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DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
GROUND WATER BRANCH

AN APPRAISAL OF THE GROUND-WATER RESOURCES OF THE JUNIATA RIVER BASIN

(An interim report)

BY

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INTRODUCTION

This report describes the availability, quantity, quality, variability, and cost of development of the ground-water resources in the Juniata River basin, one of the larger sub-basins of the Susquehanna River basin. The report has been prepared for and under specifications established by the Corps of Engineers, U. S. Army, and the Public Health Service, Department of Health, Education, and Welfare.

A comprehensive study of the water and related land resources of the Susquehanna River basin was authorized by the Congress of the United States in October 1961, and the task of preparing a report and of coordinating the work being done by others in support of the study was assigned to the Corps of Engineers. The comprehensive study is being conducted by several Federal departments and independent agencies in cooperation with the States of New York, Pennsylvania, and Maryland. The Public Health Service under its authority in the Federal Water Pollution Control Act (P. L. 660) initiated a comprehensive water quality control program for the Chesapeake drainage basin, which includes the Susquehanna River basin.

This report is intended to serve the specific needs for ground-water information of both the Corps of Engineers and the Public Health Service, as well as those of the other participating Federal and State agencies.

This study is being conducted under the guidelines for river-basin planning set forth by the Congress of the United States. On July 26, 1956, in the 84th Congress, the Senate expressed its sense relative to the conservation and development of water and related land resources in Senate Resolution 281 which stated:

> "Land and water resources development should be planned on a comprehensive basis and with a view to such an ultimately integrated operation of component segments as will insure the realization of the optimum degree of physical and economic efficiency."

The policies, standards, and procedures to be used in the formulation, evaluation, and review of plans for use and development of water and related land resources in river basins are set forth in Senate Document 97, under date of May 29, 1962. These policies, standards, and procedures were prepared by the Secretaries of the Army, Agriculture, Health, Education, and Welfare, and Interior and were approved by the President of the United States.

Senate Document 97 in Part III, Section B, states that:

> "Planning for the use and development of water and related land resources shall be on a fully comprehensive basis so as to consider--

(1) The needs and possibilities for all significant resource uses and purposes of development, including, but not limited to domestic, municipal, agricultural, and industrial uses of water; water quality control;...., and

(2) All relevant means (including nonstructural as well as structural measures) singly, in combination, or in alternative combinations reflecting different basic choice patterns for providing such uses and purposes."

The consideration of alternative combinations for water supply and water-quality control requires that comparison be made of the use of either surface or ground water. The Geological Survey has been assigned the responsibility of investigating the ground waters of the basin to provide the facts necessary for the action agencies to make such a comparison. It is the only agency directly involved in a study of basin-wide ground-water conditions and potentials.

The report includes facts concerning the geologic and hydrologic parameters necessary for a preliminary evaluation of the role of ground water in the formulation of the comprehensive plan. The report also includes facts on costs of raw ground water delivered at the well head. The cost of ground water is included in response to requirements expressed in Part V, Section E of Senate Document 97 as follows:

"E. Types of primary benefits and standards for their measurement

1. Domestic, municipal, and industrial water supply benefits: Improvements in quantity, dependability, quality, and physical convenience of water use. The amount water users should be willing to pay for such improvements in lieu of foregoing them affords an appropriate measure of this value. In practice, however, the measure of the benefit will be approximated by the cost of achieving the same results by the most likely alternative means that would be utilized in the absence of the project. Where such an alternative source is not available or would not be economically feasible, the benefits may be valued on such a basis as the value of water to users or to the average cost of raw water (for comparable units of dependable yield) from municipal or industrial water supply projects planned or recently constructed in the general region."

In conformance with Senate Document 97, the Geological Survey has been assigned the responsibility of determining the costs of ground-water sources as "the most likely alternative means that would be utilized in the absence of the project."

The Corps of Engineers and the Public Health Service are jointly determining the present and future water requirements of several water-development areas in the basin as shown on figure 1. They will formulate plans based on the likelihood of supplying these areas with the most economically feasible source of water. They will use this report to determine if ground water is a possible economical source of supply that is comparable with surface-water sources in terms of quantity, dependability, quality, and physical convenience of water use.

The generalized estimates given in the report will be used not only to determine if ground water is likely to be the best choice in any given area, but also in deciding whether it is necessary to further investigate ground water as a potential source of supply in these areas. The decision to recommend the use of either surface or ground water at a particular site will most likely depend almost entirely upon the hydrologic and economic advantages or disadvantages of one source or the other. The actual decisions concerning ground-water feasibility, cost benefits, and its comparison with alternate sources of supply will not, of course, be made by the Geological Survey. The objective of this report is only to present the facts upon which decisions may be based.

The estimated water costs given in this report are based on the design and operation of hypothetical wells which in turn is based on a series of arbitrary assumptions and are valid only for a comparison with estimates of cost of water from surface water sources, which are being developed by other agencies, and as a comparison between rock units. Because of this general treatment, the figures given are not directly applicable to nor intended for use in the planning and design of any ground-water development project. The planning, design, and construction of specific ground-water supply systems require hydrologic and geologic data of the immediate localities and also the services of specialists such as consulting engineers, geologists, and well drilling contractors.

This report is the second of a series of interim ground-water reports. It is preliminary and subject to revision as the study progresses. In order to facilitate the work of the various agencies involved in the comprehensive study, a system of interim reports has been developed by which the various agencies exchange knowledge.

It was agreed that interim information on the ground-water resources would be most useful if reported in a series of five reports on relatively arbitrary subdivisions of the basin. These subdivisions are: (1) the lower Susquehanna basin, (2) the Juniata River basin, which is covered by this report, (3) the West Branch of the Susquehanna River basin, (4) the upper basin in Pennsylvania, and (5) the upper basin in New York State. After the interim reports have been completed, a report will be prepared on the ground-water resources of the entire basin.

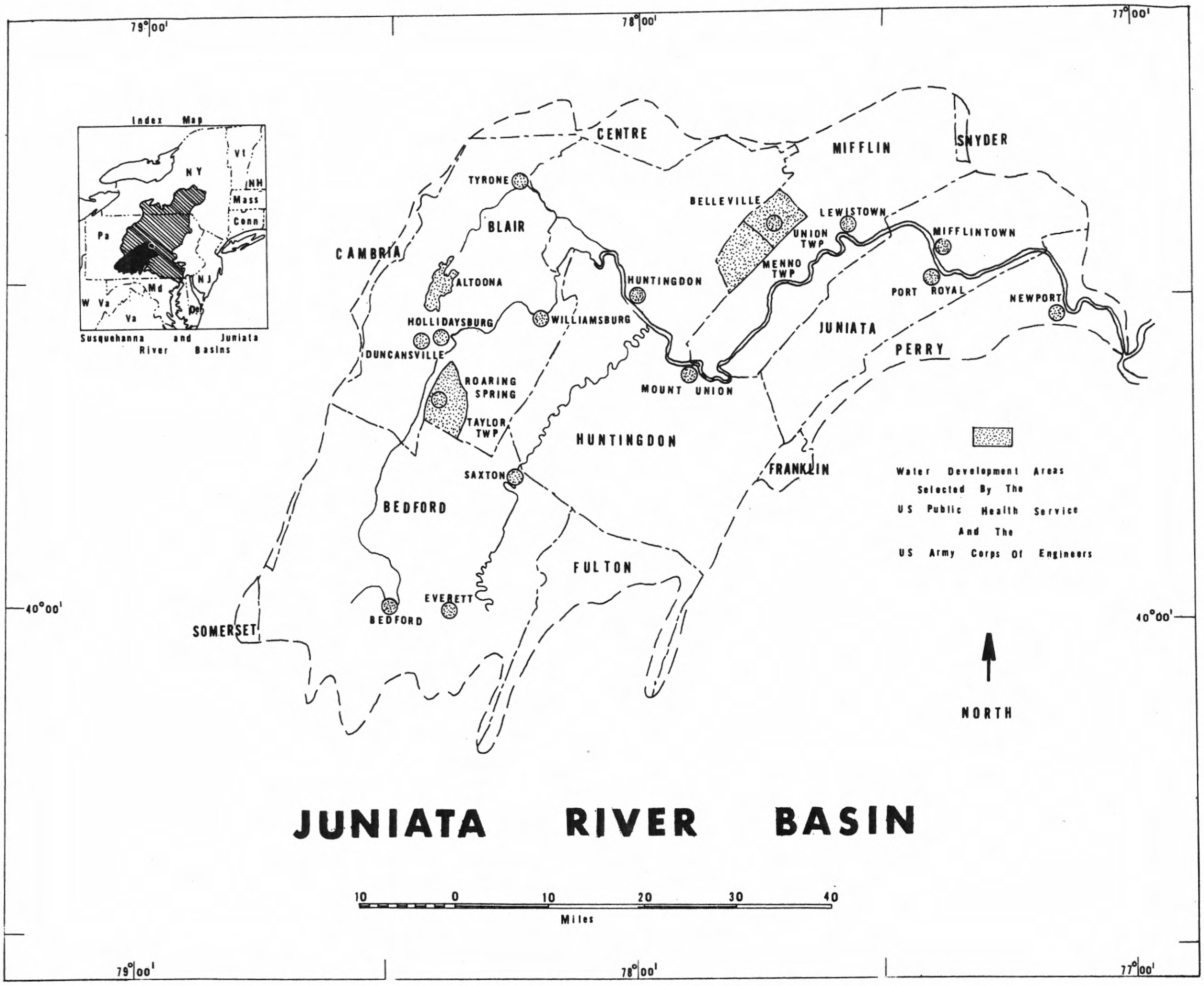

Figure 1.--Map showing designated water-development areas in the Juniata River basin

SUMMARY OF GROUND-WATER RESOURCES

Importance of Ground Water

Ground water plays a vital part in the hydrologic cycle, which is the endless circulation of water from the primary reservoir, the ocean, to the atmosphere, the land, and back to the ocean over and beneath the land surface.

One major role ground water plays is its relation to surface water. In humid areas discharge from ground-water storage maintains the flow of streams during periods of little or no precipitation. In such areas geology determines the dependability of streamflow. Streams underlain by shale tend to have flashy runoff characteristics compared to streams underlain by unconsolidated sands. Hence, a correlation can be made between streamflow characteristics and the water-yielding characteristics of the rocks of a basin. Basins whose streams have flashy runoff characteristics are usually underlain by rocks of lower permeability and storage capacity than are basins whose streams have a more uniform flow.

Most of the streams in the Susquehanna River basin are effluent, that is, water moves from the ground-water reservoir to the surface streams. This condition may be reversed in some instances, and water may move from the stream to the ground-water body. An extreme case of this condition could exist in which wells pumping along a stream intercepted such quantities of water that the stream completely dried up.

The quality of streamflow, as well as the quantity, is related to the contiguous ground-water reservoir. If the major part of streamflow is base flow from ground water, the water in the stream will usually be high in dissolved solids and low in suspended solids. On the other hand, if most of the streamflow is from overland runoff, the water in the stream will usually be low in dissolved solids and high in suspended solids.

Ground water can also contribute to dilution and neutralization of acid mine drainage and reduce its effects downstream, as it does in the Swatara Creek basin near Harrisburg, Pa. Ground water flowing into effluent streams from carbonate rocks contributes alkaline bicarbonate water that neutralizes and dilutes the acid sulfate waters from the coal mining regions upstream.

At one time ground water could be thought of as a widely distributed and generally rather easily obtained substance whose principal usefulness lay in meeting small-scale domestic and stock requirements in rural areas and in small towns. Later, community wells were drilled to replace polluted individual wells and to supply residents of those parts of the towns where ground water was hard to get. Commercial and industrial establishments began to drill their own wells for reasons of economy.

Around the turn of the century and for some years thereafter, ground water tended to fall into disfavor as a source to meet large demands. However, as techniques of well construction and pump design improved, it became possible in many areas to obtain needed supplies of water from wells at a cost in time, money, and initial materials less than that required for development of a surface-water source.

Ground water has developed from a quantitatively minor (though critically important) source for domestic supply to a source supplying something like 1/6 to 1/5 of the national water-supply requirements. We can foresee ground-water reservoirs not only continuing to be a major source for meeting withdrawal requirements, but emerging as a medium for storing even larger quantities of surplus streamflow for cyclic withdrawal as a phase of multipurpose water management.

Where available in suitable quantity and quality, ground water provides a source of water without the necessity of long transmission lines. In areas where the available supplies of ground water may not equal the ultimately anticipated requirements, it may, nevertheless, be advisable to develop ground water locally to meet the needs until larger sources become economically feasible. The ground-water sources developed earlier could then be used as a supplementary supply.

Ground water may be preferred to surface waters because of its relatively uniform temperature, quantity, and quality throughout the year. Currently at least 1/4 the population of the Susquehanna River basin is believed to use water derived from underground sources. More than 400 municipalities having a centralized water system depend upon ground water for all or part of their supply. The total quantity of ground-water use may be expected to increase even as major urban supplies of surface water are developed.

Ground water is one of the earth's most widely distributed resources and one of its most important. Nevertheless, to offset its advantages certain disadvantages are or may be inherent in any large-scale development of ground water. Among them are: (1) generally a lack of knowledge as to occurrence, movement, distribution, and availability in a particular aquifer--and the cost of the requisite studies in time, materials, and personnel; (2) costs associated with drilling wells and pumping them instead of collecting water by gravity flow; (3) complexities in management; (4) slowness and generally unknown or uncertain response of ground-water reservoirs to development; and (5) all forms of potential contamination. Nevertheless, history and hydrologic realities signify clearly that we will depend on the ground-water reservoirs for a large part of our total water supply.

Physiographic Provinces

The availability of ground water in any area is determined first by natural conditions--the type, distribution, and structure of the rocks, and the physiography and climate--and second by the extent to which the natural conditions have been changed by the actions of man. These generalizations are true everywhere, but in the Susquehanna River basin they seem especially true because of the complexity of the ground-water hydrology.

The Susquehanna River basin can be divided into three large geologic regions distinguished on the basis of age, character, and structure of the rocks and physiography. The availability of ground water and the yield of wells differs from one region to another, but there are many similarities also. The three regions--from south to north--are the Piedmont, the Mountainous Area, and the Appalachian Plateau. (See fig. 2.) A fourth region can be considered to include the glacial deposits, which are mainly in the Appalachian Plateau but extend into the other regions. The Juniata River basin lies within the Mountainous Area except for a small area that drains a part of the Appalachian Plateau on the western edge of the basin. The Juniata River basin lies south of the glacial border and contains no significant amounts of glacial outwash.

Mountainous Area

The Mountainous Area, as defined in the Susquehanna River basin, includes the Blue Ridge, the Great Valley, and the Valley and Ridge Provinces and occupies the broad northeastward-trending belt between the Piedmont on the south and the Appalachian Plateau on the north. The Valley and Ridge is the only province of the Mountainous Area present in the Juniata River basin. It is underlain by folded and faulted rocks.

The predominant rock type in the Valley and Ridge Province is a sequence of alternating shale, sandstone, and limestone of Paleozoic age. The rocks in this sequence can yield to individual wells 20 to 1,000 gpm (gallons per minute), averaging 125 gpm, of soft to very hard water. The limestones and dolomites are presently the most productive aquifers in the Valley and Ridge Province. Large spings, some producing several thousand gallons of hard water per minute, issue from the rocks. The sandstones are potentially good sources of water. Many of the wells that tap sandstones are used only for domestic purposes, as most municipalities are supplied by surface water, but reported well yields of 100 to 500 gpm of soft water indicate the possible importance of sandstones as a source of water. The shales supply water that is generally high in iron and hydrogen sulfide. They ordinarily do not supply more than 75 gpm per well.

In the southwestern part of the Juniata River basin is an area of folded shale, sandstone, conglomerate, and anthracite coal (mostly of Pennsylvanian age) usually referred to as the Broad Top coal field.

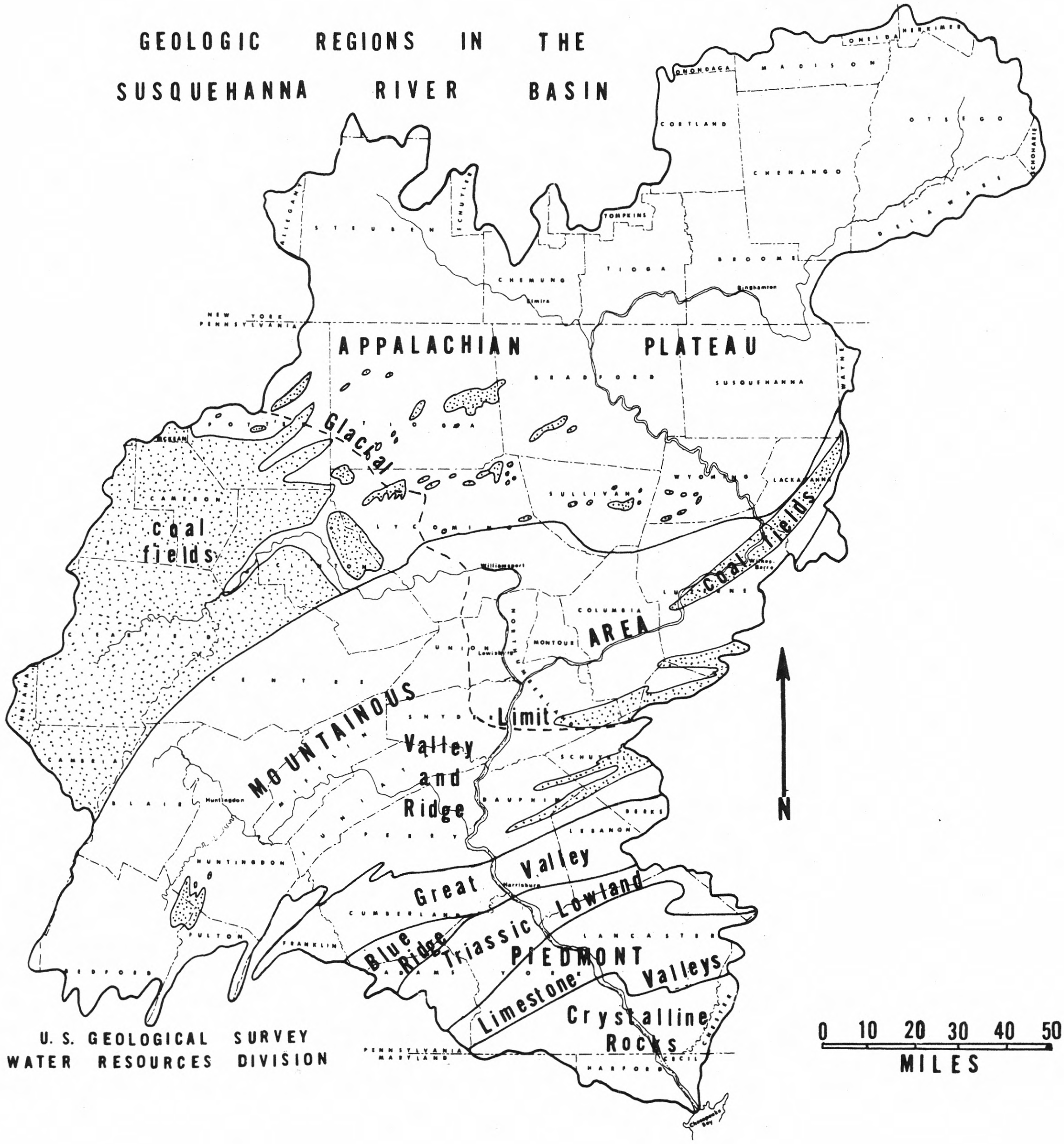

Figure 2.--Map showing the geologic regions in the Susquehanna River basin

Wells tapping these rocks can yield from 75 to 750 gpm, averaging 225 gpm, of water whose quality is generally good except near coal mines, where it is acidic and high in iron as a result of oxidation of sulfide minerals.

The rocks in the Mountainous Area have been folded and faulted so that they dip steeply throughout most of the region. This folded and faulted structure results in northeastward trending beds of rocks of different types. The deformation of these rocks decreases northwestward, and ultimately there is a zone in which the folded rocks give way to the nearly horizontal rocks of the Appalachian Plateau.

Appalachian Plateau

The Appalachian Plateau makes up only a small part of the Juniata River basin. The rocks are nearly horizontal and are of Devonian, Mississippian, and Pennsylvanian age. They consist of alternating shale, sandstone, limestone, and bituminous coal. The rocks of the plateau have not been widely utilized as a source of water, and have not, therefore, been adequately evaluated.

Despite the lack of widespread exploration there is evidence that these rocks can yield appreciable amounts of water. The rocks are known to yield to individual wells small to large supplies of up to 600 gpm, averaging 50 to 75 gpm, of water that is generally of good quality except near coal mines.

Ground-Water Problems

The Susquehanna River basin (and the Juniata River sub-basin) has a humid climate and a large supply of water, and there is no present or foreseeable overall shortage of water. Water related problems are numerous but generally are not as critical as they are in many other parts of the United States. Hence, in this water-rich area, problems of water supply are largely local. There are problems of determining the local availability of water, regulating the use of water to prevent overdevelopment, and protecting the water from contamination.

Availability of Supply

Because of the complexity of the geology and hydrology, locating ground-water supplies is a problem in many places in the Juniata River basin. Existing reports form a good basis for more detailed studies of areas of prospective development, but only a small start has been made on the detailed studies themselves. The basin is underlain by a great variety of rocks that differ greatly in their areal extent, composition and texture, thickness, structural attitude and relation to each other, and in their physiographic expression. All these factors affect their capacity to store and transmit water. More study is needed to support more accurate predictions of just where and how deep it will be necessary to drill, what quantity and quality of water can be expected, and what will be the hydrologic effects of withdrawing water at various rates.

Ground-water conditions not only differ from one stratigraphic unit to another, but also differ within a given unit. Hence, though it is possible to generalize about ground-water conditions in areas of various sizes, it is rarely possible to predict accurately the availability of ground water at a specific locality in the Juniata River basin in advance of drilling, even if there are wells of known performance nearby.

Overdevelopment

Overdevelopment of ground water is presently a problem in very few areas in the Juniata River basin. On the whole, much additional ground-water development is feasible. The ground-water resources appear to be ample to meet future needs and the problems that may develop are those of distribution of the supply--not of the total resource. Where development is intense in the Susquehanna River basin--such as in lower Broome County, New York, or at State College, Pennsylvania--legal control to prevent overdevelopment or contamination may be necessary.

Domestic, municipal, and industrial users have been generally successful in obtaining all the water they need at a cost within their ability to pay. This does not mean that there have not been individual hardship cases. In any area the size of the Juniata River basin there may be found rural or suburban householders, or small communities in unfavorable ground-water areas, that have spent several thousand dollars in drilling wells and still do not have an ample supply. In general, however, the ground-water supplies have met the demands reasonably placed upon them. Water for full-scale irrigation of a very large acreage from one or a few wells is usually not available.

Contamination

Contamination is sometimes a major problem with ground-water supplies as it often is with surface supplies. Population expansion and heavy industrialization have combined to produce large quantities of pollutants. Mines, chiefly coal mines, are one of the main sources. Though streams are the principal recipients of acid mine wastes, ground water may also be affected. Contamination of ground water by domestic or industrial wastes is a potential threat in some expanding urban areas. In valleys underlain by cavernous limestone in the basin, contamination of ground water by sewage and industrial wastes is rather common.

A type of contamination whose extent and importance are only beginning to be realized is that resulting from movement of rainwater and snowmelt through sanitary land fill and, thence, into aquifers and streams. As population grows and accumulates solid waste products, which are disposed by filling low areas, the problem is bound to increase and ultimately will necessitate remedial action.

As the practice of returning heated water (which has been used for cooling) to the ground increases, thermal pollution will become an increasingly serious problem in some areas.

Industries using chemical processes are producing an increasing variety of contaminants--some of which are of unknown and possibly high toxicity, or are difficult to remove from water, or both. To these contaminants can be added synthetic detergents, which are being used increasingly in homes and industry, pesticides and insecticides, and radioactive substances. All these contaminants tend to find their way into our water supplies. Against most of them, however, ground waters are better protected than surface waters.

EXPLANATION OF DATA AND TERMS USED IN THIS REPORT

Geologic

The reader is referred to the Geologic Map of Pennsylvania (Pennsylvania Geological Survey, 1960) for the location of the geologic units discussed in this report. The stratigraphic nomenclature and age assignments used in the map referred to above differ only slightly from those approved for use by the U. S. Geological Survey. No confusion will therefore result from simultaneous usage of the map and this report.

Hydrologic

The following hydrologic terms are used in this report as indicated.

Aquifer

An aquifer is a hydrologic unit comprising water-bearing rocks from which water is collectable in usable quantities. Aquifers are of two principal kinds: water table (unconfined) and artesian (confined). An aquifer may be a single geologic formation, a part of a formation, or two or more formations that are hydraulically connected to form a single aquifer. In this report, the terms aquifer and ground-water reservoir are considered synonymous. Aquifers serve as both underground reservoirs and as pipelines, for in addition to storing water they transmit it from places of recharge to places of discharge.

Specific Capacity

The rate of yield of a well per unit drawdown of water level is known as the specific capacity of the well. Thus, a well yielding 100 gpm with a drawdown of 5 feet has a specific capacity of 20 gpm per foot of drawdown. Specific-capacity data provide a basis for comparing wells of different yields and estimating the hydraulic properties of the aquifer units thus tested.

Availability

The term "availability" is used in this report in a special sense to indicate the accessibility and location of aquifers with respect to a given municipality, township, or water-development area. Sections of the report concerned with availability will deal with the location of geologic units, in the area under discussion, that are capable of yielding usable ground-water supplies. All such units listed as available to an area are inside of or within one mile of the political boundaries of that area.

Quantity

The quantity of water that can be obtained from a single hypothetical well is computed from specific-capacity data and from assumed available drawdowns, and is based on a statistical analysis of records obtained chiefly from existing successful municipal and industrial wells. Such wells were used for the analysis because usually an effort is made to obtain the largest possible yield from municipal and industrial wells. In contrast, domestic wells are usually developed only to the extent necessary to provide a supply for one household. Records of domestic wells were used sparingly or eliminated from the analyses.

Well yields in gallons per minute often depend as much upon the effort made to obtain water from the well as upon the characteristics of the aquifer. For instance, a larger diameter well, a larger capacity pump, a deeper pumping level, a deeper well, or additional well development may all result in an increased well yield. Partial penetration of the aquifer, well loss, and geohydrologic boundaries may affect specific-capacity data. The use of specific-capacity data allows the computation of well yields in gallons per minute for any well diameter or depth if a static water level and available drawdown are known. This assumes that specific capacity is uniform with depth; that is, with increased penetration of the aquifer. The specific-capacity data used in this report are those obtained, for the most part, at the time the well was first constructed. Specific capacities theoretically decline as time passes if all pumpage is from storage in the rocks. The reported specific capacities were, therefore, all adjusted to what they theoretically would be after 180 days of pumping without recharge. In addition, specific capacities sometimes vary seasonally, usually being higher in the winter than in the summer owing to higher natural static water levels in the winter.

By using the median figure for specific capacity and yield data shown in table 1, a reasonable estimate of predicted well yields is obtainable. The quantities listed in later sections of this report as being available from each geologic unit or to any specific area are based upon reasonably predicted yields of single wells. The wells are assumed to be located by an expert engineer or geologist and not to be affected by the pumping of any other well.

In recent years, great progress has been made in the scientific spacing, design, construction, development, and maintenance of wells. The design and operation of a well or of well fields, to recover the maximum yield of ground water, are usually the responsibility of specialists outside of the Geological Survey.

Data are generally insufficient in the Juniata River basin to permit applying theory to the problem of well spacing over large areas, but there is the opportunity for steady improvement in the design of individual well fields in localities where the required data are available or can be obtained.

There is an upper limit to the amount of ground water that can be obtained from an area on a long-term basis, just as the watershed above a surface reservoir can be expected to provide only certain amounts of water. Estimates made in the adjacent Delaware River basin (Parker and others, 1964, p. 91) of 0.75 mgd (million gallons per day) per sq. mi. of natural ground-water recharge for similar rocks give some indication of the amount of ground water available to this area. Either more or less than 0.75 mgd may be available for consumptive use in any particular area, depending on local conditions. Generally less will be available in areas remote from major streams and much larger amounts will generally be available near major streams. However, the major limiting factor for ground-water availability will be the transmitting and storage capacity of the major rock units in the basin. Because of the relatively low productivity and small storage capacity of many of the rock units, and also because of many practical limitations, chiefly economic, only a small part of the ground-water discharge at natural outlets in the Juniata River basin can be diverted for man's use. However, pumpage substantially in excess of the 1965 rate could be maintained with increased ground-water development. The general assumption can be made, however, that all the water necessary to an area can be obtained from ground-water sources--if not from nearby wells, then from more distant wells--and that the only limitation is the cost of the water. However, the total quantity or "safe yield" of a particular area cannot generally be predicted without further study. The cost in time, materials, and personnel necessary to determine the "safe yield" of even a small area is high.

No water-requirement figures were supplied to the U. S. Geological Survey for any of the water-development areas designated; therefore, no estimates of the available supply in terms of requirements can be made. The terms inadequate or abundant supply of water are meaningless unless judged against requirements. For example, a supply of 1 mgd is inadequate for an industry needing 5 mgd, but would be abundant for a town needing only 0.1 mgd.

METHOD OF ANALYSIS

For the sake of uniformity, the analyses in this paper are based upon hypothetical wells of a uniform depth and diameter for assumed conditions. The characteristics of the hypothetical wells are made to conform to the characteristics of the aquifers by an analysis of existing wells of various depths and diameters. A brief discussion of the general approach used in this report follows. More detailed explanations are given in the section of the report entitled "Explanation of Tables."

A list of 13 water-development areas (containing a total of 18 political subdivisions) chosen by the U. S. Public Health Service and the U. S. Army Corps of Engineers in the Juniata River basin were analyzed to meet the objectives of the Comprehensive Study of the basin. All geologic units occurring in or within 1 mile of these areas were tabulated. Specific-capacity, geologic, hydrologic, and well-record data were collected and organized for wells tapping these units. The specific-capacity data were analyzed statistically by plotting specific capacities of wells against percentage of wells on logarithmic-probability paper. The reported specific capacities were all adjusted to what they would theoretically be after 180 days of pumping with no recharge. Static water levels were estimated for each geologic unit. Pumping water levels were assumed for two major rock groups--100 feet for carbonate rocks and 200 feet for the sandstone, shales, and other rocks. Available drawdowns for each geologic unit were then obtained by subtracting the static water level from the pumping water level. It was assumed that any well yielding less than 10 gpm would be considered unsuccessful, and the specific capacities that would result in such yields were eliminated from the distribution on the graphs.

The remaining percentage of specific capacities of successful wells was redistributed. Specific capacities at the points equalled or exceeded in 75 percent, 50 percent, and 25 percent of these successful wells were picked from the new distribution graphs. These specific capacities were multiplied by the available drawdown to obtain a range in the quantity of water available from each rock unit in terms of gallons per minute per well. These yields were classified as poor, medium, and good and correspond to the 75, 50, and 25 percent categories of specific capacities, respectively. Continuous pumping of 24 hours a day for 365 days a year was assumed in the computation of daily and yearly well yields.

Wells were then designed using the computed probable yields to obtain a range in probable costs of ground water delivered at the well head. Completed well depths were chosen to be 300 feet in carbonate rocks and 400 feet in all other rock types. Well diameters were selected on the basis of pump size, which in turn were based on the anticipated yield of the well. The length of casing was selected as 40 feet in all wells. Deep-well turbine units for each hypothetical well were selected to produce the anticipated yields at the smallest value of pump working horsepower from the assumed pumping levels.

The costs of the ground water from these hypothetical wells were then found by compiling the initial costs to construct the well and computing the cost of operation and maintenance, which includes depreciation and power costs. The total annual cost of producing the water was divided by the amount of water produced from each well to arrive at ground-water costs.

The costs estimated for well construction, that is, initial costs, were obtained from published reports and from industries, such as well drilling firms that install such equipment. These initial costs include only those costs necessary for works to collect the water, and do not include costs to treat or distribute the water. The initial costs include costs to drill an exploratory well and to drill, develop, and pump test the production well; equipment, including casing, strainer, pump, column, shaft, motor, meter, local piping, pumphouse, and electrical controls; land and rights of way; and contingencies and engineering, including administration.

The costs of the annual payment to retire the initial cost of the well installation were found by amortizing the initial cost of the well at four percent over a period of 25 years by the capital-recover-factor method of cost accounting.

Annual power rates were based upon Pennsylvania Power and Light Company electric power rate schedules for municipal use, assuming 24-hour a day use and 75 percent wire to motor efficiency. Annual maintenance costs were estimated from data obtained from the Pennsylvania Utility Commission and taken as four percent of the initial cost of the equipment.

The total annual cost to operate a single well was then taken as the sum of the annual payments to retire the initial cost, the power cost, and the annual maintenance cost. The costs in dollars per thousand gallons were found by dividing the total annual cost by the production figure from each well in thousand gallons per year. The costs in dollars per million gallons a day were found by dividing the total annual cost by the production figure from each well in million gallons per day and reported as the average annual cost in dollars per million gallons a day of the design yield. This cost figure is only valid for the design yield given and for a well identical in cost and construction characteristics to the hypothetical well. Obviously, the assumptions made in the well design, aquifer characteristics, probability analysis, pumping schedule, and cost analysis make this figure impossible to apply to an actual well in the field. The figures are only meant to be used as a rough guideline for a preliminary screening of potential alternate sources of water supply for the designated water-development areas. Actual site analysis of both yields and costs will have to be done by those competent in the field. However, the yields and cost figures given in this report are thought to be within the range of what can reasonably be expected at an average well site if the work in designing and constructing the well is done by competent personnel. It must be emphasized that because of the general treatment used in this report, it is not intended for use in design of engineering projects.

EXPLANATION OF TABLES

The estimated specific capacity and the yield of the hypothetical wells are summarized in table 1 in the appendix. The design of the hypothetical wells is summarized in table 2. Estimates of the cost of the hypothetical wells and of the cost of obtaining ground water from them are summarized in table 3. Representative chemical quality of ground water in each geologic unit is summarized in table 4. A cross reference of geologic units and water-development areas is given in table 5. Following is an explanation of the reference columns introducing data tabulated in tables 1, 2, 3, and 4.

The geologic formations or groups are listed according to increasing geologic age. Only those units that could be considered as aquifers, and for which well data are available, are listed. The geologic names and ages are those in current usage. The symbols used are those shown on the Geologic Map of Pennsylvania (Pennsylvania Geological Survey, 1960). The name of the geologic unit is given on all four tables, whereas the age and symbol are given only in table 1. The geologic age given is that formal period (or periods) in geologic time when the geologic rock unit is believed to have been formed. The first letter of each symbol indicates the period in geologic time. Succeeding letters in each symbol indicate the name of the geologic unit. These symbols may be found within colored rectangles in the legend below the map that gives geologic-unit descriptions, and within corresponding color patterns on the map.

Table 1.--Specific Capacity and Yield of Hypothetical Wells

For this report, the hydraulic properties of aquifers were estimated on the basis of geologic maps, water levels, and specific-capacity data. High specific capacities generally indicate that the rocks are capable of transmitting large quantities of water, and low specific capacities generally indicate the rocks are capable of transmitting only small quantities of water. The specific capacity of a well cannot be an exact criteria of the ability of the rock to transmit water, because specific capacity is often affected by partial penetration, well losses, and hydrologic boundaries. These factors adversely affect specific capacity; thus, the actual transmitting properties of the rocks are greater than those computed from the specific-capacity data.

The theoretical specific capacity of a well discharging at a constant rate in a homogeneous, isotropic, non-leaky artesian aquifer, infinite in areal extent, is taken from the Theis equation modified in the following equation (Walton, 1962, p. 12):

$$\frac{Q}{s} = \frac{T}{264 \log\left(\frac{Tt}{2693\ r_w^2\ S}\right) - 65.5} \qquad (1)$$

where:

$\frac{Q}{s}$ = specific capacity, in gpm/ft

Q = discharge in gpm

s = drawdown, in feet

T = coefficient of transmissibility, in gpd/ft

S = coefficient of storage

r_w = nominal radius of well, in feet

t = time after pumping started, in minutes

In addition to the assumption of an idealized aquifer as given above, the equation assumes that: (1) the well penetrates the total saturated thickness of the aquifer, (2) well loss is negligible, and (3) the effective radius of the well has not been affected by the drilling and the development of the well and is equal to the nominal radius of the well.

Hence, the specific capacity of any individual well is dependent upon the following: the transmissibility of the rock, the storage coefficient of the rock, the pumping period, well losses, effective well radius, the effects of partial penetration, and geohydrologic boundaries.

The productivity of even an ideal aquifer, therefore, differs greatly from place to place depending upon all the above factors. The geologic units in the Juniata River basin are not idealized aquifers; hence, it is impossible to predict with a high degree of accuracy the yield of a single well at any specific location before drilling. In fact, it might be possible to drill what is essentially a dry hole at any location in the area. However, methods of statistical analysis can be a great help in appraising the role of individual geologic units as producers of water. In this way, the probable range of specific capacities of wells can be estimated based on frequency graphs. Specific-capacity data were available for wells penetrating each of the several units under consideration, and these data were used to estimate the range of productivity and the relative consistency of the productivity of the units.

Specific capacities for wells in each geologic unit were tabulated in order of magnitude, and frequencies were computed with the following equation (Kimball, 1946):

$$F = \frac{m_o}{(n_w + 1)} 100 \qquad (2)$$

where:

m_o = the order number

n_w = total number of wells

F = percentage of wells whose specific capacities are equal to, or greater than, the specific capacity of order number m_o.

Specific capacities were then plotted aginst percentage of wells on logarithmic-probability paper. (See figure 3 as an example of such a plot.) Straight lines were fitted to the data. The slope of the specific-capacity frequency graph varies with the variability of production, a steeper line indicating greater range in productivity.

Yields of the aquifers at specific wells were estimated from the specific-capacity frequency graphs, which, in turn, were based on areal geologic maps, water-level data, and well-production data. Well yields were estimated on the basis of the specific capacities equaled or exceeded in 75 (poor), 50 (medium), and 25 (good) percent of the existing wells. Specific capacities (see table 1) were multiplied by the 180-day drawdown (see table 2) to determine the probable yields (see table 1).

As can be seen in equation (1), specific capacities theoretically decrease with time during periods of continuous pumping. Specific capacities used in this analysis were obtained at various pumping rates and for various periods of continuous pumping, which were mainly of short duration. One of the objectives of the study was to compute a substained yield for each well. Hence, all the specific capacity data were adjusted to a conservative, common pumping period. The figure used was that of 180 days, which is probably the longest period in which no recharge would occur. In general, this cut the reported specific capacities (which were generally obtained after one hour or

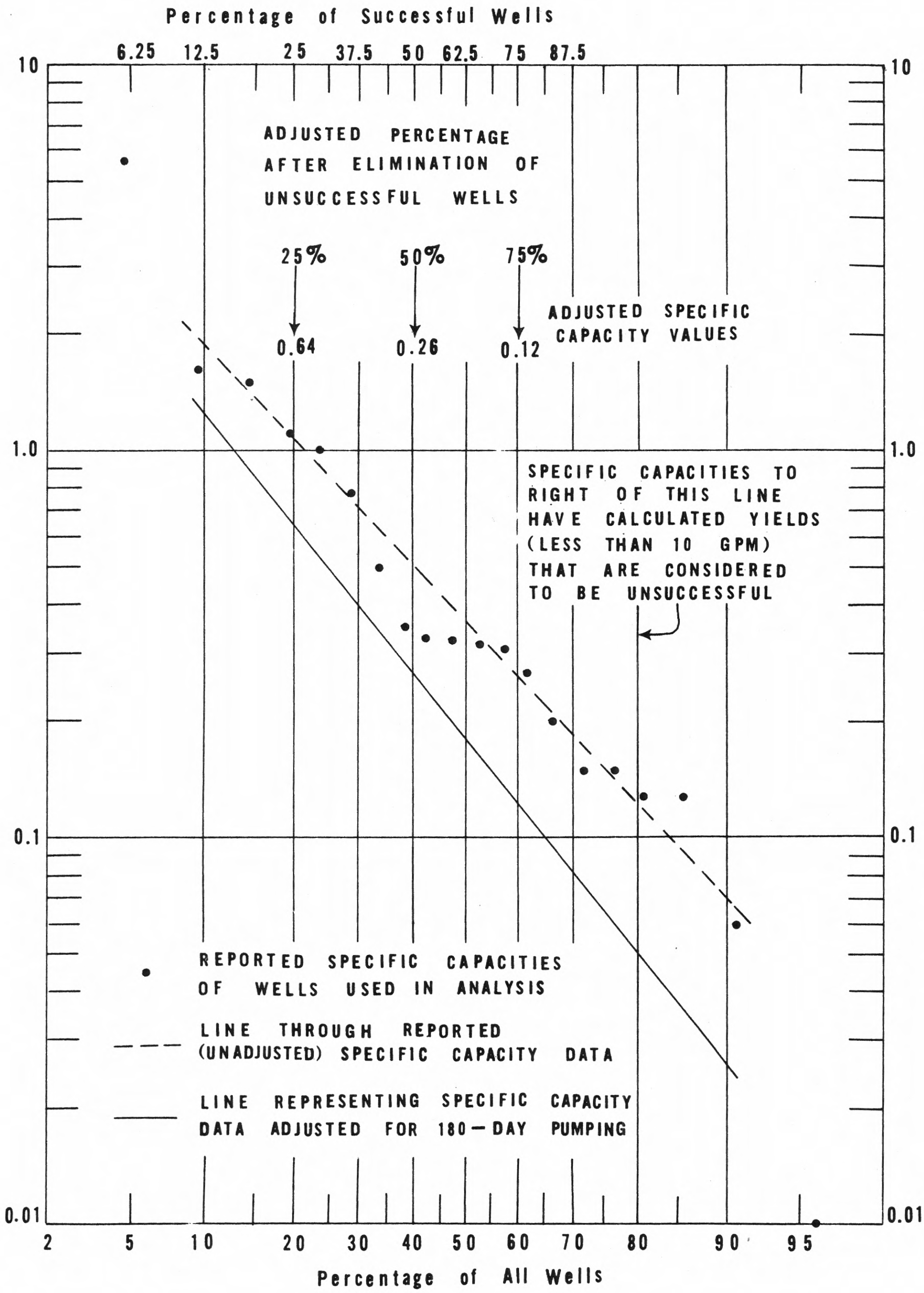

Figure 3.--Specific-capacity frequency distribution graph for the Devonian marine beds.

one day of pumping) to less than one-half their original value. The decline in theoretical specific capacity from 180 to 365 days is very small. A specific capacity based on 180 days of pumping probably represents a good average for a well pumped 24-hours a day for 365 days a year. In practice, the well would most likely be pumped only 12 hours a day and allowed to recover for 12 hours. The 180-day specific-capacity figure used reflects 24-hour a day pumping and allows a realistic yearly pumping figure to be computed without excessively tedious computations.

The coefficient of storage S in equation (1) can usually be estimated from well log and water-level data. Because specific capacity varies with the logarithm of $\frac{1}{S}$, large errors in estimating coefficients of storage result in comparatively small errors in specific-capacity data adjusted to a common time base. Hence, a coefficient of storage of 0.2, which is a water-table coefficient, was used to adjust the specific-capacity data. This is a conservative figure to use for the computations of well yields because it gives a greater reduction in specific capacity with time during the period over which the specific capacity was adjusted than would be obtained by using a smaller or artesian coefficient of storage.

It was assumed that any well yielding less than 10 gpm (based upon time-adjusted specific capacity and available drawdown) would be considered unsuccessful by a municipality, industry, or irrigator. After the specific-capacity frequency distributions had been constructed, using all the available data, the percentage of the sample obtaining less than 10 gpm was eliminated from the distribution. For only one geologic unit, the Chemung Formation, were more than 30 percent of the wells eliminated. The remaining percentage of specific capacities of successful wells was redistributed. Specific capacities exceeded in 75, 50, and 25 percent of these successful wells were picked from the new distribution graph and reported in table 1. When considering the cost of wells and ground water (in order to accounf for the unsuccessful wells that were eliminated) it was assumed that two wells would be contracted and drilled in every formation to obtain one successful well. It was further assumed that the well sites actually chosen would be based upon the best of engineering, geologic, and well-construction advice. The wells used in the analysis may not all have had this advice in their location, construction, and design.

Even though the above assumptions may have very little relationship to the actual yield of a specific well, it is believed that the resulting figures are realistic for the formation as a whole, and are probably conservative. This method appears to give some basis for estimating what long-term yields may reasonably be expected from a series of wells drilled in a particular aquifer.

Following is a discussion of some of the columns listed in table 1:

Specific Capacity Data

Specific capacity exceeded by indicated percentage of successful wells.

75 percent.--This figure represents the specific capacities estimated to be equaled or exceeded in 75 percent of existing successful wells. It is considered to represent a poor specific capacity expected in the prediction of the productivity of the geologic unit under discussion.

50 percent.--This figure represents the specific capacities estimated to be equaled or exceeded in 50 percent of the existing successful wells. It is considered to represent a medium specific capacity expected in the prediction of the productivity of the geologic unit under discussion.

25 percent.--This figure represents the specific capacity estimated to be equaled or exceeded in 25 percent of the existing successful wells. It is considered to represent a good specific capacity expected in the prediction of the productivity of the geologic unit under discussion.

Number of Wells Used for Specific-Capacity Frequency Distribution Analysis

This column refers to the number of wells in the geologic unit for which specific-capacity data were available. The number listed is an indication of the reliability to be placed upon the analysis of the specific-capacity data. The greater the number the better the results of the analysis.

Percentage of Unsuccessful Wells

This column refers to the percentage of wells in the original data analyzed, having an adjusted specific capacity that would result in a yield of less than 10 gpm. For limestones and related carbonate rocks this was a specific capacity of less than about 0.12 and for all other rocks a specific capacity of less than about 0.05. This number is partially a reflection of the number of domestic wells used in the analysis and partially a reflection on the chance of drilling an unsuccessful well in the aquifer.

Yield Exceeded by Indicated Percentage of Successful Wells

The yields given in gallons per minute represent the probable yields for the 75 percent (poor), 50 percent (medium), and 25 percent (good) specific capacities multiplied by the available drawdowns given in table 2. Three-quarters, one-half, and one-quarter of existing wells, respectively, should yield this amount of water if pumped to the drawdowns given in table 2. The yields given in million gallons per day represent the yields in gallons per minute multiplied by 1,440. The yields given in million gallons per year represent the yields in gallons per day multiplied by 365. The yields in million gallons per day can be converted to cubic feet per second by multiplying by 1.55.

Table 2.--Design of Hypothetical Wells

The design of the hypothetical wells is summarized in table 2. Following is a discussion of some of the columns listed in table 2.

Well Depth (feet)

It was decided to drill all wells in limestones and related carbonate rocks to a depth of 300 feet and to drill all wells in other types of rock to a depth of 400 feet. Studies have shown that the majority of solution openings in limestones and related carbonate rocks occur above a depth of 300 feet. Other studies have shown that the majority of fractures and joints in other types of rocks, such as sandstone and shale, occur above a depth of 400 feet. Hence, the depth of drilling was selected on the basis that the wells would penetrate almost all the water-bearing openings in the rocks to be drilled. At any given site, it may not be necessary in actual practice to drill to the above listed depths to obtain the indicated quantity of water, or drilling may proceed to greater depths without success in obtaining the indicated yield.

Well Diameter (inches)

The diameter of the well selected in inches was based on the pump size, which in turn was based on the anticipated yield of the well. The relationship of the anticipated yield of the well to the well diameter and pump size is shown in the table below:

Yield in gallons per minute	Pump size in inches	Well diameter in inches
0 - 100	4	6
100 - 250	6	8
250 - 500	8	10
500 - 1,000	10	12

The diameters listed in table 2 for poor, medium, and good yields are the smallest well diameters that can be used to produce, respectively, the 75 percent, 50 percent, and 25 percent estimated yields listed in table 1. This assumes the most economical well construction and operating conditions.

Length of Casing (feet)

Examination of the existing data and discussion with well drillers revealed that generally 40 feet of casing was installed for large-capacity municipal and industrial wells, regardless of rock type. Hence, 40 feet of casing was used as the average length installed for all the wells.

Static Water Level (feet below land surface)

The figure given is an approximate average of the water-level data available for each geologic unit. Ground-water levels fluctuate greatly throughout the year. The fluctuations are controlled by geologic, climatic, and hydrologic factors, and by the activities of man. At any given instant, water levels in a particular aquifer are not everywhere at the same level. Furthermore, the water levels given would certainly not be the same throughout the year. The figure shown is only an estimate; therefore, even if available data indicated a higher static water level, a static water level of 20 feet below land surface was used in the computations. Accordingly, 20 feet below land surface is the highest static water level shown in table 2.

Pumping Water Level (feet below land surface)

A pumping water level of 100 feet was used for most limestones and related carbonate rocks. A pumping water level of 200 feet was used for all the other rocks, such as the sedimentary sandstones and shales. These levels were chosen so that at least one half of the water-bearing openings in the rocks would be below the pumping water level.

Though these pumping water levels were selected without sufficient knowledge of the geohydrologic framework, they are probably the maximum depths to which the static water levels may be drawn down due to pumping without seriously impairing the water-yielding properties of the aquifers. They were chosen to give the largest yields under any given set of conditions.

The pumping water level, as well as the drawdown, are each separated into subheadings for poor, medium, and good yields, in order to show the pumping water levels and drawdowns in those rare cases where the computed maximum yields in carbonate rocks would exceed 1,000 gpm if a pumping water level of 100 feet were used.

Drawdown (pumping water level minus static water level in feet)

Drawdowns calculated from values listed under static water level and pumping water level are considered probable maximum available drawdowns. These values were multiplied by the corresponding specific capacities given in table 1 to obtain the estimated yields given in table 1.

Pump Working Horsepower

Pump working horsepower for a given hypothetical well is the actual working power necessary to lift the corresponding yield given in table 1 from the corresponding pumping water level given in table 2 to the land surface. Pump bowl horsepower (HP) was computed from the following formula:

$$HP = \frac{\text{Well yield (gpm) X pump bowl head (ft)}}{\text{Pump-bowl efficiency (decimal) X } 3{,}960\left(\frac{\text{ft-gal/min.}}{\text{HP}}\right)}$$

Deep-well turbine units for each hypothetical well were selected from available pump manufacturers' stock catalogues to produce the corresponding yields in table 1 at the smallest value of pump working horsepower and, hence, at the lowest operating cost.

Table 3.--Cost of Hypothetical Wells and of Ground Water

The feasibility of ground-water development is here defined to mean whether or not ground water can be managed or utilized successfully. The assumption is made that ground water is available for all needs if the user is willing to pay for the supply. This assumption is based upon the fact that all widespread aquifers will yield large quantities of water, although the yields of individual wells are generally greater from good aquifers than from poor ones. Hence, the question of whether the ground-water reservoirs are capable of being used feasibly is to a large extent a matter of cost of water. This section deals with the costs of developing ground water, and these costs are summarized in table 3.

The cost of water supply can be divided into the costs of: (1) works for collection of water, (2) works for the purification of water, and (3) works for the conveyance of water. For consistency with other estimates being made in the Susquehanna River basin study, this report will discuss only those costs related to the collection of water. These costs for the construction, operation, and maintenance of the hypothetical wells may be broken down into (1) initial costs and (2) annual costs. The initial costs are those costs to initially construct the well. The annual costs are those costs to operate and maintain the well, which include costs to amortize the initial cost, power costs, and maintenance costs.

For ground-water development initial costs at the well include: (1) drilling exploratory wells, and drilling, developing, and testing the production well; (2) equipment--including casing, strainer, pump, column, shaft, motor, meter, and inside piping; (3) pump house and electric controls; (4) land and rights of way; and (5) contingencies and engineering, including administration.

Initial Costs

Cost estimates were obtained from published reports and from industries, such as well drilling firms that install such equipment. The costs given herein are only estimated costs which will vary from place to place and from time to time. The costs will vary with the regional location of the well, the geohydrologic setting at the well, the well construction and methods used in well construction by the contractor, and the need of each contractor bidding to obtain the construction contract. The costs are September 1964 prices and can be converted to approximate present prices by comparison with the Engineering News-Record Construction Cost Index, which was 947 in September 1964 (Eng. News-Rec., vol. 173, no. 12, p. 93).

The factors considered in arriving at the initial cost of the wells are discussed below. The numbers given refer to the numbers of the column headings in table 3.

1.--Drilling two wells.

The depth, casing length, and diameter of the proposed well are discussed in the section on well design. One exploratory well (which could later be converted to an observation well) for every production well was assumed to be a reasonable average for the area. This allows for the additional well to be used in determining the hydraulic properties of the aquifer in the area and for monitoring water-level fluctuations. The estimated cost of drilling each well by percussion or cable-tool method in various rock types in the area is shown below in the table. These figures are based upon cost estimates supplied by several drilling firms in the Susquehanna River basin and upon the experience of the personnel of the Ground Water Branch at the Harrisburg District. It should be emphasized that they are merely estimates and not what actually may be charged in any specific location or circumstance.

Estimates of costs of drilling and casing hypothetical wells in the Susquehanna River basin.

Diameter of well (inches)	Shale (400 feet) (dollars)	Sandstone and quartzite (400 feet) (dollars)	Limestone and related carbonate rocks (300 feet) (dollars)	Casing surface to 40 feet (dollars)
6	$1,200	$1,600	$1,300	$140
8	1,800	2,600	2,800	200
10	2,600	3,800	3,700	280
12	3,400	5,000	4,900	400

2.--Pump testing production well.

A pumping test of 24-hours duration on the production well was deemed satisfactory for designing the deep-well turbine pumping unit. A pumping test on a well that would need a pump less than 10 inches in diameter was estimated to cost $500, and a pumping test on a well that would need a pump equal to or greater than 10 inches in diameter was estimated to cost $800.

3.--Casing production well.

The casings in the production wells are all designed to be 40 feet long. The estimated cost of casings of various diameters, delivered and installed in the well, were shown in the preceding table.

4.--Motor, column, shaft, pump, and strainer (deep-well turbine unit).

Cost curves were developed relating the cost of deep-well turbine units to well yields for the designed pumping water levels of 100 feet, 150 feet, and 200 feet. (See fig. 4.) Costs of the equipment were obtained from current manufacturers' price tables. Yields were arbitrarily chosen from the estimated yields reported in table 1. Units designed to yield 1,000 gpm at pumping water levels less than 100 feet were individually computed.

5.--Fixed land and equipment cost.

The estimated cost of land and rights of way is $1,000 per well. The estimated cost of the pump house is $1,500 per well. The estimated cost of other equipment (wiring, meter, piping, and appurtenances) is $1,500 per well. Thus, the total fixed cost in column 5 is $4,000 per well.

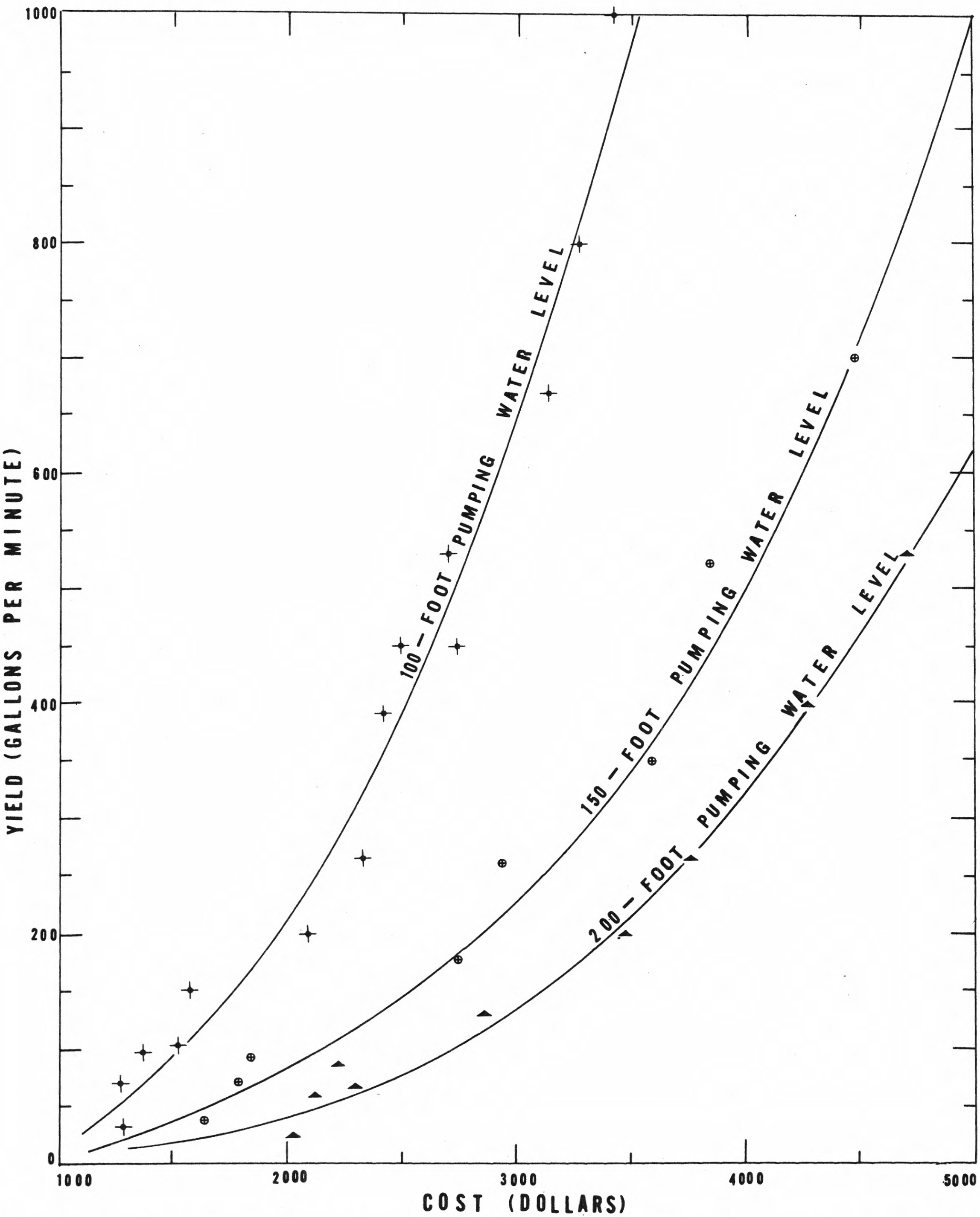

Figure 4.--Graph showing the relation of yield of hypothetical wells to cost of motor, column, shaft, pump, and strainer for selected pumping water levels.

6.--Contingencies.

The allowance for contingencies is 10 percent of the estimated construction and equipment costs (sum of columns 1 through 5).

7.--Engineering and administration.

The allowance for engineering, including contract administration and financing, has been set at 15 percent of the total construction cost, including contingencies (sum of columns 1 through 7).

8.--Total initial cost.

The total initial cost (sum of columns 1 through 7) is the initial cost of a single well, ready to discharge the corresponding yield given in table 1 at the land surface.

9.--Total initial cost in dollars per million gallons a day of design yield.

The total initial cost in thousands of dollars per million gallons per day added to the system at the well head is given to allow a comparison between alternative sources of water supply. The total initial cost in column 8 of table 3 was divided by the corresponding yield in million gallons per day given in table 1.

Annual Costs

10.--Annual payments to retire initial cost.

A single end-of-year payment to cover interest on the initial cost and payments to a depreciation fund may be calculated using the formula for uniform annual series of end-of-year payments. This method is referred to as the capitol-recovery-factor method of cost accounting (Grant and Ireson, 1960, p. 45):

$$R = P \frac{i\ (1 + i)^n}{(1 + i)^n - 1}$$

in which:

R = The end-of-period payment in a uniform series of equal payments continuing for the coming n periods.

P = Total initial costs - column 8.

i = Annual interest rate, taken as 4 percent on municipal bonds in this case.

n = Number of interest periods, taken as 25 years in this case.

$\frac{i\,(1 + i)^n}{(1 + i)^n - 1}$ = The capital recovery factor which, when multiplied by a present debt, gives the uniform end-of-year payment necessary to repay the debt in n years with interest rate i. This factor is 0.06401 where the annual interest rate is 4 percent, and the length of the period is 25 years, using a uniform series of payments.

11.--Annual power costs.

Annual power costs used herein were based upon Pennsylvania Power and Light Co.'s electrical power rate schedules SGS and LP-3 for municipal use. Total power consumption was estimated by using the operating horsepower of the individually designed pumping equipment from table 2, by assuming a 24-hour a day use, and by assuming 75 percent wire to motor efficiency so that 1 horsepower equals 1 kilowatt. Figure 5 was used in the calculations of annual power costs.

12.--Annual maintenance costs.

Annual maintenance costs were estimated from data obtained from the Pennsylvania Utility Commission and are here taken as 4 percent of the cost of the equipment given in column 4 of table 3. Over a period of 25 years, which is assumed to be the life of the equipment, this equals the cost given in column 4 and amounts to replacing the deep-well turbine unit once within the 25 years of assumed life of the equipment. No labor costs for operation were included. The well is assumed to be added to an existing distribution system and labor costs would not be great.

13.--Total annual cost.

The total annual cost is the sum of the annual payments to retire the initial cost (column 10), the annual power costs (column 11), and the annual maintenance costs (column 12). It is again emphasized that this is the cost to add a well to an existing distribution system, and does not include cost of treating the water or of delivering the water to the consumer.

14.--Average annual cost to produce ground water in dollars per thousand gallons of design yield.

This cost in dollars per thousand gallons is found by dividing the total annual cost (column 13, table 3) by the corresponding well yield in million gallons per year given in table 1. This result is divided by 1,000 to convert to cost per thousand gallons. The figures were reported to nearest tenth of a cent.

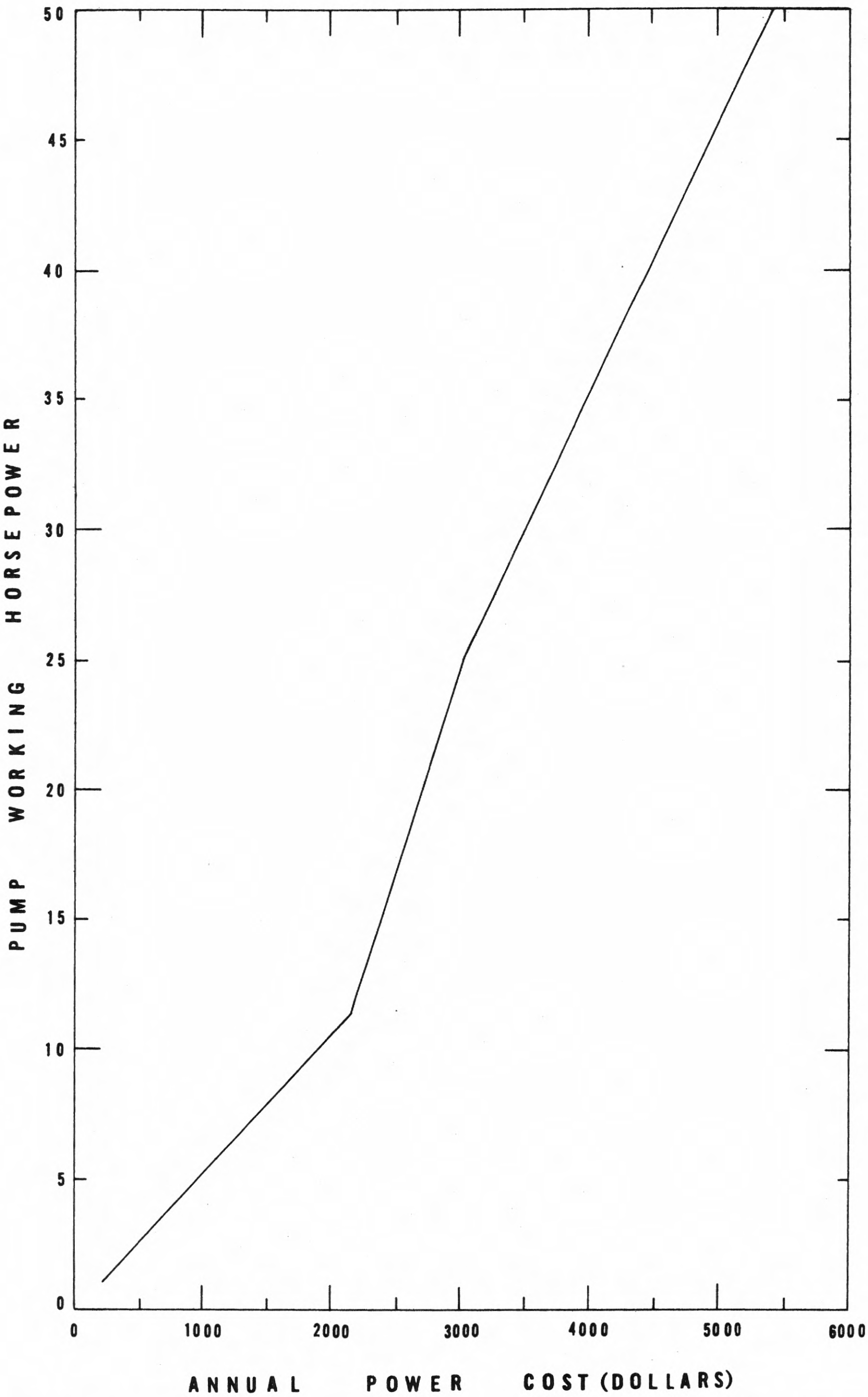

Figure 5.--Graph showing the relation of annual power cost to pump working horsepower given in table 2, assuming a power demand of 24-hours a day.

15.--Average annual cost to producer in dollars per million gallons per day of design yield.

This cost in dollars per million gallons per day is found by dividing that total annual cost (column 13, table 3) by the production figure in million gallons per day given in table 1. The costs given in columns 14 and 15 are valid only for the design yield and only if all the assumptions given earlier are met. They are not valid for a specific site or situation except in the almost inconceivable instance where all actual conditions equal all the assumptions made. These costs are given only to show a probable range in expected costs from an aquifer in order to compare alternate sources of water supply, both surface and ground.

Table 4.--Quality of Ground Water

Table 4 contains a summary of the water-quality characteristics of the geologic units. The values given in the table refer to the 75 percent (good), 50 percent (medium), and 25 percent (poor) categories for a normal frequency distribution of the reported values for each geologic unit from which chemical analyses were available. Because the values given in the table represent a range for only 50 percent of the available analyses, higher and lower values may occur in water from any particular well tapping a particular geologic unit. Although table 4 shows a range in concentration for any particular constituent in the water of each geologic unit, a single well will usually yield water of uniform quality throughout the year.

Table 5.--Cross Reference of Geologic Units and Water-Development Areas.

A cross reference of geologic units and water-development areas is given in table 5. This table shows which aquifers are available to a given water-development area and how many water-development areas are potential users of a particular rock unit. A distinction is made in the table between (1) those geologic units that immediately underlie the water-development areas, and (2) those that do not, but are within 1 mile of the political boundaries of the water-development areas.

APPRAISAL BY GEOLOGIC UNIT

The geologic units listed in the tables and discussed in this section are those that are capable of yielding usable quantities of ground-water supplies to the water-development areas. All such geologic units listed as available to a water-development area either underlie or are within 1 mile of the political boundaries of that area. The names of the geologic formations or groups listed are those used by the U. S. Geological Survey. The symbols used to identify the formations are those shown on the Geologic Map of Pennsylvania (1960) published by the State Geological Survey.

Formations or groups shown on the "Geologic Map of Pennsylvania" that are not discussed in this section are not "available to" the water-development areas for which specific information was requested (see fig. 1). The geologic units not discussed occupy only a small part of the Juniata River basin, and generally are not considered to be potential aquifers for municipal, industrial, or irrigational use in any part of the basin.

The discussion by geologic units allows an evaluation of additional areas not specifically requested at this time. The units are discussed according to geologic age, from youngest to oldest. A short discussion of the grouping of geologic units shown on the geologic map will be included where appropriate.

The discussion of water in each geologic unit includes sections on (1) availability, (2) quantity, (3) annual cost, and (4) quality.

(1) Availability--this section will list the availability of this geologic unit for those specific water-development areas requested. The listing of an area under a geologic unit implies that the unit occurs inside or within 1 mile of the boundaries of the area.

(2) Quantity--this section will briefly discuss the quantity available for the 75 percent (poor), 50 percent (medium), and 25 percent (good) probability of occurrence of well yields for the aquifer in gallons per minute. The computed yields were rounded to the nearest 5 gpm for all yields under 100 gpm and to 2 significant figures above 100 gpm. Yields in excess of 1,000 gpm were reduced to 1,000 gpm.

(3) Annual cost--this section will show the average annual cost of water in dollars per million gallons per day for the 75 percent (poor), 50 percent (medium), and 25 percent (good) probability of occurrence of the design well yields. The costs in dollars were rounded to 2 significant figures. The costs in dollars per million gallons a day can be converted to dollars per cubic foot per second (cfs) by multiplying by 0.646.

(4) Quality--this section will discuss briefly any quality problems known to occur in water from this geologic unit. Emphasis will be on dissolved solids, hardness, and iron content of the ground waters. The ranges discussed are only for the values given in table 4 between the 75 percent and 25 percent occurrence categories for a normal frequency distribution for the available analyses. Higher and lower values may occur in water from any particular well tapping this geologic unit. Where the higher values may be particularly significant, they are also mentioned. In addition, data available for other constituents that exceed the Public Health Service standards in at least 25 percent of the samples are mentioned.

The terms low, moderate, and high are used in the text to describe the relative concentration of dissolved solids, hardness, and iron in accordance with the following concentration ranges chosen for the Susquehanna River basin:

	Dissolved solids (ppm)	Hardness (ppm)	Iron (ppm)
Low	0 - 150	0 - 100	0.0 - 0.3
Moderate	150 - 500	100 - 300	0.3 - 1.0
High	>500	>300	>1.0

Pennsylvanian Rocks

The rocks of Pennsylvanian age cropping out in the Juniata basin include, in descending order: The Conemaugh Formation (IPc), Allegheny Group (IPa), and Pottsville Formation (IPp). They crop out in the Appalachian Plateau and in the Broad Top Coal Field. These rocks are composed of variable sequences of sandstone, shale, clay, limestone, and coal.

They are potentially very productive aquifers but have not been utilized extensively, except as a source of water for domestic wells. The quality of the water is good to excellent except in the vicinity of coal mines where the water is acidic and high in iron content. Insufficient data are available for a detailed analysis of these rocks. These rocks do not crop out in the vicinity of any of the water-development areas.

Mississippian Rocks

Mauch Chunk Shale

The Mauch Chunk Shale (Mmc) and the underlying Pocono Formation crop out at the edge of the Appalachian Plateau and in the Broad Top Coal Field. The Mauch Chunk Shale is a red shale containing greenish-gray sandstones and siltstones. The Mauch Chunk is potentially a moderately productive aquifer, but it has not been utilized extensively, except as a source of water for domestic wells.

Insufficient data are available for a detailed analysis of its water-bearing properties, although the unit is a potential aquifer in the Saxton area.

Pocono Formation

The Pocono Formation (Mp) is a gray conglomerate and sandstone containing some shale. The Pocono is potentially a very productive aquifer where it lies below drainage level but unimportant in rugged outcrop areas. The Pocono has not been utilized extensively. Insufficient data are available for a detailed analysis, although the unit is a potential aquifer in the Saxton area.

Devonian Rocks

Susquehanna Group

The Susquehanna Group is composed of sandstones and shales. The Susquehanna Group includes, in descending order: The Oswayo Formation, Catskill Formation, Chemung Formation, Trimmers Rock Sandstone, Brallier Shale, and Harrell Shale. On the 1960 edition of the Geologic Map of Pennsylvania, the Oswayo Formation is mapped as Doo, the Catskill Formation as Dck, and the remaining section as marine beds (Dm). The rocks mapped as Dm on the 1960 map are shown as the Chemung Formation (Dc) and the Portage Group (Dpg) on the 1932 edition of the Geologic Map of Pennsylvania. The entire Susquehanna Group is a gradational sequence in which formational contacts are established to a certain extent on predominance of one rock type over another.

In the text a summary of only the Catskill Formation and the marine beds is given. In the tables, however, additional information is given for the Chemung Formation, the Portage Group, and the combined Catskill Formation and Devonian marine beds. This was done to allow the use of the various available geologic maps that may show different classifications of the rock units.

Catskill Formation.

The Catskill Formation (Dck) is composed chiefly of red and brown shale, but it also contains red, brown, and gray sandstone and gray and greenish shale.

Availability.--The Catskill Formation is an available aquifer in the Everett, Saxton, Altoona, and Newport areas.

Quantity.--Poor yield - 35 gpm
Medium yield - 120 gpm
Good yield - 490 gpm

Annual cost.--For poor yield - $28,000 per mgd
For medium yield - $16,000 per mgd
For good yield - $7,500 per mgd

Quality.--The water from the Catskill Formation in the Valley and Ridge Province is generally of good quality for most purposes. The water contains low to moderate amounts of dissolved solids and low amounts of hardness and iron. Wells drilled deep enough to encounter the Catskill in the Appalachian Plateau Province are likely to encounter salt water.

Marine beds.

Devonian marine beds (Dm) are composed of shale, graywacke, and sandstone. The sequence includes the Chemung Formation, Trimmers Rock Sandstone, Brallier Shale, and Harrell Shale. The latter three units are shown on the 1932 edition of the Geologic Map of Pennsylvania as the Portage Group (Dpg).

Availability.--The Devonian marine beds are available aquifers in the Everett, Saxton, Altoona, Hollidaysburg, Duncansville, Tyrone, Huntingdon, and Newport areas.

Quantity.--Poor yield - 20 gpm
Medium yield - 45 gpm
Good yield - 110 gpm

Annual cost.--For poor yield - $40,000 per mgd
For medium yield - $24,000 per mgd
For good yield - $17,000 per mgd

Quality.--The water from the Devonian marine beds is of generally good quality for most uses. The water contains low to moderate amounts of dissolved solids and hardness. The iron content is low. Some of the water contains hydrogen sulfide.

Hamilton Group and Onondaga Formation

The Hamilton Group (Dh) and Onondaga Formation (Don) are composed of shale and limestone. The combined Hamilton Group and Onondaga Formation are mapped as Dho. The Mahantango Formation of the Hamilton Group is mapped as Dmh. The Marcellus Shale of the Hamilton Group and the underlying Onondaga Formation are combined and mapped as Dmo.

Availability.--The Hamilton Group and Onondaga Formation are available aquifers in the Bedford, Everett, Saxton, Altoona, Hollidaysburg, Duncansville, Tyrone, Huntingdon, Mt. Union, Port Royal, Lewistown, and Newport areas.

Quantity.--Poor yield - 45 gpm
Medium yield - 110 gpm
Good yield - 250 gpm

Annual cost.--For poor yield - $23,000 per mgd
For medium yield - $16,000 per mgd
For good yield - $10,000 per mgd

Quality.--The water from these rocks is of generally good quality for most uses. The water contains low to moderate amounts of dissolved solids and hardness. The iron content ranges from low to high. Hydrogen sulfide has been reported in water from several wells in each formation.

Mahantango Formation.

Availability.--The Mahantango Formation is an available aquifer in the Bedford, Everett, Saxton, Altoona, Hollidaysburg, Duncansville, Tyrone, Huntingdon, Mt. Union, Port Royal, and Newport areas.

Quantity.--Poor yield - 40 gpm
Medium yield - 120 gpm
Good yield - 370 gpm

Annual cost.--For poor yield - $24,000 per mgd
For medium yield - $13,000 per mgd
For good yield - $7,000 per mgd

Quality.--The water from the Mahantango Formation is generally of fair quality for most purposes. The water contains moderate amounts of dissolved solids and hardness. The iron content is high. Hydrogen sulfide has been reported in water from several wells in the Mahantango Formation.

Oriskany Group

The Oriskany Group (Do) is composed of sandstone, limestone, and shale. The Oriskany Group is composed of the Ridgeley Sandstone and the Shriver Chert. The combined Oriskany Group and underlying Helderberg Limestone are mapped as Doh.

Availability.--The Oriskany Group is an available aquifer in the Bedford, Everett, Altoona, Hollidaysburg, Duncansville, Tyrone, Huntingdon, Mt. Union, Port Royal, and Lewistown areas.

Quantity.--Poor yield - 290 gpm
Medium yield - 420 gpm
Good yield - 620 gpm

Annual cost.--For poor yield - $9,900 per mgd
For medium yield - $8,100 per mgd
For good yield - $7,200 per mgd

Quality.--The water from the Oriskany Group is of good quality for most uses. The water contains low to moderate amounts of dissolved solids, hardness, and iron.

Helderberg Limestone

The Helderberg Limestone (Dhb) is composed of shale and limestone. The combined Oriskany Group and Helderberg Limestone are mapped as Doh. Additional information is given in the tables for the combined Helderberg Limestone and underlying Keyser and Tonoloway Limestones.

Availability.--The Helderberg Limestone is an available aquifer in the Bedford, Everett, Altoona, Hollidaysburg, Duncansville, Tyrone, Huntingdon, Mt. Union, Port Royal, and Lewistown areas.

Quantity.--Poor yield - 35 gpm
Medium yield - 140 gpm
Good yield - 600 gpm

Annual cost.--For poor yield - $21,000 per mgd
For medium yield - $10,000 per mgd
For good yield - $5,000 per mgd

Quality.--Water from the Helderberg Limestone is of fairly good quality. The water contains a moderate amount of dissolved solids and a moderate to high amount of hardness. The iron content is low. A few samples indicate a dissolved-solids content that is too high for most industrial uses, and some of the water is unfit for practically any use except cooling.

Devonian (?) and Silurian Rocks

Keyser and Tonoloway Limestones

The Keyser and Tonoloway Limestones are predominately limestones. The combined Keyser and Tonoloway Limestones are mapped as Skt. The combined Keyser and Tonoloway Limestones and the underlying Wills Creek Shale are mapped as Skw. The undifferentiated Keyser, Tonoloway, Wills Creek, Bloomsburg, and McKenzie Formations are mapped as Skm. Additional information is given in the tables for the combined Helderberg, Keyser, and Tonoloway Limestones.

Availability.--The Keyser and Tonoloway Limestones are available aquifers in the Bedford, Everett, Altoona, Hollidaysburg, Duncansville, Tyrone, Taylor, Mt. Union, Mifflintown, Port Royal, and Lewistown areas.

Quantity.--Poor yield - 50 gpm
Medium yield - 230 gpm
Good yield - 1,000 gpm

Annual cost.--For poor yield - $16,000 per mgd
For moderate yield - $7,800 per mgd
For good yield - $3,400 per mgd

Quality.--The water from the Keyser and Tonoloway Limestones is of fairly good quality for most uses. The water contains a moderate amount of dissolved solids and hardness. The iron content is low. A few samples have high nitrate concentrations. A few wells yield water that contains large amounts of calcium, sulfate, and iron. Some of this water is too hard for many industrial uses and is unfit for practically any use except cooling.

Silurian Rocks

Wills Creek Shale, Bloomsburg Shale, and McKenzie Formation

The Wills Creek Shale (Sw) is a greenish-gray shale containing some beds of limestone and sandstone. The Bloomsburg Shale is predominately a red siltstone and shale containing some beds of sandstone and limestone. The McKenzie Formation is predominately a greenish-gray shale containing some thin limestones and red shale. The combined Keyser, Tonoloway, and Wills Creek Formations are mapped as Skw. The combined Bloomsburg and McKenzie Formations are mapped as Sbm. The combined Wills Creek, Bloomsburg, and McKenzie Formations are mapped as Swm. The undifferentiated Keyser, Tonoloway, Wills Creek, Bloomsburg, and McKenzie Formations are mapped as Skm. Additional information is given in the tables for the combined Wills Creek, Bloomsburg, and McKenzie Formations and the underlying Clinton Group.

Availability.--The Wills Creek, Bloomsburg, and McKenzie Formations are available aquifers in the Bedford, Everett, Altoona, Hollidaysburg, Duncansville, Tyrone, Taylor, Mt. Union, Mifflintown, Port Royal, and Lewistown areas.

Quantity.--Poor yield - 30 gpm
Medium yield - 85 gpm
Good yield - 200 gpm

Annual cost.--For poor yield - $30,000 per mgd
For medium yield - $17,000 per mgd
For good yield - $12,000 per mgd

Quality.--The water from these rocks is of fairly good quality for most purposes. The water contains a moderate amount of dissolved solids, low to moderate amounts of hardness, and a low iron content. A few wells yield water that contains large amounts of calcium sulfate. Some of this water is unfit for practically any use except cooling.

Clinton Group

The Clinton Group is composed chiefly of gray and greenish sandstone and shale and a small proportion of limestone and red sandstone. The Clinton Group is mapped as Sc and includes, in descending order: the Rochester Shale, Keefer Sandstone, and Rose Hill Formation. Additional information is given in the tables for the combined Wills Creek, Bloomsburg, and McKenzie Formations and the Clinton Group.

Availability.--The Clinton Group is an available aquifer in the Bedford, Everett, Altoona, Hollidaysburg, Duncansville, Tyrone, Taylor, Mt. Union, Mifflintown, Port Royal, and Lewistown areas.

Quantity.--Poor yield - 30 gpm
Medium yield - 70 gpm
Good yield - 150 gpm

Annual cost.--Poor yield - $30,000 per mgd
Medium yield - $19,000 per mgd
Good yield - $14,000 per mgd

Quality.--The water from the Clinton Group is of good quality for most uses. The water contains a low amount of dissolved solids and hardness. The iron content ranges from low to moderate. One deep well sample contained water with a dissolved-solids content greater than 2,300 ppm, most of which was sodium chloride.

Tuscarora Quartzite

The Tuscarora Quartzite (St) is a fine-grained, quartzitic sandstone that is conglomeratic in part. The Tuscarora Quartzite is unimportant as a source of ground water owing to its topographic position on the summits of the highest ridges.

Ordovician Rocks

Juniata Formation and Oswego Sandstone

The Juniata Formation (Oj) is red quartzite interbedded with red shale. The Oswego sandstone (Obe), named the Bald Eagle Formation by the Pennsylvania Geological Survey, is a greenish-gray sandstone interbedded with greenish-gray shale. The combined Juniata Formation and Oswego Sandstone is mapped as Ojb. Additional information is given in the tables for the combined Juniata, Oswego, and Reedsville Formations.

Availability.--The Juniata and Oswego Formations are available aquifers in the Roaring Springs, Mt. Union, and Belleville areas.

Quantity.--Poor yield - 20 gpm
Medium yield - 30 gpm
Good yield - 60 gpm

Annual cost.--For poor yield - $40,000 per mgd
For medium yield - $30,000 per mgd
For good yield - $20,000 per mgd

Quality.--The water from these formations is of excellent quality for most uses. The water contains a low amount of dissolved solids, hardness, and iron.

Reedsville Shale

The Reedsville Shale (Or) is a gray shale containing silty and sandy interbeds. The Reedsville is the central Pennsylvania equivalent of the Martinsburg Shale. Additional information is given in the tables for the combined Juniata, Oswego, and Reedsville Formations, and for the combined Reedsville and Martinsburg Formations.

Availability.--The Reedsville Shale is an available aquifer in the Belleville area.

Quantity.--Poor yield - 20 gpm
Medium yield - 30 gpm
Good yield - 50 gpm

Annual cost.--For poor yield - $38,000 per mgd
For medium yield - $30,000 per mgd
For good yield - $21,000 per mgd

Quality.--The water from the Reedsville Shale is of fairly good quality for most uses. The water contains a low to moderate amount of dissolved solids, hardness, and iron. A few samples contain high amounts of iron and nitrate and small quantities of hydrogen sulfide.

Middle Ordovician Limestones

The Middle Ordovician Limestones are composed almost entirely of calcium and magnesium limestones. They contain the Trenton Limestone, the Black River Group (which includes the Rodman Limestone, the Lowville Limestone, and the equivalent Chambersburg Limestone), and the Coburn Limestone and the equivalent St. Paul Group. On the Geologic Map of Pennsylvania (1960) these units are shown as the Coburn, Salona, and Nealmont Formations mapped as Ocn; and the Curtin, Benner, Hatter, and Loysburg Formations mapped as Ovl. The entire section is also shown on the Geologic Map of Pennsylvania as Ocl.

Availability.--The Middle Ordovician Limestones are available aquifers in the Roaring Springs and Belleville areas.

Quantity.--Poor yield - 40 gpm
Medium yield - 130 gpm
Good yield - 420 gpm

Annual cost.--For poor yield - $19,000 per mgd
For medium yield - $10,000 per mgd
For good yield - $6,000 per mgd

Quality.--The water from these rocks does not appear to be typical limestone water. It is of excellent quality for most uses as it contains low amounts of dissolved solids, hardness, and iron. A few samples have high nitrate concentrations.

Beekmantown Group

The Beekmantown Group (Ob) is composed of interbedded limestone and dolomite and some cherty layers. The Beekmantown consists of the Bellefonte Dolomite (Obf), Axemann Formation (Oa), Nittany Formation (On), Stonehenge Limestone (Os), and Larke Dolomite (Os). The U. S. Geological Survey includes the Mines Dolomite (€m) in the Beekmantown Group, whereas the Pennsylvania Geological Survey considers the Mines Formation to be of Cambrian age. In this report it has been analyzed with the Cambrian rocks. The combined Bellefonte and Axemann Formations are shown on the Geologic Map of Pennsylvania as Oba, and the combined Nittany, Stonehenge, and Larke Formations as Ons.

Availability.--The Beekmantown Group is an available aquifer in the Roaring Springs, Williamsburg, and Belleville areas.

Quantity.--Poor yield - 60 gpm
Medium yield - 480 gpm
Good yield - 1,000 gpm

Annual cost.--For poor yield - $14,000 per mgd
For medium yield - $5,400 per mgd
For good yield - $3,000 per mgd

Quality.--The water from the Beekmantown Group is typical limestone water of fairly good quality. The water contains a moderate amount of dissolved solids and hardness. The iron content is low. A few samples indicate high nitrate concentrations.

Ordovician and Cambrian Rocks

Mines Dolomite and Gatesburg Formation

The Mines Dolomite (Ꞓm) is a dolomite containing much chert, and the Gatesburg Formation(Ꞓg) is a dolomite containing many interbedded sandstones. The combined formations are shown on the map as Ꞓmg. The U. S. Geological Survey considers the Mines Dolomite to be of Ordovician age and a member of the Beekmantown Group, whereas the Pennsylvania Geological Survey considers it to be of Cambrian age, and not a member of the Beekmantown.

Availability.--The Mines Dolomite and Gatesburg Formation are available aquifers in the Roaring Springs and Williamsburg areas.

Quantity.--Poor yield - 110 gpm
Medium yield - 240 gpm
Good yield - 520 gpm

Annual cost.--For poor yield - $11,000 per mgd
For medium yield - $7,500 per mgd
For good yield - $5,400 per mgd

Quality.--The water from the Mines and Gatesburg is typical limestone water of fairly good quality. The water contains a low to moderate amount of dissolved solids and a moderate amount of hardness. The iron content is generally low. A few samples have a high nitrate content.

Warrior Limestone

The Warrior Limestone (€w) is a bluish-gray, fine-grained dolomite containing some thin shale layers. The Warrior Limestone is potentially a moderately productive aquifer, but it has not been utilized extensively, except as a source of water for domestic wells. Insufficient data are available for a detailed analysis of its water-bearing properties, although the unit is a potential aquifer in the Williamsburg area. The water quality probably is similar to that of other typical limestone waters.

APPRAISAL BY AREA

The water-development areas within the Juniata River basin selected for study by the U. S. Public Health Service and concurred on by the U. S. Army Corps of Engineers are shown in figure 1. These areas are those that are considered to be the nucleus around which future population growth in the Juniata basin will occur. Most of them have a population in excess of 5,000 according to the 1960 Bureau of Census Report, but a few smaller areas are listed because these Federal agencies were specifically concerned about the availability of ground water for use as a source for public water supply. The areas are discussed by county, in alphabetical order. The corporate units (municipality or township) included within each water-development area are listed in the text. The geologic units listed as being available occur either inside of or within 1 mile of the boundaries of the areas under discussion.

The exact location of the geologic unit may be found by referring to the Geologic Map of Pennsylvania (Pennsylvania Geological Survey, 1960). The aquifers available to each local area may be compared as to yield, cost, and quality of ground water by reference to tables 1, 2, 3, and 4 and to the section on appraisal by geologic unit. A cross reference of geologic units and the water-development areas to which they are available are given in table 5.

In appraising and evaluating various geologic units available to a local area, a tabulation of ground-water yields, costs, and chemical quality by aquifer should be made. This tabulation would assist the water resources planner or manager to select the most promising aquifers for ground-water development. Such a tabulation was not made because it would have been duplication of work presented elsewhere in the report.

Bedford County, Pa.

Bedford - Everett Area

The Bedford - Everett area includes the Boroughs of Bedford and Everett. The available aquifers in this area are: the Catskill Formation (Dck), Devonian marine beds (Dm), the combined Hamilton Group and Onondaga Formation (Dho), the combined Oriskany Group and Helderberg Limestone (Doh), the combined Keyser and Tonoloway Limestones (Skt, Skm), the combined Wills Creek Shale, Bloomsburg Shale, and McKenzie Formation (Swm, Skm), the Clinton Group (Sc), and the Tuscarora Quartzite (St). The Keyser, Tonoloway, Wills Creek, Bloomsburg, and McKenzie Formations underlie the Borough of Bedford. The Onondaga, Helderberg, Keyser, Tonoloway, Wills Creek, Bloomsburg, and McKenzie Formations and the Hamilton and Oriskany Groups underlie the Borough of Everett.

Saxton Area

The Saxton area includes the Borough of Saxton. The available aquifers in this area are: the Mauch Chunk Shale (Mmc), Pocono Formation (Mp), Catskill Formation (Dck), Devonian marine beds (Dm), and the combined Hamilton Group and Onondaga Formation (Dho). The Catskill Formation and Devonian marine beds underlie the Borough of Saxton.

Blair County, Pa.

Altoona Area

The Altoona area includes the City of Altoona. The available aquifers in this area are: the Catskill Formation (Dck), Devonian marine beds (Dm), the combined Hamilton Group and Onondaga Formation (Dho), the combined Oriskany Group and Helderberg Limestone (Doh), the combined Keyser and Tonoloway Limestones (Skt, Skm), the combined Wills Creek Shale, Bloomsburg Shale, and McKenzie Formation (Swm, Skm), and the Clinton Group (Sc). The Catskill Formation and the Clinton Group are the only units of those listed above that do not underlie the City of Altoona.

Hollidaysburg - Duncansville Area

The Hollidaysburg - Duncansville area includes the boroughs of Hollidaysburg and Duncansville. The available aquifers in this area are: the Devonian marine beds (Dm), the combined Hamilton Group and Onondaga Formation (Dho), the combined Oriskany Group and Helderberg Limestone (Doh), the combined Keyser and Tonoloway Limestones (Skt), the combined Wills Creek, Bloomsburg Shale, and McKenzie Formation (Swm), and the Clinton Group (Sc). The Keyser, Tonoloway, Wills Creek, Bloomsburg, McKenzie Formations and the Clinton Group underlie the Borough of Hollidaysburg. The Onondaga and Helderberg Formations and the Hamilton and Oriskany Groups underlie the Borough of Duncansville.

Tyrone Area

The Tyrone area includes the Borough of Tyrone. The available aquifers in this area are: The Devonian marine beds (Dm), the combined Hamilton Group and Onondaga Formation (Dho), the combined Oriskany Group and Helderberg Limestone (Doh), the combined Keyser Limestone, Tonoloway Limestone, Wills Creek Shale, Bloomsburg Shale and McKenzie Formation (Skm), the Clinton Group (Sc), and the Tuscarora Quartzite (St). The Devonian marine beds, the Hamilton and Oriskany Groups, and the Onondaga and Helderberg Formations underlie the Borough of Tyrone.

Roaring Springs Area

The Roaring Springs area includes the Borough of Roaring Springs and Taylor Township. The available aquifers in this area are: the combined Keyser and Tonoloway Limestones (Skt), the combined Wills Creek Shale, Bloomsburg Shale, and McKenzie Formation (Swm), the Tuscarora Quartzite (St), the Juniata Formation (Oj), the Oswego Sandstone (Obe), the Reedsville Shale (Or), the Middle Ordovician Limestones (Ocl), the combined Bellefonte Dolomite and Axemann Limestone (Oba) and the combined Nittany Dolomite, Stonehenge Limestone, and Larke Dolomite (Ons) of the Beekmantown Group, and the combined Mines Dolomite and Gatesburg Formation (€mg). The Middle Ordovician Limestones and the Beekmantown Group underlie the Borough of Roaring Springs.

Williamsburg Area

The Williamsburg area includes the Borough of Williamsburg. The available aquifers in this area are: the combined Bellefonte Dolomite and Axemann Limestone (Oba) and the combined Nittany Dolomite, Stonehenge Limestone, and Larke Dolomite (Ons) of the Beekmantown Group, the combined Mines Dolomite and Gatesburg Formation (€mg), and the Warrior Limestone (€w). The Nittany, Stonehenge, Larke, Mines, and Gatesburg Formations underlie Williamsburg Borough.

Cambria County, Pa.

No area with a population in excess of 5,000 occurs within the Juniata River basin part of Cambria County.

Centre County, Pa.

No area with a population in excess of 5,000 occurs within the Juniata River basin part of Centre County.

Franklin County, Pa.

No area with a population in excess of 5,000 occurs within the Juniata River basin part of Franklin County.

Fulton County, Pa.

No area with a population in excess of 5,000 occurs within the Juniata River basin part of Fulton County.

Huntingdon County, Pa.

Huntingdon Area

The Huntingdon area includes the Borough of Huntingdon. The available aquifers in this area are: The Devonian marine beds (Dm), Mahantango Formation (Dmh), the combined Marcellus and Onondaga Formation (Dmo), Oriskany Group (Do), and the Helderberg Limestone (Dhb). The Helderberg Limestone is the only aquifer that does not underlie the Borough of Huntingdon.

Mt. Union Area

The Mt. Union area includes the Borough of Mt. Union. The available aquifers in this area are: The Mahantango Formation (Dmh), the combined Marcellus Shale and Onondaga Formation (Dmo), the combined Oriskany Group and Helderberg Limestone (Doh), the combined Keyser Limestone, Tonoloway Limestone, and Wills Creek Shale (Skw), the combined Bloomsburg Shale and McKenzie Formation (Sbm), the Clinton Group (Sc), the Tuscarora Quartzite (St), and the Juniata Formation (Oj). The Oriskany and Clinton Groups and the Helderberg, Keyser, Tonoloway, Wills Creek, Bloomsburg, and McKenzie Formations underlie the Borough of Mt. Union.

Juniata County, Pa.

Mifflintown - Port Royal Area

The Mifflintown - Port Royal area includes the Boroughs of Mifflintown and Port Royal. The available aquifers in this area are: The combined Hamilton Group and Onondaga Formation (Dho), the combined Oriskany Group and Helderberg Limestone (Doh), the combined Keyser and Tonoloway Limestones (Skt), Wills Creek Shale (Sw), the combined Bloomsburg and McKenzie Formations (Sbm), and the Clinton Group (Sc). The Keyser, Tonoloway, and Wills Creek Formations underlie both boroughs.

Mifflin County, Pa.

Belleville Area

The Belleville area includes the Borough of Belleville and the Townships of Union and Menno. The available aquifers in this area are: The Tuscarora Quartzite (St), Juniata Formation (Oj), Oswego Sandstone (Obe), Reedsville Shale (Or), Middle Ordovician Limestones (Ocn, Ovl, Ocl), and the Bellefonte Dolomite (Obf) and Axemann Limestone (Oa) of the Beekmantown Group. The Bellefonte and Axemann Formations underlie the Borough of Belleville.

Lewistown Area

The Lewistown area includes the Borough of Lewistown. The available aquifers in this area are: The combined Hamilton Group and Onondaga Formation (Dho, Dmo), the combined Oriskany Group and Helderberg Limestone (Doh), the combined Keyser Limestone, Tonoloway Limestone, Wills Creek Shale, Bloomsburg Shale, and the McKenzie Formation (Skt, Skm), the Clinton Group (Sc), and the Tuscarora Quartzite (St). The Mahantango Formation of the Hamilton Group and the Tuscarora Quartzite are the only aquifers that do not underlie the Borough of Lewistown.

Perry County, Pa.

Newport Area

The Newport area includes the Borough of Newport. The available aquifers in this area are: The Catskill Formation (Dck), Devonian marine beds (Dm), and the combined Hamilton Group and Onondaga Formation (Dho). The Catskill Formation and the Devonian marine beds underlie the Borough of Newport.

Snyder County, Pa.

No area with a population in excess of 5,000 occurs within the Juniata River basin part of Snyder County.

Somerset County, Pa.

No area with a population in excess of 5,000 occurs within the Juniata River basin part of Somerset County.

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Table 1.--Estimated specific capacities and yields of hypothetical wells in the geologic units of the Juniata River basin

Specific capacity, exceeded by indicated percentage of successful wells: Tabulated values are taken from log-normal frequency distribution of reported data, adjusted for 180 days continuous pumping; 75, 50, and 25 percent are referred to as poor, medium, and good, respectively, in the text.
Percentage of unsuccessful wells: The statistical percentage of wells, in the sample analyzed, that would yield less than 10 gallons per minute based on the well design given in table 2.
Yield equaled or exceeded by indicated percentage of successful wells: Derived from specific-capacity data and well design given in table 2; 75, 50, and 25 percent are referred to as poor, medium, and good, respectively, in the text and tables 2 and 3.

Geologic unit (Formation or Group)	Geologic age	Symbol on Geologic Map of Pennsylvania scale 1:250,000	Area in which well analyses are valid	Specific-capacity data: Specific capacity exceeded by indicated percentage of successful wells: 75 percent (poor)	50 percent (medium)	25 percent (good)	Number of wells used for specific capacity frequency distribution analysis	Percentage of unsuccessful wells	Yield exceeded by indicated percentage of successful wells: 75 percent (poor): Gallons per minute	Million gallons per day	Million gallons per year	50 percent (medium): Gallons per minute	Million gallons per day	Million gallons per year	25 percent (good): Gallons per minute	Million gallons per day	Million gallons per year
Catskill	Devonian	Dck	Entire Juniata basin	0.22	0.72	2.9	8	17	35	0.050	18	120	0.17	63	490	0.71	260
Catskill and marine beds	Devonian	Dck, Dm	Entire Juniata basin	.14	.32	.84	28	17	25	.036	13	55	.079	29	150	.22	80
Marine beds	Devonian	Dm	Entire Juniata basin	.12	.26	.64	20	20	20	.029	11	45	.065	24	110	.16	58
Marine beds (Chemung)	Devonian	Dm (Chemung)	Entire Juniata basin	.10	.19	.42	9	32	20	.029	11	35	.050	18	75	.11	39
Marine beds (Portage)	Devonian	Dm (Portage)	Entire Juniata basin	.15	.35	.89	11	13	35	.036	13	65	.094	34	160	.23	84
Hamilton and Onondaga	Devonian	Dmh, Dho, Dmo	Entire Juniata basin	.26	.60	1.4	29	3	45	.065	24	110	.16	58	250	.36	130
Mahantango	Devonian	Dmh	Entire Juniata basin	.25	.72	2.2	11	8	40	.058	21	120	.17	63	370	.53	190
Oriskany	Devonian	Do, Doh	Entire Juniata basin	1.8	2.6	3.9	8	2	290	.42	150	420	.60	220	620	.89	330
Helderberg	Devonian	Dhb, Doh	Entire Juniata basin	.62	2.3	10	9	18	35	.050	18	140	.20	74	600	.86	320
Helderberg, Keyser, and Tonoloway	Devonian(?) and Silurian	Doh, Dhb, Skt, Skw, Skm	Entire Juniata basin	.57	2.5	15	31	25	40	.058	21	180	.26	95	1,000	1.4	530
Keyser and Tonoloway	Devonian(?) and Silurian	Skt, Skw, Skm	Entire Juniata basin	.62	2.9	18	22	26	50	.072	26	230	.33	120	1,000	1.4	530
Wills Creek, Bloomsburg, and McKenzie	Silurian	Skw, Skm, Sw, Swm, Sbm	Entire Juniata basin	.16	.46	1.1	27	2	30	.043	16	85	.12	45	200	.29	110

Table 1.--Estimated specific capacities and yields of hypothetical wells in the geologic units of the Juniata River basin--Continued

Geologic unit (Formation or Group)	Geologic age	Symbol on Geologic Map of Pennsylvania scale 1:250,000	Area in which well analyses are valid	Specific-capacity data: Specific capacity exceeded by indicated percentage of successful wells			Specific-capacity data: Number of wells used for specific capacity frequency distribution analysis	Specific-capacity data: Percentage of unsuccessful wells	Yield exceeded by indicated percentage of successful wells: 75 percent (poor)			50 percent (medium)			25 percent (good)		
				75 percent (poor)	50 percent (medium)	25 percent (good)			Gallons per minute	Million gallons per day	Million gallons per year	Gallons per minute	Million gallons per day	Million gallons per year	Gallons per minute	Million gallons per day	Million gallons per year
Wills Creek, Bloomsburg, McKenzie, and Clinton	Silurian	Skw, Skm, Sw, Swm, Sbm, Sc	Entire Juniata basin	0.19	0.43	0.94	40	4	35	0.050	18	75	0.11	39	170	.24	89
Clinton	Silurian	Sc	Entire Juniata basin	.18	.38	.85	13	6	30	.043	16	70	.10	37	150	.22	79
Juniata and Oswego	Ordovician	Oj, Obe	Entire Juniata basin	.11	.19	.36	6	10	20	.029	11	30	.043	16	60	.086	32
Juniata, Oswego, and Reedsville	Ordovician	Oj, Obe, Or	Entire Juniata basin	.13	.18	.28	11	2	20	.029	11	30	.043	16	50	.072	26
Reedsville	Ordovician	Or	Entire Juniata basin	.12	.18	.29	5	4	20	.029	11	30	.043	16	50	.072	26
Martinsburg and Reedsville	Ordovician	Om, Or	Entire Juniata basin	.17	.32	.75	23	4	30	.043	16	60	.086	32	140	.20	74
Middle Ordovician limestones	Ordovician	Ocn, Ocl, Ovl	Entire Juniata basin	.60	1.8	5.8	6	10	40	.058	21	130	.19	68	420	.60	220
Beekmantown	Ordovician	Obf, Oa, Oba, On, Os, Ons, Ob	Entire Juniata basin	1.0	8.0	72	13	18	60	.086	32	480	.69	250	1,000	1.4	530
Mines and Gatesburg	Ordovician and Cambrian	Ꞓm, Ꞓmg, Ꞓg	Entire Juniata basin	2.7	6.0	13	18	2	110	.16	58	240	.35	130	520	.75	270

Table 2.--Well design of hypothetical wells in the geologic units of the Juniata River basin

Well diameter: Chosen according to pump diameter, which is based on yields given in table 1; 0 to 100 gallons per minute, 4-inch pump, 6-inch well; 100 to 250 gallons per minute, 6-inch pump, 8-inch well; 250 to 500 gallons per minute, 8-inch pump, 10-inch well; 500 to 1,000 gallons per minute, 10-inch pump, 12-inch well.
Poor, medium, and good yields refer to yields of 75, 50, and 25 percent of wells, respectively, given in table 1.
Pump working horsepower: The power necessary to produce hypothetical yields given in table 1, for use in calculating electrical power cost.

Geologic unit (Formation or Group)	Area in which well analyses are valid	Well depth (feet)	Well diameter (inches)			Length of casing	Static water level (feet below land surface)	Pumping water level (feet below land surface)		Drawdown (pumping water level minus static water level) (feet)		Pump working horsepower		
			For poor yield	For medium yield	For good yield			For good and medium yields	For good yield	For poor and medium yields	For good yield	For poor yield	For medium yield	For good yield
Catskill	Entire Juniata basin	400	6	8	10	40	30	200	200	170	170	2.8	8.4	33.0
Catskill and Devonian marine beds	Entire Juniata basin	400	6	6	8	40	25	200	200	175	175	2.2	4.2	10.4
Devonian marine beds	Entire Juniata basin	400	6	6	8	40	25	200	200	175	175	1.8	3.5	7.8
Devonian marine beds (Chemung)	Entire Juniata basin	400	6	6	6	40	25	200	200	175	175	1.8	2.8	5.5
Devonian marine beds (Portage)	Entire Juniata basin	400	6	6	8	40	20	200	200	180	180	2.2	4.7	11.1
Hamilton and Onondaga	Entire Juniata basin	400	6	8	10	40	20	200	200	180	180	3.5	7.8	17.1
Mahantango	Entire Juniata basin	400	6	8	10	40	30	200	200	170	170	3.1	8.4	15.0
Oriskany	Entire Juniata basin	400	10	10	12	40	40	200	200	160	160	19.8	28.4	41.7
Helderberg	Entire Juniata basin	300	6	8	12	40	40	100	100	60	60	1.6	5.0	20.0
Helderberg, Keyser, and Tonoloway	Entire Juniata basin	300	6	8	12	40	30	100	97	70	67	1.7	6.4	33.5
Keyser and Tonoloway	Entire Juniata basin	300	6	8	12	40	20	100	76	80	56	2.1	8.0	26.3
Wills Creek, Bloomsburg, and McKenzie	Entire Juniata basin	400	6	6	8	40	20	200	200	180	180	2.5	6.1	14.0
Wills Creek, Bloomsburg, McKenzie, and Clinton	Entire Juniata basin	400	6	6	8	40	20	200	200	180	180	2.8	5.5	11.8

Table 2.--Well design of hypothetical wells in the geologic units of the Juniata River basin--Continued

Geologic unit (Formation or Group)	Area in which well analyses are valid	Well depth (feet)	Well diameter (inches)			Length of casing	Static water level (feet below land surface)	Pumping water level (feet below land surface)		Drawdown (pumping water level minus static water level) (feet)		Pump working horsepower		
			For poor yield	For medium yield	For good yield			For good and medium yields	For good yields	For poor and medium yields	For good yield	For poor yield	For medium yield	For good yield
Clinton	Entire Juniata basin	400	6	6	8	40	20	200	200	180	180	2.5	5.2	10.4
Juniata and Oswego	Entire Juniata basin	400	6	6	6	40	30	200	200	170	170	1.8	2.5	4.5
Juniata, Oswego, and Reedsville	Entire Juniata basin	400	6	6	6	40	30	200	200	170	170	1.8	2.5	3.8
Reedsville	Entire Juniata basin	400	6	6	6	40	20	200	200	180	180	1.8	2.5	3.8
Martinsburg and Reedsville	Entire Juniata basin	400	6	6	8	40	20	200	200	180	180	2.5	4.5	9.8
Middle Ordovician limestones	Entire Juniata basin	300	6	8	10	40	30	100	100	70	70	1.7	4.7	14.2
Beekmantown	Entire Juniata basin	300	6	10	12	40	40	100	54	60	14	2.4	16.0	18.7
Mines and Gatesburg	Entire Juniata basin	300	8	8	12	40	60	100	100	40	60	4.0	8.3	17.3

Table 3.--Estimated costs of hypothetical wells and ground water in the geologic units of the Juniata River basin

Yield category: Poor, medium, and good refer to yields equaled or exceeded for 75, 50, and 25 percent of successful wells, respectively, given in table 1.
Estimated costs of wells: Costs are based on well designs given in table 2 for wells producing poor, medium, and good yields given in table 1. Cost estimates obtained from several local well drilling companies.
Annual payments to retire total initial cost: Initial investment compounded at 4 percent over 25 years according to capitol-recovery-factor method of accounting.
Annual power costs: Cost estimates based on Pennsylvania Power and Light Company rate schedules for municipal use.
Estimated costs of ground water: Average annual cost of water delivered at the well head at land surface based on yields given in table 1, well designs in table 2, and costs given in this table.

			Estimated costs of construction, operation, and maintenance of hypothetical wells													Estimated unit costs of ground water (dollars)	
			Initial costs									Annual costs					
			Estimated costs of initial construction of wells (dollars)									Estimated costs of operation and maintenance of wells (dollars)					
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Geologic unit (Formation or Group)	Area for which well analyses are valid	Yield category	Drilling (two wells-one production and one exploratory well)	Pump test production well	Casing production well	Motor, column, shaft, pump, and strainer	Land, pumphouse, meter, wiring, and piping	Contingencies (10% of sum of columns 1 thru 5)	Engineering and administration (15% of sum of columns 1 thru 6)	Total initial cost (sum of columns 1 thru 7)	Total initial cost per mgd of design yield	Annual payments to retire total initial cost	Annual power cost	Annual maintenance cost (4% of column 4)	Total annual cost (sum of columns 10 thru 12)	Average annual cost per thousand gallons of design yield	Average annual cost pe mgd of design yield
Catskill	Entire Juniata basin	Poor	3,200	500	140	1,930	4,000	980	1,610	12,360	250,000	790	550	80	1,420	0.079	28,000
		Medium	5,200	500	200	2,890	4,000	1,280	2,110	16,180	95,000	1,040	1,600	120	2,760	.044	16,000
		Good	7,600	500	280	4,600	4,000	1,700	2,800	21,480	30,000	1,370	3,800	180	5,350	.021	7,500
Catskill and Devonian marine beds	Entire Juniata basin	Poor	3,200	500	140	1,720	4,000	960	1,580	12,100	340,000	770	400	70	1,240	.095	34,000
		Medium	3,200	500	140	2,230	4,000	1,010	1,660	12,740	160,000	820	800	90	1,710	.059	22,000
		Good	5,200	500	200	3,110	4,000	1,300	2,150	16,460	75,000	1,050	1,950	120	3,120	.039	14,000
Devonian marine beds	Entire Juniata basin	Poor	3,200	500	140	1,600	4,000	940	1,560	11,940	410,000	760	350	60	1,170	.106	40,000
		Medium	3,200	500	140	2,100	4,000	990	1,640	12,570	190,000	800	650	80	1,530	.064	24,000
		Good	5,200	500	200	2,810	4,000	1,270	2,100	16,080	100,000	1,030	1,500	110	2,640	.046	17,000
Devonian marine beds (Chemung)	Entire Juniata basin	Poor	3,200	500	140	1,600	4,000	940	1,560	11,940	410,000	760	350	60	1,170	.106	40,000
		Medium	3,200	500	140	1,930	4,000	980	1,610	12,360	250,000	790	550	80	1,420	.079	28,000
		Good	3,200	500	140	2,480	4,000	1,030	1,700	13,050	120,000	840	1,050	100	1,990	.051	18,000
Devonian marine beds (Portage)	Entire Juniata basin	Poor	3,200	500	140	1,720	4,000	960	1,580	12,100	340,000	770	400	70	1,240	.095	34,000
		Medium	3,200	500	140	2,370	4,000	1,020	1,680	12,910	140,000	830	900	90	1,820	.054	19,000
		Good	5,200	500	200	3,180	4,000	1,310	2,160	16,550	72,000	1,060	2,100	130	3,290	.039	14,000
Hamilton and Onondaga	Entire Juniata basin	Poor	2,400	500	140	2,100	4,000	910	1,510	11,560	180,000	740	650	80	1,470	.061	23,000
		Medium	3,600	500	200	2,810	4,000	1,110	1,830	14,050	88,000	900	1,500	110	2,510	.043	16,000
		Good	5,200	500	280	3,680	4,000	1,370	2,250	17,280	48,000	1,110	2,500	150	3,760	.029	10,000
Mahantango	Entire Juniata basin	Poor	2,400	500	140	2,020	4,000	910	1,500	11,470	200,000	730	600	80	1,410	.067	24,000
		Medium	3,600	500	200	2,890	4,000	1,120	1,850	14,160	83,000	910	1,600	120	2,630	.042	15,000
		Good	5,200	500	280	4,180	4,000	1,420	2,340	17,920	35,000	1,150	2,400	170	3,720	.020	7,000
Oriskany	Entire Juniata basin	Poor	7,600	500	280	3,860	4,000	1,620	2,680	20,540	49,000	1,310	2,700	150	4,160	.028	9,900
		Medium	7,600	500	280	4,360	4,000	1,670	2,760	21,170	34,000	1,350	3,350	170	4,870	.022	8,100
		Good	10,000	800	400	4,990	4,000	2,020	3,330	25,540	29,000	1,630	4,600	200	6,430	.091	7,200
Helderberg	Entire Juniata basin	Poor	2,600	500	140	1,170	4,000	840	1,390	10,640	210,000	680	300	50	1,030	.057	21,000
		Medium	5,600	500	200	1,630	4,000	1,190	1,970	15,090	75,000	970	950	70	1,990	.027	10,000
		Good	9,800	800	400	2,900	4,000	1,790	2,950	22,640	26,000	1,450	2,700	120	4,270	.013	5,000
Helderberg, Keyser, and Tonoloway	Entire Juniata basin	Poor	2,600	500	140	1,200	4,000	840	1,390	10,670	180,000	680	350	50	1,080	.051	19,000
		Medium	5,600	500	200	1,880	4,000	1,220	2,010	15,410	59,000	990	1,200	80	2,270	.024	8,700
		Good	9,800	800	400	3,370	4,000	1,840	3,030	23,240	17,000	1,490	3,850	130	5,470	.010	3,900

Table 3.--Estimated costs of hypothetical wells and ground water in the geologic units of the Juniata River basin--Continued

			Estimated costs of construction, operation, and maintenance of hypothetical wells													Estimated unit costs of ground water (dollars)	
			Initial costs									Annual costs					
			Estimated costs of initial construction of wells (dollars)									Estimated costs of operation and maintenance of wells (dollars)					
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Geologic unit (Formation or Group)	Area for which well analyses are valid	Yield category	Drilling (two wells-one production and one exploratory well)	Pump test production well	Casing production well	Motor, column, shaft, pump, and strainer	Land, pumphouse, meter, wiring, and piping	Contingencies (10% of sum of columns 1 thru 5)	Engineering and administration (15% of sum of columns 1 thru 6)	Total initial cost (sum of columns 1 thru 7)	Total initial cost per mgd of design yield	Annual payments to retire total initial cost	Annual power cost	Annual maintenance cost (4% of column 4)	Total annual cost (sum of columns 10 thru 12)	Average annual cost per thousand gallons of design yield	Average annual cost per mgd of design yield
Keyser	Entire	Poor	2,600	500	140	1,260	4,000	850	1,400	10,750	150,000	690	400	50	1,140	0.044	16,000
and	Juniata	Medium	5,600	500	200	2,060	4,000	1,240	2,040	15,640	47,000	1,000	1,500	80	2,580	.022	7,800
Tonoloway	basin	Good	9,800	800	400	2,860	4,000	1,790	2,950	22,600	16,000	1,450	3,150	110	4,710	.009	3,400
Wills Creek,	Entire	Poor	2,400	500	140	1,830	4,000	890	1,460	11,220	260,000	720	500	70	1,290	.081	30,000
Bloomsburg,	Juniata	Medium	2,400	500	140	2,580	4,000	960	1,590	12,170	100,000	780	1,150	100	2,030	.045	17,000
and McKenzie	basin	Good	3,600	500	200	3,430	4,000	1,170	1,940	14,840	51,000	950	2,300	140	3,390	.031	12,000
Wills Creek, Bloomsburg,	Entire	Poor	2,400	500	140	1,930	4,000	900	1,480	11,350	230,000	730	550	80	1,360	.076	27,000
McKenzie, and	Juniata	Medium	2,400	500	140	2,480	4,000	950	1,570	12,040	110,000	770	1,050	100	1,920	.049	17,000
Clinton	basin	Good	3,600	500	200	3,250	4,000	1,160	1,910	14,620	61,000	940	2,200	130	3,270	.037	14,000
	Entire	Poor	2,400	500	140	1,830	4,000	890	1,460	11,220	260,000	720	500	70	1,290	.081	30,000
Clinton	Juniata	Medium	2,400	500	140	2,420	4,000	950	1,560	11,970	120,000	770	1,000	100	1,870	.051	19,000
	basin	Good	3,600	500	200	3,110	4,000	1,140	1,880	14,430	66,000	920	1,950	120	2,990	.038	14,000
Juniata	Entire	Poor	3,200	500	140	1,600	4,000	940	1,560	11,940	410,000	760	350	60	1,170	.106	40,000
and	Juniata	Medium	3,200	500	140	1,830	4,000	970	1,600	11,240	260,000	720	500	70	1,290	.081	30,000
Oswego	basin	Good	3,200	500	140	2,300	4,000	1,010	1,670	12,820	150,000	820	850	90	1,760	.055	20,000
Juniata,	Entire	Poor	3,200	500	140	1,600	4,000	940	1,560	11,940	410,000	760	350	60	1,170	.106	40,000
Oswego, and	Juniata	Medium	3,200	500	140	1,830	4,000	970	1,600	12,240	280,000	780	500	70	1,350	.084	31,000
Reedsville	basin	Good	3,200	500	140	2,160	4,000	1,000	1,650	12,650	180,000	810	700	90	1,600	.062	22,000
	Entire	Poor	2,400	500	140	1,600	4,000	860	1,410	10,810	370,000	690	350	60	1,100	.100	38,000
Reedsville	Juniata	Medium	2,400	500	140	1,830	4,000	890	1,460	11,220	260,000	720	500	70	1,290	.081	30,000
	basin	Good	2,400	500	140	2,160	4,000	920	1,520	11,640	160,000	740	700	90	1,530	.059	21,000
Martinsburg	Entire	Poor	2,400	500	140	1,830	4,000	890	1,460	11,200	260,000	720	500	70	1,290	.081	30,000
and	Juniata	Medium	2,400	500	140	2,300	4,000	930	1,540	11,810	140,000	760	850	90	1,700	.053	20,000
Reedsville	basin	Good	3,600	500	200	3,050	4,000	1,140	1,870	14,360	72,000	920	1,850	120	2,890	.039	14,000
Middle	Entire	Poor	2,600	500	140	1,200	4,000	840	1,390	10,670	180,000	680	350	50	1,080	.051	19,000
Ordovician	Juniata	Medium	5,600	500	200	1,680	4,000	1,200	1,980	15,160	80,000	970	900	70	1,940	.029	10,000
limestones	basin	Good	7,400	500	280	2,550	4,000	1,470	2,430	18,630	31,000	1,190	2,300	100	3,590	.016	6,000
	Entire	Poor	2,600	500	140	1,330	4,000	860	1,410	10,840	130,000	690	450	50	1,190	.037	14,000
Beekmantown	Juniata	Medium	7,400	500	280	2,680	4,000	1,490	2,450	18,800	27,000	1,200	2,450	110	3,760	.015	5,400
	basin	Good	9,800	800	400	2,330	4,000	1,730	2,860	22,920	16,000	1,470	2,600	90	4,160	.008	3,000
Mines	Entire	Poor	5,600	500	200	1,580	4,000	1,190	1,960	15,030	94,000	960	750	60	1,770	.031	11,000
and	Juniata	Medium	5,600	500	200	2,100	4,000	1,240	2,050	15,690	45,000	1,000	1,550	80	2,630	.020	7,500
Gatesburg	basin	Good	9,800	500	400	2,760	4,000	1,750	2,880	22,090	29,000	1,410	2,550	110	4,070	.015	5,400

Table 4.--Quality of ground water in the geologic units of the Juniata River basin

Values in parts per million except as indicated.
Chemical characteristic category: Values tabulated are taken from a frequency distribution of reported chemical analyses of well water. Good, medium, and poor refer to values which are exceed in 75, 50, and 25 percent, respectively, of reported analyses.

Geologic unit (Formation or Group)	Area in which well analyses are valid	Chemical characteristic category	Temperature (°F)	Silica (SiO_2)	Total iron (Fe)	Total manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Calcium magnesium Hardness as $CaCO_3$	Alkalinity	pH	Color	Remarks
	Entire	Good	54	----	0.0	----	18	----	10		40	10	3	----	6	110	60	62	7.3	0	
Catskill	Juniata	Medium	54	12	.15	----	27	13	17		95	17	8	----	18	120	75	70	7.4	3	
	basin	Poor	54	----	.21	----	28	----	18		100	25	10	----	[a] 45	170	95	80	7.4	17	
Catskill and	Entire	Good	53	----	.04	----	12	----	6		50	6	3	----	.5	110	60	60	7.3	0	
Devonian	Juniata	Medium	53	12	.18	0	27	13	15		100	17	8	----	.8	160	75	75	7.4	5	
marine beds	basin	Poor	54	----	.22	----	28	----	18		130	29	14	----	16	190	110	120	7.5	14	
Devonian	Entire	Good	54	----	.20	----	7	----	4		60	4	3	----	0	75	60	---	---	---	
marine	Juniata	Medium	54	----	.21	0	24	----	12		100	13	10	0.0	.5	180	90	250	7.9	15	
beds	basin	Poor	55	----	.22	----	28	----	19		140	32	15	----	8	250	140	---	---	---	
Devonian	Entire	Good	--	----	.20	----	10	5	3		16	5	4	----	0	100	50	---	---	---	
marine beds	Juniata	Medoum	54	----	.21	0	19	9	14		81	20	7	.0	.5	250	70	250	7.9	15	H_2S reported from one
(Chemung)	basin	Poof	--	----	.22	----	40	13	26		140	65	13	----	6	320	140	---	---	---	well.
Devonian	Entire	Good	53	----	-----	----	12	----	6		85	5	5	----	0	95	80	---	---	---	
marine beds	Juniata	Medium	54	----	-----	----	28	----	12		110	7	13	----	.5	160	110	---	---	---	
(Portage)	basin	Poor	56	----	-----	----	28	----	16		140	25	20	----	11	180	140	---	---	---	
Hamilton	Entire	Good	53	----	.1	----	30	5	3		90	14	0	----	.1	110	70	50	6.9	0	
and	Juniata	Medium	55	----	[a] .7	----	50	8	10		130	60	1	----	.1	160	95	80	7.1	5	H_2S has been reported
Onondaga	basin	Poor	56	----	[a]3.0	----	60	26	17		150	110	7	----	.3	190	140	100	7.5	10	from a few wells.
	Entire	Good	--	----	[a]1.3	----	--	----	--		---	---	5	----	----	180	110	80	6.7	5	
Mahantango	Juniata	Medium	--	----	[a]2.8	----	--	----	--		---	145	7	----	----	310	140	92	7.1	8	
	basin	Poor	--	----	[a]3.3	----	--	----	--		---	---	8	----	----	440	150	100	7.2	30	H_2S odor reported.
	Entire	Good	53	----	.0	----	15	----	2		42	6	.6	----	2	60	45	38	7.0	0	
Oriskany	Juniata	Medium	53	----	.2	----	18	5.8	3		60	10	1.0	----	3	120	85	90	7.3	0	
	basin	Poor	54	----	[a] .4	----	52	----	5		100	34	2.7	----	6	180	150	110	7.8	6	
	Entire	Good	51	----	-----	----	76	11	3		190	20	4	----	3	200	170	---	---	---	2,300 ppm $CaSO_4$
Helderberg	Juniata	Medium	53	----	.0	----	95	13	4		200	44	6	----	9.8	280	250	115	7.7	0	reported from one well;
	basin	Poor	58	----	-----	----	110	14	20		200	67	8	----	15	400	310	---	---	---	> 1,700 ppm SO_4.
Helderberg,	Entire	Good	51	10	.0	----	59	11	3.7		190	19	2	.0	1	190	150	130	7.4	0	A few samples indicate
Keyser, and	Juniata	Medium	52	12	.01	----	64	19	5.8		200	50	3	.05	2	240	180	150	7.7	0	high nitrate
Tonoloway	basin	Poor	53	13	.12	----	85	33	16		210	63	9	.10	11	330	250	170	7.9	0	concentrations.
Keyser	Entire	Good	51	10	.0	----	57	13	4.7		180	20	1.3	.0	1	190	150	130	7.4	0	A few samples indicate
and	Juniata	Medium	53	12	.02	----	61	25	6.0		200	50	3	.05	2	230	180	160	7.6	0	high nitrate
Tonoloway	basin	Poor	54	13	.15	----	79	38	13		220	60	8	.1	7	320	210	170	7.9	0	concentrations.
Wills Creek,	Entire	Good	53	----	.07	----	60	18	3		220	20	2	----	3	160	90	90	7.0	0	Greater than 700 ppm
Bloomsburg,	Juniata	Medium	53	----	.1	----	83	32	5		260	20	3	----	9.2	250	190	130	7.5	0	$CaSO_4$ and 500 ppm SO_4
and McKenzie	basin	Poor	53	----	.1	----	89	60	6		280	85	11	----	21	320	300	180	7.8	0	reported from 2 wells.

Table 4.--Quality of ground water in the geologic units of the Juniata River basin--Continued

Geologic unit (Formation or Group)	Area in which well analyses are valid	Chemical character-istic category	Temperature (°F)	Silica (SiO_2)	Total iron (Fe)	Total manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Calcium magnesium Hardness as $CaCO_3$	Alkalinity	pH	Color	Remarks
Wills Creek,	Entire	Good	52	----	0.01	----	16	10	2		40	4	0.6	----	0.4	100	50	80	7.0	0	Greater than 700 ppm
Bloomsburg, McKenzie, and	Juniata	Medium	53	5.9	.05	----	76	30	4		210	20	2	----	5.2	170	90	110	7.2	0	$CaSO_4$ and 500 SO_4
Clinton	basin	Poor	53	----	.10	----	90	54	5		260	20	4	----	11	270	250	160	7.7	3	reported from 2 wells.
	Entire	Good	51	----	.01	----	2	----	1		12	2.5	.1	----	.06	55	22	50	6.9	0	1,700 ppm NaCl reported
Clinton	Juniata	Medium	54	5.9	.20	----	2.4	2.5	3		15	3.5	.6	----	.10	110	48	90	7.1	3	from one well;
	basin	Poor	54	----	a .40	----	11	----	4		35	4.0	1.5	----	.21	140	85	140	7.4	10	>1,000 ppm Cl.
Juniata	Entire	Good	--	----	.0	----	----	----	--		----	----	0	----	----	35	15	11	6.1	0	
and	Juniata	Medium	52	----	.0	----	32	17	2		160	20	0	.1	.0	82	28	24	6.7	0	
Oswego	basin	Poor	--	----	.0	----	----	----	--		----	----	2	----	----	110	50	42	7.3	2	
Juniata,	Entire	Good	52	----	.0	----	27	----	4		48	13	0	----	.0	35	15	15	6.5	0	
Oswego, and	Juniata	Medium	52	----	.0	----	30	17	8		160	20	1	.1	.0	100	40	38	7.0	0	
Reedsville	basin	Poor	55	----	.2	----	32	----	12		160	20	2	----	.1	130	68	93	7.7	2	
	Entire	Good	52	----	.09	----	26	----	8		140	10	1	----	.0	120	60	80	7.4	---	A few samples indicate high
Reedsville	Juniata	Medium	54	----	.20	----	28	----	11		150	15	1	----	.05	140	100	95	7.8	---	nitrate concentrations and
	basin	Poor	56	----	a .45	----	30	----	14		160	20	2	----	.10	150	120	100	8.0	---	small quantities of H_2S.
Martinsburg	Entire	Good	52	11	.0	----	28	10	2.0	---	90	8	1.0	----	.0	130	90	95	7.2	---	A few samples
and	Juniata	Medium	54	13	.10	----	30	11	5.3	---	130	11	1.5	----	.05	160	130	110	7.8	0	indicate high
Reedsville	basin	Poor	56	13	.27	----	31	11	8.5	---	150	21	8.0	----	.10	180	140	130	8.0	---	nitrate concentrations.
Middle	Entire	Good	--	----	.0	----	----	----	---	---	----	----	.6	----	----	70	60	---	---	---	A few samples
Ordovician	Juniata	Medium	53	5.5	.005	----	14	3.8	1.3	.7	55	6.3	1.3	.0	.24	90	78	---	---	---	indicate high
limestones	basin	Poor	--	----	.01	----	----	----	---	---	----	----	2.0	----	----	98	95	---	---	---	nitrate concentrations.
	Entire	Good	51	7	.01	----	35	17	3.2	.8	180	11	2	.0	8	190	190	170	7.6	0	A few samples
Beekmantown	Juniata	Medium	52	8	.03	----	49	24	4.7	1.1	220	12	5	.0	14	220	200	180	7.6	5	indicate high
	basin	Poor	53	9	.20	----	60	29	6.8	1.7	280	15	8	.1	18	260	250	190	8.0	10	nitrate concentrations.
Mines	Entire	Good	--	----	.01	----	----	----	---	---	---	----	1.5	----	----	140	110	120	7.4	0	A few samples
and	Juniata	Medium	52	----	.08	----	30	----	---	---	150	3	3.0	----	2.2	190	130	150	7.7	2	indicate high
Gatesburg	basin	Poor	--	----	.16	----	----	----	---	---	---	----	3.7	----	----	330	200	210	8.0	5	nitrate concentrations.

a/ Exceeds limits listed in Drinking Water Standards, 1962, issued by the U.S. Public Health Service.

Table 5.--Cross reference of geologic units and water-development areas in the Juniata River basin

U indicates that the corresponding geologic unit underlies the water-development area.
W indicates that the corresponding geologic unit is within 1 mile of the water-development area.

County	Water-development area	Political subdivision	Mississippian		Devonian					Silurian			Ordovician					Cambrian
			Mauch Chunk	Pocono	Catskill	Marine beds	Hamilton and Onondaga	Oriskany	Helderberg	Keyser and Tonoloway	Wills Creek, Bloomsburg, and McKenzie	Clinton	Tuscarora	Juniata and Oswego	Reedsville	Middle Ordovician limestones	Beekmantown	Mines and Gatesburg
Bedford	Bedford-Everett	Bedford Borough					W	W	W	U	U	W						
		Everett Borough			W	W	U	U	U	U	U	W	W					
	Saxton	Saxton Borough	W	W	U	U	W											
Blair	Altoona	Altonna City			W	U	U	U	U	U	U	W						
	Hollidaysburg-Duncansville	Hollidaysburg Borough				W	W	U	W	U	U	U						
		Duncansville Borough				W	U	U	U	W	W	W						
	Tyrone	Tyrone Borough				U	U	U	U	W	W	W	W					
	Roaring Springs	Roaring Springs Borough														W	U	W
		Taylor Township								U	U	U	U	U				
	Williamsburg	Williamsburg Borough															U	U
Huntingdon	Huntingdon	Huntingdon Borough				U	U	U	W									
	Mt. Union	Mt. Union Borough					W	U	U	U	U	U	W					
Juniata	Mifflintown-Port Royal	Mifflintown Borough								U	U	W		W				
		Port Royal Borough					W	W	W	U	U	W						
Mifflin	Belleville	Belleville Borough														W	U	
		Union and Menno Townships											U	U	U	U	U	
	Lewistown	Lewistown Borough					U	U	U	U	U	U	W					
Perry	Newport	Newport Borough			U	U	W											