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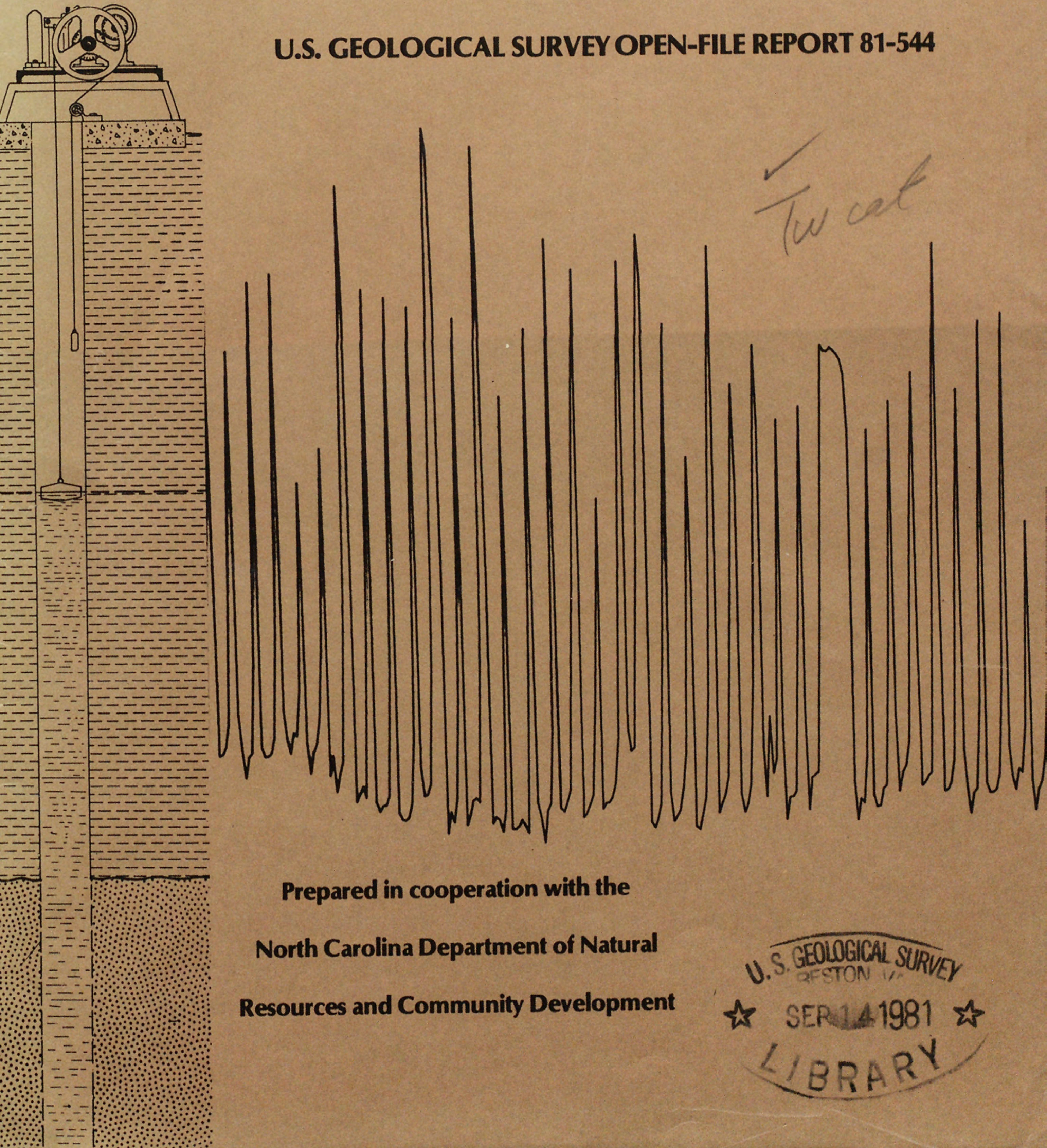
Proposed Observation-Well Networks and Ground-Water Level Program for North Carolina

U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT 81-544



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Prepared in cooperation with the

North Carolina Department of Natural Resources and Community Development

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PROPOSED OBSERVATION-WELL NETWORKS AND GROUND-WATER LEVEL PROGRAM FOR NORTH CAROLINA

By M. D. Winner, Jr.

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OPEN-FILE REPORT 81-544

Prepared in cooperation with the
North Carolina Department of Natural Resources
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Raleigh, North Carolina
1981

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Doyle G. Frederick, Acting Director

For Additional Information write to:

U.S. Geological Survey
Post Office Box 2857
Raleigh, North Carolina 27602

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PROPOSED OBSERVATION-WELL NETWORKS
AND
GROUND-WATER LEVEL PROGRAM FOR NORTH CAROLINA

by

M. D. Winner, Jr.

ABSTRACT

An initial system of 223 observation wells is proposed for monitoring ground-water levels in North Carolina. These wells are suggested to replace and upgrade nearly 650 observation wells currently measured in separate State and Federal programs, and are arranged in four groups or networks each having specific objectives. These groups are (1) a climatic-effects network, (2) a terrane-effects network, (3) a local-effects network, and (4) an areal-effects network. Recommendations are also made regarding additional observation-well coverage in some areas of the State.

Records-review and network-review procedures constituted the largest amount of effort in this study and required a considerable amount of organization to keep track of well records and water-level data. These procedures are outlined in this report as a guide for those who are contemplating an observation-well program review.

The report also contains suggested organizational contents of a data file, including procedures for records processing, and various forms used to document the review and data-collection efforts.

INTRODUCTION

For many years the State of North Carolina has cooperated with the U.S. Geological Survey in a ground-water data-collection program involving many hundreds of observation wells throughout the State. This program currently (1979) consists of two independently operated observation-well networks, a State network operated by the North Carolina Department of Natural Resources and Community Development (NRCD) and a network operated by the Survey. The State network consists of nearly 600 observation wells maintained from seven regional offices and one field office (fig. 1) and supervised by hydrologists in the respective regions. The Survey network consists of nearly 50 observation wells maintained from three field offices and supervised from the Raleigh District office.

In 1976 the Survey completed a review of its observation well program, which was then reorganized under an observation-well concept as described by Heath (1976) in which each observation well satisfies a specific objective and is assigned to one of four networks. As modified by Winner (1981), these are (1) a climatic-effects network, (2) a terrane-effects network, (3) a local-effects network, and (4) an areal-effects network. In 1977, Harry M. Peek, Chief of the Groundwater Section, NRCD, requested the Survey to make a similar review of the State observation wells so that the two programs could be merged, unnecessary wells eliminated, and operational procedures streamlined.

In the latter part of 1977, M. D. Winner, Jr., of the Survey and Richard R. Peace, Jr., of NRCD began visits to hydrologists in the NRCD regional and field offices. During 1978, Katherine H. Tew joined in this effort. Together they reviewed well and water-level records of about 650 wells, delineated hydrogeologic units, assigned wells with good water-level records to one of the above networks, eliminated those that duplicated the records of other wells, and proposed an initial combined statewide observation-well system of 223 wells.

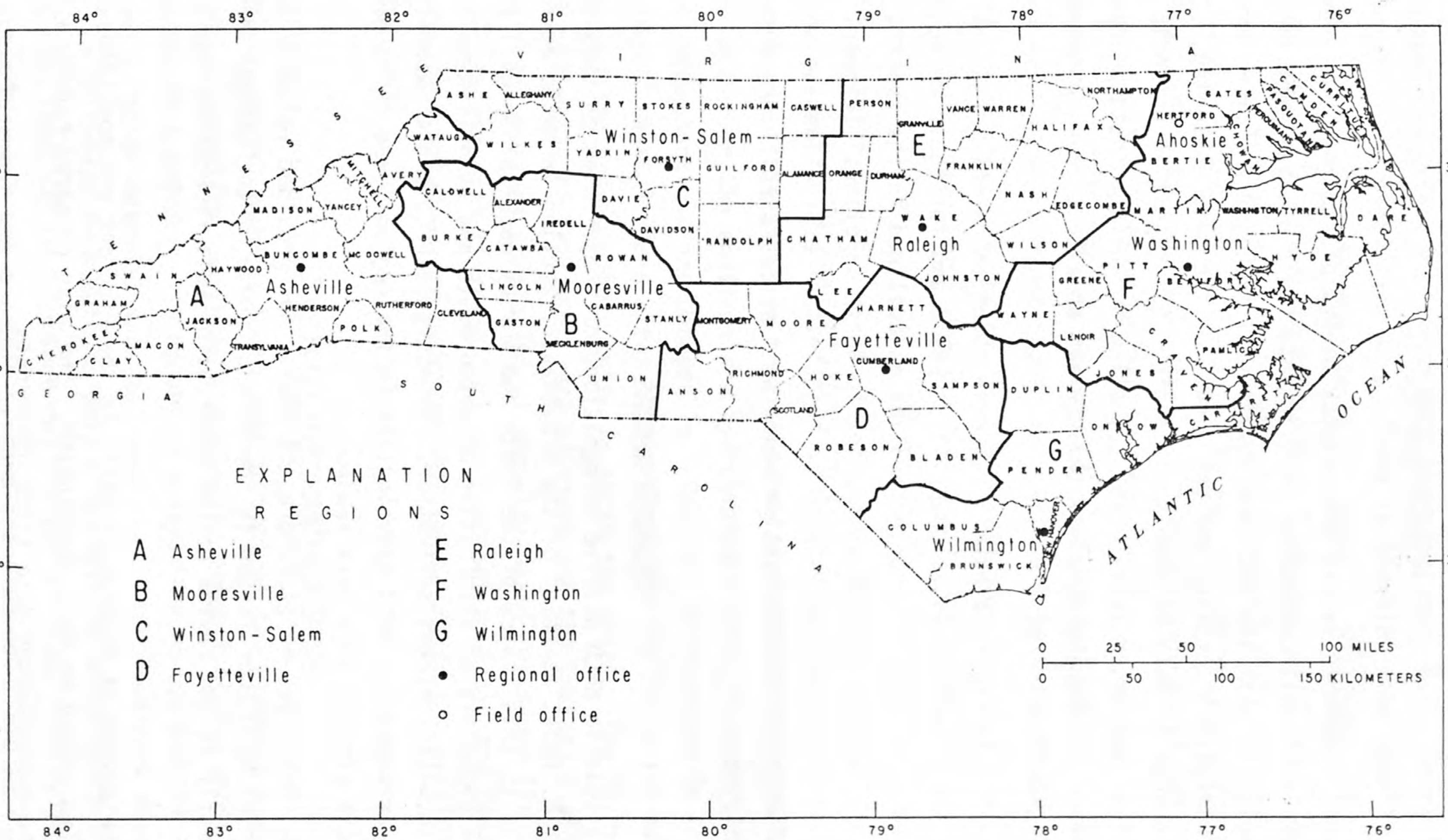

Figure 1.--NRCD regions and regional and field office locations in 1979.

Purpose and Scope

This report describes record and network review procedures, and proposes a ground-water level data-collection program that could utilize many existing observation wells in both the NRCD and Survey networks. Such a program would (1) insure the greatest accuracy and usefulness of the data collected, (2) facilitate exchange of data between the agencies, (3) result in periodic publication of ground-water level data, (4) allow unpublished data to be made quickly available for public use, and (5) provide an effective management tool for potential ground-water problems.

The 650 wells in separate NRCD and Survey observation-well programs were appraised for their usefulness as observation wells and for their value in meeting network objectives for North Carolina as outlined in the report, "An Observation-Well Network Concept as Applied to North Carolina," (Winner, 1981). The systematic procedures used in this initial evaluation and which can be used also to review observation wells on a periodic basis are documented in this report.

Acknowledgments

Several people in NRCD deserve recognition for their roles in this undertaking. Harry M. Peek, as Chief of the Groundwater Section in NRCD, gave the initial impetus to this review of the State and Survey observation-well programs with the objective of eliminating unneeded wells and establishing a joint effort in basic-records collection. He assigned NRCD coordinators to the study and arranged for NRCD hydrologists in the regional and field offices to channel their efforts into this review.

Richard R. Peace served as co-project leader and provided valuable assistance as chief NRCD coordinator in the initial phase of the study. He participated directly in the review of the observation-well records in the Coastal Plain.

During the review of records of wells in the Piedmont and mountains, Katherine H. Tew served as NRCD coordinator. She also prepared hydrographs and brought the ground-water data files up-to-date.

Special thanks are due these NRCD hydrologists: E. L. Berry in Raleigh, W. E. Bright in Fayetteville, R. B. Cheek in Ahoskie, John Choplin in Winston-Salem, M. R. Groves in Mooresville, W. C. Jeter in Washington, D. R. Link in Asheville, and R. S. Shiver in Wilmington. They and their staffs generously provided time, office space, and access to files at their offices during review of their records. Their input to the records review process was especially valuable with regard to their first-hand knowledge of the observation wells and to discussions about hydrogeologic units.

Technical review of this report was provided by H. M. Peek, P. F. Nelson, L. L. Laymon, and L. A. Register of the NRCD, and by R. C. Heath and R. W. Coble of the Survey. Typing of the manuscript was done by Catherine Harrington, and John R. Teel, Jr., drafted the illustrations and prepared the cover artwork.

HYDROGEOLOGIC UNITS IN NORTH CAROLINA

One of the initial tasks in organizing a statewide observation-well network is to define the aquifers and hydrogeologic units in order to make the network comprehensible and manageable. Geologic differences in the Piedmont-mountain and Coastal Plain areas of the State are the basis for separate discussions of the hydrogeologic units in these two areas. The Piedmont-mountain area is underlain by fractured rock aquifers and the Coastal Plain area is underlain by aquifers consisting of unconsolidated rocks and limestone. The near-surface material covering both the Piedmont-mountain and Coastal Plain areas can be treated as one hydrogeologic unit, called the surficial hydrogeologic unit.

Surficial Hydrogeologic Unit

The surficial hydrogeologic unit in most of the Piedmont and mountains consists of saprolite, which is a weathering product of the underlying igneous and metamorphic bedrock. It occurs as a residuum on the bedrock and consists of loose granular material such as sandy clay, clay, and rock fragments. It ranges in thickness from zero to only a few feet in areas where bedrock crops out to more than 100 feet in some major river valleys. The valley floors of many major Piedmont and mountain streams are also underlain by alluvium which consists of stream deposited sand, clay, and gravel. Alluvium is part of the surficial unit.

The surficial hydrogeologic unit of the Coastal Plain is composed of unconsolidated sedimentary deposits consisting of sand, clay, and shell beds. They occur at least as a veneer over the entire area, ranging in thickness from a few feet to as much as 150 feet in the extreme eastern part of the State at Manteo.

Water occurs under unconfined conditions in the surficial deposits almost everywhere in the State, commonly being confined only in the deeper beds where this unit is very thick in the eastern part of the Coastal Plain.

Coastal Plain Hydrogeologic Units

The Coastal Plain deposits, which cover nearly the eastern one-half of the State, consist of a wedge-shaped body of sedimentary rock. The deposits range in thickness from a feather edge at the western boundary of the Coastal Plain to 10,000 feet at Cape Hatteras. These sedimentary rocks form a complex system of aquifers and confining beds.

The Coastal Plain hydrogeologic units are based on established geologic formations, and thus are groups of rock layers having similar or recognizable lithologic characteristics and, for the most part, layers which were deposited during the same geologic time. Each hydrogeologic unit may have more than one aquifer layer, such as sand or limestone, or confining bed at any one place; however the units have been chosen so that each has considerable hydrologic continuity, or at least, similarity among the aquifer layers within the unit.

Hydrogeologic units are named for either the single geologic formation which makes up the entire unit, or the most prominent formation in the sequence of formations that compose the unit.

The sedimentary rocks underlying the surficial hydrogeologic unit, which was described previously, have been grouped into five major units. These are described in table 1. The areas in which the five units occur beneath the surficial hydrogeologic unit are shown in figure 2. The relationships of the older units (Cape Fear is the oldest) being overlapped in part by the younger units and covered by the surficial unit is shown by cross sections (fig. 3).

Table 1.--Hydrogeologic units in the Coastal Plain

Hydrogeologic unit	Composition	Rock units and geologic age	Remarks
Yorktown	Clay, marl, sand, and shell beds.	Yorktown Formation and Pungo River Formation. Early Miocene to Pliocene in age.	
Castle Hayne	Limestone, calcareous sand, and calcareous clay.	Castle Hayne Limestone of middle Eocene age and younger, overlying limestone beds of Oligocene age.	Source of large ground-water supplies. Hydraulic contact with some beds of the upper part of the Peedee Formation in Brunswick and New Hanover Counties.
Beaufort	Sand, clay, and possibly some calcareous beds.	Beaufort Formation of Paleocene age and possibly overlying beds of early Eocene age.	Unit exposed or subcrops beneath surficial materials in a few small areas. Not shown on accompanying areal-extent map. Present mostly beneath Yorktown and Castle Hayne units.
Peedee-Black Creek.	Sand and clay.	Peedee Formation and Black Creek Formation. Late Cretaceous age.	Major sand aquifer of the Coastal Plain. Peedee generally contains more sand than the Black Creek.
Cape Fear	Sand and clay.	1/Middendorf and Cape Fear Formations of Late Cretaceous age and older unnamed Cretaceous units.	Middendorf Formation is the updip age equivalent of the Black Creek Formation. However, Middendorf is hydrologically part of the Cape Fear unit.

1/See Sohl (1976) for a discussion of the name Cape Fear Formation.

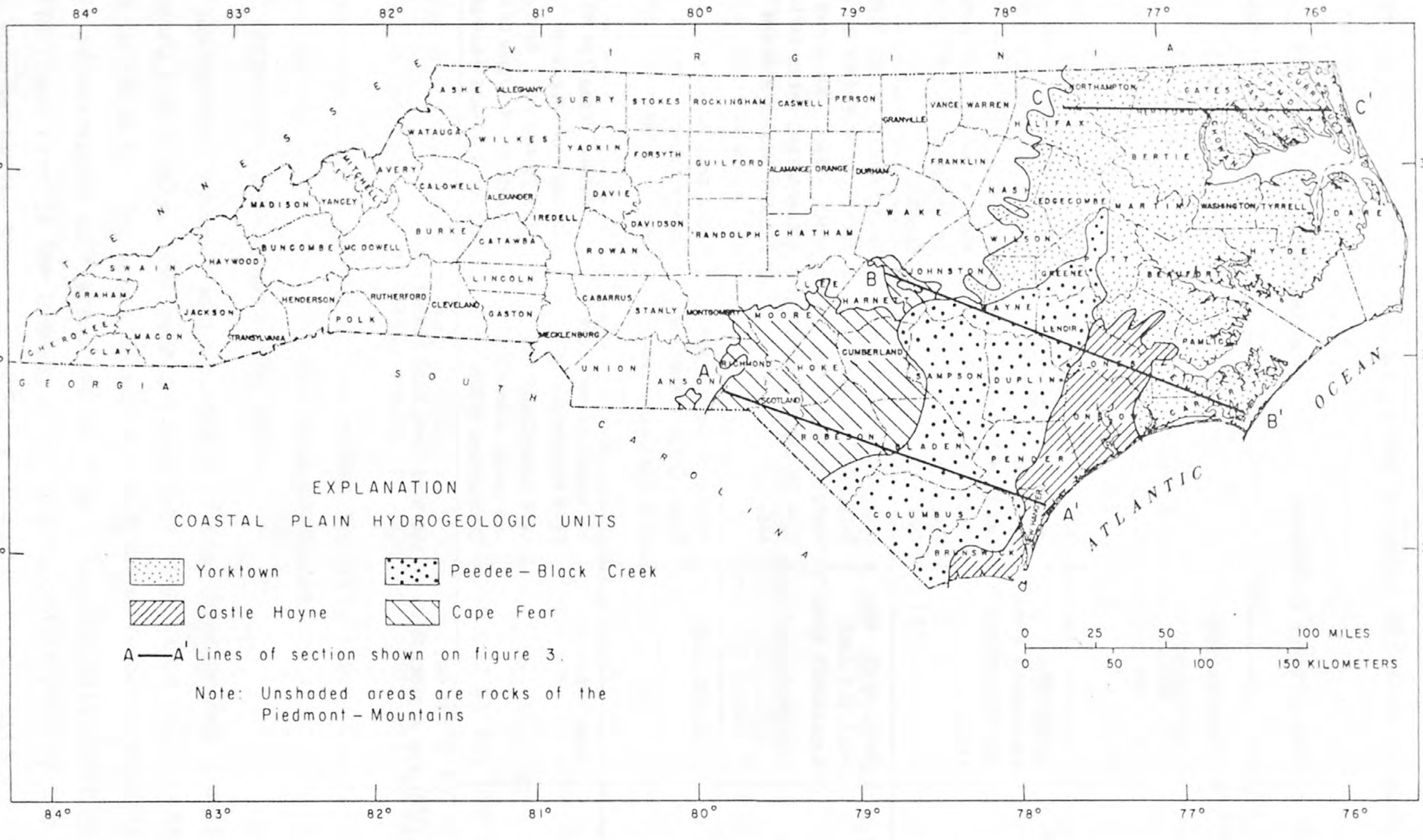

Figure 2.--Areal extent of the outcrop areas of the Coastal Plain hydrogeologic units.

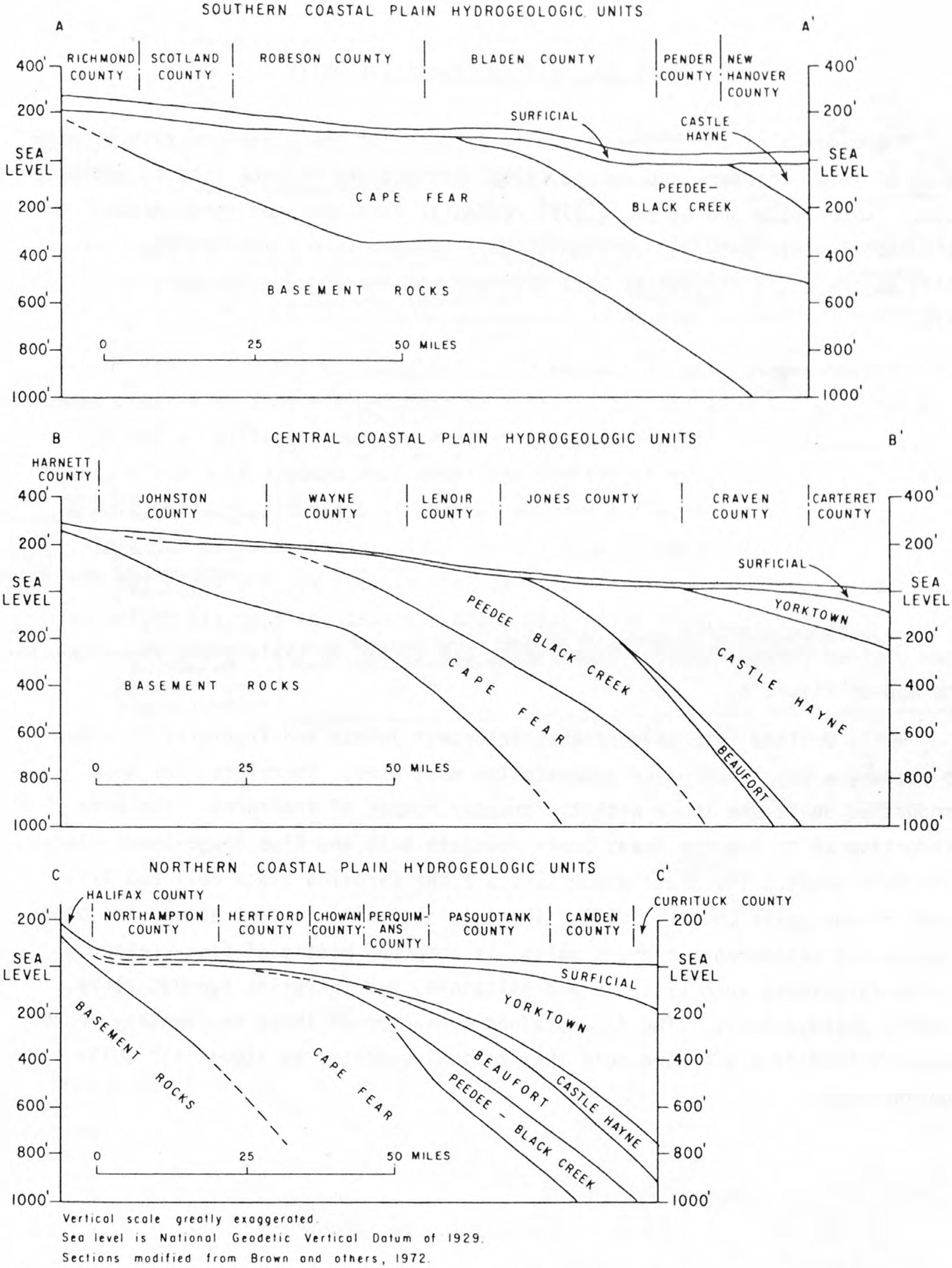

Figure 3.--Generalized sections showing hydrogeologic units in the Coastal Plain of North Carolina.

Piedmont-Mountain Hydrogeologic Units

The bedrock of the Piedmont-mountain region of the State consists of many types of rock. Stuckey and Conrad (1958) divided the bedrock into 48 geologic units. Espenshade and others (1975) recognize even more geologic units. For this report these many geologic units were grouped into a few hydrogeologic units on the basis of similar rock type and similar hydrologic characteristics.

Preliminary results of a study being conducted by the Geological Survey in North Carolina were used as a basis for grouping the rock units into hydrogeologic units. The study on regionalization of low streamflow (which is derived from ground-water discharge) has shown that bedrock type and drainage area are the most important parameters related to estimating the low flow of streams. The similarities in rock type of various bedrock units and similarities in low-flow contributions to surface streams was the basis for the five bedrock hydrogeologic units into which the Piedmont-mountain region has been divided (Heath, 1980). These units are listed in table 2 and shown on the map in figure 4.

Wells drilled into bedrock must intersect joints and fractures in order to produce a supply of water adequate for most uses. Therefore, the most productive units are those with the greater number of fractures. The most productive units are the Great Smoky Mountain Belt and Blue Ridge-Inner Piedmont Belt units. The least productive are the Carolina Slate Belt and Triassic Basins units (Heath, 1980). The Triassic unit, in contrast to the other igneous and metamorphic bedrock units, is composed mostly of fine-grained sedimentary rocks such as shale and siltstone, and intrusive igneous rocks, chiefly diabase dikes. The fine-grained character of these sedimentary rocks prevents them from yielding more than minimal supplies to almost all wells tapping them.

Table 2.--Bedrock hydrogeologic units in the Piedmont-mountain region

Hydrogeologic unit	Composition	Rock units (Modified from Stuckey and Conrad, 1958)
Great Smoky Mountain Belt	Sedimentary and metasedimentary rocks and some schist	Rome Formation, Shady Dolomite, Erwin Formation, Hampton Formation, Unicoi Formation, Sandsuck shale, Nantahala Slate, Great Smoky Group, Snowbird Group, Murphy Marble, Valleytown Formation, Brasstown Schist, Brevard Schist, and undifferentiated shale and conglomerate of Paleozoic age.
Blue Ridge-Inner Piedmont Belt	Granite, granite gneiss, schist, and metavolcanic rocks	Mount Rogers Formation, Flattop Schist, Montezuma member of Grandfather Mountain Formation, Linville Metadiabase, Whiteside Granite, Kings Mountain Quartzite, Cherryville Quartz Monzonite, Toluca Quartz Monzonite, so-called Mount Airy Granite, Beech Granite, Max Patch Granite, Blowing Rock Gneiss, Cranberry Gneiss, Henderson Gneiss, unnamed granite-gneiss complexes, hornblende gneiss, mica schist, mica gneiss, metarhyolite, alaskite, and dunite of Precambrian or Paleozoic age.
Charlotte Belt	Igneous intrusive rocks	Unnamed Paleozoic granite, gabbro, syenite, and diorite.
Carolina Slate Belt	Metasedimentary and metavolcanic rocks	Unnamed Precambrian bedded argillites, mafic volcanics, and felsic volcanics.
Triassic Basins	Shale, sandstone, siltstone, and conglomerate and igneous intrusives	Sanford Formation, Cumnock Formation, Pekin Formation, undifferentiated rocks of the Newark Group, and unnamed diabase dikes.

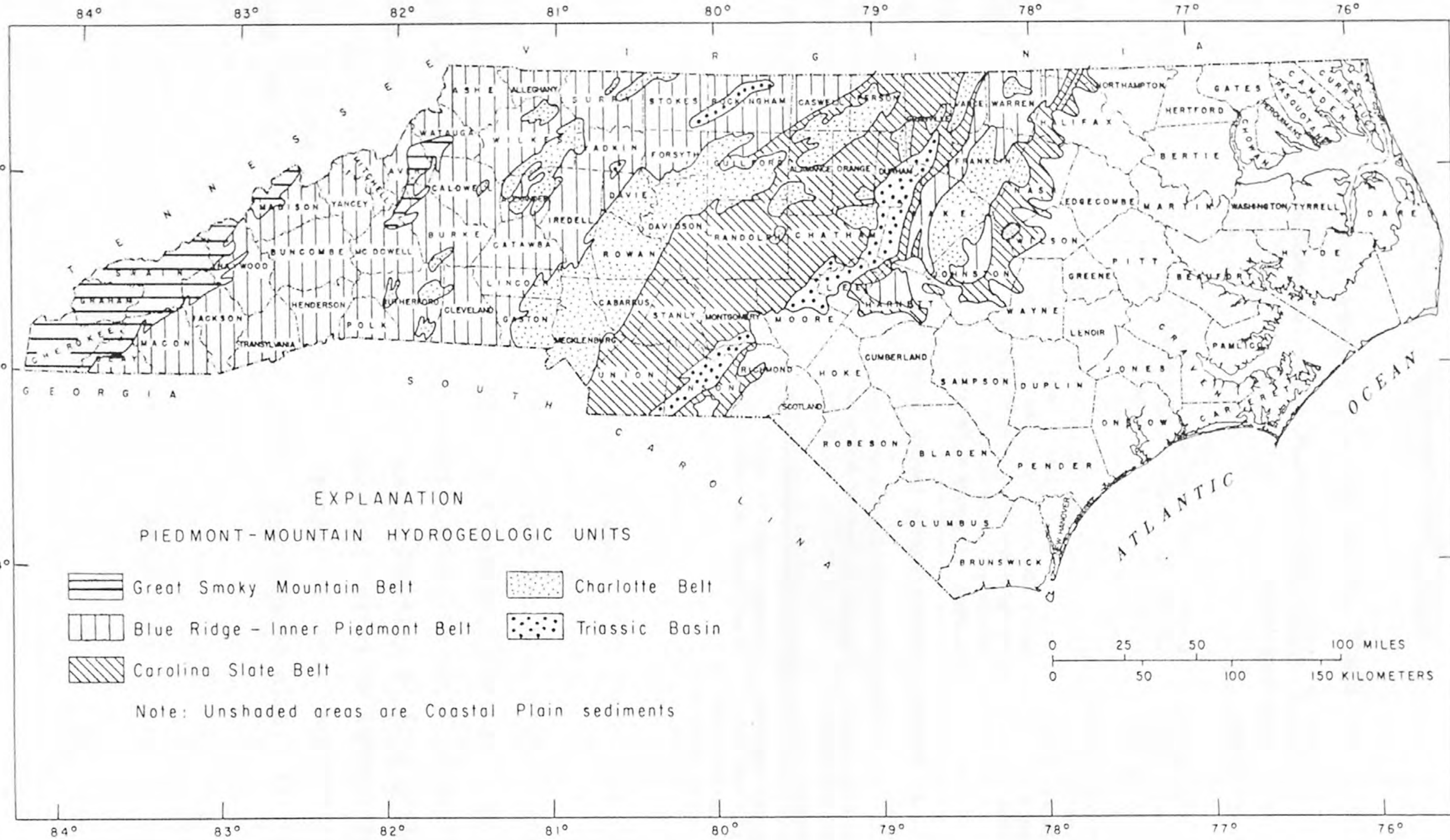

Figure 4.--Areal extent of the bedrock hydrogeologic units in the Piedmont-mountain region.

RECORDS REVIEW

Before the process of network review could begin, the records of each observation well currently being measured were examined to determine (1) how accurately the depth, intervals well is open to aquifer, aquifer, and location of the well are known, (2) what the water-level data reveal, and (3) if there are any problems related to the collection of data from the well. For the review of the State-operated observation wells, each of the eight Regional offices of the NRCD were visited (fig. 1) and, with the aid of the NRCD hydrologists and technicians in charge of collecting ground-water data, the records of each observation well were examined. It was essential that each of the field hydrologists and their technicians be given opportunity to record their knowledge and experience about each observation well under their control. Problems unrelated to hydrology often occur with observation wells for which only the field man has first-hand knowledge.

To record this knowledge and experience and incorporate it in network review, questionnaires were forwarded to each Regional office to be completed for each well prior to records review. The questions were devised to focus on the objective of each observation well and on problems in collecting data.

The questionnaires were consulted during both the well-records review and the network review. The answers to these questions often prompted other questions, resulting in good background information about each well.

To help document the records review, two forms were used for each well, an observation-well record and checklist forms. These completed forms have been made a part of the permanent observation-well record that should be kept in a station file folder as discussed in detail in a later section of this report.

Observation-Well Records

Pertinent data for each observation well was recorded on a form, record of observation well (figs. 5 and 6), which is intended to be made part of a station file folder (described in a following section). Most of the data required by this form are self-explanatory, but a few specific items need some additional comment:

RECORD OF OBSERVATION WELL

Well no. N20-f1

Serial no. Bo-1499

State North Carolina County Beaufort USGS no. NC-14

Owner National Spinning Co. Address Washington, N.C.

Location North side of plant; northwest corner of parking lot

Latitude 35° 33' 14" Longitude 77° 04' 10" Depth/openings 90-100 ft

Aquifer Castle Hayne hydrogeologic unit (upper ls.)

Altitude of LSD 9.42 ft How determined? leveled to MP1 date May 1948

Topographic setting flat

River Basin: CHOWAN PAMLICO CAPE FEAR PEE DEE KANAWHA ROANOKE NEUSE WACCAMAW SANTEE TENNESSEE — 03020104 hydrologic unit code

Nearest stream Pamlico River

Nearest basin gaging station basin ungaged

Nearest Weather Service stations Washington Main St.

HISTORY OF OBSERVATIONS

Objective Local-effects network; monitor effects of pumping for industrial supply.

Record began May 1948 Record ended

Types of record available periodic taped meas. From May 1948 to 12-1-71

digital recorder From 12-1-71 to

From to

From to

From to

High WL 1.02 ft above/below LSD, date 4-10-64 Low WL 25.37 ft above/below LSD, date 7-22-72

Progressive trends slight rising trend since 1972 indicates decrease in withdrawals

Water level affected by plant pumpage from 7 wells; nearest well to observation well about 300 ft away.

Record published USGS Water Resources Data Reports

Prepared by M.D.W., date Feb. 1978 Revisions

Figure 5.--Example of a completed observation-well record.

MP DESCRIPTION

MP #1 top of 8-in. casing, at LSD ft above/below LSD, date May 1948

MP #2 top of cut-off 8-in casing, 3.17 ft above/below LSD, date 1-30-69

MP #3 top of recorder shelf, at LSD ft above/below LSD, date 12-1-71

MP #4 ________, ________ ft above/below LSD, date ________

Reference bench mark description ________

CHANGES IN INSTRUMENTS, SHELTERS, USE OF WELL, NEW WELLS NEARBY, ETC.

Date 1-30-69, 3.17 ft of casing cut off and land surface lowered by 3.77 ft for parking lot. Keep original LSD corr.

Date 12-1-71, Added 3.08 ft of 3-in casing for recorder-shelter support; MP is top of 3-in casing even with recorder

Date ________, shelf, and 0.09 ft below original LSD. Ignore this correction and use LSD = MP

Date 12-1-71, 2 supply wells added at plant.

Date ________, ________

Date ________, ________

Date ________, ________

Date ________, ________

VANDALISM RECORD: ________

Figure 6.--Example of a completed observation-well record, page 2.

Hydrologic unit code.--This is taken from the North Carolina Hydrologic Unit Map (U.S. Geological Survey, 1975) so that observation wells may be cross-referenced with other hydrologic data that are collected.

Objective.--First list the network, as explained in the next section of this report, in which the observation well is placed--climatic-effects, terrane-effects, local-effects, or areal-effects--followed by pertinent remarks, qualifications, or secondary objectives. This provides a short summary of the original purpose of the observation well.

Types of record available.--This provides the measurement history of the well and shows the frequency of tapedown measurements, or when recorders were operated. This information is needed to formulate recommendations during network review.

Progressive trends.--Rates of change in the water-level trend should be given in feet per year, if it is evident. This will reflect changes in stresses such as pumping and precipitation.

Water level affected by.--This narrative should describe as fully as possible all known natural and manmade causes of water-level fluctuations seen in the observation well. Distances to the nearest known pumping wells should be recorded, as well as known or estimated pumpage figures.

Observation-Well Records Checklist

The following checklist (fig. 7) serves two purposes. One is to remind the reviewer of the pertinent data needed to accomplish the records review. The second purpose is to maintain a record of deficiencies where the observation-well record needs upgrading. Missing or inadequate data often can be scheduled to be collected, if not during routine visits to the well, then during special visits. For example, geophysical logging or determination of the elevation of the measuring point often is more efficiently done for several wells at one time rather than individually, whereas a sketch can be revised during a routine visit.

OBSERVATION-WELL RECORDS CHECK LIST

Well No. N20-f1

County Beaufort

Well Numbers
- ✓ serial
- ✓ office
- ✓ lat-long

Ownership
- ✓ names
- ✓ address

Locations
- ✓ description
- ✓ sketch

Aquifer or Formation
- ✓ intervals well is open
- top and bottom of unit
- fracture zones

Altitude
- ✓ MP
- ✓ LSD
- ✓ how determined

History of Observations
- ✓ objective
- ✓ begin record
- ✓ types of record
- ✓ dates
- ✓ hi-lo WL
- ✓ trends

Observation Well Pumped?
- ✓ never
- rarely
- occasionally
- periodically
- continually

Other Wells Nearby
- ✓ pumping
- abandoned

Hydrographs
- ✓ up-to-date
- ✓ back record plotted
- odd scale

Missing Record
- none
- less than 10%
- ✓ 10-25%
- 25-50%
- more than 50%

MP Description
- ✓ description
- ✓ sketch
- ✓ casing size
- ✓ photographs (USGS)
- ✓ referenced to LSD
- description of Reference Mark
- ✓ dates

Is Well also a QW Monitor? NO

Other Records Available
- ✓ drillers log
- geologists log
- geophysical log
- water quality
- pumpage data
- ✓ construction data
- pumping tests

should establish reference mark(s)
should schedule gamma-ray log
2/78

Figure 7.--Example of a completed checklist of observation-well records.

Because of the hydrogeologic dissimilarities between the Coastal Plain and the Piedmont-mountain regions of the State, network review was done on a regional basis. The Coastal Plain review was begun first because of the larger number of observation wells and more complex hydrogeologic situation. The review process, however, was the same for each region.

The observation-well records were separated by hydrogeologic unit, and arranged by county and by well-identification number for each unit, and the wells located on maps of each hydrogeologic unit. These maps also show known areas where ground water is being pumped from the unit.

Network evaluation then proceeded for each hydrogeologic unit by examining the records of each observation well (figs. 5-7) and considering other factors such as areal spacing, more than one well near site, the influence of local or regional pumping--either from the unit considered or from overlying or underlying units, specific problems in collecting data, potential problems in maintaining the well, and recommendations of the field office hydrologist.

Each record was then evaluated with respect to its contribution to a specific objective, that is, conformity with the network concept of observation wells described by Winner (1981) and as summarized in table 3. In a few cases it was found that a well belonged in a different network than was assigned during records review. Also in a few cases it was uncertain to which network a well belonged, pending the collection of additional water-level data. Such wells were provisionally assigned to a network with a note for special reevaluation when the appropriate data were collected.

Network Review Form

Network review is an ongoing process. Any change in the status of an observation well that requires a decision also requires a review of the records of the well as part of the decision-making process. Furthermore, all observation wells should be reviewed periodically to see if they continue to fulfill their objectives. A form was devised (fig. 8) to summarize the plans and decisions for each well during network review. This summary and subsequent reviews are essential reference documents in the station file.

Table 3.--Summary of Observation-Well Networks

Networks	Objectives	Products
To monitor natural stresses		
Climatic effects	To define effects of climate on ground-water storage.	Hydrographs showing natural changes in storage.
Terrane effects	To define the effects of climate on ground-water storage as modified by topography and geology.	Hydrographs showing natural changes in storage as modified by topography and geology.

Networks	Objectives	Products
To monitor manmade stresses		
Local effects	To define effects of stresses on recharge and discharge conditions. To define hydraulic characteristics of aquifers. To assess degree of confinement.	Maps of cones of depression. Hydrographs showing changes in water levels with time. Graphs of water levels versus pumping rates.
Areal effects	To determine status of storage. To define regional continuity of aquifers.	Regional water-level maps. Maps showing net change in water levels or storage over a selected period.

NETWORK REVIEW FORM

Date 1978

Serial no. Bo - 1499

Well no. N20-f1

USGS no. NC-14

Location at Washington, Beaufort Co.

Owner National Spinning Co. Aquifer Castle Hayne hydrogeologic unit

WATER-LEVEL RECORD Confined aquifer; well open 90 to 100 ft; responds to nearby industrial pumpage; hydrograph shows drawdown/recovery cycles of about 15 ft; slight rising trend in plot of monthly highs and lows -- likely due to decrease in local pumpage; need to obtain pumpage records; estimated pumpage: 35% from upper part of the Castle Hayne and 65% from the underlying Beaufort unit; pumpage estimated to be 1.6 Mgal/d for 6 days/week; effects of pumping from phosphate mining area 20 mi south are unknown, but slight, if any.

CHANGES IN PHYSICAL SETTING None.

FUTURE PLANS None.

ALTERNATE WELLS NEARBY Nearby well is unused, but has pump in it.

SUMMARY AND RECOMMENDATIONS Retain in LOCAL-EFFECTS NETWORK to monitor progress of recovery trend; obtain pumpage records and correlate with hydrographs, and possibly evaluate transmissivity and storage coefficients. Because of extreme water-level fluctuations, hydrograph should be constructed using monthly highest and lowest water levels. Consider constructing or obtaining observation well in Beaufort unit to monitor the effects of pumping from that unit.

Prepared by M.D.W., date 7-11-78 Reviewed by ________, date ________

Figure 8.--Example of a completed network-review record.

Water-level record.--This narrative is intended to summarize the character of the water-level record and note significant changes or unusual fluctuations in the hydrograph. The normal range of seasonal fluctuations are recorded, as well as any indications of water-level response to pumpage or changes in pumpage. Where continuous records are available the responses of the water-level to rainfall, stream-stage changes, tides, barometric fluctuations, earthquakes, and loading phenomena are also noted.

The distance and direction of nearby pumping wells or well fields are also recorded in this space. Conversely, if pumping wells are not in the immediate area, this fact should be recorded.

Changes in physical setting.--Space on the network review form is provided to record changes since the last review in the physical setting of the well that may hinder the collection of record or impair the accuracy of measurements. For example, there may be construction in or around the well or there may be objects thrown or dropped in the well causing an obstruction.

Future plans.--Here, factors that may affect the future use of the well for observation purposes should be recorded. Highway construction plans may call for removal of the well; the well owner may object to measurements of the water level, or he may plan to resume use of the well as a source of water supply.

Alternate wells nearby.--A list should be made of known measurable wells open to the same hydrogeologic unit within a reasonable distance. These wells can be considered as replacement observation wells should future plans indicate changes will be necessary. If such wells are not known, then possible areas in which an alternate well may be found should be noted. For example, a local industry or a town may have suitable unused wells available.

Summary and recommendations.--This is where the objectives of each observation well are described in detail and where necessary work is specified. Recommendations can include changes in recording instrumentation, changes in frequency of measurements, inventory of alternate wells, or the discontinuance of the well from the network.

Details of unusual hydrologic circumstances are noted here also. These can include recommendations for the provisional measurement of water levels to test for specific conditions for specific periods of time. There are cases where the interpretation of the past water-level record is uncertain and the additional collection of specific data will resolve the issue.

Together with the observation-well record checklist these recommendations form the nucleus of a work plan for the routine maintenance of the observation-well network.

Discontinued Observation Wells

Part of the purpose of network review is to identify observation wells that should no longer be measured. One main reason to discontinue measuring an observation well is that the water-level data are not or no longer are representative of conditions in a hydrogeologic unit. This includes:

1. Wells that have leaky casings; and
2. Wells affected by surface runoff.

A second general category of reasons to discontinue measurements is a well condition that could lead to erroneous data. This includes:

1. Wells open to more than one hydrogeologic unit;
2. Wells with types of pumps that make water-level measurement difficult;
3. Wells with obstructions in them;
4. Wells of unknown depth or construction; and
5. Wells that are pumped, or subject to pumping influence of nearby wells--a condition unacceptable for climatic-effects, terrane-effects, and areal-effects wells.

Other reasons for discontinuing observation wells are:

1. Sufficient record to meet the objective;
2. Duplication of record from adjacent wells;
3. Water level affected by stream, lake, or reservoir; and
4. Discontinuance of the owner's cooperation.

During review of the North Carolina well records, it was not unusual to find that for one or more of the above reasons wells should be dropped from the network. However, the most common reasons were related to the areal spacing of wells and to the duplication of data from adjacent wells. Nearly 80 wells were recommended to be discontinued for these reasons alone.

A GROUND-WATER LEVEL DATA PROGRAM

Paramount in the review of the existing NRCD and Survey observation-well programs was the need to identify wells that are no longer contributing useful data, and to establish an initial observation-well system organized on the basis of four networks. Climatic-effects network and terrane-effects network wells are required statewide; local-effects network wells are essential in all major pumping areas; and areal-effects network wells are needed only in the major defined hydrogeologic units of the Coastal Plain region of the State. Areas where specific objectives need to be satisfied were identified, and suitable existing observation wells were assigned to the appropriate network in these places. Where no observation wells currently exist, recommendations for installing or acquiring new observation wells have been made. The recommendations were then discussed with NRCD regional and field-office hydrologists.

For nearly fifteen years NRCD has had a test-hole and observation-well construction program in the Coastal Plain, the purpose of which is to define the stratigraphy and geohydrology of the Coastal Plain deposits. This is accomplished by drilling test holes, analyzing rock cuttings, making borehole geophysical logs, conducting aquifer tests, and by constructing observation wells. Each location where this work is done is called a research station by NRCD and may consist of several observation wells at any one location. The most important elements of the NRCD observation-well program in the Coastal Plain are the wells constructed by the agency at these research stations.

One or more of these research stations has been established in 22 Coastal Plain counties. The deepest test hole at each station is usually 1,200 to 1,500 feet deep. A completed research station may have several observation wells tapping each significant aquifer in one or more hydrogeologic units.

This section outlines a proposed statewide observation-well program based on the foregoing discussion and utilizing existing observation wells selected from nearly 650 wells maintained by the NRCD and the Survey. Those wells selected to be included in the statewide program are listed in tables 4 to 13 by county and showing NRCD well number, a latitude-longitude location, network designation, suggested frequency of measurement, and other comments as may be appropriate. A map showing the location of the selected wells accompanies each table.

Natural-Stress Observation Wells

Climatic-Effects Network

Heath (1976, p. 77) outlined some characteristics of all observation wells belonging to a network that monitors the effects of areal variation in climate on ground-water storage. These characteristics include (1) wells open to a permeable, unconfined surficial aquifer; (2) similar depth to water table below land surface at all sites; (3) similar geologic and topographic situations; and (4) similar well construction.

The wells comprising a climatic-effects network for North Carolina should be constructed or acquired with the above characteristics in mind. More specifically, it is suggested that (1) the depth to the water table in these wells should be between 5 and 15 feet below land surface; (2) wells should be located in relatively flat areas at sites that are not affected by concentrated overland runoff (as in draws), by stream flooding (as in flood plains), or ponding in upland flat areas; (3) wells should be 4 to 6 inches in diameter to accomodate recording devices; and (4) wells should be no more than 20 feet in depth (to avoid confined conditions) with at least 5 feet of screen placed at the bottom of the well.

Because the analysis of the water-level record will be made in conjunction with precipitation data collected by the National Weather Service of the National Oceanic and Atmospheric Administration, it is proposed that the climatic-effects network consist of one well in each of the eight National Weather Service divisions of the State (fig. 9) and each should be monitored continuously. As none of the wells in the existing networks meet all of the criteria above, it is suggested that a study be initiated to identify potential locations consistent with the above network characteristics, and that observation wells be constructed according to the guidelines given above.

Terrane-Effects Network

During the course of classifying and selecting existing observation wells, over 140 wells in the surficial hydrogeologic unit or in one of the bedrock units were considered as potentially suitable to a terrane-effects network. That is, the water levels in these wells reflect the influence on ground-water storage of different geological situations and topographic positions than for those wells proposed for the climatic-effects network.

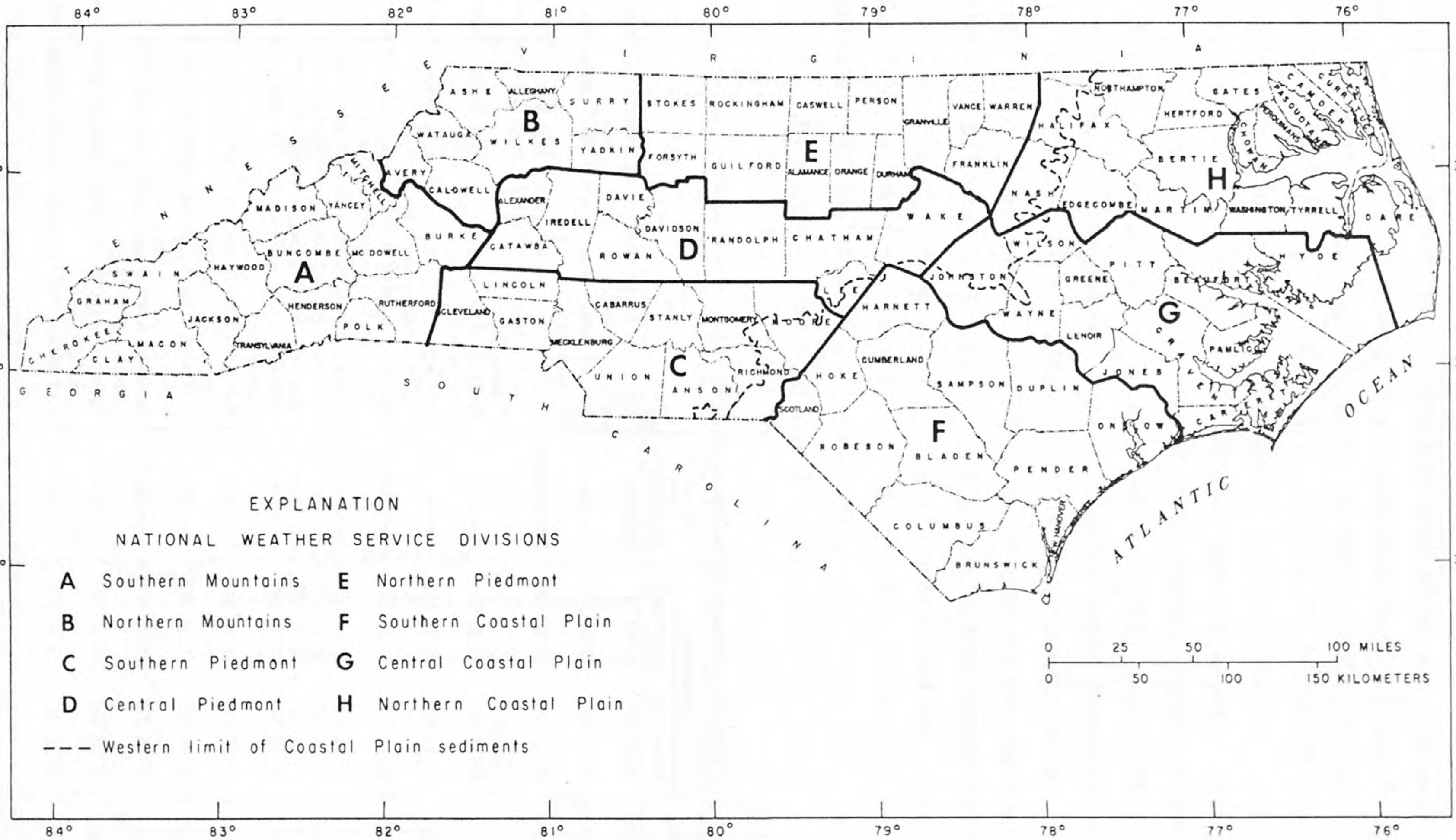

Figure 9.--National Weather Service divisions of North Carolina.

Those terrane-effects wells selected are in the several bedrock hydrogeologic units of the Piedmont-mountain region and were chosen to represent (1) water levels under a high slope or ridgetop topographic position, and (2) water levels in different hydrogeologic units in each of the National Weather Service divisions; however, not all possible combinations of topography, geology, or climatic areas are represented through existing observation wells.

Other terrane-efects network wells needed include those at the same site as a climatic-effects well but in a deeper aquifer, and those at the same depth but in a different topographic setting. Measurement frequency for terrane-effects wells near climatic-effects wells should be continuous, but others could be measured monthly or annually after a period of continuous record. Terrane-effects wells should be located and constructed in conjunction with the construction of the climatic-effects wells, possibly as an extension of the NRCD test-hole and observation-well program as previously described. The proposed terrane-effects wells selected from the existing observation wells are listed in table 4 and located in figure 10.

Table 4.--Proposed observation wells in the terrane-effects network

County	Well No.	Location		Frequency of measurement	Comment
		North lat.	West long.		
Avery	H78-d8	36°04'55"	81°53'00"	Annually	Moderately steep slope on hillside; Great Smoky Mountains Belt hydrogeologic unit.
Haywood	N90-l4	35°32'43"	82°51'38"	-----do-----	Nose of Ridge; Blue Ridge - Inner Piedmont Belt Hydrogeologic unit.
Surry	D61-m2	36°22'57"	80°27'54"	Continuously	Moderate slope near hilltop; Blue Ridge - Inner Piedmont Belt hydrogeologic unit; sensitive to earthquakes and earth tides.
Gaston	Q71-l2	35°17'50"	81°16'50"	Annually	Moderate slope near hilltop; Blue Ridge - Inner Piedmont Belt hydrogeologic unit.
Catawba	K71-w1	35°45'08"	81°17'14"	-----do-----	Moderate slope near hilltop; Blue Ridge - Inner Piedmont Belt hydrogeologic unit.
Caswell	C46-p1	36°26'35"	79°14'30"	-----do-----	Moderate to steep slope on hillside; Blue Ridge - Inner Piedmont Belt hydrogeologic unit.
Mecklenburg	P64-y1	35°20'08"	80°44'24"	-----do-----	Hilltop; Charlotte Belt hydrogeologic unit.
Davidson	I58-y2	35°55'38"	80°14'47"	-----do-----	Hilltop; Charlotte Belt hydrogeologic unit.
Granville	E39-y1	36°15'10"	78°39'45"	-----do-----	Hilltop; Charlotte Belt hydrogeologic unit.
Union	U62-a1	34°59'16"	80°30'13"	-----do-----	Moderate slope near hilltop; Carolina Slate Belt hydrogeologic unit.
Randolph	J50-q3	35°51'04	79°33'30"	-----do-----	Flat area along ridgeline; Carolina Slate Belt hydrogeologic unit.
Guilford	H55-a1	36°04'43"	79°55'29"	-----do-----	Flat area along ridgeline; Carolina Slate Belt hydrogeologic unit.
Wilson	K32-x1	35°45'27"	78°03'44"	-----do-----	Moderate slope near hilltop; Carolina Slate Belt hydrogeologic unit.
Wake	J41-q1	35°51'56"	78°53'08"	-----do-----	Moderate slope on hillside; Triassic Basins hydrogeologic unit.
Rockingham	C54-o1	36°27'38"	79°54'25"	-----do-----	Flat area along ridgeline; Triassic Basins hydrogeologic unit.

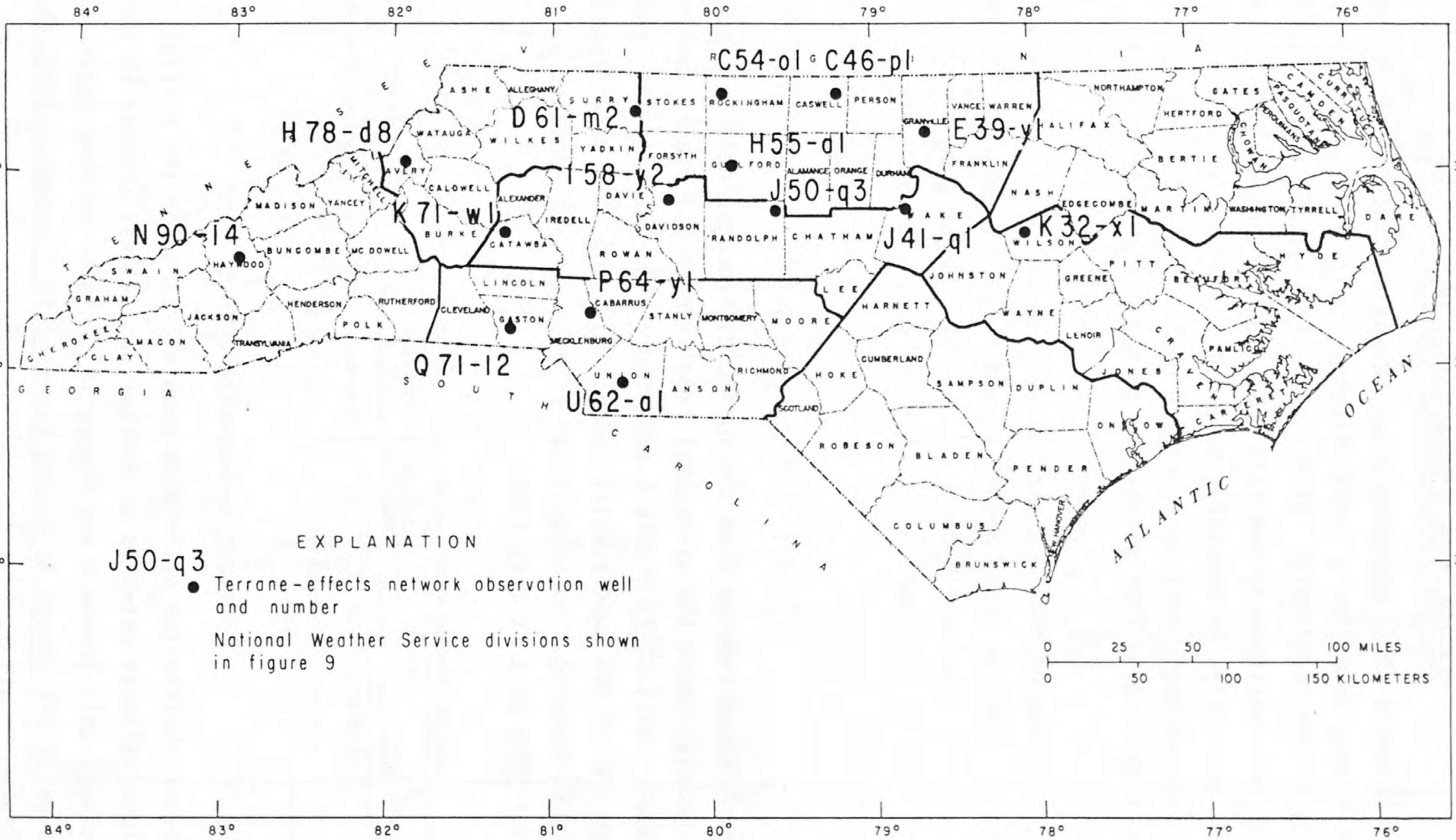

Figure 10.--Proposed terrane-effects observation wells in the Piedmont-mountain region.

Manmade-Stress Observation Wells

Observation wells whose changing water levels reflect the effects of manmade stresses belong to either a local-effects network or an areal-effects network, as described previously. It is suggested that all local-effects wells be monitored continuously and that most areal-effects wells can be measured monthly, quarterly, or annually, but that at least one areal-effects well in each hydrogeologic unit be monitored continuously to serve as a reference well and interpretive link amongst the other wells in the network (Winner, 1981).

During the review of the NRCD and Survey observation-wells, 208 were selected to be included in these networks, and these are presented in the following discussions for each hydrogeologic unit. Major pumping centers affecting each unit are outlined along with proposals for additional observation-well coverage.

Surficial Hydrogeologic Unit

The largest known pumpage from the surficial hydrogeologic unit occurs at Manteo, Dare County, where the withdrawal rate exceeds 0.1 Mgal/d (million gallons per day). Well J3-f3 (table 5 and figure 11), which is less than 500 feet away from one of the supply wells, adequately shows the water level changes caused by pumping. No other local-effects or areal-effects wells are recommended for this unit at this time.

TABLE 5.--PROPOSED OBSERVATION WELL IN THE SURFICIAL HYDROGEOLOGIC UNIT

County	Well No.	Location		Network[1/] objective	Frequency of measurement	Comment
		North lat.	West long.			
Dare	J3-f3	35°52'51"	75°39'59"	L	Continuously	NRCD research station; monitor Manteo-Roanoke Island Supply.

[1/] L, local-effects network.

Yorktown Hydrogeologic Unit

Twenty-seven observation wells have been selected for the initial areal-effects and local-effects networks to monitor water-level changes in the Yorktown hydrogeologic unit (table 6 and figure 12). Three or four additional areal-effects wells are needed to extend coverage in Edgecombe, Pitt, Martin, Bertie, and Craven Counties.

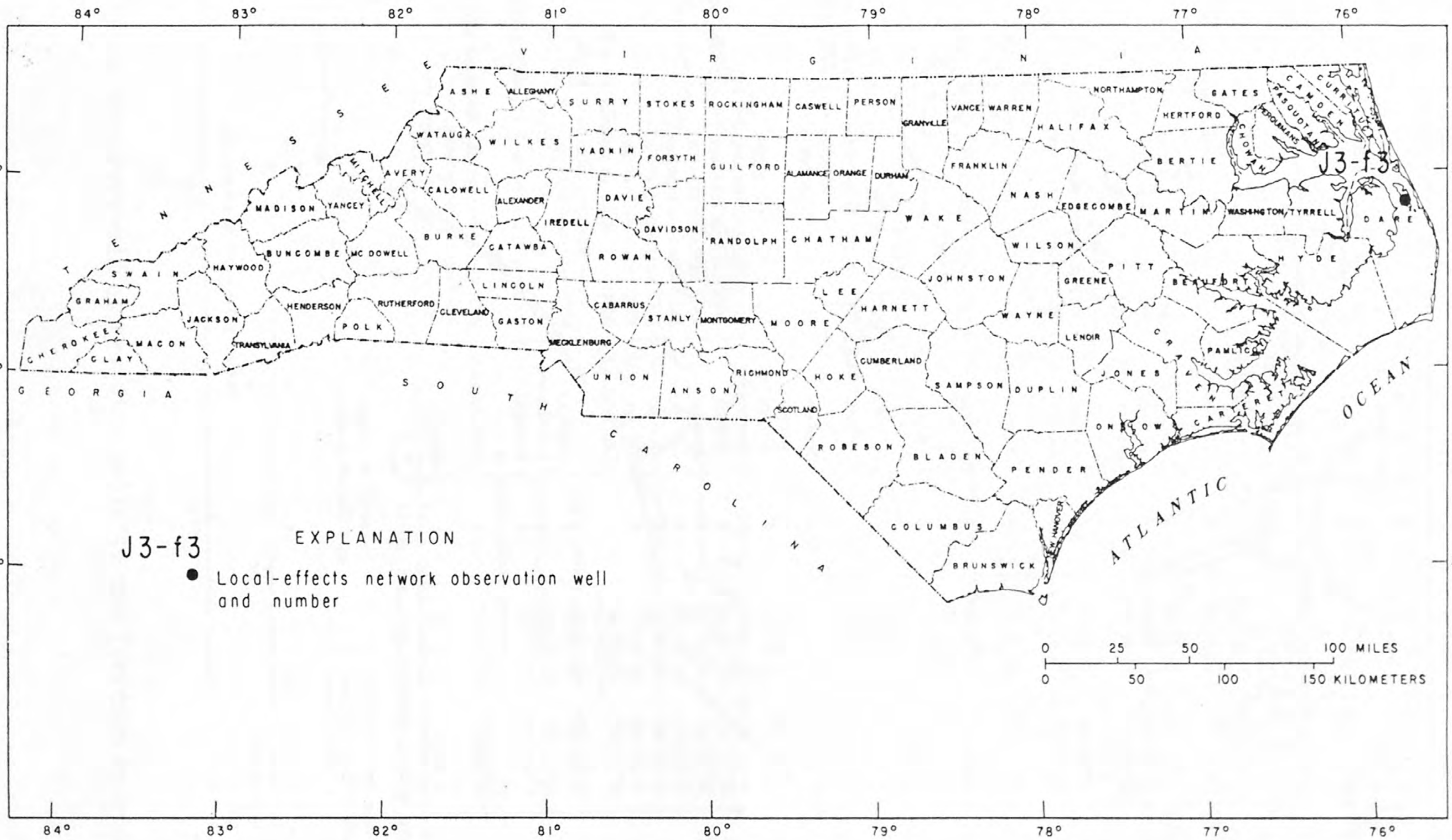

Figure 11.--Proposed observation well in the surficial hydrogeologic unit.

Table 6.--Proposed observation wells in the Yorktown hydrogeologic unit

County	Well No.	Location		Network[1/] objective	Frequency of measurement	Comment
		North lat.	West long.			
Beaufort	N15-h5	35°33'43"	76°37'18"	L	Continuously	NRCD research station; monitor Belhaven pumpage effects; USGS well NC-75.
Do---------	N15-m12	35°32'23"	76°37'40"	A	Annually	NRCD research station.
Do---------	O15-n3	35°27'50"	76°38'10"	A	-----do-----	NRCD research station.
Do---------	O17-i1	35°28'24"	76°46'59"	A	Quarterly	Seasonal fluctuation 3 ft; NRCD research station.
Do---------	P16-o2	35°22'39"	76°44'58"	A	Annually	NRCD research station.
Do---------	P17-h7	35°23'10"	76°47'00"	L	Continuously	Monitor potential vertical leakage; NRCD research station.
Do---------	P19-m2	35°22'19"	76°57'04"	A	Monthly	Seasonal fluctuations 4-5 ft; NRCD research station.
Bertie	G19-b2	36°09'53"	76°56'16"	A	-----do-----	Seasonal fluctuations 5-6 ft; NRCD research station.
Carteret	W13-m1	34°47'56"	76°27'45"	A	Annually	
Chowan	E15-b1	36°19'06"	76°36'55"	A	-----do-----	USGS well NC-31.
Currituck	H5-c1	36°04'54"	75°47'28"	A	-----do-----	USGS well NC-34.
Gates	C17-n1	36°27'51"	76°48'47"	L	Continuously	Monitor potential vertical leakage effects of pumpage at Franklin, Va.; USGS well NC-54.
Hertford	E19-s1	36°16'42"	76°56'30"	A	Monthly	Seasonal fluctuation 4 ft.
Do---------	E22-t2	36°16'59"	77°10'04"	A	Annually	
Hyde	O10-w1	35°25'27"	76°12'31"	A	-----do-----	NRCD research station.
Northampton	D26-b2	36°24'34"	76°31'05"	A	Quarterly	Seasonal fluctuations 2-4 ft.
Do---------	E23-s1	36°16'08"	77°16'26"	A	Monthly	Seasonal fluctuations 4-5 ft; USGS well NC-27.
Pamlico	Q15-u6	35°15'16"	76°35'54"	A	Annually	NRCD research station.
Do---------	R17-i1	35°13'11"	76°46'28"	A	-----do-----	NRCD research station.
Do---------	S18-u7	35°05'08"	76°50'08"	A	-----do-----	NRCD research station.
Pasquotank	D11-v5	36°20'50"	76°16'37"	A	-----do-----	NRCD research station.
Do---------	E10-u1	36°15'56"	76°10'24"	L	Continuously	Monitor effects of pumpage at U.S. Coast Guard station; USGS well NC-29.
Do---------	F11-i4	36°13'08"	76°16'37"	A	Annually	NRCD research station.
Tyrrell	I10-y3	35°55'08"	76°14'51"	A	-----do-----	
Do---------	J11-v6	35°49'51"	76°18'12"	A	Quarterly	Seasonal fluctuation 3 ft; NRCD research station.
Washington	L13-i2	35°43'55"	76°26'25"	A	Continuously	NRCD research station; reference well for areal-effects network.
Wilson	L28-x1	35°40'05"	77°43'57"	A	Monthly	Seasonal fluctuations 6-7 ft.

[1/] A, areal-effects network; L, local-effects network.

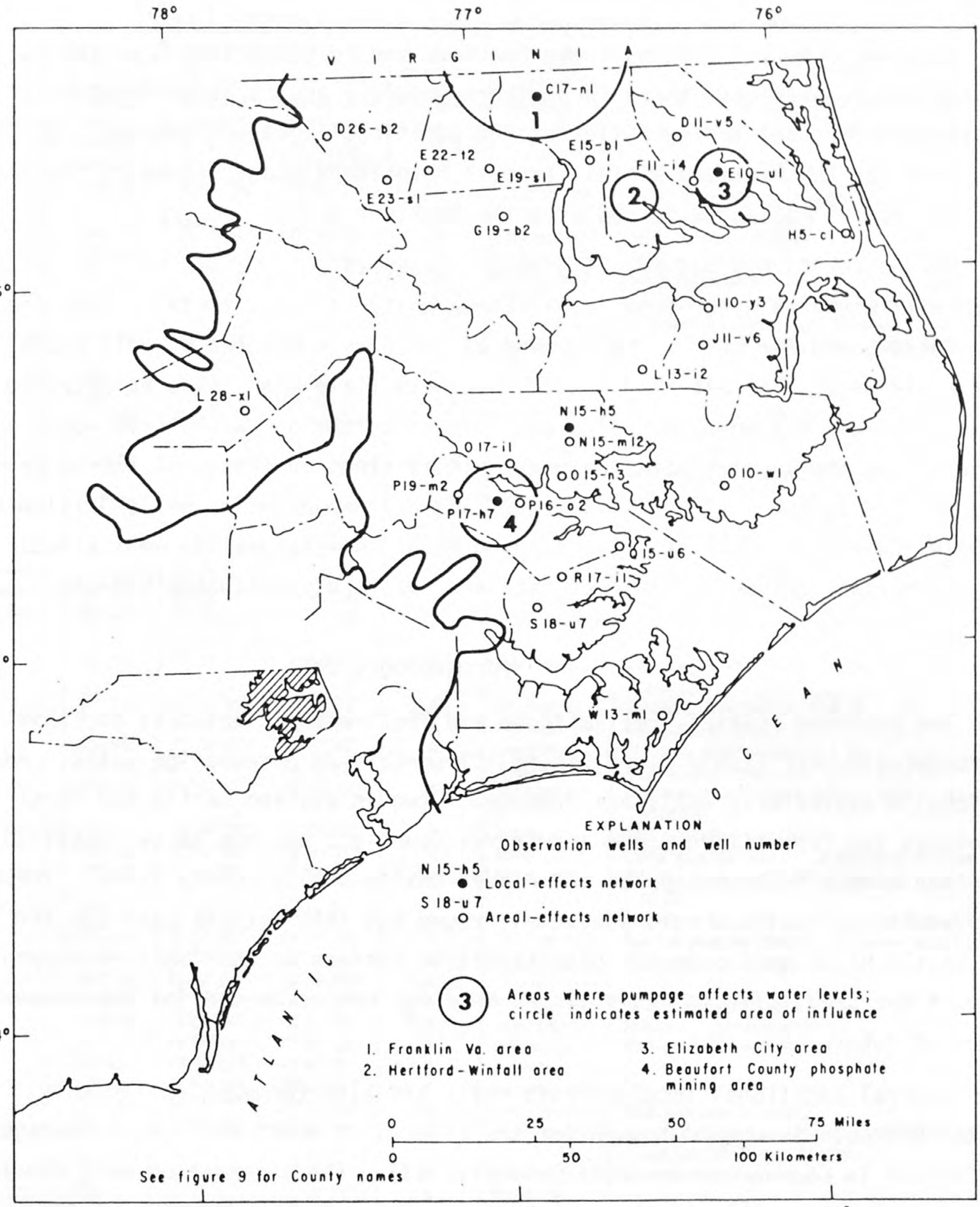

Figure 12.--Proposed observation wells in the Yorktown hydrogeologic unit.

Local-effects wells in northern Beaufort and in Pasquotank Counties monitor pumping effects; those in southern Beaufort and in Gates Counties monitor for vertical leakage effects. An additional local-effects well is suggested for the Hertford-Winfall area in Perquimans County (area 2, fig. 14) where about 0.5 Mgal/d is pumped from the Yorktown unit.

Pasquotank County has recently begun construction of a new well field which will withdraw water from the Yorktown unit. The new field is near the U.S. Coast Guard Air base whose pumping effects are monitored by well E10-ul at the air base. The effects from the new well field might also be detected in well E10-ul, but an observation well closer to the new well field would better serve the local-effects network. It is proposed that well E10-ul be discontinued in favor of one of several candidate observation wells drilled by NRCD in the well field area. Overlapping record of one year of well E10-ul and the replacement well should be obtained before discontinuing E10-ul.

Castle Hayne Hydrogeologic Unit

The proposed initial areal-effects and local-effects networks for this hydrogeologic unit (table 7 and figure 13) contain 78 observation wells. Additional areal-effects wells are proposed: two in eastern Bertie and Martin Counties; two for western Jones and Craven Counties; and one to be installed near the common intersection of the Pender-Onslow-Duplin County lines. These five additional wells should adequately round out this network coverage for the Castle Hayne unit. Once a potentiometric surface in this unit is mapped, many of the areal-effects wells listed here may not be needed for the preparation of future maps.

Several additional local-effects wells are also recommended for this unit. One well is needed to monitor the effects of about 0.6 Mgal/d pumpage at Edenton in Chowan County (area 1 in fig. 13). The observation well should be as close as possible to the center of pumping. Several town wells are reportedly not in use, and one might serve as an observation well.

A local-effects observation well is needed at Plymouth in Washington County (area 2, fig. 13) where the combined pumpage of the Town and Weyerhaeuser Corporation from the Castle Hayne unit is greater than 1.5 Mgal/d.

Table 7.--Proposed observation wells in the Castle Hayne Hydrogeologic unit

County	Well No.	Location		Network[1/] objective	Frequency of measurement	Comment
		North lat.	West long.			
Beaufort	M17-u2	35°35'40"	76°45'34"	A	Annually	
Do----------	N15-m1	35°32'27"	76°37'30"	A	-----do-----	NRCD research station; USGS well NC-15.
Do---------	N16-w2	35°30'36"	76°42'21"	A	-----do-----	
Do---------	N19-p1	35°31'28"	76°59'42"	A	-----do-----	NRCD research station.
Do---------	N20-f1	35°33'14"	77°04'10"	L	Continuously	Monitor effects of industrial pumping; USGS well NC-14.
Do---------	N20-p1	35°31'53"	77°04'23"	A	Annually	NRCD research station.
Do---------	015-n5	35°27'50"	76°38'10"	A	-----do-----	NRCD research station.
Do---------	015-u1	35°25'38"	76°35'21"	A	-----do-----	NRCD research station.
Do---------	017-i2	35°28'24"	76°46'59"	L	Continuously	Monitor effects of pumping at phosphate mines; NRCD research station.
Do---------	017-i4	35°28'24"	76°46'59"	A	Annually	Monitors lower part of unit; NRCD research station.
Do---------	018-c2	35°29'48"	76°52'46"	A	-----do-----	
Do---------	018-p1a	35°26'41"	76°54'12"	A	-----do-----	
Do---------	018-f1a	35°28'57"	76°58'16"	A	-----do-----	
Do---------	019-m1a	35°27'40"	76°57'36"	A	-----do-----	
Do---------	021-i1	35°28'07"	77°06'52"	A	Quarterly	Seasonal fluctuations 2-3 ft; NRCD research station.
Do---------	021-q1	35°26'15"	77°08'34"	A	Continuously	Reference well for areal-effects network; NRCD research station; USGS well NC-137.
Do---------	P14-f2	35°23'18"	76°34'33"	A	Annually	
Do---------	P16-d1b	35°24'53"	76°43'13"	A	-----do-----	NRCD research station.
Do---------	P17-d1a	35°24'53"	76°48'18"	A	-----do-----	
Do---------	P17-h6	35°23'10"	76°47'00"	L	Continuously	Monitor pumping effects at phosphate mines; NRCD research station.
Do---------	P19-m3	35°22'19"	76°57'04"	A	Quarterly	Seasonal fluctuations 2-4 ft; NRCD research station.
Do---------	Q16-m4	35°17'36"	76°42'01"	A	-----do-----	Seasonal fluctuations 2-3 ft.
Do---------	Q17-c1	35°19'32"	76°48'00"	A	Annually	USGS well NC-13.
Do---------	Q18-h1	35°18'07"	76°52'45"	A	Quarterly	Seasonal fluctuations 1-3 ft.
Brunswick	FF32-m2	34°02'44"	78°02'08"	A	Annually	NRCD research station.
Do---------	FF35-v1	34°00'59"	78°01'15"	A	Quarterly	Seasonal fluctuations 2-3 ft; NRCD research station.
Do---------	GG32-i1	33°58'03"	78°01'37'	A	Annually	NRCD research station.
Do---------	GG32-u2	33°55'53"	78°00'55"	A	Monthly	Large fluctuations; NRCD research station.
Do---------	GG32-v4	33°55'35"	78°01'10"	L	Continuously	Monitor Southport Pumping effects; USGS well NC-22.
Do---------	GG33-c1	33°59'29"	78°07'11"	A	-----do-----	Reference well for areal-effects network.
Do---------	GG33-l5	33°57'09"	78°06'29"	L	-----do-----	Monitor pumping effects of County well Field.
Do---------	GG34-s5	33°56'23"	78°11'54"	A	Annually	NRCD research station.
Do---------	GG35-l1	33°57'07"	78°16'03"	A	-----do-----	
Do---------	GG37-b4	33°59'30"	78°26'20"	A	-----do-----	NRCD research station.
Do---------	HH33-c2	33°54'48"	78°07'59"	A	Quarterly	Seasonal fluctuation 3 ft.
Do---------	HH35-b3	33°54'53"	78°16'19"	A	Annually	NRCD research station.
Carteret	W18-k1	34°50'59"	76°47'48"	A	-----do-----	
Do---------	X15-m1	34°42'28"	76°37'06"	A	-----do-----	
Do---------	X17-i3	34°43'23"	76°45'13"	A	-----do-----	NRCD research station.
Do---------	X17-i5	34°43'23"	76°45'13"	A	-----do-----	Monitors upper part of unit; NRCD research station; USGS well NC-139.
Craven	P21-k2	35°22'10"	77°05'09"	A	Quarterly	Seasonal fluctuations 2-3 ft.
Do---------	P21-p1	35°20'57"	77°09'25"	A	Annually	
Do---------	Q19-q1	35°16'05"	76°58'02"	A	Monthly	Seasonal fluctuation 4 ft.
Do---------	Q21-t1	35°16'05"	77°05'09"	A	Quarterly	Seasonal fluctuations 2-3 ft.
Do---------	T22-a1	35°04'58"	77°10'49"	A	Annually	USGS well NC-45.
Hyde	M12-l1	35°37'20"	76°21'18"	A	-----do-----	NRCD research station.
Do---------	010-w3	35°25'27"	76°12'31"	A	-----do-----	NRCD research station.
Do---------	013-c2	35°29'47"	76°27'09"	A	-----do-----	
Do---------	013-f1	35°29'00"	76°29'06"	A	-----do-----	NRCD research station.
Jones	T22-x1	35°00'55"	77°13'05"	A	-----do-----	
New Hanover	BB30-r3	34°21'35"	77°52'52"	L	Continuously	Monitors quarry dewatering operations.

Table 7.--Proposed observation wells in the Castle Hayne hydrogeologic unit--Continued

County	Well No.	Location		Network[1/] objective	Frequency of measurement	Comment
		North lat.	West long.			
New Hanover	CC31-a1	34°19'15"	77°55'02"	A	Quarterly	Seasonal fluctuations 2-3 ft.
Do---------	GG31-k4	33°57'45"	77°55'47"	A	Annually	NRCD research station.
Onslow	W25-u1	34°45'25"	77°25'45"	A	Monthly	Seasonal fluctuations 4-5 ft; USGS well NC-85.
Do---------	X25-b1	34°44'25"	77°27'25"	A	Annually	USGS well NC-52.
Do---------	AA26-e1	34°29'31"	77°34'21"	A	-----do-----	
Pamlico	Q15-u3	35°15'16"	76°35'54"	A	-----do-----	NRCD research station.
Do---------	R17-i2	35°13'13"	76°46'28"	L	Continuously	Monitors pumping effects at phosphate mines; NRCD research station.
Do---------	R17-i3	35°13'13"	76°46'28"	A	Annually	Monitors lower part of unit; NRCD research station.
Do---------	S15-y4	35°05'25"	76°39'24"	A	-----do-----	NRCD research station.
Do---------	S16-e1	35°09'28"	76°44'47"	A	-----do-----	
Do---------	S18-k1	35°07'28"	76°50'27"	A	-----do-----	NRCD research station.
Do---------	S18-u5	35°05'08"	76°50'08"	A	-----do-----	NRCD research station.
Pasquotank	G9-c4	36°09'09"	76°07'49"	A	-----do-----	NRCD research station.
Pender	AA26-q1	34°26'44"	77°33'41"	A	-----do-----	NRCD research station.
Perquimans	E13-m3	36°17'36"	76°27'37"	A	-----do-----	NRCD research station.
Pitt	N23-u1	35°30'43"	77°15'00"	A	Monthly	Seasonal fluctuation 4 ft; NRCD research station.
Do---------	O22-v5	35°25'44"	77°11'18"	A	Annually	
Do---------	O23-t1	35°26'18"	77°15'48"	A	Monthly	Seasonal fluctuations 4-6 ft; NRCD research station.
Tyrrell	J11-v4	35°49'51"	76°18'12"	A	Annually	NRCD research station.
Do---------	L10-a3	35°44'19"	76°10'57"	A	-----do-----	NRCD research station.
Washington	J12-n2	35°52'05"	76°23'31"	A	-----do-----	
Do---------	J13-d2	35°54'59"	76°28'14"	A	-----do-----	NRCD research station.
Do---------	J15-p6	35°51'24"	76°39'24"	A	-----do-----	NRCD research station.
Do---------	J16-a1	35°54'04"	76°41'25"	A	-----do-----	
Do---------	K13-c1	35°49'52"	76°27'48"	A	-----do-----	
Do---------	L13-i1	35°43'55"	76°26'25"	L	Continuously	Monitors effects of pumping at phosphate mines, NRCD research station.
Do---------	L15-g2	35°43'51"	76°38'33"	A	Annually	

1/A, areal-effects network; L, local-effects network.

In Craven County pumpage from the Castle Hayne unit in the Cherry Point-Havelock area is more than 3 Mgal/d (area 5, fig. 13). At least one local-effects well is needed here to observe the effects of pumping, principally at the Cherry Point Marine Corps Air Station. Similarly, an observation well is needed at Camp Lejeune in Onslow County (area 6, fig. 13) where about 3.5 Mgal/d are pumped from the Castle Hayne unit.

Area 7 in figure 13 represents about 3 Mgal/d combined pumpage for industrial use and for quarry dewatering operations. The pumping effects at the quarry are currently monitored by well BB30-r1 (table 7); however, this observation well shows signs of caving problems and should be replaced as soon as possible.

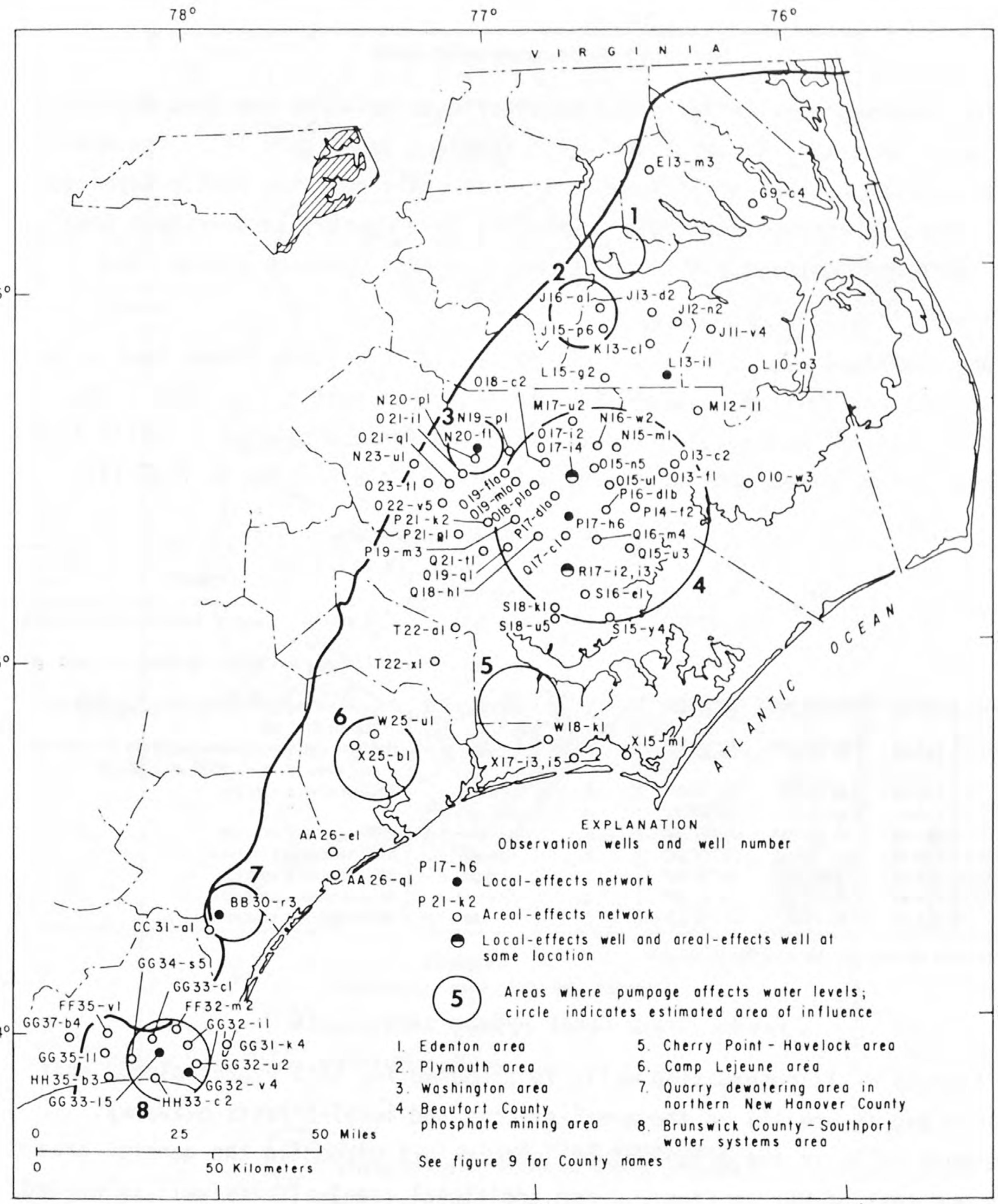

Figure 13.--Proposed observation wells in the Castle Hayne hydrogeologic unit.

Beaufort Hydrogeologic Unit

The proposed areal-effects and local-effects networks for this hydrogeologic unit contains 11 observation wells (table 8 and figure 14). The areal-effects network would benefit from additional wells near the Martin-Washington County line, in northwestern Hyde County, in Dare County, in Currituck County, in northern and southwestern Craven County, in east Carteret County, and in Bertie County.

One additional local-effects well is needed in western Craven County to monitor possible vertical leakage from the Beaufort unit to the underlying Peedee-Black Creek hydrogeologic unit resulting from pumpage of 3 Mgal/d from the Peedee-Black Creek unit at the Cove City well field (area 3, fig. 14).

Table 8.--Proposed observation wells in the Beaufort hydrogeologic unit

County	Well No.	Location		Network[1/] objective	Frequency of measurement	Comment
		North lat.	West long.			
Beaufort	M21-q2	35°36'17"	77°08'24"	A	Quarterly	NRCD research station; seasonal fluctuations 2 - 2-1/2 ft.
Do---------	O17-i3	35°28'24"	76°46'59"	A	-----do-----	NRCD research station; seasonal fluctuation 3 ft.
Do---------	P17-h5	35°23'10"	76°47'00"	L	Continuously	Monitor vertical leakage effects; NRCD research station.
Chowan	F15-e1	36°14'27"	76°39'30"	L	-----do-----	Monitor vertical leakage effects of pumping at Franklin, Va.; USGS well NC-58.
Gates	C15-s6	36°26'50"	76°36'06"	A	Annually	NRCD research station.
Hertford	E16-g6	36°18'35"	76°43'39"	A	-----do-----	
Pamlico	Q15-u2	35°15'16"	76°35'54"	A	-----do-----	NRCD research station.
Do---------	S15-y2	35°05'25"	76°39'24"	A	-----do-----	NRCD research station.
Do---------	S18-u4	35°05'08"	76°50'08"	A	-----do-----	NRCD research station.
Pasquotank	C12-r4	36°26'01"	76°23'07"	A	-----do-----	NRCD research station.
Tyrrell	J11-v8	35°49'50"	76°18'12"	A	-----do-----	NRCD research station.

1/A, areal-effects network; L, local-effects network.

Peedee-Black Creek Hydrogeologic Unit

A group of 33 observation wells is proposed for this hydrogeologic unit (table 9 and figure 15) in the areal-effects and local-effects networks. Additional wells in the areal-effects network are needed in the general area north and east of Martin County. One additional areal-effects well is needed in southeastern Duplin County, one in northern Sampson County, and one in eastern Pender County.

No observation wells are in this unit in the northeastern Coastal Plain. Water levels in the Peedee-Black Creek unit in this area are influenced by withdrawals in southeastern Virginia (area 1, fig. 15), and at least one local-effects well should be in the area nearest the pumping center.

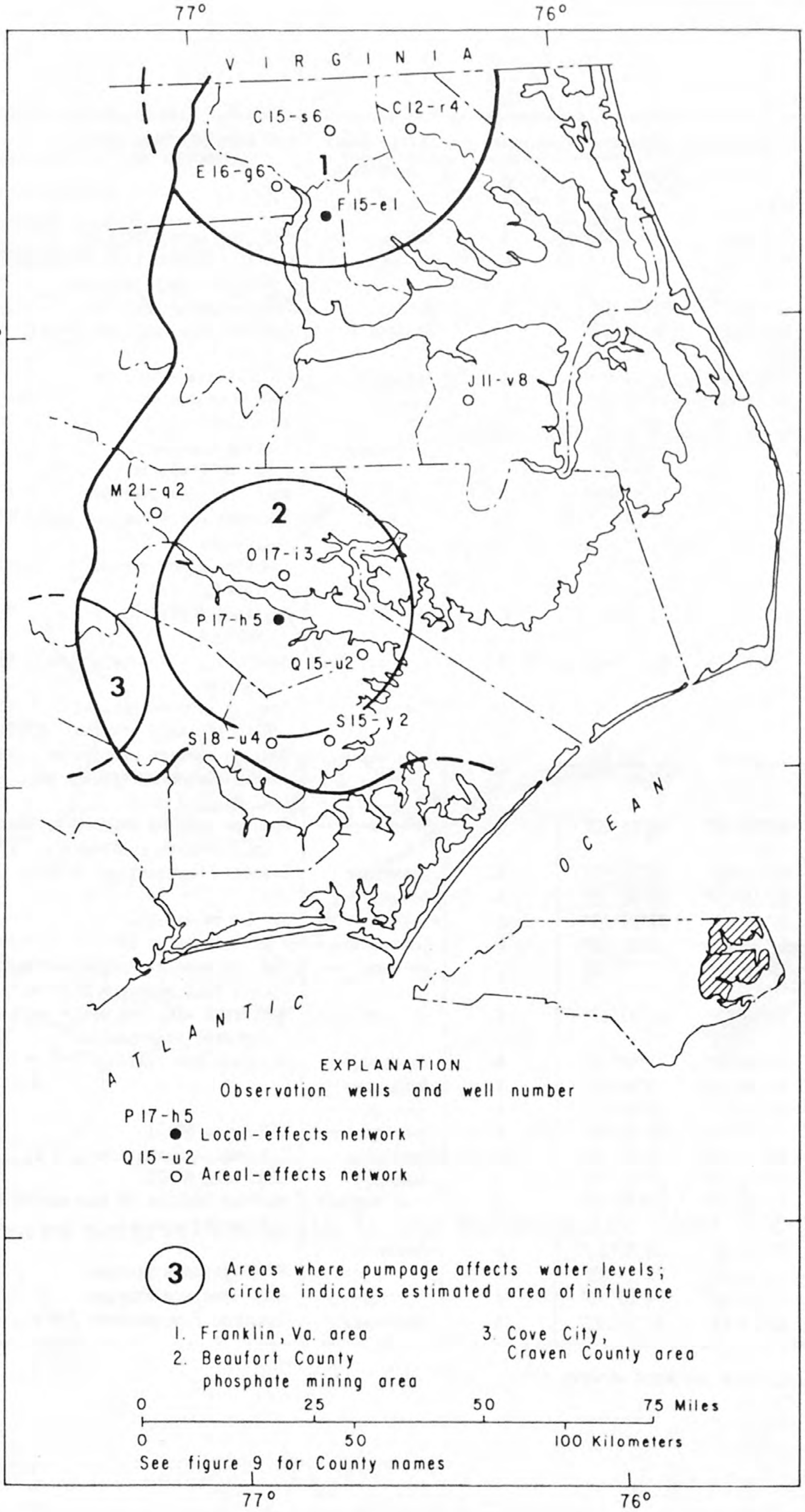

Figure 14.--Proposed Observation wells in the Beaufort hydrogeologic unit.

Table 9.--Proposed observation wells in the Peedee-Black Creek Hydrogeologic unit

County	Well No.	Location: North lat.	Location: West long.	Network[1/] objective	Frequency of measurement	Comment
Beaufort	P17-h4	35°23′10″	76°47′00″	A	Annually	NRCD research station.
Do---------	P19-m4	35°22′19″	76°57′04″	L	Monthly	Monitor pumping effects in Lenoir Co. area; NRCD research station.
Do---------	P21-k7	35°22′53″	77°05′19″	A	Annually	NRCD research station.
Bladen	Z41-u4	34°30′28″	78°45′19″	A	Quarterly	Seasonal fluctuations 3-4 ft; NRCD research station.
Brunswick	EE32-v1	34°05′27″	78°01′03″	A	Annually	NRCD research station.
Do---------	EE36-k5	34°07′58″	78°20′08″	A	-----do-----	NRCD research station.
Do---------	GG34-s3	33°56′23″	78°11′54″	A	-----do-----	NRCD research station
Do---------	HH39-j4	33°53′36″	78°35′19″	L	Continuously	Monitor pumping effects in Myrtle Beach area, SC; NRCD research station.
Columbus	AA39-v4	34°25′08″	78°35′07″	A	Annually	NRCD research station.
Do---------	CC38-b6	34°19′32″	78°31′45″	A	-----do-----	Monitors upper part of unit; NRCD research station.
Do---------	CC38-b9	34°19′32″	78°31′45″	A	-----do-----	Monitors lower part of unit; NRCD research station.
Do---------	DD42-n1	34°12′37″	78°53′48″	A	-----do-----	Monitors upper part of unit; NRCD research station.
Do---------	DD42-n3	34°12′37″	78°53′48″	A	-----do-----	Monitors lower part of unit; NRCD research station.
Craven	P22-j1	35°23′09″	77°10′29″	L	Monthly	Monitor pumping effects in Lenoir Co. area; NRCD research station; USGS well NC-16.
Do---------	S22-d1	35°09′24″	77°13′06″	L	Continuously	Monitor pumping effects at Cove City, Craven Co.; recommend replace well; USGS well NC-48.
Duplin	T33-u1	35°00′30″	78°06′00″	L	-----do-----	Monitor pumping effects at Warsaw, Duplin Co.; USGS well NC-69.
Greene	O26-o1	35°27′48″	77°34′57″	A	Quarterly	Seasonal fluctuations 4-5 ft.
Jones	R26-b1	35°13′45″	77°31′16″	A	Annually	
Do---------	T24-i2	35°04′03″	77°21′13″	A	-----do-----	
Lenoir	P25-v1	35°21′00″	77°26′45″	L	Continuously	Monitor pumping effects at Dupont, Inc. plant.
Do---------	Q27-r7	35°16′11″	77°37′13″	L	-----do-----	Monitor pumping effects at Kinston, Lenoir Co.; NRCD research station.
Do---------	Q27-r10	35°16′11″	77°37′13″	A	-----do-----	Reference well for upper part of unit; NRCD research station.
Do---------	Q29-h1	35°18′30″	77°47′30″	A	Quarterly	Seasonal fluctuations 2-3 ft.
Do---------	R29-j1	35°14′01″	77°46′13″	A	Annually	
Do---------	S28-d1	35°09′11″	77°43′57″	A	-----do-----	
Do---------	T28-f3	35°03′06″	77°44′42″	A	-----do-----	USGS well NC-51.
New Hanover	CC31-t1	34°16′16″	77°55′18″	A	Quarterly	Seasonal fluctuations 2-3 ft.
Do---------	DD30-w1	34°09′58″	77°52′39″	A	Annually	USGS well NC-20.
Pitt	M27-u8	35°35′42″	77°35′40″	L	Continuously	Monitor effects of pumpage at Farmville, Pitt Co.
Sampson	T38-t1	35°01′38″	78°30′11″	A	Annually	
Do---------	Y34-p2	34°36′25″	78°14′32″	A	-----do-----	NRCD research station.
Wayne	Q32-d2	35°19′30″	78°03′30″	A	-----do-----	NRCD research station.
Do---------	R30-q1	35°11′41″	77°53′01″	A	Quarterly	Seasonal Fluctuations 3-4 ft.

1/A, Areal-effects network; L, Local-effects network.

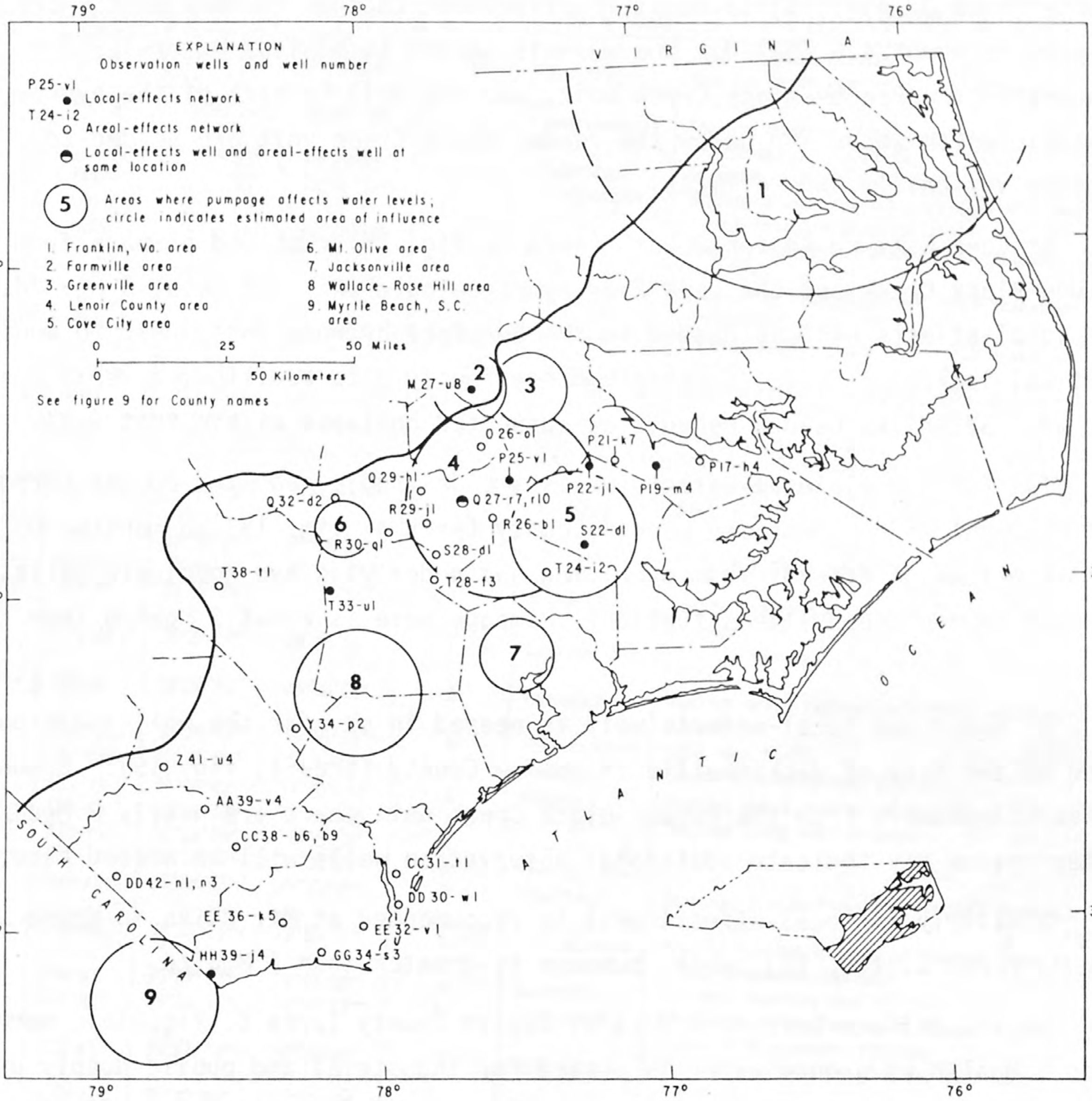

Figure 15.--Proposed observation wells in the Peedee-Black Creek hydrogeologic unit.

Three wells in the local-effects network are needed at Greenville, Pitt County (area 3, fig. 15) to monitor water-level changes in this unit where pumpage is about 4.6 Mgal/d. One well is needed to monitor water-level changes in the Peedee-Black Creek unit, and one well in each of the hydrogeologic units above and below the Peedee-Black Creek unit are needed to monitor verical leakage effects.

At Cove City in Craven County (area 5, fig. 15) combined pumpage from the Peedee-Black Creek and the Cape Fear hydrogeologic units is about 3 Mgal/d. One local-effects well is needed in the Beaufort hydrogeologic unit to monitor vertical leakage effects as described previously. In addition, a replacement for well S22-dl is needed because of suspected collapse within that well.

Two additional local-effects wells are desirable near the Dupont Corporation plant in northeastern Lenoir County (area 4, fig. 15) to monitor possible leakage effects from overlying and underlying hydrogeologic units, similar to the Greenville situation. Pumpage here is about 3 Mgal/d from the Peedee-Black Creek unit.

At least one local-effects well is needed in or near the well field operated by the City of Jacksonville in Onslow County (area 7, fig. 15). Groundwater withdrawals from the Peedee-Black Creek unit there are nearly 2 Mgal/d. Later review may indicate additional observation wells will be needed here.

Similarly, a local-effects well is recommended at Mt. Olive in Wayne County (area 6, fig. 15), where pumpage is greater than 1 Mgal/d.

In the Wallace-Rose Hill area of Duplin County (area 8, fig. 15), more than 6 Mgal/d of ground water is pumped for industrial and public-supply uses. At least three local-effects wells are recommended to monitor the effects of these withdrawals on water levels in the Peedee-Black Creek unit and in overlying and underlying units.

Cape Fear Hydrogeologic Unit

The proposed 50 observation wells for the areal-effects and local-effects network in this hydrogeologic unit are listed in table 10 and shown in figure 16. Additional wells for the areal-effects network are needed in the following counties: Duplin, Pender, Onslow, Carteret, Pamlico, Beaufort, and Hyde.

TABLE 10.--PROPOSED OBSERVATION WELLS IN THE CAPE FEAR HYDROGEOLOGIC UNIT

County	Well No.	Location		Network[1/] objective	Frequency of measurement	Comment
		North lat.	West long.			
Beaufort	P21-k5	35°22'53"	77°05'19"	A	Annually	NRCD research station.
Bertie	G19-b3	36°09'53"	76°56'16"	A	Quarterly	Monitor upper part of unit; NRCD research station.
Do---------	G19-b4	36°09'53"	76°56'16"	L	Continuously	Monitor pumping effects at Franklin, Va.; NRCD research station.
Bladen	Y37-e1	34°29'21"	78°29'43"	A	Quarterly	Seasonal fluctuation 4 ft.
Do---------	Z41-u2	34°30'27"	78°45'19"	A	Continuously	Reference well for areal-effects network; NRCD research station.
Brunswick	EE36-k2	34°07'58"	78°20'08"	A	Annually	Monitor geopressured zone; NRCD research station.
Do---------	GG34-s2	33°56'23"	78°11'54"	A	-----do-----	Monitor geopressured zone; NRCD research station.
Do---------	HH39-j2	33°53'36"	78°35'19"	A	-----do-----	Monitor geopressured zone; NRCD research station.
Columbus	CC38-b7	34°19'32"	78°31'45"	A	-----do-----	Monitor geopressured zone; NRCD research station.
Do---------	DD42-n2	34°12'37"	78°53'48"	A	-----do-----	NRCD research station.
Craven	R23-w2	35°10'49"	77°17'55"	L	Continuously	Monitor pumping effects at Cove City, Craven Co.; USGS well NC-44.
Cumberland	R43-x3	35°10'04"	78°58'15"	L	Monthly	Monitor pumping effects at Spring lake, Cumberland Co.
Edgecombe	I25-i2	35°58'11"	77°26'08"	A	Continuously	Reference well for areal effects network.
Do---------	K25-c2	35°49'19"	77°27'27"	A	Annually	
Do---------	K27-n1	35°47'28"	77°38'42"	L	Monthly	Monitor pumping effects at Pinetops, Edgecombe Co.
Gates	C15-s4	36°26'50"	76°36'06"	L	Continuously	Monitor pumping effects at Franklin, Va.; NRCD research station.
Do---------	C15-s5	36°26'50"	76°36'06"	A	Annually	Monitor upper part of unit; NRCD research station.
Do---------	D15-v1	36°20'44"	76°36'23"	A	-----do-----	USGS well NC-30.
Greene	O27-k1	35°28'01"	77°35'03"	A	Quarterly	Seasonal fluctuations 2-3 ft.
Hertford	C21-t1	36°26'42"	77°05'15"	A	Annually	Monitor upper part of unit; USGS well NC-81.
Do---------	C21-t3	36°26'37"	77°05'58"	A	-----do-----	Monitor lower part of unit.
Do---------	E19-t5	36°16'28"	76°55'38"	A	-----do-----	
Do---------	E20-i1	36°18'32"	77°01'25"	A	-----do-----	
Hoke	T48-i2	35°03'35"	79°21'20"	A	Quarterly	Seasonal fluctuations 2-3 ft; NRCD research station.
Do---------	U46-e6	34°59'25"	79°14'26"	L	Continuously	Monitor pumping effects at Raeford, Hoke Co.; NRCD research station.
Lee	O44-n1	35°27'22"	79°03'03"	A	Quarterly	Seasonal fluctuations 1-2 ft.
Lenoir	Q27-r5	35°16'11"	77°37'13"	L	Continuously	Monitor pumping effects at Kinston, Lenoir Co.; NRCD research station.
Martin	I23-n1	35°57'34"	77°18'00"	A	Quarterly	Seasonal fluctuations 3-4 ft; USGS well NC-43.
Northampton	B22-v1	36°30'48"	77°11'14"	A	Annually	
Do---------	D25-j1	36°23'45"	77°25'12"	A	-----do-----	
Do---------	E23-r1	36°16'57"	77°17'04"	A	-----do-----	
Pasquotank	C12-r5	36°26'01"	76°23'07"	A	-----do-----	Monitor lower part of unit; NRCD research station.
Do---------	C12-r6	36°26'01"	76°23'07"	A	-----do-----	Monitor upper part of unit; NRCD research station.
Perquimans	E13-m2	36°17'36"	76°27'37"	A	-----do-----	NRCD research station.
Pitt	M27-u1	35°35'43"	77°35'40"	L	Monthly	Monitor pumping effects at Farmville, Pitt Co.
Richmond	T53-a1	35°04'34"	79°45'31"	A	Quarterly	Seasonal fluctuation 2 ft.
Robeson	V45-u2	34°50'39"	79°05'09"	A	Annually	Monitor lower part of unit; NRCD research station.
Do---------	V45-u4	34°50'39"	79°05'09"	A	-----do-----	Monitor upper part of unit; NRCD research station.
Do---------	X47-f1	34°43'42"	79°19'46"	L	Monthly	Monitor pumping effects at Maxton.

TABLE 10.--PROPOSED OBSERVATION WELLS IN THE CAPE FEAR HYDROGEOLOGIC UNIT--CONTINUED

County	Well No.	Location		Network[1/] objective	Frequency of measurement	Comment
		North lat.	West long.			
Robeson	Y42-F3	34°38'36"	78°54'49"	L	Continuously	Monitor pumping effects in Lumberton area, Robeson Co.; NRCD research station.
Do---------	Y42-F5	34°38'36"	78°54'49"	A	Annually	Monitor upper part of unit; NRCD research station.
Do---------	Y45-T1	34°36'09"	79°05'47"	A	-----do-----	
Do---------	Z47-M1	34°32'09"	79°17'37"	A	-----do-----	Monitor lower part of unit; NRCD research station.
Do---------	Z47-M3	34°32'09"	79°17'37"	A	-----do-----	Monitor upper part of unit; NRCD research station.
Do---------	BB45-M3	34°22'21"	79°07'39"	A	-----do-----	NRCD research station.
Sampson	U35-D2	34°59'17"	78°18'55"	L	Continuously	Monitor pumping effects at Clinton, Sampson Co.
Do---------	Y34-P4	34°36'25"	78°14'32"	A	Annually	NRCD research station.
Tyrrell	J11-V5	35°49'50"	76°18'12"	A	-----do-----	NRCD research station.
Wayne	Q32-D1	35°19'30"	78°03'30"	A	Quarterly	Seasonal fluctuation 2 ft; NRCD research station.
Wilson	M29-P1	35°36'15"	77°49'42"	A	Annually	

[1/] A, areal-effects network; L, local-effects network.

Several additional observation wells in this unit have been proposed that were discussed as part of the local-effects network for monitoring vertical leakage to the overlying Peedee-Black Creek unit at Greenville in Pitt County, Cove City in Craven County, and near the Dupont Plant in Lenoir County. One well is also needed to monitor water-level fluctuations in the Cape Fear unit in the Hamilton-Robersonville in Martin County (area 2, fig. 16), where nearly 2 Mgal/d of ground water is pumped from that unit for industrial and public supplies.

At Laurinburg in Scotland County (area 8, fig. 16) about 2 Mgal/d is withdrawn from the Cape Fear unit. One local-effects well is needed close to the center of this pumping.

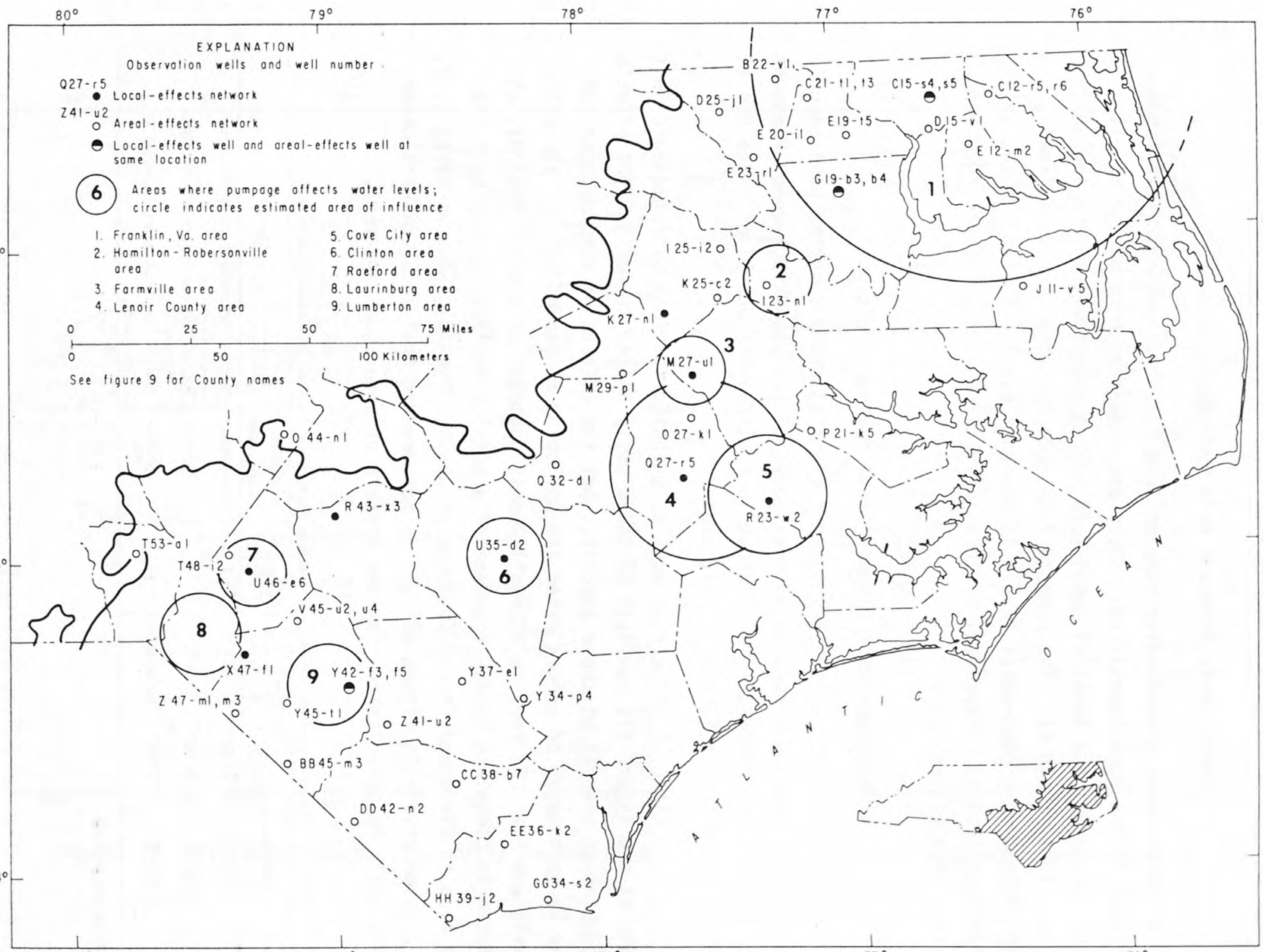

Figure 16.--Proposed observation wells in the Cape Fear hydrogeologic unit.

Great Smoky Mountain Belt Hydrogeologic Unit

No large-scale ground-water pumpage from this hydrogeologic unit (shown in figure 4) has been identified. There are, however, nine public supply systems withdrawing a total of about 0.75 Mgal/d ground water from the unit (Winner, 1981, table 6). The pumpage from each of these sources is small, and their effects on ground-water levels in the unit are likely too limited to warrant monitoring. Therefore, no local-effects network wells are recommended for this unit at this time.

Blue Ridge-Inner Piedmont Belt Hydrogeologic Unit

Fifty-seven public, commercial and industrial water supplies have been identified as pumping ground water from rocks of the Blue Ridge-Inner Piedmont Belt unit at the combined rate of about 15 Mgal/d. All but 21 of these use at least 0.1 Mgal/d each (Winner, 1981, table 7).

The initial local-effects network as proposed for this hydrogeologic unit (table 11 and figure 17) consists of three wells needed to monitor the effects of pumping at several of these supplies, but the effects of pumping near the three largest users of ground water are not being monitored now. These withdrawals are near Old Fort in McDowell County (pumpage of about 4 Mgal/d), at Fallston in Cleveland County (pumpage of about 1.5 Mgal/d), and at Earl Station also in Cleveland County (pumpage of about 2 Mgal/d) shown as areas 1, 2, and 3 respectively in figure 17. It is recommended that local-effects observation wells be established near the centers of these pumping areas.

Table 11.--Proposed observation wells in the Blue Ridge-Inner Piedmont Belt hydrogeologic unit

County	Well No.	Location		Network[1/] objective	Frequency of measurement	Comment
		North lat.	West long.			
Clay	T101-g5	35°03'09"	83°48'42"	L	Continuously	Monitor pumping effects at Hayesville, Clay Co.
Halifax	C30-y1	36°26'00"	77°54'52"	L	-----do-----	Monitor pumping effects at Littleton, Halifax Co.
Lincoln	070-e2	35°29'00"	81°14'40"	L	-----do-----	Monitor industrial pumping effects at Lincolnton.

1/ L, local-effects network.

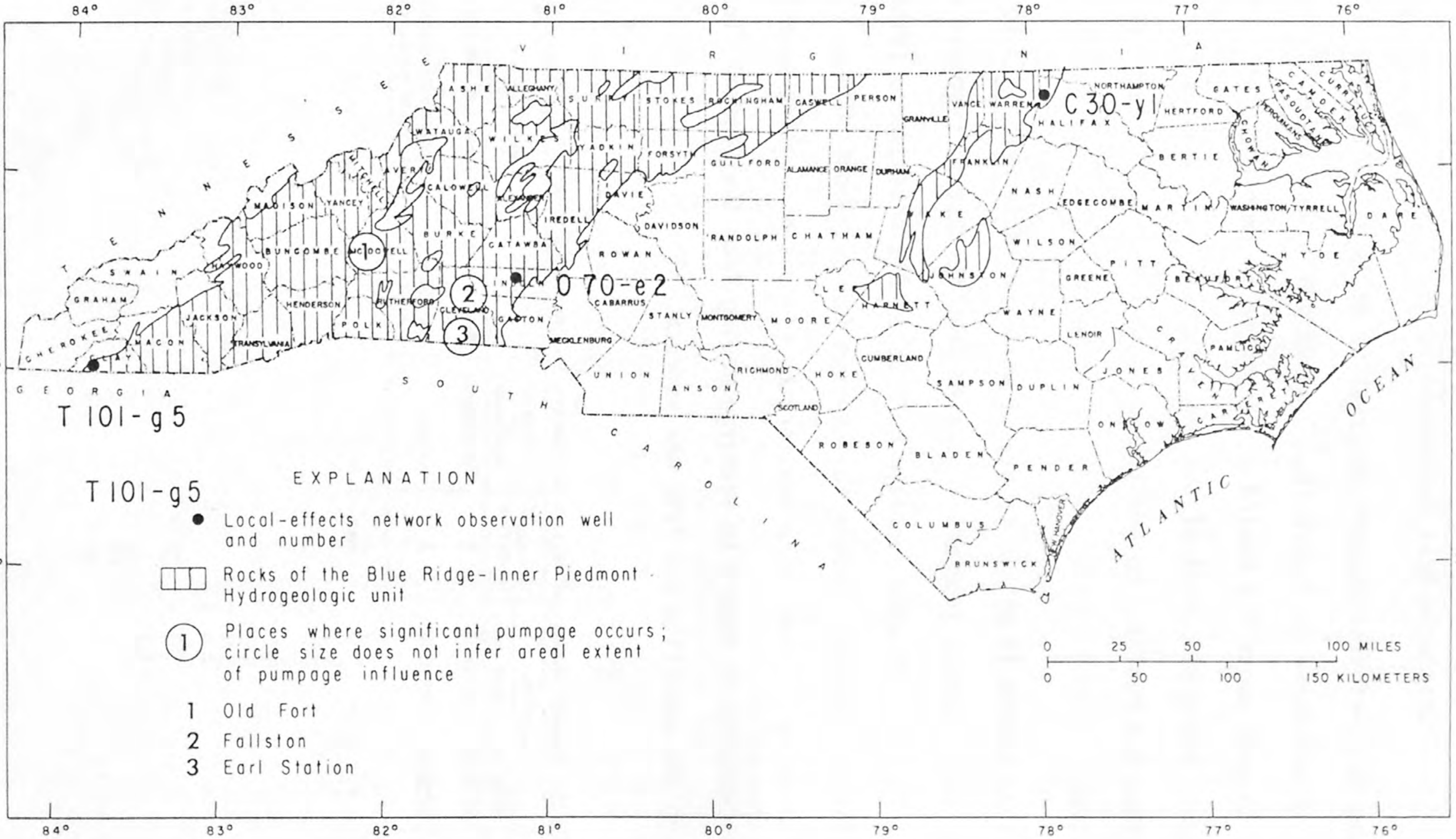

Figure 17.--Proposed observation wells in the Blue Ridge-Inner Piedmont Belt hydrogeologic unit.

Charlotte Belt Hydrogeologic Unit

Two proposed local-effects network observation wells for this unit are listed in table 12 and shown in figure 18. Over 25 public and industrial supplies are known to pump about 3.5 Mgal/d of ground water from rocks of this unit (Winner, 1981, table 8). Most of the water systems report pumpage of generally less than 0.2 Mgal/d. No additional local-effects wells are recommended at this time.

Well M32-j1 at Lucama in Wilson County is worthy of note here because the Town obtains its water supply from wells open to granite that is overlain by saprolite which, in turn, is also overlain by Coastal Plain sediments (Winner, 1976, p. 64). Although water use from this system is only about 50,000 gal/day, it is believed worthwhile to monitor the effects of pumping from the bedrock here, especially in regard to recharge moving from the Coastal Plain sediments through the saprolite and into the bedrock.

Table 12.--Proposed observation wells in the Charlotte Belt hydrogeologic unit

County	Well No.	Location		Network[1/] objective	Frequency of measurement	Comment
		North lat.	West long.			
Rowan	N63-j1	35°33′25″	80°35′15″	L	Continuously	Monitor effects of industrial pumpage at China Grove.
Wilson	M32-j1	35°38′29″	78°00′08″	L	-----do-----	Monitor effects of pumpage from granite buried under Coastal Plain sediments.

1/ L, local-effects network.

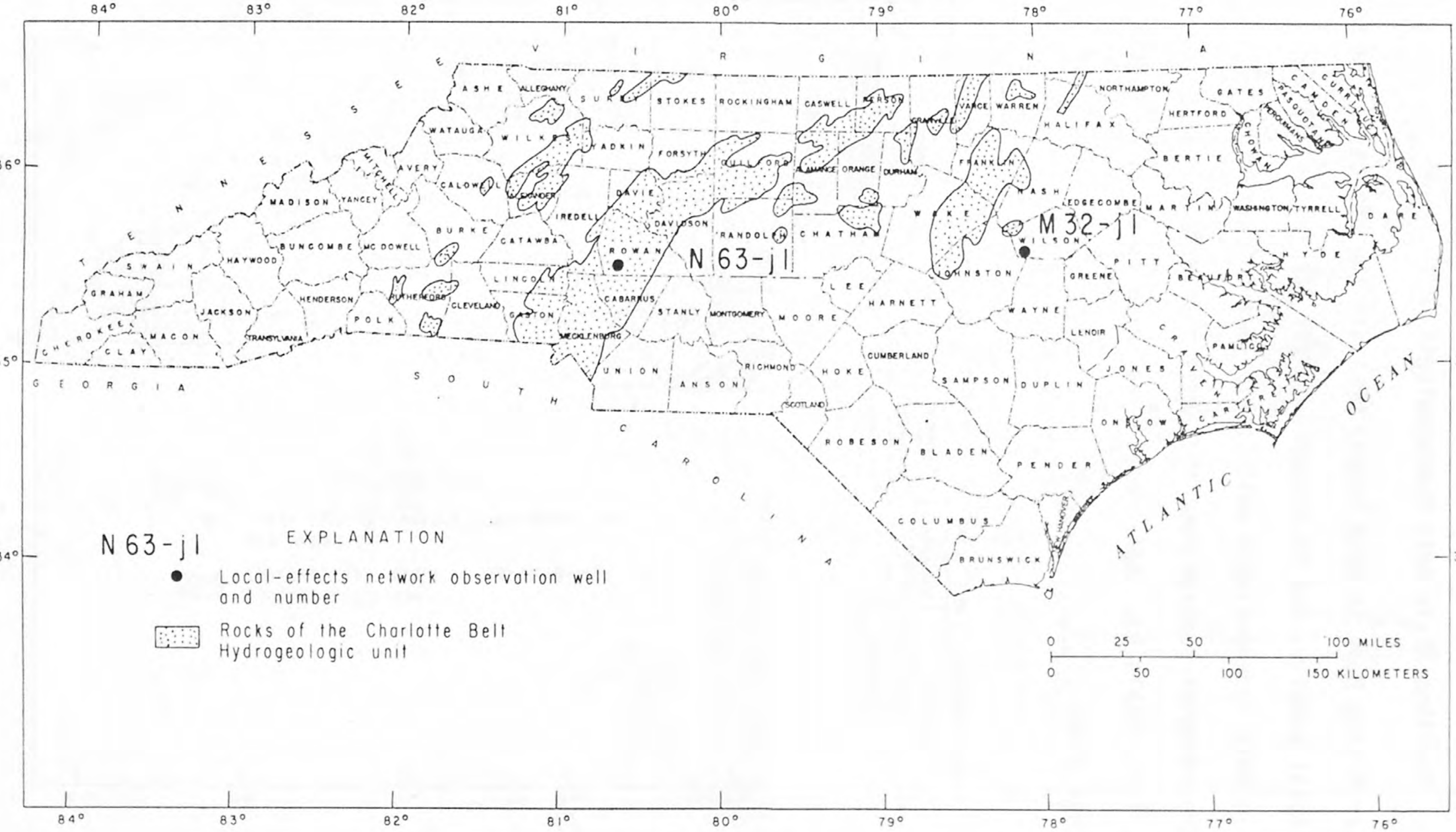

Figure 18.--Proposed observation wells in the Charlotte Belt hydrogeologic unit.

Carolina Slate Belt Hydrogeologic Unit

One well near Spring Hope in Nash County Monitors the effects of up to 0.4 Mgal/d industrial pumpage, and is recommended for the initial local-effects network in this hydrogeologic unit (table 13 and figure 19). The total reported ground-water pumpage from this unit is nearly 5 Mgal/d from 24 sources (Winner, 1981, table 9). Additional local-effects wells are not recommended at this time.

TABLE 13.--PROPOSED OBSERVATION WELL IN THE CAROLINA SLATE BELT HYDROGEOLOGIC UNIT

COUNTY	WELL NO.	LOCATION		NETWORK[1/] OBJECTIVE	FREQUENCY OF MEASUREMENT	COMMENT
		NORTH LAT.	WEST LONG.			
NASH	132-o1	35°57′14″	78°04′18″	L	CONTINUOUSLY	MONITOR EFFECTS OF INDUSTRIAL PUMPAGE.

1/L, LOCAL-EFFECTS NETWORK.

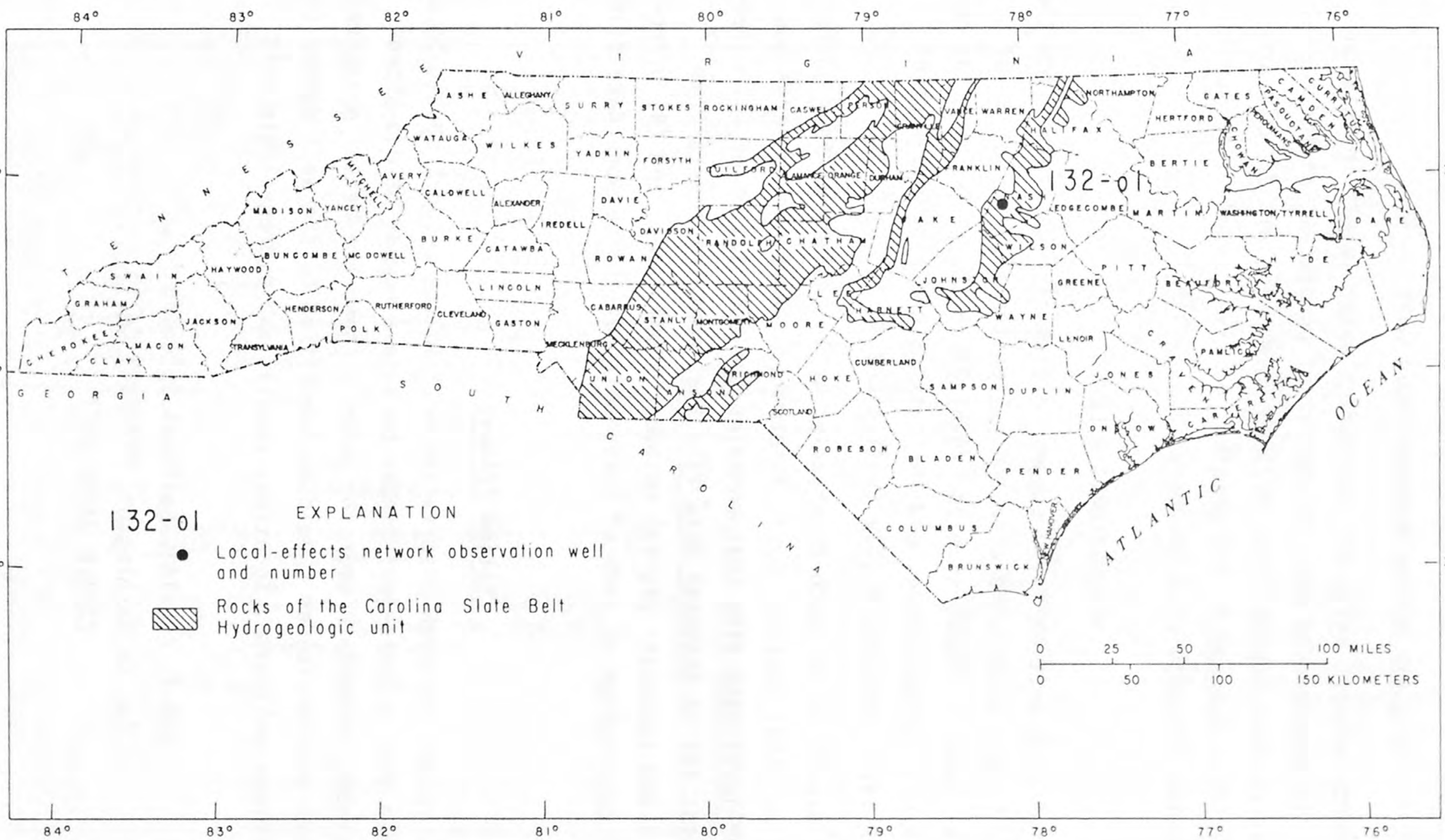

Figure 19.--Proposed observation well in the Carolina Slate Belt hydrogeologic unit.

Triassic Basins Hydrogeologic Unit

No local-effects network wells are monitoring water levels in this unit. However, one well is recommended near the center of pumping at an industrial site near Moncure, Chatham County (fig. 20), where average withdrawals are about 0.2 Mgal/d. This pumpage is the greatest of five ground-water supplies taking water from the Triassic unit (Winner, 1981, table 10).

NETWORK DATA FILE

The purpose of this section is to suggest a plan of organization for the records generated by and associated with the collection and evaluation of ground-water level data. Without such an organization the proper evaluation of the network is nearly impossible, and the task of checking and sorting publishable water levels becomes highly inefficient.

The network data file for each observation well consists of four units: (1) a station folder that contains basic information about each observation well; (2) a water-level data file that contains the compilation of all water-level measurements; (3) an original data file that contains charts from graphic recorders and automatic digital recorder (ADR) tapes; and (4) hydrographs. A brief description of each of these units of the network data file follows.

Station Folders

The station folder for each observation well in the network should be a file folder rather than a loose-leaf binder because a number of odd-sized notes and photographs accumulate over the years. These are better preserved in a folder. Each station folder should be identified by the well number (or numbers), an informal well name, location, county, and hydrogeologic unit. For example:

N20-f1 (NC-14)--National Spinning
Co. in Washington, BEAUFORT Co.
CASTLE HAYNE UNIT

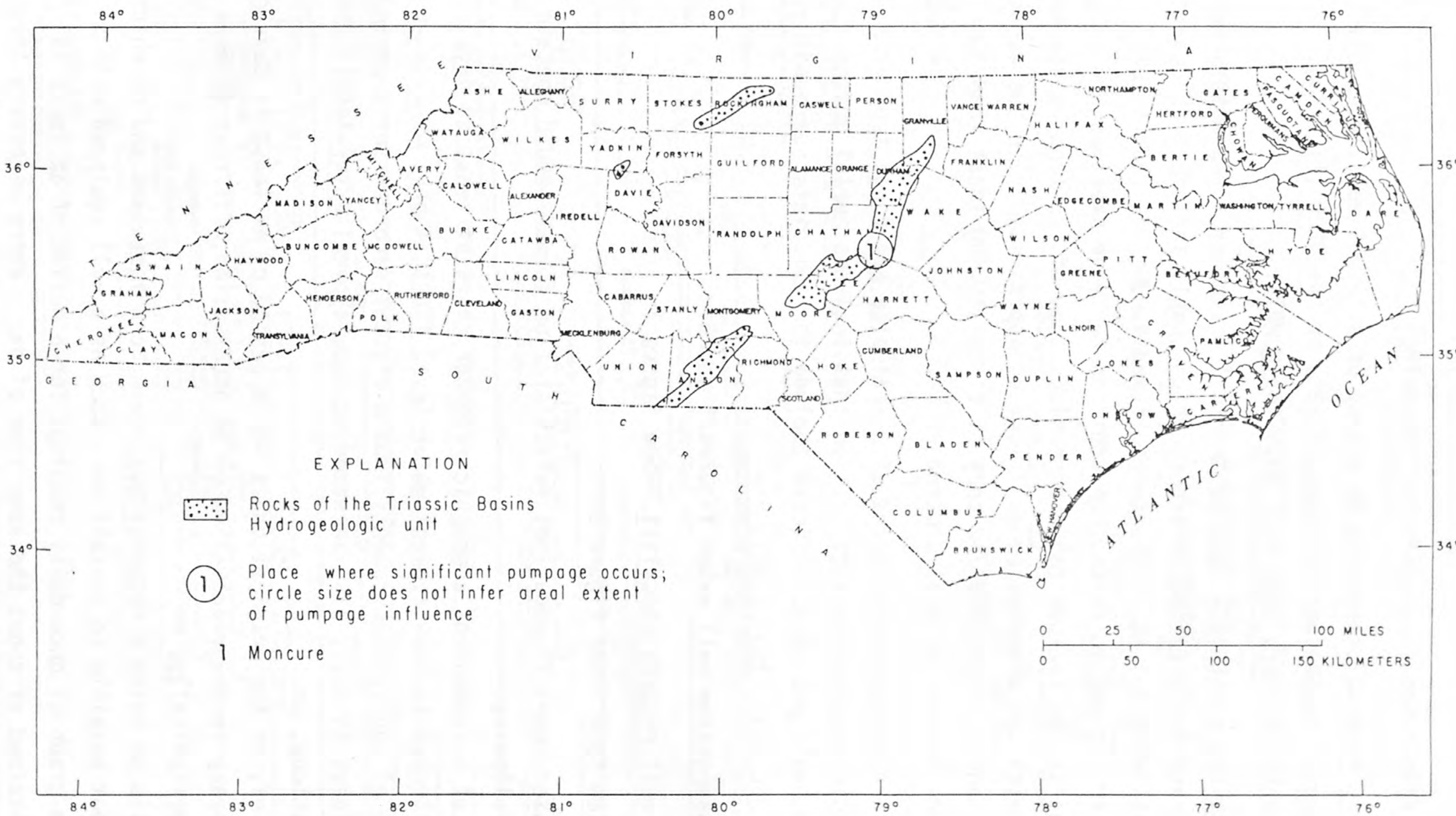

Figure 20.--Proposed location for a local-effects network observation well in the Triassic Basins hydrogeologic unit.

The station folder should contain the following:

1. <u>Well inventory form</u>.--This should be a copy of a formal well inventory form such as used by the Survey (figs. 21-24) or the NRCD (Fig. 25). These provide the primary source of data for a well.

2. <u>Location maps and sketches</u>.--Each of the well inventory forms described above have space for detailed sketches, which should include a sketch of the well, measuring points, distances to fixed landmarks, road intersections, bridges, and so forth. In addition to these sketches other location maps should include (a) a page-sized copy of the topographic map of the area with the observation well located approximately in the center of the page; and (b) a page-sized copy of a map showing local road numbers with the observation well plotted on it.

3. <u>Photographs</u>.--A photographic record of a well site can range from a simple polaroid snapshot to a collection that includes aerial photography. The basic photographs should include the immediate surroundings of the well and measuring points.

4. <u>Record of observation well</u>.--See figures 5 and 6.

5. <u>Observation-well records checklist</u>.--See figure 7.

6. <u>Network review form</u>.--See figure 8.

7. <u>Graphs of water-level fluctuations</u>.--Each station folder should contain <u>one</u> of the following:
   a. A copy of a segment of a graphic recorder chart at least 30 days long selected to show typical water-level fluctuations, or
   b. A graph of hourly measurements from a digital recorder for a period of at least 14 days, also selected to show typical water-level fluctuations, or
   c. A copy of, or the original chart for a period of at least 14 days of a temporary recorder installed on an observation well that is measured periodically, or
   d. For wells on which a recorder has never been installed and on which it is not possible to install one--such as a well equipped with a pump--a graph of once-daily readings for a period of at least 14 days obtained at about the same time of day. Where necessary these measurements can be obtained by an observer.

U.S. DEPT. OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SITE SCHEDULE

Recorded by ____________ Date ____________

Check One ____ English ____ Metric Units

GENERAL SITE DATA

Site Ident No [ ] 5 19 | RG Number [R - 0 *] | Transaction [T - A D M V *] add, delete, modify, verified

Site-Type [2 - C D M P T W *] collector, drain, multiple, pond, tunnel or shaft, well | Data Reliability [3 - C U L M *] field checked, unchecked, location not accurate, minimal data | Source Agency [4 - *]

Project No. [5 - *] | District [6 - *] | State [7 - *] | County (or town) ____ [8 - *]

Latitude [9 - *] deg min sec | Longitude [10 - *] deg min sec | Lat-Long Accuracy [11 - S F T M *] sec, 5 sec, 10 sec, Min

Local Number [12 - *] | Land Net Loc. [13 - S T R *] 1/4 1/4 1/4 section, township, range, merid

Location Map [14 - *] | Scale [15 - *]

Altitude [16 - . *] | Method of Measurement [17 - A L M *] altimeter, level, map | Accuracy [18 - *]

Topo Setting [19 - D C E F H K L O P S T U V *] depression, stream channel, dunes, flat, hilltop, sink, swamp, offshore, pediment, hillside, terrace, undulating, valley flat | Hydrologic Unit (OWDC) [20 - *]

Date of First Construction/Completion [21 - / / *] month day year | Use of Site [23 - A D E G H Ø M P R S T U W X Z *] anode, drain, geo-thermal, seismic, heat, reserv., observ-ation, mine, oil or gas, recharge, repress, test, unused, with-drawal, waste, destroyed

Use of Water [24 - A B C D E F H I M N P R S T U Y Z *] air cond., bottling, commercial, dewater, power, fire, domestic, irrigation, medicinal, industrial, public supply, recreation, stock, institution, unused, desal, other

Secondary Water Use [25 - *] | Tertiary Use of Water [26 - *] | Depth of Hole [27 - . *] | Depth of Well [28 - . *] | Source of Depth Data ① [29 - *]

Static Water Level [30 - . *] | Date Measured [31 - / / *] month day year | Source ① [33 - *]

Method of Measurement [34 - A C E G H L M R S T Z *] airline, calibrated airline, estimated, pressure gage, calibrated pressure gage, geophysical logs, manometer, reported, steel tape, electric tape, other

Site Status [37 - D F G H Ø P R S T Z] dry, flowing, nearby flowing, nearby recently flowing, obstruction, pumping, recently pumped, nearby pumping, nearby recently pumped, other

Source of Geohydrologic Data ① [36 - *] | Pump Used [35 - *] no

OWNER IDENTIFICATION

[R - 158 *] [T - A D M *] add, delete, modify | Date of Ownership [159 # / / *] month day year

Name: Last [161 - *] | First [162 - *] | Middle Initial [163 - *]

OTHER SITE IDENTIFICATION NUMBERS

[R - 189 *] [T - A D M *] add, delete, modify | Ident [190 # *] | Assigner [191 - *]

[New Card Same R & T] | ID [190 # *] | Assigner [191 - *]

SITE VISIT DATA

[R - 186 *] [T - A D M *] add, delete, modify | Date of Visit [187 # / / *] month day year | Name of Person [188 - *]

FIELD WATER QUALITY MEASUREMENTS

[R - 192 *] [T - A D M *] add, delete, modify | Date [193 # / / *] month day year | Geohydrologic Unit [195 # *]

[New Card Same R thru 195]

Temperature [196 # 0 0 0 1 0 *] | Degrees C [197 - . *]

Conductance [196 # 0 0 0 9 5 *] | μ Mhos [197 - . *]

Other (STORET) Parameter [196 # *] | Value [197 - . *]

Other (STORET) Parameter [196 # *] | Value [197 - . *]

FOOT NOTES:

① Source of Data Codes:

[S D O A R L G Z]
USGS, driller, owner, other gov't, other reported, logs, geologist, other

Figure 21.--U.S. Geological Survey site schedule, page 1.

WELL CONSTRUCTION DATA

R = 58 * | T = A D M * (add, delete, modify) | Entry No 59 # * | Date of Construction Completion 60 = / / * (month day year) | Source of ① Const. Data 64 = *

Name of Contractor/Driller 63 = *

Method of Construction 65 = A B C D H J P R T V W Z *
air-rotary, bored, or angered, cable-tool, dug, hydraulic rotary, jetted, air-percussion, reverse rotary, trenching, driven, drive wash, other

Finish 66 = C F G H Ø P S T W X Z *
porous concrete, gravel w. perf, gravel screen, horizontal gallery, open end, perforated or slotted, screen, sand point, walled, open hole, other

Type of Seal 67 = B C G Z *
bentonite, clay, cement grout, other

Bottom of Seal 68 = *

Method of Development 69 = A B C J N P S Z *
air-lift, bailed, compressed air, jetted, none, other, surged, other pump, pump

Number of Hours in Development 70 = *

Special Treatment During Development 71 = C D E F H M Z *
chemicals, dry ice, explosives, deflocculent, hydrofracturing, mechanical, other

DIMENSIONS OF THE HOLE CONSTRUCTED

R = 72 * | T = A D M * (add, delete, modify) | Construction Entry No 59 # *

New Card for Each Hole Segment Same R, T & Field 5 9

Top of Hole Segment Below LSD	Bottom of Hole Segment below LSD	Diameter of Hole Segment
73 # . *	74 = . *	75 = . *
73 # . *	74 = . *	75 = . *
73 # . *	74 = . *	75 = . *
73 # . *	74 = . *	75 = . *
73 # . *	74 = . *	75 = . *

CASING SCHEDULE

R = 76 * | T = A D M * (add, delete, modify) | Construction Entry No 59 # *

New Card for Each Casing With Same R, T & Field 5 9

Top of Casing Segment Below LSD	Bottom of Casing Segment Below LSD	Diameter of Casing Segment	Casing Material ⑤	Thickness of Casing
77 = . *	78 = . *	79 # . *	80 = *	81 = . *
77 = . *	78 = . *	79 # . *	80 = *	81 = . *
77 = . *	78 = . *	79 # . *	80 = *	81 = . *
77 = . *	78 = . *	79 # . *	80 = *	81 = . *
77 = . *	78 = . *	79 # . *	80 = *	81 = . *

OPENINGS SCHEDULE

R = 82 * | T = A D M * (add, delete, modify) | Construction Entry No 59 # *

New Card for Each Open Section With Same R, T and Field 5 9

	(Openings Data)	(Openings Data)	(Openings Data)
Top of Section Below LSD	83 # . *	83 # . *	83 # . *
Bottom of Section Below LSD	84 = . *	84 = . *	84 = . *
Type of Openings ⑥	85 = *	85 = *	85 = *
Type of Material ⑦	86 = *	86 = *	86 = *
Diameter of Open Section	87 = . *	87 = . *	87 = . *
Width of Opening	88 = . *	88 = . *	88 = . *
Length of Opening	89 = . *	89 = . *	89 = . *

FOOT NOTES:

① Source of Data Codes:
S D Ø A R L G Z
USGS, driller, owner, other gov't, other reported, logs, geologist, other

⑤ Casing Material Codes
B C G I M P R S T U W Z
brick, concrete, galv. iron, wrought iron, other metal, PVC or plastic, rock or stone, steel, tile, coated steel, wood, other

⑥ Type of Openings Codes
L M P R S T W X Z
louvered, shuttered, mesh, perforated or slotted, wire-wound, screen (unknown), sand point, walled, open hole, other

⑦ Type of Material Codes for Open Sections
B C G I M P R S T Z
brass or bronze, concrete, galv. iron, wrought iron, other metal, PVC or plastic, stainless steel, steel, tile, other

Figure 22.--U.S. Geological Survey site schedule, page 2.

PRODUCTION DATA

R = 134 146 * (flowing, pumped) | T = A D M * (add, delete, modify) | Entry No 147 # * | Date 148 = / / * (month, day, year)

Discharge 150 = . * | Source of Data ① 151 = *

Method of Measurement 152 = B C E F M O P R T U V W Z *
bailer, current meter, estimated, flume, totaling meter, orifice, pitot-tube meter, reported, trajectory, venturi, volumetric, weir, other

Production Level 153 = . * | Static Level 154 = . * | Source of Data ① 155 = *

Method of Measurement 156 = A C E G H L M R S T Z *
airline, calibrated airline, estimated, pressure gage, calibrated pressure gage, geophysical logs, manometer, reported, steel tape, electric tape, other

Pumping Period 157 = . *

LIFT DATA

R = 42 * | T = A D M * (add, delete, modify) | Type of Lift 43 # A B C J P R S T U Z *
air, bucket, centrifugal, jet, piston, rotary, submergible, turbine, unknown, other

Pump Intake Setting 44 = * | Type of Power 45 = D E G H L N W Z *
diesel, electric, gasoline, hand, LP gas, natural gas, windmill, other

Date 38 = / / * (month, day, year) | Horsepower 46 = . *

MAJOR PUMP DATA (Only one per Type of Lift)

R = 47 * | T = A D M * (add, delete, modify) | Type of Lift 43 # * (See LIFT DATA for legal values of field 43) | Manufacturer of Pump 48 = *

Serial No of Pump 49 = * | Name of Power Company 50 = *

Power Company Account No 51 = * | Power Meter No 52 = * | Pump Rating 53 = . *

Person or Company Who Maintains the Pump 54 = *

STANDBY POWER DATA (Only one per Type of Lift) (See LIFT DATA for codes of fields 43 and 56 below)

R = 55 * | T = A D M * (add, delete, modify) | Type of Lift 43 # * | Type of Power 56 = * | Horsepower 57 = . *

OTHER DATA AVAILABLE

R = 180 * | T = A D M * (add, delete, modify) | Type of Data 181 # * | Location 182 = C D M R Z *
cooperator, district, machine readable, report, other

New Card Same R & T | Type of Data 181 # * | Location 182 = C D M R Z *

AVAILABLE LOG DATA

R = 198 * | T = A D M * (add, delete, modify) | New Card for Each Log Type Same R & T

Type of Log ②	Begin Depth	End Depth	Source of Data ①
199 # *	200 = . *	201 = . *	202 = *
199 # *	200 = . *	201 = . *	202 = *
199 # *	200 = . *	201 = . *	202 = *
199 # *	200 = . *	201 = . *	202 = *

WATER QUALITY DATA COLLECTION

R = 114 * | T = A D M * (add, delete, modify) | Begin Year 115 = * | End Year 116 = * | Source Agency 117 = *

Frequency of Collection ③ 118 = * | Type of Analyses ④ 120 = *

WATER LEVEL DATA COLLECTION

R = 121 * | T = A D M * (add, delete, modify) | Begin Year 122 = * | End Year 123 = * | Source Agency 124 = *

Frequency of Collection ③ 125 = *

WATER PUMPAGE/WITHDRAWAL DATA COLLECTION

R = 127 * | T = A D M * (add, delete, modify) | Begin Year 128 = * | End Year 129 = * | Source Agency 130 = *

Frequency of Collection ③ 131 = * | Method of Collection 133 = C E M Z *
calculated, estimated, metered, other

FOOT NOTES:

① Source of Data Codes:

S D O A R L G Z
USGS, driller, owner, other gov't, other reported, logs, geologist, other

② Type of Log Codes

A B C D E F G H I J K L M N Ø P Q
time, collar, caliper, driller's, electric, fluid conduct, geologist, magnetic, induction, gamma ray, dipmeter, laterlog, microlog, neutron, μ later, photo, radio-active

S T U V Z
sonic, temp, gamma-gamma, fluid velocity, other

③ Frequency of Collection Codes

A B C D F I M Ø O S Z
annual, bi-monthly, continuous, daily, semi-monthly, intermittent, monthly, one time only, quarter annual, semi-annual, other

④ Type of Quality Analyses Codes

A B C D E F G H J K L Z
physical, common chemical, trace elements, pesticides, nutrients, sanitary, codes B&D, codes B&E, codes B&F, codes D&E, codes C,D&E, other

Figure 23.--U.S. Geological Survey site schedule, page 3.

GEOHYDROLOGIC UNIT DESCRIPTIONS

R = 90 * T = A D M * add, delete, modify Depth to Top 91 # . * Depth to Bottom 92 = . *

Unit Identifier 93 = * Lithology 96 = * Lithologic Modifier 97 = *

AQUIFER DATA

R = 94 * T = A D M * add, delete, modify Depth to Top 91 # . *

Date 119 = / / * month day year Water Level 39 = . * % Water Contributed 95 = *

GEOHYDROLOGIC UNIT DESCRIPTIONS

R = 90 * T = A D M * add, delete, modify Depth to Top 91 # . * Depth to Bottom 92 = . *

Unit Identifier 93 = * Lithology 96 = * Lithologic Modifier 97 = *

AQUIFER DATA

R = 94 * T = A D M * add, delete, modify Depth to Top 91 # . *

Date 119 = / / * month day year Water Level 39 = . * % Water Contributed 95 = *

PERTINENT REMARKS

R = 183 * T = A D * add, delete

185 = ' ' *

New Card Same R&T

185 = ' ' *

185 = ' ' *

NOTES:

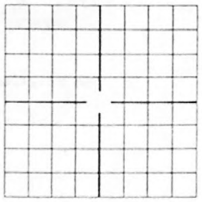

Figure 24.--U.S. Geological Survey site schedule, page 4.

NORTH CAROLINA DEPARTMENT OF NATURAL AND ECONOMIC RESOURCES
DIVISION OF ENVIRONMENTAL MANAGEMENT
GROUNDWATER SECTION
P.O. BOX 27687 - RALEIGH, N.C. 27611

WELL RECORD

DRILLING CONTRACTOR ______ REG. NO. ______ WELL CONSTRUCTION PERMIT NO. ______

1. WELL LOCATION: (Show sketch of the location below)

   Nearest Town: ______ County: ______

   ______ Quadrangle No. ______

   (Road, Community or Subdivision and Lot No.)

2. OWNER: ______
3. ADDRESS: ______
4. TOPOGRAPHY: draw, valley, slope, hilltop, flat (circle one)
5. USE OF WELL: ______ DATE: ______
6. DOES THIS WELL REPLACE AN EXISTING WELL? ______
7. TOTAL DEPTH: ______ RIG TYPE OR METHOD: ______
8. FORMATION SAMPLES COLLECTED: YES ______ NO ______
9. CASING: Depth / Inside Dia. / Wall thick. or weight/ft. / type

   From ___ to ___ ft ___ ___ ___

10. GROUT: Depth / Material / Method

    From ___ to ___ ft ___ ___

11. SCREEN: Depth / Dia. / Type & Opening

    From ___ to ___ ft ___ ___

12. GRAVEL: Depth / Size / Material

    From ___ to ___ ft ___ ___

13. WATER ZONES (depth): ______
14. STATIC WATER LEVEL: ______ ft. above/below top of casing

    Casing is ___ ft. above land surface ELEV: ___

15. YIELD (gpm): ______ METHOD OF TESTING: ______
16. PUMPING WATER LEVEL: ______ ft after ______ hours

    at ______ gpm.

17. CHLORINATION: Type ______ Amount ______
18. WATER QUALITY: ______ TEMPERATURE (°F) ______
19. PERMANENT PUMP: Date Installed ______

    Type ______ Capacity ______ (gpm) HP ______

    Make ______ Intake Depth ______

    Airline Depth ______

DRILLING LOG		
DEPTH FROM	TO	FORMATION DESCRIPTION

If additional space is needed, use back of form

LOCATION SKETCH
(Show distance to numbered roads, or other map reference points)

20. HAS THE OWNER BEEN PROVIDED A COPY OF THIS RECORD AND INFORMED OF THE DEPARTMENTS REQUIREMENTS AND RECOMMENDATIONS? ______
21. REMARKS ______

I do hereby certify that this well was constructed in accordance with N.C. Well Construction Regulations and Standards and that this well record is true and exact.

______
SIGNATURE OF CONTRACTOR OR AGENT DATE

Form GW-1 Revised 10/1/76

Submit one copy to Groundwater Section and one to owner

Figure 25.--North Carolina Department of Natural Resources and Community Development well record.

8. Correspondence and notes.--Copies of all correspondence and other notes relating to the observation well and data obtained from it should be included in the station folder. Examples of this type of material are inter-office memoranda, letters of transmittal of data, letters or notes of special cooperative arrangements, names and addresses of persons who are to routinely receive copies of data, observer contracts, and leveling notes.

Water-Level Data File

This file consists of the final checked results of the water-level measurements. These data are ready for release to the public or to be published in data reports. It is recommended that the water-level data folder be filed with the station folder, and be identified with a label similar to:

WATER-LEVEL DATA FILE
N20-f1 (NC-14) BEAUFORT CO.
1978

Material to be contained in the water-level data file include:

1. Water-level record forms for non-recording observation wells measured periodically similar to those used by the Survey and NRCD (figs. 26 and 27). Where daily or weekly measurements are made by an observer, these could be recorded on a form similar to that used by the Survey (fig. 28).

2. For observation wells that are equipped with recorders, the periodic measurements taken to re-calibrate the instrument should be transcribed to a form similar to figures 26 or 27.

3. The computer printout of hourly water-level measurements recorded with an ADR should be filed as soon as the printout is received from the computer center. At the end of a year, a computer-generated summary table can be produced that shows the mean daily water level in the observation well. This table is also included in the data file.

FORM 9-148

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Report Page No. ____________

WATER RESOURCES DIVISION

COUNTY ______________________ STATE ______________

WATER LEVELS IN OBSERVATION WELLS

Highest water level ______________________ 19 ____ ; lowest ______________________ 19 ____
Records available ______________________ Water level ______________________

Date	Water level	Date	Water level	Date	Water level	Date	Water level

GPO 935799

Figure 26.--U.S. Geological Survey periodic water-level record.

NORTH CAROLINA
DEPARTMENT OF NATURAL AND ECONOMIC RESOURCES
GROUNDWATER SECTION

WATER LEVEL MEASUREMENTS (Office) Well No.: Field______

Project______ Office______

Location: Town______ County______ USGS______

Map______

Owner______ Depth______ft.; Diam.______in.; Yield______gpm

Aquifer______ Screen______ Spec. cap.______

Measuring point______ Elev.______ft. above MSL

Date	Hour	Depth to water	Elev. of W. L.		Date	Hour	Depth to water	Elev. of W. L.	

Form GW-4

Figure 27.--North Carolina Department of Natural Resources and Community Deveopment water-level record.

FORM 9-145

UNITED STATES DEPARTMENT OF THE INTERIOR-GEOLOGICAL SURVEY-WATER RESOURCES DIVISION-GROUND WATER BRANCH

COUNTY ______ **WATER LEVELS IN OBSERVATION WELLS** STATE ______ YEAR ______

Highest water level ______ **19** ____ ; **lowest** ______ **19** ____ ; **Records available** ______

(Daily ______ **water level** ______ **from recorder graph)**

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												

GPO 872-841 **Report Page No.** ______

Figure 28.--U.S. Geological Survey daily water-level record.

Original Data File

This file consists of the field sheets on which the periodic measurements are recorded, the graphic charts from continuous recorders, and the digital tapes from the ADR units. Current records in this file might include graphic charts and digital tapes from about three years, after which they could be put in storage.

1. Field water-level measurements.--This is the form used to record the field water-level measurements, for example, a field form used by the Survey in North Carolina (fig. 29).
2. Graphic recorder charts.--Recorder charts should be folded approximately to page-size for ease in examination, and filed after processing. During the processing of the chart, all notes, dates, calculations, and water levels should be made in pencil on the chart. No marks should be made across the ink trace on the chart. The name of the processor and the date should appear at the end of the chart. Each file folder should be identified by well numbers and date, for example:

   J62-g1 (NC-110)
   1958 WATER-LEVEL CHARTS

3. Digital tapes.--After computer processing, each tape is individually folded without creasing to fit special envelopes. Digital tapes should not be taped or glued together to form continuous record, as this slows the reprocessing effort if it should become necessary. It also is recommended that the tapes not be rolled for storage.

Hydrographs

The hydrograph is one of the end products of the ground-water network data-collection effort and is a key interpretive tool. The following standard procedures are recommended for their preparation and handling:

1. Preparation of hydrographs.--In order to maintain orderly files and to have hydrographs ready for interpretive use or publication, some suggested practices are:
   a. Hydrographs should be prepared on 11x17-inch graph paper with either 1-year or 10-year time scales, and maintained on a current basis.

STATION NAME ______________________ STATION NUMBER ____________

TYPE OF RECORDER ______________

LOCATION OF MP ____

CORRECTION TO LSD OR ELEVATION ______________

Date	Observer	Tape Readings at		Depth to water	Elev. or LSD of WL	Timer No.	Recorder No.	Remarks: List problems, such as timer stopped, float hanging, recorder fast., etc.
		Meas.Pt.	W L					

Figure 29.--U.S. Geological Survey field water-level measurements.

b. All hydrographs should be filed in a flat file, or (preferably) bound in a flat book; the hydrographs should not be rolled or folded.

c. For observation wells that are measured only periodically, only the decade hydrograph need be maintained.

d. For those observation wells equipped with graphic recorders, both an annual and a decade hydrograph should be maintained. Where the water level shows pronounced fluctuations due to nearby pumpage, the annual hydrograph should be plotted from the daily highest and lowest readings.

e. Where ADR units are installed on observation wells the hydrographs should consist of an annual hydrograph of mean daily water levels (or of daily high and low water level where pumping effects are significant), and a decade hydrograph consisting of monthly high and low-measurements.

f. Computer-generated hydrographs from ADR tapes can be produced at any specified scale.

2. Plotting schedule.--A summary of the recommended plotting schedules for the preparation of annual and decade hydrographs is shown in table 14.

Table 14.--Summary of recommended plotting schedules for hydrograph preparation

Data source	Annual hydrograph water levels			Decade hydrograph water levels	
	Noon daily	Mean daily	Daily high-low	Monthly high-low	Monthly or periodic
Periodic measurements					X
Graphic recorders:					
no pumping effects	X			X	
pumping effects			X	X	
Digital recorders:					
no pumping effects		X		X	
pumping effects			X	X	

3. <u>Scales and headings</u>.--Hydrographs are often compared by overlaying them on light tables. It is helpful to have them, insofar as possible, plotted at the same scales and with other identifying data in consistent locations on the graph. Some useful suggestions are:

   a. Annual and decade hydrograph paper is preprinted with the appropriate time scale for each.
   b. The vertical scale of water level should be chosen for each observation well so that the hydrograph should not run beyond the top or bottom margin before the end of the sheet.
   c. The recommended vertical scale should be one of the following: 1 inch (approximately) equals 5 feet, 1 inch equals 1 foot, or 1 inch equals 0.5 foot.
   d. The vertical scale should be labeled on the left margin with the appropriate water level that is measured (noon daily, mean daily, and so forth) above or below land surface datum.
   e. The upper right-hand corner of each hydrograph should contain the well number and year (or years) covered by the measurements.
   f. The upper left-hand corner of the hydrograph should show ownership, location, and county information.

4. <u>Plotting details</u>.--To minimize errors in plotting:

   a. Other than those generated by computer, hydrographs should be prepared using a sharp, black pencil and a straight edge.
   b. Do not use an excessively large dot or open circle when plotting individual points, but rather make a small, pencil-point dot that is dark enough to follow accurately in drawing the straight line connector.
   c. The connecting lines should come up to but not run over the plotted dot, so that the point location is readily discernable.

SUMMARY

The process of reviewing the observation-well network began with an examination of the records of each observation well to determine how accurately the physical data were known. The appropriate hydrogeologic unit (or units) were determined for each well, and their water-level records were scanned. During this process, NRCD hydrologists and technicians in charge of collecting the data lent their first-hand knowledge in discussions about each well, and several forms were devised to keep track of the review notes and discussions.

The observation-well records were then organized by hydrogeologic unit, by county, and by well number, and the wells located on maps of each unit. Network review proceeded on the basis of concepts outlined by Heath (1976) and Winner (1981) wherein the water-level fluctuations in each well are monitored for a specific purpose: effects of climate (climatic-effects network); effects of geology or topography (terrane-effects network); effects of pumping (local-effects network); or the status of ground-water storage (areal-effects network). Other factors such as the review notes and discussions, areal spacing, record duplication, influence of pumping, problems in collecting data, problems in well maintenance, and recommendations of the hydrologists were considered in the final recommendation to retain a well in the observation-well network.

The wells so recommended were used as the basis for an initial Statewide observation-well program using the foregoing concepts. Wells in each hydrogeologic unit are tabulated and areas needing additional coverage are described.

A network data file for each observation well is suggested that consists of four sections, a station folder, a water-level data file, an original data file, and hydrographs. Each of these is discussed relative to the collection, organization, evaluation, and publication of ground-water level data.

REFERENCES

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Metric Conversion Factors

The inch-pound system of units is used in this report. For readers who prefer the International System of Units (SI), the conversion factors for the terms in this report are listed below:

Multiply inch-pound unit	By	To obtain SI unit
	Length	
inches (in)	25.4	millimeters (mm)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
	Area	
square miles (mi^2)	2.590	square kilometers (km^2)
	Flow	
gallons per day (gal/d)	0.044	cubic meters per second (m^3/s)