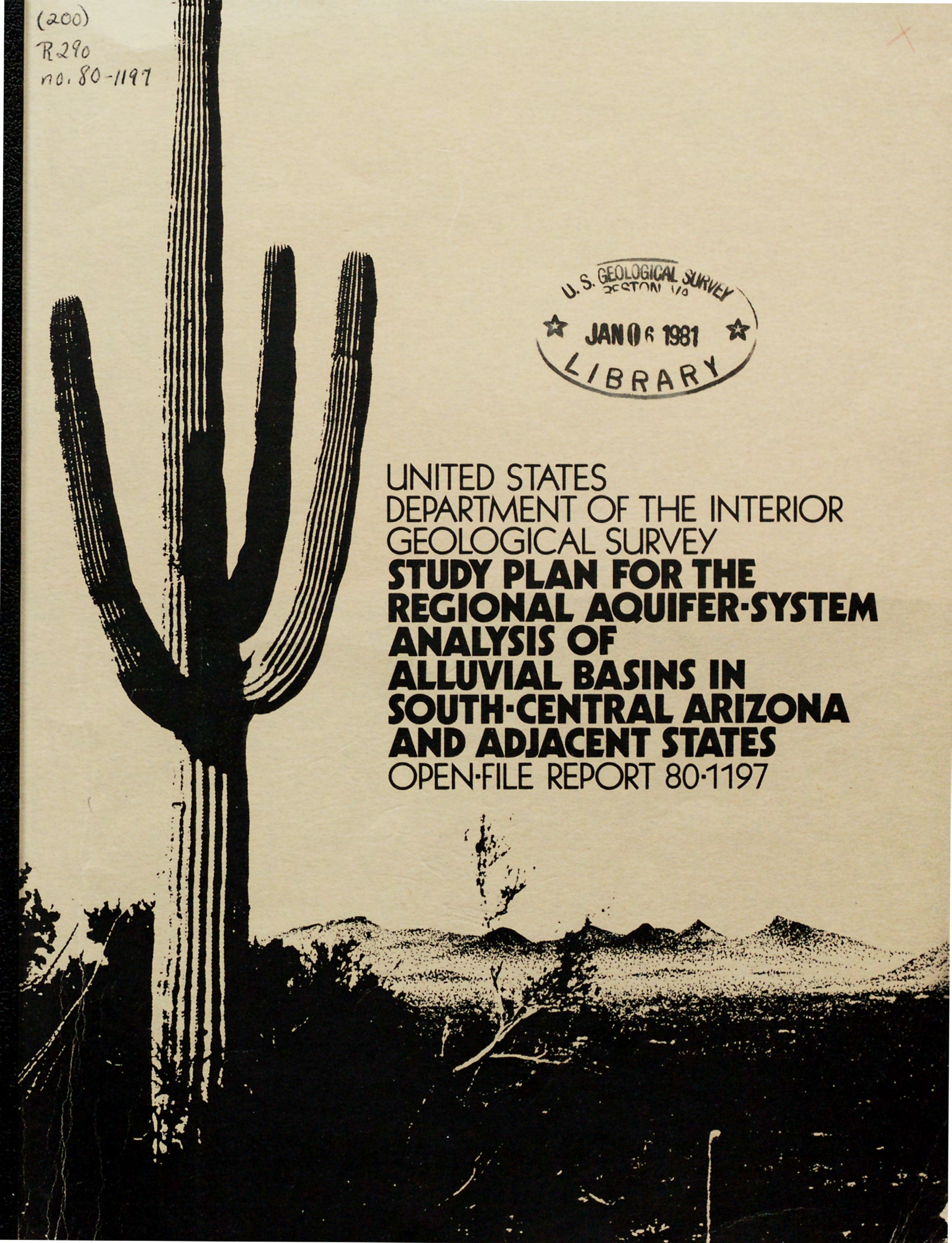

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STUDY PLAN FOR THE REGIONAL AQUIFER-SYSTEM ANALYSIS OF ALLUVIAL BASINS IN SOUTH-CENTRAL ARIZONA AND ADJACENT STATES

OPEN-FILE REPORT 80-1197

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By T. W. Anderson

Open-File Report 80-1197

Tucson, Arizona
October 1980

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

For readers who prefer to use metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)

STUDY PLAN FOR THE REGIONAL AQUIFER-SYSTEM ANALYSIS OF ALLUVIAL BASINS IN SOUTH-CENTRAL ARIZONA AND ADJACENT STATES

By

T. W. Anderson

ABSTRACT

The alluvial basins in the Southwestern United States constitute a major source of ground water and are relied upon extensively for agricultural, industrial, and public water supplies. Large-scale depletion of ground water is directly related to pumping that has occurred in the past few decades and is continuing today. The U.S. Geological Survey has started a 4-year study of the alluvial basins in south-central Arizona and parts of California, Nevada, and New Mexico. The study is designed to document and describe the hydrologic setting in the basins, the ground-water resources available, and the effects of historical development on the ground-water system. To aid in the study, mathematical models of selected basins will be developed for appraising the local and regional flow systems.

Major tasks necessary to accomplish the study objectives include accumulating existing data on ground-water quantity and quality, entering the data into a computer file, identifying data deficiencies, and developing a program to remedy the deficiencies by collection of additional data. The approach to the study will be to develop and calibrate models of selected basins for which sufficient data exist and then to develop interpretation-transfer techniques whereby general predevelopment and postdevelopment conceptual models of the hydrologic system in other basins may be synthesized. The results will be applied to selected basins for testing, calibration, and modification. The end result of the project will be a better definition of the hydrologic parameters and a better understanding of the workings of the hydrologic system in the alluvial basins. The results will include models that can be used to study the effects of management alternatives and water-resources development on the hydrologic system.

INTRODUCTION

The desert regions of southern Arizona, California, Nevada, and New Mexico are characterized by sharply rising mountains that are separated by wide, flat basins filled with varying amounts of alluvial deposits, which store large amounts of ground water. Development and use of these ground-water resources have been associated primarily with agricultural development.

Surface-water use predates historical records; however, surface-water supplies are highly variable, and to assure the dependability of a water supply, ground water has been used either in conjunction with surface water or as the principal source since the late 1800's. As a result of ground-water pumping in excess of recharge—overdraft—large water-level declines and large depletions in the amount of water in storage have occurred in many basins. The overdrafts have caused increasing pumping lifts, decreasing well productivity, and, in some areas, land subsidence and earth fissures. Economic problems associated with the overdrafts include increased pumping costs through increased power requirements, need for deeper wells, and need for larger pumps.

National Regional Aquifer-System Analysis Program

The Southwest alluvial basins (Swab) study is one of many planned or ongoing regional aquifer-system analysis (RASA) studies included in a major effort by the U.S. Geological Survey. The program began in 1976 and represents a systematic effort to study regional ground-water systems that cover large interstate or intrastate areas. This approach has the advantage of overcoming problems associated with political boundaries that may transect the hydrologic system; also, an entire area can be studied with equal emphasis and a uniform approach, and the study will not be dependent on local funding. Specific objectives of the regional studies depend largely on the local hydrologic problems. General objectives are (1) to describe the hydraulics and geochemistry of the predevelopment and postdevelopment ground-water system, (2) to analyze the changes that have taken place as a result of development, (3) to tie together previous small-scale studies, and (4) to provide a predictive tool by using mathematical modeling techniques whereby management alternatives can be evaluated.

Purpose and Scope of the Study

The primary purpose of the Southwest alluvial basins study, which coincides with that of the national RASA program, is to describe and define the hydrologic system in the alluvial basins. The study will include a quantitative description of the predevelopment and postdevelopment flow system. In addition, the study will include efforts to define the geologic boundaries of the ground-water basins, the ground-water resources available in the basins, the degree of interconnection between adjacent basins, and the extent to which a regional flow system may exist. Mathematical models of the regional ground-water flow system and the flow systems in individual basins will be developed to aid in meeting the study objectives. Subsidiary and necessary parts of the study will be the accumulation of existing data on ground-water quantity and quality, entering the data into a computer file suitable for rapid mathematical analysis, identification of data deficiencies and the subsequent collection of necessary data, and design of networks for monitoring the quantity and quality of ground water. The mathematical models developed for individual basins may be well-calibrated multilayered models, simple lumped-parameter models, or conceptual models.

Area of Study

The study area includes about 84,000 mi^2 in southern and central Arizona and small areas in California, Nevada, New Mexico, and Mexico (fig. 1). For the basins that straddle the international boundary, the part of the basin in Mexico will be included as required for development of useful models if data are available.

The study area is in three water provinces—the Basin and Range lowlands province, the Central highlands province, and the Plateau uplands province (fig. 1). The occurrence of ground water is influenced by the different geologic, physiographic, and climatic conditions in the provinces. The small part of the study area that is in the Plateau uplands is atypical of that province and is typical of the Central highlands province; therefore, the occurrence of ground water in the Plateau uplands is not discussed in this report.

Approach

The distribution of available data creates study limitations in some of the basins and the regional system. The nature of the study, the large area, and the diversity of the area in terms of development and hydrologic conditions necessitates a phased approach. The study will be done in three phases in a 4-year period, and the individual phases will overlap as much as 6 months.

The initial phase will include a preliminary evaluation of the available data, prioritization of the basins to be modeled, review of previous studies and available mathematical models, and development of communication between the project staff and State, local, and Federal water interests in the project area. Phase two will include (1) accumulation of existing data, (2) overall data analysis to explore the general relations among parameters, (3) development of general descriptions and definitions of the hydrologic system in the alluvial basins, (4) building of models or modification of existing models for basins selected as first priority, (5) collection of additional data using the results of the preliminary mathematical models to determine where and what types of additional data are needed, (6) development of categories of hydrologic properties and the assignment of basins to their respective categories, and (7) development of interpretation-transfer techniques. The transfer techniques will aid in development of models of basins that presently are undeveloped and for which there are minimal hydrologic data. Where possible, transfer techniques will be developed for each hydrologic property—such as basin geometry, lithology, water chemistry, and

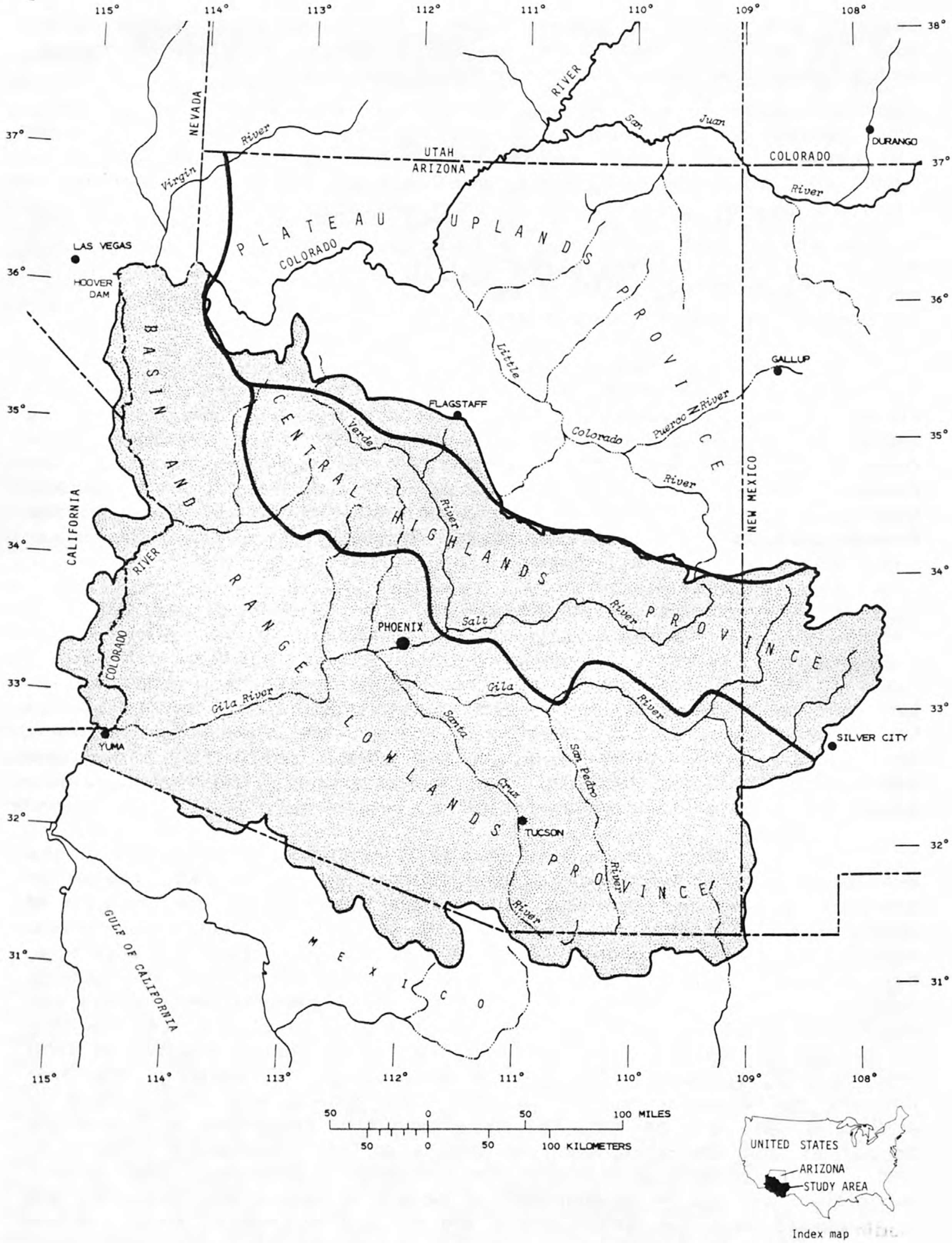

Figure 1.--Area of study (shaded) and water provinces.

stress-strain relations in the ground-water system—used in categorizing the basins. Phase three will include documentation of the study results and completion of the basin models, which will be calibrated to the extent possible using the available data.

The basins were divided into three levels of priority for modeling. First-priority basins are basins in which the hydrologic and geologic conditions are representative of those in the study area for which large amounts of data are available. Second-priority basins are basins for which lesser amounts of data are available; third-priority basins are basins for which little or no data are available. From the analysis of the first-priority basins in conjunction with the overall data analysis, it is assumed that general models can be developed that will be representative of the hydrologic and geologic conditions in other basins. The models then will be applied to the second-priority basins for which data generally are sufficient to allow calibration of the general models. Mathematical models of the ground-water flow system may not be developed for third-priority basins, but some general concept of the hydrologic system will be formulated. For third-priority basins, the final product may be only a statement of anticipated geologic and hydrologic conditions and the evidence for the statement or the assignment of the basin to a category or set of categories that can be used to compare and contrast the hydrologic conditions to those in other basins.

GEOHYDROLOGY

Regional Setting

The Basin and Range lowlands province (fig. 1) is characterized by mountains separated by broad alluvium-filled basins. The mountains consist of igneous, metamorphic, and sedimentary rocks that are extensively folded or faulted, and the basins contain thick stratified deposits and mixtures of gravel, sand, silt, clay, evaporites, and volcanic rocks. The Central highlands province (fig. 1) is primarily mountainous and contains alluvial basins that are generally smaller than those in the Basin and Range lowlands. Igneous, metamorphic, and sedimentary rocks compose the mountains.

The consolidated and unconsolidated sedimentary rocks that fill the basins constitute about 50 percent of the area and represent the geologic environment of major concern in this study (fig. 2). The alluvial deposits are highly heterogeneous and anisotropic and range in size from clay and silt to cobble and boulder. The basin deposits also include volcanic rocks and evaporite deposits.

The basin deposits include moderately to strongly consolidated sedimentary rocks at the basin margins and perhaps at depth within the basins and unconsolidated sedimentary rocks in the upper and central parts of the basins. The consolidated sedimentary rocks may have

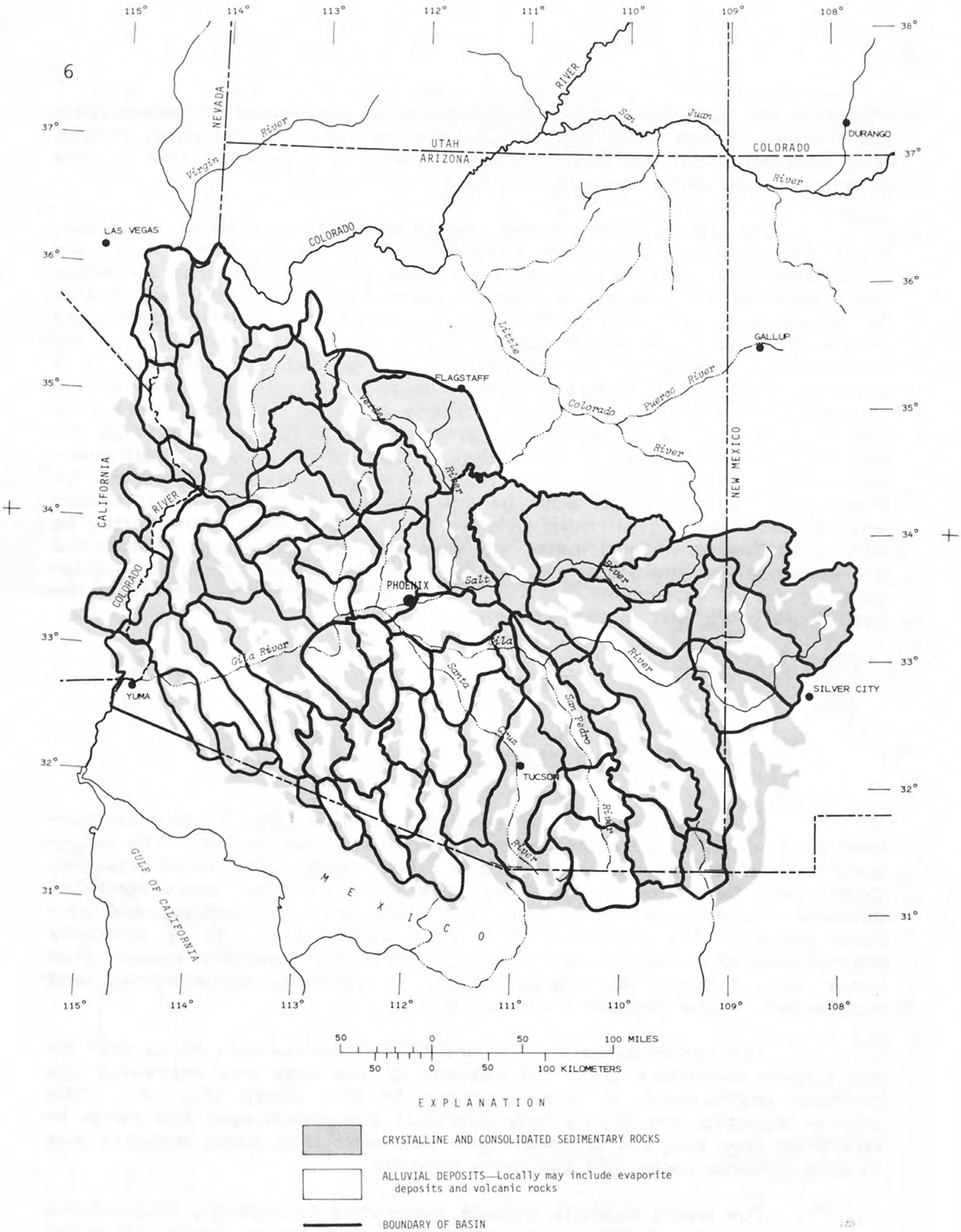

Figure 2.--Boundaries of the basins and approximate areal extent of the alluvial deposits and crystalline and consolidated sedimentary rocks.

undergone local structural deformation and are commonly tilted where exposed; the rocks are unconformably overlain by the unconsolidated sedimentary rocks, which are generally undeformed. The unconsolidated units are generally coarse grained at the basin margins and become finer grained in the central part of the basins. This also may be true of the older units.

Some units have been described and named in a few of the basins but have not been correlated over large areas. Although it is beyond the scope of this report to attempt such a correlation, a knowledge of the similarities and differences in the units from basin to basin is essential for the development of interpretation-transfer techniques and ultimately for evaluation of the regional ground-water system.

Occurrence and Movement of Ground Water in the Alluvial Basins

The largest and most extensive source of ground water is the pore spaces in the alluvial deposits that fill the basins. Ground water occurs under either confined or unconfined conditions. The upper part of the alluvial deposits is a productive aquifer where saturated, and ground water generally occurs under unconfined conditions. Ground water in the deeper deposits occurs in the permeable lenses of sand and gravel; the occurrence is greatly influenced by the heterogeneity of the material. A wide range exists in the vertical interconnection between lenses or layers of coarse material and in the lateral continuity of the lenses. The result is that ground water may occur under either unconfined or locally confined conditions.

Water stored in the alluvial deposits has been accumulating for thousands of years, and recharge is limited. Possible sources of recharge are infiltration of direct precipitation and runoff, seepage from permanent surface-water bodies, and irrigation return flow. Although precipitation is the ultimate source of all ground water, it serves as a direct source of recharge to the alluvial basins only during abnormally wet years. Most of the precipitation that falls on the basin floors is lost to evaporation or transpiration. Infiltration of runoff is the single most important source of recharge to the ground-water systems (Halpenny and others, 1952). Perennial streams, such as the Colorado River and some reaches of the Salt, Gila, and Verde Rivers, are important sources of recharge in a small number of basins. Irrigation return flow is an important consideration in agriculturally developed basins.

The rate and direction of ground-water movement in the alluvial deposits depend on the physical and hydraulic characteristics of the material; locally, faults in the alluvium also may affect ground-water movement. In most basins ground water moves from the basin margins, where it originates as recharge from runoff in the mountains, toward the axis of the basin or to a point where discharge occurs, either naturally or by pumping. The rate of ground-water movement in the alluvial deposits generally is a few feet to a few hundred feet per year.

Where basins are connected by an alluvium-filled bedrock trough, a substantial transfer of ground water is possible between basins. Where only bedrock material separates the basins, ground-water transfer is probably slight, except where an extensive bedrock fracture system connects the basins.

Occurrence and Movement of Ground Water in the Mountains

The occurrence of ground water in the mountains is indicated by the presence of springs and producing wells. Ground-water movement occurs through zones of high permeability, either primary or secondary. Primary permeability, which is the movement of water through the pore spaces of a material, generally is low for the consolidated rocks that make up the mountains. Secondary permeability in the form of cracks, fractures, and solution channels is the more likely avenue for any substantial amount of ground-water flow. Zones of secondary permeability may supply large amounts of water to wells and are known to influence the presence of springs. An integral part of this study will be to examine the extent of interbasin ground-water connection through zones of secondary permeability and the possibility of a regional ground-water flow system in the study area.

Occurrence of Surface Water and its Effect on the Ground-Water System

In the study area surface-water flow is derived from precipitation, ground-water discharge, and inflow into the area via the Colorado River. Except for the Colorado River, the perennial streams generally originate in the Central highlands province. The province receives 15 to 40 in. per year of precipitation, which results in sufficient base flow from ground water to maintain the year-round flow of many streams. Flow in the Gila, Salt, and Verde Rivers historically provided recharge to the ground-water systems where the streams enter the Basin and Range lowlands province. The recharge occurred along the streams where extensive coarse-grained alluvial deposits permitted rapid infiltration. Now, flow in these rivers is controlled by reservoir storage except during times of extremely large runoff. Downstream from the reservoirs, the surface-water flow regimen has changed from perennial to intermittent, and associated with this change has been a parallel change in recharge to the ground-water system. In some areas, such as parts of the Salt River Valley near Phoenix, ground water and surface water are used conjunctively; ground water is used to augment surface-water supplies for irrigation and public supply.

Most streams that originate in the Basin and Range lowlands province are intermittent or ephemeral; only short reaches of a few streams are perennial. The surface-water flow regimen in several of the major streams has changed from perennial to intermittent or ephemeral and in some instances from intermittent to ephemeral as a result of water-level declines coincident with ground-water development. Both ephemeral and intermittent streams play a role in furnishing recharge to the ground-water reservoirs through the infiltration of surface water into the alluvial deposits that underlie the stream channels. In addition to recharge from natural surface-water flow, the water in reservoirs and canals is a potentially large source of recharge to the ground-water systems. Reservoirs must be considered as a potential source of recharge where ground-water levels are lower than the reservoir surface because of the possibility of such water bodies overlying permeable material. Canal systems also are known to contribute recharge through seepage. Canal-lining practices affect the amount and location of recharge.

Chemical Quality of Water

The quality of ground water in the alluvial basins is closely related to geology, mineralogy, structure, internal and external drainage patterns, and historical development. Drainage features, such as the Colorado, Salt, and Gila Rivers, influence or have influenced ground-water quality in the basins along the rivers. To some extent, water quality in these basins is dependent on the quality of the river water, which is dependent, in part, on the geologic terrane from which the water originates or flows over.

The ground water can be grouped into chemical types based on the relative amounts of the major ions. In the study area the most common types are sodium bicarbonate and calcium bicarbonate, and the water generally is of good chemical quality; the dissolved-solids concentration generally is less than 500 mg/L (milligrams per liter). Other types of ground water in the study area include sodium and calcium chloride, calcium and magnesium sulfate, sodium calcium sulfate chloride, or mixtures of these. These types often contain high dissolved-solids concentrations—generally greater than 500 mg/L and occasionally greater than 4,000 mg/L. Large vertical and horizontal variations in the water having high dissolved-solids concentrations are common. Some processes that may account for the deterioration of water quality are evapotranspiration along the flood plains, sulfate reduction, carbonate precipitation, and mineral dissolution and precipitation.

In several basins the ground water contains high concentrations of one or more of the following constituents: fluoride, arsenic, chromium, lead, and cadmium. Fluoride is probably the most widely distributed of these constituents and thus has the most potential for creating health hazards, but the other constituents may create local health hazards. Although these constituents appear to be naturally occurring, they generally are not associated with any specific water type. In addition to excessive amounts of these and other constituents that control the acceptance or rejection of water for human consumption, the chemical quality of some water may not be acceptable for agricultural purposes. High salinity, high sodium calcium ratios, and boron may seriously affect the water for agricultural use.

GROUND-WATER DEVELOPMENT

Through 1977, more than 170 million acre-ft of ground water was pumped for agricultural, industrial, drainage, public-supply, domestic, and livestock purposes in Arizona (U.S. Geological Survey, 1978). During 1968-77, the annual pumpage averaged about 5.5 million acre-ft. The volume of water withdrawn has greatly exceeded the volume of natural recharge in most basins, resulting in water-level declines. Near Phoenix, the greatest decline was more than 400 ft during 1923-76 (Laney and others, 1978). Since 1923, declines of nearly 500 ft have occurred in a major agricultural area between Phoenix and Tucson (Konieczki and English, 1979). In parts of some basins water levels are declining as much as 10 ft per year.

Land subsidence and earth fissures are associated with the water-level declines in some areas. During 1952-77, subsidence of 12.5 ft was measured at a point about 50 mi northwest of Tucson (Laney and others, 1978). Smaller amounts of subsidence have taken place over extensive areas in most basins where large water-level declines have occurred.

RELATED GEOHYDROLOGIC STUDIES BY OTHER AGENCIES

Many agencies are or have been involved in water-resources related studies in south-central Arizona. The Arizona Department of Water Resources (formerly the Arizona Water Commission) assessed the impact of development on ground-water resources in all or part of 11 basins in the study area. Preliminary mathematical models were developed for eight of the basins and, in addition, three site-specific models were developed. These models are available for use in this study. The Arizona Department of Water Resources is developing a more comprehensive two-dimensional model of the Salt River Valley near Phoenix. As part of the preliminary Central Arizona Project studies, the U.S. Water and Power Resources Service analyzed the geology and ground-water conditions in several basins adjacent to the Salt and Gila Rivers. The analysis provides a comprehensive evaluation of the ground water in storage and the amount of overdraft taking place in the Central Arizona Project service area. The city of Tucson, Salt River Project, Corps of Engineers, University of Arizona, and Arizona State University are among the other agencies doing site-specific investigations.

PLAN OF STUDY

The Southwest alluvial basins, regional aquifer-system analysis will include all the major alluvial basins in the study area (fig. 2); in addition, the study will include an analysis of the ground-water flow system in the hard-rock areas and the influence of this system on the alluvial basins. Interbasin and intrabasin effects of ground-water development will be studied. The final product of this effort will be reports that document and describe the hydrologic setting, available ground-water resources, and effects of historical development on the ground-water system in the basins. Mathematical models of selected basins and the regional system will be developed to aid in understanding and defining the hydrologic system. The general steps to be taken to accomplish the objectives are:

1. Define and prioritize the basins to be studied.

2. Evaluate and acquire appropriate hydrologic data, and store the data in a data-management system.

3. Develop and calibrate models of first-priority basins.

4. Develop and evaluate interpretation-transfer techniques based on available data, and develop categorization criteria for transferring results of the analyses.

5. Develop plans for and initiate additional data collection to refine models and interpretation-transfer techniques.

6. Develop and calibrate models of second-priority basins.

7. Reevaluate interpretation-transfer techniques.

8. Develop conceptual models and, if data are sufficient, water-budget analyses of third-priority basins and the regional system.

9. Refine and finalize all models.

10. Evaluate results.

A basic premise of this study assumes some commonality within groups of basins; from this comes the concept of categorization of basins based on physical and hydrologic properties, such as size, shape, and depth to water. The degree to which the basins are similar will affect the degree to which the interpretations may be transferred from one basin to another in a category, which, in turn, will affect the degree to which the models adequately simulate the actual system. The models of the first basins that are simulated will be useful in evaluating the values and distributions of the parameters and in verifying the relative sensitivity of the models to variations in the parameters.

The generalized plan for completion of the principal work units and how the units relate to the three phases of the study are shown in figure 3. The work shown as predating this report is completed, and the study is on schedule.

Basin Definition and Prioritization

The study area was divided into 71 basins using available geologic and thickness-of-alluvium maps. The basin boundaries (fig. 2) are similar to but slightly more detailed than the ground-water area boundaries defined by the U.S. Geological Survey and the Arizona Department of Water Resources in 1974 (Babcock, 1975, p. 2-4).

Establishing a priority for developing models of the basins was based on data availability, which influences the ability to simulate adequately the hydrologic system in the basin. Ten basins were selected for the initial model development—first-priority basins (fig. 4). The basins include the entire spectrum of known hydrologic and geologic conditions in the study area. Second-priority basins are those for which slightly less data are available. Reliability in the transferring of information or interpretations between what are thought to be similar basins will be tested during this part of the modeling and will involve models of an additional 14 basins. Third-priority basins are those for which few data are available, and the interpretation-transfer techniques developed and tested in the first and second stages of the modeling effort will be relied on when attempting to describe the hydrologic environment in these basins.

Data Evaluation, Acquisition, and Interpretation

Review of available data.--A large amount of data for individual hydrologic parameters is available for some basins. An initial work effort will be to sample the available data and assess its adequacy. As the reliability of the data is established, it will be input to a master data file. This file will supplement the U.S. Geological Survey WATSTORE data file by including a large amount of data from other sources; it will represent the first systematic attempt in Arizona to put all the available ground-water data into one system. The data will be stored in local computer facilities for ease of access, use, and manipulation. Major files to be established include (1) well-site information, (2) water-level data, (3) water-quality parameters, (4) water-use data, (5) aquifer-test data (transmissivity and storage coefficient), (6) well-log data, and (7) geophysical data.

Data-acquisition techniques.--The lack of geohydrologic data is a major constraint in the orderly management of the water resources of south-central Arizona; therefore, in addition to indicating the

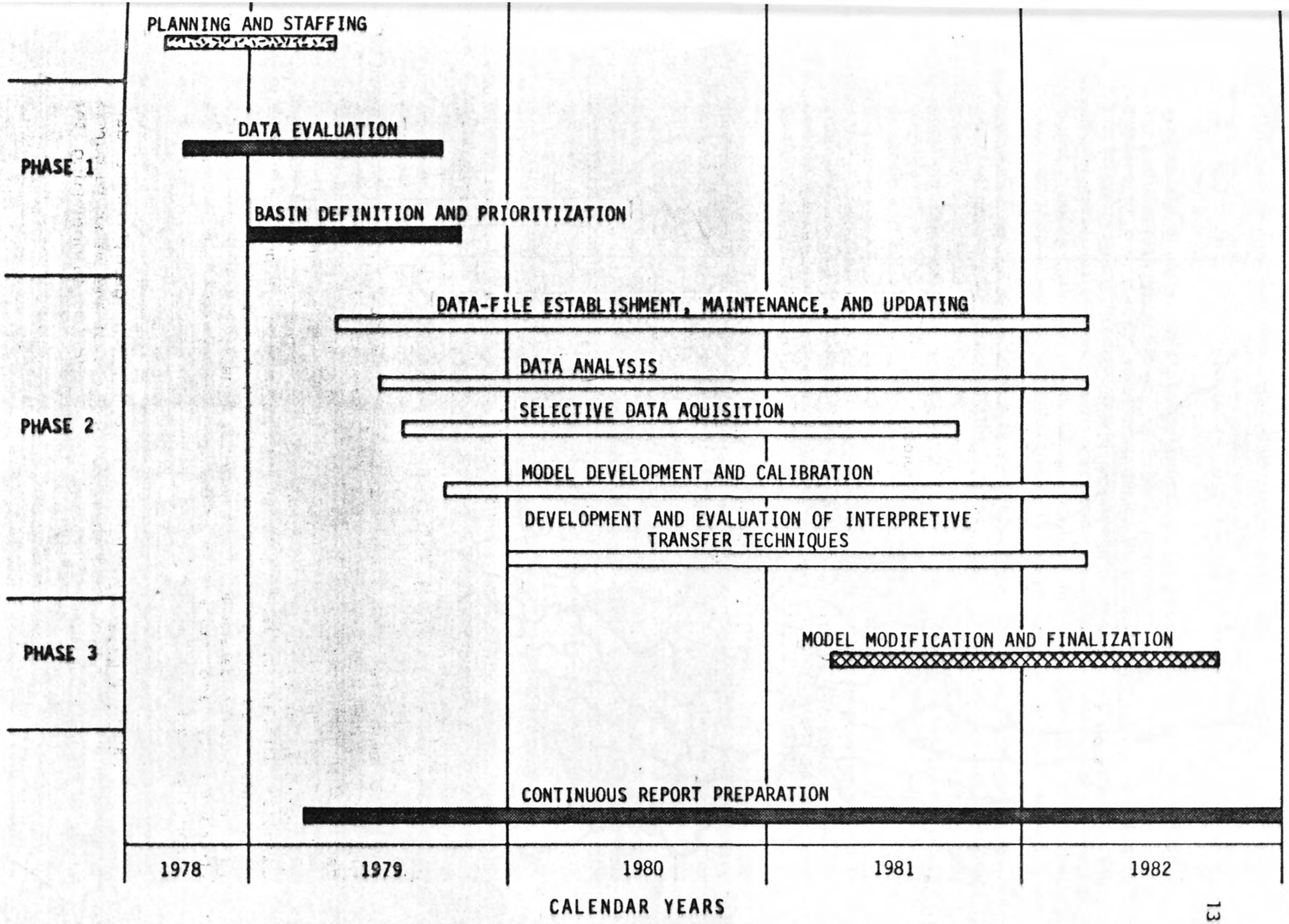

Figure 3.--General schedule of principal work units.

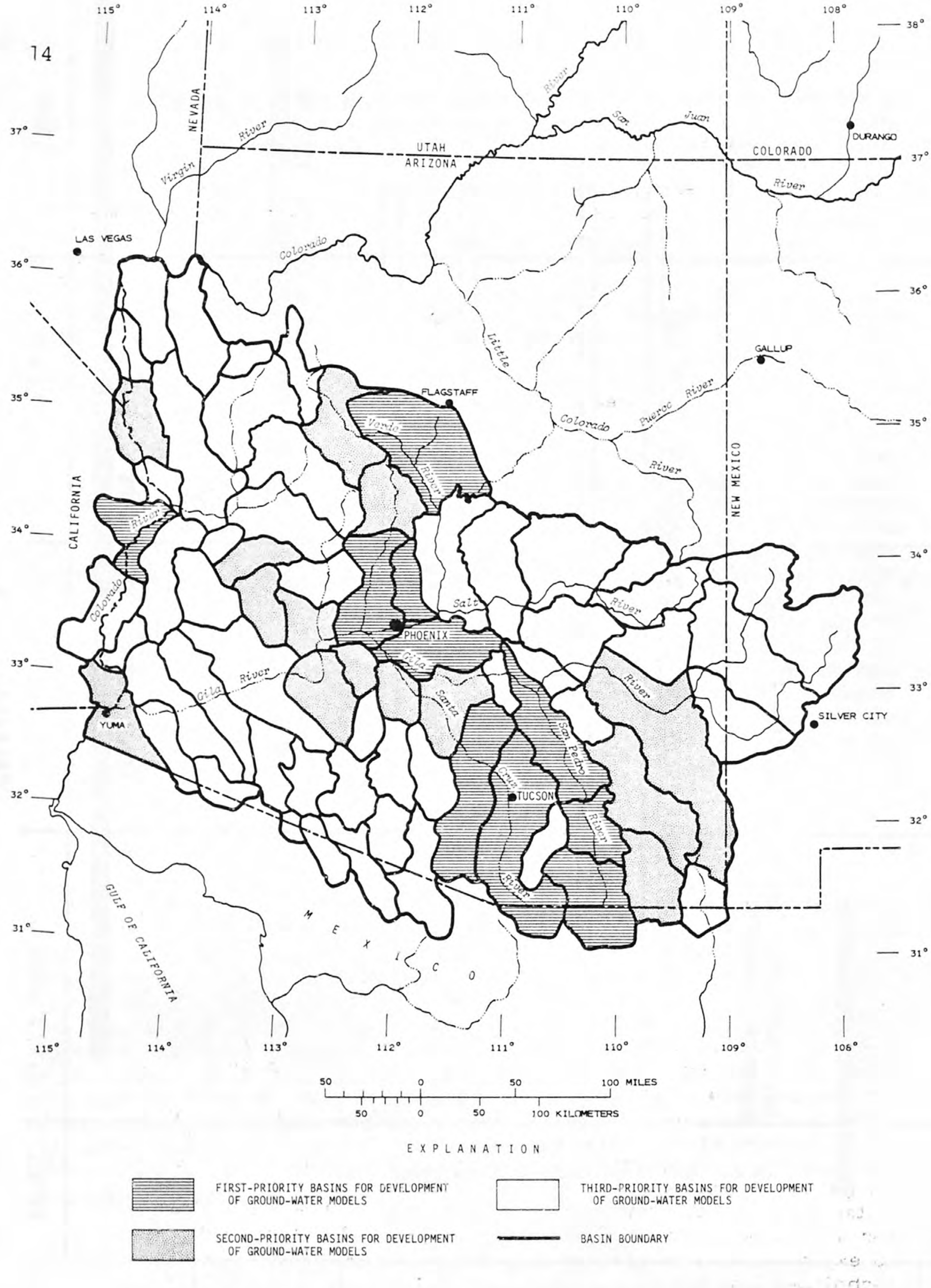

Figure 4.--Priorities for the development of ground-water models.

availability of data, this study hopefully will provide a means of identifying deficiencies in areal and individual parameter data. During the first 3 years of the study, additional data will be collected where possible to fill these gaps. Present plans include the acquisition of geophysical, aquifer-test, water-use, recharge, and water-quality data. Preliminary model results will be used to guide further data-collection activities.

Surface and subsurface geophysical data will be used to describe the geologic framework, the degree of basin interconnection, and subsurface characteristics. The geophysical work will include gravity surveys, resistivity and seismic surface techniques, and several borehole physical and geophysical techniques. Test drilling is not being considered as a tool to define the subsurface lithology owing to the great expense and possible areal insignificance of site-specific data.

A major source of data will be the work being done by other agencies. A liaison committee has been established to maintain lines of communication and to provide an interchange of information between the Swab-RASA staff and other Federal, State, and local agencies.

Data for the hydraulic properties of the alluvial deposits and the moderately to strongly consolidated sedimentary rocks are necessary in order to quantify the ground-water regimen. The primary source for this information will be existing logs and specific-capacity and aquifer-test data for wells. During the study, supplemental data may be obtained from new drill-hole information, aquifer tests at selected wells, and geophysical surveys. Analysis of subsurface geologic data, such as geophysical and lithologic logs, may provide better definition of the vertical and areal distribution of aquifer properties and lithology.

Water-use data include ground-water and surface-water use. These data are necessary to determine the stress imposed on the aquifer system as a result of developments. From a modeling aspect, water-use data are one of the most important input parameters. In basins of large-scale ground-water depletion, a knowledge of pumpage distribution may be the most sensitive factor in the model verification procedure because the areal distribution of pumpage is directly related to the areal distribution of water-level declines. Areal distribution of historical pumpage for all the basins must be generated in order to insure that the models are reasonable simulations of the prototype. Data to be used to determine pumpage include power-use records, crop surveys, irrigated-acreage maps, aerial land-use imagery, and well locations. The land-use data will be used to aid in quantifying one aspect of recharge to the ground-water systems. In addition to natural recharge through infiltration of surface water, a major component of the water budget for basins having large agricultural developments is recharge associated with irrigation. Previous studies have defined recharge as the amount of water required to balance the water budget in the basin after accounting for all other components in the budget. Research will be conducted to explore relations between recharge values determined by different techniques in the study area or a similar area and the controlling geohydrologic parameters.

The first part of the water-quality study will include determinations of problem areas and water chemistry by water types. In addition to the accumulation of existing water-quality data from other agencies, water samples will be collected from selected wells and analyzed. During the first 2 years of the project, a reconnaissance sampling and analysis program will be made to fill data deficiencies. The field reconnaissance will be directed toward site-specific investigations and will include sampling from the unsaturated zone. Field-temperature, pH, Eh, dissolved oxygen, alkalinity, and isotope data will be collected for use in calibration of selected chemical models. The field data will be collected during and subsequent to development of the preliminary flow models. Results of the preliminary models will be used to guide data collection and to develop a better understanding of the flow patterns and their possible effects on the water-rock chemical relations.

Interpretation.--Development of generic relations among hydrologic variables is a goal of the study, and the results will serve as a means of estimating the parameter values for some basins. The ability to quantify the parameters of the hydrologic system, such as lithology and water-rock quality relations, will facilitate attainment of the program objectives.

Statistical testing of the data will involve correlation and regression analyses to relate variables and to compare the variables in and among basins. The results will serve as a key in establishing the transferability of interpretations of the hydrologic system from basin to basin. The interpretation-transfer techniques that result could assist in the development of first-cut models usable for a cursory examination of the possible hydrologic conditions or management alternatives. The final product for a remote undeveloped basin may be only a statement of anticipated geologic and hydrologic conditions and supporting evidence or the assignment of the basin to a specific category or set of categories that could be used to compare and contrast the hydrologic conditions to those in other basins.

The categorization of individual ground-water basins is designed to provide a means by which known hydrologic characteristics in basins that have a large amount of data can be projected to basins in the same category that have little or no data. Categorization will be an ongoing process concurrent with preliminary model development. The factors to be considered initially include a broad range of physical and hydrologic properties. The final factors will include all those critical in the models.

Data Files

The large amount of ground-water data available presents a significant data-management problem. In order to use the information effectively in developing models, an integrated data-handling, analysis, and plotting system is needed. In its simplest form, this computer-based system would consist of a set of files for the different types of data and plotting and statistical routines. The files will consist of well, water-level, water-quality, water-use, aquifer-test, well-log, and geophysical data. In addition, files have been established to store digitized basin-boundary maps; model nodal arrays for individual basins; and township, range, and section-corner locations. All the files will be linked by appropriate software to provide rapid search, sort, and retrieval of the data in variable formats for different areas, specific parameters, or a combination of area and parameter. The general layout and interrelations of the data files are illustrated in figure 5. The data files are established in a local computer system, which will enable rapid access to the data by members of the study team and by cooperating agencies.

Modeling of Aquifer Systems

The term "model" can encompass a broad spectrum of analytical and physical representations of a parameter or a system. A model, as used in this report, will be either a mathematical description of a physical property of the hydrologic system or a simulation of an entire hydrologic system. The modeling to be included in this study will consist initially of two parts—a general analysis of the hydrologic parameters and the development of specific basin models.

The assemblage of available ground-water data and the establishment of these data in manageable files in an appropriate computer system are a necessary precursor to accomplishing the modeling objectives of the study. The hydrologic data for particular parameters will be analyzed in such a manner as to explore areal, vertical, and, in some instances, temporal trends in the values of the different parameters. At the same time, the reliability of these general models will be assessed.

Another initial effort in the study is the evaluation of existing models. Several of the basins included in the first-priority modeling category have been included in previous electric-analog and mathematical-model analyses. All are simple two-dimensional models having nodal arrays ranging from 0.50- to 6-mile centers. For this study, all existing models will be used where possible and generally will serve as the starting point for the development of new models.

Initially, two-dimensional models of steady-state and transient conditions will be developed for each of the first-priority basins. The nodal array for the models will be on 1-mile centers. These mathematical models of the basins will be used to evaluate the conceptual models and to guide further data collection. In many basins data deficiencies will preclude development and use of more complex or detailed models. Multilayer or three-dimensional models will be developed for some basins, especially for those in which the layered lithology is well documented. The models will allow study of the possible effects of aquifer anisotropy

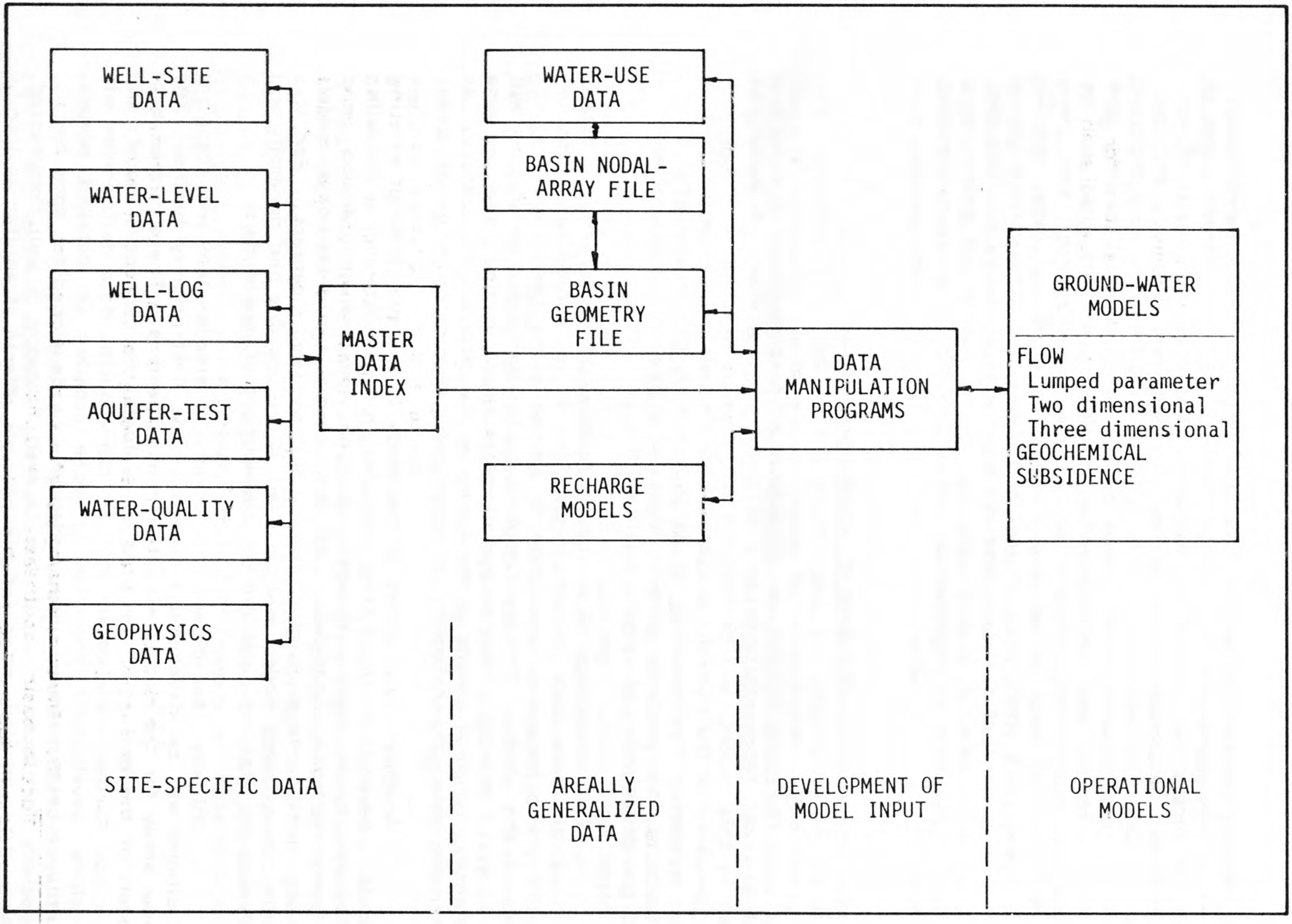

Figure 5.--General relations among data files and software for data handling, analysis, and modeling.

and temporal changes in aquifer parameters on the development and use of the water resources. In addition to modeling the hydraulics of the basins, chemical-reaction and subsidence modeling will be done to the extent allowable using the available data to verify the models.

The feasibility of simulating a regional flow system for the entire study area will be explored. The simulation will be pursued at the level of intensity warranted by the results of the individual basin models. The regional flow-system model will be one of the last models developed and, at first, will be only a linkage of lumped-parameter models of the individual basins. The model will be used to evaluate the interaction of the regional flow system on the individual basins—assuming that effect is measurable—and will allow the study of the effects of development in one basin on the water resources in adjacent basins.

One end product of this study will be a set of systematically constructed ground-water models that will represent the state-of-the-art knowledge of the hydrologic characteristics in the alluvial basins. The models can be readily modified or refined as additional data are collected and entered in the data base. Defining the actual system is and will continue to be the most difficult and important part of the study. The models will be available for use as tools in the decision making, but they continually must be recognized as tools and must be updated to maintain a valid representation of the actual system. The proper application of these tools will expedite and clarify management alternatives.

ORGANIZATION AND STAFFING

The project organization consists of one unit headquartered in the Arizona District office in Tucson. The project staff consists of the project chief, three hydrologist-modelers, a geochemist, a computer specialist, and a hydrologic technician. In addition, Geological Survey specialists will furnish technical assistance and will provide periodic technical review of all aspects of the work. A liaison committee composed of State, Federal, and local agencies concerned with water resources in the project area has been established and will meet regularly. The committee will provide interchange of information and ideas and will aid in coordinating this study with other ongoing studies.

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