PRESENT AND PROPOSED GROUND-WATER-LEVEL PROGRAM IN MAINE

by James T. Adamik

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CONVERSION FACTORS

Values given in this report are in inch-pound units. For readers who prefer to use the International System (SI), the conversion factors for the terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain SI unit
foot (ft)	0.3058	meter (m)
mile (mi)	1.609	kilometer (km)

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ABSTRACT

A statewide observation-well program was designed for Maine. Three networks were designed to provide reliable data to describe the effects of natural and man-made stress on water levels in the State. They are: A climatic-effects network, a terrain-effects networks, and a local-effects network.

Review of the 32 observation wells in the current (1984) program showed that only 17 wells should be retained. Each of these wells was assigned to one of the three effects networks. Fourteen wells were deactivated because of reliability problems, and one was deactivated because it provided redundant data.

The installation of seven additional wells in climatic-effects network is the highest priority of the proposed program. The next priority is to install 22 additional wells in the terrain-effects network. Implementation of local-effects network sites will be responsive to increases in ground-water usage and the data needs of water-resources managers.

INTRODUCTION

The U.S. Geological Survey (Survey) and the Maine Geological Survey (MGS) cooperatively maintain a ground-water data program of 32 wells. Data from this program are used to define the current (1984) and long-term variations in ground-water levels throughout the state.

The issue of ground-water management has recently come into focus as one of the major priorities in the State's water-resources program. As a consequence, the State has recommended an improvement and expansion of the MGS-Survey observation-well program (Ground-Water Quality Subcommittee, 1980). This program was seen as an integral part of the State's ground-water data base.

The Survey and MGS made a prelimimary review of the program in which they defined the need to improve the water-level data available for Maine. Several factors led to a decision for a detailed study to evaluate the current program. First, the geographic distribution of wells was not based on any specific network-design criteria. Secondly, continuation of cooperative funding by the State during fiscally demanding times required that the program yield data in the most effective and efficient manner possible. Finally, the Survey has stressed the review and evaluation of data programs to insure their usefulness and effectiveness.

Purpose and Scope

This report presents the results of a study to describe the current (1984) ground-water level program in Maine and to design a new ground-water level program. The objectives are to (1) select design criteria for the ground-water level program, (2) determine if current sites meet these criteria and if data redundancy is present, and (3) identify areas of deficient coverage.

History of the Program

The observation-well program in Maine began in 1939. By 1945, five abandoned dug wells were included in the program. Two of the wells were in northern Maine and three were in the southern part of the State.

From 1958 to 1963, eight wells were added to the observation-well program to increase statewide coverage. This expansion increased coverage in coastal areas of Washington County, and in parts of east-central and southwestern interior Maine. Five of these wells were finished in bedrock and the remaining three were finished in unconsolidated deposits. During the next several years, the program was modified by adding or deactivating wells. Data collection at some wells was discontinued when the observer either moved or could not be depended upon to collect good data. One well was destroyed.

In 1975, federal funding was provided to drill wells and locate additional abandoned wells. From 1975 to 1982, the number of active program wells increased to 32. Three quarters of these wells were in unconsolidated materials and one quarter were in bedrock. The locations and other pertinent information for the 39 active and deactivated wells that comprise the present program are shown in figure 1 and table 1.

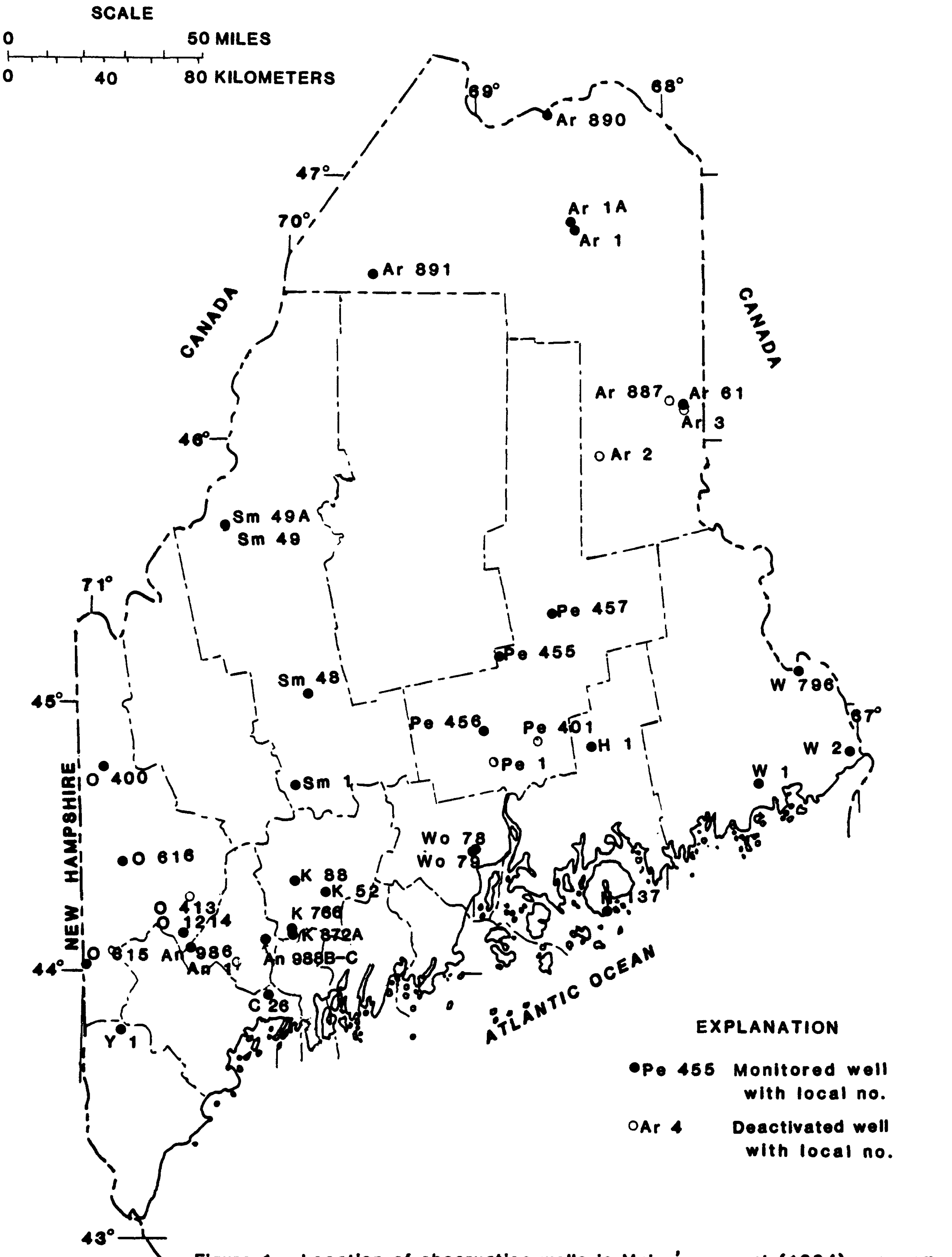


Figure 1.--Location of observation wells in Maine's present (1984) program.

Table 1-- Present observation well program

County	Local No.	Location: Lat.	Location: Long.	Period of Record	Aquifer
Androscoggin	An 1	44°02'27"	70°12'41"	July 1959 to July 1976	Marine Deposits
do	An 986	44°04'38"	70°26'16"	June 1976 to current year	Sand and Gravel
do	An 988B	44°07'23"	70°04'02"	November 1976 to current year	do
do	An 988C	do		October 1976 to current year	do
Aroostook	Ar 2	45°56'11"	68°19'46"	July 1939 to September 1966 July 1968 to October 1970 and Nov. 1975 to Nov. 1978	Sand & Bedrock
do	Ar 1	46°46'19"	68°28'04"	November 1942 to current year	Till
do	Ar 1A	46°48'07"	68°28'44"	November 1975 to current year	Bedrock
do	Ar 3	46°06'57"	67°51'22"	October 1959 to April 1975	do
do	Ar 61	46°17'28"	67°51'32"	September 1980 to current year	Sand and Gravel
do	Ar 887	46°08'55"	67°55'22"	November 1975 to February 1981	Till
do	Ar 890	47°14'57"	68°35'30"	November 1976 to current year	Sand and Gravel
do	Ar 891	46°36'42"	69°34'46"	July 1978 to current year	Bedrock
Cumberland	C 26	43°54'53"	70°01'36"	April 1958 to current year	Sand and Gravel
Hancock	H 1	44°49'50"	68°22'06"	November 1943 to current year	Till
	H 137	44°14'40"	68°18'27"	June 1981 to current year	Bedrock
Kennebec	K 52	44°18'49"	69°44'20"	December 1960 to current year	Till
do	K 88	44°20'21"	69°55'37"	April 1962 to current year	Bedrock
do	K 766	44°09'18"	69°56'40"	June 1976 to current year	Sand and Gravel
do	K 872A	44°08'17"	69°55'36"	November 1978 to current year	Bedrock

Table 1-- Present observation well program (continued)

County	Local No.	Location Lat.	Location Long.	Period of Record	Aquifer
Oxford	O 400	44°46'37"	70°55'23"	April 1944 to current year	Till
do	O 413	44°15'07"	70°31'12"	May 1976 to September 1978	Sand and Gravel
do	O 615	44°06'41"	70°58'32"	August 1978 to current year	do
do	O 616	44°25'15"	70°48'11"	August 1978 to current year	do
do	O 1214	44°08'23"	70°29'15"	September 1980 to current year	do
Penobscot	Pe 1	44°47'20"	68°52'30"	March 1958 to December 1960	Bedrock
do	Pe 401	44°49'53"	68°42'47"	July 1963 to July 1967	Sand and Gravel
do	Pe 455	45°10'47"	68°51'22"	November 1975 to current year	Till
do	Pe 456	44°53'19"	68°56'01"	April 1978 to current year	Bedrock
do	Pe 457	45°19'55"	68°34'45"	July 1982 to current year	Sand and Gravel
Somerset	Sm 1	44°42'19"	69°54'58"	November 1942 to current year	Sand
do	Sm 48	45°02'34"	69°52'57"	July 1981 to current year	Sand and Gravel
do	Sm 49	45°41'05"	70°17'02"	May 1981 to current year	Till
do	Sm 49A	do		June 1981 to current year	do
Waldo	Wo 78	44°28'58"	68°59'32"	February 1980 to current year	Sand and Gravel
do	Wo 79	do		do	do
Washington	W 1	44°42'39"	67°28'39"	July 1958 to August 1973 October 1974 to current year	Bedrock
do	W 2	44°49'53"	67°00'05"	July 1958 to current year	Sand and Gravel
do	W 796	45°07'13"	67°16'28"	September 1980 to current year	Bedrock
York	Y 1	43°48'19"	70°48'28"	November 1943 to current year	Sand and Gravel

Wells are numbered consecutively by county in the Survey's local numbering system. Each local well number consists of a letter or letters indicating the county and a sequential number. For example, Ar 1 indicates the first well inventoried in Aroostook County. If more than one well near the same location was inventoried, these are usually differentiated by a letter following the number, for example Ar 1A.

The Survey also uses a national numbering system based on the latitude and longitude coordinates of each well in degrees, minutes, and seconds. This is followed by a sequence number which indicates the order the well was inventoried within the latitude and longitude area. For an example, well Ar 1 which is located at 46°46'19", north latitude and 68°28'04" west longitude was the first well inventoried within this latitude and longitude and was given the location number 464619068280401. This number can be used to retrieve information on specific wells from the Survey's Ground Water Site Inventory file in the WATSTORE data system.

For the purpose of this report, the local well number designation is used to identify the observation wells.

Methods of Investigation

The first phase of the study required a field inspection of each active well in the present program. The inspections were made in late 1982. During the inspection, reference marks were established to provide datum control at the sites. A slug-injection or a slug-recovery test was performed to evaluate the integrity of the hydraulic connection of the well to the aquifer. Well construction and near-site conditions were described. This included measuring the depth of the well and noting any water withdrawl or injection activities that might affect natural ground-water levels.

The next phase of the study was to design ground-water level networks which could provide information about natural and man-made stresses on the State's ground-water resources. Concepts developed by Heath (1976) and modified by Winner (1981) were used to design three networks to observe water levels in the major aquifers of the State. Two of these--the climatic-effects and terrain-effects networks--were designed to evaluate the influence of natural stresses. The natural-stress networks required the use of climatic, hydrogeologic, and topographic information to categorize the State into broad zones of similar environments. The third network--the local-effects network--was designed to evaluate the effects of pumping in heavily used aquifers.

Active wells in the present program that were deemed representative of a particular environment from the individual site reviews were assigned to the appropriate design networks. Wells assigned to one of the natural-stress networks were further assigned to the appropriate category based upon climate, geology, and topography. If two or more wells were classified in the same category, their records were examined to identify data redundancy. If data redundancy was identified, the well that provided the most reliable data was retained in the network, and the other was scheduled for deactivation.

Acknowledgments

The author expresses his appreciation to three people in the Maine Geological Survey for their assistance in this study. Andrews L. Tolman has provided much assistance and review during the study. Woodrow Thompson assisted by compiling the surficial geologic units in the State. Mark Loiselle assisted through his interpretation of the bedrock geologic units.

HYDROGEOLOGY

Hydrogeology deals with the occurrence and movement of subterranean waters. It is one of the more important factors to be considered in developing a ground-water level program for describing current and long-term conditions. For this study, the hydrogeologic units were grouped into two broad categories, the bedrock and surficial units. Both of these broad categories were further subdivided into general hydrogeologic units that are representative of the major aquifer types in the State.

Bedrock Hydrogeologic Units

Bedrock in Maine is comprised of numerous rock types having very complex structures. More than 100 bedrock geologic units have been mapped in the State (Hussey, 1967). To develop a manageable water-level program for the State, these geologic units have to be grouped into a few general units. Denny (1982) identified three major lithologic units based on mineral compositon and diagenetic processes. Denny's "major" units were modified based upon the work of Hussey (1967) and suggestions from Mark Loiselle (MGS, oral communication, 1983). These units are calcareous-metasedimentary, igneous, and metamorphic; and are the basis for the two bedrock hydrogeologic units which will be used for the study.

These two bedrock hydrogeologic units are crystalline and carbonate (fig 2). Their water-bearing characteristics are due to secondary porosity, Caswell (1979). The igneous and metmorphic units are grouped as the crystalline hydrogeologic unit, because there are no studies that suggest water levels in either unit act differently. The calcareous-metasedimentary units make up the carbonate hydrogeologic unit. The secondary porosity of the calcareous-metasedimentary units involves solutioning enlargement and results in a different hydrogeologic unit.

Surficial Hydrogeologic Units

The surficial hydrogeologic units were derived from glaciation that occurred from 2,000,000 to 10,000 years ago, during the Pleistocene Epoch. Tolman and others (1981) suggest that Maine was covered at least twice by continental ice sheets which advanced southward from the region around Hudson Bay. The glaciers moved southward and soil and rock became incorporated into the ice. As the ice melted and the glacier receded, soil and rock were deposited. There were two major ways of deposition. One was by the melting of the ice which left an unsorted mixture ranging from clay to rock fragments. This is refered to as till. The other was by meltwater streams that transported large amounts of material which were deposited as sorted and stratified silt, sand, and gravel.

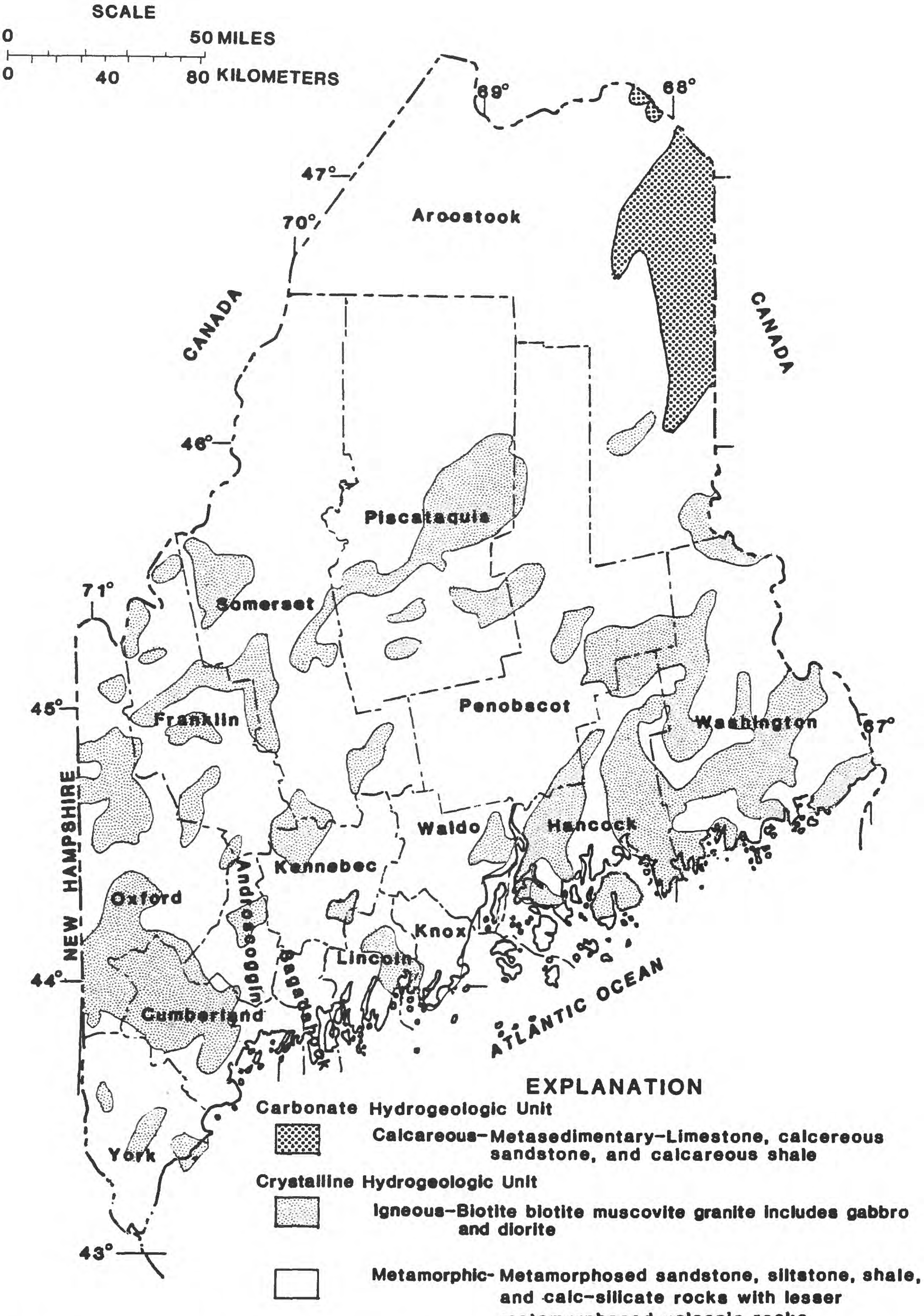


Figure 2.--Generalized bedrock hydrogeologic units in Maine (Modified from Denny, 1982, plate 1 and Hussey and others, 1967).

As the ice accumulated in the continental glacier, it depressed the Earth's crust in Maine by as much as 790 feet (Stuiver and Borns, 1975). As sea levels rose, the sea transgressed this depressed surface and flooded parts of southern Maine up to the present-day altitudes of 425 ft. (Tolman and others, 1981) Silt and clay carried by the meltwater streams were deposited as marine sediments over sand, gravel and till.

Crustal rebound above sea level, accompanied by either increased melting of the glacier or a slight readvance of the glacier caused sand and gravel to be deposited on the marine sediments at some locations.

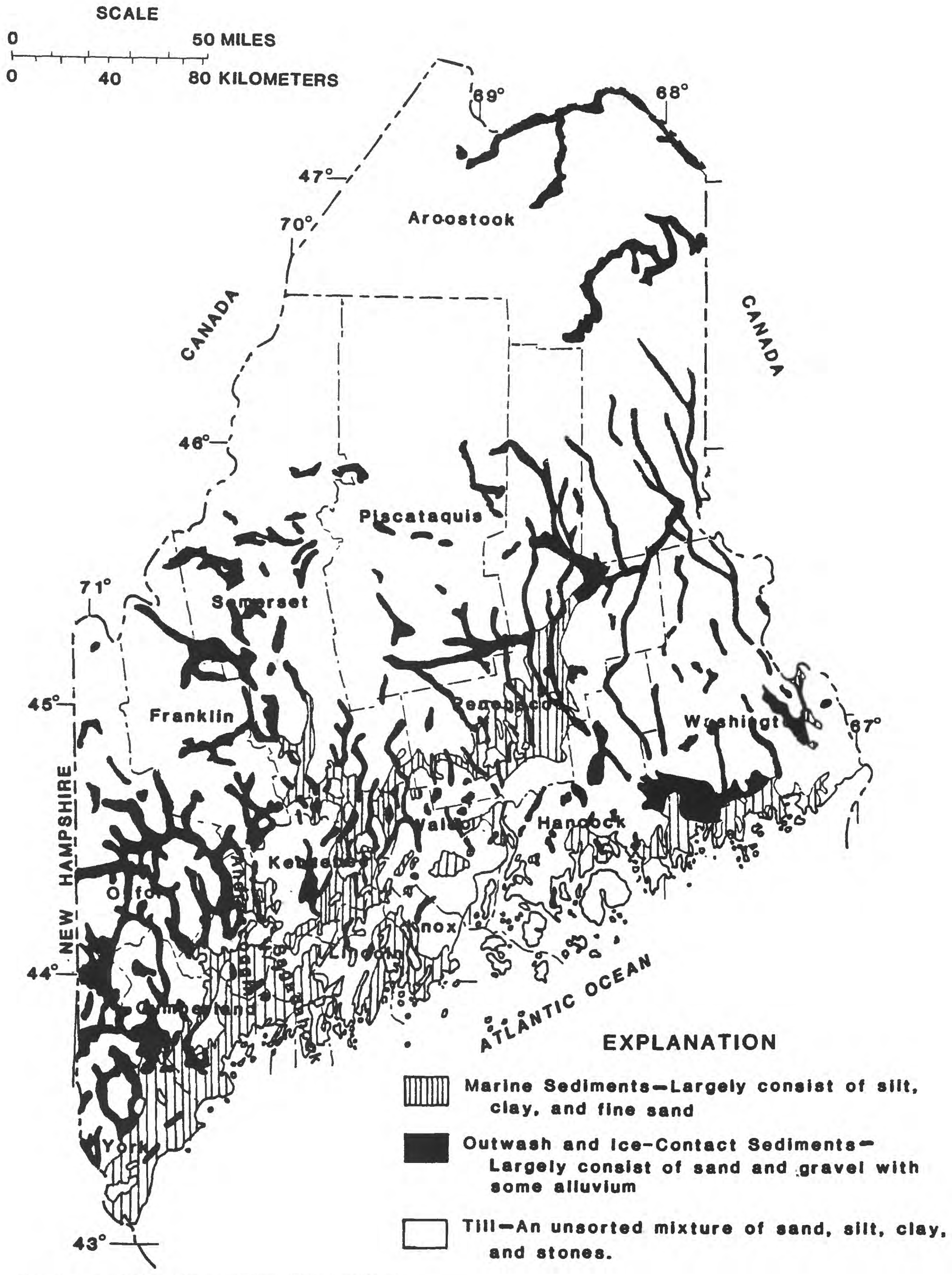
Figures 3 and 4, respectively, show the distribution of surficial hydrogeologic units and approximate extent of the marine limit.

Water-bearing characteristics of the surficial deposits are defined by their permeability and porosity, which represent their ability to transmit and store water. Permeability ranges from excellent in sand and gravel deposits to virtually nonexistent in marine sediments; whereas, porosity is high in both types of deposits. For the purposes of this report the marine sediments will be considered impermeable.

Sand and gravel deposits (Tolman and others, 1981) have thicknesses up to 350 ft. They are found primarily in valleys. Their areal extent is dependent upon valley geometry and mode of deposition. Prescott (1963) reported yields from sand and gravel as high as 1,250 gallons per minute. Yields of surficial aquifers may be very high if they are in contact with and receive discharge from a surface-water body.

Till has considerably lower permeability and porosity than sand and gravel. Deposits of till up to 100 ft have been reported in Maine (Thompson, 1979). Wells in till usually yield only enough water for domestic purposes, but the large areal extent of till makes it a widely used aquifer.

Ground water found in the unconsolidated deposits is generally unconfined, but where marine sediments or other relatively impermeable sediments overlie the permeable deposits water may be confined.



Base modified from The Geological Society of America, 1:750,000, 1959.

Figure 3.--Generalized surficial hydrogeologic units in Maine.

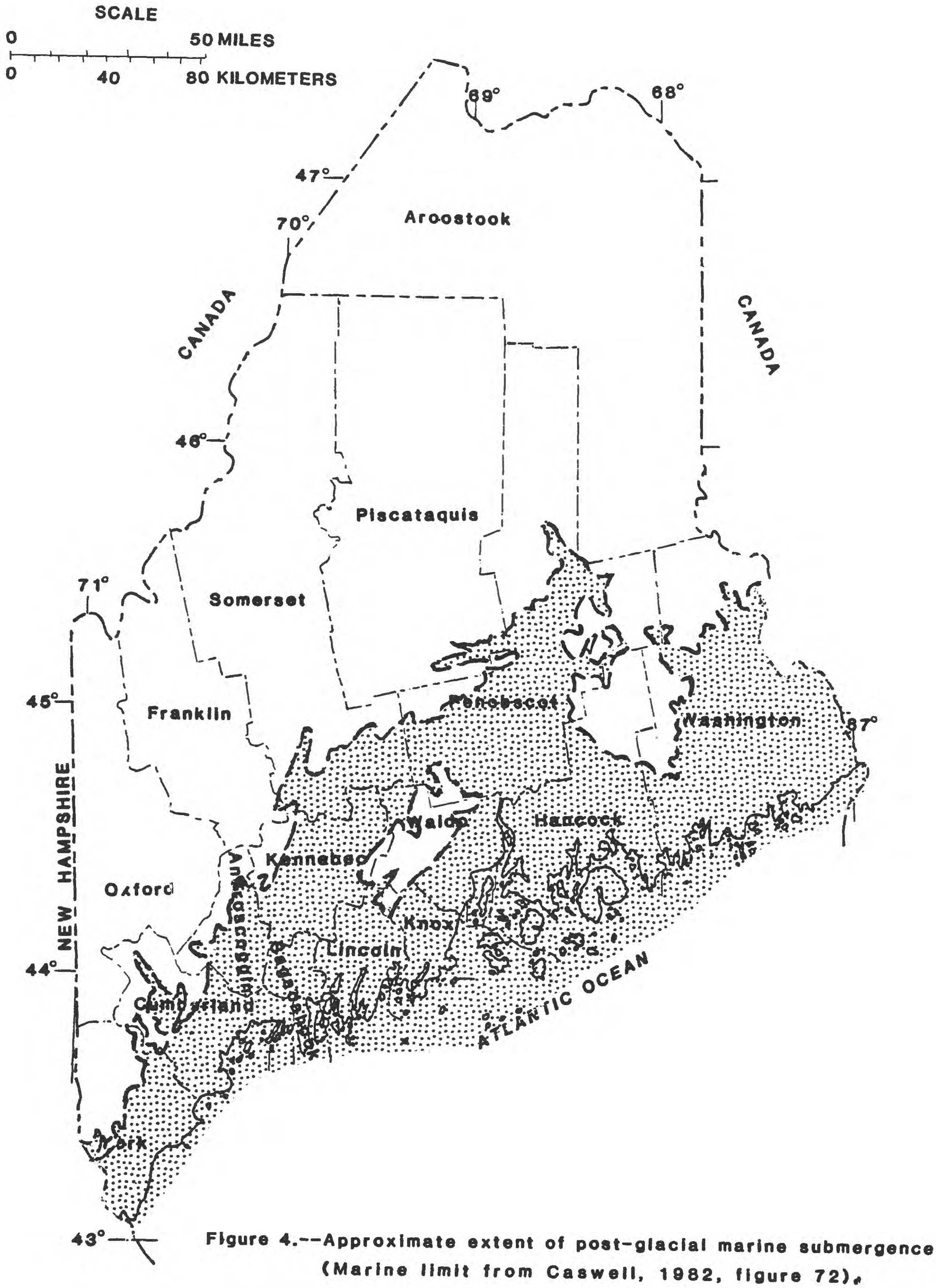


Figure 4.--Approximate extent of post-glacial marine submergence (Marine limit from Caswell, 1982, figure 72).

GROUND-WATER-LEVEL NETWORK CONCEPTS

Data-collection programs should be designed and implemented with specific objectives to insure collection of meaningful data. The first step in designing a data collection program as outlined by Heath (1976) is to define the objectives and then to determine the environmental setting, well type, and number of wells necessary to fulfill these objectives.

The current ground-water-level program in Maine is being modified to meet the following objectives:

- Define seasonal and long term variations in ground-water levels induced by natural stresses for different climatic, hydrogeologic and topographic settings;

- define seasonal and long-term changes in ground-water levels induced by man-made stresses for different hydrogeologic and topographic settings.

Meeting these objectives will provide information on 1) changes in storage, 2) the design and management of water withdrawal and waste disposal systems, 3) the calibration and verification of aquifer models, 4) the degree of confinement by considering the effect of precipitation, temperature, and barometric pressure on the water levels, and 5) the evaluation of potential groundwater use problems.

Concepts developed by Heath (1976) and modified by Winner (1981) were used to design a program that will meet the objectives. These concepts are presented in table 2 and will be developed in the following sections.

Table 2.--Observation-well network concepts

NETWORK	OBJECTIVES	PRODUCTS
Natural Stresses		
Climatic Effects	To define the effect of climate in shallow ground-water storage in unconfined systems.	Hydrographs showing natural changes in water levels.
Terrain Effects	To define the effects of topography and hydrogeology on ground-water storage in confined and unconfined systems as modified by climate.	Hydrographs showing natural changes in water levels for different topographic and hydrogeologic settings.
Man-made Stresses		
Local Effects	To define how man affects recharge and discharge conditions.	Maps of cones of depression. Hydrographs showing changes in water levels with time. Graphs of water levels versus pumping rates.

Modified from Winner, 1981, Table 1.

Observing Natural Stresses

Wells in the climatic- and terrain-effects networks are selected to avoid any influence by manmade stresses. Water levels are affected by variations in recharge from precipitation and by discharge from both evapotranspiration and ground-water runoff.

Typically, hydrographs from these wells indicate that recharge occurs during periods of precipitation and/or low evapotranspiration and discharge occurs during periods of low rainfall and/or high evapotranspiration. Water levels in unconfined aquifers usually react rapidly to precipitation events and snowmelt (fig. 5), whereas water levels in confined aquifers react more slowly to precipitation, and water-level fluctuations are of lesser magnitude (fig. 6)

The climatic-effects network consists of wells in unconfined aquifers. In Maine, these include sand and gravel, and till. These wells show the effect of climate on shallow ground-water levels. Climate zones for Maine will be discussed in a later section. The following criteria were used for the climatic-effects wells: 1) The mean annual fluctuation of the water table should be 5 to 20 feet below land surface, 2) wells should be located in valley flat areas, 3) wells should not be affected by surface water bodies, 4) wells should be between 6 and 12 inches in diameter, 5) water levels should be recorded continuously, 6) wells should total no more than 40 feet in depth, and 7) for each climate zone one well should be in sand and gravel and another in till.

The terrain-effects network consists of wells in confined and unconfined aquifers. All topographic and hydrogeologic settings, except those defined in the climatic-effects network, are represented by the terrain-effects network. The terrain-effects network wells are used to show the influences of hydrogeology and topography on the response of the ground-water levels to climatic stress (Winner, 1981). Wells in this network will differ in depth to water table and well construction. However, the well diameters should be between 6 and 12 inches.

Figure 7 illustrates idealized locations of wells to meet the needs of both of these networks in Maine. The topographic settings for these locations are valley flat, terrace, hilltop, and hillside. Valley flat is the low or nearly level ground lying between valley walls and bordering a stream channel. Terrace is a relatively level or gently inclined surface but elevated above the valley flat. Hilltop is the upper part of the hill or ridge above a well-defined break in slope. Hillside is the sloping side of the hill that is between a hilltop and valley flat. Data acquired from these networks is essential in assessing the influence of climate, topography, and hydrogeology on water-level fluctuations. This knowledge will also help determine the effects of man-made stress on production aquifers.

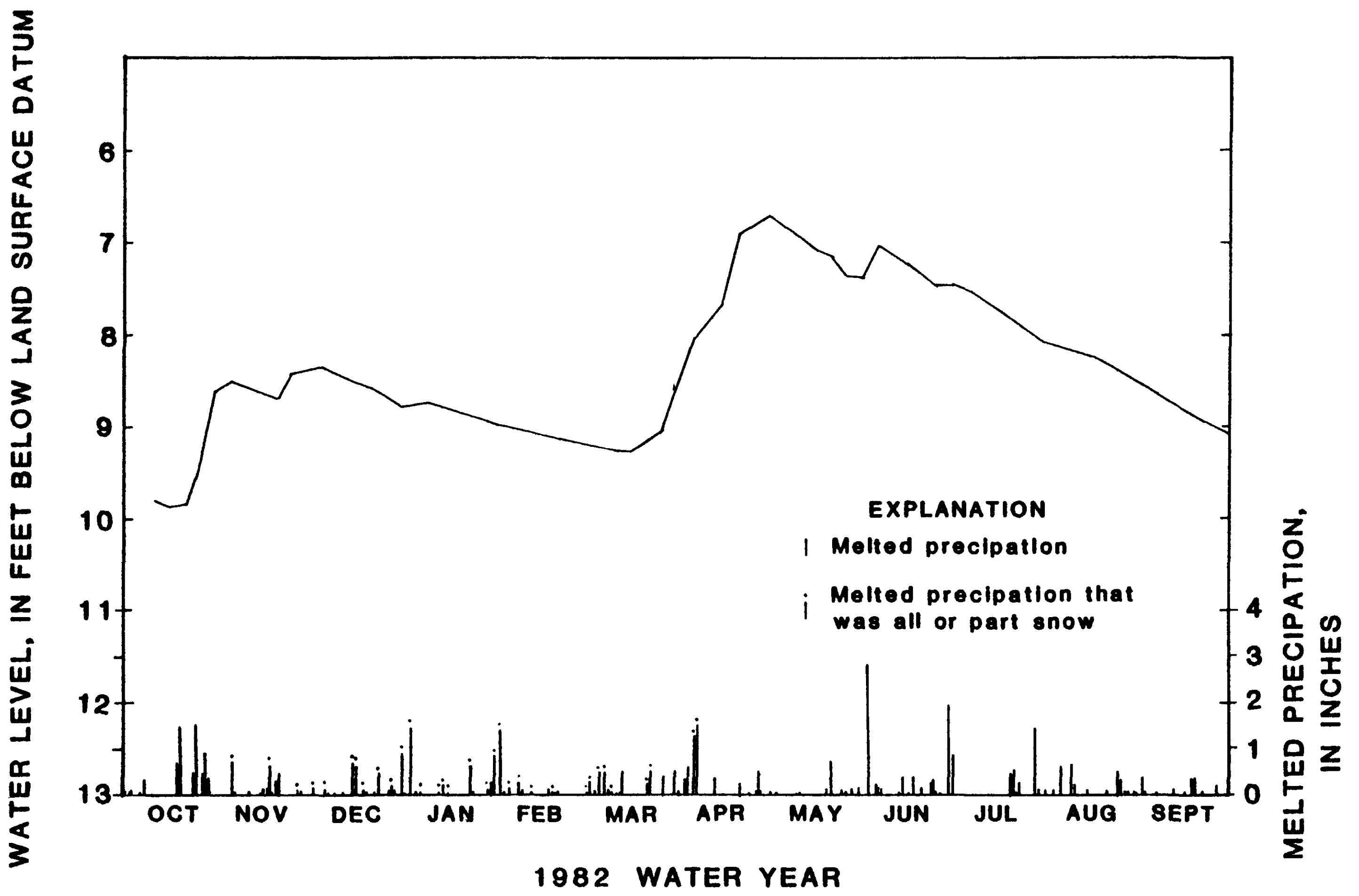


Figure 5.--Water-level fluctuations in an unconfined aquifer--Well O 1214.

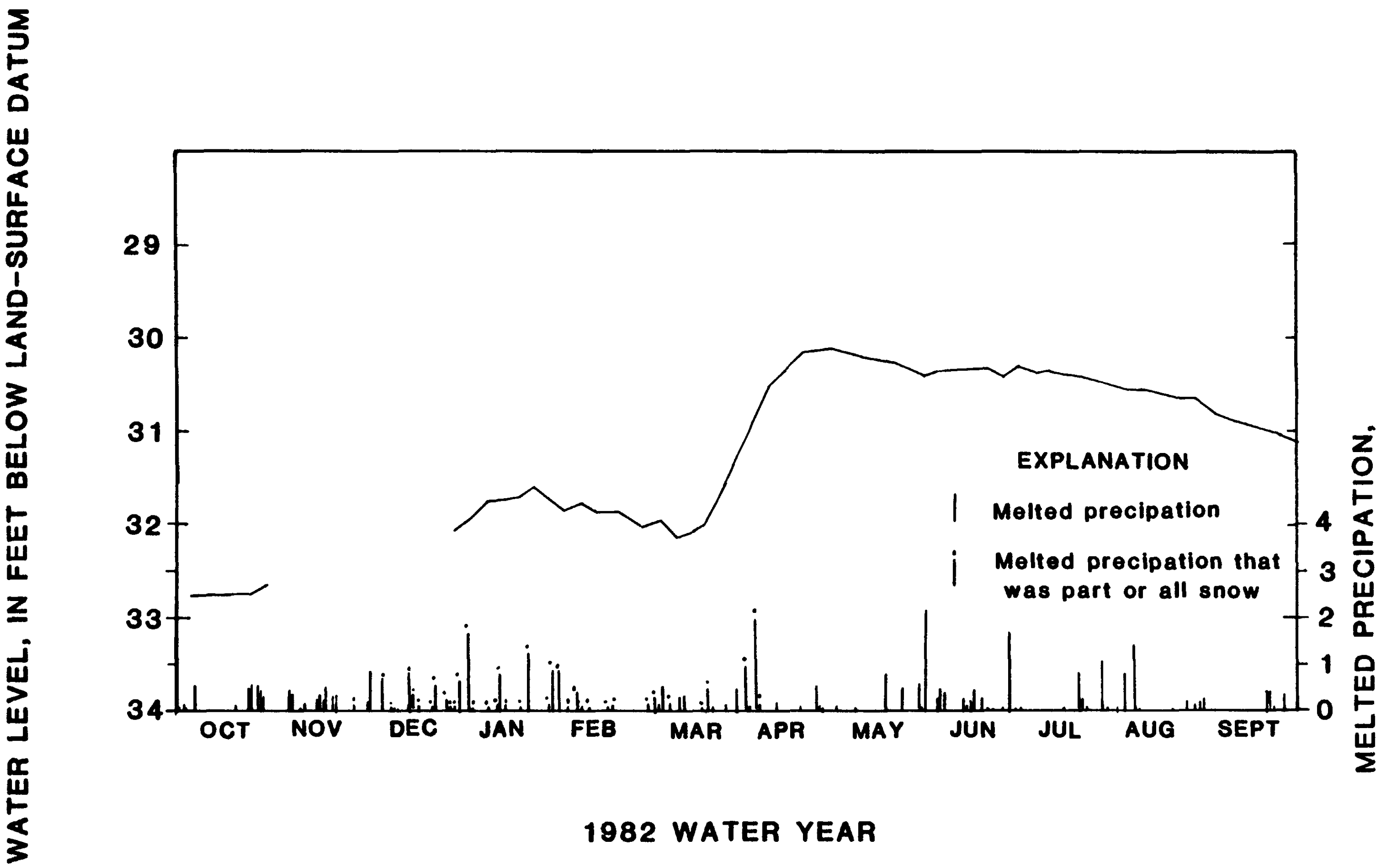
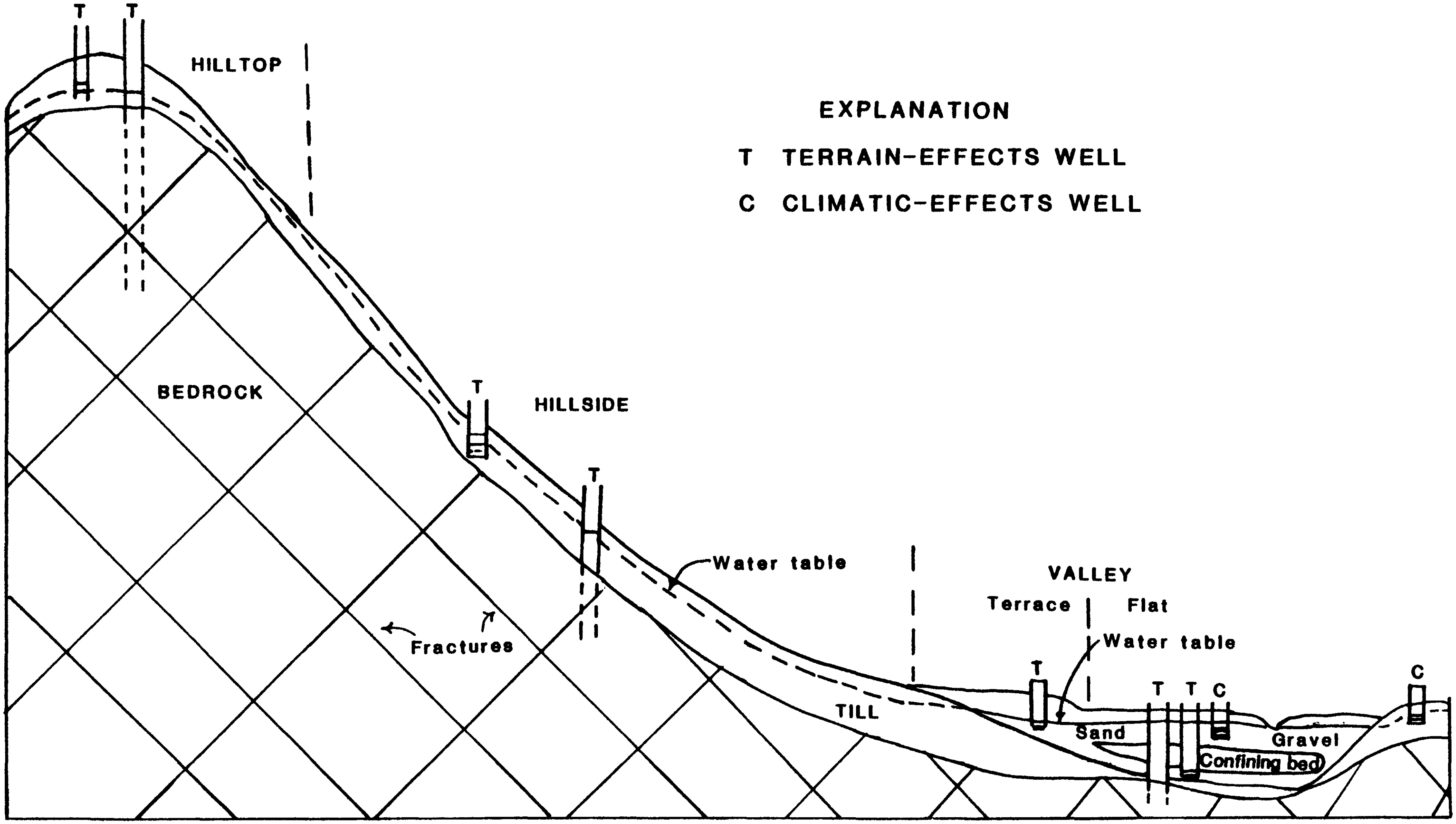


Figure 6.--Water level fluctuations in a confined aquifer--Well C 26.



Modified from Winner, 1981, figure 9.

Figure 7.--Idealized locations of terrain-effects and climatic-effects wells.

Observing Manmade Stresses

The wells in the local-effects network are affected by significant withdrawals. Winner (1981) presented the following objectives for these wells: 1) Hydrographs should show drawdown and recovery cycles in response to pumping schedules; 2) a long-term decline in the rate of recovery due to pumping can be determined; 3) or a combination of both (1) and (2) can be observed.

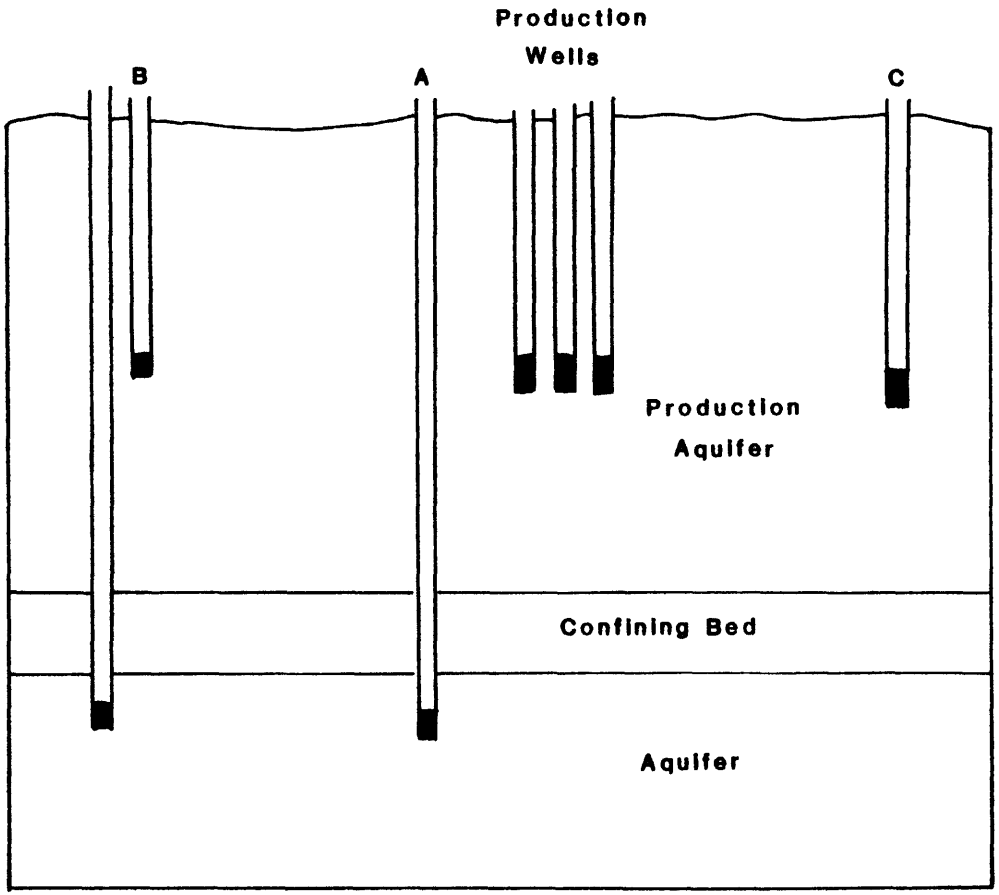
Observation wells also aid in defining the hydraulic characteristics of the producing aquifer. Information from these network wells can be used to determine where withdrawals have been increasing, if drawdowns have stabilized, long-term yields, and areas of possible over-development.

The placement of the local-effects wells has been outlined by Heath (1976). It is proposed that at least one well be located near each major pumping center. Ideally, wells should be placed at different distances from the pumping center and open to the producing aquifer. Wells should also be located in permeable deposits that overlie or underlie the producing aquifer. Water levels in wells in all of these zones would allow the vertical as well as horizontal components of ground-water flow to be determined. Figure 8 shows the idealized locations of local-effects wells near a pumping center. Winner (1981) suggests that priority should be given to determining the vertical component of flow followed by spatial distribution.

Frequency of Measurement

The frequency of observations made at each well is ultimately dependent upon the objectives to be fulfilled. Initially, water levels in all wells should be monitored continuously for 1 year to determine the natural and man-made stresses on the ground-water system.

Wells that are in the climatic- and local-effects networks should be monitored continously for the entire period of record. Wells that are in the terrain-effects network should have at least one year of continuous measurements. After the year, the measurement frequency could be evaluated and possibly reduced to twice monthly, monthly, quarterly or semi-annually.



Modified from Heath, 1976 Figure 4.

Figure--8. Generalized local-effects network wells: (A) Observation well is located near the pumping center and is open to the aquifer below the production aquifer; (B) observation wells are located a distance from the production wells to permit monitoring the composite effect of the pumping center; and (C) observation well located near the outer limit of the cone of depression in the production aquifer.

EVALUATION OF THE CURRENT PROGRAM

In order to include wells with historical record in the proposed observation well program, each active well was examined as to the reliability and accuracy of its ground-water level record. To accomplish this evaluation, site-description and network-review documentation were reviewed for each active site in the present program.

Site Description

The site description describes the location, datum control, and physical constraints at each site. The road log and site maps should provide enough information for someone who has never visited the site to be able to locate the well. An example is presented in figure 9 (at the back of the report). The following items in the site description need further explanation:

GWSI Site ID- This number is derived from the latitude and longitude coordinates of the well in degrees, minutes, and seconds. The last two numbers indicate the order in which the well was numbered within the latitude and longitude coordinates. This number can be use to request information stored in the Survey's Ground-Water Site Inventory file in the WATSTORE data system.

Sketches - There should be at least two location maps. One should have the site located on the latest available Survey topographic quadrangle. The other should be a sketch of the site showing the important features around the well with measured distances to the well. This would include reference marks, recorder access, and site plan view.

Network-Review Documentation

Winner (1981) recommended that network review be a continual process. Conditions may change at a site that would preclude it from fulfilling the objectives for which it was selected. Any changes in the status of the site should be documented, evaluated, and the appropriate changes made to reclassify or eliminate the site if necessary.

A network-review document was used to record how well each site fulfills the network concepts presented in table 2. The document format was adopted from Winner (1981). It is composed of several elements that enable one to decide the adequacy of the record, to describe the aquifer conditons, the plans for each site, and which network objective the site fulfills. Figure 10, at the back of the report, is an example of a completed network review document. The elements of the schedule warrant further explanation:

Water-level record--This element describes the natural and man-made influences on the water-level fluctuations. The response of the well to the slug test is noted. If the well is affected by pumping from nearby wells, the distance and direction to these sites should be noted. The range of water levels is also given.

Changes in physical setting--This element is used to record changes since the site was constructed. It is important to note conditions that may adversely affect the collection and/or adequacy of the records. As an example, construction near the well or a significant decrease in well depth caused by an obstruction may impair the well-aquifer connection.

Plans--If the well is privately owned there is always the possibility that it may be reactivated as a supply well, or future construction may adversely affect water levels. Known plans for the site should be documented here.

Alternative wells--Sites nearby that would fulfill the same network objective are listed here. A list of these sites should be maintained in the event that changes to the present site preclude its continued use as an observation well.

Summary and recommendation--This element is used to classify the site into a particular network by the objectives it fulfills. If conditions render the well unreliable, it should be deactivated. The reasons for deactivation should be described in detail. This paragraph is also used to comment on any unusual hydrologic conditions, changes in operations at the site, and other pertinent information.

The network-review documentation and the site description are the core of the site information for the observation-well program.

Observation Wells to be Deactivated

Unreliable Wells

One of the major goals of the evalution of the current program was to identify and deactivate sites that do not represent the water level in the aquifer. Winner (1981) and Remson and Fox (1954) have identified conditions that render a site unreliable. The following is a discussion of conditions found which resulted in deactivation of a well from the program.

One important condition to study is the hydraulic connection between the well and the aquifer. The method used to evaluate well-aquifer hydraulic connections is the conventional slug test. This test involves either removing or adding a known volume of water and then observing the time necessary for the water level to recover to the initial static level. The data collected from these tests was used to compute the horizontal hydraulic conductivity at each site. These comuputed conductivity values were then compared with the expected range of conductivity values for the particular aquifer materials (Freeze and Cherry, 1979).

If the computed hydraulic conductivity was within the expected range of values for the aquifer material, the well-aquifer connection was considered acceptable. Conversely, if the computed hydraulic conductivity was below the expected range of values for the auifer material, the well-aquifer connection was considered unacceptable and the well was scheduled for deactivation.

Remson and Fox (1954) have also shown that when wells are screened above the water table or are open at the surface, they have a tendency to act as sumps during periods of precipitation. They receive water not only from the aquifer, but from the unsaturated zone and surface water seeping in around the well casing and running directly into open dug wells. As a result, artificially high water levels occur in wells that do not have the ability to equilibrate to aquifer levels. Dug wells are notorious for this problem.

Additional conditions that make a site unreliable include the following: 1) Obstructions in a well may restrict water level measurements; 2) Wells where the construction details or hydrogeology are unknown cannot be assigned to a particular network; 3) Wells that periodically go dry cannot by used to define aquifer conditions during drought; 4) Wells that have widely dissimilar construction. Remson and Fox, (1954), reported that large diameter wells take longer to adjust to aquifer conditions than small diameter wells. Thus the water level rises and declines in large diameter wells may give misleading information about recharge conditions in the aquifer; and 5) Wells that are affected by man's activities. This condition is undesirable at all sites that are classed as being influenced by natural stresses or through direct pumping of any well.

Data Redundancy

Sites which were not eliminated due to unreliability were assigned to one of three effects networks. All wells within a network category, especially those that were in close proximity and in the same aquifer, were analyzed to identify wells providing redundant data. This was an important consideration in the program evaluation to allow the design of the most efficient program.

Hydrograph comparison could not be used in most analyses for redundant data because the length of record, the frequency of measurement, and the day of measurement varied widely. The mathematical-statistical approach of Marie (1976) was modified and used to make the analyses. Simple linear regression was used to compare water-level readings between sites. The following statistics were obtained: Correlation coefficient, equation of the relationship, standard deviation, and the standard error of estimate. The standard error of estimate was used as the primary statistic to evaluate the correlation. As recommended by Marie (1976), the standard error should be within 20 percent of the mean-annual fluctuation of the dependent site to support the correlation.

Fourteen wells were deactivated because of unreliability conditions and one because of data redundancy. A summary of the deactivated observation wells, and the reason they were deactivated is presented in table 3. During the course of the review, some sites were found to yield acceptable quality data with some minor deficiencies. These sites, which are listed in table 4, will be retained until suitable replacements are available.

Table 3.--Deactivated observation wells

Local number	Reasons for deactivation
An 986	Redundant data collection with respect to site O 1214.
An 988B	Screen is filled-in or obstructed resulting in an unacceptable well-aquifer connection.
Ar 1	Casing is obstructed. Well goes dry frequently and is affected by surface runoff.
Ar 61	Well is affected by an excavation north of site.
K 88	Well is partially obstructed, and affected by surface runoff.
Pe 455	Well is intermittently pumped.
Sm 1	Well goes dry occasionally.
Sm 48	Well has an unacceptable well-aquifer connection.
Sm 49	Well goes dry occasionally. It is also infrequently pumped.
Sm 49A	It is affected by surface runoff and is infrequently pumped.
Wo 78	This is a municipal well and is frequently pumped.
Wo 79	Casing is obstructed resulting in an unacceptable well-aquifer connection.
W 1	Intermittently pumped.
W 2	Well is obstructed. The casing may be broken.
Y 1	Well has an unacceptable well-aquifer connection.

Table 4.--Interim observation wells

Local number	Reasons
H 1	Well has been dry infrequently and is of large diameter, but it has an acceptable well-aquifer connection.
K 52	Well may be acting as a sump, but the well-aquifer connection mitigates this problem.
O 400	This is a large diameter well (24 in.), but the well-aquifer connection mitigates the associated problems.

PROPOSED GROUND-WATER-LEVEL DATA PROGRAM

This section outlines a proposed ground-water-level data program consisting of three networks. Wells with historical records form the core of the networks. Each network is discussed and a map showing well locations and gaps in the network is provided.

Climatic-Effects Network

Wells in this network are used to define variations in ground-water storage as a result of climatic influence. Heath (1976) recommended that well characteristics include: (1) Wells open to a permeable, unconfined surficial aquifer; (2) similar depths to water table below land surface; (3) similar topographic settings and geologic units; and (4) similar casing diameter and screen length.

Precipitation, evapotranspiration, and temperature are the climatic factors that most affect water levels in shallow unconfined aquifers. The National Climatic Center (1982) has developed climatic zones for Maine based upon these factors. These zones, as modified with some consideration of the physiographic regions of the State, have been used to establish the four subdivisions for the climatic-effects network as shown in figure 11.

Three wells from the current network meet the climatic-effect network criteria and summary information on them is given in the climatic-effects section of table 5. The locations of these wells are illustrated in figure 11. However, only the Southern Interior "Unconfined Sand and Gravel" aquifer category of the climatic-effects network is represented by these wells, as shown in table 6. Highest priority should be given to completing this network by the installation of at least one observation well in each of the remaining seven categories.

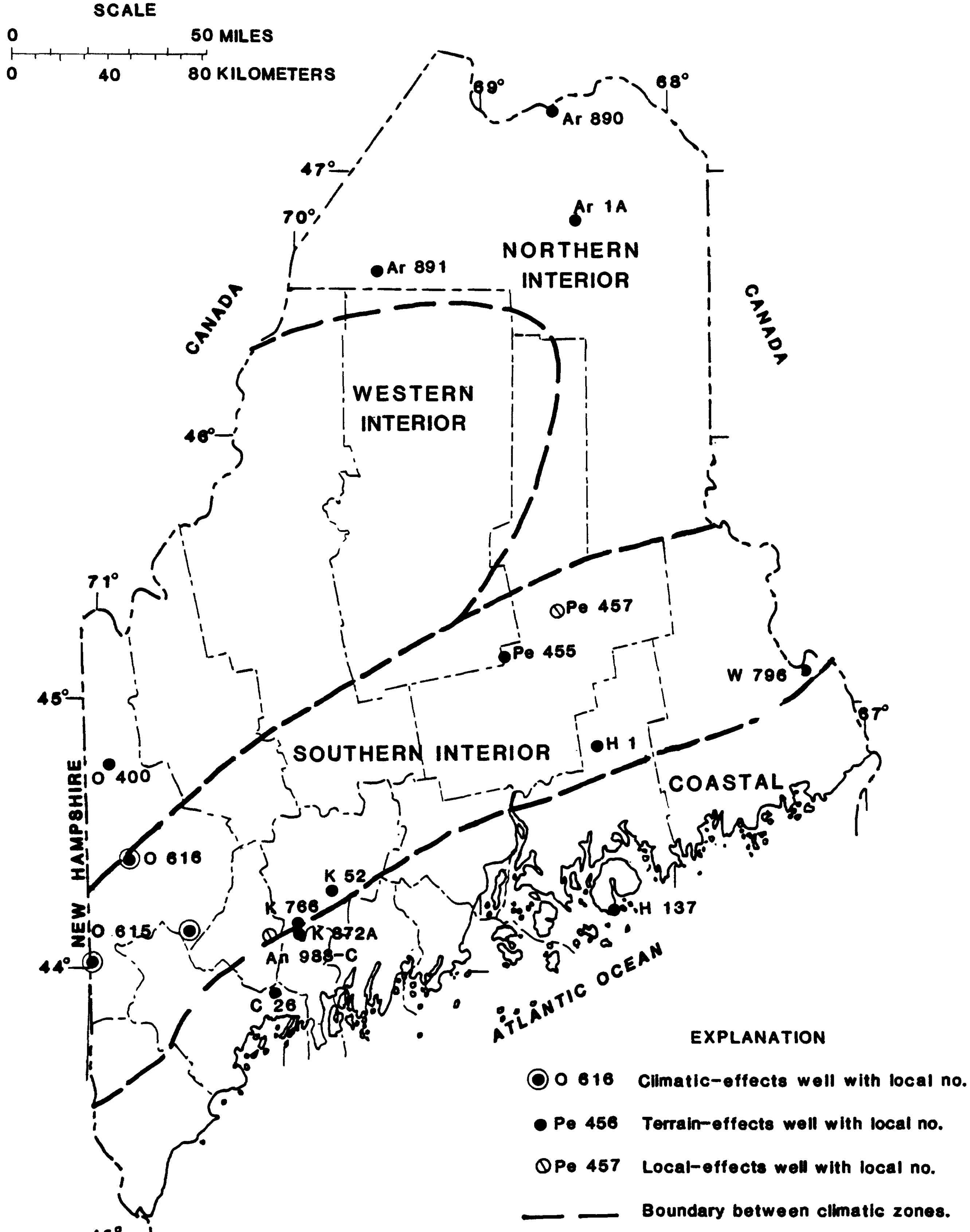


Figure 11.--Climatic zones for Maine (Modified from National Climatic Center, 1982) and location of observation wells retained from the present program.

Table 5.--Retained observation wells for the proposed ground-water-level data program

Climatic-effects observation wells

Local No.	Well Depth (feet)	Geologic Unit	Topographic Setting	Remarks
O 616	20	Sand and Gravel	Valley Flat	Well may have to be redrilled to be equipped with a recorder
O 615	40	Sand and Gravel	Valley Flat	
O 1214	38	Sand and Gravel	Valley Flat	

Terrain-effects observation wells

Local No.	Well Depth (feet)	Geologic Unit	Topographic Setting	Remarks
Ar 1A	81	Crystalline Bedrock	Hillside	Cannot be equipped with a recorder
Ar 890	48	Sand and Gravel (confined)	Valley Flat	
Ar 891	80	Crystalline Bedrock	Hillside	
C 26	96	Sand and Gravel (confined)	Valley Flat	
H 1	14	Till	Hillside	replace with a drilled well
H 137	175	Crystalline Bedrock	Valley Flat	
K 52	22	Till	Hillside	replace with a drilled well
K 766	62	Sand and Gravel	Valley Terrace	
K 872A	404	Crystalline Bedrock	Hillside	
O 400	15	Till	Hillside	replace with a drilled well
Pe 456	98	Crystalline Bedrock	Hillside	
W 796	146	Granite	Hillside	

Local-effects observation wells

Local No.	Well Depth (feet)	Geologic Unit	Topographic Setting	Remarks
An 988C	43	Sand and Gravel	N/A	Well may have to be redrilled to accommodate recording equipment
Pe 457	39	Sand and Gravel	N/A	Well may have to be redrilled to accommodate recording equipment

N/A--Not applicable

Table 6.--Natural-stress network categories and observation wells

Climatic-Effects Network

Hydrogeologic Unit	Topographic Setting	Climatic Subdivisions			
		Coastal	Southern Interior	Northern Interior	Western Interior
Unconfined Sand and Gravel	Valley Flat		O 615 O 616 O 1214		
Till	Valley Flat				

Terrain-Effects Network

Hydrogeologic Unit	Topographic Setting	Coastal	Southern Interior	Northern Interior	Western Interior
Confined Sand and Gravel	Valley Flat	C 26		Ar 890	
Sand and Gravel	Valley Terrace		K 766		
Till	Hillside		H 1 K 52		O 400
Till	Hilltop				
Crystalline Bedrock	Valley Flat	H 137			
Crystalline Bedrock	Hillside	K 872	W 796 Pe 456	Ar 891 Ar 1A	
Crystalline Bedrock	Hilltop				
Carbonate Bedrock	Valley Flat	*	*		*
Carbonate Bedrock	Hillside	*	*		*
Carbonate Bedrock	Hilltop	*	*		*

* Deposit not present

Terrain-Effects Network

Wells in this network are used to define the combined influence of geology and topography on water to water levels in response to climatic changes (Winner, 1981). In Maine, the network wells will be distributed through a cross section of the hydrogeologic units, topographic settings, and climatic zones discussed in earlier sections but not already represented by wells in the climatic-effects network.

According to Heath (1976), some of these terrain-effects wells should be located near the climatic-effects wells to directly observe the effects caused by different topographic and hydrogeologic conditions. The observation wells should be measured continuously for the first year of operation and a review scheduled after the first year to determine the required frequency of measurement.

The majority of wells retained for the current program were classified as terrain-effects wells. Summary information on these wells is given in the terrain-effects section of table 5 and the locations of these wells are illustrated on figure 11. Table 6 shows that observation wells are still needed to represent 22 of the network categories. The installation of these network wells is second in priority to the installation of the climatic-effects network wells.

Local-Effects Network

The local-effects network is made up of observation wells that have water levels affected by pumpage. In some sections of the State, ground-water supplies have been developed nearly to their potential. The steadily increasing demand on existing supplies has resulted in some water-supply shortages (U.S. Geological Survey, 1984). There is very little data on the effects water-supply development is having on the sand and gravel aquifers, particularly in southwestern and coastal Maine where development is heaviest.

Two of the current observation wells were found to meet the criteria of the local effects network. These wells are Pe 457 and An 988C. Summary information for the wells is given in table 5 and locations are shown in figure 11. The supply fields where these wells are located are not fully instrumented following the guidelines suggested by Heath (1976) and Winner (1981) presented earlier in this report.

The location of potential sites for new wells in the local-effects network requires information on ground-water use for the different hydrogeologic environments presented in figures 2 and 3. Priority for implementation of the local-effects network wells will be determined after the information on water use is reviewed and the data needs of water resources managers have been assessed.

SUMMARY

The design of the observation-well program in Maine began by defining the objectives of the program and determining the hydrogeologic units and climate zones of the State. This information was used to design three observation-well networks. They are (1) the climatic-effects network, (2) the terrain-effects network, and (3) the local-effects network. The climatic-effects network defines the effects of climate on ground-water levels in shallow unconfined aquifers; the terrain-effects network defines the effect of topography and hydrogeology on ground-water levels; and the local-effects network defines the effects of pumping on ground-water levels in producing aquifers.

A review of the adequacy of the 32 wells in the current program to fulfill the objectives of the new program, showed that only 17 wells should be retained. Fourteen wells were deactivated because of unrealibility problems and one well was deactivated because it provided redundant data.

The highest priority of the State program is to complete the climate-effects network. Seven categories in this network require well installation. The information from this statewide network is very important in the analyses of monthly, seasonal, and long-term water-level fluctuations.

The second highest priority network for completion is the terrain-effects network. Twenty-two network categories require well installation. This network complements the climate-effects network and aids in the analyses of natural water-level fluctuations.

The priority to implement local-effects network wells will be determined after water-use information is reviewed. This network will provide data for analyses of pumping stress on important water-supply aquifers. As ground-water development increases, the local-effects network will become more important and will need to be expanded to provide the data required by water-resources managers.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

Description Prepared by J.T. Adamik
March 1984
(date)

Description of Observation Well at Fort Kent, Maine

Local ID No. -- Ar 890

GWSI Site ID No. -- 471457068353001

Location -- Lat 47°14'57", long 68°35'30". Eagle Lake 15 min Quad., Aroostook County, 0.25 mi southwest of the intersection of State Highways 11 and 161 and U.S. Highway 1 in Fort Kent.

Road Log -- Mile 0 is at the junction of Interstate Route 95 and U.S. Route 202 in Augusta. Proceed north on Interstate 95 for 155 miles to the junction of State Route 158, Exit 58. Proceed west on State Route 158 for 0.4 mile to the intersection of State Route 11 in Sherman. Proceed north on State Route 11 for 102 miles to Fort Kent. At this point the University of Maine at Fort Kent will be on your right. School Street will be on your left. Take the left on School Street and proceed to the end. It opens up to the parking lot of the UMF Field house. Follow to where the drive ends. Cross the field towards the southwest. The well is located approximately 300 ft from the drive and approximately 15 ft into the woods from the edge of the field.

Well -- It is a drilled well, diameter 6 in., depth 48 ft, casing length 50 ft, open end. It is equipped with a F and P ADR, housed in a metal box. The box is secured to the top of the 6 in. casing which is 3 ft above land surface. Access to the recorder is gained by unlocking and opening the door to the metal box. The observer is John Coe, he works at XYZ and can be contacted there (555-1212). He reports recorder values twice a month.

Reference Marks. --
RM-1 (Established 1982) Lagbolt on southwest base of ash tree about 12 feet southeast of well.
Altitude 527.850 ft msl.

RM-2 (Established 1982) Lagbolt on northwest base of ash tree about 40 feet southeast of well.
Altitude 527.117 ft msl.

Land surface datum (LSD) is the MP. This is the northern rim of well marked with orange paint.
Altitude 530.00 ft msl.

Land surface at well site.
Altitude 527.00 ft msl.

Page 1 of 4

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

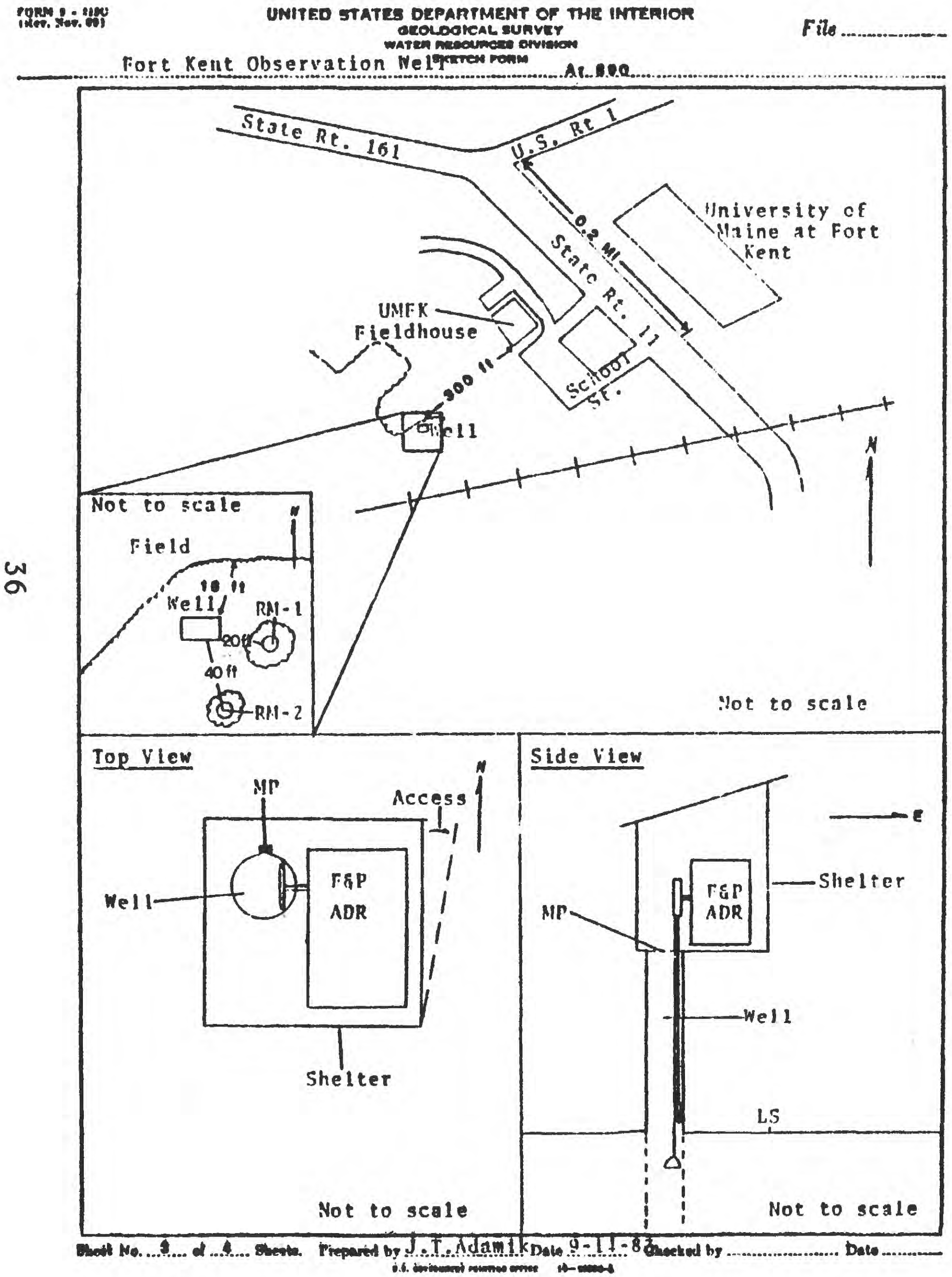
Levels Summary of Observation Well at Fort Kent, Maine

Local ID No.--Ar 890

Date	Party	RM-1	RM-2	LSD and MP	Land Surface	
11/4/82	J.T. Adamik G.C. Prescott	527.850	527.117	530.000	527.000	

Page 2 of 4

Figure 9.--Example of a completed site description, pages 1 and 2.



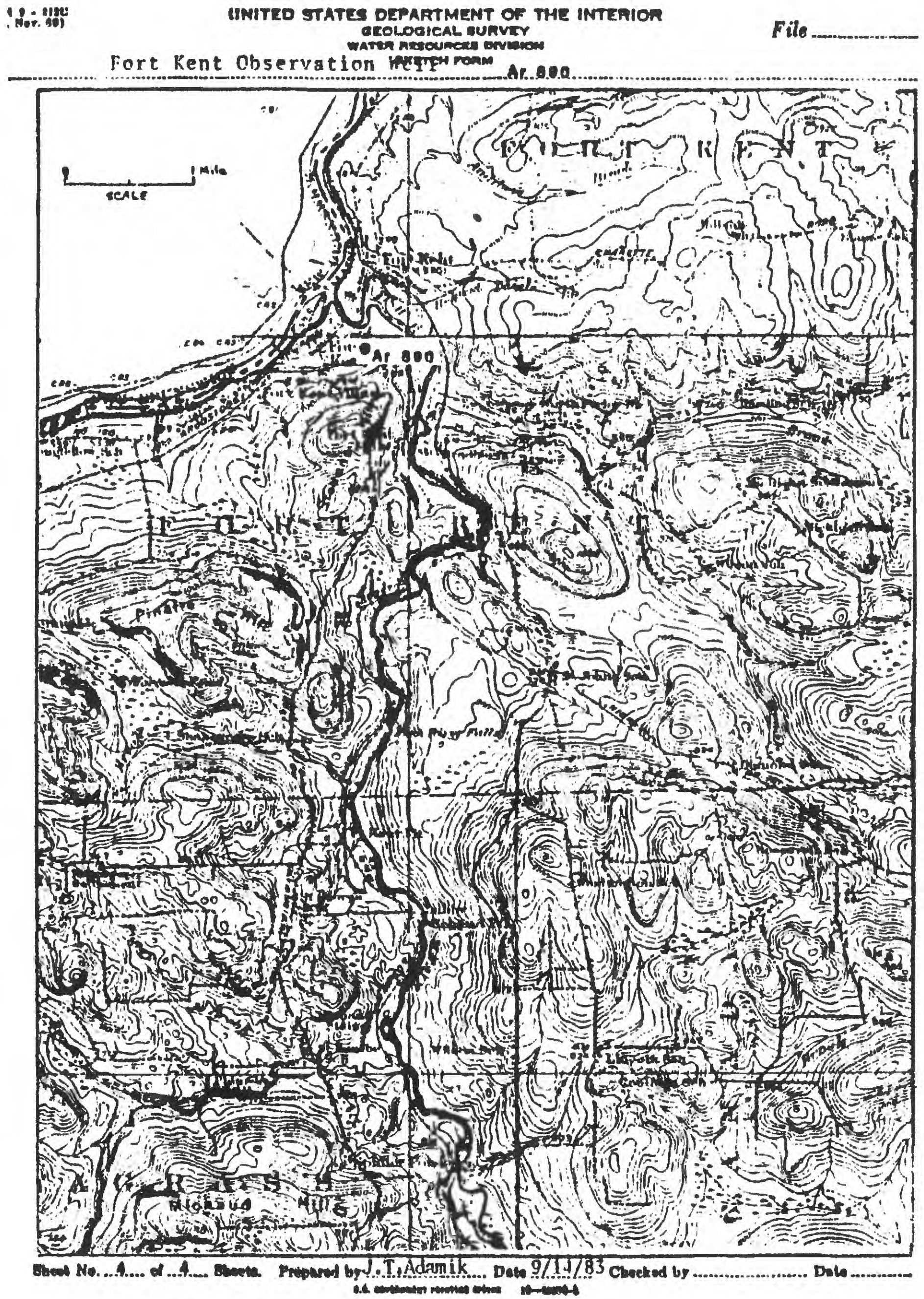


Figure 9.--Example of a completed site description, pages 3 and 4.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

Description Prepared by J. T. Adamik
March 1984
(date)

Network Review of Observation Well at Bethel, Maine

Local ID No. -- 0 616

Water Level Record -- There are no known pumping wells in the immediate area. Integrity test results indicate acceptable well-aquifer connection. Water levels range from 7.3 ft to 12.6 ft below land surface datum. Unable to compare ground-water levels to Androscoggin River water levels because the river at Gorham, N.H. and Rumford, Me. is affected by a considerable amount of regulation. A comparison with the Fryeburg Well 0615 shows a fair correlation. Thus it is concluded that the ground-water levels are not affected by the Androscoggin River.

Changes in physical setting -- The well depth was measured in November 1982 as 20 ft. Constructed depth was 21 ft in August 1978. In June 1982 Glenn Prescott noted that the well casing had dropped 0.6 ft. This drop does not appear to have affected water levels. There are openings at land surface that may allow surface runoff to infiltrate into the well.

Future Plans -- Seal the openings at land surface around the base of the well.

Alternate Wells -- There are no known suitable replacements in the immediate area.

Summary and Recommendations -- The well depth and screened length meet the criteria for the climatic-effects network. The one drawback is the casing diameter. It will not accommodate a float. The well is classed in the climatic-effects network under the category for unconfined outwash and ice contact deposits in southern interior Maine.

Figure 10. --Example of a completed network-review document.

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