UNITED STATES
DEPARTMENT OF THE INTERIOR
Geological Survey

# RECONNAISSANCE OF GROUND-WATER CONDITIONS AT HORSENECK BEACH AND GOOSEBERRY NECK, WESTPORT, MASSACHUSETTS

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U. S. Geological Survey

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CONTENTS

## ILLUSTRATIONS



## TABLES

# RECONNAISSANCE OF GROUND-WATER CONDITIONS AT HORSENECK BEACH AND GOOSEBERRY NECK, WESTPORT, MASSACHUSETTS

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## INTRODUCTION

### Purpose and Scope of the Investigation

This report describes the conditions controlling the occurrence of ground water on Horseneck Beach and Gooseberry Neck in the town of Westport, Mass. Also, it points out several of the factors that should be weighed in considering the development of ground water in that area.

The report was prepared in response to a request by the Commonwealth of Massachusetts, Department of Public Works, for aid in evaluating possible sources of water for a State recreation area at Horseneck Beach. In order to serve the facilities to be installed at the recreation area, the Commonwealth wishes to obtain a suitable supply of ground water from sources either on Horseneck Beach or on Gooseberry Neck, a small island nearby. It is understood that the Commonwealth will need no more than 170,000 gpd (gallons per day) of fresh water for its facilities at Horseneck Beach during the period June-September and that the average rate of use will be about 150,000 gpd.

The ground-water resources of Horseneck Beach and Gooseberry Neck are practically untapped at present. Summer homes and beach concessions formerly present on Horseneck Beach used ground water, but most of these were destroyed by hurricanes during the summer of 1954 and have not been rebuilt. Subsequently the use of water there has been insignificant. The few homes on Gooseberry Neck use small amounts of ground water.

This report is based on a field reconnaissance carried on intermittently in December 1956 by R. J. Hecht and on data from an exploratory program by the Massachusetts Department of Public Works during the fall and winter of 1956-57. Data on pumping tests of wells on Gooseberry Neck, made by the Layne-New York Co., Inc., in January 1957 were collected by R. J. Hecht and H. N. Halberg. Logs of test wells were furnished by the Layne-New York Co., Inc. The investigation is part of a continuing program of ground-water investigations in Massachusetts by the U. S. Geological Survey in cooperation with the Commonwealth of Massachusetts, Department of Public Works. The work in Massachusetts is under the immediate supervision of O. M. Hackett, district geologist.

Records of selected wells and borings on Horseneck Beach and Gooseberry Neck are given in table 1, and logs of test wells and borings on Horseneck Beach are given in table 2. Locations of test wells and borings are shown on figure 2.

## Location and Description of the Area

Horseneck Beach and Gooseberry Neck are in the town of Westport, Bristol County, Mass. The area is along the south coast of Massachusetts facing the Atlantic Ocean, and is just east of the Massachusetts-Rhode Island boundary. The town of Westport is about 50 miles due south of Boston.

Horseneck Beach is an offshore bar at the mouths of the East and West Branches of the Westport River. The bar is in the shape of a gentle east-trending arc, convex to the north, about 2 1/2 miles long and from less than two-tenths to about half a mile wide. It is formed of parallel east-trending beach ridges, which in most places are less than 10 feet above sea level. Its seaward or south half is veneered by dunes whose crests locally are more than 40 feet above the general level of the bar, and its landward or north margin is bordered by tidal marshes. Except for an extensive beach along its south coast the bar is covered by vegetation. East Horseneck Beach forms a natural causeway connecting the northeast end of the bar to the mainland. The area of Horseneck Beach exclusive of the tidal marshes is about nine-tenths of a square mile.

An artificial causeway links the southeast end of Horseneck Beach to Gooseberry Neck, a small island farther offshore composed of glacial drift. In shape, Gooseberry Neck is irregular and is elongated in a southerly direction. The main body of the island is moundlike. Its surface is uneven and most of it is between 10 and 20 feet above sea level. The southern and north-central coasts of the island are low, flat, and marshy. Gooseberry Neck is about seven-tenths of a mile long and one-tenth to two-tenths of a mile wide. Its area is about one-tenth of a square mile.

## GEOLOGIC UNITS AND THEIR WATER-BEARING CHARACTERISTICS

With respect to their water-bearing characteristics, the rocks in the Horseneck Beach-Gooseberry Neck area are described below under two main categories: the consolidated rocks, hereafter referred to as bedrock, and the unconsolidated deposits.

### Bedrock

Bedrock in the Horseneck Beach-Gooseberry Neck area has been mapped _/ as the Dedham granodiorite, a formation consisting of

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_/ Emerson, B. K., 1917, Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, pl. X.

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crystalline igneous rocks of early Paleozoic(?) age. These differ in composition from place to place. In general the formation is folded and faulted throughout southeastern Massachusetts, but in the Horseneck Beach-Gooseberry Neck area its structure is undetermined.

The bedrock surface reflects the preglacial topography of the area. On Horseneck Beach bedrock crops out at the north end of Central Avenue. It protrudes from the sea near the south tip of the bar just west of the causeway linking Horseneck Beach and Gooseberry Neck, and it is reported to underlie the surface of the eastern end of the bar at shallow depth. A test well, Westport 25, drilled near the center of the island reached bedrock at a depth of 75 feet--about 60 feet below sea level. A nearby test well, Westport 24, was drilled to refusal at 92 feet, or about 77 feet below sea level; and another test well, about 1,000 feet east of Westport 25, was drilled to refusal at 86 feet, or about 71 feet below sea level. These wells are roughly in line with the channel of the East Branch of the Westport River. Their depths and locations, together with the location of the exposed bedrock, suggest that a buried preglacial channel of the East Branch passes southward approximately beneath the center of Horseneck Beach. These data suggest also that the bedrock surface slopes upward both east and west of the buried channel toward the crests of south-trending buried bedrock ridges near either end of the bar. The west ridge may terminate at or near Horseneck Beach, as no trace to seaward is shown on the United States Coast and Geodetic Survey hydrographic chart of the area. The east ridge extends southward some distance to sea and underlies Gooseberry Neck. Rather sparse and incomplete data suggest that depths to bedrock on Gooseberry Neck are less than 25 feet in most places.

Crystalline rocks such as the Dedham granodiorite contain water in fractures, and the permeability and porosity of these rocks--the properties that determine the capacity of a rock to transmit and store water, respectively--depend on the number, size, extent, and degree of interconnection of the fractures. In general the permeability and porosity of crystalline rocks are low; therefore they commonly neither store nor yield much water.

The bedrock in the Horseneck Beach-Gooseberry Neck area proves no exception to the above statement. The specific capacities (yield per unit of drawdown) of the four wells in bedrock for which data are available range from less than 1 to about 4 gpm (gallons per minute) per foot.

## Unconsolidated Deposits

Known unconsolidated deposits overlying bedrock in the Horseneck Beach-Gooseberry Neck area consist of glacial drift, beach sand and related marine deposits, dune sand, and marsh deposits, probably all of Quaternary age.

The unconsolidated deposits differ considerably in their hydrologic properties. Water is contained in openings between constituent grains, and permeability and porosity are determined chiefly by grain size, sorting, and packing. In general the permeability of coarse materials such as sand or gravel is large, especially if the materials are well sorted. In contrast, the permeability of fine-grained materials such as silt and clay is small, even though they may be relatively porous.

## Glacial Drift

The glacial drift in this area consists mostly of till, which is a mixture of rock materials of all sizes deposited by glacial ice and characterized by poor sorting and little or no stratification. It crops out only on Gooseberry Neck, where it forms the bulk of the unconsolidated deposits. If present in Horseneck Beach it is buried by younger deposits from which it cannot be differentiated on the basis of the few existing well logs. Some of the wells on Gooseberry Neck reportedly penetrate deposits of sand and gravel. These may be local lenses of stratified, sorted material enclosed within the till. The glacial drift probably is less than 25 feet thick in most places. It overlies bedrock and in turn is overlain by a thin superficial mantle of lag gravel and beach sand.

The water-bearing characteristics of the glacial drift differ somewhat from place to place. Till, because it is poorly sorted and contains a large proportion of fine-grained material, has a low porosity and permeability. The lenses of sand and gravel may have a relatively high porosity and permeability. Considered as a unit, however, the glacial drift in this area consists mostly of till; therefore, its average porosity and permeability are low, and it neither stores nor yields much water. Shallow dug wells furnish enough water for domestic use to a few of the homes on Gooseberry Neck, but the sustained yield of these wells probably does not exceed a few gallons per minute.

## Beach Sand and Related Marine Deposits

On Horseneck Beach the upper part of the deposits that form the bar consists of beach sand. Where exposed the sand is mostly of medium grain size, but the logs of wells Westport 27-47 list most of it as fine grained. Its thickness, though indeterminate on the basis of existing data, is more than 50 feet in places and probably exceeds 30 feet on the average. Throughout much of the area the beach sand is mantled by dune sand. Downward the beach sand apparently grades into somewhat finer grained deposits containing silt and clay as well as sand. These in turn overlie tightly packed sand and gravel. (See logs of wells Westport 24-26.)

The log of Westport 25 indicates the presence of shells between depths of 56 and 70 feet, thereby suggesting a marine origin for at least part of the lowermost deposits. As the beach sand, too, may be considered of marine origin, most if not all of the sequence penetrated by well Westport 24 apparently is related. A possible exception is the sand and gravel immediately overlying bedrock, which may consist partly of glacial drift.

In general the beach sand is relatively porous and permeable; it stores an appreciable amount of water and should yield water rather freely in most places. Information on test borings Westport 37-48 indicates that at the site of these borings the uppermost part of the beach sand is "loose," but below a depth of 10 feet the sand becomes increasingly compact. If this condition is general, the uppermost several feet of material may constitute the most permeable part of the beach sand nearly everywhere.

Of 10 small-diameter test wells penetrating the beach sand--and perhaps also the overlying dune sand--2 were reported to yield no water; the yields of the others ranged from 7 to 60 gpm. The average yield of the group was about 15 gpm and the median yield was between 8 and 15 gpm. These data suggest that the permeability of the sand is not uniform or that some wells are better developed than others. Nevertheless, properly constructed and developed wells in the beach sand are expected to yield small to moderate amounts of water in most places.

Because the marine deposits underlying the beach sand in the area tested by wells Westport 24-26 consist partly of silt and clay and partly of tightly packed sand and gravel, which in wells Westport 24 and 26 also contains clay, these deposits probably are relatively impermeable. This conclusion is supported by the driller's record, in which water in these deposits is not mentioned.

## Dune Sand

The dune sand is restricted to Horseneck Beach. It overlies beach sand and is practically indistinguishable therefrom. The known thickness of the dune sand ranges from less than 1 to about 40 feet. The water-bearing characteristics are similar to those of the uppermost beach sand.

### Marsh Deposits

Marsh deposits, which consist of decayed or decaying organic matter mixed chiefly with sand and silt, occur from place to place on both Horseneck Beach and Gooseberry Neck. Their distribution is shown approximately by the marsh symbol on the map of the area (fig. 2). Marsh deposits may have been buried locally by beach and dune sand on Horseneck Beach, but no trace of them was recognized in logs of the test wells in the area. The marsh deposits are not considered to be a potential source of ground water.

## GROUND-WATER CONDITIONS

### Horseneck Beach

#### Occurrence of Ground Water

The ground water in Horseneck Beach occurs in bedrock and in all the overlying unconsolidated deposits, but with respect to fresh water the beach and dune sand, considered as a single unit, forms the principal ground-water reservoir. This reservoir coincides in area with that of the bar proper. Based on the logs of the few test wells for which data are available, the saturated thickness of the beach and dune sand is estimated to be at least 30 feet. Water occurs under water-table (unconfined) conditions. The depth to water is less than 10 feet below the lower parts of the rather irregular land surface but is somewhat greater below the crests of the dunes.

Fresh water in the beach and dune sand occurs as a lens-shaped body floating on salty water. The exact shape and thickness of the fresh-water body are unknown, but it is estimated that along the axis of the bar, where the body is expected to be thickest, the lower limit of water containing less than 250 ppm (parts per million) of chloride is at least 15 feet below sea level. (See section to follow on Quality of Water.) The relationship between fresh and salty water is illustrated by figure 1.

In general the bedrock and the unconsolidated deposits underlying the beach and dune sand are expected to yield but small amounts of water. Furthermore they lie at such depths that they probably contain only salty water.

## Recharge, Discharge, and Storage

Recharge, or the addition of water to the ground-water reservoir, in this area normally occurs only by the infiltration of precipitation. Because the beach and dune sand is relatively permeable it absorbs a large part of the precipitation, and only a small part runs off directly to the sea. Some of the water absorbed by the soil is retained there, and the remainder percolates downward to the ground-water reservoir. During exceptional storms, when Horseneck Beach is flooded by sea water, recharge by the infiltration of the sea water also may take place.

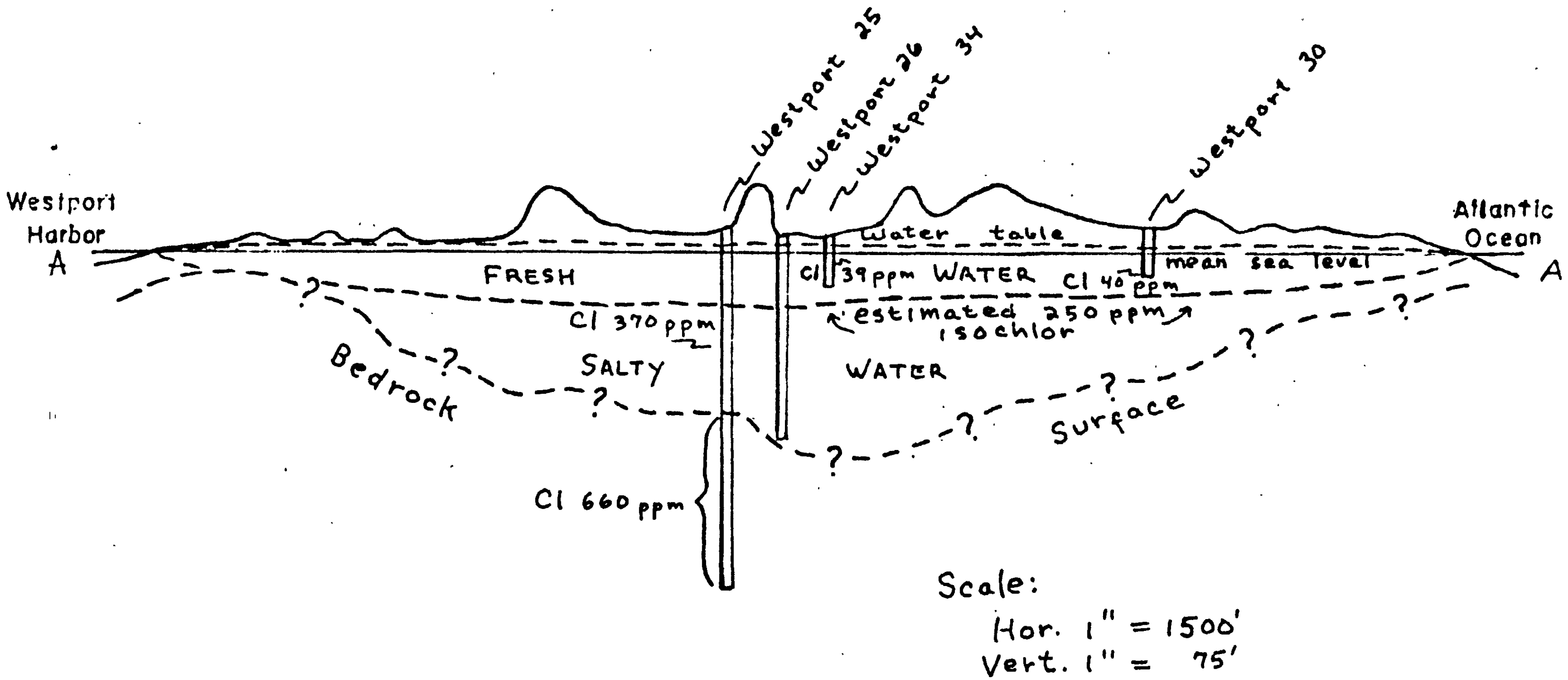


Figure 1. Generalized cross-section of Horseneck Beach along line A-A', [redacted] showing the approximate relationship of fresh and salty water.

No data are available by which to determine the actual amount of fresh-water recharge, but measurements of precipitation and estimates of average evapotranspiration for southeastern Massachusetts provide a basis for making a rough estimate of effective recharge. The average annual precipitation at Fall River and New Bedford is about 45 inches. The average annual water loss by evapotranspiration in southeastern Massachusetts is estimated to be about 20 inches; _/

_/ Knox, C. E., and Nordenson, T. J., 1955, Average annual runoff and precipitation in the New England-New York area; U. S. Geol. Survey Hydrol. Inv. Atlas HA-7.

that is, about 20 inches of the precipitation is returned to the atmosphere by evaporation and transpiration. The residue, about 25 inches, is the average net amount of water available for recharge annually. As pointed out earlier, direct runoff from Horseneck Beach is believed to be very small; therefore recharge may approach 25 inches. Applying this amount to the area of Horseneck Beach proper, which is about nine-tenths of a square mile, the average effective recharge should approximate 400 million gallons per year, or about 1.1 mgd (million gallons per day).

Ground water is discharged mainly by effluent seepage to the sea. In addition it is discharged by evaporation, especially from the marshes and along the beach, and by transpiration from the vegetation that covers most of the area. The discharge by evapotranspiration is assumed to be included in the 20 inches mentioned previously; thus the estimated net recharge of 25 inches is assumed to be disposed of entirely by effluent seepage.

The position of the water table and the volume of fresh ground water in storage fluctuate with changes in the ratio of recharge to discharge. When the ground-water reservoir is replenished, the water table rises and the fresh-water body enlarges if the rate of recharge exceeds the rate of discharge. At the same time, owing to the increased head, the discharge of fresh water by effluent seepage increases. When recharge ceases, discharge by seepage continues, but at a decreasing rate; the water table falls and the fresh-water body becomes smaller. During a so-called "normal" year, recharge takes place chiefly during the fall, winter, and early spring months. The water table usually reaches its highest position and the volume of the fresh-water body is greatest during this period. Conversely, during the growing season, in late spring, summer, and early autumn, recharge is relatively small, partly because some of the rainfall is intercepted in the soil zone and returned to the atmosphere by evapotranspiration and partly because the monthly rainfall usually is less than during the rest of the year. Also, during the growing season some ground water is discharged by evapotranspiration. Accordingly, the water table usually reaches its lowest position during the summer or early autumn, and the volume of the fresh-water body then is smallest. Owing to the relatively high porosity and permeability of the beach and dune sand the magnitude of water-level fluctuations is expected to be relatively small.

The water level in well Westport 24, measured by the Department of Public Works on September 14, 1956, was 2.2 feet above mean sea level. As the water table stands in fairly homogeneous material throughout the bar, the water level in this well is believed to be fairly representative of the position of the water table along the axial zone of Horseneck Beach. Precipitation, as measured at New Bedford and Fall River, was considerably below normal during the summer, there being little in August and September. Accordingly this water level indicates roughly the position of the water table that might be expected along the axial zone of the bar after a dry summer when the water table is lowest.

## Utilization of the Ground-Water Reservoir

The use of a ground-water reservoir such as that described above for Horseneck Beach presents a twofold problem: first, whether the amount of fresh water is adequate to satisfy the requirements of the user; second, the fresh water must be withdrawn in such a manner as to avoid inducing encroachment of salty water.

The State will need about 150,000 gpd of fresh water for its facilities at Horseneck Beach during the 4-month period June-September. As this period coincides roughly with the growing season, during which little recharge normally takes place, practically all the water must be taken from storage. It is readily apparent that, under these conditions, (1) the amount of water in storage must be sufficient to supply the summer demand; (2) the amount of recharge during the remainder of the year must be sufficient to replace the summer draft; and (3) the withdrawal from storage must not result in salt-water contamination of the water frmm the wells.

The existing data are much too scanty to justify a determination of the amount of fresh water in storage, but even a crude estimate provides a basis by which to compare the probable magnitude of storage with the amount of water required. The area of the bar proper is about nine-tenths of a square mile and the average thickness of the fresh-water body is estimated to be at least 15 feet. If the specific yield (drainable pore space) of the beach and dune sand were 15 percent, a conservative figure, the amount of fresh water in storage would be about 400 million gallons. Even were this estimate as much as twice too high, 200 million gallons would be ample to meet the requirement of the State which, at the rate of 150,000 gpd, amounts to about 20 million gallons for the period June-September--always assuming that the water can be withdrawn wihout salt-water contamination.

Earlier in this report the average annual effective recharge to the fresh-water body was estimated to be roughly 400 million gallons. If so, the amount of recharge is so much in excess of the anticipated summer draft that the fresh-water body probably would be fully replenished each year.

Assuming that the annual recharge is sufficient to replace the anticipated withdrawal, there remains the problem of making the withdrawal without drawing salty water into the wells. To prevent contamination by the movement of salty water from below, wells should be kept as shallow as possible and the water levels in them should not be drawn down to or below mean sea level for more than short periods. To prevent lateral encroachment of sea water, a water-table divide at a level higher than mean sea level must be maintained between the shore and the point or area of withdrawal. Accordingly, withdrawals should generally be made as far inland from the shore as possible and in places where the water table is highest. The most suitable installations would be large-diameter shallow wells or horizontal collecting galleries extending only a few feet below the water table. If collecting galleries were used, some of them also might be installed just above mean sea level parallel to and near the shore so as to intercept by gravity flow the ground water moving toward the shoreline.

Under the conditions described above only a part of the total recharge can be recovered. Whether enough of it can be recovered to meet the needs of the State cannot be resolved on the basis of the scant existing data. However, if slightly salty water containing, say, as much as 2,000 ppm of chloride, were acceptable for showers, toilets, and fire protection, the probability that the ground-water reservoir would meet the requirements of the State would be greatly increased. For example, at one end of the island the reservoir might be developed only as needed to provide enough potable water for human consumption. Meanwhile, without the restriction imposed by the need for completely avoiding salty water, the reservoir might be developed much more intensively at the other end of the island to provide enough water for sanitary facilities and fire protection.

One additional factor should be given attention in considering the use of the ground-water reservoir. Any change in natural conditions will alter the ground-water regimen. For example, the installation of drains on the island would serve to lower the water table, locally at least, and would decrease the volume of fresh water in storage. If salt water were allowed to enter such drains, they would become potential sources of contamination. Also, paving large areas would eliminate infiltration of rain in those areas, and unless care were taken to dispose of the runoff so as to put it underground in comparable areas, the total replenishment would be reduced proportionately.

## Gooseberry Neck

### Occurrence of Ground Water

Fresh ground water in Gooseberry Neck occurs in both glacial drift and bedrock.

The glacial drift consists mostly of till, but lenses of sand and gravel were reportedly penetrated by some of the wells on the island. Much of the glacial drift is above the water table and the saturated thickness is small. Consequently, even though the till may be moderately porous and permeable locally, it contains only a small amount of water in storage.

The fresh-water body extends downward into the bedrock for some distance--at least to 40 feet below sea level at well Westport 19. The storage provided by the bedrock is so limited, however, that the supply of fresh water soon is exhausted whenever wells in bedrock are pumped. This conclusion is supported by the results of three tests of bedrock wells on Gooseberry Neck. Well Westport 18 was pumped at a rate of about 39 gpm with a drawdown of 9.0 feet after 26 hours. The chloride concentration in the water increased steadily from 148 ppm at the beginning of the test to 380 ppm at the end. Well Westport 20 was pumped at a rate of about 6 gpm with a drawdown of 1.59 feet after 20 hours. The chloride concentration in the water increased from 180 ppm at the beginning of the test to 280 ppm at the end. Well Westport 19 was pumped at a rate of about 2 gpm with a drawdown of 2.18 feet after 95 minutes. The chloride concentration in the water near the end of the test was 230 ppm.

The water in the glacial drift occurs under water-table conditions, but locally the water in the bedrock may be confined. The depth to water on Gooseberry Neck ranges from a few feet to at least 18 feet. In December 1956, when water levels on the island were measured, the water table was nowhere more than 3 feet above sea level.

## Recharge, Discharge, and Storage

Just as on Horseneck Beach, recharge on Gooseberry Neck occurs by the infiltration of local precipitation, and discharge mostly by seepage to the sea. The surface of Gooseberry Neck is underlain chiefly by till. As till is much less permeable than beach and dune sand, it seems likely that the ratio of direct runoff to recharge is greater on Gooseberry Neck than on Horseneck Beach and that the rate of recharge on Gooseberry Neck is correspondingly less than on Horseneck Beach.

Owing to the small area of Gooseberry Neck and the relatively small storage capacity of till and bedrock, the amount of fresh water stored in Gooseberry Neck is small. The available water probably is not adequate to support a draft of 150,000 gpd.

## QUALITY OF WATER

With respect to physical and chemical quality, the ground water of southeastern Massachusetts generally is satisfactory for most uses, but locally it has a high iron content and noticeable color and odor. In addition, possible contamination by salt water must be considered when planning to develop ground water from sources near the sea. These factors, as they relate to the Horseneck Beach-Gooseberry Neck area, are discussed below. Copies of chemical analyses, made by the Massachusetts Department of Public Health at the request of the Department of Public Works, are on file in the office of the Department of Public Health and in the Boston office of the Ground Water Branch, U. S. Geological Survey.

The concentration of chloride in potable water, according to the standards of the United States Public Health Service, should not exceed 250 ppm. In this report water having a concentration of less than 250 ppm of chloride is referred to as fresh water.

Samples of water from wells on Horseneck Beach and Gooseberry Neck had chloride concentrations ranging from 39 to 660 ppm. (See table 1, Remarks.) Samples were taken from 5 test wells that tapped the beach and dune sand on Horseneck Beach. The chloride concentration in water from 4 wells, Westport 30, 34, 35, and 36, which were sampled at depths of 4 to 14 feet below the water table, ranged from 39 to 102 ppm. The chloride concentration in water from the 5th well, Westport 25, which was sampled at 45-50 feet below the water table, was 370 ppm. Water from a point about 19 feet below the water table in well Westport 27, which also was drilled in the beach and dune sand, reportedly tasted salty. A second sample was taken from well Westport 25 after it was finished in bedrock at a final depth of 147 feet, or about 138 feet below the water table. The chloride concentration in this sample was 660 ppm. Several samples also were taken from three wells on Gooseberry Neck, Westport 18, 19, and 20. These wells were finished in bedrock at depths ranging from about 11 to about 40 feet below the water table. The chloride concentrations in the initial samples ranged from 148 to 230 ppm.

The data reviewed above do not permit a close correlation of chloride content with depth below the water table. Nevertheless, with respect to Horseneck Beach, the samples from the four wells penetrating less than 20 feet below the water table each had less than 105 ppm of chloride, whereas samples from the deeper well had 370 ppm at 45-50 feet and 660 ppm at 138 feet. These data demonstrate that salty water underlies the fresh-water body. Furthermore, these data together with reports from drillers and others acquainted with the area suggest that the chloride concentration does increase with depth, but that the average thickness of the zone containing ground water having less than 250 ppm of chloride should be at least 15 feet. With respect to Gooseberry Neck, samples were taken while pumping tests were under way, and a valid comparison of chloride content under static conditions could not be made. The chloride concentration in water from none of the wells on Gooseberry Neck exceeded 250 ppm when first sampled.

Although the source of most of the chloride undoubtedly is the salt water adjacent to and underlying the fresh water both in Horseneck Beach and Gooseberry Neck, chloride sometimes may be derived from the infiltration of salt water when high seas flood parts of these areas. Also, chloride deposited on the land surface by the flooding sea water and by salt-water spray subsequently may be carried downward to the ground-water reservoir when the soils are leached by normal recharge. For example, the land surrounding well Westport 7 was flooded as a result of the hurricanes in 1954, and water from the well reportedly beeame salty immediately thereafter.

According to the standards of the U. S. Public Health Service, potable water should not contain more than 0.3 ppm of iron and manganese together, nor should color exceed 20 (platinum-cobalt scale). In samples from wells Westport 30, 34, 35, and 36 on Horseneck Beach, the iron concentration ranged from 0.19 to 4.0 ppm, and the color from 14 to 180. Also, water from well Westport 27 reportedly was highly colored, and water from several wells had a "boggy" or "sulfurous" odor. High iron, color, and odor all may be associated with organic compounds derived from organic material in the existing marshes along the landward part of the island or from older marshes now buried by beach and dune sand.

The sanitary quality of the ground water on Horseneck Beach also presents a problem. Collecting galleries installed at shallow depths or very shallow wells are the only practical means of obtaining fresh water in large amounts. Unfortunately, such shallow installations are particularly liable to pollution. Furthermore, because of the small size of the bar the collection system must draw from a large part of the reservoir area in order to supply the required yield, and this area cannot readily be isolated from the areas of human activity.

## CONCLUSIONS

1. Sufficient fresh water to meet the requirements of the State probably is not available from ground-water sources in Gooseberry Neck.

2. Enough fresh water to meet the requirements of the State probably is available in the beach and dune sand of Horseneck Beach, providing the fresh water can be recovered without drawing in adjoining salty water.

3. The best method of withdrawing large amounts of fresh water from the ground-water reservoir in Horseneck Beach is by skimming it from the top of the fresh-water body.

4. In developing a ground-water supply, problems of water quality--such as color, high iron content, and at times high chloride content--are to be expected. Sanitary quality also is a problem.

5. Ideally, before the development of a ground-water supply is undertaken a detailed investigation should be made to provide a reasonably firm estimate of the quantity of fresh water available. Specifically, information is needed on the quality of the water, on the hydrologic characteristics of the beach and dune sand, and on the shape and position of the water table at various times during the year. To obtain the needed information would require the systematic drilling, sampling, and logging of test wells, periodic collection and analysis of water samples, controlled pumping tests, and observation of water levels over an extended period. Obviously the time and cost involved in completing a detailed investigation are considerable, and in view of the immediate need of the State for water at Horseneck Beach such an investigation probably is not practical.

6. If further investigation is not practical, the only way of testing the reservoir is by actually constructing and operating one or two pilot installations. For example, two 10-foot-diameter wells lined with concrete might be installed to a depth of 3 or 4 feet below the water table along the axial zone of the bar, and then pumped. If water-stage recorders were installed to measure the drawdown at the wells, and the discharge monitored for chloride content at regular intervals, the data so collected would provide an empirical basis for a decision as to further development. Meanwhile, a water-stage recorder should be installed also on an observation well near the strand line to provide information on the effect of tidal fluctuations on the water table. It should be pointed out that, even if the results of the pilot installations were favorable, there is still a possibility that later the facilities might have to be abandoned, or the supply supplemented from other sources, even though it was initially adequate.

7. In summary, it is apparent that existing information does not provide a basis for a satisfactory solution to the problem of obtaining an adequate and permanent supply of fresh water for the State facilities at Horseneck Beach. The only source of fresh ground water worth considering is the reservoir formed by the beach and dune sand in Horseneck Beach. Both recharge of and storage in this reservoir probably are adequate to provide the fresh water needed, but the question of withdrawing enough water while avoiding both saline and organic contamination is unresolved. If salty water can be utilized for some of the facilities, such as toilets, showers, and fire protection, it seems likely that enough fresh water can be withdrawn for drinking and culinary use.

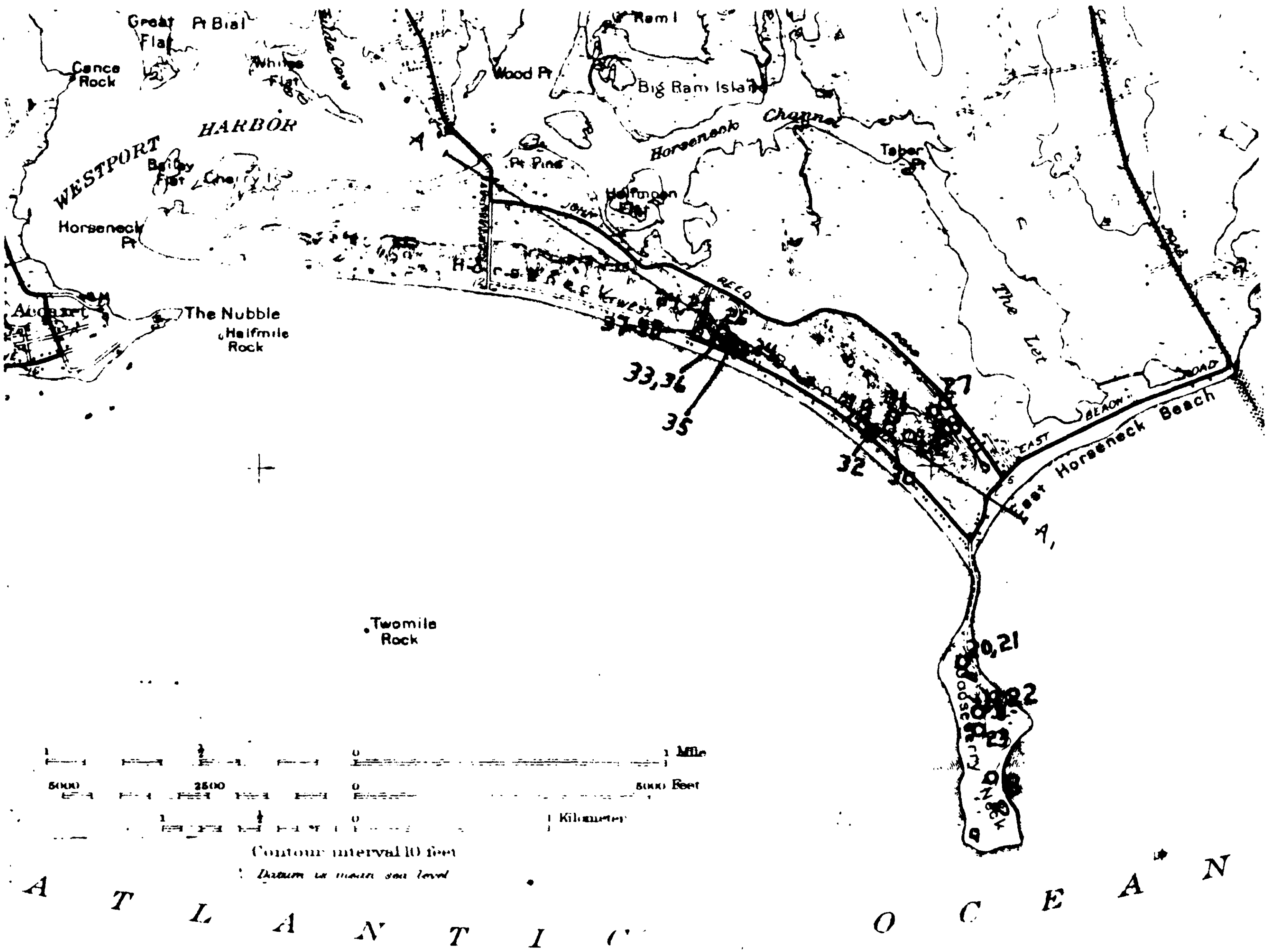


Figure 2. Map of Horseneck Beach and Gooseberry Neck, Massachusetts, showing the location of wells and springs

Page 28 (Table 1)

Table 1.--Records of wells and borings in Horseneck Beach and Gooseberry Neck, Massachusetts

| Well No. | Land surface altitude above sea level (feet) | Type of well | Depth of well (feet) | Diameter of well (inches) | Water-bearing unit | Water level: Depth below land surface (feet) | Water level: Date of measurement | Yield: GPM (gallons per minute) | Yield: Draw-down (feet) | Yield: Duration of test (hours) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 10 | Driven | 15 | 1¼ | Unconsolidated deposits (beach) | - | - | - | - | - | The water tasted salty after ocean flooded land around well. |
| 8 | 10 | do | 17 | 1¼ | do | 12 | - | - | - | - | |
| 18 | 15.1 | Drilled | 36.8 | 8 | Bedrock | 12.33 | Dec. 19, 1956 | 39 | 9.0 | 26 1/3 | Chloride: 148 ppm (1½ min. after pumping began) 380 ppm (at completion of pumping test) |
| 19 | 19.54 | do | 58.4 | 6 | do | 17.78 | Dec. 19, 1956 | 2 | 2.18 | 95 min. | ~~Water reported to be brackish~~ Chloride: 230 ppm(at completion of pumping test). |
| 20 | 15.25 | do | 24.8 | 6 | do | 13.76 | Dec. 20, 1956 | 5 3/4 | 1.59 | 20 | Chloride: 180 ppm (40 min. after pumping began) 280 ppm (at completion of pumping test) ~~[illegible]~~. |
| 21 | 10.07 | Dug | 11.4 | 24 | Bedrock (?) | 7.59 | Dec. 27, 1956 | - | - | - | |
| 22 | 16.90 | do | 17.5 | 24 | Unconsolidated deposits | 15.46 | Dec. 27, 1956 | - | - | - | |
| 23 | 12.95 | do | 12.5 | 30 | do | 11.14 | Dec. 28, 1956 | - | - | - | |
| 24 | 11.5 | Jetted | 92 | 2½ | Unconsolidated deposits (beach and dune) | 8.92 | Sept. 14, 1956 | - | - | - | |
| 25 | - | Drilled | 147 | 8 | Bedrock | 9.17 | Oct. 29, 1956 | 4-5 | 81-82 | - | Chloride: 376 ppm (sample from unconsolidated deposits at depth of 55-60 feet). 660 ppm (from completed well) Bedrock at depth of 77 feet. |
| 26 | - | Jetted | 86 | 2½ | Unconsolidated deposits (beach and dune) | 3.83 | Nov. 9, 1956 | - | - | - | Driller reported "no water below 12 feet". |
| 27 | - | do | 35 | 2½ | do | 3.42 | Nov. 13, 1956 | 60(at depth of 12') 25(at depth of 17') 8(at depth of 22') | - - | - - | Water at 12 feet was highly colored. Water at 22 feet tasted salty. |
| 28 | - | do | 55 | 2½ | do | 7.17 | Nov. 15, 1956 | 7(at depth of 17') 15(at depth of 22') | - | - | |
| 29 | - | do | 20 | 2½ | do | 7.25 | Nov. 19, 1956 | - | - | - | "No good". |
| 30 | - | do | 19 | 2½ | do | 3.66 | Nov. 20, 1956 | 7(at depth of 17') | - | - | Chloride 40 ppm; Odor "Boggy"; Color 40; Iron 4.0 ppm. |
| 31 | - | do | 19 | 2½ | do | 12.25 | Nov. 21, 1956 | - | - | - | "Would not pump". |
| 32 | - | do | 20 | 2½ | do | 6.25 | Nov. 28, 1956 | 15(at depth of 12') | - | - | |
| 33 | - | do | 19 | 2½ | do | 6.17 | Nov. 28, 1956 | 15(at depth of 13') | - | - | |
| 34 | - | do | 19 | 2½ | do | 9.33 | Nov. 25, 1956 | 8(at depth of 13') | - | - | Chloride 39 ppm; Color 14; Iron 0.28 ppm. |
| 35 | - | do | 13.5 | 2½ | do | 9.17 | Nov. 24, 1956 | Pumped for 3 hrs. Yield not given | - | - | First sample: Chloride 102 ppm; Odor sulfurous; Color 70; Iron 0.19 ppm. Second sample(after pumping for one hour) Chloride 90 ppm; Odor 0; Color 180; Iron 0.70 ppm |
| 36 | - | do | 15 | 2½ | do | 10.58 | Nov. 30, 1956 | 8(at depth of 15') | - | - | First sample: Chloride 100 ppm; Odor sulfurous; Color 35; Iron 0.25 ppm. Second sample(after pumping for 30 minutes): Chloride 45 ppm; Odor 0; Color 160; Iron 1.0. |
| 37-48 | - | Driven | 24' to 35' | 2½ | do | - | - | - | - | - | Twelve test borings. |

## Table 2.—Logs of wells and borings in Horseneck Beach,

[redacted]

The terminology used in the logs tabulated below conforms to that of the drillers or others from whom the data were collected, although in places the wording has been rearranged.

### 24

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, yellow, fine . . . . . . . . . . . . . . . . | 20 | 20 |
| Sand, gray, fine . . . . . . . . . . . . . . . . . | 27 | 47 |
| Sand, gray, fine, silty, and clay. . . . . . . | 11 | 58 |
| Sand, gray, coarse, and clay . . . . . . . . . . | 11 | 69 |
| Sand, brown, fine, and gravel and clay (packed tightly) . . . . . . . . . . . . . . . . . . . . | 23 | 92 |
| Refusal . . . . . . . . . . . . . . . . . . . . . | at | 92 |

### 25

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, yellow, fine . . . . . . . . . . . . . . . . | 8 | 8 |
| Sand, gray . . . . . . . . . . . . . . . . . . . . | 37 | 45 |
| Sand, gray, and silt . . . . . . . . . . . . . . . | 7 | 52 |
| Silt, gray, and clay . . . . . . . . . . . . . . . | 4 | 56 |
| Sand, brown, tight, and gravel and sea shells. | 14 | 70 |
| Gravel and brown sand . . . . . . . . . . . . . . | 5 | 75 |
| Ledge (bedrock), broken. . . . . . . . . . . . . | 2 | 77 |
| Rock (bedrock) . . . . . . . . . . . . . . . . . | 70 | 147 |

26

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, yellow, fine . . . . . . . . . . . . . . . . . . | 7 | 7 |
| Sand, gray, fine, silty. . . . . . . . . . . . . . . . | 23 | 30 |
| Sand, gray, fine . . . . . . . . . . . . . . . . . . . | 10 | 40 |
| Sand, gray, fine, silty. . . . . . . . . . . . . . . . | 27 | 67 |
| Clay, gray, and silt . . . . . . . . . . . . . . . . . | 14 | 81 |
| Sand, brown, tight, and gravel and silt. . . . . . | 5 | 86 |
| Refusal . . . . . . . . . . . . . . . . . . . . . . . | at | 86 |

27

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, yellow, fine . . . . . . . . . . . . . . . . . . | 8 | 8 |
| Sand, yellow-gray, fine. . . . . . . . . . . . . . . . | 4 | 12 |
| Sand, gray, fine . . . . . . . . . . . . . . . . . . . | 10 | 22 |
| Sand, gray, fine, tight. . . . . . . . . . . . . . . . | 5 | 27 |
| Sand, gray, fine, tight, silty . . . . . . . . . . . | 8 | 35 |

28

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, yellow, fine . . . . . . . . . . . . . . . . . . | 4 | 4 |
| Sand, brown, fine . . . . . . . . . . . . . . . . . . | 10 | 14 |
| Sand, yellow-gray, fine. . . . . . . . . . . . . . . . | 5 | 19 |
| Sand, gray, fine, and silt . . . . . . . . . . . . . | 23 | 42 |
| Sand, gray, fine, tight. . . . . . . . . . . . . . . . | 13 | 55 |

29

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, yellow, fine . . . . . . . . . . . . . . . . . . | 4 | 4 |
| Sand, yellow-gray, very fine . . . . . . . . . . . . | 6 | 10 |
| Sand, gray, very fine. . . . . . . . . . . . . . . . . | 10 | 20 |

30

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, yellow, fine . . . . . . . . . . . . . . . . . . | 7 | 7 |
| Sand, yellow-gray, fine. . . . . . . . . . . . . . . | 10 | 17 |
| Sand, gray, fine, tight. . . . . . . . . . . . . . . | 2 | 19 |

31

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, yellow, fine . . . . . . . . . . . . . . . . . . | 14 | 14 |
| Sand, yellow, gray, fine . . . . . . . . . . . . . . | 4 | 18 |
| Sand, gray, fine, tight. . . . . . . . . . . . . . . | 1 | 19 |

32

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, yellow, fine . . . . . . . . . . . . . . . . . . | 17 | 17 |
| Sand, gray, fine, tight. . . . . . . . . . . . . . . | 3 | 20 |

33

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, yellow, fine . . . . . . . . . . . . . . . . . . | 14 | 14 |
| Sand, gray, fine . . . . . . . . . . . . . . . . . . . | 5 | 19 |

34

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, yellow, fine . . . . . . . . . . . . . . . . . . | 14 | 14 |
| Sand, gray, fine, tight. . . . . . . . . . . . . . . | 5 | 19 |

35

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, yellow, fine . . . . . . . . . . . . . . . . | 13.5 | 13.5 |

36

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, yellow, fine . . . . . . . . . . . . . . . . . . | 15 | 15 |

39

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, yellow, fine . . . . . . . . . . . . . . . . . . | 21 | 21 |
| Sand, gray, fine . . . . . . . . . . . . . . . . . . | 4 | 25 |

43

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, yellow, fine . . . . . . . . . . . . . . . . . . | 12 | 12 |
| Sand, white, fine . . . . . . . . . . . . . . . . . . | 5 | 17 |
| Sand, yellow-gray, fine. . . . . . . . . . . . . . . . | 3 | 20 |
| Sand, gray, fine . . . . . . . . . . . . . . . . . . . | 5 | 25 |

45

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, brown, fine . . . . . . . . . . . . . . . . . . | 14 | 14 |
| Sand, yellow, fine. . . . . . . . . . . . . . . . . . | 10 | 24 |
| Sand, gray, fine . . . . . . . . . . . . . . . . . . | 4 | 28 |

47

| | Thickness (Feet) | Depth (Feet) |
|---|---|---|
| Sand, brown, fine . . . . . . . . . . . . . . . . . . | 15 | 15 |
| Sand, yellow, fine. . . . . . . . . . . . . . . . . . | 17 | 32 |
| Sand, gray, fine . . . . . . . . . . . . . . . . . . | 3 | 35 |