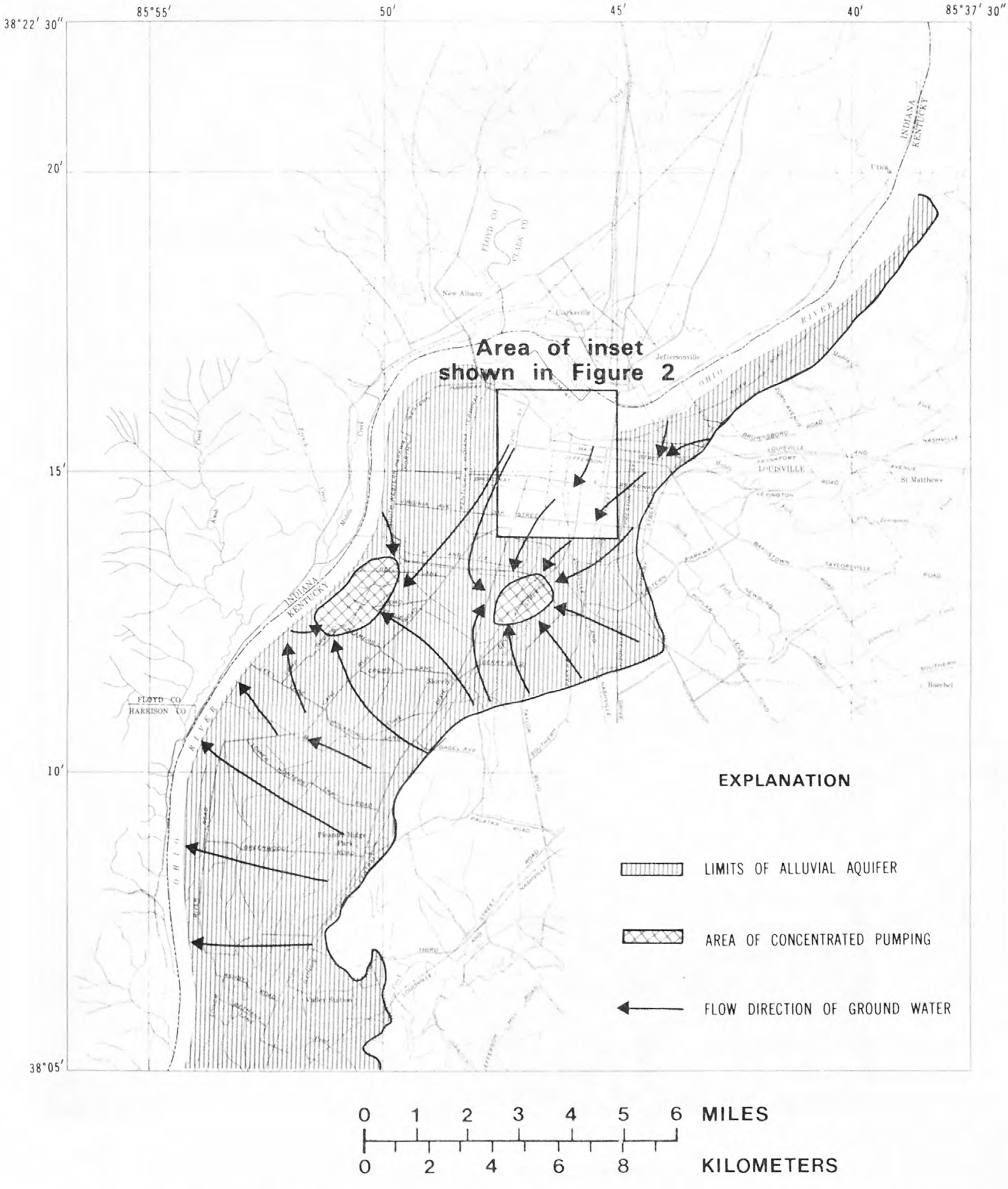

Figure 1-- Louisville and part of Jefferson County, Kentucky, showing ground-water-flow directions, the limits of the alluvial aquifer, and areas of concentrated pumping.

Figure 2-- Downtown Louisville, Kentucky, showing locations of section lin
and observation wells.

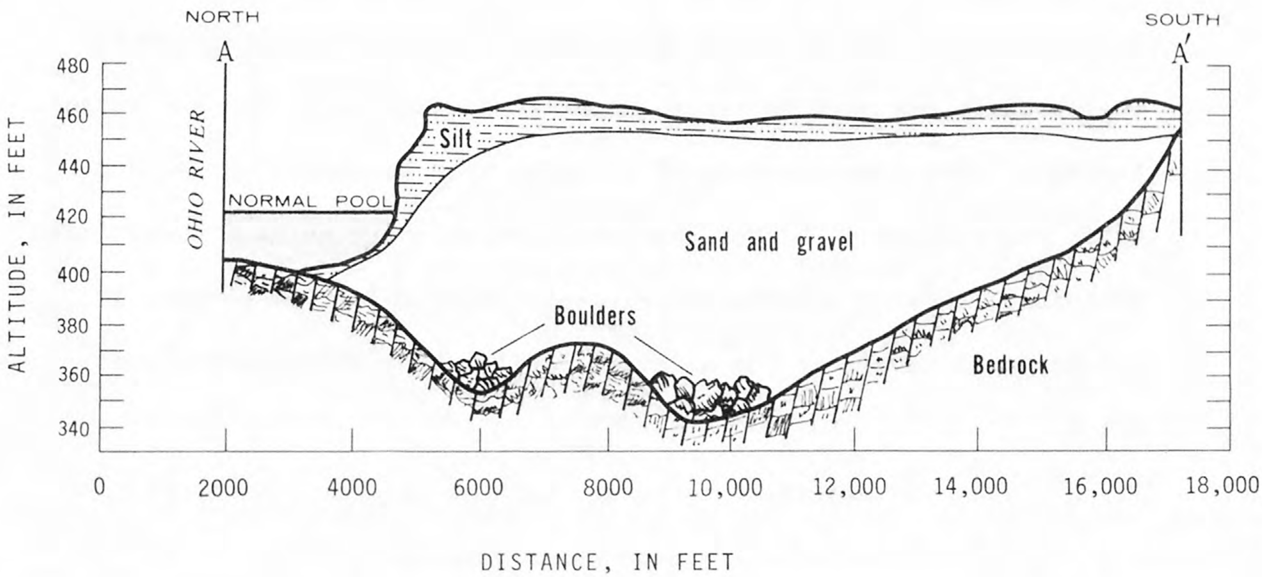

Figure 3-- Generalized lithologic profile through downtown Louisville, Kentucky.

level and resaturate the spaces until water levels again stabilize.

Natural sources of recharge to the alluvial aquifer include downward percolation of water from precipitation and flow into the alluvium from the adjacent hills. This recharge causes the water level to rise and therefore causes ground water to flow toward the low point in the ground-water system which is either the Ohio River or a pumped well. In addition to the natural sources of recharge an unknown amount of water enters the ground-water system in Louisville from man-made sources including leaking water mains, recharge wells (wells which are used to return water to the aquifer), and sewer-line leakage. These last sources of recharge tend to maintain a ground-water level which is higher than would occur under natural conditions. Therefore, there are three key elements which determine changes in ground-water levels in the alluvial aquifer beneath downtown Louisville:

(1) The amount of recharge, both natural and man made;

(2) the amount of ground water pumped;

and, (3) the elevation of the Ohio River, which is the low point in the ground-water system under natural conditions and may be the high point if the amount of ground water pumped is large.

Figures 4A, B and C are idealized water-level profiles along the section line shown in figure 2. These figures also show modes of recharge and discharge along with flow directions for ground-water movement.

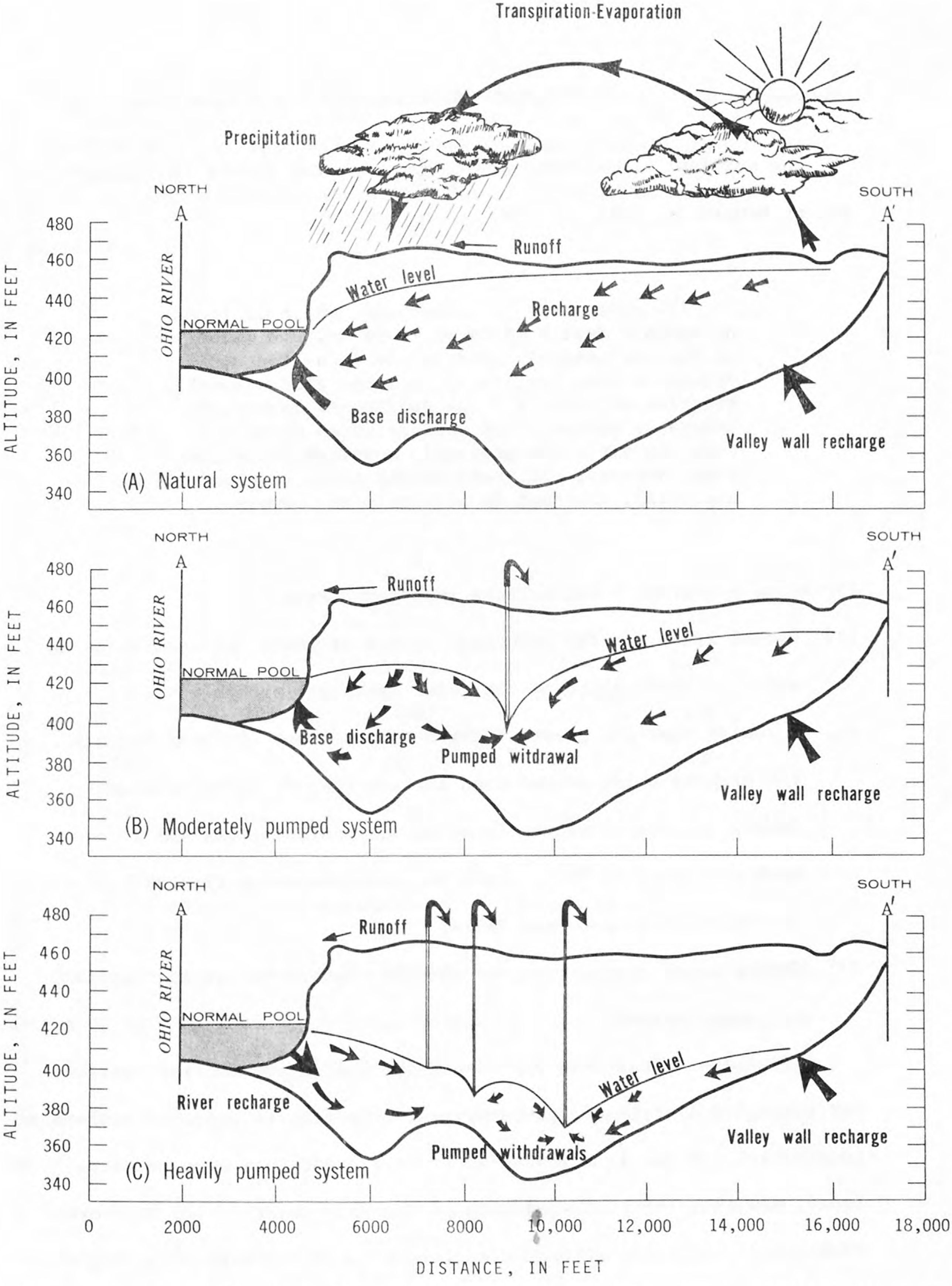

Figure 4-- Generalized profile showing recharge and discharge and direction of flow for ground water. A, Natural system; B, Moderately pumped system; C, Heavily pumped system.

GROUND-WATER LEVELS

The earliest known reference to ground-water levels in Louisville was by McMurtrie, 1819, p. 138:

> The well water of Louisville, which is found at various depths, from 16 to 40 ft, and which is the one commonly used by the inhabitants, is extremely bad, containing, besides a considerable quantity of lime, a large portion of decomposed vegetable matter. The springs which break out near the river are generally considered unwholesome, whereas, (if there be any truth in chemical analysis), the fact is precisely the reverse.

The above paragraph reveals three important facts:

(1) Ground water was the principal source of water for Louisville as early as 1819, although the total draft was probably small;

(2) Assuming that the greatest depth to water was observed beneath the highest point of the land surface (465 ft above mean sea level) the ground-water elevation was approximately 425 ft above mean sea level or 30 ft above the pool elevation (in 1819) of the Ohio River above the Falls;

(3) Ground water discharged into the Ohio River via springs (which no longer exist).

This set of conditions represents the best approximation possible for the natural state of ground water in the alluvial aquifer beneath Louisville. If the same ground-water flow conditions were to exist today, now that the pool elevation of the Ohio River is 420 ft above mean sea level (msl), ground-water levels could be expected to reach a maximum elevation of between 440 and 450 ft above msl.

Water-level data from 1819 to 1937 (the year of the flood of record on the Ohio River at Louisville) are scarce. The following table is a summary of available water-level data for this period for downtown Louisville.

Year	Average Water-level elevation	Pool elevation of Ohio River
1819	425 a/	395
1909	-	412
1915	405 b/	412
1923	411 b/	412
1924	411 b/	412
1927	-	420
1933	410 b/	420
1934	405 b/	420
1935	407	420
1936	404	420

a/ Estimate based on McMurtrie, 1819.
b/ Fewer than five observations from nonpumping wells.

This table shows that the ground-water level had declined approximately 20 ft from 1819 to 1936 regardless of the counteracting effect of a 25-foot increase in pool elevation of the Ohio River. The decline was due to increased use of ground water for industrial and commercial applications.

The flood of 1937 caused an increase in ground-water levels of about 40 ft (see fig. 5), which initiated a concerted effort to

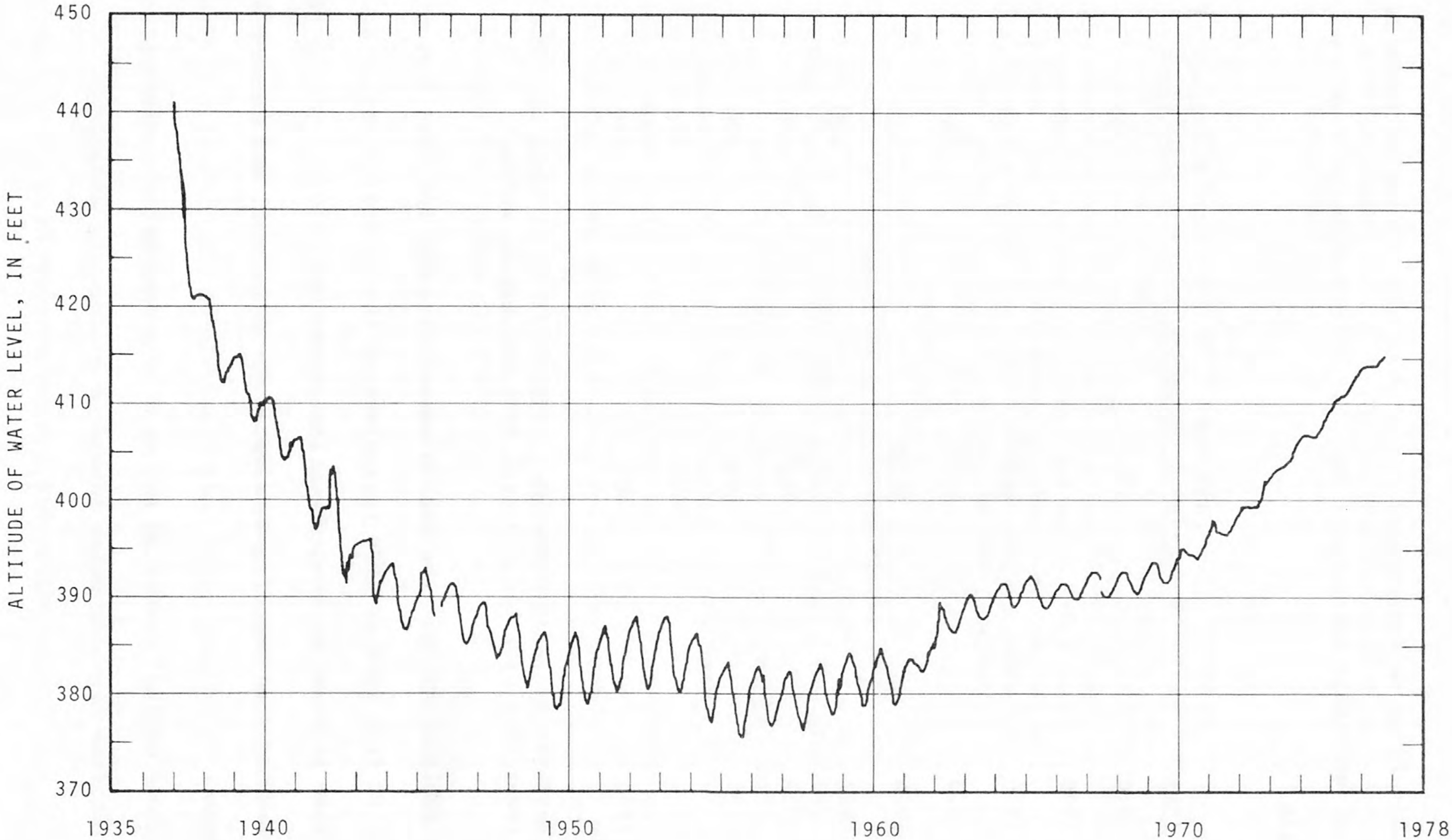

Figure 5-- Water-level hydrograph for well 381441085452701, City of Louisville well A-2, located near Third and York Streets.

construct and pump wells to dewater the aquifer to a level below the basements in downtown Louisville. The use of ground water for cooling and refrigeration was just becoming popular and, as the threat of basement flooding by ground water diminished, many downtown businesses began to use the water being pumped for air conditioning. By 1938 there was concern about the rate of decline of the water table.

Soon thereafter, heavy industrial development and increased production (especially ethyl alcohol by local distilleries) associated with the war effort placed a great demand on the ground-water supply. Conservation of ground water became essential and downtown users were encouraged (via a sewer tax) to convert to closed-system or mechanical cooling systems, and to use recharge wells. However, because of the large industrial demand, ground-water levels continued to decline until the end of World War II. After a period of slight recovery due to abnormally high precipitation (1949-51), water levels remained generally stable until the 1960's (figs. 5, 6, and 7). Water levels then recovered slowly during the 1960's and until 1972, at which time the recovery accelerated to its present rate of from 2 to more than 4 ft per year (figs. 5, 6, 7, and 8).

The general causes for the accelerated rate of increase in ground-water levels are known. What is unknown is the relative importance of each possible cause. Figures 5, 6, and 7 show a reduction in the amplitude of the annual water-level peaks during the middle or late 1960's and a nearly complete disappearance of the annual fluctuations in 1972 or 1973. These changes probably correspond to two stages of

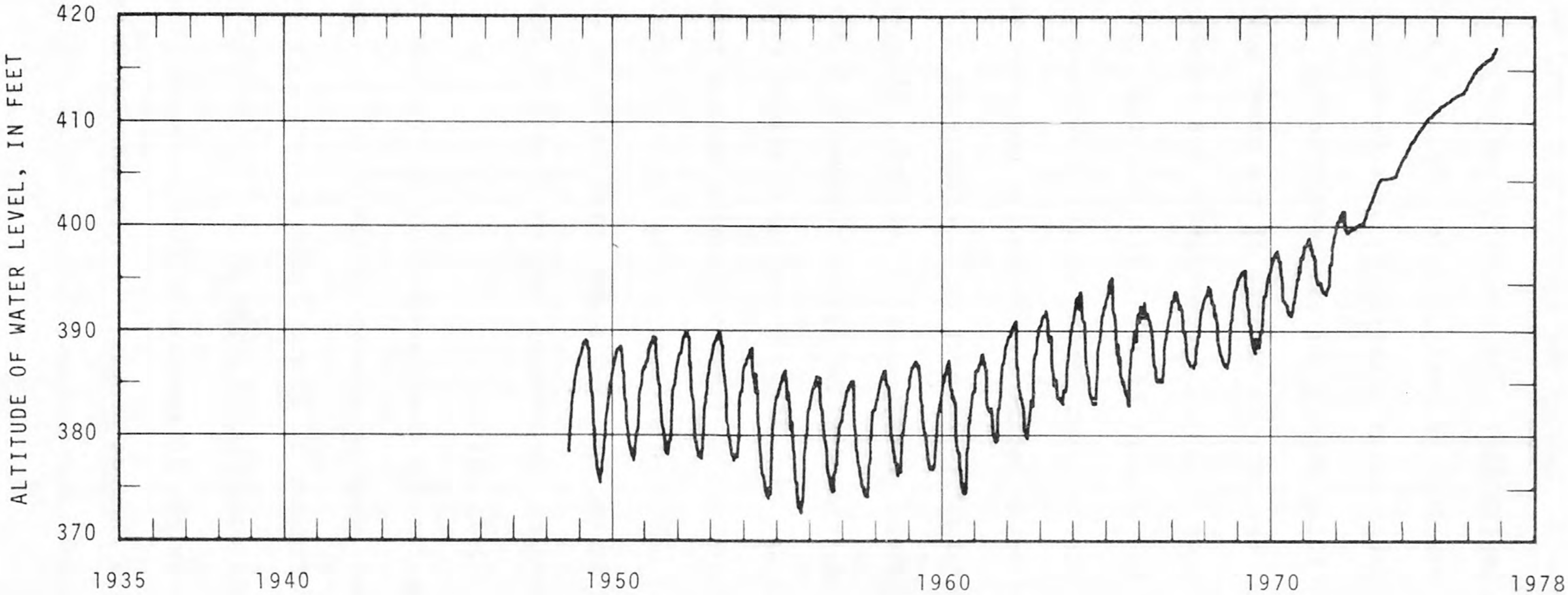

Figure 6-- Water-level hydrograph for well 381447085454001, owned by the Courier Journal and Louisville Times, located near Sixth Street and Broadway.

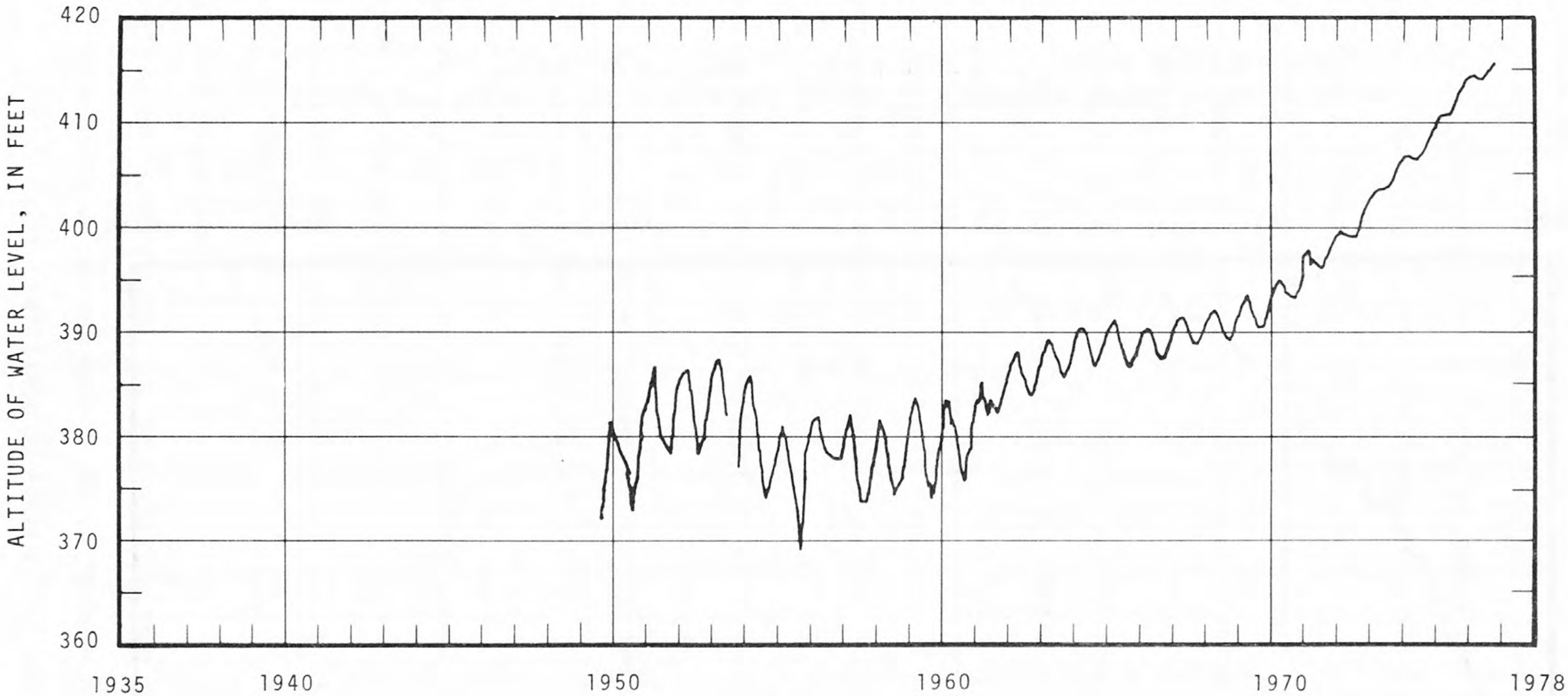

Figure 7-- Water-level hydrograph for well 381503085453301, located near Fifth and Walnut Streets (Kentucky Towers Building).

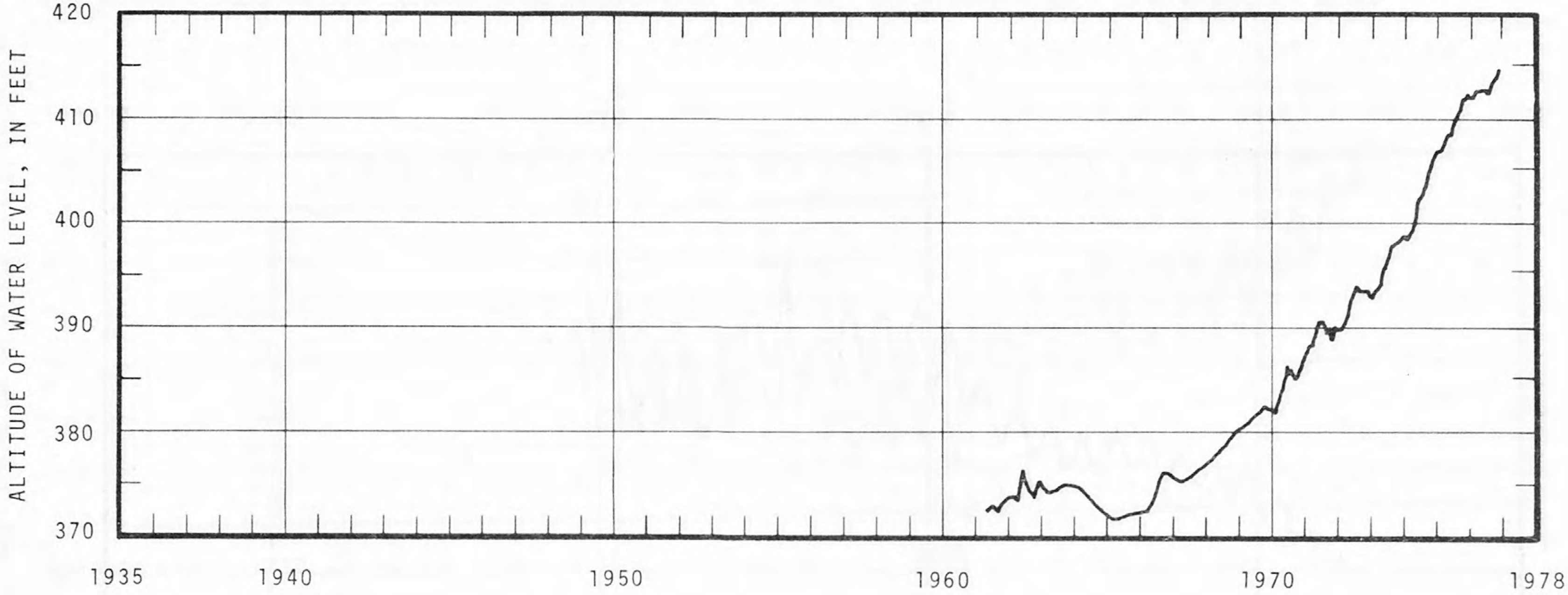

Figure 8-- Water-level hydrograph for well 381446085470601, owned by Brown-Foreman Distillers, located near 18th Street and Broadway.

reduction in withdrawal of ground water for cooling purposes. However, the nearly linear rise in water levels since 1972 indicates that other factors are also involved, or that the water-level recovery from 1972 to 1977 is only the first part of a long-term recovery trend toward much higher water levels. In either case, the possibility exists for damage to deep basements and underground utility services by 1982. Figure 9 shows the severity of the problem should water levels continue to rise at the current rate.

The accuracy of this prediction depends on some data which are not available: (1) the amount of runoff and recharge from precipitation in the urban area in Louisville; and, (2) the amount of recharge contributed by water-main and sewer leaks. Other data including Ohio River stages, ground-water levels, and hydrologic characteristics of the alluvial aquifer are sufficient.

Possible measures that could be taken to prevent damage from rising ground-water levels are:

(1) Encourage the use of ground water by business and industry by means of some incentives (care must be exercised to prevent overuse),

(2) Encourage regular maintenance of existing unused wells and pumps so that businesses can deal individually with a threat to their own buildings. These wells could provide standby or emergency water supplies in the event of fire, or of malfunction of the city distribution system,

(3) Install relief wells along the floodwall to vent ground water during large floods on the Ohio River. There is a possibility,

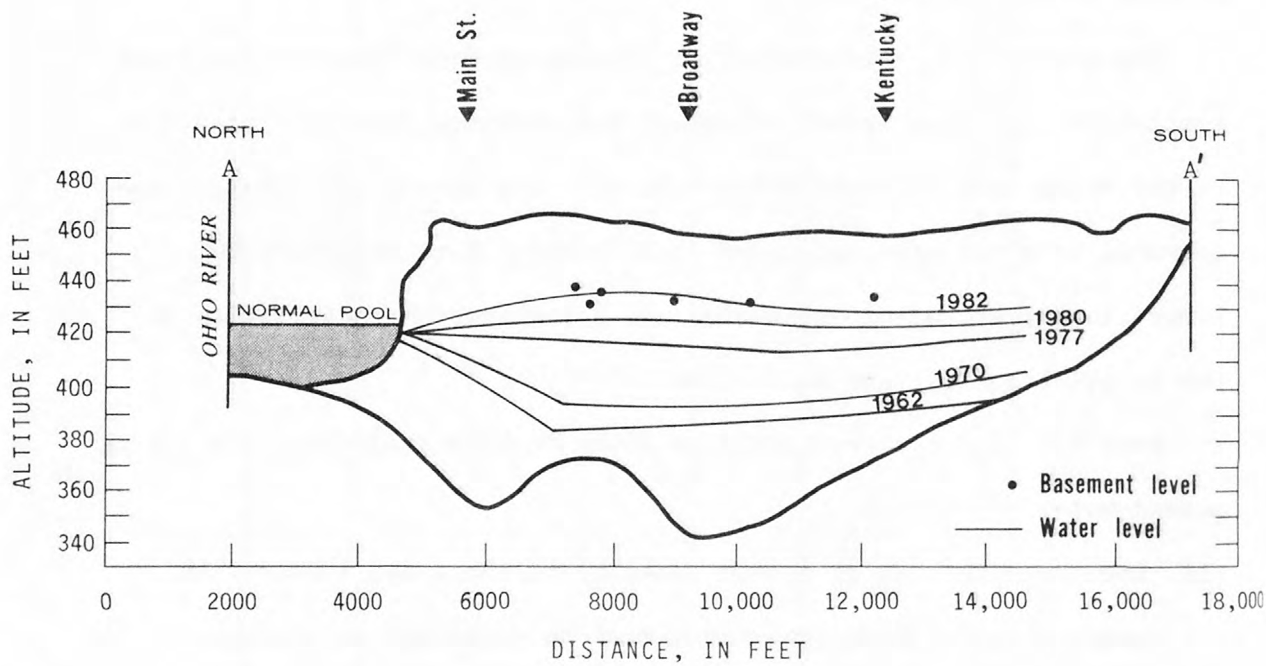

Figure 9-- Generalized profile showing past, present, and projected water levels beneath downtown Louisville, Kentucky.

owing to the observed steady rise in water levels, that by 1982 the aquifer will no longer be capable of storing the quantity of water which it accepted during the 1937 or 1945 floods during which the water level rose about 40 and 8 ft, respectively. Because of the expense involved in the construction of relief wells, a study could be undertaken to determine if construction of these wells is absolutely essential.

SUMMARY

Ground-water levels are rising dramatically in the alluvial aquifer beneath downtown Louisville, Ky., primarily because of the decrease in withdrawal of ground water. The largest observed increase has been 32 ft from 1972 to 1977 and 4.35 ft for the 11 months preceding March 1977. At the rate of increase observed between 1972 and 1977 the ground-water level could, in 1982, be high enough to cause basement flooding in many downtown buildings. The reasons for the increase are known qualitatively but not quantitatively; therefore, the range of error of the predicted increase is unknown.

Three courses of action are proposed to prepare for and minimize the threat of damage to structures by rising ground-water levels. The first is a positive approach to slow or halt the rise by encouraging greater use of ground water. The second approach is more passive in the sense that it encourages preparedness in the form of maintaining existing wells and pumps. The first two courses of action involve response by private concerns to incentives provided by public agencies. The third course of action, to construct relief wells behing existing floodwalls, is intended to minimize the damage that would occur due to rising ground-water levels in the event of a large flood on the Ohio River. This last approach would have no effect on the observed steady increase in water level.

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