Development and Application of A Groundwater Quality Management Model to the Equus Beds Aquifer, Southcentral Kansas

by:

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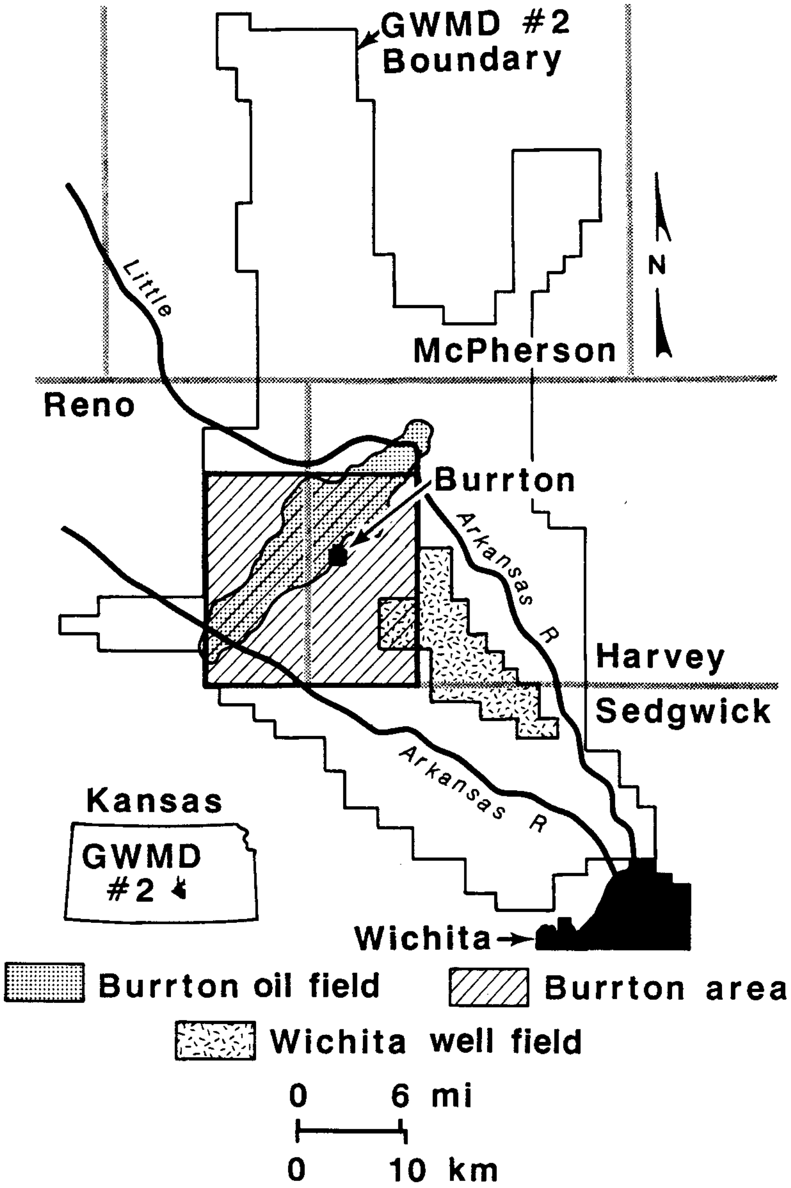


Figure 1. Location of Equus Beds aquifer.

Chapter 1

INTRODUCTION

In recent years, a nationwide concern has risen over the quality of existing ground-water supplies, which are being threatened by the consequences of past waste-disposal practices of various kinds. Although many of these waste-disposal operations are being identified and terminated as a result of perceived contamination potential, increasing evidence exists that continuous movement of remaining pollutants in affected aquifers will persist as a serious hazard to the existing freshwater resources. This report is concerned with the problem of managing ground-water reserves under such circumstances for purposes of reducing the adverse effects of past disposal practices on limited freshwater resources.

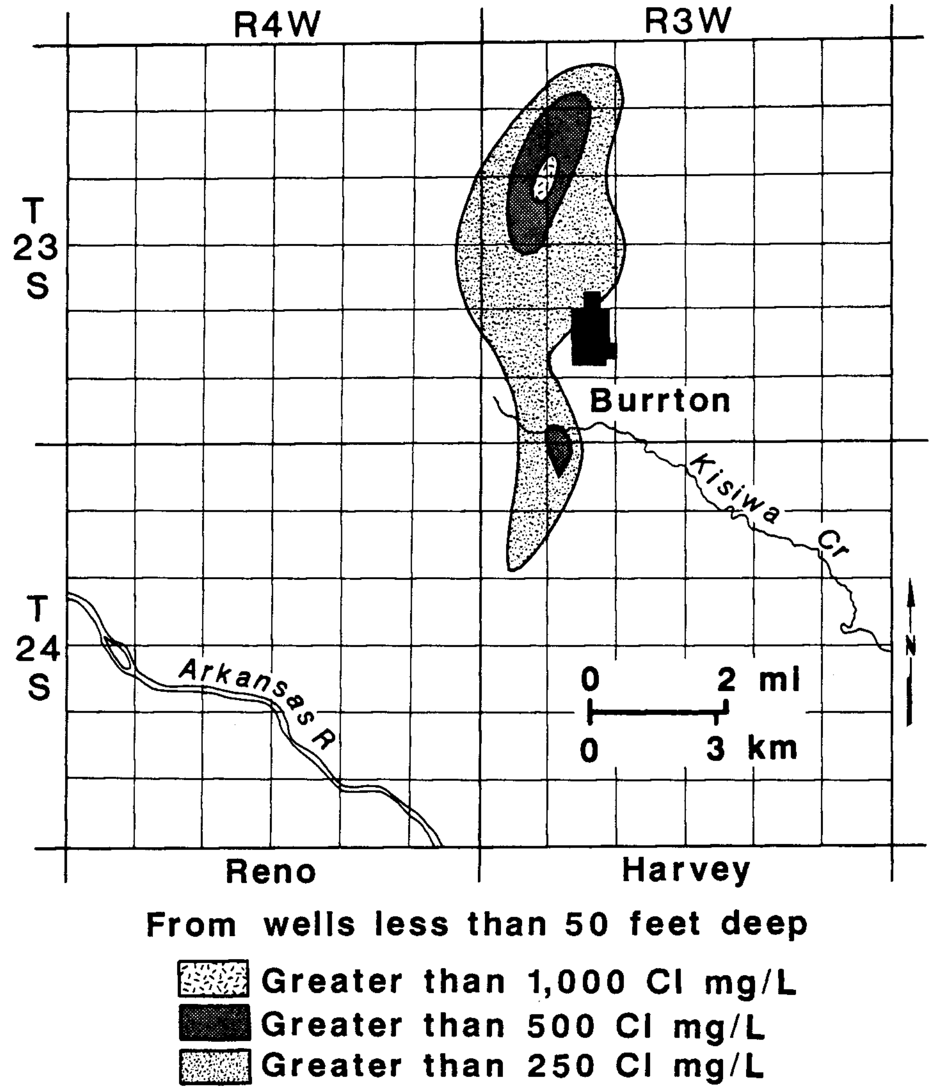
1.1 Statement of Problem

Equus Beds aquifer in south-central Kansas (Fig. 1) is one of the most productive aquifers in Kansas. Substantial amounts of water of generally high quality are pumped from this aquifer each year for municipal, industrial, and agricultural activities. In 1931, an oil field (Burrton oil field) was discovered near the town of Burrton in the west-central part of the aquifer (Fig. 1). Prior to this discovery no records of water-quality problems in the Burrton area existed. A water-quality report of the area in 1938 showed that, in the Burrton area, chloride concentration ranged from 10 to 100 mg/L (Burrton Task Force, 1984). Due to extensive oil-industry activities in the area, surface-disposal ponds were used to dispose of the oil-field brine. This activity together with leaks from the distribution lines and pressurized shallow-disposal wells created a general ground-water-quality degradation in the area whose extent became apparent in early 1948. Since then the area has been monitored by State and Federal agencies. In recent years, some efforts have been made on the part of the local groundwater management district (G.W.M.D. #2) to clean up the contaminant plume. The disposed oil brine had an average chloride concentration of approximately 100,000 mg/L. In the period from 1931 to 1948, this practice increased the chloride concentration of the ground water in the vicinity of the ponds to 250 mg/L, and in an area of about 1/4 mi^2, concentration of 1000 mg/L were observed (Whittemore et al., 1985). In Figs. 2a and 2b the distribution of chloride concentration in 1948 for shallow (less than 50 ft) and deep (more than 50 ft) observation wells as reported by Burrton Task Force (1984) are shown. In Fig. 3 the concentration and major sources of chloride at shallow and intermediate aquifer depths for 1982-84 as reported by Whittemore et al. (1985) are shown. As can be observed, the plume is dispersing in the direction of the Wichita well field.

The basic question in the minds of the managers of this water resource are: a) how can an aquifer reclamation and restoration program be initiated in this area so that the impact of this plume on the agricultural, industrial, and municipal wells is minimized, and b) is such a program economically and physically feasible?

1.2 Review of Previous Work

The geology and hydrology of the study area have been investigated since the 1940's. Several studies by the Kansas Department of Health and Environment were not formally published. One of the first comprehensive hydrogeologic reports was by Williams and Lohman (1949). In this report the geography, geology, and ground-water resources of the region comprising McPherson County, almost all of Harvey County, and portions of Sedgwick, Reno,



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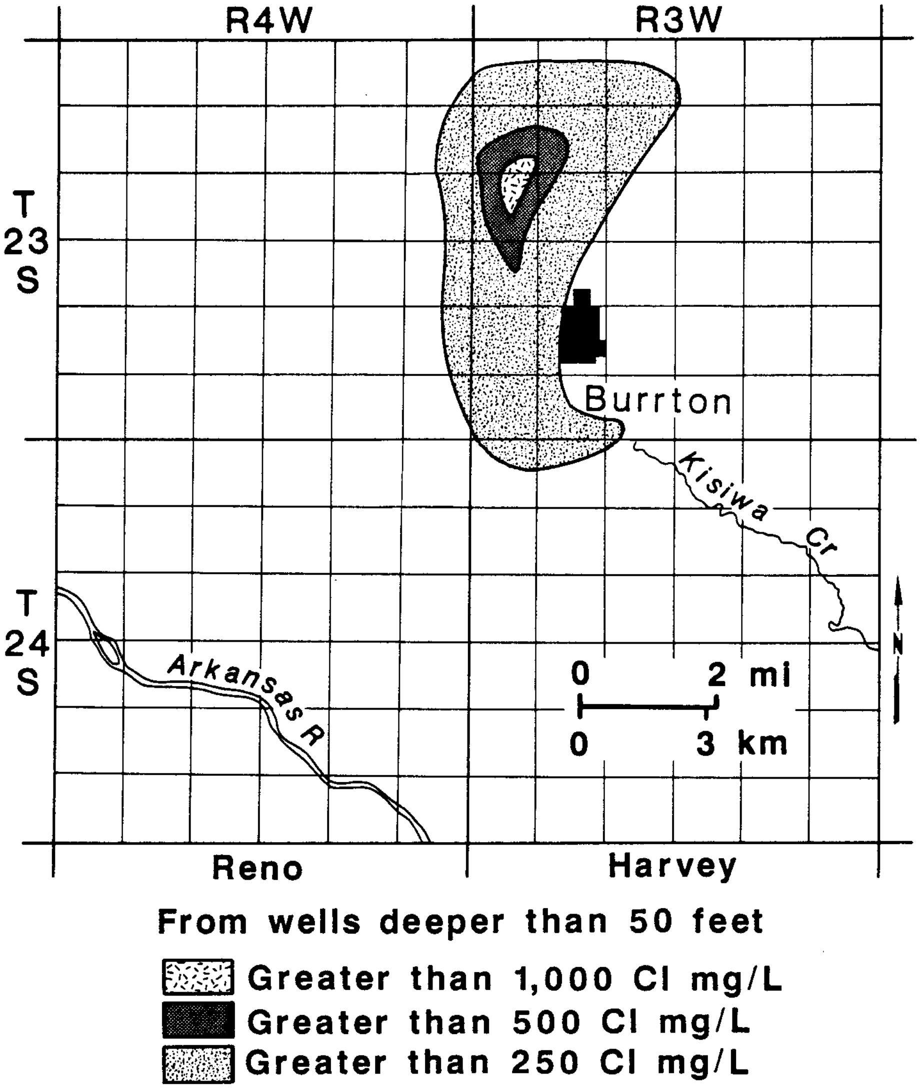

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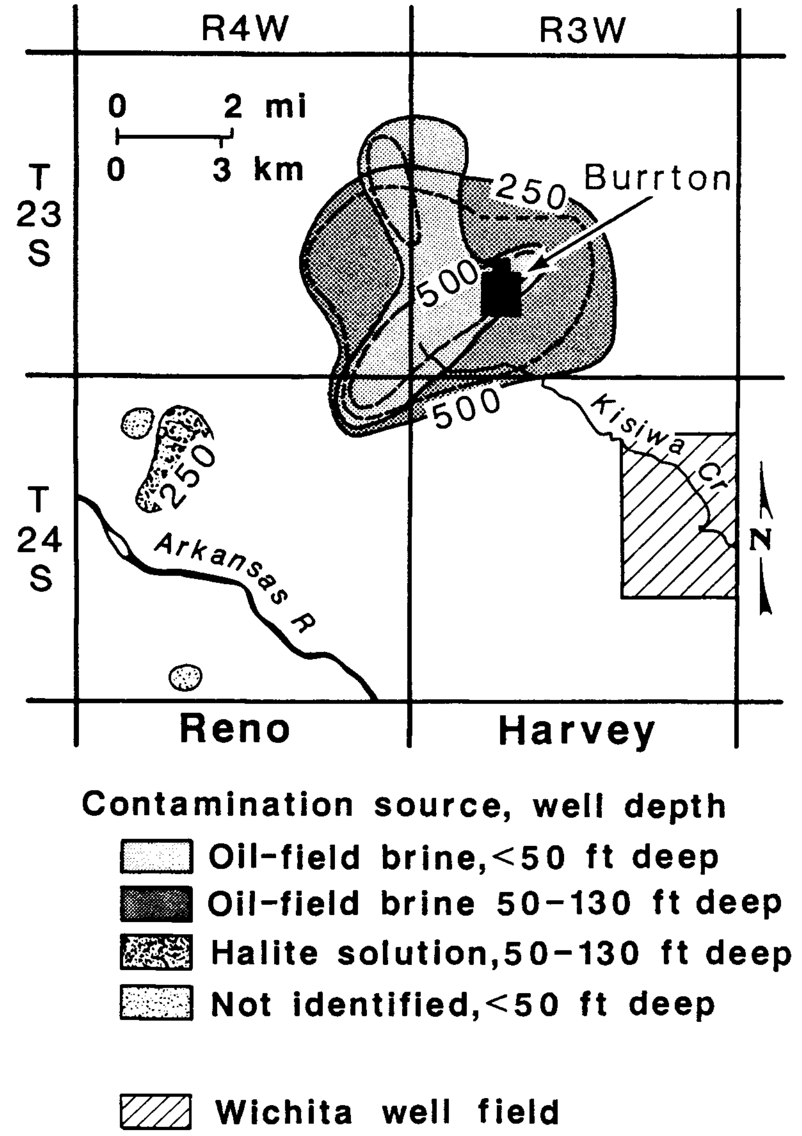

Figure 3. 1982-84 distribution of major source of chloride at shallow and intermediate aquifer depths in Burrton area. (After Whittemore et al., 1985).

and Marion counties were investigated (Fig. 1). The emphasis is put on the Pleistocene water-bearing McPherson (the Equus beds) formation, because this formation was the source of freshwater for several communities. The saltwater, which has resulted from improper disposal of oil-field brines, is formally documented to be a source of saltwater intrusion into several nearby wells. Fent (1950) described the geology and ground-water resources of Rice County. The cross section map representing the distribution of the unconsolidated material prepared by Fent shows a noticeable variation in bedrock topography in this county.

Stramel (1956, 1966) reviewed the work of Williams and Lohman and concluded that approximately 67% of the water pumped from the well field of the City of Wichita had come from recharge by precipitation. This is an indication of high productivity of this aquifer.

Bayne (1956) described the geography, geology, and ground-water resources of Reno County. Other studies by Petri et al. (1964), Lane and Miller (1965), Pinney et al. (1975), Leonard and Kleinschmidt (1976), and Hathaway et al. (1981) have investigated the geohydrology and hydrogeochemistry of the Equus beds area. Gogel (1981) investigated the geohydrology of the Wellington aquifer which underlies the Equus Beds aquifer in the western half of the area.

Since 1972 several investigators have developed and, to a degree of success, have applied digital computer models to predict the future water quantity and quality of the area. Halepaska et al. (1972) developed a digital computer model and applied it to the Equus beds. Their investigation does not state clearly how the calibration for aquifer parameters was performed, nor what the parameters obtained from the calibration were. Whereas, although a resemblance exists between the 1970 measured and calculated head reported by

Halepaska et al. (1972), discrepancies can be detected even visually. Knapp (1973) developed a digital basin model to simulate the hydrology of a stream basin. This model, which requires precipitation data, climatic information, boundary, and initial conditions, was designed to calculate both streamflow and ground-water levels. The basic block of this model consists of units to perform a mass-balance for different components of the system.

Green and Pogge (1973) expanded on the technical description of Knapp's model. The application of their model to the Equus Beds aquifer is well documented. The ground-water component of the model assumes the aquifer transmissivity does not change with time (confined aquifer). By a trial and error procedure, a transmissivity matrix was calculated. A storage coefficient of .15 was assigned to all nodes in the modeled area. In general, the model made a good simulation of the average condition in the area. Some discrepancies are present during extreme weather conditions (drought or wet periods), which may be associated with assumptions in the model.

Sophocleous et al. (1982) and Sophocleous (1984) used a multiple-regression technique developed by Cooley (1977, 1979) to calibrate a steady-state ground-water-flow model of the same area. The velocities calculated by this model were then used in a transient mass-transport model developed by Konikow and Bredehoeft (1978). The steady-state condition was based on the 1940 water table which was assumed to have persisted up to the present time. However, we will demonstrate in this report that the velocity vectors in the area show variations with time. Therefore, the assumption of steady-state velocity may be questionable as far as velocity vectors are concerned.

Recently, Spinazola et al. (1985) have calibrated a transient flow and mass-transport model for this area. Because the results of their study play an important role in the model development and application of our proposed management model, their study will be reviewed in more details.

The three-dimensional flow model used by Spinazola et al. (1985) was developed by McDonald and Harbaugh (1984). The use of a three-dimensional model was justified because of the vertical leakages into and out of the Equus Beds aquifer. To simulate the rate of fluid exchange between the Equus Beds aquifer and the underlying Wellington aquifer, the vertical leakages calculated by Gogel (1981) were used. The recharge was considered to be a function of precipitation, the nature of the land surface, and the nature of the unsaturated material between the land surface and the water table. Evapotranspiration was assumed to exist for cells where the altitude of the water table was less than 10 feet below land surface. River leakages were calculated using a vertical hydraulic conductance and the record of hydraulic head at different points in the river. Using the data obtained from the above analysis, first a steady-state model of the 1940 water table was calibrated. Then, aquifer properties and boundary conditions described in this model were used to represent the flow in a transient simulation for the period from 1940 to 1979. The calibrated model was verified by comparing its results with the measured heads for 1971 and 1980.

In the second part of their study, Spinazola et al. (1985) used a transient mass-transport model developed by Konikow and Bredehoeft (1978) to predict the future location of the plume in a portion of the aquifer where a saltwater plume exists. Their conclusion is that because of lack of exact knowledge about the volume and concentration of the disposed brine, as well as several other factors, a precise simulation of the distribution of chloride ion would be unlikely. In spite of the uncertainties which existed in the initial condition of simulation and data with which the results were compared, an acceptable degree of correlation seems to exist between the observed and calculated concentrations. By large, their conclusions are similar to that of Sophocleous (1984). According to their mass-transport projection, if the pumpage rate of 1971-1979 is continued to the year 2020, the 500-mg/L contour of equal chloride ion will arrive at the northwest corner of the Wichita well field.

1.3 Scope and contents of study

The primary objectives of our study are: (1) to develop an optimal management strategy for containment and removal of oil-field brine in the Equus Beds aquifer in south-central, Kansas; (2) to evaluate the practicality of the proposed ground-water-management options; and (3) to gain insights into the development of improved ground-water-management models for large-scale aquifer systems. A strong emphasis will be placed in this investigation on both the theoretical and the practical aspects of the solution procedures.

Chapter 2 presents a literature review of the previous studies in conjunction with optimal management of ground-water-aquifer systems. The basic requirements of a ground-water-management model will be discussed in detail along with a description of techniques that are currently used to incorporate the flow model into the management problem.

In Chapter 3, the ground-water-management problem is formulated in terms of an optimization problem. The objective of the optimization problem is to minimize the total pumpage required at a set of interception wells, which is designed to contain the movement of contaminant plume to a limited area of the aquifer. An innovative decomposition technique presented in this chapter is of practical importance for large-scale field application of ground-water-management models.

We start Chapter 4 by describing the construction of a flow model for the Equus Beds aquifer. The model is calibrated and validated with the observed water-level distributions. In the second part of this chapter, the management model will utilize the hydrogeologic parameters determined from the calibration phase and will develop management options for containment of pollution in this aquifer. The management options will be evaluated with respect to their practicality and effectiveness.

In Chapter 5, a solute-transport model is developed to simulate the transient movement of chloride particles in the aquifer. The model will be used as a predictive tool to demonstrate the effects of different management plans on the projected solute-concentration distributions.

Chapter 6 summarizes the major findings of this study and lists some recommendations. The main conclusion is that without proper management, the Wichita well field is likely to be affected by the saltwater plume. Whereas the degree of saltwater intrusion may be controlled by some of the management plans proposed in this study, the cost of these plans will be a major factor in their implementation. It is recommended that on selective sites (hot spots), aquifer clean-ups be considered. The scale of these clean-ups must be decided based on the availability of funds.

Appendix I contains theoretical development for linearization of non-linear flow equations describing the flow of water through unconfined aquifers.

In Appendices II and III, the input data to the flow model, velocity vectors, and optimum pumpage rates for the three management plans are listed.

Chapter 2

GROUND-WATER-QUALITY MANAGEMENT MODELS

2.1 Literature Review

In recent years the reclamation and clean-up of contaminated aquifers have become the subject of considerable research. The basic objectives of these studies are to formulate an effective method for containment of the plume and/or to take steps which will lead to clean-up of the aquifer. In theory, the development of hydraulic barriers combined with mass-transport models should provide a reliable method for containment of a plume and for prediction of what will happen to the plume as a result of this containment.

In using this approach for containment and clean-up of ground-water pollution, investigators have become aware that the large number of feasible combinations of management options prohibit their practical use. The use of the numerical models simulating the flow and mass-transport through porous media, combined with an optimization technique, reduces the number of acceptable solutions substantially. The models which use simulators together with optimization techniques are called the "ground-water-quality management models." The management models provide us with the ability to investigate the best management options for aquifers which are used for freshwater supply as well as for temporary storage of liquid waste. The solutions to these problems require strategies for containment and clean-up of waste, while providing for the freshwater demands. The use of simulation models alone has been well documented [see Reddell and Sunada (1970), Bredehoeft and Pinder (1973), and Konikow and Grove (1977)]. One of the models which deals with the combined use of optimization techniques and ground-water models is given by Willis (1976a). This study assumes that steady-state conditions exist in the aquifer whose assimilative waste capacity is considered to be an integral component of a waste-treatment system. The cost of the system to be minimized was assumed to be the sum of the treatment costs and the cost of imported water for recharge. Constraints were imposed on the water quality at the supply wells and recharge wells. Due to the assumption of constant velocity (steady-state), first solving the steady-state solute distribution for each constituent is possible. Then, these distributions are used as constraints in a management model which minimizes the cost as defined above. Futagami et al. (1976) used a linear-programming model to maximize total-waste disposal under local waste-load restrictions to a surface-water system. They used finite-difference or finite-element techniques to account for the physical behavior of the system. Their approach involves the embedding of ground-water-flow equations into the management model as constraints, which creates large matrices for large systems.

The management of aquifers under steady-state condition may not be representative of the conditions of many aquifers in use today. As the demand for water from these aquifers increases, the steady velocity fields gradually disappear and, therefore, future management of these systems must be based on transient models. To consider transient-flow conditions, some investigators have suggested the embedding method. That is, by the use of finite-difference or finite-element methods, the equations of state may be discretized and included in the management model in the form of constraints. The work of Willis (1976b) is an example of the embedding method applied to food-processing wastes used for spray irrigation to determine effluent disposal standards. A one-dimensional finite-element model which considered advective and dispersive transport, adsorption, and first-order kinetic decay in the unsaturated zone was embedded in the constraint matrix. Whereas the embedding method is successful for small problems, its application to large problems is subject to numerical instability and inaccuracies. Gorelick et al. (1979) developed a transient model for the management of an aquifer with a river as a possible source of pollution. In their paper the authors did not use standard optimization techniques. Rather, the block structure of the constraint matrix is exploited. By assuming the pollutant concentration at the source location as a parameter, the concentrations throughout the system are expressed as a function of this parameter. By varying this parameter, its minimum value over time is defined as the maximum concentration allowable in the source water over the management period. Willis (1979) developed a management model for conjunctive management of water supply and quality of an aquifer. He decomposed the model into two components: a ground-water hydraulic-management component, and a pollutant-source management component. This decoupling technique enabled him to set up two linear-programming problems. In the first problem, the hydraulic heads were controlled at pumping wells and injection wells to satisfy a targeted demand. In the second problem, the waste-injection concentrations were maximized while satisfying a waste load and providing for water quality at all wells for all periods. Rather than using transient hydraulic properties, an average ground-water-velocity field over a certain period was assumed for the water-quality-management model. This assumption forces the water quality to be evaluated at the end of the period for which the velocity field is assumed to be constant. This can lead to erroneous conclusions, because the peak contaminant plumes may not arrive at the beginning or at the end of the periods.

Gorelick and Remson (1982) proposed the use of concentration-response matrix in order to alleviate the numerical difficulties associated with the use of embedding techniques. They considered a one-dimensional ground-water model with multiple sources of pollution. The objective was the management of waste disposal in an aquifer so that solute concentrations at supply wells do not exceed water-quality standards. By assuming that the velocity field is constant, unit-response functions for the concentration were developed. Then a linear-programming solution of the concentration at the supply wells was obtained.

In another study, Gorelick (1982) generated the concentration-response matrix from the mass-transport model of Konikow and Bredehoeft (1978) for a linear-programming management model to maximize waste injection at several plant sites subject to a limit on solute concentration at observation wells. The model was used to evaluate several patterns of waste disposal, and the conclusion was reached that pulsing method is superior over continuous method of injection. The basic shortcoming of the ground-water-flow and mass-transport optimization models is that the flow field must be determined prior to pollution-management studies. This somewhat inhibits the ability of the investigators to answer a basic question, i.e., what is the "best" flow field so that the "best" pollution management is achieved.

Colarullo et al. (1984) designed and demonstrated the use of a plume-containment model for an aquifer used for freshwater supply. They used the present worth of the total cost of pumpage for all wells over all time periods as the objective function to be minimized. The constraints associated with this model were the maximum rate of pumpage, maximum permissible drawdown, and reversal of velocity vectors in the x and y directions at certain observation points. They used drawdown unit-response functions as described by Maddock (1972) and extended it to velocity field to calculate the velocity unit-response functions. Then by assuming that linear-system theory is valid for the problem under investigation, they used these functions to generate coefficients for the velocity constraints. The objective function created a quadratic-programming problem with linear constraints whose solution was demonstrated for a hypothetical but realistic aquifer. They calculated the optimal pumping policies for eight freshwater well fields and 11 plume-interception wells. They successfully reversed the velocity vectors at five observation wells and calculated the minimum cost of the operation for a five-year planning period. Whereas this demonstrative model was quite successful, it convinced the investigators that the application of these types of management models to real-life aquifers with 50-100 pumping wells and a reasonable length of planning period, is beyond the means of available computing facilities.

Atwood and Gorelick (1985) designed a model to reverse the gradient at certain points in the aquifer optimally. Their objective function minimized the sum of pumping and recharge rates. For each control point, two decision variables were included in the management model: the pumping rate and recharge rate. Their approach guaranteed a fixed hydraulic gradient around the shrinking plume's perimeter. This approach is an extension of the unit-response matrix method used by Colarullo et al. (1984). They applied this model successfully to the Rocky Mountain arsenal. The statistics on the linear-programming models are indicative of the computing demands required by these models. Their constraint matrix contained 832 decision variables (columns) and 512 constraints (rows) with a total non-zero matrix elements of 198,258 for 32 pumping periods, 32 observation wells, and 15 potentially active wells.

In another study, Lefkoff and Gorelick (1985) designed a model for optimal rapid removal of contaminant plume in an aquifer. Using Darcy's Law, they calculated the minimum average velocity required to move a particle of pollutant from a point on the periphery of the plume to the interception wells. Then this velocity was used to calculate the hydraulic-head variation required to achieve the objective. The unit-response function method was used to generate the coefficients of the constraint matrix. The objective function was assumed to be the total cost of pumpage for all time periods, similar to the one formulated by Maddock (1972) and used by Colarullo et al. (1984). The results of this study are very supportive of conclusions concerning the capabilities of these models for large systems.

2.2 Basic Requirements of Ground-water-management Models

The major role of the ground-water-management models is to find policies which can be used for the subsurface environment and then evaluate the effects of these policies on surface waters. The management of the ground-water resources clearly must consider the conflicting environmental, economic, and institutional factors. Whereas, formerly many ground-water resources have been tapped and used to the advantage of economic development, their future exploitation clearly is jeopardized. This is due to the fact that many of these resources are being depleted faster than they are being replenished, and the effects of their exploitation on surface waters and environment are now being felt.

The main structure of the management models consists of three basic items.

1. A set of partial differential equations describes the flow of water and perhaps chemicals through porous media. These equations provide the state of the system such as drawdown, hydraulic head, and concentration of certain species as a function of decision variable (pumpage). These equations require pre-assigned spatially distributed parameters of the porous media such as

transmissivity, storage coefficient, and dispersivity coefficients.

2. Boundary-condition equations specify the conditions at the boundaries such as recharge, head, and/or concentration.

3. Initial-condition equations specify the state of the system prior to the initiation of new steps taken for its management.

Because these equations may be nonlinear functions of state and decision variables, the parameters describing the physical properties of the system are spatially distributed, and the shape of the subsurface environment is irregular, a closed analytical solution representing these systems does not exist. Therefore, numerical solutions such as finite-difference or finite-element techniques should be used to obtain approximate solutions. These solutions are generally referred to as the predictive solutions, i.e., the state of the system for a given stress condition can be approximated.

When ground-water-flow and contaminant-transport models are solved in conjunction with an objective function and an optimization technique, they are called the management models. Management models seek to identify the best strategy for the management of the ground-water or ground-water/surface-water resources. In these models, both quality and quantity may be considered as decision variables.

Generally speaking two types of objective functions can be formulated. In the first type, the explicit economic functions such as net benefit or cost-per-unit decision variable may be included into the management model. Examples of this type of models are the work of Maddock (1972, 1973, 1974), and its extension by Colarullo et al. (1984). In the second type, the objective functions contain the economic terms implicitly. Examples of this type of objective function are the minimization of the total drawdown or maximization of total hydraulic heads, minimization of the total water shortage (Willis, 1983), or maximization of total pumpage (Heidari, 1982b).

For all these objective functions, the differential equations describing the state of the system must be incorporated either in the objective function or in the constraints. This process provides a link between the objective function and the distributed parameter ground-water models. This linkage is, generally, referred to as embedding.

2.3 Ground-water-flow Models

The equation describing the transient flow of water through a confined two-dimensional, heterogeneous aquifer is

$$\frac{\partial}{\partial x}(T\frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(T\frac{\partial h}{\partial y}) = S\frac{\partial h}{\partial t} + R + Q \qquad (1)$$

where

T = transmissivity tensor, L^2/T;
h = hydraulic head, L;
S = storage coefficient, L^o;
R = source term representing average volume flux per unit area of natural or artificial recharge, L/T;
$Q = \sum_{j=1}^{NW} q(j,n)\,\delta(x,x_w)$, a sink term representing the total pumpage rate per unit area from NW wells during time step n, L/T;
$q(j,n)$ = pumpage rate per unit area of well j during period n, L/T; and
$\delta(x,x_j)$ = is a Dirac delta function indicating that wells are to be treated as a point source.
t = time variable, T; and
x and y = Cartesian coordinates, L.

Equation (1) is linear with respect to variable h. In an unconfined aquifer $T = Kh$, where K is the hydraulic-conductivity tensor. Then the head distribution is given by the Boussinesq equation (Bear, 1979)

$$\frac{\partial}{\partial x}[Kh\frac{\partial h}{\partial x}] + \frac{\partial}{\partial y}[Kh\frac{\partial h}{\partial y}] = S_y\frac{\partial h}{\partial t} + R + Q \qquad (2)$$

where S_y is the specific yield of the aquifer. This equation is nonlinear in terms of variable h. Since the solution of a linear-distributed model is more convenient, techniques have been developed for the linearization of equation (2) (see Bear, 1972). In Appendix I, a linearization technique for equation (2) is presented. This linearization technique may become important, because the management model adapted in this study uses the linearized form of the flow equation only.

Equation (1) or a linearized form of (2) may be written as

$$\frac{\partial}{\partial x}(T\frac{\partial(H_o-s)}{\partial x}) + \frac{\partial}{\partial y}(T\frac{\partial(H_o-s)}{\partial y}) = S\frac{\partial(H_o-s)}{\partial t} + R + Q \qquad (3)$$

which can be expanded to

$$\frac{\partial}{\partial x}(T\frac{\partial H_o}{\partial x}) - \frac{\partial}{\partial x}(T\frac{\partial s}{\partial x}) + \frac{\partial}{\partial y}(T\frac{\partial H_o}{\partial y}) - \frac{\partial}{\partial y}(T\frac{\partial s}{\partial y}) = S\frac{\partial H_o}{\partial t} - S\frac{\partial s}{\partial t} + R + Q \qquad (3\text{-a})$$

where H_o = steady-state hydraulic head, L; and

s = drawdown, L.

Equation (3-a) may be written as two equations:

$$\frac{\partial}{\partial x}(T\frac{\partial H_o}{\partial x}) + \frac{\partial}{\partial y}(T\frac{\partial H_o}{\partial y}) - R = 0 \qquad (4\text{-a})$$

$$\frac{\partial}{\partial x}(T\frac{\partial s}{\partial x}) + \frac{\partial}{\partial y}(T\frac{\partial s}{\partial y}) = S\frac{\partial s}{\partial t} + Q \qquad (4\text{-b})$$

Equation (4-a) represents the steady-state condition of the system, and equation (4-b) is the transient component which when superimposed on the solution of (4-a) will give the total response of the system. It is important to realize that in decomposing (1) or linearizing the form of (2) into (4-a) and (4-b), one has to consider two sets of equations, if a transient solution is required. One set, (4-a), will provide the steady-state capture terms such as R(x,y) for a given $H_o(x,y)$ and T(x,y). The other set of equations (4-b) will provide the drawdown, s(x,y,t), as a function of T(x,y), S(x,y), and Q(x,y,t). To obtain the hydraulic head at a time t, this drawdown must be superimposed on $H_o(x,y)$. Realizing that the pumpage, Q, in (4-b) has to be satisfied from storage is important. Boundary contributions (capture terms) are assumed unperturbed, and they are included in term R of equation (4-a). In reality pumpage may disrupt the boundary conditions and natural recharge or discharge, R, can change with time. If these changes are known, they can be included in the transient part, (4-b). Note that when T(x,y) is constant in (1), Kh in (2) is a function of time. Therefore, linearization of (2) is subject to limitations. Experience shows that the solution of equation (2) may be approximated by the solution of equation (1), if $s = H_o - h \leqslant .25H_o$ (see Jacob, 1944, Bear, 1979).

For equations (1) and (2) the boundary conditions are:

1) constant head along the portion, Γ_1, of the boundary, i.e., $h = H_o$ or $s = 0$; and
2) constant flow along the portion, Γ_2, of the boundary, i.e., $\frac{\partial h}{\partial n} =$, constant where n = the unit vector normal to Γ_2.

Therefore, if flow is to remain constant $\frac{\partial s}{\partial n} = \frac{\partial Ho}{\partial n} - \frac{\partial h}{\partial n} = 0$, which indicates that natural recharge and discharge terms will remain constant on Γ_2.

The initial condition, H_o, is the hydraulic head on which future drawdowns are superimposed. Most commonly, the hydraulic head associated with the steady-state is used for H_o, i.e.,

$$h(x,y,0) = H_o \text{ and } s(x,y,0) = 0 \text{ at } t = 0.$$

2.4 Embedding Approach

The incorporation of the equations describing the flow of water and mass in porous media into a management model is called embedding. Basically there are two types of embedding techniques (Maddock, 1983), namely, difference (direct) embedding and response function. These techniques are described below.

2.4.1 Difference-embedding Technique

In this technique the governing equations are discretized and directly embedded into the management model as constraints. For example, let us assume that the following ground-water-quality management model is formulated:

$$\text{Max } Q = \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{n=1}^{N} Q(i,j,n) \qquad (5)$$

subject to

$$\underline{Q}(i,j,n) < Q(i,j,n) < \overline{Q}(i,j,n) \qquad (6\text{-a})$$

$$\underline{s}(i,j,n) < s(i,j,n) < \overline{s}(i,j,n) \qquad (6\text{-b})$$

where $Q(i,j,n)$ = pumpage or induced recharge at node (i,j) during time-period n;

$\overline{Q}$ and $\underline{Q}$ = upper and lower limits of Q;

s(i,j,n) = drawdown at node (i,j) at the end of time-step n;

$\overline{s}$ and $\underline{s}$ = upper and lower limits of s;

I and J = total number of nodes in x and y directions, respectively;

i and j = node incidence; and

N = total time.

If drawdown in (6-b) is represented by equation (4-b), then for time-step n, constraint (6-b) for a rectangular-grid system with Δx and Δy spacing between nodes may be written as

$$A(i,j)\ [s(i-1,j,n) - s(i,j,n)] - B(i,j)\ [s(i+1,j,n) - s(i,j,n)]$$

$$+\ C(i,j)\ [s(i,j-1,n) - s(i,j,n)] - D(i,j)\ [s(i,j+1,n) - s(i,j,n)]$$

$$-\ \frac{S(i,j)}{\Delta t}\, s(i,j,n) - \frac{S(i,j)}{\Delta t}\, s(i,j,n-1) - Q(i,j,n)$$

By rearranging the terms in (7), the unknown s(i,j,n) may be expressed as a function of known variables. Then this expression may be constrainted as

$$\underline{s}(i,j,n) < s(i,j,n) < \overline{s}(i,j,n)$$

where

$$A(i,j) = \frac{2}{\Delta y^2} \frac{T(i-1,j)T(i,j)}{T(i-1,j)+T(i,j)}$$

$$B(i,j) = \frac{2}{\Delta y^2} \frac{T(i+1,j)T(i,j)}{T(i+1,j)+T(i,j)}$$

$$C(i,j) = \frac{2}{\Delta x^2} \frac{T(i,j-1)T(i,j)}{T(i,j-1)+T(i,j)}$$

$$D(i,j) = \frac{2}{\Delta x^2} \frac{T(i,j+1)T(i,j)}{T(i,j+1)+T(i,j)}$$

Δt = length of time step.

Excellent examples of this approach to embedding are works of Aquado and Remson (1974), Alley et al. (1976) and Nisai et al. (1983). This type of embedding can be used to investigate optimal recharge and discharge policies. In addition, it can handle linear as well as non-linear equations if proper mathematical programming packages for handling non-linear constraints are available. Its disadvantages appear when it is used for large problems. Since in these problems the number of unknowns is high, the number of constraints also is high. This is because for every node, (i,j), an equation such as (7) must be written for each time step n, regardless of whether that node is a pumping node or not. For example, for a system with 1000 nodes and 30 time steps, 30,000 decision variables corresponding to hydraulic heads over space and time exist (Gorelick, 1983). Solution of this problem with readily available equipment and software is at the least impractical. Another severe problem associated with this technique is that even if a solution can be secured, its accuracy is suspect, as the number of mathematical operations required increases enormously and noticeable errors can be introduced.

2.4.2 Response-function Technique

The response-function embedding technique is an approach based on the assumption that a linear relationship exists between the drawdown and pumpage. This assumption is valid only for linear, partial-differential equations such as (4-b) or (I-11) in Appendix I. Any system which is stationary, i.e., the boundary conditions do not change with time, and which satisfies the laws of superposition is considered a linear system (Cheng, 1959). The response of the linear system to a given excitation can be evaluated by its response to a unit impulse. For these systems, convolution integral may be written so that (Maddock, 1972)

$$s(\tilde{x},t) = \int_{\tilde{x}} \int_{0}^{t} F(\tilde{x},\tau)\, G(\tilde{x},x,t-\tau)\, d\tilde{x}\, d\tau \qquad (8)$$

where

$s(\tilde{x},t)$ = response of the system (drawdown) at point $\tilde{x}$ and time t;

$F(\tilde{x},\tau)$ = time-rate change of the system input (pumpage); and

$G(\tilde{x},x,t-\tau)$ = the Green's function.

In discrete form, equation (8) for a system consisting of NW wells may be expressed as

$$s(k,n) = \sum_{j=1}^{NW} \sum_{n'=1}^{n} p(j,n')\, \beta(k,j,n-n'+1) \qquad (9)$$

where

s(k,n) = total drawdown at well k, at time period n;

β(k,j,n-n'+1) = unit-drawdown response function at point k at time-step n-n'+1 due to a unit pulse generated at point j; and

p(j,n') = pumpage at well j at time period n'.

Since $s = H_o - h$, $h = H_o - s$. Then hydraulic head at point k at the end of time-step n may be written as

$$h(k,n) = H_o(k) - \sum_{j=1}^{NW} \sum_{n'=1}^{n} \beta(k,j,n-n'+1) \quad p(j,n') \qquad (10)$$

With the use of Darcy's Law and equation (10), x and y velocity components at each point k at the end of time step n may be written as

$$V_x(k,n) = \frac{K}{\theta} \frac{\partial h}{\partial x} = \frac{K}{\theta} \frac{\partial H_o(k)}{\partial x} - \sum_{j=1}^{NW} \sum_{n'=1}^{n} \frac{K}{\theta} \frac{\partial \beta(k,j,n-n'+1)}{\partial x} p(j,n')$$

and (11)

$$V_y(k,n) = \frac{K}{\theta} \frac{\partial h}{\partial y} = \frac{K}{\theta} \frac{\partial H_o(k)}{\partial y} - \sum_{j=1}^{NW} \sum_{n'=1}^{n} \frac{K}{\theta} \frac{\partial \beta(k,j,n-n'+1)}{\partial y} p(j,n')$$

or

$$V_x(k,n) = V_{ox}(k) - \sum_{j=1}^{NW} \sum_{n'=1}^{n} \beta_{vx}(k,j,n-n'+1) \; p(j,n')$$

and (12)

$$V_y(k,n) = V_{oy}(k) - \sum_{j=1}^{NW} \sum_{n'=1}^{n} \beta_{vy}(k,j,n-n'+1)\, p(j,n')$$

where

$V_{ox}(k)$ and $V_{oy}(k)$ = steady-state velocities in x and y directions at point k given by the first terms on the right-hand sides of (11);

β_{vx} and β_{vy} = unit-velocity-response functions in x and y direction given by the pumpage coefficients in the second terms on the right-hand side of (11);

θ = porosity; and

K = isotropic hydraulic conductivity

Further information on the description of these equations and the procedure for their calculations can be obtained from Colarullo et al. (1984, 1985).

2.4.3 Advantages and Disadvantages of Unit-response Functions:

The unit-response functions have been used extensively in the management and simulation models [see Maddock (1972, 1973, 1974), Haimes and Dreizen (1977), Morel-Seytoux (1975), Heidari (1982a, b)]. Because these functions can be generated only for nodes where some change in the system such as drawdown or velocity is being managed, they are clearly superior over the difference-embedding technique. Their use does not encounter the numerical inaccuracies normally associated with the difference-embedding technique for large systems. Once they are calculated for a particular system, they can be used in a simulation or a management model repeatedly with different scenarios or constraints.

In practice the use of these functions exhibits several difficulties. Since the derivation of these functions is based on the assumptions of linear-systems theory, their accuracy is subject to deviation from this theory. There is a range of decision variables for which these assumptions are valid. For example, drawdowns calculated by these functions are valid if they do not exceed 25% of the total saturated thickness. Above this limit the drawdowns must be corrected using Jacob's correction (Jacob, 1944).

Another disadvantage of these functions is in their demand for large computer storage when applied to a large system. Whereas these functions require less computational capability than the direct embedding technique, for large systems, they require computational capabilities that can only be provided on main frame computers. For example, if the management policies of 100 wells in an aquifer are being investigated for 20 time steps, the drawdown-response function, β, requires a storage of (100 X 100 X 20) which many small computers can not possibly provide. If the objective function or constraints also include velocity consideration for, say, 10 observation points, a storage of (100 X 10 X 20) must be assigned to each velocity-response functions β_{vx} and β_{vy}. Even if such storage were available, one has to question the wisdom of using the computer resources in such a restrictive way. This storage requirement is in addition to the storage and computer-time requirements which will be needed for a mathematical-programming algorithm such as linear or quadratic programming. For the case posed above a total of 2000 columns (unknowns) and as many or more rows (constraints) exist. Solution of a mathematical-programming matrix of this magnitude on minicomputers with available mathematical-programming packages such as MINOS [Murtagh and Saunders (1977)] or LINDO [Schrage (1981)] if not impossible, is impractical.

Chapter 3

APPROACH IN THIS STUDY

The main objective of our proposed management model is to find a set of optimal pumpage rates for several interception wells so that the contaminant plume near the town of Burrton, Kansas, is contained and gradually cleaned up. To achieve this objective, an approach similar to that of Colarullo et al. (1984) was adopted. The main differences between the approach in this study and that of Colarullo et al. (1984) are in the objective function and in a decomposition technique which makes the solution of large management models on minicomputers possible. The model and the decomposition technique are described below.

3.1 Formulation of a Ground-water-management Model

The management model was designed to find the optimum pumpage rates at prespecified locations which: 1) reverse the velocities at certain observation points, 2) provide for the freshwater demand, and 3) limit the drawdown at pumping wells to prespecified levels. As will be seen, this prespecified level of drawdown was set as a linear function of saturated thickness. The choice of an objective function plays as important role in the design of this model. From previous experience [see Colarullo et al. (1984)], whereas an objective function based on total cost is quite logical and can be implemented for a limited number of unknowns, its application to systems with large numbers of unknowns clearly will require computing capabilities beyond the capacity of the available facilities. Also the cost functions required for this objective function are not readily available. Therefore, instead of minimizing the total cost, an objective function based on minimizing the total pumpage was selected. In mathematical form, this function and its associated constraints may be represented as follows:

$$\text{Min } F = \sum_{j=1}^{NW} \sum_{n=1}^{N} p(j,n) \qquad (13)$$

subject to

1) Velocity-reversal constraints:

$$v(k,n) \lessgtr v_o(k,n) \qquad \begin{array}{l} k = 1, NO \\ n = 1, . . ., N \end{array} \qquad (14\text{-a})$$

2) Freshwater constraints:

$$\sum_{j=1}^{FW} p(j,n) > D(n) \qquad n=1, . . ., N \qquad (14\text{-b})$$

3) Drawdown constraints:

$$s(j,n) < \bar{s}(j) \qquad \begin{array}{l} j = 1, . . ., NW \\ n = 1, . . ., N \end{array} \qquad (14\text{-c})$$

4) Pumpage-rate constraints:

$$o < p(j,n) < \bar{p}(j) \qquad \begin{array}{l} j = 1, . . ., NW \\ n = 1, . . ., N \end{array} \qquad (14\text{-d})$$

where F = objective function to be minimized;

$p(j,n)$ = pumpage rate of well j during time-period n;

$v(k,n)$ = resultant average velocity at observation-point k at end of time-period n created as a result of all pumping activities;

$v_o(k,n)$ = premanagement average velocity at observation point k at end of time-period n;

$D(n)$ = freshwater demand during period n;

$s(j,n)$ = drawdown at pumping well j at end of time-period n;

$\bar{s}(j)$ = upper limit of drawdown at well j;

$\bar{p}(j)$ = upper limit of pumpage rate for well j;

NW = total number of potential active wells, from which the first FW wells are the freshwater wells;

NO = number of velocity-observation wells; and

N = total number of time periods.

The state of the system was assumed to be represented by linear equation (1) and its equivalent, equations (4-a) and (4-b). The solution of the transient component of equation (1) was assumed to be represented by equation (9). The velocities in x and y directions were assumed to be represented by equation (12).

3.2 Decomposition Technique

Concerns over the dimensionality requirements of the unit-response functions have led us to the development of the following decomposition technique. This technique effectively reduces the computer-storage requirements of the unit-response functions and mathematical-programming packages to a point that solution of models with several thousand unknowns becomes possible on minicomputers. The major part of the following paragraphs on the development of this technique is from Heidari (1985 a, b).

Consider a large aquifer with several hundred pumping wells. One may write the following management model for this aquifer:

$$\text{Optimize } F = f(p,s) \qquad (15)$$

$$\text{subject to: } \quad \underline{p} < p < \overline{p} \qquad (16\text{-a})$$

$$\underline{s} < s < \overline{s} \qquad (16\text{-b})$$

$$\underline{v_x} < v_x < \overline{v_x} \qquad (16\text{-c})$$

$$\underline{v_y} < v_y < \overline{v_y} \qquad (16\text{-d})$$

where

F = objective function to be optimized;
p = pumpage;
$\overline{p}$ and $\underline{p}$ = upper and lower limits of pumpage;
s = drawdown;
$\overline{s}$ and $\underline{s}$ = upper and lower limits of drawdown;
v_x and v_y = velocities at observation points in x and y directions; and
$\overline{v}_x$, $\overline{v}_y$, $\underline{v}_x$, and $\underline{v}_y$ = upper and lower limits of velocities in x and y directions at observation points.

If NW active wells and NO velocity-observation points are in the system, the drawdown and velocities at points j and k at time-step n may be written as

$$s(i,n) = s(i,0) + \sum_{j=1}^{NW} \delta(i,j,n) \qquad (17)$$

$$v_x(k,n) = v_x(k,0) + \sum_{j=1}^{NW} \delta_{vx}(k,j,n) \qquad (18)$$

$$v_y(k,n) = v_y(k,0) + \sum_{j=1}^{NW} \delta_{vy}(k,j,n) \qquad (19)$$

where:

$s(i,n)$ = drawdown at well i at end of time-step n;

$s(i,0)$ = drawdown at well i before initiation of pumpage policy;

$\delta(i,j,n)$ = incremental drawdown at well i due to pumpage of well j from start of pumpage policy to end of time-step n;

$v_x(k,n)$ and $v_y(k,n)$ = x and y components of velocities at observation-point k at end of time-step n;

$v_x(k,0)$ and $v_y(k,0)$ = x and y component of velocities at observation-point k before initiation of pumping policy; and

$\delta_{vx}(k,j,n)$ and $\delta_{vy}(k,j,n)$= incremental velocities in x and y directions at observation-point k due to pumpage of well j from initiation of pumpage policy to end of time-step n.

Note that in equations (17) through (19), pumpage, p, is included implicitly through δ's.

Now if the aquifer is divided into C cells, each with M_c pumping wells such that $NW = \sum_{c=1}^{C} M_c$ and K_c velocity-observation points, equations (17) through (19) for nodes in cell c may be written as

$$s(j,c,n) = s(j,c,0) + \sum_{i=1}^{M_c} \delta(j,c,i,c,n) + \sum_{\substack{c'=1 \\ c'\neq c}}^{C} \sum_{i=1}^{M_{c'}} \delta(j,c,i,c',n) \qquad (20)$$

$$v_x(k,c,n) = v_x(k,c,0) + \sum_{i=1}^{M_c} \delta_{vx}(k,c,i,c,n) + \sum_{\substack{c'=1 \\ c'\neq c}}^{C} \sum_{i=1}^{M_{c'}} \delta_{vx}(k,c,j,c',n) \qquad (21)$$

$$v_y(k,c,n) = v_y(k,c,0) + \sum_{i=1}^{M_c} \delta_{vy}(k,c,i,c,n) + \sum_{\substack{c'=1 \\ c'\neq c}}^{C} \sum_{i=1}^{M_{c'}} \delta_{vy}(k,c,i,c',n) \qquad (22)$$

where subscript c or c' designates the cell where a pumping well or an observation point is located.

In (20) through (22), if the last terms on the right-hand sides are known, the computational demands will be restricted to that of $\delta(j,c,i,c,n)$, $\delta_{vx}(k,c,i,c,n)$ and $\delta_{vy}(k,c,i,c,n)$ only. In practice, the last two terms on the right hand sides of (20) through (22) are not known. One may write these equations for cell c=1, make a "reasonable" guess for the third terms on the right-hand sides of these equations, and calculate the second terms for cell c=1. Then the same equations may be written in the context of the management model (13) through (14-d) for cell c=2. Now, the third term on the right-hand sides of these equations may be calculated by using the results obtained for cell c=1 and "reasonable" guesses for the values associated for cells c=3 through C. Continuing in this manner, these equations may be written for each cell c, and the third terms on the right-hand sides may be calculated by using the calculated results of cells c'=1,2, . . . c-1, and a "reasonable" guess for this term for cells c+1, c+2,...C. Once the second terms for these equations are calculated for C cells, the "reasonable" guesses can now be replaced by the new values. This completes one iteration. The next iteration uses the exact same procedure, except the values of the third terms are now those obtained in the first iteration. Iterations may continue until convergence is reached, based on some iteration criteria such as

$$\| p(k,c,n,m) - p(k,c,n,m+1) \| < \varepsilon_1 \text{ for all } c \qquad (23)$$

or

$$\| s(k,c,n,m) - s(k,c,n,m+1) \| < \varepsilon_2 \text{ for all } c \qquad (24)$$

where

$p(k,c,n,m)$ = pumpage for well k in cell c during time-period n calculated in iteration m;

$s(k,c,n,m)$ = drawdown at well k in cell c at end of time-period n calculated in iteration m; and

ε_1 and ε_2 = criteria set depending on degree of accuracy required.

The advantage of this technique is that rather than solving a large mathematical-programming matrix, one solves a series of small matrices whose sizes can be adjusted to the available computing facilities. Therefore, very large mathematical-programming problems can be decomposed and solved on minicomputers.

3.3 Radius of Influence

To make this iterative technique even more efficient, one may estimate an upper limit for the radius of influence, R_k, for each pumping well, k. Then the above computational procedure may be confined to the nodes which fall within this radius. Thus in (20) through (22) instead of adding all terms for i=1, M_c, or $M_{c'}$, only terms which are associated with wells within R_k may be considered. This reduces the computational efforts, as only a subset of M_c or $M_{c'}$ affects the drawdown s or velocities V_x and V_y.

The value of R_k for each pumping-well k may be estimated using an empirical formula such as the one given by Bear (1979). In this study the following emperical formula was used:

$$R_k(t) = [1.5 \ (t\overline{T}/\overline{S})^{1/2}] \ \alpha \tag{25}$$

where $R_k(t)$ = radius of influence at time t for well k (L);

$\overline{T}$ = average transmissivity in vicinity of well k, $w(\frac{L^2}{T})$;

t = time;

$\overline{S}$ = average storage coefficient in vicinity of well k, (L^0) ; and

α = multiplier > 1 to guarantee that all wells affected by k fall within R_k.

Heidari (1985b) gives a flow chart for the iterative procedure outlined above.

3.4 Velocity Calculations

In order to carry out the computations of a management model such as (13) through (14-d), the velocities at observation points must be calculated. This was done using Darcy's law:

$$v_x(k,n) = -\frac{K}{\theta}\frac{\partial h(k,n)}{\partial x} = -\frac{K}{\theta}\frac{\partial H_o(k)}{\partial x} - \frac{K}{\theta}\frac{\partial s(k,n)}{\partial x}$$

$$= v_{ox}(k) - \frac{K}{\theta}\frac{\partial s(k,n)}{\partial x} \qquad (25\text{-a})$$

$$v_y(k,n) = -\frac{K}{\theta}\frac{\partial h(k,n)}{\partial y} = -\frac{K}{\theta}\frac{\partial H_o(k)}{\partial y} - \frac{K}{\theta}\frac{\partial s(k,n)}{\partial y}$$

$$= v_{oy}(k) - \frac{K}{\theta}\frac{\partial s(k,n)}{\partial y} \qquad (25\text{-b})$$

where K = permeability;

$h(k,n)$ = hydraulic head at well k at time-step n;

θ = porosity;

$H_o(k)$ = steady-state head at well k;

$s(k,n)$ = drawdown at well k at end of time period n; and

$v_{ox}(k)$ and $v_{oy}(k)$ = steady-state velocities in x and y directions.

Using a finite-difference formulation these equations for well k designated by indices i in y direction and j in x direction may be written as

$$v_x(i,j,n) = -\frac{K}{\theta}\left[\frac{H_o(i,j-1) - H_o(i,j+1)}{2\Delta x} - \frac{s(i,j-1,n) - s(i,j+1,n)}{2\Delta x}\right]$$

$$v_y(i,j,n) = -\frac{K}{\theta}\left[\frac{H_o(i-1,j) - H_o(i+1,j)}{2\Delta y} - \frac{s(i-1,j,n) - s(i+1,j,n)}{2\Delta y}\right] \tag{26}$$

where Δx and Δy increments in x and y directions. This finite difference approximation of velocities assumes that K and θ are constant between node (i, j) and its adjacent nodes, and H_o and s vary linearly across the adjacent nodes. All these assumptions are subject to questions and may introduce errors in the calculation of velocities. In particular the assumption of linearity can introduce noticeable errors. A more accurate method of obtaining velocities is to conduct their calculations directly as a continuous function of space and time (see Zijl, 1984).

Chapter 4

DESIGN AND APPLICATION OF A MANAGEMENT MODEL

As stated before, the main objective of this study is to design a management model for the oil-brine-polluted Equus Beds aquifer in south-central Kansas such that the rate of plume advancement can be controlled. For an advancing plume, installation of interception wells is a viable option. In making decisions to install interception wells, some major questions must be answered if a cost-benefit analysis is the basis for the final decision. These questions are:

1) Where should the interception wells be installed?
2) What is the minimum rate of pumpage for each interception well so that the main purpose for their installation, i.e. containment of the plume, is achieved?
3) How long should the interception wells be operated?
4) What should be done with the intercepted fluid?
5) Is the process economically feasible?

In this chapter first a flow model is constructed for the area. Then a management model is designed, constructed, and applied to the management area. The output from this model provides direct answers to some of the questions raised above. Other questions can be answered by inferring from the results of the model.

4.1 Flow-model Development and Validation

A specific-aquifer digital model requires two main components: an appropriate digital simulator capable of representing the actual flow conditions (boundaries and dimension of flow) and a set of aquifer parameters such as the hydraulic conductivity, the recharge/discharge, and the storage coefficient.

To build such a flow model for a given aquifer, one needs

1) to select a suitable numerical simulator,
2) to gather all available data relevant to the aquifer, particularly data relating to the properties of the aquifer;
3) to adjust the aquifer parameters through calibration stages, steady-state as well as transient, until calculated hydraulic heads match the observed ones for given periods of time; and
4) to validate the flow model, that is to ensure that the flow model defined by the chosen digital simulator and the adjusted set of aquifer parameters will be able to closely simulate observed hydraulic-head values beyond the calibration time period.

4.1.1 Numerical Simulator

Because the management model is built on the assumption of horizontal flow only and because consistency throughout this study is highly desirable, the numerical-simulator selection had to be restricted to two-dimensional models only.

A two-dimensional, finite-difference, ground-water-flow model developed by the U.S. Geological Survey (Trescott et al., 1976) was chosen to simulate the Equus Beds aquifer. This model is designed to simulate ground-water flow in a confined or water-table aquifer, or in an aquifer where both conditions may exist. Heterogeneity, anisotropy, and irregular boundaries of the aquifer may be handled by the model. Well discharge, constant recharge, leakage from confining beds, and evapotranspiration may also be represented.

For confined or unconfined aquifers, the governing equation for a two-dimensional flow, as given by Pinder and Bredehoeft (1968) is

$$\frac{\partial}{\partial x}\left(K_{xx} b \frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_{yy} b \frac{\partial h}{\partial y}\right) = S \frac{\partial h}{\partial t} + w(x,y,t) \qquad (27)$$

where K_{xx} and K_{yy} = the principal components of hydraulic-conductivity tensor (L/T), which are assumed to coincide with Cartesian-coordinates axis;

b = saturated thickness;

h = hydraulic head (L);

S = storage coefficient or specific yield (dimensionless); and

$w(x,y,t)$ = volumetric flux of recharge or withdrawal per unit surface area of aquifer (LT^{-1}).

Equation (27) may be discretized using a finite-difference grid. When this equation is written for every grid node, a matrix is generated which may be solved by one of three matrix-solving schemes: the strongly implicit procedure (SIP), the alternating-direction implicit procedure (ADI), or the line-successive overrelaxation procedure (LSOR). All three methods should yield comparable solutions. However, one may be more appropriate than the others depending on the problem under consideration. ADI is, in general, the most competetive method in terms of convergence and convergence rate as well. It may have trouble converging in steady-state simulations involving extremely variable coefficients.

4.1.2. Data Sources and Set-up

It was originally planned to base the management study in the Equus beds on the flow model developed by Spinazola et al. (1985). The results of that study revealed differences in basic assumptions such as the use of a three-dimensional simulator versus the necessity to use a two-dimensional simulator in this study. For the sake of consistency between the two projects, considerable efforts were made to alter Spinazola's model minimally while satisfying all the additional assumptions and restrictions imposed by the management model. In this section, the data obtained from the Spinazola et al. study, its sources, and the alterations will be described.

A 63 by 44 one-mile-spacing finite-difference grid was selected to represent the area extending over the Equus beds (Fig. 4). The grid cells or nodes are defined as active if the hydraulic conductivity is positive and inactive otherwise. An active node may be set to represent a constant-head grid cell as a part of a set of boundary conditions. Inactive nodes adjacent to active nodes represent no-flow boundaries of the aquifer.

The aquifer parameters were then assigned to nodes following the grid configuration described above and shown in Fig. 4. The hydraulic-conductivity distribution was based on the transmissivity map generated by Richards and Dunaway (1972). Other sources of hydraulic conductivity data included

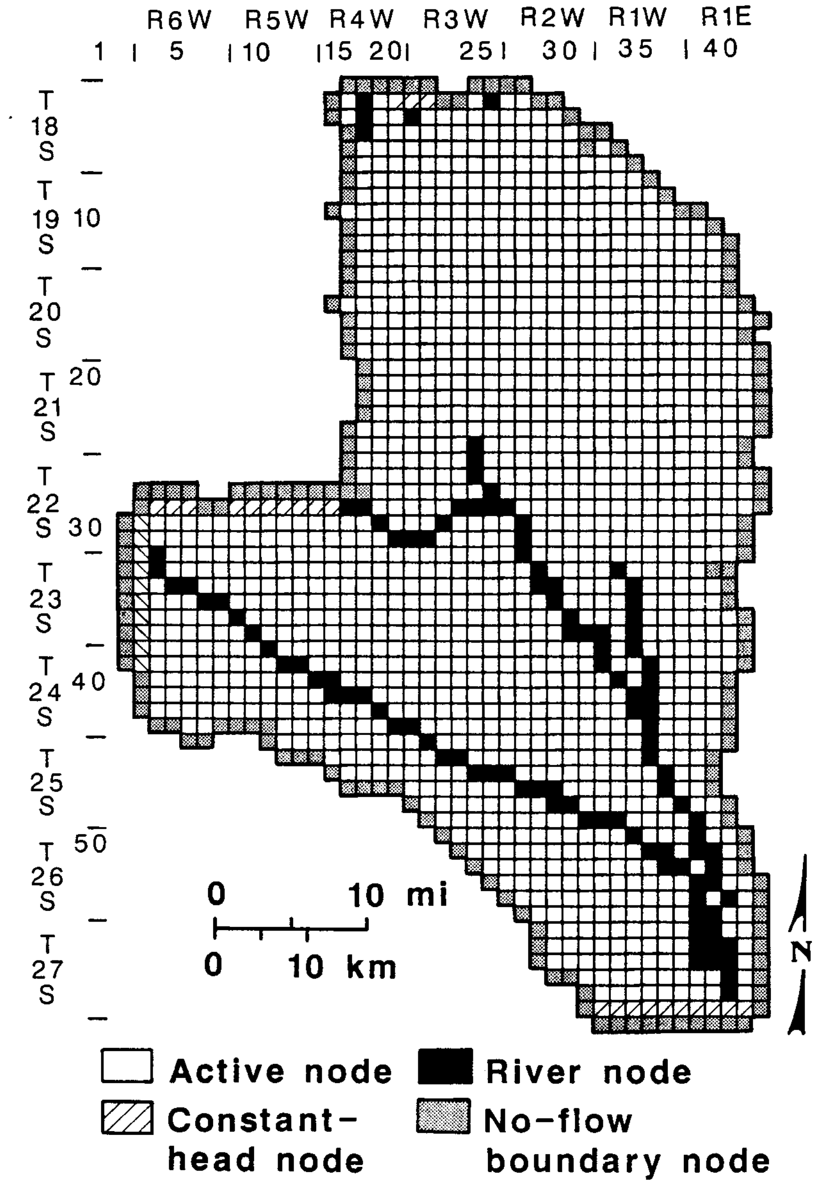

Figure 4. Finite-difference grid of Equus Beds aquifer.

aquifer-test analyses (Reed and Burnett, 1985) and laboratory analysis of samples (Williams and Lohman, 1949, p. 101). The hydraulic conductivity ranges from 15 to 800 ft/day. Fig. 5 shows a distribution of the adjusted hydraulic conductivity. Actual values for hydraulic conductivity are listed in column 4 of Table 1 in Appendix II.

Because the unit-response function generator associated with the management model is not designed to account for evapotranspiration, the evapotranspiration was combined with the areal recharge to yield a net or effective recharge for consistency between all stages of this study. The effect of evapotranspiration would therefore be accounted for through recharge. Note that the digital simulator allows the recharge to vary spatially but not with time. The net recharge is the difference between the steady-state areal recharge and evapotranspiration. Spinazola et al. (1985) calculated the steady-state areal recharge as the product of a recharge factor which is a function of soil type and clay thickness and the normal average precipitation prevailing up to 1940. The evapotranspiration was considered only for those nodes where the steady-state water-table level was not more than 10 ft below the land elevation.

The Arkansas and Little Arkansas rivers were represented as leakage nodes between a confining bed and the aquifer. Leakage is controlled by the river stage and the vertical hydraulic conductance of the confining bed and its thickness. The vertical conductance is simply the product of the vertical-hydraulic conductivity and the area occupied by the river within the grid cell, divided by the confining-bed thickness. Nodal values for the vertical conductance C and the river stage are listed in columns 10 and 11 of Table 1 in Appendix II. Fig. 4 shows the locations of the two rivers. The thickness of the confining bed was set at one foot for all river nodes.

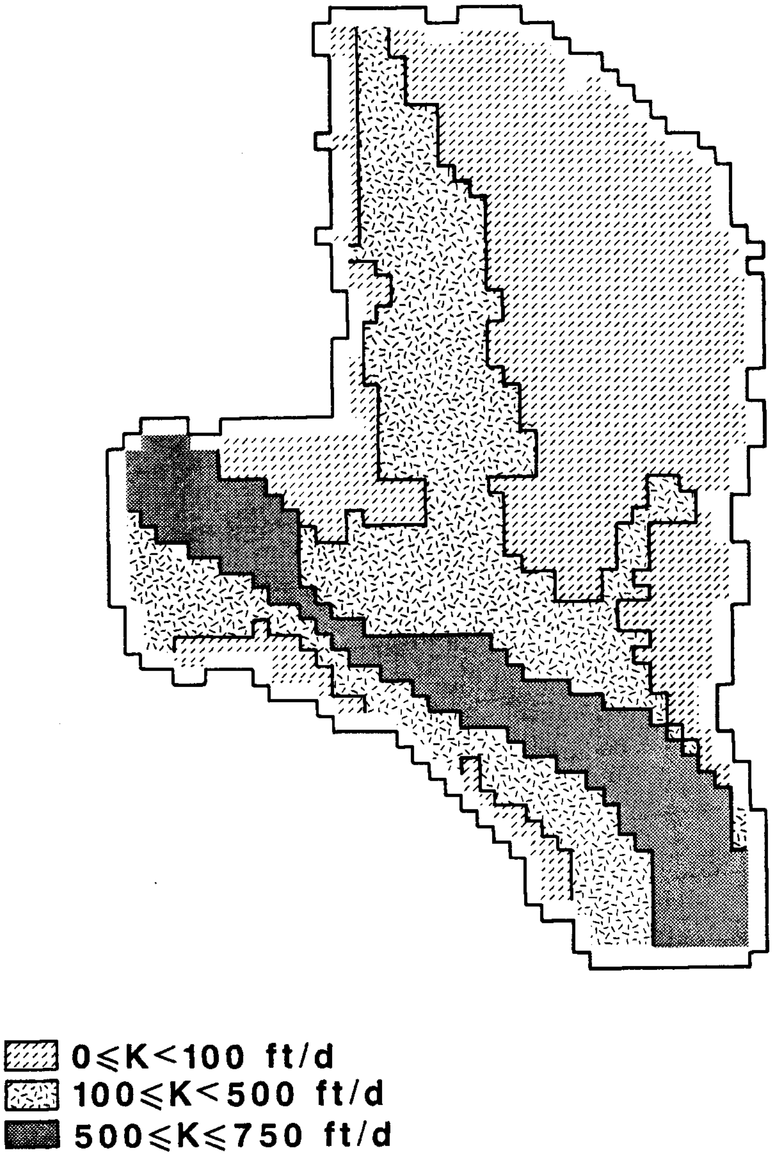

Figure 5. Hydraulic-conductivity distribution of Equus Beds aquifer. (After Spinazola et al., 1985).

The western edge of the Equus Beds aquifer is underlain by a brine-saturated stratum, the Wellington Formation. The two formations are however separated by impermeable layers of shale averaging 250 ft in thickness. Their interactions were shown to be negligible by Spinazola et al. (1985). Using the U.S. Geological Survey's modular three-dimensional flow model (McDonald and Harbaugh, 1984), Spinazola et al. (1985) incorporated the effects of the Wellington Formation in their analysis as a second layer and calculated the fluxes between the two formations. These fluxes are negligible compared to other sources of discharge/recharge, and they mostly occur from the Wellington to the Equus beds. These fluxes were accounted for in this study as discharge wells (see last column on Table 1 in Appendix II).

4.1.3. Steady-state Calibration of 2-D Model

A steady-state calibration was performed to adjust for recharge and hydraulic conductivity wherever necessary. The aquifer parameters described in the previous section along with the steady-state water table calculated by Spinazola et al. (1985) were taken as initial guesses for the two-dimensional steady-state simulation. Actual pumping wells existing before 1940 (see Table 2 in Appendix II) were combined with the Wellington fluxes and were considered in the model as discharge nodes.

The results of the steady-state calibration were in good agreement with those obtained by Spinazola et al. (1985) despite the additional constraints reported above. The difference between the calculated steady-state head and that of Spinazola et al. (1985) varied between 0 and 0.3 ft. For a few nodes, the difference was greater than 0.3 ft but never exceeded 2 ft. Therefore we concluded that the initially chosen parameters did not need further adjustment.

4.1.4. Transient Calibration of 2-D Model

Transient calibration is a means of adjusting for the storage coefficient. In addition to the data required for a steady-state simulation and the aquifer parameters derived from the steady-state calibration, transient hydraulic-head data and discharge rates are needed. The two-dimensional model of Trescott et al. (1976) does not allow for transient recharge as does the three-dimensional model of McDonald and Harbaugh (1984). Therefore, discharge by wells remains as the only time-dependent factor in the model.

Annual withdrawal rates from the Equus Beds aquifer from existing wells were originally obtained from the Division of Water Resources, Kansas State Board of Agriculture. The total annual discharge was then plotted versus time as shown on Fig. 6 and divided into segments of approximately constant slopes. Each segment defines a period of time over which the discharge rate is averaged for each well; discharges within a grid cell were added together, and this discharge value was assigned to the associated node. These periods will be referred to as the stress periods. Five stress periods were defined from 1940 to 1980, the first one from 1940 to 1952, the second from 1953 to 1958, the third from 1959 to 1964, the fourth from 1965 to 1971, and the fifth from 1971 to the end of 1979. Table 3 in Appendix II lists the average discharge (in cfs) for each stress period by grid location. The maximum observed value for discharge is of the order of 6 cfs.

Figs. 7 to 11 show the locations of the pumping wells for each stress period. Their succession reveals that the Wichita well field evolved during the 1940's and substantially increased in size between 1940 and 1980.

A transient simulation was performed with one-year pumping periods using the discharge rates defined above. This time step was also adopted for the

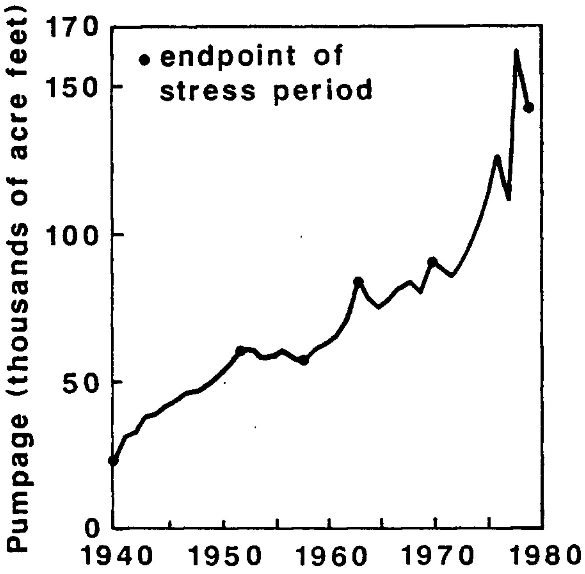

Figure 6. Total annual ground-water withdrawal from Equus Beds aquifer, 1940-1979.

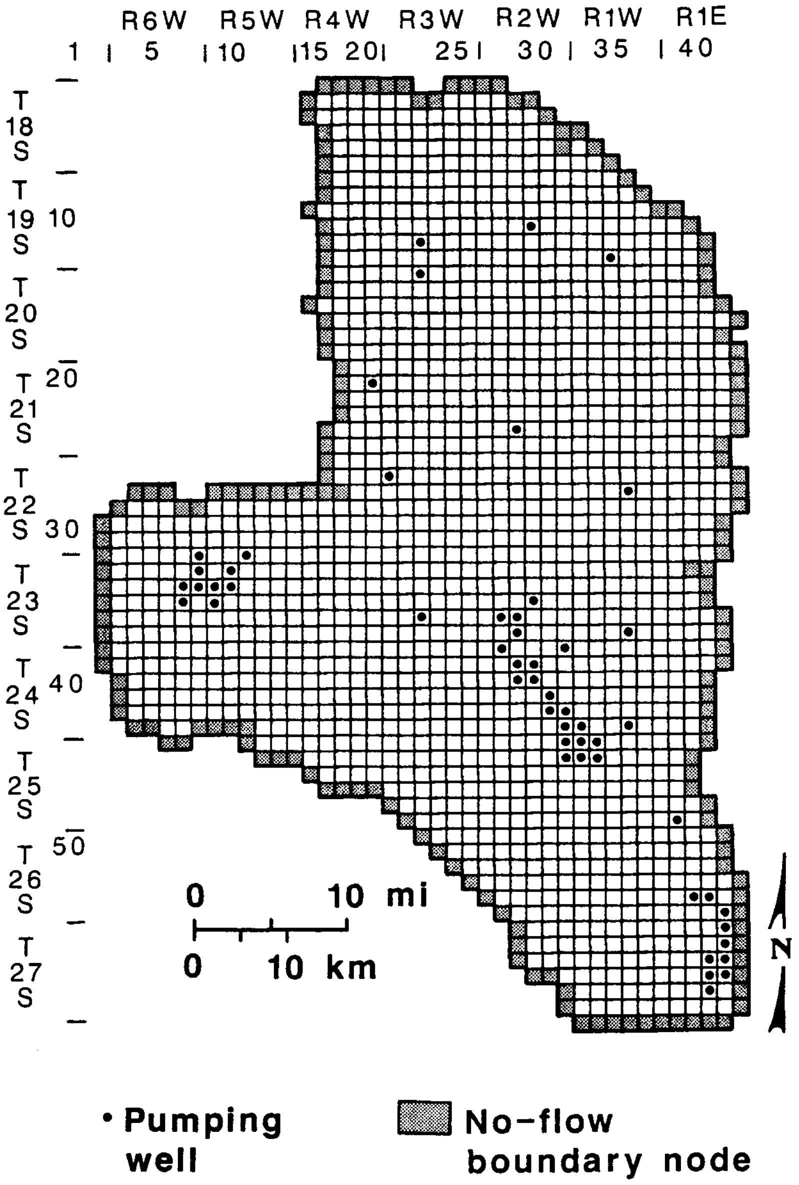

Figure 7. Location of pumping nodes in period from 1949 to 1952 in Equus Beds aquifer.

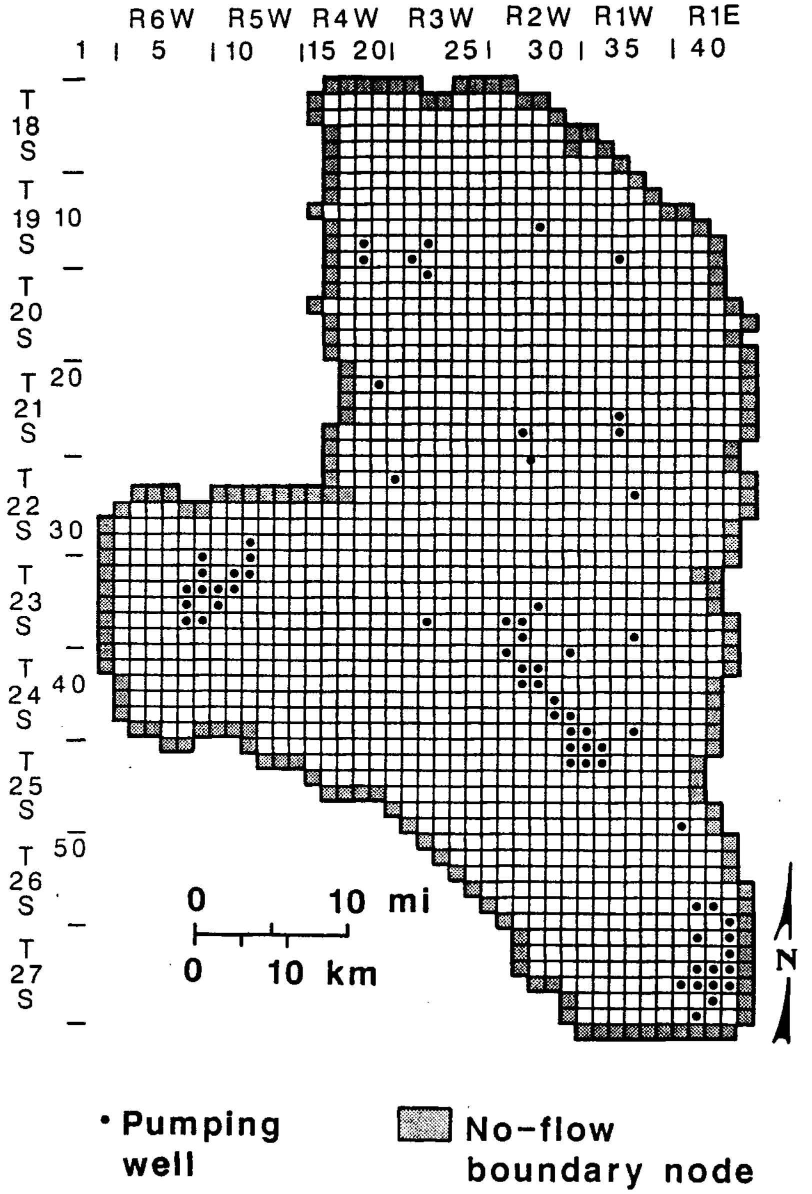

Figure 8. Location of pumping nodes in period from 1953 to 1958 in Equus Beds aquifer.

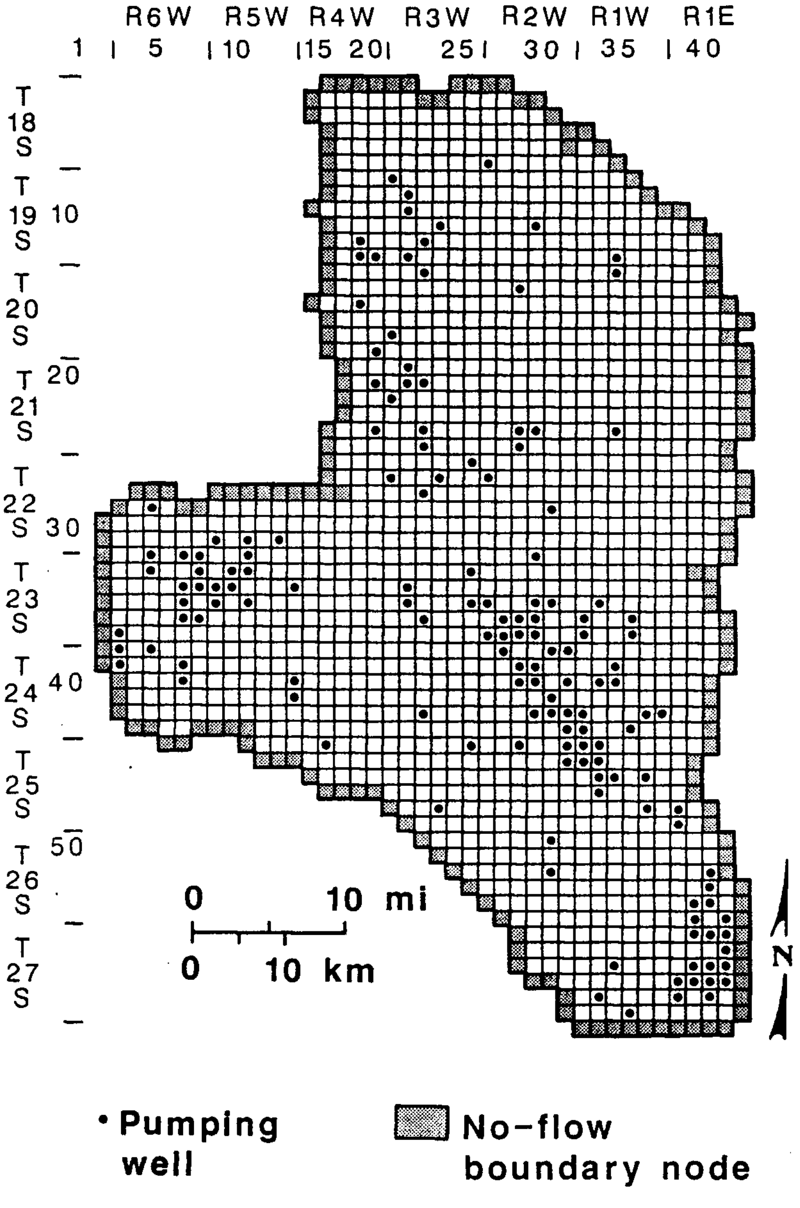

Figure 9. Location of pumping nodes in period from 1959 to 1963 in Equus Beds aquifer.

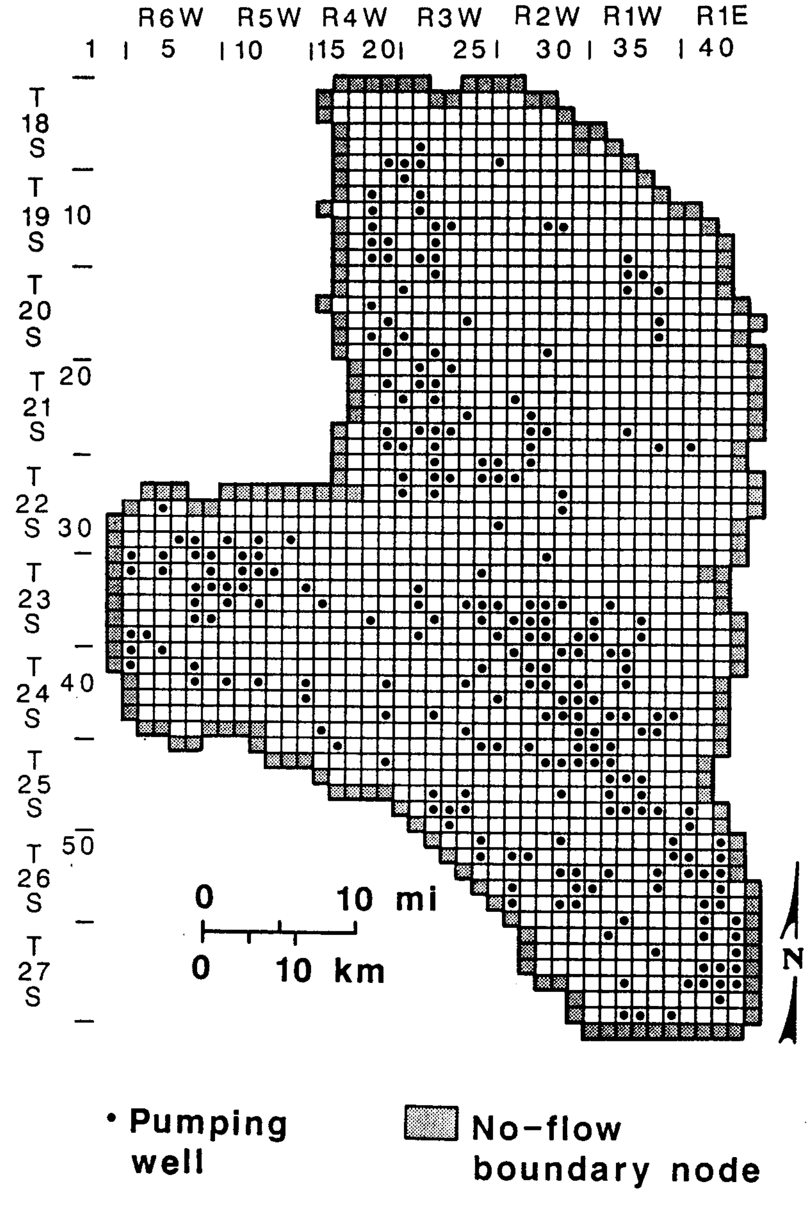

Figure 10. Location of pumping nodes in period from 1964 to 1971 in Equus Beds aquifer.

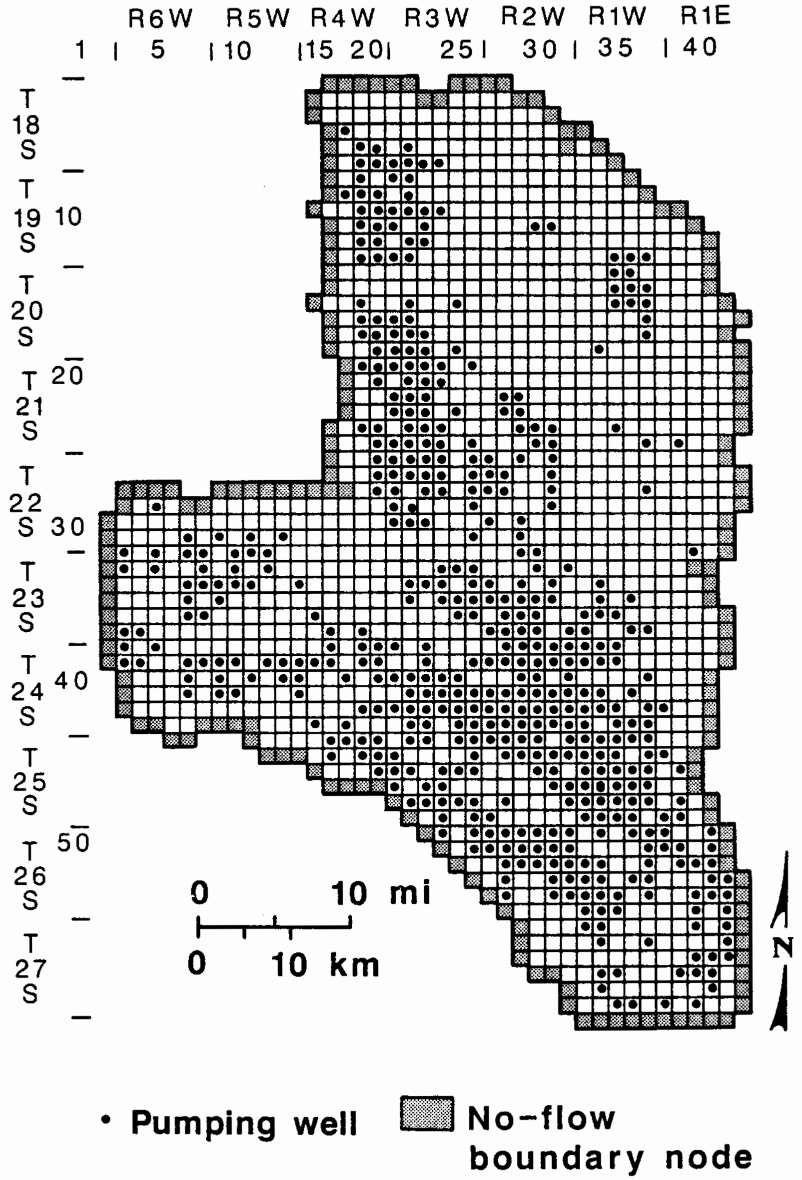

Figure 11. Location of pumping nodes in period from 1972 to 1979.

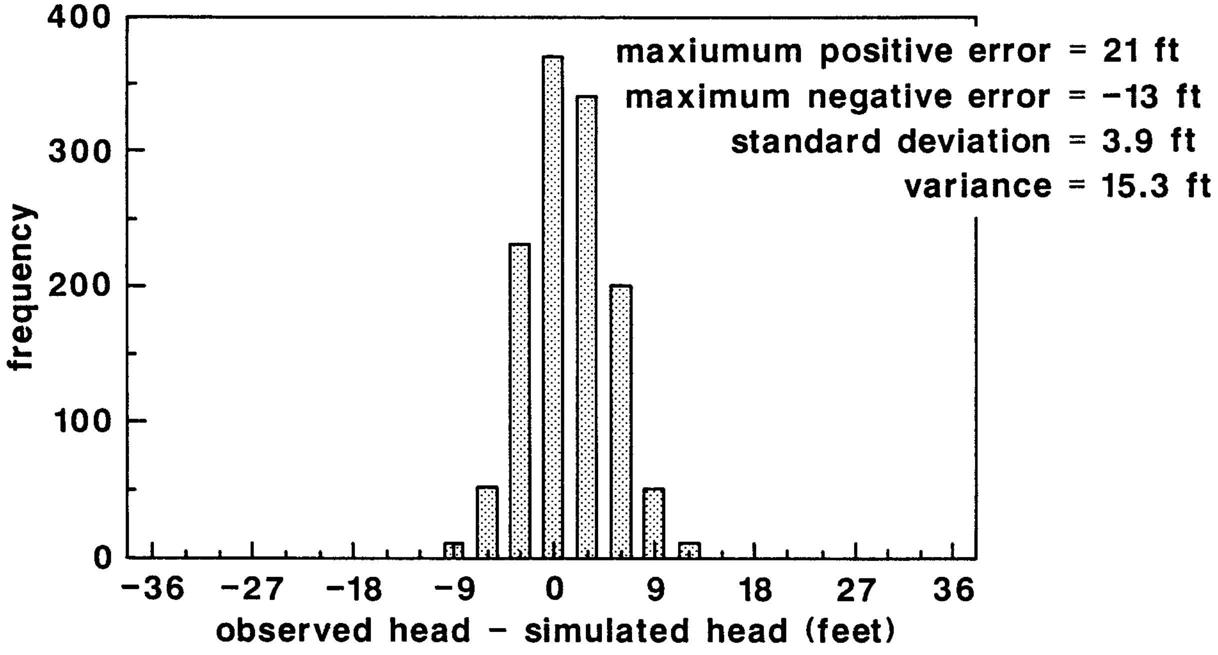

Figure 12. Histogram of error distribution for 1971 water table (observed head vs. simulated head).

management model. The storage coefficient was set at 0.15 and assigned uniformly to all active nodes. The results were then analyzed statistically by comparing the 1971 simulated water table with the observed 1971 water table. The histogram in Fig. 12 shows that the assumed parameters yield a satisfying head distribution since the standard deviation between the observed and calculated head is of the order of 4.4 ft. Furthermore the histogram displays a normal error distribution. Fig. 13 shows the comparison of the calculated hydraulic head contours with the observed head for 1971. The contour lines match closely, showing that the choice of the parameters, including 0.15 for the storage coefficient, is satisfactory.

4.1.5 Validation of Flow Model

The flow model developed at this point must be further validated. Hydraulic heads were calculated for the end of 1979 using the previously defined model. They were then compared with the water-table distribution observed in early 1980. The results are shown on Figs. 14 and 15. The histogram (Fig. 14) displays a normal distribution of the error (obs. head - calc. head) with a standard deviation of 3.9 ft. Therefore we concluded that the parameters and boundary conditions assumed for the flow model adequately represent the general condition of the aquifer. These parameters and boundary conditions are presented for each node in Table 1 of Appendix II.

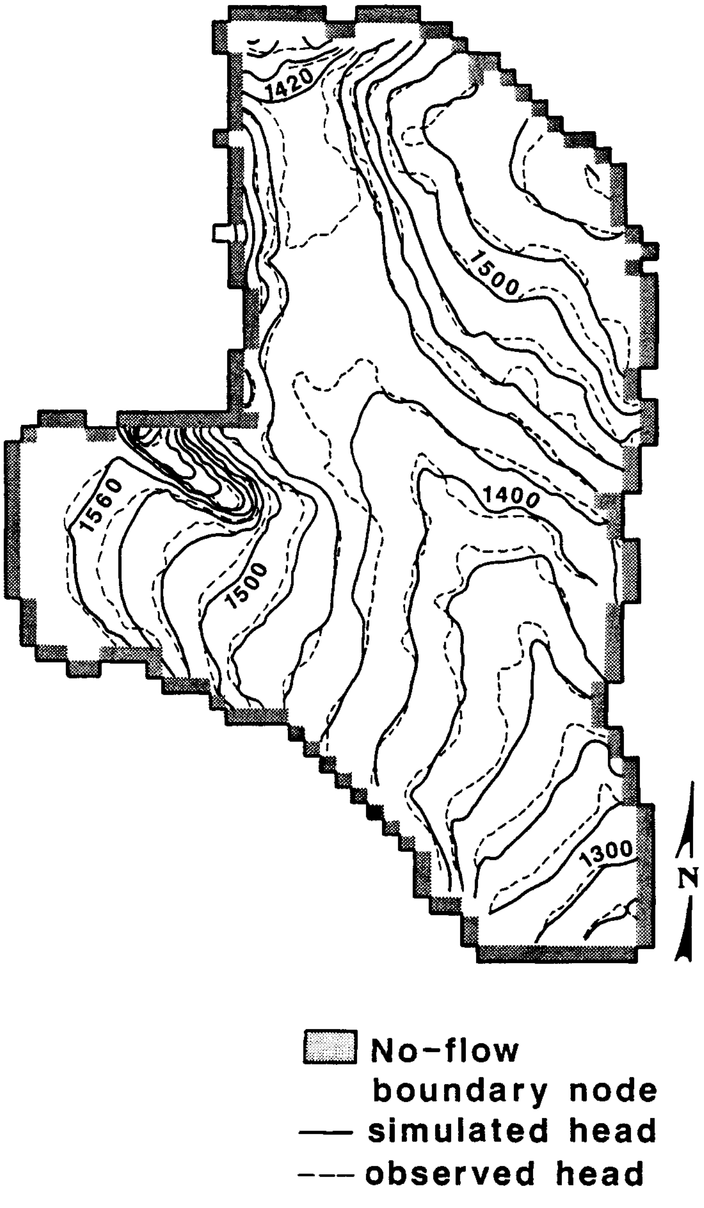

Figure 13. Simulated vs. observed head for 1971 in Equus Beds aquifer.

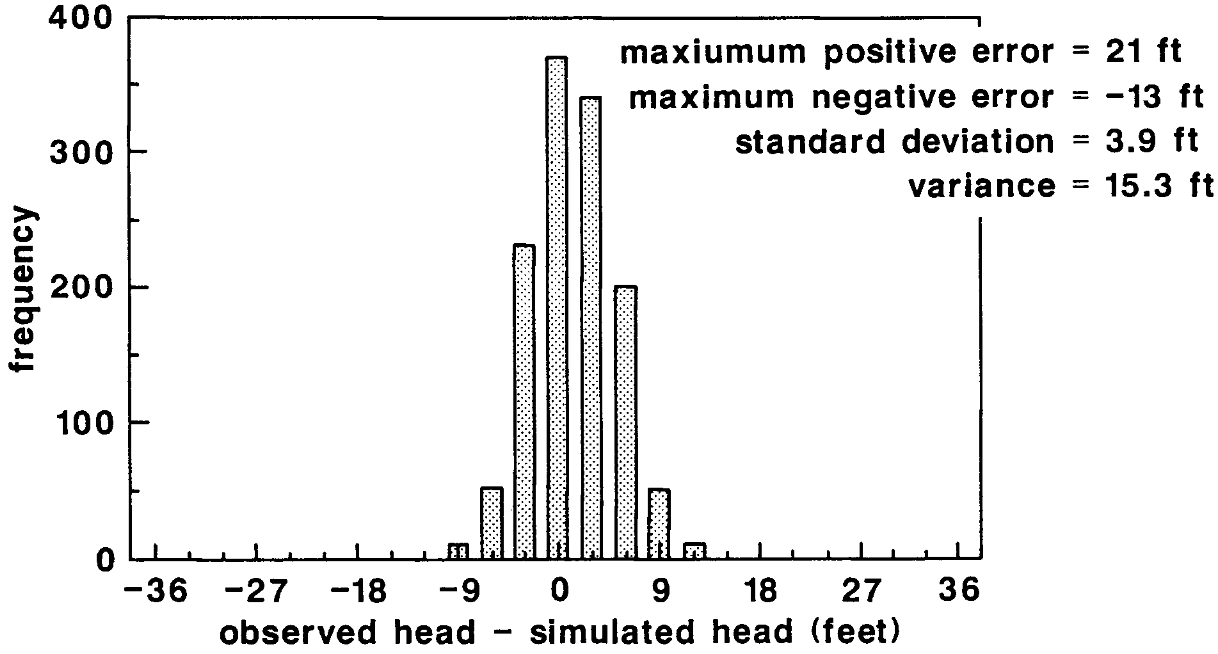

Figure 14. Histogram of error distribution for 1980 water table (observed head vs. simulated head).

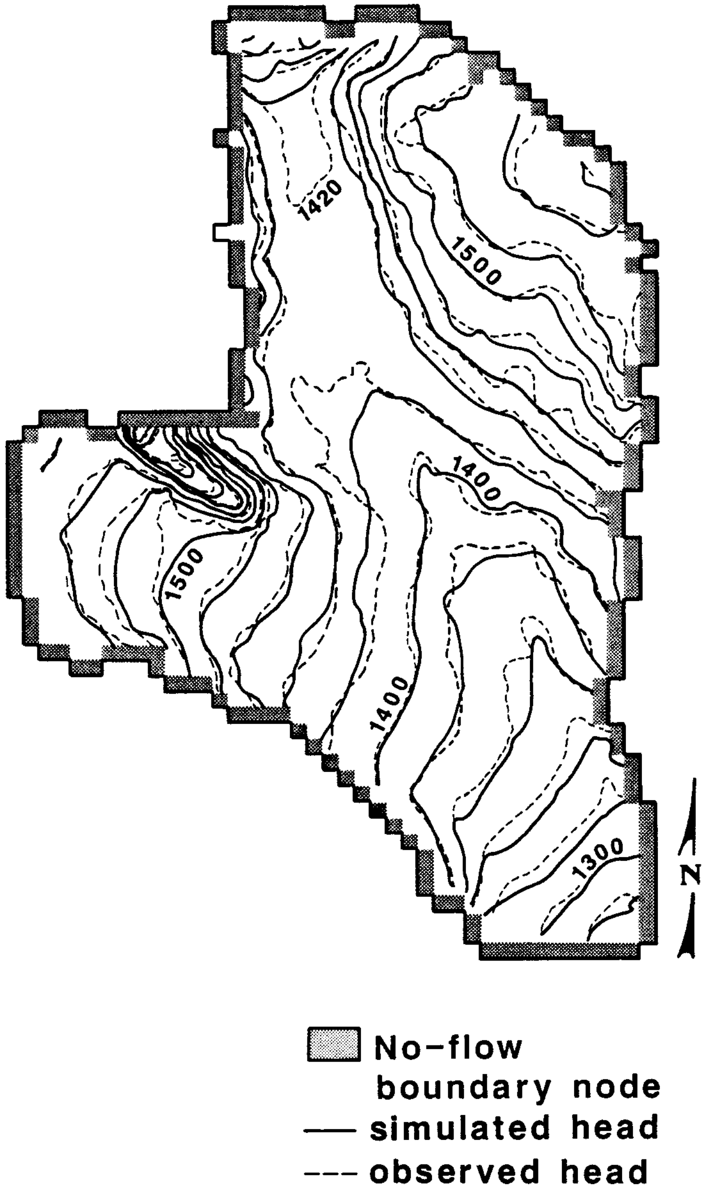

Figure 15. Simulated vs. observed head for 1980 in Equus Beds aquifer.

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point k:

$$\sum_{j=1}^{M_2} \sum_{n'=n_1+1}^{n} \beta_{vx}(k,j,n-n'+1)\ p_2(j,n') \lessgtr v_x(k,n) \qquad (29\text{-a})$$

$$\sum_{j=1}^{M_2} \sum_{n'=n_1+1}^{n} \beta_{vy}(k,j,n-n'+1)\ p_2(j,n') \lessgtr v_y(k,n) \qquad (29\text{-b})$$

where k = 1, . . . , K is the number of the observation points, and v_x and v_y are the summations of the first two terms on the right-hand side of (28-a) and (28-b). The signs of the equations in (29-a) and (29-b) depend on the signs of v_x and v_y (see Colarullo et al., 1985). In these equations v_x and v_y represent the velocities at a particular point k, at time $n > n_1$ if pumpage policy p_1 were in effect from time step 1 to n_1. The left-hand side of these equations represents the induced velocities due to pumpage policy p_2 initiated during time period from $n_1 + 1$ to n, which will reverse or neutralize v_x and v_y. Then depending on what the signs of v_x and v_y are at time-period n, a proper sign for these equations must be chosen.

The objective function (13) together with constraints (14-a) through (14-d) represents a linear-programming model which can be solved with readily available packages such as MINOS (Murtagh and Saunders, 1977) or LINDO (Schrage, 1981).

4.2.2 Application of Management Model

The management model was applied to the area of the aquifer shown in Fig. 16. The reasoning for the choice of this area was based on the location of the 500-ppm contour of the plume shown in Fig. 16. Within the management area

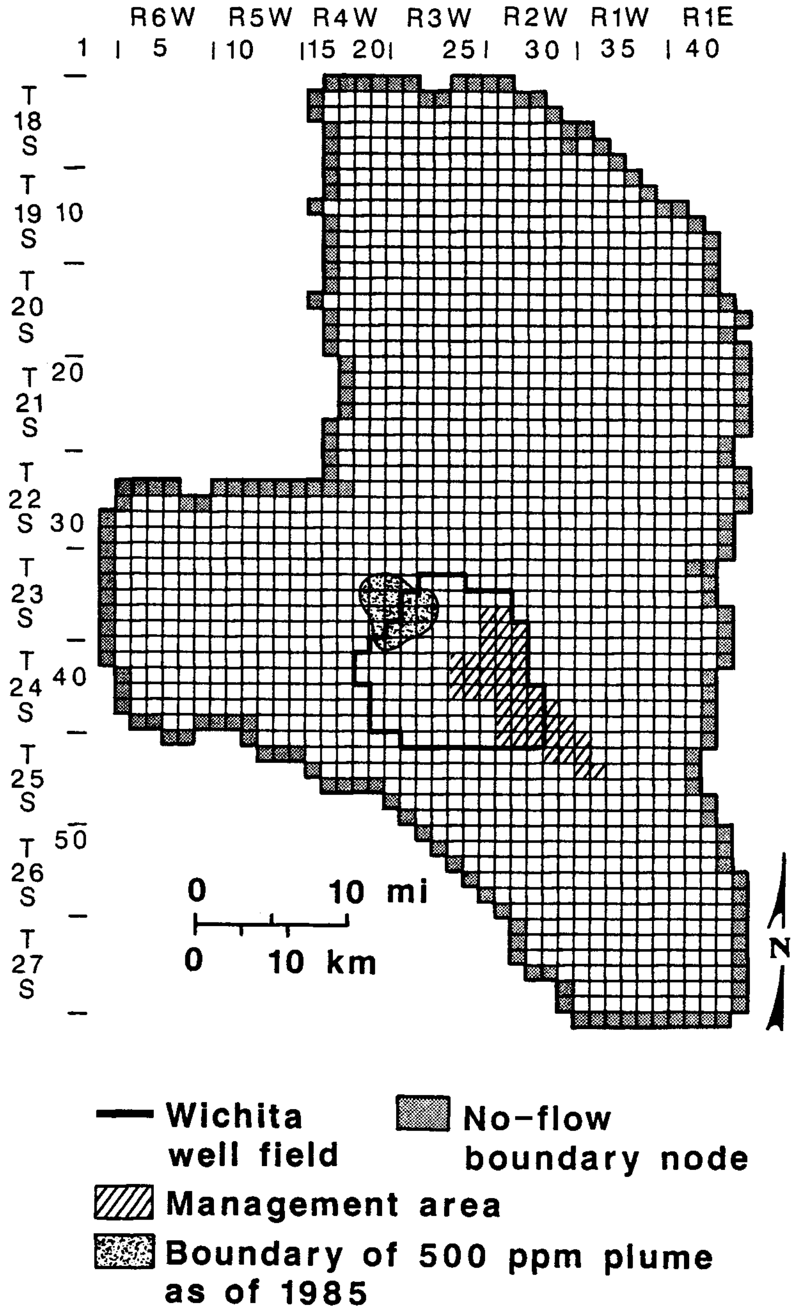


Figure 16. Location of management area.

as of 1985, a total of 35.7 cfs is allocated for irrigation, industry, and municipalities. Fig. 17 shows the location of the nodes within this area and the 1985 pumpages based on Division of Water Resources allocation of ground water in the vicinity of each node. The management model seeks to find new policies for nodes within the management area which will achieve the objectives of this study. Other nodes in the model (outside the management area) were kept at the pumpage rates of 1985. The management period was set from 1985 to 2020. Based on the ground-water-withdrawal rates given in Fig. 6, five periods of constant-pumpage rates were established for each node from 1940 to 1985. Table 3 of Appendix II lists these pumpages for the five time periods for all nodes. This variation in pumpage rates has affected the velocities in the study area.

In Figs. 18-a and 18-b the groundwater flow velocities at eight observation points are plotted versus time. In calculating these velocities the pumpages of Table 3 of Appendix II were used from 1940 to 1985, and pumpages of 1985 were assumed to remain constant to the year 2020. Velocities responding to the changes in pumpage policies from period to period can be observed. With constant pumpage of 1985, the velocities become constant at about 1995. In Figs. 19-a and 19-b the changes of velocities with time at the same nodes are plotted versus time. From 1940 to about 1960, some nodes are decelerating. However, with the unusual increase in pumpage starting at about 1960 (see Fig. 3), a considerable increase in velocities occured. Figs. 18 and 19 are indicative of the transient water level in this area. Therefore, the steady-state condition assumed by Sophocleous (1984) is not prevailed.

.0 freshwater discharge (cfs)

				0.	0.	0.					
			0.	.2	.37	0.	0.	.31	.45		
			.13	0.	.27	0.	0.	.28	2.35		
		.01	0.	0.	0.	0.	0.	.39	1.32	.16	
	.14	0.	0.	0.	0.	0.	.52	.59	.12	0	
.04	0.	0.	0.	0.	0.	.25	.11	.11	3.17	2.33	
.28	.19	0.	.16	.24	.54	0.	0.	.0	1.09	2.96	
	0.	.21	.26	.36	.39	.69	.05	.11	.1	.21	1.22
	.1	.15	.08	.14	.03	.61	.11	.21	.36	3.52	.76
	0.	.17	.24	0.	.47	.27	.11	.16	.26	.13	.09
			.03	0.	.33	.03	.22	.29	4.06	.09	0.

Figure 17. 1971-1985 pumpage rates (cfs) in management area.

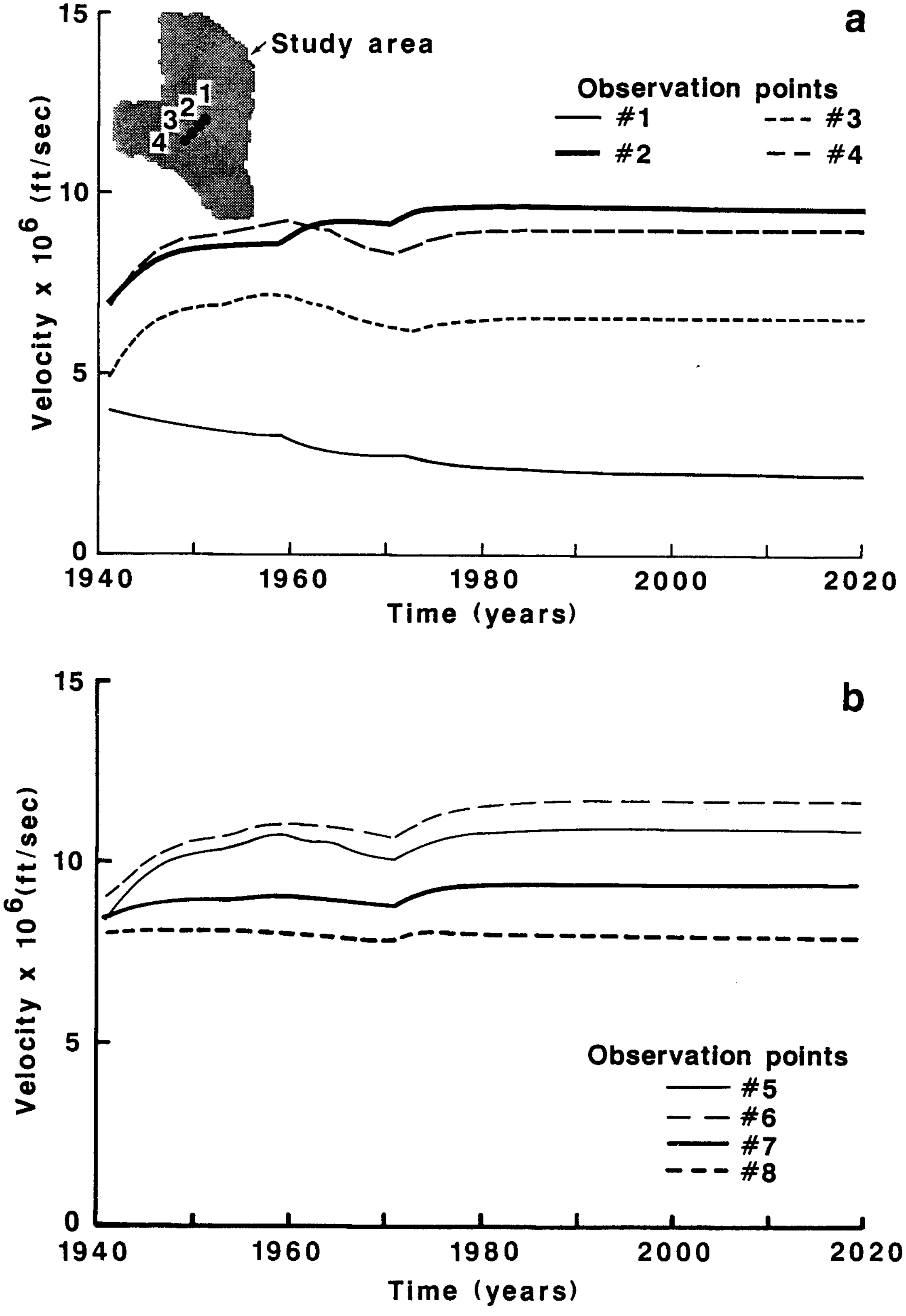
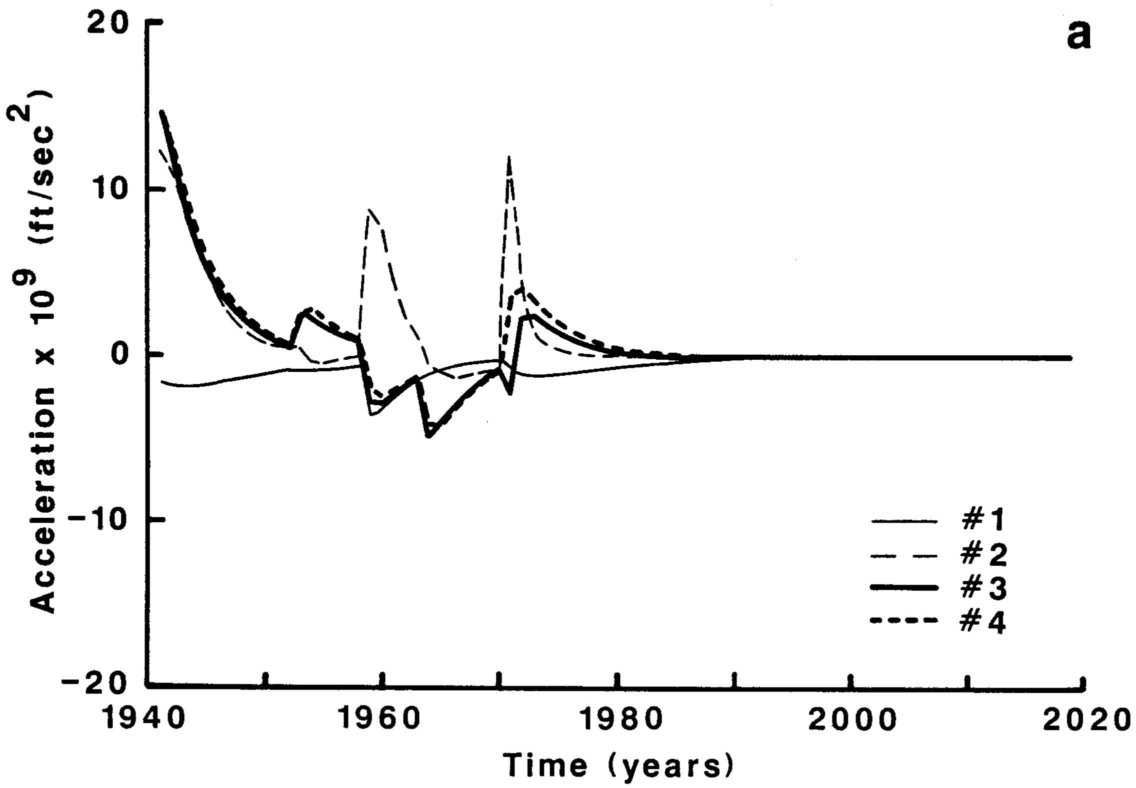


Figure 18. Velocity variations vs. time for selected observation points.



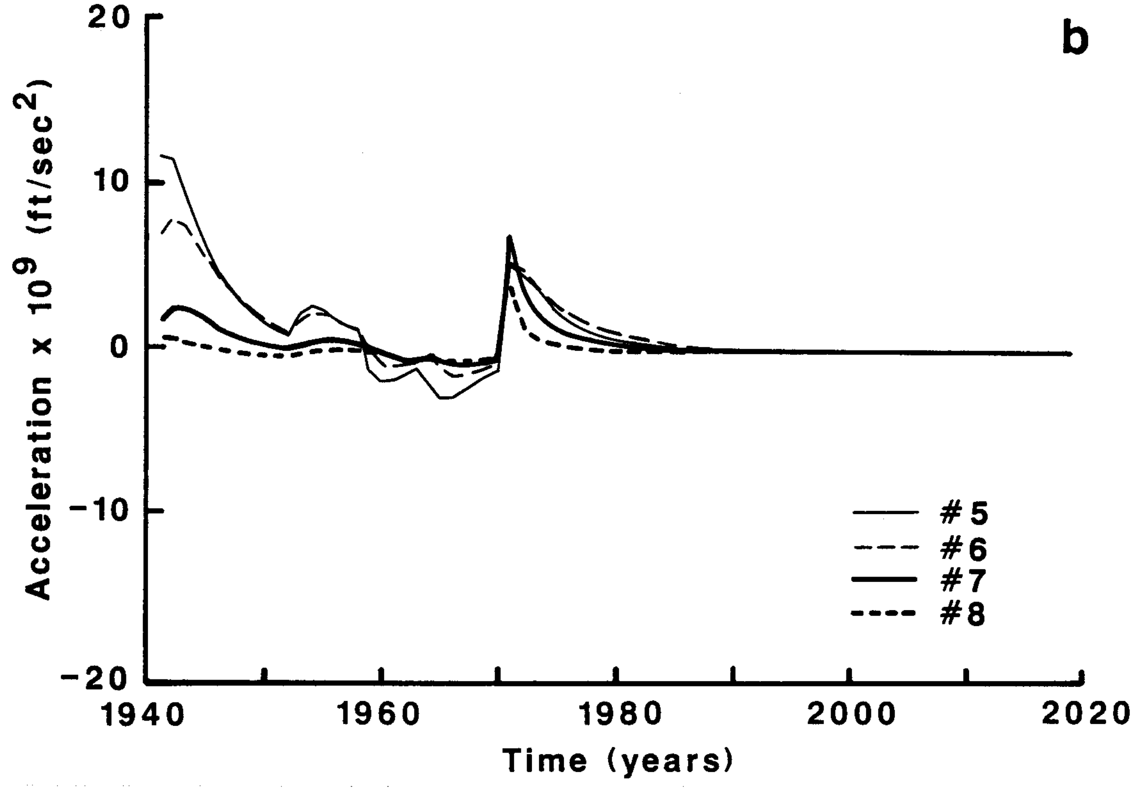


Figure 19. Variations of velocity with time vs. time for selected observation points.

4.2.3 Results of Management Model

In application of the management model to the management area, three different management plans were considered. These plans and their results are described below.

4.2.3 - a) Management Plan A:

In this plan pumpage rates in the management area given in Fig. 17 were assumed to be kept constant to year 2020. Then, interception wells were placed along the 500-ppm-contour line of the plume to neutralize the plume's rate of advancement at specified observation points. In Fig. 20 the 1985 velocity directions and the location of the interception wells and the observation points are shown for this scenario. The arrows designating the velocities as shown in this figure do not represent the magnitude of the actual velocity vectors. This is because in this figure, all velocities were to be shown no matter how small or large. This figure may be used to conclude the direction of water flow. In the upper left of Fig. 20, the velocity vectors within the window are plotted to scale. The actual velocity vectors in Fig. 20 may be used to compare the relative magnitude of velocities within the window. In Table 1 of Appendix III, the magnitude of velocities in the x and y directions for the observation points within the window of Fig. 20 to be neutralized by the interception wells are listed for years 1985 to 2020. These relatively high velocities are indicative of the amount of interception pumpage which has to be carried on for their neutralization. In Fig. 21, the total optimum pumpage of the interception wells is plotted versus time. The initial interception rate during the first year is 90.15 cfs, a pumpage rate whose economic feasibility is seriously questioned. In Table 2 of Appendix III, the pumpage rate of the interception wells are listed for years 1985 to

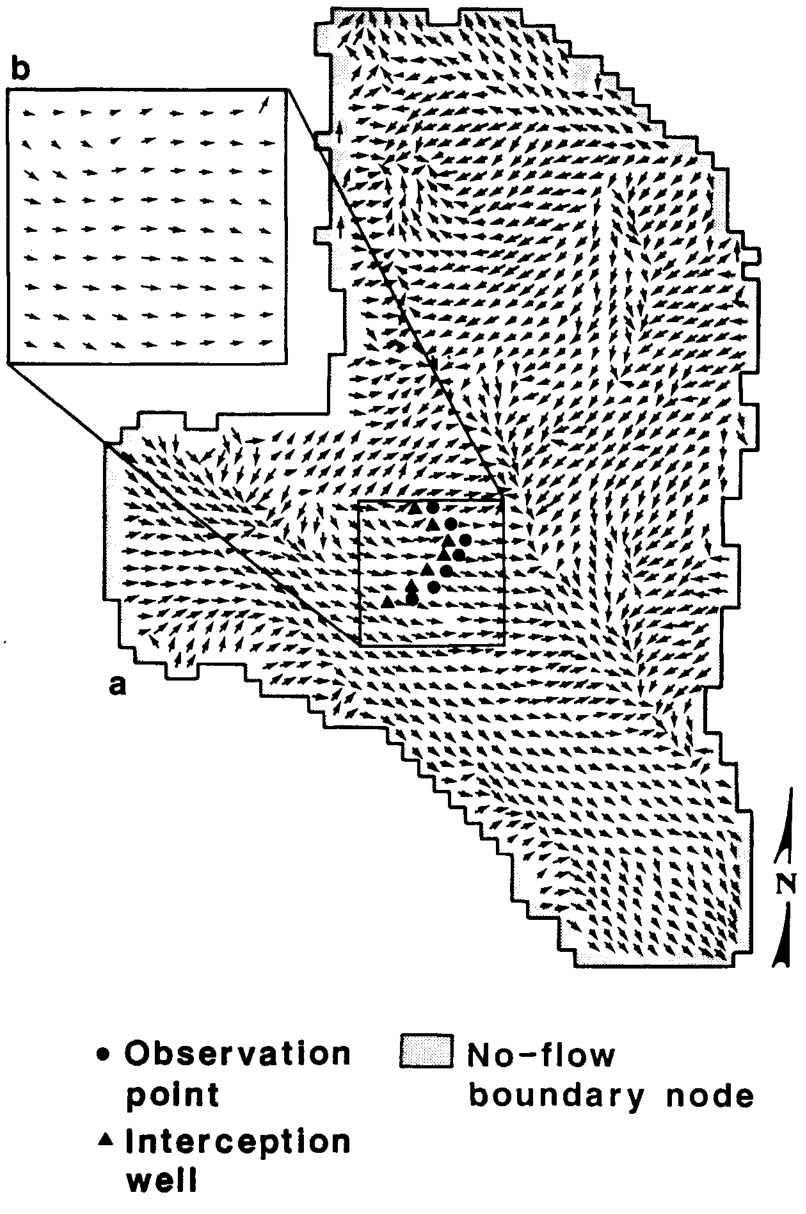


Figure 20. 1985 velocity field, boundary of management area, and location of interception wells and velocity-observation points for Management Plan A.

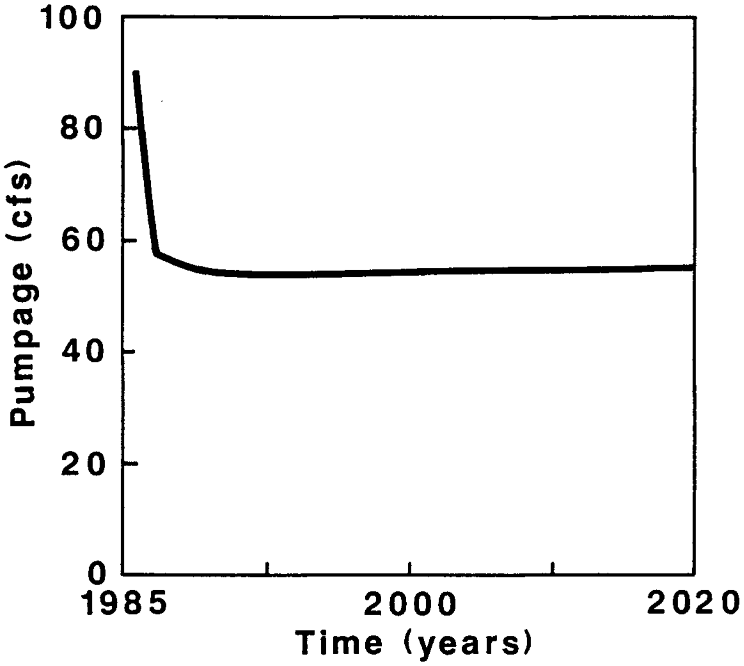


Figure 21. Optimal brine-interception rate vs. time for Management Plan A.

2020. These high pumpage rates are required in order to reverse the velocity vectors of the observation points listed in Table 1 of Appendix III. These rates drop to a total of 55 cfs after 3 years of interception and remain constant to year 2020. The reason that the rates remain constant is that other pumpages in the management area remain constant to year 2020, and therefore the system reaches steady state in about 3 years. In Fig. 22 the velocity directions for the entire aquifer are shown for year 1986 after the interception pumpages started. This pattern of velocity reversals is observed for other time steps in the management period. It must be emphasized again that the arrows in Fig. 22 show the direction of water movement and not the relative magnitude of velocity vectors. The actual velocity vectors one year after the initiation of the interception for the window shown in Fig. 20 are plotted to scale in the upper left of Fig. 22. A comparison of this figure with Fig. 20 reveals that velocity vectors at the observation points are either reversed or their magnitudes have been made very small. After one year of interception (Fig. 22), the interception wells have created a stagnation zone in front of the plume. This stagnation zone is kept to year 2020 by the total pumpage rate given in Fig. 21. In Fig. 22, velocity vectors are representative of the average velocities over each cell. They do not represent the velocity vectors at the pumping wells which by definition are infinity. The overall effect of the pumpage at the interception wells is that the direction and magnitude of the velocities at the observation points are changed drastically.

4.2.3 - b) Management Plan B:

In this plan, the freshwater pumpage rates were included together with the pumpage rates of the interception wells in the management area as

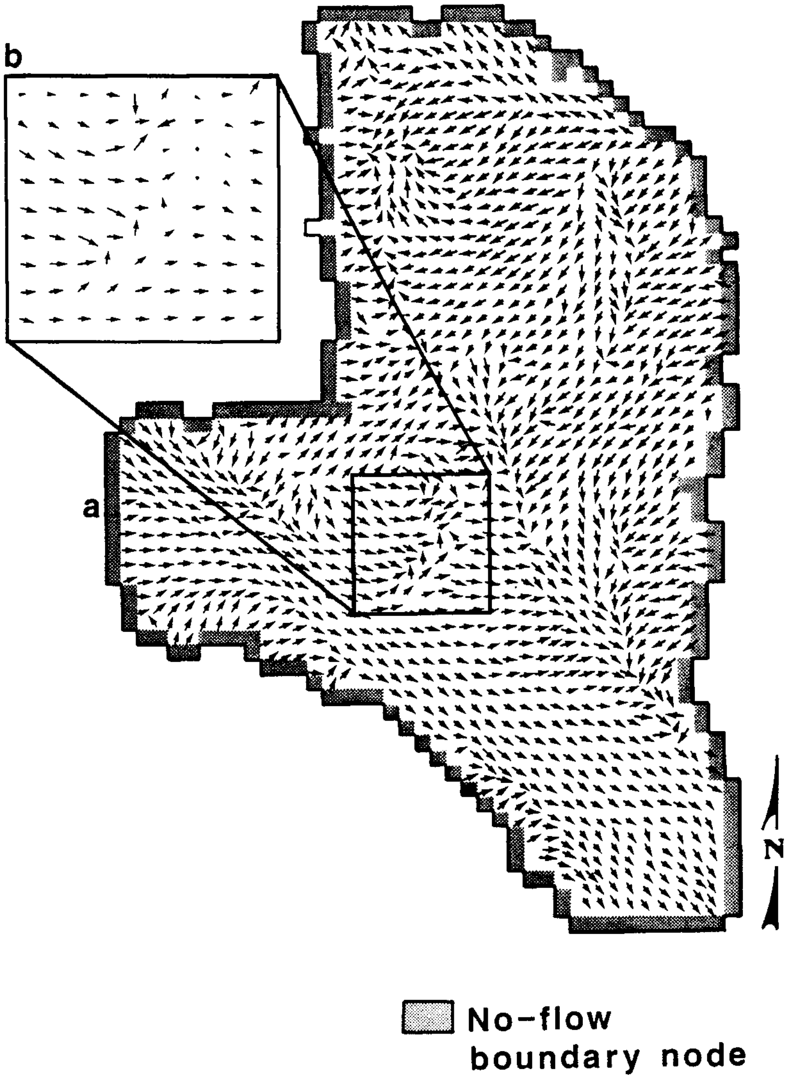


Figure 22. 1986 velocity field obtained from results of Management Plan A.

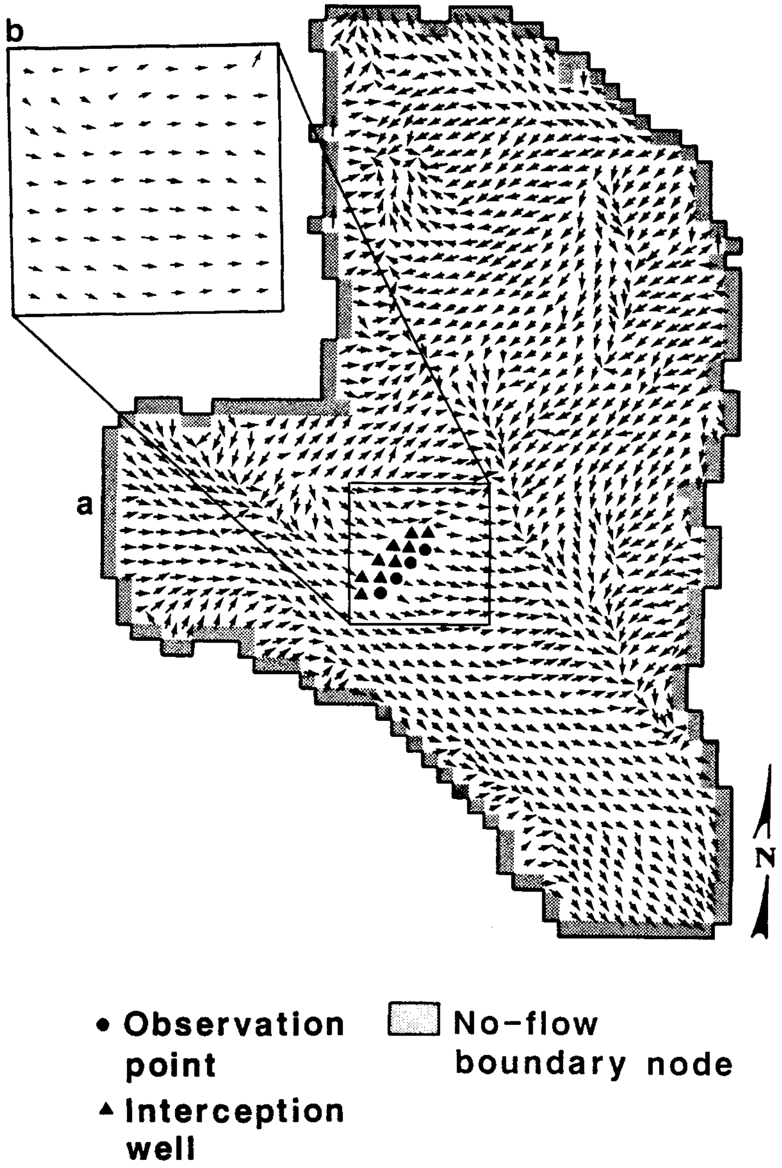


Figure 23a. Boundary of management area, location of velocity-observation points and brine-interception wells for Management Plan B.

unknowns. The interception wells and observation-point configuration together with the fresh-water nodes are shown in Figs. 23-a and b. In Table 3 of Appendix III the velocity vectors in the x and y directions for each observation point in this plan are listed for years 1985 to 2020. These vectors were calculated by setting the pumpage within the management area equal to zero and by keeping the pumpages outside the management area constant. For a management period from 1985 to 2020 (35 years) there exist 78 X 35 fresh-water-pumping-rate unknowns and 13 X 35 brine-interception pumping-rate unknowns, totaling 3185 unknowns. The respective linear-programming model will have a total of 3185 columns and 3185 + 2 (4 X 35) + 35 + 1 rows. The 3185 constraints are associated with the drawdown constraints. Because there are four velocity-observation points, and for each point during each time step two velocity constraints (x and y directions) must be satisfied, a total of 280 velocity constraints exist. During each time step the total fresh-water demand adds a total of 35 fresh-water-demand contraints. Finally there is the objective row, which when added to the other constraints generates a total of 3501 rows. Since the solution of an LP model with 3185 columns and 3501 rows is beyond the capability of the available computing facilities, the decomposition technique described in Chapter 3 was used. A total of 10 arbitrary zones were set up as shown in Fig. 23-b. In doing so some interception wells had to be divided between two adjacent cells. This is because of the nature of the decomposition technique described in Chapter 3. During each iteration, each cell must have the capability to control its own velocity vectors as well as velocity vectors in the adjacent cells. Therefore, if an interception well is located on the boundary between two cells, its pumpage must be divided into two unknowns which must be calculated during the solution of the LP models for those cells. During each time step, 10 small LP models were solved iteratively until the convergence criterion (23) was satisfied for all cells and all wells. ε was set equal to .01 cfs.

To satisfy the freshwater demand, the total freshwater demand was divided among the 10 cells proportional to the allocated rights in each cell. Table 1 lists the freshwater demand for each of the 10 cells.

Cell	1985 Freshwater Demand	
1	2.88	
2	2.79	
3	3.40	
4	3.72	
5	3.87	
6	5.08	
7	3.70	
8	3.87	
9	3.78	
10	2.91	
	36.00 cfs	TOTAL

TABLE 1. Freshwater-demand distribution in management area.

The decomposition reduced the size of the LP models effectively. The largest LP model had 561 rows and 455 columns which could be solved easily on the minicomputer Data General MV-8000.

In Fig. 24, the total-optimum pumpage (freshwater and intercepted water), the freshwater pumpage, and the intercepted water are plotted versus time. As can be observed, the total freshwater demand of 36 cfs is constantly satisfied. However, the interception rate which starts at 55.22 cfs for 1986 and drops to a constant value of 42.5 cfs in year 2020 clearly is not economically a viable option. In Table 4-a and b of Appendix III, the pumpage rates of the interception wells and freshwater wells are listed. The pumpage rates of the freshwater wells remain constant with time. Therefore only one value is listed. Since the pumpage rates of the interception wells change with time, they are listed for each year in the management period. In Fig. 25 the velocity distribution for one year after the initiation of the interception is plotted. Fig. 25 also includes the actual velocity vectors of the nodes within the window of Fig. 20. As may be seen the velocities at the observation points have been diverted toward the interception wells or neutralized effectively.

4.2.3 - c) Management Plan C:

In this plan the re-allocation procedure for freshwater demand subject to neutralization of velocity vectors in the management area of Fig. 20 was repeated for a different set of interception wells and observation points. The location of these wells and points together with the nodes used for pumpage of freshwater are shown in Fig. 28-a.

In Table 5 of Appendix III the velocity vectors for the observation points for year 1985 to 2020 to be neutralized by the management model are

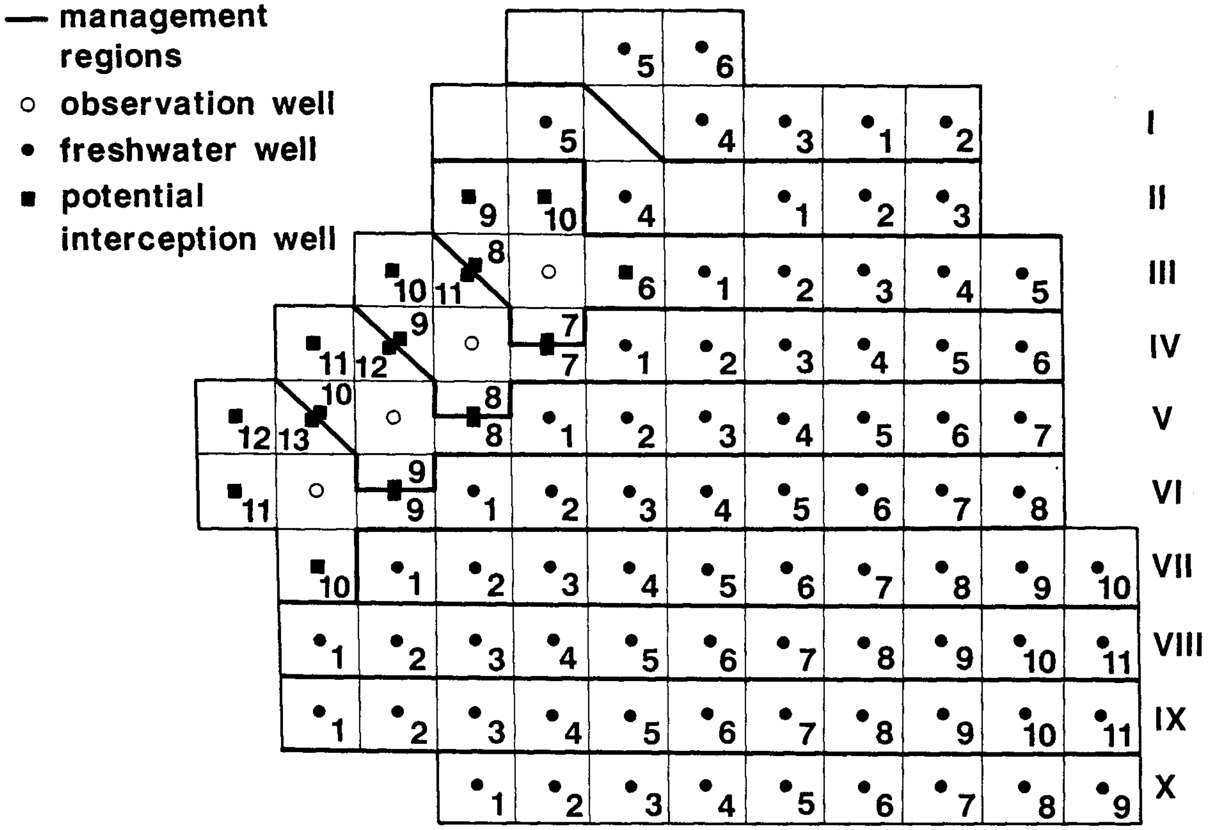


Figure 23b. Location of cells, fresh-water wells, velocity-observation points, and brine-interception wells for Management Plan B.

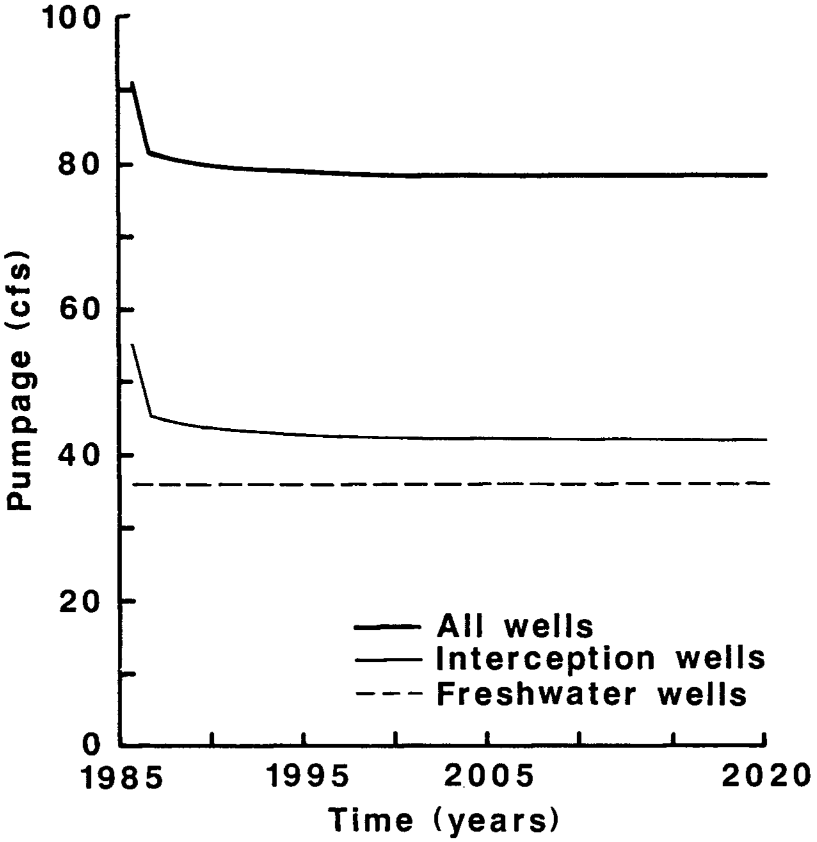


Figure 24. Optimal pumpage rates for Management Plan B.

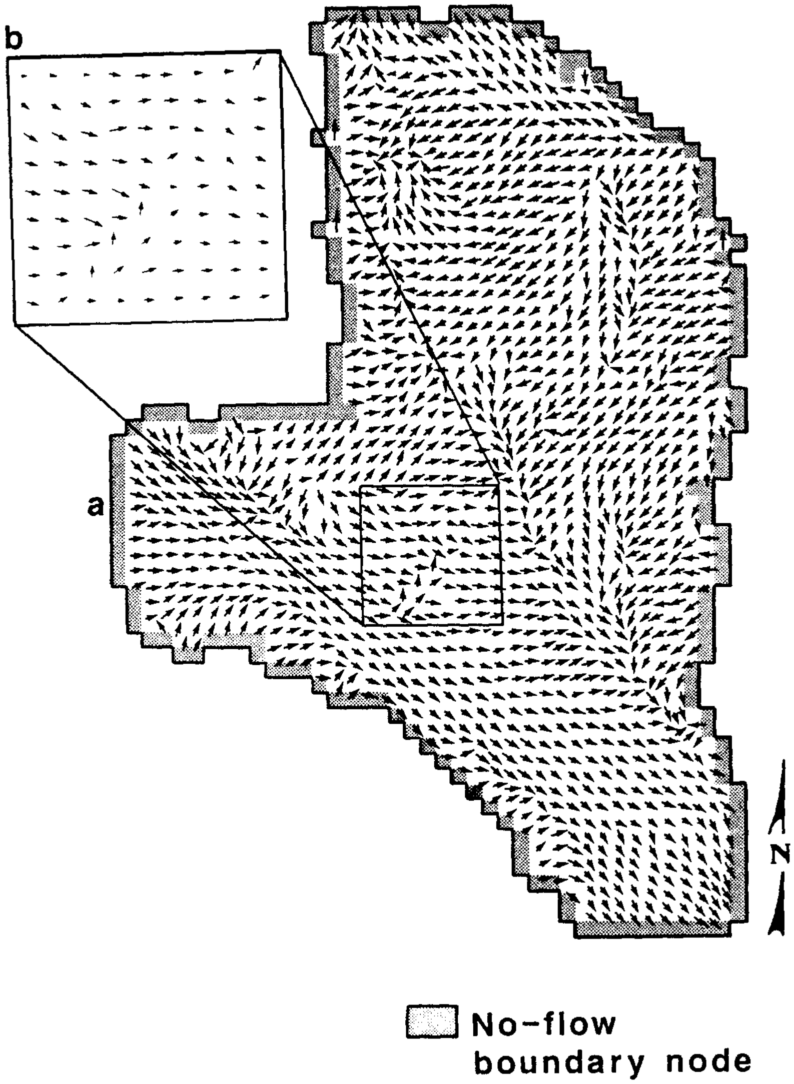


Figure 25. 1986 velocity field obtained from results of Management Plan B.

listed. These vectors were calculated by setting the pumpage rates of the nodes within the management area to zero and keeping the pumpage rate outside this area to the level of 1985.

The LP model for this plan contains 3115 unknowns representing the pumpage rates for 89 active nodes. It contains 3115 constraint rows representing the drawdown constraints, 280 constraint rows representing the velocity constraints, 35 constraint rows representing the demand constraints, and 1 row representing the objective function. Since the solution of an LP model consisting of 3115 columns and 3431 rows with the available computing facilities was not possible, the area was decomposed into 10 zones as shown in Fig. 26-b. This decomposition generated 10 LP models whose solution was obtained iteratively on minicomputer Data General MV-8000.

In Fig. 27 the total pumpage rate (freshwater and intercepted water), freshwater-pumpage rate, and intercepted-water-pumpage rate are plotted versus time. The freshwater-pumpage rates are constantly satisfied at the rate of 35 cfs. In Table 6-a and b of Appendix III the optimal freshwater-pumpage rates and interception-pumpage rates for this plan are listed.

The interception-pumpage rate starts at 51.42 cfs in 1985 and drops to about 35 cfs in seven years. Table 7 of Appendix II lists the optimal pumpage rates of the interception wells for each year. Again this plan produced an unrealistic interception pumpage rate.

In Fig. 28 the directions of flow are shown for the entire aquifer after one year of brine interception. In the upper left of Fig. 28, the actual velocity vectors after one year of interception within the window shown in Fig. 20 are plotted to scale for comparison purposes. The velocity vectors at observation points are redirected or reduced to a very small value. However,

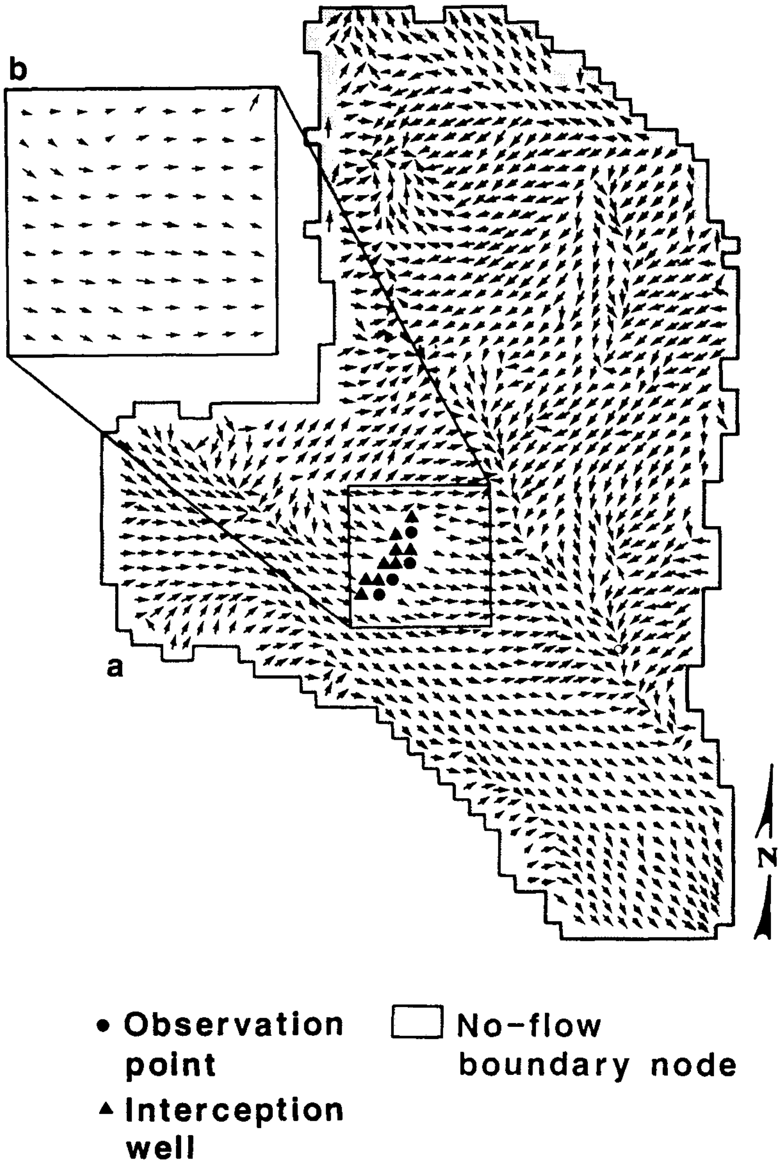


Figure 26a. Boundary of management area and location of velocity-observation points and brine-interception wells for Management Plan C.

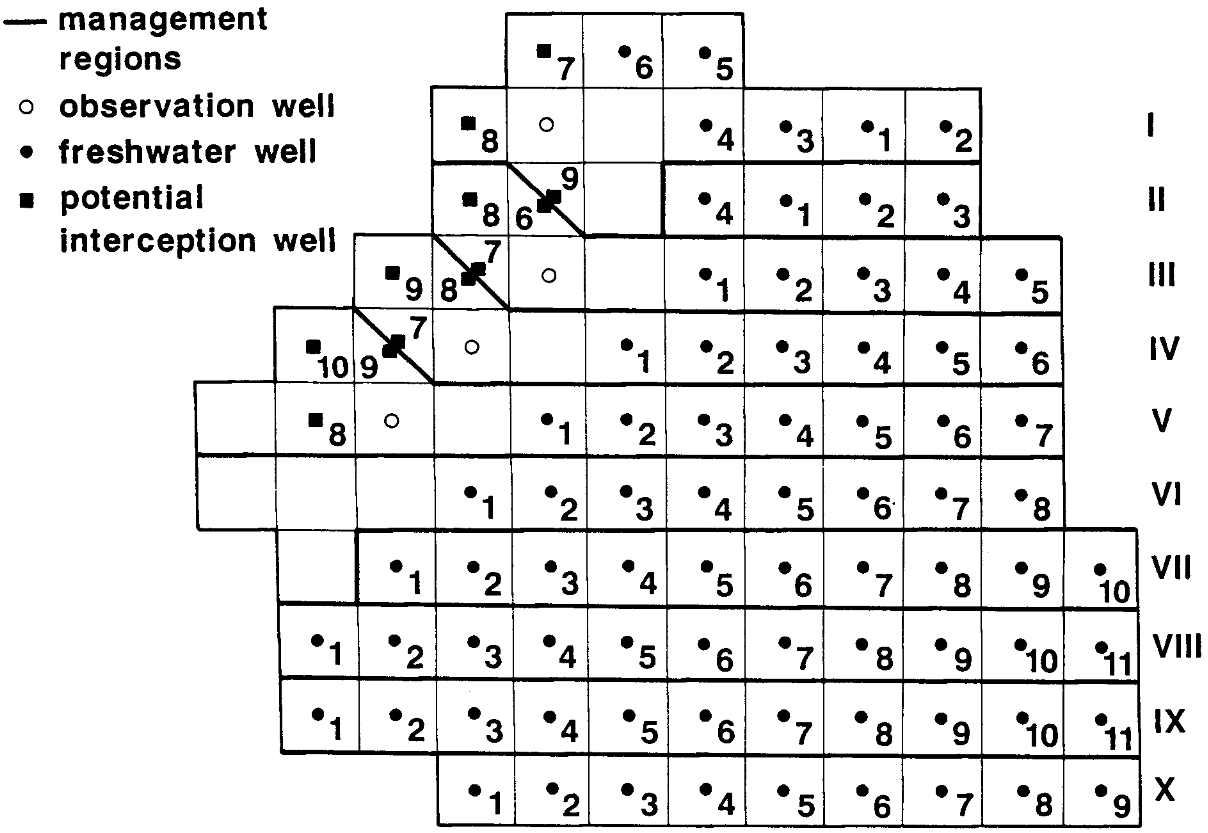


Figure 26b. Location of cells, freshwater wells, velocity-observation points, and brine-interception wells for Management Plan C.

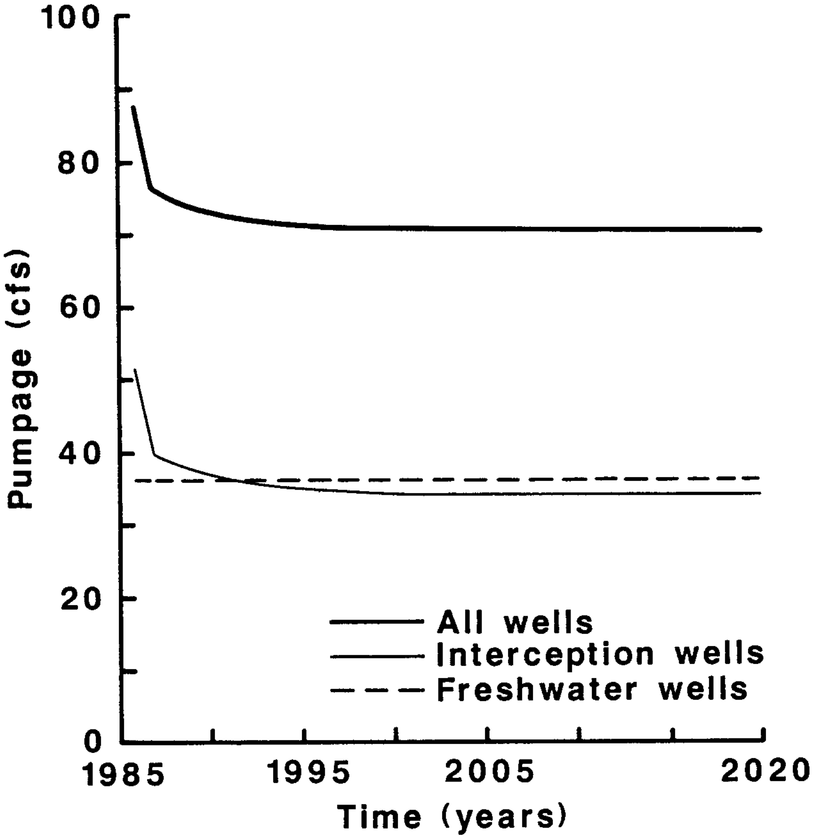


Figure 27. Optimal pumpage rates for Management Plan C.

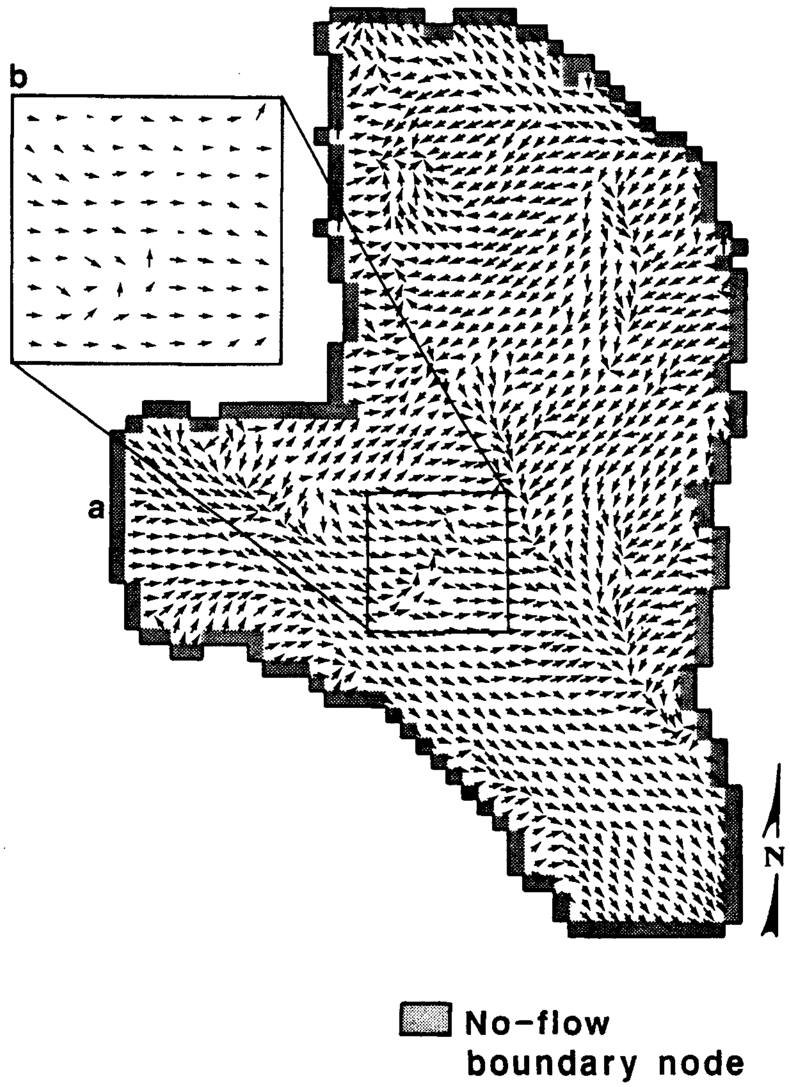


Figure 28. 1986 velocity field obtained from results of Management Plan C.

a velocity vector associated with the interception well seems to be still active.

As will be shown in the next chapter, the three management plans reverse the movement of the pollutant from the north west to the city wells. It will be also shown that management plan A is most effective from the point of view of speed in clean up. However, as was shown this is also the most expensive plan. Therefore, depending on the urgency to clean up the pollutant, one may choose plan A which is the most efficient or other two plans which are less efficient but also less expensive.

Chapter 5

TRANSIENT MODELING OF CHLORIDE MOVEMENT

In this chapter, a solute-transport model is used to determine the extent of the chloride movement over a selected area of the Equus Beds aquifer where a major well field supplies water for the city of Wichita. We start the modeling analysis by specifying initial and boundary conditions and assigning appropriate hydrogeologic parameters to all nodes in the aquifer. Subsequently, the model will be evaluated mainly on the basis of available observed chloride distributions. The injection rate and concentration of contamination sources required for modeling analysis are obtained from previous hydrologic reports of the same area. Once the process of model evaluation is satisfactorily completed, the model will be used to study the effects of proposed ground-water withdrawal and management policies on the migration of contaminants throughout the ground-water system.

5.1 Solute-transport Process

The major components of the transport process in a ground-water-aquifer system are advection and dispersion (including molecular diffusion). Advection is a process by which fluid particles are moved as a result of pressure and elevation differences, while dispersion refers to the mixing and spreading of liquid particles caused by molecular diffusion, pore-size scale variations of velocity, and large-scale heterogeneities. The effects of chemical reactions and ion exchange on solute concentration are negligible for most field problems and are not considered in our analysis. Moreover, the density and viscosity are assumed to be constant and independent of the concentration.

The transport of a dissolved-chemical species in flowing ground water is mathematically described by the solute-mass continuity equation or the so-called advection-dispersion equation. The two-dimensional transient form of the transport equation for a conservative (nonreactive) solute may be written as (Bear, 1979)

$$\frac{\partial}{\partial x_i}\left(bD_{ij}\frac{\partial c}{\partial x_j}\right) - \frac{\partial}{\partial x_i}(bcv_i) - \frac{\tilde{c}W}{\theta} = \frac{\partial(c.b)}{\partial t} \qquad (30)$$

where c(x,y,t) is the solute concentration, M/L^3; b is the saturated thickness of the aquifer, L; D_{ij} is the hydrodynamic dispersion tensor, L^2/T; v_i is the seepage or average pore velocity, L/T; $\tilde{c}$ is the solute concentration in a source or sink fluid, M/L^3; W is the net volume flux [(Q + R in Eq. (1)] per unit area at a source or sink, L/T; θ is the effective porosity of the aquifer, dimensionless; x_i, x_j are the spatial coordinates, L; and t is the time variable, T.

The term on the right side of equation (30) represents the temporal variation of the solute concentration within the system. The changes in concentration due to the hydrodynamic dispersion, advective transport, and fluid sources and sinks are described by their respective terms on the left side of equation (30).

The seepage velocity, v_i, required for solution of the transport equation is derived by simultaneous solutions of the ground-water-flow or fluid-continuity equation and the Darcy equation. The ground-water-governing equation for the two-dimensional transient flow in an inhomogeneous and anisotropic aquifer is represented by (Bear, 1979)

$$\frac{\partial}{\partial x_i}\left(T_{ij}\frac{\partial h}{\partial x_j}\right) = S\frac{\partial h}{\partial t} + W \qquad (31)$$

where h(x,y,t) is the hydraulic head or water-level elevation, L; T_{ij} is the transmissivity tensor, L^2/T; S is the storage coefficient, dimensionless; and W, x, and t are as defined previously.

The hyraulic-head function calculated from equation (31) is inserted into the Darcy equation to compute the distribution of the seepage-velocity field, v_i:

$$v_i = -\frac{K_{ij}}{\theta}\frac{\partial h}{\partial x_j} \tag{32}$$

Note that in equation (32), K_{ij} is the hydraulic-conductivity tensor, which is related to the transmissivity by the expression $T_{ij} = bK_{ij}$.

In summary, the equations for solute-mass continuity, fluid continuity, and seepage velocity, respectively, equations (30), (31), and (32), together with a set of initial and boundary conditions provide a complete mathematical description of the solute-transport process. One has to start the transport simulation by solving equations (31) and (32) first. The velocity distribution resulted from solution of these equations is, then, used to define the advective-transport term in equation (30) and also to derive the values of the hydrodynamic-dispersion coefficients which depend on the velocity. Subsequently, equation (1) is solved to find the spatial and temporal variation of the solute concentration in the ground-water system.

5.2 Numerical Model

The U.S. Geological Survey solute-transport model (Konikow and Bredehoeft, 1978) selected for our analysis is one of the most widely used models for predictions of contaminant movements in actual field situations. The model combines finite-difference solutions to the ground-water-flow and seepage-velocity equations with the method of characteristics solution to the solute-transport equation. The set of approximate equations from ground-water-flow equation are solved using an iterative alternating-direction implicit procedure.

In the method of characteristics, the numerical solution of the solute-transport equation is achieved by introducing a set of moving points that can be traced with reference to the stationary coordinates of the finite-difference grid. Each point has a concentration associated with it and is moved through the flow system in proportion to the time increment and the velocity at the location of the point. The moving points simulate advective transport because the average concentration over each cell of the finite-difference grid will change with time as different points enter and leave the area of the cell. The additional changes in concentration caused by hydrodynamic dispersion and fluid sources are computed using an explicit finite-difference equation. More details of the numerical procedures used in the model may be obtained by referring to Konikow and Bredehoeff (1978).

5.3 Area of Investigation

For practical reasons, the location of study is limited to a 560 mi^2 area in the south-central part of the Equus Beds aquifer (Fig. 29). The study area contains the main brine-pollution sources near the city of Burrton and a well field which is a significant source of water supply for the city of Wichita. The areas of the Equus Beds aquifer not to be affected by the pollution are excluded from this analysis. The Arkansas River along the southwestern boundary and Little Arkansas River in the north are the two major streams in the region. Note that the selected area for solute-transport investigation contains the area considered previously for exploring the pollution-containment options.

The area of interest is subdivided into a network of rectangular, uniformally spaced cells which constitutes the finite-difference grid (Fig.

line-successive overrelaxation procedure (LSOR). All three methods should yield comparable solutions. However, one may be more appropriate than the others depending on the problem under consideration. ADI is, in general, the most competetive method in terms of convergence and convergence rate as well. It may have trouble converging in steady-state simulations involving extremely variable coefficients.

4.1.2. Data Sources and Set-up

It was originally planned to base the management study in the Equus beds on the flow model developed by Spinazola et al. (1985). The results of that study revealed differences in basic assumptions such as the use of a three-dimensional simulator versus the necessity to use a two-dimensional simulator in this study. For the sake of consistency between the two projects, considerable efforts were made to alter Spinazola's model minimally while satisfying all the additional assumptions and restrictions imposed by the management model. In this section, the data obtained from the Spinazola et al. study, its sources, and the alterations will be described.

A 63 by 44 one-mile-spacing finite-difference grid was selected to represent the area extending over the Equus beds (Fig. 4). The grid cells or nodes are defined as active if the hydraulic conductivity is positive and inactive otherwise. An active node may be set to represent a constant-head grid cell as a part of a set of boundary conditions. Inactive nodes adjacent to active nodes represent no-flow boundaries of the aquifer.

The aquifer parameters were then assigned to nodes following the grid configuration described above and shown in Fig. 4. The hydraulic-conductivity distribution was based on the transmissivity map generated by Richards and Dunaway (1972). Other sources of hydraulic conductivity data included

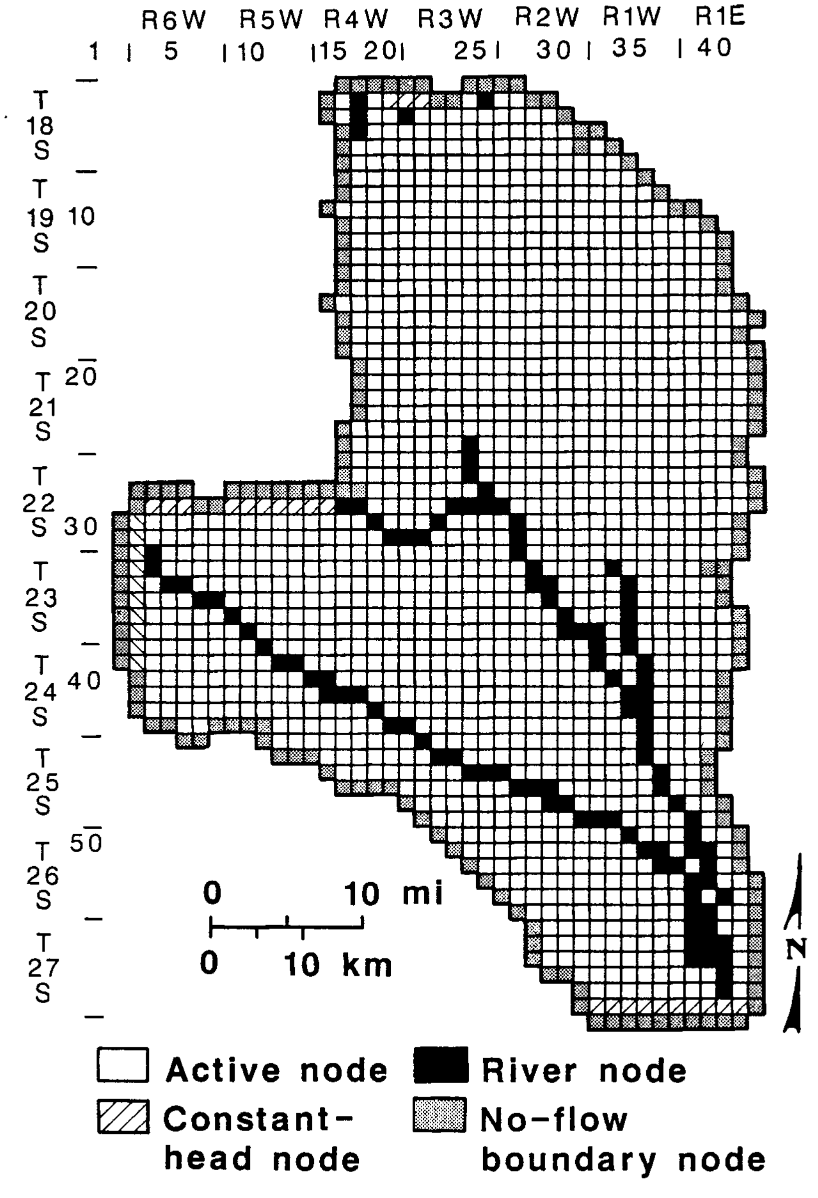


Figure 4. Finite-difference grid of Equus Beds aquifer.

aquifer-test analyses (Reed and Burnett, 1985) and laboratory analysis of samples (Williams and Lohman, 1949, p. 101). The hydraulic conductivity ranges from 15 to 800 ft/day. Fig. 5 shows a distribution of the adjusted hydraulic conductivity. Actual values for hydraulic conductivity are listed in column 4 of Table 1 in Appendix II.

Because the unit-response function generator associated with the management model is not designed to account for evapotranspiration, the evapotranspiration was combined with the areal recharge to yield a net or effective recharge for consistency between all stages of this study. The effect of evapotranspiration would therefore be accounted for through recharge. Note that the digital simulator allows the recharge to vary spatially but not with time. The net recharge is the difference between the steady-state areal recharge and evapotranspiration. Spinazola et al. (1985) calculated the steady-state areal recharge as the product of a recharge factor which is a function of soil type and clay thickness and the normal average precipitation prevailing up to 1940. The evapotranspiration was considered only for those nodes where the steady-state water-table level was not more than 10 ft below the land elevation.

The Arkansas and Little Arkansas rivers were represented as leakage nodes between a confining bed and the aquifer. Leakage is controlled by the river stage and the vertical hydraulic conductance of the confining bed and its thickness. The vertical conductance is simply the product of the vertical-hydraulic conductivity and the area occupied by the river within the grid cell, divided by the confining-bed thickness. Nodal values for the vertical conductance C and the river stage are listed in columns 10 and 11 of Table 1 in Appendix II. Fig. 4 shows the locations of the two rivers. The thickness of the confining bed was set at one foot for all river nodes.

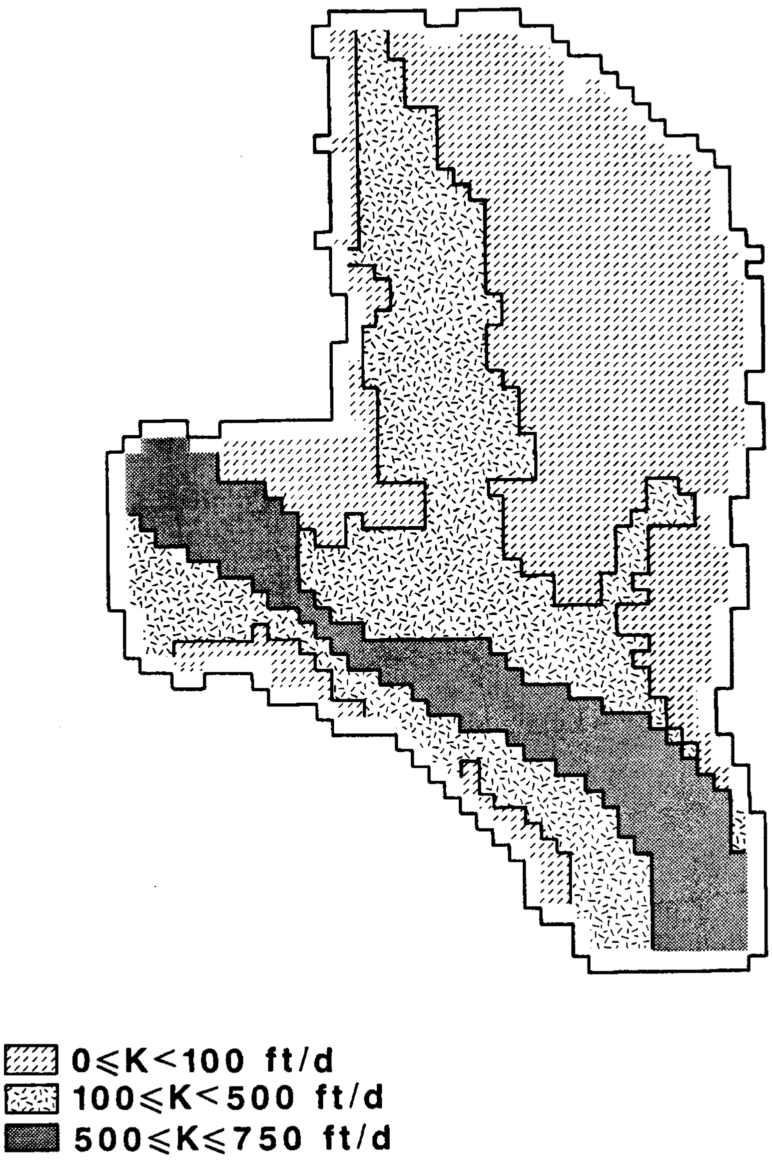


Figure 5. Hydraulic-conductivity distribution of Equus Beds aquifer. (After Spinazola et al., 1985).

The western edge of the Equus Beds aquifer is underlain by a brine-saturated stratum, the Wellington Formation. The two formations are however separated by impermeable layers of shale averaging 250 ft in thickness. Their interactions were shown to be negligible by Spinazola et al. (1985). Using the U.S. Geological Survey's modular three-dimensional flow model (McDonald and Harbaugh, 1984), Spinazola et al. (1985) incorporated the effects of the Wellington Formation in their analysis as a second layer and calculated the fluxes between the two formations. These fluxes are negligible compared to other sources of discharge/recharge, and they mostly occur from the Wellington to the Equus beds. These fluxes were accounted for in this study as discharge wells (see last column on Table 1 in Appendix II).

4.1.3. Steady-state Calibration of 2-D Model

A steady-state calibration was performed to adjust for recharge and hydraulic conductivity wherever necessary. The aquifer parameters described in the previous section along with the steady-state water table calculated by Spinazola et al. (1985) were taken as initial guesses for the two-dimensional steady-state simulation. Actual pumping wells existing before 1940 (see Table 2 in Appendix II) were combined with the Wellington fluxes and were considered in the model as discharge nodes.

The results of the steady-state calibration were in good agreement with those obtained by Spinazola et al. (1985) despite the additional constraints reported above. The difference between the calculated steady-state head and that of Spinazola et al. (1985) varied between 0 and 0.3 ft. For a few nodes, the difference was greater than 0.3 ft but never exceeded 2 ft. Therefore we concluded that the initially chosen parameters did not need further adjustment.

4.1.4. Transient Calibration of 2-D Model

Transient calibration is a means of adjusting for the storage coefficient. In addition to the data required for a steady-state simulation and the aquifer parameters derived from the steady-state calibration, transient hydraulic-head data and discharge rates are needed. The two-dimensional model of Trescott et al. (1976) does not allow for transient recharge as does the three-dimensional model of McDonald and Harbaugh (1984). Therefore, discharge by wells remains as the only time-dependent factor in the model.

Annual withdrawal rates from the Equus Beds aquifer from existing wells were originally obtained from the Division of Water Resources, Kansas State Board of Agriculture. The total annual discharge was then plotted versus time as shown on Fig. 6 and divided into segments of approximately constant slopes. Each segment defines a period of time over which the discharge rate is averaged for each well; discharges within a grid cell were added together, and this discharge value was assigned to the associated node. These periods will be referred to as the stress periods. Five stress periods were defined from 1940 to 1980, the first one from 1940 to 1952, the second from 1953 to 1958, the third from 1959 to 1964, the fourth from 1965 to 1971, and the fifth from 1971 to the end of 1979. Table 3 in Appendix II lists the average discharge (in cfs) for each stress period by grid location. The maximum observed value for discharge is of the order of 6 cfs.

Figs. 7 to 11 show the locations of the pumping wells for each stress period. Their succession reveals that the Wichita well field evolved during the 1940's and substantially increased in size between 1940 and 1980.

A transient simulation was performed with one-year pumping periods using the discharge rates defined above. This time step was also adopted for the

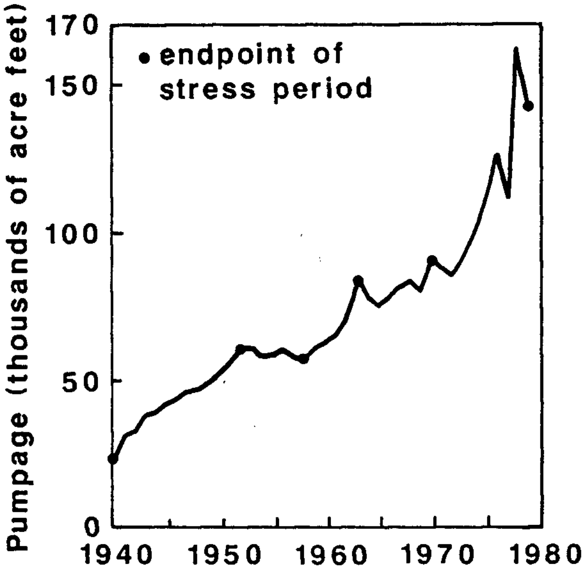


Figure 6. Total annual ground-water withdrawal from Equus Beds aquifer, 1940-1979.

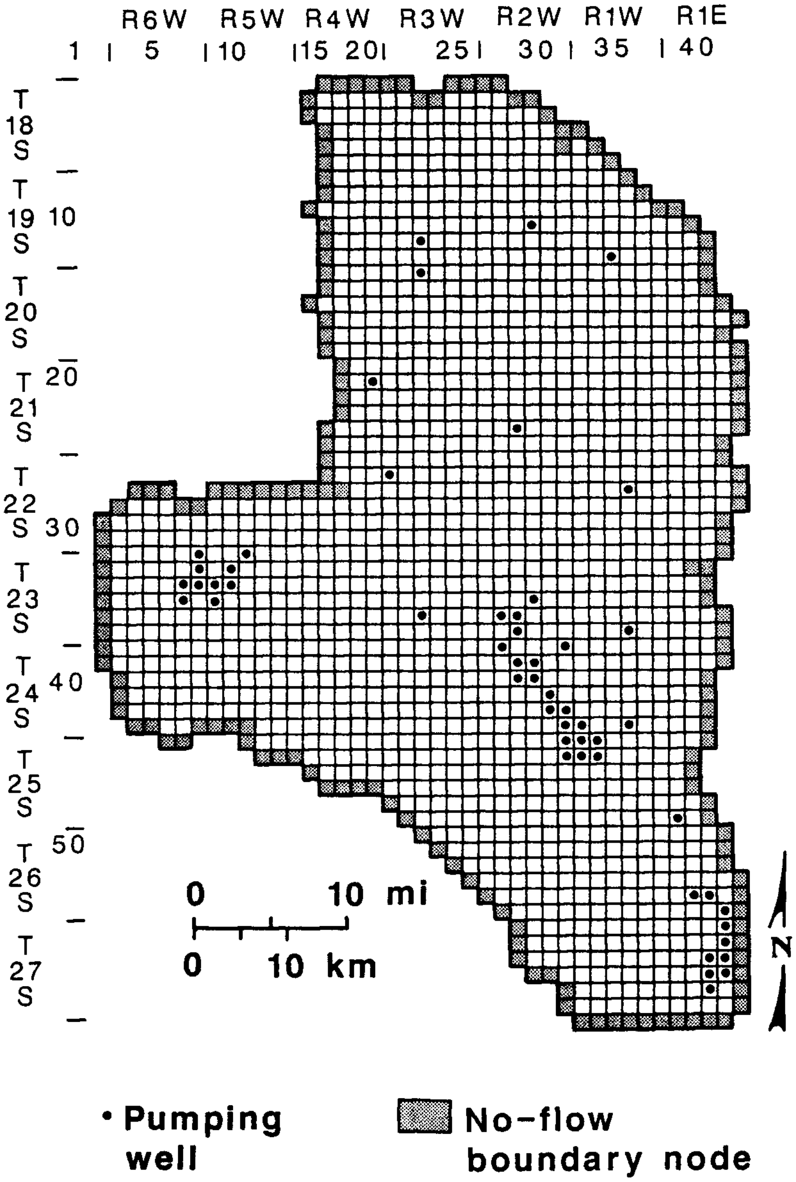


Figure 7. Location of pumping nodes in period from 1949 to 1952 in Equus Beds aquifer.

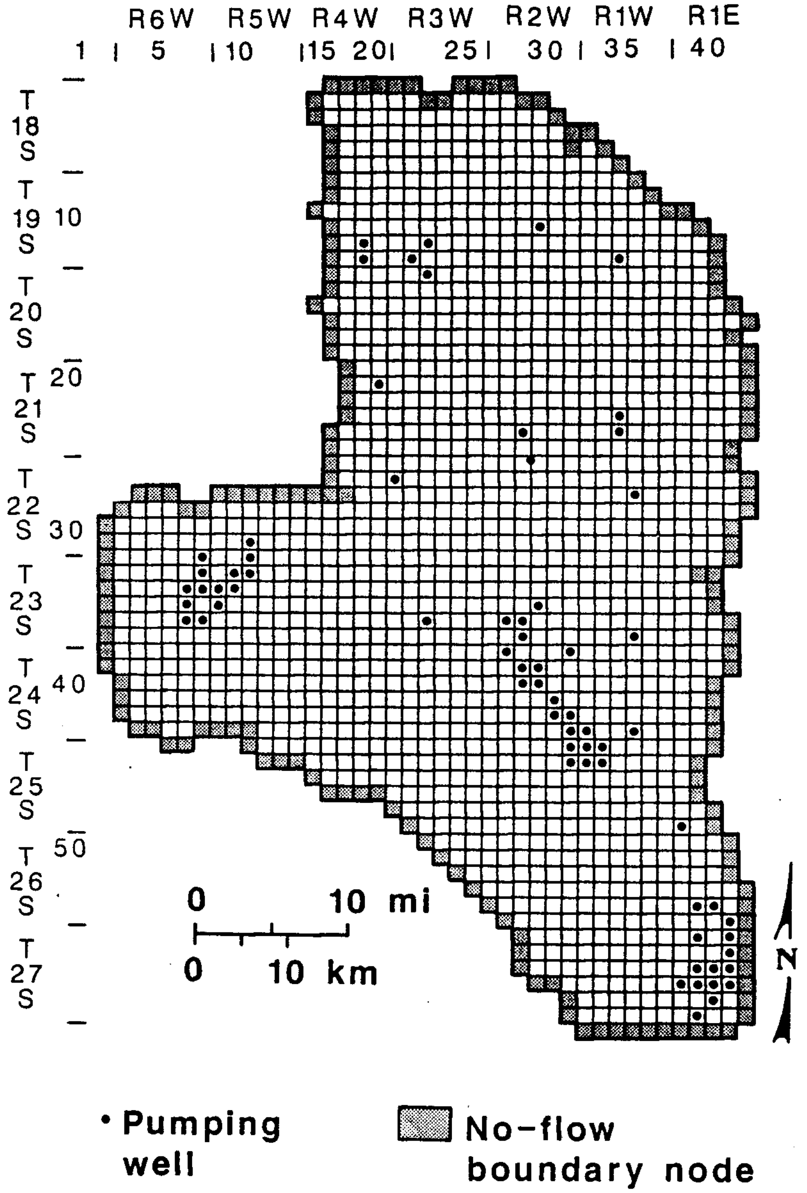


Figure 8. Location of pumping nodes in period from 1953 to 1958 in Equus Beds aquifer.

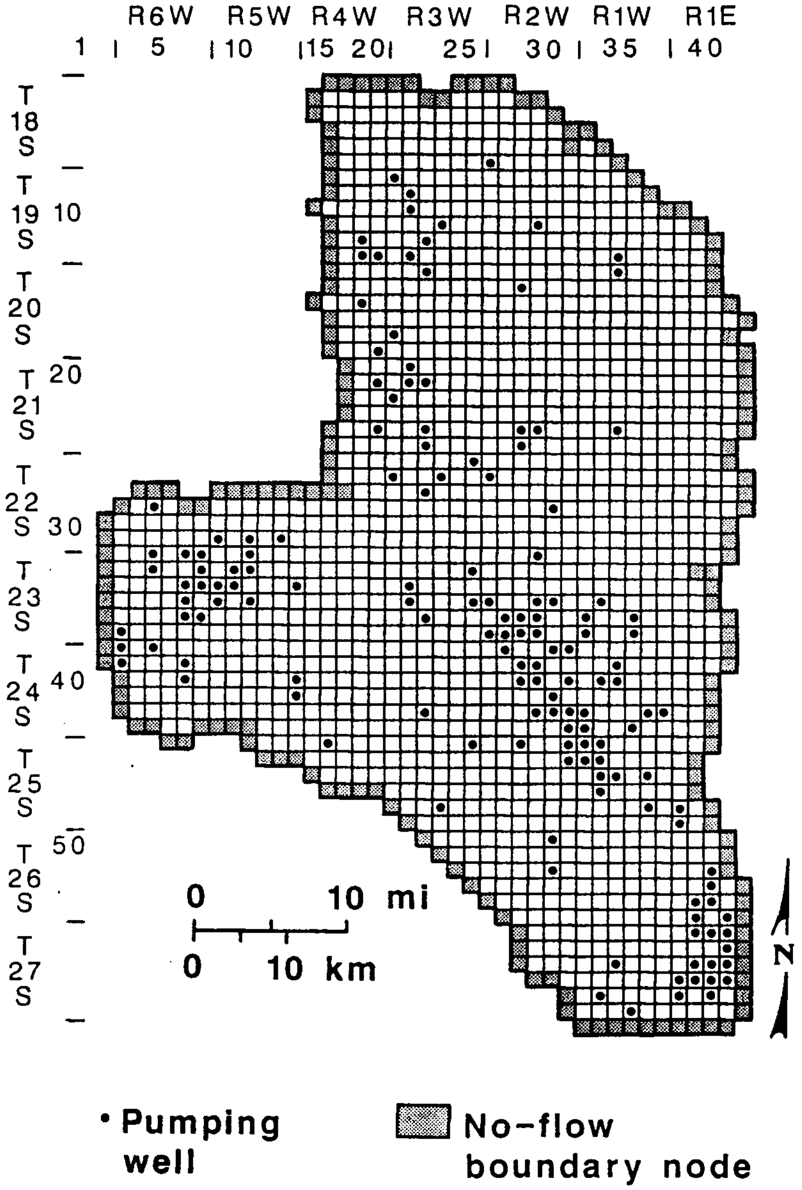


Figure 9. Location of pumping nodes in period from 1959 to 1963 in Equus Beds aquifer.

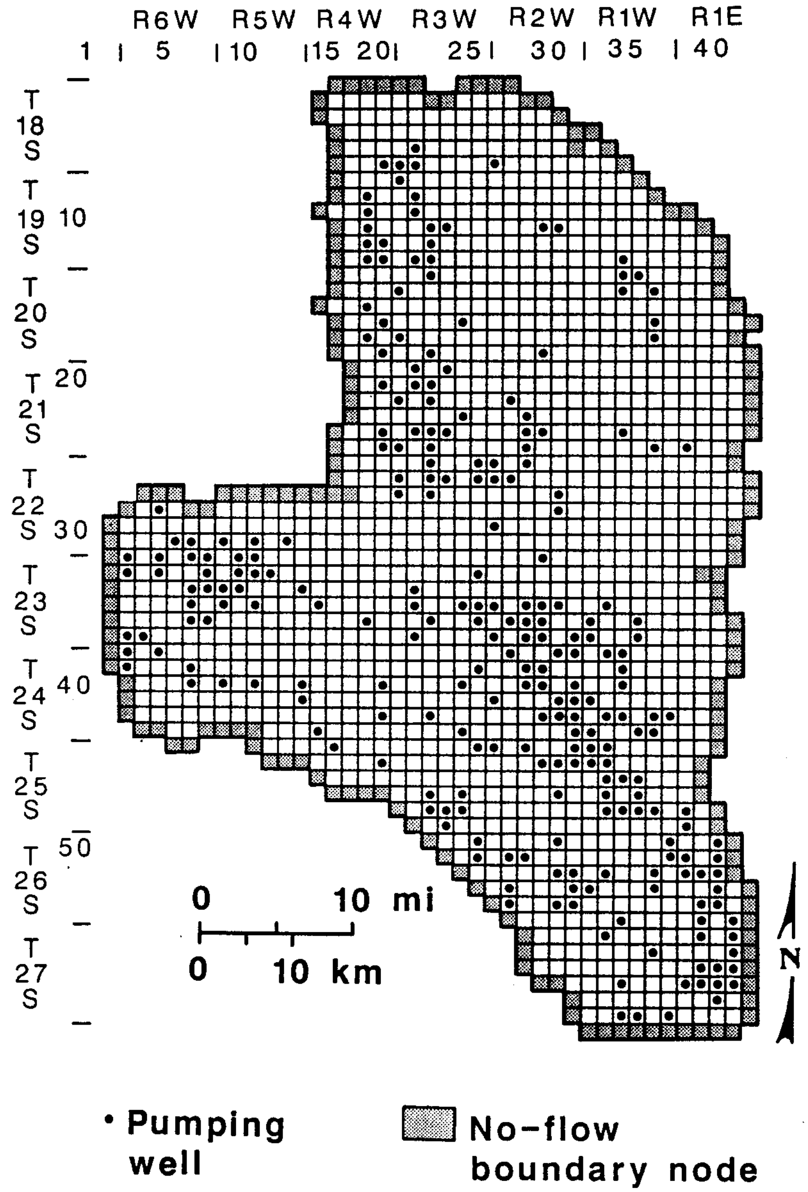


Figure 10. Location of pumping nodes in period from 1964 to 1971 in Equus Beds aquifer.

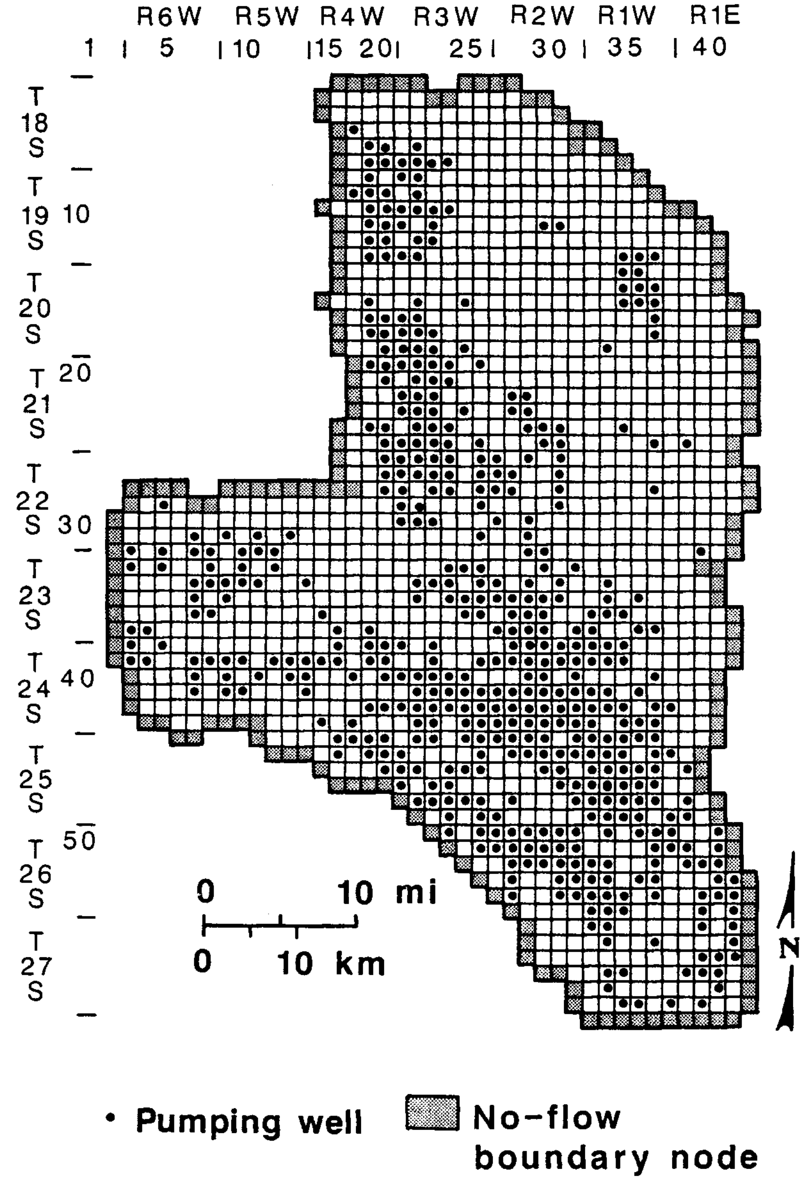


Figure 11. Location of pumping nodes in period from 1972 to 1979.

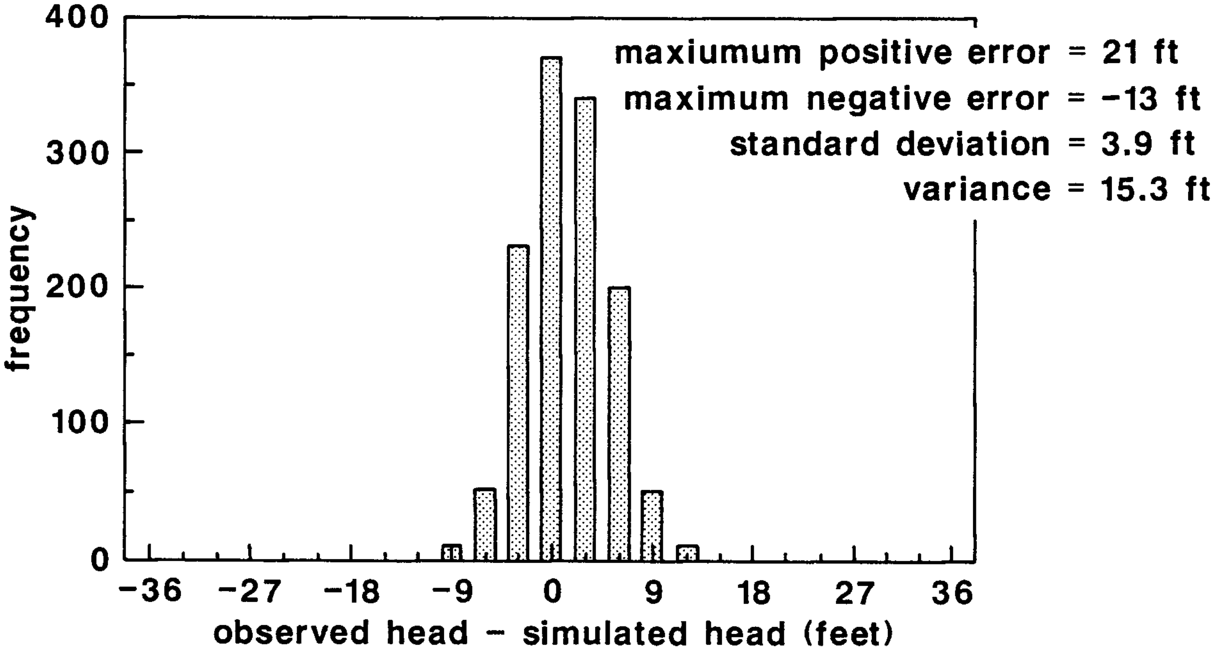


Figure 12. Histogram of error distribution for 1971 water table (observed head vs. simulated head).

management model. The storage coefficient was set at 0.15 and assigned uniformly to all active nodes. The results were then analyzed statistically by comparing the 1971 simulated water table with the observed 1971 water table. The histogram in Fig. 12 shows that the assumed parameters yield a satisfying head distribution since the standard deviation between the observed and calculated head is of the order of 4.4 ft. Furthermore the histogram displays a normal error distribution. Fig. 13 shows the comparison of the calculated hydraulic head contours with the observed head for 1971. The contour lines match closely, showing that the choice of the parameters, including 0.15 for the storage coefficient, is satisfactory.

4.1.5 Validation of Flow Model

The flow model developed at this point must be further validated. Hydraulic heads were calculated for the end of 1979 using the previously defined model. They were then compared with the water-table distribution observed in early 1980. The results are shown on Figs. 14 and 15. The histogram (Fig. 14) displays a normal distribution of the error (obs. head - calc. head) with a standard deviation of 3.9 ft. Therefore we concluded that the parameters and boundary conditions assumed for the flow model adequately represent the general condition of the aquifer. These parameters and boundary conditions are presented for each node in Table 1 of Appendix II.

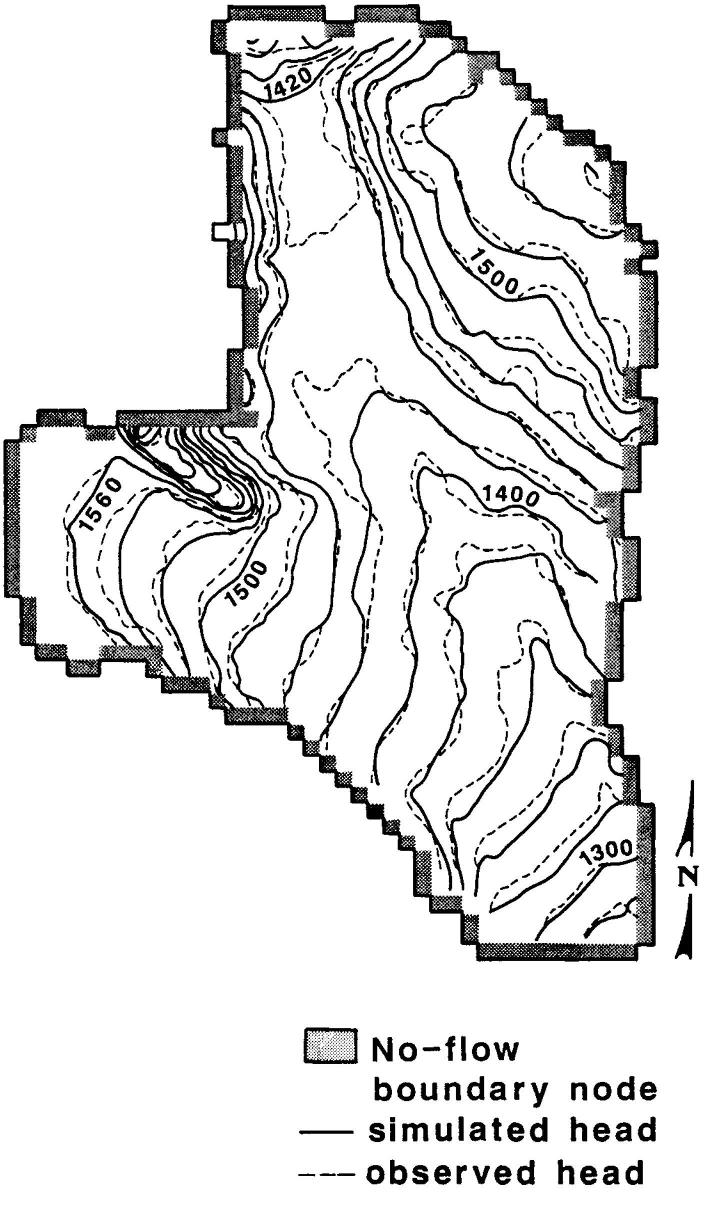


Figure 13. Simulated vs. observed head for 1971 in Equus Beds aquifer.

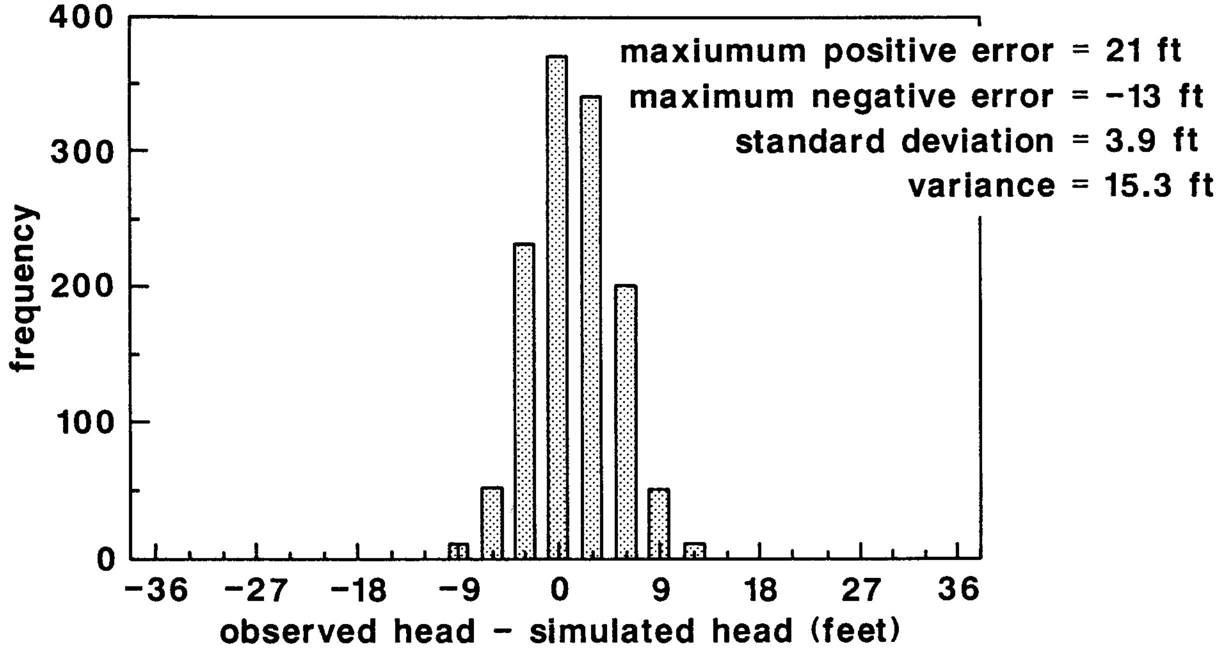


Figure 14. Histogram of error distribution for 1980 water table (observed head vs. simulated head).

Figure 15. Simulated vs. observed head for 1980 in Equus Beds aquifer.

point k:

$$\sum_{j=1}^{M_2} \sum_{n'=n_1+1}^{n} \beta_{vx}(k,j,n-n'+1)\; p_2(j,n') \overset{<}{>} v_x(k,n) \qquad (29\text{-a})$$

$$\sum_{j=1}^{M_2} \sum_{n'=n_1+1}^{n} \beta_{vy}(k,j,n-n'+1)\; p_2(j,n') \overset{<}{>} v_y(k,n) \qquad (29\text{-b})$$

where k = 1, . . . , K is the number of the observation points, and v_x and v_y are the summations of the first two terms on the right-hand side of (28-a) and (28-b). The signs of the equations in (29-a) and (29-b) depend on the signs of v_x and v_y (see Colarullo et al., 1985). In these equations v_x and v_y represent the velocities at a particular point k, at time $n > n_1$ if pumpage policy p_1 were in effect from time step 1 to n_1. The left-hand side of these equations represents the induced velocities due to pumpage policy p_2 initiated during time period from $n_1 + 1$ to n, which will reverse or neutralize v_x and v_y. Then depending on what the signs of v_x and v_y are at time-period n, a proper sign for these equations must be chosen.

The objective function (13) together with constraints (14-a) through (14-d) represents a linear-programming model which can be solved with readily available packages such as MINOS (Murtagh and Saunders, 1977) or LINDO (Schrage, 1981).

4.2.2 Application of Management Model

The management model was applied to the area of the aquifer shown in Fig. 16. The reasoning for the choice of this area was based on the location of the 500-ppm contour of the plume shown in Fig. 16. Within the management area

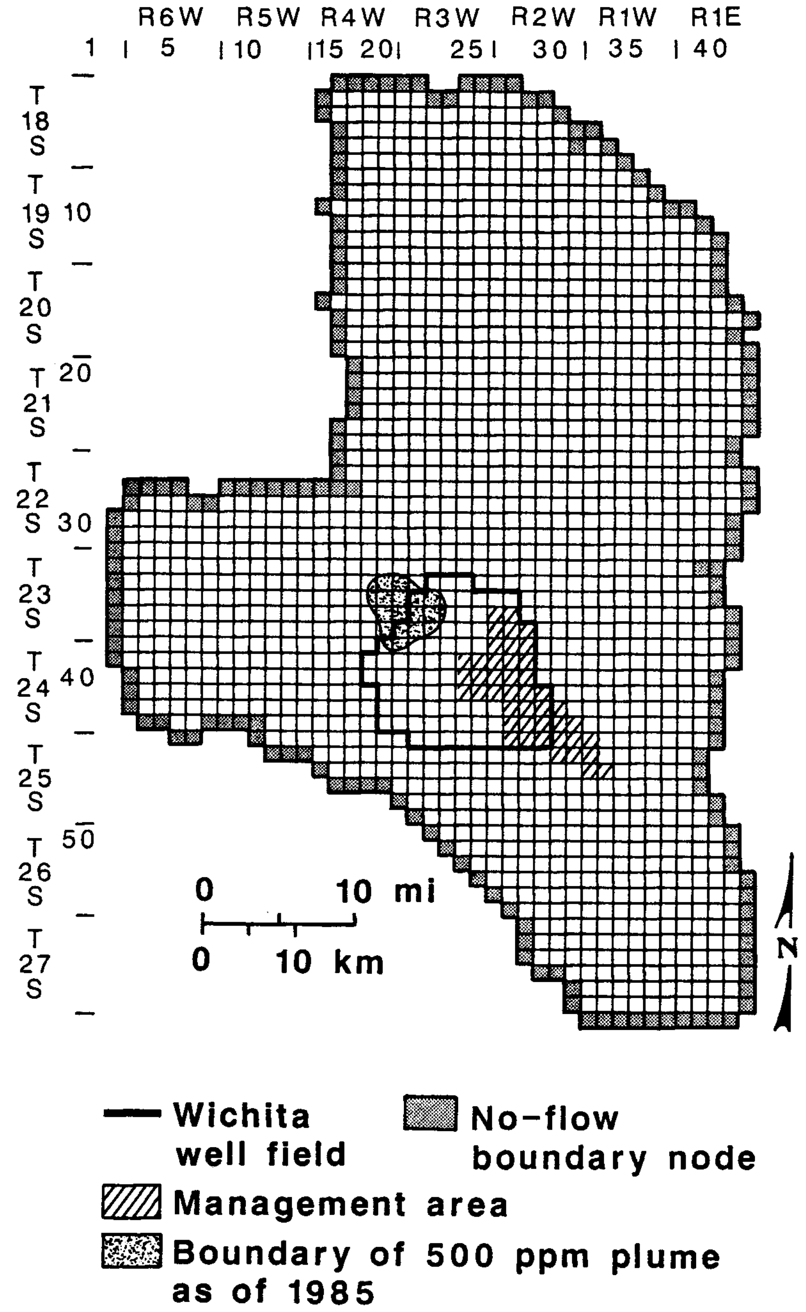


Figure 16. Location of management area.

as of 1985, a total of 35.7 cfs is allocated for irrigation, industry, and municipalities. Fig. 17 shows the location of the nodes within this area and the 1985 pumpages based on Division of Water Resources allocation of ground water in the vicinity of each node. The management model seeks to find new policies for nodes within the management area which will achieve the objectives of this study. Other nodes in the model (outside the management area) were kept at the pumpage rates of 1985. The management period was set from 1985 to 2020. Based on the ground-water-withdrawal rates given in Fig. 6, five periods of constant-pumpage rates were established for each node from 1940 to 1985. Table 3 of Appendix II lists these pumpages for the five time periods for all nodes. This variation in pumpage rates has affected the velocities in the study area.

In Figs. 18-a and 18-b the groundwater flow velocities at eight observation points are plotted versus time. In calculating these velocities the pumpages of Table 3 of Appendix II were used from 1940 to 1985, and pumpages of 1985 were assumed to remain constant to the year 2020. Velocities responding to the changes in pumpage policies from period to period can be observed. With constant pumpage of 1985, the velocities become constant at about 1995. In Figs. 19-a and 19-b the changes of velocities with time at the same nodes are plotted versus time. From 1940 to about 1960, some nodes are decelerating. However, with the unusual increase in pumpage starting at about 1960 (see Fig. 3), a considerable increase in velocities occured. Figs. 18 and 19 are indicative of the transient water level in this area. Therefore, the steady-state condition assumed by Sophocleous (1984) is not prevailed.

.0 freshwater discharge (cfs)

				0.	0.	0.					
			0.	.2	.37	0.	0.	.31	.45		
			.13	0.	.27	0.	0.	.28	2.35		
		.01	0.	0.	0.	0.	0.	.39	1.32	.16	
	.14	0.	0.	0.	0.	0.	.52	.59	.12	0	
.04	0.	0.	0.	0.	0.	.25	.11	.11	3.17	2.33	
.28	.19	0.	.16	.24	.54	0.	0.	.0	1.09	2.96	
	0.	.21	.26	.36	.39	.69	.05	.11	.1	.21	1.22
	.1	.15	.08	.14	.03	.61	.11	.21	.36	3.52	.76
	0.	.17	.24	0.	.47	.27	.11	.16	.26	.13	.09
			.03	0.	.33	.03	.22	.29	4.06	.09	0.

Figure 17. 1971-1985 pumpage rates (cfs) in management area.

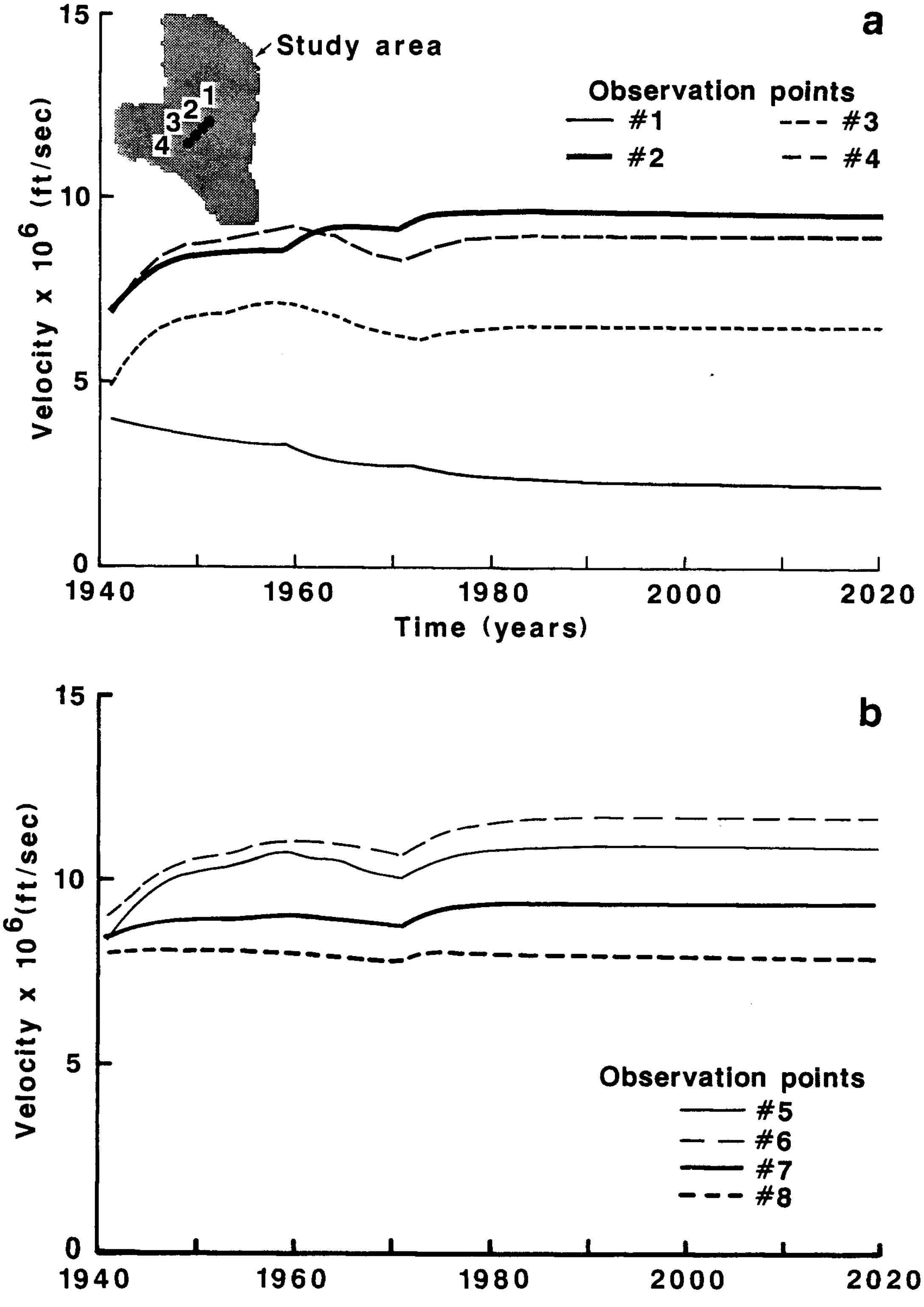


Figure 18. Velocity variations vs. time for selected observation points.

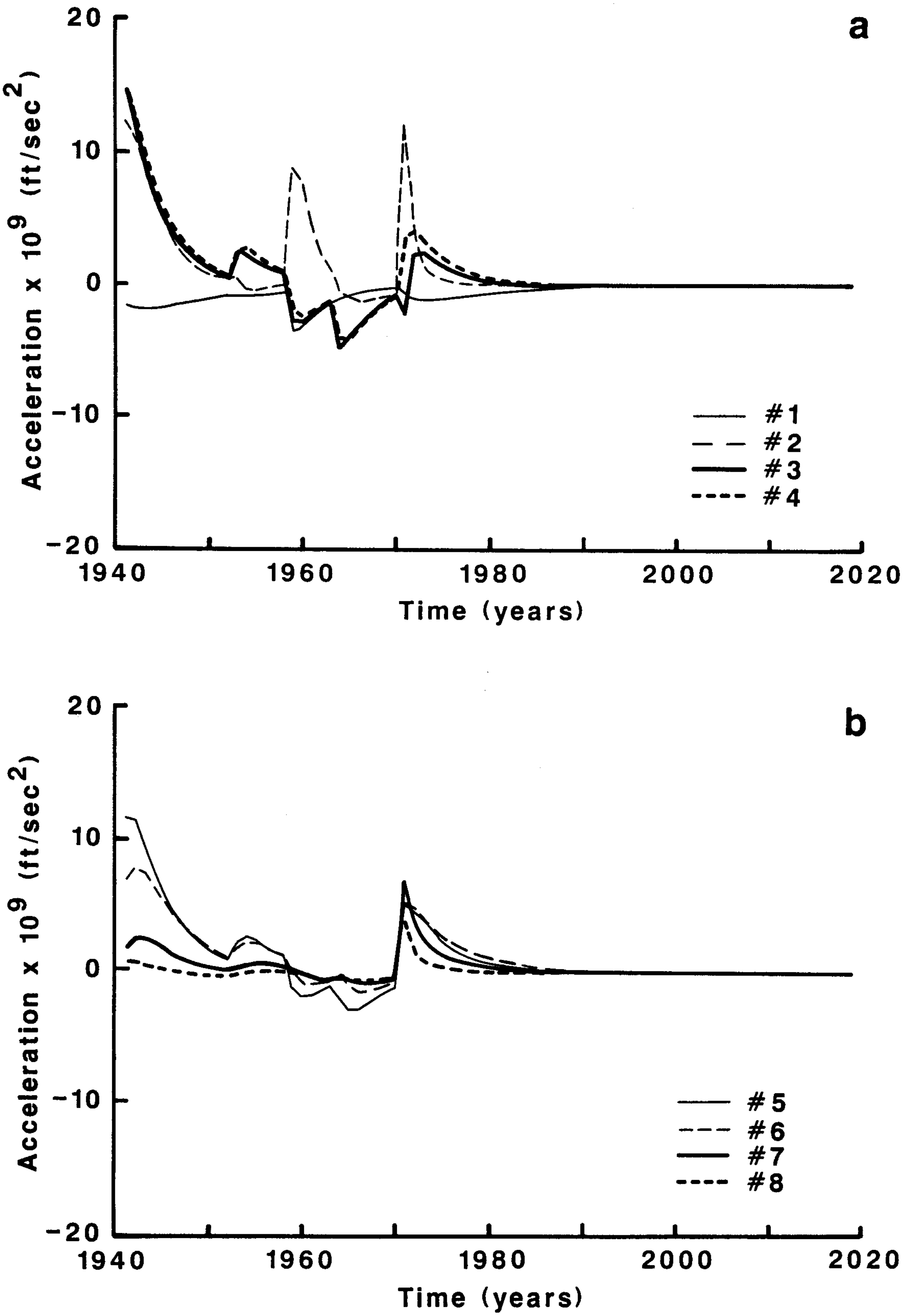


Figure 19. Variations of velocity with time vs. time for selected observation points.

4.2.3 Results of Management Model

In application of the management model to the management area, three different management plans were considered. These plans and their results are described below.

4.2.3 - a) Management Plan A:

In this plan pumpage rates in the management area given in Fig. 17 were assumed to be kept constant to year 2020. Then, interception wells were placed along the 500-ppm-contour line of the plume to neutralize the plume's rate of advancement at specified observation points. In Fig. 20 the 1985 velocity directions and the location of the interception wells and the observation points are shown for this scenario. The arrows designating the velocities as shown in this figure do not represent the magnitude of the actual velocity vectors. This is because in this figure, all velocities were to be shown no matter how small or large. This figure may be used to conclude the direction of water flow. In the upper left of Fig. 20, the velocity vectors within the window are plotted to scale. The actual velocity vectors in Fig. 20 may be used to compare the relative magnitude of velocities within the window. In Table 1 of Appendix III, the magnitude of velocities in the x and y directions for the observation points within the window of Fig. 20 to be neutralized by the interception wells are listed for years 1985 to 2020. These relatively high velocities are indicative of the amount of interception pumpage which has to be carried on for their neutralization. In Fig. 21, the total optimum pumpage of the interception wells is plotted versus time. The initial interception rate during the first year is 90.15 cfs, a pumpage rate whose economic feasibility is seriously questioned. In Table 2 of Appendix III, the pumpage rate of the interception wells are listed for years 1985 to

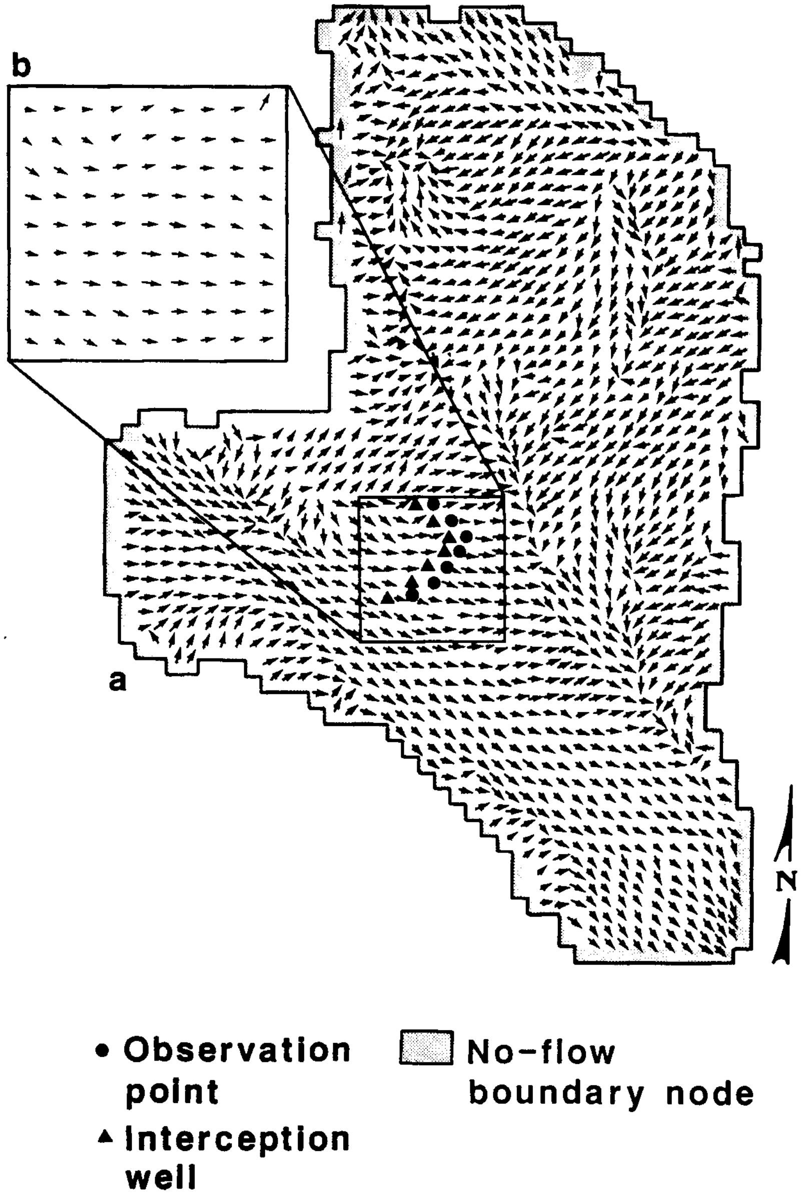


Figure 20. 1985 velocity field, boundary of management area, and location of interception wells and velocity-observation points for Management Plan A.

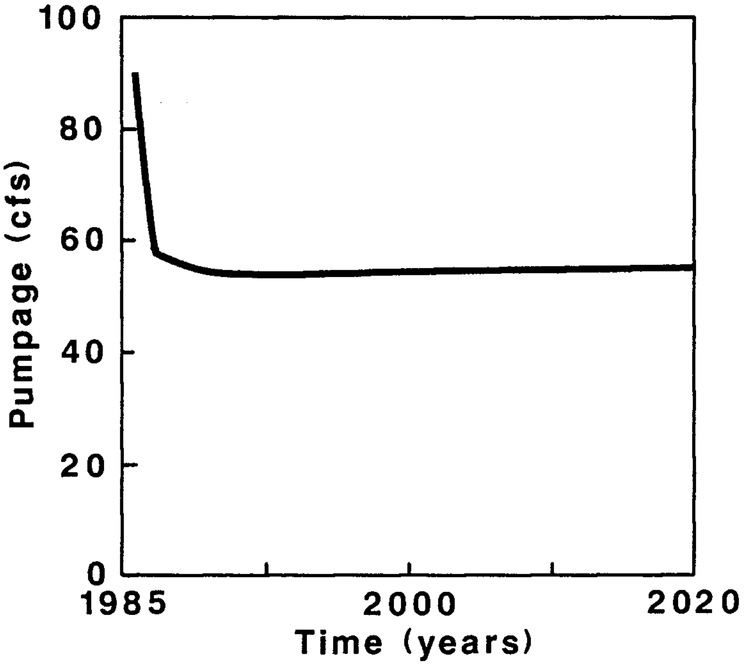


Figure 21. Optimal brine-interception rate vs. time for Management Plan A.

2020. These high pumpage rates are required in order to reverse the velocity vectors of the observation points listed in Table 1 of Appendix III. These rates drop to a total of 55 cfs after 3 years of interception and remain constant to year 2020. The reason that the rates remain constant is that other pumpages in the management area remain constant to year 2020, and therefore the system reaches steady state in about 3 years. In Fig. 22 the velocity directions for the entire aquifer are shown for year 1986 after the interception pumpages started. This pattern of velocity reversals is observed for other time steps in the management period. It must be emphasized again that the arrows in Fig. 22 show the direction of water movement and not the relative magnitude of velocity vectors. The actual velocity vectors one year after the initiation of the interception for the window shown in Fig. 20 are plotted to scale in the upper left of Fig. 22. A comparison of this figure with Fig. 20 reveals that velocity vectors at the observation points are either reversed or their magnitudes have been made very small. After one year of interception (Fig. 22), the interception wells have created a stagnation zone in front of the plume. This stagnation zone is kept to year 2020 by the total pumpage rate given in Fig. 21. In Fig. 22, velocity vectors are representative of the average velocities over each cell. They do not represent the velocity vectors at the pumping wells which by definition are infinity. The overall effect of the pumpage at the interception wells is that the direction and magnitude of the velocities at the observation points are changed drastically.

4.2.3 - b) <u>Management Plan B</u>:

In this plan, the freshwater pumpage rates were included together with the pumpage rates of the interception wells in the management area as

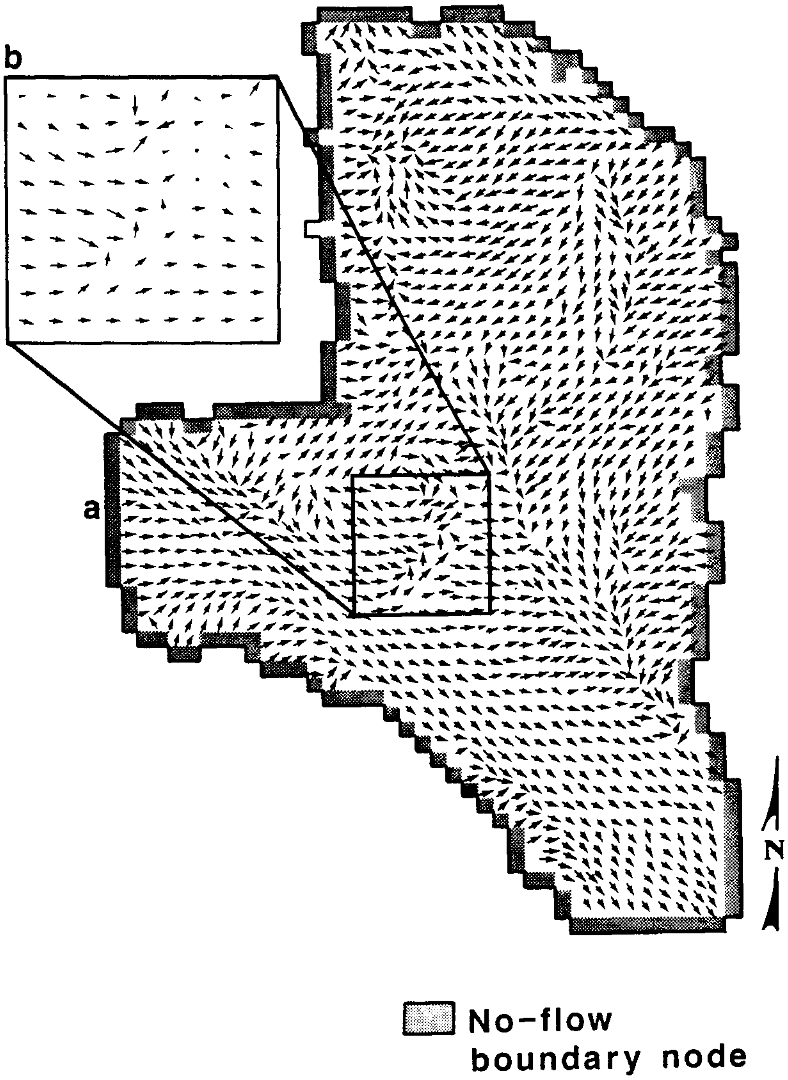


Figure 22. 1986 velocity field obtained from results of Management Plan A.

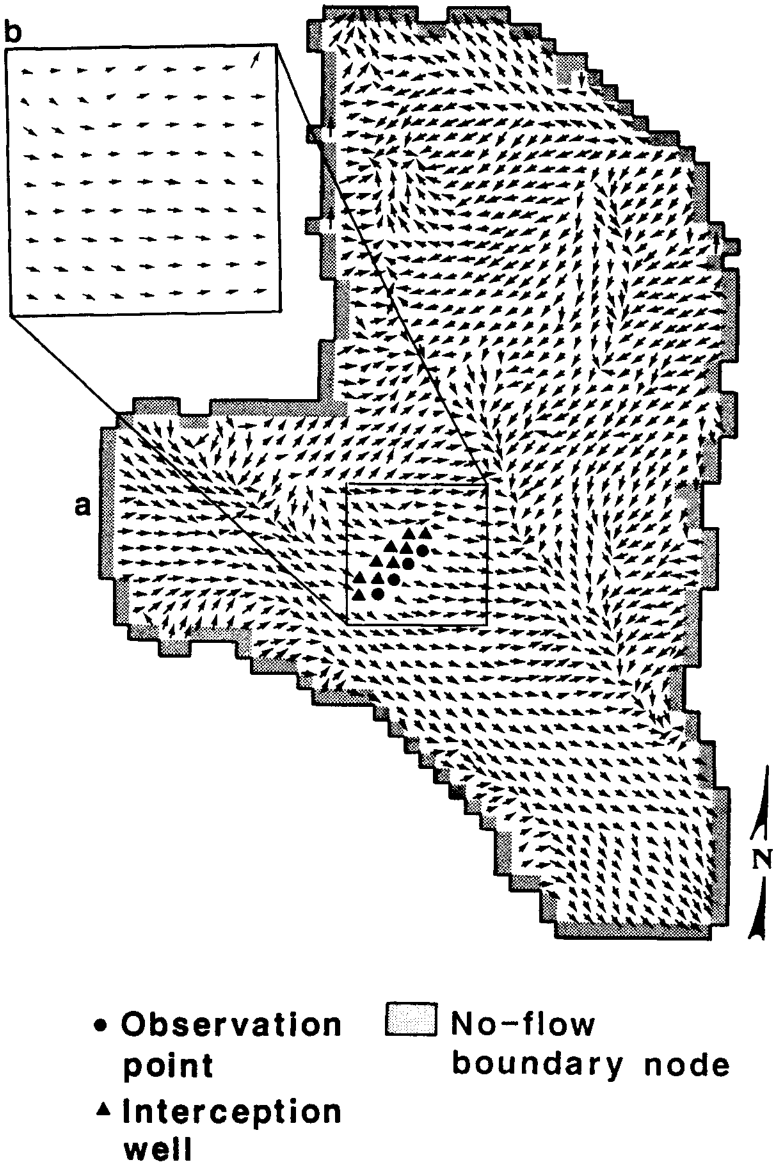


Figure 23a. Boundary of management area, location of velocity-observation points and brine-interception wells for Management Plan B.

unknowns. The interception wells and observation-point configuration together with the fresh-water nodes are shown in Figs. 23-a and b. In Table 3 of Appendix III the velocity vectors in the x and y directions for each observation point in this plan are listed for years 1985 to 2020. These vectors were calculated by setting the pumpage within the management area equal to zero and by keeping the pumpages outside the management area constant. For a management period from 1985 to 2020 (35 years) there exist 78 X 35 fresh-water-pumping-rate unknowns and 13 X 35 brine-interception pumping-rate unknowns, totaling 3185 unknowns. The respective linear-programming model will have a total of 3185 columns and 3185 + 2 (4 X 35) + 35 + 1 rows. The 3185 constraints are associated with the drawdown constraints. Because there are four velocity-observation points, and for each point during each time step two velocity constraints (x and y directions) must be satisfied, a total of 280 velocity constraints exist. During each time step the total fresh-water demand adds a total of 35 fresh-water-demand contraints. Finally there is the objective row, which when added to the other constraints generates a total of 3501 rows. Since the solution of an LP model with 3185 columns and 3501 rows is beyond the capability of the available computing facilities, the decomposition technique described in Chapter 3 was used. A total of 10 arbitrary zones were set up as shown in Fig. 23-b. In doing so some interception wells had to be divided between two adjacent cells. This is because of the nature of the decomposition technique described in Chapter 3. During each iteration, each cell must have the capability to control its own velocity vectors as well as velocity vectors in the adjacent cells. Therefore, if an interception well is located on the boundary between two cells, its pumpage must be divided into two unknowns which must be calculated during the solution of the LP models for those cells. During each time step, 10 small LP models were solved iteratively until the convergence criterion (23) was satisfied for all cells and all wells. ε was set equal to .01 cfs.

To satisfy the freshwater demand, the total freshwater demand was divided among the 10 cells proportional to the allocated rights in each cell. Table 1 lists the freshwater demand for each of the 10 cells.

Cell	1985 Freshwater Demand	
1	2.88	
2	2.79	
3	3.40	
4	3.72	
5	3.87	
6	5.08	
7	3.70	
8	3.87	
9	3.78	
10	2.91	
	36.00 cfs	TOTAL

TABLE 1. Freshwater-demand distribution in management area.

The decomposition reduced the size of the LP models effectively. The largest LP model had 561 rows and 455 columns which could be solved easily on the minicomputer Data General MV-8000.

In Fig. 24, the total-optimum pumpage (freshwater and intercepted water), the freshwater pumpage, and the intercepted water are plotted versus time. As can be observed, the total freshwater demand of 36 cfs is constantly satisfied. However, the interception rate which starts at 55.22 cfs for 1986 and drops to a constant value of 42.5 cfs in year 2020 clearly is not economically a viable option. In Table 4-a and b of Appendix III, the pumpage rates of the interception wells and freshwater wells are listed. The pumpage rates of the freshwater wells remain constant with time. Therefore only one value is listed. Since the pumpage rates of the interception wells change with time, they are listed for each year in the management period. In Fig. 25 the velocity distribution for one year after the initiation of the interception is plotted. Fig. 25 also includes the actual velocity vectors of the nodes within the window of Fig. 20. As may be seen the velocities at the observation points have been diverted toward the interception wells or neutralized effectively.

4.2.3 - c) <u>Management Plan C:</u>

In this plan the re-allocation procedure for freshwater demand subject to neutralization of velocity vectors in the management area of Fig. 20 was repeated for a different set of interception wells and observation points. The location of these wells and points together with the nodes used for pumpage of freshwater are shown in Fig. 28-a.

In Table 5 of Appendix III the velocity vectors for the observation points for year 1985 to 2020 to be neutralized by the management model are

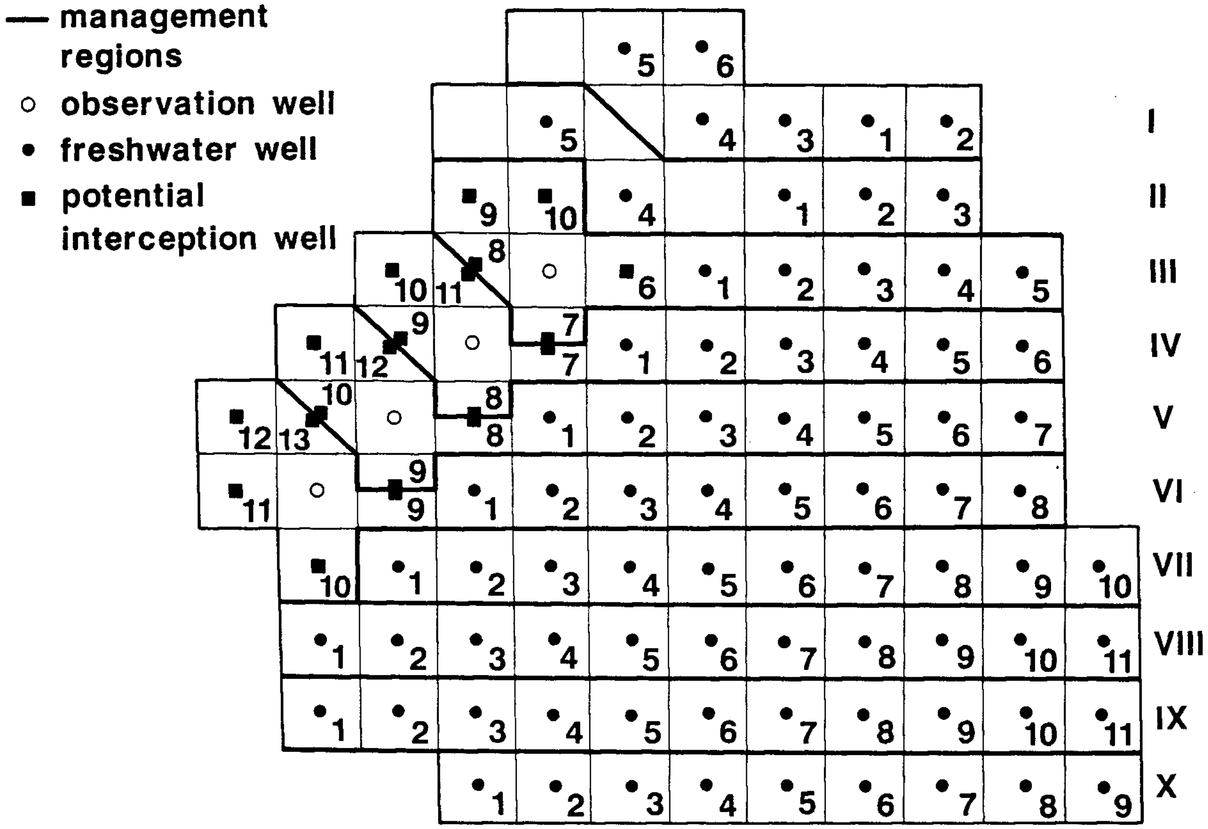


Figure 23b. Location of cells, fresh-water wells, velocity-observation points, and brine-interception wells for Management Plan B.

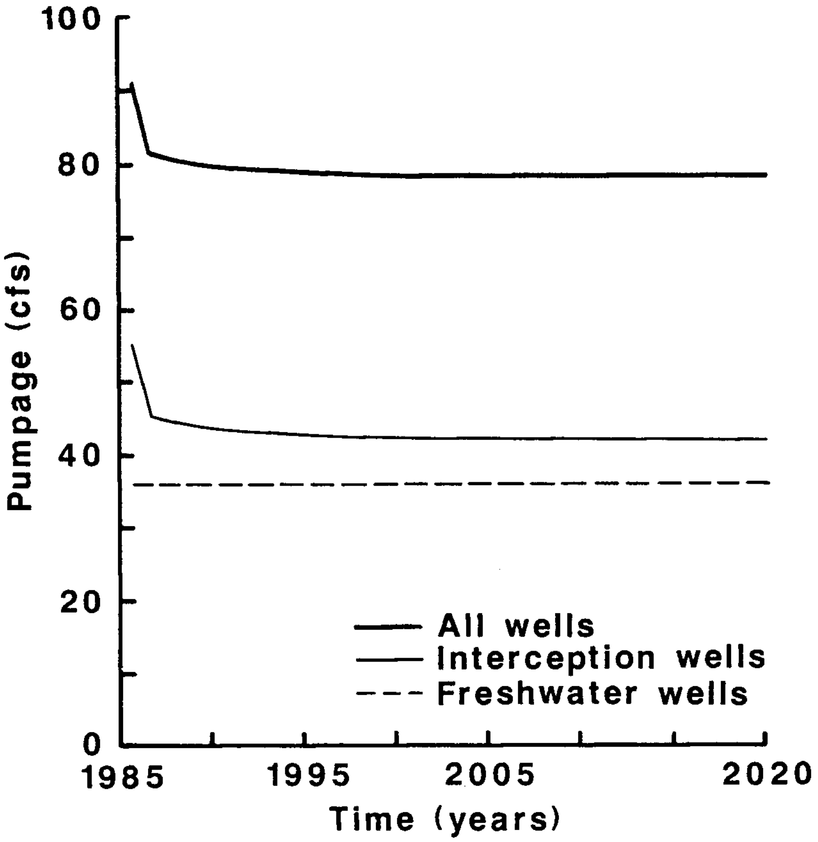


Figure 24. Optimal pumpage rates for Management Plan B.

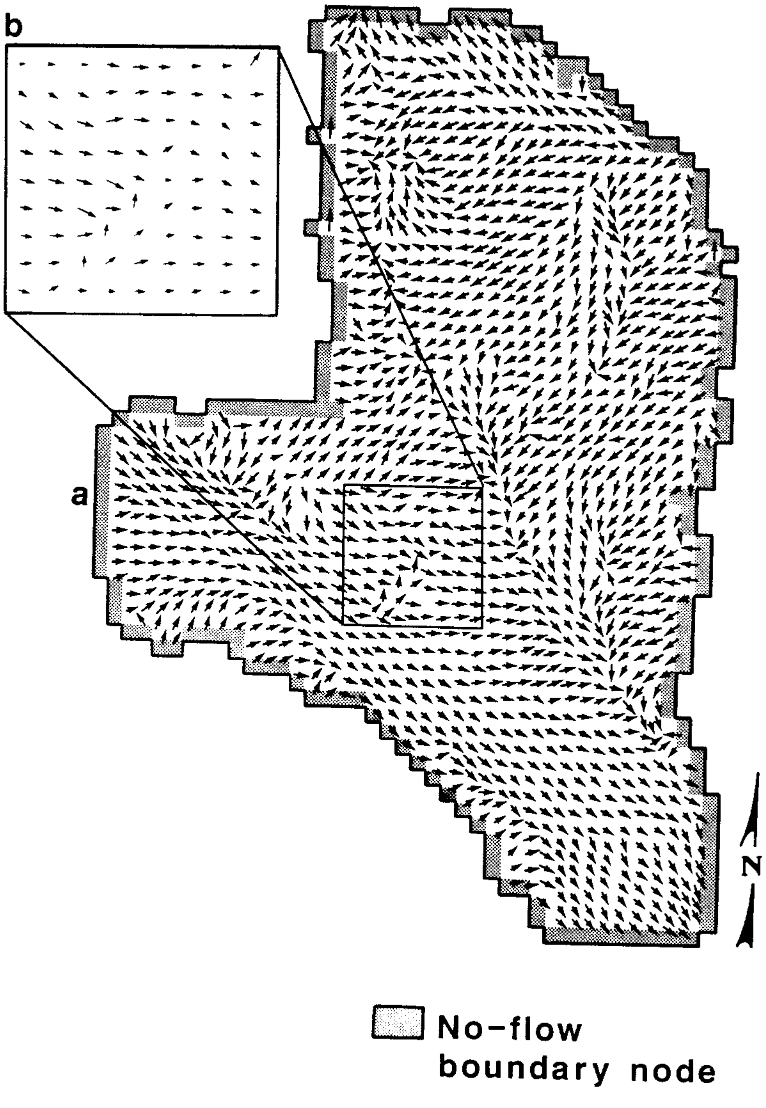


Figure 25. 1986 velocity field obtained from results of Management Plan B.

listed. These vectors were calculated by setting the pumpage rates of the nodes within the management area to zero and keeping the pumpage rate outside this area to the level of 1985.

The LP model for this plan contains 3115 unknowns representing the pumpage rates for 89 active nodes. It contains 3115 constraint rows representing the drawdown constraints, 280 constraint rows representing the velocity constraints, 35 constraint rows representing the demand constraints, and 1 row representing the objective function. Since the solution of an LP model consisting of 3115 columns and 3431 rows with the available computing facilities was not possible, the area was decomposed into 10 zones as shown in Fig. 26-b. This decomposition generated 10 LP models whose solution was obtained iteratively on minicomputer Data General MV-8000.

In Fig. 27 the total pumpage rate (freshwater and intercepted water), freshwater-pumpage rate, and intercepted-water-pumpage rate are plotted versus time. The freshwater-pumpage rates are constantly satisfied at the rate of 35 cfs. In Table 6-a and b of Appendix III the optimal freshwater-pumpage rates and interception-pumpage rates for this plan are listed.

The interception-pumpage rate starts at 51.42 cfs in 1985 and drops to about 35 cfs in seven years. Table 7 of Appendix II lists the optimal pumpage rates of the interception wells for each year. Again this plan produced an unrealistic interception pumpage rate.

In Fig. 28 the directions of flow are shown for the entire aquifer after one year of brine interception. In the upper left of Fig. 28, the actual velocity vectors after one year of interception within the window shown in Fig. 20 are plotted to scale for comparison purposes. The velocity vectors at observation points are redirected or reduced to a very small value. However,

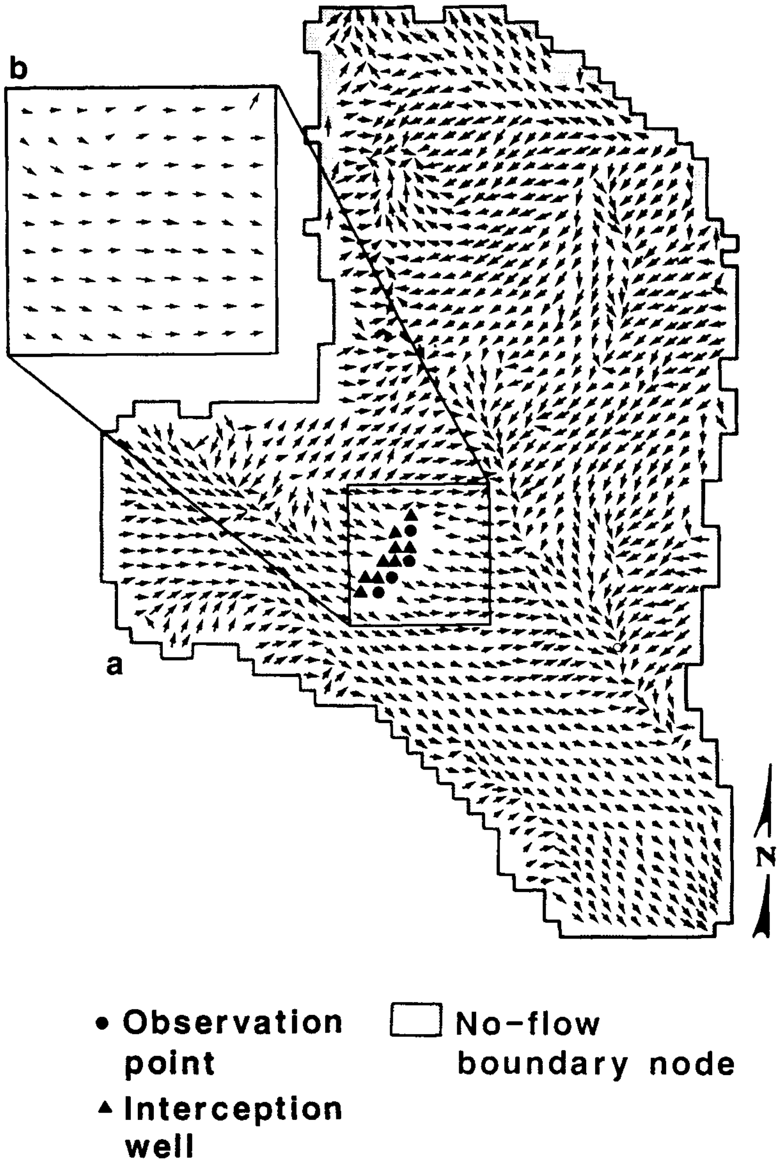


Figure 26a. Boundary of management area and location of velocity-observation points and brine-interception wells for Management Plan C.

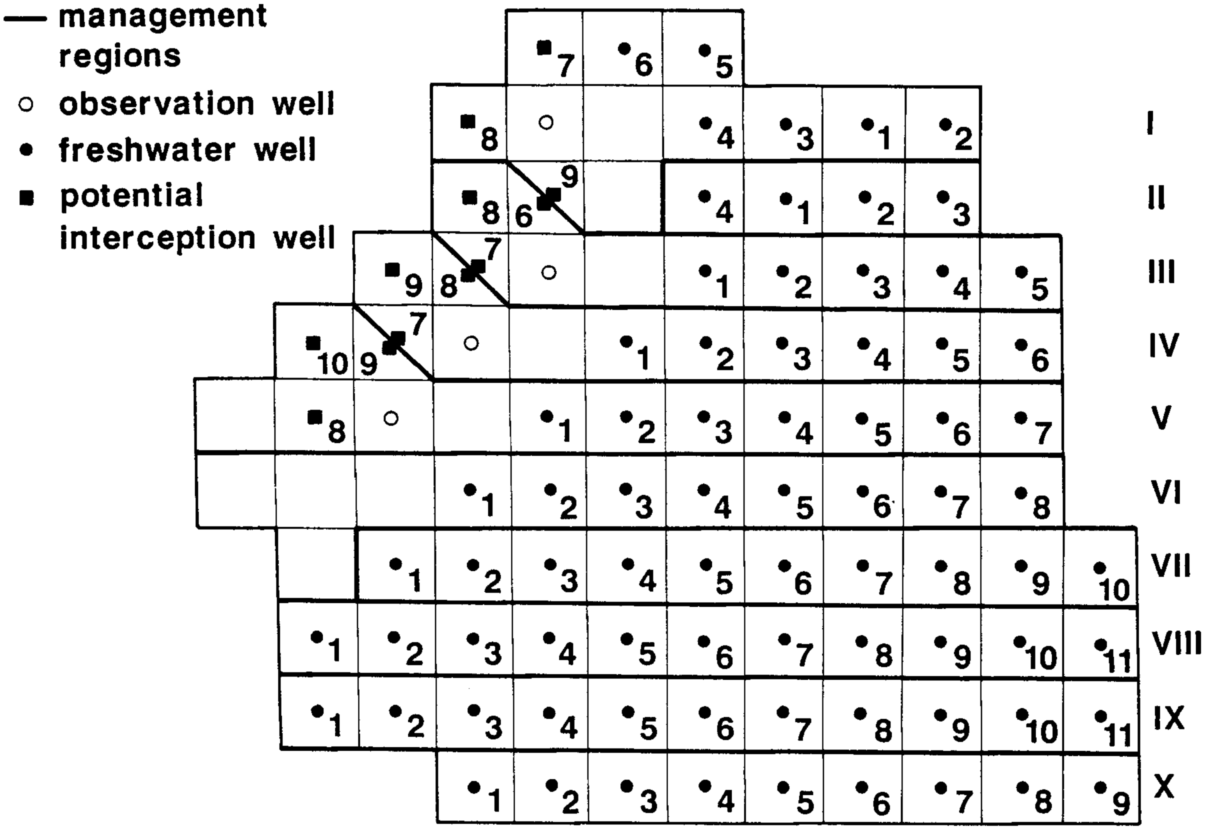


Figure 26b. Location of cells, freshwater wells, velocity-observation points, and brine-interception wells for Management Plan C.

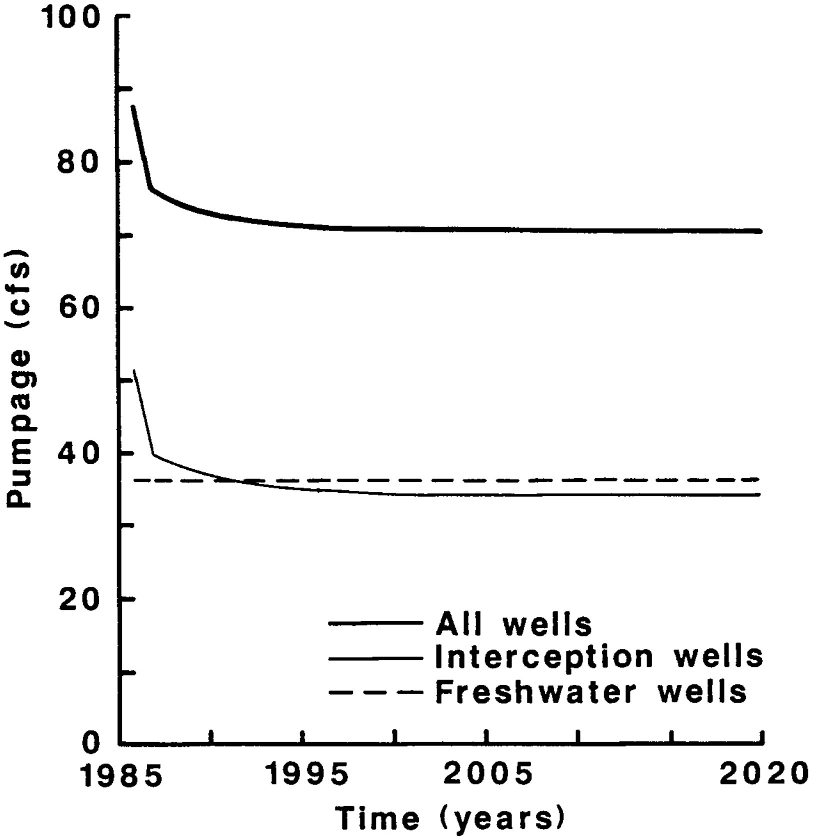


Figure 27. Optimal pumpage rates for Management Plan C.

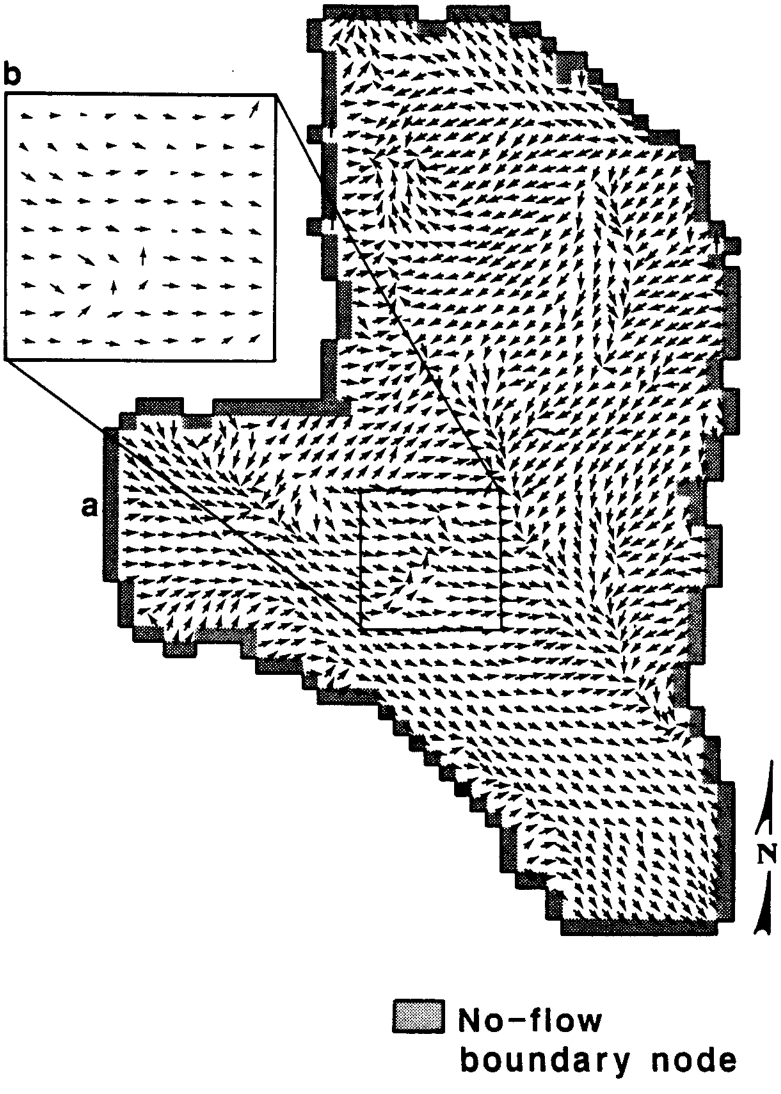


Figure 28. 1986 velocity field obtained from results of Management Plan C.

a velocity vector associated with the interception well seems to be still active.

As will be shown in the next chapter, the three management plans reverse the movement of the pollutant from the north west to the city wells. It will be also shown that management plan A is most effective from the point of view of speed in clean up. However, as was shown this is also the most expensive plan. Therefore, depending on the urgency to clean up the pollutant, one may choose plan A which is the most efficient or other two plans which are less efficient but also less expensive.

Chapter 5

TRANSIENT MODELING OF CHLORIDE MOVEMENT

In this chapter, a solute-transport model is used to determine the extent of the chloride movement over a selected area of the Equus Beds aquifer where a major well field supplies water for the city of Wichita. We start the modeling analysis by specifying initial and boundary conditions and assigning appropriate hydrogeologic parameters to all nodes in the aquifer. Subsequently, the model will be evaluated mainly on the basis of available observed chloride distributions. The injection rate and concentration of contamination sources required for modeling analysis are obtained from previous hydrologic reports of the same area. Once the process of model evaluation is satisfactorily completed, the model will be used to study the effects of proposed ground-water withdrawal and management policies on the migration of contaminants throughout the ground-water system.

5.1 Solute-transport Process

The major components of the transport process in a ground-water-aquifer system are advection and dispersion (including molecular diffusion). Advection is a process by which fluid particles are moved as a result of pressure and elevation differences, while dispersion refers to the mixing and spreading of liquid particles caused by molecular diffusion, pore-size scale variations of velocity, and large-scale heterogeneities. The effects of chemical reactions and ion exchange on solute concentration are negligible for most field problems and are not considered in our analysis. Moreover, the density and viscosity are assumed to be constant and independent of the concentration.

The transport of a dissolved-chemical species in flowing ground water is mathematically described by the solute-mass continuity equation or the so-called advection-dispersion equation. The two-dimensional transient form of the transport equation for a conservative (nonreactive) solute may be written as (Bear, 1979)

$$\frac{\partial}{\partial x_i}(bD_{ij}\frac{\partial c}{\partial x_j}) - \frac{\partial}{\partial x_i}(bcv_i) - \frac{\tilde{c}W}{\theta} = \frac{\partial(c \cdot b)}{\partial t} \qquad (30)$$

where c(x,y,t) is the solute concentration, M/L^3; b is the saturated thickness of the aquifer, L; D_{ij} is the hydrodynamic dispersion tensor, L^2/T; v_i is the seepage or average pore velocity, L/T; $\tilde{c}$ is the solute concentration in a source or sink fluid, M/L^3; W is the net volume flux [(Q + R in Eq. (1)] per unit area at a source or sink, L/T; θ is the effective porosity of the aquifer, dimensionless; x_i, x_j are the spatial coordinates, L; and t is the time variable, T.

The term on the right side of equation (30) represents the temporal variation of the solute concentration within the system. The changes in concentration due to the hydrodynamic dispersion, advective transport, and fluid sources and sinks are described by their respective terms on the left side of equation (30).

The seepage velocity, v_i, required for solution of the transport equation is derived by simultaneous solutions of the ground-water-flow or fluid-continuity equation and the Darcy equation. The ground-water-governing equation for the two-dimensional transient flow in an inhomogeneous and anisotropic aquifer is represented by (Bear, 1979)

$$\frac{\partial}{\partial x_i}(T_{ij}\frac{\partial h}{\partial x_j}) = S\frac{\partial h}{\partial t} + W \qquad (31)$$

where h(x,y,t) is the hydraulic head or water-level elevation, L; T_{ij} is the transmissivity tensor, L^2/T; S is the storage coefficient, dimensionless; and W, x, and t are as defined previously.

The hyraulic-head function calculated from equation (31) is inserted into the Darcy equation to compute the distribution of the seepage-velocity field, v_i:

$$v_i = -\frac{K_{ij}}{\theta}\frac{\partial h}{\partial x_j} \qquad (32)$$

Note that in equation (32), K_{ij} is the hydraulic-conductivity tensor, which is related to the transmissivity by the expression $T_{ij} = bK_{ij}$.

In summary, the equations for solute-mass continuity, fluid continuity, and seepage velocity, respectively, equations (30), (31), and (32), together with a set of initial and boundary conditions provide a complete mathematical description of the solute-transport process. One has to start the transport simulation by solving equations (31) and (32) first. The velocity distribution resulted from solution of these equations is, then, used to define the advective-transport term in equation (30) and also to derive the values of the hydrodynamic-dispersion coefficients which depend on the velocity. Subsequently, equation (1) is solved to find the spatial and temporal variation of the solute concentration in the ground-water system.

5.2 Numerical Model

The U.S. Geological Survey solute-transport model (Konikow and Bredehoeft, 1978) selected for our analysis is one of the most widely used models for predictions of contaminant movements in actual field situations. The model combines finite-difference solutions to the ground-water-flow and seepage-velocity equations with the method of characteristics solution to the solute-transport equation. The set of approximate equations from ground-water-flow equation are solved using an iterative alternating-direction implicit procedure.

In the method of characteristics, the numerical solution of the solute-transport equation is achieved by introducing a set of moving points that can be traced with reference to the stationary coordinates of the finite-difference grid. Each point has a concentration associated with it and is moved through the flow system in proportion to the time increment and the velocity at the location of the point. The moving points simulate advective transport because the average concentration over each cell of the finite-difference grid will change with time as different points enter and leave the area of the cell. The additional changes in concentration caused by hydrodynamic dispersion and fluid sources are computed using an explicit finite-difference equation. More details of the numerical procedures used in the model may be obtained by referring to Konikow and Bredehoeff (1978).

5.3 Area of Investigation

For practical reasons, the location of study is limited to a 560 mi^2 area in the south-central part of the Equus Beds aquifer (Fig. 29). The study area contains the main brine-pollution sources near the city of Burrton and a well field which is a significant source of water supply for the city of Wichita. The areas of the Equus Beds aquifer not to be affected by the pollution are excluded from this analysis. The Arkansas River along the southwestern boundary and Little Arkansas River in the north are the two major streams in the region. Note that the selected area for solute-transport investigation contains the area considered previously for exploring the pollution-containment options.

The area of interest is subdivided into a network of rectangular, uniformally spaced cells which constitutes the finite-difference grid (Fig.

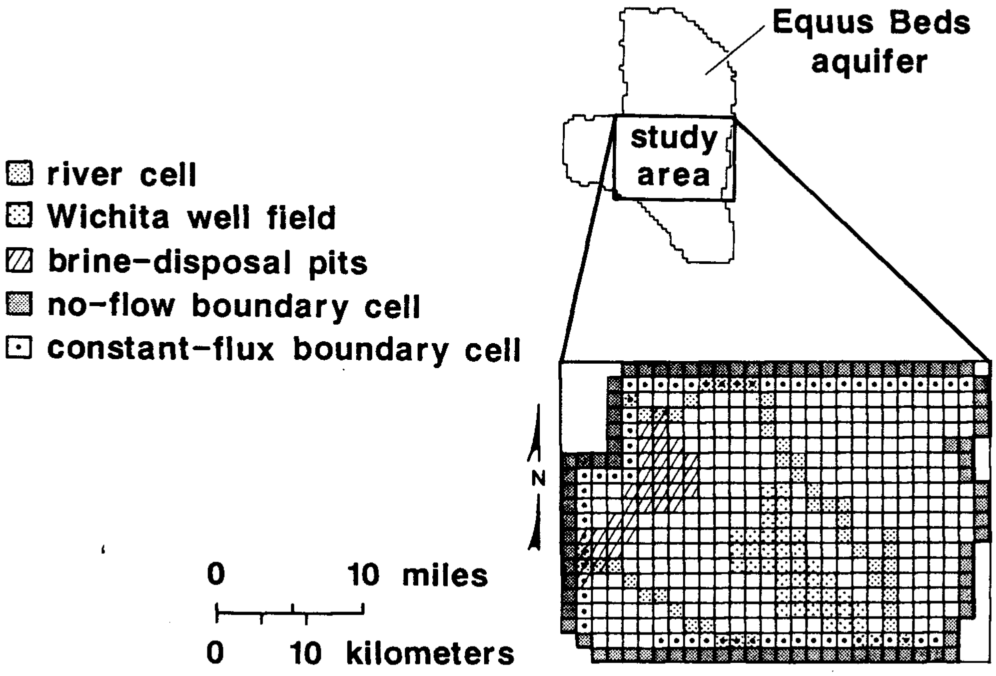


Figure 29. Location of study area for solute-transport modeling.

29). Each cell has dimensions of 1 mile by 1 mile. A total number of 451 active cells are in the area. The model is based on the block-centered finite-difference grid; in other words, associated with each cell are average values of solute concentration, water-level elevation, and any other hydrogeologic parameter defined at the center of the numerical block.

5.4 Sources of Contamination

As described before, the main source of ground-water contamination in the study area is believed to be the brine-disposal ponds used during the oil-recovery operations of the 1930's and 1940's (Williams and Lohman, 1949; Leonard and Kleinschmidt, 1976). Initially, the brine had leaked from the ponds into the soil and alluvial aquifer causing localized pollution of water supplies in the vicinity of the city of Burrton. Since then, the saline water has been gradually carried eastward and south-eastward in the general direction of ground-water flow.

Spinazola et al. (1985) have analyzed published and unpublished information about the brine-disposal ponds and concluded that the major brine penetration into the aquifer had occurred between 1932 and 1943. The total volume of brine estimated by Spinazola et al. (1985) was distributed over the areas where surface-disposal "evaporation pits" were located (Fig. 1). For modeling purposes, these areas were assigned a high chloride-concentration distribution during 1940, which was determined by mixing the volume of brine entering each section with volume of water in storage beneath that section (Spinazola et al., 1985). This same information has been provided by Spinazola et al. (1985) and will be used in our solute-transport analysis.

In addition to the oil-field brine, the high concentration of chloride in the Arkansas River is known to have been contributing to the deterioration of ground-water quality through the stream-aquifer interaction. However, the extent of the saline-water pollution, in this case, has been limited to the areas adjacent to the river. The numerical model incorporates the effects of the Arkansas River into simulation by assigning high chloride concentration to the leakage flux at the stream cells.

Several other sources of chloride contamination are in the study area such as upwelling of brine from the lower Permian Wellington Formation or leakage of brine from corroded and improperly cased disposal wells (Leonard and Kleinschmidt, 1976). These sources have, however, been recognized as small-scale problems and will not have any significant effects on the regional ground-water quality.

5.5 Required Input Data for Solute-transport Modeling

In addition to the contaminant-source information, the solute-transport modeling requires prior knowledge about the boundary conditions, the initial distributions of hydraulic head and solute concentration, various aquifer hydrogeologic parameters, natural recharge, leakage from stream-aquifer interactions, and the rates and locations of pumping wells. In chapter 4, we described the specified values of some of this information obtained from Spinazola et al. (1985) for an area which covers the entire Equus Beds aquifer and contains the selected area for solute-transport analysis. Utilizing the same information, appropriate values of hydraulic conductivity, natural recharge, storage coefficient, porosity, and discharge rates were assigned to the corresponding numerical cells of the area under investigation. The specification of the remaining input data requires a more detailed explanation.

An accurate initial description of water quality in the aquifer is essential if reliable projections of chloride concentration are to be expected from the model. However, previous reports of this aquifer have revealed serious deficiency in available water-quality data (Sophocleous et al., 1982). Among other factors, sporadic distributions of water analyses in time and space and widely different techniques used for collection and analysis of water samples were mentioned to have contributed to the poor and inaccurate water-quality records. Despite considerable data deficiency, the initial chloride distribution required for the transient solute-transport simulations was determined based on a 1940 chloride-distribution map of the Equus Beds aquifer by Williams and Lohman (1949) (Fig. 33). Note that the concentration of chloride ions within the areas of evapotranspiration pits are calculated using the analysis described in the previous section. As can be seen from Fig. 30, the areas with high chloride concentration were initially limited to the western and southwestern boundary of the study area where the major sources of contamination are located. The remaining areas have a concentration of less than 100 mg/L representing ground waters of relatively high quality at the beginning of simulations. The chloride concentration of net recharge was assumed to be 10 mg/L.

The prescribed flow-boundary conditions were assumed along the perimeter of the study area. The specification of this boundary condition requires additional simulations with the ground-water-flow model developed in chapter 4. The results of these simulations will determine the ground-water velocities along the boundary which, in turn, are used to calculate the rates of ground waters flowing into the system. Note that the boundary fluxes will vary with time and will also depend on the existing and projected ground-water-withdrawal conditions. In a similar manner, we calculate the leakage fluxes from the Arkansas River and Little Arkansas River. The specified boundary and leakage fluxes for each time interval are added to the lists of pumping and interception wells in the input data.

				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
			0	10	10	10	20	20	20	10	10	20	20	20	30	30	30	30	30	30	20	30	30	30	30	30	0
			0	10	10	10	10	10	10	10	10	10	20	20	30	30	30	30	30	20	30	30	30	30	30	30	0
			0	10	20	360	10	10	10	10	10	10	10	20	30	30	30	30	30	20	30	30	30	30	30	30	0
			0	100	570	1300	100	50	10	20	20	10	10	20	30	30	30	20	20	20	20	30	30	30	30	30	0
			0	100	3900	1920	550	20	30	30	30	20	10	20	30	30	20	20	20	20	20	20	20	10	0	0	
0	0	0	0	100	3020	970	240	530	20	20	20	10	10	20	20	20	20	20	20	20	20	10	10	10	30	0	
0	30	20	20	100	3480	1580	1420	280	10	10	10	10	20	10	10	20	20	20	20	10	10	10	10	30	30	0	
0	50	30	50	960	1860	1710	3040	30	20	20	10	20	30	20	10	20	20	10	10	10	10	10	10	20	30	30	0
0	200	50	200	1490	2510	860	140	20	20	20	20	10	10	10	10	10	10	10	10	10	10	10	10	20	30	30	0
0	200	100	320	1540	200	75	50	50	30	30	30	20	20	20	10	10	10	10	10	10	10	10	20	20	30	30	0
0	580	780	730	680	150	100	100	100	75	75	50	50	50	20	20	30	10	10	10	10	10	20	20	20	30	30	0
0	590	1520	1220	300	200	150	100	150	150	150	125	100	50	40	30	30	20	10	10	10	10	20	20	20	30	0	
0	500	800	500	200	75	75	100	75	125	125	100	75	100	100	50	40	30	30	20	10	10	10	20	30	30	0	
0	420	300	300	500	200	100	50	50	50	75	75	50	75	100	50	50	50	30	40	10	20	30	30	30	30	0	
0	75	75	75	400	500	200	200	150	75	50	50	50	50	50	40	50	50	30	40	10	10	10	30	30	30	0	
0	30	30	30	50	300	500	500	500	200	100	75	50	75	75	50	50	30	50	30	10	10	10	20	30	30	0	
0	20	30	20	20	50	100	300	400	500	400	150	100	100	100	75	75	75	50	20	20	20	10	10	30	0		
	0	20	20	20	20	20	50	100	300	500	500	500	500	500	500	75	75	50	40	40	30	10	10	10	0		
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Figure 30. Initial distribution of chloride concentration (in mg/L) for solute-transport modeling.

As mentioned before, the movement of solute particles is directly related to the advection and dispersion process. The advective transport of solute depends on ground-water-velocity field which is calculated internally by the model. However, the evaluation of dispersion transport requires as input data, the values of longitudinal dispersivity and the ratio of transverse to lateral dispersivity. These parameters cannot be easily measured in the field. Sophocleous et al. (1982) have performed a sensitivity analysis to determine the effects of model response to realistic values of the dispersivity coefficients. Their analysis shows that for this specific field application, the model results are relatively insensitive to the variations in these parameters. Obviously, advection process is the predominant driving force for solute transport in this area. Our modeling analysis will be based on values of 100 ft and 0.3 for longitudinal dispersivity and the ratio of transverse to lateral dispersitivity, respectively.

5.6 Results of Model Evaluation and Projection

An initial evaluation of the predictive capability of the solute-transport model is required before proceeding to use the model for projections of chloride concentrations obtained under different management policies.

As stated before, due to the manner in which the past data were collected, the historical evolution of contaminant's spreading cannot be determined for this aquifer. Therefore, only recent (1980) water-quality data were utilized for a comparison of simulated and observed chloride distributions. The result of this comparison is shown in Fig. 31. The differences in chloride concentrations are attributed to the measurement errors, modeling errors, and numerical discretization errors involved in this analysis. In view of all these uncertainties, the agreement between the two sets of concentrations seems to be satisfactory. A large discrepancy is seen

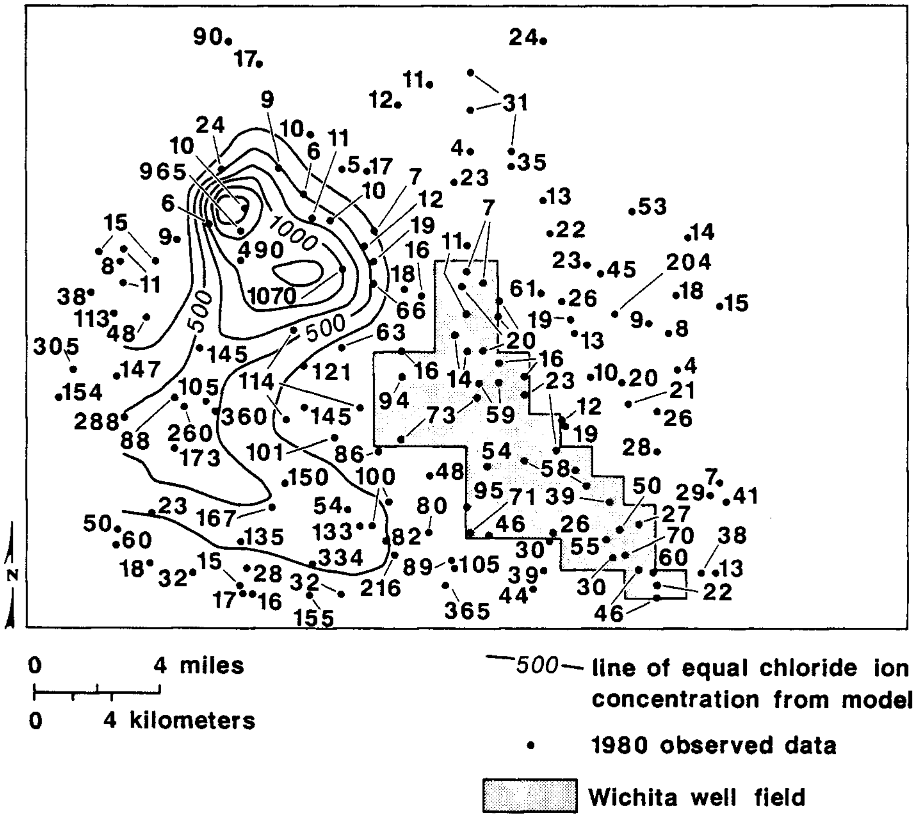


Figure 31. Comparison of 1980 simulated and observed chloride ion distributions (in mg/L).

between the actual chloride-concentration measurements at several locations that are in the vicinity of each other (see Fig. 31). This is believed to be due to the complex multi-layering nature of the Equus beds aquifer in these areas. Clearly some layers have been affected by the contaminant-plume migration, while the others still contain freshwaters with high quality. The solute-transport model used in our analysis can not take the existing multi-aquifer conditions into consideration.

Further evaluation of the model is obtained by comparing the 1980 cones of depressions from the flow model of chapter 4 and the solute-transport model (see Fig. 32). Fig. 32 indicates that the hydraulic gradients and therefore the ground-water velocities generated from the two models are in close agreement. This ensures that the advective terms which play a significant role in the transport of chloride particles are computed with reasonable accuracy in the solute-transport model.

The next phase of our modeling analysis involves using the model for prediction of chloride concentrations under different management policies. Obviously, we should first examine where the future locations of contaminant front would be if no efforts were taken for pollution control or containment. Assuming the current ground-water pumpage will persist in the future, and no remedial action is taken, the chloride-concentration distributions are estimated for the period 1985 through 2020 (see Fig. 33-a). As can be seen from Fig. 33-a, the line representing 250-mg/L concentration will reach the Wichita well field by the year 2020. The contaminant plume, which was originated from the two major pollution sources at the Burrton area and Arkansas River, advances from the southwest and northwest directions toward the well field. The results of this analysis indicate that an effective ground-water-management program should be

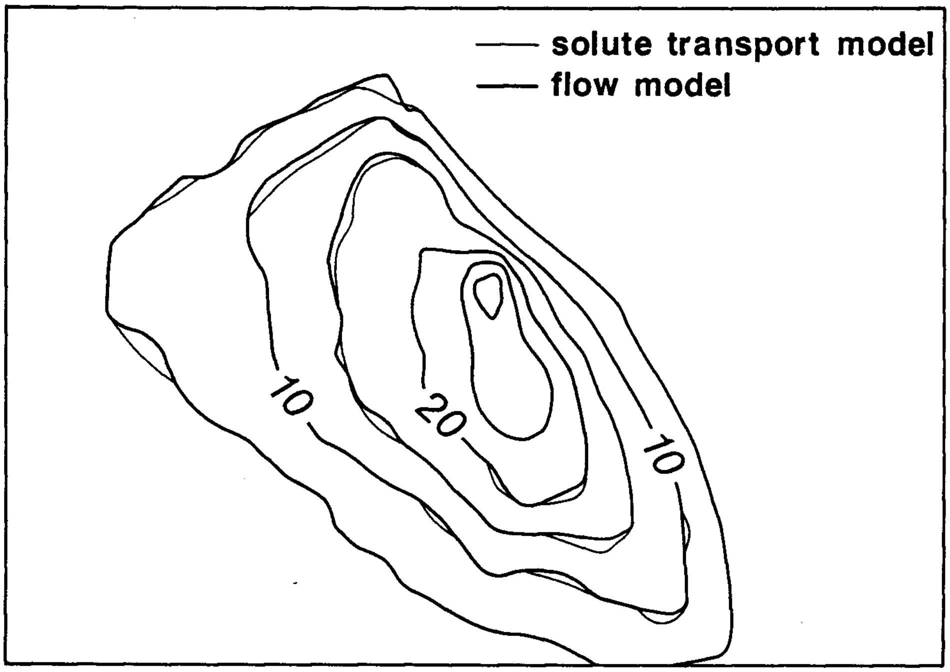


Figure 32. Comparison of 1980 drawdown contour lines (in ft.) calculated with flow model of Chapter 4 and solute-transport model.

implemented in this area if protection of water supply of the Wichita well field is of concern to the managers of the Equus Beds aquifer.

In chapter 4, we proposed three management plans for the containment of oil-field brine. These plans involved considerable pumpage of contaminated water at a set of interception wells located along the line of advancing contaminant plume. These pumpages are used in three additional solute-transport simulations, and the future chloride-concentration distributions from application of the management programs were projected for the period 1985 to 2020. Figs. 33 b, c, and d represent, respectively, the chloride concentrations associated with the management plans A, B and C. In all these cases, the contaminant plume from the Burrton area was prevented from reaching the Wichita well field. This was the main purpose of our management programs. The shrinkage of 250-mg/L concentration profile obtained under management plan A has been more effective than that of plan B and C (Fig. 33-b, c, and d). This was, however, at the expense of increased pumpages at the interception wells. Fig. 33 demonstrates also that the contaminant plume continues to advance from the Arkansas River. This is due to the fact that no effort has been taken to control the pollution caused by the Arkansas River. Additional interception wells are needed in the southwestern part of the Wichita well field if the pollution advancement from the Arkansas River is to be avoided.

The results of solute-transport modeling verify that the hydraulic barrier or stagnation zone created by implementation of the proposed management plans is effective in containment of polluted waters from the Burrton area. The economical feasibility and engineering design as well as several other issues involve further investigations and evaluations.

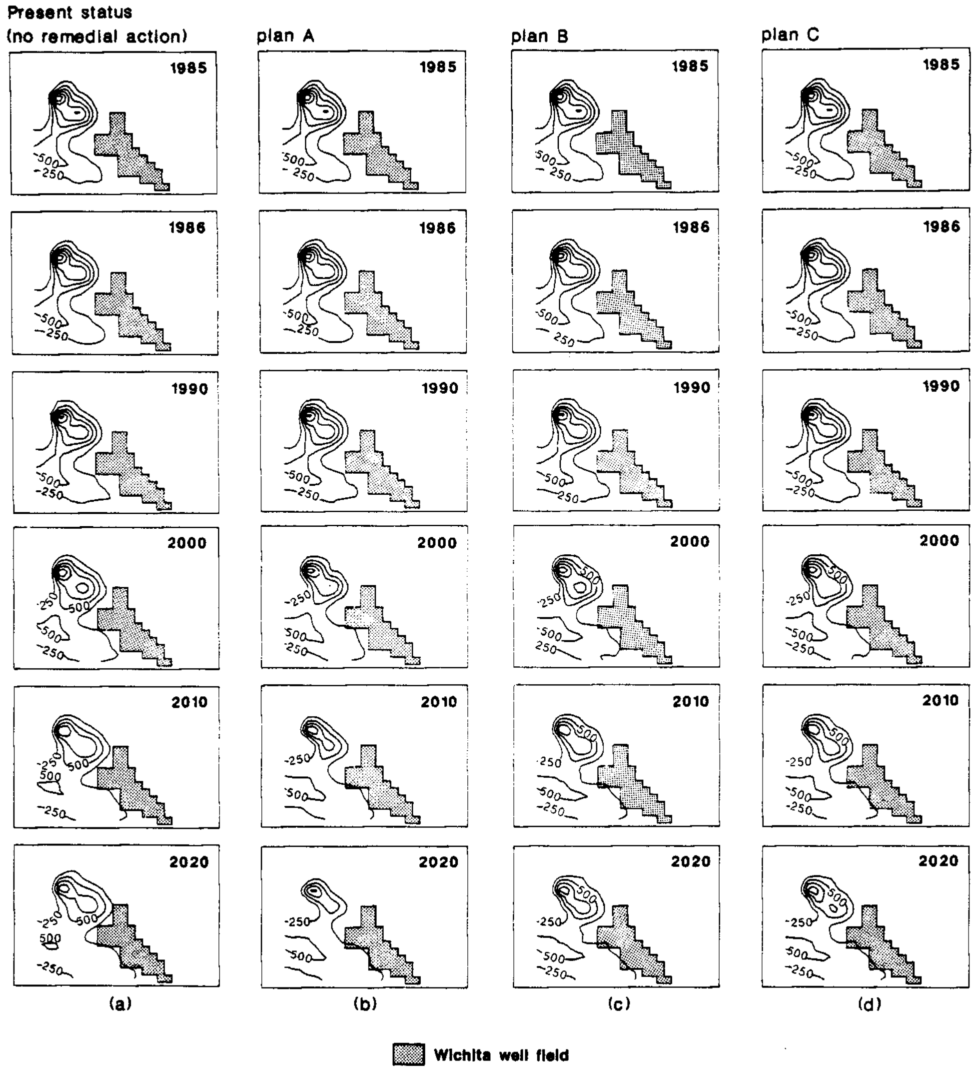


Figure 33. Projected chloride-concentration distributions (in mg/L) under different management plans.

Chapter 6

SUMMARY AND CONCLUSIONS

6.1 Summary

This study investigated the optimal containment and gradual removal of a saltwater-brine plume in the Equus Beds aquifer in south-central Kansas. The brine movement in this area is considered to be a major threat to the Wichita well field, which is a significant source of water supply for the city of Wichita.

Initially, using the available data from previous investigations, a ground-water-flow model of the area was constructed and used to define the shape and direction of the plume advancement. The results of ground-water-flow simulations indicate that if no management action is taken for isolation of the contaminated water, the Wichita well field will be in danger of contamination by the year 2020.

This study proposed a technique for controlling the migration of contaminants by pumping water from a set of interception wells that were designed to reverse the ground-water velocities along the anticipated front of the contaminant plume. The required minimum discharge rates at the interception wells were obtained, in a systemic routine, with the use of a ground-water-management model. The desirable property of the management model is that it eliminates the need for excessive multiple-flow simulations by searching for the optimum-discharge rates in an efficient manner using a linear-programming routine. Large-scale field application of the management model can be carried out by an iterative-decomposition solution procedure proposed in this study. This latter approach greatly reduces the computational demands of the management model for large systems. Finally, the results of the management model were used in a solute-transport model for verification of the plume containment and gradual removal.

6.2 Conclusions

In this study, we developed a model for use in management and planning of large aquifer systems and then demonstrated the practical application of the model to an actual ground-water-contamination problem in Kansas. The specific conclusions reached from the development of the management model are summarized below.

1. The ground-water-management models which are constructed by combining optimization techniques with ground-water-flow or solute-transport simulators are valuable tools in designing the most efficient plan for containment and gradual removal of liquid wastes or contaminated water.
2. The governing equation of ground-water flow can best be incorporated into the management models in the form of unit-response embedding technique. The fundamental assumption associated with this technique is the linearity of the system response with respect to the pumpages.
3. The excessive computer storage and computational time associated with large-scale applications of the management models necessitate the use of a decomposition method such as the one proposed in this study.
4. Using reversal of velocities or hydraulic gradients along the plume front as constraints, a zone of plume containment or stagnation can be created by the management model results. The validity of the results must be checked, however, with a solute-transport model such as the one used in our analysis.

The application of the proposed management model to the brine plume in the Equus Beds aquifer in Kansas indicates that

1. Under the present pumping strategy, the 250 mg/L chloride-concentration profile will reach the Wichita well field by the year 2020. To preserve the fresh ground-water resource of this area, implementation of a ground-water-management plan is essential.
2. All proposed management plans were successful in controlling the movement of the contaminants. The total discharge rate at interception wells is about 40 to 50 cfs. The chloride concentration of the intercepted water is at least 250 mg/L. For containment and gradual removal of the contaminated water, a period of at least 30 years will be needed. The total cost of withdrawal and disposition of contaminated water of such quantity is excessive, however, which makes the proposed management plans economically inefficient.
3. Using a solute-transport model, the 250-mg/L concentration profile was shown to be kept away from the Wichita well field for all three management plans. Plan A has shown to be more effective than plans B and C but at the expense of increased pumpage at the proposed interception wells.
4. The contaminant plume will continue to advance from the Arkansas River eastward in the direction of the well field. A set of interception wells should be constructed along the front of the advancing plume if ground-water contamination from the Arkansas River is to be avoided.
5. The conclusions reached with respect to the economic feasibility of the results of the management model are restricted to these specific management plans. These results, should not, under any circumstances, be extrapolated to other cases of containment and clean-up problems. It is proposed here that based on the

availability of funds for clean-up of the aquifer, interception wells may be designed for the high concentration areas (hot spots). It is believed that such investment will be high and will contribute to the future water quality in the study area.

REFERENCES

Alley, W. M., E. Aquado, and Irwin Remson, 1976. Aquifer management under transient and steady-state conditions. Water Resources Bulletin, v. 12, no. 5, pp. 903-972.

Aquado, E., and I. Remson, 1974. Ground-water hydraulics in aquifer management. Jour. Hy. Div. ASCE, v. 100, no. HY1, paper 10287, pp. 103-118.

Atwood, D. F., and S. Gorelick, 1985. Hydraulic gradient control for groundwater containment removal. Jour. of Hydro., v. 76, pp. 85-106.

Bayne, C. K., 1956. Geology and groundwater resources of Reno County, Kansas. Bull. 120, Kansas Geological Survey, Lawrence, Kansas, 130 pp.

Bear, J., 1972. Dynamics of fluids in porous media, American Elsevier, 764 pp.

Bredehoeft, J. D., and G. F. Pinder, 1973, Mass transport in flowing groundwater, Water Resour. Res., v. 9, no. 1, pp. 194-210.

Bear, J., 1979. Hydraulics of groundwater. McGraw-Hill, 567 pp.

Burrton Task Force, 1984. Report of the Burrton Task Force concerning the proposed Burrton Intensive Groundwater Control Area. Report for the Kansas State Board of Agriculture, Divisiòn of Water Resources, Topeka, Kansas, 103 pp.

Cheng, D. K., 1959. Analysis of linear systems. Addison-Wesley Publishing Company, Inc., Reading, Mass. 431 pp.

Colarullo, S. J., M. Heidari, and T. Maddock III, 1984. Identification of an optimal groundwater management strategy in a contaminated aquifer. Water Resources Bull., American Water Resources Association, v. 20, no. 5, pp. 747-760.

Colarullo, S. J., M. Heidari, and T. Maddock III, 1985. Demonstrative model for identifying ground-water management options in a contaminated aquifer. Ground-Water Series 8, Kansas Geological Survey, Lawrence, Kansas.

Cooley, R. L. 1979. A method of estimating parameters and assessing reliability for models of steady-state groundwater flow, 2: Application of statistical analysis. Water Resour. Res., v. 15 no. 3, pp. 603-617.

Cooley, R. L. 1977. A method of estimating parameters and assessing reliability for models of steady-state ground-water flow, 1: Theory and numerical properties. Water Resour. Res., v. 13, no. 2, pp. 313-324.

Fent, O. S., 1950. Geology and ground-water resources of Rice County, Kansas. Bull. 85, Kansas Geological Survey, Lawrence, Kansas, 142 pp.

Futagami, T., N. Tamai, and M. Yatsuzuka, 1976. FEM coupled with LP for water pollution control. J. Hydraul. Div. Am. Soc. Civ. Eng., v. 102 (HY7), pp. 881-897.

Gogel, T., 1981. Discharge of saltwater from Permian rocks to major stream-aquifer systems in central Kansas: Kansas Geological Survey, Chemical Quality Series 9, 60 pp.

Gorelick, S. M., 1982. A model for managing sources of groundwater pollution. Water Resources Res., v. 18, no. 4, pp. 773-781.

Gorelick, S. M., I. Remson, and R. W. Cottle, 1979. Management model of a groundwater system with a transient pollutant source. Water Resources Res., v. 15, no. 5, pp. 1243-1249.

Gorelick, S. M., and I. Remson, 1982. Optimal dynamic management of groundwater pollutant sources. Water Resour. Res., v. 18, no. 1, pp. 71-76.

Gorelick, S. M., 1983, A review of distributed parameter groundwater management modeling methods, Water Resour. Res., v. 19, no. 2, pp. 305-319.

Green, D. W. and E. C. Pogge, 1973, The development and field testing of a basin hydrology simulator, completion report No. C-2039, The University of Kansas, Center for Research Inc., Lawrence, Kansas, 193 pp.

Haimes, Y. Y., and Y. C. Dreizin, 1977. Management of groundwater on surface water via decomposition. Water Resour. Res., v. 13, no. 1, pp. 69-77.

Halepaska, J. C., L. Kearns, and F. W. Hartman. 1972. Theory, sensitivity, and regional unconfined ground-water model. Kansas Geological Survey, Open File Report #72-10, 44pp.

Hathaway, L. R., T. C. Waugh, O. K. Galle, and H. P. Dickey, 1981. Chemical quality of irrigation waters in the Equus Beds area, south-central Kansas. Kansas Geological Survey chemical quality Series 10, 45 pp.

Heidari, M., 1982a. Groundwater management options for the Pawnee Valley of south-central Kansas. Kansas Geological Survey, Groundwater Series 4, 54 pp.

Heidari, M., 1982b. Application of linear systems theory and linear programming to groundwater management in Kansas. Water Resour. Bull., v. 18, no. 6, pp. 1003-1012.

Heidari, M., 1985-a. Optimal management of large aquifers for irrigation activities. Proceedings of IWRA, Vth World Congress on Water Resources: Water Resources for Rural Areas and their Communities, paper number 261, pp. 1003-1013, June 9-15.

Heidari, M., 1985-b. Optimal management of large aquifers with uncertain demands. Proceedings of the Specialty Conference: Hydraulics and Hydrology in Small Computer Age, HY Div./ASCE, pp. 1358-1363, Aug. 12-17.

Jacob, C. E., 1944. Notes on determining permeability by pumping tests under water table conditions. U.S. Geol. Survey, Mineo Rept., 25 pp.

Knapp, R. M., 1973. The development and field testing of a basin hydrology simulator. Doctor of Engineering Thesis, University of Kansas, Lawrence, Kansas, 96 pp.

Konikow, L. F., and D. B. Grove, 1977. Derivation of equations describing solute transport in ground-water. U.S. Geol. Survey, Water Resour. Invest. 77-19, 20 pp.

Konikow, L. F. and J. D. Bredehoeft, 1978. Computer model of two-dimensional solute transport and dispersion in groundwaters. U.S. Geol. Survey Techniques of Water Resources Investigations, Ch. 22, Book 7, 38 pp.

Lane, C. W. and D. E. Miller, 1965. Geohydrology of Sedgwick County, Kansas. Bull. 176, Kansas Geological Survey, Lawrence, Kansas, 93 pp.

Lefkoff, L. J., and S. Gorelick, 1985, Rapid removal of a groundwater contaminant plume Proceedings of Symposium of Ground-Water Contamination and Reclamation. Edited by K. D. Schmidt, Aug. 14-15, 1985. Tucson, Arizona, pp. 125-133.

Leonard, R. B. and M. K. Kleinschmidt, 1976. Saline water in the Little Arkansas River basin area, south-central Kansas. Kansas Geological Survey, Chemical Quality Series No. 3, 24 pp.

Maddock, T., III, 1972. Algebraic technological function from a simulation model. Water Resources Research, v. 8 no. 1, pp. 129-134.

Maddock, T., III, 1973. Management model as a tool for studying the worth of data. Water Resources Research, v. 9, no. 2, pp. 270-280.

Maddock, T., III, 1974. The operation of a stream-aquifer system under stochastic demands. Water Resources Research, vol. 10, no. 1, pp. 1-10.

Maddock, T., III. 1983. Ground-water flow management modeling. Kansas Geological Survey, Open-File Report 83-32, 41 pp.

McDonald, M. G., and A. W. Harbaugh, 1984. A modular three-dimensional finite-difference ground-water flow model. U.S. Geol. Survey, Open File Report 83-875, 528 pp.

Morel-Seytoux, H. J. 1975. A simple case of conjunctive surface-groundwater management. Groundwater, vol. 13, no. 6, pp. 506-515.

Murtagh, B. A., and M. A. Saunders, 1977. MINOS: A large-scale nonlinear programming system. Stanford University, Dept. Operations Res., Systems Operation Lab, Technical Report SOL 77-9, 127 pp.

Nisai, W., L. W. Mays, and L. Lasdon, 1983. Development of a model for determining optimal pumping and recharge of large scale aquifers. Progress Report, University of Texas at Austin, Austin, Texas, 95 pp.

Petri, L. R., C. W. Lane, and L. W. Furness, 1964. Water resources of the Wichita area, Kansas. U.S. Geol. Survey, Water Supply Paper 1499-I, 69 pp.

Pinder, G. F., and J. D. Bredehoeft, 1968. Application of the digital computer for aquifer evaluation. Water Resources Research, v. 4, no. 5, pp. 1069-1093.

Pinney, J. J., J. A. Henderson, and D. F. Kosteki, 1975. Little Arkansas River basin. Kansas Water Resources Board, Topeka, Kansas, 147 pp.

Reddell, D. L., and D. K. Sunada, 1970. Numerical simulation of dispersion in groundwater aquifer. Hydrol. Pap. 41, Colorado State University, Fort Collins, 79 pp.

Reed, T. B., and R. D. Burnett, 1985. Compilation and analysis of aquifer performance test in eastern Kansas. U.S. Geological Survey, Open-File Report 85-200, 125 pp.

Richards, D. B., and T. W. Dunaway, 1972. Geohydrologic data for numerical modeling of ground-water withdrawals in the Little Arkansas River basin area, south-central Kansas. U.S. Geological Survey, Open-File Report, 426 pp.

Schrage, L., 1981. Linear, integer and quadratic programming with LINDO. The Scientific Press, Palo Alto, California, 274 pp.

Sophocleous, M. A., 1984. Groundwater-flow parameter estimation and quality modeling of the Equus Beds aquifer in Kansas, U.S.A. Journal of Hydrology, v. 69, no. 1984, pp. 197-222.

Sophocleous, M. A., M. Heidari, and C. McElwee, 1982. Water quality modeling of the Equus Beds aquifer in south-central Kansas. Technical Completion Report #231. Kansas Water Resources Research Institute, University of Kansas, Lawrence, Kansas, 67 pp.

Spinazola, J. M., J. B. Gillispie, and R.J. Hart, 1985. Ground-water flow and solute transport in the Equus Beds area, South-Central Kansas, 1940-79, U.S. Geological Survey, Water-Resources Investigations Report 85-4336, prepared in cooperation with Kansas Geological Survey, Lawrence, Kansas, 68 pp.

Stramel, G. J., 1956. Progress report on the groundwater hydrology of the Equus Beds area, Kansas. Bull. 119, part 1, Kansas Geological Survey, Lawrence, Kansas, pp. 1-59.

Stramel, G. J., 1966. Progress report on the groundwater hydrology of the Equus Beds area, Kansas. Bull. 187, part 2, Kansas Geological Survey, Lawrence, Kansas, 27 pp.

Trescott, P. C., G. F. Pinder, and S. P. Larson, 1976. Finite-difference model for aquifer simulation in two dimensions with results of numerical experiments. U.S. Geol. Survey, Techniques of Water Resources Investigations, Book 7, Chapter C1, 116 pp.

Whittemore, D. O., M. Sophocleous, W. R. Bryson, J. Schoof, and T. C. Bell, 1985. An interagency study of oil-field brine pollution in Kansas. Proceedings of Symposium on Groundwater Contamination and Reclamation. Amer. Water Resources Association, Kenneth D. Schmidt, ed., pp. 109-116.

Williams, C. G. and S. W. Lohman, 1949. Geology and ground-water resources of a part of south-central Kansas with special reference to the Wichita municipal water supply. Bull. 79, Kansas Geological Survey, Lawrence, Kansas, 455 pp.

Willis, R., 1976a. Optimal groundwater quality management: Well injection of wastewater. Water Resour. Res., v. 12, no. 1, pp. 47-53.

Willis, R., 1976b. A management model for determining effluent standards for the artificial recharge of municipal and industrial wastewaters; in, Advances in Groundwater Hydrology, ed. by Z. Saleem. American Water Resources Association, Minneapolis, Minnesota, pp. 227-308.

Willis, R., 1979. A planning model for the management of groundwater quality. Water Resources Res., v. 15, no. 6, pp 1305-1312.

Willis, R., 1983. A unified approach to regional water management in groundwater hydraulics. Water Res. Monogram Series, ed. by J.S. Rosenshein and G.D. Bennett, AGU, Washington, D.C.

Zigl, Wouter, 1984. Finite-element methods based on a transport velocity representation for groundwater motion. Water Resources Research, v. 20, no. 1, pp. 137-145.

APPENDIX I

Linearization of Flow Equation for Unconfined Aquifer

Boussinesq equation describes the two-dimensional ground-water flow in an unconfined aquifer (Bear, 1979):

$$\frac{\partial}{\partial x}[Kh \frac{\partial h}{\partial x}] + \frac{\partial}{\partial y}[Kh \quad \frac{\partial h}{\partial y}] = S_y \frac{\partial h}{\partial t} + R + Q \qquad \text{(I-1)}$$

Let initial head in the aquifer be H_o. Then:

$$\frac{\partial}{\partial x}[K(H_o-s)\frac{\partial (H_o-s)}{\partial x}] + \frac{\partial}{\partial h}[K(H_o-s)\frac{\partial (H_o-s)}{\partial y}] = S_y\frac{\partial (H_o-s)}{\partial t} + R + Q$$

where s = drawdown.

Assume $$\frac{h}{\overline{H}} \approx 1 \qquad \text{(I-2)}$$

then $$\frac{S_y}{h} \approx \frac{S_y}{\overline{H}} \qquad \text{(I-3)}$$

and let $$s^* = \frac{1}{\overline{H}} (sH_o - \frac{s^2}{2}) \qquad \text{(I-4)}$$

where $\overline{H} = \frac{1}{A} \int \int H_o da$; A = area of the aquifer; and H_o = initial water table.

From (I-4)

$$s^* - \frac{sH_o}{\overline{H}} + \frac{s^2}{2\overline{H}} = 0$$

then $$s = \frac{{}^{H}o/\overline{H} \pm \sqrt{({}^{H}o/\overline{H})^2 - 4(1/2\ \overline{H})s^*}}{2(1/2\overline{H})}$$

or

$$s = H_o - \sqrt{H_o^{\,2} - 2\overline{H}s^*}$$

or

$$H_o - s = \sqrt{H_o^{\,2} - 2\overline{H}s^*} \qquad \text{(I-5)}$$

using (I-5)

$$\frac{\partial}{\partial x}[K(H_o - s)\frac{\partial}{\partial x}(H_o - s)] = -\frac{\partial}{\partial x}(K\overline{H}\frac{\partial s^*}{\partial x}) \qquad \text{(I-6)}$$

and

$$\frac{\partial}{\partial y}[K(H_o - s)\frac{\partial}{\partial y}(H_o - s)] = -\frac{\partial}{\partial y}(K\overline{H}\frac{\partial s^*}{\partial y}) \qquad \text{(I-7)}$$

and $$S_y\frac{\partial s}{\partial t} = \frac{h}{\overline{H}} S_y \frac{\partial}{\partial t}(H_o - s)$$

$$= -\frac{H_o - s}{(Ho^2 - 2\overline{H}s^*)^{1/2}} S_y \frac{\partial s^*}{\partial t}$$

$$= -\frac{(H_o - s)}{[H_o^{\,2} - 2\overline{H}\,(\frac{1}{\overline{H}}\, sHo - \frac{1}{\overline{H}}\,\frac{s^2}{2})]^{1/2}} S_y \frac{\partial s^*}{\partial t}$$

$$= -\frac{H_o - s}{\sqrt{(H-s)^2}} S_y \frac{\partial s^*}{\partial t}$$

or $$S_y\frac{\partial s}{\partial t} = - S_y\frac{\partial s^*}{\partial t} \qquad \text{(I-8)}$$

with (I-6), (I-7), and (I-8), (I-1) becomes:

$$\frac{\partial}{\partial x}(K\overline{H}\frac{\partial s^*}{\partial x}) + \frac{\partial}{\partial y}(K\overline{H}\frac{\partial s^*}{\partial y}) = S_y\frac{\partial s^*}{\partial t} + R + Q \qquad \text{(I-9)}$$

which is linear and may be written as

$$\frac{\partial}{\partial x}\left(T^* \frac{\partial s^*}{\partial x}\right) + \frac{\partial}{\partial y}\left(T^* \frac{\partial s^*}{\partial y}\right) = S_y \frac{\partial s^*}{\partial t} + R + Q \qquad \text{(I-10)}$$

APPENDIX II

Aquifer Properties and Observed Data for Equus Beds Aquifer

TABLE II.1: Historical and calculated data for grid points

Contents:

COLUMN		
1	I	Row index in finite-difference grid.
2	J	Column index in finite-difference grid.
3	CHN	-1 indicates constant-head node. 0 indicates active node.
4	K	Hydraulic conductivity, in ft/day (ft/d).
5	R	Net recharge = areal recharge - evapotranspiration as evaluated in 1940, in inches/year (in/y).
6	B	Bedrock elevation, in ft.
7	HO	Steady-state head, in ft.
8	H71	Observed 1971 head, in ft.
9	H80	Observed 1980 head, in ft.
10	C	Confining-bed conductance = (vertical hydraulic conductivity times area covered by river in cell)÷ thickness of confining bed; in ft^2/day (ft^2/d).
11	H_r	River stage, in ft.
12	Q_w	Flux from the Equus beds to Wellington Formation, in cfs.

I	J	CHN	K	R	B	HO	H71	H80	C	H_r	Q_w
			ft/d	in/y	ft	ft	ft	ft	ft^2/d	ft	cfs
3	16	0	25.	.97	1355	1383.26	1378	1378	.0000E+00	0	.0000
3	17	0	25.	.10	1340	1370.00	1371	1371	.1118E-02	1370	.0219
3	18	0	150.	.10	1295	1387.82	1379	1376	.0000E+00	0	.0451
3	19	0	150.	.00	1320	1388.31	1383	1377	.0000E+00	0	.0839
3	20	-1	25.	.00	1360	1379.00	1379	1379	.0000E+00	0	.0001
3	21	-1	25.	.00	1380	1389.00	1389	1389	.0000E+00	0	.0000
3	24	0	25.	.10	1395	1440.71	1436	1436	.0000E+00	0	.0000
3	25	0	25.	.39	1395	1445.00	1448	1446	.1118E-02	1445	.0000
3	26	0	25.	.39	1395	1466.49	1463	1462	.0000E+00	0	.0000
3	27	0	10.	-.11	1390	1478.27	1481	1480	.0000E+00	0	.0000
4	16	0	5.	.97	1360	1391.84	1392	1394	.0000E+00	0	.0172
4	17	0	25.	.97	1350	1379.00	1382	1384	.1118E-02	1379	.0207
4	18	0	150.	.39	1300	1398.97	1398	1393	.0000E+00	0	.0295
4	19	0	150.	.39	1325	1401.12	1394	1396	.0000E+00	0	.0340
4	20	0	25.	.39	1350	1399.00	1399	1399	.1118E-02	1399	.0041
4	21	0	25.	.10	1380	1416.94	1409	1410	.0000E+00	0	.0000
4	22	0	25.	-3.28	1375	1429.23	1427	1420	.0000E+00	0	.0000
4	23	0	25.	.10	1410	1447.60	1441	1440	.0000E+00	0	.0000
4	24	0	25.	.10	1410	1455.42	1450	1449	.0000E+00	0	.0000
4	25	0	25.	-.63	1410	1463.11	1463	1465	.0000E+00	0	.0000
4	26	0	10.	.39	1410	1479.81	1480	1478	.0000E+00	0	.0000
4	27	0	25.	-1.36	1410	1490.18	1492	1492	.0000E+00	0	.0000
4	28	0	25.	.39	1420	1499.44	1500	1499	.0000E+00	0	.0000
4	29	0	25.	-.42	1420	1502.45	1505	1505	.0000E+00	0	.0000
5	17	0	10.	.97	1350	1387.00	1393	1394	.1118E-02	1387	.0143
5	18	0	150.	.39	1320	1410.23	1402	1403	.0000E+00	0	.0184
5	19	0	150.	.39	1305	1413.44	1406	1407	.0000E+00	0	.0184
5	20	0	150.	.39	1325	1418.43	1410	1412	.0000E+00	0	.0090
5	21	0	25.	2.41	1355	1427.87	1423	1423	.0000E+00	0	.0012
5	22	0	25.	1.43	1405	1442.57	1438	1436	.0000E+00	0	.0000
5	23	0	25.	.39	1405	1458.17	1455	1456	.0000E+00	0	.0000
5	24	0	25.	.39	1440	1471.31	1470	1469	.0000E+00	0	.0000
5	25	0	10.	.39	1415	1484.76	1482	1482	.0000E+00	0	.0000
5	26	0	25.	.39	1430	1495.46	1493	1493	.0000E+00	0	.0000
5	27	0	25.	.39	1440	1499.61	1501	1501	.0000E+00	0	.0000
5	28	0	25.	.35	1445	1505.14	1508	1508	.0000E+00	0	.0000
5	29	0	25.	-.57	1455	1507.91	1512	1512	.0000E+00	0	.0000
5	30	0	25.	-.34	1455	1512.36	1515	1515	.0000E+00	0	.0000
6	17	0	25.	.97	1350	1418.48	1410	1408	.0000E+00	0	.0091
6	18	0	150.	.10	1320	1419.21	1411	1408	.0000E+00	0	.0116
6	19	0	150.	.10	1290	1421.12	1413	1408	.0000E+00	0	.0123
6	20	0	150.	2.41	1320	1424.14	1411	1409	.0000E+00	0	.0122
6	21	0	25.	2.41	1320	1432.31	1426	1423	.0000E+00	0	.0224
6	22	0	10.	2.41	1360	1449.71	1447	1448	.0000E+00	0	.0000
6	23	0	10.	2.41	1390	1471.27	1468	1468	.0000E+00	0	.0000
6	24	0	10.	2.41	1405	1489.85	1485	1484	.0000E+00	0	.0000
6	25	0	25.	2.41	1410	1500.36	1496	1496	.0000E+00	0	.0000
6	26	0	25.	2.41	1450	1506.47	1503	1504	.0000E+00	0	.0000
6	27	0	25.	.39	1475	1510.21	1511	1510	.0000E+00	0	.0000
6	28	0	25.	.39	1460	1513.75	1514	1514	.0000E+00	0	.0000

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
6	29	0	25.	.39	1470	1516.45	1518	1518	.0000E+00	0	.0000
6	30	0	25.	.39	1470	1518.58	1520	1520	.0000E+00	0	.0000
6	32	0	25.	.10	1490	1535.84	1527	1527	.0000E+00	0	.0000
7	17	0	25.	.97	1380	1426.31	1425	1420	.0000E+00	0	.0053
7	18	0	150.	.10	1330	1425.88	1411	1409	.0000E+00	0	.0068
7	19	0	150.	.10	1295	1427.02	1416	1408	.0000E+00	0	.0070
7	20	0	150.	.39	1310	1429.13	1414	1408	.0000E+00	0	.0054
7	21	0	25.	2.41	1295	1435.86	1430	1420	.0000E+00	0	.0000
7	22	0	25.	2.41	1355	1446.56	1439	1438	.0000E+00	0	.0000
7	23	0	10.	2.41	1370	1471.64	1467	1468	.0000E+00	0	.0000
7	24	0	25.	2.41	1380	1491.20	1490	1490	.0000E+00	0	.0000
7	25	0	25.	2.41	1390	1501.64	1502	1502	.0000E+00	0	.0000
7	26	0	25.	2.41	1455	1511.76	1511	1512	.0000E+00	0	.0000
7	27	0	25.	2.41	1455	1518.54	1515	1514	.0000E+00	0	.0000
7	28	0	25.	.97	1455	1520.55	1519	1518	.0000E+00	0	.0000
7	29	0	25.	.97	1455	1522.84	1522	1522	.0000E+00	0	.0000
7	30	0	25.	.39	1470	1524.88	1524	1524	.0000E+00	0	.0000
7	31	0	25.	.10	1500	1530.31	1527	1527	.0000E+00	0	.0000
7	32	0	25.	.10	1505	1535.15	1529	1529	.0000E+00	0	.0000
7	33	0	25.	.10	1505	1537.43	1532	1533	.0000E+00	0	.0000
8	17	0	10.	.97	1400	1436.32	1435	1428	.0000E+00	0	.0025
8	18	0	150.	.97	1330	1431.12	1421	1416	.0000E+00	0	.0034
8	19	0	150.	.10	1290	1431.70	1412	1408	.0000E+00	0	.0036
8	20	0	150.	.10	1305	1433.49	1410	1408	.0000E+00	0	.0025
8	21	0	150.	.10	1295	1436.71	1421	1423	.0000E+00	0	.0000
8	22	0	150.	.10	1355	1439.99	1430	1429	.0000E+00	0	.0000
8	23	0	10.	.10	1380	1461.33	1451	1454	.0000E+00	0	.0000
8	24	0	25.	.39	1400	1485.39	1478	1479	.0000E+00	0	.0000
8	25	0	25.	.97	1455	1500.08	1503	1503	.0000E+00	0	.0000
8	26	0	25.	.97	1455	1512.15	1516	1515	.0000E+00	0	.0000
8	27	0	25.	.97	1455	1518.91	1521	1517	.0000E+00	0	.0000
8	28	0	25.	.97	1455	1522.33	1523	1523	.0000E+00	0	.0000
8	29	0	25.	.39	1455	1524.58	1525	1525	.0000E+00	0	.0000
8	30	0	25.	.39	1480	1527.50	1527	1527	.0000E+00	0	.0000
8	31	0	25.	.10	1505	1531.77	1529	1528	.0000E+00	0	.0000
8	32	0	25.	.10	1505	1535.99	1532	1533	.0000E+00	0	.0000
8	33	0	25.	.10	1505	1538.82	1534	1534	.0000E+00	0	.0000
8	34	0	25.	.10	1505	1541.06	1535	1535	.0000E+00	0	.0000
9	17	0	10.	.97	1400	1442.95	1440	1434	.0000E+00	0	.0003
9	18	0	150.	.97	1330	1434.79	1428	1418	.0000E+00	0	.0010
9	19	0	150.	.10	1290	1434.96	1413	1408	.0000E+00	0	.0013
9	20	0	150.	.10	1290	1435.98	1414	1408	.0000E+00	0	.0009
9	21	0	150.	.10	1300	1437.54	1419	1423	.0000E+00	0	.0000
9	22	0	150.	.10	1355	1439.47	1427	1423	.0000E+00	0	.0000
9	23	0	10.	.10	1370	1454.44	1440	1443	.0000E+00	0	.0000
9	24	0	10.	.10	1380	1477.97	1468	1469	.0000E+00	0	.0000
9	25	0	10.	.97	1405	1497.49	1491	1493	.0000E+00	0	.0000
9	26	0	25.	.97	1450	1511.50	1512	1513	.0000E+00	0	.0000
9	27	0	25.	.97	1455	1518.05	1523	1522	.0000E+00	0	.0000
9	28	0	25.	.60	1440	1521.35	1525	1525	.0000E+00	0	.0000

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
9	29	0	25.	.39	1470	1524.69	1525	1525	.0000E+00	0	.0000
9	30	0	25.	.39	1480	1528.52	1529	1529	.0000E+00	0	.0000
9	31	0	25.	.39	1505	1533.31	1532	1533	.0000E+00	0	.0000
9	32	0	25.	.10	1500	1536.88	1534	1534	.0000E+00	0	.0000
9	33	0	25.	.10	1505	1539.83	1535	1535	.0000E+00	0	.0000
9	34	0	25.	.10	1505	1542.50	1538	1538	.0000E+00	0	.0000
9	35	0	25.	.10	1505	1544.82	1544	1543	.0000E+00	0	.0000
10	16	0	10.	.97	1450	1471.12	1470	1469	.0000E+00	0	.0000
10	17	0	10.	.97	1400	1449.12	1443	1442	.0000E+00	0	.0000
10	18	0	150.	.97	1340	1437.43	1423	1414	.0000E+00	0	.0000
10	19	0	150.	.10	1290	1437.24	1415	1409	.0000E+00	0	.0000
10	20	0	150.	.10	1270	1437.67	1416	1409	.0000E+00	0	.0001
10	21	0	150.	.10	1280	1438.43	1417	1415	.0000E+00	0	.0000
10	22	0	150.	.10	1300	1439.43	1422	1414	.0000E+00	0	.0000
10	23	0	10.	.10	1350	1450.04	1433	1440	.0000E+00	0	.0000
10	24	0	10.	.10	1370	1470.08	1459	1466	.0000E+00	0	.0000
10	25	0	10.	.97	1405	1489.84	1485	1488	.0000E+00	0	.0000
10	26	0	10.	.97	1480	1508.39	1510	1510	.0000E+00	0	.0000
10	27	0	25.	.95	1470	1515.35	1513	1509	.0000E+00	0	.0000
10	28	0	25.	.39	1445	1518.63	1517	1516	.0000E+00	0	.0000
10	29	0	25.	.39	1480	1523.11	1522	1522	.0000E+00	0	.0000
10	30	0	25.	.39	1480	1527.95	1530	1529	.0000E+00	0	.0000
10	31	0	25.	.39	1505	1533.17	1533	1532	.0000E+00	0	.0000
10	32	0	25.	.10	1480	1537.20	1535	1535	.0000E+00	0	.0000
10	33	0	25.	.10	1480	1540.28	1538	1538	.0000E+00	0	.0000
10	34	0	25.	.10	1500	1543.36	1542	1541	.0000E+00	0	.0000
10	35	0	25.	.10	1510	1546.51	1546	1546	.0000E+00	0	.0000
10	36	0	25.	.34	1520	1550.08	1550	1549	.0000E+00	0	.0000
11	17	0	10.	.97	1430	1451.92	1449	1448	.0000E+00	0	.0000
11	18	0	150.	.97	1355	1439.33	1421	1416	.0000E+00	0	.0000
11	19	0	150.	.10	1300	1438.92	1417	1409	.0000E+00	0	.0000
11	20	0	150.	.10	1285	1438.94	1417	1409	.0000E+00	0	.0000
11	21	0	150.	.10	1315	1439.15	1418	1412	.0000E+00	0	.0000
11	22	0	150.	.10	1320	1439.47	1422	1411	.0000E+00	0	.0000
11	23	0	10.	.10	1340	1445.67	1429	1419	.0000E+00	0	.0000
11	24	0	10.	.10	1380	1462.87	1454	1457	.0000E+00	0	.0000
11	25	0	10.	.97	1430	1485.29	1489	1490	.0000E+00	0	.0000
11	26	0	25.	.97	1470	1500.44	1502	1502	.0000E+00	0	.0000
11	27	0	25.	-.46	1440	1506.83	1502	1502	.0000E+00	0	.0000
11	28	0	25.	.10	1455	1512.87	1508	1508	.0000E+00	0	.0000
11	29	0	25.	.10	1480	1519.36	1516	1515	.0000E+00	0	.0726
11	30	0	25.	.10	1480	1525.91	1523	1523	.0000E+00	0	.0000
11	31	0	25.	.03	1480	1531.12	1528	1528	.0000E+00	0	.0000
11	32	0	25.	.39	1480	1536.53	1538	1533	.0000E+00	0	.0000
11	33	0	25.	.39	1500	1540.69	1538	1537	.0000E+00	0	.0000
11	34	0	25.	.39	1505	1544.34	1543	1542	.0000E+00	0	.0000
11	35	0	25.	.39	1510	1547.77	1545	1545	.0000E+00	0	.0000
11	36	0	25.	.39	1500	1551.14	1547	1547	.0000E+00	0	.0000
11	37	0	25.	.39	1520	1555.20	1553	1553	.0000E+00	0	.0000
11	38	0	25.	.97	1520	1559.64	1562	1563	.0000E+00	0	.0000

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
12	17	0	25.	.97	1435	1450.83	1449	1447	.0000E+00	0	.0000
12	18	0	150.	.97	1360	1440.94	1420	1412	.0000E+00	0	.0000
12	19	0	150.	.10	1300	1440.28	1418	1409	.0000E+00	0	.0000
12	20	0	150.	.10	1290	1440.06	1419	1409	.0000E+00	0	.0000
12	21	0	150.	.10	1320	1439.85	1421	1413	.0000E+00	0	.0000
12	22	0	150.	.10	1320	1439.11	1424	1416	.0000E+00	0	.0000
12	23	0	150.	.10	1340	1441.23	1428	1419	.0000E+00	0	.0000
12	24	0	10.	.10	1400	1453.56	1444	1443	.0000E+00	0	.0000
12	25	0	25.	.97	1450	1478.20	1475	1474	.0000E+00	0	.0000
12	26	0	25.	.10	1460	1491.70	1490	1489	.0000E+00	0	.0000
12	27	0	25.	.10	1435	1500.29	1494	1492	.0000E+00	0	.0000
12	28	0	25.	.10	1460	1506.54	1501	1500	.0000E+00	0	.0000
12	29	0	25.	.10	1480	1515.30	1514	1513	.0000E+00	0	.0000
12	30	0	25.	.39	1480	1523.80	1523	1523	.0000E+00	0	.0000
12	31	0	25.	-.89	1480	1528.91	1526	1526	.0000E+00	0	.0000
12	32	0	25.	.39	1480	1535.66	1531	1531	.0000E+00	0	.0000
12	33	0	25.	.39	1490	1539.96	1537	1536	.0000E+00	0	.0000
12	34	0	25.	.39	1490	1543.27	1542	1541	.0000E+00	0	.0000
12	35	0	25.	.39	1490	1546.20	1543	1543	.0000E+00	0	.0000
12	36	0	25.	.39	1505	1549.32	1545	1547	.0000E+00	0	.0000
12	37	0	25.	.39	1510	1552.64	1549	1549	.0000E+00	0	.0000
12	38	0	25.	.97	1520	1557.13	1560	1560	.0000E+00	0	.0000
12	39	0	25.	.52	1520	1556.39	1562	1563	.0000E+00	0	.0000
13	17	0	25.	.97	1435	1452.48	1449	1448	.0000E+00	0	.0004
13	18	0	150.	.97	1370	1442.34	1426	1414	.0000E+00	0	.0001
13	19	0	150.	.10	1320	1441.43	1419	1409	.0000E+00	0	.0000
13	20	0	150.	.10	1270	1441.08	1421	1413	.0000E+00	0	.0000
13	21	0	150.	.10	1300	1440.95	1422	1414	.0000E+00	0	.0000
13	22	0	150.	.10	1320	1441.00	1424	1418	.0000E+00	0	.0000
13	23	0	150.	.10	1370	1442.22	1428	1419	.0000E+00	0	.0000
13	24	0	150.	.10	1400	1444.55	1435	1428	.0000E+00	0	.0000
13	25	0	25.	.10	1452	1462.38	1460	1460	.0000E+00	0	.0000
13	26	0	25.	.10	1440	1484.73	1478	1478	.0000E+00	0	.0000
13	27	0	25.	.10	1430	1493.64	1486	1486	.0000E+00	0	.0000
13	28	0	25.	-2.54	1450	1498.95	1497	1497	.0000E+00	0	.0000
13	29	0	25.	.39	1470	1511.23	1512	1512	.0000E+00	0	.0000
13	30	0	25.	.39	1490	1521.02	1522	1522	.0000E+00	0	.0000
13	31	0	25.	.39	1500	1529.27	1526	1526	.0000E+00	0	.0000
13	32	0	25.	.39	1490	1535.13	1531	1530	.0000E+00	0	.0000
13	33	0	25.	.39	1480	1538.48	1535	1535	.0000E+00	0	.0000
13	34	0	25.	.39	1480	1540.77	1535	1535	.0000E+00	0	.0000
13	35	0	25.	.39	1495	1542.93	1542	1541	.0000E+00	0	.0000
13	36	0	25.	.39	1505	1545.09	1543	1542	.0000E+00	0	.0000
13	37	0	25.	-1.29	1520	1545.16	1545	1546	.0000E+00	0	.0000
13	38	0	25.	.97	1520	1552.79	1550	1550	.0000E+00	0	.0000
13	39	0	25.	.12	1505	1552.59	1555	1557	.0000E+00	0	.0000
14	17	0	10.	2.41	1403	1457.91	1455	1454	.0000E+00	0	.0091
14	18	0	150.	.97	1360	1443.49	1434	1419	.0000E+00	0	.0028
14	19	0	150.	.10	1330	1442.39	1425	1415	.0000E+00	0	.0008
14	20	0	150.	.10	1285	1441.87	1424	1415	.0000E+00	0	.0001

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
14	21	0	150.	.10	1290	1441.71	1424	1417	.0000E+00	0	.0000
14	22	0	150.	.10	1320	1441.97	1425	1419	.0000E+00	0	.0000
14	23	0	150.	.10	1335	1442.94	1428	1424	.0000E+00	0	.0000
14	24	0	150.	.10	1370	1444.64	1437	1429	.0000E+00	0	.0000
14	25	0	150.	.39	1410	1448.00	1436	1438	.0000E+00	0	.0000
14	26	0	10.	.39	1420	1471.46	1466	1467	.0000E+00	0	.0000
14	27	0	25.	.10	1430	1489.13	1485	1485	.0000E+00	0	.0000
14	28	0	25.	.97	1450	1499.86	1497	1497	.0000E+00	0	.0000
14	29	0	25.	.97	1460	1510.02	1510	1510	.0000E+00	0	.0000
14	30	0	25.	.39	1480	1517.92	1518	1519	.0000E+00	0	.0000
14	31	0	25.	.39	1510	1526.97	1523	1523	.0000E+00	0	.0000
14	32	0	25.	.39	1490	1533.03	1528	1528	.0000E+00	0	.0000
14	33	0	25.	.39	1480	1535.88	1532	1532	.0000E+00	0	.0000
14	34	0	25.	.39	1470	1537.27	1535	1535	.0000E+00	0	.0000
14	35	0	25.	.39	1470	1538.48	1537	1536	.0000E+00	0	.0000
14	36	0	25.	.39	1505	1540.03	1538	1539	.0000E+00	0	.0000
14	37	0	25.	-.01	1510	1541.36	1540	1541	.0000E+00	0	.0000
14	38	0	25.	.39	1520	1546.35	1543	1544	.0000E+00	0	.0000
14	39	0	25.	.39	1505	1548.43	1550	1550	.0000E+00	0	.0000
15	17	0	5.	2.41	1400	1463.14	1463	1461	.0000E+00	0	.0026
15	18	0	150.	.97	1350	1444.04	1434	1420	.0000E+00	0	.0013
15	19	0	150.	.10	1300	1442.96	1427	1418	.0000E+00	0	.0004
15	20	0	150.	.10	1260	1442.35	1426	1419	.0000E+00	0	.0000
15	21	0	150.	.10	1350	1442.11	1427	1419	.0000E+00	0	.0000
15	22	0	150.	.10	1350	1442.34	1427	1423	.0000E+00	0	.0000
15	23	0	150.	.10	1345	1443.11	1428	1425	.0000E+00	0	.0000
15	24	0	150.	.10	1360	1444.42	1435	1428	.0000E+00	0	.0000
15	25	0	150.	.39	1405	1446.92	1438	1439	.0000E+00	0	.0000
15	26	0	10.	.39	1410	1465.33	1459	1461	.0000E+00	0	.0000
15	27	0	25.	-.72	1420	1483.56	1484	1485	.0000E+00	0	.0000
15	28	0	25.	.97	1455	1496.73	1496	1496	.0000E+00	0	.0000
15	29	0	25.	.97	1460	1506.98	1507	1506	.0000E+00	0	.0000
15	30	0	25.	.39	1495	1514.85	1514	1513	.0000E+00	0	.0000
15	31	0	25.	.39	1500	1522.46	1519	1518	.0000E+00	0	.0000
15	32	0	25.	.10	1500	1527.48	1523	1522	.0000E+00	0	.0000
15	33	0	25.	.10	1500	1530.90	1527	1527	.0000E+00	0	.0000
15	34	0	25.	.10	1460	1532.64	1529	1528	.0000E+00	0	.0000
15	35	0	25.	.39	1460	1533.63	1529	1529	.0000E+00	0	.0000
15	36	0	25.	.39	1460	1534.47	1530	1531	.0000E+00	0	.0000
15	37	0	25.	-.01	1480	1536.35	1533	1533	.0000E+00	0	.0000
15	38	0	25.	.39	1490	1540.09	1537	1537	.0000E+00	0	.0000
15	39	0	25.	.39	1505	1542.90	1540	1539	.0000E+00	0	.0000
16	16	0	5.	1.95	1435	1490.99	1490	1489	.0000E+00	0	.0000
16	17	0	10.	2.41	1395	1458.64	1460	1455	.0000E+00	0	.0000
16	18	0	150.	.97	1340	1444.52	1438	1425	.0000E+00	0	.0000
16	19	0	150.	.10	1280	1443.25	1431	1420	.0000E+00	0	.0000
16	20	0	150.	.10	1355	1442.44	1428	1423	.0000E+00	0	.0000
16	21	0	150.	.10	1370	1441.99	1428	1423	.0000E+00	0	.0000
16	22	0	150.	.10	1360	1442.13	1428	1424	.0000E+00	0	.0000
16	23	0	150.	.10	1340	1442.78	1429	1428	.0000E+00	0	.0000

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
16	24	0	150.	.10	1345	1443.95	1435	1429	.0000E+00	0	.0000
16	25	0	150.	.39	1390	1445.97	1441	1443	.0000E+00	0	.0000
16	26	0	10.	.39	1395	1461.88	1456	1454	.0000E+00	0	.0000
16	27	0	25.	.97	1420	1480.03	1480	1480	.0000E+00	0	.0000
16	28	0	25.	.43	1455	1491.83	1494	1493	.0000E+00	0	.0000
16	29	0	25.	.97	1460	1503.10	1501	1500	.0000E+00	0	.0000
16	30	0	25.	.97	1470	1510.24	1507	1506	.0000E+00	0	.0000
16	31	0	25.	.10	1490	1516.08	1512	1512	.0000E+00	0	.0000
16	32	0	25.	.10	1490	1521.10	1517	1517	.0000E+00	0	.0000
16	33	0	25.	.39	1490	1524.84	1521	1521	.0000E+00	0	.0000
16	34	0	25.	.10	1480	1526.57	1519	1519	.0000E+00	0	.0000
16	35	0	25.	.10	1460	1527.40	1519	1519	.0000E+00	0	.0000
16	36	0	25.	.10	1460	1528.52	1522	1521	.0000E+00	0	.0000
16	37	0	25.	.39	1470	1531.64	1527	1528	.0000E+00	0	.0000
16	38	0	25.	.39	1490	1535.00	1531	1532	.0000E+00	0	.0000
16	39	0	25.	.39	1500	1537.42	1535	1535	.0000E+00	0	.0000
16	40	0	25.	-.53	1505	1534.75	1537	1535	.0000E+00	0	.0000
17	17	0	150.	2.41	1380	1447.77	1440	1434	.0000E+00	0	.0000
17	18	0	150.	.97	1340	1445.00	1437	1429	.0000E+00	0	.0000
17	19	0	150.	.39	1295	1443.07	1435	1424	.0000E+00	0	.0000
17	20	0	150.	.39	1355	1441.83	1432	1423	.0000E+00	0	.0000
17	21	0	150.	.39	1360	1441.20	1431	1422	.0000E+00	0	.0000
17	22	0	150.	.39	1355	1441.28	1432	1426	.0000E+00	0	.0000
17	23	0	150.	.39	1330	1441.91	1433	1428	.0000E+00	0	.0000
17	24	0	150.	.39	1370	1443.06	1436	1430	.0000E+00	0	.0000
17	25	0	150.	.39	1405	1444.90	1437	1437	.0000E+00	0	.0000
17	26	0	10.	.39	1410	1458.79	1455	1457	.0000E+00	0	.0000
17	27	0	25.	-.44	1410	1474.48	1470	1470	.0000E+00	0	.0000
17	28	0	25.	.97	1445	1486.65	1489	1488	.0000E+00	0	.0000
17	29	0	25.	.34	1455	1496.34	1496	1495	.0000E+00	0	.0000
17	30	0	25.	.97	1455	1504.12	1501	1500	.0000E+00	0	.0000
17	31	0	25.	.39	1490	1510.11	1507	1507	.0000E+00	0	.0000
17	32	0	25.	.39	1480	1515.37	1512	1513	.0000E+00	0	.0000
17	33	0	25.	.10	1480	1518.02	1516	1516	.0000E+00	0	.0000
17	34	0	25.	.10	1470	1519.35	1515	1515	.0000E+00	0	.0000
17	35	0	25.	.10	1460	1519.64	1514	1513	.0000E+00	0	.0000
17	36	0	25.	-2.40	1470	1518.35	1514	1514	.0000E+00	0	.0000
17	37	0	25.	.39	1480	1524.84	1519	1520	.0000E+00	0	.0000
17	38	0	25.	-.77	1490	1528.53	1527	1528	.0000E+00	0	.0000
17	39	0	25.	.39	1495	1534.24	1533	1532	.0000E+00	0	.0000
17	40	0	25.	.97	1505	1536.26	1536	1536	.0000E+00	0	.0000
17	41	0	25.	-.66	1505	1529.55	1530	1530	.0000E+00	0	.0000
18	17	0	5.	.97	1380	1455.17	1450	1448	.0000E+00	0	.0000
18	18	0	25.	.97	1370	1445.70	1439	1427	.0000E+00	0	.0000
18	19	0	150.	.39	1320	1441.96	1436	1425	.0000E+00	0	.0000
18	20	0	150.	.39	1325	1440.31	1433	1422	.0000E+00	0	.0000
18	21	0	150.	.39	1330	1439.71	1432	1423	.0000E+00	0	.0000
18	22	0	150.	.39	1330	1439.81	1437	1427	.0000E+00	0	.0000
18	23	0	150.	.39	1345	1440.44	1437	1428	.0000E+00	0	.0000
18	24	0	150.	.39	1400	1441.43	1436	1429	.0000E+00	0	.0000

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
18	25	0	150.	.39	1405	1443.48	1438	1438	.0000E+00	0	.0000
18	26	0	25.	.39	1410	1453.53	1451	1451	.0000E+00	0	.0000
18	27	0	25.	.39	1410	1468.22	1463	1463	.0000E+00	0	.0000
18	28	0	25.	.39	1440	1480.60	1480	1479	.0000E+00	0	.0000
18	29	0	25.	.39	1420	1490.43	1493	1492	.0000E+00	0	.0000
18	30	0	25.	.39	1445	1497.15	1497	1498	.0000E+00	0	.0000
18	31	0	25.	-.20	1470	1501.89	1502	1502	.0000E+00	0	.0000
18	32	0	25.	.39	1470	1508.42	1508	1508	.0000E+00	0	.0000
18	33	0	25.	.39	1480	1511.28	1511	1511	.0000E+00	0	.0000
18	34	0	25.	.39	1470	1512.12	1511	1511	.0000E+00	0	.0000
18	35	0	25.	.10	1460	1511.86	1507	1506	.0000E+00	0	.0000
18	36	0	25.	-.60	1460	1512.14	1506	1507	.0000E+00	0	.0000
18	37	0	25.	-.67	1480	1517.30	1512	1512	.0000E+00	0	.0000
18	38	0	25.	.10	1490	1525.13	1523	1522	.0000E+00	0	.0000
18	39	0	25.	.39	1495	1532.34	1529	1529	.0000E+00	0	.0000
18	40	0	25.	.97	1505	1537.48	1536	1536	.0000E+00	0	.0000
19	17	0	5.	2.41	1390	1467.61	1465	1463	.0000E+00	0	.0000
19	18	0	10.	.97	1350	1447.78	1445	1435	.0000E+00	0	.0000
19	19	0	25.	.39	1320	1440.31	1435	1427	.0000E+00	0	.0000
19	20	0	150.	.39	1270	1438.15	1434	1425	.0000E+00	0	.0000
19	21	0	150.	.39	1280	1437.88	1434	1423	.0000E+00	0	.0000
19	22	0	150.	.39	1320	1437.96	1434	1424	.0000E+00	0	.0000
19	23	0	150.	.39	1370	1438.40	1436	1429	.0000E+00	0	.0000
19	24	0	150.	.39	1370	1438.95	1436	1428	.0000E+00	0	.0000
19	25	0	150.	.39	1405	1440.39	1432	1437	.0000E+00	0	.0000
19	26	0	25.	.39	1410	1447.55	1444	1444	.0000E+00	0	.0000
19	27	0	25.	.39	1410	1461.91	1457	1457	.0000E+00	0	.0000
19	28	0	25.	.39	1430	1474.34	1469	1469	.0000E+00	0	.0000
19	29	0	25.	.39	1430	1485.49	1482	1483	.0000E+00	0	.0000
19	30	0	25.	.39	1445	1492.32	1493	1492	.0000E+00	0	.0000
19	31	0	25.	-.06	1460	1496.37	1497	1497	.0000E+00	0	.0000
19	32	0	25.	.39	1470	1501.83	1501	1502	.0000E+00	0	.0000
19	33	0	25.	.39	1460	1503.99	1506	1504	.0000E+00	0	.0000
19	34	0	25.	.39	1440	1504.47	1500	1499	.0000E+00	0	.0000
19	35	0	25.	-.71	1440	1503.41	1497	1496	.0000E+00	0	.0000
19	36	0	25.	-1.42	1460	1504.62	1498	1498	.0000E+00	0	.0000
19	37	0	25.	.10	1480	1512.10	1507	1508	.0000E+00	0	.0000
19	38	0	25.	.10	1485	1521.58	1519	1519	.0000E+00	0	.0000
19	39	0	25.	.39	1495	1529.74	1529	1528	.0000E+00	0	.0000
19	40	0	25.	.97	1505	1536.10	1534	1534	.0000E+00	0	.0000
19	41	0	25.	-.58	1510	1534.67	1535	1535	.0000E+00	0	.0000
20	18	0	10.	.97	1370	1443.18	1440	1430	.0000E+00	0	.0000
20	19	0	25.	.39	1310	1436.89	1432	1426	.0000E+00	0	.0000
20	20	0	150.	.39	1260	1436.13	1432	1422	.0000E+00	0	.0000
20	21	0	150.	.39	1270	1435.98	1429	1423	.0000E+00	0	.0000
20	22	0	150.	.39	1300	1435.93	1433	1423	.0000E+00	0	.0000
20	23	0	150.	.39	1350	1436.04	1434	1424	.0000E+00	0	.0000
20	24	0	150.	.39	1360	1436.55	1434	1427	.0000E+00	0	.0000
20	25	0	150.	.39	1360	1437.51	1436	1435	.0000E+00	0	.0000
20	26	0	150.	.39	1395	1439.76	1437	1432	.0000E+00	0	.0000

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
20	27	0	25.	.39	1410	1453.03	1452	1452	.0000E+00	0	.0000
20	28	0	25.	.39	1420	1467.27	1464	1462	.0000E+00	0	.0000
20	29	0	25.	.39	1450	1480.13	1481	1478	.0000E+00	0	.0000
20	30	0	25.	.39	1455	1488.20	1488	1485	.0000E+00	0	.0000
20	31	0	25.	.39	1450	1491.82	1491	1490	.0000E+00	0	.0000
20	32	0	25.	.39	1455	1495.43	1494	1493	.0000E+00	0	.0000
20	33	0	25.	.39	1440	1497.68	1495	1495	.0000E+00	0	.0000
20	34	0	25.	.10	1440	1497.90	1491	1491	.0000E+00	0	.0000
20	35	0	25.	-2.51	1460	1493.72	1488	1488	.0000E+00	0	.0000
20	36	0	25.	.10	1460	1499.71	1489	1489	.0000E+00	0	.0000
20	37	0	25.	-2.15	1480	1502.76	1499	1499	.0000E+00	0	.0000
20	38	0	25.	.39	1490	1517.87	1515	1513	.0000E+00	0	.0000
20	39	0	25.	.01	1495	1526.25	1524	1524	.0000E+00	0	.0000
20	40	0	25.	.39	1505	1534.20	1533	1533	.0000E+00	0	.0000
20	41	0	25.	.97	1505	1538.93	1537	1537	.0000E+00	0	.0000
21	18	0	10.	.97	1390	1438.15	1437	1431	.0000E+00	0	.0000
21	19	0	150.	.39	1320	1433.82	1429	1422	.0000E+00	0	.0000
21	20	0	150.	.39	1260	1434.05	1429	1424	.0000E+00	0	.0000
21	21	0	150.	.39	1260	1433.94	1429	1424	.0000E+00	0	.0000
21	22	0	150.	.39	1290	1433.84	1429	1423	.0000E+00	0	.0000
21	23	0	150.	.39	1310	1433.81	1429	1423	.0000E+00	0	.0000
21	24	0	150.	.39	1320	1434.09	1429	1428	.0000E+00	0	.0000
21	25	0	150.	.39	1340	1435.04	1428	1428	.0000E+00	0	.0000
21	26	0	150.	.39	1360	1437.29	1433	1429	.0000E+00	0	.0000
21	27	0	10.	.39	1370	1448.12	1450	1443	.0000E+00	0	.0000
21	28	0	25.	.97	1410	1462.08	1464	1462	.0000E+00	0	.0000
21	29	0	25.	.97	1460	1475.52	1473	1473	.0000E+00	0	.0000
21	30	0	25.	1.11	1450	1483.93	1481	1480	.0000E+00	0	.0000
21	31	0	25.	-.56	1445	1484.57	1483	1483	.0000E+00	0	.0000
21	32	0	25.	.39	1440	1488.88	1488	1487	.0000E+00	0	.0000
21	33	0	25.	.39	1440	1491.74	1489	1488	.0000E+00	0	.0000
21	34	0	25.	.39	1460	1492.26	1487	1486	.0000E+00	0	.0000
21	35	0	25.	-1.72	1470	1486.39	1485	1485	.0000E+00	0	.0000
21	36	0	25.	.10	1470	1496.54	1488	1488	.0000E+00	0	.0000
21	37	0	25.	.10	1480	1503.51	1493	1491	.0000E+00	0	.0000
21	38	0	25.	.39	1490	1514.46	1507	1510	.0000E+00	0	.0000
21	39	0	25.	.11	1495	1522.62	1520	1519	.0000E+00	0	.0000
21	40	0	25.	.20	1505	1531.72	1529	1529	.0000E+00	0	.0000
21	41	0	25.	.97	1505	1539.18	1537	1537	.0000E+00	0	.0000
22	18	0	150.	.39	1400	1431.93	1430	1423	.0000E+00	0	.0020
22	19	0	150.	-1.91	1350	1431.89	1428	1423	.0000E+00	0	.0012
22	20	0	150.	.39	1260	1432.12	1427	1422	.0000E+00	0	.0005
22	21	0	150.	-.23	1240	1431.94	1429	1423	.0000E+00	0	.0000
22	22	0	150.	.39	1270	1431.75	1429	1423	.0000E+00	0	.0000
22	23	0	150.	.39	1310	1431.50	1428	1423	.0000E+00	0	.0000
22	24	0	150.	-1.74	1320	1431.37	1426	1423	.0000E+00	0	.0000
22	25	0	150.	.39	1310	1432.03	1428	1428	.0000E+00	0	.0000
22	26	0	25.	.39	1320	1435.00	1429	1429	.0000E+00	0	.0000
22	27	0	10.	.39	1350	1442.43	1439	1434	.0000E+00	0	.0000
22	28	0	10.	.97	1370	1454.90	1449	1447	.0000E+00	0	.0000

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
22	29	0	25.	2.41	1420	1466.32	1464	1463	.0000E+00	0	.0000
22	30	0	25.	2.10	1440	1476.04	1472	1473	.0000E+00	0	.0000
22	31	0	25.	-1.24	1440	1476.70	1477	1477	.0000E+00	0	.0000
22	32	0	25.	.39	1430	1481.94	1480	1479	.0000E+00	0	.0000
22	33	0	25.	.39	1445	1484.99	1479	1479	.0000E+00	0	.0000
22	34	0	25.	.10	1460	1485.63	1481	1481	.0000E+00	0	.0000
22	35	0	25.	-.77	1470	1483.38	1483	1483	.0000E+00	0	.0000
22	36	0	25.	.10	1470	1492.75	1486	1485	.0000E+00	0	.0000
22	37	0	25.	.10	1470	1499.86	1495	1498	.0000E+00	0	.0000
22	38	0	25.	.39	1480	1509.14	1502	1502	.0000E+00	0	.0000
22	39	0	25.	-.42	1490	1516.48	1516	1517	.0000E+00	0	.0000
22	40	0	25.	-.19	1505	1527.80	1524	1524	.0000E+00	0	.0000
22	41	0	25.	1.36	1505	1538.30	1537	1537	.0000E+00	0	.0000
23	18	0	150.	.20	1380	1430.62	1428	1423	.0000E+00	0	.0074
23	19	0	150.	.25	1330	1430.48	1425	1422	.0000E+00	0	.0027
23	20	0	150.	.39	1260	1430.40	1426	1422	.0000E+00	0	.0009
23	21	0	150.	.39	1240	1430.07	1429	1421	.0000E+00	0	.0000
23	22	0	150.	.39	1280	1429.58	1428	1421	.0000E+00	0	.0000
23	23	0	150.	.39	1305	1428.91	1425	1423	.0000E+00	0	.0000
23	24	0	150.	-2.44	1320	1428.40	1424	1423	.0000E+00	0	.0000
23	25	0	150.	.39	1310	1429.04	1427	1426	.0000E+00	0	.0000
23	26	0	25.	.39	1330	1431.76	1428	1428	.0000E+00	0	.0000
23	27	0	25.	.10	1330	1436.57	1427	1428	.0000E+00	0	.0000
23	28	0	25.	.10	1350	1443.59	1438	1436	.0000E+00	0	.0000
23	29	0	25.	.10	1380	1452.32	1450	1448	.0000E+00	0	.0000
23	30	0	25.	.10	1430	1462.70	1462	1460	.0000E+00	0	.0000
23	31	0	25.	2.41	1420	1472.45	1470	1468	.0000E+00	0	.0000
23	32	0	25.	.39	1420	1475.11	1471	1469	.0000E+00	0	.0000
23	33	0	25.	.10	1445	1476.77	1472	1471	.0000E+00	0	.0000
23	34	0	25.	.10	1460	1478.44	1473	1473	.0000E+00	0	.0000
23	35	0	25.	-.15	1455	1481.75	1478	1476	.0000E+00	0	.0000
23	36	0	25.	.10	1445	1487.91	1483	1483	.0000E+00	0	.0000
23	37	0	25.	.10	1455	1493.59	1485	1486	.0000E+00	0	.0000
23	38	0	25.	.23	1480	1502.13	1493	1492	.0000E+00	0	.0000
23	39	0	25.	.09	1480	1511.90	1510	1514	.0000E+00	0	.0000
23	40	0	25.	.52	1505	1525.52	1523	1523	.0000E+00	0	.0000
23	41	0	25.	.82	1505	1534.67	1534	1534	.0000E+00	0	.0000
24	17	0	5.	.04	1420	1437.36	1442	1442	.0000E+00	0	.0009
24	18	0	150.	.39	1360	1429.81	1430	1423	.0000E+00	0	.0043
24	19	0	150.	-1.02	1310	1429.22	1425	1422	.0000E+00	0	.0016
24	20	0	150.	.39	1255	1428.87	1426	1423	.0000E+00	0	.0003
24	21	0	150.	.39	1235	1428.25	1429	1423	.0000E+00	0	.0000
24	22	0	150.	.39	1270	1427.33	1426	1422	.0000E+00	0	.0000
24	23	0	150.	.39	1280	1426.18	1419	1418	.0000E+00	0	.0000
24	24	0	150.	.34	1320	1425.12	1420	1419	.0000E+00	0	.0000
24	25	0	150.	.39	1330	1425.38	1425	1423	.0000E+00	0	.0000
24	26	0	25.	.39	1340	1426.72	1425	1426	.0000E+00	0	.0000
24	27	0	25.	.39	1320	1431.57	1426	1427	.0000E+00	0	.0000
24	28	0	25.	.10	1340	1437.29	1429	1428	.0000E+00	0	.0000
24	29	0	25.	.10	1375	1444.25	1438	1437	.0000E+00	0	.0000

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
24	30	0	25.	.10	1405	1452.14	1449	1448	.0000E+00	0	.0000
24	31	0	25.	.97	1410	1461.60	1462	1461	.0000E+00	0	.0000
24	32	0	25.	.39	1430	1466.10	1465	1464	.0000E+00	0	.0000
24	33	0	25.	-.27	1440	1466.88	1463	1461	.0000E+00	0	.0000
24	34	0	25.	-1.67	1450	1466.01	1464	1463	.0000E+00	0	.0000
24	35	0	25.	.10	1440	1477.51	1469	1469	.0000E+00	0	.0000
24	36	0	25.	.10	1440	1483.33	1477	1477	.0000E+00	0	.0000
24	37	0	25.	.10	1440	1487.82	1479	1479	.0000E+00	0	.0000
24	38	0	25.	-.90	1460	1492.95	1487	1487	.0000E+00	0	.0000
24	39	0	25.	-.55	1470	1504.56	1502	1502	.0000E+00	0	.0000
24	40	0	25.	1.63	1505	1522.19	1520	1520	.0000E+00	0	.0000
24	41	0	25.	.33	1505	1530.98	1530	1530	.0000E+00	0	.0000
25	17	0	5.	.97	1420	1449.07	1448	1446	.0000E+00	0	.0001
25	18	0	150.	.39	1360	1429.54	1430	1424	.0000E+00	0	.0000
25	19	0	150.	.39	1310	1428.41	1420	1419	.0000E+00	0	.0000
25	20	0	150.	.39	1270	1427.55	1421	1420	.0000E+00	0	.0000
25	21	0	150.	.39	1240	1426.56	1423	1422	.0000E+00	0	.0000
25	22	0	150.	.39	1260	1425.19	1419	1418	.0000E+00	0	.0000
25	23	0	150.	.39	1275	1423.25	1419	1418	.0000E+00	0	.0000
25	24	0	150.	-1.36	1320	1418.00	1420	1419	.1432E-02	1418	.0000
25	25	0	150.	.39	1330	1420.96	1423	1423	.0000E+00	0	.0000
25	26	0	150.	.39	1340	1420.97	1423	1419	.0000E+00	0	.0000
25	27	0	25.	.39	1320	1424.42	1426	1420	.0000E+00	0	.0000
25	28	0	25.	.39	1330	1431.31	1427	1426	.0000E+00	0	.0000
25	29	0	25.	.10	1360	1437.77	1429	1429	.0000E+00	0	.0000
25	30	0	25.	.10	1370	1444.23	1439	1439	.0000E+00	0	.0000
25	31	0	25.	.97	1390	1451.79	1451	1450	.0000E+00	0	.0000
25	32	0	25.	2.41	1410	1458.09	1465	1459	.0000E+00	0	.0000
25	33	0	25.	.10	1440	1459.56	1458	1457	.0000E+00	0	.0000
25	34	0	25.	.10	1430	1464.20	1458	1459	.0000E+00	0	.0000
25	35	0	25.	.10	1455	1471.70	1464	1464	.0000E+00	0	.0000
25	36	0	25.	.10	1455	1476.64	1473	1472	.0000E+00	0	.0000
25	37	0	25.	-.69	1460	1477.19	1474	1474	.0000E+00	0	.0000
25	38	0	25.	-1.77	1470	1481.09	1479	1479	.0000E+00	0	.0000
25	39	0	25.	-.12	1470	1500.71	1497	1493	.0000E+00	0	.0000
25	40	0	25.	1.92	1470	1511.43	1513	1510	.0000E+00	0	.0000
26	17	0	10.	.97	1430	1451.08	1455	1453	.0000E+00	0	.0000
26	18	0	25.	.39	1410	1433.06	1430	1429	.0000E+00	0	.0000
26	19	0	150.	.10	1320	1427.55	1421	1421	.0000E+00	0	.0000
26	20	0	150.	-.39	1250	1426.45	1417	1419	.0000E+00	0	.0000
26	21	0	150.	.10	1240	1425.14	1419	1419	.0000E+00	0	.0000
26	22	0	150.	.10	1260	1423.34	1417	1417	.0000E+00	0	.0000
26	23	0	150.	.10	1280	1420.72	1417	1417	.0000E+00	0	.0000
26	24	0	150.	-1.76	1320	1414.00	1417	1417	.1551E-02	1414	.0000
26	25	0	150.	.39	1330	1417.12	1418	1418	.0000E+00	0	.0000
26	26	0	150.	.39	1340	1417.73	1420	1419	.0000E+00	0	.0000
26	27	0	150.	.39	1340	1418.62	1424	1419	.0000E+00	0	.0000
26	28	0	25.	.39	1345	1425.06	1424	1424	.0000E+00	0	.0000
26	29	0	25.	.39	1355	1432.33	1428	1427	.0000E+00	0	.0000
26	30	0	25.	.39	1355	1437.85	1430	1430	.0000E+00	0	.0000

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C_2 ft^2/d	H_r ft	Q_w cfs
26	31	0	25.	.39	1360	1442.69	1440	1441	.0000E+00	0	.0000
26	32	0	25.	.02	1380	1446.20	1445	1445	.0000E+00	0	.0000
26	33	0	25.	-.85	1420	1448.02	1445	1445	.0000E+00	0	.0000
26	34	0	25.	.10	1445	1457.91	1453	1452	.0000E+00	0	.0000
26	35	0	25.	.10	1450	1466.60	1463	1462	.0000E+00	0	.0000
26	36	0	25.	.10	1450	1470.08	1468	1467	.0000E+00	0	.0000
26	37	0	25.	-1.28	1455	1468.96	1469	1468	.0000E+00	0	.0000
26	38	0	25.	.10	1465	1481.74	1478	1478	.0000E+00	0	.0000
26	39	0	25.	.10	1470	1495.04	1490	1487	.0000E+00	0	.0000
26	40	0	25.	-.01	1460	1502.24	1499	1498	.0000E+00	0	.0000
27	17	0	25.	.97	1430	1449.00	1452	1450	.0000E+00	0	.0000
27	18	0	25.	.97	1410	1436.00	1438	1436	.0000E+00	0	.0000
27	19	0	150.	.97	1320	1427.61	1426	1425	.0000E+00	0	.0000
27	20	0	150.	.10	1280	1425.96	1419	1419	.0000E+00	0	.0000
27	21	0	150.	.10	1230	1424.13	1419	1419	.0000E+00	0	.0000
27	22	0	150.	.39	1240	1422.04	1418	1418	.0000E+00	0	.0000
27	23	0	150.	.10	1270	1418.98	1415	1415	.0000E+00	0	.0000
27	24	0	150.	.39	1320	1410.00	1412	1412	.1193E-02	1410	.0000
27	25	0	150.	.39	1330	1413.28	1413	1413	.0000E+00	0	.0000
27	26	0	150.	.39	1340	1413.85	1415	1417	.0000E+00	0	.0000
27	27	0	150.	.39	1355	1414.78	1418	1418	.0000E+00	0	.0000
27	28	0	25.	.39	1360	1419.90	1422	1420	.0000E+00	0	.0000
27	29	0	25.	.39	1355	1427.04	1424	1424	.0000E+00	0	.0000
27	30	0	25.	-.15	1330	1431.67	1428	1428	.0000E+00	0	.0000
27	31	0	25.	.39	1340	1435.86	1432	1432	.0000E+00	0	.0000
27	32	0	25.	.39	1370	1439.19	1439	1438	.0000E+00	0	.0000
27	33	0	25.	.10	1420	1441.61	1438	1438	.0000E+00	0	.0000
27	34	0	25.	.10	1440	1448.94	1444	1446	.0000E+00	0	.0000
27	35	0	25.	.10	1455	1458.81	1460	1458	.0000E+00	0	.0000
27	36	0	25.	.10	1450	1465.41	1464	1464	.0000E+00	0	.0000
27	37	0	25.	.10	1440	1469.09	1464	1464	.0000E+00	0	.0000
27	38	0	25.	.10	1455	1477.01	1474	1469	.0000E+00	0	.0000
27	39	0	25.	.10	1470	1488.34	1481	1481	.0000E+00	0	.0000
27	40	0	25.	.97	1470	1497.52	1495	1492	.0000E+00	0	.0000
27	41	0	25.	.62	1470	1495.23	1493	1491	.0000E+00	0	.0000
28	18	0	25.	2.41	1350	1434.56	1437	1436	.0000E+00	0	.0046
28	19	0	150.	2.41	1320	1428.50	1430	1429	.0000E+00	0	.0036
28	20	0	150.	.59	1305	1426.09	1422	1422	.0000E+00	0	.0013
28	21	0	150.	-2.82	1220	1423.59	1419	1419	.0000E+00	0	.0000
28	22	0	150.	.39	1230	1421.31	1419	1419	.0000E+00	0	.0000
28	23	0	150.	.39	1270	1418.00	1415	1416	.0000E+00	0	.0000
28	24	0	150.	.39	1320	1413.52	1412	1412	.0000E+00	0	.0000
28	25	0	150.	.39	1330	1405.00	1408	1408	.1670E-02	1405	.0000
28	26	0	150.	-.83	1355	1408.56	1409	1409	.0000E+00	0	.0000
28	27	0	150.	.39	1355	1409.44	1412	1412	.0000E+00	0	.0000
28	28	0	25.	.39	1360	1412.79	1415	1416	.0000E+00	0	.0000
28	29	0	25.	.39	1355	1420.92	1421	1422	.0000E+00	0	.0000
28	30	0	25.	.39	1320	1426.55	1424	1424	.0000E+00	0	.0000
28	31	0	25.	.39	1330	1430.11	1425	1425	.0000E+00	0	.0000
28	32	0	25.	.39	1380	1432.69	1428	1428	.0000E+00	0	.0000

			ft/d	in/y	ft	ft	ft	ft	ft^2/d	r ft	w cfs
28	33	0	25.	-.52	1410	1432.86	1431	1431	.0000E+00	0	.0000
28	34	0	25.	.10	1430	1440.75	1437	1437	.0000E+00	0	.0000
28	35	0	25.	.10	1435	1448.46	1445	1447	.0000E+00	0	.0000
28	36	0	25.	.10	1440	1456.59	1457	1457	.0000E+00	0	.0000
28	37	0	25.	.10	1440	1463.37	1459	1460	.0000E+00	0	.0000
28	38	0	25.	.10	1450	1470.16	1467	1464	.0000E+00	0	.0000
28	39	0	25.	.10	1465	1479.53	1477	1476	.0000E+00	0	.0000
28	40	0	25.	.97	1475	1489.00	1487	1486	.0000E+00	0	.0000
28	41	0	25.	-.73	1470	1480.48	1482	1481	.0000E+00	0	.0000
29	4	-1	750.	.00	1495	1560.00	1560	1560	.0000E+00	0	.0000
29	5	-1	750.	.00	1495	1555.00	1555	1555	.0000E+00	0	.0000
29	6	-1	750.	.00	1495	1554.00	1554	1554	.0000E+00	0	.0000
29	9	-1	5.	.00	1555	1620.00	1620	1620	.0000E+00	0	.0000
29	10	-1	5.	.00	1540	1615.00	1615	1617	.0000E+00	0	.0000
29	11	-1	5.	.00	1500	1595.00	1595	1595	.0000E+00	0	.0000
29	12	-1	5.	.00	1460	1555.00	1555	1555	.0000E+00	0	.0000
29	13	-1	5.	.00	1450	1520.00	1520	1520	.0000E+00	0	.0000
29	14	-1	25.	.00	1420	1485.00	1485	1485	.0000E+00	0	.0230
29	15	-1	25.	.00	1380	1468.00	1468	1466	.0000E+00	0	.0334
29	16	0	25.	2.32	1380	1449.00	1455	1458	.2391E-02	1449	.0329
29	17	0	25.	2.41	1350	1441.00	1442	1440	.2391E-02	1441	.0444
29	18	0	25.	4.35	1330	1436.89	1436	1437	.0000E+00	0	.0203
29	19	0	150.	2.41	1310	1429.54	1432	1432	.0000E+00	0	.0103
29	20	0	150.	2.41	1300	1426.85	1427	1427	.0000E+00	0	.0048
29	21	0	150.	.39	1210	1424.01	1422	1422	.0000E+00	0	.0013
29	22	0	150.	-1.66	1230	1421.04	1415	1415	.0000E+00	0	.0000
29	23	0	150.	-2.54	1270	1415.00	1413	1413	.2690E-02	1415	.0000
29	24	0	150.	.39	1310	1411.00	1410	1409	.1943E-02	1411	.0000
29	25	0	150.	.39	1330	1406.00	1407	1407	.2092E-02	1406	.0000
29	26	0	150.	-2.41	1340	1402.00	1398	1398	.3288E-02	1402	.0000
29	27	0	150.	.39	1340	1403.93	1403	1403	.0000E+00	0	.0000
29	28	0	150.	.39	1355	1405.26	1408	1409	.0000E+00	0	.0000
29	29	0	25.	.97	1340	1413.60	1414	1415	.0000E+00	0	.0000
29	30	0	25.	.39	1330	1420.98	1418	1418	.0000E+00	0	.0000
29	31	0	25.	.39	1330	1425.22	1420	1420	.0000E+00	0	.0000
29	32	0	25.	.39	1360	1427.26	1423	1422	.0000E+00	0	.0000
29	33	0	25.	-.37	1380	1427.34	1426	1426	.0000E+00	0	.0000
29	34	0	25.	.10	1420	1434.08	1429	1429	.0000E+00	0	.0000
29	35	0	25.	.10	1420	1441.49	1435	1436	.0000E+00	0	.0000
29	36	0	25.	-.32	1425	1447.29	1446	1446	.0000E+00	0	.0000
29	37	0	25.	.39	1430	1455.65	1453	1452	.0000E+00	0	.0000
29	38	0	25.	.10	1440	1461.51	1458	1458	.0000E+00	0	.0000
29	39	0	25.	.10	1455	1469.62	1469	1468	.0000E+00	0	.0000
29	40	0	25.	.97	1460	1477.15	1479	1480	.0000E+00	0	.0000
29	41	0	25.	-.92	1450	1471.14	1473	1473	.0000E+00	0	.0000
30	3	-1	750.	.00	1505	1562.00	1562	1562	.0000E+00	0	.0000
30	4	0	750.	-1.09	1495	1556.08	1558	1559	.0000E+00	0	.0000
30	5	0	750.	.49	1495	1551.41	1550	1550	.0000E+00	0	.0000
30	6	0	750.	.16	1490	1547.40	1546	1546	.0000E+00	0	.0000
30	7	0	750.	.45	1480	1541.53	1543	1543	.0000E+00	0	.0000

										r	w
			ft/d	in/y	ft	ft	ft	ft	ft^2/d	ft	cfs
30	8	0	750.	.97	1500	1538.45	1540	1540	.0000E+00	0	.0000
30	9	0	5.	.97	1510	1568.98	1560	1560	.0000E+00	0	.0000
30	10	0	5.	4.83	1520	1600.97	1600	1592	.0000E+00	0	.0000
30	11	0	5.	4.83	1505	1608.49	1609	1610	.0000E+00	0	.0000
30	12	0	5.	3.63	1490	1593.27	1591	1593	.0000E+00	0	.0000
30	13	0	5.	1.93	1440	1565.57	1560	1560	.0000E+00	0	.0000
30	14	0	5.	2.87	1430	1525.04	1525	1525	.0000E+00	0	.0141
30	15	0	25.	3.08	1390	1490.27	1492	1492	.0000E+00	0	.0298
30	16	0	25.	1.15	1360	1473.04	1470	1468	.0000E+00	0	.0314
30	17	0	25.	.97	1320	1455.82	1450	1448	.0000E+00	0	.0320
30	18	0	25.	2.41	1310	1436.00	1438	1439	.2690E-02	1436	.0216
30	19	0	150.	4.35	1300	1430.51	1433	1433	.0000E+00	0	.0125
30	20	0	150.	4.35	1230	1427.55	1427	1428	.0000E+00	0	.0063
30	21	0	150.	4.35	1195	1425.00	1422	1422	.0000E+00	0	.0011
30	22	0	150.	3.72	1230	1419.00	1418	1418	.2242E-02	1419	.0000
30	23	0	150.	2.41	1310	1420.37	1418	1418	.0000E+00	0	.0000
30	24	0	150.	2.41	1310	1417.44	1416	1417	.0000E+00	0	.0000
30	25	0	150.	2.41	1320	1413.09	1413	1413	.0000E+00	0	.0000
30	26	0	150.	2.41	1330	1406.51	1409	1408	.0000E+00	0	.0000
30	27	0	150.	.39	1320	1396.00	1398	1398	.2242E-02	1396	.0000
30	28	0	150.	.39	1330	1401.53	1403	1402	.0000E+00	0	.0000
30	29	0	25.	.39	1340	1408.19	1408	1408	.0000E+00	0	.0000
30	30	0	25.	.39	1330	1415.94	1411	1411	.0000E+00	0	.0000
30	31	0	25.	.39	1340	1421.24	1413	1412	.0000E+00	0	.0000
30	32	0	25.	.39	1360	1423.15	1417	1417	.0000E+00	0	.0000
30	33	0	25.	-.52	1380	1422.79	1419	1419	.0000E+00	0	.0000
30	34	0	25.	.39	1410	1428.76	1423	1423	.0000E+00	0	.0000
30	35	0	25.	.10	1410	1435.46	1428	1429	.0000E+00	0	.0000
30	36	0	25.	.19	1410	1440.76	1436	1437	.0000E+00	0	.0000
30	37	0	25.	.39	1420	1446.88	1446	1446	.0000E+00	0	.0000
30	38	0	25.	-.20	1430	1451.88	1453	1452	.0000E+00	0	.0000
30	39	0	25.	.39	1445	1459.64	1458	1458	.0000E+00	0	.0000
30	40	0	25.	.03	1450	1462.72	1464	1464	.0000E+00	0	.0000
31	3	-1	750.	.00	1450	1557.00	1557	1557	.0000E+00	0	.0000
31	4	0	750.	-1.34	1460	1551.82	1552	1552	.0000E+00	0	.0000
31	5	0	750.	-1.55	1470	1547.45	1545	1545	.0000E+00	0	.0000
31	6	0	750.	-.04	1480	1542.97	1542	1541	.0000E+00	0	.0000
31	7	0	750.	-.08	1480	1538.07	1537	1537	.0000E+00	0	.0000
31	8	0	750.	.97	1480	1534.49	1534	1532	.0000E+00	0	.0000
31	9	0	25.	-.74	1495	1535.06	1530	1530	.0000E+00	0	.0000
31	10	0	25.	4.35	1510	1549.36	1540	1540	.0000E+00	0	.0000
31	11	0	5.	4.83	1505	1575.98	1580	1578	.0000E+00	0	.0000
31	12	0	5.	4.83	1495	1599.04	1595	1593	.0000E+00	0	.0000
31	13	0	5.	4.73	1480	1589.65	1585	1585	.0000E+00	0	.0018
31	14	0	5.	3.85	1440	1556.61	1560	1560	.0000E+00	0	.0126
31	15	0	25.	4.83	1430	1513.24	1525	1525	.0000E+00	0	.0259
31	16	0	25.	5.31	1390	1492.47	1503	1503	.0000E+00	0	.0327
31	17	0	25.	2.41	1350	1469.37	1470	1469	.0000E+00	0	.0304
31	18	0	25.	5.31	1320	1448.44	1455	1453	.0000E+00	0	.0215
31	19	0	150.	4.83	1260	1431.00	1437	1435	.1943E-02	1431	.0117

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
31	20	0	150.	2.41	1210	1426.00	1428	1429	.2391E-02	1426	.0065
31	21	0	150.	4.12	1195	1423.00	1423	1423	.1943E-02	1423	.0026
31	22	0	150.	2.16	1250	1425.74	1419	1419	.0000E+00	0	.0000
31	23	0	150.	2.41	1310	1424.64	1418	1419	.0000E+00	0	.0000
31	24	0	150.	1.76	1305	1421.92	1415	1418	.0000E+00	0	.0000
31	25	0	150.	2.41	1305	1417.71	1413	1415	.0000E+00	0	.0000
31	26	0	150.	1.16	1320	1408.70	1410	1409	.0000E+00	0	.0000
31	27	0	150.	-2.99	1310	1394.00	1390	1390	.2092E-02	1394	.0000
31	28	0	150.	.39	1330	1399.40	1397	1395	.0000E+00	0	.0000
31	29	0	25.	.39	1330	1404.03	1400	1400	.0000E+00	0	.0000
31	30	0	25.	.39	1355	1409.93	1404	1404	.0000E+00	0	.0000
31	31	0	25.	.39	1400	1415.72	1408	1408	.0000E+00	0	.0000
31	32	0	25.	.10	1380	1418.60	1409	1410	.0000E+00	0	.0000
31	33	0	25.	-.39	1370	1417.35	1412	1413	.0000E+00	0	.0000
31	34	0	25.	.39	1390	1421.14	1417	1416	.0000E+00	0	.0000
31	35	0	25.	.39	1410	1427.30	1419	1418	.0000E+00	0	.0000
31	36	0	25.	.10	1410	1430.80	1428	1424	.0000E+00	0	.0000
31	37	0	25.	.39	1410	1436.39	1438	1434	.0000E+00	0	.0000
31	38	0	25.	.39	1420	1444.56	1443	1443	.0000E+00	0	.0000
31	39	0	25.	.97	1420	1451.88	1454	1451	.0000E+00	0	.0000
31	40	0	25.	.12	1430	1452.41	1455	1454	.0000E+00	0	.0000
32	3	-1	750.	.00	1395	1552.00	1552	1552	.0000E+00	0	.0000
32	4	0	750.	.01	1405	1547.00	1548	1548	.4484E-02	1547	.0000
32	5	0	750.	-.29	1460	1543.71	1542	1542	.0000E+00	0	.0000
32	6	0	750.	-.28	1470	1538.69	1536	1536	.0000E+00	0	.0000
32	7	0	750.	-.20	1460	1533.44	1529	1529	.0000E+00	0	.0000
32	8	0	750.	-.65	1460	1528.06	1526	1526	.0000E+00	0	.0000
32	9	0	750.	3.39	1470	1522.79	1523	1522	.0000E+00	0	.0000
32	10	0	750.	4.35	1465	1519.37	1517	1518	.0000E+00	0	.0000
32	11	0	750.	4.35	1475	1517.33	1509	1519	.0000E+00	0	.0000
32	12	0	5.	4.63	1505	1560.41	1555	1552	.0000E+00	0	.0000
32	13	0	5.	4.83	1500	1582.90	1580	1584	.0000E+00	0	.0034
32	14	0	5.	4.83	1490	1581.25	1580	1582	.0000E+00	0	.0086
32	15	0	5.	4.83	1460	1553.63	1562	1560	.0000E+00	0	.0117
32	16	0	5.	4.83	1390	1525.98	1539	1539	.0000E+00	0	.0070
32	17	0	5.	3.79	1360	1497.06	1494	1494	.0000E+00	0	.0026
32	18	0	5.	4.21	1310	1474.83	1468	1468	.0000E+00	0	.0023
32	19	0	5.	4.83	1275	1458.86	1462	1462	.0000E+00	0	.0064
32	20	0	5.	4.83	1230	1444.90	1450	1450	.0000E+00	0	.0054
32	21	0	25.	4.35	1190	1432.42	1435	1434	.0000E+00	0	.0033
32	22	0	150.	2.41	1240	1430.08	1423	1423	.0000E+00	0	.0011
32	23	0	150.	2.41	1260	1428.56	1419	1419	.0000E+00	0	.0000
32	24	0	150.	2.41	1250	1426.13	1410	1415	.0000E+00	0	.0000
32	25	0	150.	2.41	1255	1423.47	1414	1413	.0000E+00	0	.0000
32	26	0	25.	.40	1280	1415.94	1406	1406	.0000E+00	0	.0000
32	27	0	25.	1.20	1310	1392.00	1390	1390	.1943E-02	1392	.0000
32	28	0	25.	.39	1310	1396.12	1392	1391	.0000E+00	0	.0000
32	29	0	25.	2.41	1320	1401.59	1395	1393	.0000E+00	0	.0000
32	30	0	25.	.39	1350	1404.89	1400	1400	.0000E+00	0	.0000
32	31	0	25.	.39	1370	1407.94	1405	1405	.0000E+00	0	.0000

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
32	32	0	25.	.39	1400	1411.58	1407	1407	.0000E+00	0	.0000
32	33	0	25.	.22	1360	1410.53	1407	1407	.0000E+00	0	.0000
32	34	0	25.	.39	1370	1413.50	1409	1410	.0000E+00	0	.0000
32	35	0	25.	.39	1390	1417.90	1413	1414	.0000E+00	0	.0000
32	36	0	150.	.10	1405	1420.99	1419	1418	.0000E+00	0	.0000
32	37	0	150.	.10	1410	1425.11	1423	1421	.0000E+00	0	.0000
32	38	0	25.	.39	1410	1433.31	1433	1433	.0000E+00	0	.0000
32	39	0	25.	.39	1410	1445.02	1442	1440	.0000E+00	0	.0000
32	40	0	25.	-.69	1420	1444.82	1445	1443	.0000E+00	0	.0000
33	3	-1	750.	.00	1390	1549.00	1549	1549	.0000E+00	0	.0000
33	4	0	750.	-.54	1390	1543.00	1543	1543	.4484E-02	1543	.0000
33	5	0	750.	.96	1430	1540.00	1539	1539	.0000E+00	0	.0000
33	6	0	750.	-.63	1460	1534.72	1532	1531	.0000E+00	0	.0000
33	7	0	750.	-1.09	1460	1529.36	1526	1526	.0000E+00	0	.0000
33	8	0	750.	.39	1460	1523.63	1522	1522	.0000E+00	0	.0000
33	9	0	750.	.39	1460	1519.36	1517	1514	.0000E+00	0	.0000
33	10	0	750.	2.11	1455	1515.89	1504	1509	.0000E+00	0	.0000
33	11	0	750.	3.46	1460	1512.60	1496	1509	.0000E+00	0	.0000
33	12	0	750.	2.86	1454	1509.35	1509	1509	.0000E+00	0	.0000
33	13	0	25.	2.41	1505	1528.50	1523	1522	.0000E+00	0	.0033
33	14	0	5.	4.35	1510	1561.92	1560	1560	.0000E+00	0	.0065
33	15	0	5.	4.83	1500	1560.80	1564	1562	.0000E+00	0	.0071
33	16	0	5.	4.83	1455	1543.19	1550	1549	.0000E+00	0	.0048
33	17	0	5.	4.35	1400	1501.90	1495	1495	.0000E+00	0	.0036
33	18	0	25.	4.35	1340	1478.07	1475	1474	.0000E+00	0	.0049
33	19	0	25.	4.83	1320	1470.50	1465	1465	.0000E+00	0	.0060
33	20	0	5.	4.83	1250	1458.04	1458	1458	.0000E+00	0	.0055
33	21	0	25.	4.83	1195	1439.36	1445	1444	.0000E+00	0	.0040
33	22	0	150.	4.35	1195	1433.88	1429	1428	.0000E+00	0	.0017
33	23	0	150.	2.41	1195	1431.48	1423	1417	.0000E+00	0	.0000
33	24	0	150.	2.41	1195	1428.74	1414	1413	.0000E+00	0	.0000
33	25	0	150.	2.41	1195	1426.12	1411	1410	.0000E+00	0	.0000
33	26	0	150.	2.41	1220	1423.72	1409	1405	.0000E+00	0	.0000
33	27	0	25.	4.35	1255	1411.34	1404	1400	.0000E+00	0	.0000
33	28	0	25.	4.35	1260	1385.00	1390	1390	.2242E-02	1385	.0000
33	29	0	25.	2.41	1300	1394.99	1393	1391	.0000E+00	0	.0000
33	30	0	25.	2.27	1310	1400.46	1398	1398	.0000E+00	0	.0000
33	31	0	25.	2.41	1320	1404.02	1403	1404	.0000E+00	0	.0000
33	32	0	25.	2.41	1340	1404.16	1404	1404	.0000E+00	0	.0000
33	33	0	25.	2.41	1355	1398.00	1403	1403	.1118E-02	1398	.0000
33	34	0	25.	.39	1370	1403.09	1402	1402	.0000E+00	0	.0000
33	35	0	25.	.39	1380	1407.45	1408	1408	.0000E+00	0	.0000
33	36	0	150.	.39	1400	1414.23	1413	1412	.0000E+00	0	.0000
33	37	0	150.	.10	1410	1419.19	1416	1415	.0000E+00	0	.0000
33	38	0	150.	.10	1410	1422.04	1419	1418	.0000E+00	0	.0000
34	3	-1	150.	.00	1390	1549.00	1549	1549	.0000E+00	0	.0000
34	4	0	750.	.97	1390	1541.81	1544	1543	.0000E+00	0	.0000
34	5	0	750.	.51	1390	1535.00	1537	1537	.4484E-02	1535	.0000
34	6	0	750.	-1.04	1395	1529.00	1528	1532	.3886E-02	1529	.0000
34	7	0	750.	-1.48	1445	1525.51	1522	1521	.0000E+00	0	.0000

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
34	8	0	750.	.39	1460	1519.49	1517	1517	.0000E+00	0	.0000
34	9	0	750.	.37	1460	1515.02	1511	1509	.0000E+00	0	.0000
34	10	0	750.	2.09	1470	1510.93	1502	1508	.0000E+00	0	.0000
34	11	0	750.	2.41	1452	1507.76	1498	1504	.0000E+00	0	.0000
34	12	0	750.	2.41	1452	1504.38	1498	1502	.0000E+00	0	.0000
34	13	0	750.	.40	1457	1500.91	1499	1500	.0000E+00	0	.0004
34	14	0	25.	1.26	1470	1508.27	1500	1500	.0000E+00	0	.0008
34	15	0	25.	4.48	1460	1515.76	1520	1520	.0000E+00	0	.0018
34	16	0	5.	4.83	1460	1517.36	1528	1529	.0000E+00	0	.0022
34	17	0	150.	4.35	1420	1477.32	1482	1479	.0000E+00	0	.0023
34	18	0	25.	4.35	1350	1472.68	1468	1468	.0000E+00	0	.0021
34	19	0	25.	4.82	1320	1464.83	1464	1462	.0000E+00	0	.0006
34	20	0	25.	4.83	1245	1455.51	1457	1457	.0000E+00	0	.0002
34	21	0	25.	4.83	1220	1445.31	1448	1448	.0000E+00	0	.0000
34	22	0	150.	4.35	1230	1437.50	1439	1433	.0000E+00	0	.0000
34	23	0	150.	2.41	1240	1434.05	1428	1423	.0000E+00	0	.0000
34	24	0	150.	2.41	1240	1430.57	1419	1412	.0000E+00	0	.0000
34	25	0	150.	2.41	1205	1427.53	1414	1408	.0000E+00	0	.0000
34	26	0	150.	2.41	1190	1424.94	1409	1407	.0000E+00	0	.0000
34	27	0	25.	2.41	1205	1414.88	1404	1403	.0000E+00	0	.0000
34	28	0	25.	4.35	1240	1385.00	1395	1393	.1494E-02	1385	.0000
34	29	0	25.	2.41	1255	1385.00	1389	1386	.1345E-02	1385	.0000
34	30	0	25.	1.18	1270	1393.66	1391	1390	.0000E+00	0	.0000
34	31	0	25.	2.41	1305	1397.92	1395	1394	.0000E+00	0	.0000
34	32	0	25.	2.41	1305	1397.61	1396	1396	.0000E+00	0	.0000
34	33	0	25.	2.41	1320	1390.00	1395	1395	.5219E-03	1390	.0000
34	34	0	25.	2.41	1350	1389.00	1395	1395	.7455E-03	1389	.0000
34	35	0	150.	.39	1370	1395.77	1399	1399	.0000E+00	0	.0000
34	36	0	150.	.39	1390	1405.69	1405	1404	.0000E+00	0	.0000
34	37	0	150.	.10	1405	1414.14	1412	1411	.0000E+00	0	.0000
34	38	0	150.	.39	1405	1418.88	1416	1416	.0000E+00	0	.0000
34	39	0	25.	.39	1395	1419.43	1418	1418	.0000E+00	0	.0000
35	3	-1	150.	.00	1405	1554.00	1554	1554	.0000E+00	0	.0000
35	4	0	150.	.97	1390	1542.32	1545	1545	.0000E+00	0	.0000
35	5	0	750.	.97	1390	1534.30	1532	1532	.0000E+00	0	.0000
35	6	0	750.	.97	1390	1528.84	1525	1525	.0000E+00	0	.0000
35	7	0	750.	.97	1390	1517.00	1518	1518	.3587E-02	1517	.0000
35	8	0	750.	-2.99	1395	1514.00	1514	1514	.5082E-02	1514	.0000
35	9	0	750.	-.38	1455	1512.24	1508	1508	.0000E+00	0	.0000
35	10	0	750.	.97	1460	1507.63	1503	1504	.0000E+00	0	.0000
35	11	0	750.	.97	1450	1503.18	1498	1502	.0000E+00	0	.0000
35	12	0	750.	.97	1420	1499.53	1496	1498	.0000E+00	0	.0000
35	13	0	750.	-1.34	1420	1496.80	1495	1495	.0000E+00	0	.0004
35	14	0	150.	1.07	1420	1493.93	1493	1493	.0000E+00	0	.0009
35	15	0	25.	2.10	1385	1491.56	1493	1493	.0000E+00	0	.0014
35	16	0	25.	3.50	1405	1482.36	1485	1485	.0000E+00	0	.0015
35	17	0	150.	4.35	1405	1471.58	1470	1469	.0000E+00	0	.0015
35	18	0	150.	4.35	1355	1464.83	1465	1464	.0000E+00	0	.0012
35	19	0	150.	4.35	1290	1458.74	1460	1459	.0000E+00	0	.0006
35	20	0	150.	4.83	1240	1453.25	1454	1454	.0000E+00	0	.0003

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
35	21	0	150.	4.35	1220	1447.60	1445	1445	.0000E+00	0	.0000
35	22	0	150.	4.35	1230	1441.38	1440	1439	.0000E+00	0	.0000
35	23	0	150.	3.89	1260	1436.30	1432	1426	.0000E+00	0	.0000
35	24	0	150.	2.41	1230	1431.76	1417	1414	.0000E+00	0	.0000
35	25	0	150.	2.41	1190	1428.32	1410	1409	.0000E+00	0	.0000
35	26	0	150.	2.17	1180	1425.69	1409	1407	.0000E+00	0	.0000
35	27	0	25.	2.41	1190	1418.43	1401	1400	.0000E+00	0	.0000
35	28	0	25.	2.41	1220	1403.24	1393	1390	.0000E+00	0	.0000
35	29	0	25.	2.41	1250	1383.00	1388	1387	.1794E-02	1383	.0000
35	30	0	25.	2.41	1270	1388.75	1384	1385	.0000E+00	0	.0000
35	31	0	25.	2.41	1280	1391.13	1389	1388	.0000E+00	0	.0000
35	32	0	25.	2.41	1280	1390.84	1387	1387	.0000E+00	0	.0000
35	33	0	25.	2.41	1280	1386.69	1387	1388	.0000E+00	0	.0000
35	34	0	150.	.39	1290	1382.00	1385	1385	.9694E-03	1382	.0000
35	35	0	150.	.39	1360	1386.54	1390	1391	.0000E+00	0	.0000
35	36	0	25.	.97	1370	1399.05	1402	1402	.0000E+00	0	.0000
35	37	0	25.	.39	1405	1411.68	1414	1412	.0000E+00	0	.0000
35	38	0	25.	.39	1400	1416.88	1414	1410	.0000E+00	0	.0000
35	39	0	25.	.01	1390	1416.13	1417	1416	.0000E+00	0	.0000
36	3	-1	150.	.00	1430	1556.00	1556	1556	.0000E+00	0	.0000
36	4	0	150.	.97	1400	1544.63	1548	1547	.0000E+00	0	.0000
36	5	0	150.	.97	1390	1535.61	1532	1532	.0000E+00	0	.0000
36	6	0	150.	.97	1390	1527.46	1524	1524	.0000E+00	0	.0000
36	7	0	750.	.97	1390	1520.00	1517	1517	.0000E+00	0	.0000
36	8	0	750.	.90	1400	1515.19	1512	1512	.0000E+00	0	.0000
36	9	0	750.	-.46	1400	1507.00	1507	1509	.3587E-02	1507	.0000
36	10	0	750.	-.50	1450	1504.31	1503	1504	.0000E+00	0	.0000
36	11	0	750.	.97	1420	1499.25	1498	1498	.0000E+00	0	.0000
36	12	0	750.	.73	1400	1495.67	1494	1495	.0000E+00	0	.0000
36	13	0	750.	-.05	1370	1492.99	1492	1492	.0000E+00	0	.0002
36	14	0	150.	-.19	1370	1488.39	1489	1488	.0000E+00	0	.0004
36	15	0	150.	2.29	1360	1481.31	1486	1484	.0000E+00	0	.0007
36	16	0	150.	2.41	1370	1474.78	1478	1478	.0000E+00	0	.0009
36	17	0	150.	2.97	1360	1468.97	1469	1469	.0000E+00	0	.0009
36	18	0	150.	3.29	1340	1463.02	1464	1463	.0000E+00	0	.0007
36	19	0	150.	3.49	1280	1457.46	1457	1457	.0000E+00	0	.0005
36	20	0	150.	3.43	1220	1452.62	1452	1452	.0000E+00	0	.0002
36	21	0	150.	3.33	1200	1447.94	1445	1445	.0000E+00	0	.0000
36	22	0	150.	3.46	1255	1442.58	1438	1438	.0000E+00	0	.0000
36	23	0	150.	4.35	1260	1436.99	1432	1426	.0000E+00	0	.0000
36	24	0	150.	1.76	1230	1431.90	1416	1413	.0000E+00	0	.0000
36	25	0	150.	2.41	1180	1428.15	1414	1408	.0000E+00	0	.0000
36	26	0	150.	2.27	1180	1425.39	1409	1404	.0000E+00	0	.0000
36	27	0	25.	2.40	1190	1420.02	1403	1393	.0000E+00	0	.0000
36	28	0	25.	2.41	1200	1409.85	1384	1380	.0000E+00	0	.0000
36	29	0	25.	2.41	1255	1396.75	1381	1383	.0000E+00	0	.0000
36	30	0	25.	-.96	1270	1378.00	1377	1377	.2989E-02	1378	.0000
36	31	0	25.	.39	1280	1381.55	1378	1378	.0000E+00	0	.0000
36	32	0	25.	2.41	1280	1382.44	1378	1378	.0000E+00	0	.0000
36	33	0	25.	.39	1280	1379.94	1377	1377	.0000E+00	0	.0000

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
36	34	0	150.	.39	1280	1376.00	1375	1375	.9694E-03	1376	.0000
36	35	0	150.	.39	1340	1381.01	1385	1385	.0000E+00	0	.0000
36	36	0	25.	2.41	1370	1396.15	1391	1391	.0000E+00	0	.0000
36	37	0	25.	.97	1390	1406.85	1401	1401	.0000E+00	0	.0000
36	38	0	25.	.39	1390	1411.89	1410	1407	.0000E+00	0	.0000
36	39	0	25.	-.67	1370	1413.15	1415	1413	.0000E+00	0	.0000
36	40	0	25.	.97	1405	1423.04	1420	1419	.0000E+00	0	.0000
37	3	-1	150.	.00	1470	1556.00	1556	1556	.0000E+00	0	.0000
37	4	0	150.	.97	1440	1545.27	1548	1546	.0000E+00	0	.0000
37	5	0	150.	.97	1400	1536.45	1531	1531	.0000E+00	0	.0000
37	6	0	150.	.97	1390	1528.73	1524	1523	.0000E+00	0	.0000
37	7	0	150.	.97	1380	1521.22	1518	1518	.0000E+00	0	.0000
37	8	0	150.	.97	1380	1513.98	1512	1512	.0000E+00	0	.0000
37	9	0	750.	3.60	1370	1507.20	1507	1508	.0000E+00	0	.0000
37	10	0	750.	1.89	1405	1500.00	1502	1506	.4783E-02	1500	.0000
37	11	0	750.	-1.18	1380	1496.32	1497	1497	.0000E+00	0	.0000
37	12	0	750.	.14	1360	1492.42	1492	1492	.0000E+00	0	.0001
37	13	0	750.	.97	1340	1489.54	1488	1489	.0000E+00	0	.0002
37	14	0	150.	-.51	1320	1484.33	1485	1484	.0000E+00	0	.0004
37	15	0	150.	1.52	1300	1477.61	1481	1480	.0000E+00	0	.0005
37	16	0	150.	2.41	1250	1472.02	1476	1475	.0000E+00	0	.0006
37	17	0	150.	3.69	1295	1466.88	1469	1469	.0000E+00	0	.0006
37	18	0	150.	3.84	1280	1461.43	1464	1463	.0000E+00	0	.0005
37	19	0	150.	2.17	1250	1456.38	1458	1457	.0000E+00	0	.0004
37	20	0	150.	3.63	1200	1452.05	1451	1450	.0000E+00	0	.0002
37	21	0	150.	3.40	1220	1447.74	1445	1444	.0000E+00	0	.0000
37	22	0	150.	1.85	1270	1442.34	1436	1434	.0000E+00	0	.0000
37	23	0	150.	2.22	1270	1436.26	1429	1427	.0000E+00	0	.0000
37	24	0	150.	2.41	1230	1431.04	1414	1412	.0000E+00	0	.0000
37	25	0	150.	2.41	1190	1426.90	1413	1406	.0000E+00	0	.0000
37	26	0	150.	2.41	1180	1423.34	1405	1404	.0000E+00	0	.0000
37	27	0	150.	2.41	1180	1419.58	1399	1393	.0000E+00	0	.0000
37	28	0	25.	2.41	1200	1412.90	1386	1382	.0000E+00	0	.0000
37	29	0	25.	2.41	1220	1402.24	1383	1382	.0000E+00	0	.0000
37	30	0	25.	2.41	1255	1374.00	1375	1378	.1196E-02	1374	.0000
37	31	0	25.	-.66	1250	1372.00	1367	1367	.1943E-02	1372	.0000
37	32	0	25.	2.41	1260	1370.00	1373	1372	.1345E-02	1370	.0000
37	33	0	25.	.39	1260	1373.57	1373	1374	.0000E+00	0	.0000
37	34	0	150.	.39	1260	1372.00	1375	1375	.1118E-02	1372	.0000
37	35	0	150.	5.31	1310	1378.57	1373	1372	.0000E+00	0	.0000
37	36	0	25.	2.41	1350	1389.29	1384	1383	.0000E+00	0	.0000
37	37	0	25.	.97	1370	1398.07	1399	1400	.0000E+00	0	.0000
37	38	0	25.	-.10	1390	1403.55	1401	1400	.0000E+00	0	.0000
37	39	0	25.	-1.16	1380	1409.58	1409	1408	.0000E+00	0	.0000
37	40	0	25.	.97	1405	1422.48	1421	1420	.0000E+00	0	.0000
38	3	-1	150.	.00	1500	1556.00	1556	1556	.0000E+00	0	.0000
38	4	0	150.	.97	1470	1546.03	1547	1547	.0000E+00	0	.0000
38	5	0	150.	.97	1440	1537.23	1531	1531	.0000E+00	0	.0000
38	6	0	150.	.97	1400	1529.64	1525	1525	.0000E+00	0	.0000
38	7	0	150.	.97	1395	1522.58	1519	1518	.0000E+00	0	.0000

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
38	8	0	150.	.97	1380	1515.60	1514	1512	.0000E+00	0	.0000
38	9	0	150.	4.35	1380	1508.64	1508	1508	.0000E+00	0	.0000
38	10	0	150.	4.35	1370	1500.78	1501	1500	.0000E+00	0	.0000
38	11	0	750.	1.14	1350	1494.00	1495	1495	.4783E-02	1494	.0000
38	12	0	750.	-.54	1320	1489.44	1491	1489	.0000E+00	0	.0002
38	13	0	750.	.67	1310	1485.85	1486	1484	.0000E+00	0	.0002
38	14	0	150.	.87	1240	1480.26	1482	1479	.0000E+00	0	.0003
38	15	0	150.	2.41	1205	1474.61	1477	1477	.0000E+00	0	.0004
38	16	0	150.	2.41	1195	1469.56	1473	1474	.0000E+00	0	.0005
38	17	0	150.	2.41	1230	1464.49	1467	1467	.0000E+00	0	.0005
38	18	0	150.	2.41	1230	1459.52	1463	1462	.0000E+00	0	.0004
38	19	0	150.	2.39	1220	1455.01	1457	1456	.0000E+00	0	.0003
38	20	0	150.	2.05	1220	1451.03	1449	1449	.0000E+00	0	.0002
38	21	0	150.	2.01	1280	1446.88	1445	1444	.0000E+00	0	.0001
38	22	0	150.	3.98	1345	1441.05	1438	1438	.0000E+00	0	.0001
38	23	0	150.	2.84	1270	1434.43	1427	1426	.0000E+00	0	.0000
38	24	0	150.	2.85	1230	1429.40	1419	1417	.0000E+00	0	.0000
38	25	0	150.	.73	1190	1424.97	1409	1406	.0000E+00	0	.0000
38	26	0	150.	2.05	1180	1421.06	1406	1402	.0000E+00	0	.0000
38	27	0	150.	2.41	1180	1416.94	1399	1394	.0000E+00	0	.0000
38	28	0	150.	2.41	1180	1411.90	1388	1389	.0000E+00	0	.0000
38	29	0	150.	2.41	1195	1407.40	1382	1385	.0000E+00	0	.0000
38	30	0	25.	2.16	1220	1395.76	1376	1380	.0000E+00	0	.0000
38	31	0	25.	.97	1255	1382.20	1372	1378	.0000E+00	0	.0000
38	32	0	25.	-1.19	1250	1369.00	1366	1366	.1943E-02	1369	.0000
38	33	0	150.	.39	1250	1370.37	1374	1373	.0000E+00	0	.0000
38	34	0	150.	.97	1260	1370.00	1375	1375	.1044E-02	1370	.0000
38	35	0	25.	2.41	1270	1374.94	1377	1377	.0000E+00	0	.0000
38	36	0	25.	.97	1300	1382.44	1379	1379	.0000E+00	0	.0000
38	37	0	25.	.97	1350	1390.22	1386	1386	.0000E+00	0	.0000
38	38	0	25.	-1.13	1380	1394.87	1393	1394	.0000E+00	0	.0000
38	39	0	25.	.39	1390	1410.52	1408	1408	.0000E+00	0	.0000
38	40	0	25.	.97	1405	1423.14	1420	1417	.0000E+00	0	.0000
39	3	-1	150.	.00	1510	1560.00	1560	1560	.0000E+00	0	.0000
39	4	0	150.	.97	1505	1548.39	1548	1548	.0000E+00	0	.0000
39	5	0	150.	.97	1490	1539.32	1538	1538	.0000E+00	0	.0000
39	6	0	150.	.97	1450	1531.08	1532	1532	.0000E+00	0	.0000
39	7	0	150.	.97	1440	1524.01	1520	1519	.0000E+00	0	.0000
39	8	0	150.	.97	1400	1517.02	1515	1514	.0000E+00	0	.0000
39	9	0	150.	4.35	1395	1510.47	1510	1509	.0000E+00	0	.0000
39	10	0	150.	4.35	1390	1502.38	1500	1500	.0000E+00	0	.0000
39	11	0	150.	2.41	1370	1493.16	1494	1494	.0000E+00	0	.0000
39	12	0	750.	2.41	1330	1487.00	1488	1489	.3886E-02	1487	.0000
39	13	0	750.	-1.34	1255	1481.00	1481	1480	.4484E-02	1481	.0002
39	14	0	750.	-1.26	1195	1476.58	1475	1475	.0000E+00	0	.0003
39	15	0	150.	1.84	1190	1471.69	1472	1472	.0000E+00	0	.0004
39	16	0	150.	2.41	1190	1466.63	1469	1469	.0000E+00	0	.0004
39	17	0	150.	1.86	1200	1461.63	1464	1464	.0000E+00	0	.0004
39	18	0	150.	2.41	1190	1457.10	1459	1459	.0000E+00	0	.0004
39	19	0	150.	2.41	1190	1452.91	1455	1454	.0000E+00	0	.0003

I	J	CHN	K	R	B	HO	H71	H80	C	H_r	Q_w
			ft/d	in/y	ft	ft	ft	ft	ft^2/d	ft	cfs
39	20	0	150.	1.04	1220	1449.01	1448	1448	.0000E+00	0	.0002
39	21	0	150.	.83	1300	1444.65	1444	1444	.0000E+00	0	.0001
39	22	0	150.	-.42	1355	1438.35	1438	1438	.0000E+00	0	.0001
39	23	0	150.	1.65	1300	1432.24	1430	1429	.0000E+00	0	.0001
39	24	0	150.	3.57	1250	1427.26	1418	1417	.0000E+00	0	.0002
39	25	0	150.	1.48	1195	1422.75	1408	1405	.0000E+00	0	.0001
39	26	0	150.	-.52	1170	1418.67	1403	1402	.0000E+00	0	.0000
39	27	0	150.	2.41	1170	1414.72	1392	1391	.0000E+00	0	.0000
39	28	0	150.	2.28	1180	1410.37	1387	1381	.0000E+00	0	.0000
39	29	0	150.	1.96	1195	1406.32	1381	1377	.0000E+00	0	.0000
39	30	0	25.	1.51	1220	1397.64	1377	1376	.0000E+00	0	.0000
39	31	0	25.	.64	1230	1385.21	1374	1374	.0000E+00	0	.0000
39	32	0	25.	-2.37	1240	1366.00	1366	1366	.1794E-02	1366	.0000
39	33	0	150.	.97	1255	1368.83	1373	1372	.0000E+00	0	.0000
39	34	0	150.	.97	1260	1369.20	1373	1372	.0000E+00	0	.0000
39	35	0	150.	.39	1280	1366.00	1372	1372	.1118E-02	1366	.0000
39	36	0	25.	.39	1330	1376.46	1375	1375	.0000E+00	0	.0000
39	37	0	25.	.39	1340	1385.52	1383	1383	.0000E+00	0	.0000
39	38	0	25.	.39	1370	1394.98	1390	1392	.0000E+00	0	.0000
39	39	0	25.	.39	1390	1407.73	1408	1407	.0000E+00	0	.0000
39	40	0	25.	.97	1405	1422.78	1420	1417	.0000E+00	0	.0000
40	4	0	150.	2.41	1500	1547.66	1552	1551	.0000E+00	0	.0000
40	5	0	150.	2.41	1505	1543.44	1544	1545	.0000E+00	0	.0000
40	6	0	150.	2.41	1505	1535.14	1537	1538	.0000E+00	0	.0000
40	7	0	150.	2.41	1475	1527.17	1530	1530	.0000E+00	0	.0000
40	8	0	150.	.97	1460	1519.68	1515	1515	.0000E+00	0	.0000
40	9	0	150.	4.35	1455	1513.00	1513	1513	.0000E+00	0	.0000
40	10	0	150.	2.41	1440	1504.41	1505	1504	.0000E+00	0	.0000
40	11	0	150.	2.41	1420	1494.40	1495	1495	.0000E+00	0	.0000
40	12	0	150.	5.31	1370	1485.96	1488	1488	.0000E+00	0	.0000
40	13	0	150.	2.41	1300	1478.61	1480	1479	.0000E+00	0	.0000
40	14	0	750.	1.58	1195	1472.00	1473	1472	.4484E-02	1472	.0002
40	15	0	750.	1.42	1180	1468.00	1466	1466	.4185E-02	1468	.0003
40	16	0	150.	1.35	1180	1463.13	1464	1464	.0000E+00	0	.0003
40	17	0	150.	2.00	1170	1458.22	1460	1460	.0000E+00	0	.0004
40	18	0	150.	1.02	1190	1454.11	1457	1456	.0000E+00	0	.0003
40	19	0	150.	2.41	1195	1449.89	1452	1452	.0000E+00	0	.0003
40	20	0	150.	2.15	1250	1445.76	1447	1447	.0000E+00	0	.0003
40	21	0	150.	2.26	1305	1441.15	1443	1443	.0000E+00	0	.0002
40	22	0	150.	2.44	1320	1435.62	1437	1437	.0000E+00	0	.0002
40	23	0	150.	2.65	1320	1430.00	1430	1429	.0000E+00	0	.0002
40	24	0	150.	2.69	1255	1424.89	1417	1415	.0000E+00	0	.0002
40	25	0	150.	.57	1205	1420.44	1412	1405	.0000E+00	0	.0002
40	26	0	150.	.25	1180	1416.38	1402	1402	.0000E+00	0	.0003
40	27	0	150.	1.64	1180	1412.26	1394	1391	.0000E+00	0	.0000
40	28	0	150.	2.41	1180	1407.79	1387	1385	.0000E+00	0	.0000
40	29	0	150.	1.77	1205	1402.61	1379	1380	.0000E+00	0	.0000
40	30	0	150.	2.54	1220	1395.32	1376	1376	.0000E+00	0	.0000
40	31	0	150.	4.35	1230	1387.45	1373	1373	.0000E+00	0	.0000
40	32	0	150.	3.26	1250	1378.17	1369	1369	.0000E+00	0	.0000

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
40	33	0	150.	-2.99	1270	1362.00	1361	1361	.2391E-02	1362	.0000
40	34	0	25.	.97	1270	1366.27	1365	1365	.0000E+00	0	.0000
40	35	0	25.	.39	1300	1363.00	1365	1365	.1193E-02	1363	.0000
40	36	0	25.	.39	1330	1373.26	1370	1372	.0000E+00	0	.0000
40	37	0	25.	-.07	1330	1381.53	1383	1382	.0000E+00	0	.0000
40	38	0	25.	.97	1370	1392.49	1383	1384	.0000E+00	0	.0000
40	39	0	25.	.39	1380	1399.12	1388	1398	.0000E+00	0	.0000
41	4	0	150.	2.41	1495	1548.47	1550	1550	.0000E+00	0	.0000
41	5	0	150.	2.41	1505	1547.74	1552	1553	.0000E+00	0	.0000
41	6	0	25.	2.41	1505	1544.18	1546	1548	.0000E+00	0	.0000
41	7	0	150.	2.41	1510	1533.61	1537	1539	.0000E+00	0	.0000
41	8	0	150.	.97	1510	1525.51	1522	1522	.0000E+00	0	.0000
41	9	0	150.	2.41	1500	1517.99	1517	1519	.0000E+00	0	.0000
41	10	0	150.	2.41	1480	1509.99	1510	1509	.0000E+00	0	.0000
41	11	0	25.	2.41	1450	1500.00	1500	1499	.0000E+00	0	.0000
41	12	0	150.	5.31	1420	1485.21	1489	1489	.0000E+00	0	.0000
41	13	0	150.	2.41	1370	1477.26	1480	1480	.0000E+00	0	.0000
41	14	0	150.	2.41	1300	1469.37	1471	1469	.0000E+00	0	.0000
41	15	0	750.	2.41	1195	1464.00	1465	1465	.1793E-02	1464	.0000
41	16	0	750.	1.05	1190	1459.00	1461	1460	.3886E-02	1459	.0001
41	17	0	750.	.55	1180	1456.00	1457	1457	.3886E-02	1456	.0002
41	18	0	150.	2.41	1170	1450.89	1453	1453	.0000E+00	0	.0002
41	19	0	150.	2.17	1190	1445.70	1450	1449	.0000E+00	0	.0002
41	20	0	150.	2.02	1220	1441.16	1445	1445	.0000E+00	0	.0002
41	21	0	150.	3.74	1280	1436.76	1440	1439	.0000E+00	0	.0002
41	22	0	150.	3.66	1310	1432.00	1435	1434	.0000E+00	0	.0002
41	23	0	150.	3.64	1310	1427.07	1429	1428	.0000E+00	0	.0002
41	24	0	150.	3.56	1300	1422.31	1421	1414	.0000E+00	0	.0002
41	25	0	150.	4.35	1240	1418.04	1412	1407	.0000E+00	0	.0003
41	26	0	150.	2.95	1190	1414.11	1402	1403	.0000E+00	0	.0004
41	27	0	150.	1.06	1180	1409.71	1395	1396	.0000E+00	0	.0007
41	28	0	150.	2.65	1180	1404.99	1388	1388	.0000E+00	0	.0004
41	29	0	150.	4.35	1170	1399.89	1381	1382	.0000E+00	0	.0000
41	30	0	150.	3.06	1210	1393.78	1375	1374	.0000E+00	0	.0000
41	31	0	150.	1.99	1220	1386.93	1372	1371	.0000E+00	0	.0000
41	32	0	150.	2.76	1250	1379.66	1368	1367	.0000E+00	0	.0000
41	33	0	150.	3.43	1250	1372.66	1364	1365	.0000E+00	0	.0000
41	34	0	25.	-2.58	1290	1358.00	1355	1355	.2092E-02	1358	.0000
41	35	0	25.	2.41	1310	1357.00	1358	1358	.1342E-02	1357	.0000
41	36	0	25.	.39	1330	1369.78	1367	1368	.0000E+00	0	.0000
41	37	0	25.	.39	1330	1379.19	1377	1378	.0000E+00	0	.0000
41	38	0	25.	.39	1360	1387.93	1384	1385	.0000E+00	0	.0000
41	39	0	25.	.39	1370	1393.26	1385	1390	.0000E+00	0	.0000
42	4	0	150.	-2.41	1495	1547.90	1537	1537	.0000E+00	0	.0000
42	5	0	150.	2.41	1495	1549.30	1549	1552	.0000E+00	0	.0000
42	6	0	25.	2.41	1505	1552.50	1551	1551	.0000E+00	0	.0000
42	7	0	25.	2.41	1510	1548.27	1544	1546	.0000E+00	0	.0000
42	8	0	25.	.97	1520	1539.29	1535	1535	.0000E+00	0	.0000
42	9	0	25.	2.41	1520	1536.24	1529	1533	.0000E+00	0	.0000
42	10	0	25.	2.41	1510	1525.47	1519	1519	.0000E+00	0	.0000

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
42	11	0	25.	2.41	1470	1509.12	1507	1506	.0000E+00	0	.0000
42	12	0	25.	2.41	1450	1494.91	1492	1491	.0000E+00	0	.0000
42	13	0	25.	5.31	1420	1482.74	1483	1483	.0000E+00	0	.0000
42	14	0	150.	2.41	1370	1466.53	1471	1470	.0000E+00	0	.0000
42	15	0	350.	2.41	1300	1460.49	1462	1460	.0000E+00	0	.0000
42	16	0	750.	1.96	1240	1456.34	1455	1455	.0000E+00	0	.0000
42	17	0	750.	1.65	1195	1452.25	1455	1454	.0000E+00	0	.0000
42	18	0	750.	2.41	1180	1447.00	1451	1451	.5082E-02	1447	.0001
42	19	0	750.	3.59	1190	1442.23	1447	1447	.0000E+00	0	.0002
42	20	0	750.	3.44	1195	1437.66	1443	1443	.0000E+00	0	.0002
42	21	0	750.	4.35	1230	1433.25	1435	1435	.0000E+00	0	.0002
42	22	0	750.	3.02	1260	1428.92	1433	1432	.0000E+00	0	.0002
42	23	0	750.	4.35	1305	1424.47	1427	1427	.0000E+00	0	.0002
42	24	0	750.	4.35	1310	1419.93	1421	1419	.0000E+00	0	.0003
42	25	0	750.	3.90	1275	1416.30	1412	1412	.0000E+00	0	.0003
42	26	0	150.	2.62	1200	1412.10	1402	1401	.0000E+00	0	.0004
42	27	0	150.	3.58	1180	1407.26	1397	1397	.0000E+00	0	.0006
42	28	0	150.	1.69	1160	1402.13	1387	1388	.0000E+00	0	.0007
42	29	0	150.	2.41	1160	1397.00	1381	1377	.0000E+00	0	.0008
42	30	0	150.	1.96	1200	1391.31	1372	1371	.0000E+00	0	.0000
42	31	0	150.	.67	1210	1385.13	1368	1365	.0000E+00	0	.0000
42	32	0	150.	1.07	1190	1378.93	1365	1365	.0000E+00	0	.0000
42	33	0	150.	1.71	1240	1372.03	1364	1366	.0000E+00	0	.0000
42	34	0	150.	.39	1280	1355.00	1360	1359	.1345E-02	1355	.0000
42	35	0	150.	.39	1310	1354.00	1355	1355	.2242E-02	1354	.0000
42	36	0	25.	.97	1330	1366.00	1366	1367	.0000E+00	0	.0000
42	37	0	25.	.97	1330	1376.73	1374	1375	.0000E+00	0	.0000
42	38	0	25.	.97	1360	1386.47	1380	1382	.0000E+00	0	.0000
42	39	0	25.	.39	1360	1389.81	1385	1386	.0000E+00	0	.0000
43	6	0	25.	.78	1495	1555.69	1551	1551	.0000E+00	0	.0000
43	7	0	25.	.97	1500	1554.99	1549	1551	.0000E+00	0	.0000
43	12	0	25.	2.41	1455	1499.22	1501	1499	.0000E+00	0	.0000
43	13	0	25.	2.41	1414	1489.00	1487	1488	.0000E+00	0	.0000
43	14	0	25.	5.31	1400	1474.16	1478	1476	.0000E+00	0	.0000
43	15	0	350.	2.41	1345	1458.69	1460	1458	.0000E+00	0	.0000
43	16	0	350.	2.41	1345	1454.30	1455	1455	.0000E+00	0	.0000
43	17	0	750.	2.41	1290	1449.72	1452	1451	.0000E+00	0	.0000
43	18	0	750.	.64	1245	1445.25	1448	1447	.0000E+00	0	.0000
43	19	0	750.	4.22	1200	1440.00	1445	1445	.4185E-02	1440	.0002
43	20	0	750.	4.07	1195	1435.00	1440	1440	.2690E-02	1435	.0002
43	21	0	750.	3.87	1195	1431.40	1434	1432	.0000E+00	0	.0002
43	22	0	750.	4.35	1220	1427.12	1429	1428	.0000E+00	0	.0002
43	23	0	750.	3.45	1280	1422.62	1424	1423	.0000E+00	0	.0002
43	24	0	750.	4.35	1300	1418.12	1419	1418	.0000E+00	0	.0003
43	25	0	750.	3.08	1310	1413.74	1412	1412	.0000E+00	0	.0004
43	26	0	750.	2.82	1260	1409.49	1405	1408	.0000E+00	0	.0005
43	27	0	150.	2.83	1220	1404.45	1398	1399	.0000E+00	0	.0006
43	28	0	150.	3.01	1190	1398.92	1387	1388	.0000E+00	0	.0008
43	29	0	150.	2.41	1170	1393.50	1380	1379	.0000E+00	0	.0011
43	30	0	150.	2.41	1150	1388.38	1372	1372	.0000E+00	0	.0013

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
43	31	0	150.	1.29	1180	1383.29	1367	1364	.0000E+00	0	.0000
43	32	0	150.	1.46	1200	1377.78	1363	1361	.0000E+00	0	.0000
43	33	0	150.	1.81	1210	1371.74	1362	1362	.0000E+00	0	.0000
43	34	0	150.	.72	1250	1364.96	1361	1359	.0000E+00	0	.0000
43	35	0	25.	.39	1290	1352.00	1355	1355	.1794E-02	1352	.0000
43	36	0	25.	.97	1310	1362.59	1362	1364	.0000E+00	0	.0000
43	37	0	25.	.97	1320	1371.16	1372	1373	.0000E+00	0	.0000
43	38	0	25.	.97	1370	1382.67	1378	1379	.0000E+00	0	.0000
43	39	0	25.	.39	1360	1386.31	1385	1384	.0000E+00	0	.0000
44	12	0	25.	2.41	1445	1501.79	1510	1509	.0000E+00	0	.0000
44	13	0	25.	2.41	1425	1493.66	1491	1489	.0000E+00	0	.0000
44	14	0	25.	5.31	1400	1482.96	1481	1479	.0000E+00	0	.0000
44	15	0	25.	2.41	1390	1463.59	1459	1459	.0000E+00	0	.0000
44	16	0	350.	2.41	1395	1452.49	1454	1454	.0000E+00	0	.0000
44	17	0	350.	2.41	1370	1448.41	1447	1447	.0000E+00	0	.0000
44	18	0	350.	2.41	1340	1443.21	1444	1443	.0000E+00	0	.0000
44	19	0	750.	2.41	1290	1438.10	1440	1439	.0000E+00	0	.0000
44	20	0	750.	1.14	1230	1433.77	1435	1434	.0000E+00	0	.0003
44	21	0	750.	4.35	1210	1428.00	1429	1429	.3587E-02	1428	.0003
44	22	0	750.	2.80	1195	1424.56	1425	1425	.0000E+00	0	.0003
44	23	0	750.	2.65	1205	1420.01	1422	1421	.0000E+00	0	.0003
44	24	0	750.	4.14	1260	1415.59	1417	1415	.0000E+00	0	.0003
44	25	0	750.	4.02	1300	1410.96	1410	1409	.0000E+00	0	.0004
44	26	0	750.	4.00	1305	1406.00	1405	1405	.0000E+00	0	.0005
44	27	0	750.	4.11	1260	1400.68	1399	1398	.0000E+00	0	.0007
44	28	0	150.	4.30	1205	1395.10	1392	1391	.0000E+00	0	.0009
44	29	0	150.	4.35	1180	1389.32	1384	1385	.0000E+00	0	.0014
44	30	0	150.	2.41	1160	1384.96	1374	1374	.0000E+00	0	.0019
44	31	0	150.	3.98	1160	1381.06	1367	1366	.0000E+00	0	.0221
44	32	0	150.	2.04	1200	1376.08	1362	1361	.0000E+00	0	.0000
44	33	0	150.	2.30	1210	1370.29	1358	1358	.0000E+00	0	.0000
44	34	0	150.	1.44	1230	1362.84	1354	1355	.0000E+00	0	.0000
44	35	0	150.	-2.07	1245	1350.00	1349	1349	.2989E-02	1350	.0000
44	36	0	25.	.97	1300	1357.00	1357	1355	.0000E+00	0	.0000
44	37	0	25.	.97	1320	1364.37	1367	1368	.0000E+00	0	.0000
44	38	0	25.	.39	1355	1372.01	1373	1373	.0000E+00	0	.0000
44	39	0	25.	.16	1355	1381.06	1379	1379	.0000E+00	0	.0000
45	15	0	25.	2.41	1440	1464.69	1465	1465	.0000E+00	0	.0000
45	16	0	350.	2.41	1420	1452.05	1458	1458	.0000E+00	0	.0000
45	17	0	350.	2.41	1410	1448.02	1449	1449	.0000E+00	0	.0000
45	18	0	350.	2.41	1400	1442.37	1443	1443	.0000E+00	0	.0000
45	19	0	350.	2.41	1370	1436.82	1435	1435	.0000E+00	0	.0000
45	20	0	350.	2.41	1320	1431.42	1430	1429	.0000E+00	0	.0000
45	21	0	750.	3.87	1275	1426.40	1425	1425	.0000E+00	0	.0004
45	22	0	750.	2.09	1250	1421.00	1422	1423	.3587E-02	1421	.0003
45	23	0	750.	2.03	1200	1416.00	1418	1418	.4484E-02	1416	.0003
45	24	0	750.	3.53	1200	1412.40	1413	1412	.0000E+00	0	.0004
45	25	0	750.	1.73	1260	1407.72	1407	1407	.0000E+00	0	.0004
45	26	0	750.	3.51	1305	1402.45	1403	1403	.0000E+00	0	.0004
45	27	0	750.	3.81	1270	1396.56	1398	1398	.0000E+00	0	.0006

I	J	CHN	K	R	B	HO	H71	H80	C	H_r	Q_w
			ft/d	in/y	ft	ft	ft	ft	ft^2/d	ft	cfs
45	28	0	750.	4.22	1225	1390.36	1391	1390	.0000E+00	0	.0010
45	29	0	750.	3.46	1180	1385.60	1385	1385	.0000E+00	0	.0018
45	30	0	750.	3.54	1160	1382.37	1377	1377	.0000E+00	0	.0033
45	31	0	150.	4.35	1160	1378.59	1368	1368	.0000E+00	0	.0027
45	32	0	150.	2.41	1190	1373.89	1364	1362	.0000E+00	0	.0031
45	33	0	150.	4.35	1220	1368.82	1359	1358	.0000E+00	0	.0000
45	34	0	150.	3.73	1230	1361.76	1355	1354	.0000E+00	0	.0000
45	35	0	150.	-2.00	1240	1348.00	1349	1349	.1794E-02	1348	.0000
45	36	0	25.	.04	1250	1351.03	1348	1348	.0000E+00	0	.0000
45	37	0	25.	.16	1305	1355.83	1357	1358	.0000E+00	0	.0000
45	38	0	25.	.39	1330	1360.30	1362	1364	.0000E+00	0	.0000
46	16	0	25.	2.41	1455	1469.41	1465	1463	.0000E+00	0	.0000
46	17	0	25.	2.41	1445	1459.03	1455	1454	.0000E+00	0	.0000
46	18	0	350.	2.41	1420	1441.13	1445	1445	.0000E+00	0	.0000
46	19	0	350.	2.41	1410	1436.24	1435	1435	.0000E+00	0	.0000
46	20	0	350.	2.41	1400	1429.73	1427	1427	.0000E+00	0	.0000
46	21	0	350.	4.35	1360	1423.86	1423	1423	.0000E+00	0	.0000
46	22	0	750.	4.35	1340	1418.65	1419	1419	.0000E+00	0	.0005
46	23	0	750.	4.35	1255	1413.88	1414	1413	.0000E+00	0	.0007
46	24	0	750.	4.35	1200	1408.00	1409	1409	.3587E-02	1408	.0008
46	25	0	750.	4.35	1200	1402.00	1405	1404	.4185E-02	1402	.0008
46	26	0	750.	2.87	1260	1399.00	1401	1401	.4185E-02	1399	.0008
46	27	0	750.	3.04	1270	1393.85	1397	1397	.0000E+00	0	.0007
46	28	0	750.	3.64	1250	1388.07	1392	1391	.0000E+00	0	.0009
46	29	0	750.	3.25	1190	1383.23	1386	1386	.0000E+00	0	.0015
46	30	0	750.	4.35	1160	1379.47	1378	1378	.0000E+00	0	.0023
46	31	0	750.	2.53	1170	1375.34	1372	1372	.0000E+00	0	.0027
46	32	0	750.	1.74	1180	1371.95	1365	1363	.0000E+00	0	.0033
46	33	0	150.	2.41	1205	1367.14	1358	1357	.0000E+00	0	.0045
46	34	0	150.	2.09	1230	1360.93	1355	1354	.0000E+00	0	.0026
46	35	0	150.	2.41	1240	1354.28	1352	1351	.0000E+00	0	.0000
46	36	0	150.	-1.53	1245	1344.00	1344	1344	.3438E-02	1344	.0000
46	37	0	25.	.39	1305	1349.51	1348	1349	.0000E+00	0	.0000
46	38	0	25.	.39	1330	1353.08	1352	1353	.0000E+00	0	.0000
47	20	0	350.	2.41	1410	1426.52	1428	1428	.0000E+00	0	.0000
47	21	0	350.	4.35	1380	1421.73	1422	1422	.0000E+00	0	.0000
47	22	0	350.	4.35	1355	1416.56	1415	1415	.0000E+00	0	.0007
47	23	0	350.	4.35	1330	1410.95	1410	1409	.0000E+00	0	.0009
47	24	0	750.	4.35	1250	1405.70	1406	1406	.0000E+00	0	.0010
47	25	0	750.	4.35	1190	1401.53	1402	1402	.0000E+00	0	.0010
47	26	0	750.	2.01	1205	1396.90	1398	1398	.0000E+00	0	.0007
47	27	0	750.	4.35	1260	1391.00	1395	1395	.4185E-02	1391	.0006
47	28	0	750.	4.22	1260	1385.00	1390	1390	.4185E-02	1385	.0007
47	29	0	750.	4.16	1195	1380.00	1384	1386	.1793E-02	1380	.0011
47	30	0	750.	3.70	1155	1376.88	1378	1378	.0000E+00	0	.0017
47	31	0	750.	3.29	1170	1373.09	1373	1373	.0000E+00	0	.0024
47	32	0	750.	2.95	1180	1369.10	1367	1366	.0000E+00	0	.0031
47	33	0	750.	4.35	1200	1364.20	1359	1359	.0000E+00	0	.0036
47	34	0	750.	2.41	1210	1359.62	1357	1356	.0000E+00	0	.0034
47	35	0	750.	2.18	1230	1355.66	1353	1352	.0000E+00	0	.0000

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
47	36	0	150.	-1.49	1270	1339.00	1346	1346	.1494E-02	1339	.0000
47	37	0	25.	.39	1305	1344.91	1340	1340	.0000E+00	0	.0000
47	38	0	25.	.39	1310	1346.57	1343	1344	.0000E+00	0	.0000
4[illegible]	[illegible]	0	350.	4.35	1405	1419.66	1423	1423	.0000E+00	0	.0000
48	22	0	350.	4.35	1375	1413.75	1415	1414	.0000E+00	0	.0000
48	23	0	350.	4.35	1340	1408.61	1408	1408	.0000E+00	0	.0012
48	24	0	350.	4.35	1290	1403.45	1404	1404	.0000E+00	0	.0014
48	25	0	350.	4.35	1200	1398.53	1399	1399	.0000E+00	0	.0014
48	26	0	350.	4.35	1175	1393.43	1395	1395	.0000E+00	0	.0005
48	27	0	750.	3.30	1220	1388.07	1392	1392	.0000E+00	0	.0003
48	28	0	750.	4.35	1240	1382.69	1387	1388	.0000E+00	0	.0003
48	29	0	750.	4.35	1150	1378.00	1383	1384	.3587E-02	1378	.0004
48	30	0	750.	4.35	1145	1374.00	1377	1378	.3886E-02	1374	.0008
48	31	0	750.	4.12	1160	1370.64	1372	1372	.0000E+00	0	.0023
48	32	0	750.	3.80	1170	1366.58	1366	1366	.0000E+00	0	.0031
48	33	0	750.	3.60	1190	1362.17	1360	1359	.0000E+00	0	.0035
48	34	0	750.	1.41	1205	1357.93	1355	1355	.0000E+00	0	.0037
48	35	0	750.	2.41	1220	1353.86	1353	1352	.0000E+00	0	.0038
48	36	0	750.	2.41	1240	1349.37	1345	1344	.0000E+00	0	.0040
48	37	0	150.	-2.74	1270	1336.00	1335	1335	.2690E-02	1336	.0000
48	38	0	25.	.89	1305	1340.30	1337	1337	.0000E+00	0	.0000
48	39	0	25.	.66	1305	1341.10	1339	1339	.0000E+00	0	.0000
49	22	0	350.	4.35	1375	1411.46	1414	1414	.0000E+00	0	.0000
49	23	0	350.	4.35	1360	1407.41	1408	1407	.0000E+00	0	.0000
49	24	0	350.	4.35	1320	1401.43	1403	1402	.0000E+00	0	.0021
49	25	0	350.	4.35	1250	1395.19	1397	1397	.0000E+00	0	.0025
49	26	0	350.	4.26	1190	1390.20	1393	1392	.0000E+00	0	.0037
49	27	0	350.	4.35	1195	1385.12	1388	1388	.0000E+00	0	.0043
49	28	0	750.	4.35	1180	1380.08	1384	1383	.0000E+00	0	.0043
49	29	0	750.	3.92	1140	1376.21	1379	1379	.0000E+00	0	.0039
49	30	0	750.	2.92	1145	1372.19	1374	1373	.0000E+00	0	.0025
49	31	0	750.	1.63	1155	1367.00	1368	1368	.5380E-02	1367	.0029
49	32	0	750.	3.04	1170	1363.00	1364	1364	.3886E-02	1363	.0034
49	33	0	750.	1.19	1190	1357.00	1357	1357	.3886E-02	1357	.0038
49	34	0	750.	2.22	1195	1355.52	1353	1352	.0000E+00	0	.0040
49	35	0	750.	1.84	1220	1351.65	1349	1349	.0000E+00	0	.0040
49	36	0	750.	-.10	1240	1347.41	1343	1343	.0000E+00	0	.0034
49	37	0	750.	.03	1260	1342.73	1333	1333	.0000E+00	0	.0000
49	38	0	150.	.39	1290	1332.00	1332	1333	.2391E-02	1332	.0000
49	39	0	25.	.49	1305	1336.47	1335	1337	.0000E+00	0	.0000
50	23	0	350.	4.35	1365	1408.36	1410	1409	.0000E+00	0	.0000
50	24	0	25.	4.35	1340	1403.76	1403	1402	.0000E+00	0	.0000
50	25	0	350.	4.35	1300	1391.16	1395	1395	.0000E+00	0	.0015
50	26	0	350.	4.35	1205	1387.02	1388	1389	.0000E+00	0	.0032
50	27	0	350.	4.35	1190	1382.61	1384	1383	.0000E+00	0	.0041
50	28	0	350.	4.35	1180	1378.09	1379	1379	.0000E+00	0	.0042
50	29	0	350.	4.35	1125	1373.67	1374	1374	.0000E+00	0	.0040
50	30	0	750.	4.35	1145	1369.74	1369	1369	.0000E+00	0	.0036
50	31	0	750.	2.35	1155	1365.87	1365	1365	.0000E+00	0	.0036
50	32	0	750.	2.14	1160	1361.47	1360	1360	.0000E+00	0	.0039

I	J	CHN	K ft/d	R in/y	B ft	HO ft	H71 ft	H80 ft	C ft^2/d	H_r ft	Q_w cfs
50	33	0	750.	3.60	1180	1357.15	1355	1356	.0000E+00	0	.0042
50	34	0	750.	1.53	1205	1351.00	1349	1349	.5639E-02	1351	.0046
50	35	0	750.	1.10	1220	1348.84	1345	1346	.0000E+00	0	.0048
50	36	0	750.	.78	1240	1344.80	1341	1340	.0000E+00	0	.0053
50	37	0	750.	.81	1280	1339.71	1335	1336	.0000E+00	0	.0068
50	38	0	750.	-2.99	1290	1328.00	1329	1329	.2541E-02	1328	.0000
50	39	0	25.	1.34	1290	1333.12	1330	1330	.0000E+00	0	.0000
50	40	0	25.	4.83	1300	1344.84	1340	1344	.0000E+00	0	.0000
51	24	0	25.	4.35	1380	1407.59	1405	1404	.0000E+00	0	.0000
51	25	0	350.	4.35	1340	1389.00	1395	1395	.0000E+00	0	.0027
51	26	0	350.	4.35	1275	1384.37	1385	1385	.0000E+00	0	.0037
51	27	0	350.	2.41	1200	1379.92	1379	1378	.0000E+00	0	.0043
51	28	0	350.	2.26	1180	1375.38	1374	1373	.0000E+00	0	.0043
51	29	0	350.	2.41	1125	1371.22	1369	1368	.0000E+00	0	.0043
51	30	0	350.	2.41	1135	1367.33	1365	1363	.0000E+00	0	.0041
51	31	0	350.	1.42	1150	1362.87	1361	1359	.0000E+00	0	.0042
51	32	0	750.	1.18	1160	1358.57	1357	1357	.0000E+00	0	.0044
51	33	0	750.	.90	1180	1354.43	1352	1353	.0000E+00	0	.0048
51	34	0	750.	.68	1200	1350.08	1347	1347	.0000E+00	0	.0051
51	35	0	750.	.52	1220	1344.00	1343	1344	.3886E-02	1344	.0055
51	36	0	750.	.29	1240	1340.00	1338	1338	.4185E-02	1340	.0058
51	37	0	750.	1.95	1280	1336.35	1334	1333	.0000E+00	0	.0062
51	38	0	750.	.39	1290	1326.00	1328	1328	.1193E-02	1326	.0062
51	39	0	750.	-.35	1280	1322.00	1319	1319	.2989E-02	1322	.0000
51	40	0	25.	1.50	1285	1327.68	1328	1329	.0000E+00	0	.0000
52	25	0	25.	4.35	1360	1394.27	1395	1395	.0000E+00	0	.0000
52	26	0	350.	4.35	1330	1382.21	1384	1383	.0000E+00	0	.0044
52	27	0	350.	2.41	1270	1377.71	1375	1375	.0000E+00	0	.0048
52	28	0	350.	1.50	1195	1372.60	1370	1369	.0000E+00	0	.0046
52	29	0	350.	1.27	1180	1368.29	1363	1362	.0000E+00	0	.0046
52	30	0	350.	2.41	1140	1364.09	1360	1358	.0000E+00	0	.0045
52	31	0	350.	2.41	1140	1359.79	1357	1356	.0000E+00	0	.0047
52	32	0	350.	2.23	1160	1355.47	1353	1352	.0000E+00	0	.0049
52	33	0	750.	.28	1180	1351.22	1348	1349	.0000E+00	0	.0054
52	34	0	750.	.02	1200	1347.00	1344	1343	.0000E+00	0	.0057
52	35	0	750.	1.44	1220	1342.82	1339	1339	.0000E+00	0	.0060
52	36	0	750.	1.28	1240	1337.00	1335	1335	.2391E-02	1337	.0062
52	37	0	750.	1.62	1280	1331.00	1331	1332	.4185E-02	1331	.0060
52	38	0	750.	2.04	1280	1326.08	1326	1327	.0000E+00	0	.0047
52	39	0	750.	-.97	1270	1318.00	1317	1317	.1943E-02	1318	.0000
52	40	0	750.	2.41	1280	1318.31	1321	1322	.0000E+00	0	.0000
53	26	0	25.	2.41	1360	1389.19	1392	1388	.0000E+00	0	.0000
53	27	0	25.	2.41	1340	1382.22	1379	1378	.0000E+00	0	.0056
53	28	0	350.	2.41	1250	1369.52	1371	1369	.0000E+00	0	.0047
53	29	0	350.	-.97	1190	1365.10	1362	1360	.0000E+00	0	.0048
53	30	0	350.	2.16	1180	1360.64	1356	1355	.0000E+00	0	.0049
53	31	0	350.	2.41	1145	1356.24	1352	1352	.0000E+00	0	.0051
53	32	0	350.	2.41	1160	1351.93	1348	1348	.0000E+00	0	.0054
53	33	0	350.	2.41	1180	1347.56	1343	1343	.0000E+00	0	.0059
53	34	0	750.	-.36	1200	1343.11	1339	1339	.0000E+00	0	.0063

I	J	CHN	K	R	B	HO	H71	H80	C	H_r	Q_w
			ft/d	in/y	ft	ft	ft	ft	ft^2/d	ft	cfs
53	35	0	750.	-.83	1210	1339.50	1335	1335	.0000E+00	0	.0067
53	36	0	750.	.51	1240	1335.56	1332	1332	.0000E+00	0	.0068
53	37	0	750.	.76	1280	1329.85	1327	1328	.0000E+00	0	.0067
53	38	0	750.	1.52	1280	1322.00	1322	1324	.3886E-02	1322	.0064
53	39	0	750.	1.96	1280	1314.00	1317	1318	.2840E-02	1314	.0077
53	40	0	750.	2.41	1280	1314.73	1312	1313	.0000E+00	0	.0000
53	41	0	350.	2.41	1291	1313.09	1314	1315	.0000E+00	0	.0000
54	27	0	25.	5.31	1360	1396.57	1395	1393	.0000E+00	0	.0000
54	28	0	25.	5.31	1320	1377.96	1378	1376	.0000E+00	0	.0037
54	29	0	350.	1.74	1270	1361.85	1365	1363	.0000E+00	0	.0048
54	30	0	350.	.07	1190	1356.79	1354	1352	.0000E+00	0	.0052
54	31	0	350.	-.97	1170	1352.15	1347	1346	.0000E+00	0	.0055
54	32	0	350.	-.25	1150	1347.75	1342	1341	.0000E+00	0	.0058
54	33	0	350.	2.41	1170	1343.44	1338	1338	.0000E+00	0	.0066
54	34	0	750.	2.41	1180	1339.68	1335	1335	.0000E+00	0	.0071
54	35	0	750.	-.66	1200	1335.98	1332	1332	.0000E+00	0	.0074
54	36	0	750.	.01	1240	1332.03	1327	1327	.0000E+00	0	.0075
54	37	0	750.	.30	1280	1326.19	1323	1323	.0000E+00	0	.0074
54	38	0	750.	1.18	1280	1318.00	1317	1318	.3886E-02	1318	.0066
54	39	0	750.	2.41	1280	1312.69	1312	1312	.0000E+00	0	.0048
54	40	0	750.	1.07	1280	1307.00	1306	1306	.2386E-02	1307	.0000
54	41	0	350.	2.41	1278	1309.18	1311	1311	.0000E+00	0	.0000
55	28	0	25.	5.31	1350	1388.98	1386	1384	.0000E+00	0	.0052
55	29	0	25.	3.84	1320	1369.07	1370	1369	.0000E+00	0	.0056
55	30	0	350.	1.36	1260	1352.95	1355	1351	.0000E+00	0	.0056
55	31	0	350.	2.41	1190	1347.67	1344	1341	.0000E+00	0	.0059
55	32	0	350.	1.19	1145	1343.48	1338	1338	.0000E+00	0	.0063
55	33	0	350.	2.41	1160	1339.61	1335	1334	.0000E+00	0	.0072
55	34	0	350.	2.41	1170	1335.84	1332	1333	.0000E+00	0	.0078
55	35	0	750.	-.97	1170	1332.11	1327	1328	.0000E+00	0	.0083
55	36	0	750.	-.32	1220	1327.97	1323	1323	.0000E+00	0	.0086
55	37	0	750.	-.01	1260	1322.09	1317	1318	.0000E+00	0	.0086
55	38	0	750.	1.29	1280	1313.00	1312	1314	.3886E-02	1313	.0076
55	39	0	750.	2.41	1270	1304.00	1306	1308	.5380E-02	1304	.0050
55	40	0	750.	2.41	1270	1304.74	1301	1302	.0000E+00	0	.0000
55	41	0	350.	2.41	1278	1304.38	1310	1310	.0000E+00	0	.0000
56	29	0	25.	4.90	1320	1375.93	1376	1372	.0000E+00	0	.0068
56	30	0	25.	2.41	1290	1355.71	1358	1353	.0000E+00	0	.0058
56	31	0	350.	1.61	1240	1342.20	1342	1339	.0000E+00	0	.0061
56	32	0	350.	-.52	1180	1338.52	1335	1335	.0000E+00	0	.0067
56	33	0	350.	2.41	1160	1335.10	1331	1332	.0000E+00	0	.0077
56	34	0	350.	2.41	1170	1331.47	1327	1328	.0000E+00	0	.0085
56	35	0	350.	2.41	1180	1327.82	1322	1323	.0000E+00	0	.0093
56	36	0	750.	-.41	1230	1323.23	1317	1318	.0000E+00	0	.0101
56	37	0	750.	1.69	1260	1317.05	1312	1313	.0000E+00	0	.0106
56	38	0	750.	2.29	1270	1302.00	1305	1304	.3886E-02	1302	.0102
56	39	0	750.	2.33	1270	1299.00	1297	1299	.3587E-02	1299	.0078
56	40	0	750.	2.41	1270	1299.10	1294	1295	.0000E+00	0	.0000
56	41	0	750.	2.41	1276	1298.62	1304	1307	.0000E+00	0	.0000
57	29	0	25.	5.31	1340	1382.39	1379	1376	.0000E+00	0	.0000

I	J	CHN	K	R	B	HO	H71	H80	C	H_r	Q_w
			ft/d	in/y	ft	ft	ft	ft	ft^2/d	ft	cfs
57	30	0	25.	5.31	1300	1359.08	1359	1358	.0000E+00	0	.0044
57	31	0	350.	2.41	1270	1337.63	1340	1340	.0000E+00	0	.0061
57	32	0	350.	-.59	1180	1333.72	1331	1332	.0000E+00	0	.0070
57	33	0	350.	2.41	1180	1330.12	1325	1325	.0000E+00	0	.0081
57	34	0	350.	.19	1170	1326.41	1321	1323	.0000E+00	0	.0091
57	35	0	350.	2.41	1190	1322.70	1317	1318	.0000E+00	0	.0104
57	36	0	750.	-.41	1250	1318.22	1313	1314	.0000E+00	0	.0118
57	37	0	750.	-.97	1280	1311.14	1308	1308	.0000E+00	0	.0135
57	38	0	750.	2.25	1270	1298.00	1300	1302	.2690E-02	1298	.0149
57	39	0	750.	-1.41	1260	1295.00	1292	1295	.4185E-02	1295	.0158
57	40	0	750.	-.23	1260	1291.00	1288	1288	.6875E-02	1291	.0194
57	41	0	750.	2.41	1272	1292.87	1291	1296	.0000E+00	0	.0000
58	29	0	25.	2.41	1355	1384.26	1380	1378	.0000E+00	0	.0000
58	30	0	25.	2.41	1340	1361.05	1360	1360	.0000E+00	0	.0059
58	31	0	350.	2.41	1290	1333.52	1338	1339	.0000E+00	0	.0067
58	32	0	350.	2.41	1240	1328.75	1325	1325	.0000E+00	0	.0075
58	33	0	350.	-.86	1180	1324.52	1317	1319	.0000E+00	0	.0085
58	34	0	350.	-.97	1170	1320.94	1313	1314	.0000E+00	0	.0096
58	35	0	350.	2.41	1210	1317.06	1312	1313	.0000E+00	0	.0112
58	36	0	750.	.07	1260	1311.79	1309	1309	.0000E+00	0	.0134
58	37	0	750.	.66	1270	1305.05	1303	1304	.0000E+00	0	.0167
58	38	0	750.	2.41	1260	1297.46	1294	1295	.0000E+00	0	.0201
58	39	0	750.	.39	1260	1290.00	1287	1288	.4783E-02	1290	.0217
58	40	0	750.	.39	1260	1286.00	1283	1285	.8967E-02	1286	.0150
58	41	0	750.	.39	1265	1287.35	1284	1284	.0000E+00	0	.0000
59	31	0	350.	2.41	1320	1329.51	1329	1330	.0000E+00	0	.0073
59	32	0	350.	-.39	1260	1323.10	1320	1320	.0000E+00	0	.0081
59	33	0	350.	2.41	1180	1319.29	1312	1312	.0000E+00	0	.0083
59	34	0	350.	-.97	1170	1315.11	1307	1307	.0000E+00	0	.0098
59	35	0	350.	2.41	1225	1310.50	1304	1305	.0000E+00	0	.0115
59	36	0	750.	2.41	1250	1304.97	1301	1303	.0000E+00	0	.0140
59	37	0	750.	2.41	1260	1299.33	1296	1298	.0000E+00	0	.0197
59	38	0	750.	.39	1255	1293.04	1289	1290	.0000E+00	0	.0271
59	39	0	750.	.39	1255	1286.96	1283	1285	.0000E+00	0	.0366
59	40	0	750.	.39	1260	1279.00	1278	1280	.4484E-02	1279	.0190
59	41	0	750.	.39	1267	1281.60	1281	1281	.0000E+00	0	.0000
60	32	0	350.	.36	1300	1315.97	1318	1318	.0000E+00	0	.0094
60	33	0	350.	1.56	1260	1312.44	1309	1309	.0000E+00	0	.0069
60	34	0	350.	2.41	1170	1308.49	1306	1306	.0000E+00	0	.0097
60	35	0	350.	2.41	1190	1304.22	1302	1303	.0000E+00	0	.0109
60	36	0	750.	1.00	1220	1299.11	1295	1295	.0000E+00	0	.0116
60	37	0	750.	.94	1230	1294.27	1292	1293	.0000E+00	0	.0212
60	38	0	750.	.39	1250	1287.79	1285	1285	.0000E+00	0	.0318
60	39	0	750.	.39	1255	1281.15	1277	1280	.0000E+00	0	.0790
60	40	0	750.	.39	1255	1276.00	1273	1275	.3587E-02	1276	.0244
60	41	0	750.	.39	1260	1276.04	1274	1277	.0000E+00	0	.0000
61	32	-1	350.	.00	1250	1312.00	1312	1312	.0000E+00	0	.0223
61	33	-1	350.	.00	1170	1308.00	1308	1308	.0000E+00	0	.0000
61	34	-1	350.	.00	1170	1303.00	1303	1303	.0000E+00	0	.0112
61	35	-1	350.	.00	1180	1300.00	1300	1300	.0000E+00	0	.0112

I	J	CHN	K	R	B	HO	H71	H80	C	H_r	Q_w
			ft/d	in/y	ft	ft	ft	ft	ft^2/d	ft	cfs
61	36	-1	750.	.00	1190	1295.00	1295	1295	.0000E+00	0	.0000
61	37	-1	750.	.00	1220	1290.00	1290	1290	.0000E+00	0	.0223
61	38	-1	750.	.00	1240	1280.00	1280	1280	.0000E+00	0	.0003
61	39	-1	750.	.00	1250	1270.00	1270	1270	.0000E+00	0	.2234
61	40	-1	750.	.00	1255	1265.00	1265	1265	.0000E+00	0	.0003
61	41	-1	750.	.00	1255	1270.00	1270	1270	.0000E+00	0	.0000

TABLE II.2: Discharge from wells prior to 1940

Grid Indices		Rate (cfs)
I	J	
12	22	1.035
34	8	1.380
33	8	1.380
32	8	1.380
34	9	1.380
34	10	1.380

TABLE II.3: Pumpage rates for grid points in different stress periods from 1940 to 1980

Contents:

COLUMN		
1	I	Row index in finite-difference grid.
2	J	Column index in finite-difference grid.
3	P#1	Pumpage rate from 1940 to 1952, in cfs.
4	P#2	Pumpage rate from 1953 to 1958, in cfs.
5	P#3	Pumpage rate from 1959 to 1964, in cfs.
6	P#4	Pumpage rate from 1965 to 1971, in cfs.
7	P#5	Pumpage rate from 1972 to 1980, in cfs.

I	J	P#1	P#2	P#3	P#4	P#5
5	17	.00000	.00000	.00000	.00000	-.10184
6	16	.00000	.00000	.00000	.00000	-.16345
6	18	.00000	.00000	.00000	.00000	-.12052
6	19	.00000	.00000	.00000	.00000	-.15456
6	21	.00000	.00000	.00000	-.17158	-.14335
7	18	.00000	.00000	.00000	.00000	-.23460
7	19	.00000	.00000	.00000	-.12248	-.29256
7	20	.00000	.00000	.00000	-.15272	-.38349
7	21	.00000	.00000	.00000	-.09407	-.14091
7	22	.00000	.00000	.00000	.00000	-.20838
7	23	.00000	.00000	.00000	.00000	-.11362
7	26	.00000	.00000	-.15421	-.20976	-.16934
8	18	.00000	.00000	.00000	.00000	-.17968
8	20	.00000	.00000	-.03036	-.02484	-.29146
8	21	.00000	.00000	.00000	.00000	-.08970
9	17	.00000	.00000	.00000	.00000	-.24461
9	18	.00000	.00000	.00000	-.19136	-.17231
9	19	.00000	.00000	.00000	.00000	-.15364
9	21	.00000	.00000	-.13662	-.10764	-.35496
10	18	.00000	.00000	.00000	-.18354	-.30437
10	19	.00000	.00000	.00000	.00000	-.26717
10	20	.00000	.00000	.00000	.00000	-.11316
10	21	.00000	.00000	-.12351	-.13552	-.07797
10	22	.00000	.00000	.00000	.00000	-.05900
10	23	.00000	.00000	.00000	.00000	-.09706
11	18	.00000	.00000	.00000	-1.54008	-1.20281
11	19	.00000	.00000	.00000	.00000	-.19517
11	20	.00000	.00000	.00000	.00000	-.53130
11	22	.00000	.00000	.00000	-1.25350	-2.20187
11	29	-.07262	-.09660	-.14131	-.11828	-.07544
11	30	.00000	.00000	.00000	-.16974	-.06159
12	18	.00000	-.32200	-.92212	-1.01311	-1.92249
12	19	.00000	.00000	.00000	-.30602	-.63722
12	21	.00000	.00000	.00000	.00000	-.28808
12	22	-1.87829	-2.66432	-2.49118	-2.77361	-1.41680
13	18	.00000	-.38318	-.34466	-.52973	-.44283
13	19	.00000	.00000	-.02795	-.03707	-.04569
13	20	.00000	.00000	.00000	.00000	-.49749
13	21	.00000	-.08556	-.26275	-.19832	-.44973
13	34	-.14469	-.17871	-.21197	-.29729	-.34362
13	35	.00000	.00000	.00000	.00000	-.06440
13	36	.00000	.00000	.00000	.00000	-.04499
14	20	.00000	.00000	.00000	.00000	-.27986
14	21	.00000	.00000	.00000	.00000	-.20493
14	22	-2.07000	-2.07000	-3.16517	-3.55567	-1.55832
14	34	.00000	.00000	-.04347	-.08188	-.13772
14	35	.00000	.00000	.00000	-.11960	-.15057
15	18	.00000	.00000	.00000	.00000	-.17836
15	19	.00000	.00000	.00000	.00000	-.37840
15	20	.00000	.00000	.00000	-.16629	-.27539

I	J	P#1	P#2	P#3	P#4	P#5
15	22	.00000	.00000	.00000	.00000	-.16422
15	34	.00000	.00000	.00000	-.13179	-.24944
15	35	.00000	.00000	.00000	.00000	-.09964
15	36	.00000	.00000	.00000	-.01656	-.03416
16	18	.00000	.00000	-.07866	-.20907	-.14490
16	21	.00000	.00000	.00000	.00000	-.14386
16	24	.00000	.00000	.00000	.00000	-.00966
16	34	.00000	.00000	.00000	.00000	-.06394
16	35	.00000	.00000	.00000	.00000	-.27545
16	36	.00000	.00000	.00000	.00000	-.15732
17	18	.00000	.00000	.00000	.00000	-.46322
17	19	.00000	.00000	.00000	-.27600	-.35861
17	20	.00000	.00000	.00000	.00000	-.19251
17	21	.00000	.00000	.00000	.00000	-.11914
17	36	.00000	.00000	.00000	-.07866	-.17986
18	18	.00000	.00000	.00000	-.15613	-.47932
18	19	.00000	.00000	.00000	.00000	-.38116
18	20	.00000	.00000	-.18584	-.26588	-.52670
18	21	.00000	.00000	.00000	.00000	-.32816
18	22	.00000	.00000	.00000	.00000	-.01932
18	36	.00000	.00000	.00000	-.01173	-.01104
19	19	.00000	.00000	-.14283	-.14881	-.35770
19	20	.00000	.00000	.00000	.00000	-.58167
19	21	.00000	.00000	.00000	.00000	-.15628
19	22	.00000	.00000	.00000	-.05244	-.06026
19	24	.00000	.00000	.00000	.00000	-.10246
19	33	.00000	.00000	.00000	.00000	-.21183
20	18	.00000	.00000	.00000	.00000	-.11765
20	19	.00000	.00000	.00000	.00000	-.12144
20	20	.00000	.00000	.00000	.00000	-.33368
20	21	.00000	.00000	-.04830	-.09136	-.27945
20	22	.00000	.00000	.00000	.00000	-.30636
20	23	.00000	.00000	.00000	-.02622	-.26987
20	25	.00000	.00000	.00000	.00000	-.16229
21	19	-.05138	-.11500	-.13303	-.14168	-.16560
21	21	.00000	.00000	-.00690	-.03174	-.37709
21	22	.00000	.00000	-.09350	-.12775	-.16164
21	23	.00000	.00000	.00000	.00000	-.32872
22	20	.00000	.00000	-.07590	-.08602	-.22163
22	21	.00000	.00000	.00000	.00000	-.09906
22	22	.00000	.00000	.00000	-.12834	-.26052
22	27	.00000	.00000	.00000	-.15180	-.20231
22	28	.00000	.00000	.00000	.00000	-.13317
23	20	.00000	.00000	.00000	.00000	-.06505
23	21	.00000	.00000	.00000	.00000	-.26634
23	22	.00000	.00000	.00000	.00000	-.15925
23	24	.00000	.00000	.00000	-.06072	-.03450
23	27	.00000	.00000	.00000	.00000	-.22632
23	28	.00000	.00000	.00000	-.11868	-.13855
24	18	.00000	.00000	.00000	.00000	-.04002

I	J	P#1	P#2	P#3	P#4	P#5
24	19	.00000	.00000	-.02622	-.03795	-.16658
24	21	.00000	.00000	.00000	-.16836	-.28919
24	22	.00000	.00000	-.22218	-.18878	-.45708
24	23	.00000	.00000	.00000	-.29394	-.67344
24	28	-.13610	-.19504	-.38088	-.46723	-.67528
24	29	.00000	.00000	-.07969	-.08659	-.08998
24	30	.00000	.00000	.00000	.00000	-.02429
24	34	.00000	-.04416	-.03588	-.01794	-.18906
25	19	.00000	.00000	.00000	-.28842	-.20746
25	20	.00000	.00000	.00000	-.27911	-.20447
25	21	.00000	.00000	.00000	.00000	-.34472
25	22	.00000	.00000	-.08832	-.13731	-.35673
25	23	.00000	.00000	.00000	.00000	-.30360
25	25	.00000	.00000	.00000	.00000	-.09626
25	27	.00000	.00000	.00000	.00000	-.16192
25	28	.00000	.00000	-.09246	-.12029	-.22597
25	36	.00000	.00000	.00000	-.04830	-.07314
25	38	.00000	.00000	.00000	-.08878	-.03754
26	19	.00000	.00000	.00000	.00000	-.06394
26	20	.00000	.00000	.00000	.00000	-.21942
26	21	.00000	.00000	.00000	.00000	-.12788
26	22	.00000	.00000	.00000	-.12460	-.30526
26	23	.00000	.00000	.00000	.00000	-.05313
26	25	.00000	.00000	-.10902	-.17152	-.37398
26	26	.00000	.00000	.00000	-.00138	-.06959
26	28	.00000	.00000	.00000	-.01794	-.16919
26	30	.00000	.00000	.00000	.00000	-.14697
27	19	.00000	.00000	.00000	.00000	-.03450
27	20	-.08332	-.15732	-.24674	-.24821	-.22269
27	21	.00000	.00000	.00000	.00000	-.20459
27	22	.00000	.00000	.00000	-.19918	-.28244
27	23	.00000	.00000	-.06578	-.08326	-.21390
27	25	.00000	.00000	.00000	-.03381	-.10442
27	26	.00000	.00000	-.06244	-.08477	-.20991
27	27	.00000	.00000	.00000	-.13386	-.07728
27	30	.00000	.00000	.00000	.00000	-.38054
28	3	.00000	.00000	-.03381	-.02346	-.08867
28	4	.00000	.00000	-.04416	-.07912	-.05964
28	19	.00000	.00000	.00000	.00000	-.06992
28	20	.00000	.00000	.00000	-.18814	-.12328
28	22	.00000	.00000	-.05382	-.16054	-.23123
28	23	.00000	.00000	.00000	.00000	-.18244
28	25	.00000	.00000	.00000	.00000	-.06659
28	26	.00000	.00000	.00000	.00000	-.03381
28	27	.00000	.00000	.00000	.00000	-.08349
28	30	.00000	.00000	.00000	-.43424	-.58711
28	36	.00000	.00000	.00000	.00000	-.00276
29	5	.00000	.00000	-.05686	-.15082	-.08556
29	7	.00000	.00000	.00000	.00000	-.13179
29	8	.00000	.00000	-.06486	-.03560	-.03726

I	J	P#1	P#2	P#3	P#4	P#5
29	20	.00000	.00000	.00000	.00000	-.21562
29	21	.00000	.00000	.00000	.00000	-.07176
29	25	.00000	.00000	.00000	.00000	-.09025
29	30	.00000	.00000	-.00552	-.07412	-.02469
30	20	.00000	.00000	.00000	.00000	-.19964
30	21	.00000	.00000	.00000	.00000	-.04209
30	22	.00000	.00000	.00000	.00000	-.08437
30	26	.00000	.00000	.00000	-.04278	-.09522
30	28	.00000	.00000	.00000	.00000	-.06044
31	7	.00000	.00000	.00000	-1.16334	-1.68130
31	9	.00000	.00000	-.01794	-.02254	-.01533
31	11	.00000	-.01656	-1.09958	-.57724	-.19044
31	13	.00000	.00000	-.23736	-.18768	-.02040
31	25	.00000	.00000	.00000	.00000	-.55559
31	28	.00000	.00000	.00000	.00000	-.18975
32	3	.00000	.00000	.00000	-.92460	-.89961
32	5	.00000	.00000	-.02760	-.05336	-.01794
32	7	.00000	-2.16212	-3.16820	-1.75438	-.72634
32	8	-.19148	-.35328	-.35411	-.41538	-.95971
32	10	.00000	.00000	.00000	-.87492	-.90311
32	11	-1.85426	-1.71258	-1.71700	-1.65817	-1.59006
32	12	.00000	.00000	.00000	.00000	-.05520
32	28	.00000	.00000	.00000	.00000	-.06624
32	29	.00000	.00000	-.18354	-.27916	-.32430
32	39	.00000	.00000	.00000	.00000	-.00414
33	3	.00000	.00000	.00000	-.09764	-.76099
33	5	.00000	.00000	-.05658	-.05539	-.05313
33	8	-2.04171	-2.58060	-.50536	-.91513	-1.60985
33	10	-2.07000	-2.07000	-3.19967	-3.58840	-.99161
33	12	.00000	.00000	.00000	-3.96860	-3.24729
33	23	.00000	.00000	.00000	.00000	-.01242
33	24	.00000	.00000	.00000	.00000	-.04968
33	25	.00000	.00000	-3.99841	-4.16996	-4.02285
33	29	.00000	.00000	.00000	.00000	-.10557
33	31	.00000	.00000	.00000	.00000	-.01104
34	7	-.05520	-.05520	-.05520	-.05520	-.06486
34	8	-.09108	-.20125	-1.07474	-.71800	-.69782
34	9	-.28756	-.37904	-.37619	-.55121	-.20803
34	10	-2.28263	-3.76027	-2.58916	-4.53449	-4.52594
34	11	.00000	.00000	.00000	.00000	-.01587
34	14	.00000	.00000	-1.00119	-.66792	-.18691
34	21	.00000	.00000	-.12006	-.54694	-.14179
34	22	.00000	.00000	.00000	.00000	-.04471
34	23	.00000	.00000	.00000	.00000	-.35135
34	25	.00000	.00000	.00000	.00000	-.07866
34	26	.00000	.00000	.00000	.00000	-.16422
34	28	.00000	.00000	.00000	.00000	-.04692
34	30	.00000	.00000	.00000	.00000	-.11247
34	33	.00000	.00000	.00000	.00000	-.10649
35	7	-6.07200	-6.09294	-5.79379	-6.56585	-6.25615

I	J	P#1	P#2	P#3	P#4	P#5
35	9	-2.76000	-2.76000	-3.24438	-3.54719	-5.63592
35	21	.00000	.00000	-.10902	-.50278	-.17549
35	23	.00000	.00000	.00000	.00000	-.20102
35	24	.00000	.00000	.00000	-.25530	-.36689
35	25	.00000	.00000	-1.46004	-1.22642	-.87431
35	26	.00000	.00000	-1.11062	-1.13396	-1.31713
35	27	.00000	.00000	.00000	.00000	-.31050
35	28	.00000	.00000	.00000	-.27600	-.44666
35	29	-.01380	-.01380	-.01132	-.05410	-.14382
35	30	.00000	.00000	-.04899	-.06923	-.17885
35	33	.00000	.00000	-.04554	-.04174	-.01637
35	35	.00000	.00000	.00000	.00000	-.08786
36	7	.00000	-.04664	-.09329	-.12006	-.16437
36	8	.00000	-.04664	-.09329	-.12006	-.16437
36	15	.00000	.00000	.00000	-.01766	-.10488
36	24	.00000	.00000	.00000	.00000	-.27117
36	25	.00000	.00000	.00000	-.04140	-.26381
36	27	-.30105	-.53452	-.22108	-.38956	-.27799
36	28	-2.71647	-2.14475	-2.36725	-2.17252	-2.35091
36	29	.00000	.00000	-.05106	-.06578	-.14197
36	32	.00000	.00000	-.26579	-.18722	-.23706
36	33	.00000	.00000	.00000	.00000	-.01173
36	34	.00000	.00000	.00000	.00000	-.05762
37	3	.00000	.00000	-.07314	-.06624	-.03892
37	4	.00000	.00000	.00000	-.15686	-.08510
37	16	.00000	.00000	.00000	.00000	-.03220
37	18	.00000	.00000	.00000	-.03795	-.32982
37	26	.00000	.00000	-.08728	-.10304	-.25691
37	27	.00000	.00000	-.09936	.00000	-.39054
37	28	-2.03412	-1.70867	-1.95298	-1.07048	-1.31882
37	29	.00000	.00000	-.10005	-.13634	-.16118
37	31	.00000	.00000	.00000	-.00966	-.01656
37	32	.00000	.00000	-.04416	-.13869	-.02622
37	35	-3.21074	-3.17584	-3.04897	-2.85779	-2.44459
37	36	.00000	.00000	.00000	.00000	-.00483
38	3	.00000	.00000	-.09660	-.08211	-.06872
38	5	.00000	.00000	-.07452	-.05677	-.04727
38	8	.00000	.00000	.00000	.00000	-.01518
38	10	.00000	.00000	.00000	.00000	-.07590
38	16	.00000	.00000	.00000	.00000	-.38502
38	18	.00000	.00000	.00000	.00000	-.18871
38	19	.00000	.00000	.00000	.00000	-.28566
38	20	.00000	.00000	.00000	.00000	-.14490
38	22	.00000	.00000	.00000	.00000	-.12236
38	27	-1.08765	-1.35516	-1.08330	-.68329	-.59493
38	28	.00000	.00000	.00000	.00000	-.12305
38	30	.00000	.00000	-.11661	-.05658	-.16087
38	31	-.15902	-.36800	-.39827	-.42523	-.38617
38	32	.00000	.00000	.00000	.00000	-.11592
38	33	.00000	.00000	.00000	-.71208	-.94438

I	J	P#1	P#2	P#3	P#4	P#5
38	34	.00000	.00000	.00000	-1.28616	-.06785
39	3	.00000	.00000	-.12466	-.16526	-.07383
39	4	.00000	.00000	.00000	.00000	-.16330
39	7	.00000	.00000	-2.10174	-.72490	-.08367
39	8	.00000	.00000	.00000	.00000	-.20838
39	9	.00000	.00000	.00000	.00000	-.21114
39	10	.00000	.00000	.00000	.00000	-.18689
39	12	.00000	.00000	.00000	.00000	-.02277
39	13	.00000	.00000	.00000	.00000	-.12972
39	14	.00000	.00000	.00000	.00000	-.35052
39	15	.00000	.00000	.00000	.00000	-.27496
39	16	.00000	.00000	.00000	.00000	-.28382
39	18	.00000	.00000	.00000	.00000	-.11523
39	19	.00000	.00000	.00000	.00000	-.04140
39	22	.00000	.00000	.00000	.00000	-.16450
39	25	.00000	.00000	.00000	-.04278	-.24932
39	26	.00000	.00000	.00000	.00000	-.10764
39	27	.00000	.00000	.00000	.00000	-.10930
39	28	-4.10455	-5.19340	-2.69845	-1.92529	-3.17232
39	29	-3.10394	-3.93691	-2.48096	-2.17409	-2.32944
39	30	.00000	.00000	.00000	.00000	-.03962
39	31	.00000	.00000	.00000	.00000	-.03174
39	32	.00000	.00000	.00000	.00000	-.15346
39	33	.00000	.00000	.00000	.00000	-.14628
39	34	.00000	.00000	-.02001	-.00874	-.06821
40	7	.00000	.00000	-.40123	-.75762	-.63557
40	9	.00000	.00000	.00000	-.27324	-.30176
40	11	.00000	.00000	.00000	-.07314	-.36156
40	13	.00000	.00000	.00000	.00000	-.11684
40	14	.00000	.00000	-.06762	-.05327	-.08004
40	17	.00000	.00000	.00000	.00000	-.03588
40	19	.00000	.00000	.00000	-.10948	-.27554
40	20	.00000	.00000	.00000	.00000	-.18699
40	21	.00000	.00000	.00000	.00000	-.00276
40	22	.00000	.00000	.00000	.00000	-.03588
40	23	.00000	.00000	.00000	.00000	-.07636
40	24	.00000	.00000	.00000	-.31740	-.54295
40	28	-1.14275	-1.75582	-1.19453	-.80119	-1.09081
40	29	-3.92291	-4.85921	-3.33739	-2.31781	-2.95842
40	31	.00000	.00000	-.11488	-.10902	-.23263
40	36	.00000	.00000	.00000	.00000	-.07521
41	7	.00000	.00000	.00000	.00000	-.08142
41	9	.00000	.00000	.00000	.00000	-.09108
41	10	.00000	.00000	.00000	.00000	-.09660
41	14	.00000	.00000	-.10729	-.14628	-.15180
41	21	.00000	.00000	.00000	.00000	-.20562
41	22	.00000	.00000	.00000	.00000	-.26082
41	23	.00000	.00000	.00000	.00000	-.36018
41	24	.00000	.00000	.00000	.00000	-.39247
41	25	.00000	.00000	.00000	.00000	-.69304

I	J	P#1	P#2	P#3	P#4	P#5
41	26	.00000	.00000	.00000	-.07659	-.05262
41	27	.00000	.00000	.00000	.00000	-.10695
41	28	.00000	.00000	.00000	.00000	-.10143
41	29	.00000	.00000	.00000	.00000	-.21160
41	30	-1.55854	-2.41868	-1.03417	-.86348	-1.21686
41	31	.00000	.00000	.00000	-.30406	-.51415
41	32	.00000	.00000	.00000	-.18630	-.21589
41	33	.00000	.00000	.00000	.00000	-.03726
41	35	.00000	.00000	.00000	.00000	-.06716
42	18	.00000	.00000	.00000	.00000	-.00276
42	19	.00000	.00000	.00000	-.06555	-.06781
42	20	.00000	.00000	.00000	.00000	-.09798
42	21	.00000	.00000	.00000	.00000	-.14789
42	22	.00000	.00000	-.02116	-.02760	-.07885
42	23	.00000	.00000	.00000	.00000	-.14306
42	24	.00000	.00000	.00000	.00000	-.02760
42	25	.00000	.00000	.00000	.00000	-.61065
42	26	.00000	.00000	.00000	.00000	-.11040
42	27	.00000	.00000	.00000	.00000	-.20838
42	28	.00000	.00000	.00000	.00000	-.36329
42	29	.00000	.00000	-3.39922	-3.39775	-3.51777
42	30	-.65369	-.87538	-.52771	-.45737	-.76115
42	31	-2.06385	-1.43037	-.98725	-1.20455	-1.50390
42	32	.00000	.00000	-.04416	.00000	-.00460
42	33	.00000	.00000	.00000	-.52854	-.58236
42	34	.00000	.00000	.00000	-.35742	-.40725
42	36	.00000	.00000	-.08096	-.18906	-.12420
42	37	.00000	.00000	-.02760	-.08753	-.09323
43	15	.00000	.00000	.00000	-.19182	-.31247
43	17	.00000	.00000	.00000	.00000	-.06693
43	21	.00000	.00000	.00000	.00000	-.16767
43	22	.00000	.00000	.00000	.00000	-.23920
43	24	.00000	.00000	.00000	-.70932	-.46843
43	25	.00000	.00000	.00000	.00000	-.26615
43	26	.00000	.00000	.00000	.00000	-.11316
43	27	.00000	.00000	.00000	.00000	-.15677
43	28	.00000	.00000	.00000	.00000	-.25622
43	29	.00000	.00000	.00000	.00000	-.12604
43	30	.00000	.00000	.00000	.00000	-.09453
43	31	-1.86513	-2.16246	-.84622	-.72331	-.92046
43	32	-.98840	-1.46740	-.77722	-.68567	-1.02105
43	34	.00000	.00000	.00000	.00000	-.10281
43	35	-.06538	-.10741	-.12448	-.13583	-.15060
43	36	.00000	.00000	.00000	-.08418	-.07762
44	16	.00000	.00000	-.21804	-.38502	-.49020
44	17	.00000	.00000	.00000	.00000	-.11546
44	18	.00000	.00000	.00000	.00000	-.03174
44	19	.00000	.00000	.00000	.00000	-.13064
44	21	.00000	.00000	.00000	.00000	-.20976
44	22	.00000	.00000	.00000	.00000	-.03082

I	J	P#1	P#2	P#3	P#4	P#5
44	24	.00000	.00000	.00000	.00000	-.33368
44	25	.00000	.00000	-.01104	-.01104	-.02760
44	26	.00000	.00000	.00000	-.17940	-.21789
44	27	.00000	.00000	.00000	.00000	-.29366
44	28	.00000	.00000	-2.02556	-2.77656	-4.05597
44	29	.00000	.00000	.00000	.00000	-.09384
44	31	-1.71017	-1.39541	-1.44017	-1.02101	-1.03899
44	32	-.60272	-.71001	-.28097	-.38502	-.41232
44	33	-1.24545	-1.57780	-.36763	-.40867	-.56595
44	34	.00000	.00000	.00000	.00000	-.31119
44	35	.00000	.00000	.00000	.00000	-.04416
44	36	.00000	.00000	.00000	.00000	-.00690
45	16	.00000	.00000	.00000	.00000	-.13800
45	18	.00000	.00000	.00000	.00000	-.24219
45	19	.00000	.00000	.00000	-.02898	-.10402
45	20	.00000	.00000	.00000	.00000	-.30774
45	25	.00000	.00000	.00000	.00000	-.24917
45	27	.00000	.00000	.00000	.00000	-.29256
45	28	.00000	.00000	.00000	.00000	-.44804
45	29	.00000	.00000	.00000	-.02898	-.38748
45	30	.00000	.00000	.00000	-.03312	-.08023
45	31	-2.39878	-2.40120	-1.65490	-1.64496	-1.54452
45	32	-2.22594	-2.70043	-1.76171	-1.42456	-1.54299
45	33	-1.38897	-1.69211	-1.42637	-1.54579	-1.93813
45	34	.00000	.00000	.00000	.00000	-.26174
45	36	.00000	.00000	.00000	.00000	-.17457
45	37	.00000	.00000	.00000	.00000	-.09177
46	19	.00000	.00000	.00000	.00000	-.68678
46	20	.00000	.00000	.00000	.00000	-.10442
46	21	.00000	.00000	.00000	.00000	-.39928
46	23	.00000	.00000	.00000	.00000	-.16238
46	24	.00000	.00000	.00000	.00000	-.28097
46	25	.00000	.00000	.00000	.00000	-.18722
46	29	.00000	.00000	.00000	.00000	-.54709
46	30	.00000	.00000	.00000	.00000	-.31395
46	32	.00000	.00000	.00000	.00000	-.14973
46	33	.00000	.00000	-1.45728	-1.40996	-1.57795
46	34	.00000	.00000	-2.05013	-1.77961	-1.83003
46	35	.00000	.00000	.00000	-.40867	-.49189
46	36	.00000	.00000	-.12558	.00000	-.34863
46	38	.00000	.00000	.00000	.00000	-.15663
47	20	.00000	.00000	.00000	.00000	-.17802
47	22	.00000	.00000	.00000	-.07176	-.11006
47	23	.00000	.00000	.00000	.00000	-.13938
47	30	.00000	.00000	.00000	-.08878	-.37475
47	31	.00000	.00000	.00000	.00000	-.18400
47	32	.00000	.00000	.00000	.00000	-.20148
47	33	.00000	.00000	-.06762	-.05879	-.21785
47	34	.00000	.00000	.00000	.00000	-.15663
47	35	.00000	.00000	.00000	-.04232	-.11945

I	J	P#1	P#2	P#3	P#4	P#5
47	36	.00000	.00000	.00000	.00000	-.27324
48	21	.00000	.00000	.00000	.00000	-.34362
48	22	.00000	.00000	.00000	-.16767	-.21960
48	23	.00000	.00000	-.09108	-.22287	-.22880
48	24	.00000	.00000	.00000	-.08901	-.28091
48	25	.00000	.00000	.00000	.00000	-.16215
48	27	.00000	.00000	.00000	.00000	-.02967
48	31	.00000	.00000	.00000	.00000	-.21827
48	32	.00000	.00000	.00000	.00000	-.27485
48	33	.00000	.00000	.00000	-.21735	-.23065
48	34	.00000	.00000	.00000	-.08142	-.24316
48	35	.00000	.00000	.00000	-.04968	-.21169
48	36	.00000	.00000	-.13800	-.11730	-.34189
48	38	.00000	.00000	-.06003	-.05106	-.66433
49	23	.00000	.00000	.00000	-.06106	-.06664
49	25	.00000	.00000	.00000	.00000	-.25760
49	26	.00000	.00000	.00000	.00000	-.01932
49	32	.00000	.00000	.00000	.00000	-.50066
49	33	.00000	.00000	.00000	.00000	-.20608
49	34	.00000	.00000	.00000	.00000	-.35006
49	35	.00000	.00000	.00000	.00000	-.03496
49	37	.00000	.00000	.00000	.00000	-.14122
49	38	-.07262	-.10741	-.20120	-.31799	-.37275
50	23	.00000	.00000	.00000	.00000	-.14938
50	25	.00000	.00000	.00000	-.00276	-.05503
50	26	.00000	.00000	.00000	.00000	-.11651
50	27	.00000	.00000	.00000	.00000	-.14812
50	28	.00000	.00000	.00000	.00000	-.09620
50	29	.00000	.00000	.00000	.00000	-.23638
50	30	.00000	.00000	-.02180	-.34895	-.60950
50	32	.00000	.00000	.00000	.00000	-.06762
50	34	.00000	.00000	.00000	.00000	-.26358
50	35	.00000	.00000	.00000	.00000	-.14628
50	37	.00000	.00000	.00000	-.35576	-.60812
50	40	.00000	.00000	.00000	-.00138	-.45954
51	25	.00000	.00000	.00000	-.06141	-.17710
51	26	.00000	.00000	.00000	.00000	-.16836
51	27	.00000	.00000	.00000	-.16312	-.27263
51	28	.00000	.00000	.00000	-.14536	-.55491
51	29	.00000	.00000	.00000	.00000	-.41124
51	30	.00000	.00000	.00000	.00000	-.01380
51	31	.00000	.00000	.00000	.00000	-.11799
51	36	.00000	.00000	.00000	.00000	-.01104
51	37	.00000	.00000	.00000	-.21666	-.42581
51	38	.00000	.00000	.00000	-.24840	-.26713
51	40	.00000	.00000	.00000	-.14076	-.25599
52	27	.00000	.00000	.00000	.00000	-.27255
52	28	.00000	.00000	.00000	.00000	-.28612
52	29	.00000	.00000	.00000	.00000	-.31464
52	30	.00000	.00000	-1.36206	-2.85641	-3.32334

I	J	P#1	P#2	P#3	P#4	P#5
52	31	.00000	.00000	.00000	-.83932	-.90405
52	32	.00000	.00000	.00000	.00000	-.16854
52	33	.00000	.00000	.00000	-.02594	-.06854
52	36	.00000	.00000	.00000	-.10718	-.09798
52	38	.00000	.00000	.00000	-.01877	-.03358
52	39	.00000	.00000	.00000	-.14559	-.08280
52	40	.00000	.00000	-.24288	-.57063	-.53728
53	27	.00000	.00000	.00000	-.05382	-.13031
53	30	.00000	.00000	.00000	.00000	-.02795
53	31	.00000	.00000	.00000	-2.00624	-2.25569
53	32	.00000	.00000	.00000	-.04784	-.31345
53	33	.00000	.00000	.00000	.00000	-.21804
53	35	.00000	.00000	.00000	.00000	-.12351
53	36	.00000	.00000	.00000	-.27508	-.32182
53	40	.00000	.00000	-.28649	-.24978	-.29032
54	27	.00000	.00000	.00000	-.03680	-.02967
54	30	.00000	.00000	.00000	-.22080	-.05762
54	31	.00000	.00000	.00000	-1.26960	-2.62614
54	32	.00000	.00000	.00000	.00000	-.15824
54	33	.00000	.00000	.00000	.00000	-.30912
54	34	.00000	.00000	.00000	.00000	-.00414
54	36	.00000	.00000	.00000	.00000	-.00414
54	39	-.75369	-1.38000	-.93647	-.72667	-1.13528
54	40	-.75369	-1.38000	-1.42057	-1.69621	-2.16721
54	41	.00000	.00000	.00000	.00000	-.07958
55	32	.00000	.00000	.00000	.00000	-.10902
55	33	.00000	.00000	.00000	.00000	-.10460
55	34	.00000	.00000	.00000	-.04140	-.08108
55	39	.00000	.00000	-.00621	-.01242	-.03450
55	41	-.02760	-.02875	-.02760	-.00621	-.11385
56	32	.00000	.00000	.00000	.00000	-.11316
56	33	.00000	.00000	.00000	-.09881	-.35449
56	39	.00000	-.00276	-.01311	-.01361	-.01441
56	41	-.81101	-.96416	-1.18956	-2.67917	-1.22222
57	33	.00000	.00000	.00000	.00000	-.09384
57	36	.00000	.00000	.00000	-.00966	-.54924
57	41	-.27600	-.27945	-.42559	-.34046	-.03558
58	39	.00000	-.12006	-.12116	-.48457	-.90528
58	40	-.03450	-.03772	-.13524	-.17171	-.16269
58	41	-1.65600	-1.65600	-1.68829	-1.60126	-.55430
59	33	.00000	.00000	.00000	.00000	-.35466
59	34	.00000	.00000	.00000	-.24104	-.30114
59	38	.00000	-.00276	-.00345	-.00828	-.01027
59	39	-.00276	-.00391	-.02539	-.05125	-.05750
59	40	-1.87893	-2.11715	-2.93940	-2.59559	-.91464
60	33	.00000	.00000	-.01610	.00000	-.00690
60	40	-.20700	-.20700	-.13340	-.22691	-.16422
61	34	.00000	.00000	.00000	-.25852	-.66317
61	35	.00000	.00000	-.44022	-.72974	-1.04356
61	37	.00000	.00000	.00000	-.04899	-.04036

I	J	P#1	P#2	P#3	P#4	P#5
61	39	.00000	-.00138	.00000	.00000	-.02346

APPENDIX III

Velocity Vectors and Optimal Pumpage Policies for Three Management Plans

TABLE III.1: Calculated velocities at observation points for management plan A

Contents:

COLUMN	
1	Year or management period.
2	Observation well #.
3	Observation-well row index in finite-difference grid.
4	Observation-well column index in finite-difference grid.
5	Velocity in X-direction at observation well (ft/sec).
6	Velocity in Y-direction at observation well (ft/sec).

YEAR	WELL #	I	J	X-VEL ft/sec	Y-VEL ft/sec
1986	1	33	22	.68687E-05	-.25484E-05
1986	2	34	23	.64135E-05	-.17740E-05
1986	3	35	24	.72917E-05	.13534E-06
1986	4	36	24	.81635E-05	.77140E-06
1986	5	37	23	.10303E-04	.15140E-05
1986	6	38	22	.11254E-04	.16237E-05
1986	7	39	21	.94028E-05	.21416E-05
1987	1	33	22	.68677E-05	-.25303E-05
1987	2	34	23	.64153E-05	-.17647E-05
1987	3	35	24	.72932E-05	.13956E-06
1987	4	36	24	.81655E-05	.77002E-06
1987	5	37	23	.10309E-04	.15069E-05
1987	6	38	22	.11267E-04	.16077E-05
1987	7	39	21	.94170E-05	.21197E-05
1988	1	33	22	.68662E-05	-.25146E-05
1988	2	34	23	.64165E-05	-.17569E-05
1988	3	35	24	.72941E-05	.14282E-06
1988	4	36	24	.81668E-05	.76834E-06
1988	5	37	23	.10313E-04	.15002E-05
1988	6	38	22	.11278E-04	.15933E-05
1988	7	39	21	.94292E-05	.21001E-05
1989	1	33	22	.68644E-05	-.25011E-05
1989	2	34	23	.64172E-05	-.17503E-05
1989	3	35	24	.72945E-05	.14532E-06
1989	4	36	24	.81676E-05	.76649E-06
1989	5	37	23	.10317E-04	.14940E-05
1989	6	38	22	.11286E-04	.15803E-05
1989	7	39	21	.94397E-05	.20825E-05
1990	1	33	22	.68624E-05	-.24893E-05
1990	2	34	23	.64176E-05	-.17447E-05
1990	3	35	24	.72946E-05	.14720E-06
1990	4	36	24	.81680E-05	.764454E-06
1990	5	37	23	.10320E-04	.14882E-05
1990	6	38	22	.11294E-04	.15686E-05
1990	7	39	21	.94487E-05	.20668E-05
1991	1	33	22	.68602E-05	-.24793E-05
1991	2	34	23	.64178E-05	-.17400E-05
1991	3	35	24	.72944E-05	.14860E-06
1991	4	36	24	.81681E-05	.76257E-06
1991	5	37	23	.10322E-04	.14829E-05

YEAR	WELL #	I	J	X-VEL ft/sec	Y-VEL ft/sec
1991	6	38	22	.11300E-04	.15580E-05
1991	7	39	21	.94564E-05	.20529E-05
1992	1	33	22	.68580E-05	-.24706E-05
1992	2	34	23	.64177E-05	-.17361E-05
1992	3	35	24	.72941E-05	.14959E-06
1992	4	36	24	.81679E-05	.76061E-06
1992	5	37	23	.10324E-04	.14780E-05
1992	6	38	22	.11306E-04	.15485E-05
1992	7	39	21	.94631E-05	.20403E-05
1993	1	33	22	.68559E-05	-.24632E-05
1993	2	34	23	.64175E-05	-.17329E-05
1993	3	35	24	.72936E-05	.15025E-06
1993	4	36	24	.81677E-05	.75870E-06
1993	5	37	23	.10325E-04	.14735E-05
1993	6	38	22	.11310E-04	.15400E-05
1993	7	39	21	.94689E-05	.20292E-05
1994	1	33	22	.68537E-05	-.24569E-05
1994	2	34	23	.64171E-05	-.17302E-05
1994	3	35	24	.72930E-05	.15066E-06
1994	4	36	24	.81673E-05	.75684E-06
1994	5	37	23	.10326E-04	.14693E-05
1994	6	38	22	.11314E-04	.15323E-05
1994	7	39	21	.94739E-05	.20192E-05
1995	1	33	22	.68516E-05	-.24516E-05
1995	2	34	23	.64167E-05	-.17281E-05
1995	3	35	24	.72924E-05	.15086E-06
1995	4	36	24	.81668E-05	.75505E-06
1995	5	37	23	.10326E-04	.14655E-05
1995	6	38	22	.11317E-04	.15254E-05
1995	7	39	21	.94782E-05	.20103E-05
1996	1	33	22	.68496E-05	-.24472E-05
1996	2	34	23	.64162E-05	-.17263E-05
1996	3	35	24	.72917E-05	.15088E-06
1996	4	36	24	.81663E-05	.75333E-06
1996	5	37	23	.10327E-04	.14621E-05
1996	6	38	22	.11320E-04	.15192E-05
1996	7	39	21	.94819E-05	.20023E-05
1997	1	33	22	.68477E-05	-.24434E-05

YEAR	WELL #	I	J	X-VEL ft/sec	Y-VEL ft/sec
1997	2	34	23	.64157E-05	-.17249E-05
1997	3	35	24	.72911E-05	.15075E-06
1997	4	36	24	.81657E-05	.75169E-06
1997	5	37	23	.10327E-04	.14589E-05
1997	6	38	22	.11322E-04	.15136E-05
1997	7	39	21	.94852E-05	.19951E-05
1998	1	33	22	.68459E-05	-.24403E-05
1998	2	34	23	.64151E-05	-.17238E-05
1998	3	35	24	.72904E-05	.15051E-06
1998	4	36	24	.81652E-05	.75013E-06
1998	5	37	23	.10327E-04	.14560E-05
1998	6	38	22	.11324E-04	.15085E-05
1998	7	39	21	.94880E-05	.19887E-05
1999	1	33	22	.68441E-05	-.24378E-05
1999	2	34	23	.64146E-05	-.17231E-05
1999	3	35	24	.72897E-05	.15018E-06
1999	4	36	24	.81646E-05	.74864E-06
1999	5	37	23	.10328E-04	.14533E-05
1999	6	38	22	.11326E-04	.15040E-05
1999	7	39	21	.94905E-05	.19830E-05
2000	1	33	22	.68425E-05	-.24358E-05
2000	2	34	23	.64140E-05	-.17225E-05
2000	3	35	24	.72890E-05	.14975E-06
2000	4	36	24	.81641E-05	.74722E-06
2000	5	37	23	.10328E-04	.14508E-05
2000	6	38	22	.11328E-04	.14998E-05
2000	7	39	21	.94927E-05	.19778E-05
2001	1	33	22	.68410E-05	-.24342E-05
2001	2	34	23	.64134E-05	-.17221E-05
2001	3	35	24	.72884E-05	.14927E-06
2001	4	36	24	.81635E-05	.74587E-06
2001	5	37	23	.10328E-04	.14485E-05
2001	6	38	22	.11329E-04	.14961E-05
2001	7	39	21	.94946E-05	.19731E-05
2002	1	33	22	.68396E-05	-.24330E-05
2002	2	34	23	.64129E-05	-.17220E-05
2002	3	35	24	.72877E-05	.14872E-06
2002	4	36	24	.81630E-05	.74455E-06
2002	5	37	23	.10328E-04	.14464E-05
2002	6	38	22	.11330E-04	.14927E-05

YEAR	WELL #	I	J	X-VEL ft/sec	Y-VEL ft/sec
2002	7	39	21	.94963E-05	.19689E-05
2003	1	33	22	.68382E-05	-.24321E-05
2003	2	34	23	.64123E-05	-.17219E-05
2003	3	35	24	.72871E-05	.14815E-06
2003	4	36	24	.81625E-05	.74333E-06
2003	5	37	23	.10327E-04	.14445E-05
2003	6	38	22	.11331E-04	.14896E-05
2003	7	39	21	.94978E-05	.19651E-05
2004	1	33	22	.68370E-05	-.24315E-05
2004	2	34	23	.64119E-05	-.17221E-05
2004	3	35	24	.72865E-05	.14753E-06
2004	4	36	24	.81619E-05	.74212E-06
2004	5	37	23	.10327E-04	.14427E-05
2004	6	38	22	.11332E-04	.14867E-05
2004	7	39	21	.94991E-05	.19617E-05
2005	1	33	22	.68358E-05	-.24311E-05
2005	2	34	23	.64113E-05	-.17223E-05
2005	3	35	24	.72859E-05	.14691E-06
2005	4	36	24	.81615E-05	.74102E-06
2005	5	37	23	.10327E-04	.14410E-05
2005	6	38	22	.11333E-04	.14842E-05
2005	7	39	21	.95002E-05	.19585E-05
2006	1	33	22	.68347E-05	-.24310E-05
2006	2	34	23	.64108E-05	-.17226E-05
2006	3	35	24	.72854E-05	.14623E-06
2006	4	36	24	.81610E-05	.73993E-06
2006	5	37	23	.10327E-04	.14394E-05
2006	6	38	22	.11333E-04	.14818E-05
2006	7	39	21	.95013E-05	.19557E-05
2007	1	33	22	.68337E-05	-.24311E-05
2007	2	34	23	.64103E-05	-.17230E-05
2007	3	35	24	.72848E-05	.14556E-06
2007	4	36	24	.81606E-05	.73888E-06
2007	5	37	23	.10327E-04	.14380E-05
2007	6	38	22	.11334E-04	.14796E-05
2007	7	39	21	.95022E-05	.19531E-05
2008	1	33	22	.68327E-05	-.24313E-05
2008	2	34	23	.64099E-05	-.17235E-05

YEAR	WELL #	I	J	X-VEL ft/sec	Y-VEL ft/sec
2008	3	35	24	.72843E-05	.14486E-06
2008	4	36	24	.81602E-05	.73789E-06
2008	5	37	23	.10327E-04	.14366E-05
2008	6	38	22	.11334E-04	.14776E-05
2008	7	39	21	.95030E-05	.19507E-05
2009	1	33	22	.68318E-05	-.24316E-05
2009	2	34	23	.64094E-05	-.17240E-05
2009	3	35	24	.72838E-05	.14416E-06
2009	4	36	24	.81598E-05	.73691E-06
2009	5	37	23	.10327E-04	.14353E-05
2009	6	38	22	.11335E-04	.14758E-05
2009	7	39	21	.95037E-05	.19486E-05
2010	1	33	22	.68310E-05	-.24321E-05
2010	2	34	23	.64090E-05	-.17246E-05
2010	3	35	24	.72834E-05	.14345E-06
2010	4	36	24	.81594E-05	.73599E-06
2010	5	37	23	.10327E-04	.14341E-05
2010	6	38	22	.11335E-04	.14741E-05
2010	7	39	21	.95044E-05	.19466E-05
2011	1	33	22	.68302E-05	-.24327E-05
2011	2	34	23	.64085E-05	-.17252E-05
2011	3	35	24	.72830E-05	.14274E-06
2011	4	36	24	.81591E-05	.73509E-06
2011	5	37	23	.10326E-04	.14330E-05
2011	6	38	22	.11335E-04	.14725E-05
2011	7	39	21	.95050E-05	.19448E-05
2012	1	33	22	.68294E-05	-.24334E-05
2012	2	34	23	.64081E-05	-.17259E-05
2012	3	35	24	.72825E-05	.14203E-06
2012	4	36	24	.81588E-05	.73421E-06
2012	5	37	23	.10326E-04	.14319E-05
2012	6	38	22	.11336E-04	.14710E-05
2012	7	39	21	.95055E-05	.19431E-05
2013	1	33	22	.68287E-05	-.24342E-05
2013	2	34	23	.64078E-05	-.17266E-05
2013	3	35	24	.72821E-05	.14131E-06
2013	4	36	24	.81584E-05	.73339E-06
2013	5	37	23	.10326E-04	.14309E-05
2013	6	38	22	.11336E-04	.14696E-05
2013	7	39	21	.95060E-05	.19415E-05

YEAR	WELL #	I	J	X-VEL ft/sec	Y-VEL ft/sec
2014	1	33	22	.68281E-05	-.24350E-05
2014	2	34	23	.64074E-05	-.17273E-05
2014	3	35	24	.72817E-05	.14061E-06
2014	4	36	24	.81581E-05	.73258E-06
2014	5	37	23	.10326E-04	.14299E-05
2014	6	38	22	.11336E-04	.14683E-05
2014	7	39	21	.95065E-05	.19401E-05
2015	1	33	22	.68275E-05	-.24359E-05
2015	2	34	23	.64070E-05	-.17281E-05
2015	3	35	24	.72814E-05	.13990E-06
2015	4	36	24	.81579E-05	.73178E-06
2015	5	37	23	.10326E-04	.14290E-05
2015	6	38	22	.11336E-04	.14671E-05
2015	7	39	21	.95069E-05	.19388E-05
2016	1	33	22	.68269E-05	-.24368E-05
2016	2	34	23	.64067E-05	-.17288E-05
2016	3	35	24	.72810E-05	.13918E-06
2016	4	36	24	.81576E-05	.73101E-06
2016	5	37	23	.10326E-04	.14281E-05
2016	6	38	22	.11337E-04	.14660E-05
2016	7	39	21	.95073E-05	.19375E-05
2017	1	33	22	.68264E-05	-.24378E-05
2017	2	34	23	.64063E-05	-.17296E-05
2017	3	35	24	.72807E-05	.13849E-06
2017	4	36	24	.81573E-05	.73027E-06
2017	5	37	23	.10326E-04	.14272E-05
2017	6	38	22	.11337E-04	.14649E-05
2017	7	39	21	.95076E-05	.19363E-05
2018	1	33	22	.68259E-05	-.24388E-05
2018	2	34	23	.64060E-05	-.17304E-05
2018	3	35	24	.72803E-05	.13780E-06
2018	4	36	24	.81571E-05	.72955E-06
2018	5	37	23	.10326E-04	.14264E-05
2018	6	38	22	.11337E-04	.14639E-05
2018	7	39	21	.95079E-05	.19353E-05
2019	1	33	22	.68254E-05	-.24398E-05
2019	2	34	23	.64057E-05	-.17312E-05
2019	3	35	24	.72800E-05	.13710E-06
2019	4	36	24	.81568E-05	.72884E-06
2019	5	37	23	.10325E-04	.14257E-05
2019	6	38	22	.11337E-04	.14630E-05

YEAR	WELL #	I	J	X-VEL ft/sec	Y-VEL ft/sec
2020	1	33	22	.68249E-05	-.24409E-05
2020	2	34	23	.64054E-05	-.17320E-05
2020	3	35	24	.72797E-05	.13641E-06
2020	4	36	24	.81566E-05	.72813E-06
2020	5	37	23	.10325E-04	.14249E-05
2020	6	38	22	.11337E-04	.14621E-05
2020	7	39	21	.95085E-05	.19333E-05

TABLE III.2: Optimal pumpage rates for interception wells of management plan A

Contents:

COLUMN	
1	Year or management time step.
2	Row index in finite-difference grid.
3	Column index in finite-difference grid.
4	Optimal-flow rate in cfs.

YEAR	WELL #	I	J	Q cfs
1986	1	33	21	5.10683
1986	2	34	22	30.20000
1986	3	35	23	2.88702
1986	4	36	23	7.28594
1986	5	37	22	11.82168
1986	6	38	21	14.46284
1986	7	39	20	18.38074
1987	1	33	21	2.92977
1987	2	34	22	15.87110
1987	3	35	23	.97563
1987	4	36	23	4.24513
1987	5	37	22	7.59395
1987	6	38	21	10.36879
1987	7	39	20	16.37022
1988	1	33	21	2.73906
1988	2	34	22	16.35403
1988	3	35	23	.70019
1988	4	36	23	3.70281
1988	5	37	22	6.77230
1988	6	38	21	9.67293
1988	7	39	20	16.59335
1989	1	33	21	2.65485
1989	2	34	22	16.19112
1989	3	35	23	.50118
1989	4	36	23	3.42917
1989	5	37	22	6.39349
1989	6	38	21	9.35397
1989	7	39	20	16.82980
1990	1	33	21	2.59674
1990	2	34	22	16.17674
1990	3	35	23	.35858
1990	4	36	23	3.25762
1990	5	37	22	6.16987
1990	6	38	21	9.20176
1990	7	39	20	17.04848
1991	1	33	21	2.55159
1991	2	34	22	16.22517
1991	3	35	23	.24919
1991	4	36	23	3.13639
1991	5	37	22	6.01069

YEAR	WELL #	I	J	Q cfs
1991	6	38	21	9.11834
1991	7	39	20	17.24350
1992	1	33	21	2.51438
1992	2	34	22	16.33072
1992	3	35	23	.15399
1992	4	36	23	3.04707
1992	5	37	22	5.90568
1992	6	38	21	9.07937
1992	7	39	20	17.42500
1993	1	33	21	2.48145
1993	2	34	22	16.44925
1993	3	35	23	.06962
1993	4	36	23	2.97701
1993	5	37	22	5.82714
1993	6	38	21	9.05918
1993	7	39	20	17.58762
1994	1	33	21	2.45333
1994	2	34	22	16.56429
1994	3	36	23	2.91898
1994	4	37	22	5.76790
1994	5	38	21	9.04796
1994	6	39	20	17.73274
1995	1	33	21	2.42951
1995	2	34	22	16.63641
1995	3	36	23	2.85654
1995	4	37	22	5.72024
1995	5	38	21	9.04596
1995	6	39	20	17.86169
1996	1	33	21	2.40873
1996	2	34	22	16.70982
1996	3	36	23	2.80171
1996	4	37	22	5.68054
1996	5	38	21	9.04606
1996	6	39	20	17.97600
1997	1	33	21	2.39015
1997	2	34	22	16.77771
1997	3	36	23	2.75383

YEAR	WELL #	I	J	Q cfs
1997	4	37	22	5.64755
1997	5	38	21	9.04968
1997	6	39	20	18.07721
1998	1	33	21	2.37339
1998	2	34	22	16.83963
1998	3	36	23	2.71251
1998	4	37	22	5.61829
1998	5	38	21	9.05199
1998	6	39	20	18.16653
1999	1	33	21	2.35808
1999	2	34	22	16.89473
1999	3	36	23	2.67613
1999	4	37	22	5.59327
1999	5	38	21	9.05579
1999	6	39	20	18.24507
2000	1	33	21	2.34422
2000	2	34	22	16.94318
2000	3	36	23	2.64443
2000	4	37	22	5.57013
2000	5	38	21	9.05864
2000	6	39	20	18.31396
2001	1	33	21	2.33166
2001	2	34	22	16.98611
2001	3	36	23	2.61636
2001	4	37	22	5.55154
2001	5	38	21	9.06196
2001	6	39	20	18.37442
2002	1	33	21	2.32026
2002	2	34	22	17.02277
2002	3	36	23	2.59176
2002	4	37	22	5.53363
2002	5	38	21	9.06382
2002	6	39	20	18.42754
2003	1	33	21	2.30994
2003	2	34	22	17.05505
2003	3	36	23	2.57034
2003	4	37	22	5.51772

YEAR	WELL #	I	J	Q cfs
2003	5	38	21	9.06599
2003	6	39	20	18.47383
2004	1	33	21	2.30053
2004	2	34	22	17.08272
2004	3	36	23	2.55090
2004	4	37	22	5.50561
2004	5	38	21	9.06801
2004	6	39	20	18.51456
2005	1	33	21	2.29208
2005	2	34	22	17.10620
2005	3	36	23	2.53408
2005	4	37	22	5.49316
2005	5	38	21	9.06997
2005	6	39	20	18.55009
2006	1	33	21	2.29208
2006	2	34	22	17.10620
2006	3	36	23	2.53408
2006	4	37	22	5.49316
2006	5	38	21	9.06997
2006	6	39	20	18.55009
2007	1	33	21	2.29208
2007	2	34	22	17.10620
2007	3	36	23	2.53408
2007	4	37	22	5.49316
2007	5	38	21	9.06997
2007	6	39	20	18.55009
2008	1	33	21	2.29208
2008	2	34	22	17.10620
2008	3	36	23	2.53408
2008	4	37	22	5.49316
2008	5	38	21	9.06997
2008	6	39	20	18.55009
2009	1	33	21	2.29208
2009	2	34	22	17.10620
2009	3	36	23	2.53408
2009	4	37	22	5.49316
2009	5	38	21	9.06997
2009	6	39	20	18.55009

YEAR	WELL #	I	J	Q cfs
2010	1	33	21	2.29208
2010	2	34	22	17.10620
2010	3	36	23	2.53408
2010	4	37	22	5.49316
2010	5	38	21	9.06997
2010	6	39	20	18.55009
2011	1	33	21	2.29208
2011	2	34	22	17.10620
2011	3	36	23	2.53408
2011	4	37	22	5.49316
2011	5	38	21	9.06997
2011	6	39	20	18.55009
2012	1	33	21	2.29208
2012	2	34	22	17.10620
2012	3	36	23	2.53408
2012	4	37	22	5.49316
2012	5	38	21	9.06997
2012	6	39	20	18.55009
2013	1	33	21	2.29208
2013	2	34	22	17.10620
2013	3	36	23	2.53408
2013	4	37	22	5.49316
2013	5	38	21	9.06997
2013	6	39	20	18.55009
2014	1	33	21	2.29208
2014	2	34	22	17.10620
2014	3	36	23	2.53408
2014	4	37	22	5.49316
2014	5	38	21	9.06997
2014	6	39	20	18.55009
2015	1	33	21	2.29208
2015	2	34	22	17.10620
2015	3	36	23	2.53408
2015	4	37	22	5.49316
2015	5	38	21	9.06997
2015	6	39	20	18.55009
2016	1	33	21	2.29208
2016	2	34	22	17.10620

YEAR	WELL #	I	J	Q cfs
2016	3	36	23	2.53408
2016	4	37	22	5.49316
2016	5	38	21	9.06997
2016	6	39	20	18.55009
2017	1	33	21	2.29208
2017	2	34	22	17.10620
2017	3	36	23	2.53408
2017	4	37	22	5.49316
2017	5	38	21	9.06997
2017	6	39	20	18.55009
2018	1	33	21	2.29208
2018	2	34	22	17.10620
2018	3	36	23	2.53408
2018	4	37	22	5.49316
2018	5	38	21	9.06997
2018	6	39	20	18.55009
2019	1	33	21	2.29208
2019	2	34	22	17.10620
2019	3	36	23	2.53408
2019	4	37	22	5.49316
2019	5	38	21	9.06997
2019	6	39	20	18.55009
2020	1	33	21	2.29208
2020	2	34	22	17.10620
2020	3	36	23	2.53408
2020	4	37	22	5.49316
2020	5	38	21	9.06997
2020	6	39	20	18.55009

TABLE III.3: Calculated velocities at observation points for management plan B

Contents:

COLUMN	
1	Year or management period.
2	Observation well #.
3	Observation-well row index in finite-difference grid.
4	Observation-well column index in finite-difference grid.
5	Velocity in X-direction at observation well (ft/sec).
6	Velocity in Y-direction at observation well (ft/sec).

YEAR	WELL #	I	J	V_x (ft/s)	V_y (ft/s)
1986	1	37	23	.85814E-05	.11544E-05
1986	2	38	22	.94034E-05	.10610E-05
1986	3	39	21	.78144E-05	.13557E-05
1986	4	40	20	.59217E-05	.22964E-05
1987	1	37	23	.82992E-05	.10216E-05
1987	2	38	22	.91662E-05	.95215E-06
1987	3	39	21	.76568E-05	.12698E-05
1987	4	40	20	.58138E-05	.22773E-05
1988	1	37	23	.80057E-05	.87966E-06
1988	2	38	22	.88962E-05	.87165E-06
1988	3	39	21	.74752E-05	.12345E-05
1988	4	40	20	.57069E-05	.22857E-05
1989	1	37	23	.77377E-05	.75645E-06
1989	2	38	22	.86330E-05	.82049E-06
1989	3	39	21	.72945E-05	.12333E-05
1989	4	40	20	.56090E-05	.23123E-05
1990	1	37	23	.75066E-05	.65847E-06
1990	2	38	22	.83941E-05	.79310E-06
1990	3	39	21	.71260E-05	.12537E-05
1990	4	40	20	.55206E-05	.23505E-05
1991	1	37	23	.73130E-05	.58428E-06
1991	2	38	22	.81852E-05	.78358E-06
1991	3	39	21	.69742E-05	.12876E-05
1991	4	40	20	.54413E-05	.23961E-05
1992	1	37	23	.71532E-05	.53014E-06
1992	2	38	22	.80062E-05	.78696E-06
1992	3	39	21	.68404E-05	.13297E-05
1992	4	40	20	.53708E-05	.24458E-05
1993	1	37	23	.70221E-05	.49192E-06
1993	2	38	22	.78544E-05	.79936E-06
1993	3	39	21	.67237E-05	.13761E-05
1993	4	40	20	.53085E-05	.24971E-05
1994	1	37	23	.69150E-05	.46600E-06
1994	2	38	22	.77264E-05	.81779E-06

YEAR	WELL #	I	J	V_x (ft/s)	V_y (ft/s)
1994	3	39	21	.66227E-05	.14243E-05
1994	4	40	20	.52537E-05	.25484E-05
1995	1	37	23	.68276E-05	.44938E-06
1995	2	38	22	.76187E-05	.83999E-06
1995	3	39	21	.65357E-05	.14725E-05
1995	4	40	20	.52056E-05	.25985E-05
1996	1	37	23	.67561E-05	.43966E-06
1996	2	38	22	.75281E-05	.86430E-06
1996	3	39	21	.64607E-05	.15196E-05
1996	4	40	20	.51634E-05	.26466E-05
1997	1	37	23	.66978E-05	.43499E-06
1997	2	38	22	.74519E-05	.88953E-06
1997	3	39	21	.63962E-05	.15648E-05
1997	4	40	20	.51266E-05	.26922E-05
1998	1	37	23	.66500E-05	.43392E-06
1998	2	38	22	.73878E-05	.91476E-06
1998	3	39	21	.63407E-05	.16076E-05
1998	4	40	20	.50943E-05	.27350E-05
1999	1	37	23	.66109E-05	.43541E-06
1999	2	38	22	.73337E-05	.93947E-06
1999	3	39	21	.62929E-05	.16478E-05
1999	4	40	20	.50661E-05	.27749E-05
2000	1	37	23	.65789E-05	.43861E-06
2000	2	38	22	.72879E-05	.96314E-06
2000	3	39	21	.62516E-05	.16851E-05
2000	4	40	20	.50413E-05	.28118E-05
2001	1	37	23	.65526E-05	.44296E-06
2001	2	38	22	.72492E-05	.98569E-06
2001	3	39	21	.62161E-05	.17197E-05
2001	4	40	20	.50197E-05	.28458E-05
2002	1	37	23	.65310E-05	.44796E-06
2002	2	38	22	.72164E-05	.10068E-05
2002	3	39	21	.61852E-05	.17514E-05
2002	4	40	20	.50006E-05	.28769E-05

YEAR	WELL #	I	J	V_x (ft/s)	V_y (ft/s)
2003	1	37	23	.65133E-05	.45335E-06
2003	2	38	22	.71886E-05	.10266E-05
2003	3	39	21	.61586E-05	.17806E-05
2003	4	40	20	.49840E-05	.29054E-05
2004	1	37	23	.64987E-05	.45882E-06
2004	2	38	22	.71649E-05	.10447E-05
2004	3	39	21	.61355E-05	.18072E-05
2004	4	40	20	.49693E-05	.29314E-05
2005	1	37	23	.64866E-05	.46422E-06
2005	2	38	22	.71447E-05	.10614E-05
2005	3	39	21	.61153E-05	.18314E-05
2005	4	40	20	.49564E-05	.29550E-05
2006	1	37	23	.64767E-05	.46947E-06
2006	2	38	22	.71274E-05	.10766E-05
2006	3	39	21	.60978E-05	.18534E-05
2006	4	40	20	.49450E-05	.29765E-05
2007	1	37	23	.64685E-05	.47448E-06
2007	2	38	22	.71127E-05	.10906E-05
2007	3	39	21	.60826E-05	.18734E-05
2007	4	40	20	.49350E-05	.29959E-05
2008	1	37	23	.64617E-05	.47920E-06
2008	2	38	22	.71001E-05	.11032E-05
2008	3	39	21	.60693E-05	.18914E-05
2008	4	40	20	.49262E-05	.30135E-05
2009	1	37	23	.64561E-05	.48361E-06
2009	2	38	22	.70893E-05	.11148E-05
2009	3	39	21	.60577E-05	.19078E-05
2009	4	40	20	.49184E-05	.30294E-05
2010	1	37	23	.64515E-05	.48769E-06
2010	2	38	22	.70800E-05	.11252E-05
2010	3	39	21	.60476E-05	.19225E-05
2010	4	40	20	.49115E-05	.30437E-05

YEAR	WELL #	I	J	V_x (ft/s)	V_y (ft/s)
2011	1	37	23	.64478E-05	.49145E-06
2011	2	38	22	.70721E-05	.11346E-05
2011	3	39	21	.60387E-05	.19358E-05
2011	4	40	20	.49054E-05	.30566E-05
2012	1	37	23	.64446E-05	.49490E-06
2012	2	38	22	.70652E-05	.11431E-05
2012	3	39	21	.60310E-05	.19478E-05
2012	4	40	20	.49000E-05	.30683E-05
2013	1	37	23	.64421E-05	.49803E-06
2013	2	38	22	.70593E-05	.11508E-05
2013	3	39	21	.60242E-05	.19586E-05
2013	4	40	20	.48953E-05	.30788E-05
2014	1	37	23	.64400E-05	.50088E-06
2014	2	38	22	.70543E-05	.11577E-05
2014	3	39	21	.60182E-05	.19683E-05
2014	4	40	20	.48911E-05	.30882E-05
2015	1	37	23	.64383E-05	.50345E-06
2015	2	38	22	.70499E-05	.11639E-05
2015	3	39	21	.60130E-05	.19770E-05
2015	4	40	20	.48874E-05	.30967E-05
2016	1	37	23	.64369E-05	.50576E-06
2016	2	38	22	.70461E-05	.11695E-05
2016	3	39	21	.60084E-05	.19848E-05
2016	4	40	20	.48841E-05	.31043E-05
2017	1	37	23	.64357E-05	.50784E-06
2017	2	38	22	.70429E-05	.11745E-05
2017	3	39	21	.60044E-05	.19918E-05
2017	4	40	20	.48812E-05	.31111E-05
2018	1	37	23	.64348E-05	.50969E-06
2018	2	38	22	.70401E-05	.11790E-05
2018	3	39	21	.60009E-05	.19981E-05
2018	4	40	20	.48786E-05	.31173E-05

YEAR	WELL #	I	J	V_x (ft/s)	V_y (ft/s)
2019	1	37	23	.64341E-05	.51134E-06
2019	2	38	22	.70376E-05	.11830E-05
2019	3	39	21	.59978E-05	.20038E-05
2019	4	40	20	.48764E-05	.31228E-05
2020	1	37	23	.64335E-05	.51281E-06
2020	2	38	22	.70355E-05	.11866E-05
2020	3	39	21	.59951E-05	.20088E-05
2020	4	40	20	.48743E-05	.31278E-05

TABLE III.4.a: Optimal freshwater pumpage rates for management plan B in management area

Contents:

COLUMN	
1	Row index of freshwater-supply wells in finite-difference grid.
2	Column index of freshwater-supply wells in finite-difference grid.
3	Freshwater-discharge rate in cfs.

I	J	Q cfs
35	27	.50000
35	28	.50000
35	26	.00000
35	25	.00000
34	24	.00000
34	25	.00000
36	26	.50000
36	27	.50000
36	28	.00000
36	24	.00000
35	23	.00000
37	25	.00000
37	26	.00000
37	27	.00000
37	28	1.00000
37	29	1.00000
38	24	.00000
38	25	.00000
38	26	.00000
38	27	1.00000
38	28	1.00000
38	29	1.00000
39	23	.00000
39	24	.00000
39	25	.00000
39	26	1.00000
39	27	1.00000
39	28	1.00000
39	29	1.00000
40	22	.00000
40	23	.00000
40	24	.00000
40	25	1.00000
40	26	1.00000
40	27	1.00000
40	28	1.00000
40	29	1.00000
41	21	1.00000
41	22	1.00000
41	23	1.00000
41	24	1.00000
41	25	1.00000
41	26	.00000
41	27	.00000
41	28	.00000
41	29	.00000
41	30	.00000
42	20	1.00000
42	21	1.00000
42	22	1.00000

I	J	Q cfs
42	23	1.00000
42	24	1.00000
42	25	.00000
42	26	.00000
42	27	.00000
42	28	.00000
42	29	.00000
42	30	.00000
43	20	1.00000
43	21	1.00000
43	22	1.00000
43	23	1.00000
43	24	1.00000
43	25	.00000
43	26	.00000
43	27	.00000
43	28	.00000
43	29	.00000
43	30	.00000
44	22	1.00000
44	23	1.00000
44	24	1.00000
44	25	1.00000
44	26	1.00000
44	27	.00000
44	28	.00000
44	29	.00000
44	30	.00000

TABLE III.4.b: Optimal brine-interception rates for management plan B in management area

Contents:

COLUMN	
1	Year or management time step.
2	Row index in finite-difference grid.
3	Column index in finite-difference grid.
4	Optimal-flow rate in cfs.

YEAR	I	J	Q cfs
1986	37	22	11.19002
1986	36	23	3.16274
1986	38	21	11.95935
1986	39	20	12.82016
1986	40	19	16.08392
1987	37	22	7.71834
1987	36	23	3.28075
1987	38	21	8.44382
1987	39	20	10.38756
1987	40	19	15.73597
1988	37	22	6.98583
1988	36	23	3.40082
1988	38	21	7.82127
1988	39	20	10.29988
1988	40	19	16.30862
1989	37	22	6.53688
1989	36	23	3.37090
1989	38	21	7.48447
1989	39	20	10.30897
1989	40	19	16.67982
1990	37	22	6.25099
1990	36	23	3.27787
1990	38	21	7.27272
1990	39	20	10.32538
1990	40	19	16.93874
1991	37	22	6.04143
1991	36	23	3.15390
1991	38	21	7.12044
1991	39	20	10.32969
1991	40	19	17.11658
1992	37	22	5.89522
1992	36	23	3.03013
1992	38	21	7.01217
1992	39	20	10.33433
1992	40	19	17.24651

YEAR	I	J	Q cfs
1993	37	22	5.78983
1993	36	23	2.91578
1993	38	21	6.93241
1993	39	20	10.33862
1993	40	19	17.34328
1994	37	22	5.71216
1994	36	23	2.81446
1994	38	21	6.87219
1994	39	20	10.34290
1994	40	19	17.41685
1995	37	22	5.65352
1995	36	23	2.72678
1995	38	21	6.82563
1995	39	20	10.34720
1995	40	19	17.47366
1996	37	22	5.60802
1996	36	23	2.65198
1996	38	21	6.78892
1996	39	20	10.35092
1996	40	19	17.51791
1997	37	22	5.57239
1997	36	23	2.58870
1997	38	21	6.75952
1997	39	20	10.35416
1997	40	19	17.55319
1998	37	22	5.54358
1998	36	23	2.53543
1998	38	21	6.73569
1998	39	20	10.35682
1998	40	19	17.58099
1999	37	22	5.52020
1999	36	23	2.49074
1999	38	21	6.71593
1999	39	20	10.35881
1999	40	19	17.60333
2000	37	22	5.50101
2000	36	23	2.45324
2000	38	21	6.69933
2000	39	20	10.36004

YEAR	I	J	Q cfs
2000	40	19	17.62088
2001	37	22	5.48494
2001	36	23	2.42186
2001	38	21	6.68538
2001	39	20	10.36100
2001	40	19	17.63515
2002	37	22	5.47144
2002	36	23	2.39550
2002	38	21	6.67356
2002	39	20	10.36102
2002	40	19	17.64607
2003	37	22	5.46009
2003	36	23	2.37345
2003	38	21	6.66346
2003	39	20	10.36094
2003	40	19	17.65506
2004	37	22	5.45035
2004	36	23	2.35483
2004	38	21	6.65465
2004	39	20	10.36040
2004	40	19	17.66176
2005	37	22	5.44193
2005	36	23	2.33912
2005	38	21	6.64704
2005	39	20	10.35928
2005	40	19	17.66695
2006	37	22	5.43483
2006	36	23	2.32587
2006	38	21	6.64032
2006	39	20	10.35817
2006	40	19	17.67072
2007	37	22	5.42862
2007	36	23	2.31467
2007	38	21	6.63457
2007	39	20	10.35692
2007	40	19	17.67357

YEAR	I	J	Q cfs
2008	37	22	5.42321
2008	36	23	2.30517
2008	38	21	6.62950
2008	39	20	10.35544
2008	40	19	17.67561
2009	37	22	5.41850
2009	36	23	2.29709
2009	38	21	6.62501
2009	39	20	10.35391
2009	40	19	17.67685
2010	37	22	5.41444
2010	36	23	2.29020
2010	38	21	6.62100
2010	39	20	10.35244
2010	40	19	17.67754
2011	37	22	5.41110
2011	36	23	2.28433
2011	38	21	6.61764
2011	39	20	10.35082
2011	40	19	17.67778
2012	37	22	5.40797
2012	36	23	2.27930
2012	38	21	6.61442
2012	39	20	10.34941
2012	40	19	17.67766
2013	37	22	5.40546
2013	36	23	2.27495
2013	38	21	6.61165
2013	39	20	10.34787
2013	40	19	17.67744
2014	37	22	5.40317
2014	36	23	2.27122

YEAR	I	J	Q cfs
2014	38	21	6.60929
2014	39	20	10.34635
2014	40	19	17.67690
2015	37	22	5.40124
2015	36	23	2.26798
2015	38	21	6.60703
2015	39	20	10.34500
2015	40	19	17.67628
2016	37	22	5.39954
2016	36	23	2.26514
2016	38	21	6.60501
2016	39	20	10.34359
2016	40	19	17.67549
2017	37	22	5.39791
2017	36	23	2.26270
2017	38	21	6.60327
2017	39	20	10.34232
2017	40	19	17.67465
2018	37	22	5.39663
2018	36	23	2.26055
2018	38	21	6.60167
2018	39	20	10.34116
2018	40	19	17.67369
2019	37	22	5.39564
2019	36	23	2.25865
2019	38	21	6.60009
2019	39	20	10.33992
2019	40	19	17.67291
2020	37	22	5.39476
2020	36	23	2.25698
2020	38	21	6.59856
2020	39	20	10.33889
2020	40	19	17.67177

TABLE III.5: Calculated Velocities at Observation Points for Management Plan B

Contents:

COLUMN	
1	Year or management period.
2	Observation well #.
3	Observation-well row index in finite-difference grid.
4	Observation-well column index in finite-difference grid.
5	Velocity in X-direction at observation well (ft/sec).
6	Velocity in Y-direction at observation well (ft/sec).

YEAR	WELL #	I	J	V_x ft/s	V_y ft/s
1986	1	35	23	.71073E-05	-.10907E-05
1986	2	37	23	.85418E-05	.11578E-05
1986	3	38	22	.94023E-05	.10567E-05
1986	4	39	21	.78410E-05	.13295E-05
1987	1	35	23	.69302E-05	-.12227E-05
1987	2	37	23	.82454E-05	.10224E-05
1987	3	38	22	.91639E-05	.94354E-06
1987	4	39	21	.76904E-05	.12351E-05
1988	1	35	23	.67608E-05	-.13593E-05
1988	2	37	23	.79473E-05	.87766E-06
1988	3	38	22	.88927E-05	.86026E-06
1988	4	39	21	.75092E-05	.11980E-05
1989	1	35	23	.66005E-05	-.14892E-05
1989	2	37	23	.76775E-05	.75248E-06
1989	3	38	22	.86284E-05	.80766E-06
1989	4	39	21	.73272E-05	.11971E-05
1990	1	35	23	.64564E-05	-.16050E-05
1990	2	37	23	.74456E-05	.65329E-06
1990	3	38	22	.83885E-05	.77971E-06
1990	4	39	21	.71573E-05	.12185E-05
1991	1	35	23	.63312E-05	-.17043E-05
1991	2	37	23	.72515E-05	.57843E-06
1991	3	38	22	.81788E-05	.77013E-06
1991	4	39	21	.70042E-05	.12536E-05
1992	1	35	23	.62248E-05	-.17876E-05
1992	2	37	23	.70913E-05	.52394E-06
1992	3	38	22	.79990E-05	.77374E-06
1992	4	39	21	.68693E-05	.12967E-05
1993	1	35	23	.61355E-05	-.18566E-05
1993	2	37	23	.69600E-05	.48558E-06
1993	3	38	22	.78466E-05	.78650E-06
1993	4	39	21	.67517E-05	.13440E-05
1994	1	35	23	.60613E-05	-.19136E-05
1994	2	37	23	.68527E-05	.45966E-06

YEAR	WELL #	I	J	V_x ft/s	V_y ft/s
1994	3	38	22	.77181E-05	.80534E-06
1994	4	39	21	.66500E-05	.13931E-05
1995	1	35	23	.59997E-05	-.19604E-05
1995	2	37	23	.67651E-05	.44309E-06
1995	3	38	22	.76099E-05	.82797E-06
1995	4	39	21	.65624E-05	.14422E-05
1996	1	35	23	.59489E-05	-.19991E-05
1996	2	37	23	.66935E-05	.43348E-06
1996	3	38	22	.75189E-05	.85270E-06
1996	4	39	21	.64869E-05	.14900E-05
1997	1	35	23	.59070E-05	-.20311E-05
1997	2	37	23	.66350E-05	.42892E-06
1997	3	38	22	.74424E-05	.87833E-06
1997	4	39	21	.64220E-05	.15359E-05
1998	1	35	23	.58725E-05	-.20577E-05
1998	2	37	23	.65871E-05	.42799E-06
1998	3	38	22	.73779E-05	.90394E-06
1998	4	39	21	.63661E-05	.15793E-05
1999	1	35	23	.58441E-05	-.20799E-05
1999	2	37	23	.65480E-05	.42961E-06
1999	3	38	22	.73236E-05	.92899E-06
1999	4	39	21	.63180E-05	.16199E-05
2000	1	35	23	.58207E-05	-.20986E-05
2000	2	37	23	.65158E-05	.43293E-06
2000	3	38	22	.72776E-05	.95299E-06
2000	4	39	21	.62764E-05	.16577E-05
2001	1	35	23	.58016E-05	-.21144E-05
2001	2	37	23	.64895E-05	.43740E-06
2001	3	38	22	.72387E-05	.97583E-06
2001	4	39	21	.62406E-05	.16927E-05
2002	1	35	23	.57859E-05	-.21278E-05
2002	2	37	23	.64678E-05	.44251E-06
2002	3	38	22	.72057E-05	.99715E-06
2002	4	39	21	.62095E-05	.17248E-05

YEAR	WELL #	I	J	V_x ft/s	V_y ft/s
2003	1	35	23	.57730E-05	-.21393E-05
2003	2	37	23	.64501E-05	.44801E-06
2003	3	38	22	.71777E-05	.10172E-05
2003	4	39	21	.61827E-05	.17543E-05
2004	1	35	23	.57624E-05	-.21492E-05
2004	2	37	23	.64354E-05	.45357E-06
2004	3	38	22	.71539E-05	.10356E-05
2004	4	39	21	.61594E-05	.17812E-05
2005	1	35	23	.57538E-05	-.21578E-05
2005	2	37	23	.64233E-05	.45907E-06
2005	3	38	22	.71336E-05	.10524E-05
2005	4	39	21	.61391E-05	.18057E-05
2006	1	35	23	.57468E-05	-.21652E-05
2006	2	37	23	.64133E-05	.46440E-06
2006	3	38	22	.71163E-05	.10679E-05
2006	4	39	21	.61215E-05	.18280E-05
2007	1	35	23	.57411E-05	-.21717E-05
2007	2	37	23	.64051E-05	.46948E-06
2007	3	38	22	.71014E-05	.10819E-05
2007	4	39	21	.61061E-05	.18481E-05
2008	1	35	23	.57364E-05	-.21775E-05
2008	2	37	23	.63983E-05	.47427E-06
2008	3	38	22	.70887E-05	.10948E-05
2008	4	39	21	.60927E-05	.18664E-05
2009	1	35	23	.57327E-05	-.21825E-05
2009	2	37	23	.63927E-05	.47874E-06
2009	3	38	22	.70779E-05	.11064E-05
2009	4	39	21	.60811E-05	.18829E-05
2010	1	35	23	.57297E-05	-.21870E-05
2010	2	37	23	.63881E-05	.48288E-06
2010	3	38	22	.70685E-05	.11170E-05
2010	4	39	21	.60708E-05	.18978E-05
2011	1	35	23	.57273E-05	-.21910E-05
2011	2	37	23	.63843E-05	.48669E-06

YEAR	WELL #	I	J	V_x ft/s	V_y ft/s
2011	3	38	22	.70605E-05	.11265E-05
2011	4	39	21	.60619E-05	.19113E-05
2012	1	35	23	.57253E-05	-.21945E-05
2012	2	37	23	.63812E-05	.49018E-06
2012	3	38	22	.70536E-05	.11351E-05
2012	4	39	21	.60541E-05	.19234E-05
2013	1	35	23	.57238E-05	-.21978E-05
2013	2	37	23	.63786E-05	.49335E-06
2013	3	38	22	.70477E-05	.11429E-05
2013	4	39	21	.60473E-05	.19343E-05
2014	1	35	23	.57226E-05	-.22006E-05
2014	2	37	23	.63765E-05	.49624E-06
2014	3	38	22	.70426E-05	.11499E-05
2014	4	39	21	.60413E-05	.19441E-05
2015	1	35	23	.57217E-05	-.22033E-05
2015	2	37	23	.63748E-05	.49884E-06
2015	3	38	22	.70382E-05	.11561E-05
2015	4	39	21	.60360E-05	.19529E-05
2016	1	35	23	.57210E-05	-.22057E-05
2016	2	37	23	.63734E-05	.50118E-06
2016	3	38	22	.70344E-05	.11618E-05
2016	4	39	21	.60314E-05	.19608E-05
2017	1	35	23	.57205E-05	-.22078E-05
2017	2	37	23	.63723E-05	.50329E-06
2017	3	38	22	.70311E-05	.11669E-05
2017	4	39	21	.60274E-05	.19679E-05
2018	1	35	23	.57201E-05	-.22098E-05
2018	2	37	23	.63714E-05	.50517E-06
2018	3	38	22	.70283E-05	.11714E-05
2018	4	39	21	.60238E-05	.19742E-05
2019	1	35	23	.57199E-05	-.22116E-05
2019	2	37	23	.63706E-05	.50684E-06
2019	3	38	22	.70259E-05	.11754E-05
2019	4	39	21	.60207E-05	.19799E-05

YEAR	WELL #	I	J	V_x ft/s	V_y ft/s
2020	1	35	23	.57197E-05	-.22133E-05
2020	2	37	23	.63700E-05	.50834E-06
2020	3	38	22	.70238E-05	.11791E-05
2020	4	39	21	.60179E-05	.19850E-05

TABLE III.6.a: Optimal freshwater-pumpage rates for management plan C in management area

Contents:

COLUMN	
1	Row index of fresh water supply well in finite-difference grid.
2	Column index of fresh water supply well in finite-difference grid.
3	Fresh water discharge rate in cfs.

I	J	Q cfs
35	27	.50000
35	28	.50000
35	26	.00000
35	25	.00000
34	25	.00000
34	24	.00000
36	26	.50000
36	27	.50000
36	28	.00000
36	25	.00000
37	25	.00000
37	26	.00000
37	27	.00000
37	28	1.00000
37	29	1.00000
38	24	.00000
38	25	.00000
38	26	.00000
38	27	1.00000
38	28	1.00000
38	29	1.00000
39	23	.00000
39	24	.00000
39	25	.00000
39	26	1.00000
39	27	1.00000
39	28	1.00000
39	29	1.00000
40	22	1.00000
40	23	1.00000
40	24	1.00000
40	25	1.00000
40	26	1.00000
40	27	.00000
40	28	.00000
40	29	.00000
41	21	1.00000
41	22	1.00000
41	23	1.00000
41	24	1.00000
41	25	1.00000
41	26	.00000
41	27	.00000
41	28	.00000
41	29	.00000
41	30	.00000
42	20	1.00000
42	21	1.00000
42	22	1.00000
42	23	1.00000

I	J	Q cfs
42	24	1.00000
42	25	.00000
42	26	.00000
42	27	.00000
42	28	.00000
42	29	.00000
42	30	.00000
43	20	1.00000
43	21	1.00000
43	22	1.00000
43	23	1.00000
43	24	1.00000
43	25	.00000
43	26	.00000
43	27	.00000
43	28	.00000
43	29	.00000
43	30	.00000
44	22	1.00000
44	23	1.00000
44	24	1.00000
44	25	1.00000
44	26	1.00000
44	27	.00000
44	28	.00000
44	29	.00000
44	30	.00000

TABLE III.6.b: Optimal brine-interception rates for management plan C

Contents:

COLUMN	
1	Year or management time step.
2	Row index in finite-difference grid.
3	Column index in finite-difference grid.
4	Optimal-flow rate in cfs.

YEAR	I	J	Q cfs
1986	35	22	11.10150
1986	36	23	1.44490
1986	37	22	10.11860
1986	38	21	12.04040
1986	39	20	16.42850
1987	35	22	8.06570
1987	36	23	1.40670
1987	37	22	6.52010
1987	38	21	8.57620
1987	39	20	15.05190
1988	35	22	7.41270
1988	36	23	1.55550
1988	37	22	5.80320
1988	38	21	7.99510
1988	39	20	15.37910
1989	35	22	7.01390
1989	36	23	1.55740
1989	37	22	5.39250
1989	38	21	7.68760
1989	39	20	15.60060
1990	35	22	6.75580
1990	36	23	1.49490
1990	37	22	5.13730
1990	38	21	7.49350
1990	39	20	15.74490
1991	35	22	6.55500
1991	36	23	1.40020
1991	37	22	4.95550
1991	38	21	7.35670
1991	39	20	15.84010
1992	35	22	6.40490
1992	36	23	1.30340
1992	37	22	4.83270
1992	38	21	7.25880
1992	39	20	15.90600

YEAR	I	J	Q cfs
1993	35	22	6.28930
1993	36	23	1.21320
1993	37	22	4.74650
1993	38	21	7.18700
1993	39	20	15.95350
1994	35	22	6.19890
1994	36	23	1.13290
1994	37	22	4.68420
1994	38	21	7.13300
1994	39	20	15.98930
1995	35	22	6.12660
1995	36	23	1.06390
1995	37	22	4.63800
1995	38	21	7.09130
1995	39	20	16.01691
1996	35	22	6.06830
1996	36	23	1.00520
1996	37	22	4.60260
1996	38	21	7.05870
1996	39	20	16.03830
1997	35	22	6.02040
1997	36	23	.95610
1997	37	22	4.57510
1997	38	21	7.03270
1997	39	20	16.05530
1998	35	22	5.98070
1998	36	23	.91540
1998	37	22	4.55320
1998	38	21	7.01150
1998	39	20	16.06850
1999	35	22	5.94740
1999	36	23	.88160
1999	37	22	4.53570
1999	38	21	6.99430
1999	39	20	16.07880

YEAR	I	J	Q cfs
2000	35	22	5.91910
2000	36	23	.85390
2000	37	22	4.52120
2000	38	21	6.97970
2000	39	20	16.08650
2001	35	22	5.89530
2001	36	23	.83100
2001	37	22	4.50940
2001	38	21	6.96750
2001	39	20	16.09250
2002	35	22	5.87480
2002	36	23	.81210
2002	37	22	4.49930
2002	38	21	6.95700
2002	39	20	16.09650
2003	35	22	5.85720
2003	36	23	.79660
2003	37	22	4.49120
2003	38	21	6.94810
2003	39	20	16.09950
2004	35	22	5.84200
2004	36	23	.78390
2004	37	22	4.48400
2004	38	21	6.94050
2004	39	20	16.10130
2005	35	22	5.82890
2005	36	23	.77340
2005	37	22	4.47790
2005	38	21	6.93380
2005	39	20	16.10210
2006	35	22	5.81770
2006	36	23	.76470
2006	37	22	4.47270
2006	38	21	6.92800
2006	39	20	16.10229

YEAR	I	J	Q cfs
2007	35	22	5.80780
2007	36	23	.75750
2007	37	22	4.46830
2007	38	21	6.92270
2007	39	20	16.10190
2008	35	22	5.79920
2008	36	23	.75160
2008	37	22	4.46450
2008	38	21	6.91820
2008	39	20	16.10110
2009	35	22	5.79190
2009	36	23	.74660
2009	37	22	4.46110
2009	38	21	6.91430
2009	39	20	16.10010
2010	35	22	5.78560
2010	36	23	.74240
2010	37	22	4.45830
2010	38	21	6.91070
2010	39	20	16.09860
2011	35	22	5.78010
2011	36	23	.73890
2011	37	22	4.45580
2011	38	21	6.90760
2011	39	20	16.09720
2012	35	22	5.77510
2012	36	23	.73610
2012	37	22	4.45370
2012	38	21	6.90480
2012	39	20	16.09570
2013	35	22	5.77100
2013	36	23	.73360
2013	37	22	4.45190
2013	38	21	6.90230
2013	39	20	16.09410

YEAR	I	J	Q cfs
2014	35	22	5.76730
2014	36	23	.73150
2014	37	22	4.45030
2014	38	21	6.90000
2014	39	20	16.09250
2015	35	22	5.76430
2015	36	23	.72970
2015	37	22	4.44900
2015	38	21	6.89800
2015	39	20	16.09070
2016	35	22	5.76150
2016	36	23	.72810
2016	37	22	4.44780
2016	38	21	6.89620
2016	39	20	16.08910
2017	35	22	5.75920
2017	36	23	.72680
2017	37	22	4.44690
2017	38	21	6.89440
2017	39	20	16.08771
2018	35	22	5.75700
2018	36	23	.72560
2018	37	22	4.44610
2018	38	21	6.89300
2018	39	20	16.08600
2019	35	22	5.75530
2019	36	23	.72450
2019	37	22	4.44530
2019	38	21	6.89170
2019	39	20	16.08450
2020	35	22	5.75360
2020	36	23	.72360
2020	37	22	4.44470
2020	38	21	6.89050
2020	39	20	16.08299