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STATE OF DELAWARE

DELAWARE GEOLOGICAL SURVEY

REPORT OF INVESTIGATIONS NO. 8

EVALUATION OF THE WATER RESOURCES OF DELAWARE

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March, 1966

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Prepared for the

Delaware State Planning Office

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FOREWORD

The great importance of water resources to the growth and continued well-being of the State of Delaware has been emphasized in recent years by rapidly increasing demands coupled with a period of below average rainfall. In response to the need of the Delaware State Planning Office for a definitive evaluation of Delaware's water resources, this report has been prepared by the Delaware Geological Survey, principally as a contribution to the comprehensive plan of the State. We acknowledge the foresight of Mr. John A. Bivens, Jr., Director of the State Planning Office, and the support which has been received from that office.

The information contained herein is a direct outgrowth of fifteen years of study of the hydrology and geology of the State by the Delaware Geological Survey. In the course of that effort technical bulletins and reports of investigations have been prepared which treat the geology and hydrology of both the entire State and specific areas within it. Consultation has been provided to many municipalities, industries, state agencies, and individuals. This evaluation of water resources draws upon the Survey's accumulated knowledge and experience to provide a statewide summary which is directly applicable to the problems of growth and planning. It is a guide to the relatively water-rich and water-poor areas and to the difficulties which may be anticipated in various regions. With such information in hand, we may prepare for the challenges of water supply which will come in the future and we may focus with increasing accuracy upon the detailed and specific problems of those challenges. We are pleased to note that several of Delaware's alert communities have already improved their water supply capabilities since the text of this report was finalized.

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INTRODUCTION[1]

As in all other rapidly developing regions, the principal water problem of Delaware might be stated simply as one of providing an adequate supply of high quality water as the State's economy continues to expand. The broad statement is an almost meaningless platitude, however, because the terms "inadequate" and "high quality" must first be defined, and they do not have specific meanings except in specific cases.

A water resource may be adequate for domestic and municipal use, but totally inadequate to supply huge industries or irrigation systems. It may be of good quality for irrigation or industrial cooling, but unpotable for human use. Consequently the statement of the problem must be expanded to cover the proposed uses, and these cannot be easily anticipated nor can they always be controlled unless legislation is enacted.

A more realistic approach would be to rephrase the problem in terms of knowledge of the water resources. Thus, the problem becomes one of understanding thoroughly the behavior of the resource under all sorts of assumed conditions so that the proper steps can be taken to manage it wisely. In this sense, the state or county would perhaps zone lands; limit water use; specify locations, depths, and yields of wells; insist on certain waste-treatment practices; undertake recharging of aquifers and damming of streams; specify the uses to which water should be put; and cooperate with neighboring states in the development of interstate waters.

Problems such as declines of ground-water levels, drying up of streams, encroachment of salt water, pollution, depletion of aquifers, etc., might actually be permitted under such a management scheme, because their bad effects would be more than balanced by the socio-economic benefits that would accrue to the state. Thus, a particular stream might be allowed to become polluted as long as nearby streams were maintained in a pure condition as sources of good water. West Germany has established exactly such a program, with great success, in the heavily industrialized Ruhr, where one river serves as an open sewer so that others are kept fresh for both water supply and recreation. Similarly, salt water might be allowed to contaminate some shoreline wells because it would permit heavier drafts of ground water in inland areas.

Another way of stating the case is to say that none of the so-called troublesome effects listed in the preceding paragraph is necessarily a problem, as the word is customarily understood. Ground-water levels must be lowered as a result of any amount of pumping; stream quality has to be impaired wherever wastes, treated or untreated, are dumped into stream channels; and salty water will begin to encroach wherever ground-water heads are reduced at all. It is only when the economic damage resulting from these causes becomes greater than the economic benefits that a true problem arises. In one sense it is like pumping oil from the earth – where every drop extracted does irreparable damage to the quantity of the resource, although everyone is in full accord with the procedure because of the immense benefits resulting therefrom.

Water, of course, is not petroleum. When a water resource is depleted or destroyed, significant harm usually follows, although one can point to cities like New York and Los Angeles that simply extend their water-collection facilities as rapidly as they exhaust local sources; the only real problem to these cities is a financial one.

In most instances where a water resource has suffered quantity or quality damage, it is customary for public officials to demand action to halt the abuse. Generally, they make their pronouncements in the absence of any real knowledge of the behavior of the resource. And all too often, their proposed solutions cause more economic harm to the community than if they had permitted the damage to continue but had taken steps to contain it or to reorganize the pattern of water use and waste disposal.

Every so-called "water problem" can only be evaluated in relation to the total picture of water-resource and economic development. Ideally, Delaware should have a model set of working drawings depicting how the hydrologic system works under natural conditions and how it is modified when man taps it for water sup-

[1]The introduction to this report is based on an unpublished report by the Delaware Geological Survey.

ply. Each new withdrawal should be considered in the light of its benefit to Delaware as the economy continues to expand. In a wisely managed development program, some of the traditional "abuses" of water resources may be tolerated, or in fact may actually be instigated to achieve the purpose of the program. This is a complex matter and is not easy to define what constitutes a true danger and what is simply a necessary result of normal water-development procedures.

As will be pointed out, water carried away to the sea in sewers constitutes a net draft on Delaware's available water resources. Considered solely in this light, sewer systems help to deplete Delaware's water supplies. But, there are realistic reasons why a sanitary sewer system is desirable, particularly where it eliminates pollution of streams or ground-water bodies and provides a higher degree of health protection. Moreover, economics is also involved in the problem of waste disposal. It may be far cheaper, for example, for a community near the sea to simply dump its wastes overboard without treatment than it would be to construct a costly treatment facility so that the water could be returned in a potable condition to the fresh-water hydrologic system.

Delaware, taken as a whole, has more fresh water now than it can conceivably use in the near future. One might argue that wasting some of this water by dumping it into the sea through sewer system constitutes a wise management procedure, for the other alternative is to try to conserve every single drop, perhaps at very high cost, in a misguided notion that no waste of water is ever to be permitted. Others might argue, however, that any scheme allowing water to be wasted is short-sighted and that some day the citizens of the state will pay the penalty for today's mismanagement. An obvious reply to the latter argument is that technology will help to solve tomorrow's water problems in ways that we cannot anticipate now. And, if worse comes to worse, there would be no real difficulty tomorrow in providing complete treatment for sewage and returning it directly into the hydrologic system instead of carrying it away to the sea in sewers.

Similar arguments can be raised regarding the use and management of ground-water resources. If growing net pumpage causes a steady decline of ground-water levels in an area, and if ultimately this decline begins to wreak economic havoc by drying up wells or by causing salt-water encroachment, there is absolutely no reason why the used water cannot be recharged directly into the aquifers to halt the process of depletion. Even sewage wastes, properly treated, could be used in such a scheme. The real decision to be made in Delaware is more a matter of timing than of technique. In that sense it might be more sensible to simply adopt an empirical approach and to let nature take its course, keeping a watchful eye on developments and being prepared with a set of procedures to overcome any serious problems that may arise.

Water resources cannot be considered out of context with all the other social and economic factors which are at play in a given region. In some parts of the country, efforts have been made to apportion water resources in much the same way that petroleum is regulated in oil-producing states. There is something very satisfying to many public officials in this approach, for it allows them to draw a checkerboard grid on the map and to put in assumed numbers on each little square to represent the maximum allowable withdrawal rate. Unfortunately, management schemes of this kind seldom take into account the variability of the water resource or the interrelation of surface waters and ground waters. For example, no particular square mile of land in Delaware can be assigned a specific number to indicate the quantity of water available within its borders. In theory, such a number could probably be computed, to represent the absolute maximum amount of water that could be obtained from wells and surface-water bodies within that particular square-mile area. However, this theoretical number would not be a simple proportion of the total water available in Delaware nor would it be based on the rainfall within the square-mile tract. Actually, it would be a rather large number, simply because heavy pumping would induce water to move in from much more distant regions, so that in effect the hypothetical square mile would be capturing recharge from a tremendously large region. Thus, even though large volumes of water could be withdrawn within a limited area, it would be at the expense of water development in the surrounding regions.

This report will describe the general hydrologic setting of Delaware, the present water use and proposed alternate schemes for future water development based upon the above philosophy. Proposals will be based on technical and socio-economic considerations which will be stated.

HYDROLOGIC AND GEOLOGIC SETTING

The form and constitution of the land surface, as well as the structure and composition of the subsurface, provides the framework for the hydrology of a region. This is the relationship between hydrology and geology. Delaware encompasses two distinct geologic provinces, each with its own characteristics and complex subdivisions. The geology of Delaware is treated in various publications of the Delaware Geological Survey and a number of articles in technical journals which are reviewed in Delaware Geological Survey Bulletin 9. Many papers are cited in the references to the present report.

The two geologic subdivisions of which Delaware is a part are the Appalachian Piedmont Province and the Atlantic Coastal Plain Province. Only a fraction of each is included in the boundaries of Delaware; the Piedmont extends along the eastern flank of the Appalachian Mountains from New Jersey to Alabama, and the Atlantic Coastal Plain of Delaware is a small emergent portion of a great mass of sedimentary rock known as the Atlantic Continental Shelf, which stretches from Florida to Newfoundland. The rocks of the Piedmont are very old, hard, crystalline rocks, whereas those of the Coastal Plain are younger, largely unconsolidated sediments. A seaward extension of the ancient Piedmont rocks forms a platform, or "basement" upon which the thick wedge of Coastal Plain sediment is constructed. The layers or beds of rock in the Coastal Plain are arranged like the shingles of a roof, offlapping seaward so that the older units are exposed near the Piedmont and are buried under successively younger rocks to the southeast. A layer of ice-age sand and gravel forms an almost complete cover over this entire structure.

The Interrelationship Of Water Resources

Water resources are usually classified under separate headings: surface water and ground water. This viewpoint, however, is somewhat arbitrary because both forms are closely interrelated, and are part of the same hydrologic system. Much of the water in streams and ponds is derived from effluent groundwater seepage. For the same reason, the removal by man of ground water from storage will not only cause the lowering of the water levels but also affect surface flow in nearby streams.

To study the water resources of Delaware properly, an attempt should be made to evaluate the hydrologic system as completely as possible. An evaluation, therefore, of the water resources in an area would require some understanding of:

(1) the interrelationships among the different elements of the hydrologic system;

(2) the cause and effect relationships among the natural and man-made forces exerted on this hydrologic system.

The three main elements which have to be determined in a hydrologic system are the input, the output, and the storage capacity. Under natural conditions, where water is not being pumped for consumptive purposes, the input is equal to the output, over long periods of time.

The relationships between the different components of the hydrologic system may also be expressed by the hydrologic budget equation:

INPUT = OUTPUT + STORAGE

or

Precipitation = Evapotranspiration + Stream Flow + Ground Water Flow + Change in Surface Water Storage + Change in Ground Water Storage

Precipitation falls upon land and is dispersed in several ways. A considerable part of the water is returned to the atmosphere again by evapotranspiration. Some of the water will enter the soil zone and eventually reach the ground water reservoir. This water, slowly moving through the rock, will after considerable time reappear either as surface water or as vapor released to the atmosphere. Another part of the water that reaches the land surface will form direct surface runoff.

Large scale development of the water resources of Delaware will exert a hydrologic stress on the natural system, previously in a state of dynamic equilibrium. Consumptive use of water has, in general, to be balanced by increased input, decreased output or loss of storage.

In terms of components of the hydrologic system and the forces exerted on that system, the water problem in Delaware concerns:

(1) the removal of ground water from storage
(2) the retention of water on the land surface, streams and reservoirs
(3) the natural and artificial recharge to the ground water and to the surface water systems
(4) the deterioration of water quality by waste and sewage disposal or contamination by sea water.

It should be clearly understood that both surface and underground water move freely across the state's boundaries. Development and management of Delaware's water resources cannot be carried on without regard to water developments in neighboring states. The development of water resources causing lowering of the ground water levels, diminution of surface flow or deterioration of water quality not only affects Delaware's water supplies but those of the neighboring states as well.

Surface Water Resources

Streams in drainage basins whose discharges mainly originate out of the state are the present and principal future sources of surface water for northern Delaware. Drainage basins whose flows mainly originate within the state but which discharge into Maryland, and drainage basins that are entirely contained within the state are of minor importance at the present time.

The Christina River is the major drainage basin in northern Delaware, but only about 24% of the total drainage basin area is located within the State of Delaware. The four sub-basins of the Christina River are the Brandywine Creek, Red Clay Creek, White Clay Creek, and Christina River.

In addition to the Christina River, Naaman Creek, located in northeastern New Castle County, derives its drainage from both Delaware and Pennsylvania. Table 1 lists the discharges of the drainage basins deriving part of their flow from out of state.

Table 1

Discharges of Streams which Partly Originate Out of State (in mgd)

Stream	Total Flow	Out of State Flow	Flow originating in Delaware
Naaman Creek	10	5	5
Brandywine Creek	236	222	14
Red Clay Creek	40	25	15
White Clay Creek	77	46	31
Christina River	29	8	21
Total	392	306	86

The water which flows in these streams is both derived from surface runoff and supplied by the ground water reservoir. As a general rule we may expect that streams flowing through areas of moderate relief, underlain by relatively poorly permeable rock types, derive much of their flow from overland runoff. Ground water is the main supply for streams in areas of low relief, underlain by relatively permeable materials. However, the total amount of flow from any drainage basin will directly depend on the amount made available by the precipitation-evaporation balance. As a general rule this amounts to 1 mgd per sq. mi. of drainage basin.

The larger streams in northern New Castle County, particularly those whose discharges originate out of the state, mainly flow over the relatively impermeable rocks of the Piedmont area. It is therefore surprising that in a recent study in Brandywine Creek in Pennsylvania it was found that about two thirds of the stream's discharge, an unusually high percentage, is apparently derived from ground water base flow. This percentage is probably even higher by the time the stream reaches the Coastal Plain.

The nature of surface water flow is such that commonly the frequency of discharge of the stream is inappropriate for man's needs. Sometimes the stream discharge is too low (late summer), but at other times of the year (winter and early spring), usually when least desirable, the flow is quite large. The result has been that attempts have been made to damp large scale fluctuations by building dams to provide additional storage space. Raw water obtained from surface reservoirs is presently used after treatment to supply industrial and municipal facilities, particularly in the Piedmont. The existing reservoirs in the Piedmont area occupy only a small part of the potential storage space available.

The Delaware River, which receives practically all the surface and subsurface water draining northern Delaware, is saline along the entire eastern boundary of the state. This low-quality water can only be used for certain industrial uses and is not at present economically adaptable as a fresh water source for municipal use.

The streams entering the Delaware River estuary are subject to cyclic tidal fluctuations. During high tides saline water moves inland contaminating shallow-water aquifers in the coastal areas.

Ground Water Resources

From a ground water point of view, Delaware may be divided into two distinct geologic provinces mentioned above. The first is the Piedmont region, which is north of a line passing through Wilmington and Newark, and the second is the Coastal Plain province which constitutes the major portion of the state.

The flow of ground water in the underground segment of the hydrologic system is principally controlled by the nature of the rocks underlying the land surface. The most important hydrologic properties of the water-bearing rocks are the permeability, the ability to pass water through, and the porosity, the amount of water that may be recovered from pore space of the rock.

The Piedmont Province covers only 6% of the State of Delaware, but almost 40% of the area north of the Chesapeake and Delaware Canal. The Piedmont region is underlain by hard, poorly permeable, crystalline rocks, which are covered in most places by clayey soils. Ground water is not abundant in these hard materials, and individual wells seldom yield more than a few gallons per minute. Local occurrences of gravel and sand deposits on top of the crystalline rocks are the only exceptions.

The Coastal Plain consists of unconsolidated beds of gravel, sand, silt, and clay, forming a wedge-shaped mass of sediments. The wedge of sediment tapers to a feather edge along the line between Wilmington and Newark where the Coastal Plain laps up on the Piedmont. To the southeast the wedge thickens regularly until it is about 8500 feet thick under Fenwick Island.

This simplified picture of the arrangement of the units of rock in Delaware provides a framework in which the properties of individual units may be considered. The geologist identifies rock units by their time of formation (age) and rock type (lithology). The concept of time provides the means of placing the rocks in a sequence so as to help understand their relationships. The physical properties of the rock, including hydrologic properties, are largely dependent on the rock type and distinctive rocks are given names taken from the geographic locality in which they are best developed and originally described. These formally named units are formations. Thus, we may, in Delaware, refer to the Potomac Formation of Cretaceous Age. The Potomac is the oldest of our Coastal Plain units and is at the base of the mass of sediments forming the Coastal Plain. It is a distinctive type of rock consisting of beds of variegated clay alternating with beds of sand, and may be studied where it was originally described in the valley of the Potomac River. Other units of local extent, and of interest in this report, may be informally designated as aquifers.

Throughout this report it will be necessary to refer to these divisions of rock underlying Delaware. Table 2 provides a list of the units, placed in order of age. Not all of these units are present at any one locality; rather, they are present in various combinations in the vertical sections which are penetrated by wells at different localities throughout Delaware. The geologist, on the basis of study of the information from the relatively few control points provided by existing wells can predict the nature of the materials to be encountered in wells at any locality in the State. Much of our ability to produce water economically rests on the continuing refinement of the accuracy of these predictions.

Under the Coastal Plain of Delaware several aquifers of some extent are recognized. These aquifers are underlined in Table 2. Very few records of deep wells are available, and it is not known with certainty at what depth salt water occurs beneath the surface. These aquifers cannot entirely be considered as separate hydrologic units. The various aquifers are to a great extent hydraulically inter-connected, and comparatively free interchange of water takes place between aquifers. Thus, if water levels are artificially lowered by pumping, thereby decreasing the head or potential in one aquifer, water will leak into that aquifer through overlying and underlying beds, from water-bearing rocks with a relatively higher hydraulic potential. Elsewhere on the Atlantic Coastal Plain, studies have shown that deep artesian aquifers may be replenished almost entirely through overlying beds.

Pleistocene channel deposits, covered only by a relatively thin layer of Recent material, constitute some of the most prolific aquifers in the Coastal Plain of Delaware. These channel fillings of water-bearing gravels and sands are not as broad and extensive as the deeper lying artesian aquifers. However, their high water yields and their occurrence at shallow depths, make them attractive as a source for ground water.

The geological occurrence of the water-bearing rocks, especially in northern Delaware, is not always favorable to the development of ground water supplies where the community finds it most desirable. Factors other than where the most abundant water supplies are available often play a more important role in the planning of community and industrial developments. Adequate geological knowledge of the aquifers in Delaware is necessary to develop the ground water supplies as an integrated part of community planning.

Table 2

Geologic Units Found in Delaware

Age	Name	Rock Type	Occurrence
Pleistocene	Columbia Gp.	Sand with gravel; also silt in south	Continuous sheet over Coastal Plain. Thickness varies.
Pliocene	Bryn Mawr Fm.	Sand and gravel	Thin cap on Piedmont hills north of Wilmington.
Miocene	Chesapeake Gp.	Sand alternating with silt	Kent and Sussex Co.
	Sands include:		
	Pokomoke Aquifer	Sand	SE Sussex Co.
	Manokin Aquifer	Sand	SE Sussex Co.
	Frederica Aquifer	Sand	S Kent, N Sussex Co.
	Cheswold Aquifer	Sand	Central and S Kent, N Sussex Co.
Eocene	Piney Point Fm.	Greensand	Central and S Kent Co. N Sussex Co. (?)
	Unit C	Silt	S New Castle and N Kent Co.
	Unit A	Silt and clay	S Kent and Sussex Co.
Paleocene	Rancocas Fm.	Greensand	S New Castle, N Kent Co.
	Unit B	Silt	S New Castle, N Kent Co.
Upper Cretaceous	Redbank Fm.	Sand	Central New Castle Co.
	Mount Laurel-Navesink Fm.	Greensand and silt	Central New Castle Co.
	Monmouth Fm.	Greensand and silt	S New Castle Co. and Kent Co.
	Wenonah Fm.	Fine sand	Central New Castle Co.
	Merchantville Fm.	Fine sand and silt	Central New Castle Co.
	Matawan Fm.	Fine sand; silt and clay	S New Castle Co. and Kent Co.
	Magothy Fm.	Sand and silt interbedded	Central and S New Castle Co; Kent Co.
Lower Cretaceous	Potomac Fm.	Variegated clay and sand, interbedded	Throughout Coastal Plain
Paleozoic	Wilmington Complex	Gneiss, amphibolite, granite, gabbro	Wilmington and northern environs; Newark area.
Lower Paleozoic	Wissahickon Schist	Schist, migmatite	NW New Castle Co.
	Cockeysville Marble	Marble	Parts of NW New Castle Co.

STATEWIDE WATER RESOURCES EVALUATION

The purpose of this section is to portray our present (July 1965) evaluation of the water resources of Delaware within limits of available data. Such an evaluation can only be meaningful, however, if the criteria on which it is based are clearly defined. Thus, this section consists of two main parts: (1) a text which includes definitions and a brief explanation of the water resources of Delaware and, a map, which illustrates the text, Figure 1.

Delaware has been divided into three major types of areas: (1) Areas of impending problems, (2) Caution areas, and (3) Areas without known problems. (1) and (2) are subdivided into three sub-categories each to indicate the types of problems that occur.

The boundary of the drainage basin of the Delaware River and Bay in Delaware is shown on the map by a heavy dashed line. Because of its location, the area to the east of the divide line is subject to the authority and regulations of the Delaware River Basin Commission. The Commission's purpose is to promote and coordinate policies for water conservation, use and management in the basin.

Definitions

Areas of Impending Problems

a. Quantity. Areas where maximum monthly water demand approximates the maximum available supply.

   Areas fall in this category if there is evidence that for any month of the year the maximum water demand approximates or exceeds the maximum available supply known to be present within that particular area. Practically all water supply systems experience temporary shortages during periods of peak demand. Only those areas are designated as having impending problems where for at least one month of the year the source of water supply is incapable of supplying all demands.

b. Quality. Areas where the quality of the water is approaching those tolerable limits for potable use set by the U. S. Public Health Service. These standards apply to the source of water supply as it occurs in nature before the water has undergone any form of treatment.

c. Inadequate water supply system. Areas where maximum monthly water utilization approaches the capacity of the water supply system. Water supply systems generally comprise:

   (1) collection works, water well systems, pumping installations;

   (2) water treatment plants;

   (3) water storage facilities;

   (4) transportation works (water mains connecting the collection works with the distribution system);

   (5) distribution works, system of conduits that conveys water to the points of use from the terminus of the supply conduit.

Caution Areas

a. Quantity less than 0.5 million gallons per day per square mile or marginal supply. Areas which, on the basis of present geologic-hydrologic knowledge are incapable of reliably producing 0.5 mgd/sq. mi.

   Areas fall in this category if the combined available surface-water and ground-water resources are insufficient to produce water at a rate of 0.5 mgd/sq. mi. without eventually depleting the source or significantly interfering with already existing water-supply developments.

b. Quality. Areas, which on the basis of present geologic-hydrologic knowledge, will present quality problems in terms of U.S. Public Health Service standards, if additional water development occurs.

c. Inadequate water supply system. Areas where additional water development may cause overloading of the water supply system.

Areas Without Known Problems

a. 0.5 mgd/sq. mi. available. Areas where available geologic-hydrologic information indicates that water supplies of 0.5 mgd/sq. mi. of satisfactory quality can be developed.

b. Municipal or water company systems, either municipal or private, presently producing below their designed capacity.

In the definitions the figure of 0.5 mgd/sq. mi. is used, and an explanation for the choice of this figure is in order.

Under natural conditions, an estimated 50 percent of precipitation seeps into the ground to replenish ground-water reservoirs. This is roughly equivalent to one million gallons daily on each square mile of land surface. After traveling some distance through the underground deposits, this water is discharged through evaporation, transpiration, submarine leakage along the coast, and streamflow.

It would be physically impossible to recover the entire 1 million gallons per day per square mile. But, depending on the nature of the ground-water reservoirs or the surface-storage sites in a given area, a significant proportion of the available water may be recovered. In areas underlain by permeable formations that can yield most of the water they hold, it is feasible to withdraw about 0.5 mgd/sq. mi. with proper engineering procedures. These are the water-rich areas. In contrast, areas underlain by formations that do not yield water readily will be areas where it is difficult to withdraw 0.5 mgd/sq. mi.

Along with the discussion of the definitions a few comments on water quality are appropriate. The term "quality" as applied to water includes its combined physical, chemical, and biological characteristics. In nature, water is never found in its pure state. Water quality is a dominant factor in determining the ability of any source of supply to satisfy the requirements for which it is to be used. The value of a water supply for a specific use depends on, first, its water quality requirements and, second, the feasibility and costs of treating the raw water to meet these requirements.

Water supplies for domestic and municipal purposes should meet certain physical, chemical, and bacterial criteria to render the water safe for ingestion and sanitary purposes as well as to make it wholesome and palatable. The general water quality requirements of most municipal supplies in the United States are related to the U. S. Public Health Drinking Water Standards of 1962 which will be used in this report as a basis of determining the water quality in the State. The maximum chemical requirements of the 1962 Drinking Water Standards and are divided into mandatory and recommended criteria and are listed in Table 3.

Table 3

1962 Drinking Water Standards
(Maximum Permissible Amounts)

Mandatory Chemical	ppm	Recommended Chemical	ppm
Arsenic	.05	Iron	.3
Fluoride	3.4*	Manganese	.05
Lead	.05	Nitrate	45
Selenium	.01	Detergent (ABS)	.5
Silver	.05	Copper	1.0
Barium	1.0	Magnesium	50
Cadmium	.01	Zinc	5
Chromium	.05	Chloride	250
Cyanide	.2	Sulfate	250
		Chloroform (soluble extract)	.2
		Phenol	.001
		Total dissolved solids	500

* subject to water temperature

Explanation of the Water Resources Evaluation Map of Delaware

Delaware North of the Chesapeake and Delaware Canal

The Piedmont, the northern six percent of Delaware, differs geologically from the remainder of the State. It is underlain by rocks having hydrologic properties different from those of the rocks of the Coastal Plain. Surface water is the principal source of water in this region and the water resources can be considered highly adequate at present along any of the major streams. However, problems increase with distance from the major streams or with distance from the Coastal Plain to the south. Thus, this region of Delaware is characterized by abundant water along the stream courses and by considerably less water available locally in the interstream areas. The solution has been the construction of water supply systems.

This portion of the map has a two-fold division: (1) those areas that obtain water from municipal or private water supply systems; the water is transported from the major streams or from the Coastal Plain and distributed to the users; and (2) those areas which are not reached by water supply systems and which must rely on the relatively poor local supplies of ground water. These latter areas must be considered as "caution" areas with respect to the quantity that they are capable of supplying. In addition, the proximity of a potential user to a water supply system does not remove the caution designation. A system which is quite adequate to meet its present demands may not have the capacity to supply a greater area. Therefore, any potential water user in this area must proceed with caution and not simply assume that all problems can be immediately solved by construction of a pipeline.

Proceeding southward, the geology and hydrology change as the Coastal Plain is encountered. Sedimentary formations are found and ground water becomes the principal source of supply. However, this region of the Coastal Plain is not underlain by highly productive sands. The exceptions are the presence of linear belts of thick surficial sands or channel sands. The occurrence of abundant water in these ancient stream courses presents a situation quite analogous to the situation farther north: the water is concentrated in narrow belts and must be transported and distributed to the areas between those belts. As expected, the water supply system is the answer and the municipal and private water companies have extended into the Coastal Plain.

Owing to the uncertainty of obtaining 0.5 mgd/sq. mi. from the deeper sands and the unknown locations of the channel sands, the remainder of Delaware north of the Chesapeake and Delaware Canal must be considered a caution area with regard to quantity. Likewise, the solution in those areas of the Coastal Plain near a water supply system may be to connect with the system. However, as stated above, the capacity of the system may not be sufficient to allow it to expand and any potential user should exercise caution when considering additional development.

More specifically, within northern Delaware, there are three other problems which must be considered. First, there are three municipalities with similar situations. Newark, Newport, and New Castle have their own municipal systems and all obtain their water from beneath their immediate areas. (Newark and Newport have emergency connections with private water companies.) All three are reaching the point where their proven supplies are becoming inadequate; thus, there is an impending problem in terms of quantity. Fortunately, all three are planning ahead and will shortly initiate steps to alleviate their problems.

Secondly, there is a strip of land along the Delaware Bay and along the Chesapeake and Delaware Canal where the danger of saline-water encroachment is ever present and, therefore, caution must be exercised with any new or continued development. To compound the problem, part of New Castle's existing supply is virtually useless because of high concentrations of iron in the surficial sands near the Delaware River.

Finally, there is a special situation at Delaware City. The area is underlain by water-producing formations but these are presently being developed by the Tidewater Oil Company. Any further development by Delaware City will be affected by this situation and, thus, caution is necessary.

Delaware South of the Chesapeake and Delaware Canal (exclusive of the coastal area)

A large caution area is present in the region south of the Chesapeake and Delaware Canal. Within this area water is available from several aquifers, but these units cannot reliably produce 0.5 mgd/sq. mi. and the area is therefore categorized as a caution area by reason of quantity. This is a geologically-controlled phenomenon and it is essentially a continuation of the situation existing north of the Canal. In this area, as in other portions of northern Delaware, thick surficial sands occur in very restricted channels. These channel sands supply very large quantities of water locally but their detection requires extensive exploration.

Because of the ever present possibility of inducing contamination into aquifers intercepted by bodies of saline water, additional caution must be exercised in the development of water resources in the area immediately adjacent to the Chesapeake and Delaware Canal.

Farther south, an additional aquifer and the known occurrence of some surficial channel sands indicate improved availability of water. This is the region in which Smyrna and Townsend are located.

Special note should be made of two proposed industrial sites. The first of these is southeast of St. Georges and represents the area proposed for industrial development by the Union Carbide Corporation, and the other located on Thoroughfare Neck, is the site of the proposed Shell Oil Company refinery. Present knowledge indicates that the required supplies are difficult to develop; therefore, once the necessary systems are constructed it is anticipated that these locations will become impending quantity and quality problem areas.

A belt across the State from the vicinity of Cheswold to the City of Dover is indicated as an area where the development of quantities of 0.5 mgd/sq. mi. must be approached with caution. This is a geologically-controlled belt in which one of the northern aquifers becomes unproductive and the older units occur at rather great depths and are suspected of containing saline water. The choice of aquifers is thereby limited. The attempts of the International Latex Corporation to develop a moderately large water supply system at their Cheswold facility may be considered indicative of the difficulty of producing large quantities of water elsewhere in this belt.

Most of the southern half of Kent County and almost all of Sussex County are indicated as relatively water-rich. The northern limit of this area is denoted by the appearance of a thick water-bearing formation which then becomes a major aquifer at Dover. This is reinforced by the addition of another shallower aquifer farther south. In addition, the surficial sands increase in thickness and consistency toward the south and become the major aquifer of Sussex County.

This very favorable situation is interrupted by the presence, in certain areas, of quality problems . These arise, in the inland areas, from the sometimes high iron content of the abundant waters of the surficial sands. Many isolated occurrences of high-iron water have been reported, particularly in the southeastern part of Sussex County. There can be no doubt that this is a considerable problem, but it is of a different magnitude than the lack of sufficient quantity of water or the presence of saline water.

The distribution systems of Dover, Camden-Wyoming, Milford, Seaford, Laurel, and Georgetown will require caution in additional development. The towns are enclosed in the relatively water rich areas and no severe problems are anticipated; however, the towns, and therefore water supply systems, are approaching a size where they deserve attention and planning for future growth. Dover, particularly, has been exercising such planning in recent years with good results.

In addition to its water supply system problem, the City of Milford must also exercise caution in development as, within the boundaries of the City and surrounding area east of the City, the available quantity of water from shallow aquifers is limited. This judgment is based upon the information available due to the concentration of wells within the City. It may also be noted that Milford's municipal system does not serve all of the water users in the City; many small supplies are derived from private wells.

A difficulty in the evaluation of small municipal water supply systems is that records are almost invariably inadequate. Systems are often marginal but because no critical demands are made upon them, the situation may be tolerated for many years. The smaller communities in Delaware which have municipal systems may prudently be regarded as caution areas because such a system represents a point of concentrated pumpage and, as such, should be carefully planned. Towns currently lacking municipal water supplies also lack the problems associated with them, except that with growth, the problem of developing a system becomes imminent. These generalities may be applied to the smaller communities which are not otherwise characterized on the map.

Any less than perfect rating of a municipal supply must not be considered as a condemnation of that city. It should be noted that the systems which are so designated are near water-rich areas and that geologic conditions are generally favorable; the problems are essentially ''mechanical'' and may be solved by judicious expenditures.

The Coastal Area South of the Chesapeake and Delaware Canal

For the purpose of this report the coastal area of the State of Delaware is defined as the area adjacent to surface water bodies containing saline water. The area adjacent to the Delaware Bay is characterized by extensive low-lying salt marshes extending inland along tidal streams. They are separated by relatively narrow projections of land called necks; where these necks reach the shore beaches are formed. Along the Atlantic Ocean, the coast line consists of sandbars and shorelines of the barrier beach type with marshes and bays covering a large area behind the beach.

The extent of saline water in the tidal streams is variable and depends on the tidal action and stream discharge. The maximum inland extent of saline water in the tidal streams coincides with high tides and periods of low flow. It is therefore difficult to precisely draw the boundaries of the coastal area.

In the coastal area of Delaware shallow unconfined aquifers are exposed to bodies of saline water. For this reason water supply development in the coastal region should be approached with caution. Wherever salinity, and in some cases also the presence of iron, has interfered with the development of water supply, the designation as an area of impending problems is more appropriate.

Because of the variable nature of the geological conditions and the differences in the stage of economic development of the different parts of the coastal region, a brief discussion is included.

The area of New Castle County immediately south of the Chesapeake and Delaware Canal is underlain by geological formations unable to reliably yield 0.5 mgd/sq. mi.. A similar situation prevails in a belt across Kent County roughly situated between the Town of Cheswold and the City of Dover.

In Sussex County surficial sands of good water-bearing properties are in general present. However, where large scale development of ground water has taken place close to the ocean and inland bays, saline-water encroachment has been detected. At Lewes and Rehoboth Beach this situation has been remedied

WATER RESOURCES EVALUATION MAP OF DELAWARE

PREPARED BY

DELAWARE STATE PLANNING OFFICE

AND

DELAWARE GEOLOGICAL SURVEY

MARCH, 1966

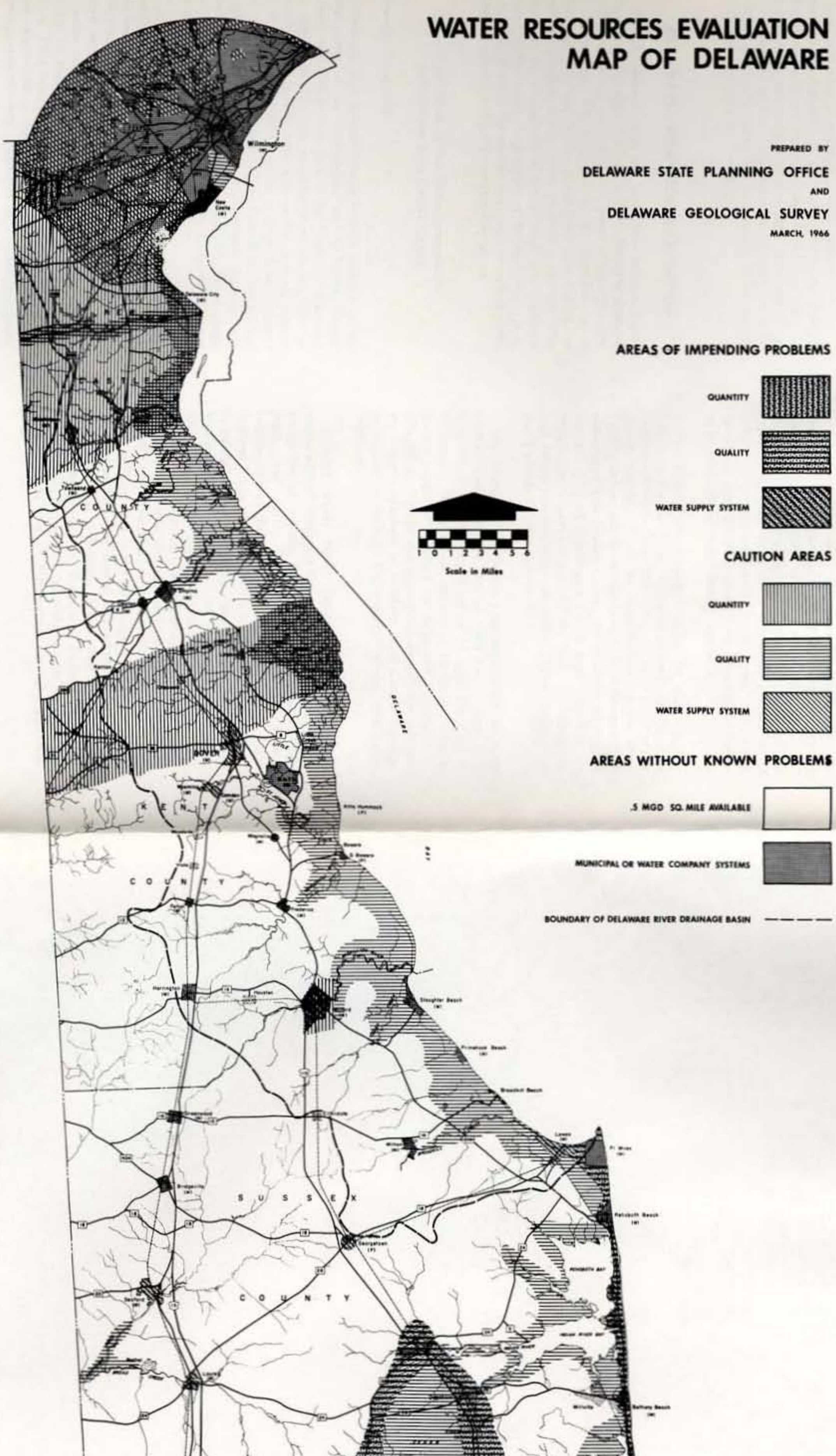


FIGURE 1

by relocating the sources of water supply farther inland at a safe distance from the areas where quality remains an impending problem.

It may be added that the Town of Lewes is having some difficulty in supplying peak demand because of the limited capacity of its water mains. At Bethany Beach the source of water supply within the town limits appears adequate within respect to quantity but the capacity of the water treatment facility is insufficient to handle the influx of summer resort visitors especially at holiday weekends.

AREA WATER RESOURCES EVALUATION

Specific areas within the state have been selected for a more detailed study. These areas were delineated because: (1) they represent areas of rapid growth, (2) a potential danger exists for the deterioration of water quality, and (3) the areas were depicted as impending problem areas in the preceding section. The areas to be discussed in the section are: Northern New Castle County, Smyrna-Dover, Milford-Harrington, Laurel-Seaford, Millsboro-Selbyville, Lewes-Rehoboth, Bethany Beach and the Delaware Bay Shore.

Evaluation of the Water Resources in Northern New Castle County

General Statement

Northern New Castle County may be defined as the area north of the Chesapeake and Delaware Canal. About 40% of this area lies in the Piedmont Province in which ground water is difficult to obtain. The remaining 60% of this area lies on the northern portion of the Coastal Plain where small to moderate amounts of water can be obtained from individual wells. Exceptions exist where the Pleistocene deposits are thick enough to form a suitable aquifer. These sands are very prolific and are capable of yielding large quantities of water.

In northern New Castle County the most readily available sources of water are the streams of the Piedmont and the ancient stream channels filled with Pleistocene sand found in the Coastal Plain. Both of these sources are confined to restricted linear belts. In areas removed from these favorable localities difficulty is experienced in obtaining large water supplies. This necessitates the transportation of water from water-rich to water-poor areas, and the consequent growth of water companies in northern Delaware.

Water Supply Systems, Industrial Users, and Consumption

The water-supply systems in northern New Castle County may be divided into two types by ownership: municipal and private. There are five municipal systems and seven privately-owned companies presently operating in northern New Castle County. In 1963 these systems supplied an average of 46.2 million gallons of water daily to an estimated population of 300,000 plus industrial users in the area. Thus, close to 90% of the population in northern New Castle County is supplied by water-supply systems.

The City of Wilmington obtains its water supply from Brandywine Creek. The water-supply system also includes Hoopes Reservoir which is used as an emergency supply. Since its construction in the early 1930's, it has only been used once. With Hoopes Reservoir and Brandywine Creek, the minimum safe yield for the City of Wilmington is 63 mgd. The City of Wilmington's service area is the City of Wilmington and suburbs to the north along Rt. 202 to Talleyville and Kennett Pike to Greenville.

The average daily water consumption for the City of Wilmington service area in 1963 was 25 mgd with a maximum daily consumption of 31 mgd. The City of Wilmington water-supply system is by far the largest in the state. It supplied an estimated population of 156,000 or 54% of the population served through water supply systems in northern New Castle County. Industries account for close to 45% of the yearly consumption.

General Water Works Corporation, which is the owner of the Wilmington Suburban Water Company, Delaware Water Company, New Castle County Water Company, and Arden Water Company, is the second largest water distributor in the area. Arden Water Company was taken out of service in May 1963 and is being used as a standby source. The General Water Works water supply is obtained from White Clay Creek, Red Clay Creek, Christina River plus the smaller watersheds of Naamans Creek, Stoney Creek and Bellevue Reservoir and ground water from the Pleistocene Series near Newark. The General Water Works Corporation service area is the unincorporated area north of Wilmington plus Bellefonte, and unincorporated areas south and west of Newark. It also has a pipeline extending south to the Tidewater Refining Company area. In addition it has connections with Artesian Water Company, City of Wilmington, Newark, and Newport.

The average daily output for General Water Works in 1963 was 12.8 mgd, supplied to a population of 41,000 and various industries located in its service area. This output accounts for 27% of the total water consumption supplied through water-supply systems in northern New Castle County.

The third largest water-supply system in this area is owned by Artesian Water Company. It is the largest ground-water supplier in the area. In 1963 this company had 35 producing wells. Its service area is the unincorporated area to the south and west of Wilmington plus Elsmere.

In 1963 Artesian Water Company served an estimated population of 80,000, an average of 5.6 mgd with a maximum output of 8.5 mgd. This output accounts for approximately 11% of the water supplied through water supply systems in this area.

The other private and municipal systems in northern New Castle County account for 8% of the water supplied by distribution systems. The municipal water-supply systems are Newark, Newport, New Castle, and Delaware City. All of these use ground water as a source of supply.

Newark and Newport were depicted as problem quantity areas in the section on Statewide Water Resources Evaluation. This situation arises from the fact that the cities have marginal supplies and new sources are difficult to find. Despite the fact that both have added new wells in recent years, the supplies must still be considered marginal.

The City of Newark is the fourth largest distributor of water in northern New Castle County. In 1963 it supplied an estimated population of 12,000 and local industries with water at an average rate of 2 mgd and a maximum rate of 2.7 mgd. The City of Newark obtains its supply from eight wells located in two well fields, both located on the southern fringes of the City. As an emergency supply, Newark has two connections with Delaware Water Company.

The City of Newport is the smallest municipal system operating in this area. Currently it is supplied by three wells and has an auxiliary connection with Artesian Water Company. In 1963 its average daily output was .105 mgd.

The City of New Castle and Delaware City are depicted in the section titled Statewide Water Resources Evaluation, as problem areas due to quantity and quality. Both cities soften and treat the raw water for iron before it is released for public consumption. The main problem in these areas, since they are located adjacent to the Delaware River, is the potential danger of saline water encroachment in areas of heavy withdrawal. The City of New Castle is presently trying to avoid this threat by locating a new well field west of town in a Pleistocene channel.

The City of New Castle in 1963 supplied an average output of .6 mgd to an estimated population of 4,700. Delaware City has an average daily output of .25 mgd. Each town obtains its supply from two wells and has no additional sources.

The remaining privately-owned water companies are Anglesey, Crestfield, and North Star. These companies have their own ground-water supplies and distribution systems. Together they account for .2% of the water delivered through the water-supply systems in northern New Castle County.

It should be pointed out that the water-supply systems, with the exceptions of New Castle, Delaware City and the three smaller privately-owned companies, are interconnected. This means that a water shortage in one area might be alleviated by opening a few valves, providing, of course, that the shortage does not occur over the entire region. The water supply systems in northern New Castle County are summarized in Table 4. The service areas of the respective water-supply systems are shown in Figure 2.

The industrial users in northern New Castle County utilize large quantities of water from the hydrologic cycle. If the quantities used are divided into gross and net consumption (gross consumption amount supplied; net consumption difference between amount supplied and amount discharged back to the hydrologic cycle), the net consumption is a small percent of the gross consumption (less than 10%). Thus, most of the water used is returned to the hydrologic cycle in a slightly altered condition.

The principal sources of water for industrial purposes, with the exception of cooling, are privately-owned wells and water supply systems operating in the area. Most of the water for cooling purposes is obtained from surface sources to which it is returned. Some of the principal industrial users in this area were canvassed. Table 5 contains a list of those that replied and their gross consumption of fresh water.

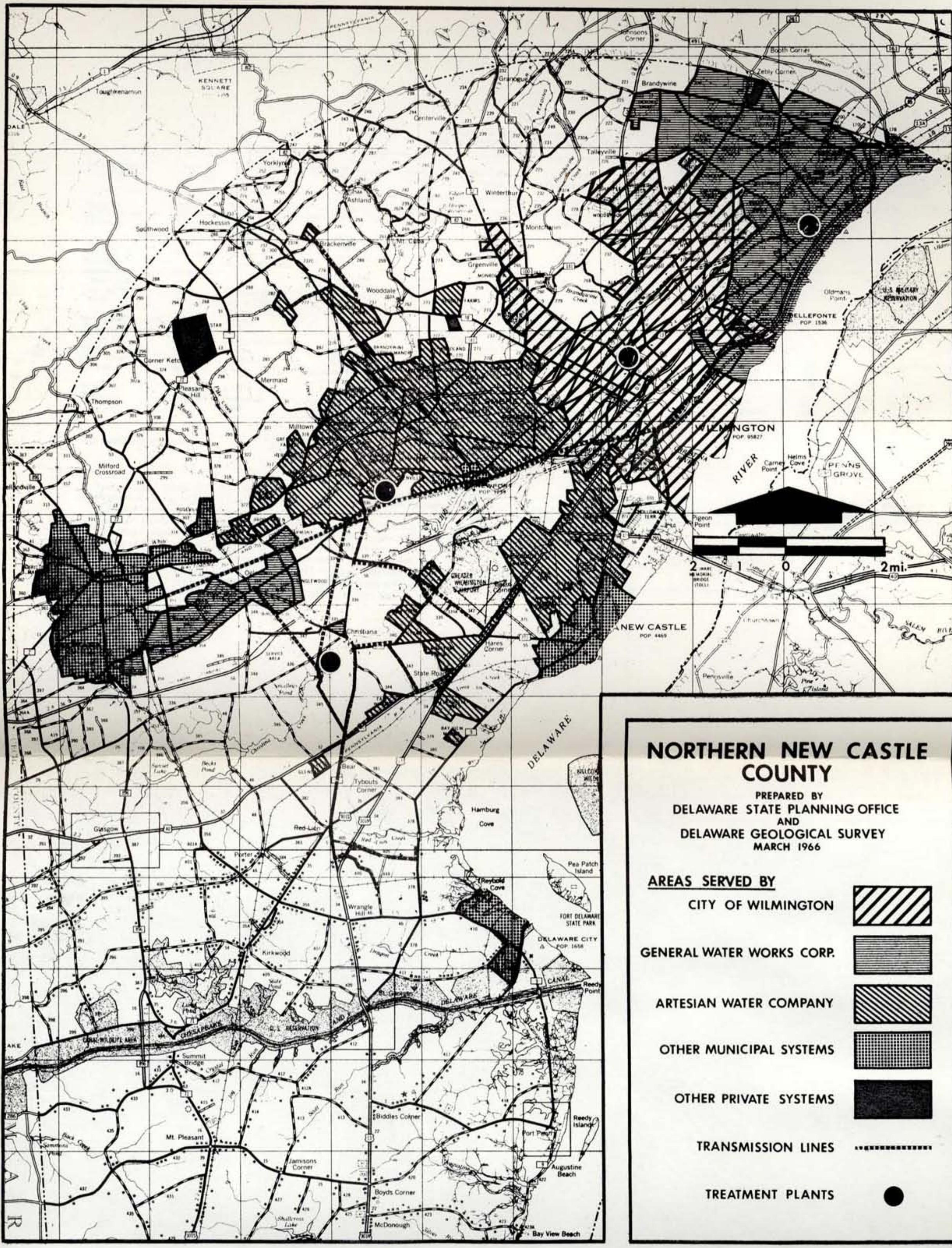

NORTHERN NEW CASTLE COUNTY
PREPARED BY
DELAWARE STATE PLANNING OFFICE
AND
DELAWARE GEOLOGICAL SURVEY
MARCH 1966
AREAS SERVED BY
CITY OF WILMINGTON
GENERAL WATER WORKS CORP.
ARTESIAN WATER COMPANY
OTHER MUNICIPAL SYSTEMS
OTHER PRIVATE SYSTEMS
TRANSMISSION LINES
TREATMENT PLANTS
2 1 0 2mi.
WILMINGTON
POP 95827
NEW CASTLE
POP 4469
BELLEFONTE
POP 1536
DELAWARE CITY
POP 1658
DELAWARE
RIVER
PENNS GROVE
U.S. MILITARY RESERVATION
Hockessin
Yorklyn
Ashland
Centerville
Greenville
Talleyville
Brandywine
Montchanin
Winterthur
Milltown
Mermaid
Pleasant Hill
Thompson
Milford Crossroad
Christiana
Hares Corner
State Road
Bear
Tybouts Corner
Red Lion
Porter
Glasgow
Kirkwood
Wrangle Hill
Summit Bridge
Mt. Pleasant
Jamisons Corner
Boyds Corner
Biddles Corner
McDonough
Port Penn
Reedy Island
Reedy Point
Augustine Beach
Bay View Beach
Pea Patch Island
FORT DELAWARE STATE PARK
Hamburg Cove
Pigeon Point
Carney Point
Helms Cove
Oldmans Point
Pennsville
Churchtown
Southwood
Toughkenamon
KENNETT SQUARE
Booth Corner
Zebly Corner
Johnsons Corner

FIGURE 2

TABLE 4

SUMMARY OF WATER SUPPLY SYSTEMS NORTH OF CHESAPEAKE AND DELAWARE CANAL

Name of Town or Water Supply	Type of Ownership	Source of Supply	Additional Sources of Supply	Average Daily Output mgd 1	Max. Capacity of System mgd 2	Treatment Plant Capacity mgd 3	Operating Percent of Max. Capacity 4	Storage of Finished Water mgd 5	Estimated Population 6	Average Daily Per Capita Consumption (gal.) 7	Excess Capacity mgd. 70% Max. - Average Daily 8
Anglesey	Private	2 wells	none	.01	.048	none	21	.006	N.A.	N.A.	N.A.
Artesian Water Co.	Private	35 wells	Delaware Water Co.	5.6	10.4	10.4	56	14.[illegible]	80,000	70	1.7
Bellefonte	–	Wilmington Sub. Water Co.	none	–	–	–	–	–	–	–	–
Crestfield	Private	2 wells	none	.01	.024	none	41	.004	N.A.	N.A.	N.A.
Delaware City	Municipal	2 wells	none	.22	.576	.576	38	.025	N.A.	N.A.	N.A.
Elsmere	–	Artesian Water Co.	none	–	–	–	–	–	–	–	–
General Water Works Corp.	Private	–	Arden Water Co. Artesian Water Co.	12.8	25	25	51	25.5	41,000	312	4.7
Delaware Water Corp.	–	Christina Creek Red and White Clay Creeks	–	–	–	–	–	–	–	–	–
New Castle Water Co.		3 wells	–	–	–	–	–	–	–	–	–
Wilmington Suburban Water Corp.		Bellevue Stoney Run Creek	–	–	–	–	–	–	–	–	–
Newark	Municipal	8 wells	Delaware Water Corp.	2.0	3.2	3.2	62	1.0	12,000	166	.24
New Castle	Municipal	2 wells	none	.6	1.0	1.0	60	.9	4,700	127	.10
Newport	Municipal	2 wells	Delaware Water Corp. Artesian Water Co.	.11	.2	none	55	.012	1,250	88	.03
North Star	Private	4 wells	none	.025	.07	none	36	.014	N.A.	N.A.	N.A.
Wilmington	Municipal	Brandywine Creek	Hoopes Reservoir Wilmington Suburban Water Corp.	25.	40.	40	62	80	156,000	160	3.00

N.A. Information not available

1. Average Daily Output (mg). The figures in this column represent the average daily output of the system in millions of gallons. This figure is the yearly pumpage divided by 365 days.
2. Maximum Capacity of System (mgd). This figure is determined by the capacity of wells, etc., in gallons per minute multiplied by 1440 (minutes per day). In some systems this figure is limited by the capacity of the treatment plant. Where this is the case the same figure appears in both this column and the column showing treatment plant capacity.
3. Treatment Plant Capacity (mgd). The capacity of the treatment plant in gallons per minute multiplied by 1440 (minutes per day).
4. Operating Percent of Maximum Capacity. The average daily output divided by Maximum capacity of system.
5. Storage of Finished Water (mg). Storage of water (after treatment were necessary) ready for consumption.
6. Estimated Population. The estimated population served by the system.
7. Average Daily Per Capita Consumption (gallons). Average daily output divided by estimated population served.
8. Excess Capacity (mgd). Seventy percent times the maximum capacity minus the average daily output. This leaves 30 percent of the maximum capacity to account for seasonal fluctuations and to supply peak demand periods during a given day.

Table 5

Principle Industrial Water Users

Industry	Fresh Water Used (gross consumption mgd)	Source
Tidewater Oil Co.	.43 3.99 *	Wells, Red Lion Creek, Dragon Run Creek and Del. Power and Light Co.
Del. Power and Light (Del. City)	7.89 (3.99 supplied to Tidewater Oil Co.)*	Wells, Red Lion Creek and Dragon Run Creek
Avison Chemical	1.01	Wells
Allied Chemical	2.20	Water Company
Curtis Paper Co.	1.44	White Clay Creek and Newark
Phoenix Steel Corp.	.35	Naaman's Creek and Water Co.
National Vulcanized Fibre	9.12	Wells, Red Clay, White Clay
General Motors Corp.	.86	City of Wilmington
Electric Hose and Rubber	1.13	City of Wilmington

Potential Development[2]

Although northern Delaware as a whole has an abundance of water at present, problems described as "water shortages" have already begun to crop up, and it is reasonable to expect that these will grow in number in the near future. Most of these so-called "shortages" are probably misnamed, and are really problems of inadequate facilities for pumping, storage or transmission. In most instances, they could be solved either through further exploration for and development of ground waters or by additional investments in equipment to make more water available from existing sources.

Nevertheless, it must be recognized that sooner or later some communities or areas, especially in the more rapidly growing regions, will find it increasingly difficult to obtain adequate supplies of good water. The existence of water in abundance in other parts of the state will not help to solve such problems, because the costs of importing this water may be prohibitive. As a consequence, consideration must be given to every feasible way in which water could be developed at minimum cost from conventional or unconventional sources.

[2] This section is based on an unpublished report by the Delaware Geological Survey.

The more conventional measures for obtaining water are tunneling, piping systems, dams and reservoirs, and water well facilities. For the most part, these involve the physical handling of an existing water resource in an improved manner. The less conventional procedures, on the other hand, tend to create an essentially new water resource, or to develop good water from sources previously considered unusable. These would include such procedures as saline-water conversion, weather modification, and water barging. This last technique has in recent years received an increasing degree of attention from the technologists as the demand for more water has become urgent. Although many of the newer procedures may hold great promise for the future, their present state of development is such that they are generally unworkable or uneconomic in supplementing the conventional ways of getting water.

The Senate Select Committee on National Water Resources outlines five major categories of effort for increasing water supply:

1. Regulating streamflow by constructing surface reservoirs and through watershed management.
2. Making better use of underground storage.
3. Increasing natural fresh-water yield by desalinization, weather modification, and other artificial means.
4. Improving quality of water through more adequate pollution abatement.
5. Increasing the efficiency of water use through elimination of wasteful practices, improved sewage treatment, recirculation of water instead of "once-through" use, and substitution of air for water cooling.

With these points as a guide, let us look at how the first three categories can be applied to the problems and conditions encountered in northern Delaware. A discussion of categories 4 and 5 goes beyond the scope of this report.

1. Regulating streamflow by constructing surface reservoirs and through watershed management.

The proposed White Clay Creek Dam above Newark is a prime example of water resource development in this category. The first stage would involve construction of a four billion gallon reservoir at a cost of $7.0 million to supply 43 million gallons a day additional water to the area. A second stage of construction has been recommended to guarantee, under severe drought conditions, a sustained flow of not less than 100 million gallons a day at the confluence of White Clay Creek and the Christina River.

The purpose of the reservoir is to increase the amount of raw water available to large water users in New Castle County. The project would be made self-sustaining and self-liquidating by the sale of water rights to water companies, municipalities, and self-supplied industries.

An analysis of the method for financing and the need for constructing a reservoir at the Newark site raises some important points. Northern Delaware has a relatively small number of large water distributors to whom water rights from the proposed project could be sold. Of these potential customers, the City of Wilmington, which accounts for about 54 percent of the total public water-supply consumption in the county, already has adequate unused water resources to satisfy its potential future requirements for many years.

Because only raw water will be provided to White Clay Creek and the Christina River, any potential customers for water rights from the Newark project would have to extend their distribution systems to the vicinity of the raw water source and would be forced to construct costly treatment facilities before they could benefit from the increased flows provided by the proposed reservoir. For example, each potential customer for water rights would be faced with an initial capital expenditure of approximately $200,000 to $400,000 for treatment works alone for each one million gallons per day of water from the Newark project. On top of this initial capital cost would be added operating costs of $40 to $50 per million gallons treated, plus the annual cost of $11,000 for each million-gallon-per-day water right.

Except for Wilmington, which is adequately supplied by Hoopes Reservoir and Brandywine Creek, most of the remaining large and small water distribution systems in northern Delaware are now supplied by ground-water developments. Because of the large expenditures involved in developing new surface-water supplies, it is conceivable that water systems in the area will continue to expand their use of local ground-water resources as long as possible before availing themselves of a more or less centralized surface-water source.

General Waterworks Corp. and a few self-supplied industries would presently benefit from increased low flows in White Clay Creek. Furthermore, this benefit would primarily be in the form of pollution control. White Clay Creek and the Christina River already have an undeveloped water resource potential which is not now being actively sought. Therefore, as outlined above, the county and/or state will have some difficulty in financing the proposed reservoir through the sale of water rights to public water-supply distributors and would be forced to carry the major financial burden of the project for some time to come if construction were undertaken.

In our opinion, moreover, the major benefit from the Newark Reservoir would be in attracting new self-supplied heavy industry into northern Delaware. The project, because of its guaranteed low-flow aspect and benefit to pollution control would make the properties along the waterways quite attractive to new industry, which now considers the area as a water-short region. A further benefit from the proposed project would be the addition of an important and well-located recreational resource, and an ultimate rise in property values in the vicinity of the areas affected by the project.

At the present time, no other economical sites exist for surface reservoirs in northern Delaware. However, the unused flow of these streams need not be wasted. The interrelation of surface and ground water has been discussed and it is in this connection that the unused surface water of the Brandywine, Red Clay, Christina, and even the White Clay may be used. The possible use of this water to increase the underground storage of the region must be considered.

2. Making better use of underground storage.

Northern Delaware, particularly the Coastal Plain region, is underlain by aquifers capable of yielding large quantities of water. However, as pointed out previously, these aquifers are not distributed evenly through the region. The Pleistocene aquifers, in particular, are restricted to narrow bands beneath the Coastal Plain surface. Where these channels have been located, large quantities of water have been obtained e.g. Newark, Farnhurst, Bear, New Castle. However, these developments constitute only a small part of the potential water supply that could be obtained from this source. It is estimated that between 8 mgd and 25 mgd, of additional ground water, can be developed; however, most of this is likely to be developed by private industry.

New wellfields can and will be found in northern Delaware at safe distances from the present wellfields. But first, consideration must be given to the better utilization of the existing wellfields. For example, Newark is presently developing its wellfields to near capacity and new sources are needed. The problem faced by Newark will be repeated many times by other water-users in northern Delaware as demand continues to increase. An existing supply, either surface or ground water, becomes inadequate. The choice is between tapping a new source or improving the existing source. If a new wellfield can be developed within a reasonable distance of the point of consumption, a solution is then found - provided that a less expensive solution does not exist. This is where improvement of existing sources must be considered and the use of water presently being wasted is one of the principal methods for accomplishing this.

If, through urbanization, the yields for a wellfield diminish in time, the life-expectancy of the water-supply is shortened and thus the cost of the development increases. The logical step is an attempt to rejuvenate the system and artificial methods must be used. In this case, it means to artificially increase the recharge to the wellfield.

Artificial recharge may be defined as the practice of increasing by artificial means the amount of water that enters a ground-water reservoir. Artificial recharge may be divided into direct and indirect methods. Direct methods include water spreading--flooding an area or admitting water into shallow basins, ditches, or furrows; extending the time during which water is recharged from a naturally influent channel, applying excess water for irrigation; recharge through pits and other excavations of moderate depth; and recharge through relatively deep wells and shafts. Indirect methods consist of inducing the movement of water from lakes and streams into underground formations by pumping water from wells, collectors, galleries located near the surface-water sources.

The above classification includes the major methods of artificial recharge. Many operations include more than one method of recharging, and the methods described grade into one another. Each has certain inherent advantages and disadvantages; the selection of methods generally is based on consideration of several of the following factors: climate, topography, soil, geology, water quality, purpose of recharge, quantity of water involved, cost, and land use.

Artificial recharge as a means of water conservation has the distinct advantages of not requiring large and elaborate structures and of utilizing available natural subsurface reservoirs. Economically it compares well, as it must, with other methods of obtaining needed water supplies. Studies of proposed conservation projects in the western United States indicate that in some places large savings could be made by developing integrated surface and subsurface storage. In such systems the size and cost of surface storage and distribution systems can be reduced by supplying artificial recharge to underground reservoirs. Evapo-transpirative losses from water stored beneath the ground are usually less than those from surface-storage units. These, together with other demonstrable advantages, suggest that future practice of artificial recharge will not be confined to areas of overdraft and limited ground-water supplies, as in the present general practice.

To illustrate this point, the existing South Well Field of the City of Newark can be cited. Increased urbanization in the immediate area has resulted in diminished yields of water over the last few years. There is a considerable investment in wells and other facilities at the site and a plan to rejuvenate this wellfield by artificial recharge is being formulated. The source of the water to be recharged is storm-sewer runoff from the City and unused water from the Christina River obtained during high flows. A typical plan would be as follows:

The storm sewer system would be modified to divert water to a recharge basin at the South Wellfield. In addition, water from the Christina River would be pumped through a 1 mile long pipeline to the basin during the ten months of high flow. It is estimated that an average of at least 5 million gallons per day of Christina water could be pumped during the ten months. This water would be recharged to the aquifer of the wellfield. The aquifer would act as a storage battery from whence the water could be withdrawn over the twelve months period of demand. The system would not be perfect and not all the recharged water would be taken by the wells. Some would move out of the system as underground flow but a great percentage would be prevented from taking this course by the pumped wells. Therefore, at least 4 million gallons per day for twelve months plus the storm sewer runoff would be added to the Newark water supply.

3. Increasing natural fresh-water yield by desalinization, weather modification, and other artificial means.

Salt-Water Conversion: Over the past twelve years, much progress has been made toward lowering the costs of converting salty and brackish water into fresh-water supplies. Through the Office of Saline Water of the U.S. Department of the Interior, new processes have been developed and are being tested in an extensive pilot plant program. Conversion costs at modern ocean-water plants have been reduced to about $1.00 per 1,000 gallons. At installations using brackish ground water, costs can be less than $1.00 per 1,000 gallons if the salinity of the raw water is very low.

Costs of supplying fresh water by conversion methods vary widely, depending on the process employed, the capacity of the plant, the distance over which water must be transported, the availability of power, and the problems of disposal of wastes. The factors that normally must be considered in arriving at a cost figure for the conversion plant alone are:

1. Plant costs, service facilities, and engineering studies.
2. Amortization based on 20-year plant life.
3. Interest at 4 percent.
4. Land costs.
5. Power costs.

The primary limiting cost factor is the capital expenditure needed for the treatment plant itself. Normally, treatment costs for water-supply systems amount to approximately 20 to 30 percent of the cost of the entire system. The construction of dams or wells, installation of water mains, valves, etc. account for 70 to 80 percent of the total cost. To convert salt water, however, the initial expenditure for the treatment plant can run as high as $1 million for each one million gallons per day of capacity. To this figure must be added normal capital costs for the development of the raw water supply and the construction of the distribution system.

The intensive research program being carried out by the government and private organizations should lead to an improvement in the cost of treating salt and brackish water, and it is not unreasonable to predict that over the next few years the price of $1.00 to treat 1,000 gallons will be lowered somewhat. However, capital costs required for construction of plant facilities have not been falling, and it is doubtful whether conversion processes can be simplified to the point where they can compete economically in the foreseeable future with traditional methods of developing fresh-water sources.

Weather modification: Within the last few years, several study groups have contributed much toward the understanding of the effects of various geographic and climatic settings on weather-control techniques. From these studies, it has become apparent that the seeding of cumuliform clouds can in certain circumstances augment natural precipitation by as much as 15 to 20 percent. However, in these studies it has repeatedly been observed that seeding is only effective in areas of orographic cloud genesis. Where seeding has been attempted over flat or undulating countrysides, no precipitation increases have been observed. It is evident, therefore, that topographic considerations are a significant limiting factor for northern Delaware. At this stage, weather modification would appear to offer very little hope for augmenting water supplies.

Water barging: the transportation of large volumes of water by ship or bag although not a common practice in the United States, has long been carried out in many other parts of the world. Under rather special circumstances, the barging of water can provide a fairly economic means of supplementing existing water supplies. Where sources of water and points of water demand are in geographic proximity and are accessible by seaway, delivery can be accomplished at surprising low cost. Furthermore, the barging of water offers the advantage of being an extremely flexible water-supply procedure.

Discussions with several shipping operators and with members of the American Merchant Marine Institute indicate that water could be delivered in this manner to the Wilmington area for distribution for approximately $0.30 per 1,000 gallons. This rate is based upon a maximum roundtrip running distance of 80 miles and a minimum daily load of 20,000 tons (almost 5 million gallons). The rate is premised on a contract to be carried out by a private carrier on a long-term contract basis. Assuming that distances could be halved and towing and barging equipment were to be owned and operated by a state agency, water delivery rates could in all probability be reduced to $0.20 to $0.24 per 1,000 gallons.

Evaluation of the Water Resources in the Dover-Smyrna Area

General Statement

The Dover-Smyrna area is defined as the corridor between Smyrna and Dover and includes the municipalities of Smyrna, Clayton, Dover and Camden-Wyoming. The principal source of water in the Dover-Smyrna area is ground water. In the Smyrna area the main aquifers are found in the Pleistocene, shallow Miocene and Eocene Series. Proceeding south toward the City of Dover the Pleistocene sands tend to become thinner. The Eocene sands (Rancocas Formation) feather out in the subsurface just north of Cheswold, and while the Miocene sands are thickening, they are not thick enough to become a significant aquifer until Dover. A strip about 7 miles wide and extending in a northeast, southwest direction between Smyrna and Dover is depicted in the Statewide Water Resources Map (Figure 1) as being a caution zone due to quantity. It is in this area where the above geologic changes have taken place, meaning that there is no single aquifer capable of yielding large amounts of water to individual wells. In Dover, the Pleistocene, Miocene and Eocene sands are all capable of yielding moderate to large quantities of water. The water quality in this area is generally good, although, it is reported as being slightly acid or hard in various locations.

Present Supply

Clayton started its municipal water supply system in 1941. The initial supply was obtained from eight 3-inch wells drilled to a depth of approximately 40 feet. These wells were connected together at the surface and were pumped simultaneously with a triplex pump. Between 1949 and 1953 the town had two wells drilled to the Rancocas Formation. The first well was screened from 298 feet to 324 feet below land surface; however, no pump was installed. The second well was constructed without a screen and began to pump sand in early 1953, which rendered it useless. In late 1953, the Town of Clayton installed a well to replace the previous well. This well is presently the main source of supply. As an emergency supply, the town has a tie in with the Wheatly Canning Company.

Smyrna began its municipal supply system in 1885. The initial source was a dug well 20 feet in diameter and 20 feet deep. This was a Pleistocene well and it supplied the town until 1948. In 1948, a deeper well was installed in the same formation. This well was screened from 55 to 95 feet below land surface and had an original capacity of 560 gpm. During the years 1956 and 1957, the town of Smyrna financed the drilling of a series of test wells in consultation with the Delaware Geological Survey to locate a Pleistocene channel. As a result the town developed a 1,000 gpm well in one of the channels in late 1957. The last two wells are the present source of supply.

Camden and Wyoming are neighboring towns having a mutual municipal water supply system, which was started in 1943. Between 1943 and 1952, the supply was obtained from a battery of seven small diameter wells ranging in depth from 45 to 55 feet (Pleistocene Series). When, in 1952, these wells failed to produce an adequate supply, a well was drilled to the deeper Miocene sand. This well is presently the main source of supply, and the initial system is used as a reserve source. At present, the quantity supplied is marginal, but plans are being made for the construction of a new well in 1966.

The exact date Dover started its municipal supply system is not known, however, it was prior to 1893. Before this date, water was obtained from dug wells located in the Pleistocene Series. In 1893, the City of Dover had its first artesian well drilled. Between the years 1893 to 1932, Dover obtained its supply from four wells screened in the Frederica aquifer, a shallow Miocene sand. These wells had yields of 200 to 800 gpm and ranged in depth from 145 to 196 feet. The period 1932 to 1955 was marked by development of the deeper Miocene sand: the Cheswold aquifer. Wells tapping this aquifer were drilled in 1932, 1938, 1948, 1952, 1955, and two in 1964. These wells range in depth from 221 to 230 feet and have yields of 450 to 650 gpm. In 1957, a test hole under the supervision of the Delaware Geological Survey was drilled to a depth of 1,422 feet at the Dover Air Force Base which revealed a thick aquifer of Eocene age (Piney Point). The City of Dover had two wells drilled to this aquifer on the northwest side of town in 1962. The two wells had a reported combined capacity of 1,100 gpm and are 380 feet deep. The City has recently, 1965, completed two additional wells to this formation on the south side of town with yields of 700 and 1,100 gpm. Presently, the City of Dover is supplied by eleven production wells producing 6,405 gpm or a maximum capacity of 9.25 mgd.

Water Supply Systems

Four municipalities are considered in this section of the report. They are: Dover, Camden-Wyoming, Smyrna, and Clayton. Figures 3, 4 and 5 show the service area and well locations for the various municipal systems. At present all have a sufficient supply of water except Camden-Wyoming. To alleviate the shortage, plans are being considered for the construction of a new well. Sufficient water is available to supply a moderately large well (.7 mgd) which should provide foreseeable needs. Upon completion of a new well, it will be the main source of supply and the existing well will be used as a reserve source.

Dover's water supply system is shown as "caution" in Figure 1. Recently, Dover has increased its area of distribution and constructed new wells to meet the demand. The City of Dover appears to be well advanced in planning for the development of its water resources. Dover has .35 million gallon overhead storage, which, in case of an emergency may not be sufficient. Recognition of this is indicated in the City's plans for the construction of an additional .25 million gallons of overhead storage.

In all systems, the water is pumped directly from the well into the distribution system with the excess flowing into overhead storage. Where treatment of water is required, as in Smyrna for acidity, and chlorination in all systems except Dover's, the treatment device is located at the well site and its capacity coincides with the capacity of the well.

DOVER – SMYRNA AREA

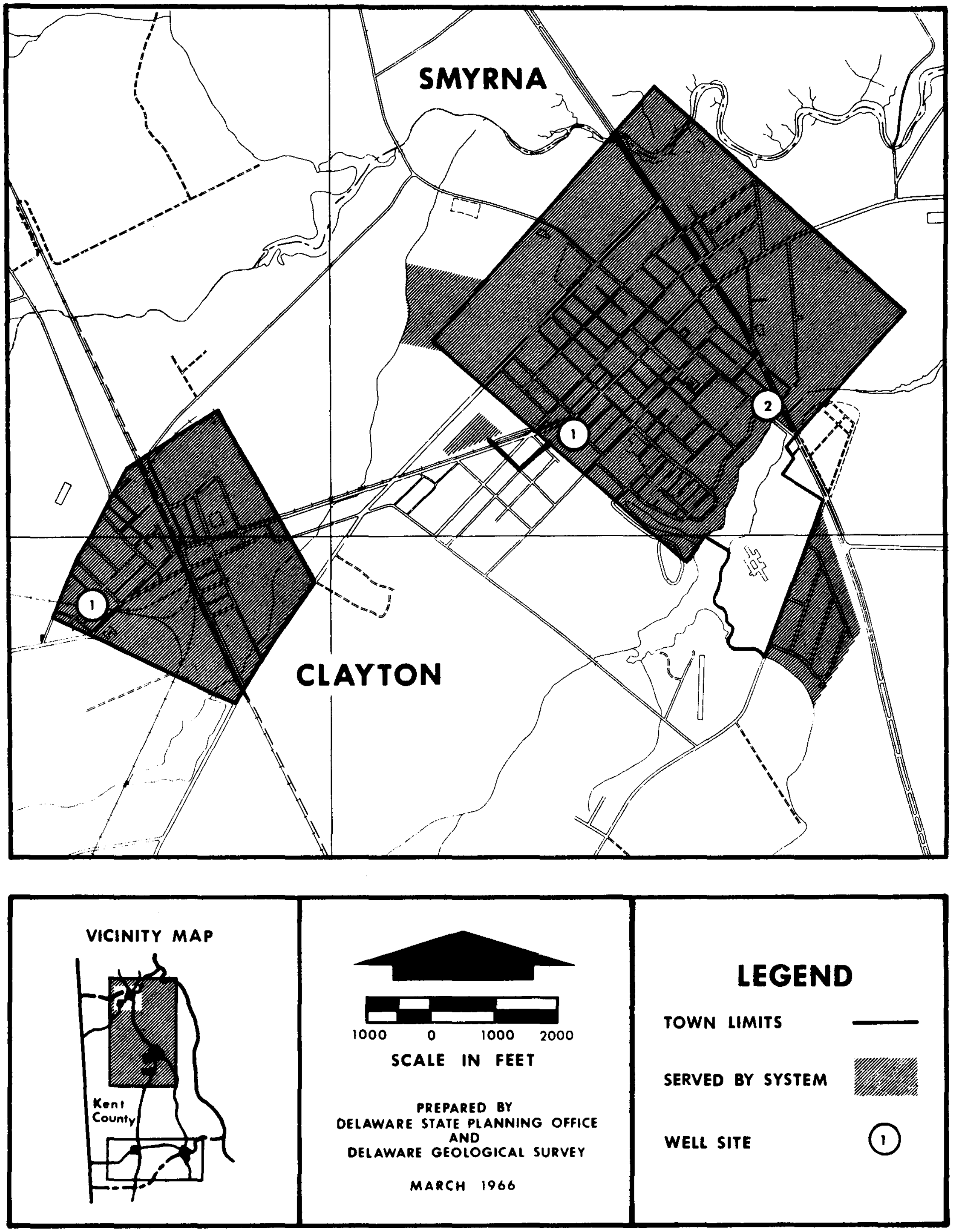


FIGURE 3

DOVER — SMYRNA AREA

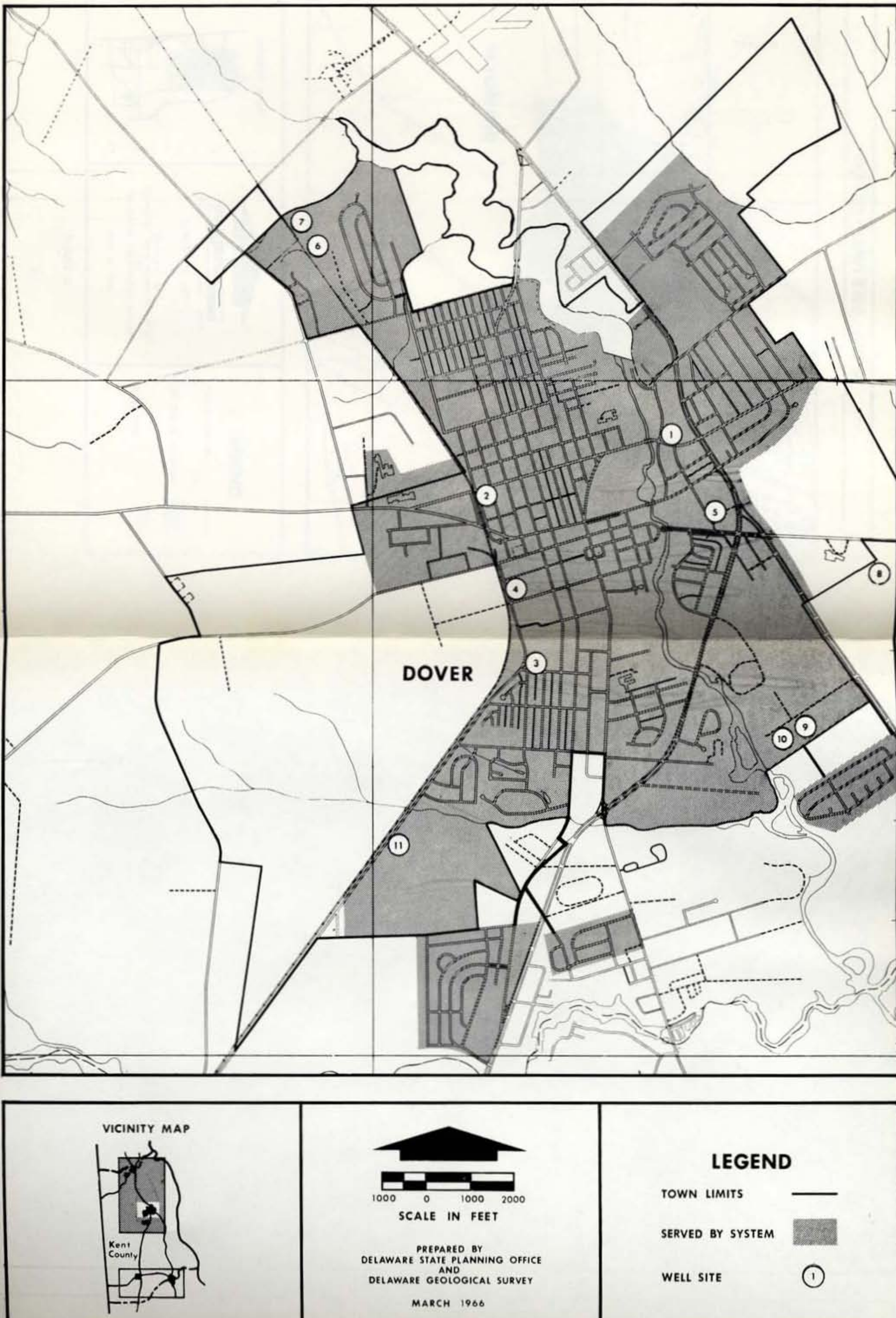
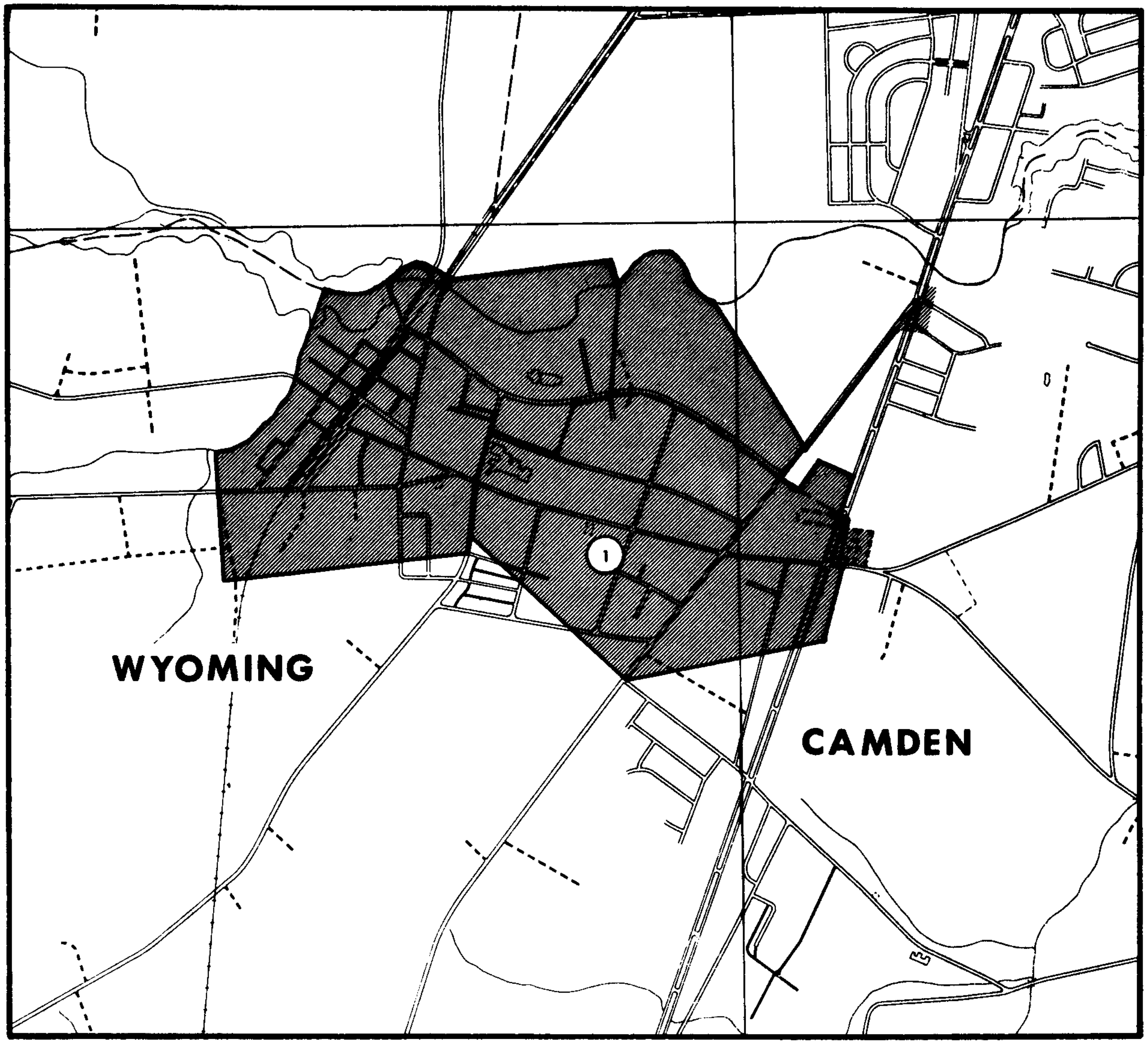
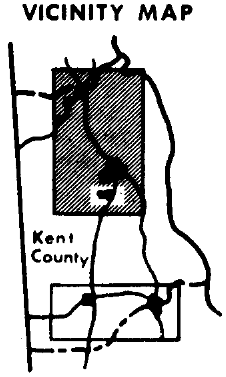


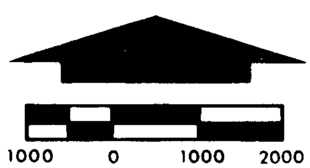
FIGURE 4

DOVER — SMYRNA AREA



VICINITY MAP





SCALE IN FEET

PREPARED BY
DELAWARE STATE PLANNING OFFICE
AND
DELAWARE GEOLOGICAL SURVEY

MARCH 1966

LEGEND

TOWN LIMITS

SERVED BY SYSTEM

WELL SITE

FIGURE 5

In Dover, water is supplied to consumers in its natural state. All the municipalities, except Clayton, supply water to consumers outside the city or town limits. In the future, Smyrna plans to supply water to a new housing development that is to be constructed east of U. S. 13. The water demanded upon the completion of the development will be around 200,000 gpd.

Camden Park, a small housing development located south of Camden-Wyoming along U. S. 13, is supplied by its own private water company. This company has one well, screened in the Cheswold aquifer, and has experienced some difficulty in meeting its demand. In a conversation with the Water Superintendent, there was some indication that the Camden-Wyoming municipality might supply this community in the future.

Consumption

Consumption data for this area were obtained by interviewing various community officials. Data for this report were obtained from the Superintendent of Public Works, Dover; Town Manager of Smyrna; Water Superintendent, Camden-Wyoming; and the Mayor of Clayton. The water use in Clayton and Camden-Wyoming is not precisely known. Dover and Smyrna both have meters to measure the amount supplied.

The per capita consumption in Smyrna during 1963 varied from a low of 110 gpd in February to a high of 158 gpd in December. Water consumption in Dover has increased from a yearly total of 496.4 million gallons, a daily average of 1.5 mg in 1961, to 1,103.8 mg and a daily average of 2.9 mg in 1964. The average per capita consumption in 1964 varied from 161 gd in March to 304 gd in August. Most of this increase since 1961 may be explained due to the operation of General Foods, which uses around 1.3 mgd. Per capita consumption in the other towns is approximately 100 gpd. Dover is the only municipality that serves large industrial users in this area. Consumption data for this area are summarized in Table 6.

Available Supply

There are many different aquifers lying beneath the Dover-Smyrna area, and their properties are variable over this broad region. In the northern section there are three major aquifers, the shallowest of which is the Pleistocene or surface water table sands. These sands range from 20 to 115 feet thick and average 40 feet thick. The thicker portions are found in "Pleistocene channels" and are capable of yielding large quantities of water to individual wells (1,000 to 1,500 gpm). This is by far the most widely used aquifer in the Smyrna-Clayton area. The next deeper aquifer is located in the Miocene Series. This sand is known as the Cheswold aquifer. It overlies a clay above the Eocene Series and is present as far south as Milford. In the Smyrna area it is a marginal aquifer as it is highly variable in thickness and production of water. Where this sand is present it lies within 120 feet of the surface about Smyrna. Many small domestic consumers utilize this sand south and southwest of Smyrna. The third aquifer is located in the Eocene Series. At Smyrna this aquifer is approximately 180 feet beneath the surface. It is a primary source of water for the Town of Clayton and Wheatly Canning Co. in Clayton. The water is somewhat hard (154 ppm); but otherwise it is of good quality. This aquifer is capable of yielding moderate quantities of water to individual wells (300 gpm).

Proceeding south toward Dover, the water-bearing characteristics of the above aquifers change. The Pleistocene sands tend to become thinner and inconsistent, decreasing to 20-60 feet in thickness. As saturated thickness is very important in the water table sands, this tends to inhibit their productivity. The Cheswold aquifer, along with a shallower local sand which becomes a principal aquifer in the Dover area (Frederica aquifer), thickens and becomes the major source at Cheswold. The water from the Miocene sands is reported to be slightly irony and hard. These sands are capable of supplying small to moderate quantities of water to individual wells (60 to 250 gpm). A very significant change occurs in the Eocene sands between Smyrna and Dover: they become thinner and discontinuous due to a facies change and are reported to be unimportant as a water-bearing sand beneath Cheswold.

In Dover the basic characteristics change again. The Pleistocene sands tend to become thicker which increases their usefulness as a source of supply. The Miocene Series here contains two principal sands, mentioned above, the Cheswold and the Frederica, of which the Cheswold is the deeper and most productive. Typical yields are around 400-600 gpm from the Cheswold aquifer and 200-350 gpm from the Frederica aquifer. North of Dover, another Eocene sand, the Piney Point aquifer, becomes an important deep source of supply. The Piney Point increases in thickness from 30 feet along the northern boundary of Dover to 250 feet at the Dover Air Force Base. Yields to individual wells from this aquifer range from 500 to 1,100 gpm depending on the thickness of the sand.

Special consideration must be given to the decreasing static water levels (swl) of the aquifers (primarily the Cheswold aquifer) located in the Miocene Series around Dover. Initially, late in the 1890's, static water levels were reported to be 12 feet above sea level. Reports in 1918 indicated little change in the first 25 years of record. Presently, because of overpumping swl fluctuates between 80 and 110 feet (average 105 feet) below sea level depending on the season of the year. This indicates a decrease in head of 117 feet in the last 46 years or an average decline of 2.5 feet per year. Although these declines of water level are not constant over the entire pressure-head surface, they denote a trend.

As there is still 80 feet of available drawdown, there is little cause for alarm. The long-run effect will be depletion, or deterioration of the water quality, in the aquifer unless some precautionary measures are taken. Steps, such as restricting pumping rates to where they equal recharge rates, and artificial recharge, are possible solutions to the problem.

Potential Sources

The ground water supplies in the Dover-Smyrna area have been explored to a depth of 1422 feet at Dover Air Force Base and 2314 at Deakyneville. The aquifers within the upper 600 feet are presently being used where they are capable of yielding a sufficient supply. Thus, additional sources must be developed from deeper aquifers, surface sources, recharge to present aquifers, importation of water from other areas, or desalinization of brackish water. At present the cost of the latter is prohibitive and development in the future will depend on its comparative cost.

The Smyrna-Clayton area is relatively water-rich because water is easily obtained from thick Pleistocene channels and deeper aquifers in the area. Thus, it is unlikely that additional sources will be needed in the near future. In the event that supplemental supplies are needed, two alternatives are available: (1) deeper aquifers and (2) surface sources.

Potential deeper aquifers in the Smyrna area are located between the presently producing Eocene sands and the nonmarine Cretaceous. The Magothy Formation which directly overlies the nonmarine Cretaceous is a major source of supply in the Middletown area. This formation is approximately 625 feet beneath the surface in the Smyrna area. Possible surface supplies consist of Lake Como and Duck Creek, which could be dammed along Rt. 13.

The potential sources for individuals located in the Cheswold area are deeper aquifers or importation of water from water-rich regions. The deeper aquifers in the area consist of alternating beds of sands and clay to a depth of approximately 1,000 feet (bottom of the Magothy Formation). Below this depth brackish water is likely to be present. The other alternative is to import water from present water surplus areas, mainly to the north of Cheswold.

Additional sources in the Dover area are essentially limited to deeper formations and surface sources. Information from the test hole drilled at the Dover Air Force Base reveals a possible aquifer at a depth between 1,100 and 1,175 feet below land surface. Water below this depth is expected to be brackish. Possible surface supplies in the area include Silver and Wyoming Lakes. The combined drainage area is approximately 40 sq. mi. having a maximum capacity of about 30 mgd. Some water from the above sources is presently being used for irrigation and cooling. Since individuals are not required to report the amount of water used for these purposes, the quantity of water used for these purposes is not known. Irrigation is a consumptive use of water, meaning that once this water is used it is unavailable for further use. Water may be pumped directly from the above reservoirs; or a series of wells may be placed around the reservoir using the reservoir water to replenish the groundwater supply. However, as the Piney Point aquifer is just being developed, it is unlikely that other sources of supply will be needed in the near future.

Summary and Recommendations

In summary this area is underlain by four principal aquifers, but at any specific location one or more may not be satisfactory as a water supply. Smyrna and Dover are relatively water-rich as compared to the area in between.

The Dover area, which in the last decade has increased its water demand at an accelerated rate, must continue to use optimum planning in development of its water resources. Static water levels in the Miocene sands seem to be decreasing at an increasing rate, not only due to the City of Dover's pumping but expanding irrigation and industrial users in the area. In order to insure future use of these aquifers, the pumping rates will have to be restricted or some means of artificial recharge will have to be pursued.

To develop additional supplies, Smyrna may construct extra wells in the Pleistocene channel around Lake Como; Clayton, Dover, Camden-Wyoming may develop wells in the Eocene Series. The Town of Cheswold can develop a limited supply from the Miocene sands.

Evaluation of the Water Resources

in the Milford-Harrington Area

General Statement

The Milford-Harrington area uses ground water as the main source of supply. The Pleistocene sands tend to be thin and patchy in the Milford area, thus, less important as a major aquifer. These sands vary in thickness ranging from 11 feet in Milford to 70 feet east of Milford and in the Harrington area. The more important aquifers in this area for municipal and industrial use are those located in the Miocene Series. These aquifers are found at depths between 200 feet and 350 feet. The water from both the Pleistocene and Miocene sands is reported to be of satisfactory quality and does not require treatment before domestic use.

Present Supply

The City of Milford started its municipal supply around the year 1891. The initial supply consisted of three wells that derived water from two aquifers: the shallow Pleistocene sands and a shallow Miocene sand. The next well was installed in the period between 1892 and 1896. It was 10 inches in diameter, 226 feet deep and had an original capacity of 250 gpm. At the time of installation the static water level was 14 feet above sea level. A turbine pump was installed in 1938 to replace an airlift pump. This well is currently producing 340 gpm. In 1914 two wells were constructed to the same depth as the above well. Due to deterioration of the casings, these wells were taken out of service in 1951.

During 1938 and 1939 Milford undertook a series of projects to develop additional ground-water supplies. The first attempt was the construction of a large capacity well from the Pleistocene sands. It was 44 inches in diameter and 40 feet deep, but due to inadequate production this well was never completed. After the failure of the shallow well, a 777 foot test hole was drilled. Based on the test hole a production well was installed to a depth of 236 feet. It had an initial capacity of 346 gpm and is presently producing water at 300 gpm. The above sources gave Milford a sufficient supply until 1951, when two wells were abandoned. To compensate for the loss, two wells were installed in 1952. The first one was drilled to 226 feet; however, after development it failed to produce an adequate supply and was abandoned. A site on the northeast side of town was selected to drill the second well. First a pilot hole was drilled and good sands were found at depths of 212-227, 293-302, and 319-329. The lower two sands were developed and a yield of 480 gpm was obtained. In 1959 another well was constructed, this time on the northwest side of town. This well was designed to be a Pleistocene well 22 inches in diameter with a concrete casing and screen alternating from 17 feet to 143 feet. Because of improper development, it failed to stop pumping sand and is now being used as a reserve source. To supplement the supply a Pleistocene well was developed in late 1963 southwest of town.

Presently the City of Milford has five production wells that are obtaining water from three different aquifers. Namely, the shallow sands of the Pleistocene Series, the Frederica and Cheswold sands of the Miocene Series. These wells have a combined capacity of 1,750 gpm or 2.5 mgd which is an adequate supply at present.

The year Harrington started its water supply system is not known; however, it was prior to 1944. The initial source was five 3-inch wells 65 feet deep. In 1944 two wells were installed to a depth of 240 feet to replace the shallow supply, which was eventually abandoned in 1949. At the time of installation these wells had a test yield of 250 gpm, since then the capacity has decreased to 150 gpm. This decline in production may be attributed to the deterioration of the wells through age rather than a poorer performance of the aquifer.

The town of Harrington is currently supplied by three wells which derive water from a shallower Miocene sand. The third well was completed during the summer of 1965. It has a capacity of 500 gpm (.7 mgd). The water is reported to be slightly hard and acid and is not treated for either condition. On the other hand, treatment is not necessary according to the 1962 Public Health Standards.

Another town that should be considered is Houston. Houston does not have a municipal supply. Water in this area is obtained from shallow wells (20 to 60 feet deep) tapping sands of the Pleistocene Series, where the water is of good quality.

Water Supply Systems

Milford's municipal supply system is depicted on the State-wide Water Reservoir Evaluation map as an impending problem. Milford's water supply system is regarded as such for the following reasons: (1) distribution does not cover the complete area bounded by the corporate limits, plus, some of the residents that could obtain City water are obtaining water from privately owned wells; (2) Milford is over-pumping the Miocene aquifers beneath the City thus creating a large cone of depression.

Harrington, on the other hand, has undertaken steps during the past year to relieve the critical demands on its water supply system. Harrington has replaced and enlarged existing water mains in addition to expanding the system to supply other sections within the town. To alleviate the supply problem Harrington has installed a well designed to supply 500 gpm. The new well is the main supply and the older wells are being used as a reserve source. Areas served by the distribution systems and well locations in Milford and Harrington are shown in Figures 6 and 7.

Available Supply

To date, Milford has exploited aquifers to a depth of 330 feet. Since the shallow Miocene sands (228 feet) were first utilized around the turn of the century, the static water levels have declined considerably (+14' to -25' sea level). Further development of the aquifers is safe; however, it should be in an area distant from the present cone of depression. In 1952, when the deeper Miocene sands (between 293 feet and 330 feet) were first developed the static water level was 5 feet below sea level reflecting slow drainage of water through the overlying aquiclude to the heavily pumped shallower sand. Additional wells may be developed in the deeper sands but, emphasis should be placed on well spacings as there could be substantial mutual interference. Well spacings will depend on the specific aquifer characteristics.

Consumers in the Milford area that do not use the Miocene sands use the Pleistocene sand which, except near the valley of the Mispillion River, is thick enough to form a significant aquifer. East of Milford along the Mispillion River and Delaware Bay these sands contain brackish water, thus individuals are forced to use the Miocene sands to obtain water of satisfactory quality. The Pleistocene sands increase in thickness to 70 plus feet south and west of Milford. North of Milford these sands average about 70 feet in thickness and are capable of supplying small to moderate quantities. The water obtained from these sands is reported to be of good quality. To the west toward Harrington the principal source of supply is from the Pleistocene sands except for the Town of Harrington which derives water from a shallow Miocene sand.

Water Consumption

Consumption figures for this area were obtained by interviewing community officials. As in other areas of the State, the water use is not precisely known. However, estimates have been made based on available information. The figures for this report were obtained from the Town Manager of the City of Milford and from the Town Manager of the Town of Harrington. The figures for Milford are meter readings whereas those from Harrington are time clock readings (capacity of pump x operating time).

Presently the City of Milford is supplying an average of 1 mgd to its industries and residents. The principal industrial users are Burris Processing, Torch Canning, and Milford Packing Company. Of these, Burris Processing is the largest user at the rate of .3 mgd. The others are seasonal and when operating use less than Burris Processing. It is estimated that Milford only serves 85 to 90 percent of its residents. The reason for this is many residents have wells that are still in good operating condition and refuse to pay the initial tapping fees to connect with the distribution system. The average per capita consumption in Milford based on 85 percent of the permanent population in 1964 (5,950) varies from 155 gpd in December to 249 gpd in August. These figures include industrial consumption.

The consumption in Harrington is not known exactly, but the following estimates have been made based on time clock readings. Harrington on the average, supplies its residents .3 mgd with fluctuations from .25 mgd in winter (100 gd per capita) to .35 mgd in summer (140 gd per capita). There are many small industries in the Harrington area but none are large water users. The average per capita consumption in Harrington is approximately 120 gpd. Table 6 summarizes the consumption data in this area.

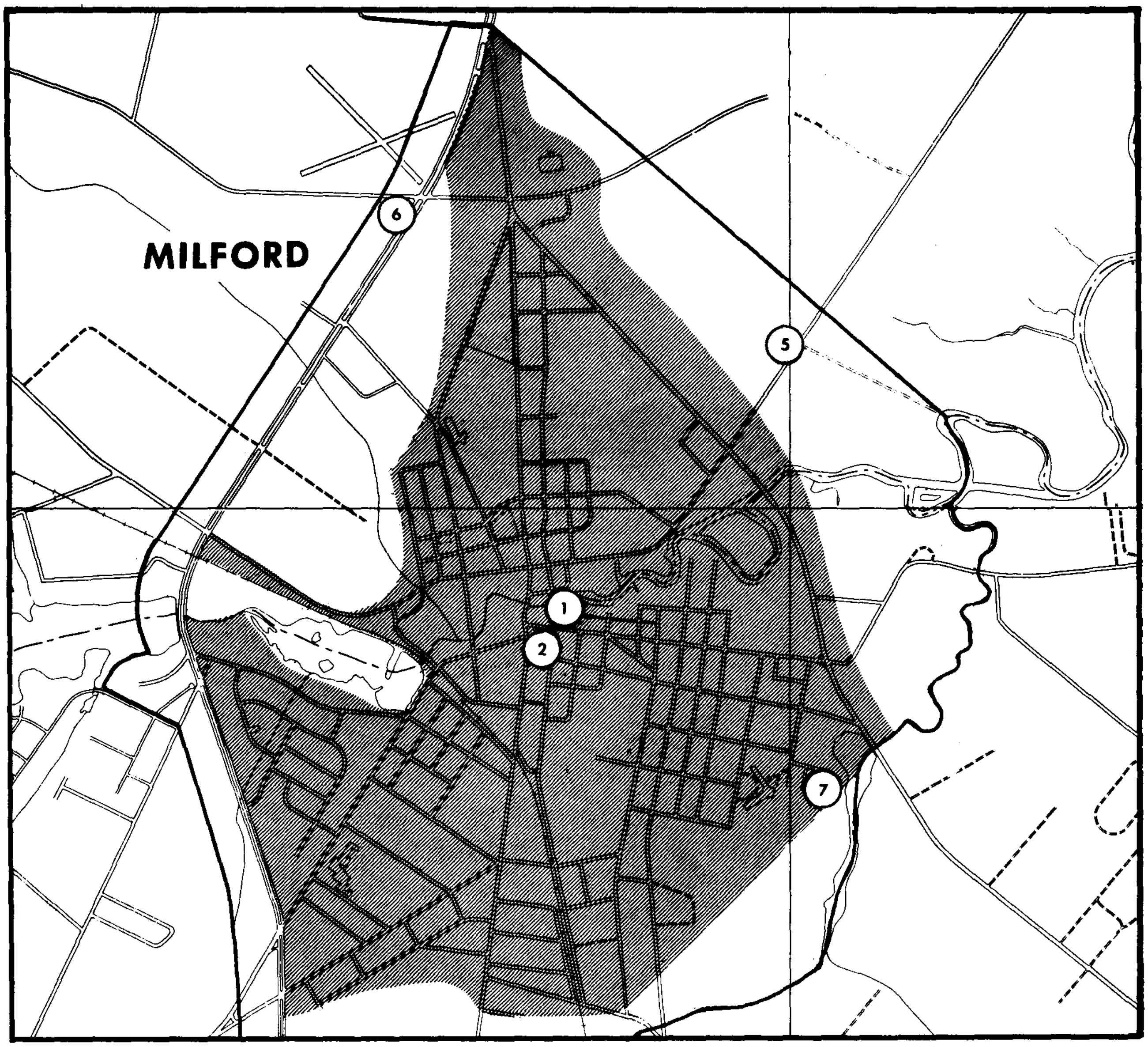
Potential Sources

The potential sources in this area are limited to undeveloped ground water resources with one exception. In essence, the Milford area has four alternatives to develop future supplies. These are (1) develop the same aquifers distant from existing wells, (2) develop deeper aquifers in the immediate area, (3) develop the Pleistocene sands south and west of the City, and (4) develop a surface supply from Haven Lake.

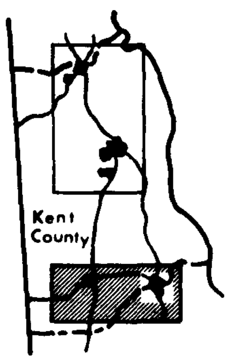
Due to the fact that Milford and the industries within it have developed to a large extent the Miocene sand beneath the City, future wells should be drilled away from the present cone of depression. To date these sands are being over pumped. Further development of these sands means importation of water from adjacent areas to the City via transmission lines.

From information based on a test well drilled in 1938 to a depth of 777 feet alternating sands and sandy clays were reported from 637 feet to an unknown depth. In Maryland and around Dover this for-

MILFORD—HARRINGTON AREA



VICINITY MAP



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SCALE IN FEET

PREPARED BY
DELAWARE STATE PLANNING OFFICE
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MARCH 1966

LEGEND

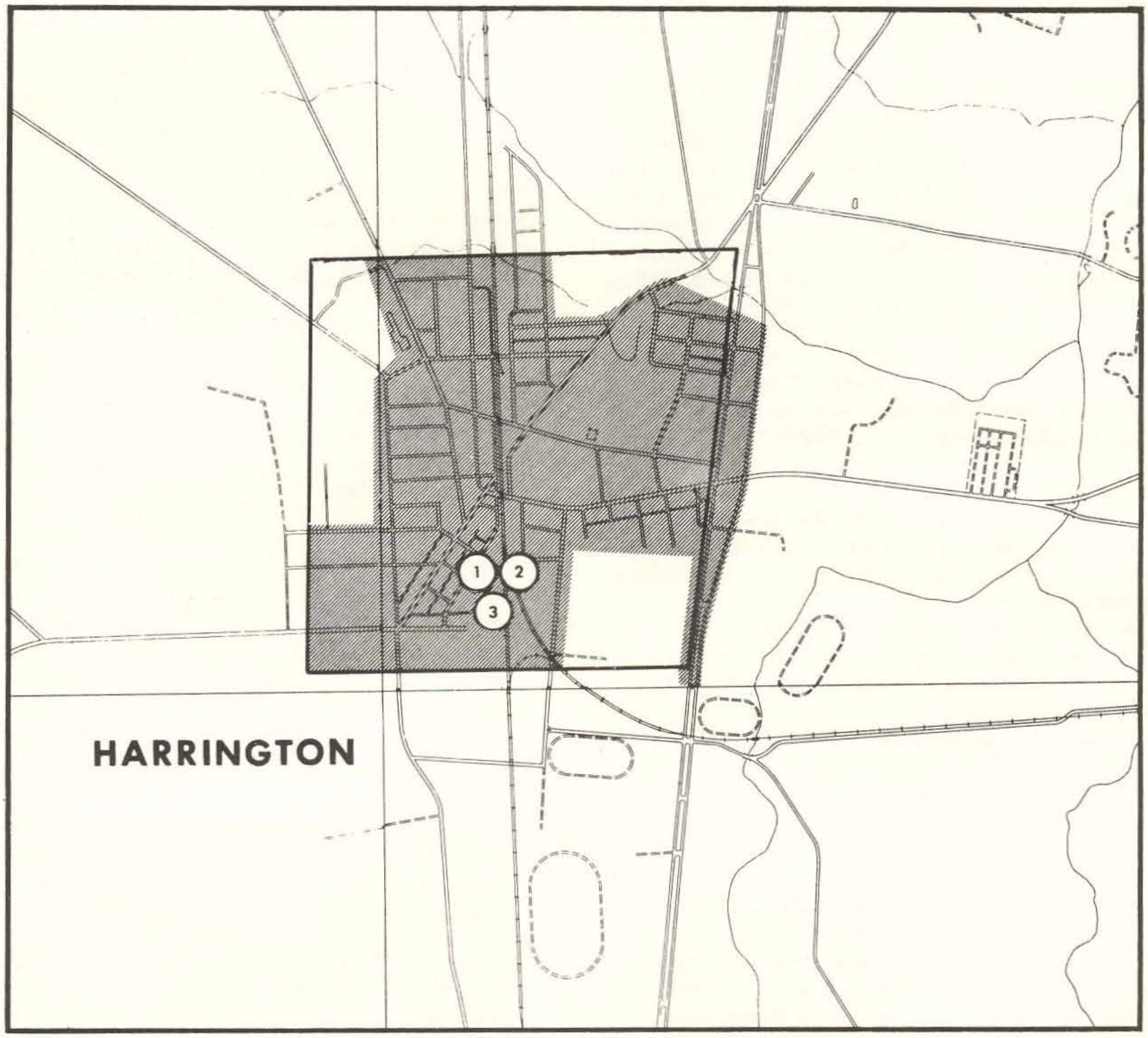
TOWN LIMITS

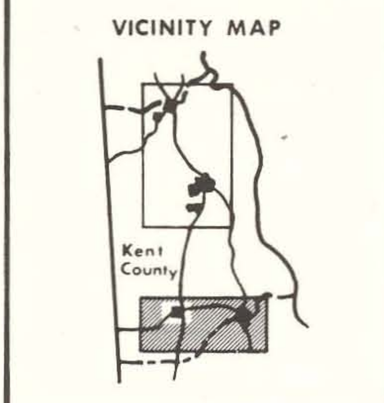
SERVED BY SYSTEM

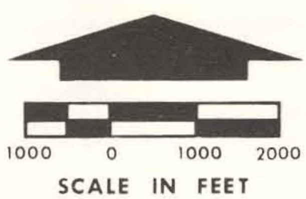
WELL SITE

FIGURE 6

MILFORD — HARRINGTON AREA







PREPARED BY
DELAWARE STATE PLANNING OFFICE
AND
DELAWARE GEOLOGICAL SURVEY

MARCH 1966

LEGEND

TOWN LIMITS

SERVED BY SYSTEM

WELL SITE (1)

FIGURE 7

mation contains an excellent aquifer. It is the southern extension of the Piney Point Formation. Development of this aquifer would have a slight effect on the existing wells. As this is a virgin aquifer in the area, the actual potential is not known.

The third possibility for additional supply is the Pleistocene sands south and west of the City. As pointed out earlier in this report these sands are thin and patchy in the vicinity of Milford and east of Milford they contain brackish water. To the north these sands become thinner which decreases their importance as a major aquifer. In the directions mentioned above these sands are thick enough to yield moderate quantities of good quality water.

A fourth potential supply is Haven Lake, which lies at the headwaters of the Mispillion River. Haven Lake, which has a drainage area of approximately 27.5 sq. mi., has a potential supply of 13 million gallons per day.

The undeveloped sources in the Harrington area are deeper aquifers. Based on information from surrounding locations, there are two virgin aquifers in the Harrington area. These aquifers are located in the deeper Miocene and Eocene series. Due to the lack of specific knowledge in the area, the potential of these aquifers cannot be determined.

Summary and Recommendations

In general, both Milford and Harrington are located in an area favorable for future water development. Presently consumers are obtaining water from two geologic units, namely the Pleistocene and Miocene Series. The Pleistocene Series contains the surficial sands from which most water users in the area obtain their supply. Where these sands are not used the deeper aquifers in the Miocene Series are utilized. In Milford, Harrington, and along the Mispillion River and Delaware Bay, this is the principal source of supply. The Miocene Series contains two major aquifers, the Cheswold and Frederica, of which the Cheswold is the deeper and appears to be the most productive.

To date both municipalities have an adequate supply. Although in the past, Milford has experienced difficulty in meeting its demand.

Additional wells may be developed in both the Miocene and Pleistocene Series but planning must be exercised in well spacings and rate of withdrawal to avoid over pumping of the aquifer. The pumping rate should not exceed .5 mgd/sq. mi. In addition to the above, wells could also be developed in an Eocene formation. This is an unused formation in the area about which little is known. In Milford another possible supply is Haven Lake which could be developed as a surface supply, and used in conjunction with the ground water supply. The capacity of Haven Lake as a source of water supply is approximately 13 mgd.

The small town of Houston, although it does not have a municipal supply, could develop a supply in any one of the above mentioned aquifers.

Evaluation of the Water Resources in the Laurel-Seaford Area

General Statement

The Laurel-Seaford area is one of the richest water areas in the State. Shallow sands of the Pleistocene Series average 95 feet in thickness and are capable of yielding large amounts of generally good quality water. The slight acidity of the water (the pH ranges from 5.4 to 6.3) is its main objectionable quality feature. The iron content of the water is generally low, although in a few places it is high enough to be troublesome.

Present Supply

Laurel's public water supply system was started in 1899, when a 4-inch well was drilled 115 feet deep and yielded 110 gpm. The next well was drilled in 1924 to a depth of 70 feet. It flowed at the time, and was still doing so in 1950 which suggests no serious dewatering of the shallow aquifers took place in the area. In 1925 an 18-inch concrete-cased wall was installed to a depth of 90 feet. Two additional wells of the same type were constructed in 1934 and 1937. These last two wells are slightly more than 90 feet deep, 24-inches in diameter, and are currently producing at rates of 500 gpm and 750 gpm respectively. Since 1937, only one new well has been drilled. It is a steel double-cased well constructed in 1953. At the time of installation it had a test yield of 1,067 gpm; however, the safe yield is limited to 750 gpm.

Currently, the water for Laurel is produced from the last three wells mentioned above, all of which are screened in the shallow sands of the Pleistocene Series. The quality of water obtained from these wells is reported to be good; the only treatment necessary is for pH correction. Laurel's rate of supply is 2.88 mgd which appears to be more than adequate at present.

Seaford started its water supply system in 1901 with the installation of two 18-inch wells, which gave the town a sufficient supply until 1938. They were then used as stand-by reserve until 1952. In 1938, a battery of five 3-inch wells were drilled to supplement the supply; these were abandoned in 1951. Seaford installed a 24-inch well with a capacity of 750 gpm in 1946; however, in 1952 it began to pump sand and the pumping rate was reduced 350 gpm. To compensate for reduced yields, abandoned wells, and growing demand, additional wells were drilled in 1952 and 1953. These wells gave Seaford an adequate supply until 1959, when a large capacity (1,000 gpm) well was constructed to supplement the town's supply.

Seaford now withdraws water from the four wells that were drilled between 1946 and 1959. As in Laurel, they are screened in sands of the Pleistocene Series and the water is treated to correct the pH. The total capacity is 2,400 gpm or 3.45 mgd which is more than adequate at present.

Neither Bethel nor Blades, small towns in the Laurel-Seaford area, have municipal supply systems. The water in these towns is obtained from privately owned wells, most of which tap the upper part of the Pleistocene sands. The water from this portion of the aquifer is of good quality; however, the lack of sewage systems, accompanied by an increasing density of dwelling units, could cause contamination of the aquifer.

Water Supply Systems

Both Laurel and Seaford have municipal water-supply systems. The distribution systems in these towns cover the areas bounded by the corporate limits of the respective towns. Figures 8 and 9 show the area served by the water supply systems and the well locations. In general, the water supply systems in both towns are adequate. Both towns are supplied by water obtained from wells located within the town limits. The water in Laurel and Seaford is pumped directly into the distribution system with the excess flowing into overhead storage. As mentioned earlier, both of these towns treat the raw water to raise the pH. As this is a relatively simple treatment, the raw water is treated at the well site which eliminates the need for a central treatment plant. Also, each treatment device has a rated capacity to meet the capacity of the respective well.

Although the above features of Laurel and Seaford's water supply systems are good, the systems are marginal in some aspects. The main fault in both distribution systems is the lack of sufficient overhead storage. As a result both towns have trouble meeting demand during periods of peak use, which usually occurs during mid-summer. To help alleviate this problem, the towns are presently restricting large consumptive uses to certain hours during the day.

Available Supply

A very large percent of the water in the Laurel-Seaford area is presently obtained from the shallow sands of the Pleistocene Series. Up until 1954, it was the only aquifer used in this area, and at present it is the most productive aquifer known to exist in the area. These sands are an average of 95 feet thick and are capable of yielding up to 1,000 gpm to individual wells. The main caution to observe in the area is not to exceed an average pumping rate of .5 mgd/sq. mi. In the Seaford area, along the Nanticoke River, yields up to 1 mgd/sq. mi. have been achieved without adverse effects. This high yield was sustained mainly by the infiltration of water from the Nanticoke River which receives water from a large drainage basin. If the pumping rate exceeds .5 mgd/sq. mi., the long run effect will be depletion of the ground-water reservoirs and this should be avoided. This will be true except for areas adjacent to the Nanticoke River and other ponds and large drainage channels in the area where recharge from the water bodies tend to maintain the water level. Although the Nanticoke River is tidal at Seaford, the water is considered as fresh. Consequently, recharge will not contaminate the ground water.

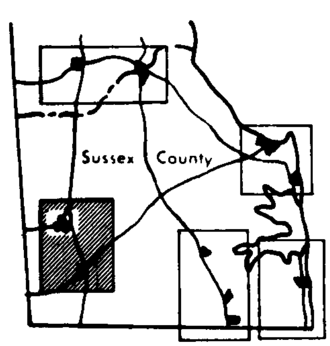
Other Potential Sources

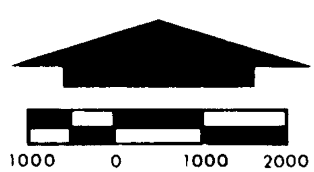
Owing to the large amount of water available from the Pleistocene Series, it is unlikely that this area will be forced to use any other source in the near future. In the event it should become necessary to develop additional sources, two alternatives are available: one is to develop the surface sources, and the other is to seek deeper aquifers.

Since both Laurel and Seaford have ponds and large drainage channels adjacent to or within the town limits, surface supplies are available. Records Pond, which lies at the head waters of Broad Creek, is a large potential supply for the town of Laurel. Likewise, Williams Pond and the Nanticoke River are potential supplies for Seaford. If these sources are developed and used in conjunction with the ground-water, a safe yield of .5 mgd/sq. mi. could be achieved throughout the drainage basin. The drainage areas of Broad Creek above Records Pond and the Nanticoke River above Seaford are approximately 90 sq. mi. and

LAUREL — SEAFORD AREA

VICINITY MAP





SCALE IN FEET

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MARCH 1966

LEGEND

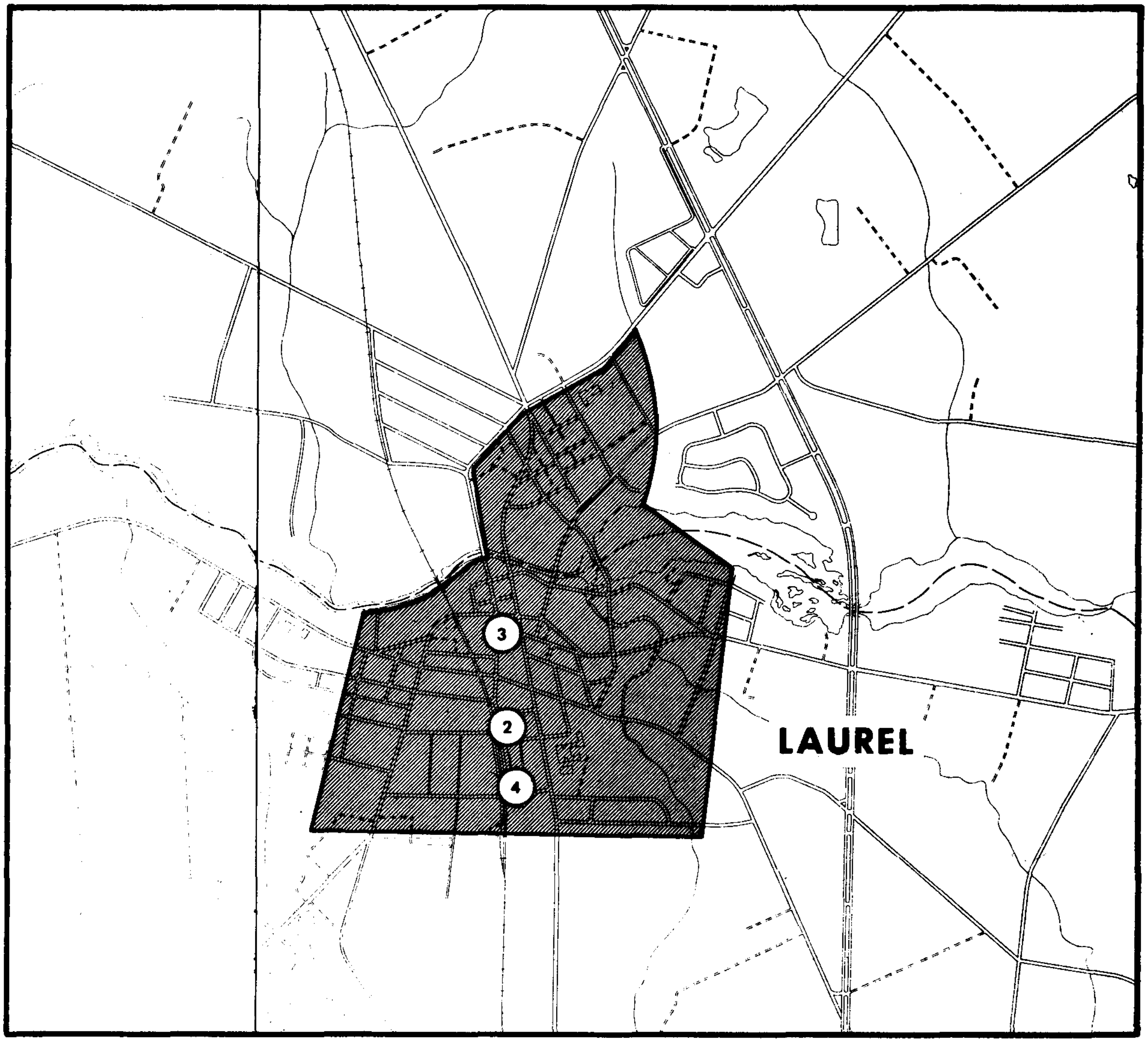
TOWN LIMITS

SERVED BY SYSTEM

WELL SITE (1)

FIGURE 8

LAUREL — SEAFORD AREA



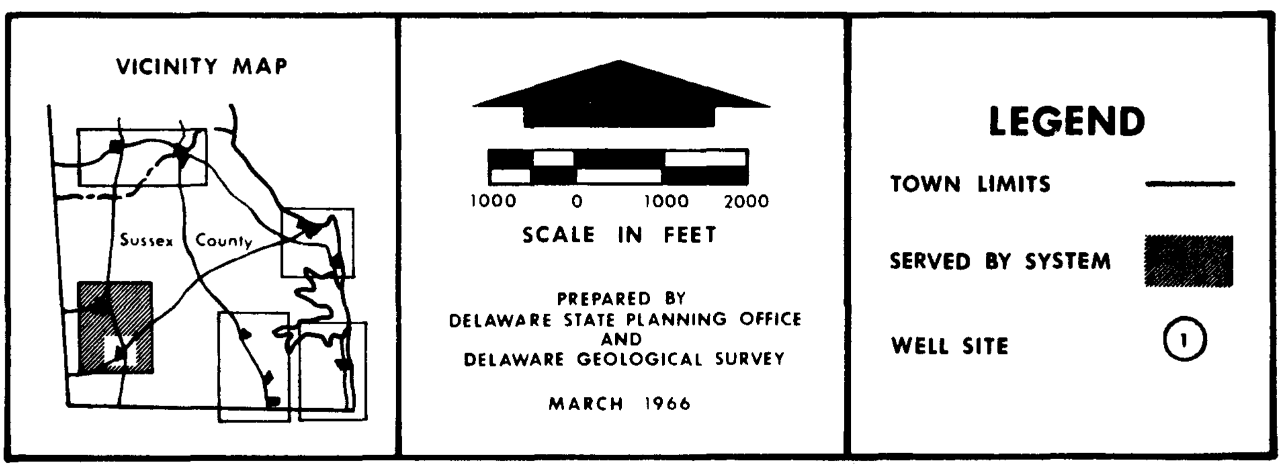


FIGURE 9

214 sq. mi., respectively. Thus, the potential of the surface sources are approximately 150 mgd, assuming no other significant withdrawals within the basin.

The deeper aquifers in this area, within the upper 500 feet, are limited to those of the Miocene Series. Although aquifers are known to exist deeper than 500 feet, there is little need to consider them at present. The aquifers in the Miocene Series, from the deepest to the shallowest, are the Cheswold, Frederica, and Manokin. All of these lie under the Laurel-Seaford area and are capable of yielding small to moderate amounts of water to individual wells. The water in these aquifers is higher in dissolved-solid content and may require more treatment than the water in the shallow aquifers.

Consumption

Consumption figures for this report were obtained from the City Manager, City of Seaford, and the Water Department, Town of Laurel. The water consumption in Seaford for 1964 varied from an average of .5 mgd in April to 1.4 mgd in June; likewise, the per capita consumption varied from 105 gd to 275 gd in the same period. From the above information, it can be seen that consumption during the peak demand period in June almost triples that of April, reflecting a relative wide fluctuation in consumption. Consumption figures are not known for Laurel. Although Laurel has meters, they are old and only work a small percentage of the time. The per capita consumption in Laurel is probably similar to that in Seaford. Both Laurel and Seaford serve small industrial accounts, but neither have any large individual users. Consumption data in Laurel and Seaford is shown in Table 6.

Located just west of Seaford is the E. I. duPont de Nemours Company Nylon Plant which uses approximately 3.2 million gallons of water a day; all, except 42,000 gallons, which comes from the Nanticoke River, is obtained by many wells tapping the shallow sands of the Pleistocene Series. Of the 3.2 mgd supplied, about 1 mg is consumed while the rest is discharged to the Nanticoke River. Because of the presence of the Nylon Plant, the Seaford area is one of the most heavily developed ground water areas in the State.

Summary and Recommendations

Owing to the geologic conditions of the area, Laurel and Seaford are located in a water-rich district. It is considered water-rich because of vast quantities of water available from the Pleistocene sands and the ease with which this water may be developed. In addition to the shallow sources in this area, the surface water from Broad Creek and the upper portion of the Nanticoke River remain potential supplies.

This area is characterized by a relatively stable population which should reflect an almost constant demand for water, with a slightly higher demand during the summer months. The consumption figures for Seaford, however, show the summer demand almost triples that of the winter.

Both Laurel and Seaford obtain water from wells screened in the shallow sands of the Pleistocene Series. These wells are located within the corporate limits of the individual towns. For additional supplies, these towns could place more wells in the surface sands, provided care is taken in locating the well sites and that pumping rate does not exceed an average of .5 mgd/sq. mi.

As pointed out earlier, a large supply of water in the area is available from surface sources as well as moderate supplies from deeper aquifers. Caution should be observed in the development of the shallow sands adjacent to Nanticoke River and Broad Creek as these streams are tidal (Nanticoke River to Seaford and Broad Creek to Records Pond). Although the water is considered fresh at Seaford and Laurel, during the period of low flow the saline water front reaches farther up stream. Thus, large scale pumping in areas adjacent to these streams could induce saltwater encroachment.

The small towns of Blades and Bethel should develop municipal supplies in the future. To avoid possible problems in the future, Blades should try to make arrangements to connect to Seaford's water supply system. In the event an agreement can not be made, a supply is available from the shallow sands. Bethel, on the other hand, should develop a supply of its own.

Evaluation of the Water Resources in the Millsboro - Selbyville Area

General Statement

This area is defined as the corridor along U. S. 113 between Millsboro and Selbyville. The towns located in this area are Millsboro, Dagsboro, Frankford, and Selbyville; all except Dagsboro, have municipal supplies.

The chief aquifers in this area are the water table sands of the Pleistocene Series and the directly underlying unconfined sands of Miocene age. These sands are an average of 120 feet thick and are capable of yielding moderate to large quantities of water to individual wells. Throughout this area, the water is generally poor in quality as it contains excessive iron accompanied by a marshy odor. This is especially true of water obtained from deeper portions of the above mentioned aquifers. The shallow wells, less than 35 feet in depth, usually yield a fairly good quality water.

Water Supply Systems and Consumption

Presently there are three municipal water supply systems operating in the area. The towns that have municipal systems are: Millsboro, Frankford, and Selbyville. These systems are small, both as to pumpage and number of people served, compared to other systems operating in the State. Regardless of their size, they are adequate considering the demand placed upon them.

Selbyville presently obtains its supply from three wells. The main sources are two wells tapping different portions of the Pleistocene Series. The third well, a small 4-inch well, is a reserve source and is screened in the Pocomoke aquifer. Total capacity of the three wells is approximately 1,000 gpm or about 1.4 mgd.

As raw water must be treated in Selbyville, the capacity of treatment facilities is important. The rated capacity of the treatment plant is 400 gpm or 576,000 gallons per day. Considering the average daily consumption which is about 250,000 gallons, the capacity of the plant is adequate. The average per capita consumption in Selbyville is 225 gallons. This high figure is due to the fact that (1) the town serves areas outside the town limits, and (2) water is supplied to industrial and commercial consumers. H and H Poultry, a poultry processing plant, is a principal consumer of water in Selbyville at the rate of 80,000 gallons per day.

Frankford obtains its supply from an 8-inch well screened in the Pleistocene sands. It has a capacity of approximately 300 gpm. Thus, as in Selbyville, the well capacity exceeds the capacity of the treatment plant which is 200 gpm or 288,000 gpd. Average daily consumption is approximately 75,000 gallons with peaks up to 150,000 gallons. Likewise per capita consumption varies from 120 gd to 240 gd.

The Town of Millsboro derives its supply from two wells tapping the Pleistocene sands. The quality of water obtained from these wells is good and does not require treatment before distribution. The average daily consumption in Millsboro is reported to be approximately 50,000 gallons. This figure seems low as per capita average consumption is only 46 gpd.

Dennis Mitchell Industries, Inc., a new industry in Millsboro, is planning to use municipal water at an estimated rate of 45,000 gd. When the plant reaches full operation in the spring of 1966, it will almost double the demand on the system. The combined capacity of the town's wells is close to 700 gpm and thus, it would not have serious effect on the over-all operation of the municipal system.

Well locations and the areas served by the municipal systems are shown in Figures 10, 11 and 12. Consumption data for Millsboro, Frankford, and Selbyville is listed in Table 6.

Available Supply

To date, the only aquifer in this area about which there is detailed knowledge is the Pleistocene Series. This is the principal aquifer and it is very productive. Properly constructed wells tapping this sand are capable of yields in excess of 500 gpm. As a result of its productivity, all the municipal systems utilize this source. Individuals living in the rural areas and Dagsboro also obtain their supply from this source, usually from small wells tapping the upper portion. Owing to the thickness (average 120 feet) and large quantities of water available from this aquifer, its potential supply is far greater than what is presently being utilized.

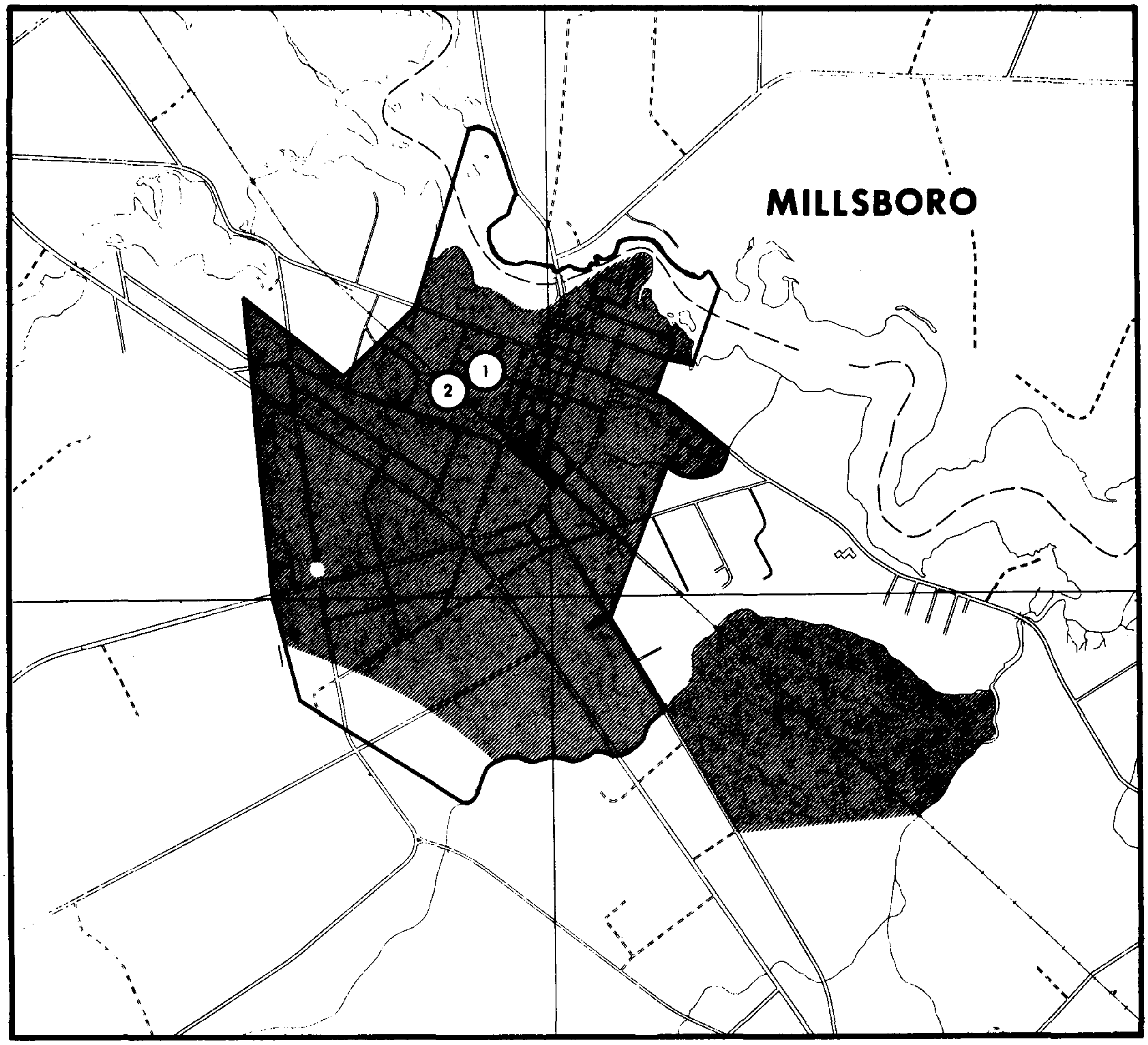
Potential Sources

Owing to the large quantities of water available from the Pleistocene sands, it is unlikely that additional sources will have to be developed in the near future. In the event that additional sources are needed, the immediate reaction would be to develop deeper aquifers.

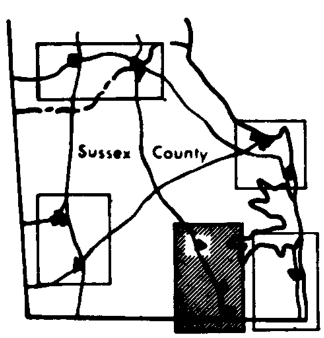
Deeper sources in this area, within the upper 650 feet, consist of aquifers located in the Miocene Series. Below this depth the water is reported to be high in chlorides. The Miocene Series underlies the sands and gravels of Pleistocene age. The Miocene Series may be divided into three formations to a depth of 650 feet: Cohansey, which in turn may be divided into four units, Upper aquiclude, Pocomoke aquifer, Lower aquiclude; Manokin aquifer; St. Mary's; and Choptank.

The shallowest aquifers in the Miocene Series are the Pocomoke and Manokin. Both aquifers are widely used in nearby Maryland and along the coast from Bethany Beach to Ocean City, Maryland. The Manokin aquifer is the deeper and more productive of the two. It also underlies the whole area, whereas the Pocomoke aquifer is found only in the southern portion. The next deeper formation is the St. Mary's.

MILLSBORO – SELBYVILLE AREA



VICINITY MAP



SCALE IN FEET

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MARCH 1966

LEGEND

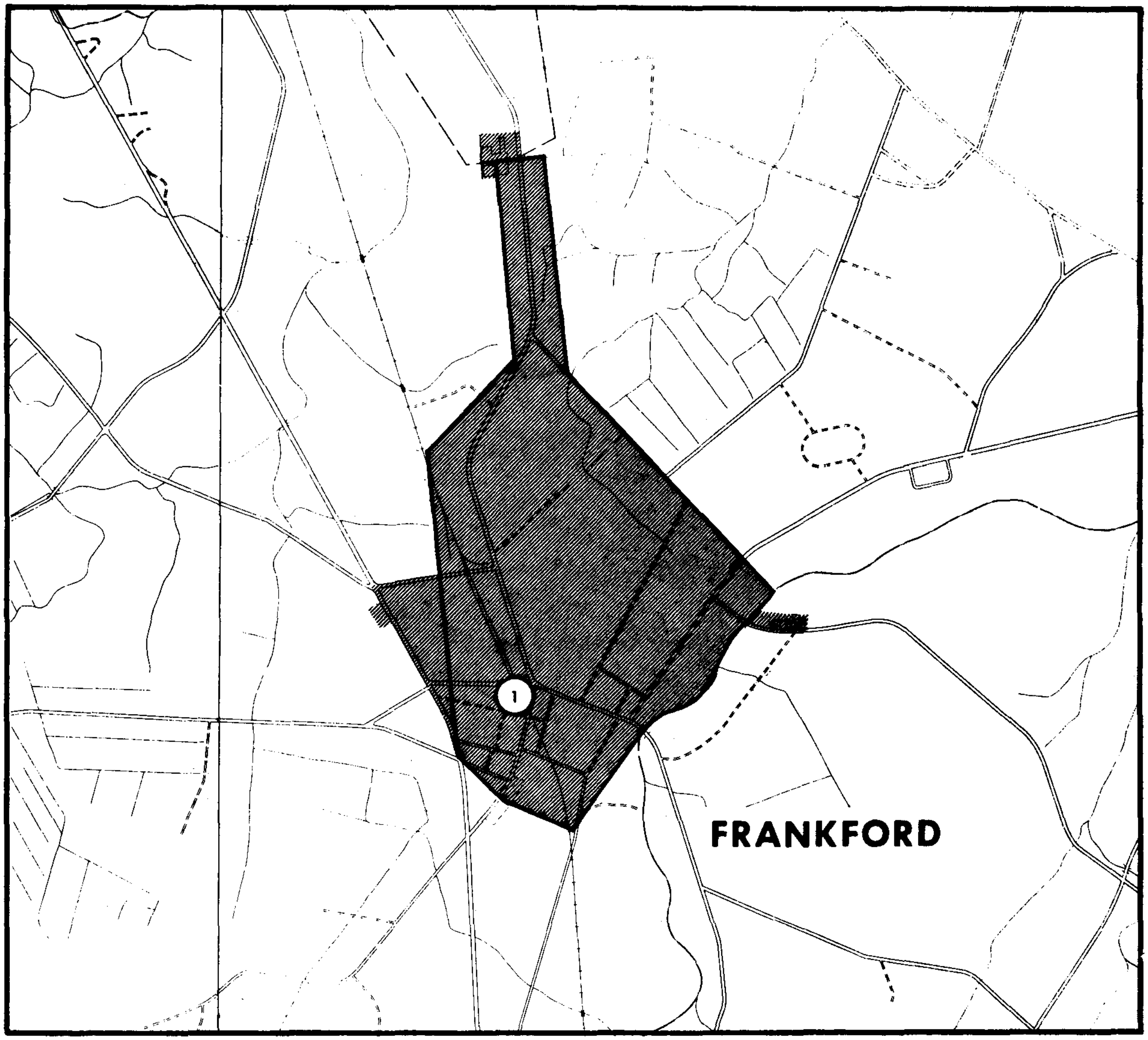
TOWN LIMITS

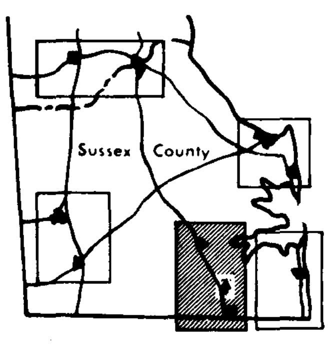
SERVED BY SYSTEM

WELL SITE (1)

FIGURE 10

MILLSBORO — SELBYVILLE AREA





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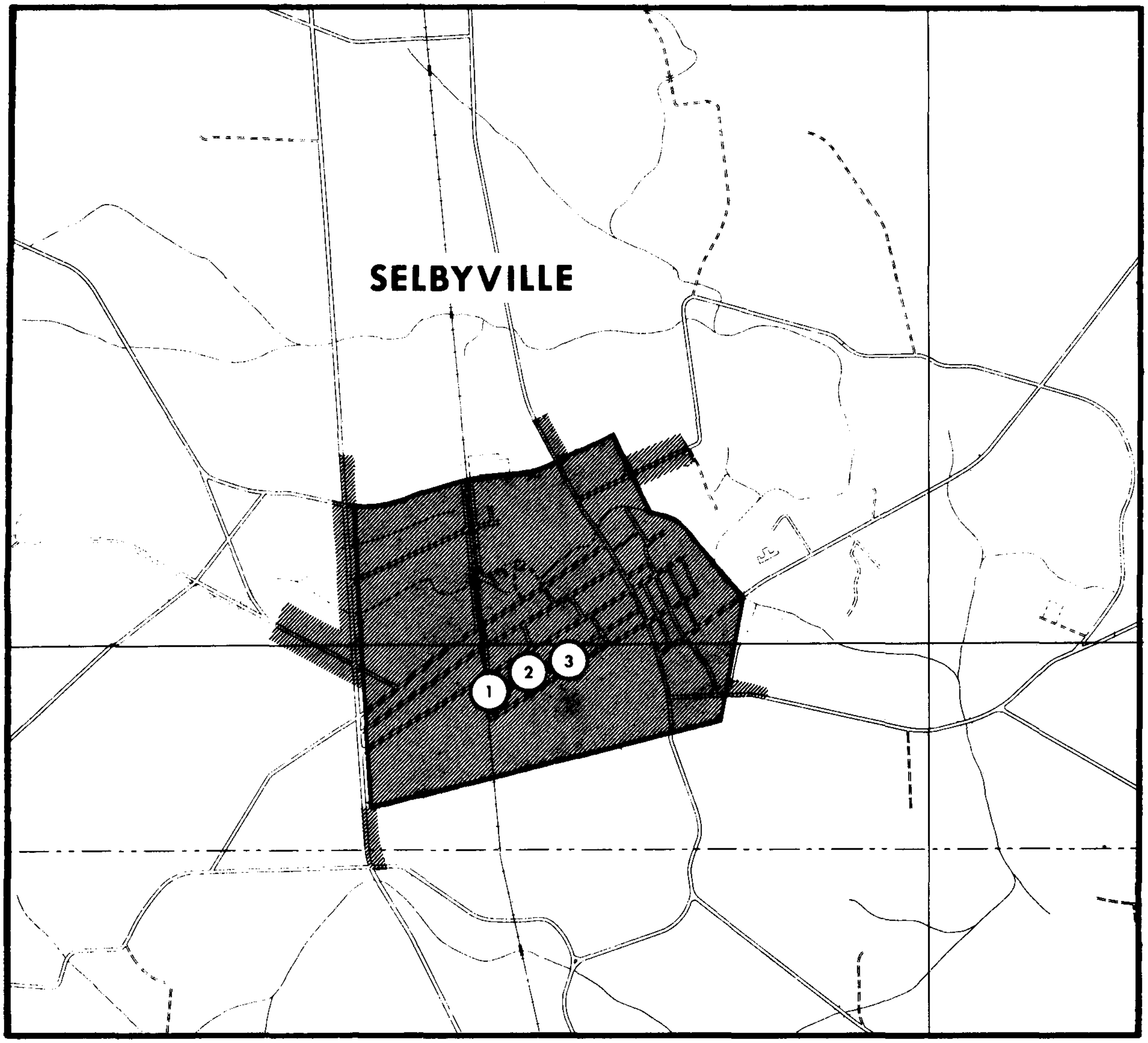
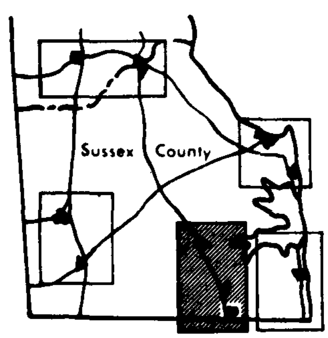
LEGEND

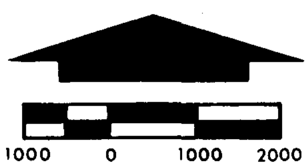
TOWN LIMITS	——
SERVED BY SYSTEM	(shaded)
WELL SITE	(1)

FIGURE 11

MILLSBORO — SELBYVILLE AREA







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LEGEND

TOWN LIMITS

SERVED BY SYSTEM

WELL SITE

FIGURE 12

This formation underlies the Manokin aquifer and is a significant aquiclude throughout this region. The Choptank Formation, which underlies the St. Mary's, is reported to contain saline water.

Water Quality

The Millsboro-Selbyville area is an impending water quality problem area as depicted on the Statewide Water Resources Map, and comments on water quality are in order. The detrimental quality factors of the water in this area are: iron, low pH, and hydrogen sulfide odor. The U. S. Department of Health, Education and Welfare Public Drinking Water Standards specify the maximum allowable limit of iron is .3 ppm. Iron content above this amount causes reddish-brown stains on clothing, utensils, and plumbing fixtures. Excessive iron in water is also troublesome to industrial users, because iron scale and deposits formed by iron reducing bacteria may result in clogging of well screens, pipes, and industrial equipment.

Summary and Recommendations

At present, this area has an abundant supply of water, without considering water quality. Large quantities of water, in excess of what is presently being used, are available from the Pleistocene sands, Additional quantities of water are also available from deeper aquifers.

Based on present information, it appears that this area must continue to treat its poor quality water. Efforts to obtain better quality water from deeper aquifers have proven unsuccessful, but possibilities have not been exhausted. One solution is importing water from other water-rich areas to the north.

Evaluation of Water Resources in Lewes-Rehoboth Beach Area

General Statement

The potential for ground-water development in the Lewes-Rehoboth area is generally good. The geology underlying the area and the prevalent hydrologic conditions are such that at the present rate of development adequate fresh water supplies can be obtained for many years in the future, if proper steps are taken in development of this resource. Little knowledge about the relationship of fresh ground water to saline water has been the main factor responsible for saline water problems in the area.

Present Supply

The town of Lewes established its water supply system in 1901. Water was initially obtained from sixteen 2-inch diameter wells located in the area of Schly Street. This supply was used for several years, but it was gradually replaced by a series of 3-inch wells. In 1934, a 16-inch well was constructed and was used as the main source of supply while the previous source was only used in periods of peak demand. In 1936, two more large-diameter wells were drilled to supplement the supply. When, in 1942, one of the older sources failed to produce, Lewes drilled two more wells. In 1944, owing to heavy pumping and the closeness of salt-water bodies, a few of these wells became contaminated with saline water. In view of this serious threat to the existing well field, a series of investigations were initiated. As a result of these investigations a new, also the present, well field was located southwest of town near Murrays Corner. In the meantime, quality checks at the old well field have shown that the encroachment of saline water has been arrested and that the contaminated wells have been flushed by the restored natural flow of fresh water to the ocean.

In summary, water for Lewes is presently obtained from five wells (capacity of 3,450 gpm or 4.96 mgd) located in line from just north of Murrays Corner stretching to the northwest toward Savannah Road. The town has room for one more well between its existing well number 5 and Savannah Road. This source of water is more than adequate for the present and anticipated needs in the immediate future.

The water supply system of Rehoboth Beach was developed in a manner similar to that of Lewes; likewise, it began to experience salt-water encroachment during the period 1943-1944. At that time, Rehoboth's municipal supply was located west of Bayard Avenue between Baltimore and Maryland Streets. Salt-water encroachment was hastened not only by the town's wells, but also by the Blue Hen Theater, Rehoboth Ice Co., and Stokely Van Camp Co., since they all had wells tapping the same aquifer. At this point, Rehoboth Beach was faced with two alternatives: the first of which was to drill to deeper aquifers; the second, to develop a source farther inland. Following the advice of the U. S. Geological Survey, the second of these alternatives was pursued. In 1946, a test well was drilled north of Rt. 14 about 1 mile west of the Rehoboth and Lewes Canal. The water at this location was found to be of high quality and the ground-water reservoir was capable of yielding from 800 to 1,000 gallons per minute to individual wells. Rehoboth Beach began the development of this source in 1952.

At present, Rehoboth Beach is obtaining water from three wells located in the area of the test well mentioned above and two larger wells further inland. These wells have a capacity of 3,850 gpm or 5.54 mgd, thus giving Rehoboth Beach a supply capable of meeting its demands in the near future.

The Cape Henlopen and Ft. Miles area, until recently a military reservation, has become available for redevelopment as a recreational and educational site. During the early period of its intensive use as a military installation, several wells had to be abandoned due to deterioration in quality, mainly as a result of salt-water encroachment. The decision was then made to develop water supplies further inland, west of the Lewes and Rehoboth Canal. The present water distribution system serving the area is supplied by two 150 gpm wells west of the Canal.

Another area that should be considered with Lewes-Rehoboth Beach is Dewey Beach. Dewey Beach does not have a municipal system and consumption is primarily restricted to the summer months. Many of the shallow domestic wells there experience some type of quality problem. The most common complaints are brackish water, high iron content and marshy odor. Little is known about the water quality at greater depths at Dewey Beach. However, from water analysis of deeper wells farther south along the coast, the water is likely to contain high iron and possibly salt.

Water Supply System

While interviewing the various communities about their consumption records, data were also obtained concerning the present condition of the water-supply systems. A good water-supply system should be capable of delivering water of good quality, adequate quantity, and adequate pressure to all consumers in a well organized and efficient manner. The fire underwriters suggest that a pressure of 40 psi be maintained in the distribution system at all times. In addition, the water system should be able to transmit all water that is made available from the source. The area served by the water-supply systems and well locations of Lewes, Rehoboth, and Fort Miles are shown in Figure 13.

When Lewes relocated its well field inland a transmission line from the well field to the water plant was placed along Kings Highway. Today, because of increased demand, this line is inadequate, since it is only capable of transmitting water at a rate of 1,500 gallons per minute. As a result, water pressure on the north side of the canal falls during periods of peak demand (especially when the fish factories are operating). Furthermore, Lewes is unable to utilize the full capacity of its well field since the wells are capable of supplying water at the rate of 3,450 gallons per minute. The town council realizes this problem, however, and it wishes to consider possible locations of future well fields or additions to the present well field before constructing a new transmission line.

The supply system of Rehoboth Beach consists of three wells that empty into a reservoir at the well site. The water is then pumped by two booster pumps through the transmission line along Rehoboth Avenue to the water plant and distributed from that point. In 1964 an additional 16-inch transmission line was constructed to connect the 2 new wells with the distribution system. This line parallels along Rt. 14 as far as Robinson Drive. Two mains are taken off this line and connected to the distribution system; one following State Road to Rehoboth Avenue, the other following Robinson Drive and crossing Silver Lake to Rodney Street.

Water Consumption

Annual and summer water consumption figures have been determined by interviewing community officials and other water users. Water use is not always precisely known, but reasonable estimates can be made based on population figures and rated capacities of well fields. The figures for water use included in this report were obtained from the Town Managers of the respective towns. The figures for Lewes are meter readings whereas those for Rehoboth are estimated based on rated capacities of the pumps. The average per capita consumption in Lewes during the summer, winter, and year of 1964 is 525, 365, and 400 respectively. These figures are unusually high due to the large industrial consumption (.42 mgd). While consumption figures are not known exactly for Rehoboth, some estimates can be made. It is known that during the summer of 1964, Rehoboth Beach's wells were producing at 100% capacity (watering of lawns, etc. was restricted from 10 a.m. to 10 p.m.) to meet its demand which was approximately 2-1/2 million gallons a day. During the winter months of 1964, the town used an estimated 0.5 million gallons a day. Average per capita consumption in summer, based on estimated permanent summer population (1964, 17,000) is 146gd; winter, based on year around population (1964, 3,030) is 165 gd. Consumption data for Lewes and Rehoboth are summarized in Table 6.

Available Supply

The main source of supply for the area has been and will continue to be ground water. Delaware has an average rainfall of 44 inches per year of which

LEWES — REHOBOTH AREA

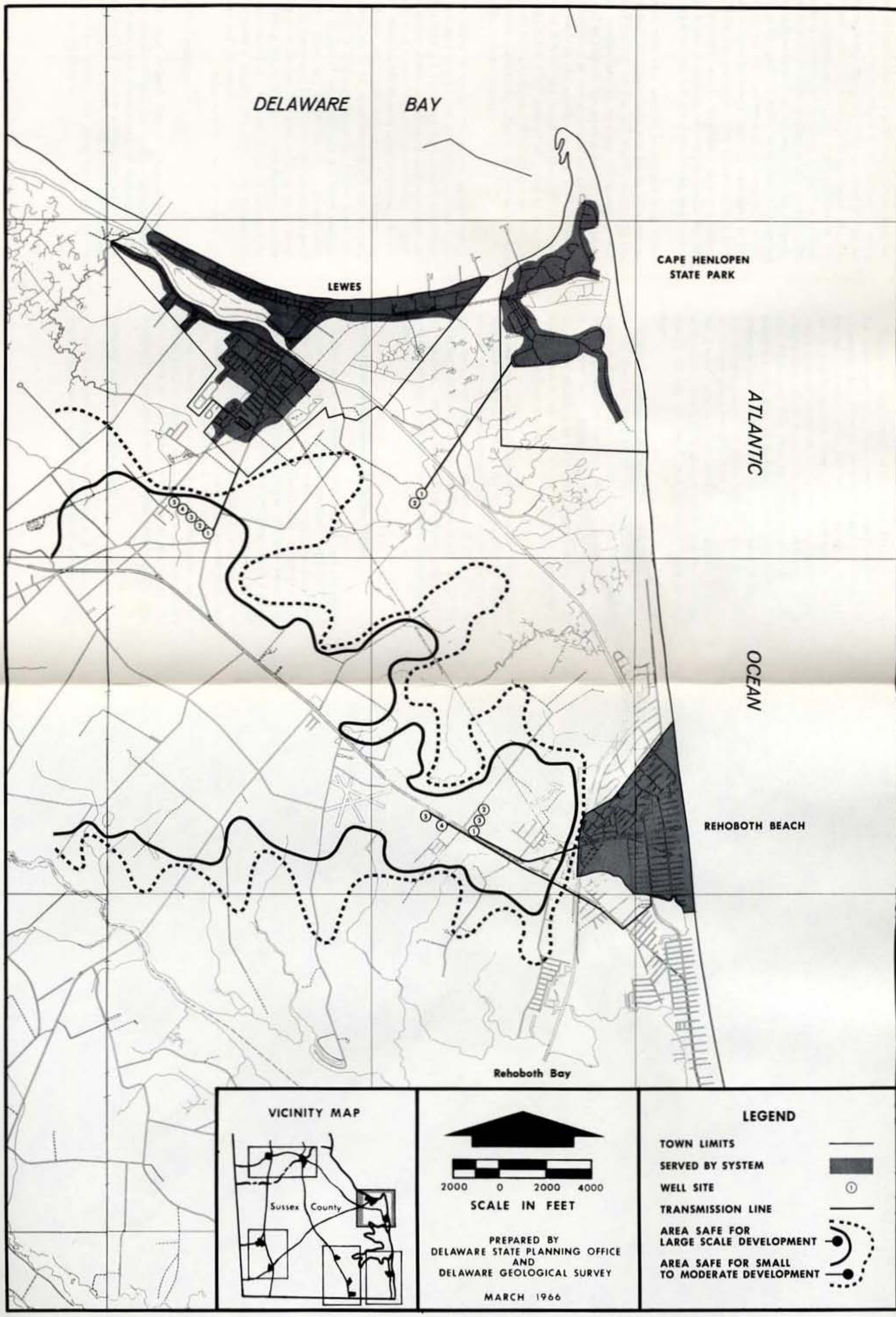

FIGURE 13

about 50% is lost through runoff and evapo-transpiration. This leaves an average of 22 inches of water per year to recharge the ground-water reservoir. In the area outlined with solid black line in Figure 13, this amounts to approximately 4,080 x 10^6 gallons of water per year, or an average of about 11 million gallons a day. Of this 11 million gallons a day another 50% is lost through evaporation and transpiration, leaving about 5.5 million gallons a day available for pumpage or .5 mgd/sq. mi. Over an area of 10.7 sq. mi., which is the area within the black line, this amounts to 5.3 mgd available for pumpage. The important fact here is that .5 mgd/sq. mi. is available on a continuous basis; likewise, 1 mgd/sq. mi. is available for 180 days; 1.5 mgd/sq. mi. for 120 days, during any year.

When more than this amount is pumped it is taken from storage. The area within the black line has an area of 10.7 sq. mi. or 3 x 10^8 sq. ft. Assuming the underlying aquifer has an average thickness of 100 ft., the total volume of the aquifer is 3 x 10^{10} cubic ft. If the porosity or water space is 20%, the total volume of water in the aquifer is .6 x 10^{10} cubic ft. An estimated 50% of this water is available for capture, leaving 22,400 x 10^6 gallons of water in storage. Assuming a 10 ft. draw down of the water table, which is the maximum allowable, 2,240 x 10^6 gallons of water are available from storage.

From the above it can be seen that approximately 2 billion gallons a year are available for use from rainfall. Presently, Lewes and Rehoboth Beach combined are using about .9 billion gallons a year, or roughly 50% of the replenishable ground-water supply in the area considered. If more than 2 billion gallons is taken in any year from this area, it is known as mining water, which is an undesirable practice, and in this area it is likely to result in saline water encroachment. It should be noted that 2 billion gallons is a yearly figure and is not to be confused with average daily pumpage. Lewes and Rehoboth are free to pump water at almost any rate as long as no more than 2 billion gallons a year is developed from the ground-water reservoir. Another point of interest is that over a year's supply of water is in storage to even out wet and dry years.

Other Potential Sources

When the time comes that the Lewes-Rehoboth Beach area has developed its shallow ground-water potential, it has four alternatives of obtaining additional supplies: (1) develop surface sources, (2) explore deeper aquifers, (3) re-use of water, (4) desalinization of ocean water. The first two will play a leading role in the future.

Since the topography of this area does not provide for large reservoir sites, present ponds and drainage channels will have to be used. Water may either be pumped directly from the reservoir, or a series of wells may be placed around the reservoir, thus using water from the reservoir to replenish the ground-water supply and at the same time taking advantage of natural filtration. The first potential source of surface water for this area is Red Mill Pond. This pond has a drainage area of 7 sq. mi. and an estimated yield of 3.5 million gallons a day. Another potential source of surface water for this area is Love Creek. At present, Love Creek is tidal; however, it could be dammed at Rt. 24. Love Creek provides drainage for approximately 14 sq. mi. and has a potential capacity of 7 mgd.

Little is known about quantity and quality of water in the deeper aquifers of this area. When water is pumped from deeper aquifers the water is obtained from a greater area around the well than from around a shallow well. Thus, any large-scale development of deeper aquifers in this area could result in saline encroachment as well as reducing the capacity of nearby shallow wells.

Multi-use and desalinization of water will become important sources of water for this area in the distant future. Improved technology will reduce the cost of converting sea water to fresh water, while cost of developing additional sources will increase cost of water, in turn causing industry and other large water users to re-use water that is currently discharged as waste.

Caution Due to Closeness of Saline Water

Salt-water encroachment into public and industrial supplies is one of the major ground-water problems in the Coastal Plain. If a water supply is developed from an aquifer that is hydraulically connected with a salt-water body, there is danger that salt water may be drawn toward the wells by pumping. Such a water supply can only operate safely if the natural seaward hydraulic gradient is not disturbed, at least not to the extent that it is reversed. This means that less water can be pumped from a well or well field that is located close to a source of salt water than one further inland. At greater depth saline water also occurs as a result of incomplete flushing of sea water that invaded the formation during higher stands of the sea.

Summary and Recommendations

The Lewes-Rehoboth Beach area is basically a resort area having high seasonal fluctuations in population. Associated with fluctuations in population are variations in water demand: high demand during the summer months, reaching a peak on weekends, and decreasing during the winter months.

In Lewes water demand in the winter decreases to about one half of the summer demand as compared to about one fifth in Rehoboth Beach and approximately one third for the Lewes-Rehoboth area.

Lewes, Rehoboth Beach, and Ft. Miles are supplied by well fields located inland, away from salt-water bodies for reasons mentioned earlier in this report. Because of the danger of salt-water contamination, an area inland has been selected for large-scale development of ground water. This is outlined in Figure 13 by a solid black line. An estimate of the annual recharge for this area indicates that the available supply is a little over twice the present demand. In areas of heavy withdrawal like Lewes and Rehoboth Beach well fields, the water table has a chance to recover during the winter months. Between the area of large-scale development and saline bodies of water there are areas where the presence of suitable ground-water is known; however, large-scale development is not recommended. This area is considered suitable for satisfying small to moderate residential and industrial needs, and is shown in Figure 13 between the solid black line and the dashed black line. This does not mean that no wells are operating safely outside the above areas, but it implies that these wells are relatively small and if more wells are needed preference should be given to locations in the direction of the areas recommended.

Dewey Beach presently does not have a municipal system and the water quality in this area is generally poor. In the future when demand becomes sufficient Dewey Beach should either connect to Rehoboth's distribution system or develop its own inland supply.

Evaluation of Water Resources in the Bethany Beach Fenwick Island Area

General Statement

The potential for water supply development of ground-water resources in this area is good. The quantity of water appears to be adequate for many years to come; however, the quality remains a problem and water treatment is required before use. This is generally true for both the shallow and deeper aquifers. At Fenwick Island, brackish water that contains objectionable amounts of iron has been found ranging from near the surface down to 90 feet, while at Bethany Beach water of adequate quality and moderate quantity is available from the same sands. A primary consideration, as in any coastal town, is the danger of salt water contamination. In this area salt water may enter the shallow aquifers from two directions, i.e. from the ocean and from inland bays.

Present Supply

The present municipal supply for Bethany Beach was initially developed by a private water company organized in 1943. At that time, two wells were drilled, one to supply the town and another to supply the National Guard Camp. By early 1950, the well at the National Guard Camp became the main supply for the town, while the town well was used as an auxiliary supply. Later that year the private water company was purchased by the town of Bethany Beach which, in the same year, drilled two additional wells. Unfortunately, one of these was reported to have deteriorated in 1953. In the summer of 1954, another shallow well was drilled farther inland. In 1959, Bethany drilled a well to the Manokin aquifer at a depth of 215 feet in the hope of obtaining a larger supply of water of better quality. The quantity of water from this well proved to be adequate, but a chemical analysis showed it to be very irony (13 ppm) and slightly acid.

Presently, the water for Bethany Beach is derived from two aquifers. Two wells produce from shallow sands (Pleistocene Series) and one from a deeper sand located in the Manokin aquifer. The Manokin in this area is an artesian aquifer located in the Miocene Series. During the summer months, when demand is high, water is mainly obtained from the deeper aquifer. During the winter when the water table is usually high and demand small, water is obtained from the shallow wells. The quality of this water is slightly better and requires less treatment than that from the Manokin aquifer. Bethany Beach's supply which is 660 gpm or .95 mgd. appears to be adequate at the present and for a few years in the future.

A small residential section immediately north of Bethany Beach is served by the Sussex Shores Water Company. This private company, started in 1958, presently serves a summer population of about 350. The original well and water plant were located between the National Guard Camp and Rt. 14. When Rt. 14 was reconstructed as a four-lane highway the water plant had to be moved. Currently, the source and treatment plant are located about 1-1/4 miles north of Bethany Beach on the west side of the highway. The water company derives its water from two wells that tap the upper portion of the Manokin aquifer. As in Bethany Beach, this water is treated for excessive iron and correction of the pH. The capacity of these wells is 500 gpm or .72 mgd.

Other towns and developments in this area, namely Millville, Ocean View, Middlesex, South Bethany, and Fenwick Island, do not have water supply systems. The water for Millville and Ocean View is mainly obtained from shallow sands which contain very irony water. In Middlesex, South Bethany and Fenwick Island most water is developed from privately-owned artesian wells in the Manokin aquifer because saline water is found in shallow sands. Many successful domestic wells have been drilled to the Manokin in the last few years; however, the iron content of the water continues to be a problem.

Water Supply System

Bethany Beach is the only town in this area that has a municipal water supply system. The over-all capacity of the town supply is adequate through most of the year. The limiting factor is its treatment plant which is rated at 300 gpm or .43 mgd. During the periods of peak demand, the capacity of the treatment plant is insufficient. At such times, water quality is sacrificed in order to meet the quantity required. Bethany Beach is planning to alleviate this situation by increasing treatment facilities from 300 to 800 gallons per minute (an increase of .7 mgd) and extending the distribution system so that everyone within the corporate limits of Bethany Beach may obtain town water.

The only other distribution system in this area is owned by Sussex Shores Water Company. This system is more than adequate for the number of people it serves. The development that is currently being constructed just north of Sussex Shores will also be supplied by Sussex Shores Water Company.

The distribution systems for Bethany Beach and Sussex Shores are shown in Figure 14.

Water Consumption

Since Bethany Beach does not have water meters, only estimates of water consumption can be presented. These figures were obtained from the Water Superintendent. It appears that average water consumption is about 75,000 gallons per day during the period from mid-June to Labor Day, with a peak demand of 125,000 gallons per day. During the remainder of the year the pumpage is about 25,000 gpd.

Per capita consumption for Bethany Beach is shown in Table 6 for both summer and winter; the indicated seasons (winter population 170, summer population 1,330). At present, Bethany Beach does not serve water to industry; however, the National Guard Camp is supplied when it is in operation.

Available Supply

As in Lewes and Rehoboth, ground water is the main source of supply for the southeastern portion of Sussex County, and it will continue to be so, for many years in the future. The outlook for available water in this area, must be viewed from two different aspects because of the geologic conditions. Millville and Ocean View are located on a portion of land referred to as a neck (surrounded on three sides by water). Bethany Beach, because of the presence of Assawoman Canal and the other communities between Indian River Inlet and Fenwick Island, is located on a strip of land referred to as a bar (narrow portion of land separating bays from the ocean).

The main supply of water for the towns located on the neck is from the water-table aquifer in the Pleistocene Series. Water may be obtained from shallow aquifers on the neck as long as the fresh water head remains great enough to prevent salt-water encroachment from the bays and canal. The water available from the shallow formations inland from the Assawoman Canal and within the area outlined in the solid black line (see Figure 14) is approximately .5 mgd/sq. mi. The quantity of fresh water available from these same sands decreases with distance from this line eastward mainly because of the presence of salt-water bodies. During the winter, moderate amounts of water can be pumped because of rate of recharge and consequently the water tables are higher; however, this rate of pumpage can not be maintained throughout the summer and early fall.

The most reliable sources of water for the bar area are aquifers located in the upper part of the Miocene formation. These aquifers are the Pocomoke and Manokin which are at depths of 75 and 200 ft., respectively. The Manokin is the deepest and most productive of the two. Large-scale pumping at Ocean City, Maryland, reveals that the Pocomoke and Manokin aquifers are capable of sustained yields of 150 and 500 gpm, respectively.

Water Quality

The variable quality of ground water in this area is of the utmost importance. In many places the iron content of the water is high enough to be objectionable, whereas in others the chloride content is high. At Fenwick Island, brackish water also high in iron content has been found in sands from the surface to a depth of 90 feet. In this area, the local clay beds near the surface are apparently thin and discontinuous allowing landward movement of salt-water in response to reduced freshwater heads. At Bethany Beach and inland from Bethany Beach, slightly irony water in adequate supply is obtainable from the Pleistocene sands. Water from the Pocomoke and the upper part of the Manokin also contains objectionable amounts of iron ranging from 8 to 14 ppm.

Encroachment of saline water through induced infiltration caused by large scale pumping is one of the most critical ground-water problems in this area. The Pocomoke and Manokin aquifers are protected from landward movement of salt-water by a clay layer 20 to 40 feet thick and by a high artesian head which helps to prevent salt-water from moving toward centers of pumping in areas along the shore.

Other Potential Sources

At present, ground-water resources below 300 feet in the Bethany Beach area are undeveloped. From available information it appears that water from aquifers occuring between 300 ft. and 2,000 ft. will be high in chlorides and dissolved solids and of moderate to high hardness. Water from below this depth (2,000 ft.) is reported to be of adequate quality. Additional information on the quantity and quality of water from the deeper untapped aquifers should be obtained by drilling test holes and water sampling. If the quality of water from these aquifers is objectionable, three alternative sources are available; reuse of water, desalinization of sea-water, or importation of water.

Summary and Recommendations

The coastal strip between Indian River Inlet and Fenwick Island is basically a resort area having high seasonal fluctuations in population. The area inland from Bethany Beach along Rt. 14 is characterized by small concentrations of residential and commercial development having a relative stable year-around population.

Water for Bethany Beach is obtained from two different hydrologic units depending on the season of the year as explained earlier in this report. To meet the growing demand for water during the summer months Bethany Beach should develop more wells in the Pocomoke and Manokin aquifers rather than utilize the shallow sands in the area. Before these aquifers are developed to any great extent aquifer tests should be performed to determine their productivity. In the event enough water is not available from these aquifers, Bethany Beach may develop a supply inland within the area outlined by the solid black line, where the shallow sands are capable of delivering .5 mgd for each sq. mile.

Presently, Millville and Ocean View do not have any type of municipal supply system, i.e. all water is obtained from privately-owned wells. If a municipal supply is desired for either or both of these communities an adequate supply is available from the shallow sands located to their southwest within the solid black line.

North of Bethany Beach toward Indian River Inlet, water is obtained from privately owned wells with the exception of Sussex Shores which is served by its own privately-owned water company. This water company is expanding its distribution system to supply a new housing development just north of Bethany Beach and plans to supply water to other housing expansions in the future. For additional supply, Sussex Shores Water Co. may drill more wells to the Manokin aquifer. The company should, like Bethany Beach, utilize information from aquifer tests to determine spacing and production of wells in order to prevent salt-water contamination.

The communities south of Bethany Beach, namely Middlesex and South Bethany, derive water from privately-owned wells. In anticipation of large demand for water during the summer months, these communities should make arrangements to connect with Bethany Beach's supply system rather than develop a supply system of their own, although a sufficient amount of water may be available from the Pocomoke and Manokin aquifers. Fenwick Island is in an analogous situation to most of the communities in their area, in that water users obtain their supplies from individual wells. Fenwick Island is unfortunate in that not even small amounts of fresh water are available from the shallow sands. In future years, if Fenwick Island decides to install a supply system, water could be obtained from the deeper aquifers or imported from areas further inland. Water is available from aquifers in the upper part of the Miocene; however, the same precautions apply as those stated for Bethany Beach and Sussex Shores.

The areas where the shallow sands are recommended for development are shown on the accompanying map. Because of the danger of salt-water encroachment, an area inland has been selected for large scale ground-water development (.5 mgd/sq. mi.). This area is located to the west of the solid black line (see Figure 14). The area between this line and the dashed black line is capable of satisfying small to moderate residential and commercial needs. Caution should be exercised in the development of the ground-water re-

BETHANY — FENWICK AREA

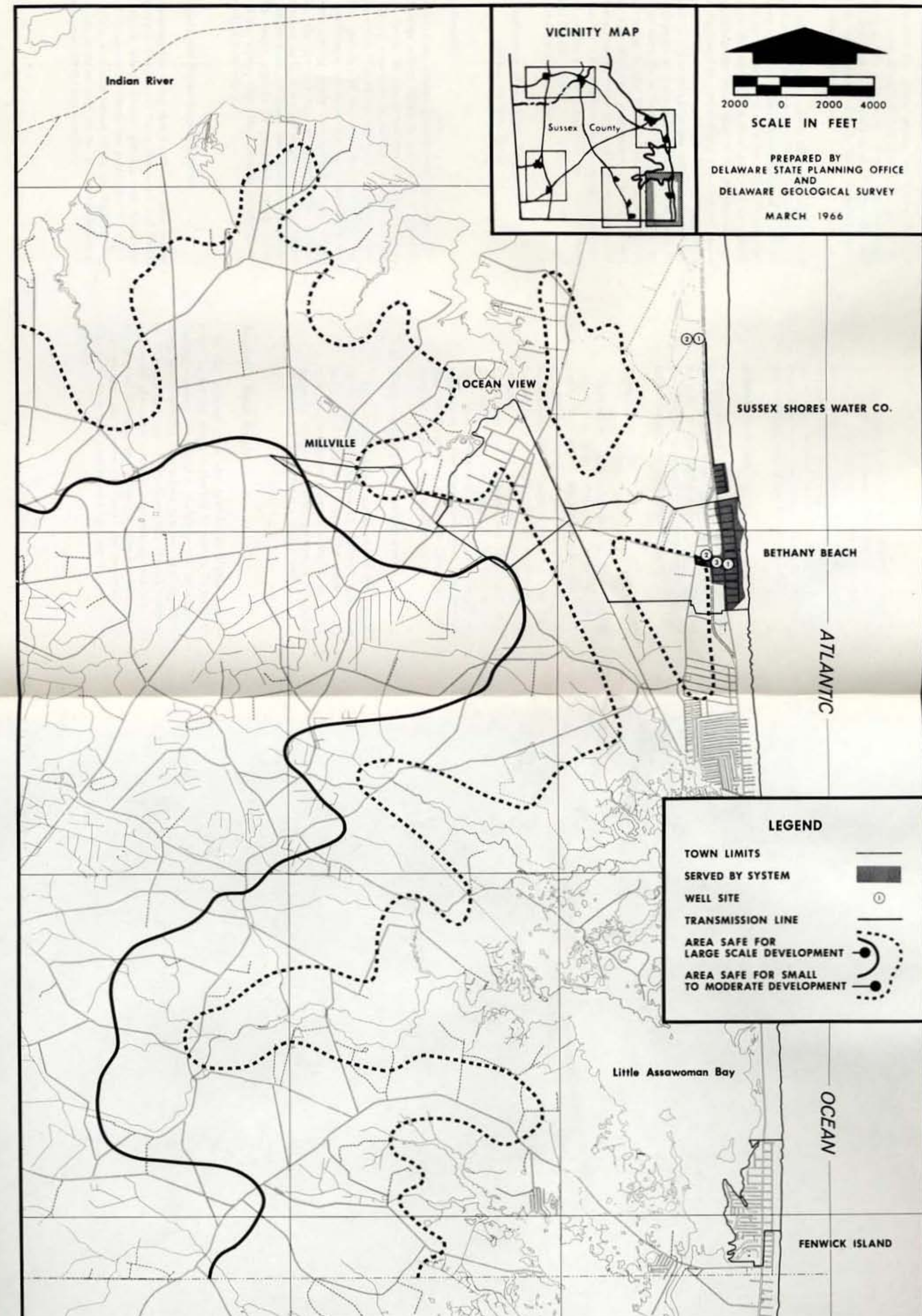

FIGURE 14

sources between the above areas and saline bodies of water. Special consideration should be given to water quality in this area as the water contains high amounts of iron and is slightly acid. Practically all the water in the Bethany Beach Area requires some treatment before domestic use.

The Delaware State Planning Office has projected the population for the Bethany Beach - Fenwick Island area to reach a summer population of 7,240 in the next 15 to 20 years. Based on this forecast the average water demand will be close to 1 mgd or around .4 billion gallons per year. Most of the projected population is expected to settle along the coastal areas where water is obtained from the Pocomoke and Manokin aquifers. If these aquifers are capable of yielding the same quantity of water along the coastal strip in Delaware as they do in Ocean City, Maryland, more than an adequate supply will be available in the year 1980. For the ultimate population (19,000) inland from Bethany Beach, water may be obtained from the shallow sands. The shallow sands in this area are capable of yields up to .5 mgd/sq. mi., thus to meet the demand in the inland area close to 6 sq. mi. of these sands must be developed.

Evaluation of the Water Resources Along the Bay Shore

General Statements

The potential for limited ground-water development along Delaware's Bay Shore is generally good. The restricting factor is the presence of saline water. The Bay Shore area may be defined as that portion of the State which lies within one mile of saline water bodies. The geology of the area and prevailing hydrologic conditions are such that adequate fresh water supplies can be made available for many years considering the present rate of growth. The typical source of water in this region is ground water which is found under both confined and unconfined conditions. The water quality is generally good. Apart from brackish water, the iron content is the most serious quality problem.

Present Supply and Water Supply Systems

Four communities along the Bay Shore have water supply systems. These are: Kitts Hummock and South Bowers, which are privately owned, and Slaughter Beach and Primehook, which are municipally owned. Because of the variable nature of the geological conditions, brief descriptions of the water situation of individual communities are provided.

1. Broadkill Beach

   Information from Broadkill Beach suggests that as of the present, attempts to find fresh water in sufficient quantities have been unsuccessful. The major source of supply is shallow wells skimming the top of the fresh-water lens located in the Pleistocene Series. One deep well has been drilled in this area and revealed salt water below this level.

2. Primehook Beach

   The primary source of water in Primehook Beach is from wells tapping artesian aquifers located in the Miocene unit. The majority of the summer residents are supplied by a centrally located well 335 feet deep.

3. Slaughter Beach

   Salt-water contamination in the shallow sands has been reported in the Slaughter Beach area and at the Mispillion Lighthouse. In order to find a supply of suitable quality, individuals have completed several successful wells in artesian aquifers of Miocene age ranging in depth from 240 feet to 300 feet. These are the Frederica and Cheswold aquifers which are also used in the City of Milford. Most residents of Slaughter Beach are connected to the municipal water supply system which obtains its water from two wells tapping the Cheswold aquifer.

4. Kitts Hummock and South Bowers

   Both communities obtain water from small wells tapping aquifers of Miocene age. The water is of suitable quality. The water supply systems in South Bowers consist of a few property owners (usually groups of less than 5) obtaining water from a single well.

Available Water Supply

In the coastal area, the readily available potable water is ground water collected by wells. In northern Sussex County the highest yielding and most promising water-bearing formations are the shallow sands of Pleistocene age. From Slaughter Beach north to Cheswold the most reliable sources are the artesian aquifers of Miocene age. From Cheswold north to the Chesapeake and Delaware Canal the artesian aquifers of Eocene and Cretaceous age are the most productive.

The most significant limitation on available supply is the presence of saline water. Apart from its presence in the ocean and in the tidal surface waters, saline water in certain instances also occurs underground. At depths exceeding 500 feet in the coastal area and up to approximately 1,000 feet farther inland, saline water probably occurs in all aquifers. Directly along the shore saline water also occurs at shallow depths. Wells can only safely operate at a reasonable distance from the saline water boundary without adverse effects. At locations close to the shoreline wells have experienced saline water intrusion because of excessive pumping. Other wells have produced nothing but brackish water, and have had to be abandoned initially. This problem has been remedied by moving wells farther inland, as illustrated in both Lewes and Rehoboth.

In the event that potable sources are not available on the spot it may be necessary to import water from areas farther inland, which must, therefore, be considered a potential source for coastal areas. Two rules may be suggested for the location of small well fields in the Pleistocene sands so that the danger of saline water contamination will be minimized: sites one mile or more from saline bodies of water, or locations where static water levels exceed ten feet above sea level are generally safe.

The quality of water, especially chlorides, in the artesian aquifers does not vary as greatly laterally over short distances as it does in surficial deposits. Therefore, wells may be located where it is most convenient. The aquifer, satisfactory or unsatisfactory, may be expected to have the same properties over the area of an entire community. Conditions may change with long term pumping, however, and test wells and pump tests should be utilized before reliance is placed on a given aquifer in order to determine the safe yield.

Other potential supplies include the utilization of small streams and desalinization of brackish water. Owing to the present rate of development along the Bay Shore and the demand for fresh water supplies, the cost of developing these sources is probably prohibitive. The cost of desalinization of sea water from experimental pilot plants is about $.75 to $1.00/1,000 gallons.

Summary and Recommendations

The Bay Shore is basically a resort area. Indicative of this is the seasonal fluctuation of population. Water in this area is obtained from artesian aquifers of Miocene and Eocene age except Broadkill Beach where the shallow unconfined sands of the Pleistocene are utilized. At the present time, no excessive ground water development has taken place along the Bay Shore south of the Chesapeake and Delaware Canal. Any large scale development could radically change the water resources in a given area. An estimate of the available annual recharge (.5 mgd/sq.mi.) to this area exceeds the present yearly consumption several times. Assuming the same trend of development prevails (no large water consuming industries competing with municipal supplies) the ground water potential from the shallow aquifers (upper 500 feet) remains good for many years to come. Optimum use of these aquifers should be planned based on aquifer test to determine their safe yields.

Information from deep wells drilled along the coast suggests that prospects of finding fresh water in large quantities at greater depths are poor. In areas where large fresh water supplies are needed (Lewes and Rehoboth) adequate quantities have been found by moving farther inland. In the remaining beach areas demands are still sufficiently small and can be supplied by local wells.

Little is known about the actual consumption in this area. Where data are available they are shown in Table 6.

SUMMARY

At present, Delaware has an abundance of water for the foreseeable future, but is already faced with water problems in some municipalities. These can only be resolved satisfactorily through complete evaluation of the State's water resources and the establishment of a coordinated program of water management.

It must be recognized, however, that studies concerned only with the subject of water use are far too narrow to provide the broad answers needed for water management. Water resources serve many different functions in a society, and it is very difficult to manage water so as to satisfy the divergent interests concerned with it. Recreation, dewatering of buried structures, irrigation of crops, navigation, sewage, drainage of land, and a host of other activities can be directly affected by the development of a region's water resources. If the only problem were to ascertain the availability of water for drinking purposes, the job of the planner would be relatively simple. But since he must take into account the needs of all segments of society, his task becomes exceedingly complicated.

With this philosophy in mind, we recommend that a master plan for the development of Delaware's water resources be prepared. Only in this way can we assure Delaware an adequate supply of high quality water as the State's economy continues to expand.

TABLE 6

SUMMARY OF WATER SUPPLY SYSTEMS SOUTH OF CHESAPEAKE AND DELAWARE CANAL

Name of Town or Water Supply	Type of Ownership	Source of Supply	Additional Sources of Supply	Average Daily Output mg 1	Max. Capacity of System mgd 2	Treatment Plant Capacity mgd 3	Operating Percent of Max. Capacity 4	Storage of finished Water mg 5	Estimated Population 6	Average Daily per Capita Consumption 7	Excess Capacity mgd 70% Max. Average Daily 8
Bethany Beach	Municipal	3 wells	none	* .08 .025	.43	.43	*19 6	.20	*1,330 170	*60 145	*.22 .275
Camden-Wyoming	Municipal	1 well	7 small wells	.30	.57	none	53	.10	2,350	130	.09
Clayton	Municipal	1 well	Wheatley Canning Co.	.15	.33	none	45	.05	990	150	.08
Dover	Municipal	11 wells	none	2.9	9.25	none	31	.35	11,260	255	2.6
Frankford	Municipal	1 well	1 Auxiliary well	.07	.28	.28	25	.065	620	110	.13
Harrington	Municipal	3 wells	none	.3	1.14	none	26	.28	2,580	115	.50
Kitts Hummock	Private	2 wells	none	N.A.	N.A.	none	N.A.	.001	N.A.	N.A.	N.A.
Laurel	Municipal	3 wells	none	.60	2.88	2.88	21	.15	2,800	210	1.4
Lewes	Municipal	5 wells	none	1.47	4.9	none	30	.375	3,670	400	1.96
Millsboro	Municipal	2 wells	none	.05	1.0	none	5	.125	1,070	46	.65
Milford	Municipal	5 wells	none	1.0	2.5	none	40	.25	5,950	170	.75
Primehook	Municipal	1 well	none	.015	.04	none	37	.002	N.A.	N.A.	.013
Rehoboth	Municipal	5 wells	none	*2.5 .5	5.5	none	*45 10	.415	*17,000 3,030	*146 165	*1.35 3.35
Seaford	Municipal	4 wells	none	.84	3.45	3.45	24	.30	4,840	175	1.58
Selbyville	Municipal	3 wells	none	.25	.57	.57	44	.65	1,110	225	.15
Slaughter Beach	Municipal	2 wells	none	.01	N.A.	none	N.A.	.003	120	85	N.A.
Smyrna	Municipal	2 wells	none	.52	2.14	none	24	.15	3,340	155	.98
Sussex Shores Water Co.	Private	2 wells	none	* .03	.72	.72	6	.104	* 350	* 90	.47

* Summer months

N.A. Information not available

1. Average Daily Output (mg). The figures in this column represent the average daily output of the system in millions of gallons. This figure is the yearly pumpage divided by 365 days.
2. Maximum Capacity of System (mgd). This figure is determined by the capacity of wells, etc., in gallons per minute multiplied by 1440 (minutes per day). In some systems this figure is limited by the capacity of the treatment plant. Where this is the case the same figure appears in both this column and the column showing treatment plant capacity.
3. Treatment Plant Capacity (mgd). The capacity of the treatment plant in gallons per minute multiplied by 1440 (minutes per day).
4. Operating Percent of Maximum Capacity. The average daily output divided by Maximum capacity of system.
5. Storage of Finished Water (mg). Storage of water (after treatment were necessary) ready for consumption.
6. Estimated Population. The estimated population served by the system.
7. Average Daily Per Capita Consumption (gallons). Average daily output divided by estimated population served.
8. Excess Capacity (mgd). Seventy percent times the maximum capacity minus the average daily output. This leaves 30 percent of the maximum capacity to account for seasonal fluctuations and to supply peak demand periods during a given day.

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