S4-254

SOME UNRELIABLE TYPES OF GROUND-WATER OBSERVATION WELLS

By Irwin Remson and G. S. Fox

(Geologist and Engineer, respectively, Seabrook, N. J., G. W.)

INTRODUCTION

Several primary requirements must be fulfilled by any observation well that is to be used as an indicator of ground-water levels over considerable distances. First of all, the water level inside the well must be the same as that outside the well. The water level inside the well must be able to adjust to water-level fluctuations in the aquifer within a certain period of time, that time dependent upon the type of study for which the observations are to be used. Finally, to be of value in most areal studies, the water level outside the well must be representative of the level throughout the aquifer, and not reflect merely some special local condition. Should any of these requirements remain unsatisfied, the derived data may be misleading.

A number of unreliable observation wells of several types have been encountered during the U. S. Geological Survey investigations at Seabrook, N. J. The misleading nature of the data from some of them was apparent at once. However, it was only because of the special nature of the studies that the spurious quality of the water-level measurements from other wells was brought to light. It may be of value, therefore, to discuss some of the pitfalls encountered at Seabrook, so that they may be avoided elsewhere. Throughout this discussion, it must be recognized that some of the faults that made certain wells unsatisfactory for the Seabrook investigations would be of no consequence in other types of studies.

WELLS THAT DO NOT REFLECT THE AQUIFER WATER LEVELS ACCURATELY

Wells With Large Entrance Losses

In many investigations, the only available observation wells are those formerly used for water supply that have been abandoned because their yields were deficient. This is the sort of well that is likely to have a poorly permeable screen, because of which its water level will not adjust rapidly to outside fluctuations.

Ground-water literature has many discussions of screen-entrance losses, and it would be fruitless to duplicate them. (Bennison, 1947; Jacob, 1946; Rorabaugh, 1948, 1949). However, it should be pointed out that this condition may be much more common than is suspected by some investigators. For example, the corrosive waters in certain areas near Seabrook, N. J., have caused deterioration of screens in wells that have never even been pumped. Furthermore, new screens become clogged when driven through certain of the local materials.

Every potential observation well should be tested to see if it will yield and take water. If necessary, it should be developed before being put into use. Many of the other well deficiencies that will be described become serious only when complicated by slow response through defective screens. Therefore, the avoidance of serious entrance losses will mitigate many of these difficulties.

Wells Without Screens

Dug wells, open-bottom pipes, and wells made of stovepipe and of perforated pipe fall into the category of wells without screens.

Each of these types of wells has been found generally unsatisfactory in the Seabrook area. The bottoms of the dug wells, the open-bottom pipes, and the stovepipe wells tended to become sealed by silt and organic matter. Those cased with perforated pipe showed little sensitivity to outside fluctuations as soon as they were installed. Wells in this category should be tested to see if they yield and take water properly.

Wells That Are Sumps

Many wells are constructed improperly so that it is possible for water to enter them from above the water table. Dug wells and those that are screened or perforated above the water table are of this type. During periods of precipitation they can act as sumps and receive water from surface drainage or from the zone of aeration. They are characterized by rapid and large rises of water level when precipitation occurs. In extreme cases, a very small rainfall can raise water levels beyond any reasonable expectation when specific yields are considered. Caution is necessary when applying this criterion to wells in waterlogged areas because a small rainfall can liberate a large amount of capillary water and thereby cause disproportionate increases in ground-water storage under certain conditions. (Blench, 1951)

Sump wells that have small entrance losses and are in fairly permeable aquifers can readjust quickly to give correct indications of the aquifer water levels. Figure 1 is the hydrograph of such a well. On the other hand, when entrance losses are large, it may take a considerable period of time for the collected water to pass out of the well. The hydrograph of such a well is shown in figure 2. The rainfalls of July 4 and July 17

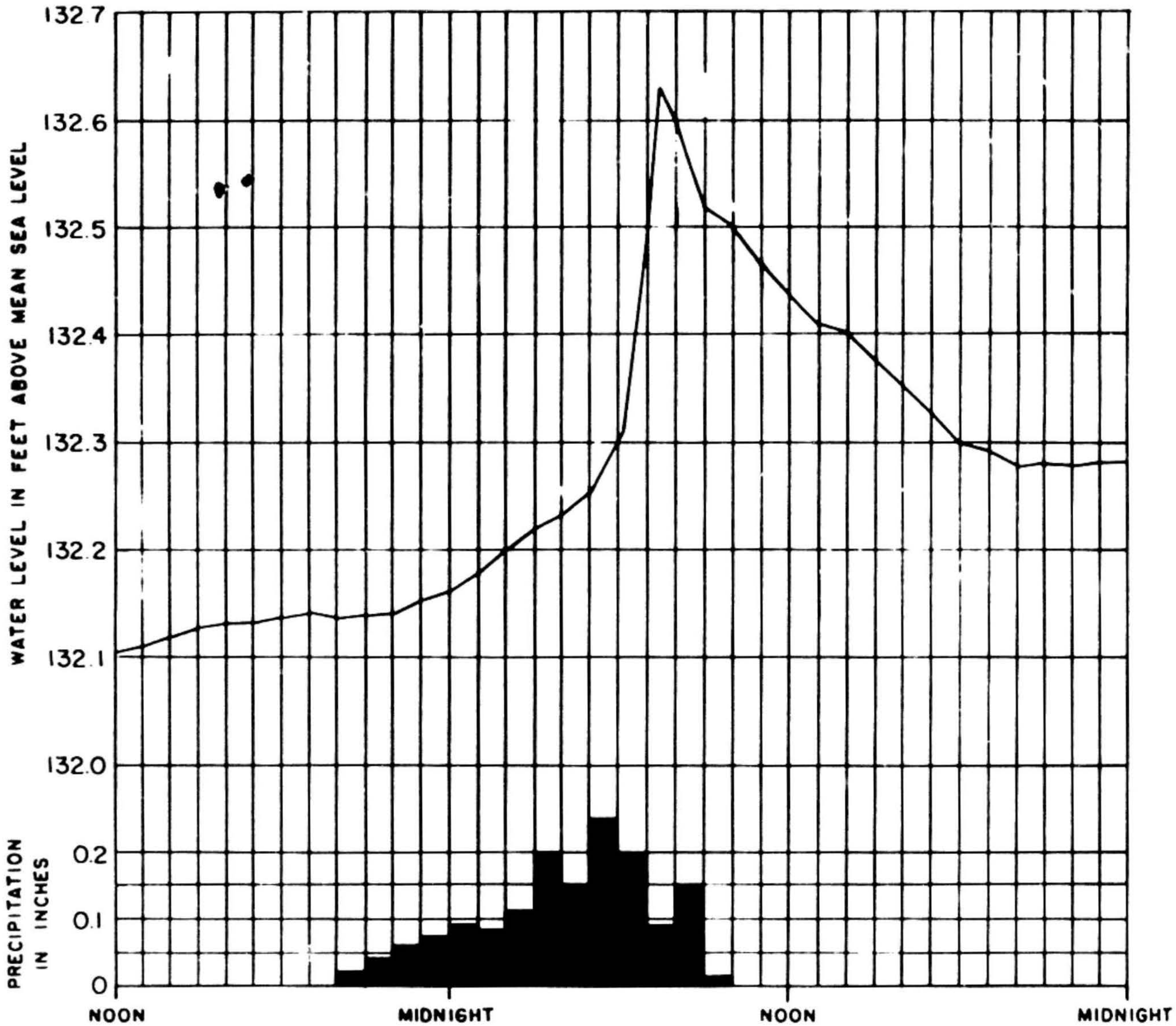

Figure 1. Hydrograph of the Shirley, N. J., well for April 6–7, 1953, showing precipitation and the type of fluctuations that occur in a sump well with small entrance losses.

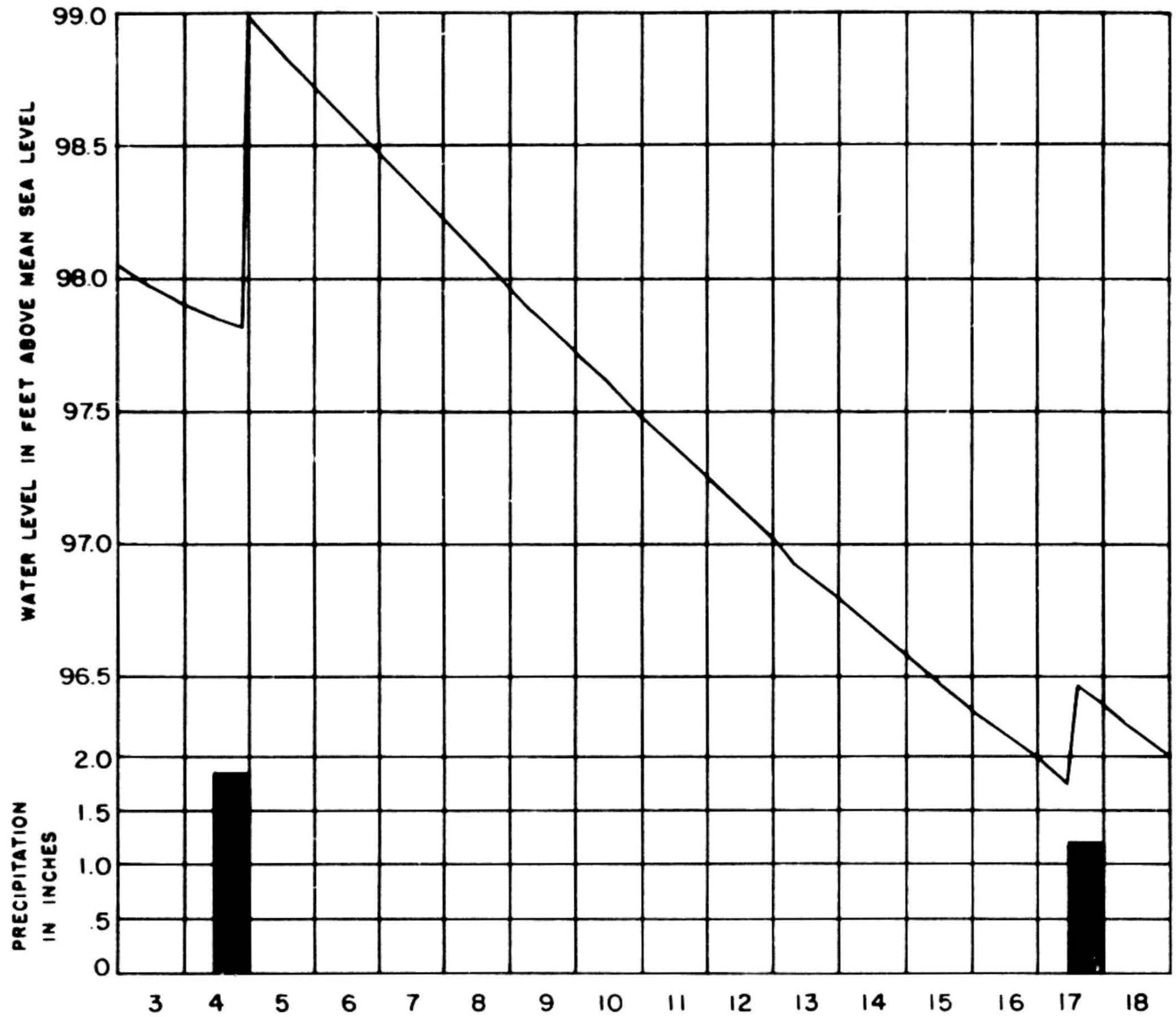

Figure 2. Hydrograph of the Spinach Road, N. J., well for July 3-18, 1951, showing precipitation and the type of fluctuations that occur in a sump well with large entrance losses.

occurred at times of large soil-moisture deficiency, and no ground-water recharge took place despite the well fluctuations. This type of well is practically worthless for water-level measurements.

Wells With Wet Casings

Erroneous measurements have been made at Seabrook because the casings of certain wells would wet the measuring tape above the water table. Sump wells have been especially faulty in this respect. Such errors can be eliminated by using unkinked tapes and by holding several different lengths of tape for a single measurement. Some workers slip a piece of curtain rod over the lower portion of the tape to make a shield that prevents the tape from being wetted by the casing. The use of electric tapes is sometimes recommended to eliminate this type of error.

Wells With Broken Casings

A broken or leaky casing can cause a well to act like a sump well. It can also cause it to receive water from an aquifer other than the one that is opposite the screen. In a pumping test that was conducted at Seabrook Farms (Remson, 1951), the aquifer being tested was recharged from a higher aquifer through the broken casing of a well. Had this not been discovered, misleading results almost surely would have been derived from the test.

Wells Equipped With Suction Pumps

Many of the small-diameter observation wells at Seabrook Farms are equipped with suction pumps for sampling the water. Before the pumps are removed to make water-level measurements, the water is held in the casing above the water table by the pump valves. When the screen is in good condition, the water will leave the well rapidly and accurate readings can be made a few minutes after the pump is removed. However, some of the wells have defective screens so that a longer time is necessary before the water level in the well adjusts to that in the aquifer.

Wells That Lack "Breather" Holes

Wells that are used for water-level measurements should be equipped with "breather" holes. Wells that lack them can not adjust freely to fluctuations in ground-water levels because of the changes in air pressure they create in the air-tight casings. Wells that lack "breather" holes but have good screens can adjust within a few minutes after the cap has been removed for measuring purposes. However, wells without either "breather" holes or adequate screens will adjust slowly to the change to normal air pressure when the cap is removed, and errors are likely to be introduced in determining the position of the water table.

Wells That Lose Water By Evaporation

Some dug wells and large-diameter wells lose water by evaporation if they are open to the atmosphere. This may be serious when the water level is close to the surface of the ground. Because water levels in dug wells are generally slow in adjusting to the water levels in the aquifer, they may be consistently low during periods of considerable evaporation.

Wells That Lose Water By Transpiration

Some old dug wells are virtually choked with roots that reach down and withdraw water from them. Just as in wells subject to evaporation, their water levels can appear too low during periods of considerable plant transpiration. This can be especially serious if the walls of a well are poorly permeable so that there is restricted passage of water between the well and the aquifer.

Wells That Are In Use

It is almost axiomatic for one to be suspicious of wells that are being used for either discharge or recharge purposes. However, the need for caution cannot be overemphasized. One observation well in the Seabrook area is used to supply no more than a hundred gallons of water a day. The well is completely unreliable for observation purposes because the large entrance losses cause slow adjustment to even these very small discharges.

Wells That Are Too Large For Observation Purposes

The porosity of the interior of a clean well is one-hundred percent. Therefore, several times as much water is needed to fill a given volume of a well than to fill an equal volume of aquifer. Furthermore, whereas well volumes vary as the second power of the radius, the wall surfaces, through which aquifer connection takes place, vary as the first power of the radius. For these reasons, more time is required for large wells to adjust to changes of aquifer water level, than for small wells. This is another factor that tends to make dug wells unreliable as indicators of water levels in the aquifer.

WELLS SITUATED WHERE LOCAL CONDITIONS ARE NOT REPRESENTATIVE

Where Discharge Or Recharge of Ground Water Is In Progress

It is well known that wells in the vicinity of either recharge or of discharge will not give proper measurements of nonpumping water levels. Many discussions in the literature point out the magnitude of these effects and the distances within which they are effective (Ferris, 1949, pp. 226-259). It is less obvious that wells in the vicinity of rapidly moving ground water do not indicate water levels accurately.

The energy of moving ground water is in three forms, velocity head, position head, and pressure head. Observation wells measure the sum of the energy appearing as position head and as pressure head. For most ground-water situations, velocities are slight enough to make velocity head negligible. Therefore, the total energy, in the form of position and pressure head, can be readily determined from an observation well. However, for rapidly moving ground water, velocity head becomes significant, and all of the energy is no longer in the form of position head and pressure head. Therefore, an observation well can no longer measure the total energy or total head of the ground water. In fact, as velocities fluctuate, the part of the total energy that is in the form of velocity head will vary so that the water level in a well will fluctuate.

Another complication is introduced when the rapid ground-water movement has a vertical component. For example, consider a stream into which ground water is being discharged with, as usual, a vertical component near and under the stream. Because the water is moving upward, and because energy will decrease in the direction of movement, the energy of the ground-water will decrease as it approaches the surface. Therefore, at the stream, a deeper well will tap a higher energy level than will a shallow one, and the water will stand higher in the deeper well. Thus, the depth of a well will have considerable bearing on the position of the water level in it where the movement of the ground water has a large vertical component.

Near Streams

Rainfall rates rarely exceed the large infiltration capacity in the Seabrook area. Fluctuations of stream levels are consequently small, and flood peaks are not much higher than the base flows. Therefore, not much thought was given to the effect upon certain wells of the fluctuating levels in a nearby stream where base flow was less than 0.5 cubic foot per second. However, the well data showed that the small rises in stream stage would be felt in wells as much as 200 feet away during an average period of storm runoff. Thus, the excellent permeability of the geologic materials, which was largely responsible for the large infiltration capacity, was also responsible for the quick transmission of stream-stage fluctuations to nearby wells.

Many areas do not have geologic materials as permeable as those in the Seabrook area, and the effects of stream-stage changes will travel less rapidly and will be damped out in shorter distances. However, these areas are likely to have smaller infiltration capacities so that the streams will be subject to larger fluctuations. Therefore, regardless of the geologic materials present, all wells in the vicinity of surface-water bodies should be examined with care.

Near Artificial Ponds

Figure 3 shows water-level contours for a wooded area near Seabrook. It is apparent that the natural surface-water bodies are effluent, or fed by ground water. However, the dam has raised the water levels in both the surface-water and ground-water bodies along the lower portions of Hands Pond, and the pond is influent there. The unusually high ground-water levels in the vicinity of the pond indicate the inapplicability of the measurement of these levels to many kinds of areal study.

Near Water-Using Vegetation

H. C. Barksdale, U. S. Geological Survey staff engineer, describes a small spring that was prone to dry up during the summer. (Personal communication) When a large oak tree nearby was cut down, the spring began to flow throughout the entire summer. This is one small example of the way in which local concentrations of vegetation can lower ground-water levels below those normal to an area, either directly by transpiration or indirectly by reducing local ground-water recharge.

In Perched Water Bodies

It had been a practice in the Seabrook area to install observation wells by hydraulic jetting. Subsequent investigation showed that some of the observation wells were not in the main aquifer but were in water-bearing materials perched above small clay lenses. This illustrates the necessity for determining the geologic conditions surrounding the immediate area penetrated by any observation well.

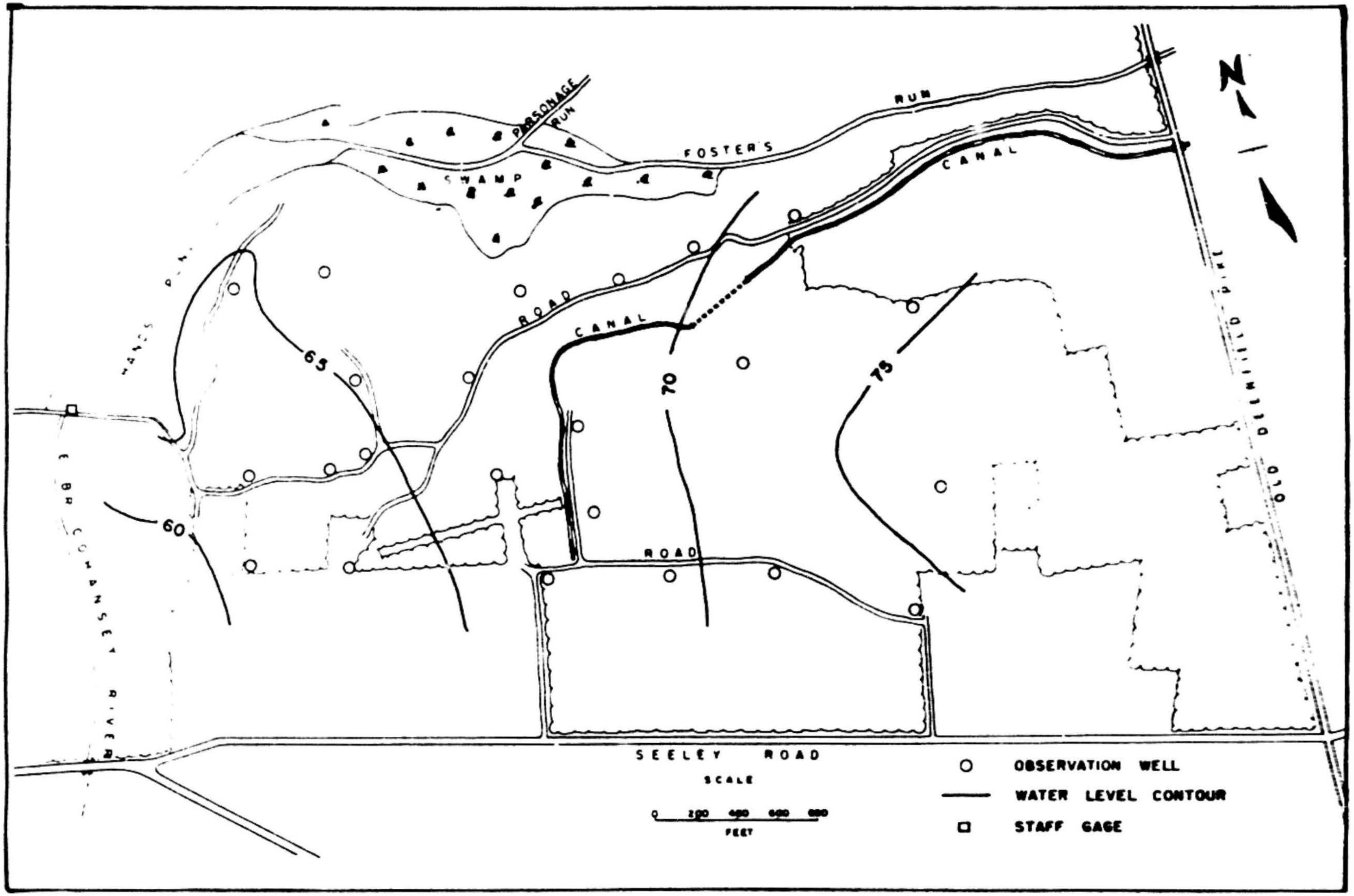

Figure 3. Map showing ground-water levels near Seabrook, N. J., on May 1, 1950. At the time of the measurements, the surface of Hands Pond was at an altitude of approximately 66.5 feet above mean sea level.

SUMMARY

This paper is not meant to be an exhaustive study of observation wells, their requirements, and their shortcomings. It is meant to show the variety of observation wells that were discovered to be defective in the course of a single investigation. The large number of unreliable observation wells encountered at Seabrook suggest that there may be many in other areas also. It is hoped that this paper will alert other investigators to the need for careful evaluation of all observation wells and to the realization that an observation well has very special requirements which can not necessarily be met by any well chosen at random.

ACKNOWLEDGMENTS

All phases of the Seabrook Farms investigations have been made possible by the helpful supervision and cooperation of H. C. Barksdale, U. S. Geological Survey staff engineer. These studies have been carried on with the close cooperation of The Laboratory of Climatology of The Johns Hopkins University and Seabrook Farms.

BIBLIOGRAPHY

Bennison, E. W., 1947, Ground water: Edward E. Johnson, Inc., St. Paul, Minn.

Blench, T., 1951, Anomalous behaviour of wells in waterlogged areas: La Houille Blanche, vol. 6, no. 1, pp. 9 - 11.

Ferris, J. G., 1949, Ground water: in Wisler, C. O., and

Brater, E. F., Hydrology, John Wiley & Sons, Inc., New York, pp. 226-259.

Jacob, C. E., 1947, Drawdown test to determine effective radius of artesian well: Am. Soc. Civil Engineers, Trans., N. 112, p. 1055.

Remson, Irwin, 1951, Results of the pumping test at Seabrook Farms, N. J., January 16 - 19, 1951: U. S. Geol. Survey open-file rept.

Rorabaugh, M. I., 1948, Ground-water resources of the northeastern part of the Louisville area, Kentucky: City of Louisville, Kentucky.

Rorabaugh, M. I., 1949, Memorandum of multiple-step drawdown tests, southwest well field, Houston, Texas: Texas Board of Water Engineers, Austin, Texas.