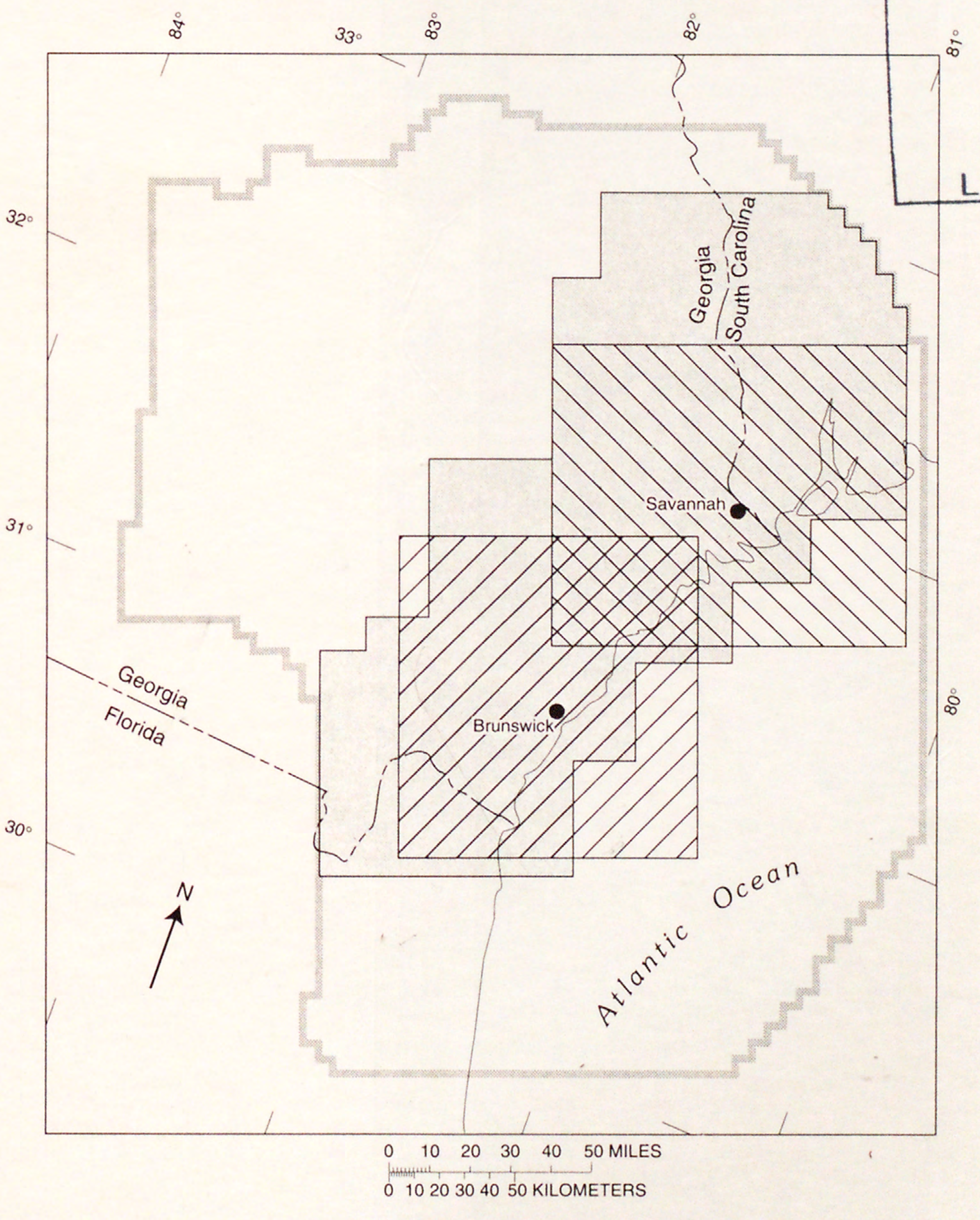
DOCUMENTATION AND GUIDELINES FOR THE APPLICATION OF TELESCOPED MODELS TO SIMULATE GROUND-WATER FLOW IN COASTAL GEORGIA AND ADJACENT PARTS OF FLORIDA AND SOUTH CAROLINA

U.S GEOLOGICAL SURVEY

Water-Resources Investigations Report 94-4091



Prepared in cooperation with the

CHATHAM COUNTY—SAVANNAH METROPOLITAN PLANNING COMMISSION

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By Reggina Garza and Christopher T. West

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Atlanta, Georgia
1995

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CONTENTS

ILLUSTRATIONS
(in text)

(in appendix)

TABLES
(in text)

(in appendix)

CONVERSION FACTORS, ACRONYMS, AND ABBREVIATIONS

Conversion Factors

Multiply	by	to obtain
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Acronyms

BAS	MODFLOW Basic Package
BCF	Block-Centered Flow
GHB	General Head Boundary
MODFLOW	Modular Three-Dimensional Finite-Difference Ground-Water Flow Model
RASA	Regional Aquifer-System Analysis Program
USGS	U.S. Geological Survey

Abbreviations

coa	Coastal area model
gly	Glynn County area model
RMSE	Root mean squared error
sav	Savannah area model

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ABSTRACT

This report presents an overview of a telescoping approach that can be used as a technique for developing a subregional ground-water flow model in areas where an existing regional model could generate boundaries for the subregional model. The subregional model will provide results at a finer resolution in the area of interest than the regional model. This report also documents computer programs used for this telescoping approach and furnishes the computer programs in ASCII format on diskettes.

The ground-water flow models use the finite-difference approach. Model simulations are executed using the code "Modular Three-Dimensional Finite-Difference Ground-Water Flow Model" (MODFLOW).

INTRODUCTION

Water supply in coastal Georgia is provided primarily from the Upper Floridan aquifer (Krause and Randolph, 1989; Randolph and Krause, 1990). Withdrawals have caused concern over the quantity and quality of the water in the aquifer and have been the subject of ground-water studies in coastal Georgia for many years.

Several ground-water flow models have been developed by the U.S. Geological Survey (USGS) for the coastal area of Georgia in an attempt to evaluate and plan for future water-supply demands. These ground-water flow models use the finite-difference approach and are based on the Modular Three-Dimensional Finite-Difference Ground-Water Flow Model (MODFLOW) (McDonald and Harbaugh, 1988).

A regional model was developed as part of the USGS Regional Aquifer-System Analysis program (RASA) (Krause and Randolph, 1989) to identify the flow properties of the Floridan aquifer system in coastal Georgia and in adjacent parts of South Carolina and Florida. Because of the coarse resolution of the RASA model (16-square mile (mi^2) blocks), it could not be used to simulate the response of the ground-water flow system in areas where ground-water pumpage and consequent ground-water level declines were affecting the quality of ground water. To enable the simulation of that response, three other ground-water flow models were developed based on the RASA model (Krause and Randolph, 1989): Glynn County model (Randolph and Krause, 1990), coastal model (Randolph and others, 1991), and the Savannah area model (Garza and Krause, 1992). Because of the technique used to develop the subregional models, they are referred to as "telescoped" models. Although the areas of the subregional models may overlap, the subregional models are independent of each other. All three subregional ground-water flow models use one level of telescoping (Ward and others, 1987). "Telescoped", as used in this report, means development of a subregional model having finer resolution and embedded in a regional model (Garza and Krause, 1992).

Several RASA studies have been completed for the Nation's aquifer systems. Most of these studies resulted in ground-water flow models that are regional in scope and scale. Subregional models in the RASA model areas can be developed and used for more detailed, site-specific information. Simulations using a telescoping approach enable the modeler to analyze the responses of the ground-water flow system at different scales, and to evaluate interaction among areas in different models within the regional model. This technique was used in the Savannah and Brunswick, Ga., areas and is described in Garza and Krause (1992). This report is a follow-up to a USGS study (Garza and Krause, 1992) conducted in cooperation with the Chatham County—Savannah Metropolitan Planning Commission.

Purpose and Scope

This report describes the development of a subregional ground-water flow model and serves as a guide for applications of telescoped models developed in previous studies in Georgia (Krause and Randolph, 1989; Randolph and Krause, 1990; Randolph and others, 1991; and Garza and Krause, 1992). An overview of the techniques used to develop subregional models is presented in the "Telescoping Approach" section. The subregional models developed in Georgia and their relation to the regional model are described in the "Telescoped Models in Georgia" section. Discussion of the organization of the models, input, output, execution of simulations, and codes developed to ensure the efficiency of transforming data between regional and subregional models are in the Appendix in the back of this report.

Computer programs used in the RASA (Krause and Randolph, 1989) and Savannah area (Garza and Krause, 1992) models are in ASCII format on two 3 1/2-inch DOS-compatible diskettes. These diskettes contain the input, output, FORTRAN source, and script files developed using the UNIX operating system.

The models use the finite-difference approach and simulations are executed using the MODFLOW code (McDonald and Harbaugh, 1988). The reader should be familiar with documentation and use of MODFLOW.

Previous Investigations

The technique of telescoping models used by Buxton and Reilly (1986) was used to predict the effects of the reduction in ground-water recharge owing to the installation of sanitary sewers and ocean outfalls in a portion of Nassau County, Long Island, N.Y. The telescoped model developed by Buxton and Reilly (1986) assumed ground-water flow under transient conditions. The simulations were performed using a finite-difference method, and the boundaries for the subregional model were generated by using the regional fluxes crossing the artificial regional-subregional boundaries.

Ward and others (1987) used a similar technique to analyze the effectiveness of a proposed remedial action for a hazardous-waste site in the vicinity of the Miami River, Oh. They developed three models that were designed at regional, subregional, and local scales to characterize the ground-water flow system. The telescoping technique included areal and vertical discretization at varied scales and used the finite-difference method for the simulations. Boundaries of the telescoped models were generated by using the heads simulated by the coarser model.

In Georgia, the technique of using regional and subregional models began with the development of the Glynn County model (Randolph and Krause, 1990). The Glynn County model was developed for the Brunswick, Ga., area to provide a tool to analyze the effects of increasing ground-water withdrawal in the area. At the same time, the coastal model (Randolph and others, 1991), was developed to encompass coastal Georgia and adjacent parts of South Carolina and Florida to estimate the potential for future development of ground-water resources in coastal Georgia. The need for a more detailed analysis of the effects of additional withdrawal on the ground-water flow system in the vicinity of Savannah, Ga., led to the development of the Savannah area model (Garza and Krause, 1992), which also used the telescoping technique. The three aforementioned models were telescoped from the regional RASA model (Krause and Randolph, 1989) and assume that ground-water flow was under steady-state conditions. All the models used the finite-difference approach (code MODFLOW), and artificial boundaries were generated from the fluxes simulated by the regional model.

Robert B. Randolph, then with the USGS, developed the telescoping approach concept to ground-water flow modeling in Georgia. Mr. Randolph wrote the original code for the telescoping approach for the Glynn County model (Randolph and Krause, 1990), the coastal area model (Randolph and others, 1991), and the Savannah area model (Garza and Krause, 1992). Mr. Randolph also initiated the concept for this report.

TELESCOPING APPROACH

The selection of boundary conditions is one of the most critical stages in modeling a ground-water flow system. Modeling literature recommends that boundaries be chosen to match the physical boundaries of the system. Such a goal might be met at a regional scale, but when it is necessary to study the system at a finer scale, the extensions of the model boundaries to the physical boundaries translate into an unnecessarily large grid, often without data to support such computations. Under these circumstances, the technique of "telescoping" can be a useful approach. The technique consists of designing nested regional and subregional grids and using the regional model (of an entire or major part of a ground-water system, including its natural hydrologic boundaries) as a tool to determine boundaries for the subregional model (Anderson and Woessner, 1991). Therefore, a local phenomenon can be simulated using a smaller model domain while maintaining consistency with the regional ground-water flow system. In this way, the ground-water flow system can be evaluated at a finer resolution than that of the regional model without having to extend the subregional boundaries to natural hydrologic boundaries. Each model pair (regional and subregional) functions as a telescoped model, the effects of stresses beyond the boundaries of the subregional model are determined by the regional model, and those effects are transferred to the subregional model through the boundaries.

Subregional models may be generated by using a regional model rediscretized (finer discretization) areally, in the x-y direction (fig. 1a); vertically, in the z direction (fig. 1b); or both (fig. 1c). Areal discretization may be used where hydraulic properties or the configuration of the potentiometric surface varies considerably. When discretizing areally, the regional flow crossing the face of a cell at the location of the boundary between the regional and subregional area is subdivided into the "n" subcells for the subregional side of the boundary (fig. 1a. shows the case for n=5.) Discretizing in the vertical direction would allow modeling local flow by using a subregional model with more layers—representing aquifers and confining beds—than those addressed by the regional model (Ward and others, 1987). The flow (Q) crossing the face of a regional cell is subdivided and, depending on the characteristics of the aquifers (new layers), the flow could be distributed equally or variably. For example, if most of the flow occurs in the upper zone, the regional flow would be affected by a higher factor in the upper zone than in the lower zone. Figure 1b shows the case for factors of 0.7 in the upper zone and 0.3 in the lower zone. When both areal and vertical rediscretization are used, the regional flow at the face of a boundary cell will be affected by each lateral and vertical factor. Figure 1c shows the case for a lateral factor of 1/3 and a uniform vertical factor of 1/2.

To determine lateral extent of a subregional model that requires vertical discretization, the aquifer system should be analyzed at the regional scale to determine the area in which the aquifer may be represented by more layers than those specified in the regional model. If both areal and vertical discretization are used, the extent of the lateral boundary for the subregional model would depend upon the area of interest; however, the vertical discretization might extend these boundaries if the conditions are such that the area where the aquifer is comprised of two zones extends beyond that area of interest (fig. 2). If the study area is larger than the area where two zones exist, then the extent of the lateral boundary would be controlled only by the area of interest.

Development of Subregional Models

Subregional models described in this report (see "Subregional models" section) were developed assuming that ground-water flow was under steady-state conditions. Therefore, the applications refer to the use of MODFLOW (McDonald and Harbaugh, 1988) for steady-state simulations. Although transient simulations using subregional models are discussed, applications are not included.

The subregional models were developed based on an existing regional, coarse resolution model (Krause and Randolph, 1989) that encompasses an area larger than the area of interest. The purpose of developing a subregional model is to refine the results by discretizing the study area using boundaries generated from the regional model.

Steady-state conditions

Simulations of ground-water flow under steady-state conditions using MODFLOW have only one stress period. The execution of the regional model generates conditions that are used as subregional boundaries (heads or flow). Then, boundary heads or flow conditions are incorporated into the subregional input-data sets (fig. 3). After inputing the subregional boundaries, the subregional model can be executed.

A calibrated regional model will reproduce a regional ground-water flow system. Depending on the specifics of the study, it may be appropriate to use either heads or flows (Ward and others, 1987) from the regional model as boundary conditions for the subregional model. In either case, there is an intermediate process needed to transform regional conditions into boundaries for the subregional model (fig. 3, regional-subregional linkage). Heads can be interpolated at the scale of a subregional model to be used as head boundaries. If flows are used as boundary conditions for a subregional model, the vector volumes of flow (Buxton and Reilly, 1987) are subdivided and transformed into stresses (artificial wells of recharge or discharge) located at the boundaries of the subregional model. The vector flows used in subregional models are those labeled as FLOW FRONT FACE and FLOW RIGHT FACE in MODFLOW's cell-by-cell output (hereafter called QFRONT and QRIGHT). The purpose of boundary wells is to reproduce fluxes crossing the artificial subregional boundary, either into or out of the subregion.

Flow across the regional and subregional boundaries, Q_{AB} (fig. 4), is computed in the regional simulation (regional resolution) and is subdivided into as many cells as needed in the subregional resolution. For example, in figure 4, Q_{AB} is subdivided and applied to four cells: b1, b2, b3, and

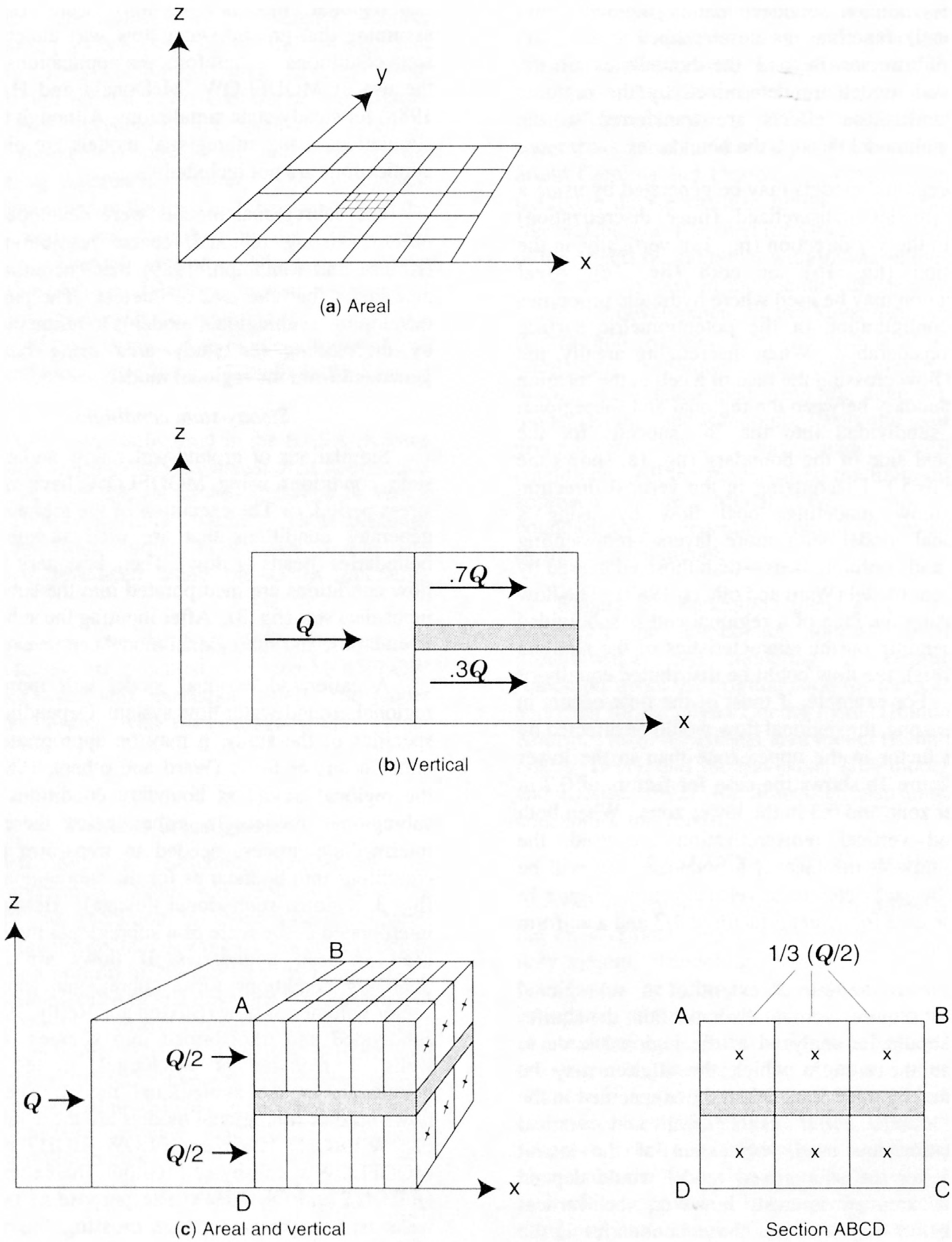
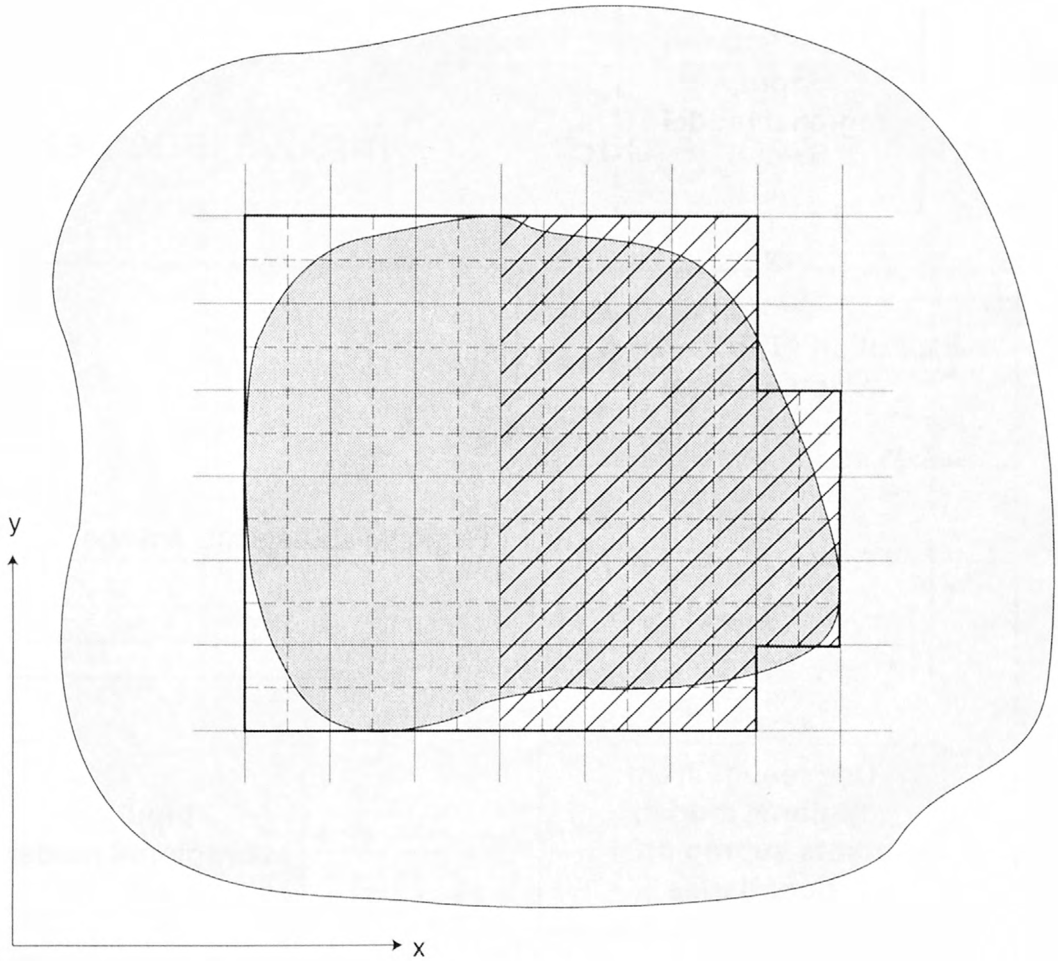


Figure 1. Rediscretization of a regional model.



EXPLANATION

Area of interest

Area in which aquifer A is represented by one layer in the regional model

Area in which aquifer A is represented by more layers than in the regional model

Boundary between regional and subregional models

Subregional discretization

Regional discretization

Figure 2. Extent of lateral boundaries in a subregional model generated by vertical discretization.

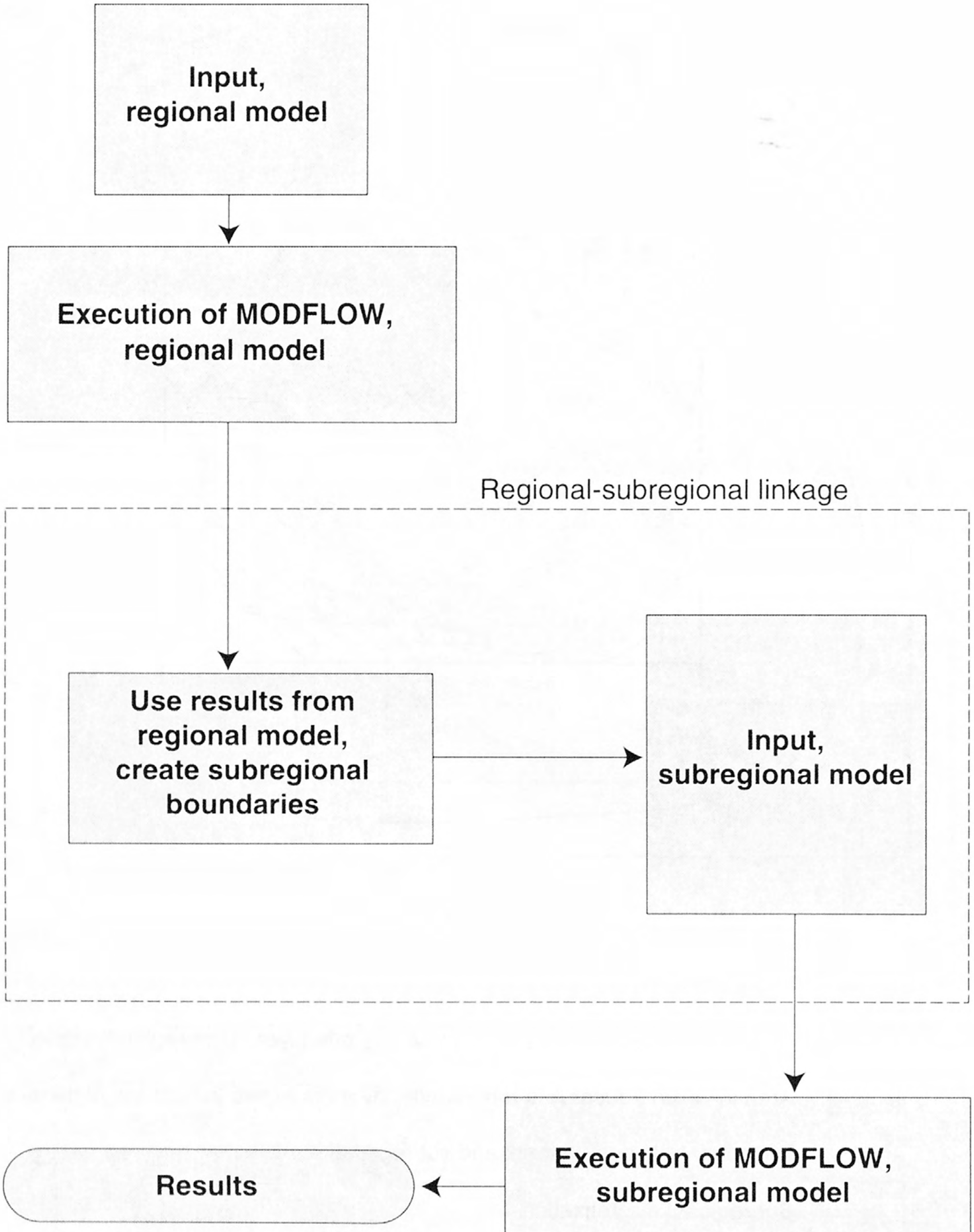


Figure 3. Simulation using a telescoped model.

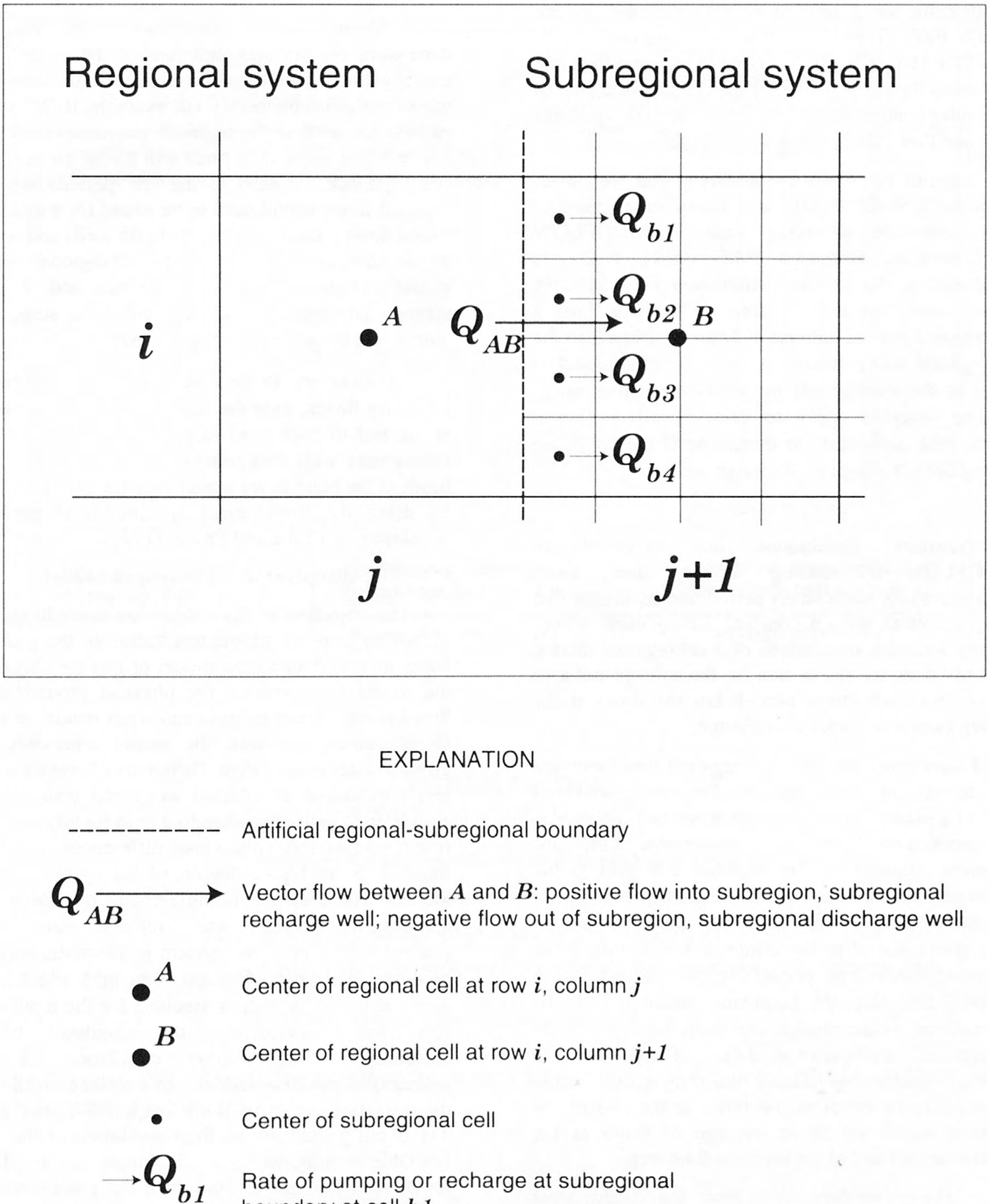


Figure 4. Subregional areal boundaries generated from regional flows.

b4. This flow is incorporated as a boundary in the subregional model by transforming computed fluxes into recharging or discharging wells. In the case of corner cells, using flows as boundaries results in one FLOW FRONT FACE (QFRONT) and one FLOW RIGHT FACE (QRIGHT). Both flows are added and applied as the stress (well) for the cell at that corner of the subregional model. The rest of the cells will have only one flow (QRIGHT or QFRONT).

Because the flows are added to the well data-input file for MODFLOW, it is important to consider the convention of signs used in MODFLOW (McDonald and Harbaugh, 1988, p. 8-1). If Q_{AB} is computed in the regional simulation as a negative value, flow direction is into cell B, or into a subregional system defined in figure 4. Flow into the subregional area is treated as wells of recharge and is input to the subregional model as a positive value. Similar analyses apply to each boundary (north, south, east, and west) to determine if the wells are subregional recharge or discharge wells.

Transient conditions

Transient simulations are executed in MODFLOW by reading pumping data (stress parameters) for each stress period and assuming that the parameters remain constant during each period. During transient simulations of a subregional model, not only does the stress data for the subregional area change for each stress period, but the flows at the subregional boundaries also change.

Flows generated from the regional simulation are transformed into wells and added to subregional well data in a manner similar to that described for steady-state conditions. When using subregional models for transient simulations, the regional and subregional stress periods are linked. Because the flows change at the end of each regional time step, the time step for each stress period in the regional model will define the subregional stress period (fig. 5). Thus, for each regional time step, the boundaries generated for the subregional model change and must be input in the subregional well-package data. Flows used to generate boundaries during the subregional stress period may be equal to the flows at the end of the regional time step or an average of flows at the beginning and end of the regional time step.

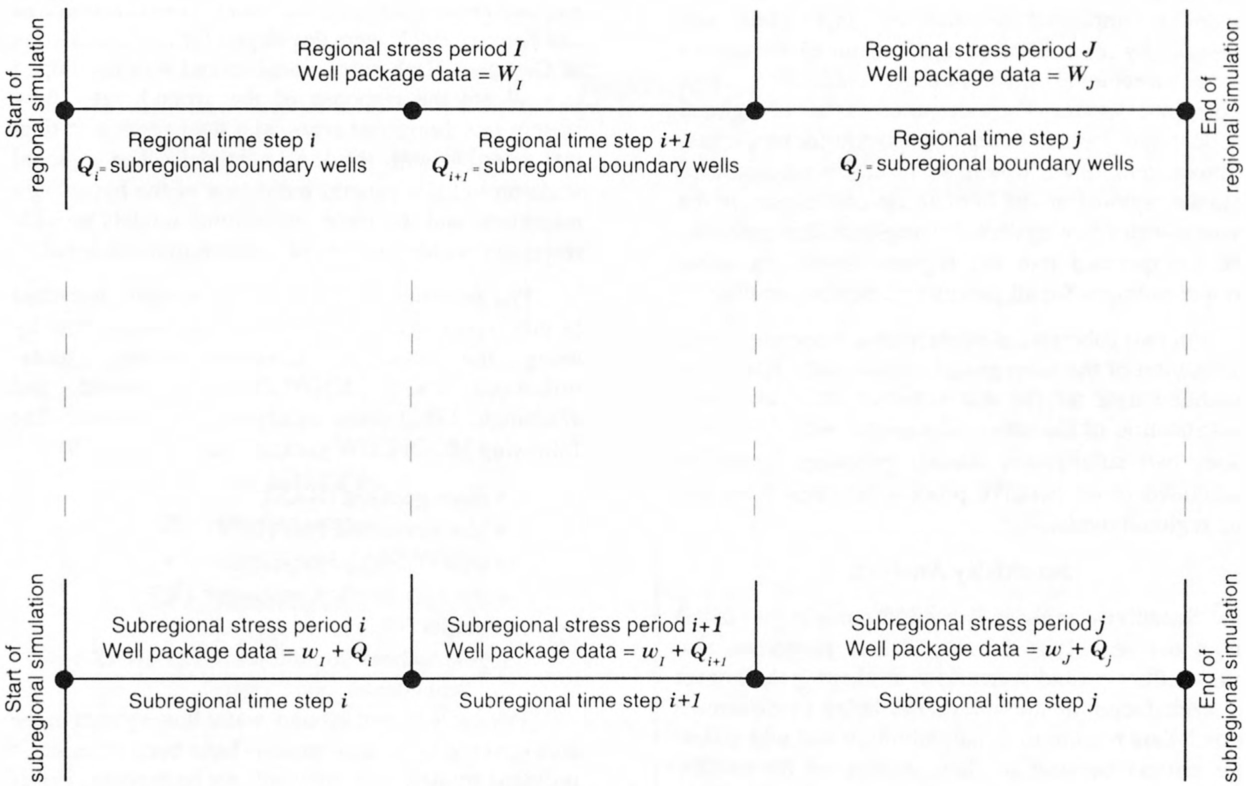
The procedure described for steady-state simulations (fig. 3) is repeated for each time step (subregional stress period) and flows at the boundaries for each regional time step are derived and converted into wells. During regional stress period I, actual pumping (w_I) for the subregional model remains constant for all subregional stress periods (regional time steps for regional stress period I) and only boundary wells (Qj) change (fig. 5). Boundary wells (Qj, fig. 5) then are added to the subregional pumping data (w_I) forming the well-package data for each subregional stress period.

When transient simulations are required, depending on the size and use of the model, the technique may become inefficient due to the intensive use of computer memory. For example, if "N" stress periods are used in the regional simulation and each has "n" time steps, then there will be "n" subregional stress periods for each of the "N" periods and the regional flows would have to be stored (N x n) times. These flows would be converted into wells and added to the subregional model. The subregional model would include (N x n) stress periods and, if each subregional stress period has "m" time steps, the output will be generated (N x n x m) times.

If heads are to be calculated for subregional boundary fluxes, then the heads would be calculated at the end of each time step. In this situation, the subregional well data would not be affected. The heads at the boundaries would vary for each time step by using the time-variant specified-head package developed by Leake and Prudic (1991).

Calibration of a Telescoped Model

The objective of the calibration procedure is to iteratively improve the representation of the ground-water flow system by the model or test the ability of the model to reproduce the physical ground-water flow system. Water budgets and water levels are used to determine how well the model represents the ground-water flow system. Differences between water levels measured at selected wells and water levels simulated in cells corresponding to those locations are referred to as residuals; small differences (residual) imply a better representation of the system by the model. The cause of the differences, providing that the measurements are reliable and the conceptualization of the system is adequate, may be owing to spatial discretization of the grid, which has a direct effect in the values assumed for the input-data sets; and consequently, the simulated heads. Development and further calibration of the subregional model contributes to a better control over discretization errors in the subregional model area. The detail gained by the finer resolution of the grid (variable or uniform) in a subregional model allows for a more accurate definition of the potentiometric surface or water table, aquifer properties (leakance, thickness, and hydraulic conductivity), and pumping location. Thus, discretization of regional parameters is not simply assigning regional values to subregional cells.



EXPLANATION

W_I Pumping for regional stress period I

w_I Pumping for subregional model, during regional stress period I

Q_i Subregional boundary wells for each regional time step i

UPPER CASE subscript indicates regional stress period

lower case subscript indicates regional time step (subregional stress period)

Figure 5. Generation of subregional well package data for transient simulation (modified from McDonald and Harbaugh, 1988, figure 21).

The calibration of the subregional model is an iterative process, both within the subregional model and between regional and subregional models, in which the final product is a calibrated subregional model and an improved regional model. The regional model is improved because the input data sets provided by the calibrated regional model are altered in a subregional area through calibration of a subregional model. The calibration of the subregional model might include better-defined aquifer properties, sources, and sinks, which, in turn, are incorporated into the regional model to maintain consistency in the ground-water flow system. Subregional data generally are incorporated into the regional model by using simple averages for all parameters except pumping.

If two subregional models have a common area, calibration of the subregional model might result in a modified data set for that common area; and thus, modification of the other subregional model. In this case, two subregional models probably would be calibrated in an iterative process between them and the regional model.

Sensitivity Analysis

Sensitivity analysis is used in modeling to determine the sensitivity of a model to properties that might affect ground-water flow. Evaluating the impact of each factor in the simulation helps to determine which data require minimal definition and which data are critical because of their impact on the results. Sensitivity is evaluated by adjusting one property at a time; therefore, its relative importance can be evaluated quantitatively by using a statistical indicator. Indicators, such as the mean of the residuals or the root mean square error (RMSE), are used to judge the adequacy of the model to represent the physical conditions.

Subregional models can not stand alone, but rather depend on the regional model. Therefore, during sensitivity analysis of the subregional model, a consistency between regional and subregional models must be maintained. Properties vary not only within the subregional area, but also outside the subregion to maintain the continuity across the boundary (fig. 6, section A-A'). For example, to test the effects of varying any aquifer property T by a factor "α", that property in the subregional model is varied by a factor "α" for all the subregional cells (T_s). Then, the values of T at subregional resolution (already affected by "α") are averaged and transformed into values of T at regional resolution (T_{sr}). In order to maintain the continuity across a boundary, the values of the property T for the regional model outside a subregional area, also have to be affected by the same factor "α" (T_r). After these transformations are applied, the models can be executed and statistics computed. A diagram showing these steps is presented in figure 7.

TELESCOPED MODELS IN GEORGIA

Following the development of the regional RASA model (Krause and Randolph, 1989), three subregional telescoped models (Randolph and Krause, 1990; Randolph and others, 1991; and Garza and Krause, 1992) were developed for the coastal area of Georgia. Each subregional model was developed to evaluate the response of the ground-water flow system in subregional areas, at a finer resolution than was possible with the RASA model. The regional scale provided a general indication of the hydrologic responses, and the three subregional models provide responses within the area of concern in more detail.

The regional and subregional models described in this report (fig. 8) simulate ground-water flow by using the modular, three-dimensional, finite-difference code MODFLOW (McDonald and Harbaugh, 1988) under steady-state conditions. The following MODFLOW packages are used (fig. 9):

- basic package (BAS),
- block centered flow (BCF),
- well (WEL),
- strongly implicit procedure (SIP),
- output (OUT),
- general head boundaries (GHB) (RASA and coastal models only).

The geology and ground-water flow system in the area covered by all four models have been reported in previous studies; thus, they will not be repeated in this report. For details, the reader is referred to Krause and Randolph (1989), Randolph and Krause (1990), Randolph and others (1991), and Garza and Krause (1992).

Regional Model

The regional model from which the subregional models are based is that of Krause and Randolph (1989) as a part of the USGS Regional Aquifer-System Analysis (RASA) program. This ground-water flow model simulated the Floridan aquifer system in the Coastal Plain of Georgia and adjacent parts of southern South Carolina, and northeastern Florida (fig. 8) using the code developed by Trescott and Larson (1976). Later, the input-data sets were adapted to simulate the ground-water flow system using MODFLOW and create model boundaries for subregional models. The total area covered by the regional model is 53,248 mi^2 and was discretized by a uniform finite-difference grid having 52 rows and 64 columns (Krause and Randolph, 1989, figs. 21 and 22). Each cell is 4 mi on a side (16 mi^2). The origin of the grid for the regional model is the bottom-left corner (Trescott and Larson, 1976), and for the three subregional models, the origin of the grid is the upper-left corner. This is important when reading rows and columns in the RASA model.

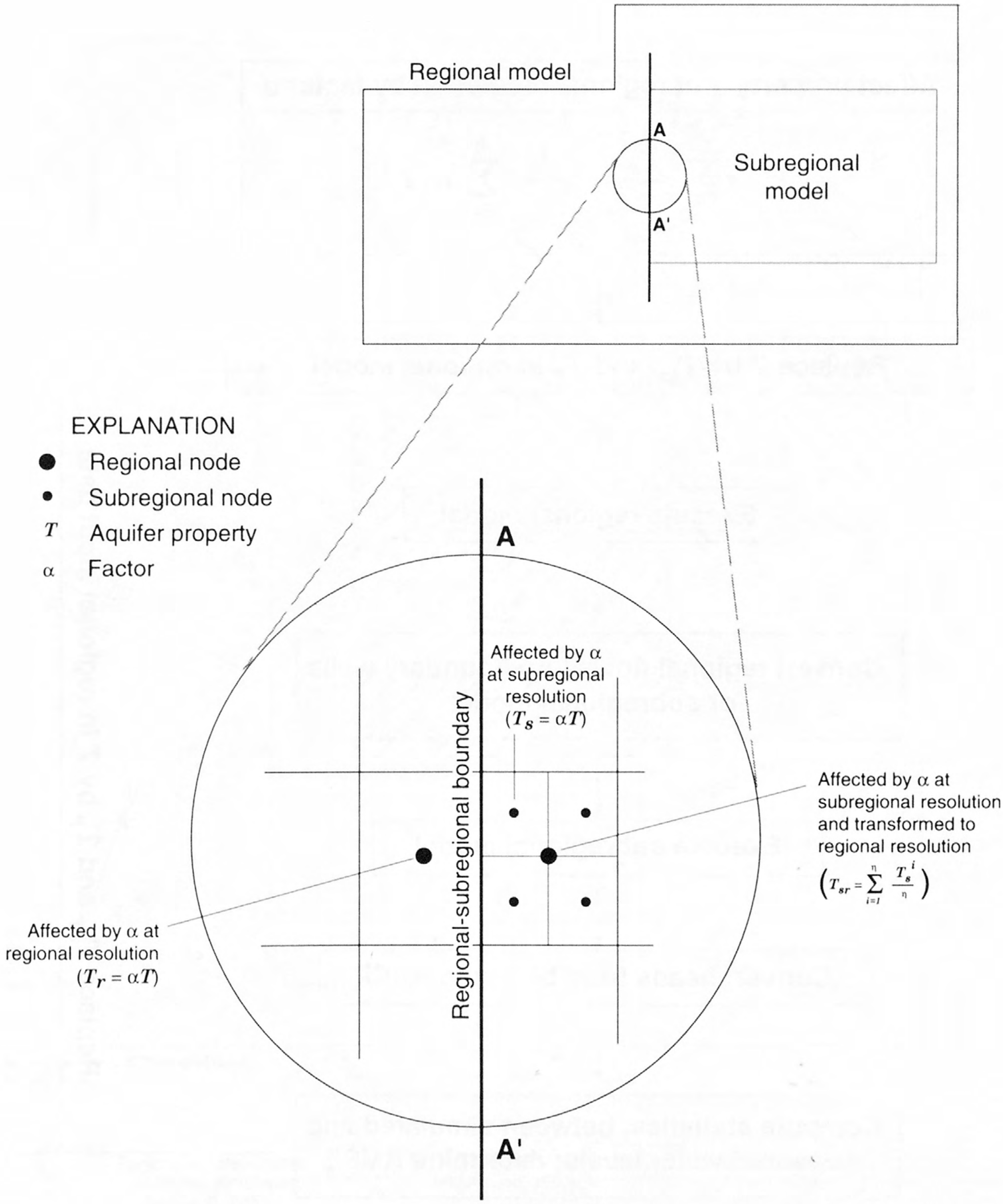


Figure 6. Continuity of a property across the regional-subregional boundary.

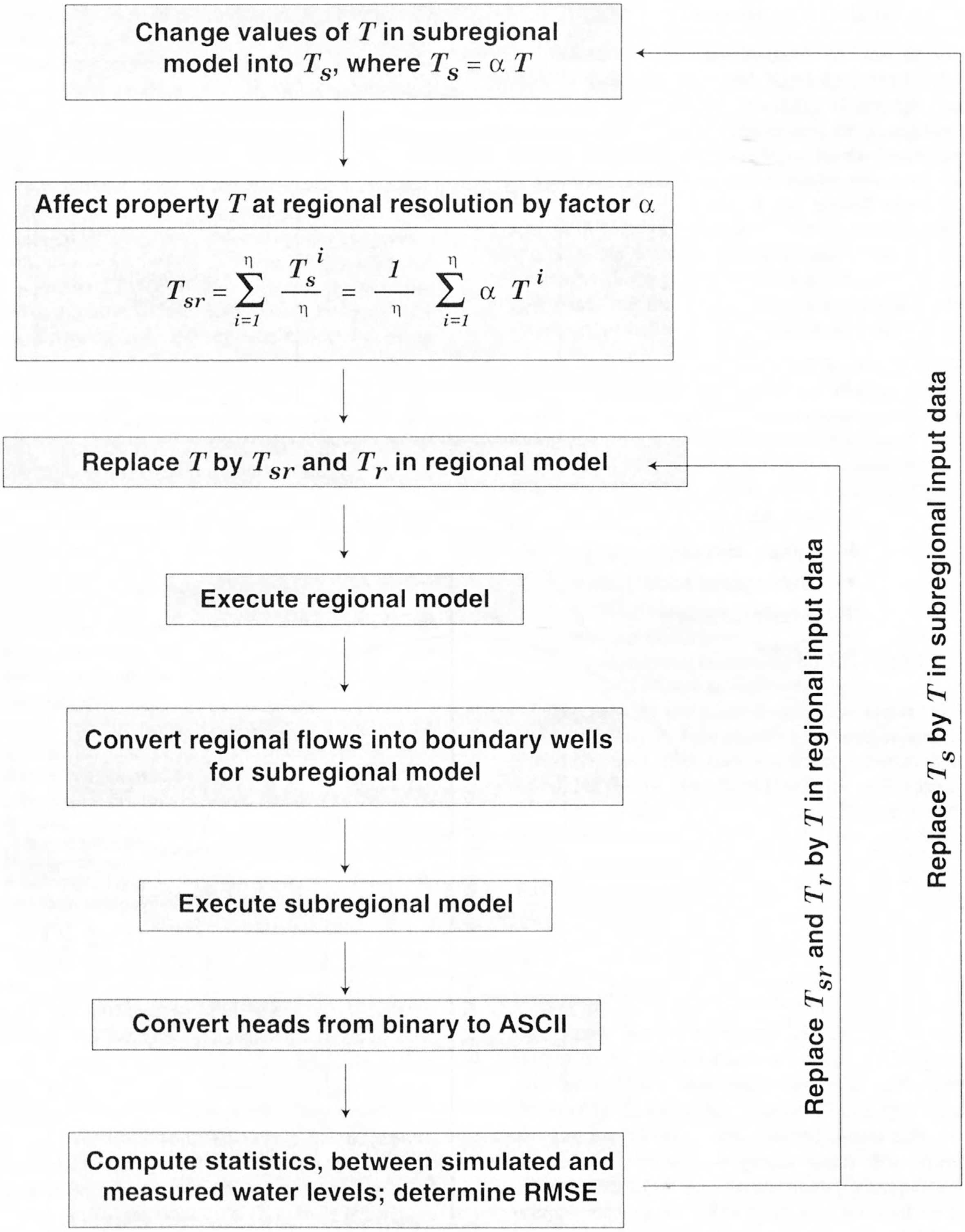


Figure 7. Sensitivity analysis for a property T, affected by factor α, using a telescoped model.

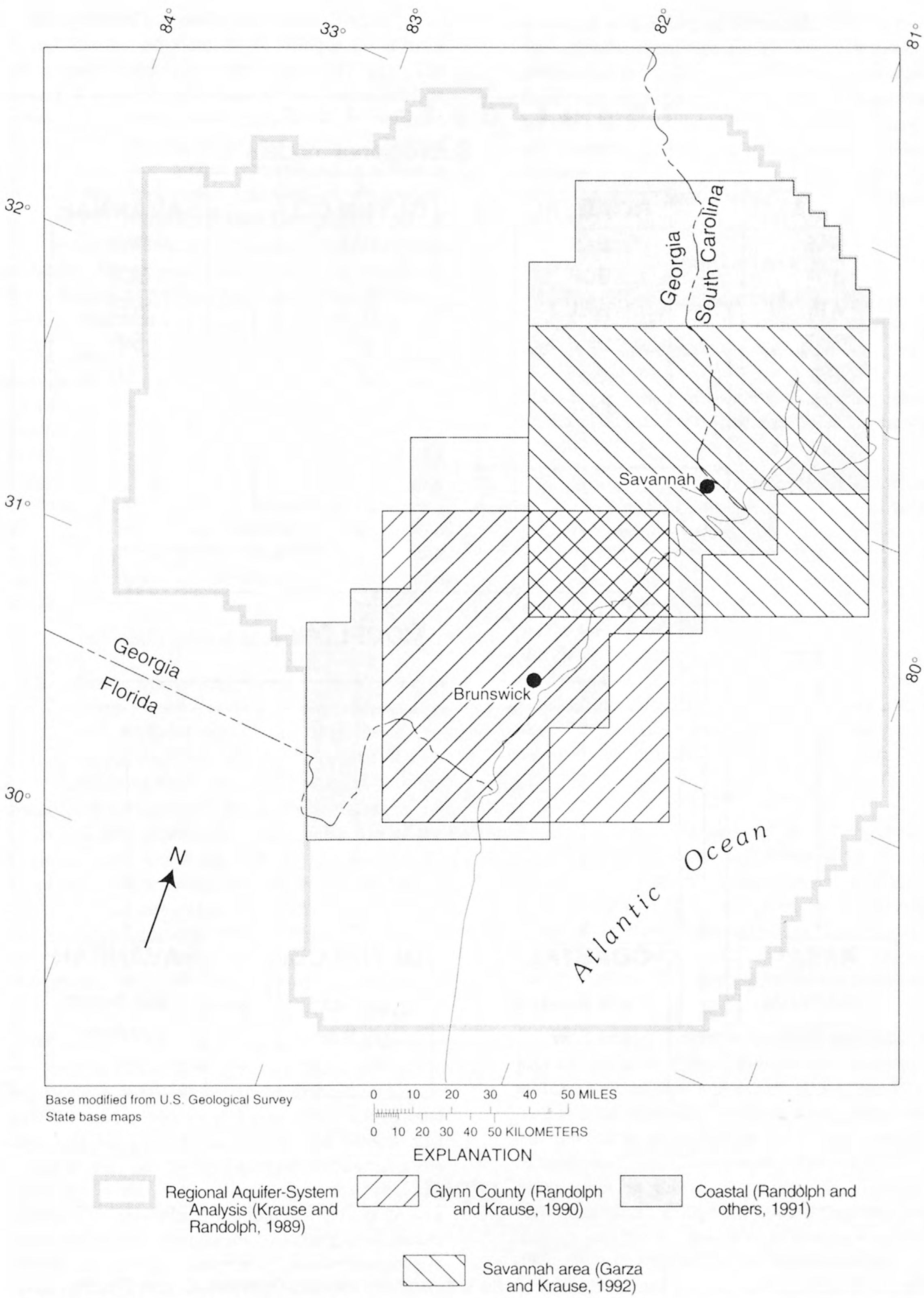


Figure 8. Boundaries of the Regional Aquifer-System Analysis, Glynn County, coastal, and Savannah area models.

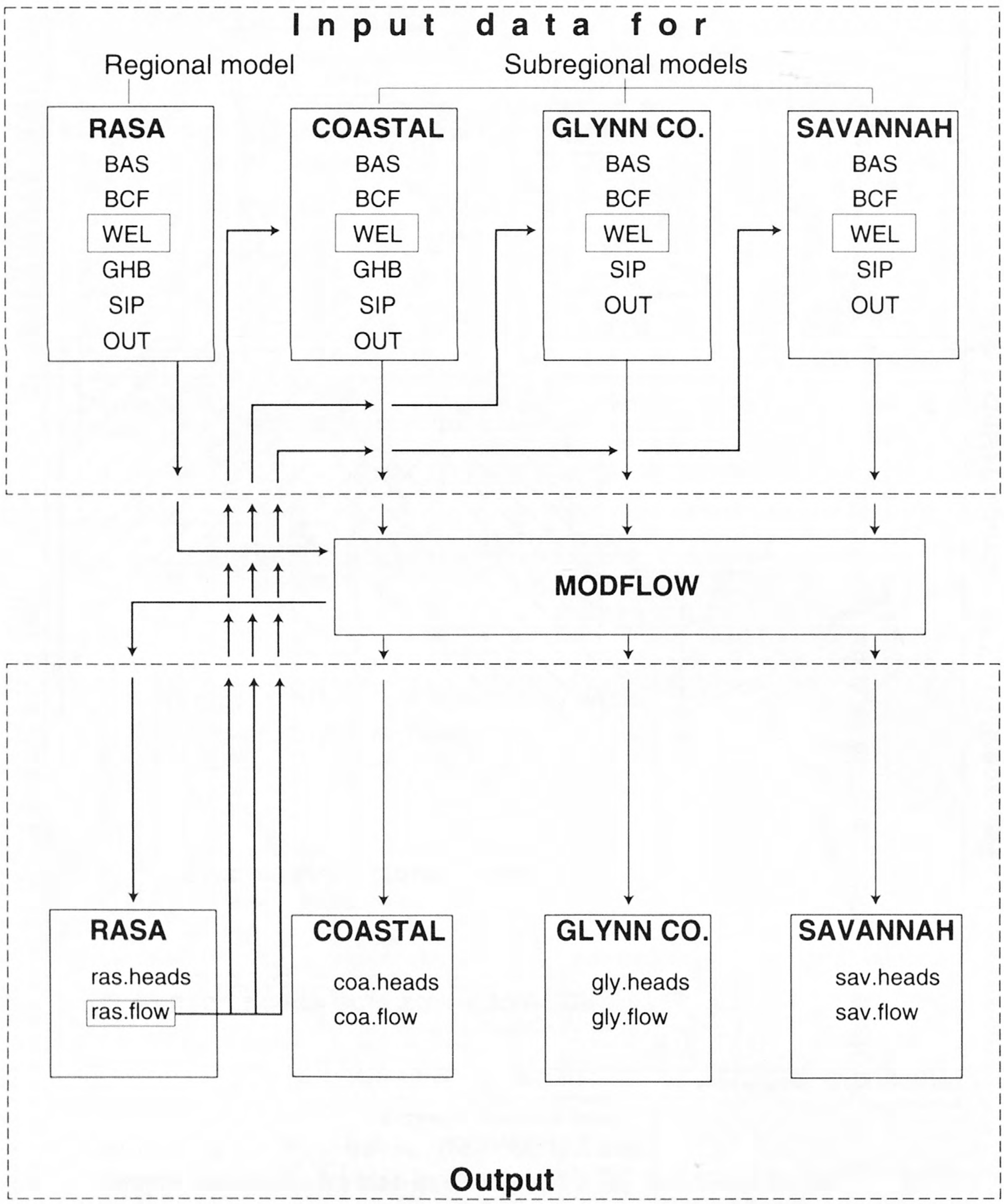


Figure 9. Interaction during the execution of the subregional models (coastal, Glynn County, and Savannah) developed in Georgia.

The extent of the study area in the RASA model is based mostly on natural hydrologic boundaries (Krause and Randolph, 1989, figs. 21, 22). The eastern and southern boundaries were delineated on the basis of ground-water divides. The northern boundary is the outcrop of the area and updip limit of the Floridan aquifer system; the outcrop in southern South Carolina; and to the extent of the freshwater flow system to the east, offshore Georgia, and part of South Carolina. There are two areas where artificial boundaries were used—the southern boundary, simulated using a specified-head and the southwestern boundary, simulated as a general-head boundary.

The vertical discretization of the Floridan aquifer system in the RASA model is described by Krause and Randolph (1989). The RASA model simulates the Floridan aquifer system using two active, confined layers representing the Upper and the Lower Floridan aquifers. The surficial aquifer is represented by using a constant-head layer and the base of the system is represented as a no-flow boundary, except in the southern part of the model, where a constant-head boundary is used to simulate the Fernandina Permeable zone.

Subregional Models

The three subregional models developed in Georgia—Glynn County, coastal, and Savannah area models—have artificial boundaries that are determined by using the flow simulated by the RASA model. The subregional models are aligned with the regional model; therefore, the grid orientation is the same for all four models (fig. 8) and the size of the subregional cells are a fraction of the size of the regional cell. These two characteristics allow for the direct transfer of simulated fluxes from the regional model to the subregional models. In Georgia, all subregional models have the same layers as the RASA model; thus, the finer discretization in the vertical direction was not used.

The subregional models developed in Georgia allow analysis of the flow system at the detail of the subregional model while maintaining continuity outside the subregional model area. The subregional models can be used to determine the effects that pumpage in one subregional area might have at a site outside the area, but still within the regional boundary. For example, if pumpage of Q1 occurs at a location within the boundaries of subregional model S1, it is possible to evaluate the effects of pumping at location IN1 (fig. 10). Also, the effects of pumping outside the boundaries of S1 can be evaluated at location IN2 by executing the telescoped subregional model S2 (fig. 11). This capability of the model sets developed in Georgia was used by Garza and Krause (1992) when assessing the ground-water development potential in the area of Savannah, Ga. In that study, the development potential was determined by evaluating the effects of additional pumpage in the Savannah area and by evaluating the effects that such an increase would have in the Brunswick area. Garza and Krause (1992) used both the Glynn County and Savannah area models to simulate ground-water development potential in the area in Savannah, Ga., and adjacent parts of South Carolina.

Glynn County model

The Glynn County model is a subregional model developed to evaluate the effects of various ground-water withdrawal alternatives on ground-water levels in the area of Glynn County (fig. 8), where the occurrence of saltwater intrusion limits the availability of freshwater supplies (Randolph and Krause, 1990).

The model covers an area of 6,100 mi^2 and was discretized into 94 columns and 110 rows by using a finite-difference grid having variable spacing (Randolph and Krause, 1990, plate 3). The cells in the grid for the Glynn County model range in area from 16 mi^2 on the four corners of the grid, to 0.0625 mi^2 at the center of the grid. The variable-spaced grid design offers the highest detail in the areas of greatest withdrawal and saltwater intrusion. The Glynn County model lies completely within the RASA model area; thus, all lateral boundaries are derived using flows simulated by the RASA model.

Coastal model

The coastal model is a subregional model developed to evaluate the potential of the Floridan aquifer system to meet future water-supply demands and assess hypothetical ground-water-development alternatives (Randolph and others, 1991). The model area includes the coastal counties of Georgia and adjacent parts of northern Florida and southern South Carolina (fig. 8).

The model covers an area of 14,016 mi^2 and the model grid is uniformly divided into 84 rows and 74 columns (Randolph and others, 1991, plate 2). Each cell is 2 mi on a side, 4 mi^2 in area, and corresponds to one-fourth of a RASA cell. The coastal model boundaries coincide with the RASA model boundaries in the outcrop area, in southern South Carolina and along the southwestern boundary. Otherwise, the coastal model boundaries are derived using flows simulated by the RASA model.

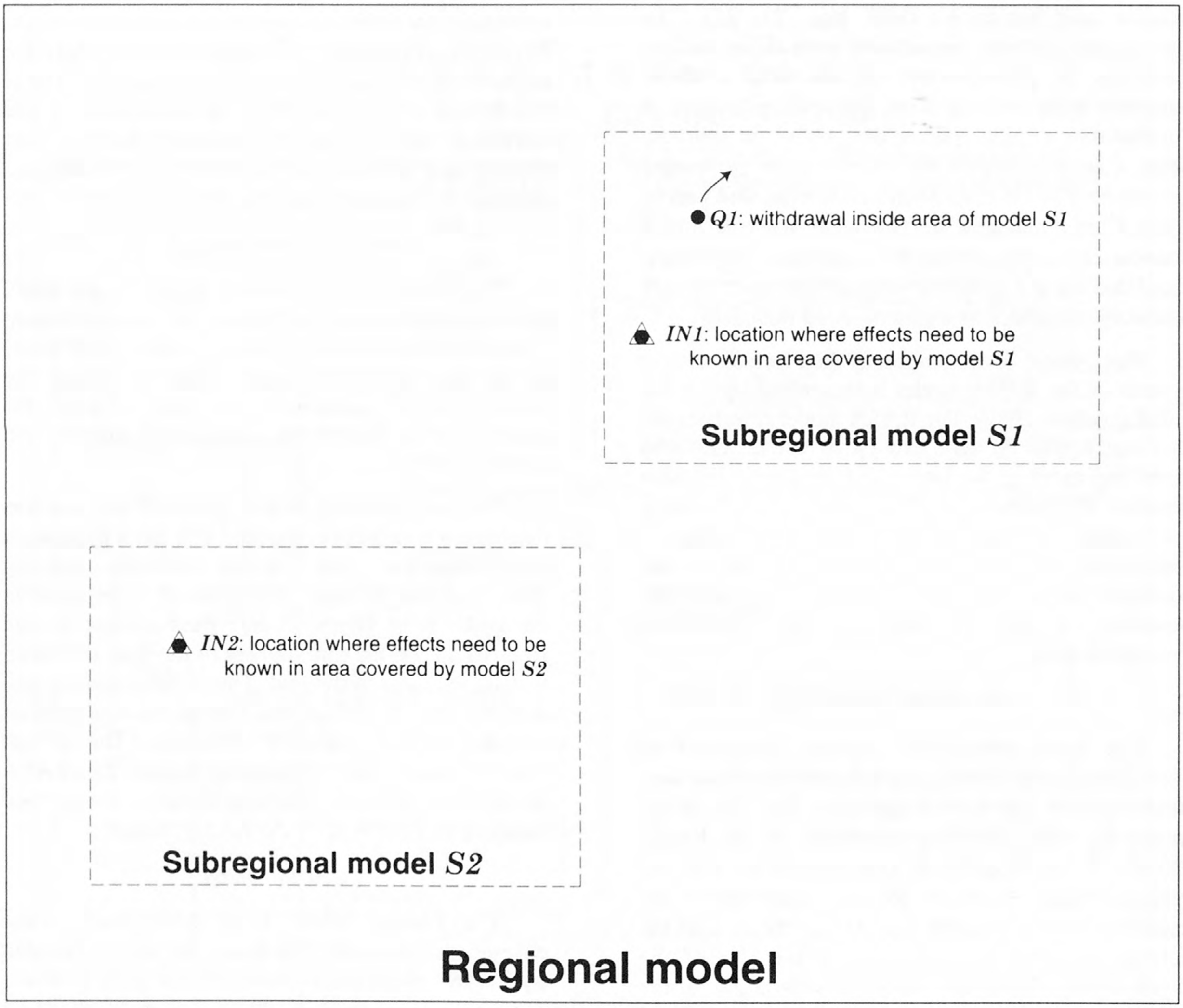


Figure 10. Withdrawal located in one subregional model evaluated outside the subregion by another subregional model.

Savannah area model

The Savannah area model is a subregional model developed to estimate the ground-water development potential in the Savannah area (Garza and Krause, 1992). This model was used together with the Glynn County and coastal models to simulate the effects that additional pumping may have on seawater encroachment in the coastal area at Hilton Head Island, S.C., and saltwater intrusion at Brunswick, Ga.

The study area covers about 3,300 mi^2, and the modeled area covers an area of 6,688 mi^2 (fig. 8). The model area was uniformly divided into 76 rows and 88 columns (Garza and Krause, 1992, plate 3). Each cell is 1 mi on a side, and 1 mi^2 in area, which corresponds to one-sixteenth of a cell from the RASA model. The boundaries for the Savannah area model are completely within the RASA model; therefore, the boundaries are derived using the flow simulated by the RASA model.

IMPLEMENTATION OF TELESCOPING MODELING APPROACH FOR GEORGIA

To implement telescoping modeling techniques, FORTRAN codes were developed to create subregional model boundaries (flow) from simulated RASA flows. Additional FORTRAN codes were written to facilitate the analyses of data and transfer data from one grid resolution to another. Later, numerous simulations were required during calibration, sensitivity analysis, and various pumping scenarios. Thus, script files (a tool for grouping together and invoking computer-system commands) were created to provide the user with a more efficient means to execute the telescoped models.

Organization of the input and output data sets (fig. 9) and codes used to execute the models are described in Appendix 1.0. Additional codes developed for preprocessing and postprocessing results of subregional models are presented in Appendix 2.0. Computer codes and script files are included on two diskettes in the pocket at the back of this report.

Development of FORTRAN Codes

The main task in using the telescoped model is to transfer data generated within the regional model into the subregional area. In the three subregional models developed in Georgia, the components of the simulated regional flow were separated, converting the flow into wells called boundary wells, and incorporating the boundary wells in the subregional model. Additional FORTRAN codes were developed to manage data in an automated manner.

All FORTRAN codes used to develop the telescoped models in Georgia are listed in table 1 and stored under the directory **source** and subdirectory **FORTRAN77** on the two diskettes (in pocket in back of this report). These codes were compiled using Green Hills FORTRAN-88000, but because the codes were written in standard FORTRAN, any compiler can be used.

In this report, all paths, directories, codes, script files, and file names appear in boldface type. In addition, the FORTRAN codes include the suffix **.f**, indicating FORTRAN; and binary data files include the suffix **.b**. Although the regional and subregional models use MODFLOW, and the code is listed in table 1, MODFLOW is not included on the diskettes. A copy of MODFLOW is available at cost from the U.S. Geological Survey, Office of Ground Water, Mail Stop 411, National Center, Reston, VA 22092.

Development of Script Files

The use of script files that invoke UNIX system commands (Data General Corporation, 1990, chap. 12) simplifies the execution of models, as shown in section 2.0 of the Appendix. The use of a script file (DG/UX, version 5.4.1 C shell), in this case, has the advantage of executing the regional simulations; and thereafter, one or all the subregional models, without user interaction. Script files created for the execution of the subregional models are under the subdirectory **script** under the directory **source** and are used for preprocessing, simulations, and postprocessing of results. A brief description of each script function is given in table 2. Script files are recorded on two diskettes in the pocket in the back of this report.

The script files were created in a UNIX environment and use a naming convention that is not DOS compatible. Many files and directories had to be renamed to transfer them onto a DOS-formatted diskette. The file **READ.ME** on the diskettes contains a table relating the original names of the files, as used in this report, to the DOS compatible names.

Table 1. FORTRAN codes used in the regional and subregional models developed in Georgia, 1989-93

FORTAN code	Subdirectory	Script file(s)	Function(s)
combine.ras.xxx.f[1]	**pre**	**update**	updates the RASA model with data generated from one of the **xxx** subregional models
compare.bcf.f	**pre**	**compare**	compares regional or subregional input-data files for any model
compare.grid.f	**pre**	**compare**	compares any property (T, TK, or heads) for any of **xxx** models
diff.ras.xxx.f[1]	**pre**	**compare**	compares RASA data with data from any of the **xxx** subregional models that have already been converted to their equivalent in RASA cells
nodes.f	**pre**	**node**	converts subregional cells to regional cells
wellsort.f	**pre**	**wells**	sorts wells by layer, row, and column
wrastoxxx.f[1]	**pre**	**wells**	outputs wells in the overlapping area of the **xxx** subregional model from the RASA well-data set
wremovxxx.f[1]	**pre**	**wells**	reads RASA well data and outputs the wells, excluding those in the **xxx** area
wxxxtoras.f[1]	**pre**	**wells**	converts pumping specified in the **xxx** grid location to the RASA grid
xxx.to.ras.f[1]	**pre**	**compare, update**	converts data at a resolution of one **xxx** subregional model to RASA resolution
bndry.f	**sim**	**telmdls.pre, telmdls**	takes the flow right and flow front from the RASA model at the boundary location with **xxx** model and converts the flows to wells
combine.f	**sim**	**telmdls**	creates final well input-data set for any pumping condition by combining pumping data (existing plus proposed) with the wells at the boundaries
convert.f[2]	**sim** **post**	**watbud, drawdown, flowdir, statistics, telmdls.pre, telmdls**	converts binary heads, drawdown, or flows into ASCII files
separate.f[2]	**sim** **post**	**watbud, flowdir, telmdls.**	separates the cell-to-cell flow already in ASCII into separate files for each component
budget.f	**post**	**watbud**	computes different water-budget components for a **xxx** models
ddn.f	**post**	**drawdown**	computes differences between two sets of heads derived from different simulations
stats.f	**post**	**statistics**	computes residuals and basic statistical parameters
vert.f	**post**	**flowdir**	displays direction of vertical flows between different layers of a model, by cells
modflow.f	**modflow**	**telmdls, telmdls.pre**	executes the ground-water flow simulations

1/The **xxx** in the names indicates that there is a code for each subregional model that can be determined by replacing the **xxx** with the appropriate model prefix: **coa**, **gly**, or **sav**.

2/Occasionally, a code may be used for two different functions; therefore, the code appears in two different subdirectories.

Table 2. Script files and functions

File name	Function(s)
compare	compares input data sets and verifies agreement of data for overlapping areas in regional and subregional models
drawdown	computes differences between calibrated and newly simulated heads from MODFLOW, for the heads identified by row and column
flowdir	calculates and displays the direction of the net vertical flows between layers of a telescoped model
link	facilitates the transfer of the telescoped models by reworking the path of the different files; useful when moving the codes from one machine to another and is executed by all script files
nodes	converts cells identified in subregional grid into cells identified at regional resolution
statistics	computes residuals and statistics for a given set of data
telmdls	executes stressed conditions for any or all subregional models developed in Georgia
telmdls.pre	executes conditions prior to development for any or all of subregional models developed in Georgia
unlink	facilitates the transfer of the codes to execute telescoped models; the "undo" of the file **link**
update	updates data in the regional model after data from the subregional model has been altered
watbud	computes various components of water budgets in a model, and also computes the change in flux resulting from various pumping scenarios
wells	compares well data-input files and converts pumping data from subregional to regional scale

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APPENDIX

This appendix describes use of a specific telescoped computer model and various postprocessing and preprocessing computer programs using the U.S. Geological Survey modular three-dimensional finite-difference ground-water flow model under steady-state conditions. The performances of these computer programs have been tested in the models described in this report. Other scenarios may reveal errors in the computer programs that were not detected. The user is requested to notify the originating office of any errors found in this report or in the telescoped computer programs.

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1.0 ORGANIZATION AND STORAGE OF THE MODELS

The telescoped models developed in Georgia are organized by directories (fig. 1A). An overview of the three main directories—**input**, **output**, and **source**—follows with a detailed discussion. Before referring to model inputs and outputs (fig. 1A), the user should be familiar with the packages defined in MODFLOW (McDonald and Harbaugh, 1988). Input data sets, or packages, or both, may vary, depending upon the model.

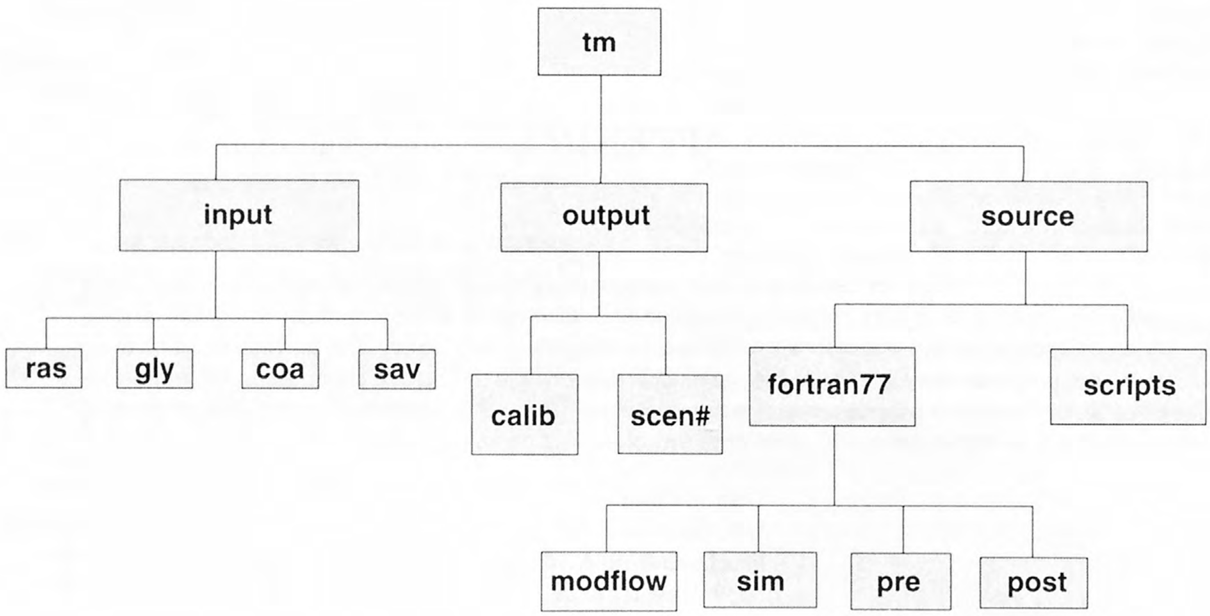


Figure 1A. Organization of the digital storage locations.

1.1 Input--This directory contains four subdirectories, one for the regional model (**ras** for RASA) and the other three for the subregional models (**coa** for coastal, **gly** for Glynn, and **sav** for Savannah). Input data sets used by each model during simulation of the ground-water flow are stored in these subdirectories. Data-set file names consist of three parts separated by periods--the prefix refers to the name of the model; the middle part corresponds to the MODFLOW package requiring the input; and the suffix is **.data**. For example, the well data set for the coastal model is named **coa.well.data**, and the data for the general head boundary for the RASA model is called **ras.ghb.data**. The files containing the proposed wells (change in pumpage) for all models are identified by using the suffix corresponding to each model as **wells.ras**, **wells.coa**, **wells.gly**, and **wells.sav**. During calibration, the models can be executed as a "no stress" scenario and the files for the proposed wells contain a zero (no change).

Several data files are required to run regional and subregional models because the data read by various packages of MODFLOW depend upon the predevelopment or postdevelopment conditions being simulated, and also on the levels of the regional or subregional model. For example, there are two BAS input files for the regional model, one to execute the model for predevelopment conditions (**ras.bas.pre.data**) and the other to execute the model for postdevelopment conditions (**ras.bas.data**).

During calibration, data continuously change; therefore, it is recommended that a temporary backup subdirectory be made until all models are calibrated. Once the models are calibrated, the input data sets are kept in the corresponding subdirectory, and the temporary subdirectory can be deleted. Details for checking regional and subregional data sets are discussed in the Appendix, section 2.1.

1.2 Output--This directory contains as many subdirectories as scenarios to be tested, plus one scenario used to keep the results of the calibrated model. Each output subdirectory contains data particular to that scenario: input proposed wells, output generated from the simulation, and any other result from postprocessing.

The subdirectories for each scenario could have any name other than **calib**, which was chosen for calibration, and contains results generated from calibrating the models. Output files generated by executing each of the models and their postprocesses are stored under the corresponding subdirectory, using the prefix of the model. For example, for storing simulated heads, the files will be: **gly.head** for the Glynn County model; **coa.head** for the coastal model; **sav.head** for the Savannah area model; and **ras.head** for the RASA model. Output generated as part of the postprocesses are discussed in Appendix, sections 2.2 and 2.3, and some examples are included in section 2.4.

1.3 Source--This directory contains two subdirectories: **fortran77** and **scripts**. Subdirectory **fortran77** is further divided into four subdirectories containing all codes required to preprocess and postprocess data; **pre**, **post**, and **sim** contains codes to execute and link the models; and **MODFLOW** contains the MODFLOW code.

Codes included in the subdirectory **fortran77/pre** are used to convert data from one model to another, compare data sets, remove parts of the data, and replace existing data with new data. Subdirectory **fortran77/sim** stores codes used to combine pumpage data with wells from the proposed pumping alternative, combines pumpage data with wells representing the boundary conditions generated from the regional model, and separates flows computed by the models into different components. Subdirectory **fortran77/post** contains all codes needed to create various outputs available as postprocessing options using the results from simulations.

Subdirectory **scripts** contains script files needed to control all steps involved in telescoping. These files are used to preprocess regional and subregional model data, simulate ground-water flow, and postprocess simulation results. Script files are included on diskettes and listed in table 2 in the text of this report.

2.0 CONVERSION OF DATA AND EXECUTION OF THE MODELS

Codes to manage data, convert data sets from one resolution to another, execute the models, and postprocess the results for analysis can be helpful during the development and ultimate use of subregional models. The codes and scripts developed for the existing subregional models in Georgia are described in this appendix and the sequence of execution is discussed. In addition, the codes and script files are included on two diskettes in the pocket in the back of this report. The path names are prefixed with **yourpath** (the directory where models are stored).

2.1 Preprocessing--Processes described in this section may be used to check agreement between or convert regional from subregional data sets. Checking, comparing, and transforming data from subregional to regional resolution; testing of sensitivity analysis; and updating the regional model are common during development and calibration of a subregional model. To facilitate the procedure, codes were developed to convert data sets automatically from one scale to another (regional from subregional).

2.1.1 *BAS and BCF Package Input Data*--The two script files developed to preprocess part or all of the data contained in the BAS and BCF packages or the complete packages are: **update** and **compare**. Both script files are found under the path: **/yourpath/source/scripts/**.

The script file **update**, as its name implies, updates data in the regional model after a modification has occurred in the subregional area (fig. 2A). When the script file is invoked, the user is prompted to choose one of the subregional models:

1. update RASA model data in coastal area;
2. update RASA model data in Savannah area;
3. update RASA model data in Glynn area.

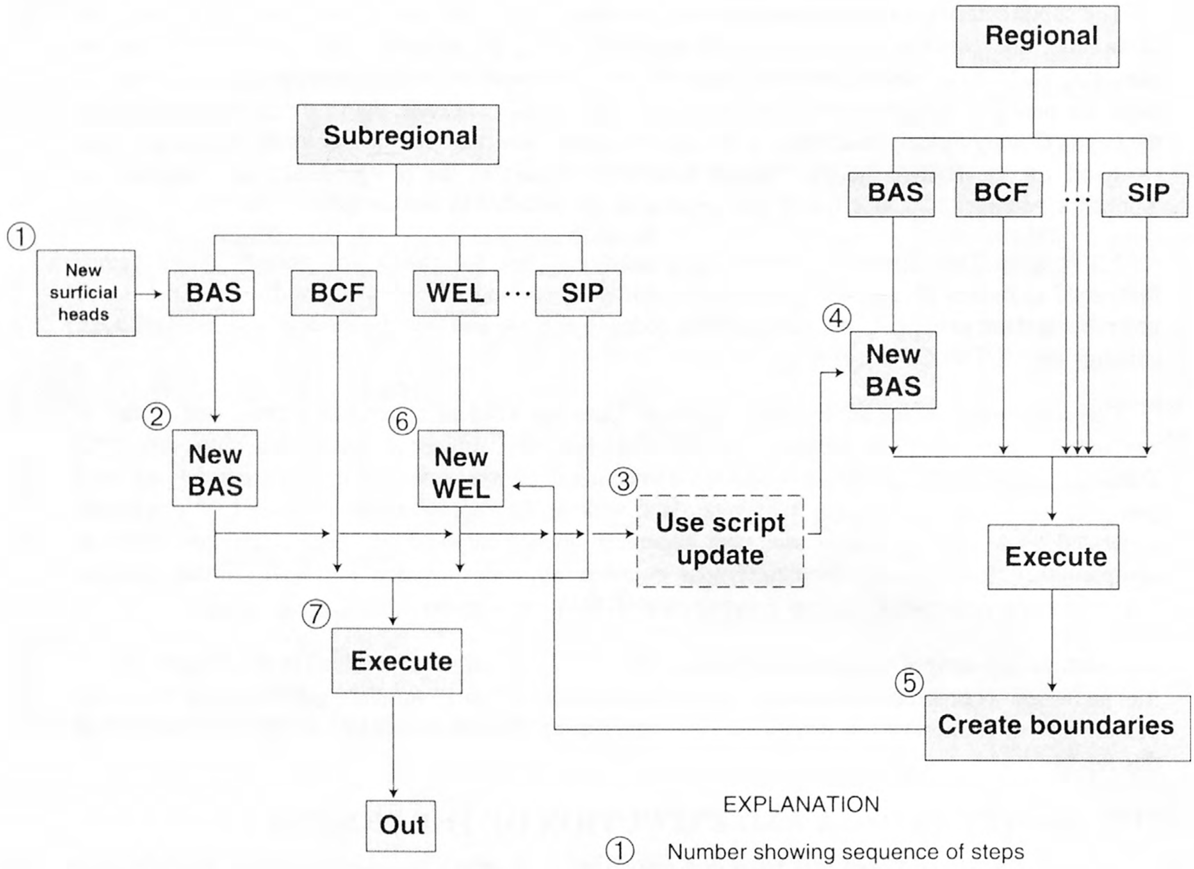


Figure 2A. Use of script file update for changes in subregional surficial heads data.

The script file **compare** is used to verify that data agree in the area common to regional and subregional models. Data sets can be compared, within the same model (old and new versions of the same data set) or between two models, by converting subregional data to regional values. For comparison of data for the same model the choices are:

1. compare BCF packages;
2. compare individual properties for two different packages; for the comparison of data between different models, the choices are:
3. compare data between RASA and Glynn models;
4. compare data between RASA and Savannah models;
5. compare data between RASA and coastal models.

These script files are applicable to any data read by BCF and BAS packages. Transmissivity, leakance, and head data in MODFLOW input files can be separated into individual data sets, including header information; thus, the format specified for a particular data set will be included with the data. Then, data can be compared between the subregional model and the data in the overlapping area of the regional model.

2.1.2 *Wells Data*--Script file **wells** is used to compare and/or convert pumpage data from one scale to another. For example, when new pumping data are available and the models require updating, the data should be converted from subregional to regional resolution. Pumping data then are added to the well data for the regional model. The options available for the script file **wells** are:

1. Coastal model wells copied from RASA data into a separate file
2. Savannah model wells copied from RASA data into a separate file
3. Glynn model wells copied from RASA data into a separate file
4. Savannah wells converted to RASA model wells
5. Glynn wells converted to RASA model wells
6. Coastal wells converted to RASA model wells
7. Savannah model wells removed from RASA model wells file
8. Glynn model wells removed from RASA model wells file
9. Coastal model wells removed from RASA model wells file
10. Sort wells, list wells in common

Options 1, 2, and 3 are used to generate a working data file in the subregional area at the resolution given by the regional model (fig. 3A(a)). These options are useful when there is a need to analyze data for a particular subregional area and compare new data sets. Options 4, 5, and 6 convert any of the subregional data into regional resolution (fig. 3A(b)). These options are used to update the regional model when new data are incorporated, or when subregional data are modified, which requires transformation to replace the existing regional data set. The conversions are for locations and pumping rates. Options 7, 8, and 9 are used when data are going to be replaced in the regional model (fig. 3A(c)). Option 10 is useful when comparing well location and rates. Figure 4A shows a practical application in which a combination of these options are used to compare data sets.

Some options require formatting input data files similar to well data input files used by MODFLOW (McDonald and Harbaugh, 1988, p. 8-1); and facilitate the input of these data to generate the final well files. For example, the option **sort** for a total of "n" wells, requires the structure shown in table 1A; thus, some editing of well data may be needed. The format I10 and F10.5 correspond to descriptors of format in FORTRAN language.

Table 1A. Structure of input well file to be sorted using script file **wells**

Line	Description (format)
1	Total number of proposed wells (I10)
2	Total number of proposed wells (I10)
3	Layer (I10), row (I10), column (I10), rate for well #1(F10.5)
4	Layer (I10), row (I10), column (I10), rate for well #2 (F10.5)
.	
.	
.	
n+2	Layer (I10), row (I10), column (I10) rate for well #n (F10.5)

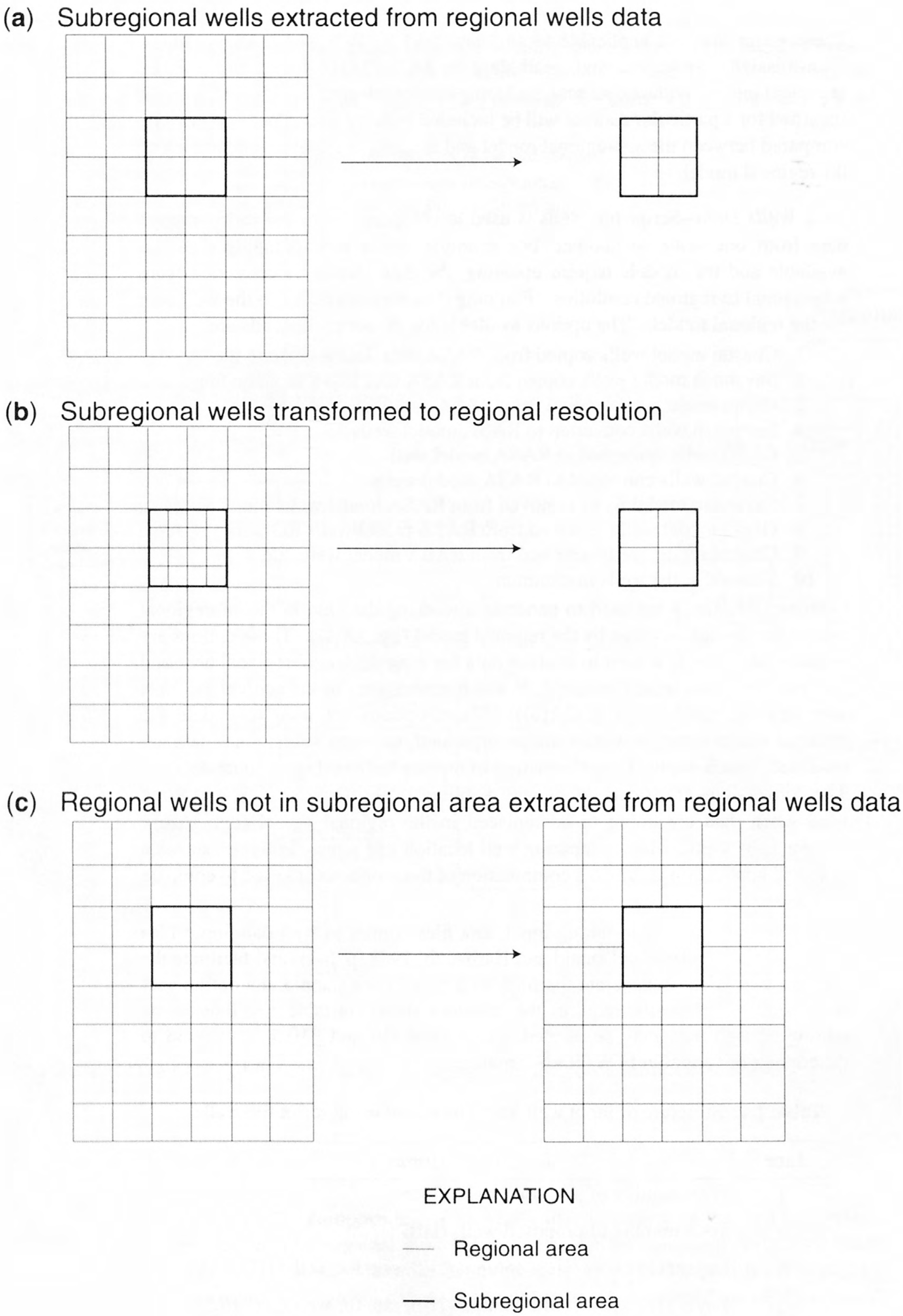
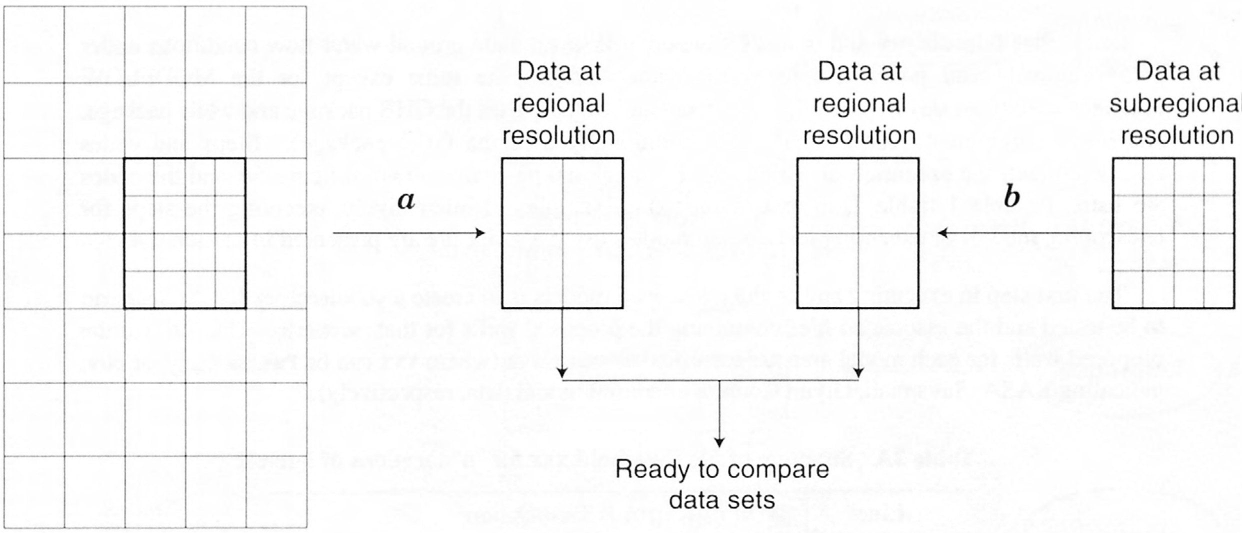


Figure 3A. Capabilities of script file **wells**.



EXPLANATION

— Regional area

— Subregional area

a Valid for script file **wells**, options 1, 2, 3

b Valid for script file **wells**, options 7, 8, 9

Figure 4A. Example of a combined application of script file **wells** used to compare data sets.

Additionally, the code **nodes** was created to convert a cell location from one model to the location in another model. For example, if a RASA location is needed for Savannah node, the RASA cell can be determined by executing **nodes**; however, the code does not convert pumping rates.

2.2 Simulations--The prescribed sequence in executing the programs that make up the telescoped model must be followed (fig. 5A). In order to execute the programs in proper sequence and ensure that proper input data sets are used at each step, the sequence of commands to execute the telescoped model can be saved in a script file. The following discussion focuses on the use of a script file to execute any scenario.

Script files **telmdls.pre** and **telmdls** were created to simulate ground-water flow conditions under predevelopment and postdevelopment conditions and are the same except for the MODFLOW packages used (post-development RASA model additionally uses the GHB package and wells package, and post-development coastal area model additionally uses the GHB package). Steps and codes associated with the execution of regional and subregional pairs are shown in figure 5A and the codes are listed in table 1 (table 1, in text of report). Examples of interactively executing the steps for telescoping models or executing telescoping models using a script file are presented in section 2.4.

The first step in executing any of the telescoped models is to create a subdirectory for the scenario to be tested and the associated files containing the proposed wells for that scenario. The files for the proposed wells for each model area are identified as **wells.xxx** (where **xxx** can be **ras**, **sav**, **gly**, or **coa**, indicating RASA, Savannah, Glynn County, or coastal model data, respectively).

Table 2A. Structure of file **threshold.xxx** for "n" locations of interest

Line	Description
1	reserved for comments
2	" " "
3	" " "
4	number of locations (I5)
5	layer (I10), row (I10), col (I10)
6	.
.	.
.	.
.	.
n+4	layer (I10), row (I10), col (I10)
n+5	threshold (F3.1)

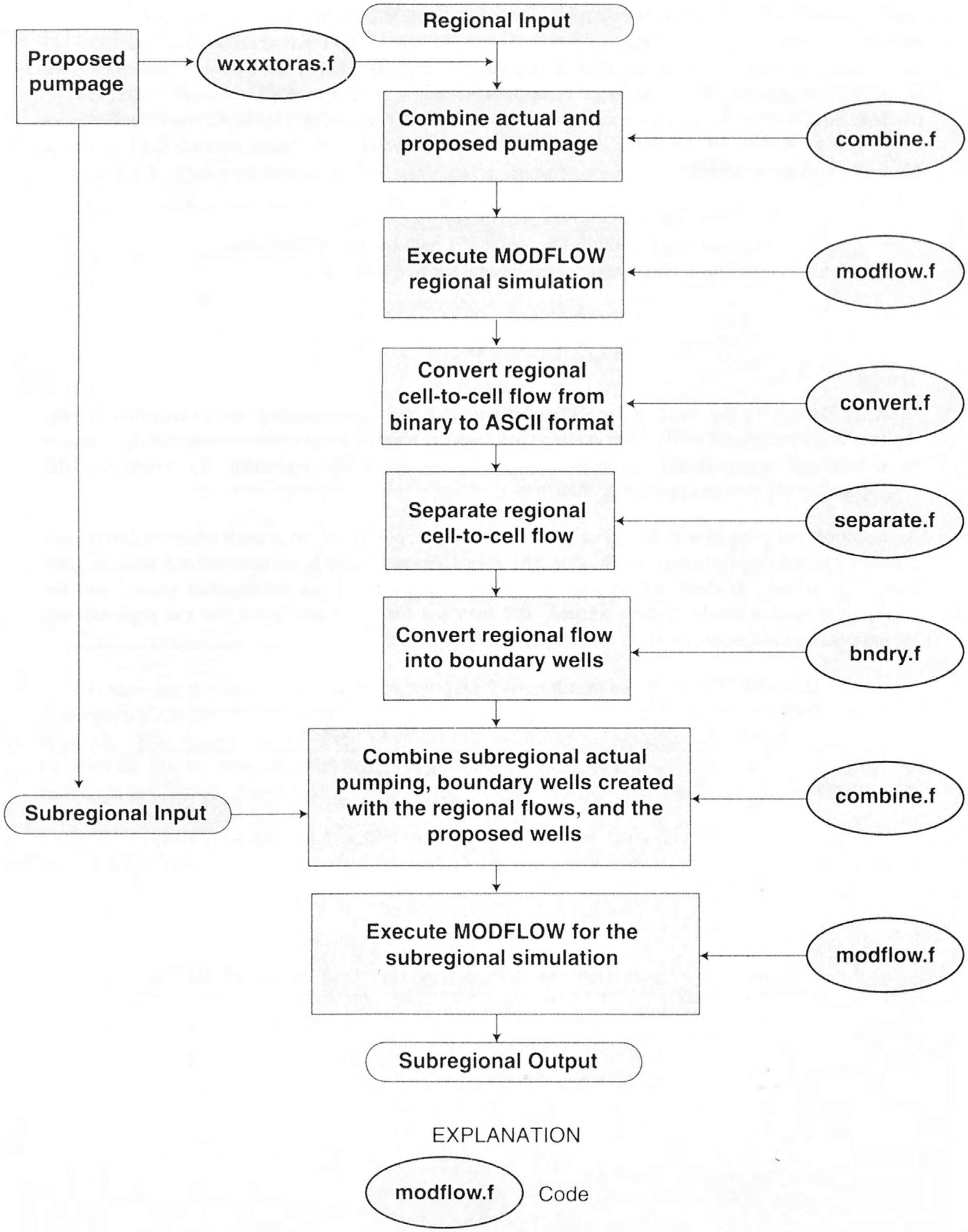


Figure 5A. Execution of codes during a telescoped model simulation.

The file **threshold.xxx**, created along with the files for the proposed wells, can be structured to include locations of specific sites of interest for the user (table 2A) and specifies a maximum value of water-level change threshold, meaning that if water-level changes are greater than the specified maximum, locations are displayed where this change occurs. This file is used by the script file called **drawdown** to generate the output **xxx.ddn.impact** (section 2.3). For example, if a water-level change needs to be displayed for two locations given by cells (60,49) and (66,48) in the Glynn County model and it is important to determine the locations for which the water-level change exceeds 0.1 ft, then the file **threshold.gly** would be:

```
C ..... first three lines are reserved for comments,
C ..... data starts on the fourth line, column 1 with number of locations
C ..... fifth line contains layer, row, column for first location.
2
         2          60          49
         2          66          48
0.1
```

After identifying the location for additional pumping, the corresponding cell is identified for the regional and subregional models involved in the scenario. Identification of the corresponding node can be determined automatically by executing the code **nodes**; or manually, by overlaying the corresponding grids to an appropriate map.

Location and rates of withdrawal or injection for the proposed well(s) in each model is determined according to the description given in table 3A. Negative rates indicate withdrawal and positive rates indicate injection. If there are no proposed wells in the area of one subregional model, and the subregional model needs to be executed, the files for the proposed wells for the regional and subregional models must contain a zero in the first line.

Table 3A. Structure of a data file for three proposed wells

Line	Description (format)
1	total number of proposed wells (I10)
2	layer (I10), row (I10), column (I10), rate for well #1 (F10.5)
3	layer (I10), row (I10), column (I10), rate for well #2 (F10.5)
.	
.	
.	
n+1	layer (I10), row (I10), column (I10), rate for well #n (F10.5)

To simulate a scenario to evaluate the effect of pumpage from four proposed wells located in an area within the Savannah area subregional model **sav**, two files will be generated (table 4A), one for the regional model **wells.ras**, and the other for the subregional model, **wells.sav**. Because of the different resolution of regional and subregional models, the number of wells may not agree between the models. The number of wells in the subregional model always will be equal to or greater than the number of wells in the regional model (table 4A, first line).

Table 4A. Two well data input files representing the same stresses at different resolutions

File 1: **wells.ras**

```
     3
             2          37          38          -21.7
             2          37          37          15.3
             2          37          37          -3.6
```

File 2: **wells.sav**

```
     4
             2          36          36          -21.7
             2          37          43          8.3
             2          37          42          7.0
             2          37          57          -3.6
```

To determine the location and pumping rates at regional resolution, the script file **wells** can be used. A temporary file can be created using the information from **wells.sav**, following the format given in table 1A. This temporary file is the input for the script file **wells**. Although the output from **wells** includes all the information needed, the output is in a different format and needs to be edited by following the format given in table 3A, to create the file **wells.ras**. After these files are created, the models can be executed.

2.3 Postprocessing--Postprocessing options were created to assist the user in the interpretation of the results by providing files that display the results. Script files created to provide these results (table 5A) are: **drawdown**, **flowdir**, **statistics**, and **watbud**. The outputs are generated for any of the subregional (**xxx**) models. The script files and FORTRAN codes used for postprocessing are included on two diskettes in the back of this report.

Table 5A. Subregional model output files generated by postprocessing script files

Script names	Output files	
	Names	Description
drawdown	**xxx.ddn**	converts the drawdown simulated from binary to an ASCII file
	xxx.ddn.label	labels the matrix of drawdown simulated (converted into ASCII file) into an output labeled by row and column in the corresponding model
	xxx.ddn.impact	shows the drawdown at locations of interest for the user, which are given in file **threshold.xxx**
	xxx.heads.label	labels matrix of simulated heads (converted into ASCII file) into an output labeled by row and column in the corresponding model
flowdir	**xxx.vert**	computes matrix containing the values of vertical flow among the different layers (semiconfining units)
	xxx.vert.table	computes matrix that displays the direction of the flows (upward or downward)
statistics	**xxx.stats**	computes residuals (difference between simulated and measured values of heads) and some basic statistics
watbud	**xxx.budget**	computes water budget for any simulation
	xxx.budget.diff	computes changes in water budget for any pair of simulations

Some MODFLOW output files are in binary format and are identified by the suffix **.b** in this report. The binary output files are converted to ASCII by FORTRAN codes that can be executed interactively or by using any postprocessing script files.

The script **drawdown**, when used to compare the heads between two pumping scenarios, is useful, especially during calibration. In this case, the file **xxx.ddn** represents the water-level change resulting from a change in pumping in the ground-water flow system. The script **budget** generates tables having different water-budget components that show the effect that various pumping scenarios have on water levels at locations of water-quality concern.

There are many software packages available to display contours on a two-dimensional map. For the models described in this report, the software package **CONTOUR** was used (Harbaugh, 1990).

2.4 Example of executing a telescoped model--Two examples of executing telescoped models (interactive-file and script-file execution) are discussed in the following sections. Examples include only the RASA and Savannah area models because the other two models are executed in the same manner. The models can be executed interactively or by using a script file. The structure of subdirectories is shown in figure 2A and examples are in **/yourpath/output/example/**. Responses that must be provided by the user during execution of the program are shown in boldface type. The examples shown use UNIX system commands.

2.4.1 *Interactive-file execution--*

a. Execution starts with the creation of files including locations and rates of pumping for the proposed wells (**wells.xxx**), and the files **threshold.xxx**.

cd /yourpath/output/example

There should be one file for the regional model and one for each subregional model (**xxx**) to be executed:

wells.ras wells.xxx threshold.xxx

b. Proposed wells can be incorporated into the regional model by editing the file containing the well data for the regional model; or by using the code **combine.f**, if the user has created a file called **wells.ras** that have the proposed wells (see explanation in Appendix 1.0).

If the code **combine.f** is used, follow these steps:

/yourpath/source/fortran77/sim/combine
Enter existing wells file path name:

/yourpath/input/ras/ras.well.data
Enter proposed wells file path name:

/yourpath/output/example/wells.ras
Enter boundary wells path name (cr=none)

<cr>
Enter path name for combined wells:
/yourpath/output/example/ras.wellpac

A message will appear on the screen listing the number of existing, proposed, and boundary wells.

c. Before executing the regional model, the input and output files must be linked to FORTRAN I/O units. Input files are linked using the UNIX link command "ln" as follows:

```
ln -s /yourpath/input/ras/ras.bas.data            fort.5
ln -s /yourpath/input/ras/ras.bcf.data            fort.7
ln -s /yourpath/input/ras/ras.ghb.data            fort.16
ln -s /yourpath/output/example/ras.wellpac        fort.9
ln -s /yourpath/input/ras/ras.sip.data            fort.8
ln -s /yourpath/input/ras/ras.out.data            fort.11
```

The output files are linked as follows:

```
ln -s /yourpath/output/example/ras.head.b         fort.13
ln -s /yourpath/output/example/ras.ddn.b          fort.14
ln -s /yourpath/output/example/ras.nodeflo.b      fort.12
ln -s /yourpath/output/example/ras.runout         fort.6
```

MODFLOW for the regional model then is executed:

```
/yourpath/source/fortran77/modflow/modflow <fort.5 >fort.6
```

d. Remove all links

```
rm fort.*
```

e. To convert flows, the binary file containing the cell-to-cell flow, **ras.nodeflo.b**, generated using MODFLOW, is converted to an ASCII file, **ras.nodeflo**, by executing the code **convert.f**:

/yourpath/source/fortran77/sim/convert
Enter model name: ras sav gly coa
ras
Enter input-file type: (h)eads (f)low
f
Enter input-file path name:
/yourpath/output/example/ras.nodeflo.b
Enter output-file path name:
/yourpath/output/example/ras.nodeflo

f. To separate the cell-to-cell flow **ras.nodeflo** into its different components, the code **separate.f** is executed:

/yourpath/source/fortran77/sim/separate
Enter model name: ras sav gly coa
ras
Enter input file path name:
/yourpath/output/example/ras.nodeflo
Enter constant head output path name:
/yourpath/output/example/ras.constflx
Enter right face flow output path name:
/yourpath/output/example/ras. rightflx
Enter front face flow output path name:
/yourpath/output/example/ras. frontflx
Enter lower face flow output path name:
ourpath/output/example/ras.vertiflx
Enter general head boundary output path name
/yourpath/output/example/ras.ghbflx

This is the end of the simulation of the regional model; results can be used to generate the boundary for one or more of the subregional models. The following steps are repeated for each subregional model; the only difference is in the execution of MODFLOW for the coastal model because of the incorporation of the general-head boundary (**GHB**) package.

g. Compute flows at the boundaries of the Savannah area model (**sav**) and convert the flows into boundary wells, **sav.bndry.wells**, executing the code **bndry.f**:

/yourpath/source/fortran77/sim/bndry
Enter model name: ras sav gly coa
sav
Enter RASA right flow input path name:
/yourpath/output/example/ras. rightflx
Enter RASA front flow input path name:
/yourpath/output/example/ras. frontflx
Enter boundary flow output pathname:
/yourpath/output/example/sav.bndry.flo
Enter boundary flow table output path name:
/yourpath/output/example/sav.bndry.flo.table
Enter boundary wells output path name:
/yourpath/output/example/sav.bndry.wells

h. Combine the existing wells **sav.well.data** and the proposed wells **wells.sav** with the boundary wells **sav.bndry.wells**, to create the new well data **sav.wellpac** executing the code **combine.f**:

/yourpath/source/fortran77/sim/combine
Enter existing wells file path name:
/yourpath/input/sav/sav.well.data
Enter proposed wells file path name:
/yourpath/output/example/wells.sav
Enter boundary wells path name (cr=none)
/yourpath/output/example/sav.bndry.wells
Enter combined wells output path name:
/yourpath/output/example/sav.wellpac

A message will appear on the screen listing the number of existing, proposed, and boundary wells.

i. Execute the simulation for the selected subregional model using MODFLOW. Input and output files of the selected subregional model must be linked to FORTRAN I/O units before executing the model:

The input files are linked as follows:

```
ln -s /yourpath/input/sav/sav.bas.data            fort.5
ln -s /yourpath/input/sav/sav.bcf.data            fort.7
ln -s /yourpath/input/sav/sav.sip.data            fort.14
ln -s /yourpath/input/sav/sav.out.data            fort.8
ln -s /yourpath/output/example/sav.wellpac        fort.9
```

If the coastal model is executed, an additional linkage is needed, and given by:

```
ln -s /yourpath/input/coa/coa.ghb.data            fort.16
```

The output files are linked as follows:

```
ln- s /yourpath/output/example/sav.head.b         fort.12
ln- s /yourpath/output/example/sav.ddn.init.b     fort.13
ln- s /yourpath/output/example/sav.nodeflo.b      fort.15
ln- s /yourpath/output/example/sav.runout         fort.6
```

The Savannah area subregional model is executed by typing:

```
/yourpath/source/fortran77/modflow/modflow <fort.5 >fort.6
```

j. Remove all links

```
rm fort.*
```

k. Postprocessing options use the following FORTRAN codes: **separate.f**, **convert.f**, **ddn.f**, **budget.f**, **stats.f**, and **vert.f**. The function of each code is explained in the "Development of FORTRAN Codes" and table 1 (in text of this report). The interactive execution of each of these codes is presented below.

```
cd /yourpath/source/fortran77/post
```

The output files for postprocessing options are indicated at the end of the interactive dialog.

(1) Code **convert.f** is executed to convert binary output of heads or flows into ASCII files:

/yourpath/source/fortran77/post/convert
Enter model name: ras sav gly coa
sav
Enter input file type: (h)eads (f)low
h
Enter input file path name:
/yourpath/output/example/sav.head.b
Enter output file path name:
/yourpath/output/example/sav.head

The only difference in the execution to convert flows is the use of the "**f**" option (f)low and the files involved: **sav.nodeflo.b** and **sav.nodeflo**. An example output file follows:

Output file **sav.head**:

```
                    (10f8.3)                76   88    2
108.057 107.508 106.876 106.147 105.338 104.534 103.644 102.648 101.435 100.012
 98.384  96.434  94.101  92.351  90.901  90.253  89.819  89.276  88.668  88.014
 87.365  86.539  85.523  84.311  82.777  81.282  79.857  78.491  77.231  75.957
 74.552  73.230  71.781  70.409  69....
```

Because the files are stored in binary form, it is necessary to convert them to ASCII files for postprocessing. These files refer to the heads and cell-to-cell flow. The heads are converted similarly to the procedure described above. The only change is the location of the heads file, which in this case, is under the directory **calib** instead of **example**. Cell-to-cell flows are converted as follows:

/yourpath/source/fortran77/post/convert
Enter model name: ras sav gly coa
sav
Enter input file type: (h)eads (f)low
f
Enter input file path name:
/yourpath/output/calib/sav.nodeflo.b
Enter output file path name:
/yourpath/output/calib/sav.nodeflo

An example output file follows:

Output file **sav.nodeflo**:

```
               (10f11.4)                 76          88           4  CONSTANT HEAD
0.0046     0.0046  0.0047     0.0047     0.0004     0.0004     0.0004  0.0004     0.0039     0.0041
0.0042     0.0043  0.0039     0.0040     0.0040     0.0040     0.0018  0.0018     0.0018     0.0018
0.0068     0.0069  0.0070     0.0070     0.0017     0.0020     0.0017 -0.0001    -0.0020     ......
```

(2) Code **separate.f** is used to separate the cell-to-cell flow into its different components, provided that the binary flows for the example have been converted to an ASCII file, and the file **sav.nodeflo** exists:

/yourpath/source/fortran77/post/separate
Enter model name: ras sav gly coa
sav
Enter input file path name:
/yourpath/output/example/sav.nodeflo
Enter constant head output path name:
/yourpath/output/example/sav.con.hd
Enter right face flow output path name:
/yourpath/output/example/sav.right
Enter front face flow output path name:
/yourpath/output/example/sav.front
Enter lower face flow output path name:
/yourpath/output/example/sav.vert
Enter general head boundary output path name:
/yourpath/output/example/sav.ghb

(3) Code **ddn.f** is used to display the simulated heads in a format labeled by row and column for each layer (option 1: label heads) or to calculate the change in heads for a simulation with respect to the calibration (option 2: calculate drawdown).

/yourpath/source/fortran77/post/ddn
Enter model name: ras sav gly coa
sav
Enter choice 1: label heads, 2: calculate ddn
1
Enter simulated heads input file path name:
/yourpath/output/example/sav.head
Enter path for output file(s):
/yourpath/output/example

The screen will display this message:

```
*******************************************
     output file(s) are:
   /yourpath/output/example/sav.heads.label
*******************************************
```

An example output file follows:

Output file **sav.heads.label**:

```
  PATH NAME:                                    yourpath/output/example
VALUES ARE SIMULATED HEADS
ROW:    1    LAYER:    2
COL     VALUE    COL     VALUE   COL   VALUE     COL     VALUE  COL     VALUE  COL     VALUE
1       108.057   18     89.276   35   69.029     52   49.648   69     35.897 86     25.722
2       107.508   19     88.668   36   67.606     53   48.995   70     35.772 87     24.589
3       106.876   20     88.014   37   66.042     54   48.328   71     35.453 88     23.412
4       106.147   21     87.365   38   64.278     55   47.582   72     35.025
5       105.338   22     86.539   39   62.271      5..........
```

If drawdown is to be calculated (option 2), the script **ddn** should be executed again, using choice **2** (calculate drawdown) instead of **1**. Before executing the code **ddn**, the file **sav.head** must exist in the directory **example**. Therefore, if **sav.head** does not appear in the directory, the code **convert.f** must be executed prior to using **ddn.f**.

/yourpath/source/fortran77/post/ddn
Enter model name: ras sav gly coa
sav
Enter choice 1: label heads, 2: calculate ddn
2
Enter simulated heads input file path name:
/yourpath/output/example/sav.head
Enter calibrated heads input file path name:
/yourpath/output/calib/sav.head
Enter proposed wells file path name:
/yourpath/output/example/wells.sav
Enter indicator nodes and threshold input file path name:
/yourpath/output/example/threshold.sav
Enter path for output file(s):
/yourpath/output/example

The screen will display the following message:

```
*******************************************
        output file(s) are:
 /yourpath/output/example/sav.ddn
 /yourpath/output/example/sav.ddn.label
 /yourpath/output/example/sav.ddn.impact
*******************************************
```

Examples of the output files follows:

Output file **sav.ddn**:

```
                    (10F8.4)
-0.5400 -0.5270 -0.5140 -0.5030 -0.4960 -0.4880 -0.4770 -0.4700 -0.4650 -0.4560
-0.4440 -0.4.................
```

Output file **sav.ddn.label**:

```
 PATH NAME:                             yourpath/output/example
VALUES ARE DRAWDOWN
ROW:   1   LAYER:   2
COL  VALUE   COL  VALUE   COL  VALUE   COL  VALUE   COL  VALUE   COL
1    -0.540  18   -0.396 35   -0.232 52   -0.035 69   0.071  86    0.010
2    -0.5......
```

Output file **sav.ddn.impact**:

```
=====================================================================
                           SAVANNAH MODEL
IMPACT ON WATER LEVELS AT PROPOSED WELLS AND INDICATOR NODES.
PATH NAME: yourpath/output/example/sav.ddn.impact
(-) INDICATES WATER-LEVEL RISE.
=====================================================================

    PROPOSED WELL            NODAL LOCATION          DRAWDOWN
                          LAYER    ROW  COLUMN          (FT)
                            2      36     36          34.4450
                            2      37     42         -11.8530
                            2      37     43         -13.5320
                            2      37     57           6.4780

    INDICATOR WELL           NODAL LOCATION          DRAWDOWN
                          LAYER    ROW   COLUMN         (FT)
                            2      36     70           0.1480
                            2      43     42           0.4060

===================================================================
DRAWDOWN AT ANY NODES GREATER THAN:      5.000
===================================================================

                             NODAL LOCATION          DRAWDOWN
                          LAYER    ROW   COLUMN         (FT)
                            2      29     32           5.2250
                            2      29     33           5.4630
                            2      29.........
```

(4) Code **stats.f**.--There are two options for computing statistics; each has a different observed-heads input format. The first option, **wrap**, reads a file in which the first line contains a format statement describing the rest of the file, which has head values for every cell in the active model layers. This option has arguable hydrologic meaning, but can be a helpful tool to compare two sets of heads. The second option, **column**, reads a file where the head values are identified by their location in the model as layer, row, column, and value corresponding to measurement. This option will compute the statistics only at locations where there are measured data.

/yourpath/source/fortran77/post/stats
Enter model name: ras sav gly coa
sav
Enter measured heads input file format:
1) wrap
2) column
2
Enter measured heads input file path name:
/yourpath/input/sav/sav.obs.head.1985
Enter simulated heads input file path name:
/yourpath/output/example/sav.head
Enter statistics output file path name:
/yourpath/output/example/sav.statistics

The output file will show:

Output file **sav.statistics**:

```
ROW    COL    MEASURED    W/LSIMULATED      W/LDIFFERENCE
2      15     84.5400     85.9080           1.3680
2      36     6.........
NUMBER OF POINTS =    136
AVE =         0.52
INPUT AND SIMULATED HEAD STATISTICS
NUMBER OF NODES USED IN ANALYSIS =     136
HEAD DIFFERENCES: MEAN =     0.51551
ST DEV =      5.5534
SUM OF THE DIFFERENCES SQUARED =     4199.6
AVERAGE SQUARED ERROR =     30.880
ROOT MEAN SQRED ERROR =     5.5569
```

(5) Code **vert.f**--Another option available for postprocessing results is to display vertical direction of flow among the different layers of a model. To execute the code **vert.f**, the conversions i) and ii) must be executed first. If these steps have already been taken, go to step iii).

(*i*) Conversion of the cell-to-cell flow into an ASCII file

/yourpath/source/fortran77/post/convert
Enter model name: ras sav gly coa
sav
Enter input file type: (h)eads (f)low
f
Enter input file path name:
/yourpath/output/example/sav.nodeflo.b
Enter output file path name:
/yourpath/output/example/sav.nodeflo

(*ii*) Separation of the different components of flow for that model:

/yourpath/source/fortran77/post/separate
Enter model name: ras sav gly coa
sav
Enter input file path name:
/yourpath/output/example/sav.nodeflo
Enter constant head output path name:
/yourpath/output/example/sav.con.hd
Enter right face flow output path name:
/yourpath/output/example/sav.right
Enter front face flow output path name:
/yourpath/output/example/sav.front
Enter lower face flow output path name:
/yourpath/output/example/sav.vert
Enter general head boundary output path name:
/yourpath/output/example/sav.ghb

(*iii*) Execute the code **vert.f** to display the direction of vertical flows:

/yourpath/source/fortran77/post/vert
Enter model name: ras sav gly coa
sav
Enter vertical flux input file path name:
/yourpath/output/example/sav.vert
Enter flux diagram output file path name:
/yourpath/output/example/sav.flux.direction

An example of output file follows:

Output file **sav.flux.direction**:

```
File:  /yourpath/output/example/sav.flux.direction
Positive flow -> downward flow out of layer
Negative flow -> upward flow into same layer


Layer:  1
Rows:   1 -  38,  Cols:   1 -  44
++++++++++++++++++++++++--++-+++++++++---
+++++++++++++++++++++++++--+-+++++++++---
+++++++++++++++++++++++++++-+++++++++++++-
++++++++++++++++++++++++++-++......
```

(6) Code **budget.f** is used to compute the water budget for a model area. Changes in the water budget for the telescoped model with respect to the calibrated values can be executed only if the flows in directory **calib** are already separated into different components.

/yourpath/source/fortran77/post/budget
Enter model name: ras sav gly coa
sav
Enter simulated vertical flow input file path name:
/yourpath/output/example/sav.vert
Enter simulated boundary flow input file path name:
/yourpath/output/example/sav.bndry.flo
Enter simulated well input file path name:
/yourpath/output/example/sav.wellpac
Are there general head boundaries? (y/n)
n
Compute budget changes between two scenarios? (y/n)
y

The following scenario will be denoted calibrated

Enter calibrated vertical flow input file path name:
/yourpath/output/calib/sav.vert
Enter calibrated boundary flow input file path name:
/yourpath/output/calib/sav.bndry.flo
Enter calibrated well input file path name:
/yourpath/input/sav/sav.well.data
Enter path for output files:
/yourpath/output/example

The screen will display the following message.

```
*****************************************
        output file(s) are:
 /yourpath/output/example/sav.budget
 /yourpath/output/example/sav.budget.diff
*****************************************
```

Examples of output files follows:

Output file **sav.budget**:

```
============================================================
   File: /yourpath/output/example/sav.budget
   Model: sav
   Table: values for water budget
============================================================
                   (positive: flow into model)
                    LAYER 2         LAYER 3
RASA BND FLUX        85.72           36.61
PUMPING             -178.66          -17.30

                LEAKANCE VALUES FOR LAYERS 1 THROUGH 3
                   DOWNWARD FLOW        UPWARD FLOW
       LAYER 1        90.47               17.54
       LAYER 2        13.08               32.71
       LAYER 3         0.00                0.24

                       |                                |
                       |                                |
                       |        17.54          90.47    |
                       |__________^______________v______|
                       |----------^--------------v------|
                       |          ^              v      |
             96.22>>>  |                                |
             10.50<<<  |        32.71          13.08    |
                       |__________^______________v______|
                       |----------^--------------v------|
                       |          ^              v      |
             36.82>>>  |                                |
              0.21<<<  |               0.2              |
                       |_________________^______________|
                       |-----------------^--------------|
                                         ^
```

and :

Output file **sav.budget.diff**

```
================================================================
   Model: sav
   Table: calibrated - simulated water budget
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

             (positive: increase pumping)
                 LAYER 2        LAYER 3
RASA BND FLUX     -4.20          -0.92
      PUMPING     -9.84           0.00

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               LEAKANCE VALUES FOR LAYERS 1 THROUGH 3
                    (negative: increase flux)

                    DOWNWARD FLOW    UPWARD FLOW
             LAYER 1     -3.70          -0.39
             LAYER 2     -0.97           2.01
             LAYER 3      0.00           0.00

                |                                 |
                |       -0.39          -3.70      |
                |__________^_____________v________|
                |----------^-------------v--------|
                |          ^             v        |
       -3.43>>> |                                 |
       -0.77<<< |        2.01          -0.97      |
                |_________________________________|
                |----------^-------------v--------|
                |          ^             v        |
       -0.92>>> |                                 |
        0.01<<< |              0.00               |
                |________________^________________|
                |----------------^----------------|
                                 ^
```

2.4.2 Script-file execution--Responses that must be provided by the user during execution of the script files are shown in boldface type.

Select the file **READ.ME.FIRST** under the directory contents. This file describes the way the telescoping procedure handles the path for the various files and codes used.

Edit the file **link**; where **/rg/tm/** appears, change to **/yourpath/**.

Ensure that the four main directories (**contents**, **input**, **source**, and **output**) are under **yourpath**. Under the directory **output** there should be subdirectories for the scenarios **example** and **calib**.

a. As described in 2.4.1, verify that the files for the proposed wells (**wells.xxx**) and **threshold.xxx** exist under the subdirectory **example**. Steps b through j, described in 2.4.1, are controlled by the execution of the script file **telmdls**, as follows:

/yourpath/source/scripts/telmdls
Enter the scenario path name:
/yourpath/output/example
Finished checking for the existence of: /yourpath/output/example
and the file name: wells.ras
Execute Savannah Model ? (y/n): **y**
Execute Glynn Model ? (y/n): **y**
Execute Coastal Model ? (y/n): **y**

```
*********************************************************
********************* End Of User Input ***********************
************* output file names listed after execution ***************
*********************************************************
```

For all script files, the prompts from the FORTRAN codes will still appear even though the script file is handling all the responses. In addition, other messages are displayed to inform the user what is occurring.

```
                -- Removing existing links to fortran units
                   No match.

BEGIN EXECUTION OF RASA MODEL
   Wed Aug 18 08:49:13 EDT 1993
   Enter existing wells file path name:
   Enter proposed wells file path name:
   Enter boundary wells path name (cr=none):
   Enter combined wells output path name:
       485 existing wells
       3 proposed wells
       0 boundary wells
-- Finished combining existing and proposed wells for RASA model
-- Begin executing MODFLOW for RASA model
-- Finished executing modflow code for RASA model
   Enter model name:  ras   sav   gly   coa
   Enter input file path name:
   Enter output file path name:
-- Finished converting binary flow to an ASCII file
   Enter model name:   ras   sav   gly   coa
   Enter input file path name:
   Enter constant head output path name:
   Enter right face flow output path name:
   Enter front face flow output path name:
   Enter lower face flow output path name:
   Enter general head boundary output path name:
      processing...
-- Finished separating components of RASA flow
   Wed Aug 18 08:50:41 EDT 1993

BEGIN EXECUTION OF SAVANNAH MODEL
   Enter model name:  ras   sav   gly   coa
   Enter RASA right flow input path name:
   Enter RASA front flow input path name:
   Enter boundary flow output path name:
   Enter boundary flow table output path name:
   Enter boundary wells output path name:
      processing...
-- Finished converting flow at the boundaries into boundary wells for:
      Savannah model
   Enter existing wells file path name:
   Enter proposed wells file path name:
   Enter boundary wells path name (cr=none):
   Enter combined wells output path name:
        181 existing wells
        4 proposed wells
        648 boundary wells
--Finished combining Savannah existing, proposed, and boundary wells
--Begin executing modflow for Savannah model
--Finished executing modflow for Savannah model
       Wed Aug 18 08:53:02 EDT 1993
```

```
BEGIN EXECUTION OF GLYNN MODEL
  Enter model name:  ras   sav   gly   coa
  Enter RASA right flow input path name:
  Enter RASA front flow input path name:
  Enter boundary flow output path name:
  Enter boundary flow table output path name:
  Enter boundary wells output path name:
     processing...
--Finished converting flow at the boundaries into boundary wells for:
     Glynn model
  Enter existing wells file path name:
  Enter proposed wells file path name:
  Enter boundary wells path name (cr=none):
  Enter combined wells output path name:
      146 existing wells
      0 proposed wells
      808 boundary wells
--Finished combining Glynn existing, proposed, and boundary wells
--Begin executing modflow for Glynn model

--Finished executing modflow for Glynn model
       Wed Aug 18 09:02:45 EDT 1993

BEGIN EXECUTION OF COASTAL MODEL
  Enter model name:  ras   sav   gly   coa
  Enter RASA right flow input path name:
  Enter RASA front flow input path name:
  Enter boundary flow output path name:
  Enter boundary flow table output path name:
  Enter boundary wells output path name:
     processing...
--Finished converting flow at the boundaries into boundary wells for:
    coastal model
  Enter existing wells file path name:
  Enter proposed wells file path name:
  Enter boundary wells path name (cr=none):
  Enter combined wells output path name:
      379 existing wells
      4 proposed wells
      504 boundary wells
-- Finished combining coastal existing, proposed, and boundary wells
-- Begin executing modflow for Coastal model
-- Finished executing modflow for Coastal model
      Wed Aug 18 09:05:44 EDT 1993

**************************************************************
              RASA MODEL OUTPUT FILES:
              /yourpath/output/example/ras.wellpac
              /yourpath/output/example/ras.head.b
              /yourpath/output/example/ras.ddn.init.b
              /yourpath/output/example/ras.nodeflo.b
              /yourpath/output/example/ras.runout
**************************************************************
```

```
************************************************************
        SAVANNAH MODEL OUTPUT FILES:
        /yourpath/output/example/sav.bndry.flo
        /yourpath/output/example/sav.bndry.flo.table
        /yourpath/output/example/sav.bndry.wells
        /yourpath/output/example/sav.wellpac
        /yourpath/output/example/sav.head.b
        /yourpath/output/example/sav.ddn.init.b
        /yourpath/output/example/sav.nodeflo.b
        /yourpath/output/example/sav.runout
************************************************************

************************************************************
        GLYNN MODEL OUTPUT FILES:
        /yourpath/output/example/gly.bndry.flo
        /yourpath/output/example/gly.bndry.flo.table
        /yourpath /output/example/gly.bndry.wells
        /yourpath/output/example/gly.wellpac
        /yourpath/output/example/gly.head.b
        /yourpath/output/example/gly.ddn.init.b
        /yourpath/output/example/gly.nodeflo.b
        /yourpath/output/example/gly.runout
************************************************************

************************************************************
        COASTAL MODEL OUTPUT FILES:
        /yourpath/output/example/coa.bndry.flo
        /yourpath/output/example/coa.bndry.flo.table
        /yourpath/output/example/coa.bndry.wells
        /yourpath/output/example/coa.wellpac
        /yourpath/output/example/coa.head.b
        /yourpath/output/example/coa.ddn.init.b
        /yourpath/output/example/coa.nodeflo.b
        /yourpath/output/example/coa.runout
************************************************************

************************************************************
```

After the model(s) have been executed, script files for postprocessing the results are stored in the subdirectory **/yourpath/source/scripts**. Script files are: **drawdown**, **flowdir**, **statistics**, and **watbud**. The use of each script file is described below: Examples for the output files are not be presented in this section; however, examples are the same as those in section 2.4.1.

1. Script drawdown.

/yourpath/source/scripts/drawdown
The current CALIBRATED data are at path: /yourpath/output/calib
(enter c to change, enter blank to continue)
<cr>
Enter the SCENARIO directory name:
/yourpath/output/example
Enter MODEL name: ras sav coa gly
sav

```
************************************************************
******************** End Of User Input ***********************
************************************************************
```

The codes for executing the models were written to be used interactively. Thus, when the models are executed using the script files, the statements still appear on the screen although the user's input to run the script file has ended.

```
Enter model name: ras  sav  gly  coa
Enter input file type: (h)eads  (f)low
Enter input file path name:
Enter output file path name:
Enter model name: ras  sav  gly  coa
Enter input file type: (h)eads  (f)low
Enter input file path name:
Enter output file path name:
Enter model name: ras  sav  gly  coa
Enter choice 1: label heads, 2: calculate ddn
Enter simulated heads input file path name:
Enter calibrated heads input file path name:
Enter proposed wells file path name:
Enter indicator nodes and factor input file path name:
Enter path for output file(s):


*********************************************

        output file(s) are:

  /yourpath/output/example/sav.ddn
  /yourpath/output/example/sav.ddn.label
  /yourpath/output/example/sav.ddn.impact
*********************************************


Enter model name:  ras  sav  gly  coa
Enter choice 1: label heads, 2: calculate ddn
Enter simulated heads input file path name:
Enter path for output file(s):


*********************************************
          output file(s) are:
 /yourpath/output/example/sav.heads.label
*********************************************
```

2. Script flowdir.

```
/yourpath/source/scripts/flowdir
Enter the scenario path name:
/yourpath/output/example
Enter model name:  sav  coa  gly
sav
*************************************************
******************** End Of User Input *************
******************** Ouput Files
           /yourpath/output/example/sav.vert
           /yourpath/output/example/sav.vert.table
*************************************************
```

The following statements appear on the screen to show the process taking place at the various stages. They do not require any input from the user.

```
Enter model name:   ras   sav   gly   coa
Enter input file type: (h)eads  (f)low
Enter input file path name:
Enter output file path name:
Enter model name:   ras   sav   gly   coa
Enter input file path name:
Enter constant head output path name:
Enter right face flow output path name:
Enter front face flow output path name:
Enter lower face flow output path name:
Enter general head boundary output path name:
     processing...
Enter model name:   ras   sav   gly   coa
Enter vertical flux input file path name:
Enter flux diagram output file path name:
     processing....
```

3. Script statistics.

/yourpath/source/scripts/statistics
Enter scenario path name:
/yourpath/output/example
Enter MODEL: sav   gly   coa:
sav
Enter measured water-level file format
  1) wrap
  2) column
2

```
*****************************************************
********************* End Of User Input ********************
*****************************************************
********************* output file is:
********************* /yourpath/output/example/sav.stats
*****************************************************
```

The following statements appear on the screen to show the process taking place at the various stages. They do not require any input from the user.

```
Enter model name: ras   sav   gly   coa
Enter input file type: (h)eads  (f)low
Enter input file path name:
Enter output file path name:
Enter model name: ras   sav   gly   coa
Enter measured heads input file format:
   1) wrap
   2) column
Enter measured heads input file path name:
Enter simulated heads input file path name:
Enter statistics output file path name:
   processing....
```

4. Script watbud.

/yourpath/source/scripts/watbud
Enter model name: sav coa gly
sav
Enter the SCENARIO path name:
/yourpath/output/example
Compare budget to another scenario ? (y/n)
y
The current CALIBRATED data are at path:
/yourpath/output/calib
(Enter c to change or enter blank to continue)

****
****************** End Of User Input ***************
****

The following statements appear on the screen to show the process taking place at the different stages. They do not require any input from the user.

Enter model name: ras sav gly coa
Enter input file type: (h)eads (f)low
Enter input file path name:
Enter output file path name:
Enter model name: ras sav gly coa
Enter input file path name:
Enter constant head output path name:
Enter right face flow output path name:
Enter front face flow output path name:
Enter lower face flow output path name:
Enter general head boundary output path name:
processing...
Enter model name: ras sav gly coa
Enter input file type: (h)eads (f)low
Enter input file path name:
Enter output file path name:
Enter model name: ras sav gly coa
Enter input file path name:
Enter constant head output path name:
Enter right face flow output path name:
Enter front face flow output path name:
Enter lower face flow output path name:
Enter general head boundary output path name:
processing...
This model does not have General Head Boundary data
Enter model name: ras sav gly coa
Enter simulated vertical flow input file path name:
Enter simulated boundary flow input file path name:
Enter simulated well input file path name:
Are there general head boundaries? (y/n)
Compute budget changes between two scenarios? (y/n)
The following scenario will be denoted calibrated
Enter calibrated vertical flow input file path name:
Enter calibrated boundary flow input file path name:
Enter calibrated well input file path name:
Enter path for output files:

****
output file(s) are:
/yourpath/output/example/sav.budget
/yourpath/output/example/sav.budget.diff
****

Processing...
- done