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WELLS FOR THE OBSERVATION OF CHLORIDE AND WATER LEVELS IN AQUIFERS THAT CROSS THE CHESAPEAKE AND DELAWARE CANAL

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ABSTRACT

Three test wells were drilled near the banks of the Chesapeake and Delaware Canal, in aquifers formed by sand beds in two geologic units, the nonmarine Cretaceous sediments and the Magothy formation, which crop out along the sides and across the bottom of the canal. The canal carries tidal flow from the Delaware River to and from Chesapeake Bay. The purpose of the wells was to determine whether salt water from the canal has entered the water-bearing beds of these formations, and to determine the head of water in them. It was found that the sands contain fresh water, uncontaminated, and that apparently there was discharge of fresh water from the aquifers to the canal under low head, at least from the winter of late 1955 through early autumn 1957.

Measurements of chloride and specific conductance were made on water in the canal to see if there was a relation between the fluctuating quality of water there and the quality of water in the wells. The quality of water in the wells remained relatively constant and did not correlate with variations in the salt content of the water in the canal.

Enlargement of the canal, by widening it from the present width of 250 feet to the proposed 450 feet, deepening it from channel depth of 27 feet to the proposed 35 feet, straightening the bends, and constructing bypass and mooring areas, will increase the discharge of ground water and enhance the opportunity for salt-water encroachment, but in an amount and manner not yet calculable.

Two additional observation wells may eventually prove desirable along the canal: one in Wenonah sand, about 3 miles east of Summit bridge, and the other in channel fill of the Pleistocene series, just west of St. Georges.

INTRODUCTION

In the autumn of 1952 a proposal to widen, deepen, and straighten the Chesapeake and Delaware Canal was presented before the Congress of the United States. The proposal was made by the Board of Engineers for Rivers and Harbors, of the United States Army. The project called for deepening the channel along its 16-mile length from the present 27 feet to 35 feet; widening the channel from an existing 250 feet to 450 feet; correction of bends to a minimum curvature of 7,000-foot radius; construction of a cutoff channel midway in the canal; and construction of an anchorage basin at Elk River, Md.

The canal was originally built between the years 1824 and 1829 as a privately owned waterway, with locks. In 1919 the United States Government acquired ownership of the canal, widened it to 90 feet, deepened it to 12 feet at mean low tide, and made it a sea-level waterway without locks. In 1937 and 1938 the canal was enlarged further by widening it to 250 feet and deepening it to 27 feet below mean low tide. Thus, opportunity for the aquifers that cross the canal to receive salty water from the tidal inflow, the hydraulic head in the aquifers permitting, has existed since 1919.

The canal crosses the intake areas of at least three important aquifers, presenting an opportunity for the exchange of water between the canal and the aquifers. If conditions as they exist, or as they may be modified by the enlargement of the canal or the withdrawal of water from the aquifers, should result in the flow of salty water from the canal into the aquifers, serious harm might be done to the fresh-water supplies in the adjacent and downdip areas.

As a result of exchanges of correspondence 1/ and a series of conferences between personnel of the United States and Delaware Geological Surveys and the Corps of Engineers, it was decided that the factors that control the exchange of water between the canal and the aquifers should be investigated. There was concern for Government liability lest the proposed alterations to the canal increase the dangers of encroachment of brackish water into the fresh water supplies of the aquifers. Both Federal and State agencies are interested in controlling the salt-water encroachment, if possible, because encroachment would be a potential threat to industrial expansion in areas adjacent to the canal.

1/ Letter from Royal W. Davenport, U. S. Geological Survey, to the Director of the Division of Water and Power, Department of the Interior, dated March 9, 1953.

Letter from Fred G. Aandahl, Assistant Secretary of the Interior, to Major General Samuel D. Sturgis, Jr., Chief of Engineers, Department of Defense, dated May 29, 1953.

Letter from Major General B. L. Robinson, Acting Chief of Engineers, to Assistant Secretary Aandahl, dated July 22, 1953.

The Corps of Engineers, U. S. Army, therefore made funds available for a preliminary investigation by the Geological Survey of the problem, including a limited amount of test drilling. The Corps of Engineers let contracts for and supervised the test drilling.

At a field conference on September 27, 1955, 6 sites were chosen for test wells, 3 along the canal and the other 3 along a line parallel to the canal but several hundred feet south of it, to permit determination of ground-water gradients and to mark the extension of salt-water intrusion if it should be found in the wells near the canal. Because funds were limited, however, wells were drilled at only 3 of the 6 sites. The wells were drilled in December 1955 and January 1956.

Figure 1 shows the location of the observation wells, Ea44-2. Ea44-3, and Eb31-1, which were drilled in this investigation. It shows a geologic cross section of the outcrops along the canal, and the location of the lines of subsurface cross sections illustrated in plates 1 and 2. The well numbers are part of a Statewide system. Table 1 on p. 9 presents the logs of these observation wells. Sand logs and samples are available for inspection at the offices of the Federal and State Geological Surveys at Newark.

This ground-water study was under the general supervision of A. N. Sayre, Chief, Ground Water Branch, U. S. Geological Survey. It was made by W. C. Rasmussen, District Geologist, assisted by Durward H. Boggess, Engineering Technician. Geologic data were interpreted by Johan J. Groot, State Geologist of Delaware. The chemical part of the study was made by N. H. Beamer, District Chemist, Quality of Water Branch. He was assisted in the field by C. N. Durfor, Chemical Engineer, and others. A preliminary open-file release of the data was made in September 1956 (Rasmussen and Beamer).

A. J. Depman, Geologist of the Corps of Engineers, Philadelphia District, was in charge of the test drilling. The Middletown Well Drilling Co. constructed the wells.

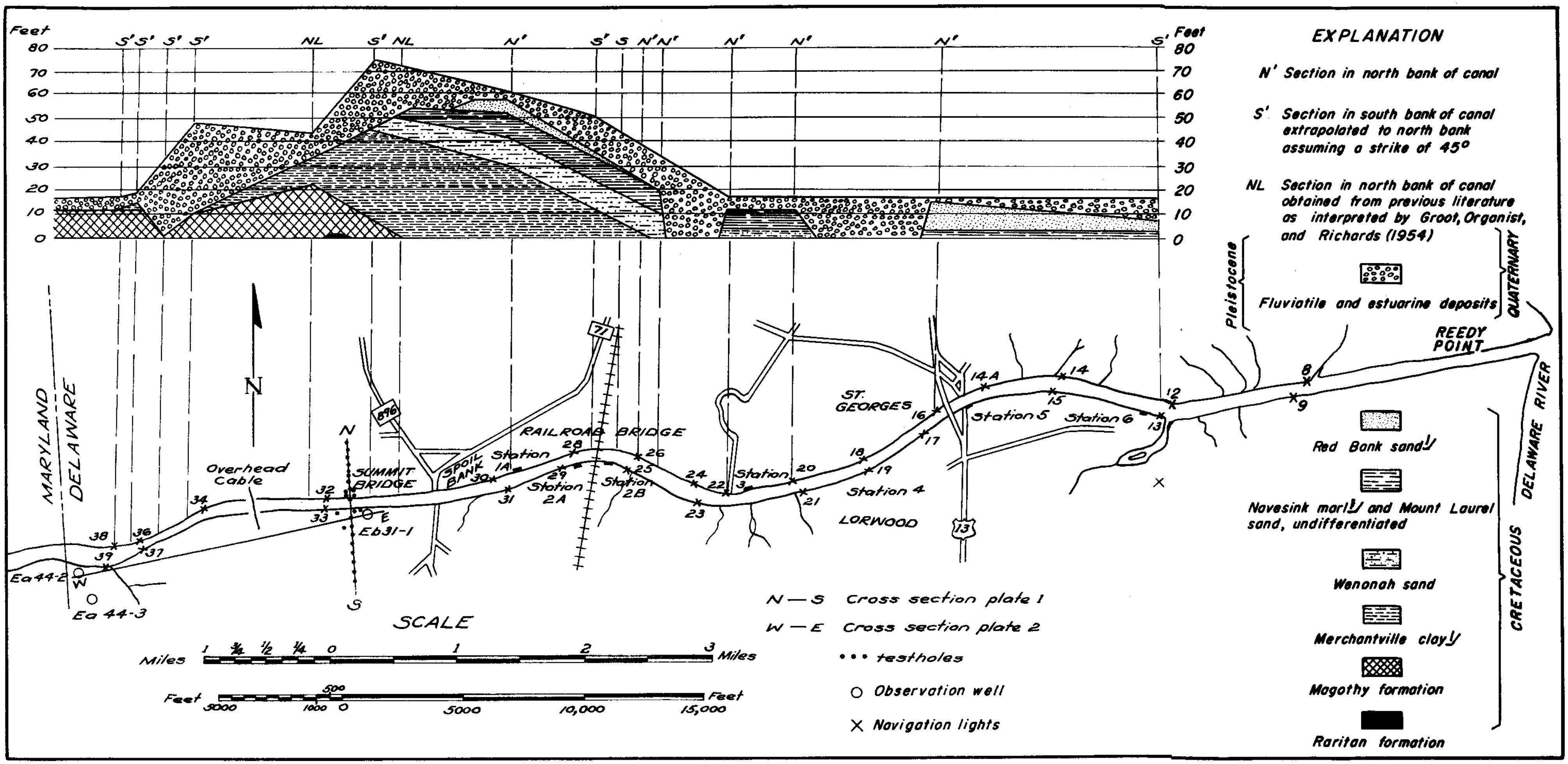
GEOLOGY

The geologic formations in the vicinity of the Chesapeake and Delaware Canal consist of unconsolidated sediments of Cretaceous and Pleistocene age. The Cretaceous formations in this area form a homoclinal structure having a southeasterly regional dip ranging from 25 to 65 feet to the mile. In one locality, however, about 1½ miles east of the Pennsylvania Railroad Bridge, a slight reverse dip can be observed in the marine Cretaceous sediments. The Pleistocene series is composed of sand, gravel, and silt which mantle the Cretaceous formations nearly everywhere, and they fill channels eroded in the Cretaceous deposits. A north-south cross section showing the geology of the canal area is presented in plate 1, and an east-west cross section in plate 2.

The nonmarine Cretaceous sediments present in northern Delaware belong to the Patuxent, Patapsco, and Raritan formations, according to Miller (Bascom and Miller, 1920). In view of their lithologic similarity and the absence of fossil remains (except pollen and spores, which are now being studied) it has not been possible to differentiate these formations. Groot (1955) subdivided the sediments into two heavy-mineral zones, called the Patuxent zone, characterized by abundant staurolite, and the Patapsco-Raritan zone, in which only very stable heavy minerals such as tourmaline, zircon, and rutile occur. In the banks of the canal, only sediments of the Patapsco-Raritan zone of Groot (1955) have been found.

These deposits consist of white, red, yellow, and gray variegated clay and white and gray sand in lenses of limited vertical and horizontal extent, changes in texture occurring within short distances. Although these sands form an important aquifer in the Delaware City area and south of the canal in Delaware and Maryland, their highly irregular lithologic character precludes accurate prediction as to the depth, thickness, and ground-water yield of specific sand strata.

The Magothy formation overlies the nonmarine Cretaceous sediments unconformably. It is composed of white sugary fine to medium sand and dark-gray to black carbonaceous clay containing lignitized branches and tree trunks. Because some of the nonmarine Cretaceous clays also are gray and contain lignite, they cannot always be easily distinguished from the clays of the Magothy formation in well samples or well logs. However, the Magothy sediments, including the clays, contain abundant staurolite, whereas the deposits of the Patapsco-Raritan zone do not contain this mineral in any appreciable quantity (Groot, 1955).



1/As used by Groot, Organist, and Richards (1954)

Figure 1. Index map showing location of observation wells adjacent to the Chesapeake and Delaware Canal, the geologic cross section from outcrops along the canal, and the location of north-south and east-west geologic cross sections. (Adapted from Groot, Organist, and Richards, 1954, pl. 2).

The Magothy formation is particularly well exposed in the south bank of the canal between Bethel and Summit Bridge, where it reaches a maximum outcrop thickness of 22 feet. It is absent in most of the Delaware City area and is therefore discontinuous. Where sands of the Magothy and Patapsco and Raritan units are in contact, they function as a hydrologic unit.

The Magothy formation, which is regarded as transitional between marine and nonmarine, forms only a minor aquifer north of the canal, but in the Middletown area it yields large quantities of water to irrigation wells.

The Matawan group overlies the Magothy formation unconformably. In Delaware it consists of the Merchantville clay and Wenonah sand (Groot, Organist, and Richards, 1954). The Merchantville clay is composed of highly micaceous, very silty and clayey very fine glauconitic sand and fine sandy silt; the name is therefore a misnomer, at least for the deposits in Delaware. It reaches a thickness of 40 feet in outcrop in the canal. In view of its texture, the Merchantville clay probably forms a semipermeable confining layer to water in the Magothy formation and nonmarine Cretaceous sands below.

The Wenonah sand, which conformably overlies the Merchantville clay as used by Groot, Organist, and Richards, (1954) consists of gray and rust-brown fine to medium slightly glauconitic, very micaceous sand containing numerous tubelike concretions identified as the problematic fossils *Halymenites major* Lesquereux. Its outcrop is only 12 feet thick, and it serves as a minor aquifer yielding water to domestic and farm wells, particularly south of the canal.

The Wenonah sand is overlain by the Monmouth group, which has been divided into three lithologic units in New Jersey: the Mount Laurel sand, the Navesink marl, and the Red Bank sand. In Delaware the lower part of the undifferentiated Mount Laurel sand and Navesink marl consists of green silty and clayey very fine glauconitic sand, grading into a dark-green to nearly black sandy silt. It contains an abundance of marine fossils such as *Exogyra cancellata* and *Exogyra costata.* The thickness of this unit in the outcrop is about 12 feet. It functions as a confining bed for water in the Wenonah sand.

The Red Bank sand conformably overlies the undifferentiated Mount Laurel sand and Navesink marl. It is composed of reddish-brown fine to medium slightly glauconitic quartz sand. The maximum outcrop thickness of this unit is 11 feet. It acts as the lower part of an unconfined aquifer in conjunction with overlying deposits of sand of the Pleistocene series.

Study of the sediments of the Pleistocene series in the vicinity of the canal has not progressed to the point that accurate differentiation into geologic formations is possible. However, the main body of the Pleistocene sediments is composed of brown medium to coarse pebbly cross-bedded sand containing, in many places, a basal layer of cobbles and boulders. This deposit occurs as channel fill in a thickness of about 90 feet, and also in interchannel areas where it is usually 20 to 25 feet thick. It is presumed to be largely or entirely of fluviatile origin.

In the western and eastern parts of the canal a different type of deposit is found: laminated gray silt and fine sand containing scattered small pebbles; these deposits are probably estuarine in origin and are tentatively correlated with the Pamlico formation.

In addition to the channel deposits mentioned previously, an entirely different type of channel fill has been noted; it consists of blue and gray clay containing organic matter, interbedded with well-sorted fine sand. Apparently this type of sedimentation occurred after deposition of the estuarine deposits of Pamlico (?) age. No other Pleistocene lithologic units have been observed in the outcrops along the canal, but study of a larger area might well reveal other units.

The main body of Pleistocene sand and gravel, particularly in the channels, forms an important aquifer capable of large yields of ground water. Where large-capacity wells are located in channel deposits adjacent to the canal, brackish-water encroachment is possible and should be carefully watched.

Review of the sediments cropping out along the canal indicates that salt-water encroachment may occur, under unfavorable conditions, into sands of the following units: Patapsco-Raritan zone of Groot (1955), Magothy formation, Wenonah sand, Red Bank sand, and Pleistocene series.

HYDROLOGY

The hydrology of the Chesapeake and Delaware Canal and vicinity is not clear because, although numerous consulting and other administrative reports have been prepared for the Corps of Engineers and others (see U. S. Geol. Survey, 1952), in no place have these been collated, analyzed, and published. The tidal flow between Chesapeake Bay and the Delaware River, the fresh-water runoff from the tributaries to the canal, the ground-water discharge, and the fluctuation in quality of water have not been thoroughly investigated or interrelated. The tides and currents and resultant tidal flow in the canal were the subject of a field investigation and an unpublished report by the Corps of Engineers in 1939-40. The regional ground-water hydrology has been described in a preliminary fashion for the entire State of Delaware (Marine and Rasmussen, 1955).

The hydrology of northern Delaware, from the canal northward, has been described in considerable detail (Rasmussen, Groot, Martin, McCarren, and others, 1957).

It was the primary purpose of this investigation to determine the ground-water hydrology along a portion of the canal, particularly the extent or possibility of salt-water intrusion, by means of the three observation wells drilled along the south bank. Continuous conductivity and periodic chloride determinations were made on water of the canal for several months. Chloride determinations on water from the wells have been made periodically at times when ground-water levels were low and the possibilities of encroachment were greatest.

Well Characteristics

Table 2 summarizes the characteristics of the observation wells. Remarks that follow enlarge upon these and other details.

The first well drilled, Eb31-1, is 2,850 feet west of old Summit Bridge, and 200 feet south of the canal. The land surface at the well is 51 feet above the water level in the canal. The well was drilled to a contract depth of 163 feet, but the driller carried a small hole ("rat-hole") down to 208 feet. No sands were found in the nonmarine Cretaceous sediments, although 107 feet of variegated clay and silt was logged. Therefore the well was completed in the Magothy formation, which had 10 feet of coarse to fine sand, 91 to 101 feet below the land surface.

The well was cased with 92.5 feet of 6-inch wrought-iron casing, reduced to 2½ inches by a nipple, connected to 10 feet of 4-inch red-brass wirewound screen (9.3 feet exposed below the casing). The 5-inch hole below the screen had been filled with stone. In regarding the site for the new bridge, 26.6 ft. of casing has been cut off. The casing protrudes 2.5 feet above the land surface and is fitted with a hinged cap, secured with a padlock. After development of the well, the water pumped was slightly milky with sediment.

The second well drilled, Ea44-2, is 600 feet east of the State line and 400 feet south of the canal. The land surface at the well is 44 feet above the water surface in the canal. This well was drilled to a contract depth of 144 feet and "rat-holed" to 165 feet. The nonmarine Cretaceous beds were penetrated for 113 feet in the lower part of the 165-foot hole; about 69 feet of the 113 was sand. Wrought-iron casing 6-inches in diameter was set for 122.3 feet, and 10 feet of 10-slot 60-gauge red-brass 4-inch screen was placed at the bottom (9.3 feet exposed). The top of the casing is 2.5 feet above the land surface, and the well is protected with a hinged cap and padlock. The well was pumped clear and yielded an estimated 75 gpm during development.

The third well, Ea44-3, is 1,170 feet south of the canal and 770 feet east of the State line. The land surface at the well is 44 feet above mean water level in the canal. Ea44-3 is 817 feet southerly from Ea44-2. The well was drilled to a contract depth of 153 feet and "rat-holed" to 165 feet. The nonmarine Cretaceous sediments were encountered at 56 feet below the land surface and penetrated for 109 feet, of which 52 feet was sand, The well was cased with 117 feet of 6-inch wrought-iron casing and screened with 28.3 feet of 4-inch red-brass screen (27.1 feet exposed). The top of the casing is 1.9 feet above the land surface, and it is protected with cap and padlock.

Short (1- to 2-hour) pumping tests were made on all three wells by pumping with a cylinder pump at relatively low rates (11 to 23 gpm). Because of the tidal influence, and the low and somewhat variable pumping rates, the drawdown and recovery water-level data was used only to determine the specific capacity of each well, as listed in table 2. This capacity is believed to indicate mainly well characteristics rather than aquifer characteristics, and no conclusions on aquifer hydraulics appear warranted on the basis of these tests.

Table 3 shows the daily lowest water levels in Ea44-2, obtained from a continuous recorder. The well is 400 feet south of the canal, and the water level in it follows the tidal cycle of the canal water, although somewhat dampened in amplitude and lagging in phase. The observations indicate a daily range of fluctuation in the well of 0.9 to 2.0 feet, whereas in the water of the canal during this same period the daily range probably was 3 to 6 feet (a tide recorder was not maintained on the canal during this investigation). There are approximately two maxima and two minima each day, and the tidal fluctuation in the canal is a resultant of tidal forces from each end, the Delaware River and Chesapeake Bay. The prediction of tidal time and height is complex; however, daily predictions of tidal heights at Reedy Point and current phases at Chesapeake City are published annually by the Coast and Geodetic Survey. The diurnal cycle is controlled by a cycle of approximately weekly wavelength, apparently following lunar control.

The tidal fluctuation in the well is probably a combination of two forces: the loading and unloading of tidal weight on the canal bottom, transmitting pressure to the water in the sand; and the actual interchange of water, in the intake area of the aquifer penetrated by the well, which crosses the canal about half a mile west of Ea44-2. This may not mean that brackish water from the canal filters back into the aquifer. However, it could mean that discharge from the aquifer, which occurs at low water, is stopped or reduced and that storage builds up. Table 3 indicates that there is a positive gradient from the formation to the canal which, even at maximum tidal height would average 2 feet in 400 feet.

Table 4 shows periodic measurements of water levels in Ea44-3 and Eb31-1.

Comparison of the water level in Ea44-3 with that in Ea44-2 on corresponding dates shows that there is a positive gradient toward the canal, ranging from 1.3 to 2.5 feet in 820 feet at low-water phase in Ea44-2. Although continuous records have not been made at Ea44-3, it is probable that the tidal fluctuation is considerably dampened in this well, which is 1,170 feet south of the canal.

Well Eb31-1, which is only 200 feet from the canal, undoubtedly fluctuates in response to tides in the canal. The 7 measurements that have been made indicate that there is a positive gradient in the Magothy formation toward the canal. The gradient indicated by the 7 measurements is less than 1 foot in the 200 feet.

The conclusion drawn from the water-level measurements is that, in 1956 and 1957, the aquifers were discharging fresh water to the canal more than half the time, and perhaps all the time.

Aquifer Hydraulics

Brief comment of the effect the program of widening, deepening, and straightening the canal may have upon the discharge of ground water and upon the opportunity for salt-water contamination is warranted. Because ground water is discharged not only along the margins of the canal but by upward leakage along the bottom as well, the discharge is a partial function of the surface area of the exposed aquifer. The surface area would be increased about 80 percent; the average hydraulic gradient would tend to approach the same value as before the enlargement of the canal.

Darcy's law, which governs the flow of ground water, may be expressed in simplified form as Q = PIA, in which:

Q is the quantity of water discharged in a unit of time
P is the coefficient of permeability
I is the hydraulic gradient
A is the cross-sectional area through which the water percolates.

The permeability of the Magothy formation as determined in a well-field test at the Governor Bacon Health Center near Delaware City (Marine and Rasmussen, 1955, p. 66, 109) is about 80 gpd per square foot. The permeability of the nonmarine Cretaceous sediments, according to well-field tests on sands in wells screened and developed for the Tidewater Oil Co. in its refinery area near Delaware City, ranges from about 20 to 200 gpd per square foot. These values represent medium to fine, somewhat silty sands. It would be difficult to arrive at an average figure because of the variability of the sands.

The hydraulic gradients determined in this study are about 0.5 feet per hundred feet near the canal. As the canal is enlarged, the exposed area will increase 80 percent but the cross-sectional area through which the ground water flows will increase much less, as the flow lines will change. The increase might amount to something like 15 to 25 percent. Near the canal the effect of the increased cross section would tend to be offset by a decrease in the average hydraulic gradient, but regionally the gradient toward the canal should tend to approach the same value as before the canal enlargement. Therefore it is possible that the amount of water draining into the canal would remain about the same, although it might be increased slightly as a result of a reduction in evapotransporation of ground water as the water levels lower in adjusting to the larger cross section of flow. However, the lowering of water levels accompanying the reduction in hydraulic gradient toward the canal would tend to increase the opportunity for salt-water encroachment from the canal. The available data are not adequate, however, for assessing the magnitude of the effect in relation to the usefulness of the aquifers as sources of water supply.

QUALITY OF WATER

During drilling of the wells, water samples were collected for partial analysis, and after each well was developed one or more samples were taken for complete analysis. All the analyses are shown in table 5; those of the water from the developed wells are marked with a "t," indicating a known source of water shown in the column headed "Geologic source." From a comparison of the analyses made on the water samples collected on February 21, it is evident that all the wells gave water of nearly the same character, except for pH. Water from the wells was soft, low in dissolved solids and chloride, and high in total iron (2.5, 5.1, and 6.3 ppm). Whereas the chloride content of the water in the canal ranges from 50 to 6,400 ppm, during the study the samples of well water did not exceed 5ppm in chloride content and there is no evidence of intrusion of salt water from the canal so far as these wells are concerned. (Compare table 5 and 6.)

Water samples taken during the progress of drilling show some change in quality with depth. Fresh water from a well near Middletown was used by the drillers to mix the drilling mud. An effort was made to remove the drilling fluid before taking a water sample, by bailing out the hole. Frequently, the bailing led to collapse of the sands in the hole. The depth was measured after each water sample was taken, and is shown in table 5. Depths of some of the later samples are less than some of the earlier ones, because of hole collapse. The water samples taken during drilling of the well tend to have higher conductances than the water taken from the well after development, but in no case is there evidence of saline intrusion, as the differences in chloride content are negligible.

Table 6 shows the quality of water of the canal, indicated by chloride content, and by measurements of specific conductance made in the laboratory. Additional conductivity measurements were taken with an automatic recorder from November 30, 1955, to June 29, 1956. The records may be consulted at the Quality of Water laboratory of the Geological Survey in Philadelphia. A rough approximation of the concentration of dissolved solids in the water may be obtained by multiplying the specific conductance by the factor 0.6. The values, ranging from 121 to more than 11,000 ppm, show a wide fluctuation in the quality of the water of the canal. There is no correlation with the quality of the fresh water in the wells. The specific conductance of the canal water is compared with the average for the wells in February and July in figure 2.

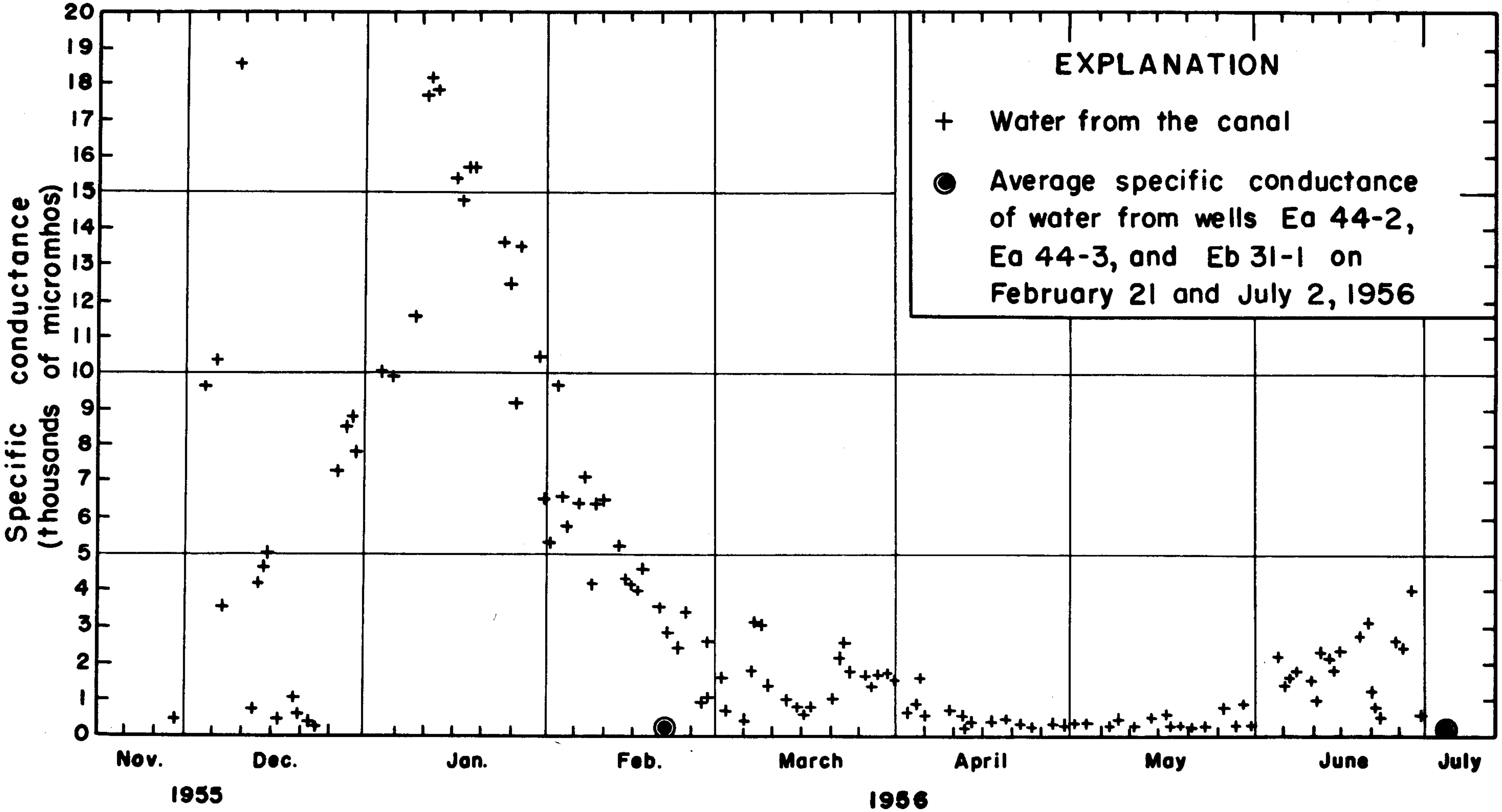


Figure 2. Graph of specific conductance of water in the Chesapeake and Delaware canal, November 1955 to July 1956, in contrast to the average specific conductance of water from the three observation wells, February 21 and July 2, 1956.

Water samples taken from the three wells in the autumn of 1956 (September 18 and October 4) and in the autumn of 1957 (September 16) indicate no appreciable change in the chloride content. These samples were taken at a time of low ground-water stage. The data further substantiate the conclusion that no brackish canal water has entered the observation wells.

The analysis of water from Eb31-1 on October 4, 1956, shows a slight increase in sulfate content. The well is screened in the Magothy formation, which has appreciable concentrations of the minerals pyrite and marcasite, both consisting of iron disulfide. At low ground-water stages exposure of these minerals to oxidizing conditions may result in formation of sulfuric acid and thus in addition of sulfate to the ground water. This observation is supported to some extent by an apparent decreasing trend in pH. However, sulfate derived from other sources might vary also; therefore no conclusion as to the reason for the apparent increase in sulfate is justified at present.

CONCLUSIONS

From data resulting from drilling and sampling three wells near the south bank of the Chesapeake and Delaware Canal, it is concluded that at least during the period from the winter of 1955-56 to the early autumn of 1957 there was no salt-water intrusion from the canal into the nonmarine Cretaceous and Magothy formations. Heavy pumping of these formations by industries in the Delaware City area 8 miles to the east began in June 1956, but as of the autumn of 1957 there is evidence neither of a decline in water level nor of intrusion of salt water from the canal in the vicinity of the test wells as a result of the pumping.

Positive hydraulic gradients toward the canal exist in the aquifers, indicating that fresh water was discharging into the canal during 1956 and 1957. The gradients are low, not more than half a foot per 100 feet, and are somewhat obscured by tidal fluctuations which effect the water levels in wells near the canal.

Fluctuations in water level in the wells near the canal follow the tidal ebb and flow of the brackish water in the canal, but this is believed to be primarily a pressure response. No correlation was detected between the quality of water in the wells and that of water in the canal.

Enlargement of the canal by widening, deepening, and straightening the channel may result in an increase in the opportunity for salt-water intrusion, but sufficient data to calculate these effects are not yet available.

It was not possible during the course of this investigation to determine the quality of water in the Wenonah sand, which crosses the canal about 3 miles east of the eastern observation well (Eb31-1), and which serves as a minor aquifer in the Delaware City area, in the area south and east of St. Georges, and in the Middletown area (see Marine and Rasmussen, 1955, pl. 7). To afford information on any effects of the canal enlargement, it would be desirable to drill an observation well tapping this aquifer near the banks of the canal and near the locality where the aquifer crosses the canal.

Recent (1956) geologic study of the Pleistocene series in northern Delaware has disclosed a major Pleistocene channel, which crosses the canal just west of St. Georges. This channel extends to more than 87 feet below sea level, and wells of reported yield as large as 1,050 gpm have been drilled into it about 2 miles north of the canal. Ground water in this channel is recharged directly by infiltration of rainfall, and by streams such as Dragon Run, that cross it. Salvage of natural discharge in areas nearer the existing well fields may be sufficient to prevent the cones of depression of those well fields from reaching the canal. Eventually, however, as a means of protection for these rather large fresh-water supplies, it would be desirable to drill an observation well in these deposits on the north bank of the canal.

REFERENCES

Bascom, Florence, and Miller, B. L., 1920, Description of the Elkton and Wilmington quadrangles (Maryland-Delaware-New Jersey-Pennsylvania): U. S. Geol. Atlas, Folio 211.

Groot, J. J., Organist, D. M., and Richards, H. G., 1954, Marine Upper Cretaceous formations of the Chesapeake and Delaware Canal: Delaware Geol. Survey Bull. 3, 64 p.

Groot, J. J., 1955, Sedimentary petrology of the Cretaceous sediments of northern Delaware in relation to paleogeographic problems: Delaware Geol. Survey Bull. 5, 157 p.

Marine, I. W., and Rasmussen, W. C., 1955, Preliminary report on the geology and groundwater resources of Delaware: Delaware Geol. Survey Bull. 4, 336 p.

Rasmussen, W. C., and Beamer, N. H., 1956, Wells for the observation of chloride and water levels in aquifers that cross the Chesapeake and Delaware Canal: U. S. Geol. Survey, open-file report (mimeographed by the Corps of Engineers, U. S. Army), 42 p.

Rasmussen, W. C., Groot, J. J., Martin, R. O. R., McCarren, E. F., and others, The water resources of northern Delaware: Delaware Geol. Survey Bull. 6, V. 1, 223 p.

Todd, D. K., 1952, An abstract of literature pertaining to sea water intrusion and its control: Univ. California, Berkely, 72 p.

U. S. Geological Survey, 1952, Index of water-resources records in the Delaware River basin to September 30, 1951: U. S. Geol. Survey Circ. 190, 19 p.

Table 1.—Well logs of observation wells adjacent to the Chesapeake and Delaware Canal.

	Thickness (feet)	Depth (feet)
Ea44-2 (Alt. 44 ft.) Logged by W. C. Rasmussen and A. J. Depman		
Recent series		
(Hydraulic fill)		
Sand, medium to coarse, brown	7	7
Clay, sandy, gray	5	12
Pleistocene(?) series		
Sand, medium to fine, tan-gray	5	17
Sand, medium, and small gravel, gray-brown	5	22
Merchantville clay		
Clay, silty, black, micaceous	5	27
Magothy formation		
Sand, medium to coarse and small gravel, orange-brown	5	32
Clay, yellow and lignite	5	37
Sand, medium, gray and lignite	5	42
Pebbles and sand, pink	1	43
Sand, coarse to medium, gray, lignitic	9	52
Nonmarine Cretaceous sediments		
Silt and sand, very fine, white	12	64
Sand, hard	1.5	65.5
Sand, very fine and silt, white	2.5	68
Silt, sand, white	4.5	72.5
(Upper aquifer)		
Sand, medium to fine, light brown	7.5	80
Sand, medium to coarse, and small gravel, light brown	4	84
Sand, fine to medium, white to tan	13	97
Sandstone "iron" balls and white silt	1	98
Sand, medium to coarse, some pebbles, tan to gray	7	105

	Thickness (feet)	Depth (feet)
Clay, silty, pink to white	1.5	106.5
Sand, medium to coarse, tan	7.5	114
Sand, very fine, silty, white	3.6	117.6
Sandstone, medium, ferruginous	2	119.6
Silt, white clayey	1	120.6
Sandstone, friable	4.2	124.8
Sand, medium to fine, white	3.2	128
Silt, clayey, white	4	132
Sand, medium, white	2	134
Clay, variegated red and white	7	141
Clay, red	4	145
Clay and sand, fine, white	5	150
Sand, gray lignitic, and clay balls, red and white	5	155
Clay, red and white	10	165
Ea44-3 (Alt. 44 ft.) Logged by W. C. Rasmussen and A. J. Depman		
Pleistocene(?) series		
Silt, sandy and clayey, yellow fragments of *Belemnitella americana* Morton (probably transported)	3.5	3.5
Sand, medium to coarse, and grit, yellow	8.5	12
Sand and gravel, orange-brown	0.5	12.5
Merchantville clay		
Clay, micaceous, orange	4.5	17
Silt and clay, micaceous, black	5	22
Sand, fine and silt, glauconitic, greenish-black	15	37
Magothy formation		
Sand, medium, with fragments of sandstone	5	42
Sand, coarse to medium, sugary, dirty	5	47
Sand, medium to coarse, sugary gray, lignitic, some mica	9	56

	Thickness (feet)	Depth (feet)
Nonmarine Cretaceous sediments		
Sand, fine and silt, light gray, hard layers, round concretions	4	60
Clay, gray	5	65
Clay, red and white	5	70
Clay, gray	6	76
Sand, fine silty, gray	4	80
Clay and sand, fine, interbedded	10	90
(Upper aquifer)		
Sand, fine to very fine, gray	3	93
Sand, medium to fine, tan	3	96
Sand, fine, silt-ball concretions	3	99
Silt and sand, very fine, gray	5	104
Silt and clay, lignitic with layers of very fine sand	9	113
Sand, medium to fine, silty, gray	7	120
Sand, medium, light gray	7	127
Sand, medium, silty, gray	3	130
Sand, medium to coarse, tan	7	137
Sand, coarse, gray-brown	5	142
Sand, very coarse, and angular pebbles	0.7	142.7
Clay, sandy, gritty, red and white	2.3	145
Sand, very fine, silty, gray	5	150
Clay, gray and red	1	151
Clay, gray	14	165
Eb31-1 (Alt. when drilled 78 ft.) Logged by W. C. Rasmussen and A. J. Depman		
Mount Laurel sand and Navesink(?) marl undifferentiated		
Sand, very fine, and silt, greenish-gray, glauconitic, and micaceous	12	12
Wenonah(?) sand		
Silt, sandy, light gray	5	17

	Thickness (feet)	Depth (feet)
Sand, medium to fine, brown	5	22
Sand, coarse to fine, brown to black glauconitic	5	27
Merchantville clay		
Silt and sand, very fine, greenish-black, glauconitic, and micaceous	20	47
Silt, sandy, black, micaceous	10	57
Sand, fine, richly glauconitic, green	10	67
Silt, sandy, greenish-black, micaceous, and glauconitic	11	78
Clay, dark gray-green, slightly micaceous	9	87
Magothy formation		
Clay, lead-black	4	91
Sand, medium to fine, tan	4	95
Sand, medium to coarse, sugary, white	3	98
Sand, medium to fine, light gray to brown, carbonaceous specks (?)	3	101
Nonmarine Cretaceous sediments		
Clay, silty, red and white variegated	85	186
Concretions, round gritty	—	186
Clay	21	207
Silt, white	1	208

Table 2.—Characteristics of the observation wells adjacent to the Chesapeake and Delaware Canal.

Well number	Date		Altitude (ft)	Depth (ft)		Diameter (in)	Geologic source	Initial static water level			Yield		Specific capacity (gpm/ft drawdown)	Remarks
	Begun	Completed		Drilled	Final			Feet below land surface	Feet above mean sea level	Date of measurement	Gpm	Date		
Ea44-2	12-14-55	1-5-56	42.9	165	131.6	6	Nonmarine Cretaceous sediments	41.5	1.4	1-5-56	22.3	1-5-56	0.93	One-hour test
Ea44-3	1-3-56	1-14-56	43.7	165	142.2	6	do	39.1	4.6	1-14-56	22.0	1-14-56	1.93	Two-hour test
Eb31-1	12-5-55	12-15-55	(78.4)_/ 51.0	208	100.1	6	Magothy formation	74.3	4.1	12-15-55	11.3	12-15-55	.5	Estimated drawdown 21 feet (inside screen), two-hour test.

_/(78.4) was the altitude of Eb31-1 prior to the summer of 1957, when the land surface was lowest during excavation for the new Summit bridge.

Table 3.—Water-level fluctuations in well Ea44-2

A.—Daily lowest water level in feet above msl from recorder charts

Date	Elevation	Date	Elevation	Date	Elevation
1-6-56	2.34	3-10-56	0.91	5-16-56	1.84
1-27-56	1.11	3-11-56	2.15	5-17-56	1.54
1-28-56	1.10	3-12-56	1.34	5-18-56	1.65
1-29-56	1.68	3-13-56	1.64	5-19-56	1.65
1-30-56	1.47	3-14-56	1.83	5-20-56	1.36
1-31-56	0.58	3-15-56	1.28	5-21-56	1.85
2-1-56	0.51	3-16-56	1.63	5-22-56	2.06
2-2-56	1.21	3-17-56	1.38	5-23-56	1.78
2-3-56	0.90	3-18-56	1.83	5-24-56	1.18
2-4-56	1.33	3-19-56	1.33	5-25-56	1.70
2-5-56	1.39	3-20-56	1.44	5-26-56	2.11
2-6-56	1.39	3-21-56	1.41	5-27-56	2.15
2-7-56	1.16	3-22-56	1.76	5-28-56	0.98
2-8-56	0.96	3-23-56	1.75	5-29-56	1.33
2-9-56	1.11	3-24-56	1.16	5-30-56	1.91
2-10-56	1.50	3-25-56	0.73	5-31-56	1.49
2-11-56	1.64	3-26-56	1.78	6-1-56	1.50
2-12-56	2.21	3-27-56	1.66	6-2-56	1.31
2-13-56	1.78	3-28-56	1.40	6-3-56	1.74
2-14-56	1.58	3-29-56	1.56	6-4-56	1.69
2-15-56	1.63	3-30-56	1.75	6-5-56	1.58
2-16-56	1.03	3-31-56	1.66	6-6-56	1.48
2-17-56	1.65	4-1-56	1.33	6-7-56	1.56
2-18-56	1.85	4-2-56	1.68	6-8-56	1.83
2-19-56	1.46	4-3-56	1.64	6-9-56	1.76
2-20-56	1.56	4-4-56	1.69	6-10-56	2.09
2-21-56	1.18	4-30-56	0.96	6-11-56	1.55
2-22-56	1.07	5-1-56	0.96	6-12-56	1.66
2-23-56	0.92	5-2-56	1.78	6-13-56	1.67
2-24-56	0.88	5-3-56	1.91	6-14-56	1.62
2-25-56	1.71	5-4-56	1.96	6-15-56	1.66
2-26-56	1.08	5-5-56	1.58	6-16-56	1.59
2-27-56	1.16	5-6-56	2.19	6-17-56	1.53
2-28-56	0.84	5-7-56	1.58	6-18-56	1.48
2-29-56	0.93	5-8-56	1.46	6-19-56	2.19
3-1-56	1.23	5-9-56	2.36	6-20-56	2.15
3-2-56	1.44	5-10-56	1.96	6-21-56	1.91
3-3-56	1.30	5-11-56	1.28	6-22-56	1.70
3-4-56	1.22	5-12-56	1.84	6-23-56	1.79
3-5-56	1.48	5-13-56	1.74	6-24-56	1.85
3-6-56	1.35	5-14-56	1.96	6-25-56	1.78
3-9-56	1.36	5-15-56	1.90		

Table 3.—Continued.

A.—Continued.

Date	Elevation	Date	Elevation	Date	Elevation
7-3-56	1.37	9-28-56	2.30	11-15-56	1.64
7-4-56	1.54	9-29-56	2.15	11-16-56	1.29
7-5-56	1.81	9-30-56	2.06	11-17-56	1.48
7-6-56	1.73	10-1-56	1.85	11-18-56	1.41
7-7-56	1.74	10-2-56	2.24	11-20-56	1.84
7-8-56	2.14	10-3-56	2.03	11-21-56	1.99
7-9-56	2.27	10-4-56	2.06	11-22-56	1.75
7-10-56	1.86	10-5-56	1.71	11-24-56	0.86
7-11-56	1.68	10-6-56	1.93	11-26-56	2.24
7-12-56	1.70	10-7-56	1.96	11-27-56	1.91
7-13-56	2.04	10-8-56	1.53	11-28-56	1.94
7-14-56	1.48	10-9-56	1.33	11-29-56	1.21
7-15-56	1.30	10-10-56	1.14	11-30-56	1.52
7-16-56	1.84	10-11-56	1.59	12-1-56	1.73
7-17-56	1.57	10-12-56	1.91	12-2-56	1.79
7-18-56	1.80	10-13-56	2.13	12-3-56	1.91
7-19-56	1.77	10-14-56	1.93	12-4-56	1.54
7-20-56	1.94	10-15-56	1.73	12-5-56	1.67
7-21-56	1.91	10-16-56	1.73	12-6-56	1.95
7-22-56	1.68	10-17-56	1.79	12-7-56	1.86
7-23-56	1.60	10-18-56	1.67	12-9-56	1.71
7-24-56	1.71	10-19-56	1.70	12-10-56	1.69
7-25-56	1.60	10-20-56	2.23	12-11-56	1.97
7-26-56	1.72	10-21-56	2.01	12-12-56	1.54
7-27-56	1.90	10-22-56	1.81	12-13-56	1.14
7-28-56	1.80	10-23-56	2.21	12-14-56	1.08
7-29-56	1.54	10-24-56	1.97	12-15-56	1.95
7-30-56	1.46	10-25-56	1.58	12-16-56	2.39
7-31-56	1.75	10-26-56	2.46	12-17-56	2.06
8-1-56	1.68	10-27-56	2.33	12-18-56	1.66
8-2-56	1.42	10-28-56	1.92	12-19-56	1.41
9-5-56	1.84	10-29-56	2.29	12-20-56	1.67
9-6-56	2.02	10-30-56	2.23	12-21-56	1.66
9-7-56	1.95	10-31-56	2.28	12-22-56	1.81
9-8-56	1.43	11-4-56	2.51	12-23-56	1.96
9-19-56	1.92	11-5-56	2.06	12-24-56	2.52
9-20-56	1.97	11-6-56	2.47	12-25-56	1.81
9-21-56	1.34	11-7-56	2.47	12-26-56	1.67
9-22-56	2.12	11-8-56	2.33	12-27-56	2.21
9-23-56	1.59	11-9-56	1.55	12-28-56	2.26
9-24-56	1.42	11-10-56	1.64	12-29-56	1.76
9-25-56	1.62	11-11-56	2.01	12-30-56	1.41
9-26-56	1.42	11-12-56	1.48	12-31-56	1.07
9-27-56	2.13	11-14-56	1.56		

Table 3.—Continued.

A.—Continued.

Date	Elevation	Date	Elevation	Date	Elevation
1-4-57	1.31	3-19-57	1.95	5-7-57	1.56
1-5-57	0.91	3-20-57	2.19	5-8-57	1.55
1-6-57	1.16	3-21-57	2.09	5-9-57	1.50
1-7-57	1.96	3-22-57	2.31	5-10-57	1.50
1-8-57	1.41	3-23-57	2.10	5-11-57	1.38
1-9-57	1.80	3-24-57	1.79	5-12-57	1.53
1-10-57	1.09	3-25-57	1.75	5-13-57	1.77
1-11-57	1.06	3-26-57	2.01	5-14-57	1.68
1-12-57	1.71	3-27-57	2.07	5-15-57	1.84
1-13-57	1.30	3-28-57	2.01	5-16-57	1.34
1-14-57	1.11	3-29-57	1.79	5-17-57	2.08
1-15-57	0.87	3-30-57	1.50	5-18-57	1.76
1-16-57	1.35	3-31-57	1.49	5-19-57	1.81
1-17-57	1.36	4-1-57	2.02	5-20-57	2.16
1-18-57	1.45	4-9-57	1.53	5-21-57	2.29
1-19-57	0.91	4-10-57	1.71	5-22-57	2.56
1-20-57	0.96	4-11-57	1.94	5-23-57	2.04
1-21-57	1.09	4-12-57	1.28	5-24-57	1.73
1-22-57	1.31	4-13-57	1.28	6-5-57	1.95
1-23-57	0.68	4-14-57	1.40	6-6-57	1.90
2-6-57	1.54	4-15-57	1.40	6-7-57	1.94
2-7-57	1.23	4-16-57	1.70	6-8-57	1.62
2-8-57	1.53	4-17-57	1.56	6-9-57	2.13
2-9-57	1.71	4-18-57	1.46	6-10-57	2.05
2-10-57	1.54	4-19-57	1.53	6-11-57	2.02
2-11-57	1.83	4-20-57	1.84	6-12-57	1.79
2-12-57	1.54	4-21-57	1.69	6-13-57	1.78
2-13-57	1.36	4-22-57	1.64	6-14-57	2.08
2-14-57	1.51	4-23-57	1.96	6-15-57	1.71
2-15-57	2.31	4-24-57	1.74	6-16-57	1.66
2-16-57	2.31	4-25-57	1.73	6-17-57	1.62
2-17-57	1.91	4-26-57	1.96	6-18-57	1.78
2-18-57	2.21	4-27-57	1.79	6-19-57	1.93
2-20-57	1.47	4-28-57	1.92	6-20-57	1.33
2-21-57	1.15	4-29-57	1.74	6-21-57	1.79
2-22-57	0.96	4-30-57	1.67	6-25-57	2.06
3-13-57	2.15	5-1-57	1.96	6-26-57	1.61
3-14-57	1.96	5-2-57	1.81	6-27-57	2.05
3-15-57	1.96	5-3-57	1.71	6-28-57	2.38
3-16-57	2.13	5-4-57	1.57	6-29-57	2.10
3-17-57	2.09	5-5-57	1.72	6-30-57	1.79
3-18-57	1.86	5-6-57	1.87		

Table 3.—Continued.

A.—Continued.

Date	Elevation	Date	Elevation	Date	Elevation
7-1-57	1.51	8-7-57	1.54	9-9-57	1.65
7-2-57	1.49	8-8-57	1.48	9-17-57	1.56
7-3-57	1.61	8-9-57	1.66	9-18-57	1.75
7-4-57	1.92	8-10-57	1.63	9-19-57	2.16
7-5-57	1.80	8-11-57	1.58	9-20-57	2.06
7-6-57	1.29	8-12-57	1.76	9-21-57	2.02
7-7-57	1.70	8-13-57	1.26	9-22-57	2.01
7-8-57	1.51	8-14-57	2.25	9-23-57	1.63
7-9-57	1.74	8-15-57	1.93	9-24-57	1.53
7-10-57	1.09	8-16-57	1.54	9-25-57	1.76
7-11-57	1.38	8-17-57	1.49	9-26-57	1.59
7-12-57	1.58	8-18-57	1.95	9-27-57	1.08
7-13-57	1.72	8-19-57	1.81	9-28-57	1.55
7-14-57	1.51	8-20-57	2.00	9-29-57	1.46
7-15-57	1.51	8-21-57	1.70	9-30-57	1.61
7-16-57	1.49	8-22-57	1.43	10-1-57	2.12
7-17-57	1.58	8-23-57	1.90	10-2-57	1.46
7-18-57	1.65	8-24-57	1.92	10-3-57	1.51
7-19-57	1.71	8-25-57	1.92	10-4-57	1.75
7-20-57	1.84	8-26-57	1.79	10-5-57	2.08
7-21-57	1.73	8-27-57	1.76	10-6-57	1.30
7-22-57	1.66	8-28-57	1.39	10-7-57	2.30
7-23-57	1.38	8-29-57	1.86	10-8-57	1.86
7-24-57	1.54	8-30-57	1.81	10-9-57	1.89
7-25-57	1.66	8-31-57	1.60	10-10-57	1.66
7-26-57	1.76	9-1-57	1.64	10-11-57	1.64
7-27-57	1.78	9-2-57	1.81	10-12-57	1.45
7-28-57	1.89	9-3-57	2.19	10-13-57	1.71
7-29-57	2.06	9-4-57	1.81	10-14-57	1.56
7-30-57	1.98	9-5-57	1.38	10-15-57	1.69
7-31-57	1.83	9-6-57	1.72	10-16-57	1.61
8-1-57	1.56	9-7-57	2.05	10-17-57	1.86
8-2-57	1.56	9-8-57	1.66		

Table 3.—Continued.

B.—Approximate weekly high water level in feet above msl from recorder charts.

Date	Elevation	Date	Elevation	Date	Elevation
1-18-56	2.78	9-20-56	3.91	4-15-57	3.49
1-25-56	2.92	9-30-56	3.79	4-24-57	3.31
2-2-56	2.82	10-6-56	3.95	5-1-57	3.60
2-11-56	3.78	10-19-56	3.88	5-6-57	3.46
2-18-56	3.63	10-26-56	4.05	5-13-57	3.53
2-25-56	3.66	11-6-56	4.01	5-22-57	3.86
3-1-56	3.21	11-14-56	3.14	6-7-57	3.86
3-11-56	3.03	11-21-56	3.93	6-12-57	3.80
3-18-56	3.59	12-3-56	3.39	6-18-57	3.47
3-24-56	3.88	12-16-56	3.91	6-28-57	4.36
3-30-56	3.42	12-24-56	4.08	7-4-57	3.59
5-2-56	3.23	12-31-56	3.13	7-9-57	3.46
5-10-56	3.73	1-7-57	3.41	7-20-57	3.26
5-16-56	4.11	1-12-57	3.13	7-27-57	3.40
5-22-56	3.58	1-18-57	3.23	7-30-57	3.71
5-27-56	3.96	1-23-57	3.39	8-9-57	3.16
6-8-56	3.61	2-8-57	2.91	8-14-57	3.58
6-10-56	3.84	2-14-57	3.40	8-25-57	3.69
6-21-56	3.88	2-18-57	4.21	9-3-57	3.76
7-8-56	4.06	3-15-57	3.85	9-8-57	3.11
7-21-56	3.81	3-20-57	3.97	9-16-57	3.34
7-27-56	3.46	3-27-57	3.65	9-22-57	3.76
8-2-56	3.04	4-2-57	4.06	10-1-57	3.53
9-7-56	3.78	4-10-57	3.34	10-6-57	4.14
				10-17-57	3.31

Table 4.—Water-level fluctuations in wells Ea44-3 and Eb31-1.

(Periodic measurements in feet)

Well Ea44-3

Date	Depth below land surface	Altitude above mean sea level
1-14-56	38.96	4.70
1-18-56	40.64	3.02
1-27-56	40.52	3.14
3-9-56	40.52	3.14
4-2-56	39.98	3.68
4-30-56	39.79	3.87
5-24-56	40.50	3.16
7-2-56	39.78	3.88
7-17-56	39.43	4.23
8-3-56	40.13	3.53
9-4-56	39.38	4.28
9-26-56	40.41	3.25
11-3-56	38.79	4.87
11-30-56	39.90	3.76
1-4-57	40.23	3.43
2-6-57	39.36	4.30
2-28-57	39.73	3.93
5-2-57	39.78	3.88
7-2-57	40.30	3.36
9-16-57	39.72	3.94
11-7-57	39.63	4.03

Well Ea44-3

Date	Depth below land surface	Altitude above mean sea level
12-15-55	74.30	4.08
1-4-56	74.42	3.96
1-27-56	74.58	3.80
1-31-56	75.28	3.10
3-9-56	74.97	3.41
4-2-56	74.03	4.35
4-30-56	74.07	4.31
5-24-56	74.64	3.74
7-2-56	73.77	4.61
7-17-56	73.38	5.00
8-3-56	74.50	3.88
9-5-56	73.18	5.20
9-26-56	74.73	3.65
11-3-56	72.84	5.54
11-30-56	73.94	4.44
1-4-57	74.65	3.73
5-2-57	74.37	4.01
9-16-57	46.26*	4.77

**Pipe cut off with excavation for new bridge.*

Table 5.— Analyses of water from observation wells adjacent to the Chesapeake and Delaware Canal.

(Chemical constituents in parts per million)

Geologic source: M indicates Magothy formation; NmC indicates nonmarine Cretaceous sediments; t indicates true aquifer water; hd indicates aquifer water mixed with hydraulic-drilling water.

Well number	Geologic Source	Depth (ft)	Time of collection (hour-date)	Temperature (°F)	Silica (SiO_2)	Iron (Fe) Dissolved	Iron (Fe) Total	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$ Total	Hardness as $CaCO_3$ Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color
Ea44-2	NmC-hd		12-15-55												2						411	3.6	
Ea44-2	NmC-hd	80	12-19-55	46							5.1		8	23	3.8		0.3		25	18	104	5.6	
Ea44-2	NmC-hd	85	12 PM 12-20-55										62		3.5		.9		67	16	145	6.5	
Ea44-2	Nmc-hd	86	2:30 PM 12-20-55	48							8.9		58	26	3.2		1.4		60	12	159	6.5	
Ea44-2	NmC-hd	128	3:20 PM 12-20-55										46	14	3.5		.9		44	6	132	6.5	
Ea44-2	NmC-hd	103	3:40 PM 12-20-55	48							6.6		114	14	3.5		.4		98	5	225	7.3	
Ea44-2	NmC-hd	111	5:10 PM 12-20-55	49							6.6		108	16	3.2		1.1		95	6	213	7.1	
Ea44-2	NmC-hd	98	12-21-55	49							.9		12	36	3.2		.5		50	45	159	5.6	
Ea44-2	NmC-hd	135	12-28-55	50							6.8		88	13	3.5		.2		76	4	181	6.9	
Ea44-2	NmC-hd		1-5-56	55											4						70.3		
Ea44-2	NmC-t		1-5-56	55		0.7							27		2						63.4	6.1	
Ea44-2	NmC-t	123	2-21-56	53	3.3	.10	2.5	0.00	8.2	2.5	5.8		28	16	2.5	0.1	.0	52	31	8	86.5	6.9	5
Ea44-2	NmC-t	123	7-2-56		5.1	.15			7.5	2.8	5.2		38	5.4	3.0	.1	.2	56	30	0.0	76.5	7.2	2
Ea44-2	NmC-t	123	9-18-56	57							8.9		35	7.8	4.5		.2		24	0	85.0	7.4	
Ea44-2	NmC-t	123	9-16-57												1.5						78		
Ea44-3	M-hd	56	1-4-56?	52									46	23	3.0						145	6.3	
Ea44-3	M-hd	51	1-4-56	54											4.0						191		
Ea44-3	M-hd	51	1-4-56	54									20		2						199	5.8	
Ea44-3	NmC-hd	97	1-5-56	53											4.0						66.4		
Ea44-3	NmC-hd	97	1-5-56	53									17	2.0	2.5						64.2	6.0	
Ea44-3	NmC-hd	113	1-6-56	54									13	12	2.5						61.9	5.8	
Ea44-3	NmC-hd	129	1-9-56	54									19	53	3		.1				98.7	5.8	
Ea44-3	NmC-hd	134	1-12-56	52									21	39	2						99.0	5.8	
Ea44-3	NmC-t	142	1-14-56	55	12	.05			8.7	2.0			38	6.0	2	.1	.1	48			79.7	7.1	
Ea44-3	NmC-t	118	2-21-56	53	1.0	.02	5.1	.00	9.4	2.8	7.9		38	11	5.0	.2	2.5		35	4	83.8	7.6	10
Ea44-3	NmC-t	118	7-2-56		.92	.01			8.6	3.8	3.8		41	4.9	4.5	.1	.0	48	37	3.4	86.6	7.3	3
Ea44-3	NmC-t	118	9-18-56	56							8.3		43	1.6	3.3		.5		24	0	82.4	7.5	
Ea44-3	NmC-t	118	9-16-57												4.0						109		
Eb31-1	M-hd	92	12-8-55	52									14		3.0				98		176	5.6	
Eb31-1	M-t	101	12-15-55	54	17	.78			4.7	1.6	2.4		18	4.2	2.8	.0	.6	50	18	4	56.7	6.3	[a]120
Eb31-1	M-t	101	2-21-56		16	.13	6.3		4.5	2.0	6.6		23	12	1.5	.1	0	56	19	1	65.3	6.1	5
Eb31-1	M-t	101	5-17-56		16	.01			5.5	2.3	4.8		29	6.3	2.1	.1	.0	55	23		67.8	7.0	5
Eb31-1	M-t	101	7-2-56		14	.01			4.7	2.7	7.2		21	16	3.0	.1	.1	64	23	5.8	73.3	6.4	2
Eb31-1	M-t	101	10-4-56	55							6.3		8	23	3.4		.5		22	15	77.3	5.9	
Eb31-1	M-t	101	9-16-57												2.5						85		

[a]Apparent color because of suspended material.

Table 6.— Quality of water of the C & D Canal

at Summit Bridge pier, November 1955 to July 1956.

Date (hour)	Specific conductance (micromhos at 25°C)	Chloride (Cl) (ppm)	Date (hour)	Specific conductance (micromhos at 25°C)	Chloride (Cl) (ppm)
11-30-55	515	100	2-9-56	6,470	2,900
12-4-55	9,680	3,000	2-10-56	6,550	3,050
12-6-55	10,400	3,200	2-13-56	5,260	2,300
12-7-55	3,650	950	2-14-56	4,370	1,750
12-10-55	18,500	6,200	2-15-56	4,310	1,450
12-12-55	894	120	2-16-56	4,140	1,400
12-13-55	4,270	1,200	2-17-56	4,670	1,650
12-14-55	4,650	1,200	2-20-56	3,610	1,200
12-15-55	5,070	1,500	2-21-56	2,980	950
12-16-55	576	82	2-23-56	2,480	685
12-19-55	1,160	300	2-24-56	3,570	1,070
12-20-55	647	135	2-27-56	1,020	250
12-21-55	1,660	300	2-28-56	1,050	255
12-22-55	494	90	2-29-56	2,480	690
12-23-55	407	72	3-1-56	1,840	500
12-27-55	7,390	2,200	3-2-56	814	185
12-28-55	8,530	2,500	3-5-56	578	125
12-29-55	9,820	3,000	3-6-56	1,890	505
12-30-55	7,930	2,500	3-7-56	3,140	940
1-3-56	10,100	3,100	3-8-56	3,110	910
1-5-56	10,000	3,200	3-9-56	1,490	395
1-9-56	11,600	3,800	3-12-56	1,060	260
1-11-56	17,700	5,700	3-14-56	961	220
1-12-56	18,100	6,400	3-15-56	843	190
1-13-56	17,800	6,100	3-16-56	952	220
1-16-56	15,400	5,200	3-20-56	1,030	250
1-17-56	14,800	4,500	3-21-56	2,070	520
1-18-56	15,700	5,200	3-22-56	2,780	800
1-19-56	15,700	5,150	3-23-56	1,950	525
1-24-56	13,600	4,300	3-26-56	1,840	500
1-25-56	12,500	3,900	3-27-56	1,590	420
1-26-56	9,290	2,900	3-28-56	1,780	480
1-27-56	13,500	4,400	3-29-56	1,830	490
1-30-56	10,500	4,250	3-30-56	1,610	430
1-31-56	6,060	2,200	4-2-56	694	150
2-1-56	5,460	2,000	4-3-56	916	220
2-2-56	9,700	3,550	4-4-56	1,610	420
2-3-56	6,670	2,350	4-5-56	687	150
(9:50 AM)			4-6-56	623	135
2-3-56	5,900	1,700	4-9-56	868	200
(2:30 PM)					
			4-10-56	721	150
2-6-56	6,530	2,300	4-11-56	646	135
2-7-56	7,200	2,650	4-12-56	363	50
2-8-56	4,270	1,950	4-13-56	451	95
			4-16-56	499	100

Table 6.—Continued.

Date (hour)	Specific conductance (micromhos at 25°C)	Chloride (Cl) (ppm)	Date (hour)	Specific conductance (micromhos at 25°C)	Chloride (Cl) (ppm)
4-17-56	479	90	5-28-56	202	19
4-18-56	473	91	5-29-56	956	21
4-19-56	480	92	5-31-56	221	18
4-20-56	454	85	6-4-56	2,120	450
4-23-56	359	63	6-5-56	1,570	380
4-24-56	279	41	6-6-56	1,720	440
4-25-56	372	66	6-7-56	1,940	505
4-26-56	374	68	6-10-56	1,750	465
4-27-56	372	67	6-11-56	1,040	260
4-30-56	341	59	6-12-56	2,370	650
5-1-56	303	47	6-13-56	2,250	600
5-2-56	303	48	6-14-56	909	205
5-3-56	306	48	6-15-56	2,310	630
5-7-56	279	42	6-18-56	2,980	830
5-8-56	482	97	6-19-56	3,200	890
5-9-56	348	60	6-20-56	1,280	305
5-10-56	253	33	6-21-56	854	195
5-11-56	255	34	6-22-56	684	150
5-14-56	515	104	6-25-56	2,790	770
5-15-56	608	132	6-26-56	2,630	715
5-16-56	685	154	6-27-56	4,070	1,160
5-17-56	297	45	6-28-56	675	145
5-18-56	282	38	6-29-56	603	120
5-21-56	256	36			
5-22-56	236	28			
5-23-56	248	26			
5-27-56	781	178			

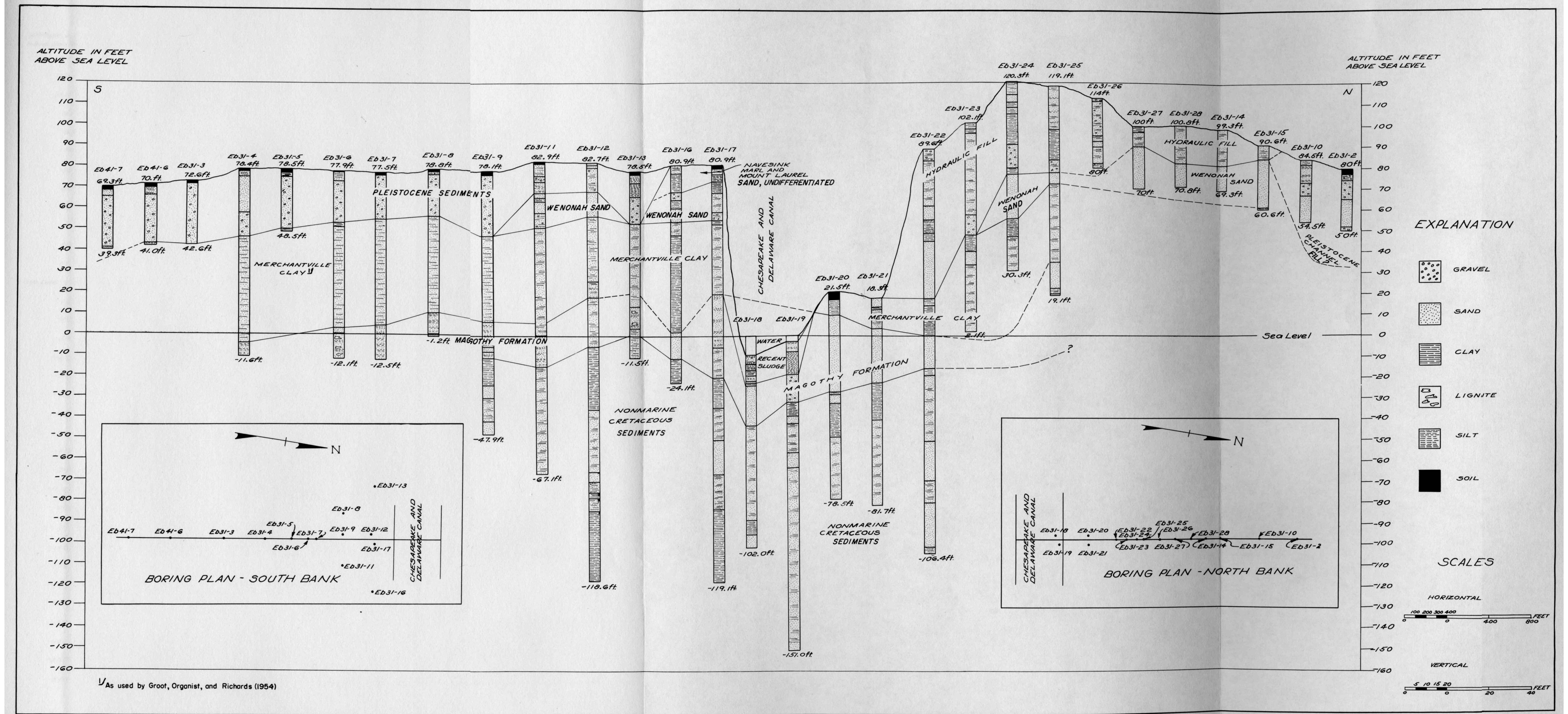

ALTITUDE IN FEET ABOVE SEA LEVEL
S
N
PLEISTOCENE SEDIMENTS
MERCHANTVILLE CLAY 1/
MAGOTHY FORMATION
WENONAH SAND
MERCHANTVILLE CLAY
NAVESINK MARL AND MOUNT LAUREL SAND, UNDIFFERENTIATED
NONMARINE CRETACEOUS SEDIMENTS
CHESAPEAKE AND DELAWARE CANAL
WATER
RECENT SLUDGE
MAGOTHY FORMATION
MERCHANTVILLE CLAY
HYDRAULIC FILL
WENONAH SAND
PLEISTOCENE CHANNEL FILL
Sea Level
BORING PLAN - SOUTH BANK
BORING PLAN - NORTH BANK
EXPLANATION
GRAVEL
SAND
CLAY
LIGNITE
SILT
SOIL
SCALES
HORIZONTAL
VERTICAL
FEET
1/ As used by Groot, Organist, and Richards (1954)

PLATE 1

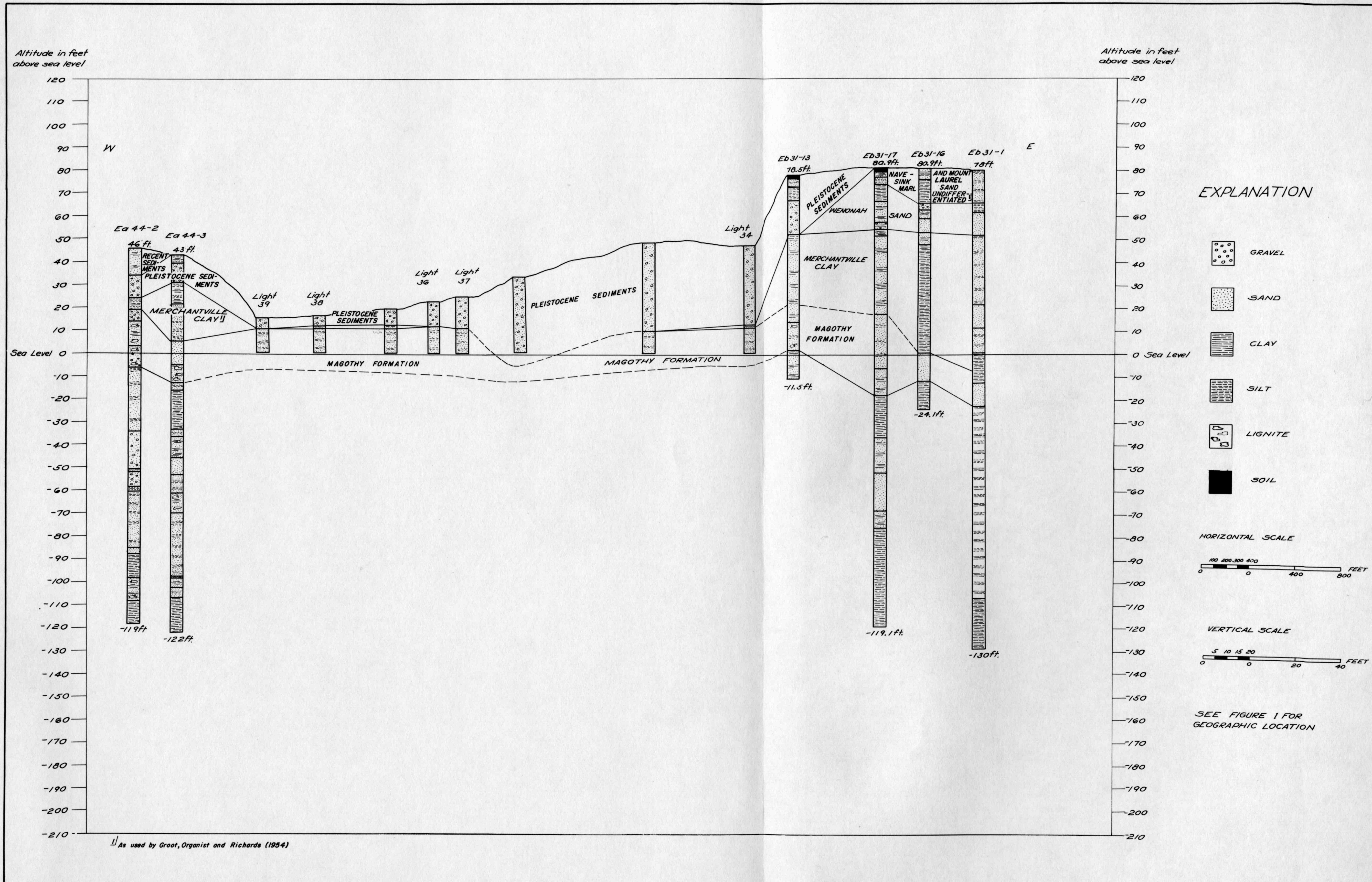

Altitude in feet above sea level
W
E
Ea 44-2
46 ft.
Ea 44-3
43 ft.
RECENT SEDIMENTS
PLEISTOCENE SEDIMENTS
MERCHANTVILLE CLAY 1/
Light 39
Light 38
PLEISTOCENE SEDIMENTS
Light 36
Light 37
PLEISTOCENE SEDIMENTS
Light 34
Eb 31-13
78.5 ft.
Eb 31-17
80.9 ft.
Eb 31-16
80.9 ft.
Eb 31-1
78 ft.
PLEISTOCENE SEDIMENTS
NAVESINK MARL
AND MOUNT LAUREL SAND UNDIFFERENTIATED 1/
WENONAH
SAND
MERCHANTVILLE CLAY
MAGOTHY FORMATION
MAGOTHY FORMATION
MAGOTHY FORMATION
Sea Level 0
-119 ft
-122 ft.
-11.5 ft.
-119.1 ft.
-24.1 ft.
-130 ft.
EXPLANATION
GRAVEL
SAND
CLAY
SILT
LIGNITE
SOIL
HORIZONTAL SCALE
FEET
VERTICAL SCALE
FEET
SEE FIGURE 1 FOR GEOGRAPHIC LOCATION
1/ As used by Groot, Organist and Richards (1954)

PLATE 2