Hydrologic Effects of the 1962–66 Drought on Long Island, New York

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1879–F

Prepared in cooperation with the New York State Department of Conservation, Division of Water Resources; the Nassau County Department of Public Works; the Suffolk County Board of Supervisors; and the Suffolk County Water Authority

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By PHILIP COHEN, O. L. FRANKE, *and* N. E. McCLYMONDS

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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ABSTRACT

The hydrologic system of Long Island, N.Y., showed a marked response to deficient precipitation in the years 1962–66. By 1966, streamflow was the lowest of record in many Long Island streams, and ground-water levels had declined a maximum of about 10 feet in the central part of the island. Although the drought apparently ended in the early months of 1967 and ground-water levels and streamflow recovered somewhat since then, ground-water levels and streamflow were still considerably below long-term average values in September 1968.

INTRODUCTION

PURPOSE AND CONTENT OF REPORT

Hydrologic records of various kinds have been collected on and near Long Island, N.Y. (fig. 1), for more than a hundred years. Since the mid-1930's, when the U.S. Geological Survey began a continuing program of water-resources studies on Long Island in cooperation with several State and county agencies, the collection of hydrologic records on Long Island has been more intensive than in most places in the United States.

The truly vast amount of hydrologic data obtained on Long Island has afforded unusually good opportunities to document and evaluate hydrologic phenomena—both natural phenomena and phenomena associated with the activities of man. One natural hydrologic phenomenon, the recent (1962–66) northeast drought, was especially well documented on Long Island and is the subject of this report. The report considers, largely in a graphic format, the deficiency in precipitation during the period 1962–66 and the hydrologic consequences of that deficiency—namely, declines of ground-water levels and related decreases in streamflow and ground-water storage in Nassau and Suffolk Counties. Kings and

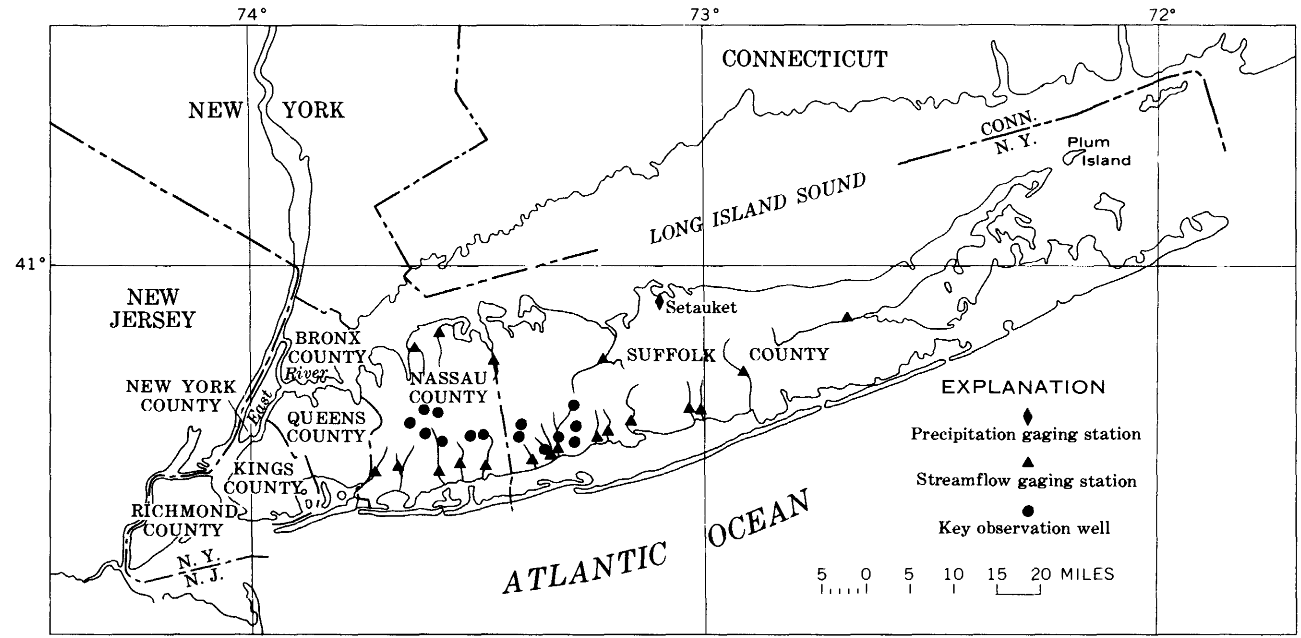

FIGURE 1.—Long Island and vicinity showing location of selected hydrologic-data-collection points.

Queens Counties are excluded from the analysis mainly because factors related to urbanization make a precise quantitative analysis of the effects of the drought on the hydrologic system in these counties virtually impossible.

For the most part, the approach taken in this report is to consider, largely in a descriptive manner, the drought and its effects as they are illustrated on the accompanying graphs, diagrams, and maps. The few statistical techniques used (except perhaps the technique of frequency analysis) and the parameters that are cited are simple and should be readily understood by most laymen.

MEANING OF "DROUGHT"

Most technical reports concerned with one or more aspects of a drought carefully develop the point that the word "drought" has many different meanings, and in one place or at one time the word may be used to describe a very different set of circumstances than in another place or time. (See Thomas, 1962, for an excellent review of the meaning of "drought".) Droughts commonly, but not always, are defined in terms of one or more of the following factors: (1) precipitation, (2) soil moisture, (3) public-water supply, (4) above-ground or underground storage capacity, (5) crop failures, and (6) general economic hardship. Almost always, regardless of the specific definition used, a "drought" is related to, or is caused by, having less water available than is desired or expected. (See Yevdjevich, 1968, for methods of determining whether a "drought" has occurred or is occurring.) Within this context the drought described in this report represented a series of events closely related to, and largely caused by, inadequate precipitation—inadequate in terms of the amount desired by local residents and the amount normally expected.

ACKNOWLEDGMENTS

Virtually all the data on ground-water levels and streamflow used to develop the information given in this report were obtained as part of a program of water-resources studies that is being carried on by the U.S. Geological Survey in cooperation with the New York State Division of Water Resources, the Nassau County Department of Public Works, the Suffolk County Water Authority, and the Suffolk County Board of Supervisors. We are grateful to our colleagues in those agencies whose support included, but was not limited to, the collection of many of the data presented in this report.

The report was prepared under the immediate supervision of B. L. Foxworthy, former Hydrologist-in-Charge of the Geological

Survey Subdistrict Office on Long Island, and under the general supervision of Garald G. Parker, District Hydrologist, U.S. Geological Survey, Albany, N.Y.

DEFICIENT PRECIPITATION

ANNUAL PRECIPITATION

During the past two decades, precipitation data have been collected at nearly 30 stations on Long Island. The maximum average annual precipitation, about 51 inches, occurs near the middle of the island, and the minimum average annual precipitation, about 40 inches, occurs along the coast in southern Nassau County and on Plum Island. The long-term average precipitation for all Long Island is about 44 inches per year (Cohen and others, 1968, p. 30).

Data collected at Setauket (fig. 1) provide the longest continuous record of precipitation on Long Island. The average for the 81-year period of record at that station, water years 1887–1967, is 44.5 inches, nearly the same as the long-term average for all stations on Long Island. (The "water year" is the 12-month period beginning October 1; it is designated by the calendar year in which the 12-month period ends.) Accordingly, precipitation data from Setauket are emphasized in this report.

Annual precipitation at Setauket ranged from a low of 30.8 inches in water year 1966 to a high of 56.4 inches in water year 1898, and, in general, years of above- and below-average precipitation seem to have been randomly distributed (fig. 2). Only twice during the entire period of record was precipitation above or below average for 5 consecutive years. It was above average from 1887 through 1891, when the cumulative excess was 33.0 inches (fig. 3), and it was below average from water years 1962 through 1966, when the cumulative deficiency was 41.7 inches.

Largely because water year 1962 was the first year of below-average precipitation in the 5-year sequence, the drought is somewhat arbitrarily assumed to have begun on Long Island in that year. The qualification "somewhat arbitrarily assumed" is used mainly because precipitation in water year 1962 was only slightly below average (1.2 in.), and because, for all practical purposes, virtually none of the adverse features associated with a drought were noted on Long Island during that year.

Two additional noteworthy features of the recent drought can be deduced from figures 2 and 3. First, the 1962–66 drought was the most severe of record in terms of the total deficiency in precipitation and in terms of its duration. The next largest deficiency in precipitation for a consecutive number of years, about 23 inches, occurred in the 3-year period, water years 1909–11. Second, the

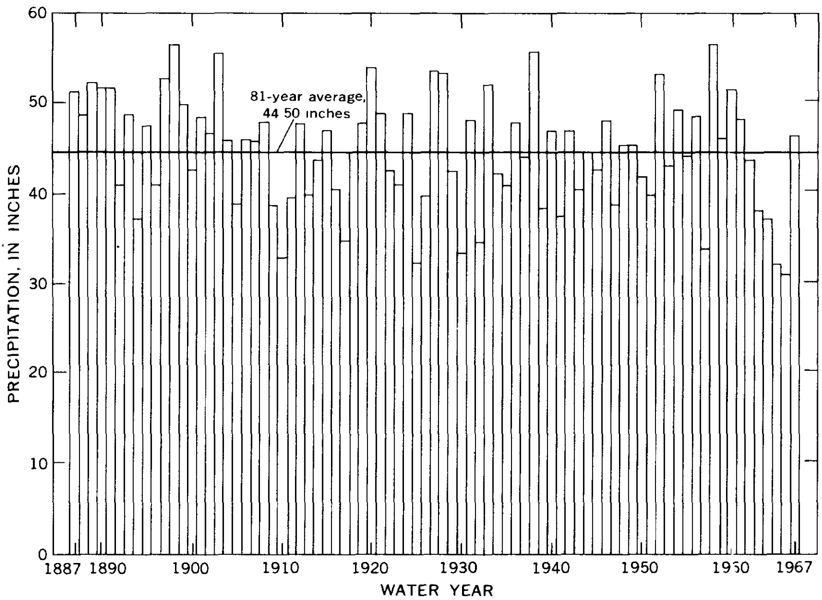

FIGURE 2.—Long-term annual precipitation at Setauket.

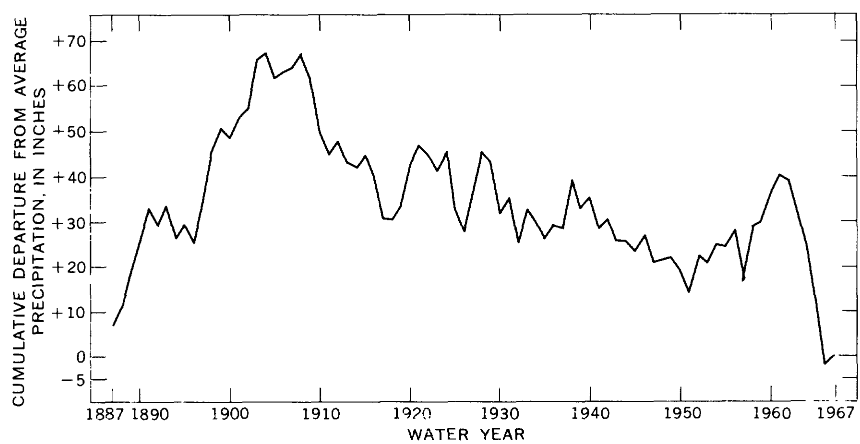

FIGURE 3.—Cumulative departure from average annual precipitation at Setauket.

increasing deficiency in annual precipitation with each succeeding year of the 1962–66 drought intensified the severity of the drought.

Sufficient data for Long Island are not available to evaluate the probable frequency of occurrence of the 5-year 1962–66 drought, and an analysis of the frequency of that multiyear event, based on regional or worldwide data, is beyond the scope of this report. Sufficient data are available, however, to evaluate the frequency of occurrence of annual precipitation (fig. 4). For example, annual precipitation probably will be equal to, or greater than, 30.8 inches, as it was in 1966, about 99 percent of the time. Similarly, annual precipitation probably will be equal to, or greater than, 31.9 inches, as it was in 1965, about 98 percent of the time. (See Mitchell, 1968, for an additional discussion of the frequency of occurrence of droughts with special reference to the drought described in this report.)

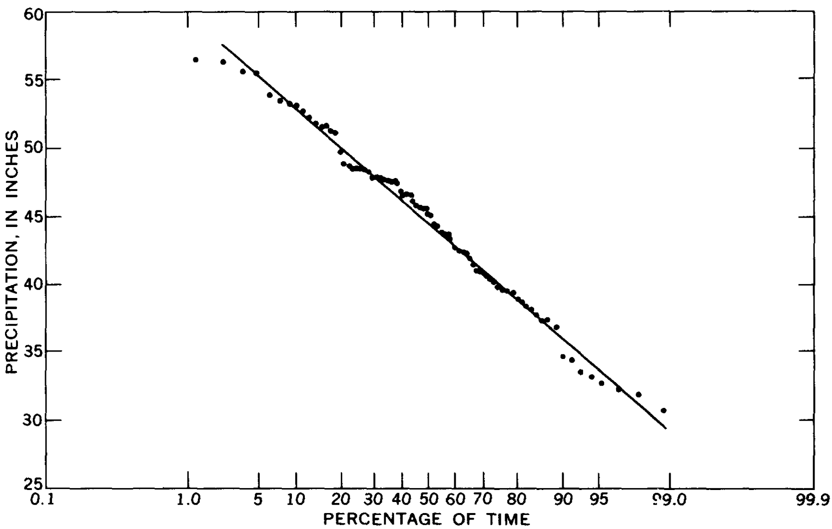

FIGURE 4.—Percentage of time that various values of annual precipitation were equaled or exceeded at Setauket for the period of record.

The odds against the annual precipitation being as little as it was in 1966 are roughly 60–80 to 1, and the odds against precipitation being as little as it was in 1965 are roughly 35–40 to 1. Thus, if the simplifying assumption is made that annual precipitation at Setauket is randomly distributed, the odds against the precipitation being as low as it was in the 2 successive years, 1965 and 1966, are considerably more than 100 to 1. The validity of the assumption of total random distribution of annual precipitation undoubtedly is questionable. However, the preceding discussion is useful inasmuch as it illustrates (1) the difficulties involved in estimating how frequently a drought of the length and severity of that experienced on Long Island in 1962–66 might occur, and

(2) the probable large order of magnitude of the odds against such an occurrence.

MONTHLY PRECIPITATION

Average monthly precipitation on Long Island is fairly uniform, and for the period of record at Setauket it ranged from a low of 3.1 inches for June to a high of 4.1 inches for August (fig. 5). The long-term monthly average was about 3.7 inches (44.50 in. per yr divided by 12 months).

Monthly averages for water years 1960–67 also are shown in figure 5 (dashed lines). Below-average precipitation and an increasing deficiency from year to year in water years 1962–66 are clearly indicated by the dashed lines. As is shown on the graph, however, precipitation was above average in some months in each of the 5 drought years.

It is significant to note that it is virtually impossible to select readily the specific month when the drought began. On the other hand, the monthly data seem to indicate that, at least with respect to precipitation, the drought may have ended in February or March 1967.

DECLINING GROUND-WATER LEVELS

ANNUAL WATER LEVELS

Ground-water levels have been measured in 14 key observation wells on Long Island (fig. 1) since the late 1930's. These wells tap the uppermost unconfined aquifer on Long Island and, accordingly, water levels in these wells respond rapidly to changes in the rate of ground-water recharge. All the natural fresh-water recharge on Long Island results from the infiltration of precipitation falling on the island. Thus, ground-water levels in the 14 wells responded markedly to the 1962–66 drought (fig. 6).

The average altitude of the water levels in the 14 key wells for the period 1940–67 was nearly 46.5 feet. The annual average level was about 1 foot above the long-term average in 1961, and it declined to a point about 1 foot below the long-term average in 1963. By 1966 the annual average level had declined about 7 feet below the 1961 level to a point about 6 feet below the long-term average level. In 1967, when the drought apparently was broken, the annual average level recovered about 0.3 foot.

The ground-water reservoir of Long Island is intensively developed for public-supply and other uses, and ground-water withdrawals, which have been on the order of 400 million gallons per day in recent years, have been increasing steadily, especially since the mid-1940's (Cohen and others, 1968). The fluctuations of

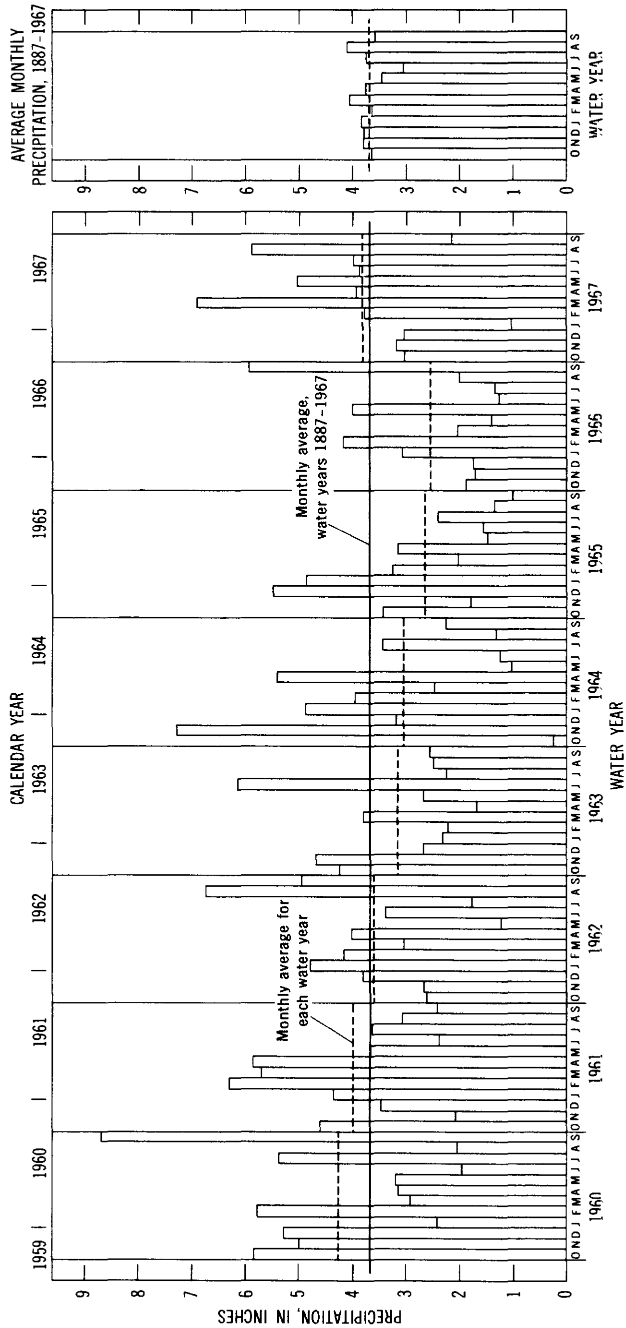

FIGURE 5.—Monthly precipitation, water years 1960–67, and long-term average monthly precipitation at Setauket.

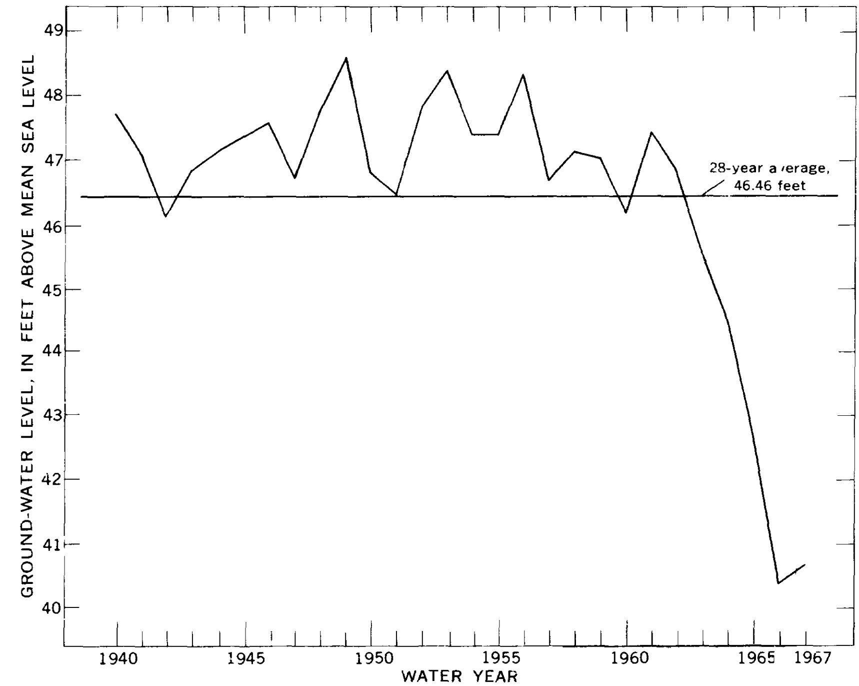

FIGURE 6.—Average annual ground-water levels in 14 key observation wells.

ground-water levels shown in figure 6 undoubtedly reflect in part the effects of pumping. In addition, other factors, such as decreased natural recharge related to urban development and decreased artificial recharge related to the discontinued use of cesspools and the construction of sanitary sewers (Franke, 1968), have been partly responsible for the declines of ground-water levels on Long Island, especially since the mid-1950's.

Sufficient data are not available to determine accurately what proportion of the decline in water levels during 1962–66 was caused (1) directly by the drought as a result of decreased precipitation and related decreased recharge, (2) indirectly by the drought as a result of increased ground-water withdrawals for lawn sprinkling and other needs related to abnormally low precipitation, or (3) by factors unrelated to the drought. Nevertheless, the striking similarity between figures 3 and 6, especially for 1961–67, strongly suggests that most of the changes in the annual average ground-water levels were related to below average precipitation and the resulting decreased recharge.

MONTHLY WATER LEVELS

Monthly water-level data from the key observation wells (fig. 7) provide additional insight into the effects of the drought on the hydrology of Long Island. The seasonal trend in water-level fluctuations—highest water levels in the winter and late spring, and lowest water levels in the late summer and early fall—can be attributed largely to seasonal variations in natural recharge rates and partly to seasonal pumping patterns. The downward trend in ground-levels from 1962 to 1966 is clearly visible. Also, the decline in ground-water levels was abruptly halted and reversed in the winter of 1967 when, as previously noted, the drought seems to have been broken by sustained average and above-average precipitation in several consecutive months.

DECREASED STREAMFLOW

ANNUAL STREAMFLOW

On the average, more than 95 percent of the streamflow on Long Island is derived by seepage into the stream channels from the ground-water reservoir. In other words, less than 5 percent of the streamflow is overland runoff (Cohen and others, 1968, p. 40). Accordingly, the flows of Long Island's streams closely reflect changes in ground-water levels in the shallow unconfined aquifer (the part of the ground-water reservoir that is in direct hydraulic continuity with the streams). The close relationship between streamflow and ground-water levels on Long Island is confirmed by the fact that the shape of the curve in figure 8, which shows the combined average flows of the 19 principal streams on Long Island, is very similar to the shape of the curve showing average annual ground-water levels (fig. 6).

In water years 1940–67 the combined flows of the principal streams averaged 291 cfs (cubic feet per second), and ranged from a high of 401 cfs in 1956 to a low of 155 cfs in 1966. The lowest flows of record were noted in 14 of the 19 streams in July or August of water year 1966, the same months in which record-low ground-water levels were noted in many of the observation wells. Flows in 1967 generally were only slightly more than those in 1966; nonetheless, a distinct upturn in the combined-flow hydrograph was noted in that year, corresponding to increased precipitation (fig. 2) and to a slight recovery of ground-water levels (fig. 6).

MONTHLY STREAMFLOW

Monthly flow data for the 19 principal streams for water years 1960–67 (fig. 9) confirm many of the observations made in the preceding text. For example, seasonal streamflow fluctuations correspond fairly closely to seasonal fluctuations in ground-water

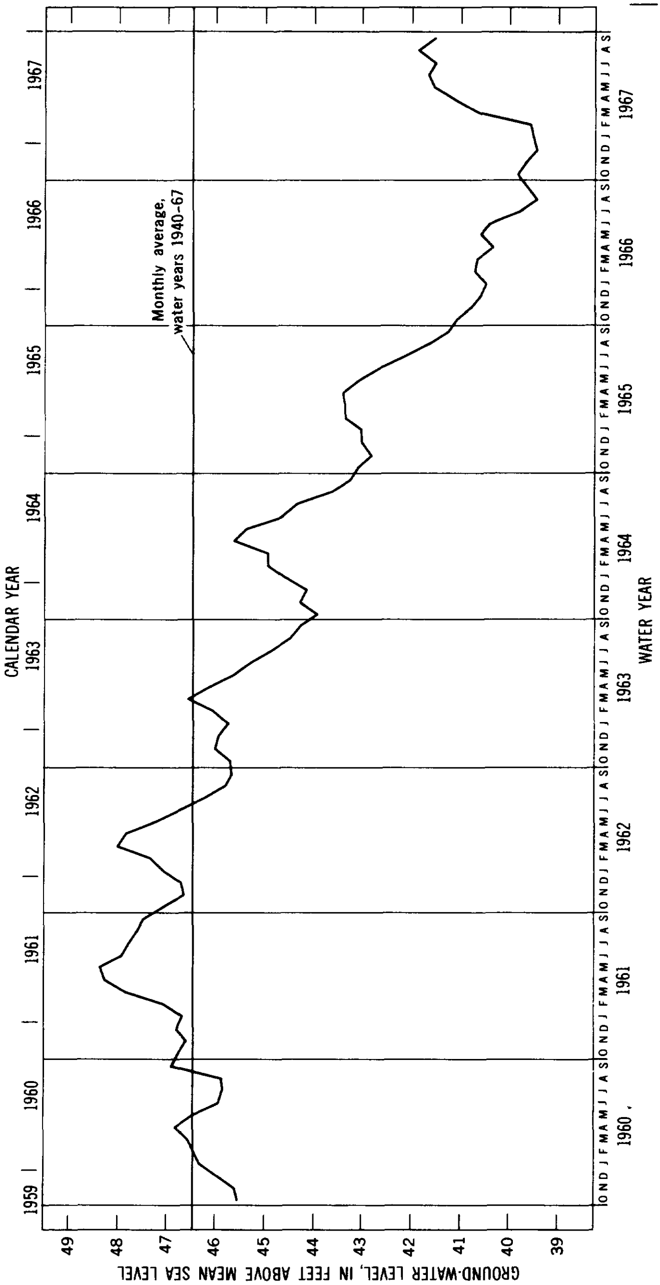

FIGURE 7.—Average monthly ground-water levels in 14 key observation wells.

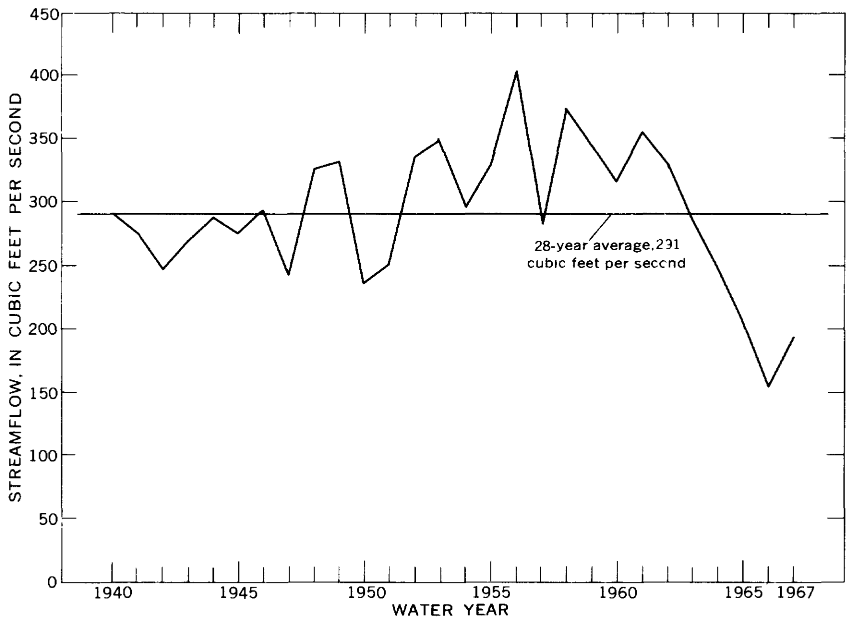

FIGURE 8.—Combined annual average streamflow of 19 principal streams.

levels. (Compare figs. 7 and 9.) In addition, the slight but distinct upturn in the streamflow hydrograph in the winter of 1967 also seems to have signaled the possible end of the drought. Despite the increase in streamflow, however, the discharge of many of Long Island's streams in 1967 was considerably below average, and record-low flows were noted in three of the streams in that year.

DECREASED WATER IN STORAGE

The amount of fresh water stored on and beneath the surface of Long Island decreased markedly as a result of the drought conditions in water years 1962–66. The decreases involved surface water, soil moisture, and ground water.

Most of Long Island's lakes are small and shallow (less than a square mile in area, and commonly only a few tens of feet or less in depth), and although a few of the lakes are perched and, therefore, their levels are not related to the water table, most of the

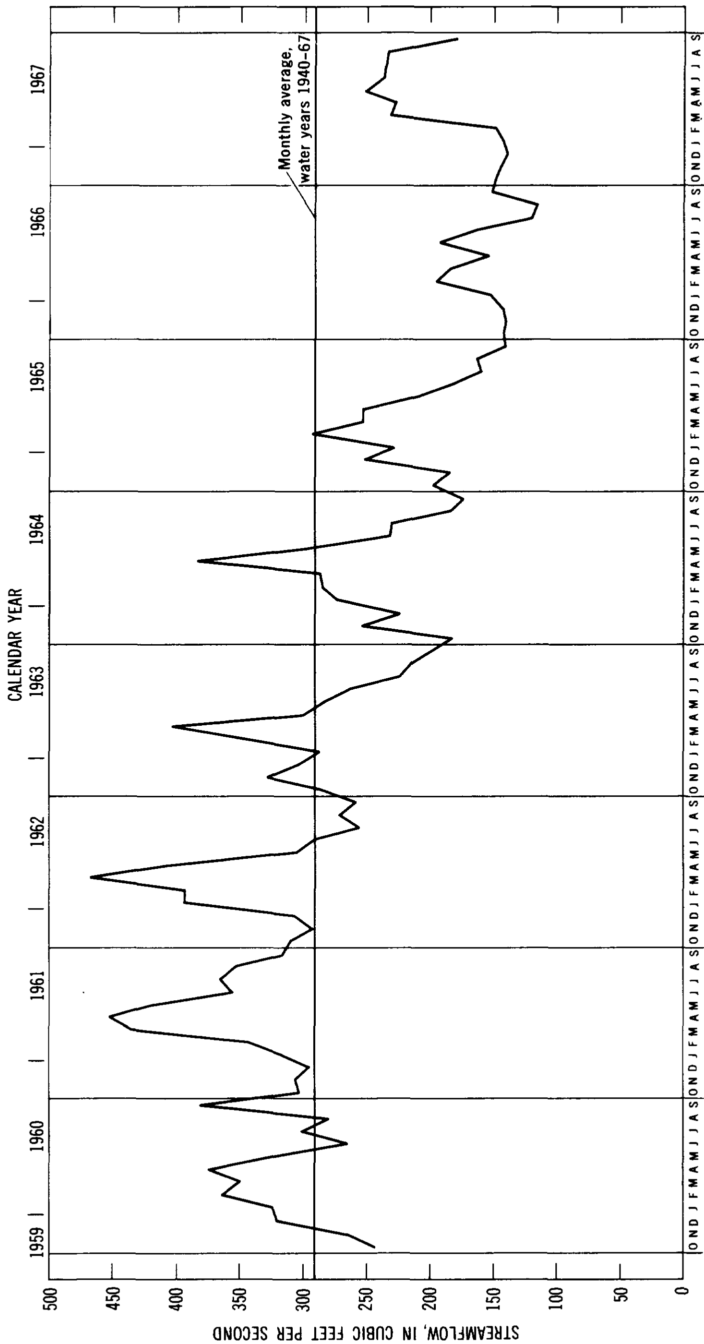

FIGURE 9.—Combined monthly average streamflow of 19 principal streams.

lakes are in direct hydraulic continuity with the shallow unconfined aquifer. Accordingly, the levels of most of the lakes are at about the same altitude as the water table adjacent to the lakes, and the lake levels fluctuate in response to changes in the altitude of the water table. Inasmuch as the lakes are shallow, declines of the water table and of the lake levels of only a few feet, such as those that occurred in water years 1962–66, caused large parts of many of Long Island's lakes to become dry and caused a decrease in the amount of water in storage therein. Unfortunately, data are not available to compute the decrease in storage in the lakes during the drought.

As the ground-water levels declined during the drought, parts of the upstream reaches of many of Long Island's streams also became dry. In addition, the depth of water in those parts of the streams in which there was perennial flow was below average during the drought. Thus, the amount of water stored in the stream channels during water years 1962–66 was below average. Again, sufficient data are not readily available to compute this decrease of surface water in storage. However, the total decrease of surface water in storage (in both the lakes and streams) during the drought was small relative to the decrease of subsurface water in storage.

The net decrease in soil moisture during the drought undoubtedly was many times greater than the decrease of surface water in storage; data again, however, are not available to evaluate quantitatively this parameter.

Sufficient data are available to estimate the net decrease of ground water in storage from water years 1961–66. As shown in figure 10, the declines in ground-water levels ranged from somewhat more than 10 feet in northeastern Nassau County and northwestern Suffolk County to less than 2 feet near the shorelines. Larger declines were noted in southwestern Nassau County (shaded area in fig. 10), largely as a result of decreased artificial recharge related to widespread sewering (Franke, 1968), but consideration of these declines is beyond the scope of this report.

The contours showing the net declines of ground-water levels (fig. 10) approximately parallel the water-table contours (not shown); the largest declines were in the area of the regional ground-water divide on Long Island which is in north-central Nassau and Suffolk Counties. This relation between the altitude of the water table and the magnitude of the decline in the water table is consistent with the theoretically expected response of the ground-water system to any factor that causes an islandwide

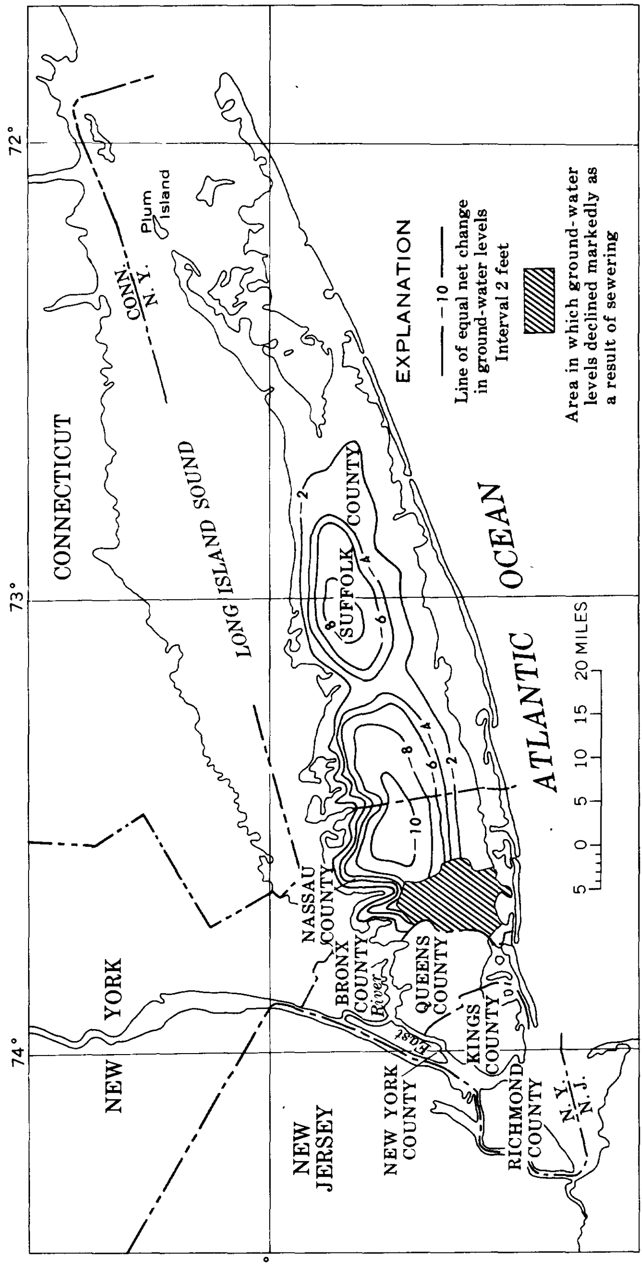

FIGURE 10.—Net change of ground-water levels in the unconfined aquifer, 1961–66.

decrease in ground-water recharge. Because the ground-water system of Long Island is hydraulically connected to the surrounding ocean, ground-water levels can decline only slightly, if at all, in the unconfined aquifer near the shorelines, and any islandwide declines will increase with increasing distance from the shorelines.

The computed volume of aquifer material that was dewatered from 1961 to 1966 was about 0.7 cubic mile. Assuming that the specific yield of the dewatered aquifer material is 0.20, it follows that the net decrease of ground water in storage during the drought in Nassau and Suffolk Counties was about 0.14 cubic mile, or about 155 billion gallons. An estimated 60 trillion gallons of fresh ground water is stored beneath the mainland of Nassau and Suffolk Counties, excluding the forks (Cohen and others, 1968, p. 26), and an estimated 35 trillion gallons of fresh ground water is stored beneath the salty bays and ocean adjacent to Long Island. Therefore, it is apparent that the most severe drought of record on Long Island caused a decrease in the amount of fresh ground water in storage that was equal to only a small fraction of 1 percent of the total fresh ground water in storage beneath the island.

CONCLUSIONS

The cumulative departure from average precipitation at Setauket during the drought years of 1962–66 was nearly 42 inches (fig. 3). In other words, during the 5-year drought period, the deficiency in precipitation was nearly equal to the entire amount of precipitation normally expected in a given year. Expressed solely in terms of deficient precipitation, the drought was the most severe of record for Long Island.

Much of the water supply for the two westernmost counties on Long Island, Kings and Queens Counties, is derived from mainland surface-water sources, and that supply was seriously affected by the drought (Barksdale and others, 1966). Virtually none of the public-supply water used on Long Island is drawn directly from surface-water sources on the island. Accordingly, the marked decrease in streamflow and the decline in lake levels had practically no effect on Long Island's water supply. However, the decreased streamflow and the decline in lake levels did impair the aesthetic and recreational features of those bodies of surface water and, therefore, caused a moderate amount of economic loss, inconvenience, and displeasure.

The ground-water reservoir of Long Island is the sole source of fresh public-supply water for the roughly 2.5 million people in Nassau and Suffolk Counties. Despite the fact that ground-water levels declined markedly in these counties, the decline had a negligible effect on the total volume of fresh ground water in storage beneath the island and on the yield of the hundreds of large-capacity public-supply wells. A few small-capacity shallow wells became dry, and the capacity of a few others was reduced markedly; but the decreases in the total water supply related to these factors were negligible. Nevertheless, where such events did occur, there was an adverse economic impact.

Deficient precipitation and soil moisture adversely affected some of the farms and nurseries on Long Island during the drought. In some places, additional agricultural costs were incurred because of the need to increase the use of ground water for irrigation. In many places, however, the fact that ground water was readily available minimized the economic loss.

The ground-water reservoir of Long Island has long been recognized as a vital and major economic asset. The 1962–66 drought very dramatically confirmed this recognition. In the midst of the most severe drought of record, residents in Nassau and Suffolk Counties were still able to water their lawns at will because of the large amount of water available from the Long Island ground-water reservoir. In contrast, their less fortunate neighbors in Kings and Queens Counties faced, first, severe restrictions on lawn watering and, eventually, during the last 2 years of the drought, complete curtailment.

Finally, in terms of precipitation, the drought seemingly ended in the winter of 1967. However, streamflow and ground-water levels are still (Sept. 1968) near record lows. Under conditions of average precipitation and average recharge rates, it may take years for ground-water levels and streamflow conditions to return to normal. Of course, abnormally high amounts of precipitation or certain changes in the hydrologic regimen resulting from the activities of man (artificial recharge, for example, see Parker and others, 1967) would shorten the time required. Other changes in the hydrologic regimen, such as increased pumpage or changes that cause decreased recharge, could result in a situation in which ground-water levels and streamflow on Long Island might never return to their pre-1961 values.

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