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DEPARTMENT OF CONSERVATION

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Division of Water Policy and Supply

# RESULTS OF THE SECOND PHASE OF THE DROUGHT-DISASTER TEST-DRILLING PROGRAM NEAR MORRISTOWN, N. J.

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# RESULTS OF THE
# SECOND PHASE OF THE DROUGHT-DISASTER
# TEST-DRILLING PROGRAM NEAR MORRISTOWN, N. J.

*by*


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The extended test-drilling program conducted near Morristown, N. J., has located an additional undeveloped ground-water supply of 2.5 million gallons daily (mgd). This supply, in the northwestern part of East Hanover Township, added to the 7.5 mgd located elsewhere during the first phase of the study, gives an aggregate supply of 10 mgd on a sustained basis from four areas in eastern Morris County. These supplies are available from deposits of sand and gravel of glacio-fluvial origin in the region known as "Glacial Lake Passaic"—a lake existing during the last glaciation.

The yields from the productive areas are as follows:

| Location | Probable sustained yield (mgd) | Probable short-term yield (mgd) |
|---|---|---|
| Southwestern East Hanover Township (Area 1) | 3.0 | 4.5 |
| Northwestern East Hanover Township | 2.5 | 3.5 |
| Southeastern Parsippany-Troy Hills Township (Area 2) | 2.5 | 3.5 |
| Northwestern Parsippany-Troy Hills Township (Area 4) | 2.0 | 3.0 |
| Totals | 10.0 | 14.5 |

Water from each of these areas is suitable chemically for potable use without treatment except for the high concentrations of manganese in water from "Area 1" and "Area 2." Manganese is present in concentrations of up to four times the U. S. Public Health Service and New Jersey Health Department recommended maximum of 0.05 parts per million (ppm).

Considerable knowledge has been obtained from this phase of the test-drilling program concerning the extent, continuity, and hydraulic characteristics of the sand and gravel aquifers in eastern Morris County. These data, together with information available from previous studies, have indicated the areas, listed above, that are capable of future development. In addition, these studies have also delineated areas of meager supply and areas of heavy pumping where conditions are favorable for the practice of artificial recharge. Finally, the studies indicate that if water use in this area continues to expand, it will eventually become necessary to import water from distant sources, develop surface reservoirs in the Passaic River basin, or undertake reuse of existing supplies.

Continued study of water-level observations throughout the area is necessary to monitor the effects of sharply increasing ground-water withdrawals resulting from the rapid urbanization of this region.

## INTRODUCTION

The continued drought in northeastern New Jersey through the summer of 1966 with its attendant water-supply problems resulted in an extension of the drought-disaster test-drilling program originally requested by the Office of Emergency Planning on August 30, 1965. Authorization to continue test drilling was given by the Office of Emergency Planning on September 26, 1966, with the stipulation that all field work be completed by January 31, 1967. Contractural costs were paid by the Office of Emergency Planning, whereas personnel costs were shared by the U. S. Geological Survey and the New Jersey Department of Conservation and Economic Development, Division of Water Policy and Supply.

The work undertaken in 1965 by the Geological Survey was ". . . to perform the necessary drilling and testing of wells to identify the extent and nature of a reserve ground-water source in the vicinity of the Passaic River near the northern New Jersey metropolitan area." Results of this first phase were made available in the fall of 1966 in Water Resources Circular 16 of the New Jersey Department of Conservation and Economic Development. Three of the five areas tested (figure 1)—two in Parsippany-Troy Hills Township (areas 2 and 4) and one in East Hanover Township (area 1), Morris County—proved capable of providing an aggregate sustained yield of 7.5 million gallons daily (mgd) from wells constructed in sand and gravel deposits. Because significant supplies of ground water for emergency use were located in the first phase of the exploratory test-drilling program, it was thought desirable to extend the originally planned studies so as to obtain maximum practicable information on emergency supplies.

During this second phase of the investigation, drilling was conducted at 16 sites in Chatham, Madison, and Florham Park Boroughs and in Hanover and East Hanover Townships, Morris County. (See figure 2.) The drilling in Hanover and East Hanover Townships, and part of the drilling done in Florham Park was to explore the availability of large undeveloped ground-water supplies. Drilling in Chatham, Madison, and Florham Park Boroughs was done primarily to determine the extent and continuity of buried valley-fill aquifers, so that a full evaluation of the effects of pumpage from other areas on these already heavily pumped areas could be made. In addition, it was anticipated that the drilling could help in defining the feasibility of artificial recharge of the heavily pumped areas and in the determination of the prospective method of recharge and points of emplacement.

Arrangements for easements with landowners, preparation of specifications for well drilling and seismic work, and supervision of well drilling and seismic contracts were all performed by the New Jersey District, Water Resources Division of the Geological Survey.

Prior to the test drilling, seismic exploration under contract with Alpine Geophysical Associates of Norwood, N. J. was conducted at five locations in the Chatham-Madison-Florham Park area and at one place in Parsippany-Troy Hills Township. The seismic work was done to determine the most favorable location for a test well at several potential test-well sites and to help in the interpretation of subsurface geology between test sites.

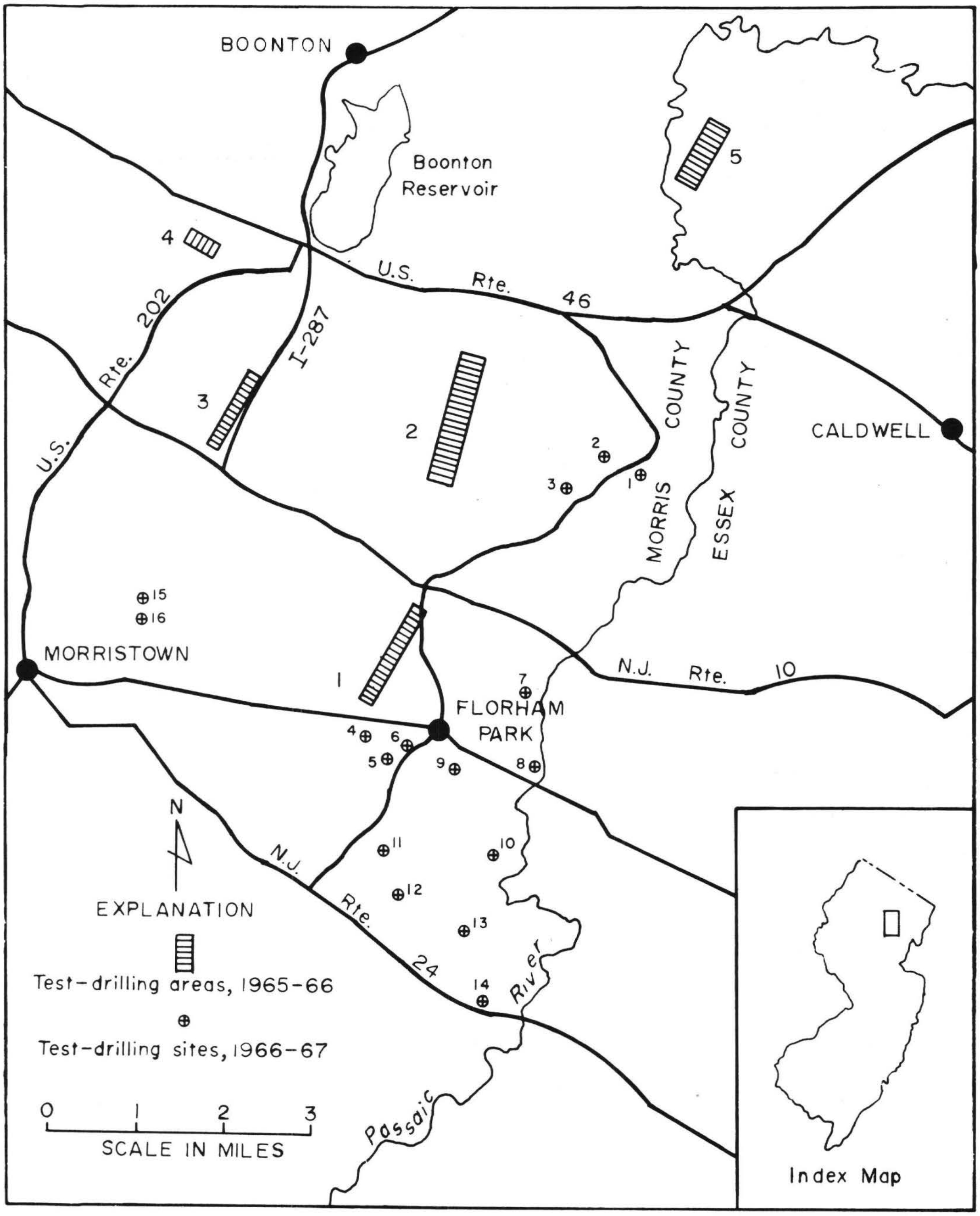


Figure 1.—Map showing areas in which test drilling was conducted in 1965-66 and sites at which test drilling was conducted in 1966-67.

Contracts for the drilling of the test holes were awarded during November, and drilling commenced on November 30. Kaye Well Drilling, Inc. of Jackson, N. J. was the recipient of a contract for eight of the test holes, and a second contract was awarded to Rinbrand Well Drilling Co., Inc. of Glen Rock, N. J.—also for eight test holes.

Acknowledgment is due to the many public officials of Chatham, Madison, Florham Park, Morristown, and East Hanover Township as well as officials of the Braidburn Corporation and Esso Research and Engineering Co., who cooperated by making their lands available for exploration.

## WORK PERFORMED

*Seismic exploration* — Seismic surveying utilizing the shallow seismic refraction technique to determine depth to bedrock was conducted at five locations in the Chatham-Madison-Florham Park area and at one location in Parsippany-Troy Hills Township. A total of ten days' field work was done during early November. The seismic study provided more than 100 determinations of depth to bedrock, and sites for four of the test holes were selected on the basis of these data. In addition, the data provided by the seismic survey permitted the extrapolation of geologic conditions found at the test-hole sites to adjacent areas.

The data acquired through the seismic survey are not presented in this report as such but rather they have been interpreted in constructing figure 2 which shows the distribution and thickness of the valley-fill aquifers in the Eastern Morris County-Western Essex County area. Depths to bedrock determined during the course of this study are being incorporated in a comprehensive mapping project of the buried bedrock surface of eastern Morris County and western Essex County.

*Test drilling* — Test holes of 6 inch diameter were drilled at 16 sites by the cable-tool method. All the holes but one penetrated at least 5 feet into bedrock; drilling difficulties in the one instance necessitated halting the drilling at bedrock.

Bailer samples of the cuttings were collected at 5-foot intervals, and core samples were obtained generally at 10-foot intervals by driving a split-spoon core barrel ahead of the test hole into the undisturbed materials below. Samples were described in the field by geologists as collected, and logs of the materials penetrated are presented in table 1. Locations of the test holes are shown in figure 2.

At sites where the materials penetrated were considered unfavorable for the development of high-yielding wells, the test hole was not completed with a screen and no tests for yield were made. These casings were removed and the holes filled.

Where the materials penetrated appeared favorable for water development, the test hole was completed by installing a well screen that was 10 feet in length and 6 inches in diameter. The screen-slot opening was determined by standard methods from size-distribution curves obtained by sieving the samples of material from the interval to be screened. Of the 16 test holes, 8 were finished with a screen, and these completed test wells have been left in place for use as observation wells.

After the casing was pulled back to expose the screen to the aquifer, the well was developed by surging with a "surge block" until the materials around the screen became stabilized, a condition which generally required about 16 hours of development. One test well was surged with compressed air. Construction details of each well are presented in table 2.

A test pump was then installed and a 48-hour continuous pumping test followed. Two of the wells were pumped for only eight hours, one because of its low yield and the other because of a request from the property owner to avoid overnight noise. Water samples for chemical analyses were obtained from each test well during pumping. Data pertaining to the yield characteristics of each well are contained in table 2. The chemical analyses are listed in table 3.

# HYDROLOGIC EVALUATION OF TEST-DRILLING DATA

## Availability of Undeveloped Supplies

A total of seven test holes were drilled in three areas for purposes of exploring for large undeveloped supplies. These areas were: (1) in northwestern East Hanover Township, (2) in southwestern Hanover Township, and (3) in northeastern Florham Park. Only in northwestern East Hanover Township were significant amounts of undeveloped groundwater found.

(1) *Northwestern East Hanover Township.*—Three test holes (Nos. 1, 2 & 3, fig. 2) were drilled in northwestern East Hanover Township, two of which were completed as wells, and upon testing proved to be very productive. (See table 2.) A very permeable sand and gravel aquifer, locally up to 100 feet thick, underlies the area as shown in figure 2. This sand is believed to be continuous with the aquifer explored last year in "Area 1" in southwestern East Hanover Township.

Little water has been developed from this aquifer in the northern part of East Hanover Township. Many domestic wells tap the aquifer and a few industrial wells draw small amounts of water from it. In the low-lying areas, water levels are at or near land surface, suggesting that water from the aquifer is discharging to the wetlands along the Whippany River.

In this area, water in the aquifer occurs under semi-confined to unconfined conditions depending upon the character of the near-surface materials. Water levels were measured in test well 3, while test well 2 was being pumped at a rate of 280 gpm. Although the wells are only 3,300 feet apart and the pumping test was conducted for 48 hours, no drawdown was noted which could be attributed to the pumping of well 2. Such lack of response is to be expected in water-table or semi-confined aquifers.

It is believed possible to develop a sustained yield of up to 2.5 mgd and a short-term yield of 3.5 mgd from the aquifer in this area. At least three wells would be required to develop the short-term yield of 3.5 mgd. These conclusions are based on pumping-test data, knowledge of the areal extent and thickness of the aquifer, and existing recharge-discharge relationships.

Water from this aquifer is chemically fit for potable use without any treatment (table 3).

(2) *Southwestern Hanover Township*—Two test holes were drilled adjacent to the Whippany River (fig. 2, nos. 15 and 16) in southwestern Hanover Township. The northernmost test hole (no. 15) did not penetrate enough water-bearing sand to warrant the installation of a screen. The southernmost test hole (no. 16) penetrated about 50 feet of water-bearing sand and a well was completed at this site. The well was initially test pumped at 150 gpm, however, the drawdown continued to decline to excessively low levels, and the pumping rate had to be reduced to 105 gpm for the last 24 hours of the test. The pumping-test data suggest that the aquifer has limited areal extent, and this is supported by the geologic data from the northern test hole. The data indicate that only wells of small to moderate capacity could be developed in this area; hence, it is considered nonproductive for purposes of this study.

Except for manganese, water from this aquifer does not contain objectionable concentrations of any constituent for use as potable water (table 3). Manganese is present in concentrations of four times the recommended limit.

(3) *Northeastern Florham Park*—Test holes were drilled at two sites (fig. 2, nos. 7 & 8) in the northeastern part of Florham Park. Neither of the test holes were productive.

### Continuity of Aquifers in the Florham Park-Madison-Chatham Area

The continuity and extent of the valley-fill aquifers in the Florham Park-Madison-Chatham area has been imperfectly understood. Many public-supply wells and a few high-capacity industrial wells tap sand and gravel deposits in widely scattered locations throughout this area. Water levels in these well fields have declined over the years, particularly during the period of the current drought. Because of the declining water levels, there has been concern over the development of additional ground-water supplies in the eastern Morris County-western Essex County region, especially in the already heavily pumped Florham Park-Madison-Chatham area and adjacent areas.

A total of nine test holes were drilled and 10 days of seismic exploration were conducted in order to better define the continuity and extent of the valley-fill aquifers in this area. Moreover, the completed test wells provided information on the yielding properties of the sand and gravel deposits and, also, water-level information in areas away from pumping well fields. Of the nine test holes, five were completed as test wells, four of these are in Florham Park and one in Chatham.

From these data, and those available from previous studies, the following conclusions are indicated:

(1) There is a continuous valley-fill aquifer from the northwestern part of East Hanover Township through the southwestern part of East Hanover Township and into the northwestern part of Florham Park. A slight question remains as to continuity through about 3,000 feet in the vicinity of N. J. Route 10, as shown on figure 2.

(2) The above aquifer is hydraulically continuous with a valley-fill aquifer extending from Florham Park through the central part of Madison and Chatham to the Passaic River and beyond.

(3) There is a lack of continuity or only slight interconnection in Florham Park between the aquifers in (1) and (2) above, and a valley-fill aquifer extending from the east-central part of Florham Park and beyond the Passaic River into Livingston and Millburn Townships. The continuity, extent, and thickness of these valley-fill aquifers are shown in figure 2. Geologic sections constructed along the axis of the major buried valley are presented in figures 3 and 4.

Of the test holes drilled in the Florham Park-Madison-Chatham area, three provided data worthy of special mention as follows:

(1) *Test hole 4*—It had previously been supposed that the valley-fill aquifer in East Hanover Township and that tapped by the Florham Park Borough wells continued across Florham Park in a southeasterly direction to the Braidburn and Dickinson well fields of the City of East Orange in Florham Park and Millburn Township (Gill and others, 1965). Hence, this aquifer was thought to be separate from that trending in a southeasterly direction through Madison and Chatham. However, seismic data indicated that bedrock lay at relatively deep depths at the site of test hole 4, and drilling confirmed the existence of a valley-fill aquifer there. The materials penetrated at this site were very similar in character and sequence to those penetrated last year to the north of

Columbia Road in "Area 1." Moreover, the high productivity of this test well compares with that of the test wells in "Area 1." The chemical nature of the water from test well 4 is, in general, similar to that obtained from the test wells in "Area 1." These facts indicate that the valley-fill aquifer of "Area 1" traverses Florham Park in a southwesterly direction and is continuous with the aquifer in Madison and Chatham.

Also supporting this conclusion are the drilling data acquired from test hole 6 and the seismic data obtained in the vicinity of this site. No significant aquifer occurs there as it would if the buried channel continued in a southeasterly direction as formerly supposed.

Although the aquifer at the site of test hole 4 is very permeable and thick enough to provide large quantities of water to a properly constructed well, tapping the aquifer at this site would only detract from the supplies already developed in the area or the supply advocated for "Area 1." Hence, no "new" water of any magnitude would be developed. However, this would be a good site for an auxiliary well. It would also be a good site for recharge wells, considering the present distribution of pumping wells, if and when the water level in the aquifer is drawn down considerably below its present position. Presently, the water level in test well 4 is about at land surface indicating that pumping of nearby wells has had little influence on the water level of the aquifer at this site.

(2) *Test hole 9*—A very permeable aquifer was penetrated at this site. The sand and gravel aquifer there is very unlike the valley-fill aquifer underlying "Area 1" but it is similar to the aquifer that fills the buried channel along the Passaic River in the Braidburn Well field. The water level in test well 9 is low, about 40 feet below land surface, which suggests that it is within the cone of influence of the Braidburn Wells. Observation of water-level fluctuations over a period of time and their correlation with pumping cycles would provide more substantiative evidence of the continuity of the aquifer at test hole 9 with that at the Braidburn Well field.

If there is continuity, then the area around test hole 9 would be favorable for the injection of recharge water through wells. The present low head and the permeable nature of the aquifer would allow the emplacement of large quantities of water.

This site would also be favorable for a high-capacity auxiliary production well. Any large-scale sustained development at this site might result in considerable mutual interference with the Braidburn wells if, indeed, there is continuity between the two.

(3) *Test hole 14*—This test hole penetrated 191 ft. of unconsolidated materials before encountering bedrock. The altitude of the bedrock surface at this site is about 25 ft. above MSL, an altitude comparable to the bedrock surface encountered by wells in the Madison and Chatham well fields and in the Commonwealth Water Co. well field just beyond the Passaic River at Route 24. Also, a sand and gravel aquifer (fig. 3) occurs at test hole 14 which is similar in lithology, thickness, and water-yielding characteristics to those reported in the Madison, Chatham, and Commonwealth Water Co. well fields. Moreover, the water level in test well 14 is low—about 83 ft. below land surface—which strongly suggests that this site is well within the cone of infiuence of a heavily pumped well field or fields.

All of these data indicate that the valley-fill aquifer in the Madison and Chatham well fields is continuous through the site of test hole 14 and to the Passaic River and beyond at least as far as the well field of the Commonwealth Water Co. Again, correlation of long-term water-level observations with pumping cycles is needed to fully verify the advocated continuity of this valley-fill aquifer.

Should the continuity of the aquifer be substantiated by the water-level observations, the site of test hole 14 would be ideally suited for the recharge of water through wells. The existing low head, the thickness, and the permeable nature of the aquifer are favorable for the injection of large quantities of water. Water levels in the aquifer are lowest in this area and recharge would be of greater benefit there than other places where the head in the aquifer is much higher. Of course, artificial recharge at this site would aid adjacent well fields more than those at a greater distance but all users of the aquifer would derive benefit of a greater head and consequently low pumping lift. Moreover, the practice of artificial recharge at this site and perhaps at other sites would permit the withdrawal of greater quantities of water than are presently tapped from this aquifer.

## RECOMMENDATIONS FOR FURTHER STUDY

The test-drilling program conducted during the two phases of this investigation has demonstrated that additional large-scale developments of ground water are possible in the Eastern Morris County region. An aggregate yield of 7.5 mgd from three areas was reported from last year's exploration (Vecchioli and Nichols, 1966), and an additional 2.5 mgd from a fourth area is described in this report. Water levels in each of these areas are presently well above the top of the aquifer, even at or above land surface in some cases.

However, as development of these areas proceeds, water levels will decline and a careful monitoring of the heads in the aquifers at numerous places is necessary to evaluate the rate of decline. The 15 test wells completed under this program are extremely useful as observation wells. After a few years of water-level record are obtained from these wells, an analysis of these data and those from other observation wells should be made.

In addition, laboratory studies of selected lithologic samples obtained through the drilling program should be made to determine hydraulic parameters of the aquifers, such as permeability, porosity, and specific yield. This information will permit more refined calculation of potential well interference, and movement and storage of water within the aquifer.

Much knowledge has been gained from the test-drilling program regarding the continuity and extent of the valley-fill aquifers. As future drilling information becomes available, a more complete picture of the subsurface geology will evolve. Such geologic and hydrologic data should be assembled periodically and added to the present knowledge of the extent of the aquifers.

Continuing consideration should be given to artifically recharging the aquifers in areas of low water levels. Some areas could be recharged through pits and canals. Others would require wells because of the deeper lying tops of aquifers.

Finally, the studies indicate that if water use in this area continues to expand much beyond present demands, the ground-water supplies will eventually be insufficient for the needs. Ground-water supplies can be overdrawn for short periods of time, such as during a drought, but sustained overdevelopment can result in a continual decline of the available supply. Eventually, it may become necessary to import water from distant sources, develop additional surface reservoirs in the Passaic River basin, or undertake reuse of existing supplies.

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# APPENDIX

## Table 1.—Logs of OEP Test Holes

### Test hole 1

Location.—185 ft. SE. of Ridgedale Ave., 2,550 ft. NE. of Overlook Ave., East Hanover Township, N. J.

Altitude 195 feet

| *Depth, in feet* | *Lithology* |
|---|---|
| 0-10 | Silt, clayey, yellow-brown, with some sand and fine gravel. |
| 10-50 | Sand, fine to medium, yellow-brown, well sorted. Contains a thin layer of till at 20 feet and a layer of brown silt at 30 feet. |
| 50-60 | Till (?), clayey, brown. |
| 60-62 | Clay, grayish-brown, sandy in part. |
| 62-70 | Sand, clayey, poorly sorted. |
| 70-90 | Till, sandy, mostly very poorly sorted medium to coarse sand with pebbles, little to no clay. |
| 90-100 | Till, clayey, dark-gray, very angular rock fragments. |
| 100-112 | Till, clayey, yellow to light-brown, highly weathered, rock fragments very angular. |
| 112-119 | Shale, gray, hard. |

### Test hole 2

Location.—250 ft. SW. of intersection of Homestead and Orchard Place and 25 ft. S. of Homestead Ave., East Hanover Twp., N. J.

Altitude 175 feet

| *Depth, in feet* | *Lithology* |
|---|---|
| 0-10 | Sand, medium, very clayey, brown. |
| 10-20 | Clay, gray, slightly silty and sandy. |
| 20-25 | Sand, very fine, brown, silty. |
| 25-50 | Sand, coarse, silty, some gravel, fair sorting. |
| 50-80 | Sand, medium, fair sorting, water-bearing. |
| 80-114 | Till, clayey, brown to rust. |
| 114-118 | Sand, coarse, fair sorting, water-bearing. |
| 118-125 | Shale, red to brown, highly weathered at top. |

**Table 1.—Logs of OEP Test Holes (Continued)**

Test hole 3

Location.—At end of Weaver Pl., 300 ft. SE. of Whippany River and 1,500 ft. NE. of intersection of Troy Rd. and Whippany River, East Hanover Twp., N. J.

Altitude, 190 feet

| *Depth, in feet* | *Lithology* |
|---|---|
| 0-5 | Sand, medium, very poorly sorted, clayey, with gravel, brown (Till?). |
| 5-10 | Till, very clayey, brown. |
| 10-16 | Silt, clayey, with gravel, dark brownish-gray. |
| 16-25 | Sand, very coarse, and fine gravel, poorly sorted, water-bearing. |
| 25-55 | Sand, coarse to very coarse, with some gravel, fair to poorly sorted, water-bearing. |
| 55-60 | Sand, medium to coarse, well sorted, water-bearing. |
| 60-70 | Sand, fine to medium, well sorted, water-bearing. |
| 70-110 | Sand, coarse, well sorted, water-bearing, very coarse to granule size between 105-110 feet. |
| 110-120 | Till, sandy, with some clay. |
| 120-125 | Shale, red and gray, highly weathered. |

Test hole 4

Location.—2,300 ft. S. of Columbia Rd., 4,300 ft. W. of intersection of Ridgedale Ave. and Elm St., Florham Park, N. J.

Altitude 185 feet

| *Depth, in feet* | *Lithology* |
|---|---|
| 0-20 | Clay, dark-gray, interbedded with silt and very fine reddish-brown sand at 20 feet. |
| 20-47 | Till, clayey, brown, becoming silty toward bottom. Contains thin lens of coarse to very coarse sand at 30 feet. |
| 47-60 | Sand, coarse to fine gravel, fairly well sorted, water-bearing. |
| 60-90 | Sand, coarse with some fine gravel, poorly sorted, water-bearing. |
| 90-124 | Sand, coarse to very coarse, very well sorted, very water-bearing. Contains few feet of medium grained very well sorted sand at 105 feet. |
| 124-130 | Shale, red and gray, interbedded, slightly weathered. |

**Table 1.—Logs of OEP Test Holes (Continued)**

Test hole 5

Location.—1,400 ft. W. of Ridgedale Ave. and 1,900 ft. SW. of intersection of Elm St. and Ridgedale Ave., Florham Park, N. J.

Altitude 200 feet

| *Depth, in feet* | *Lithology* |
|---|---|
| 0-2 | Sand, very fine, slightly clayey, and with few pebbles, yellow-brown. |
| 2-5 | Till, sandy with little clay, yellow-brown. |
| 5-10 | Till, clayey, yellow-brown. |
| 10-20 | Sand, very fine, silty, brown, with some pebbles. |
| 20-25 | Sand, very fine and silty, clayey, brown, contains few pebbles. |
| 25-33 | Till, clayey and very pebbly, brown. |
| 33-39 | Gravel, fine to medium, little sand and clay, water-bearing. |
| 39-40 | Sand, very coarse, poorly sorted, little silt and clay, water-bearing. |
| 40-50 | Sand, all sizes and gravel. |
| 50-55 | Sand, very coarse, poorly sorted, water-bearing. |
| 55-60 | Sand, all sizes, little silt and clay. |
| 60-65 | Sand, very fine, silty and clayey, brown with few pebbles and coarse sand. |
| 65-70 | Silt and very fine sand, brown. |
| 70-76 | Sand, coarse, well sorted, water-bearing. |
| 76-80 | Silt, clayey, brown. |
| 80-81 | Sand, thinly bedded, medium to fine to very fine, with beds of silt, brown, clayey; sand is well sorted. Contains streaks of limonite (?) and few shale fragments. |
| 81-85 | Silt, clayey, reddish-brown with few red and gray shale fragments. |
| 85-87 | Sand, coarse, well sorted. |
| 87-91 | Shale, interbedded gray and red, hard. |

Test hole 6

Location.—225 ft. WNW. of Ridgedale Ave., and 190 ft. NNE. of Elm St., Florham Park, N. J.

Altitude 190 feet

| *Depth, in feet* | *Lithology* |
|---|---|
| 0-60 | Till, silty, sandy, moderately to sparsely pebbly, dense, brown. |
| 60-67 | Sand, very fine to fine, silty, brown. |

### Table 1.—Logs of OEP Test Holes (Continued)

Test hole 6 (Continued)

| *Depth, in feet* | *Lithology* |
|---|---|
| 67-76 | Till, clayey, sandy, sparsely pebbly, yellowish-brown. |
| 76-78 | Clay, with shale fragments, reddish-brown. |
| 78-84 | Shale, moderately weathered, reddish-brown. |

Test hole 7

Location.—560 ft. SE. of end of Nicolet Ave. and offset 115 ft. to the SW., Florham Park, N. J.

Altitude 180 feet

| *Depth, in feet* | *Lithology* |
|---|---|
| 0-2 | Sand, clayey, with few pebbles. |
| 2-10 | Clay, dark-gray, with some sand. |
| 10-20 | Clay, dark-gray, interbedded with silt, dark, reddish-gray. |
| 20-29 | Silt, dark-gray, interbedded with sand, very fine, grayish-brown, and thin lenses of dark-gray clay. |
| 29-37 | Shale, sandy, red, extremely weathered at top to moderately weathered at base. |

Test hole 8

Location.—1,200 ft. N. of Columbia Rd. and 750 ft. W. of Passaic River, Florham Park, N. J.

Altitude 180 feet

| *Depth, in feet* | *Lithology* |
|---|---|
| 0-5 | Fill |
| 5-29 | Clay and silt, dark-gray and dark reddish-gray, with few pebbles at 5-10 feet. |
| 29-40 | Till, reddish-brown, compact, silty, and pebbly. |
| 40-42 | Sand, medium, with little gravel, silty, reddish-brown (weathered). |
| 42-50 | Till, silty, clayey, sandy, some gravel, reddish-brown. |
| 50-55 | Shale, and very fine-grained sandstone, interbedded, slightly weathered, reddish-brown. |

## Table 1.—Logs of OEP Test Holes (Continued)

### Test hole 9

Location.—400 ft. N. of intersection of Lincoln Ave. and Briarwood Rd. and 1,200 ft. S. of intersection of Crescent Rd. and Brooklake Rd., Florham Park, N. J.

Altitude 200 feet

| *Depth, in feet* | *Lithology* |
|---|---|
| 0-20 | Till, clayey, yellow-brown to brown. |
| 20-30 | Sand, medium, silty. |
| 30-50 | Till, clayey, yellow-brown, brown, and rust colored, boulders and cobbles at 38 feet and 50 feet. Crystalline pebbles and shale pebbles are highly to moderately weathered. |
| 50-57 | Sand, all sizes, slightly clayey. |
| 57-71 | Till, sandy and pebbly, some clay in upper few feet. Some pebbles highly weathered. |
| 71-103 | Sand, medium to coarse with gravel and very little silt and clay, fairly well to poorly sorted, water-bearing. |
| 103-110 | Sand, medium to coarse, well sorted, with little silt and few pebbles, water-bearing. |
| 110-120 | Sand, coarse to very coarse and gravel, water-bearing. Contains thin lens of clayey red sand at 115 feet. |
| 120-125 | Shale, red, highly weathered to fresh. |

### Test hole 10

Location.—3,000 ft. NNE. of intersection of Brooklake Rd. and E. Madison Ave. and 1,000 ft. NW. of tower, Florham Park, N. J.

Altitude 180 feet

| *Depth, in feet* | *Lithology* |
|---|---|
| 0-19 | Clay, silty, brown, changing to brownish-gray at 10 ft., few pebbles. |
| 19-30 | Till, silty, sandy, pebbly; pebbles moderately weathered, brown. |
| 30-40 | Sand, very coarse and gravelly at 30 feet, grading downward to very fine and silty at 40 feet. |
| 40-88 | Till, silty, sandy, poorly to moderately pebbly, brown. Lenses of very coarse to coarse gravely sand in top 10 feet. |
| 88-100 | Sand, fine to very coarse, few fine gravel, poorly sorted. |
| 100-104 | Sand, very coarse, some fine gravel, moderately well sorted. |
| 104-120 | Sand, medium, little fine gravel, well sorted. |
| 120-124 | Till, clayey, reddish-brown. |
| at 124 | Shale (?), red. |

**Table 1.—Logs of OEP Test Holes (Continued)**

Test hole 11

Location.—80 ft. SW. of Fairview Ave., about 25 ft. E. of Park boundary and 450 ft. W. of intersection of Fairview and Green Ave., Madison, N. J.

Altitude 260 feet

| *Depth, in feet* | *Lithology* |
|---|---|
| 0-30 | Till, silty, sandy, pebbly, brown. |
| 30-40 | Sand, fine-grained, few fine gravel, with interbedded brown silt. |
| 40-79 | Sand, medium- and coarse-grained, little fine and medium gravel, well sorted. |
| 79-88 | Till, silty, sandy, yellowish-brown. |
| 88-102 | Sand, medium-grained, little fine- and coarse-grained sand, with some fine gravel below 99 feet, well sorted, water-bearing. |
| 102-108 | Sand, fine to coarse-grained, silty, with some fine gravel, yellowish-brown (till?). |
| 108-114 | Clay, silty and silt, clayey, laminated, brown. |
| 114-138 | Till, silty, sandy, clayey, sparsely pebbly, yellowish-brown to 120 feet, reddish-brown to 120-127 feet, yellowish-brown 127-138 feet. |
| 138-141 | Sand, silty, fine to coarse grained, some shale fragments, poorly sorted, reddish-brown. |
| 141-144 | Shale, slightly weathered, reddish-brown. |

Test hole 12

Location.—525 ft. ESE. of Rosedale Ave. and 110 ft. N. of line extended from Parkside Avenue, Madison, N. J.

Altitude 190 feet

| *Depth, in feet* | *Lithology* |
|---|---|
| 0-10 | Clay, very sandy, brown. |
| 10-25 | Till, silty, very compact, brownish-red. |
| 25-30 | Sand, coarse to medium, well sorted, silty. |
| 30-50 | Till, brown to rust, silty, and sandy. |
| 50-70 | Sand, coarse, well sorted, water-bearing, silty. |
| 70-75 | Sand, medium, brown, very silty, and very clayey. |
| 75-80 | Clay, some silt and sand, brown, plastic. |
| 80-85 | Till, clayey and silty, reddish-brown. |
| 85-120 | Sand, fine, very well sorted, silty, rust-brown, water-bearing. |
| 120-125 | Till, red, clayey. |
| 125-135 | Shale, highly weathered, soft, red. |

**Table 1.—Logs of OEP Test Holes (Continued)**

Test hole 13

Location.—2,200 ft. SSW. of intersection of Brooklake Rd. and East Madison Ave. and 600 ft. SE. of Brooklake Rd., Florham Park, N. J.

Altitude 180 feet

| *Depth, in feet* | *Lithology* |
|---|---|
| 0-2.5 | Clay, dark-brown to black, with very fine sand. |
| 2.5-18 | Till, clayey and pebbly, brown. |
| 18-30 | Sand, very fine, silty, with occasional small pebbles, particularly at 26-27 feet. |
| 30-33 | Till, sandy, brown, with few pebbles and some clay and silt. |
| 33-35 | Sand, coarse to very coarse, poorly sorted. |
| 35-41 | Sand, very fine, well sorted, yellow-brown. |
| 41-49 | Till, pebbly with some clay and silt, brown. |
| 49-54 | Sand, very fine to fine, well sorted, trace of gravel and coarse sand. |
| 54-58 | Till, brown. |
| 58-60 | Sand, fine. |
| 60-75 | Sand, medium to coarse, fair sorting, with some gravel, water-bearing. |
| 75-78 | Clay, reddish-brown, with some sand and gravel. |
| 78-90 | Shale, red, gray, and tan, interbedded, highly weathered. |

Test hole 14

Location.—700 ft. N. of Main St. and 35 ft. E. of N. Passaic Ave. Opposite intersection of N. Passaic Ave. and Center Place, Chatham, N. J.

Altitude 215 feet

| *Depth, in feet* | *Lithology* |
|---|---|
| 0-38 | Till, silty, sandy, pebbly, boulders from 0-20, brown. |
| 38-42 | Sand, medium, well sorted. |
| 42-62 | Clay, silty and silt, clayey, laminated, brown. |
| 62-73 | Sand, medium, with some coarse, well sorted. |
| 73-76 | Silt, clayey, brown. |
| 76-98 | Sand, medium and coarse with little fine gravel, well sorted in part. |
| 98-110 | Clay, silty, with some fine sand below 105, brown. |
| 110-120 | Sand, very fine to very coarse, with fine gravel, poorly sorted. |
| 120-161 | Sand, medium to coarse to fine gravel, poorly sorted in part, silty. |
| 161-191 | Till (?), sandy, silty, pebbly, compact, brown. |
| 191-193 | Sandstone, reddish-brown, unweathered. |
| 193-197 | Shale, reddish-brown, unweathered. |

**Table 1.—Logs of OEP Test Holes (Continued)**

Test hole 15

Location.—100 ft. NW. of Whippany River and 1,400 ft. N. of intersection of Whippany River and Hanover Ave., Hanover Twp., N. J.

Altitude 260 feet

| *Depth, in feet* | *Lithology* |
|---|---|
| 0-5 | Sand, medium, fairly well sorted. |
| 5-20 | Till, sandy, silty, pebbly. |
| 20-26 | Silt, clayey, with some gravel. |
| 26-58 | Till, silty, clayey, sandy, pebbly, brown. |
| 58-72 | Sand, very fine and silty to very coarse, gravely in part, poorly sorted in part. |
| 72-89 | Till, silty, clayey, sandy, sparsely pebbly, very compact, brown. |
| 89-100 | Shale, extremely weathered. |

Test hole 16

Location.—20 ft. W. of Whippany River and 200 ft. N. of Hanover Ave., Hanover Twp., N. J.

Altitude 260 feet

| *Depth, in feet* | *Lithology* |
|---|---|
| 0-2 | Silt, sandy, with cobbles and boulders, brown (fill?). |
| 2-4 | Sand, fine, silty, few gravel, yellowish-brown. |
| 4-11 | Till, silty, clayey, sandy, pebbly, brown. |
| 11-13 | Silt, clayey, little sand, brown. |
| 13-20 | Till, silty, sandy, pebbly, brown. |
| 20-27 | Sand, coarse to very coarse, trace of fine gravel. |
| 27-41 | Till, silty, sandy, pebbly, brown. |
| 41-45 | Gravel, fine with little coarse sand, water-bearing. |
| 45-48 | Till (?), sandy, silty, gravely, brown. |
| 48-68 | Sand, very fine to fine with little coarse sand and trace of fine gravel, brown. |
| 68-94 | Sand, medium, some coarse to very coarse sand, and little fine gravel, water-bearing. |
| 94-128 | Silt, clayey, and silty clay, little very fine sand, laminated, brown. |
| 128-143 | Till, silty, clayey, sandy, pebbly, very weathered, brown. |
| 143-148 | Shale. |

Table 2.—Construction and Yield Characteristics of Wells Tested by Pumping.

| Test hole no. | Altitude of land surface (feet) | Total depth drilled below land surface (feet) | Screen setting (feet) | Screen-slot opening (inch) | Static level below land surface at time of pumping test (feet) | Date of pumping test | Yield (gpm) | Draw-down (feet) | Specific capacity (gpm/ft.) | Hours pumped |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 175 | 125 | 62-72 | 0.022 | 1 | 1/16-18/67 | 280 | 22 | 12.7 | 48 |
| 3 | 190 | 125 | 94-104 | .020 | 8 | 12/8-10/66 | 245 | 11 | 22.3 | 48 |
| 4 | 185 | 130 | 110-120 | .030 | 1 | 1/21-23/67 | 300 | 14 | 21.4 | 48 |
| 9 | 200 | 125 | 100-110 | .020 | 41 | 1/13-15/67 | 205 | 8 | 25.6 | 48 |
| 10 | 180 | 124 | 105-115 | .018 | 27 | 3/2-4/67 | 100 | 25 | 4.0 | 47 |
| 13 | 180 | 90 | 63-73 | .025 | 18.5 | 12/14/66 | 95 | 24.5 | 3.9 | 8 |
| 14 | 215 | 197 | 140-150 | .040 | 83 | 1/27/67 | 201 | 25 | 8.0 | 8 |
| 16 | 260 | 148 | 75-85 | .016 | 5 | 1/16-18/67 | 105 | 57 | 1.9 | 48 |

**Table 3.—Chemical Analyses of Water From OEP Test Wells.**

Results in ppm except for temperature, specific conductance, pH, and color.

| Well no. | 2 | 3 | 4 | 9 | 10 | 13 | 14 | 16 |
|---|---|---|---|---|---|---|---|---|
| Date of collection | 1/17/67 | 12/9/66 | 1/20/67 | 1/14/67 | 3/2/67 | 12/14/66 | 1/27/67 | 1/17/67 |
| Temperature (°F) | 50 | 51 | 51 | 52 | 51 | 52 | 52 | 52 |
| Silica ($SiO_2$) | 23 | 25 | 16 | 25 | 21 | 20 | 21 | 16 |
| Total iron (Fe) | .03 | .04 | .06 | .10 | .11 | .07 | .08 | .05 |
| Total manganese (Mn) | .00 | .00 | .00 | .00 | .03 | .14 | .00 | .20 |
| Calcium (Ca) | 32 | 38 | 28 | 45 | 21 | 54 | 44 | 27 |
| Magnesium (Mg) | 12 | 14 | 13 | 16 | 10 | 15 | 12 | 6.3 |
| Sodium (Na) | 5.5 | 8.2 | 10 | 7.5 | 36 | 23 | 8.0 | 6.5 |
| Potassium (K) | .6 | .6 | .6 | .7 | 1.0 | 1.0 | .7 | .6 |
| Bicarbonate ($HCO_3$) | 136 | 145 | 138 | 135 | 118 | 213 | 141 | 96 |
| Sulfate ($SO_4$) | 18 | 29 | 22 | 45 | 48 | 64 | 38 | 25 |
| Chloride (Cl) | 4.6 | 7.1 | 5.5 | 10 | 8.2 | 10 | 8.2 | 3.4 |
| Floride (F) | .0 | .0 | .0 | .0 | .1 | .1 | .0 | .1 |
| Nitrate ($NO_3$) | 4.3 | 20 | 4.2 | 35 | 13 | .4 | 9.0 | .6 |
| Dissolved solids | 158 | 220 | 167 | 252 | 219 | 295 | 220 | 136 |
| Hardness as $CaCO_3$ | | | | | | | | |
| Calcium, Magnesium | 130 | 153 | 124 | 179 | 94 | 196 | 160 | 94 |
| Noncarbonate | 18 | 34 | 11 | 68 | 0 | 22 | 44 | 15 |
| Specific Conductance (micromhos at 25°C) | 261 | 321 | 268 | 379 | 329 | 455 | 324 | 206 |
| pH | 7.9 | 7.8 | 7.9 | 7.7 | 7.8 | 7.9 | 8.0 | 7.7 |
| Color | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |