

KANSAS GEOLOGICAL SURVEY OPEN-FILE REPORT 1991-13

Coordinated Hydrologic Systems Research

A Joint KGS-USGS Program Plan for
Systematic Investigations of Stream-Aquifer
Interactions in Kansas

compiled by

Robert W. Buddemeier

Disclaimer

The Kansas Geological Survey does not guarantee this document to be free from errors or inaccuracies and disclaims any responsibility or liability for interpretations based on data used in the production of this document or decisions based thereon. This report is intended to make results of research available at the earliest possible date, but is not intended to constitute final or formal publications.

Kansas Geological Survey
1930 Constant Avenue
University of Kansas
Lawrence, KS 66047-3726

Coordinated Hydrologic Systems Research

A Joint KGS-USGS Program Plan for Systematic Investigations of
Stream-Aquifer Interactions in Kansas

Compiled by

Robert W. Buddemeier
Kansas Geological Survey

Open-file Report 91-13

Acknowledgments

This document was prepared collaboratively by the staffs of the Geohydrology Section, Kansas Geological Survey, and of the Lawrence District Office of the US Geological Survey. In particular, John Helgesen of the USGS played a major role in its preparation; his contribution is hereby acknowledged.

Introduction

This document is a modified version of a research plan (Stream-Aquifer Interactions in Kansas: A Topical Research in Development Plan) submitted to the Kansas Water Office in response to the Research Plan sub-section of the Kansas Water Plan adopted in 1990.

The Kansas Water Plan sub-section called for the development of programs to coordinate and integrate water related research by topic as well as by geographical area and local needs. In view of the growing needs for cost-effective water-related research related to many interacting issues, the authors have generalized the original submission so that it can serve as an example or planning document for a more general audience.

Relevance to the Kansas Water Plan and Water Research Needs

A review of the 1992 Basin Plans reveals the scope and generality of stream-aquifer issues. All 12 of the basins list water quality and rural and urban flooding as issues and cite problems with municipal and industrial water supply, 7 are concerned with some aspect of water recreation or habitat, and 6 identify concerns with groundwater declines. They also identify other more specific issues and manifestations of stream-aquifer interactions. With very few exceptions, these problems exist within streams, alluvial aquifers, or the nature of their interactions with each other and the surrounding environment. Clearly, an understanding of the dynamics of stream-aquifer systems is basic to solving their problems and managing their resources.

The 1988 KWA Research Needs Priority listing identifies Stream-Aquifer Interaction as one of the highest priority items; it also specifies Integrated River Basin System Analysis at the same priority level -- and stream-aquifer interactions are an essential component of basin system analysis. A review of the specific listings under the other "highest priority" categories reveals that others contain specific issues requiring understanding of stream-aquifer systems. Examples include: in item 1 (Evaluation, enhancement, and protection of water quality), needs B (definition and identification of critical areas and prevention of potential contamination of major water supplies) and C (hydrologic relations of the unconsolidated and underlying consolidated aquifers in Southwestern Kansas); in item 2 (Fate and Effects of Chemicals in the Environment), items F (movement and contamination potential of agricultural chemicals in soil and water) and W (estimation of aboriginal Kansas water quality conditions). Numerous further examples of overlap can be found in the other (high and medium priority) categories of research needs. Stream-aquifer interaction is not only an important subject in its own right, but is also pivotal to many of the other high-priority issues related to Kansas water resources.

Research Plan:

Introduction

Streams and stream-derived surface waters are an important resource for Kansas. A large fraction of the State's domestic and industrial water supplies are derived from surface (stream) waters, and significant amounts of both municipal and agricultural water are produced from groundwater in the stream (alluvial) aquifers. The streams and their associated aquifers are so

closely linked in terms of water supply and water quality that neither can be properly understood or managed by itself -- the combination must be considered in the larger context of related factors such as climate, land use, and groundwater conditions in other aquifers.

The research plan subsection of the Kansas Water Plan recognizes the importance and complexity of stream-aquifer interactions by designating the subject as one of the "topical research areas" established to address issues that transcend the boundaries of the individual basins. This document describes a proposed plan under which the Kansas Geological Survey would be the coordinating agency for stream-aquifer interaction research under the Kansas Water Plan. KGS, working closely with USGS, would structure and implement a comprehensive research program to solve a wide range of stream-aquifer interaction problems, and would apply the solutions to effective management and planning programs.

Issues and Problems

The State of Kansas and various agencies have expended substantial resources on research and intervention in stream-aquifer systems. The persistence of the problems identified in the Kansas Water Plan and the Research Needs document in the face of continued effort can be traced to two major reasons. First, although stream-aquifer interactions are governed by a limited number of physical principles and can be generally characterized by consistent terms and methods, their local manifestations and problems are strongly influenced by local geology, climate, human activities, etc. These factors cause each stream-aquifer problem to be treated as unique and local, often to a greater degree than is necessary. Each new study is therefore forced to rely on resources appropriate to a local and limited phenomenon, and can make little use of the experience and knowledge gained from similar studies in different environments or different types of knowledge about the same environment. The second major reason for the lack of overall progress on stream-aquifer problems is the complexity of the relationships involved in the stream-aquifer system -- a factor that has a number of consequences.

Figure 1 shows a conceptual schematic of some of the major interactions that may be involved in a systems-level view of stream-aquifer interactions. The figure gives a reasonable representation of complexity at one level -- the number of factors that may need to be considered to address an apparently simple problem. It does not address other important aspects of complexity -- the issues of scale and variability. The interacting components of the system exhibit significant variabilities on time scales ranging from days to centuries, and on spatial scales ranging from a few feet to the dimensions of major drainage basins. Variability and complexity contribute to uncertainty; important parameters such as recharge, runoff, and evapotranspiration are notoriously difficult to measure directly, and must be estimated in ways that place important limitations on the accuracy and precision of our knowledge. Important consequences of complexity and uncertainty include:

1. Perceived economic or practical problems may be oversimplified or misidentified when translated into a scientific problem;
2. Resources may be wasted on studies of problems that are ill-defined or practically insolvable while potentially solvable problems go unsolved for lack of adequate attention; and
3. Planners and managers must do without quantitative tools because problem- or site-specific research results lack transferability or application plans.

Objectives

The overall objective of this plan is to provide the State of Kansas with a robust and flexible means of effectively integrating scientific evaluations and problem-solving techniques into

water-related planning, assessment, and resource management for stream-aquifer systems. In pursuit of that ultimate goal, a number of intermediate objectives may be identified:

1. Establish scientifically rigorous procedures for translating perceived stream-aquifer problems into cost-effective research and for focusing the State's water-related research capabilities on realistic priorities.
2. Identify, assemble, and assist in the application of hydrologic data bases, methodologies, and conceptual models useful for understanding and managing stream-aquifer systems.
3. Solicit and coordinate the development and application of specific research projects and systems-level models that are needed to expand our understanding of and ability to manage stream-aquifer systems in specific and complex water-resource systems in general.

Conceptual Approach

The proposed implementation of the research and development plan consists of establishing a conceptual and management framework within which to prioritize and coordinate research at three different "levels" and to develop practical applications of the research results. The conceptual overview will be based on a quantified version of the model presented in Figure 1. It will use hydrologic and hydrogeochemical models to carry out sensitivity analyses of the relationships between the processes and compartments, and to examine the propagation and effects of uncertainty or inadequacy in the input data. This approach will identify the limiting uncertainties and critical parameters, which can be addressed in three concurrent approaches:

1. At the first level, compilation, assessment, and augmentation of basic hydrologic and climatologic data for individual basins or areas will provide an evaluated data set (the basin atlas approach that is already well under way) basic to assessment, management and further research.
2. The second level is the systems-model level, wherein well-characterized systems or reaches are selected to develop practical, transferable, management-oriented models of the hydrologic systems, with particular reference to limitations imposed by conceptual uncertainty and data availability.
3. The third level involves research targeted on specific information needed for improvement of the systems-level understanding and models. The emphasis here would be on strategically-identified research -- studies that would benefit a wide range of problems or localities, and/or that would contribute to a major reduction in critically limiting uncertainties.

Although the three levels are numbered and some basic progress at levels 1 and 2 is required for effective project selection at level three, all three types of activities would be carried out concurrently and interactively once initial planning and scoping was finished (Table 1).

Implementation Plan

Introduction

The research will be carried out according to a workplan structured around the levels described above. Activities will be managed as four tasks. Coordination (task 1) will run throughout the the program; in the early stages it will include identification of the scientifically addressable aspects of perceived problems and the most critical and cost effective research targets. Once projects are under way, coordination will ensure effective integration of the results and appropriate revisions of research goals and targets as understanding evolves. As the research

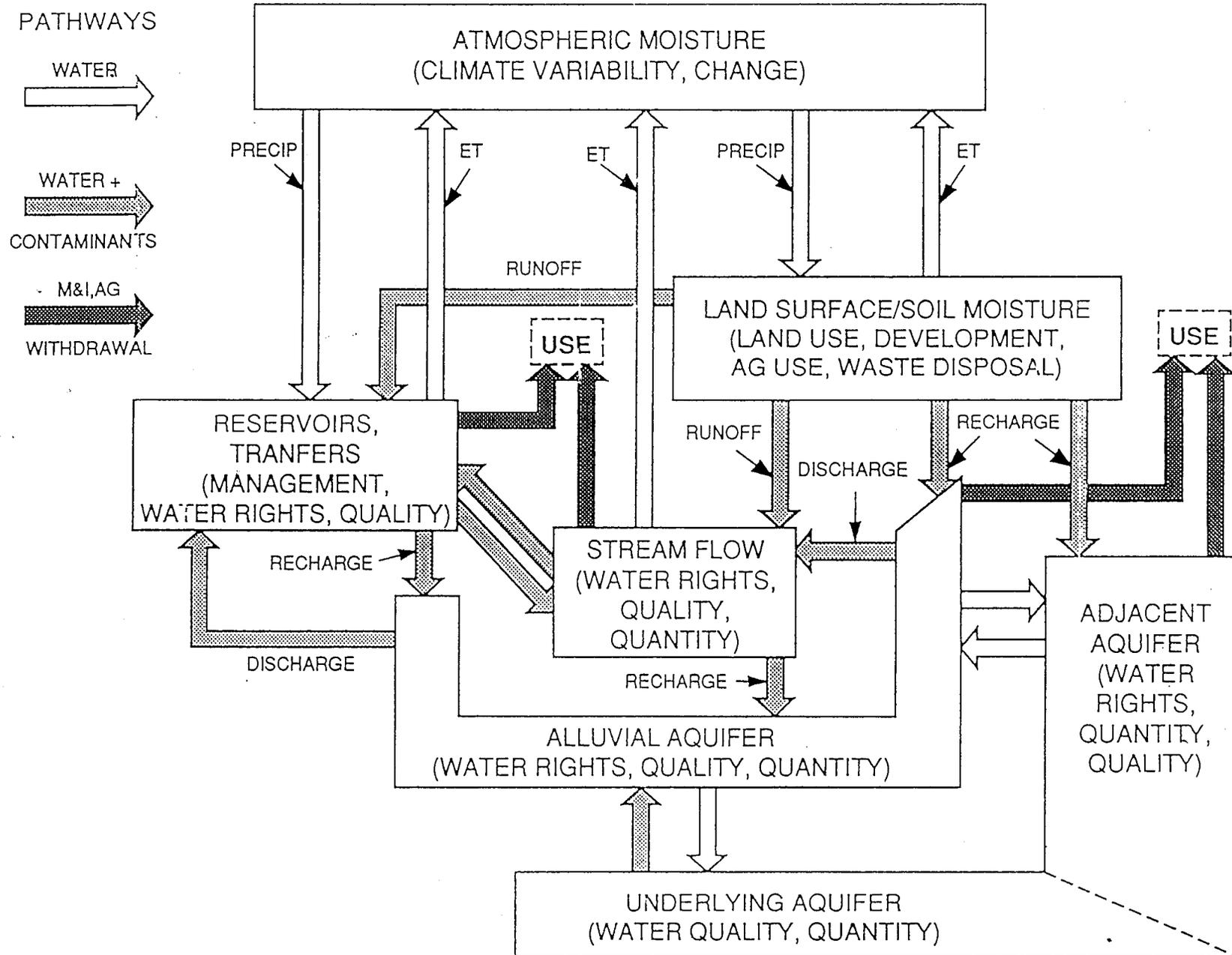


FIGURE 1: CONCEPTUAL MODEL OF FACTORS POTENTIALLY INVOLVED IN STREAM-AQUIFER INTERACTION PROBLEMS

Table 1. Study-Approach Framework

	Level 1 (Basin)	Level 2 (System/Reach)	Level 3 (Process Research)
Geographical and topical scope	All 12 basins; not issue/problem dependent or component/process dependent.	Selected systems/reaches; integration of issues, problems components, processes.	Process- or component-oriented; specific locations of study as appropriate.
Model aspects	Develop conceptual models; assess information needs.	Develop/calibrate mathematical models; sensitivity analyses; use to project system responses.	Use of detailed or special-purpose models as appropriate.
Data collection and analysis	Limited to assembly and evaluation of existing information; preliminary quantification and estimation of system components and processes.	Data collection and analysis for relevant problems, components, processes.	Detailed data collection and analysis as required.
Products	Ongoing identification and prioritization of level-2 and -3 research needs.	Planning and management models and procedures.	Support level-1 and -2 research and product development.

program matures, emphasis will shift to technology transfer -- the development, validation, and cooperative (with affected agencies) implementation of procedures and models for resource management, problem assessment, and future research targeting.

Research activities will be organized and managed according to the three levels described in the preceding section—the basin-descriptive level (task 2), the systems-process level (task 3), and the process-research level (task 4). Figure 2 provides an example of how such a task structure might evolve, but it is important to note that the structure of this research plan is specifically designed to take advantage of evolving knowledge and to maximize the effective use of available resources. Projected time lines and task definitions would be developed during Year 0 and refined during year 1 in conjunction with a review of current and past experience and results from stream-aquifer studies conducted by KGS, USGS, and others. The plan would have the capability of operating over a range of funding levels or in response to a variety of external priorities, since its underlying philosophy is to develop effective and generalizable processes for the identification and attainment of R&D objectives.

The scope and complexity of the plan makes it important that scheduling flexibility be maintained to allow for: (1) changing priorities and redirection within any one level to make best use of results provided from a study within a different level; (2) collection of new data in response to opportunities (e.g., extreme hydrologic conditions, related research by other programs or agencies, etc.); or (3) strengthening hydrologic monitoring programs. However, a general workplan is outlined below, in association with Figure 2.

Workplan

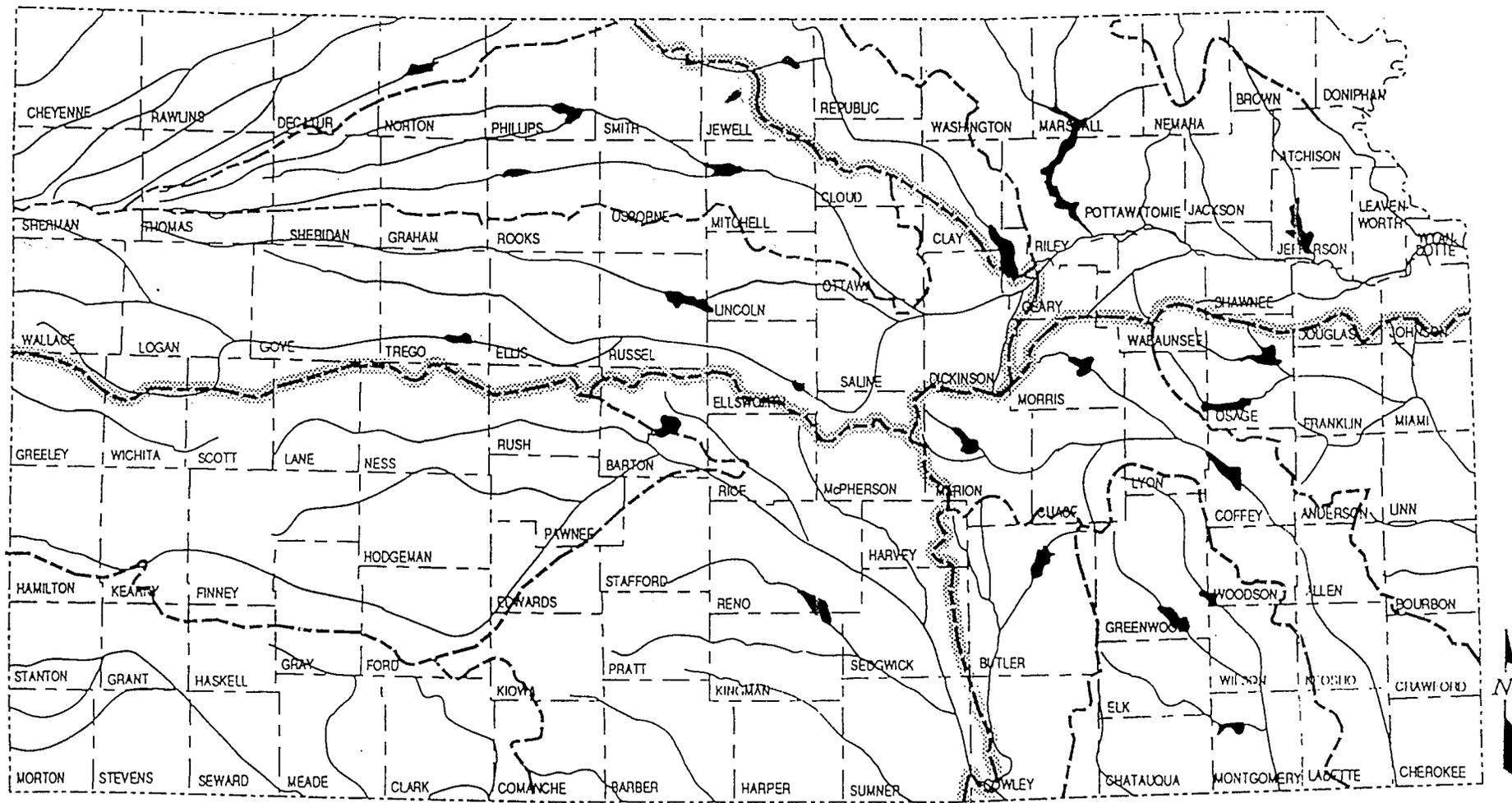
1. Coordination:
 - a. Refine the overall research and development plan. Group basins according to general climatic and hydrogeologic similarities (e.g., four groups of 2 to 4 basins as shown in Figure 3) in order to facilitate efficient and cost-effective Level-1 studies. Establish schedules, responsibilities, and staffing.
 - b. Define priorities in terms of perceived issues and problems related to stream-aquifer systems. Translate issues/problems into tentative scientifically addressable categories, providing the basis for activities in levels 2 and 3. [The planning, progress, interaction between levels, and technology transfer will be continuously integrated.]
 - c. Make provision for ongoing transfer of results to studies at other levels, and to other agencies via GIS and other computer-based information systems. [Results also will be used to identify and select subsequent studies that contribute to program objectives or the objectives of other topical research programs.]
2.
 - a. Initiate level-1 (basin-characterization) studies. To study the first basin group, assemble and evaluate existing information, aided by a GIS-based data-management system. Formulate general conceptual models for the basin hydrology, with emphasis on the stream-aquifer systems and associated issues/problems. Identify information strengths and weaknesses. Estimate basin water budgets (surface water; ground water; and interchange between them) and identify information needs. [GIS- and computer-compatible data bases and graphics will be employed throughout to maximize accessibility of the results.]
 - b. Develop a schedule for conducting initial level-2 and level-3 studies, based upon prioritized issues/problems and process-research needs. [Relative timing of level-2 and -3 studies is flexible.]
3.
 - a. Initiate level-2 (management-oriented modeling) studies. Develop a workplan, timetable, and responsibilities for the first stream-aquifer systems/reaches to be evaluated. [Detailed work elements will be system-dependent, but will include critical review of existing information; development/application of appropriate mathematical

Activity	Y E A R	0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Coordination		-----						-----
Basin-level studies (Level 1)		-----	Group 1					
			-----	Group 2				
				-----	Group 3			
					-----	Group 4		
System-level studies (Level 2)		-----						

				-----				etc.
Process-research studies (Level 3)			-----					

					-----			etc.

Figure 2. Examples of possible timelines for Stream-Aquifer Interaction Research Program.



- - - - RIVER BASIN BOUNDARY
 ■■■■ PROPOSED BASIN GROUPS

0 30 60 mi

Figure 3: Major river basin divisions in Kansas

flow and/or chemical transport models; collection and analysis of new or supplementary data; refinement/modification of conceptual and mathematical models; calibration of mathematical models and application to help assess pertinent development and/or management scenarios.]

- b. Initiate level-3 (process- or problem-specific) studies. Develop workplan, timetable, and responsibilities for the first process-research studies to be conducted. [Detailed workplan elements will be primarily dependent on the specific processes/system components of concern. However, they would include critical review of all relevant information on the topic; development/application of detailed or specific-purpose models; and detailed collection and evaluation of new data as appropriate.]

Research Results and Products

Throughout its duration, the program will maintain a focused technology transfer and liaison effort dedicated to transforming the scientific findings into tools and information useful to the larger community, and to assisting others in further development and applications. Products from the program will be in a range of forms:

1. The research and development plan itself, both in concept and in implementation, and its various progeny.
2. An evolving set of research and assessment tools and techniques for a wide range of stream-aquifer interaction and other hydrologic problems. Examples include databases, validated models and simulation results, field research and measurement procedures and protocols, etc.
3. A series of reports, professional publications, summaries and presentations, and educational materials, variously directed toward laymen, legislators, technical managers, and scientists. These will describe the functioning and sensitivities of stream-aquifer systems over a range of time and space scales, characterize existing specific problems and their possible solutions, provide access to data and information, and identify future concerns and research needs.
4. Data sets, both in the form of compilations of existing information and of new information developed from studies and research targeted to meet specific objectives. These will be available to user agencies both in published and in computerized (GIS) forms.
5. Management tools, in the form of documented and validated conceptual models, protocols, and flexible computer models designed to test and monitor management options and environmental scenarios.

Proposed coordinating and participating agencies

KGS will act as coordinating agency and will have overall responsibility for the conduct and management of research under this program. The details of this responsibility will be spelled out in memoranda of understanding between the participating agencies, and will include designation of a KGS program manager. Project planning and review will be coordinated closely with USGS; where appropriate, KGS will develop and be a party to cooperative agreements for the conduct of research projects with the USGS. Level 1 activities will have a KGS project manager who will oversee a KGS-USGS project team for each basin. Level 2 and level 3 activities may have a KGS or USGS project manager (as agreed upon for each individual project). If the project is co-op, the agency managing the project will have primary responsibility for all elements, but the project team may be staffed from both agencies. If the project is non-co-op, the managing agency will have the entire responsibility.

KGS and USGS will relate all stream-aquifer studies to this research plan and will coordinate activities with KWO and the other research agencies in order to avoid duplication. A

research operations committee will be formed consisting of the KGS program manager, a USGS liaison scientist designated by the District Chief, and principle investigators for specific tasks.

For specific tasks or functions outside of the primary expertise of KGS and USGS, KGS as the coordinating body may subcontract with or solicit proposals from other research agencies (such as KU and KSU departments, other universities, the Kansas Biological Survey, etc.)

Program management will coordinate with and report to the Steering Committee or its designee, the Council of Directors, and such other review or liaison agencies as may be formed by interested agencies. Annual reports of activities, progress and plans will be made on a scheduled basis; technical reports of substantive research accomplishments will be submitted on completion of the work or according to agreed-upon schedules.

Timetables and research schedule milestones

The conceptual outline of the research is presented in item 6 above. If the research is funded at the recommended levels, the following schedule of accomplishments may be anticipated:

1. Completion and dissemination of updated atlases for all basins by the end of the six-year program period. We regard the basin atlases as living documents, for which the data sets must be updated every 1-2 years to provide current information for management decisions. This implies the existence of an institutional mechanism for maintaining the atlases even after the conclusion of the topical research effort.
2. Completion and dissemination of 2-3 "level 2" (systems-model) studies—probably for the Solomon and Upper/Lower Arkansas basins (subject to user agency and Steering Committee input) -- in time for the proposed program review after approximately 3 years.
3. Identification, prioritization and initiation of "level-3" studies critical to further progress, also by the program review period.

Progress toward these milestones would be reported for review during the annual program review and proposal cycle.