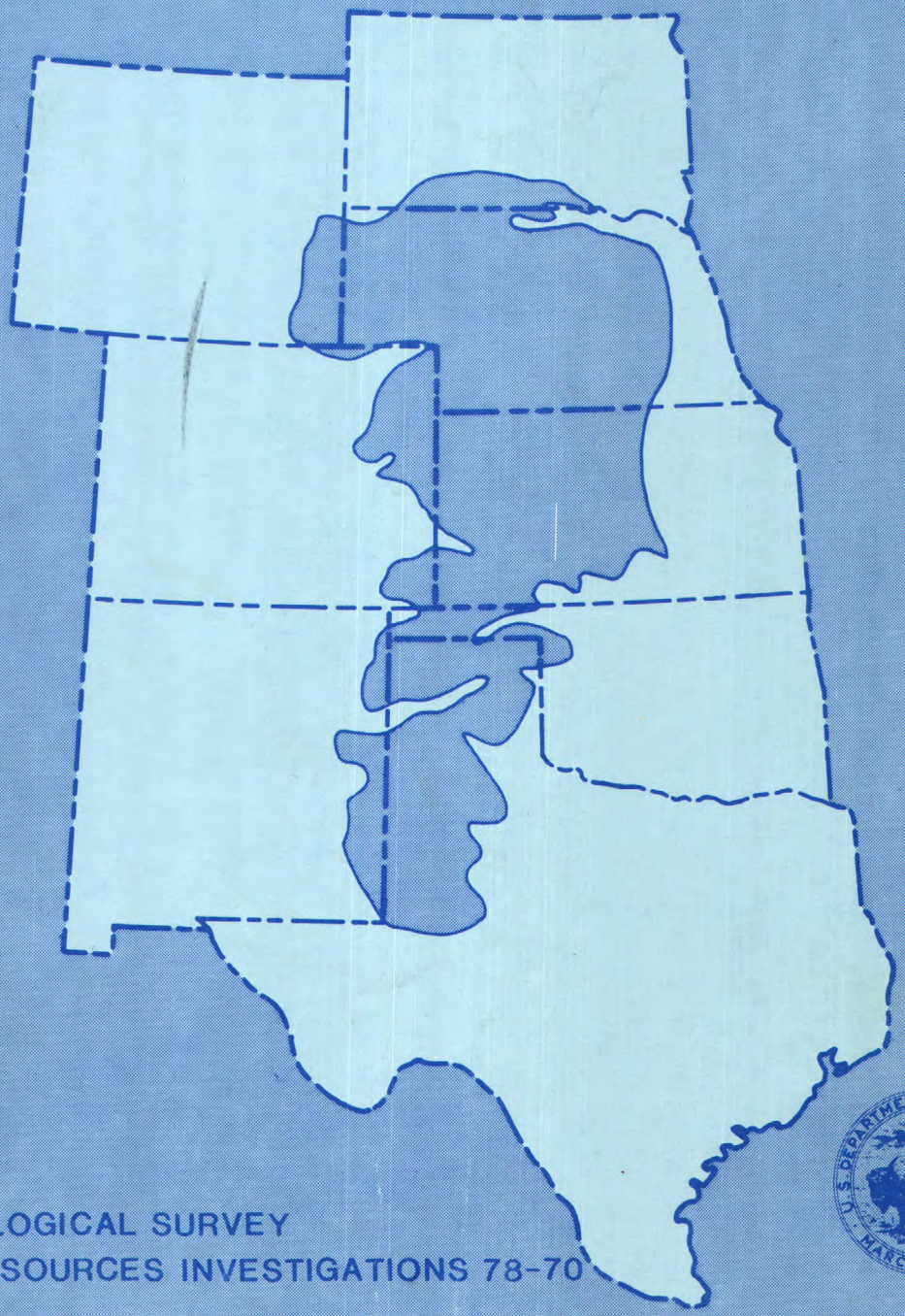
PLAN OF STUDY FOR THE HIGH PLAINS REGIONAL AQUIFER-SYSTEM ANALYSIS IN PARTS OF COLORADO, KANSAS, NEBRASKA, NEW MEXICO, OKLAHOMA, SOUTH DAKOTA, TEXAS, AND WYOMING



U. S. GEOLOGICAL SURVEY
WATER RESOURCES INVESTIGATIONS 78-70

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No.

4. Title and Subtitle: Plan of study for the High Plains Regional Aquifer-System Analysis in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming

5. Report Date: June 1978

6.

7. Author(s): John B. Weeks

8. Performing Organization Rept. No. USGS/WRI 78-70

9. Performing Organization Name and Address:
U.S. Geological Survey, Water Resources Division
Box 25046, Mail Stop 406
Denver Federal Center
Lakewood, Colorado 80225

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address:
U.S. Geological Survey, Water Resources Division
Box 25046, Mail Stop 406
Denver Federal Center
Lakewood, Colorado 80225

13. Type of Report & Period Covered: Planning

14.

15. Supplementary Notes

16. Abstracts: The Ogallala Formation and associated Tertiary and Quarternary deposits form the principal aquifers supporting irrigation in the High Plains of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming. The volume of water in storage within the aquifers is declining in most of the High Plains because water is being withdrawn in excess of the rate of replenishment. The U.S. Geological Survey has initiated a 5-year study of the High Plains aquifer system to develop the geohydrologic data base and computer models of the ground-water flow system needed to evaluate the response of the aquifer system to ground-water management alternatives. This report describes the objectives, plan, and organization of the study and outlines the work to be accomplished in each state in the study area.

17. Key Words and Document Analysis. 17a. Descriptors

*Project planning, *Scheduling, *Ground water, Aquifer management, Computer models.

17b. Identifiers/Open-Ended Terms

High Plains, Ogallala Formation, Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, Wyoming.

17c. COSATI Field/Group

18. Availability Statement: No restriction on distribution

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

21. No. of Pages: 32

22. Price

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PLAN OF STUDY FOR THE HIGH PLAINS REGIONAL AQUIFER-SYSTEM ANALYSIS IN PARTS OF COLORADO, KANSAS, NEBRASKA, NEW MEXICO, OKLAHOMA, SOUTH DAKOTA, TEXAS, AND WYOMING

By John B. Weeks

Water-Resources Investigations 78-70

Denver, Colorado

1978

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

For additional information write to:

Regional Hydrologist
Water Resources Division, Central Region
U.S. Geological Survey
Box 25046, Mail Stop 406
Denver Federal Center
Lakewood, Colorado 80225

CONTENTS

ILLUSTRATIONS

PLAN OF STUDY FOR THE HIGH PLAINS REGIONAL AQUIFER-SYSTEM ANALYSIS IN PARTS OF COLORADO, KANSAS, NEBRASKA, NEW MEXICO, OKLAHOMA, SOUTH DAKOTA, TEXAS, AND WYOMING

By John B. Weeks

ABSTRACT

The Ogallala Formation and associated Tertiary and Quaternary deposits form the principal aquifers supporting irrigation in the High Plains of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming. The volume of water in storage within the aquifers is declining in most of the High Plains because water is being withdrawn in excess of the rate of replenishment. The U.S. Geological Survey has initiated a 5-year study of the High Plains aquifer system to develop the geohydrologic data base and computer models of the ground-water flow system needed to evaluate the response of the aquifer system to ground-water management alternatives. This report describes the objectives, plan, and organization of the study and outlines the work to be accomplished in each state in the study area.

INTRODUCTION

The High Plains is a remnant of a vast eastward-sloping plain developed from deposits of gravel, sand, and silt eroded from the ancestral Rockies. These deposits once covered all the Great Plains region. Erosion of the alluvial deposits reduced the area of the plain and shaped the High Plains region as it is today. The Ogallala Formation of Tertiary age is the principal geologic unit associated with the High Plains. The Ogallala Formation occurs in eight states (Colorado, Kansas, Nebraska, New Mexico, Oklahoma, Texas, South Dakota, and Wyoming) as shown on figure 1.

Problem

The High Plains is a discontinuous upland area of about 156,000 square miles which includes about 23 percent of the irrigated land in the United States. The Ogallala Formation is the principal aquifer underlying the High Plains and the sole source of water in a large part of the High Plains. The aquifer contains on the order of 2 billion acre-feet of water in storage; but over most of the area, water is being withdrawn for irrigation in excess of the rate of natural replenishment. The economic future of the High Plains and the surrounding region is heavily dependent upon the capacity of the aquifer to sustain withdrawals.

Several water-management alternatives have been proposed by various governmental entities, including those to (1) extend the life of the aquifer by artificial recharge, more efficient soil and water-management practices, and limiting annual withdrawal, (2) supplement the water in the region by weather modification and water importation, and (3) allow unrestricted water use. Local, state, and national interests are vitally concerned about the future of the ground-water supply and its impact on the economy of the region.

A comprehensive knowledge of the High Plains aquifer system is needed so that water-management alternatives can be evaluated and the economic life of the aquifer can be projected. To fulfill this need, the U.S. Geological Survey initiated a 5-year study of the High Plains aquifer system in fiscal year 1978 (year ending September 30, 1978). The purpose of this report is to describe the objectives of the study, the work elements to be accomplished, and the organization of the study.

Objectives

In the past, hydrologic studies in the High Plains have stopped at political boundaries. However, water-supply problems that develop in a regional aquifer are regional in scope and not limited by state or county lines. Consequently, a regional investigation of the High Plains aquifer system is needed to integrate previous local studies and develop the means to evaluate regional aquifer response to changes in ground-water development. The High Plains Regional Aquifer-System Analysis project will meet this need. The objectives of the study are to:

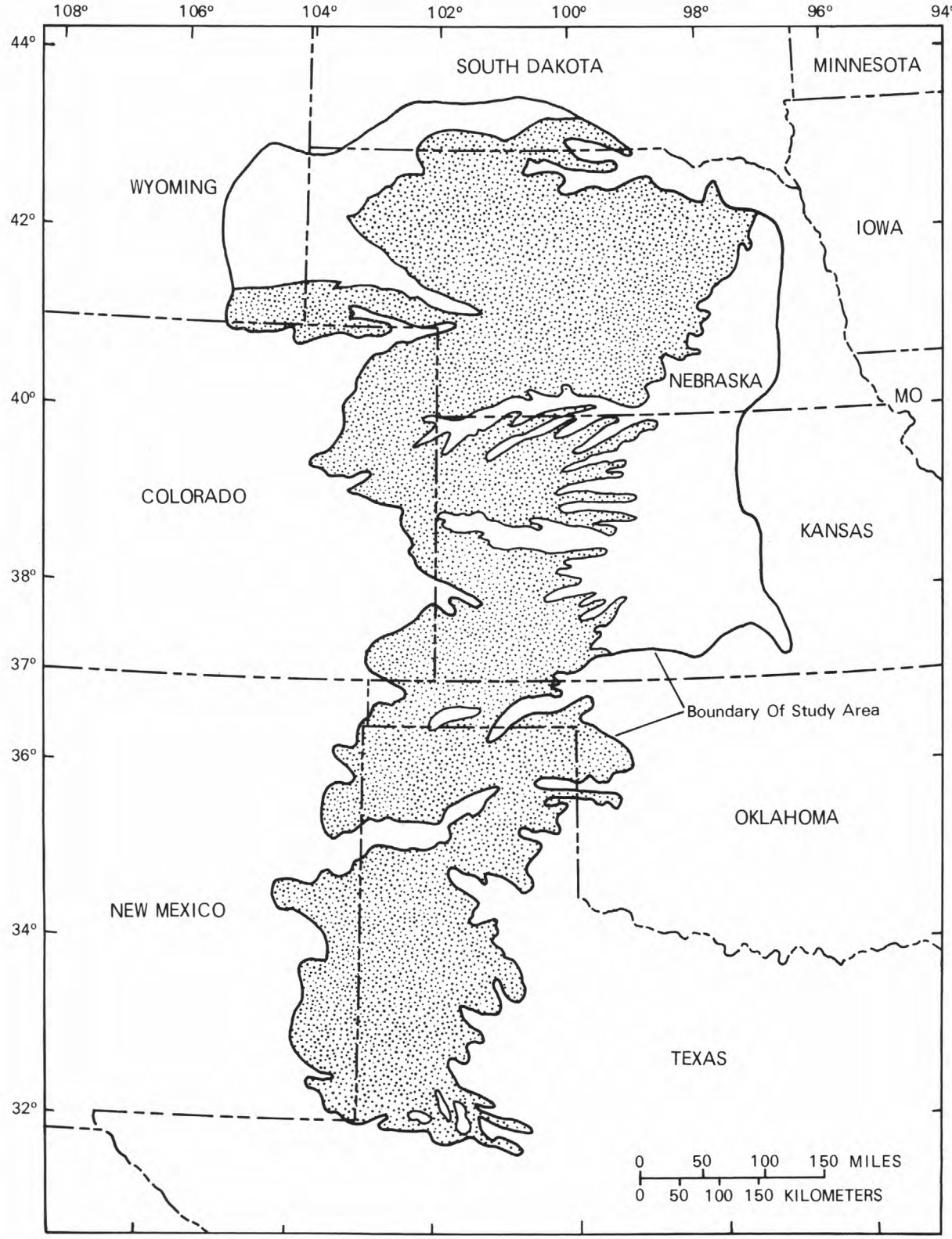


Figure 1.-- Location of study area including the Ogallala Formation.

1. Describe the quantity and quality of the water resource and the operation of the hydrologic system.

2. Develop a regional water-resources (and related) data storage and retrieval system.

3. Develop data-collection networks to monitor future water use, water-quality changes, and water-storage changes.

4. Design and develop digital computer models of the High Plains aquifer system.

5. Evaluate selected ground-water management alternatives to demonstrate the applicability of the models and provide a hydrologic basis for the economic evaluation of management alternatives.

To accomplish the above objectives, hydrologic data will be compiled for the entire High Plains to provide region-wide information for comprehensive analysis. Information from previous studies will be reviewed for deficiencies in the regional coverage of hydrologic parameters that are critical to understanding the hydrology of the High Plains.

Except for specific yield, information on aquifer characteristics--hydraulic conductivity, aquifer thickness, and altitude of the aquifer base--is relatively well known. However, test drilling may be needed in some areas to define the hydrologic parameters and to supplement data on the High Plains aquifer system. Estimates of specific yield range from 0.1 to 0.28, a range that may represent real differences; however, considerable new effort is necessary to produce quantitative values for specific yield on a region-wide basis.

A history of the changes in water levels, discharge, and recharge will be needed for a comprehensive analysis of flow in the system. Water-level changes are well documented; but, ground-water pumpage and recharge are poorly known.

Observation wells have been maintained throughout most of the High Plains for many years. Water-level records from these wells provide a history of the response of the aquifer system to the development of ground-water use. The observation-well network needs to be revised to improve the coverage for the High Plains and to insure that future water-level changes can be monitored.

Records of ground-water pumpage are generally not adequate to describe the distribution and rate of withdrawal. Where data are adequate, pumpage histories can be reconstructed on the basis of such information as numbers and locations of wells, irrigated acreage, crop demand, and energy consumed for pumping water. However, the data are not available to estimate the history of withdrawals for most of the High Plains and a monitoring network is needed to provide information on future rates and distribution of pumping.

Recharge to the aquifer system cannot be directly measured. To estimate recharge, information is needed on water requirements for crops, crop acreages, soil properties, evapotranspiration, precipitation, the effects of land-use practices and irrigation methods on water use, and the quantity of water applied to the land surface by irrigation systems. This information will be used to estimate recharge to the aquifer from applied irrigation water and precipitation.

The hydrologic information outlined above will provide a basis for the design and development of computer models of the aquifer system. The models will be used to project the future availability of water in the High Plains aquifer system under present and future conditions of ground-water withdrawal and land use.

Approach

The objectives of the study will be accomplished through (1) the assembly, compilation, and analysis of existing data, (2) the collection and analysis of data needed to provide information on parameters for which data are lacking, and (3) the development and use of computer models. Data-collection networks will be initiated in those areas where existing networks are inadequate to describe quantitatively the hydrology of the High Plains. The data compiled and collected will become part of a computerized data-management system which will provide a hydrologic (and related) data file for the entire High Plains region.

The primary product of this project will be computer models of the High Plains aquifer system capable of predicting the future state of the aquifer system given knowledge of the future stress. It is intended that these models will become a ground-water management tool to aid regional, state, and local planners in assessing the impact of management alternatives on the hydrologic and economic future of the aquifer system. The models will be developed and tested during this study and used to demonstrate the applicability of the models and evaluate selected ground-water management alternatives.

PLAN OF STUDY

The High Plains Regional Aquifer-System Analysis project area will include the Ogallala Formation as well as associated sediments that are in hydraulic connection with the Ogallala aquifer. The associated sediments include Tertiary age deposits in western Nebraska, southern South Dakota, and southeastern Wyoming (fig. 1), as well as Quaternary deposits overlying and adjacent to the Ogallala Formation in Kansas and Nebraska. Cretaceous and older rocks underlying the study area will not be studied in detail during this investigation. The Cretaceous and older rocks in contact with the Ogallala Formation will be studied only to determine the hydraulic relationship between the rocks across the contact. This information is needed to define the boundaries for the computer models of ground-water flow.

The study will begin in fiscal year 1978 and conclude at the end of fiscal year 1982. The work units to be accomplished during the 5-year study are outlined below.

A. Planning and staffing

1. Prepare detailed work plans in coordination with U.S. Geological Survey District offices in the High Plains

2. Assemble staff

B. Review and compile existing data on

1. Aquifer boundaries

a. Areal extent
b. Aquifer thickness
c. Geologic controls

2. Ground-water occurrence and movement

a. Saturated thickness
b. Water-level histories
c. Historical potentiometric maps

3. Aquifer properties

a. Hydraulic conductivity
b. Specific yield

4. Ground-water discharge and recharge

a. Pumpage from wells
b. Discharge to streams and springs
c. Recharge from streams and precipitation
d. Artificial recharge
e. Recharge from applied irrigation water
f. Recharge from and discharge to other aquifers

5. Water quality

a. Concentration histories of principal constituents
b. Concentration of minor constituents
c. Areas of chemical contamination
d. Waste-water disposal sites

6. Other data

a. Irrigated acreage and crops
b. Nonirrigated acreage and crops
c. Natural vegetation acreage and type
d. Soil type
e. Climatic data

C. Design computerized data-management system for storage and retrieval of data

1. Determine project data-storage and retrieval requirements
2. Review existing data-storage and retrieval systems
3. Develop, adapt, and revise data-management system for the High Plains

D. Evaluate adequacy of existing data for modeling and store in computer

1. Regionalize data for use in models
2. Code and enter in computer file
3. Determine additional data needs

E. Review, revise, design, and operate data collection networks

1. Water-level change
2. Ground-water pumpage
3. Water-quality change

F. Design and initiate special investigations to quantify data deficiencies such as

1. Aquifer boundaries

    a. Areal extent
    b. Aquifer thickness
    c. Geologic controls

2. Aquifer properties

    a. Hydraulic conductivity
    b. Specific yield

3. Ground-water discharge and recharge

    a. Pumpage from wells
    b. Stream-aquifer relations
    c. Natural recharge and discharge
    d. Recharge from applied irrigation water

G. Develop computer models of the aquifer system

1. Develop conceptual model of aquifer system
2. Test conceptualization of aquifer system
3. Calibrate with historical data where possible
4. Simulate response to management alternatives

H. Develop management alternatives

1. Determine institutional and economic controls
2. Formulate appropriate management alternatives
3. Determine formulas for relating model output to economics

I. Preparation of reports

1. Work plan report
2. Descriptive geohydrologic map reports
3. Special studies reports
4. Regional and local computer model reports
5. Model documentation reports

A schedule for the completion of the principal work units outlined above is shown on figure 2.

The plan of study and the schedule shown on figure 2 may require revision during the course of this study. Until the review and compilation of existing data are completed, it will not be possible to completely assess the need for additional data or special investigations.

Planning and Staffing

The manpower requirements for the High Plains study have been determined. The project staff will be assembled during the first year of the study. A general work plan (this report) will be developed which will establish the overall objectives of the study and the general approach to meet those objectives. Detailed work plans will be prepared for that part of the work to be accomplished in each state.

Compilation of Data

Existing data will be reviewed and compiled from published reports and the files of the U.S. Geological Survey and other Federal and state agencies during the first 2 years of the study. The data will be coded and prepared for computer storage. Specifically, the data will be reviewed to determine whether existing data are adequate to describe the aquifer boundaries, ground-water occurrence and movement, aquifer properties, ground-water recharge and discharge, and water quality as listed in the preceding outline of the study plan.

Data-Management System

A data-management system for computer storage and retrieval of data will be developed during the first 2 years of this study. The purpose of the computerized data file is twofold. First, the data file will provide all input data necessary for the development of a regional model of ground-water flow in the High Plains aquifer system. Second, the data file will provide all users with hydrologic and related data at a scale suitable for local

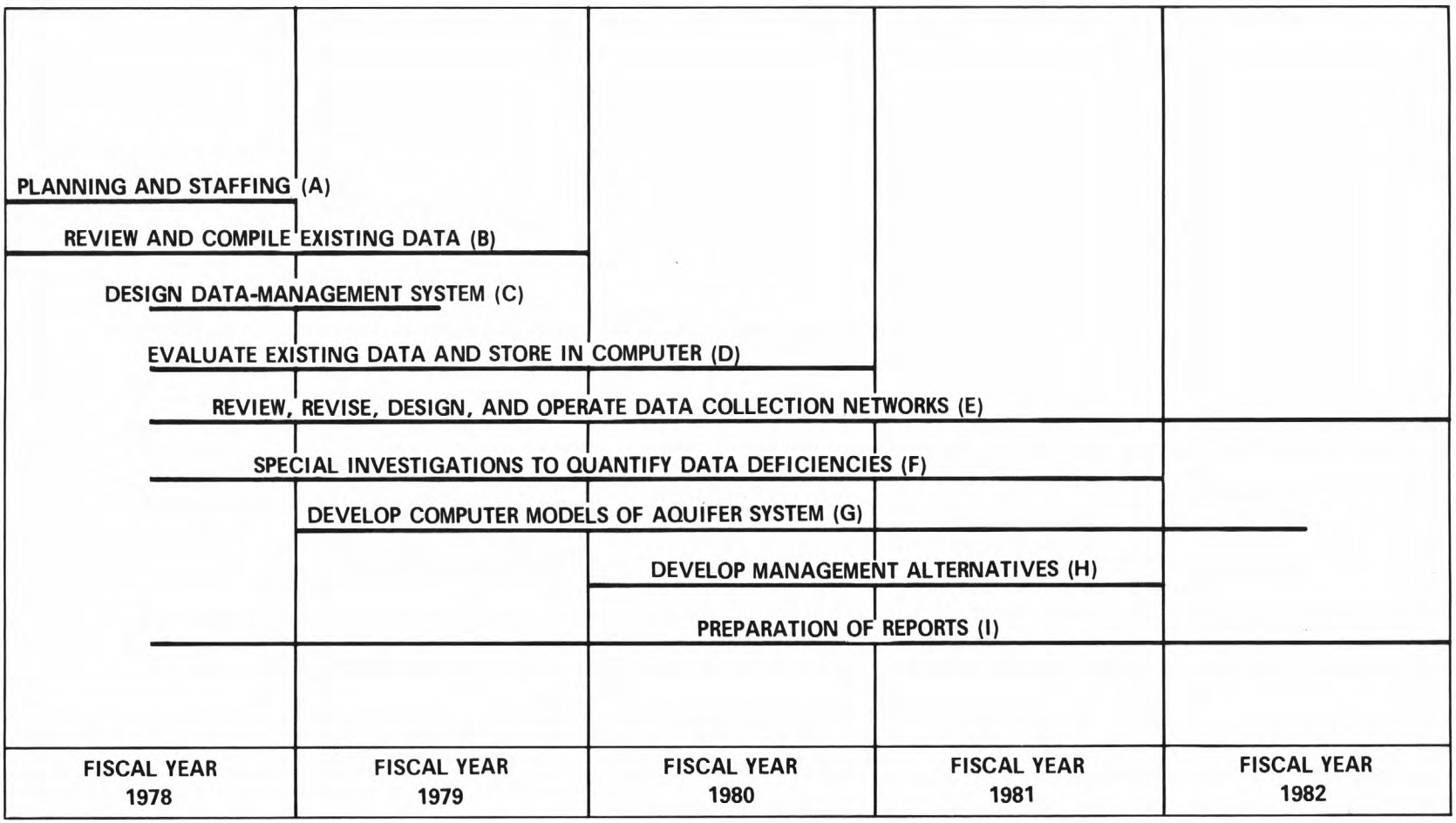


Figure 2.-- Schedule of principal work units for the High Plains aquifer study.
Letters in parentheses refer to outline headings in the text.

interpretation and modeling. The data file will be maintained on the U.S. Geological Survey computer system to provide maximum accessibility to the file. It is intended that the data file will be periodically updated and maintained beyond the life of this High Plains aquifer study for water-resource management purposes.

Evaluate Existing Data

The data compiled will be reviewed to determine the adequacy of the data to describe the regional and historical variations of the parameters needed for modeling. Data deficiencies in both areal and historical coverage will be identified. Where adequate data are available, the data will be mapped to show the regional variations in the values of the parameters which characterize the aquifer system and the regionalized data will be coded and stored in the data file. The compilation and evaluation of existing data will be completed during the first 3 years of the study. Special investigations will be initiated in those areas where additional data are needed. As additional data become available, the data will be stored in the data file.

Data Collection Networks

Water-level, pumpage, and water-quality records are the primary data sets for which historical data are needed. It is anticipated that water-level records are generally adequate to describe the historical water-level changes in the High Plains aquifer. However, it is expected that adequate data are not available to describe historical pumpage or water-quality changes for the aquifer. Existing data-collection networks for monitoring water levels, pumpage, and water quality will be reviewed, revised, and expanded as necessary to provide an accurate and extensive data base for the future. Particular emphasis will be placed on developing a monitoring network for determining annual pumpage.

The data-collection networks will provide the information needed to monitor response of the aquifer system to future stresses from pumpage. The networks will also provide the means for obtaining the data needed to evaluate the effectiveness of ground-water management plans initiated in the future. In addition, the networks will provide the data needed to check the response of the aquifer system calculated by the computer models and, if necessary, to revise the models to improve their predictive capabilities. The data-collection networks devised to provide the data needed for monitoring response should be continued beyond the life of this 5-year study.

Special Investigations

Information for several of the hydrologic variables needed for modeling is not available in adequate detail to define their regional and (or) historical variations. This is particularly true of recharge, pumpage, and specific-yield data. For these and other variables where data are sparse or nonexistent, special investigations will be planned and executed to develop the necessary data or estimation techniques to regionalize the data.

Ground-water recharge from precipitation and applied irrigation water cannot be directly measured and will have to be determined indirectly utilizing information on crops, irrigated and nonirrigated acreage, consumptive use, irrigation pumpage, evaporation rates, and soils. Ground-water pumpage cannot be completely monitored and will have to be estimated using statistical sampling and extrapolation techniques.

Ground-water discharge to (or recharge from) perennial streams can be determined from existing streamflow records. However, ground-water recharge from ephemeral streams will have to be estimated on the basis of miscellaneous measurements and indirect methods, such as channel geometry.

Data on the regional and vertical variation of specific yield are not available and will have to be developed during this study. Several methods for estimating specific yield will be studied by this project. The methods will include both field and computer model studies.

In parts of the High Plains, test drilling may be required to determine aquifer thickness, lithology, and hydraulic properties. It is expected that test drilling will be conducted in the sand hills of Nebraska, and possibly in parts of Kansas, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming. Also, test holes may be drilled where special studies are conducted on the variation of aquifer properties.

Computer Models

The computer models of the High Plains aquifer system will consist of a large-scale regional model of the entire system and several subsystem models for the evaluation of small-scale local response. The models will simulate flow in the Ogallala aquifer and provide a ground-water management tool capable of evaluating regional as well as local response to management alternatives.

Existing data will not be adequate to describe historical pumpage and recharge variations needed for the development of a regional model. Therefore, data collection networks established during this study will have to provide an adequate data base from which annual pumpage and recharge, as well as water-level changes, can be determined. A preliminary model of the regional aquifer system will be developed from existing data and refined as additional data are collected. It may be possible to partly calibrate the model if adequate data on annual pumpage and recharge can be developed during this study. Final calibration and verification of the regional model will have to be based on future measured stress and response.

Adequate data on historical stress and response may be available for simulation of the aquifer history in local areas of the High Plains. If adequate historical data are available, the subsystem models can be calibrated by simulating local history and used to test the accuracy of the response calculated by the regional model.

The areas for which local models are developed will depend on the amount of pumping stress, the availability of geohydrologic data, and the adequacy of previous studies. Computer models of ground-water flow have been developed for parts of the study area in Colorado, Nebraska, Oklahoma, and Wyoming. These models will greatly aid in the expansion of existing models and the development of models for other areas of the High Plains.

It is intended that the output of the computer models will be translated through functional relationships into terms suitable for economic evaluation. For example, water levels can be related to pumping lift or the volume of water in storage can be related to the volume of a particular crop which can be grown by using the water for irrigation. The models are intended to provide response to proposed ground-water management alternatives in terms which can readily be used for economic evaluation of the management alternatives.

The computer models will be used to simulate selected ground-water management alternatives. The management alternatives will be formulated in consultation with other Federal and state agencies. Appropriate management alternatives will be simulated to assess their impact on the ground-water supply and demonstrate the use of the models as tools to aid decision making. It is anticipated that two or three management alternatives will be analyzed during this study. However, the models will be available to analyze other management alternatives in the future.

Reports

During the first year of the study, a report on the plan of study (this report) will be prepared. During the second, third, and fourth years of the study, the regional geohydrologic system will be described in a series of 1:1,000,000 map reports which may include the following:

1. Areal extent and boundaries of the High Plains aquifer system
2. Altitude of the base of the aquifer system
3. Saturated thickness of the aquifer system
4. Altitude of the potentiometric surface of the aquifer system for two or more dates
5. Historical water-level changes
6. Rate of water-level decline
7. Aquifer-system parameters

The results of the computer-model study of the High Plains aquifer system will be published during the last year of the study to document the investigation, present a general description of the computer models, discuss the simulation of ground-water management alternatives, and present the conclusions of the study. In addition, reports documenting the computer models, including the programs and their use, will be published at the conclusion of this study.

ORGANIZATION OF STUDY

The High Plains Regional Aquifer-System Analysis project will be headquartered in Denver, Colo., at the offices of the Central Region of the Water Resources Division, U.S. Geological Survey. Separate but interrelated and integrated projects will be formally established in each Water Resources Division District (state) in the study area. Each of these District projects will be funded as part of the High Plains Regional Aquifer-System Analysis project.

The District projects will be responsible for the development and regionalization of the data in that part of the study area within the District. Existing information will be used to regionalize the data where possible. However, where adequate data are not available, investigations will be made by the District projects to develop the necessary data or regionalization techniques. The District projects will be responsible for preparation of the data for storage in the data-management system and the development of small-scale local models of the aquifer system.

The Central Region project staff will be responsible for the design and development of the data-management system and the regional ground-water flow model. The data-management system will be designed so that all Districts have direct access to the data file. The District projects will enter their data into the file from the District. The Central Region project staff will retrieve and review the data and provide quality-control feedback as well as technical support to the District projects developing the hydrologic data and local models for the High Plains.

Relation To Other Studies

State agencies, responsible for the management and regulation of ground-water development in their respective states, have maintained a history of cooperation with the U.S. Geological Survey. Their participation and support has been instrumental in the conduct of previous studies and the acquisition of hydrologic data. The cooperation of these state agencies is gratefully acknowledged. The need for hydrologic information on the High Plains aquifer system by other agencies must be considered and, wherever possible, this study plan will be revised to accommodate those needs.

Currently two other Federal agencies are conducting regional studies in the High Plains. Specifically, the U.S. Department of Commerce, Economic Development Administration (EDA), has initiated a study of the impact of declining ground-water supplies in the High Plains on the Nation's agribusiness. One of the objectives of the EDA study is to determine potential agricultural-development alternatives for the High Plains. The EDA study was initially funded in fiscal year 1977 and the final report is scheduled for July 1, 1980, although the date for the final report may be extended. In addition, the U.S. Bureau of Reclamation (USBR) has started a water-management study of the High Plains south of the Arkansas River. One of the objectives of the USBR study is to evaluate the most economical and beneficial use of the water supplies in playa lakes. The USBR study began in fiscal year 1977 and the study is scheduled for completion in fiscal year 1981.

Both the EDA and USBR studies will require hydrologic information on the High Plains aquifer system which will be developed during the High Plains Regional Aquifer-System Analysis project. Close coordination with the EDA and USBR studies will be maintained to determine their needs for information and prevent duplication of effort. Ground-water management alternatives selected for model simulation will be consistent with those developed by the EDA and USBR studies.

DISTRICT WORK PLANS

Each Water Resources Division District will execute the plan of study and perform the necessary work in that part of the study area in its state. Because of differences in the amount of available data and in the comprehensiveness of previous studies, the approach to this study will vary between the Districts (states). For example, several Districts have conducted previous model studies of the Ogallala aquifer. For those Districts, the data needed for modeling have been compiled for much of the study area. In those Districts where model studies have not been made, a much larger effort will be required to compile and evaluate data and develop local models of the aquifer system. The following sections outline the work plans for each of the Districts in the study area. The schedule for the completion of work items by each District project is the same as that shown on figure 2.

Colorado

The study will include field collection and update of basic data such as well inventory, water-level measurements, withdrawal data, and water-quality sampling, and the preparation of maps showing hydrogeologic characteristics of the aquifer system. Stress data will be compiled and presented as appropriate. Special emphasis will be given to evaluating specific yield and ground-water withdrawal estimates. Existing models will be expanded to include the entire High Plains area in Colorado.

Cooperation will be maintained with State and local agencies to provide information and data they have available. Data collection and interpretation will be coordinated with adjacent District offices to insure technical compatibility between adjacent states.

Data Collection and Analysis

Existing data for the Colorado District are in both report form and digital computer storage. These data include well inventory, water-level data, and water-quality analyses. These data will be compiled and examined for consistency and accuracy. In addition, the data will be field checked and updated. There are about 1,200 large-capacity wells which have been installed since the last well inventory in the High Plains of Colorado.

Field data collection will consist of well inventory, water-level measurements, and water-quality samples. As applicable, streamflow measurements will be made to determine the relationship between ground water and surface

water. Special studies will be directed toward determining ground-water withdrawals and specific yield of the aquifer and developing the data needed to estimate recharge.

Data analysis will consist of the preparation of maps showing the hydrogeologic characteristics of the aquifer, and calculation and compilation of stresses affecting the system. The maps will include lithology, bedrock contour, water-table contour, saturated thickness, hydraulic conductivity, and well locations. Compilation of hydrologic stresses may be either tabulated or on maps, whichever is appropriate.

Special Investigations

Special studies will include estimating ground-water withdrawals, estimates by indirect methods of percolation losses and recharge from both precipitation and irrigation water, and the specific yield of the aquifer.

Ground-water withdrawal by wells can be determined in the absence of metering by measuring the rate and duration of discharge. Frequently, the duration of operation can be determined from energy consumption data. This method is costly in terms of manpower requirements, and it may be necessary to use statistical sampling techniques whereby a few wells are monitored for ground-water withdrawal and the pumpage per well extrapolated to the total number of wells.

The recharge rates from irrigation water and precipitation will be estimated using information on soil type, crop demand, climatic data, and irrigation practices.

Specific yield may be determined in one or more of several different ways. Aquifer testing using a pumping well and observation wells is perhaps the most common method. However, this method is costly and may give poor results during a realistic time frame because of anisotropy of the formation and delayed yield from storage. Another method is to monitor both ground-water withdrawal and change in water level in a particular area, and calculate the specific yield from the volume of water pumped divided by the volume of dewatering. This method assumes that the volume of recharge is known. A third method is collection of undisturbed samples of aquifer material for laboratory analysis of specific yield. This method can be done independently or in conjunction with neutron logging above the water table to determine specific yield from changes in moisture content versus water-level changes. This last method has perhaps the best transfer value. As appropriate, the specific yield will be determined by the methods described above and categorized according to lithology. Lithologic maps will then be used to describe the spatial distribution of specific yield.

Computer Models

The study will include the construction of a digital ground-water flow model which will be used as a tool in data analysis and for predicting the long-range effects of alternative management options. Calibration of the models will be limited to those areas of the High Plains of Colorado where

adequate data are available. The criteria for calibration will be duplication of changes in ground-water levels and, where applicable, the diminution of streamflow.

Three ground-water flow models have been constructed for parts of the Northern High Plains of Colorado. These models will be updated and revised on the basis of data collected during this study. The models will be used to test the sensitivity of output results to various changes and combinations of changes in the input data. The sensitivity analysis of model parameters will be used as a guide to the definition of data requirements and to provide limits on the reliability of the output.

Reports

The proposed study will result in basic-data releases, map reports on the hydrogeologic characteristics of the aquifer, and book reports on the hydrology and modeling efforts. Data and interpretations will be coordinated with the overall Ogallala Regional Aquifer-System Analysis project for format and compatibility.

Kansas

The Ogallala aquifer is the primary source of irrigation and municipal water in western Kansas. Severe water-level declines in the aquifer have resulted from large-scale development of the ground-water resource. The study of the High Plains in Kansas will develop a detailed data base for the Ogallala aquifer which will improve the definition of the hydrologic system and provide the data needed for the development of local and regional models.

Data Collection and Analysis

Existing data on aquifer thickness, extent, lithology, specific yield, hydraulic conductivity, pumpage, water quality, and water-level records will be compiled and reviewed. Tables, maps, and graphs showing well locations, saturated thickness, water-level altitudes, specific yield, hydraulic conductivity, and water quality will be prepared for the High Plains in Kansas. Irrigated acreages, crop acreages, and soil types will be compiled from existing data. Pumpage records will be obtained from a compilation by the Kansas Water Resources Board of the records of the Kansas Board of Agriculture. All data will be coded and entered in computer storage. The observation well network in the High Plains will be reviewed and revised, if necessary, to provide for future monitoring of changes in ground-water quantity and quality.

Special Investigations

Adequate data are not currently available to describe the regional and vertical variation in specific yield and hydraulic conductivity. Special studies will be conducted to develop the necessary data for regionalization. Aquifer-test data will be reviewed and additional data will be developed utilizing geophysical logging, laboratory analysis, and aquifer-testing techniques. The results will be correlated with lithology for extrapolation to other areas in the High Plains.

Two geologic faults in the High Plains of Kansas which are known to influence flow in the Ogallala aquifer will be studied. Existing geophysical data and aerial photographs will be reviewed to provide a preliminary evaluation of the extent of the faults and to determine test drilling needs. Water-level records from existing wells will be studied to determine the influence of the faults on ground-water flow and aid in the selection of test-well sites. Test wells may be drilled at selected sites for testing and sampling to determine the hydraulic conductivity of the aquifer near the faults and the influence of the faults on lithology and water quality.

Consolidated, water-bearing rocks of Cretaceous and Permian age underly the Ogallala aquifer in Kansas. In parts of Kansas the consolidated, water-bearing rocks may be in hydraulic connection with the Ogallala aquifer. Existing data will be reviewed to determine, where possible, the head and water-quality relationships between the Ogallala and underlying aquifers. Existing data will be reviewed to determine the need for test wells to provide data needed to describe the hydrologic relationship between the aquifers. Where possible, these test wells will also be used to provide data on the characteristics of the Ogallala aquifer and the geologic faults discussed above. This study will be closely coordinated with an existing study of the consolidated-rock aquifers being conducted by the Kansas District and the Kansas Geological Survey.

The relationship between surface water and ground water in the High Plains of Kansas will be studied to estimate aquifer discharge and recharge. Discharge to streams will be estimated from the base flow characteristics of perennial streams draining the High Plains. Aquifer recharge from ephemeral streams will be estimated from transmission losses determined from channel geometry.

Computer Models

The data developed for the High Plains of Kansas will be stored in computer format for use in developing a regional model of the entire High Plains. In addition, the data will be used to develop detailed models of the High Plains in Kansas by the Kansas District. Local models will be developed for several parts of the Ogallala aquifer in Kansas. These models will have sufficient detail to be used by ground-water management districts and other water managers to aid in the evaluation of water management alternatives.

Reports

Reports on those aspects of the study of specific interest to water managers and users in Kansas will be prepared by the Kansas District. Specifically, the Kansas District will prepare reports on the influences of geologic faults and underlying consolidated-rock aquifers on the Ogallala aquifer as well as reports on the results of and documentation for the local models developed by the Kansas District.

Hydrologic data needed for the development of models of the High Plains will be compiled and reviewed. The data have already been compiled and analyzed for part of the High Plains of Nebraska for previous model studies. This previous work will aid greatly in the assembly and interpretation of data and the development of models for the High Plains Regional Aquifer-System Analysis project. However, additional data are needed, especially in the area of the Sand Hills, to develop a complete description of the Ogallala aquifer system.

Data Collection and Analysis

Existing data on the ground-water system will be compiled from previous studies. The adequacy of the data will be reviewed to aid in the collection of additional data. Observation-well records, streamflow records, and discharge measurements will be analyzed to determine stream-aquifer relations and aquifer boundary conditions. The existing observation-well network will be reviewed to determine where additional wells are needed to monitor changes in ground-water flow. The observation-well network should include at least one well per township which will require the addition of about 300 wells to the existing network. In areas of ground-water development, existing wells can be located and included in the network. However, in those areas where suitable wells cannot be located, observation wells will have to be drilled.

Ground-water quality data will be reviewed and a water-quality monitoring network will be designed to monitor changes. The monitoring network will include about 450 of the observation wells used to monitor water levels. Selected wells will be sampled on 3- to 4-year intervals to monitor long-term changes in ground-water quality.

Water-use information will be compiled from existing data and used to estimate aquifer recharge in water-budget calculations. Ground-water pumpage will be estimated using power records, meters, and crop demands. Data from about 10,000 registered wells will be used to estimate pumpage for the study area in Nebraska.

Maps, tables, and graphs of the data compiled and collected during the study will be prepared. All appropriate data will be coded and stored in computer files for use in the development of regional and local ground-water flow models of the Ogallala aquifer.

Special Investigations

Adequate data are not available to map the regional variations in hydraulic conductivity and specific yield for the entire study area in Nebraska. Hydraulic conductivity and specific yield have been estimated for part of the study area based on the grain-size distribution of the sediments. Test drilling will be needed to obtain the lithologic and geophysical logs necessary to estimate aquifer parameters. Where appropriate, test holes will be completed as observation wells for monitoring ground-water changes.

About 18,000 miles of streams and canals are in the study area in Nebraska. Most of these streams and canals are hydraulically connected to the ground-water system. Stream-aquifer relations will be defined by evaluating stream-gaging records and seepage measurements. About 10,000 miles of streams and canals will be studied to determine areal variations in the rates of accretion or depletion. These data will then be used to estimate the rates for the remaining stream and canal mileage.

Unlike most of the High Plains, direct evaporation of ground water is an important phenomenon in the Sand Hills of Nebraska. There are about 1,640 lakes larger than 10 acres in the Sand Hills. Data on potential evapotranspiration, precipitation, water levels, soils, vegetation, and lake areas will be compiled and evaluated to determine actual evapotranspiration rates. An existing water-budget model will be used to estimate ground-water recharge from precipitation and applied irrigation water for those areas where recharge takes place.

Computer Models

The data collected during this study will be used to develop a regional model of the aquifer system as well as update and improve the existing models in Nebraska. The models of the Ogallala aquifer will become valuable tools for managing the ground water.

A large part of the study area in Nebraska has been modeled in previous studies. However, in the previous studies, the models were developed from existing information, and additional data are needed to improve the predictive capabilities of the models. The data collected during this study will be used to update existing models and develop new models for those areas not previously modeled.

Reports

The data developed during this study will be documented in basic-data reports prepared by the Nebraska District. In addition, interpretive reports will be prepared on the special investigation conducted by the Nebraska District.

New Mexico

The Ogallala aquifer in the High Plains of New Mexico has experienced severe water-level declines due to pumpage for irrigation and municipal use. The High Plains Regional Aquifer-System Analysis project will provide the hydrologic evaluation needed to project the reponse of the Ogallala aquifer to future pumpage. For that part of the study area in New Mexico, the project will compile and review existing data, collect additional data, and develop a digital flow model of the aquifer.

Data Collection and Analysis

Hydrologic and related data will be compiled from existing sources where possible. The data will be analyzed for adequacy and accuracy to determine additional data requirements.

The altitude of land surface and the base of the aquifer will be compiled from existing maps and reports. Topographic maps are available for the entire study area in New Mexico. The altitude of the base of the aquifer has been detailed in several previous investigations. The results of previous investigations will be compiled for the study area. Where needed, additional data will be plotted and contoured to complete the map of the aquifer base for the study area.

About 270 observation wells are currently measured annually in the High Plains of New Mexico. Many of the water-level records begin in 1954 or 1955 and a few records extend as far back as the early 1940's. These records will be reviewed, water-level maps will be prepared, and an observation-well network will be designed to provide for future water-level and water-quality monitoring.

A saturated thickness map of the Ogallala aquifer will be prepared and used to define the western boundary of the aquifer. Saturated-thickness data, in conjunction with water-level and hydraulic-conductivity data, will be used to define and estimate the rate of ground-water discharge (other than pumpage) along the western boundary of the aquifer.

All data collected and compiled during the study will be coded and entered into computer storage. The data will be available for use in the development of local and regional ground-water flow models of the Ogallala aquifer.

Special Investigations

Existing data on hydraulic conductivity, specific yield, ground-water pumpage, and recharge will be compiled. However, existing data are not adequate to describe the variation of the above parameters and special studies will be initiated to develop the necessary data for New Mexico.

Data on the hydraulic conductivity and specific yield of the Ogallala aquifer are difficult to derive. Methods which may be used to determine the areal distribution of the aquifer parameters include sampling in outcrop areas for laboratory analysis, analyzing drawdowns in areas where irrigation return flow is negligible such as municipal and industrial well fields, electric logging available from new holes for density and moisture content, and performing analyses on well cuttings. These data can be extrapolated based on a knowledge of the depositional framework of the Ogallala Formation and available drillers' and electric logs.

Annual pumpage will be determined indirectly from available power tests and power-usage records. The pumpage estimates will then be extrapolated on the basis of total power consumption and total irrigated acreage. Municipal and industrial pumpage will be prorated between wells when not recorded by well or cluster of wells. The results will provide an estimate of power consumption and water production for each square-mile area on the High Plains in New Mexico.

Annual recharge to the Ogallala aquifer will be estimated from data on crops, precipitation, water demand, and soils. These data are generally available for the High Plains. A water-budget model can be used with the above data to calculate annual recharge.

Computer Models

A preliminary model of the Ogallala aquifer in New Mexico will be developed from existing information. The model will be used to aid in defining areas where additional data are needed and to provide preliminary estimates of future water-level declines. The model will be updated and refined as additional data become available. This procedure will make preliminary results available to the public at the earliest possible date.

Regionalized hydrologic and related data will be prepared and entered into the computerized data-management file for use in developing the New Mexico part of a regional flow model of the Ogallala aquifer. Close coordination will be maintained between the New Mexico District and the High Plains Regional Aquifer-System Analysis project staff to insure that the regional and New Mexico models provide consistent results.

Reports

Appropriate data and interpretive reports will be prepared by the New Mexico District. Reports on the computer model of the study area in New Mexico will be prepared to document the results and the computer program.

Oklahoma

The High Plains includes Beaver, Cimarron, and Texas Counties in the panhandle of Oklahoma and parts of Ellis, Harper, Roger Mills, and Woodward Counties. A computer model of ground-water flow in Texas County is currently being developed by the Oklahoma District. Experience obtained in developing the model for the Ogallala aquifer in Texas County will greatly aid the High Plains Regional Aquifer-System Analysis project. Most of the data required for the regional study have already been developed for Texas County. Hydrologic and related data will be developed for the remaining area of the High Plains in Oklahoma and the Texas County model will be expanded to include Beaver and Cimarron Counties.

Data Collection and Analysis

Existing data on the geologic framework of the aquifer system will be compiled and evaluated. Surface and subsurface geologic maps will be studied to determine geologic controls on aquifer boundaries. A map of the altitude of the base of the aquifer will be prepared and an existing map of aquifer thickness will be updated with additional well records. The work will be coordinated with adjacent Districts to insure that the data are consistent across state lines.

Annual water-level measurements from about 500 wells in the study area are available since 1966. Potentiometric and saturated thickness maps will be prepared for selected years since 1966. The current observation well network will be reviewed for adequacy of areal distribution and quality of records. The network will be revised to obtain better coverage in areas of heavy pumping and where pumping is likely to increase in the future.

Water-quality data are available from 500 to 600 wells in the Ogallala aquifer. These data include only common chemical constituents. No data on the concentration of trace elements are known to be available. The concentrations of common constituents will be plotted on maps to determine areal distribution and variability and to identify areas with water-quality problems, if any. Areas of potential water-quality problems are probably associated with cattle feed lots, meat packing plants, and surface or subsurface disposal of oil-field brine. A network of observation wells will be established for periodic monitoring of future water-quality changes.

Stream-aquifer relations will be evaluated using stream discharge and observation-well records. Ground-water discharge to streams and phreatophytes will be estimated. Related data on irrigated acreage, nonirrigated acreage, crops, vegetation, soils, and precipitation will be compiled from existing records and used in estimating recharge to the aquifer.

Special Investigations

Information on the hydraulic conductivity of the Ogallala aquifer is available from about 800 wells, and additional data may be available from other agencies. However, no data on specific yield are available. Geologic logs from several hundred wells in the study area can be used to estimate specific yield and regionalize both specific yield and hydraulic conductivity. Aquifer tests will be conducted at selected locations to check the accuracy of the aquifer parameters estimated from geologic logs.

Adequate data are not available to determine pumpage from wells in the study area. A special study will be initiated to determine pumpage rates for the High Plains of Oklahoma. Wells powered by electricity and natural gas will be surveyed and power-consumption records will be used to estimate pumpage. Crop acreage and crop demand will be used to estimate water requirements and check pumpage estimates. However, experience in developing these data for Texas County indicates that pumpage may be considerably larger than crop demand. Another check on the estimated pumpage can be made using observation-well records. If reliable estimates of specific yield can be made, water-level changes in the aquifer can be used to calculate pumpage, assuming recharge is known.

Ground-water flow between the Ogallala and underlying aquifers in Cimarron and Texas Counties will be investigated. Water-level records and geohydrologic data will be used to determine the direction and rate of flow between aquifers. If the annual volume of flow is a significant part of the annual water budget for the Ogallala aquifer, the flow between the aquifers will have to be simulated by the models.

The alluvial aquifer along Beaver River, in Beaver and Harper Counties, is an important source of water east of the High Plains. A substantial part of the natural discharge from the Ogallala aquifer in Beaver and Harper Counties might consist of underflow to the alluvial aquifer. Existing data will be analyzed to determine whether natural discharge from the Ogallala aquifer in this area occurs as seeps and springs or as unobserved underflow to the alluvial aquifer.

Computer Models

The data collected and compiled will be coded and stored in computer files for use in the development of regional and local models of flow in the Ogallala aquifer. The Oklahoma District will expand the existing model of the aquifer in Texas County to include both Beaver and Cimarron Counties. Close coordination between the Oklahoma District and the High Plains Regional Aquifer-System Analysis project staff in Denver, Colorado, will be maintained. This will insure that consistent data are used in the development of the regional model and that the regional and local models provide consistent results. The models will become important tools for use in evaluating ground-water management schemes for the High Plains.

Reports

The Oklahoma District will prepare data and interpretive reports resulting from the study. Maps, graphs, and tables of data will be prepared for publication in appropriate reports. The results of the model studies and documentation for the computer programs relating to the High Plains of Oklahoma will be prepared and published by the Oklahoma District.

South Dakota

The study area in South Dakota encompasses the major part of the Pine Ridge and the Rosebud Indian Reservations. Reconnaissance water-resources studies resulting in the publication of two Hydrologic Atlases were completed in 1969. At that time there was little ground-water development; however, in the last few years interest in irrigation has increased and there is some development in the area both on and off the reservations.

The South Dakota part of the High Plains study will describe the ground-water resources of the aquifer system including the Ogallala and Arikaree Formations. The data compiled and collected during the study will contribute to the design and development of regional and local models of the ground-water system. A water-management-oriented study is needed to determine ground-water-development options and evaluate alternatives.

Data Collection and Analysis

Emphasis in previous studies by the South Dakota District was on areal mapping of the major rock units. More than 1,500 wells were inventoried and several hundred test wells were drilled during these studies. However, the test holes were mostly shallow auger holes in alluvium, windblown sand

deposits, and terrace deposits. The principal data obtained during the well inventory were water levels and well depths. These will be valuable in constructing a historical picture for comparison with the current situation, but will not aid in delineating the bottom of the aquifer. There is no currently active data-collection network in the area.

Existing data will be collected, compiled, and evaluated. The data will include aquifer thickness, extent, lithology, specific yield, hydraulic conductivity, pumpage, water quality, and water-level records. Maps, tables, and graphs will be prepared to describe the geohydrology of the aquifer system. The adequacy of the available data will be evaluated and a data-collection network will be designed and operated to monitor water levels, pumpage, water quality, and precipitation.

At the conclusion of this study, selected data-collection stations (observation wells and stream-gaging stations) should be retained and added to the District's basic data-collection network on a continuing basis. This will permit the detection and monitoring of long-term trends and the testing and correction of predictions made in this study.

Special Investigations

The areal extent of the Ogallala and Arikaree Formations is well defined, but additional information on thicknesses will have to be obtained in some areas. An inventory of wells drilled during the past several years, and contacts with local drillers, should supply sufficient information to determine the needs for additional data. If additional data are needed, a test-drilling program will be designed to be carried out during the second and third years of this study.

During previous studies, little specific information was generated on aquifer characteristics of the Ogallala or Arikaree Formations. Aquifer tests will be conducted in selected wells to develop field data on specific yield and hydraulic conductivity. In addition, lithologic logs will be correlated with the aquifer-test results and used to estimate aquifer parameters in areas where aquifer-test data were not obtained.

The relationship between ground water and surface water will be an important part of the study. Several surface-water stations are being operated in the area. The data from these stations will be supplemented by seepage runs and low-flow studies. The data will be used to define areas of ground-water recharge or discharge from streams.

Computer Models

The data collected and compiled during this study will be coded and entered in a computerized data file. The data will be used to develop a large-scale regional model of the aquifer system. The data will also be used by the South Dakota District to develop a local model for the High Plains in South Dakota. Close coordination will be maintained between the District project and the Regional project to insure that consistent data are used in model design and that consistent results are obtained.

Reports

During the study there will be a continuing evaluation and interpretation of data to facilitate the preparation of reports and make adjustments to the models. Preparation of reports will include structure, contour, isopach, potentiometric, and geochemical maps for the Ogallala and Arikaree Formations. Reports describing the ground-water resources of the High Plains in South Dakota will be prepared by the South Dakota District.

Texas

The High Plains within Texas covers an area of about 35,000 square miles, and includes the Canadian River basin and the upper parts of the Red, Brazos, and Colorado River basins within the State. This broad area, which averages about 300 miles from north to south and about 120 miles from east to west, includes all or parts of 45 counties.

The High Plains surface slopes gently eastward to a boundary which, in most places, is sharply defined by a prominent escarpment ranging upward to several hundred feet high. The surface is characterized by thousands of small shallow depressions termed "playas," several large playa lakes, and locally, sand dunes and small stream valleys. The Ogallala Formation, and locally overlying alluvial and windblown deposits of more recent geologic age, covers virtually all of the High Plains with the exception of the Canadian River valley where erosion has exposed older geologic formations.

In this area of limited water supplies, the Ogallala Formation constitutes the principal source of ground water. The thickness of the saturated part of the formation, the specific yield, and the hydraulic conductivity of the formation vary widely. These are key factors in the performance of wells and the extent of ground-water development. Although the quality of water in the Ogallala aquifer ranges over wide limits within relatively short distances, the water is satisfactory for almost all present uses.

Annual water-level measurements, made in hundreds of selected water wells throughout the High Plains, show that the ground-water supply in the Ogallala aquifer is being depleted. This depletion is most pronounced in the major irrigation areas in the northern part of the Southern High Plains (the High Plains south of the Canadian River) and in areas where municipal and industrial supplies are pumped.

The goal of this study will be to determine more accurately the life and the dependability of the Ogallala aquifer. This will include the following: (a) develop more accurate estimates of the aquifer's areal extent, saturated thickness, hydraulic conductivity, and specific yield; (b) develop more accurate estimates of the distribution of historical, current, and future pumpage; (c) develop accurate estimates of the amounts and distribution of recharge and irrigation-water recirculation; (d) collect and compile water-quality data; and (e) develop and utilize a digital model of the aquifer.

Data Collection and Analysis

The study will include an inventory of all available data and reports in Water Resources Division files as well as in the files of state and local agencies, primarily to determine where deficiencies in data exist in order to plan effectively the collection of needed additional data. Water-resources and related data for the High Plains of Texas will be collected and compiled including well inventories, water-level records, water-use data, chemical analyses of water samples, laboratory analyses of rock samples, geophysical and lithologic logs, and aquifer-test data.

The areal extent and saturated thickness of the Ogallala aquifer will be determined from existing data and previous studies of the High Plains of Texas. Additional geophysical and lithologic logs will be obtained to complete the data needed in areas not previously studied.

Observation-well networks will be reviewed to evaluate the adequacy of coverage for the High Plains of Texas. If necessary, additional wells will be inventoried and added to the network to provide a regional network for monitoring water-level and water-quality changes.

Special Investigations

Hydraulic conductivity and specific yield of the Ogallala aquifer have been estimated for previous studies. However, the data are not adequate to describe the regional variation of these parameters for the study area. Existing data will be compiled and reviewed to determine where additional data are needed. It is expected that aquifer tests and laboratory analyses of rock samples will be used to determine hydraulic conductivity and specific yield. Geophysical and geologic logs will be used to extrapolate the data to areas where data are lacking.

Annual pumpage will be estimated using power records, well inventories, state reports, and information on crops and irrigated acreage. In addition, data on soil type, precipitation, crop demand, and climate will be compiled for use in calculating recharge. Recharge will be calculated by a water-budget model.

Computer Models

Computer models of ground-water flow in the Ogallala aquifer will be developed from the data collected during this study. The data will be used to design a regional model of the aquifer system by the Regional Aquifer-System Analysis project. Local models of the aquifer will be developed by the Texas District. The models will be used to evaluate the effects of future ground-water development on the aquifer system.

Reports

Basic-data and interpretive reports will be prepared to document the compilation, collection, and analysis of data on the aquifer system. Reports on evaluation and regionalization of specific yield for the Ogallala aquifer

in Texas will be prepared. The Texas District will prepare reports describing and documenting the local models developed for the High Plains of Texas.

Wyoming

The High Plains Regional Aquifer-System Analysis project includes about 6,100 square miles in southeastern Wyoming. The post-Cretaceous aquifers are hydraulically interconnected where they are in contact in the study area. These aquifers include the White River Formation of Oligocene age, the Arikaree Formation of early Miocene age, the Ogallala Formation of late Miocene age, and the alluvial deposits of Holocene age.

Reconnaissance studies have been made in the four counties containing the study area in southeastern Wyoming: Laramie, Platte, Goshen, and Niobrara. Several more detailed investigations have been made in smaller areas within these counties, including three digital ground-water model studies. Two other investigations are in progress that will include digital ground-water models. However, more information is needed about the different formation thicknesses and lithology, ground-water and surface-water relationship, ground-water recharge and discharge, and pumpage.

The objective of this investigation is to compile existing hydrogeologic data for the post-Cretaceous formations in southeastern Wyoming and to furnish all hydrogeologic data that are necessary to design and develop digital computer models of the High Plains aquifer system.

Data Collection and Analysis

All previous hydrogeologic studies in the area will be researched to define the areal extent of the aquifer(s). Existing geophysical logs of oil test wells will be examined to determine, where possible, the thickness of the different geologic formations or aquifers. Test drilling will be necessary in some areas. Ground-water occurrence and movement, aquifer properties, and ground-water recharge will be determined or estimated primarily from existing data. Ground-water discharge will be estimated from a pumpage inventory, irrigated-acreage inventory, and stream-discharge measurements. About 50 water samples will be collected for chemical analyses to help determine the influence of irrigation upon the quality of ground water and surface water in the system. All pertinent hydrogeologic data will be coded and entered into the computer system designed for this regional project. Mass water-level measurements in areas of ground-water development will be made to determine periodic water-level changes, and discharge measurements will be made on selected streams to determine the amount of ground-water discharge.

Special Investigations

The specific yield and hydraulic conductivity of the aquifer system have been estimated for parts of the study area. However, additional data are needed to describe the regional variation of the aquifer parameters in southeastern Wyoming. Existing geologic and geophysical data will be used to estimate specific yield and hydraulic conductivity and determine the need for

test drilling. If test holes are drilled, the additional data will aid in determining the base of the aquifer and the relationship between geology and aquifer parameters. Aquifer tests conducted in the test holes would provide data for checking specific-yield and hydraulic-conductivity values estimated on the basis of geologic and geophysical data.

Ground-water pumpage records are not available. Pumpage will be estimated on the basis of irrigated acreage, crop demand, method of irrigation, soil type, and precipitation. In addition, a pumpage inventory will be made to identify the number of wells supplying ground water for domestic, municipal, industrial, and agricultural use. Pumpage will be monitored for a selected number of wells and used to estimate total pumpage.

Computer Models

Previous model studies conducted by the Wyoming District will greatly aid the High Plains Regional Aquifer-System Analysis project. Many of the data required for modeling parts of the study area in Wyoming have already been developed. The ground-water flow models developed by the Wyoming District will be updated and used to evaluate local response to future ground-water development in Wyoming. The Wyoming District will work closely with the Regional Aquifer-System Analysis project in developing a regional model of the High Plains aquifer system.

Reports

The Wyoming District will prepare basic-data and interpretive reports resulting from the investigation of the aquifer system in southeastern Wyoming. Reports documenting local models of the aquifer system have been or will be prepared as part of other investigations being conducted by the Wyoming District.