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SURFACE WATER BRANCH

Arthur W. Harrington, District Engineer

Albany, N. Y.

A PROGRESS REPORT ON THE DISPOSAL OF STORM WATER AT AN EXPERIMENTAL SEEPAGE BASIN NEAR MINEOLA, N. Y.

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In Cooperation with

NASSAU COUNTY

NEW YORK

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Disposal of storm water in urban, and even suburban, populated areas is a problem of major concern to engineer or public-works departments in almost every section of the country. The sites of many cities in river valleys have simplified this problem to one of constructing storm-sewer systems of the usual type, through which surface-water runoff is carried directly into nearby river channels.

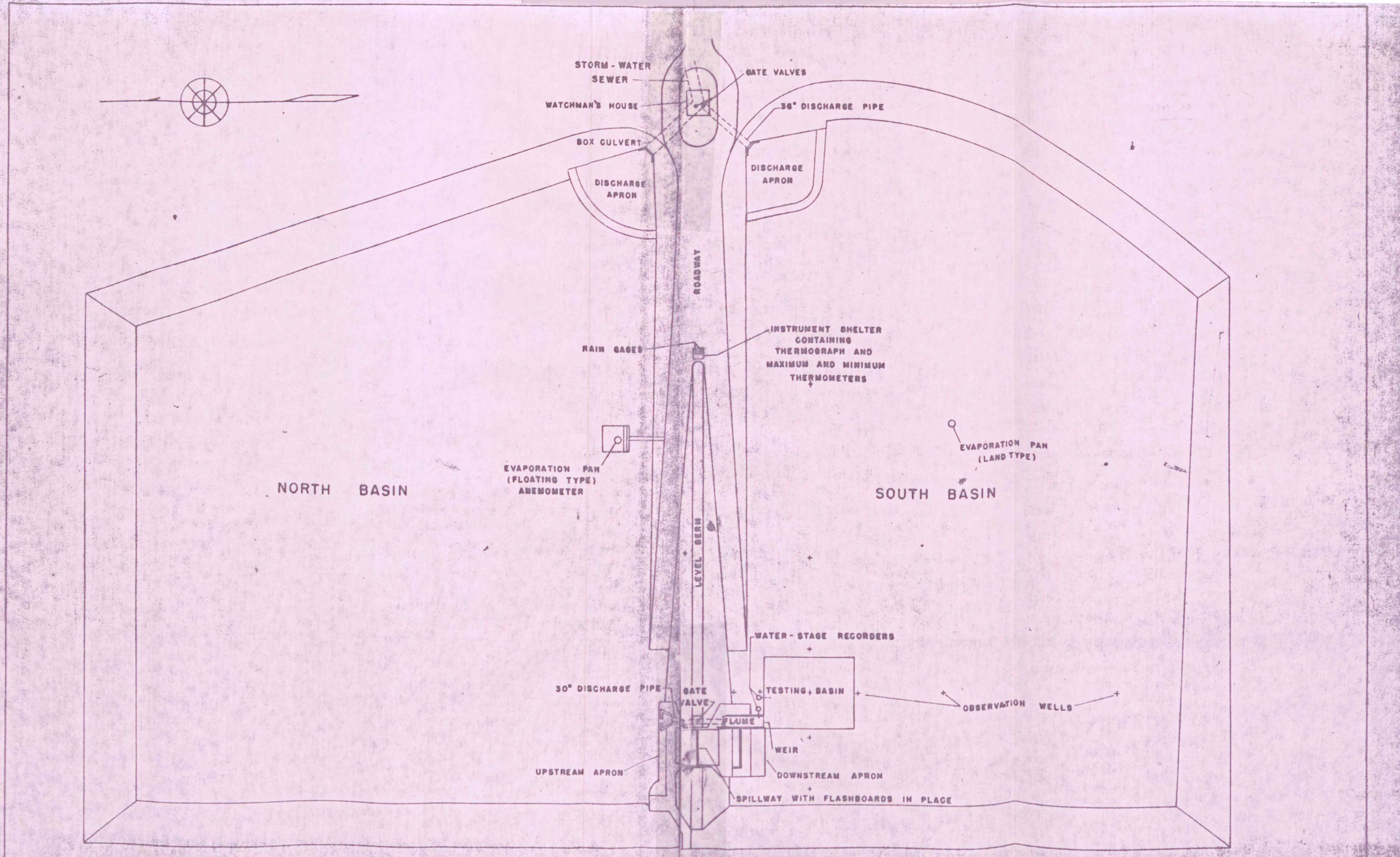
Many municipalities and heavily populated suburban communities are not so favorably situated and, especially where a rapidly increasing building program of streets, homes, and commercial buildings has caused an increase in the volume of surface-water runoff, the disposal problem is soon limited to a choice between lengthy and expensive trunk sewers to the nearest natural body of water, or to a system of storage and seepage basins situated within the community and fed by short lines of storm sewers. This latter plan has numerous obvious advantages, if the underlying material is permeable enough that rapid seepage may be expected. Areas such as the interior of Long Island are handicapped by a lack of natural drainage channels but are favored by the presence of coarse sand and gravel of glacial origin. Prior to the large expansion of housing and highway construction in the interior sections of the Island, the need for storm sewers was minimized by the small size of the impervious area and the large infiltration capacity of the surface materials. Surface water from storms of average intensity and duration was absorbed quickly and, from larger storms, was collected in shallow natural depressions from which it seeped within a short time. The movement of large numbers of people to Nassau County resulted in a building program which decreased very rapidly the land-surface area available for seepage and increased the impervious area from which storm water flows.

Such a building program of necessity must be accompanied by a program of storm-sewer construction, and Nassau County had to choose between a system of long and costly trunk sewers extending from interior sections of the county to tidewater and the south shore or a system of short sewer lines terminating in seepage basins excavated at strategic interior points. The latter system was selected as part of the long-range drainage plan in 1935, consideration having been given to the need for conservation of the county water supply. The system of long trunk sewers would have carried great quantities of this valuable resource to tidewater and thereby removed it from areas whose water supply it would have replenished. The system of short sewer lines and seepage basins, therefore, in addition to certain economies of construction, provided a means of water conservation comparable in effectiveness to the natural surface conditions of the area. By this system the surface-water runoff during a storm is carried through relatively short sewer lines to artificial collecting basins. From these basins the water seeps through the underlying natural deposits of sand and gravel and thus is returned to the underground reservoir from which most water supplies on Long Island are taken. Because of this replenishment of the water supply, the use of the term "recharge basin" commonly is used to describe these artificial depressions.

Application of this method of surface-water disposal has spread throughout the interior areas of Nassau and Suffolk Counties. It is used by the two counties and their respective towns, and by the State of New York for disposal of water from streets and roadways, by building contractors in housing projects, and by industries for disposal of treated waste water as well as storm water. Many of the small seepage basins are underground and similar in construction to the common cesspool; other small basins are built as open pits along rural roads and are barricaded by suitable fences. The larger basins are excavated as open pits of a size deemed adequate to contain the surface-water runoff from the surrounding area during a large storm.

Design criteria for such basins were lacking at the time the first group was built by Nassau County and, as the need for more basins increased, it became evident that the performance of those already in use should be studied to determine, if possible, their fundamental characteristics, including performance limitations. The expanding use of this method for disposal of storm water in Nassau County and elsewhere on Long Island may be taken for granted, but the fullest adaptation of the method can be reached only with a better understanding of the factors that control the seepage process under the operating conditions that exist within this immediate area.

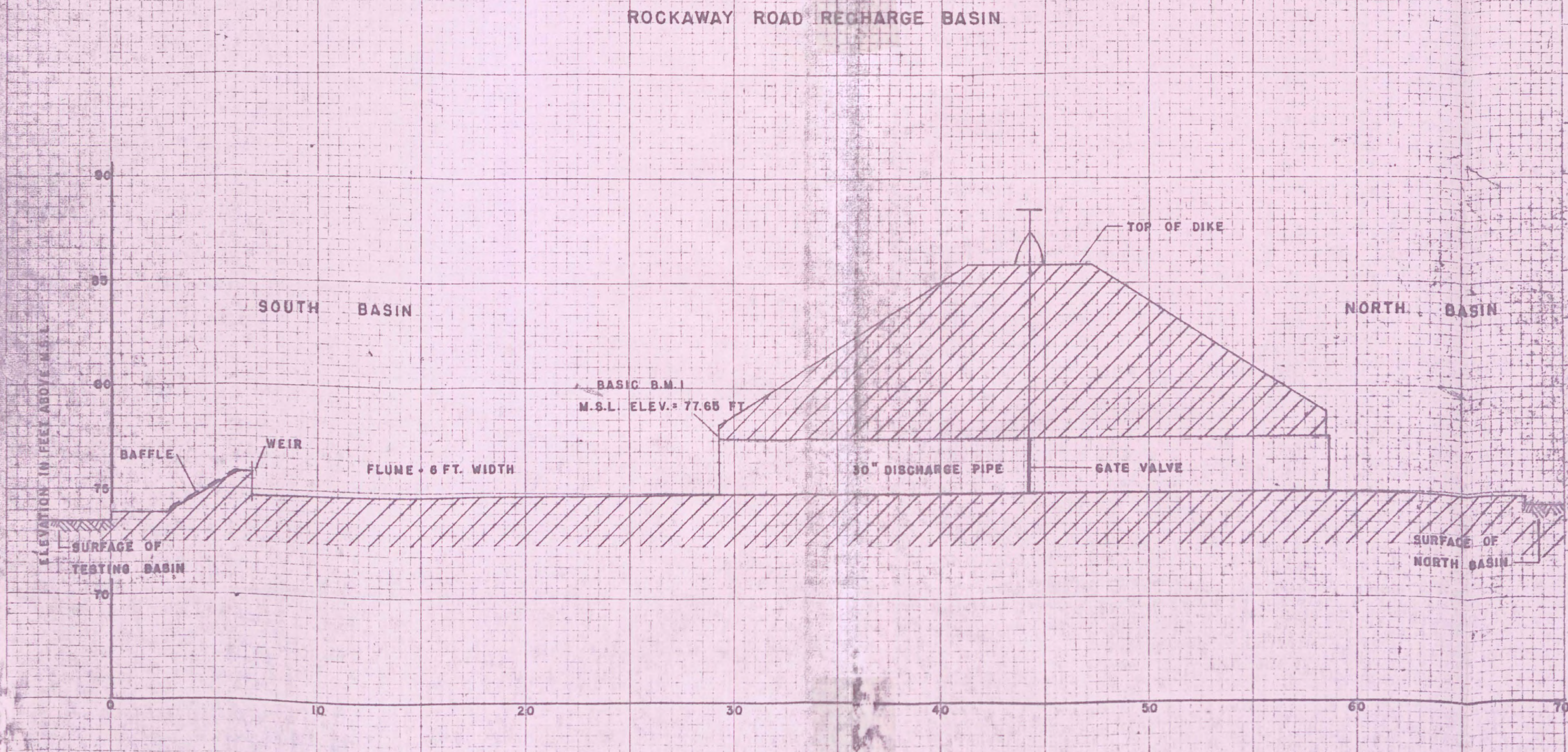
For the purpose of such studies, a cooperative agreement was concluded in 1948 between Nassau County and the U. S. Geological Survey, and plans were begun for an experimental project to be located in an existing seepage basin. The use of unfiltered storm water, rather than hydrant water, was considered essential to the success of these experiments, and for best results this water supply should be available at all times and ample in quantity. Only the Rockaway Road basin, near Mineola and Garden City, was found to meet this requirement. The layout here is shown in Plate 1. These basins are separated by an earthen dike, with



ROCKAWAY ROAD EXPERIMENTAL SEEPAGE BASIN PROJECT

PLATE 1

PLATE 2



PROFILE ALONG CENTERLINE OF FLUME AND DISCHARGE PIPE FROM TESTING BASIN TO NORTH BASIN

Year,	
Meas. Nos.,	
Max. G. H.,	
Min. G. H.,	
Plotted by	
Checked by	

Curve approved by: .... Office Engineer. .... District Engineer.

masonry spillway equipped with timber flashboards. Near the spillway a 24-inch hand-operated sluice gate is set in a 30-inch concrete pipe discharge line connecting the two basins at the floor elevation. The floor of each basin is nearly level, and the minimum height of the banks surrounding the basins is about 12 feet. Surface-water runoff, from storm rainfall or melting snow, enters the north, or desilting, basin through the system of collecting sewers. If and when the duration and intensity of the storm rainfall, or the runoff from melting snow, results in a greater volume of inflow than the capacity of this basin at that time, the excess volume flows over the spillway into the south, or seepage basin. During the period of detention in the desilting basin the heavier particles of silt settle to the bottom, and during periods of overflow only the lighter particles are carried over the spillway to the seepage basin. Over the years the accumulation of silt on the bottom and sides of the desilting basin had reduced the rate of seepage from that basin to such an extent that water was impounded to a depth of several feet between storms. This impoundment would provide a constant supply of unfiltered storm water with sufficient head for flooding a small (40 ft. x 50 ft.) experimental seepage basin to a depth of several feet and with sufficient volume for maintaining a suitable rate of inflow to the experimental basin for ample testing periods, or for repeated floodings of the plot at regular or irregular intervals of time.

Careful consideration was given to the design and layout of the project in order to make the best use of the original features, and in final form the experimental apparatus consisted of a measuring flume 6 ft. wide and 22 ft. long with a sharp-edged steel weir plate at the discharge end, a testing basin 40 ft. x 50 ft., constructed of tongue-and-grooved timber, a water-stage recorder with concrete stilling well and timber shelter for recording head on the weir, and a similar recorder installation for recording depth of water in the testing basin. The stilling wells consisted of 30-inch concrete pipe sections set vertically on concrete foundations. Timber recorder-shelters were bolted to these concrete stilling wells.

All structures of the project which were to be located on the floor of the south, or seepage, basin were designed for complete submergence. Records of water level previously collected by the County of Nassau showed that this basin would be flooded to a considerable depth during periods of unusually high runoff. Plans were made for removal of the recorders from their shelters when not in use. All testing apparatus was located and constructed so that it would not interfere in any way with the regular operation of the south seepage basin. Plate 1 illustrates the relative size and location of the north (desilting) and south (seepage) basins, the flume, weir, testing basin, recorder wells, sluice gate, and spillway. Plate 2 shows a profile of the flume and discharge pipe between the north and south basins.

The rate of inflow to the testing basin was to be measured by means of the calibrated weir, and the rate of seepage from the testing basin would be measured on the basis of the observed changes in volume of water stored in that basin, and the rate of inflow to the basin, during any selected interval of time. During periods when seepage from this basin exceeded inflow, the volume of water in storage would decrease, and vice versa. (see example in Table 1). By means of the 10:12

gage-height scale of the testing-basin water-stage recorder it was possible to determine relatively small changes in volume in storage.

Other instruments and apparatus installed in the immediate vicinity and used in connection with the seepage tests included the following: A floating evaporation pan in the desilting basin, an anemometer on the raft surrounding this pan, a land-type evaporation pan on the floor of the large seepage basin, maximum and minimum air-temperature thermometers, recording and nonrecording precipitation gages, a water-temperature thermometer, and two water-stage recorders, one on the desilting basin and the other on the main seepage basin. The observations of water loss from the so-called evaporation pans were intended to serve the twofold purpose of collecting the first data of this type in the area and of providing a record of the approximate amount of water lost from the testing basin during periods of operation. Daily observations were made at both pans during the months when the water in the pans was not frozen. The data thus collected provide a good record of the water loss from such pans at this location and under the conditions existing here. Observations of water-table fluctuations under and around the test basin, caused by the testing operations, were considered desirable, and several observation wells were installed. The relative location of these and the other instruments and apparatus also is shown in Plate 1.

Following construction of the flume, weir, testing basin, water-stage recorder wells and shelters, evaporation pans, and thermometer shelter, and the installation of the required instruments, the weir was calibrated and all equipment tested to insure satisfactory operation. Certain assumptions relating to actual operation that had been incorporated into the original plans were verified by actual test runs.

Before establishing a schedule of the experiments to be conducted, a careful study was made of the so-called infiltration phenomena to be expected under conditions such as those to be found in the average Nassau County seepage basin. In hydrologic literature infiltration is the term commonly used to describe the movement of water through the surface zone of a natural soil profile. However, because the natural soil profile in this area of Long Island is normally only a few inches in depth this material was removed during construction of the large desilting and storage basins, and the term infiltration is used herein to describe the movement of water through an artificially-created surface zone, or layer, composed of various organic and inorganic sediments deposited by storm water. It was anticipated, therefore, that the most critical conditions governing infiltration here would be those that exist in this surface zone, and that the size and arrangement of the particles of sediment and the changes which these particles undergo when wetted, dried, frozen and thawed would determine, to a great extent, the rate of movement of water through this critical zone.

Some other factors affecting infiltration relate to subsurface conditions and include soil moisture, the amount, distribution and types of colloids present, depth to the water table, the location of less permeable zones, surface tension and film forces, chemical composition of the water, and temperature of both the soil and the water. It was expected that the probable influence on infiltration of some of these factors could not be determined by the experiments to be conducted here, but other conditions such as freezing and thawing of the surface zone were expected to show a pronounced influence and plans were made to study this influence during the course of the project.

The depth, or distance, from the basin surface to the water table was expected to remain sufficient in magnitude during the testing operations to insure that seepage rates were not being influenced by the water-table position. Only on rare occasions when the south basin might be flooded to a depth of 10 feet or more was it expected that seepage from that basin would exceed the lateral seepage capacity of the surrounding materials. Only by submerging a considerable portion of the sodded and highly permeable basin walls would this be possible, but under such conditions it was expected that the water table might rise to a level equal to or higher than that of the south basin bottom. This would be a temporary condition, would occur infrequently, and would not be representative of the conditions that had been observed during the major portion of the period of operation of the Rockaway Road basin installation. The entire testing program was planned for those flooding conditions known to occur most frequently rather than unusual conditions.

Of primary interest, however, was the question of similarity of the materials underlying the area in which new seepage basins might be built to those underlying the Rockaway Road basin. As stated above, it was anticipated that the surface zone would control seepage rates because the accumulation of fine silt, etc., had reduced the permeability of that zone below that of the underlying material, but it was recognized that this condition could be modified readily by removing either the entire surface zone or the fine material therein. By thus increasing the permeability of the surface, the control zone might become any zone of lower permeability at a lower elevation and above the water table. In other words, the critical zone is believed to be the zone of lowest permeability between the surface and the water table, and only if general similarity of the underlying materials throughout the area does exist would it be possible to use at other sites within that area the results of the tests to be conducted at the Rockaway Road basin.

Most of the existing basins were excavated to depths of 10 to 15 feet and the materials exposed in these excavations were found by inspection to be more or less similar. To extend this inspection to greater depths, and include the material underlying the existing basins, a testing program was carried on by Bernard M. Rolfe, Soil Scientist, U. S. Geological Survey. By means of small excavations in seepage basins situated southeast and north of the Rockaway Road basin, Mr. Rolfe collected samples of the underlying material at various levels and reported, in part, as follows: "The stratigraphy of the basins is quite similar. They are located in sandy, gravelly outwash plain, product of Wisconsin glacial action. The material is coarse textured and extremely permeable. The direction of deposition was from north to south and occasional lenses of clay will be distributed along this axis, which lenses cause slow, restricted percolation, and may result in ponding." Descriptions of profiles for the basins at Rockaway Road, Herrick Road, and Stewart Avenue, as written by Mr. Rolfe, are as follows:

<u>Basin</u>

Site - Rockaway Road Recharge Basin (M-1).

Location - N. W. corner of main seepage basin.

Profile Description

(1) 0"-4" Dark gray, fine gravel to coarse sand containing rounded quartz gravels and scattered mica fragments. Gravel forms a surface cap and is underlain immediately by coarse sand. Structureless - single grain aggregation.

(2) 4"-13" Yellow-brown coarse to medium sand, subangular, clean quartz. Structureless. More moist than material above. (Presence of more fines than above).

(3) 13"-25" Coarser subangular quartz fragments, Muscovite (white) mica abundant. Structureless. Whitish-yellow color. Drier than preceding.

(4) 25"-30" Brown, coarse, more moist than material above, subangular, fine gravel fragments. Iron stains on quartz and other indications of slight presence of iron oxides.

(5) 39"-48" Dark, rich brown, moist, subangular coarse sand and fine gravel. Iron-stained and moist. Structureless. Presence of a few larger particles.

Note.- The dark, organic layer of fine sludge on the surface is the deposit of storm waters. These fines present a tightly-curled appearance when dry. Average soil T. = 76°F.

Basin

Site - Rockaway Road Recharge Basin (M-2).

Location - S. E. corner of seepage basin slightly higher elevation than M-1.

Profile Description

(1) 0"-4" Gravel cap evident (seems common to entire basin). Coarse sand darkened by organic material interspersed with pebbles. Structureless, brown color.

(2) 4"-13" Rich reddish-brown coarse sand. Pebbles are rounded, coarse sand fragments are angular. Structureless (but resistant to shovel).

(3) 13"-25" Same as above.

(4) 25"-39" Similar to above. Greater % fines, more moist than material above.

(5) 39"-48" More moist than material above. Color (purple) dominated by Mn-bearing pebbles.

Few gravels as large as 3" diameter. Larger ones rounded, smaller angular (a characteristic of glacially moved quartz particles.)

Structureless. Rather moist.

Note.- Profile is characterized by resistance to shovel, in contrast to M-1. Many pebbles (rounded) of size $2\frac{1}{2}$"-3" diameter. Slight increase in fines appears sufficient to cause higher moister content along with cementing influence. Slight pressure with fingers is sufficient to rupture aggregation.

Basin

Site - Rockaway Road Recharge Basin (M-3)

Location - N. W. corner of seepage basin.

Description

No pit dug for samples. Digging was easy - bulk of material is coarse sand with few large pebbles. Most lie within 1"-2" diameter range. Directly beneath surface 4" of organically darkened material lies 4" of grayish white coarse sand. This is in turn underlain by a layer of pebbles of schistose rock.

Basin

Site - Rockaway Road Recharge Basin (M-4).

Location - Directly beside test plot.

Description

Generally similar to M-1. Dark organic layer on surface is underlain by thin white coarse sandy layer; followed by a foot of decomposed granitic sand and gravel, most of which is leached; no ferruginous material.

Basin

Site - Herrick Road Basin (M-6).

Location - Near center of upper and lower levels of basin.

Profile Description

Upper Seep Area (1) Gravel cap (darkened by organic silting). This layer is 4" deep - sharply underlain by band of deep red, iron-stained sand and gravel-sized quartz fragments. Coarser fragments are sub-rounded while sand size is angular. From 6" down, similar to above. Yellow-brown coarse sand-size quartz interspersed with gravel of varying size up to 3" diameter.

Lower Seep Area (2) Similar to above. Gravel interspersed with sand size through profile. Moist at 2 ft. The finer sand extends to depth of 1 foot, contains numerous mica particles. The coarser sand is at 2 feet, moist, contains dark and light quartz particles.

Basin

Site - Stewart Avenue Basin.

Location - No pit dug.

Description

Undisturbed cover of silting has resulted in dark layer of fine material. Subsurface is similar to other basins; a coarse porous profile.

His summary states "The descriptions are those of a glacial outwash plain, little modified by cultural practices. Any variation will be caused by randomness in deposition. Generally, the basin profiles show similarity as to coarseness of texture, absence of fines, and extreme porosity".

Although the natural soil mantle covering the outwash plain is usually not more than a few inches in depth, it must be remembered that the seepage basins under study are merely large excavations with depths of 10 to 15 feet and hence do not have natural soil-surface horizons. Every profile described by Mr. Rolfe is characterized by coarse sand, rounded pebbles, and gravel of varying size up to 3 inches in diameter.

The absence of clay and colloid is noticeable and little or no swelling is expected.

Test holes were not dug inside the testing basin because the underlying materials had been examined while excavating the trench for the timber wall of the basin. This trench was 3 feet deep and surrounded completely the area to be tested. This examination showed that these materials, and their arrangement, were similar in all respects to those at surrounding basins. There were two reasons for not disturbing the surface of the testing basin. First, it was desired to eliminate from the study the unknown, and perhaps variable, effect of scarifying, and second, if the capacity of the testing basin without scarifying was found to be equal to that of the large seepage basin with scarifying, some economy could be effected by eliminating this practice as a feature of basin maintenance.

Thus, on the basis of Mr. Rolfe's observations it can be stated that the materials underlying the area in which basins are now being operated are similar in all pertinent aspects, and it may reasonably be assumed that the seepage characteristics observed at the Rockaway Road basin will not differ greatly from those of other basins in the area insofar as the subsurface materials are concerned.

Because of the greater percentage of fine silt and organic material in the surface zone of all basins examined than in the underlying material, it was assumed that the permeability of the underlying material is greater than that of the surface material. Also, as mentioned on p. 8, because of the usual 8 to 10 feet distance between the surface zone of the testing basin and the water table, and because of the lower permeability of the surface zone than that of the subsurface zone, it was assumed that the water table under the testing basin would not rise sufficiently during testing operations to interfere with or influence the seepage from the testing basin.

Further, it was recognized that the testing apparatus had certain physical limitations with respect to size and that extreme conditions such as those resulting from large, infrequent storms, could not be tested. These limitations were not believed to be serious, however, because of the relatively few flooding events that would fall outside the range of testing that would be possible and because that range was believed to cover the majority of storm events occurring in any one year. Design criteria for seepage basins are subject to certain flexibilities dictated by local conditions and it was expected that the results of testing in the experimental basin would provide a more adequate basis for adjusting design to site conditions.

With further regard to the infiltration phenomena, consideration was given to the probable accumulation of silt on the surface of the testing basin as compared with the probable accumulation on the large seepage basin. Water for the testing basin was to be drawn from the bottom of the desilting basin and was expected to have a higher sediment concentration than that of the water that flows from the top of the desilting basin into the large seepage basin during storms. However, the sediment load of this overflow was expected to vary as a result of differences in the detention period, and at times the load might be equal to the usual concentration of the water drawn from the bottom for testing in the small basin. Thus the rates of accumulation of sediment in the two basins on an annual or long-term basis might be nearly equal and it was concluded that any small differences that did exist would be impracticable to measure.

Another factor that required study in relation to the expected infiltration characteristics of the test basin was the development of what is sometimes called a saturated front in the profile between the surface of the testing basin and the water table. It was desired to learn whether or not the sub-surface material became saturated during periods of flooding of the testing basin and to establish a relationship between the depth of water in the basin and the depth of the saturation zone, if such a zone was developed. The necessary testing for this study was done by placing tensiometer cups at depths of 6, 12, 24 and 48 inches below the surface at points about 10 ft. apart across the test basin from north to south. Each was calibrated to zero, in saturated material taken from the profile, and carefully sealed with a watertight collar just under the ground surface to prevent water from running down the tube. The testing basin then was flooded to a depth of about 0.5 ft., tensiometer readings were made at brief intervals until all readings had reached equilibrium. A relatively uniform depth of water was maintained over the basin surface during the period required for this test, and the rise in the water table under the basin during the test was observed to be rather small. Readings of the tensiometers were continued until it became evident that the readings were not going to change. The flow into the testing basin then was shut off, the basin was dewatered, and the tensiometer readings were allowed to rise to their highest point, indicating that all of the water that could pass downward through the sand and gravel under the force of gravity had passed the depth of the lowest tensiometer cup. The test was repeated several times using successively greater depths of water in the testing basin. The tensiometers were left in place following these tests and additional readings were made during other types of tests such as those illustrated on Figures 15, 16, and 17. The tests illustrated by those figures were started November 5, 1951 and the testing basin was flooded continuously for several weeks thereafter, and the depth in the basin was varied from 2.8 ft. (water level at top of testing basin wall) to less than 0.5 ft. Tensiometer readings made on November 15, 1951 did not show saturation at either the 6 inch, 12 inch, 24 inch, or 48 inch depths (48 inch was maximum depth tested) although the basin had been flooded continuously since November 5, and to depths as great as 2.8 ft. November 9. The temperature of the water in the large (south) seepage basin was 54°F and in the testing basin, 53°F, at the time of the tensiometer readings November 15. During the tensiometer tests previous to those of November 15 saturation was not shown at any of the depths tested (6, 12, 24, and 48 inch), but some of the readings for the 6-inch depth indicated a greater moisture content at that level than at the lower levels. This may have resulted from a slight leakage around the seal but it is very doubtful that complete saturation was developed at that level over the entire area of testing basin, and it is certain that complete saturation did not develop at any of the lower depths. These results are believed to have verified the assumption made earlier, that the rate at which water will move downward to the water table through the material beneath the surface zone and then laterally through the surrounding material, is greater than the rate at which water will pass through the surface zone of either the testing or the south seepage basin, and, that the development of a saturated front appreciably greater than that of the surface zone is not possible. An attempt to saturate the highly permeable subsurface material with water passing through the material of low permeability at the surface would be similar to an attempt to fill a coarse sieve with water passing through a fine sieve.

The water temperatures observed November 15 indicate that the low air temperature of the preceding night had a greater effect on the smaller volume of water in the testing basin than on the larger volume in the south seepage basin, resulting in a differential of 1°F. During other simultaneous tests of the two basins the average water temperature in each basin was the same, or so nearly the same as to rule out the possibility of explaining the difference in seepage rates as the result of different water temperatures in the basins.

In addition to these preliminary studies of the factors that were expected to influence infiltration in the testing basin as well as in existing and possible future seepage basins in this area, considerable study was given during the planning of the project to the types of tests that would be most suitable.

As a result of these studies plans were made to conduct all tests for a period of several growing seasons without removing the silt or weeds and without scarifying the surface of the testing basin. The south, or seepage basin, was kept clear of weeds and was scarified occasionally by Nassau County maintenance crews.

Repeated-flooding tests and tests of continuous flooding at constant head and continuous flooding at variable head were planned for all seasons of the year. Simultaneous tests of the south seepage basin and the testing basin were planned for periods when conditions were suitable. Such conditions would exist after both basins had been flooded during a large storm and when the water level had receded to the top of the testing-basin wall and when there was no more inflow from the north basin. Below that point the two basins are separate units and their respective water-surface elevations would be recorded by the water-stage recorders installed on each. Water temperatures in the two basins would be equal or nearly equal, and both would have been flooded for about the same period of time prior to the tests, thereby eliminating these two factors from consideration in studying the results of the tests. (The possibility of making these simultaneous tests of the two basins by attempting to measure the inflow into the south seepage basin during periods of overflow of the north, or desilting basin, was given careful consideration and abandoned because of the impracticability of constructing and rating a weir on the spillway between the north and south basins by means of current-meter discharge measurements. The use of a theoretical rating for such a weir would have introduced an error of unknown magnitude into the comparative data, making the results unreliable and possibly misleading). The repeated-flooding tests were expected to show the effects on infiltration of alternate wetting and drying of the surface, and during the winter to show the effects on infiltration of freezing and thawing of the surface zone. The continuous-flooding tests were expected to develop relationships between seepage capacity and period of flooding for various periods throughout the year. The effect on infiltration of the root channels of the plants that were allowed to grow could best be determined by means of two identical testing basins operated concurrently, one with growing plants and one without. Such a plan was not feasible here and a decision was reached whereby the plants would be allowed to grow for several seasons, during which various types of tests would be conducted and after which the plants would be removed and a similar testing program repeated. The results of the two series of tests would be expected to show the approximate effect on infiltration of the plant roots at different times of the year. An exact determination of this effect of the roots would not be possible because of other factors that could not be held constant.

It was expected that tests other than those planned might be made during the course of the project as experience was gained and as the need for such tests became evident.

After calibration of the weir was completed and the instrumentation of the project had been tested under operating conditions, actual testing was begun in February 1949. In the following pages the results of most of the testing that was done between that date and October 1953 will be illustrated graphically and described. These results cover the types of tests mentioned above.

Four consecutive floodings of the testing basin were made Feb. 11, 1949. The first recession was not completed when the second flooding was made, hence the first test has not been included in Figure 1. Tests 2, 3, and 4 are shown in Figure 1 with seepage rate in gallons per square foot per day plotted against depth of water in basin in feet. The same units were used in later tests of similar nature. The surface of the testing basin had been frozen and thawed several times prior to these tests and the seepage capacity was very high. Some reduction in capacity resulted from the repeated floodings, as shown between tests 3 and 2, but the higher head used for test 4 appears to have increased the seepage rate somewhat more than the reducing effect of the repeated floodings. The difference in rates between tests 3 and 4 is negligible.

Another type of test is illustrated in Figure 2. This test was started August 15, 1949, at 11 a.m., with a rate of inflow to the testing basin of 129 gallons per square foot per day. This inflow rate represented the seepage capacity for a depth of 0.08 foot of water in the basin and that depth was maintained until August 16, 9:45 a.m. At that time the inflow rate was increased to 234 gallons per square foot per day and the depth increased gradually to 1.20 feet August 17, 3 a.m. Inflow was next increased to 279 gallons per square foot per day and the depth increased gradually to 1.54 feet August 17, 9:30 p.m. Inflow was then decreased gradually to 144 gallons per square foot per day and the depth fluctuated slightly but did not change appreciably. During the period August 19, 1 p.m., to August 22, 8:45 a.m., the depth increased slowly and reached equilibrium at 2.15 feet when the inflow rate was about 149 gallons per square foot per day. Between 8:45 a.m. and 1 p.m. August 22, the inflow decreased to 127 gallons per square foot per day and the depth decreased to 2.11 feet. The test was ended there. One of the most significant things demonstrated by this test is the final seepage capacity of the testing basin of more than 127 gallons per square foot per day for a depth of just over 2 feet, after continuous flooding for 170 hours at variable rates and heads.

Two consecutive floodings were made October 11, 1949, results of which are shown in Figures 3 and 4. Figure 3 shows a rather complete picture of the relationship between the two tests. These graphs were drawn on the basis of depth and seepage rate data taken directly from the field data for half-hour intervals. Seepage rates are compared at identical depths and it is noted that for depths down to 0.6 foot the capacity of the basin during test 10 was about 32 per cent of the capacity during test 9. At the smaller depths the relative capacities approach each other. Test 10 was started immediately after test 9 was completed, and although the initial depth for test 10 was less than that for test 9, $3\frac{1}{2}$ hours more time was needed to dewater the basin for test 10 than for test 9. Figure 4 shows the average seepage rates for the two tests in relation to the midpoint of each test. The average rate for the second test is equal to 51 per cent of the average rate for the first.

Figure 5 illustrates the results of a continuous inflow test October 26-28, 1949, during which the rate of inflow to the testing basin decreased very slowly from 168 to 124 gallons per square foot per day. At the beginning of the test run, a large proportion of the inflow went into storage, but, as the depth increased, the seepage rate increased also, and the storage rate declined. The effect of continued submergence became apparent early on October 27 when the seepage rate began to decline without a consequent decline in depth. The depth increased slowly until the inflow was shut off October 27, 1:45 p.m., at which time the seepage rate was 122 gallons per square foot per day and the depth was 2.15 feet.

Figure 6 shows the results of a pair of tests (12 and 13) with an elapsed time interval of 145 hours between the first and second. It is noted from the table on Figure 6 that although the second test had an initial depth 0.34 foot greater than the first, the time consumed in emptying the basin for the second test was $3\frac{1}{2}$ hours less than that for the first. It is observed, also, that the seepage rate for the second test is about 134 per cent of that for the first test for any depth.

Figure 7 shows the results of test 14, a single flooding December 15, 1949, soon after the basin surface had been frozen and thawed. The initial seepage rate was more than 400 gallons per square foot per day, and at the end of the dewatering period, as the basin was emptied, the rate was about half the initial rate. The initial depth was 1.39 feet and the time consumed in dewatering the basin was about 0.7 hour, as compared with 1.86 feet and 13 hours, the initial depth and time for dewatering for test 12 made Nov. 2, 1949, prior to the freezing and thawing.

Figure 8 was prepared from the results of test 15, January 5-7, 1950 during which inflow to and seepage from the testing basin were equalized at a depth of about 2 feet in the basin. This condition of equilibrium was maintained until the water table at the observation well at the center of the testing basin was observed to be approaching a constant level, about 2.8 feet higher than at the beginning of the seepage test. The observed rise in the observation well 150 feet south of the testing basin was about 0.4 foot.

Figure 9 shows the relationship between seepage rate and depth of water in the testing basin during the dewatering period of test 15. The basin had been flooded $6\frac{1}{4}$ hours to a depth of about 2 feet but was dewatered in $1\frac{1}{2}$ hours after inflow was stopped.

Table 1 is a tabulation of the pertinent data observed during test 15, with an accounting for the total inflow and the total seepage.

The rate of inflow was determined by means of the weir (calibrated by current-meter measurements), and the total inflow during each interval was computed on the basis of this rate of inflow per minute and the length of the interval in minutes. The total possible rise of the water level in this basin during each interval also was computed from the total inflow figures. The summation of this column shows the height in feet of the column of water, 40 ft. x 50 ft. in plan, that passed through the bottom of the testing basin as seepage between 10:10 a.m. and 5:40 p.m. January 5, 1950. The amount of rise or fall of the water level in the basin during each interval was determined from the graph produced by the water-stage recorder connected to this basin, and the changes in storage during each interval were computed on the basis of this record and the known area of the basin. Total seepage from the basin for each interval was computed on the basis of the total inflow and the storage changes. Each of these components was computed independently, hence the difference of 1.1% between the computed values of total net inflow and total seepage indicates a relatively high order of accuracy of the observed data.

Observations of water loss from the floating evaporation pan indicated a total loss of about 20 gallons of water from the testing basin by evaporation during the testing period. This amount was subtracted from the total inflow before comparison of the inflow and seepage figures.

Test 15, Jan. 5, 1950

Time intervals 10:10 a.m. to 5:40 p.m.	Number of minutes in interval	Measured inflow to testing basin Rate, gals.per minute	Total gals.	Total possible rise of water level in basin w/o seepage, feet	Measured rise or fall in water level in basin during interval, feet	Gain or loss in storage in basin during intervals, gals.	Total seepage from basin during interval, gals.	Average seepage rate during interval, gals.per sq.ft. per day
10:10-10:32	22	1,343	29,546	1.975	+1.760	+26,331	3,215	105
10:32-11:32	60	480	28,800	1.925	- .237	- 3,546	32,346	388
11:32-12:15	43	674	28,982	1.937	+ .504	+ 7,540	21,442	359
12:15- 1:00	45	525	23,625	1.579	+ .035	+ 524	23,101	370
1:00- 1:17	17	466	7,922	.530	- .035	- 524	8,446	358
1:17- 3:52	155	471	73,005	4.880	(- .010 (+ .010	0	73,005	339
3:52- 4:26	34	430	14,620	.977	- .063	- 943	15,563	330
Inflow shut off at 4:26								
4:26- 5:40	74	-	-	-	-1.809	-27,064	27,064	263
Totals	450	-	206,500	13.803	-	+ 2,318	204,182	-

	Gallons
Total gross inflow	206,500
Evaporation loss	20
Total net inflow	206,480
Total seepage	204,182
Difference	2,298 = 1.1%

Figure 10 shows the results of another continuous-flooding test. Inflow was started at 9:15 a.m. April 4, 1950, at a rate sufficient to cause the depth to increase in the testing basin. About 11:15 a.m. the inflow rate was decreased to 171 gallons per square foot per day and the depth became stable at about 0.82 foot. At 12:08 p.m., inflow was increased and the depth again was allowed to increase. About 2:10 p.m., the inflow was decreased to 164 gallons per square foot per day and the depth became stable at about 1.12 feet. Inflow was increased again and the depth allowed to increase until 7:15 p.m., when inflow was reduced to 138 gallons per square foot per day and the depth became stable at 1.57 feet.

Figure 11 has been prepared to show the results of another continuous-flooding test, starting first with a high inflow rate and maximum depth. Inflow was started at 9:45 a.m. April 7, 1950, and at 5 p.m. the inflow and seepage rates had reached a state of equilibrium at depth 1.84 feet. Inflow was reduced further and equilibrium was reached again at depth 0.81 foot at 7:30 a.m. April 8, 22 hours after flooding began. Inflow was increased at this point but the effect of the continued flooding resulted in equilibrium between depth, inflow and seepage being reached at a smaller seepage rate than formerly obtained for the new depth. Thus at the point marked 36 hours on Figure 11 it is observed that the seepage rate is less than 150 gallons per square foot per day at a depth of 1.05 feet, while prior to the 22-hour point the seepage rate for 1.05 feet depth was about 170 gallons per square foot per day. The next phase of this test was the reduction of inflow to 88 gallons per square foot per day. This inflow rate reached equilibrium with seepage at depth 0.51 foot at about 12 m. April 9, 51 hours after flooding began. The next lower point of equilibrium was reached at 5 a.m. April 10, with inflow equal to seepage at about 50 gallons per square foot per day at depth 0.39 foot. A further reduction in inflow resulted in an extreme low point on the graph. After 97 hours of continuous flooding, inflow and seepage rates were equalized at about 21 gallons per square foot per day at depth 0.08 foot. Thereafter the inflow rate was increased and the depth increased, but not in the same relationship as existed earlier in the test. With inflow rate at about 48 gallons per square foot per day, the depth finally became stable at 0.70 foot as compared with 50 gallons per square foot per day at depth 0.39 feet after 67 hours of flooding. The last phase of this five-day test was the reduction of inflow to about 32 gallons per square foot per day. Equilibrium at this rate was reached about 12:30 p.m. April 21 at depth 0.43 foot, 123 hours after flooding began April 7. This is more than twice the depth at which equilibrium would have been reached for the inflow rate prior to the 97-hour point in the test.

It was stated earlier in this report that plans were made for conducting simultaneous tests on the main seepage basin and on the testing basin when the main basin was flooded to a depth at or below the top of the testing basin wall. The first such test was made May 29, 1951, and is illustrated in Figure 12. About 8:15 a.m. the testing basin was flooded to a depth somewhat greater than that in the main basin and inflow was shut off. The water level in the testing basin fell rapidly, and at about 11:45 a.m. the basin was refilled. This time the rate of recession of water level in the testing basin was slightly less than that during the first recession but appreciably greater than the recession in progress on the main basin. The test was stopped shortly after 7 p.m., at which time the water level in the testing basin was lower than that in the main seepage basin.

Figures 13 and 14 are presented to show several relationships that were illustrated by the results of three floodings July 3, 1951. The first, Figure 13, is similar in character to several others preceding it and shows the effective reduction in basin capacity with successive floodings. The largest reduction between the first and second tests was in the medium depths where the seepage rate for the second test was only about 25 per cent of that for the first test at any depth. In the second and third tests, it was observed that as the depth decreases the ratio of seepage rates approached unity and at the larger depths the rate for the third test was about 53 per cent of that for the first. A similar relationship was observed between tests 9 and 10, as shown in Figure 3, in which instance the greatest reduction in seepage capacity was effected also at the larger depths, and at the smaller depths the ratios approached unity.

Figure 14 is based on the same three floodings of July 3, 1951, (tests 22, 23 and 24) and shows graphically the relationship of the depth and time elements of the three, as well as the approximate rise in the water table during each test. It was stated earlier in this report that repeated floodings resulted in a reduction in seepage rates and this in turn resulted in smaller increases in water-table elevations. This point is illustrated by the graphs of observation-well readings related to each testing-basin-flooding in Figure 14.

Additional opportunities for simultaneous testing of the main basin and the testing basin were presented beginning November 5, 1951. Figures 15, 16, 17 and 18 have been prepared from data collected November 5 to December 4, 1951, in a series of simultaneous tests on the two basins. The first test was begun November 5 by flooding the testing basin to the same level as that of the water in the main basin and then shutting off the inflow, as shown in Figure 15. The water level in the testing basin receded more rapidly than that in the main basin, and on November 7 both basins were flooded by runoff from another storm. As soon as the water level had receded to the top of the testing basin wall, the records of water level on both basins were collected independently and it was observed again that the testing basin water level receded more rapidly than that of the south seepage basin. This part of the test is illustrated in Figure 16. More storm-water runoff flowed into the south basin November 17 and 18, and the water level in the two basins was made to coincide again in the afternoon of November 18. The recession of the water level in the testing basin was again observed to be much more rapid than that of the main basin. This test is shown in Figure 17. Just prior to November 29, while the testing basin was empty, the air temperature fell sharply and the basin surface froze. The capacity of the testing basin was increased materially, and during the six floodings made November 29 to December 3 more than 6 feet of water was disposed of in the testing basin while about 0.4 foot of seepage was taking place in the main basin. The effect of this freezing is shown in Figure 18. Additional water could have been disposed of through the testing basin, but the results of the six floodings were considered sufficient to illustrate the beneficial effect of freezing and thawing.

Figure 19 shows the results of a series of repeated floodings made February 23-25, 1952. The first pair shows a reduction in seepage rate of about 60 per cent at all depths but the second pair shows a smaller reduction at the larger depths than at the smaller depths. In comparing these results with those of the three tests of July 3, 1951, it is observed that the ratios of seepage rates for the first pair of tests in each series follow a similar pattern but the ratios of the rates for the second pair in the two series are directly opposite in pattern, those for the second series decreasing and those for the first series increasing with decreasing depth. It is observed also that the shape of the curves for tests 40 and 41 indicates a smaller rate of change in seepage rates at lower depths than for tests 38 and 39.

Figure 20 is another example of the effect of elapsed time and seepage rates. Test 54 was made September 6, 1952, and shows seepage rates equal to about one-half of the rates for test 55, made 344 hours later, on September 20. By contrast, test 56 was started 9 hours after test 55 was completed and the rates for test 56 vary from 25 per cent to 54 per cent of those for test 55 at depths between 0.8 foot and 0.3 foot. Test 57 was started 94 hours after completion of test 56 and during that interval of time the capacity of the testing basin increased almost 200 per cent at depth 0.8 foot but only about 8 per cent at depth 0.3 foot.

Figure 21 illustrates another series of flooding tests made during the period October 6-25, 1952. In contrast to the results of tests 54 and 55 in the series of September 6-26, 1952, the first two tests of the October series (58 and 59) show a reduction in seepage capacity although a period of 214 hours elapsed between these tests. Test 59 shows a rate equal to about 48 per cent of that for test 58 at depth 0.9 foot and a reduction in ratio of seepage rates with decrease in depth. Further reduction in seepage capacity was observed between succeeding tests 60 and 61. Test 60 was made 61 hours after test 59, and test 61 was made 37 hours after test 60. An interval of 116 hours elapsed between tests 61 and 62, resulting in a small increase in capacity, but this increase was trivial as compared to the large increase observed between tests 56 and 57 in the September 1952 series. It should be emphasized, however, that the seepage rates observed during the October series were much larger than those of the September series.

Figure 22 has been prepared to show the results of the observations of water loss and precipitation at the Rockaway Road site. Both the water-loss and precipitation data have been used in the computation of results of the seepage experiments where such use was required. During a continuous-flooding test covering a period of several days, the water loss from the testing basin was taken into account in balancing inflow with seepage. For the single-flooding tests, the water loss was negligible.

The seasonal data for adjusted water loss from the floating pan and for precipitation are as follows:

Year	Adjusted Water Loss, Inches	Precipitation, Inches
1949 (April through November)	29.78	27.91
1950 (do. do. do.)	26.45	24.47

Year	Adjusted Water Loss, Inches	Precipitation, Inches
1951 (March through December)	27.94	42.55
1951 (April through November)	26.01	31.27
1949 (April through October)	28.08	26.40
1950 (do. do. do.)	24.53	20.59
1951 (do. do. do.)	24.73	23.93

A comparison of the data for the period April through October shows that the adjusted water loss during the growing season was slightly greater than the precipitation.

The water-loss data plotted in Figure 22 are observed floating-pan data unadjusted. The seasonal data for water loss tabulated above are the sums of the adjusted monthly totals for the periods listed. The observed monthly water-loss data consist of a summation of the observed water-loss for each day of the month. During periods of precipitation the observed catch at the standard rain gage nearby was used in the computation of net gain or loss from the floating pan. In most instances the precipitation exceeded the observed water loss between observations and the net loss from the pan was considered to be zero. The coefficient used in adjusting the observed monthly data to represent water losses from natural bodies of water was 0.80, as recommended by a Special Committee of the American Society of Civil Engineers.

Wind-movement and air-temperature data have been collected, as well as water temperatures for both floating and land pans and for the large storage basin. Temperature of the water used in the seepage tests was observed to vary from a low of 39½°F in December to a high of 78°F in July. The effect of this difference in temperature on the seepage rates cannot be evaluated because of other more significant factors. Examination of the test data shows that some of the highest seepage rates were observed when the water temperature was the lowest, and, conversely, some low rates were observed during months when water temperatures were high. This is but one example of the counterbalancing of the many factors that influence seepage rates and serves to illustrate the difficulty with which these factors are isolated and evaluated.

The tests made to date show minimum and maximum seepage rates of about 20 and 400 gallons per square foot per day, respectively, at a testing depth of 1 foot, emphasizing the large effect of factors other than depth on the seepage capacity of such basins. Seepage rates between these minimum and maximum values were observed under a wide variety of conditions, as illustrated by the following graphs, but because of the great variation in the conditions that prevailed during the many tests it is not possible to combine the observed results into one graph for comparative purposes. Neither is it possible, at this stage in the program, to draw conclusions regarding the relationships between the observed results and the prevailing conditions for all of the tests conducted to date.

It was recognized at the beginning of the project that experimental work of this type under field conditions is always handicapped by lack of control of the many factors and variables involved and that a considerable period of time would be needed to collect data that might be considered representative of any one period of the year. Certain important phases of the study, such as the determination of the similarity of the materials underlying this and other seepage basins in this part of the county, the tests showing that the seepage capacity of the testing basin continues to be equal to or greater than that of the main seepage basin without having been scarified and after having been flooded much more frequently than the main basin since the beginning of the project, the tensiometer tests that show the absence of an appreciable depth of saturation of the sand and gravel profile during testing of the basin, and the tests that show that repeated floodings at short time intervals result in reduced seepage rates and smaller successive rises in water-table elevations, have been substantiated.

As the program is continued some of the tests described above should be repeated within the same period of the year and under climatic conditions similar to those existing when the first tests were made, to determine, if possible, the seasonal seepage characteristics of the basin with the basin surface unchanged except for the natural changes produced by the elements.

When these tests have been completed the weeds and roots should be removed and the testing basin scarified to a depth sufficient to break up the surface zone. Continuous and repeated-flooding tests then will be repeated and the results compared with those obtained with the basin floor undisturbed.

Following this series of tests the entire surface zone should be removed from the testing basin and the same type tests repeated until the number of floodings equals the number of floodings of the south basin, as indicated on the recorder charts for that basin, during a period of several years. The testing-basin surface should not be disturbed during this series and any observed decrease in seepage capacity then may be attributed to the development of a new surface zone of silt, etc. Whenever possible, during the period covered by this series the south basin and the testing basin should be operated simultaneously for comparison of respective capacities.

Subsequent progress reports are to be prepared as the program is continued.

The cooperation of John C. Guibert, Commissioner of Public Works, and of W. Fred Welsch, Senior Engineer, in charge of Division of Sanitation and Water Supply, Department of Public Works, Nassau County, as well as that of other county employees who have aided materially in the collection of data for this project, is gratefully acknowledged.

U. S. Geological Survey engineers who have been responsible for the design and operation of the project, under the supervision of Arthur W. Harrington, District Engineer, Albany District, are H. D. Brice, C. L. Whitaker, and R. M. Sawyer, engineers in charge of the Jamaica and Mineola offices. Survey engineers who have assisted in the operation of the project are E. J. Pluhowski and G. S. Craig, Jr.

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Figure 1

ROCKAWAY ROAD PROJECT

Tests 2-4, Feb. 11, 1949

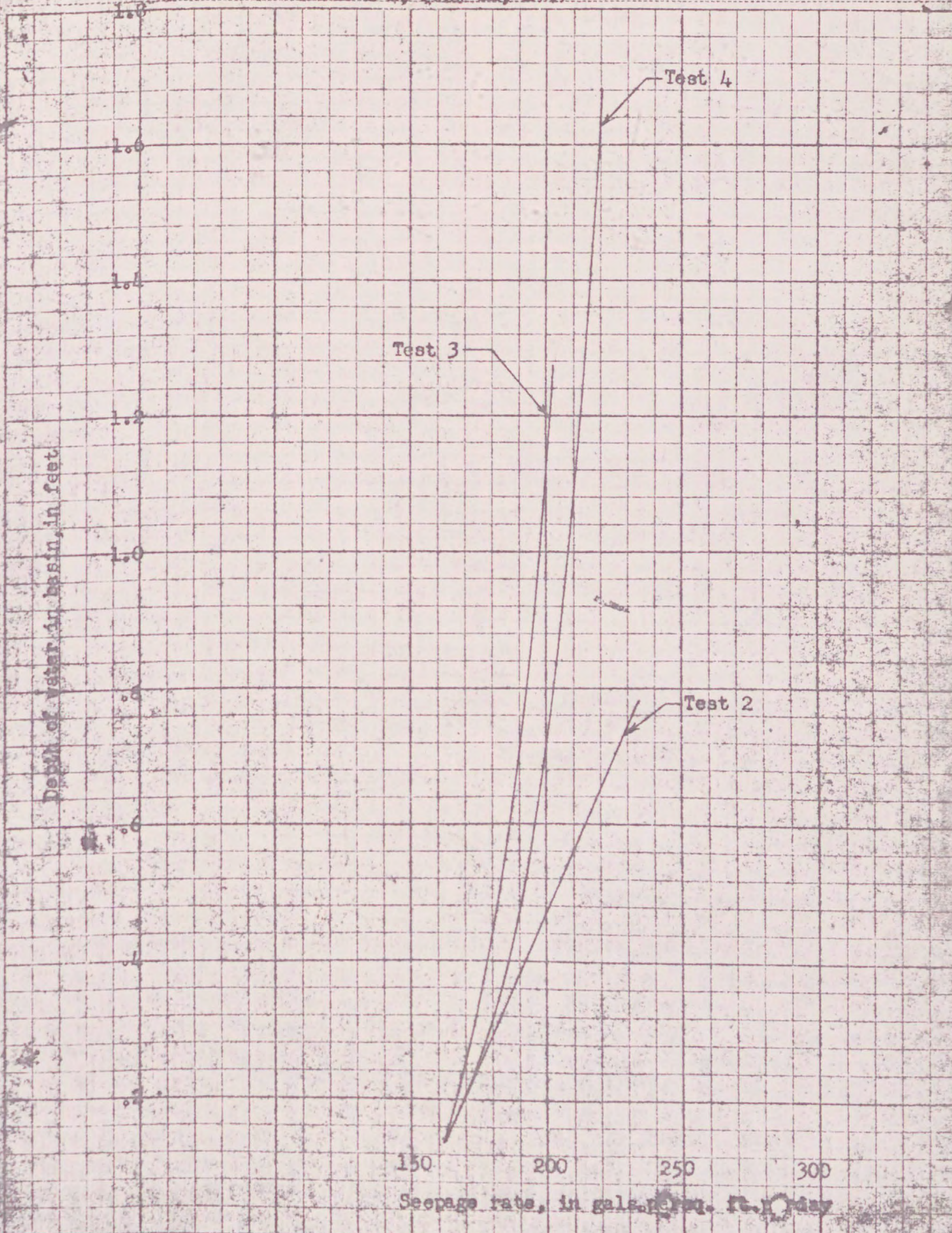

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Figure 2

ROCKAWAY ROAD PROJECT

Continuous inflow test, Aug. 15-22, 1949

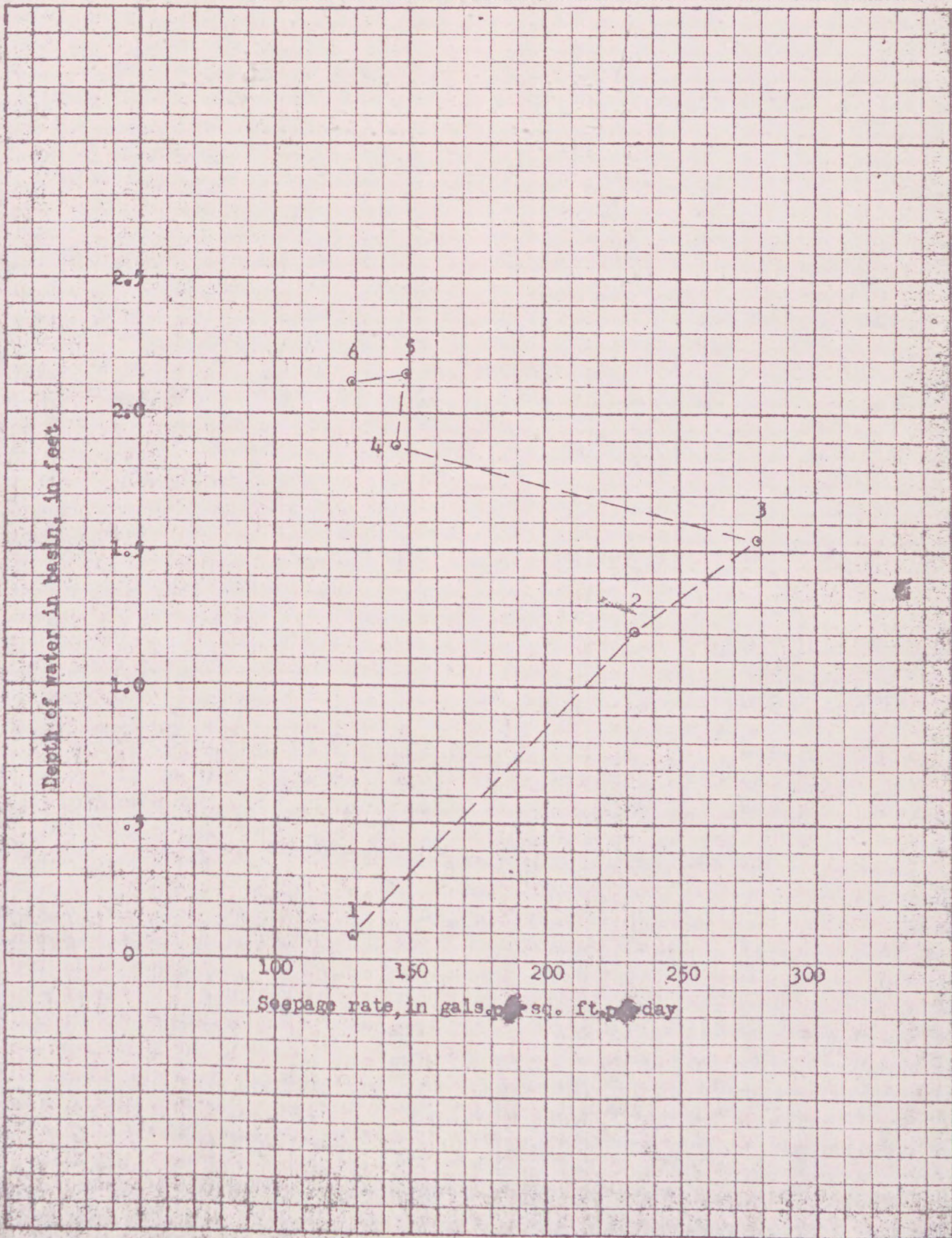

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Figure 3

ROCKAWAY ROAD PROJECT

Tests 9, 10, Oct. 11, 1949

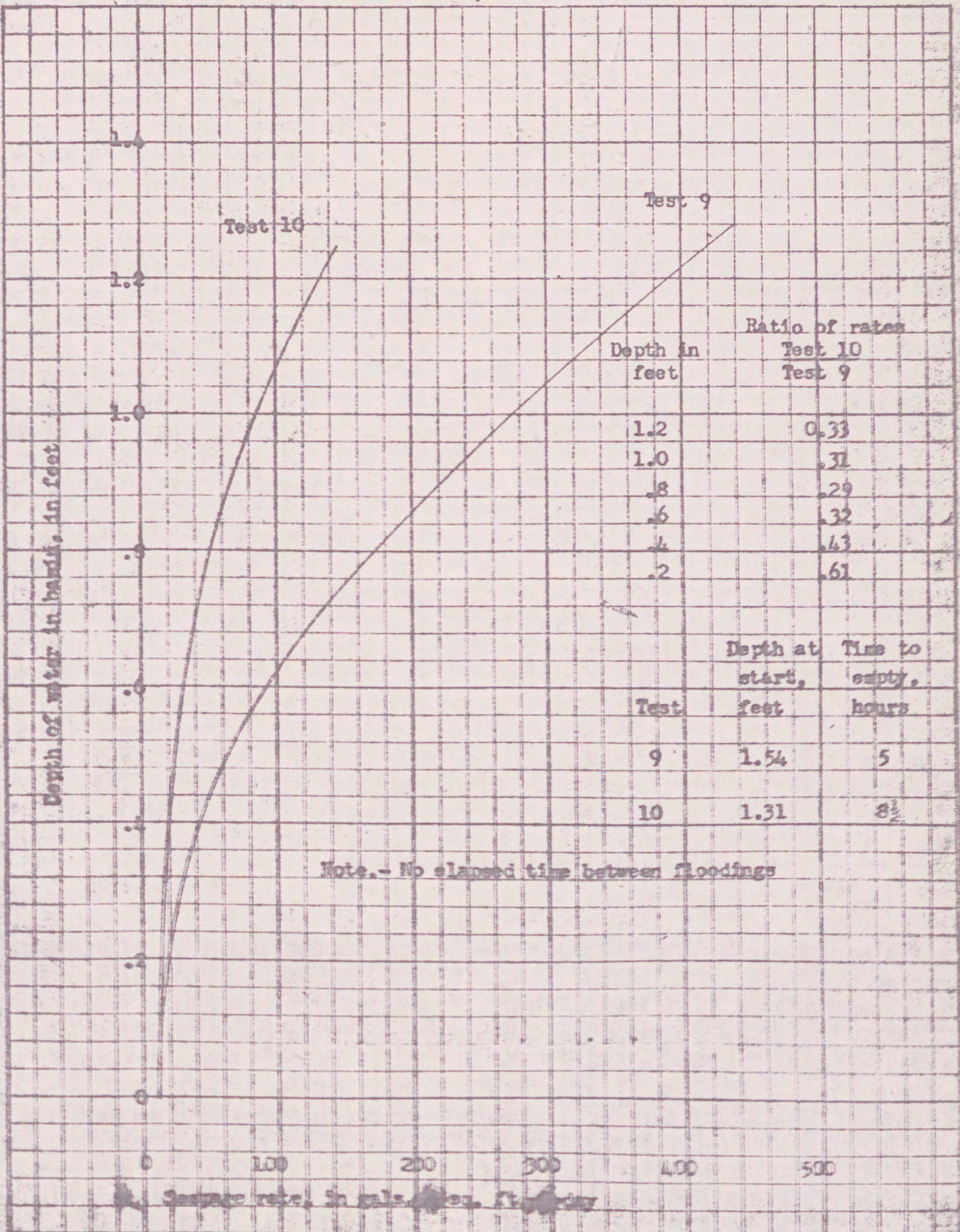

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Figure 4

Reduction in average seepage capacity resulting from repeated floodings, Oct.11,1949

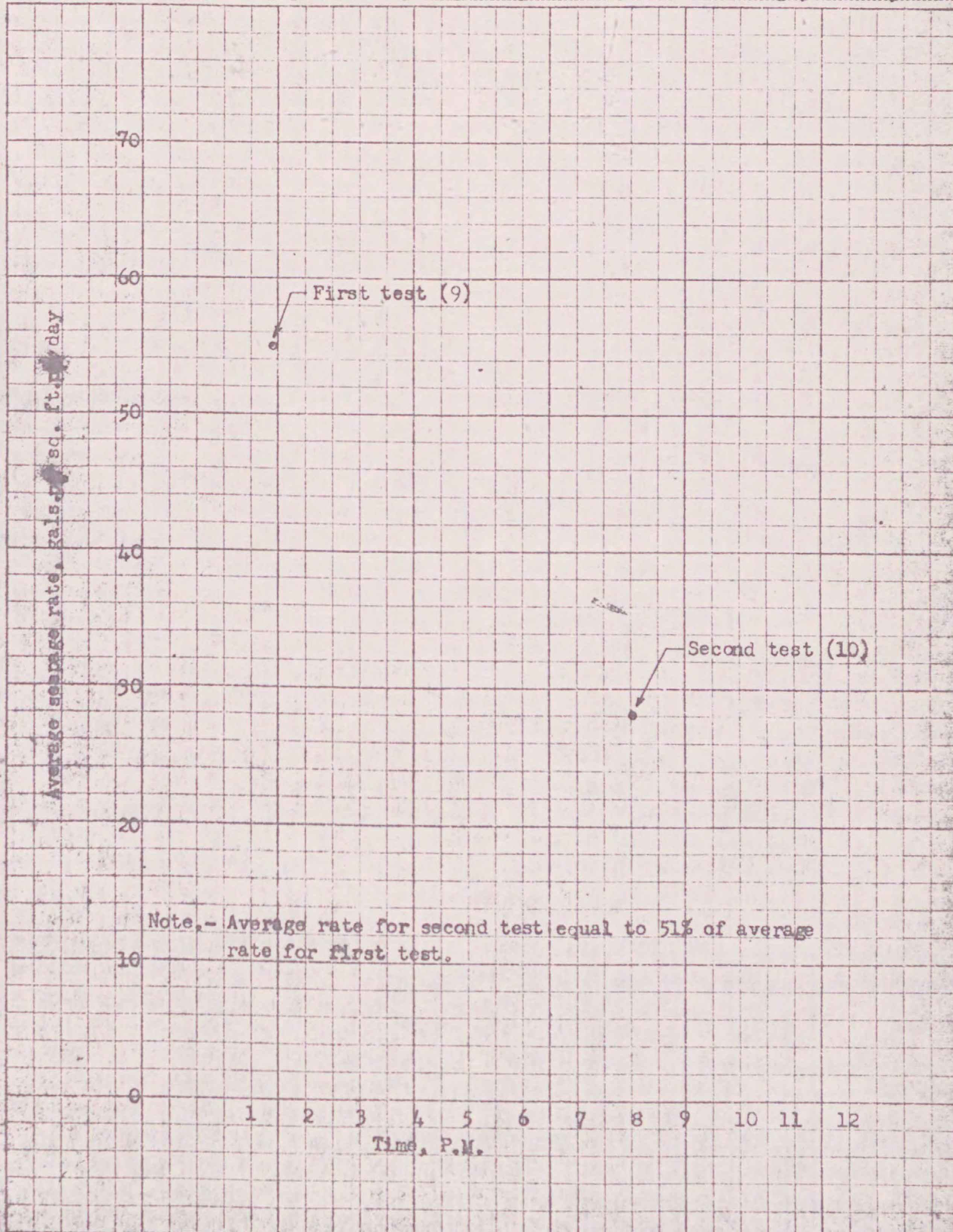

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Figure 5

ROCKAWAY ROAD PROJECT

Continuous inflow test, Oct. 26-28, 1949

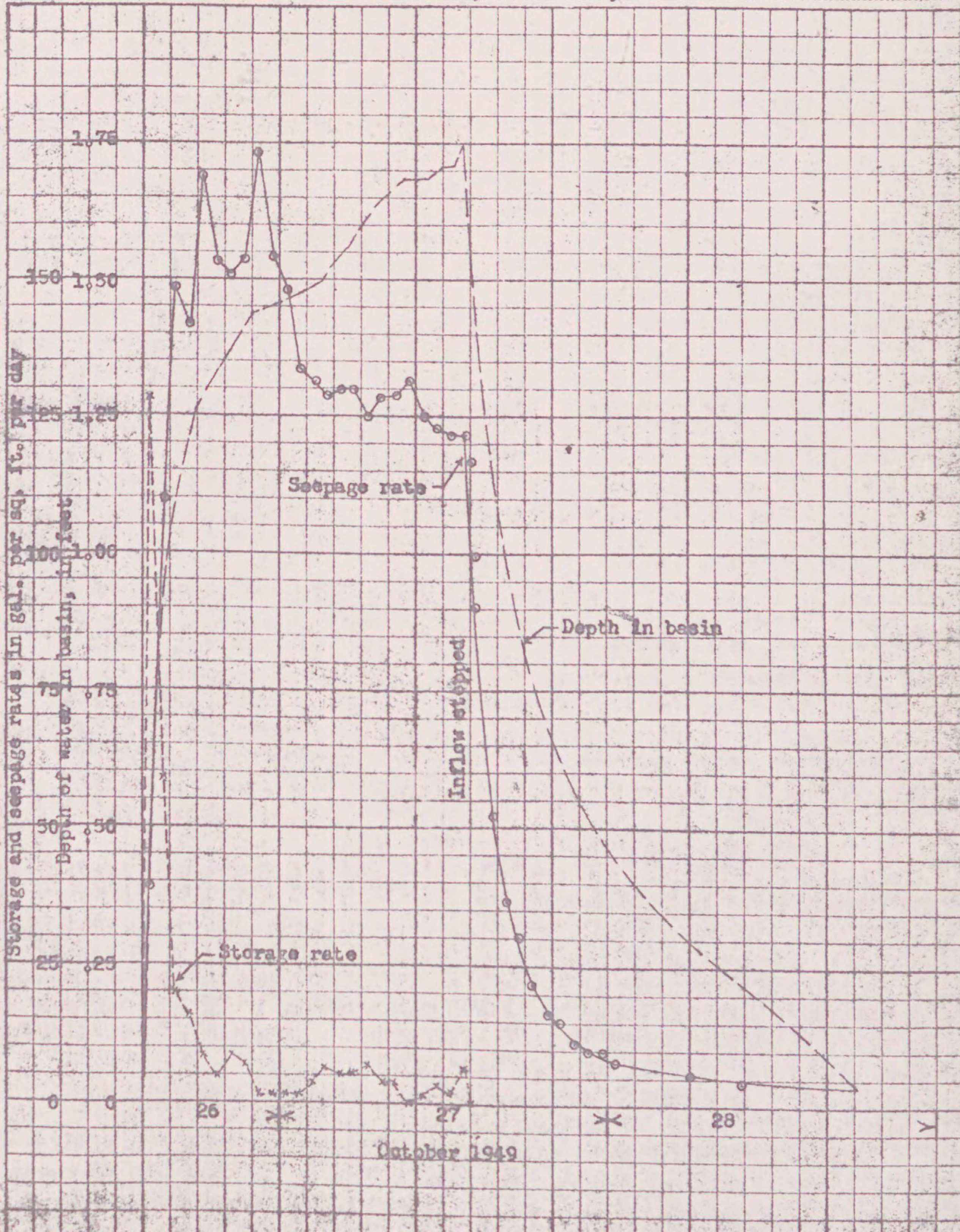

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Figure 6

ROCKAWAY ROAD PROJECT

Tests 12, 13, Nov. 2, 8, 1949

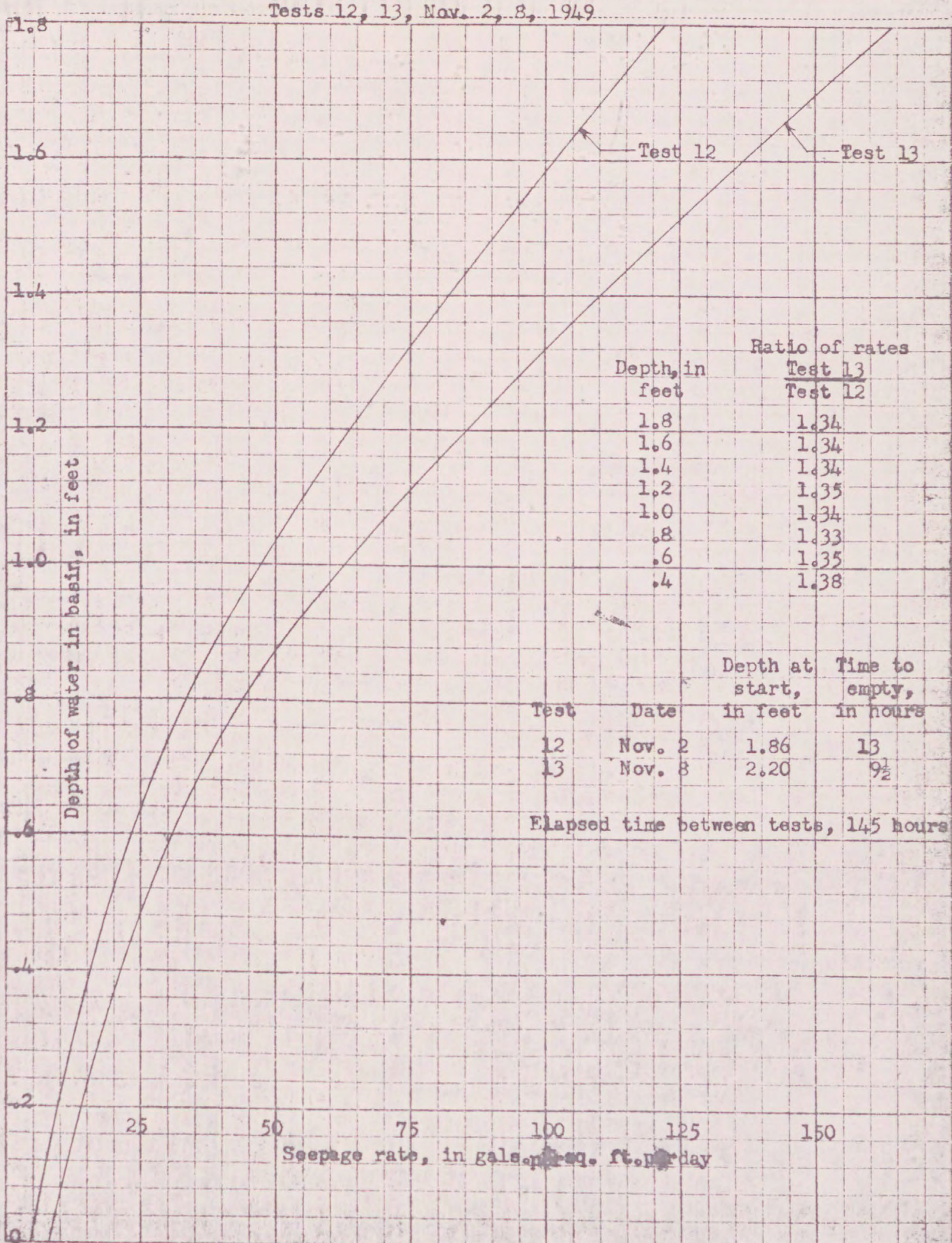

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Figure 1

ROCKAWAY ROAD PROJECT

Test 14, Dec. 15, 1949 (after basin surface was frozen)

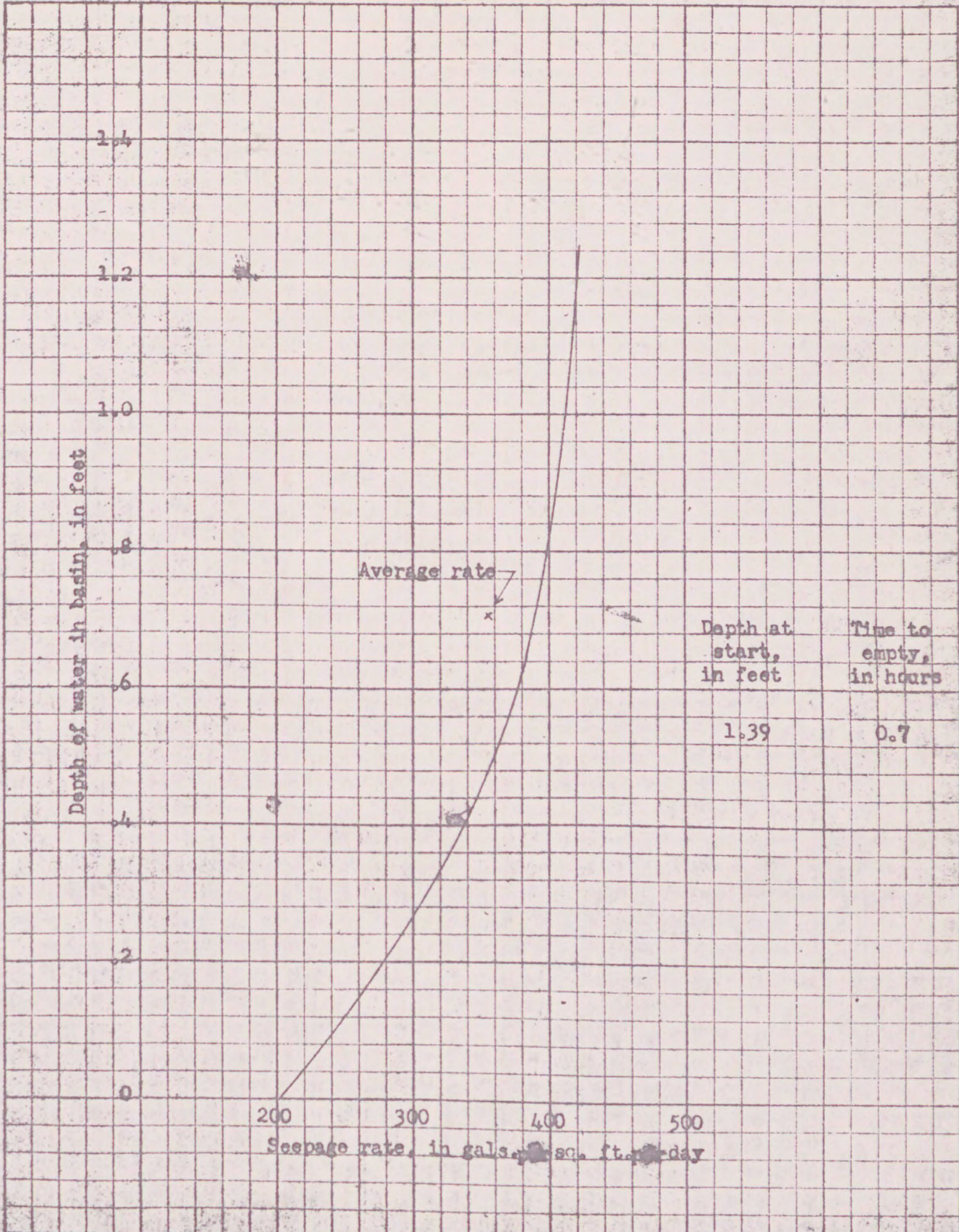

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Figure 8

ROCKAWAY ROAD PROJECT

Test 15, Jan. 5-7, 1950

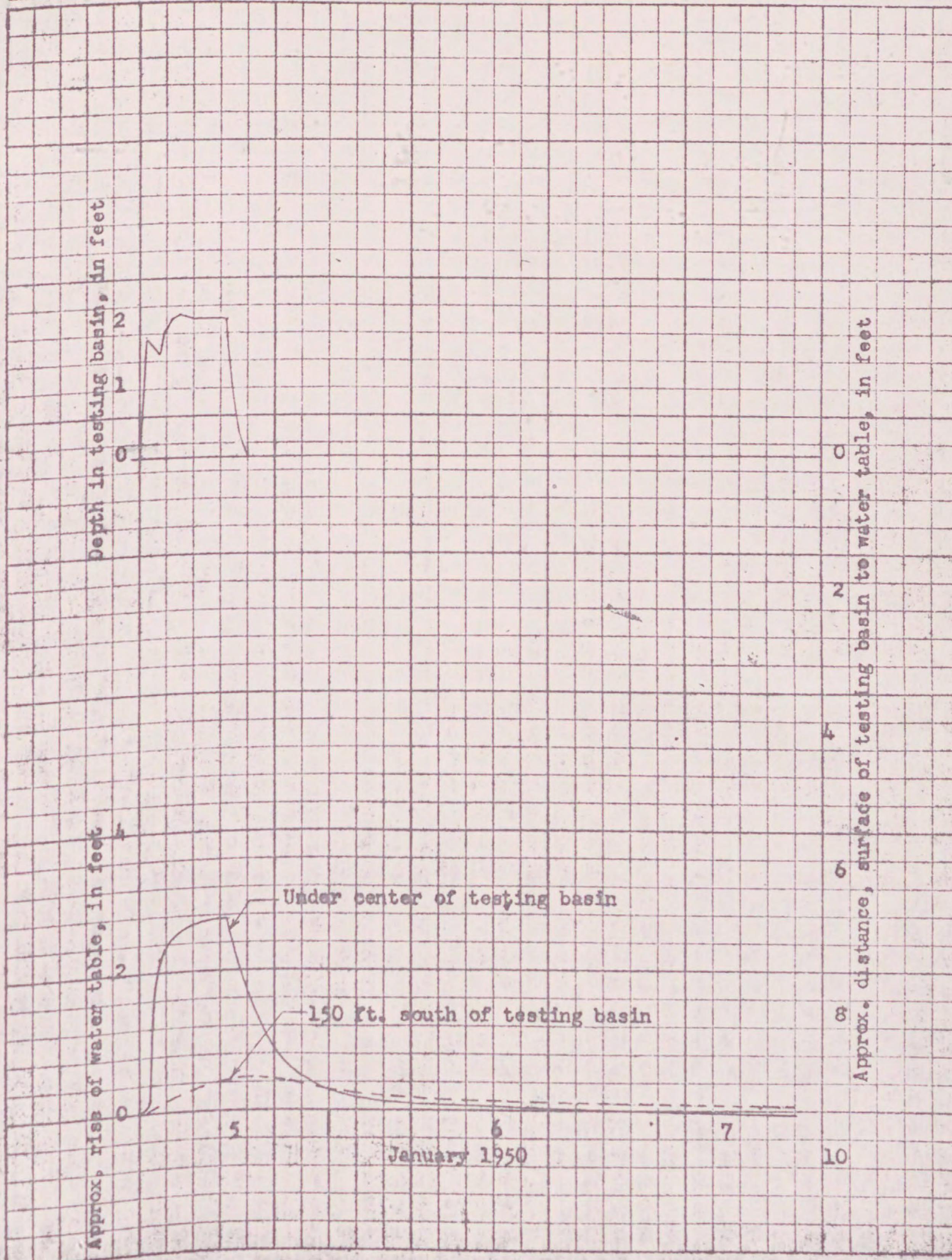

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Figure 9

ROCKAWAY ROAD PROJECT

Test 15; basin emptied after 6½ hours continuous flooding (see Figure8)

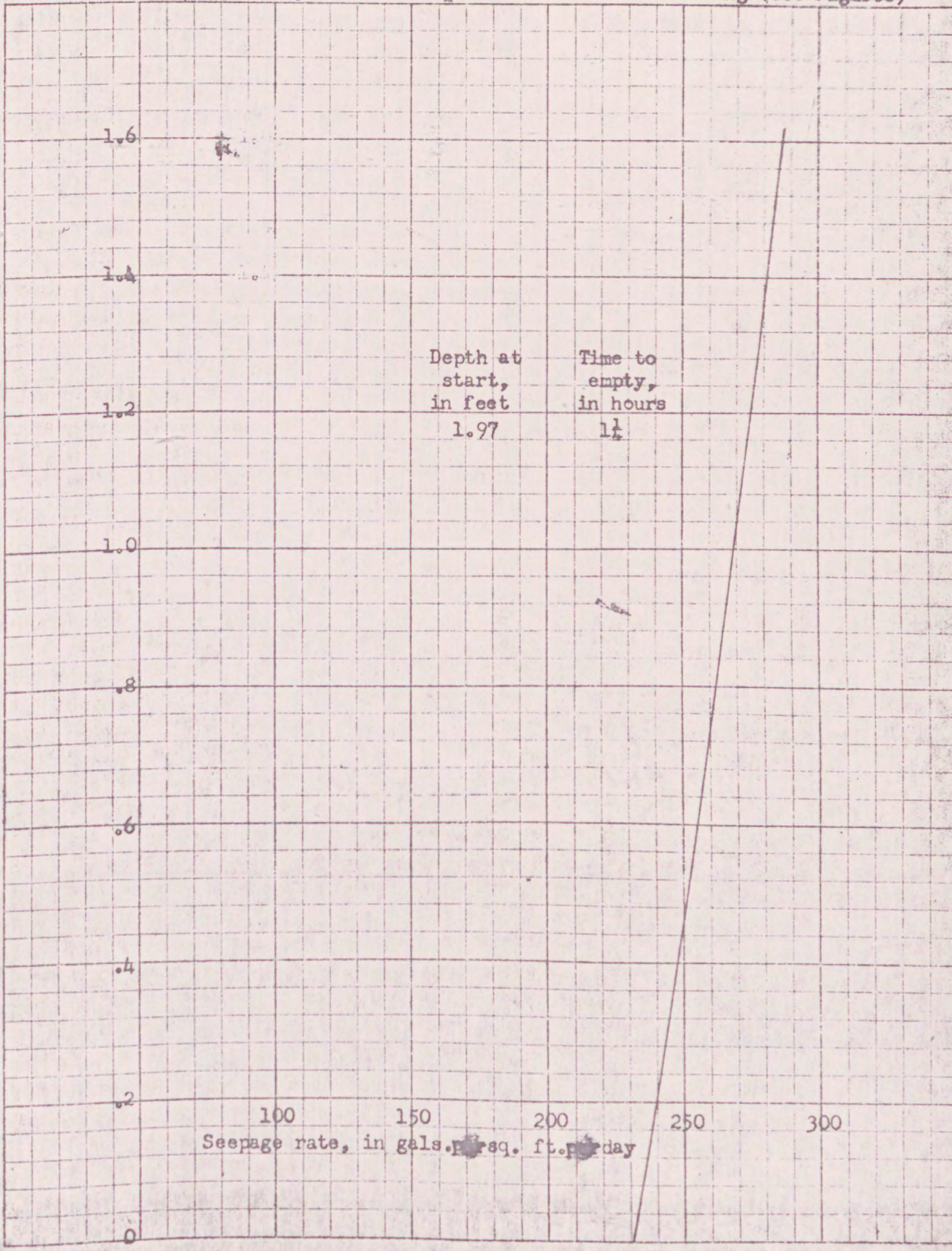

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Figure 10

ROCKAWAY ROAD PROJECT

Test 16, Apr. 4, 1950 (continuous inflow; inflow and seepage balanced)

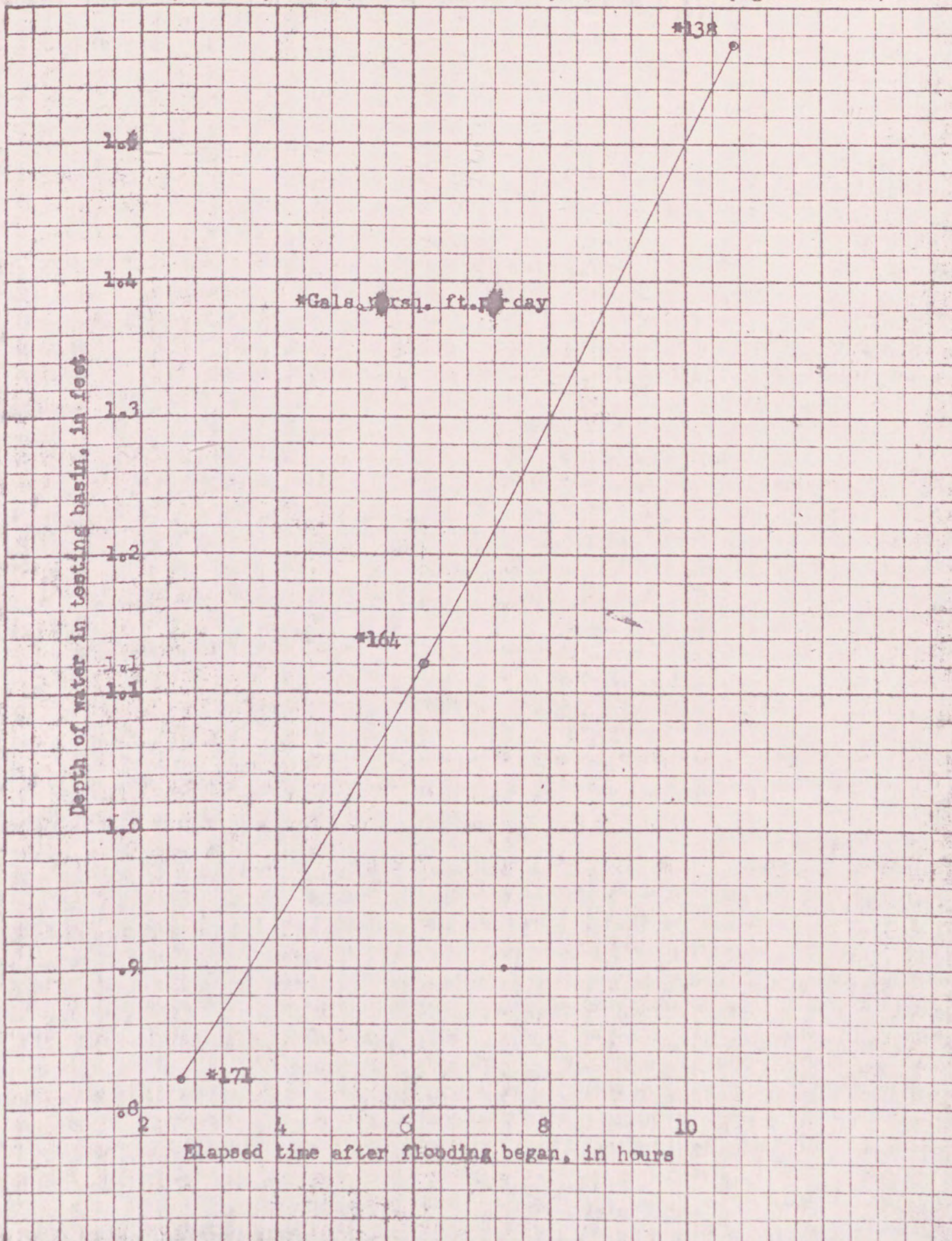

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Figure 11

ROCKAWAY ROAD PROJECT

Continuous inflow test, Apr. 7-12, 1950

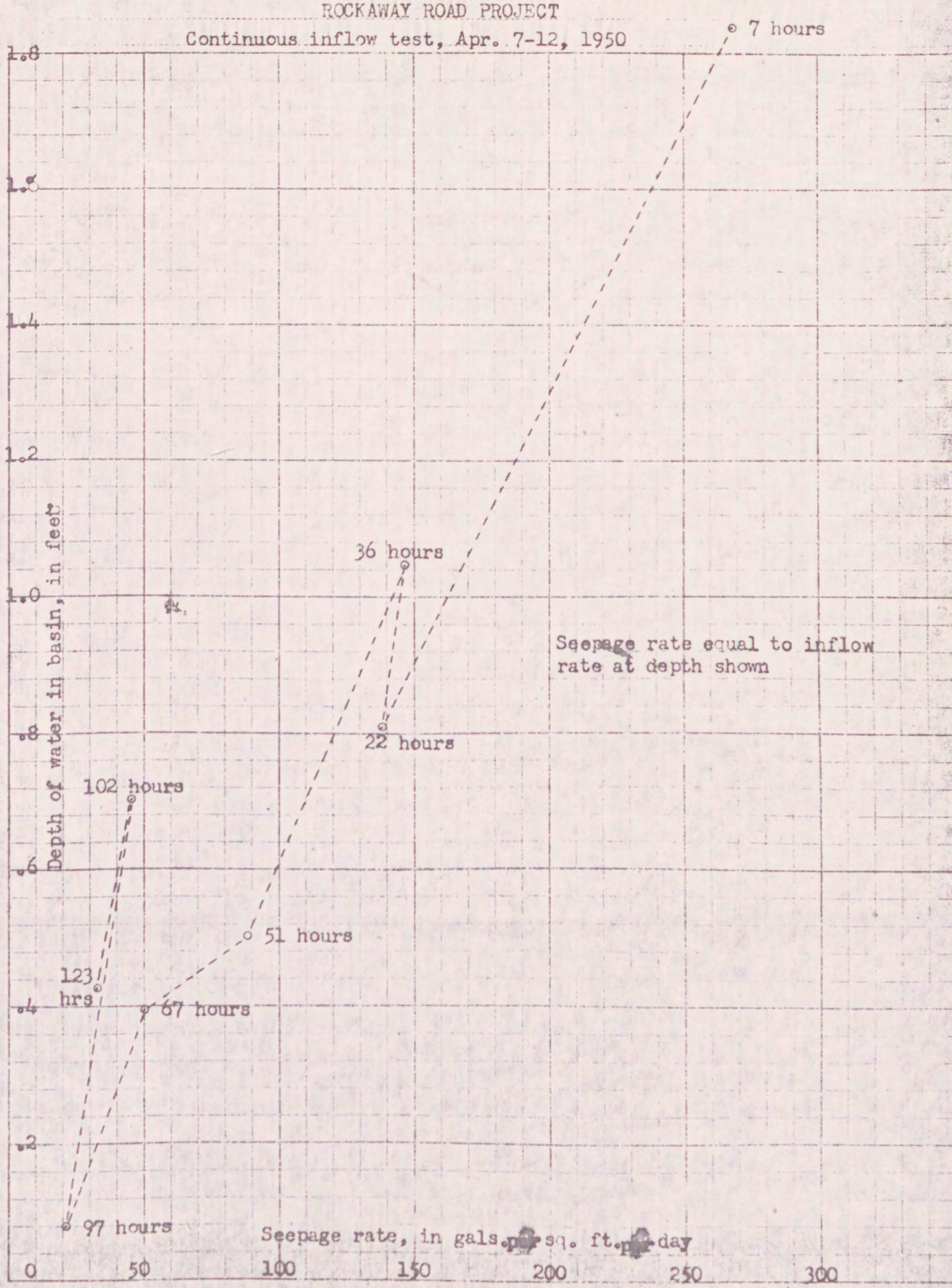

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Figure 12

ROCKAWAY ROAD PROJECT

Simultaneous testing of large and small basins, May 29, 1951

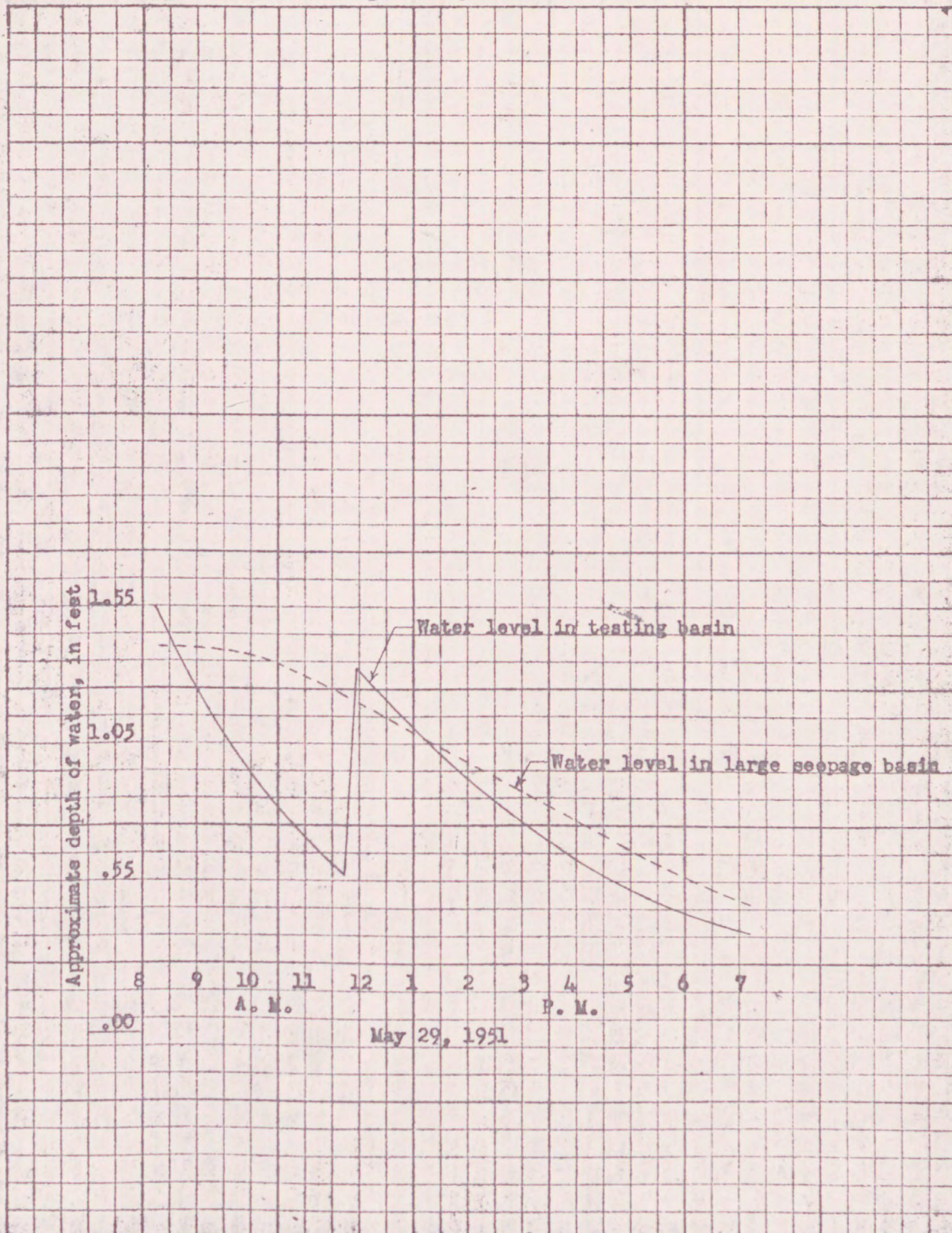

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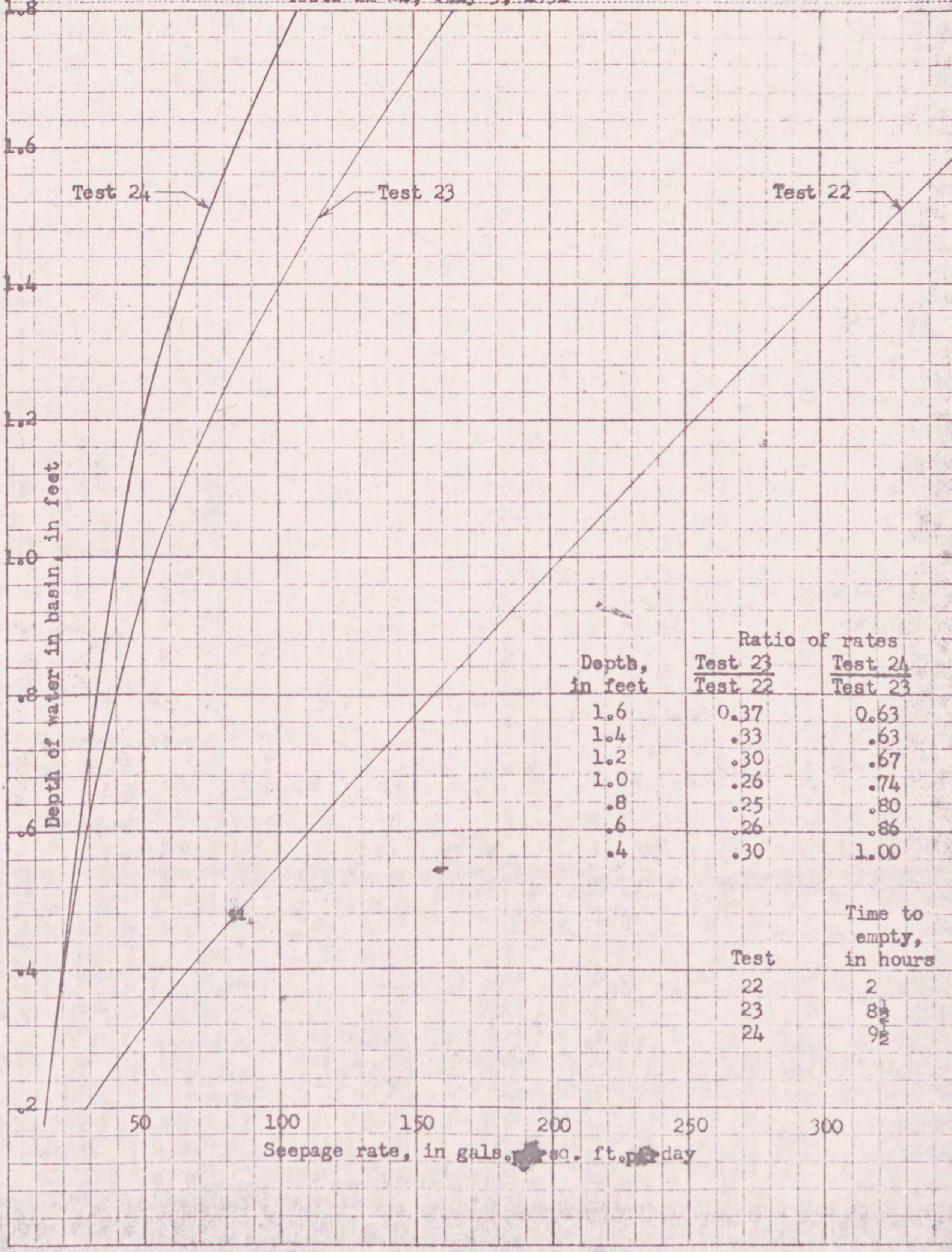
Figure 13

ROCKAWAY ROAD PROJECT

Tests 22-24, July 3, 1951



Depth, in feet	Ratio of rates: Test 23 / Test 22	Ratio of rates: Test 24 / Test 23
1.6	0.37	0.63
1.4	.33	.63
1.2	.30	.67
1.0	.26	.74
.8	.25	.80
.6	.26	.86
.4	.30	1.00

Test	Time to empty, in hours
22	2
23	8½
24	9½

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Figure 14

ROCKAWAY ROAD PROJECT

Tests 22-24, July 3, 1951

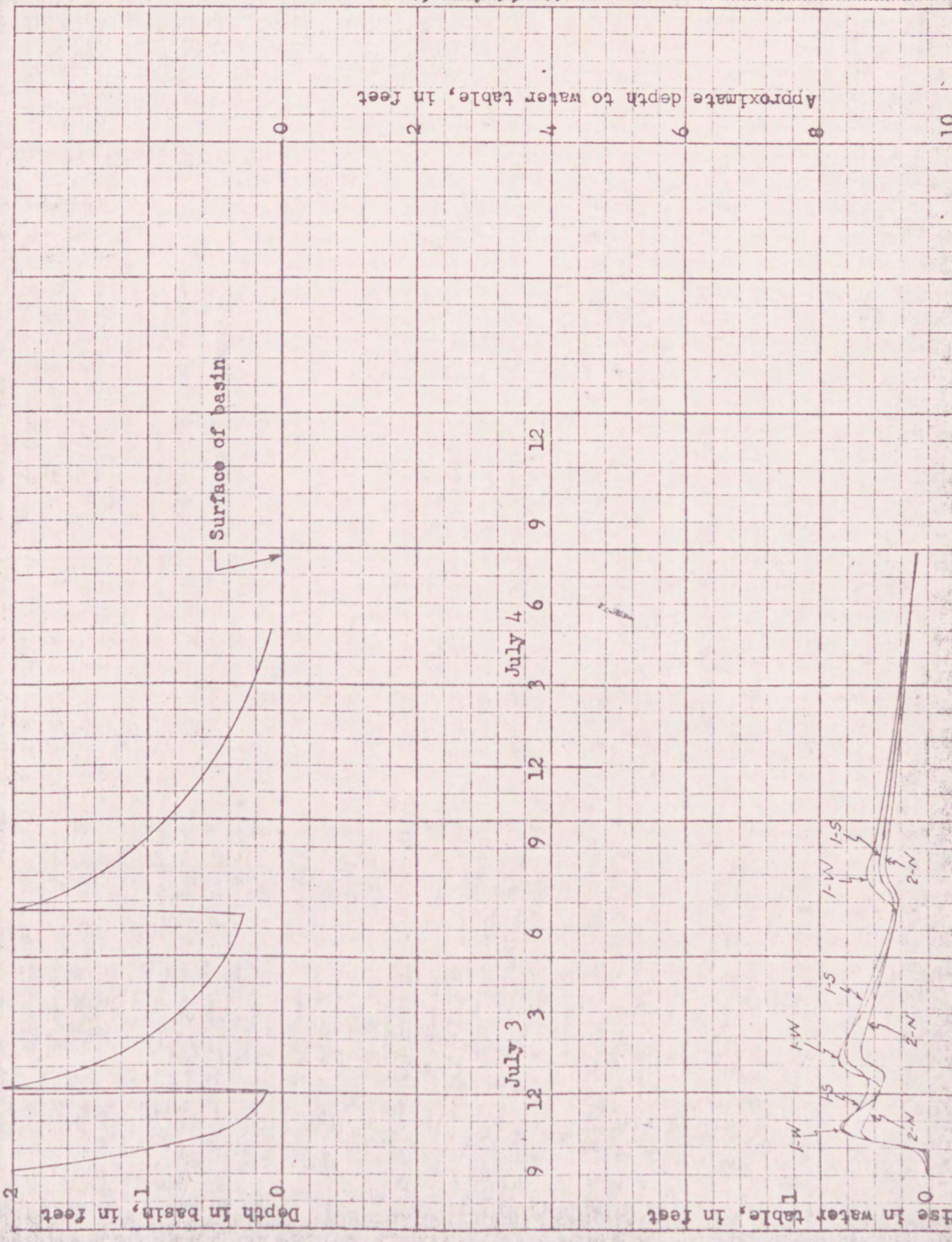

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Figure 15

ROCKAWAY ROAD PROJECT

Simultaneous testing of large and small basins, Nov. 5-11, 1951

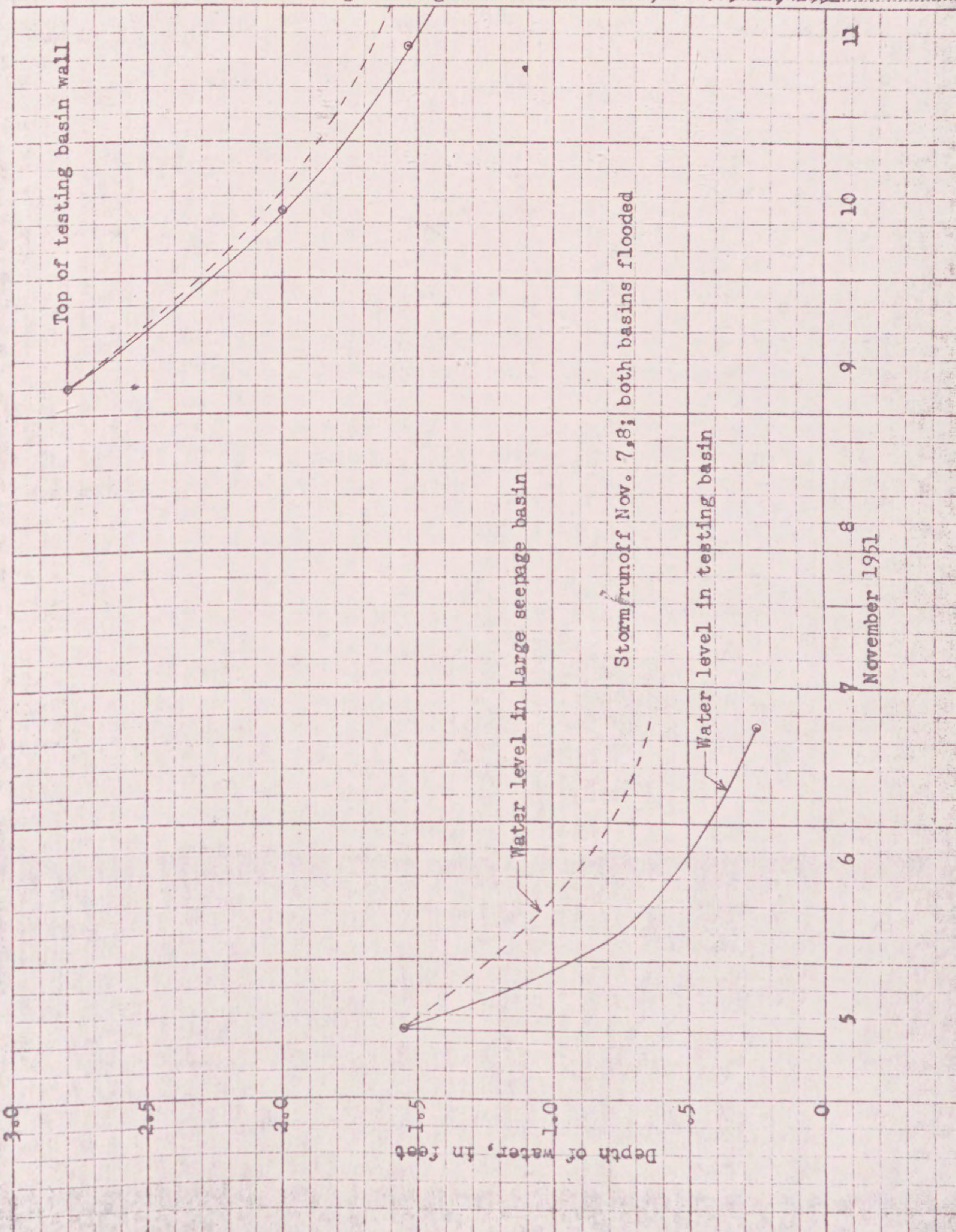

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Figure 16

ROCKAWAY ROAD PROJECT

Simultaneous testing of large and small basins, Nov. 9-14, 1951

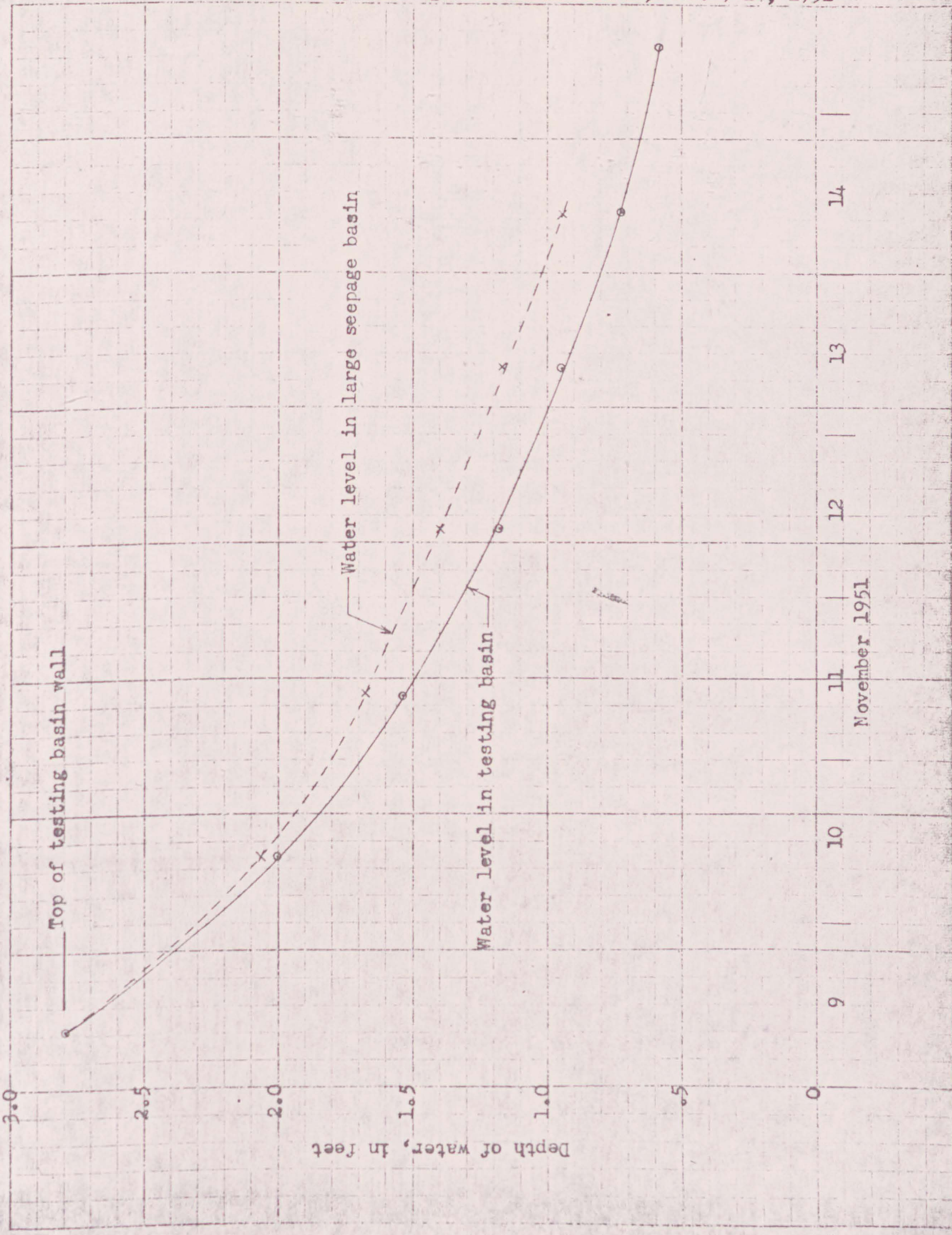

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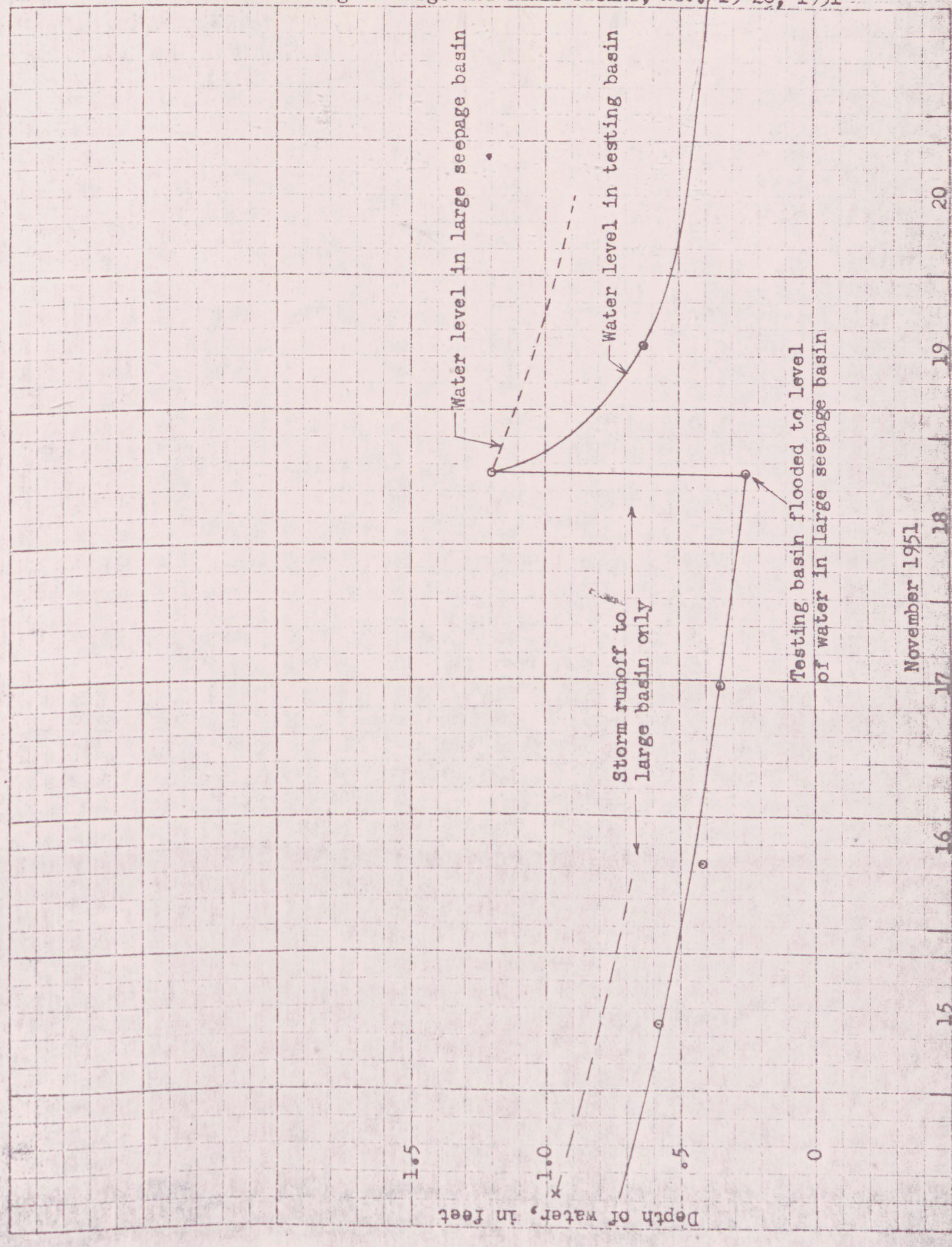
Figure 17

ROCKAWAY ROAD PROJECT

Simultaneous testing of large and small basins, Nov. 15-20, 1951



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ROCKAWAY ROAD PROJECT

Increase in seepage rate caused by freezing and thawing of basin surface

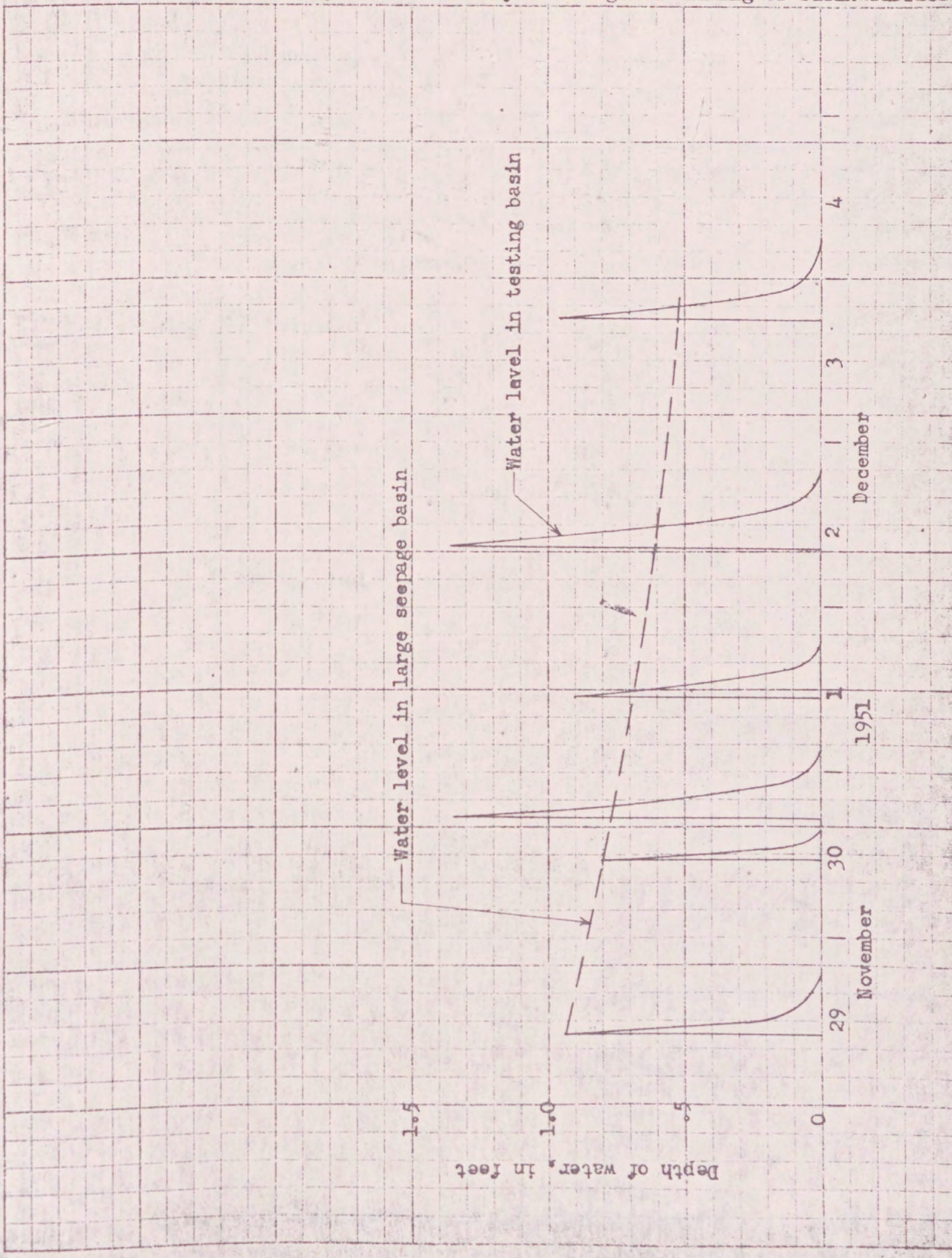

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Figure 19

ROCKAWAY ROAD PROJECT

Tests 38-41, Feb. 23-25, 1952

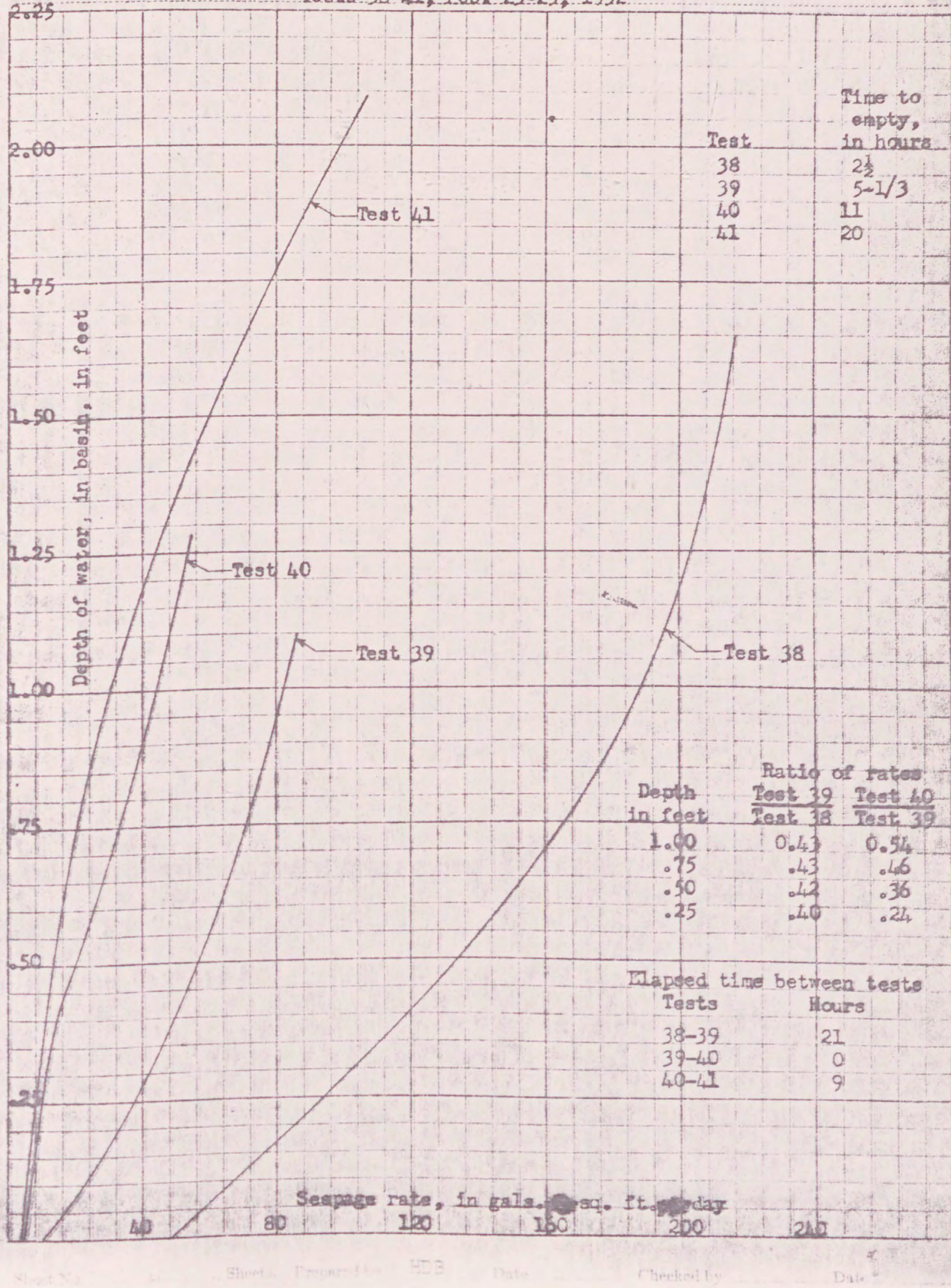

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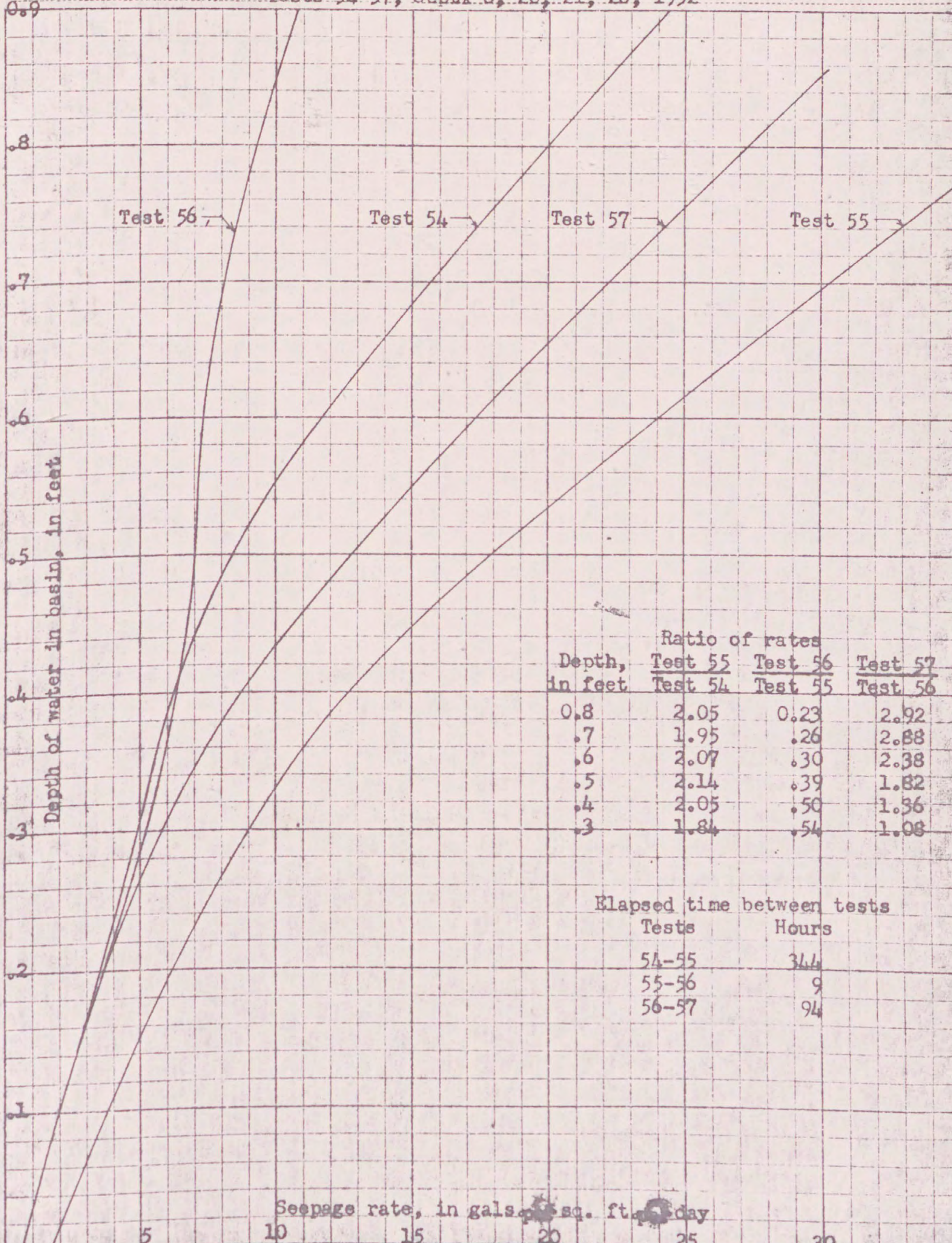
Figure 20

ROCKAWAY ROAD PROJECT

Tests 54-57, Sept. 6, 20, 21, 26, 1952



Depth, in feet	Ratio of rates: Test 55 / Test 54	Test 56 / Test 55	Test 57 / Test 56
0.8	2.05	0.23	2.92
.7	1.95	.26	2.88
.6	2.07	.30	2.38
.5	2.14	.39	1.82
.4	2.05	.50	1.36
.3	1.84	.54	1.08

Elapsed time between tests

Tests	Hours
54-55	344
55-56	9
56-57	94

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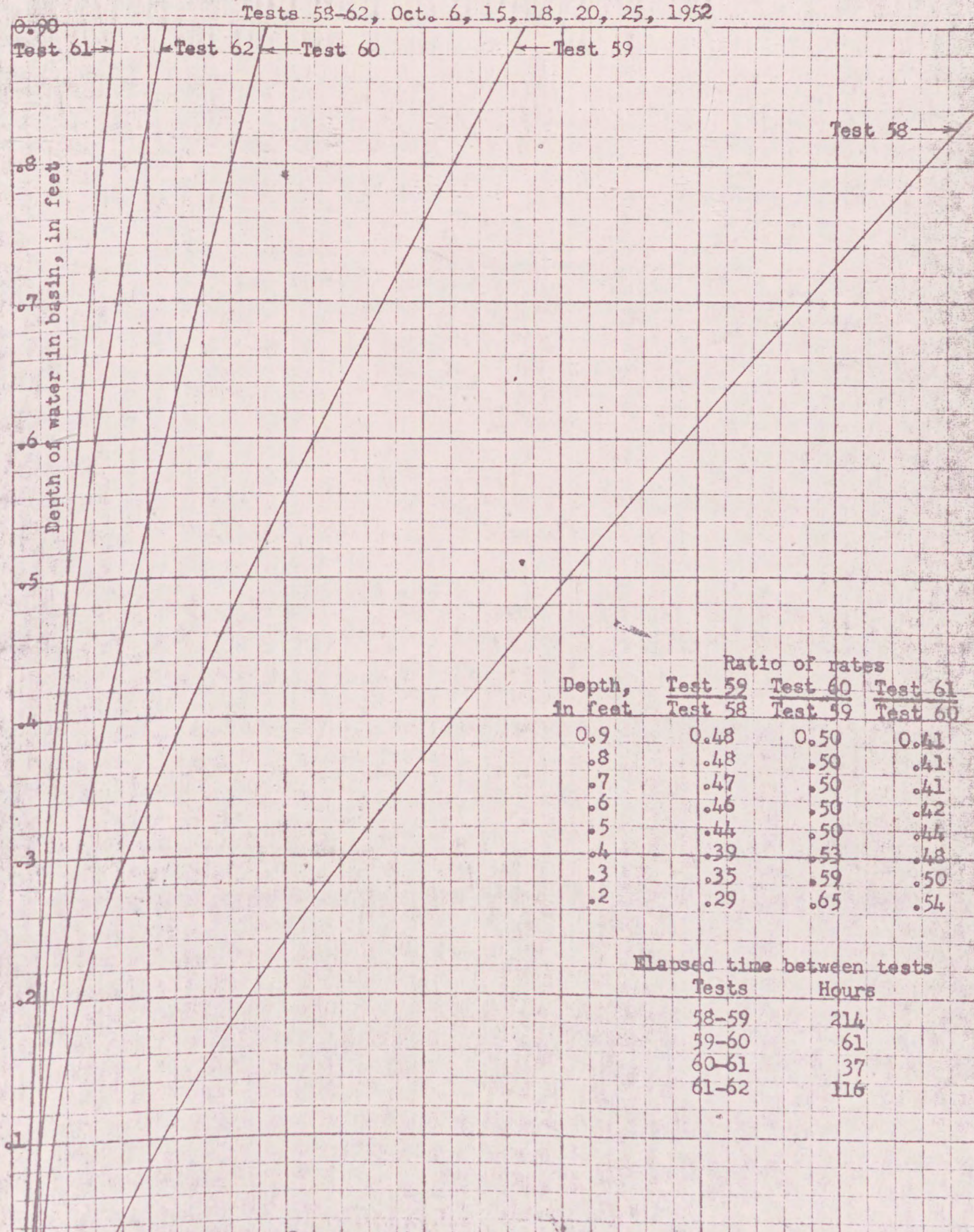
Figure 21

ROCKAWAY ROAD PROJECT

Tests 58-62, Oct. 6, 15, 18, 20, 25, 1952



Depth, in feet	Ratio of rates: Test 59 / Test 58	Test 60 / Test 59	Test 61 / Test 60
0.9	0.48	0.50	0.41
.8	.48	.50	.41
.7	.47	.50	.41
.6	.46	.50	.42
.5	.44	.50	.44
.4	.39	.53	.48
.3	.35	.59	.50
.2	.29	.65	.54

Elapsed time between tests

Tests	Hours
58-59	214
59-60	61
60-61	37
61-62	116

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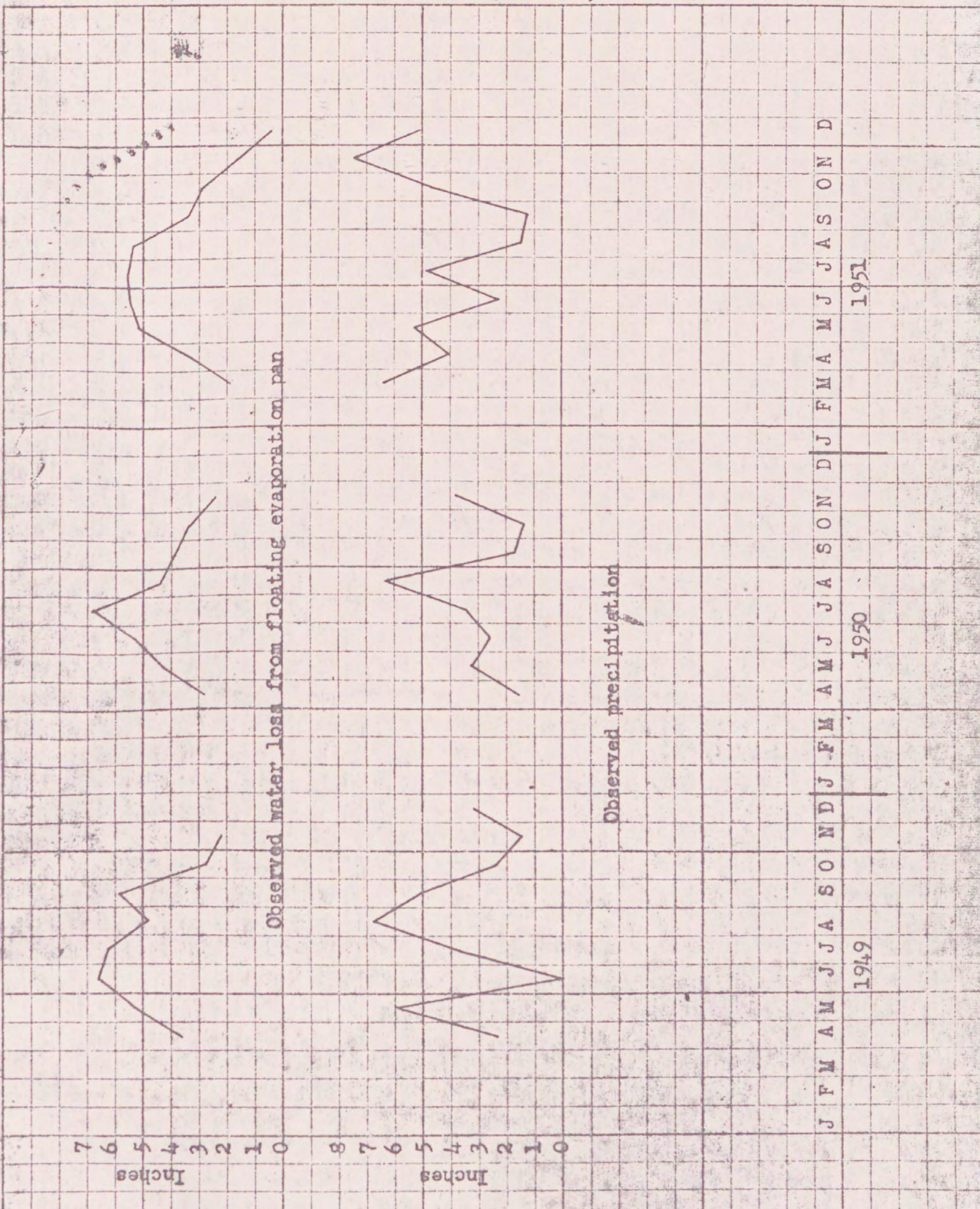
Figure 22

ROCKAWAY ROAD PROJECT

Water loss and precipitation, 1949-1951



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