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GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

MEMORANDUM REPORT ON TEST DRILLING AT NORFOLK, VIRGINIA

by
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RESUME

This memorandum is intended as a progress report on the Norfolk, Va. fresh-water injection project; it is not intended as a scientific paper. Additional geologic and hydrologic data are still being analyzed and will be reported on at a later date. The findings to date are:

1. A test hole was drilled to a depth of 2,587 feet. Analysis of the data obtained from the test well indicates no fresh water below a depth of 100 feet.

2. A sand that is geologically and hydrologically suited to accept injected fresh water is present between 900 and 1,000 feet below land surface.

   (a). the sand lies between confining beds of clay that will allow the injected water to be contained and traced laterally.
   (b). the formation water in the sand has a moderate chloride content (approximately 1,000 ppm).
   (c). the sand is thick enough to hold the volume of water required to supply the city of Norfolk over a considerable period of time.

3. The quality of the formation water in the sand from 900 to 1,000 feet and the quality of the injection water will be compatible and probably not cause chemical precipitates providing the following precautions are taken:

   (a). all chlorine is removed from the injection water.
   (b). the injection water is degassed before injection.
   (c). the injection water has no turbidity.
   (d). the calcium concentration in the injection water is less than 30 ppm.
   (e). the pH of the injected water is very nearly the pH of the formation water.

4. Fiberglass reinforced epoxy casing and stainless steel screen that is not subject to stress corrosion cracking should be used for construction of the injection well.

5. Fiberglass reinforced epoxy casing and saw-cut slotted epoxy screen should be used for the observation wells.

INTRODUCTION

Purpose and Scope of Report

In the summer of 1967, at the invitation of the city of Norfolk, Va., an agreement was reached between that city and the U. S. Geological Survey to explore the feasibility of the storage and retrieval of fresh surface water after it has been injected in an aquifer containing saline water.

The city of Norfolk is interested in finding an additional source of about 10 million gallons of water per day to support water demands during times of peak use, especially in the months of July, August, and September. The city decided to cooperate in an experimental project with the U. S. Geological Survey to explore the possibilities of storing excess water from the Moore's Bridge Filter Plant underground in sands that now contain brackish water and later pumping the injected water from the sand before committing itself to a surface reservoir-pipe line system in which several undesirable features would be inherent.

The interest of the U. S. Geological Survey in this project is severalfold: (a) to determine the geology and hydrology of the aquifers in the Norfolk area; (b) to determine the geochemical and hydrologic problems that may arise from mixing saline and fresh waters; and (c) to determine the economic aspects of underground storage versus surface reservoirs.

It is estimated that the investigation will require at least three years. About two years are needed for construction of the injection and observation well system and one year for observing geochemical and hydrologic reactions during the injection and withdrawal of water.

This memorandum report presents the results of the initial test drilling that was done to determine the local geology, hydrology, and quality of water.

DRILLING OF TEST WELL 1 (TW-1)

A conventional rotary drilling rig was used to drill the initial test hole, TW-1, at Moore's Bridge Filter Plant, Norfolk, Virginia (see figure 1). The drilling started September 14, 1967. A 20-inch hole was drilled to 81 feet and 16-inch surface casing set and cemented. A 9-5/8 inch hole was drilled to 876 feet at which depth the hole diameter was reduced to 8-5/8 inches and continued at that diameter to total depth of 2,587 feet.

Drill cuttings were collected approximately every ten feet or at major lithologic changes. To insure samples that were representative of the section being drilled, the drilling fluid was circulated a sufficient length of time to allow the cuttings to reach the surface. At considerable depths, when a sample was required it was found desirable to hold back advance of the drill rods and to circulate for as long as an hour before taking the sample.

The samples were caught in a kitchen sieve as the drilling mud passed through a cemented trough between the bore hole and the mud pits. A vertical partition was placed near the discharge end of the trough to slow the flow of drilling fluid sufficiently to allow the finer particles suspended in the drilling fluid to settle out. The mud ditch was cleaned after every sample was collected to prevent contamination of succeeding samples.

CORING

Cores were taken by a wire-line split-spoon sampler down to a depth of 876 feet. The split-spoon obtained a core 3 feet long and 1-3/8 inches in diameter. Coring was proceeding slowly by this method, therefore, to accelerate operations an A-1 wire-line core barrel was obtained that was capable of taking a core 2-7/8 inches in diameter and 10 feet long. The wire-line core barrel is retrievable through the drill pipe and causes only minor time delays during retrieval.

The cores were briefly described in the field and then cut into sections and heat sealed in heavy duty polyethelene tubing. A cut of each core taken was sent to (1) the Hydrologic Laboratory of the U.S. Geological Survey at Denver, Colo., for the purpose of making permeability tests and particle-size analyses; (2) P. M. Brown and S. M. Herrick of the U. S. Geological Survey, Raleigh, N. C., and Atlanta, Ga., for fossil identification and stratigraphic information; (3) F. T. Manheim, Woods Hole Oceanographic Institution, Woods Hole, Mass., for determination of interstitial water quality; and (4) Dr. James L. Calver, Virginia State Geologist, Charlottesville, Va., for his sample library.

Core-analysis results are not complete at this time and a supplement to this report will be presented when the data are available.

GEOPHYSICAL LOGS

Geophysical logs were made of the hole by both a commercial logging company and by Geological Survey personnel and equipment. The geophysical

logs were used to aid in lithologic identification to allow assignment of drill cuttings to their proper position, to determine the chemical quality of water throughout the depth of the hole, and to aid in the selection of a suitable injection horizon.

Prior to the completion of the hole, electric and gamma ray logs were made by Survey personnel from Raleigh, N. C. Upon completion of the test drilling, a Dual Induction Laterolog and Compensated Formation Gamma-Gamma Density log were made by Schlumberger Well Surveying Corporation. The laterolog includes a self potential (S.P.) log. The density log includes a gamma ray log and caliper log. The dual induction log indicates the electrical resistivity of the formations logged and the density log indicates the effective porosity. By using fairly simple relationships between resistivity and porosity, an estimate of the salinity of the formation waters was obtained. Accuracy is quite good in high salinity, sodium chloride waters, but decreases with decreasing salinity and increasing calcium, magnesium, and bicarbonate concentrations.

Additional logs run by Survey personnel from Denver, Colo., included caliper, electric, self-potential, gamma-ray and neutron logs. The neutron log is another type of log that indicates "effective porosity."

GEOLOGY OF TEST WELL 1 (TW-1)

No formation names and geologic ages have been applied at this time to the materials penetrated in TW-1 because interpretation of the fossil data and long range stratigraphic correlations have not been completed. However, it can be stated that basement rock (non-sedimentary rock material) was not penetrated in the test well.

The detailed lithology of TW-1 is presented in table 1. It may be generalized as follows: sand with interbedded silt extends from ground surface to a depth of 300 feet; silt and clay from 300 feet to 600 feet; sand with thin beds of silt and clay from 600 feet to 2,100 feet; silt and clay from 2,100 feet to 2,230 feet; sand with thin beds of silt from 2,230 feet to 2,540 feet; and silt and clay from 2,540 feet to 2,587 feet. Approximately 60 percent of the section penetrated is sand.

QUALITY OF WATER

Water samples were taken from seven separate and unconnected water-bearing sands. The chemical analyses are listed in table 2. The sands to be sampled were decided upon by utilizing the Dual Induction Laterolog

and the Gamma-Gamma Density log to calculate approximate salinities of the contained formation waters and the approximate effective porosity of the sands. The sands sampled were those in which major salinity changes were apparent or which appeared to fit the geologic and hydrologic requirements for hosting the injection water, or both.

To facilitate collection of water samples a torch cut, slotted drill pipe about 21 feet long was added to the end of the drill string and placed opposite the zone selected for sampling. Gravel was then pumped down the drill rods and up into the annulus between the wall of the drilled hole and the slotted pipe, thereby providing a gravel pack. In placing the gravel a specially designed graveling sleeve was used that fitted inside the slotted pipe. The upper end of the sleeve was designed to fit the wire-line core barrel retrieval tool. The sleeve was removed from inside the slotted pipe once the gravel was emplaced.

After the gravel pack was in place, the formation was pumped by air lift, using a 125 cubic ft/min. air compressor. The bottom of the air line was set at approximately 240 feet below the ground surface. Once the mudcake was broken down, a submersible pump was set in the well at about 147 feet and water discharged through a canvas fire hose into an overflow pit near the filter plant. The fire hose was connected at the well head to a 2-inch metal discharge line. The discharge line had a ½ inch bleeder line that was used for collecting water samples and for making geochemical measurements. The overflow pit discharges through sewer lines into the Elizabeth River.

When the water samples had been collected and treated, the pump was shut off and water levels were measured using an electric tape, for approximately one hour during recovery. To test the next zone, the screen was pulled up by removing drill pipe until the slotted pipe was opposite the formation to be tested. Gravel was again pumped down the drill pipe and the air line installed to initiate development of the sand.

Field measurements of pH; CO_3; HCO_3; EH; O_2; Cl; and conductivity were made while the sands were being pumped. After the water samples were collected they were acidized and analyzed for Ca, Fe, Mn, PO_4, Cu, Pb, Zn, B, Al, and NH_3. Chloroform was added to the samples to be tested for SiO_2, and NaOH and Zn $(AC)_2$ was added to the samples to be tested for H_2S.

INJECTION HORIZON

A sand bed between the depths of 895 feet and 1,000 feet below the land surface has been selected as the injection sand. Examination

of the drill cuttings indicates the sand to be slightly to moderately silty from 895 to 930 feet and to be clean, well sorted, and unconsolidated from 930 to 980 feet. It is slightly clayey and silty and poorly sorted near the base (table 1).

This zone had been selected for the following reasons:

(1) The sand, for the most part, seems to be clean, loose, well-sorted, and of high apparent permeability.

(2) The sand is essentially quartz and thus chemically inert.

(3) The sand is confined both above and below by clay, silt, and silty clay. It is essential that the injected water be confined if it is to be monitored upon retrieval. The clay in the confining beds is a swelling clay and may pose a problem if it is present in the aquifer. Tests are being conducted at this time to see if clay partings in the aquifer are the swelling variety.

(4) The sand is the shallowest confined clean permeable sand available. The use of a relatively shallow sand would be expected to result in lower installation, pumping, and maintenance costs.

(5) The gamma density log indicates the zone has a high (about 37 percent) average effective porosity. The self potential log indicates that permeable lenses are present in the zone.

(6) The formation water is less mineralized than that in most other sand horizons. Major chemical problems and high costs can be avoided if the injection water and host waters are nearly compatible.

(7) The sand zone is thick enough so that it is expected to persist for some distance laterally and, therefore, to have a large storage capacity.

For the above reasons, the test well was completed as an observation well in the proposed injection zone. The test hole was backfilled with cement from 2,150 feet up to 1,000 feet. The hole was then under-reamed to a diameter of about 24 inches from 890 feet to 970 feet. Sixty feet of 6-inch stainless stainless steel screen was set from 900 to 960 feet, with 10 feet of blank pipe from 960 to 970 feet to act as a sand trap. Layne shutter screen with openings of 0.055 inches was used. Six-inch mild steel casing extends from the screen to about 3 feet above land surface. The gravel pack was placed in the underreamed part of the hole and the hole cemented from there to the surface.

The drilling of TW-1 was completed on November 3, 1967. The screen was not set until February 15, 1968. Although it is not possible to measure directly the amount of formation damage due to mud invasion over this length of time, it could be considerable. The well was pumped by air lift for about 4 hours, then pumped by the submersible pump for about 25 hours prior to a pumping test. The pumping test was conducted using the 5 hp submersible pump that was used to collect the water samples. The pump was capable of pumping about 47 gpm against a 16-foot head. This discharge rate was not great enough to develop the well (although the water cleared) or to produce meaningful pumping data. The pumping test data were analyzed by staff hydrologists of the Geological Survey in Arlington, Va., who concluded that the data do not properly reflect formation response and that the well was not fully developed.

Plans are now in progress to reenter the well and develop it more completely by swabbing and pumping by air lift using a large air compressor and a submersible pump capable of pumping at least 200 gpm against 100 feet of head. A pumping test will then be conducted and values of transmissibility and specific capacity will be reported upon completion of data analysis.

GEOCHEMISTRY

The chemical analyses of the formation waters sampled (table 2) indicate the waters range from brines containing about 40 percent more chloride than sea water at 2,499 feet to brackish water containing about 1,000 ppm chloride at 848 feet. Both the chloride content and total solids increase with depth.

The chemistry of the formation water from 900-960 feet and the treated city water from Moore's Bridge Filter Plant were compared by use of a computer, programmed to determine compatibility of two waters. The results were interpreted by Ivan Barnes, U. S. Geological Survey, Menlo Park, Cal., and his conclusions are as follows:

1. All chlorine should be removed from the city water prior to injection to prevent the oxidation of iron and resulting deposition of iron oxide in the formation and on the screen. Failure to remove the chlorine may result in plugging of the aquifer and/or the screen by oxidized deposits.

2. Dissolved gases such as oxygen and carbon dioxide should likewise be removed to prevent oxidation of ferrous iron and consequent plugging of the aquifer and/or the screen. Removal of dissolved oxygen not only will prevent direct oxidation, but also will retard the growth of iron-oxidizing bacteria.

3. The injected water should be free of turbidity because the aquifer will act as a sand filter during recharge and will retain particulate matter during recharge stages and become plugged.

4. The pH of the injection water and the host water should be as nearly identical as possible.

5. Computations suggest that the injection water cannot exceed 30 ppm calcium without precipitating calcite. The formation water would be at equilibrium with calcite at a concentration of 15 ppm calcium but should tolerate concentrations up to the 30 ppm limit with no major difficulties.

The screen should be composed of high-chloride-resistant stainless steel that is not subject to stress corrosion cracking. Mild steel or other metal casing would be a poor choice for long-term service because of the electrolytic action caused by different types of water that will be in contact with the casing along its length. Epoxy fiberglass casing, which is chemically inert, will minimize scale buildup and fouling reactions.

PRESENT PLANS

Upon completion of contracting procedures, three observation wells will be installed near TW-1. The wells will be constructed of epoxy reinforced fiberglass casing and will have saw-cut fiberglass screens. They will be completed and developed in the proposed injection zone from approximately 900 to 1,000 feet.

In fiscal year 1969, contracts will be let and construction begun on the injection well and at least one more observation well. Current agreements are that the recharge well will be constructed to be capable of injecting approximately 400 gpm and withdrawing 800 gpm .

SUMMARY

With the completion of TW-1 at Moore's Bridge Filter Plant, Norfolk, Va., it was confirmed that no deep fresh-water source is available beneath the test area. It was also learned that the unconsolidated sedimentary section is thicker than previously believed in that 2,587 feet of sands, silts and clays were penetrated and basement rock was not reached.

Geologic and hydrologic evidence indicates that a 105-foot thick sand, which lies between the depths of 895 and 1,000 feet, is suitable for injection, storage and retrieval of fresh water.

The sand is in large part a clean, well-sorted, quartz sand, ranging up to small gravel in grain size. It is confined both above and below by silt and clay beds. It is important that the sand be bordered by aquicludes in order that the injected recharge water may be retrieved at a later date. The sand bed is thick and persistent laterally and it should be possible to store huge quantities of water within it.

Pumping-test data on the proposed injection sand are not satisfactory. Steps are being taken to develop TW-1 and conduct another pumping test on the screened zone from 900-960 feet. Examination of geophysical logs and drill cuttings and other data indicates that the permeability, porosity, transmissibility, and specific capacity are such that the sand can be successfully utilized for large scale injection.

The presence of a swelling clay in the upper and (probably) the lower confining beds may present difficulties. The clay consists of illite and mixed-layered montmorillonite-illite. If this clay type is present in the injection sand in any large quantities, it would tend to reduce permeability when subjected to the injected fresh water.

Samples of core fragments from the upper part of the sand are being studied to determine the clay types present. The clay occurs mainly in the upper 20 to 30 feet of the injection zone.

Analyses of the chemical compositions of the water in the proposed injection zone and the treated city water indicate that the water will be compatible providing that some basic precautions are taken. Chlorine, dissolved oxygen, turbidity and carbon dioxide must be removed from the injection water prior to recharge. The pH of the injection water must be very nearly that of the formation water. Calcium must not exceed 30 ppm in the injection water and ideally should be about 15 ppm.

To prevent adverse chemical reactions and to controll the enviromental conditions necessary to conduct the research aspects of this project, it will be necessary to use epoxy reinforced fiberglass casing and screens and a high-chloride-resistant stainless steel screen in well construction.

The information gathered from TW-1 has defined some anticipated chemical problems and their solutions and delineated the injection zone. The drilling of observation wells and the construction of the injection well with its necessary equipment will complete the construction phase of the project.

Table 1: Detailed lithologic description of samples from Test Well 1

Location: Moore's Bridge Filter Plant
Norfolk, Virginia

Well Number: Test Well 1
365223N761221-1
Elevation: 15 feet

Owner: U. S. Geological Survey

Driller: Layne-Atlantic Company, Norfolk, Va.

Lithologic Description: Donald L. Brown

Lithology	Depth in feet From	Depth in feet To
Sand, moderate-orange-pink to light-brown, medium- to coarse-grained (average medium), angular to sub-angular, loose to friable, slightly calcareous, cemented in part, frosted.	0	6
Sand as above except grain size ranges to very coarse-grained and probably averages coarse-grained.	6	10
Silty sand, light-gray to dark-yellowish-orange, very coarse-grained, poorly sorted, angular to sub-angular, loose to cemented by silica or possibly clay, slightly calcareous, shell fragments.	10	20
Sand, light-gray to dark-yellowish-orange, very fine- to medium-grained, slightly clayey, poorly sorted, loose to cemented, finely micaceous.	20	35
Silt, light-gray, slightly sandy with very fine-grained, fragmented, angular to sub-angular sand grains, cemented, slightly micaceous, slightly calcareous, shell fragments, soft.	35	58
No samples.	58	62
Silt as above.	62	65
No samples.	65	110
Sand, greenish-gray to grayish-olive, very fine-grained to granules (becoming coarser towards base), slightly silty, poorly to moderately sorted, angular to sub-angular, slightly micaceous, slightly to moderately glauconitic, white chalky calcareous material-possibly cement, fossiliferous with Foraminifera and shell fragments.	110	120

Lithology

	Depth in feet From	To
Sand, greenish-gray to olive-gray, very fine- to fine-grained, silty, moderately sorted, angular to sub-angular, slightly micaceous, slightly to moderately glauconitic, slightly calcareous, Foraminifera and shell fragments.	120	130
Sand, greenish-gray to olive-gray, very fine- to coarse-grained (averages fine-grained), slightly silty, poorly sorted, angular to sub-angular, loose to moderately cemented, friable, slightly micaceous, glauconitic, Foraminifera and shell fragments.	130	140
Sand as above except averages medium-grained and glauconite increased (10-15%), possibly calcareous.	140	148
No samples.	148	151
Silty sand, light-olive-gray to greenish-gray, very fine- to medium-grained (averages very fine-grained), very silty, poorly sorted, angular to sub-angular, cemented to friable, slightly calcareous, glauconitic, micaceous, Foraminifera, poor porosity.	151	170
Silt, light-gray to greenish-gray, clayey, sandy with imbedded sand grains up to fine-grained, micaceous, slightly glauconitic Foraminifera	170	190
Sandy silt to silty sand, greenish-gray, very fine-grained where sandy, moderately sorted, angular to sub-angular, micaceous, glauconitic, poor porosity.	190	203
Sand, greenish-gray, very fine- to fine-grained, moderately sorted, angular to sub-angular, loose to friable, micaceous, glauconitic, Foraminifera and shell fragments, possibly slightly calcareous, contains black, vitreous, glassy fragments.	203	215
Silt, greenish-gray, clayey, sandy with very fine- to fine-grained quartz grains, poorly sorted, angular to sub-angular, moderately consolidated, slightly micaceous, slightly glauconitic, possibly slightly calcareous, Foraminifera.	215	236

Lithology

	Depth in feet	
	From	To
Silt, light-olive-gray to greenish-gray, clayey, slightly sandy, micaceous, glauconitic, slightly calcareous.	236	249
Sand, greenish-gray to olive-gray, very fine- to coarse-grained (averages medium-grained and is coarsest at base), poorly to moderately sorted, angular to subangular, loose to moderately cemented, friable, glauconitic, slightly micaceous, partially calcareous cement, quartz grains are clear to frosted to pink, to lavender to pale green. Shell fragments in upper portion.	249	259
Sand, greenish-gray, very fine-grained, very silty, moderately sorted, angular to subangular, glauconitic, slightly to moderately micaceous, calcareous (cement and shell fragments), poor porosity.	259	272
Silt, light-gray to light-olive-gray, clayey, glauconitic, micaceous, soft, slightly calcareous.	272	282
No samples.	282	295
Silt as above except slight increase in mica and decrease in glauconite.	295	300
Silt, light-olive-gray, slightly clayey, slightly sandy (very fine-grained), slightly calcareous, slightly glauconitic, micaceous, soft, minor Foraminifera.	300	310
Silt as above but increased shell material and pieces of very light gray sandy limestone (possibly cavings from hard drilling streak at 282').	310	320
Silt, light-olive-gray, slightly clayey, slightly sandy, slightly calcareous, slightly glauconitic, micaceous, soft.	320	327
Silt, light-olive-gray to greenish-gray, clayey, slightly calcareous, micaceous, very slightly glauconitic, shell fragments, soft.	327	340
Silt, light-olive-gray to greenish-gray, clayey, micaceous, slightly calcareous, soft.	340	400

Lithology	Depth in feet From	To
Silt, light-olive-gray, clayey, finely micaceous, slightly calcareous, possibly badly weathered glauconite, soft.	400	450
Silty clay, greenish-gray to light-olive-gray, micaceous, slightly calcareous, greenish-gray streak, soft, granular texture.	450	470
Silty clay as above with pods of moderate-reddish-orange discoloration - probable iron staining.	470	480
Silty clay, greenish-gray to light-olive-gray, micaceous, slightly calcareous, greenish-gray streak, soft, granular texture.	480	490
Clayey silt, greenish-gray, micaceous, slightly calcareous, soft.	490	530
Silt as above except decrease in clay content.	530	550
Silt, light-olive-gray to greenish-gray, clayey, micaceous, with fine-grained black heavy minerals and possibly a small amount of glauconite and inclusions or thin interbeds of olive-gray silty clay, micaceous, granular texture, olive-gray streak.	550	560
Silt, light-olive-gray, sandy with very fine-grained angular to sub-angular quartz grains, slightly clayey, friable, micaceous, black vitreous phosphate grains, abundant Foraminifera.	560	572
Silt, light-olive-gray, clayey, very slightly sandy, micaceous, calcareous.	572	580
Silt, light-olive-gray, clayey, sandy, very calcareous, very fossiliferous - Foraminifera and shells.	580	603
Silty sand, light-olive-gray, very fine-grained, very clayey and silty, poorly sorted, angular to sub-angular, very calcareous, black vitreous phosphate grains, very fossiliferous, poor porosity.	603	610
Sand, light-olive-gray, very fine- to coarse-grained (averages very fine-grained), silty, clayey, poorly sorted, angular to sub-angular, very phosphatic, very calcareous, very fossiliferous.	610	621

Lithology	Depth in feet From	Depth in feet To
Sand, olive-gray, very fine- to coarse-grained (averages very fine-grained), very silty, clayey, poorly sorted, angular to sub-angular, micaceous, very fossiliferous, decrease in phosphate and increase in glauconite, very calcareous, poor porosity.	621	633
Sand, olive-gray, very fine- to very coarse-grained (averages very fine-grained) silty, clayey, poorly sorted, angular to subrounded, calcareous cement in part, Foraminifera, slightly to moderately micaceous, phosphatic, glauconitic, quartz grains are clear to slightly frosted, poor porosity.	633	648
Sand, dark-greenish-gray, very fine- to very coarse-grained (averages very fine-grained), silty, clayey, poorly sorted, angular to subrounded, micaceous, calcareous, phosphate and glauconite equals approximately 25% and average medium-grained, poor porosity.	648	660
Sandy silt, olive-gray, clayey, calcareous, Foraminifera, phosphatic, glauconitic, probably most dark minerals are glauconite, micaceous, poorly sorted.	660	670
Silt, light-olive-gray, clayey, slightly sandy, micaceous, slightly to moderately glauconitic and phosphatic, slightly calcareous.	670	680
Silt as above with white coarse crystalline dolomitic limestone particles - possibly fracture filling material.	680	692
Sand, light-olive-gray to greenish-gray, very fine- to very coarse-grained (average very fine-grained), silty, clayey, very poorly sorted, angular to sub-angular, very micaceous, consolidated, calcareous, fossiliferous, glauconitic, very coarse phosphate grains, quartz is clear to frosted, poor porosity.	692	708
Silt, light-olive-gray to greenish-gray, clayey, slightly sandy, micaceous, slightly glauconitic, granular texture, slightly iron-stained in upper portion, shell fragments in lower part.	708	730

Lithology	Depth in feet From	To
Sandy silt, olive-gray, very micaceous, moderately calcareous, slightly glauconitic, clayey, abundant shell fragments, semi-plastic in part - probably thin stringers of medium to dark gray clay.	730	740
Sand, olive-gray to medium-dark-gray, very fine- to fine-grained (averages very fine-grained), moderately sorted, angular to sub-angular, silty, very micaceous with coarse books, slightly glauconitic, lignitic, very slightly calcareous, moderately friable, poor porosity.	740	753
Sand, light-olive-gray, fine- to coarse-grained (averages medium-grained), well sorted, angular to sub-angular, clean, loose to friable, moderately to very glauconitic, slightly micaceous, Foraminifera, quartz is clear to frosted, good porosity.	753	760
Sand, yellowish-gray to light-olive-gray, medium-grained to granules (average very coarse-grained), clean, well sorted, angular to subrounded, quartz clear to frosted to slightly polished, pyrite, possibly feldspathic, good porosity.	760	770
Sand, light-olive-gray, fine-grained to granules (averages + medium-grained) moderately clean, moderately sorted, angular to sub-angular, slightly glauconitic, slightly micaceous with some coarse books, slightly pyritic, probably feldspathic, quartz clear to frosted to slightly polished, loose, good porosity.	770	783
Sand as above except becomes moderately to very glauconitic and contains Foraminifera.	783	786
Sand, light-olive-gray, very fine- to medium-grained, (averages + fine-grained), moderately sorted, angular to sub-angular, loose, increase in mica and decrease in glauconite from above, fair to good porosity, grading into sandy silt to silty sand, fine- to very coarse-grained, poorly sorted, friable, poor to fair porosity. Both zones probably feldspathic.	786	800

Lithology	Depth in feet From	To
Sand, yellowish-gray to dusky-yellow, medium-grained to granules (average + coarse-grained), slightly clayey, "dirty", poor to moderately sorted, angular to sub-angular, loose to friable, slightly micaceous, very slightly glauconitic, slightly feldspathic, quartz clear to frosted, fair porosity.	800	814
Sand, yellowish-gray to light-olive-gray, fine-grained to granules (averages + coarse-grained), fairly clean, moderately sorted, angular to sub-angular, micaceous with coarse mica books, loose, quartz frosted to clear, fair porosity.	814	830
Sand, light-olive-gray to dusky-yellow, medium-grained to granules (averages coarse-grained), clean, moderately to well sorted, angular to sub-angular, slightly micaceous, quartz clear to frosted, loose, good porosity.	830	860
Sandy silt, light-olive-gray, sand grains up to coarse-grained imbedded in silt, poorly sorted, micaceous, glauconitic, clayey, calcareous, Foraminifera, moderately consolidated, poor porosity.	860	870
Clay, light-olive-gray to greenish-gray, silty, very micaceous, glauconitic, plastic, soft, granular texture, greenish-gray streak.	870	893
Sandy silt as above grading into sand, light-olive-gray, very fine- to medium-grained (averages fine-grained), silty, clayey, moderately sorted, angular to sub-angular, micaceous with coarse mica books, slightly glauconitic, loose, fair porosity.	893	903
No samples.	903	913
Sand, light-olive-gray, fine-grained to pebbles (averages very coarse-grained) "dirty", silty, poorly sorted, angular to sub-angular, clayey, very slightly glauconitic, clear to frosted quartz, micaceous, fair porosity. Core evidence indicates good possibility of thin silty, sandy, micaceous, slightly calcareous and glauconitic, semi-plastic clay lenses.	913	923

Lithology	Depth in feet From	Depth in feet To
Sand, light-olive-gray, fine- to very coarse-grained (averages coarse-grained), slightly clayey, moderately to well sorted, angular to sub-angular, slightly to moderately micaceous with coarse books, slightly glauconitic, quartz is clear to frosted, loose to friable, fair to good porosity.	923	935
Sand as above except loose, well sorted, good porosity.	935	945
Sand, dusky-yellow to light-olive-gray, fine- to very coarse-grained (averages coarse-grained to + coarse-grained at base), clean, moderate to well sorted, angular to sub-angular, loose to friable, slightly micaceous, very slightly glauconitic, quartz clear to frosted, very good porosity.	945	975
Sand, light-olive-gray, fine- to very coarse-grained (averages very coarse-grained), clean, moderately to well sorted, angular to sub-angular, slightly micaceous, possible feldspar, quartz clear to frosted, loose, very good porosity.	975	985
Silt, light-olive-gray, very finely micaceous, glauconitic, slightly sandy, clayey grading into silty sand, very fine- to very coarse-grained, "dirty", clayey, poorly sorted, angular to sub-angular, micaceous, slightly glauconitic, loose, fair porosity.	985	995
Sand as above grading into very fine-grained silty sand to sandy silt, micaceous, glauconitic, consolidated, very poorly sorted, poor porosity.	995	1008
Clay, moderate-reddish-brown to dark-yellowish-orange to medium-dark-gray, very micaceous, slightly silty, slightly sandy, slightly to moderately glauconitic, plastic, tough, granular texture grading into light-olive-gray silty sand, very fine- to very coarse-grained, "dirty", poorly sorted, angular to sub-angular, micaceous, glauconitic, consolidated to friable, slightly calcareous, poor porosity.	1008	1018
Interbedded sand and clay as above except sand ranges from very fine-grained to granules (averages + medium-grained), poor porosity.	1018	1029
No samples.	1029	1039

Lithology	Depth in feet From	Depth in feet To
Sand, light-olive-gray, fine-grained to granules (averages coarse-grained at top to very coarse-grained near bottom) moderately clean, moderately to well sorted, angular to sub-angular, loose, slightly micaceous with coarse mica books, quartz clear to frosted to pitted, probably slightly feldspathic, very good porosity.	1039	1071
Silty clay to clayey silt, light-olive-gray to medium-light-gray to grayish-purple, very micaceous, glauconitic, granular texture, tough grading into silty sand, light-olive-gray, very fine-grained to granules, clayey, "dirty", poorly sorted, angular to sub-angular, slightly micaceous, slightly feldspathic, loose to friable, quartz clear to frosted, poor porosity.	1071	1092
Sand, light-olive-gray, fine- to very coarse-grained (averages coarse-grained), clean, moderately well sorted, angular to sub-angular, very slightly micaceous, quartz clear to frosted, loose, very good porosity.	1092	1113
Sand as above except fine-grained to granules (averages + coarse-grained) poorly to moderately sorted.	1113	1123
Interbedded silty sand as above and silty clay, greenish-gray to medium-light-gray, very micaceous, slightly to moderately silty, slightly glauconitic, granular texture.	1123	1134
Sand, medium-dark-gray, very fine-grained, silty, well sorted, angular to sub-angular, lignitic, micaceous, consolidated grading into sand, light-olive-gray, very fine- to coarse-grained (averages medium-grained) slightly clayey, poorly sorted, angular to sub-angular, micaceous, slightly lignitic, loose to friable, fair porosity.	1134	1145
Sand, light-olive-gray, very fine- to very coarse-grained (averages medium-grained) silty, slightly clayey, poorly sorted, angular to sub-angular, micaceous, slightly lignitic, loose to friable with thin interbeds of silt, yellowish-gray to light-olive-gray, sandy, consolidated, slightly calcareous, micaceous.	1145	1155

Lithology	Depth in feet From	To
Sand, light-olive-gray, fine-grained to granules (averages + coarse-grained), slightly silty and clayey, poorly sorted, angular to subrounded, micaceous, possibly slightly lignitic, quartz clear to frosted to slightly polished, loose, fair porosity.	1155	1166
Sand, light-olive-gray, fine-grained to granules (averages very coarse-grained) clean, moderately well sorted, angular to subrounded, micaceous, slightly lignitic, loose, possibly slightly feldspathic, good porosity.	1166	1186
Silt, dusky-yellow to moderate-yellowish-brown to moderate-reddish-brown, sandy, clayey, micaceous, slightly calcareous, granular texture with thin interbeds of greenish-gray silty clay.	1186	1218
Sand, light-olive-gray, very fine-grained to granules (averages + medium-grained), "dirty", silty, clayey, poorly sorted, angular to subrounded, micaceous, loose to friable, quartz clear to frosted, poor to fair porosity.	1218	1228
Sand, light-olive-gray, very fine-grained to granules (averages coarse-grained) slightly clayey and silty, poorly sorted, angular to subrounded, micaceous, quartz clear to frosted, thin silt interbed in upper portion, loose to friable, probably very slightly glauconitic, fair porosity.	1228	1250
Sand, light-olive-gray, fine-grained to granules (averages coarse-grained to very coarse-grained near base) clean, moderate to well sorted, angular to subrounded, quartz clear to frosted to slightly polished, micaceous, possibly slightly lignitic and feldspathic near top, very slightly glauconitic, loose to friable, good to very good porosity.	1250	1292
Clayey silt to silty clay, medium-gray to moderate-reddish-brown to moderate-greenish-yellow to greenish-gray, slightly sandy, slightly calcareous, slightly glauconitic, very micaceous, granular texture.	1292	1303

Lithology	Depth in feet From	Depth in feet To
Interbedded silty clay and clayey silt, light-brownish-gray to moderate-reddish-brown to greenish-gray to medium-gray, very micaceous, slightly sandy, slightly glauconitic, semi-plastic, variegated, granular texture.	1303	1324
Clayey silt, medium-light-gray, very micaceous with coarse mica books, very clayey, slightly sandy, slightly glauconitic, slightly calcareous, slightly lignitic, granular texture.	1324	1334
Sand, light-olive-gray, fine-grained to granules (averages coarse-grained) silty, clayey, poorly sorted, angular to subrounded, loose to consolidated in upper part by clay, micaceous with coarse mica books, slightly glauconitic, possibly slightly feldspathic, poor to fair porosity grading into clean loose, good, porous sand at the base.	1334	1355
Clayey silt, grayish-yellow-green to medium-gray, very micaceous, slightly sandy, slightly to moderately glauconitic, granular texture grading into silty sand.	1355	1376
Sand, light-olive-gray, fine- to very coarse-grained (averages coarse-grained) silty, moderately sorted, angular to sub-angular, loose to friable, micaceous, slightly to moderately glauconitic, quartz clear to frosted, fair porosity.	1376	1387
Sand, light-olive-gray, very fine- to very coarse-grained (averages coarse-grained), clean, moderately to well sorted, angular to sub-angular, loose, slightly to moderately glauconitic, slightly micaceous, good porosity.	1387	1408
Silt, yellowish-gray to light-greenish-gray to greenish-gray, clayey, slightly sandy, very micaceous, slightly glauconitic, slightly calcareous.	1408	1422
Sand, light-olive-gray, very fine- to coarse-grained (averages + very fine-grained) very silty, slightly clayey, poorly sorted, angular to sub-angular, consolidated, "dirty", slightly calcareous, poor porosity.	1422	1429

Lithology

	Depth in feet From	To
Sand, light-olive-gray, very fine-grained to granules (averages coarse-grained) slightly silty, poorly sorted, angular to subrounded, loose to friable, quartz clear to frosted to slightly polished, becoming slightly micaceous and feldspathic at base, fair to good porosity.	1429	1450
Sand, light-olive-gray, very fine-grained to granules (averages coarse-grained) moderately sorted, angular to subrounded, micaceous with coarse mica books, probably slightly glauconitic, quartz clear to pink to ruby red, good porosity.	1450	1471
Interbedded sand, light-olive-gray, very fine- to very coarse-grained (averages + very fine-grained), silty, slightly clayey, poorly sorted, angular to sub-angular, consolidated, glauconitic, micaceous, poor porosity and clayey silt to silty clay, dark-gray, very micaceous, granular texture.	1471	1481
Sand, light-olive-gray, very fine-grained to granules (averages + medium-grained) slightly silty, moderately sorted, angular to subrounded, micaceous, very slightly glauconitic, quartz clear to frosted to slightly polished, thin interbeds of slightly to moderately calcareous silt, fair to good porosity.	1481	1492
Sand as above but no silt interbeds, decrease in mica and glauconite, good porosity.	1492	1503
Sand, light-olive-gray, very fine-grained to granules (averages coarse-grained) poorly sorted, angular to subrounded, loose to consolidated with white clay cement, slightly micaceous, slightly calcareous, quartz clear to frosted to slightly polished, fair to good porosity.	1503	1538
Silty sand, light-olive-gray, very fine- to coarse-grained (averages + fine-grained), "dirty", poorly sorted, angular to sub-angular, calcareous and clayey cement, consolidated to friable, micaceous, poor porosity grading into and interbedded with sand, moderate-reddish-orange, very fine- to fine-grained sand, silty, clayey, consolidated, calcareous, micaceous with both muscovite and biotite, black, vitreous, non-magnetic "heavies", poor porosity.	1538	1566

Lithology

	Depth in feet From	To
Silty sand, pale-yellowish-brown to light-brown, very fine-grained to granules (averages fine-grained), very silty, clayey, poorly sorted, angular to sub-angular, glauconitic, consolidated to friable, micaceous with coarse muscovite and biotite books, clay and calcareous cement, poor porosity, some inclusions of moderate-reddish-brown silty clay.	1566	1577
Interbedded silty sand as above and silty clay, moderate-reddish-brown to greenish-gray, slightly sandy, soft, occassional rounded, highly oxidized iron pellets.	1577	1587
Interbedded clay, light-brown, slightly silty, tough, semi-plastic, and sand, pale-yellowish-brown, very fine- to very coarse-grained (averages medium-grained), very silty, clayey, poorly sorted, angular to sub-angular, slightly glauconitic, micaceous with coarse mica books, poor porosity.	1587	1598
Sand, light-olive-gray, very fine-grained to granules (averages coarse-grained) silty, moderately sorted, angular to subrounded, coarse biotite and mica books, quartz clear to frosted to slightly polished, fair porosity grading into light-brown very silty sand, clayey, slightly calcareous, consolidated to friable, very micaceous with biotite and muscovite, poor porosity.	1598	1619
Sand, light-olive-gray, very fine-grained to granules (averages + coarse-grained) silty, slightly clayey, moderately sorted, angular to subrounded, loose, micaceous, quartz clear to frosted to slightly polished to pitted, fair to good porosity.	1619	1632
Clayey silt to silty clay, light-greenish-gray to greenish-gray to light-olive-gray, sandy, grading into very fine-grained silty sand, clayey, poorly sorted, angular to sub-angular, consolidated, very micaceous with coarse books of muscovite and biotite, slightly glauconitic, slightly calcareous, minor iron-staining, "heavy minerals", poor porosity.	1632	1650

Lithology	Depth in feet From	To
Clayey silt as above grading into silty sand, yellowish-gray to light-olive-gray, very fine- to coarse-grained (averages fine-grained) very clayey, poorly sorted, angular to sub-angular, calcareous and white clay cement, consolidated, very micaceous with very coarse biotite and muscovite, slightly glauconitic, iron-stained, quartz clear to frosted, poor to fair porosity.	1650	1661
Sand, light-olive-gray, very fine-grained to granules (averages coarse-grained) clayey, silty, poorly sorted, angular to subrounded, loose to friable, calcareous and white clayey cement, micaceous, quartz clear to frosted to slightly polished, slightly pitted, possibly feldspathic, fair to good porosity.	1661	1674
Sandy silt, medium-light-gray, very clayey, very micaceous with biotite and muscovite, slightly glauconitic, nonfriable, poor porosity with interbed of silty sand as above.	1674	1692
Interbedded silty sand and sandy silt, light-olive-gray, very fine- to coarse-grained (averages fine-grained) clayey, silty, poorly sorted, angular to sub-angular, very micaceous with biotite and muscovite, calcareous, consolidated, poor porosity.	1692	1703
Silt, pale-red-purple to moderate-reddish-brown, very clayey, sandy, consolidated, very micaceous with biotite and muscovite, granular texture, possibly thin interbeds of very fine- to fine-grained sand as above.	1703	1713
Silty clay to clayey silt, light-greenish-gray to moderate-reddish-orange to moderate-reddish-brown, sandy, very micaceous with biotite and muscovite, calcareous, consolidated, tough, granular texture, possibly slightly glauconitic.	1713	1734
Silt as above grading into sand, light-olive-gray, very fine- to very coarse-grained (averages medium-grained) "dirty", poorly sorted, angular to sub-angular, muscovite and biotite, loose to friable, fair porosity.	1734	1745

Lithology	Depth in feet From	To
Sand, light-olive-gray, very fine-grained to granules (averages very coarse-grained) moderately well sorted, angular to subrounded, clean, loose, quartz clear to frosted to slightly polished, possibly feldspathic, very good porosity.	1745	1755
Sandy silt, moderate-reddish-orange to moderate-reddish-brown, clayey, very micaceous with muscovite predominant mica, granular texture, tough.	1755	1780
Sand, pale-red, very fine-grained to granules (averages + medium-grained), very silty, very clayey, "dirty", poorly sorted, angular to subrounded, calcareous cement in part, loose to friable, quartz clear to frosted to slightly polished, micaceous, possibly very slightly lignitic, fair porosity.	1780	1790
Silty clay to clayey silt, moderate-reddish-orange to moderate-reddish-brown to light-gray, micaceous, slightly calcareous, granular texture grading into white sand, very fine- to medium-grained, clayey, cemented by calcite and clay, micaceous with muscovite predominant, slightly glauconitic, poor porosity.	1790	1800
Sand, pale-red to light-olive-gray, very fine-grained to granules (averages coarse-grained) clayey, silty, moderately sorted, angular to sub-angular, slightly glauconitic, micaceous, loose to consolidated, fair porosity.	1800	1809
Sand, pale-yellowish-brown, very fine-grained to pebbles (averages coarse-grained) very silty at top becoming clean sand near the base, poorly to moderately sorted, angular to subrounded, micaceous with both biotite and muscovite, slightly lignitic, slightly calcareous, quartz clear to frosted to slightly polished, possibly slightly feldspathic, fair porosity near top to very good porosity near base.	1809	1840
Interbedded sand as above and clayey silt, light-gray to light-olive-gray, slightly sandy, micaceous, lignitic, glauconitic, granular texture, tough.	1840	1851

Lithology

	Depth in feet From	To
Silt, light-gray to greenish-gray, very clayey, slightly sandy, very micaceous, glauconitic, tough, granular texture.	1851	1870
Sand, light-olive-gray to greenish-gray, very fine-grained to granules (averages coarse-grained) very clayey and silty near top cleaning up towards base, poorly sorted, angular to sub-angular, micaceous, loose to friable, fair to good porosity.	1870	1910
Silt, light-olive-gray, clayey, slightly sandy, micaceous, tough, granular texture.	1910	1924
Sand, very light-gray to light-olive-gray, very fine- to very coarse-grained (averages medium-grained) poorly to moderately sorted, angular to sub-angular, consolidated near top by calcite and clay cement grading into loose calcareous sand, biotite and muscovite, fair to good porosity.	1924	1935
Sand, light-olive-gray, very fine-grained to granules (averages + coarse-grained) slightly clayey and silty, poorly to moderately sorted, angular to sub-angular, slightly calcareous, micaceous, loose to friable, fair to good porosity.	1935	1945
Sand, light-olive-gray, fine-grained to pebbles (averages + coarse-grained) silty, poorly to moderately sorted, angular to subrounded, micaceous, possibly feldspathic, quartz clear to frosted to polished, fair to good porosity, thin interbeds of medium-dark-gray, slightly pyritic, clayey silt.	1945	1966
Sand, light-olive-gray, very fine-grained to granules (averages + medium-grained) very silty, clayey, poorly to moderately sorted, angular to sub-angular, micaceous with minor biotite, loose to consolidated, calcareous where consolidated, poor to fair porosity.	1966	1987
Sand, light-olive-gray, very fine-grained to granules (averages + coarse-grained) silty, slightly clayey, poorly to moderately sorted, angular to sub-angular, slightly micaceous, loose to friable, calcareous and clayey cement, fair to good porosity.	1987	2010

Lithology

	Depth in feet From	To
Sand, light-olive-gray, very fine- to coarse-grained (averages fine-grained), very silty, moderately sorted, angular to sub-angular, micaceous, loose, fair porosity.	2010	2019
Sand as above except averages coarse-grained, good porosity.	2019	2029
Sand, light-olive-gray, very fine-grained to granules (averages + coarse-grained) clean, moderately sorted, angular to subrounded, loose, quartz clear to frosted to polished, good porosity.	2029	2040
Sandy silt to silty sand as above, micaceous, glauconitic, consolidated, poor porosity.	2040	2050
Sand, light-olive-gray, very fine-grained to granules (averages very coarse-grained) clean, moderately to well sorted, angular to sub-angular, slightly micaceous, possibly slightly glauconitic, quartz clear to frosted, loose, good to very good porosity.	2050	2074
Interbedded sand, light-olive-gray, very fine-grained to pebbles (averages very coarse-grained) and medium-gray, micaceous clayey silt.	2074	2090
Sand, light-olive-gray, very fine-grained to granules (averages coarse-grained) very silty, poorly sorted, angular to sub-angular, micaceous with coarse biotite and muscovite books, slightly glauconitic, loose to consolidated by silt, clay, and calcite.	2090	2111
Silt, light-gray to dark-yellowish-orange to moderate-reddish-orange to moderate-reddish-brown, very clayey variegated, very sandy with imbedded quartz grains, very micaceous, glauconitic near top, tough, granular texture, slightly calcareous.	2111	2133
Silt, grayish-yellow-green to dark-yellowish-orange to moderate-reddish-orange to moderate-reddish-brown, very clayey, very sandy with imbedded quartz grains up to granule size, very finely micaceous with biotite and muscovite, thin interbeds of light-gray very fine-grained, clayey, silty consolidated sand.	2133	2163

Lithology	Depth in feet From	To
Silt as above except slightly more clayey and slightly to moderately calcareous.	2163	2180
Silt as above except less sandy and contains thin interbeds of moderate-red silty clay.	2180	2200
Silty clay to clayey silt, moderate-reddish-brown to grayish-red-purple to grayish-yellow-green to pale-reddish-brown, slightly sandy with imbedded quartz grains, very micaceous with both biotite and muscovite, calcareous, contains pods of glauconite in the siltier zones.	2200	2224
Clayey silt as above grading into sand, very light-gray, very fine- to medium-grained, clayey, poorly sorted, angular to sub-angular, micaceous with biotite and muscovite, consolidated with calcareous and clayey cement, poor porosity.	2224	2254
Sand, light-brownish-gray, very fine-grained to granules (averaging coarse-grained) very silty, clayey, poorly sorted, angular to sub-angular, loose to consolidated, micaceous, fair porosity.	2254	2264
Sand, light-brownish-gray, very fine-grained to pebbles (average very coarse-grained), silty, clayey, poorly to moderately sorted, angular to subrounded, loose to consolidated by white clay matrix, slightly calcareous, biotite and muscovite where consolidated, quartz clear to frosted to polished, fair to good porosity.	2264	2315
Samples predominantly caved material. See core descriptions for samples in this zone.	2315	2404
Sand, light-olive-gray, very fine- to coarst-grained (averages medium-grained), very silty, clayey, moderately sorted, angular to sub-angular, micaceous, loose, fair porosity with interbeds of sandy silt, light-brownish-gray, very clayey, slightly calcareous, biotite and muscovite.	2404	2414
Sand, light-olive-gray, very fine-grained to granules (averages + medium-grained), very silty, clayey, poorly sorted, angular to sub-angular, "dirty", micaceous, slightly calcareous, poor porosity.	2414	2436

Lithology

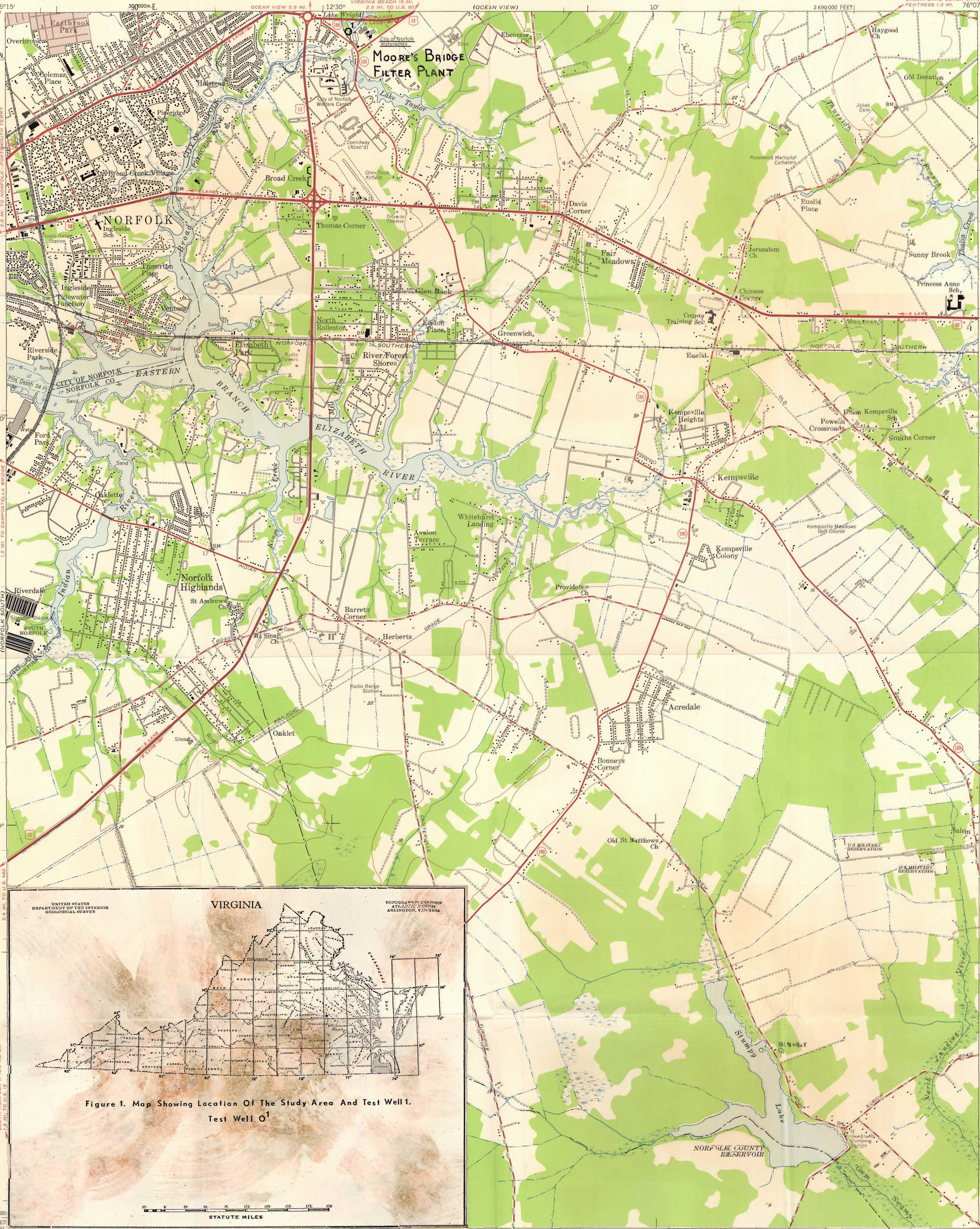
	Depth in feet From	To
Sandy silt, light-olive-gray, imbedded sand grains up to granules, very clayey, calcareous and clayey cement, micaceous with biotite and muscovite.	2436	2446
Sand, light-olive-gray, very fine- to very coarse-grained (averages coarse-grained) clean, moderately sorted, angular to sub-angular, slightly micaceous with biotite and muscovite, fair to good porosity.	2446	2455
Sand, light-olive-gray, very fine-grained to granules (averages + coarse-grained) clean, moderately well sorted, angular to sub-angular, slightly micaceous, quartz clear to frosted, loose, good porosity.	2455	2496
Sand as above with thin interbed of consolidated fairly friable sand cemented by silt and calcite, slightly glauconitic, fair to poor porosity.	2496	2506
Sand, light-olive-gray, very fine-grained to granules (averages + coarse-grained) clean, well sorted, angular to subrounded, loose, micaceous, quartz clear to frosted to slightly polished, good porosity.	2506	2526
Sand as above grading into silty sand, light-olive-gray, clayey, becoming consolidated by clay and calcite cement, fair to poor porosity.	2526	2536
Silty clay to clayey silt, light-gray to light-greenish-gray, slightly sandy, micaceous, tough, brittle, granular texture. (Samples have a lot of caved material.)	2536	2556
Silty clay, medium-light-gray to light-greenish-gray to light-gray, silty, very micaceous, tough, brittle.	2556	2587
Circulated one hour - Silty clay as above but also contains white chert, grayish-black dense siliceous pebbles that look like "jasper".	2587	
	Total Depth:	2587

Samples were interpreted and lagged to fit drilling time and electric logs where necessary.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

UNITED STATES
DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS

KEMPSVILLE QUADRANGLE
VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
SW/4 CAPE HENRY 15' QUADRANGLE



(NORFOLK NORTH)
(CAPE HENRY)
(OCEAN VIEW)
OCEAN VIEW 5.6 MI.
VIRGINIA BEACH 18 MI.
2.6 MI. TO U.S. 60
CHESAPEAKE BEACH 3.4 MI.
FENTRESS 1.3 MI.
76°15'
36°52'30"
12'30"
10'
76°07'30"
2 690 000 FEET
200 000 FEET
Moore's Bridge
Filter Plant
City of Norfolk Waterworks
Lake Wright
Lake Taylor
Eastbrook Park
Overbrook
Coleman Place
Halstead
Pineridge Sch
Broad Creek Village
Broad Creek
NORFOLK
Ingleside Sch
Thomas Corner
Glen Rock
Tipperton Place
Ingleside
Tidewater Junction
Ventosa
North Rolleston
Easton Place
Elizabeth Park
River Forest Shores
Riverside Park
CITY OF NORFOLK
NORFOLK CO
EASTERN BRANCH
ELIZABETH RIVER
Ford Park
Oaklette
Norfolk Highlands
St Andrews Ch
Riverdale
SOUTH NORFOLK
Barrets Corner
Herberts
Mt Sinai Ch
Oaklet
Ebenezer Ch
Davis Corner
Fair Meadows
Greenwich
Haygood Ch
Old Donation Ch
Jones Cem
Rosewood Memorial Cemetery
Euclid Place
Jerusalem Ch
Sunny Brook
Thalia Creek
Princess Anne Sch
Chinese Corner
County Training Sch
Euclid
Kempsville Heights
Powells Crossroads
Union Kempsville Sch
Smiths Corner
Kempsville
Kempsville Meadows Golf Course
Whitehurst Landing
Avalon Terrace
Kempsville Colony
Providence Ch
Acredale
Bonneys Corner
Old St Matthews Ch
Salem
U S MILITARY RESERVATION
Stumpy Lake
Mt Bethel Ch
NORFOLK COUNTY RESERVOIR
Northland Pumping Station
Gum Swamp
North Landing River
(PRINCESS ANNE)
PRINCESS ANNE 5 MI.
NORTH LANDING 9 MI.
NORTH LANDING 5.8 MI.
THALIA 0.2 MI.
VIRGINIA BEACH 8.8 MI.
PORTSMOUTH (JUNC. U.S. 17) 4.1 MI.
2.5 MI. TO NORFOLK–PORTSMOUTH FERRY
1.2 MI. TO CAMPOSTELLA BRIDGE
(NORFOLK SOUTH)
SUFFOLK 21 MI.
2.4 MI. TO U.S. 460
SOUTH NORFOLK (P.O.) 4.3 MI.
1.8 MI. TO U.S. 13
47'30"
50'
4081000m.N.
4068000m.N.
390000m.E.
399000m.E.
160 000 FEET
36°45'
2 660 000 FEET
OAK GROVE 1.2 MI.
ELIZABETH CITY, N. C. 41 MI.
BUTTS 1.1 MI.
(FENTRESS)
FENTRESS 4 MI.
FENTRESS 5.5 MI.
INTERIOR–GEOLOGICAL SURVEY, WASHINGTON, D. C.–1956
M R-3224
(DEEP CREEK)
(PLEASANT RIDGE)
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
VIRGINIA
ARLINGTON, VIRGINIA
STATUTE MILES

Figure 1. Map Showing Location Of The Study Area And Test Well 1.
Test Well O1

Mapped by the Army Map Service
Published for civil use by the Geological Survey

Controll by USGS and USC&GS

Topography by planetable surveys 1944. Culture revised from aerial photographs by photogrammetric methods
Aerial photographs taken 1952. Field check 1955

Hydrography compiled from USC&GS chart 452 (1952)

Polyconic projection. 1927 North American datum
10,000-foot grid based on Virginia coordinate system, south zone
1000-meter Universal Transverse Mercator grid ticks, zone 18, shown in blue

Red tint indicates area in which only landmark buildings are shown

6½°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1955

SCALE 1:24000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS APPROXIMATELY 3 FEET

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, WASHINGTON 25, D. C.
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

VIRGINIA
QUADRANGLE LOCATION

ROAD CLASSIFICATION

Heavy-duty — Light-duty
Medium-duty — Unimproved dirt
U. S. Route — State Route

KEMPSVILLE, VA.
SW/4 CAPE HENRY 15' QUADRANGLE
N3645—W7607.5/7.5

1955

Table 2. Chemical analyses of water from Test Well 1 and City of Norfolk filter plant, Norfolk, Va.

(Analyses by U. S. Geological Survey. Results in parts per million)

Well	Depth Interval (feet below land surface)	Date of Collection	Silica (SiO_2)	Alumi-num	Iron (Fe)	Manga-nese (Mn)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Calcium (Ca)	Magne-sium (Mg)	Stron-tium (Sr)	Sodium (Na)	Potas-sium (K)	Ammonia nitro-gen ($asNH_4$)	Bicar-bonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluo-ride (F)	Bromide (Br)	Iodide (I)	Nitrite (NO_2)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids (residue at 180°C	Hardness as $CaCO_3$		Specific conduct-ance (micro-mhos at 25°C)	Field pH	Density	Sul-fides (asH_2S)
																											Calcium, mag-nesium	Non carbon-ate				
Test Well 1	848-868	01-24-68	12.0	0.1	.14	0.03	0.01	<0.1	0.03	10	6.9	0.2	818	23	2.4	681	102	964	1.9	3.7	0.4	0.00	0.7	0.15	3.0	2,300	54	0	3,900	7.8	0.99548	0.0
Test Well 1	943-963	01-22-68	13	.1	.96	.04	.02	<.1	.04	15	10	.5	1,110	26	3.1	668	137	1,380	1.3	4.9	.4	.00	1.2	.15	4.0	2,950	79	0	5,080	7.82	.99576	.0
Test Well 1	1,037-1,057	01-22-68	14	.0	.08	.05	.02	<.1	.05	20	13	.7	1,290	27	3.4	616	140	1,680	1.1	6.5	.4	.00	1.0	.02	4.1	3,440	101	0	5,940	7.79	.99700	.0
Test Well 1	1,255-1,277	01-20-68	24	.3	1.2	.22	.08	.1	.09	105	58	.8	2,620	52	5.3	416	242	4,200	.5	16.	.8	.00	1.6	.01	5.4	7,630	499	154	12,600	7.42	.99987	.0
Test Well 1	1,614-1,634	01-17-68	23	1.1	14	1.3	.10	.1	.20	480	209	12.	5,280	87	5.7	217	410	9,560	.4	34.	2.1	.00	2.5	.04	5.6	17,200	2,070	1,890	26,400	6.93	1.004	.0
Test Well 1	2,370-2,391	12-18-67	54	4.1	16	11	.12	.3	.20	2,660	854	66.	12,600	124	4.7	50	1,020	26,000	.5	98.	3.7	.05	1.1	.06	4.9	45,100	10,280	10,200	61,300	7.13	1.024	.0
Test Well 1	2,499-2,520	12-16-67	12	4.5	16	13	.13	.4	.22	2,940	846	73.	12,800	123	5.7	133	1,050	26,900	.5	100.	3.7	.01	1.1	.00	4.4	47,700	10,900	10,900	63,800	6.4	1.024	.0
Test Well 1	900-960	02-21-68	14	.1	.05	.05	.01	<.1	.04	14	8.0	.5	1,045	25	3.2	630	135	1,280	1.5	4.7	.1	.01	.6	.16	3.8	2,820	68	0	4,840	8.4		.0
City Water		12-01-67	4.2	.3	.03	.00	.00	<.1	.00	26	3.3	.1	19	2.2	.30	64	36	22	1.1	.3	.0	.00	.3	.00	.14	152	78	26	258	7.8		.0