Golder Associates Inc.
CONSULTING ENGINEERS

REPORT TO

EARLY WINTERS RESORT PROJECT

GROUNDWATER FLOW MODELING FOR PROPOSED GROUNDWATER DEVELOPMENT MAZAMA, WASHINGTON

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1. INTRODUCTION

This report documents the results of groundwater flow modeling performed to determine the hydrologic impacts of the proposed groundwater development for the Early Winters Resort Project near Mazama, Washington. The Project will utilize groundwater for various purposes including residential and commercial supply, snow making, and irrigation. Studies presently under way by others will finalize the water demand for the Project. Previous studies have estimated water demand to be approximately as follows: -1,000 to 1,500 gpm year round for residential and commercial; -1,600 gpm for irrigation during the summer months only; and 1,000 to 1,500 gpm continuously for snowmaking for a thirty-day period in late November and early December. Based on these figures, the maximum demand could be between 2,000 and 3,100 gpm in critical periods of the year. Outside the period of snow making and summer irrigation, water demand could be as little as 1,000 to 1,500 gpm. For the purpose of this report, we have assumed a year round consumption of 3,100 gpm. This is therefore a worst-case scenario given the seasonal demand for water by the Project.

The primary concern regarding the development of groundwater for the Project is the potential reduction of streamflow in the Mazama River. Groundwater developments which are shown to have a "significant" impact on instream flows (significant is defined by the Washington State of Ecology as 50 percent or greater of pumpage being derived from the adjacent surface water reach) are not permitted to operate when the instream flows fall below the minimum flow established for the particular reach. The minimum flows have been established to preserve base flows and to protect instream resources such as anadromous fish. In discussions with the Department of Ecology (Ecology), Ecology indicated that their major concern regarding the depletion of instream flows is in that reach of the Methow River downstream of Mazama Bridge. Above Mazama Bridge (and particularly above Early Winters Creek) the Methow River is ephemeral and is usually dry from September through March.

Preliminary calculations indicated that the proposed groundwater development could impact groundwater levels, and hence streamflows, at and downstream of Mazama Bridge. However, the magnitude of the impact could not be adequately described by analytical methods. Therefore, a numerical groundwater flow model has been prepared to more accurately describe the hydrologic consequences of the planned groundwater development. Subsequent sections of this report describe the hydrologic conditions in the Methow Valley; the development of the model; and the results of the modeling.

2. BACKGROUND CONDITIONS

2.1 Geology

The upper Methow Valley is a northeast-southwest trending glacial valley of between one-half and two miles in width located in the North Cascades mountain range in north-central Washington (Figure 1). The valley is bounded by bedrock outcrops of sedimentary, meta-sedimentary, igneous and metamorphic rocks. Recent glacial erosion and transport of these materials has partially filled the upper valley with coarse sediment. Surficial materials in the upper valley are composed of coarse gravel, sand and cobbles indicative of a high energy depositional environment close to the source of sediment. The valley sediments extend to depth of at least 100 feet based on available well records, and may extend to depths of several hundred feet.

There are three main tributary valleys which enter the upper Methow Valley; Robinson Creek, Lost River, and Early Winters Creek (Figure 1). Well developed alluvial fans have developed at the junction of these valleys with the Methow Valley, particularly at Early Winters Creek.

2.2 Hydrogeologic Conditions

Several hydrogeologic studies have been performed in the Upper Methow River Basin over the past 15 years (Ecology, 1974, 1976 ; CH2M Hill, 1976 ; R.W. Beck and Associates, 1985). More recently, Okanogan County, in cooperation with Washington State Department of Ecology, has commenced a Groundwater Management Program (GWMP) for the Methow River Basin. The purpose of this program is to better understand the hydrology and hydrogeology of the Methow Valley and to develop programs to preserve and protect groundwater resources in the valley.

The coarse alluvial materials in the upper Methow Valley constitute the primary aquifer in this area. The surrounding bedrock has a much lower permeability and does not contain significant amounts of groundwater. Groundwater flow in the alluvial valley aquifer is controlled by the tranmissivity of the coarse surficial sediments and seasonal fluctuations in the hydrologic inputs to the upper valley. The following subsections discuss the components of the hydrologic system in the upper Methow Valley.

2.2.1 Surface-Water Hydrology

The surface-water hydrology of the upper Methow Valley reflects the seasonal fluctuations of precipitation, snow melt, and surface run-off in the area, with higher river flows during the spring and early summer, and lower flows during the fall and winter. Flows recorded by Ecology in the Methow River at Mazama Bridge during 1988 and 1989 are shown on Figure 2, and flows at Early Winters Creek prior to its confluence with the Methow River are shown on Figure 3. Both hydrographs show a seasonal variation in river flow. Early Winters Creek generally flows throughout the year, while the Methow River is usually dry for part of the year between Lost River and Mazama Bridge. There is generally water in the Methow above the Lost River confluence although this reach is not gaged. Data on long-term river flows for the upper Methow are limited. Flow data for Lost River and Robinson Creek are not available, but both streams generally flow throughout the year.

Data presented by Milhous et al. (1976) and presented in Table 1 indicate a significant interaction between surface and groundwater along the upper Methow. Table 1 summarizes discharge observations made on August 25, 1971 at each tributary to the upper Methow River, and on the Methow River at Mazama Bridge. The data indicates total surface water inflows of 190 cubic feet per second (cfs) but only 145 cfs of surface water outflow downstream at Mazama Bridge. The 45 cfs of water which is unaccounted in the surface-water flow at Mazama Bridge is assumed to have infiltrated via the bed of the Methow River and recharged the groundwater system of the upper Methow.

2.2.2 Aquifer Characteristics

Limited data are available regarding the hydraulic properties of the alluvial aquifer in the Methow Valley. A pump test was performed by CH2M Hill on the Rainbow Pines Subdivision well near Early Winters Creek in 1976. This test indicated that the transmissivity of the alluvial aquifer at this location is about 1,500,000 gpd/ft^2, or 200,000 ft^2/day (CH2M Hill, 1976). (Transmissivity is defined as the product of the hydraulic conductivity and saturated aquifer thickness). Based on the coarse nature of the alluvial materials, estimates of aquifer storativity range from 0.1 to 0.3.

2.2.3 Water-Level Fluctuations

Between May 1988 to June 1989, Ecology monitored groundwater levels in a number of existing water wells in the upper Methow Valley. The data are summarized in Appendix A. Well head casing elevations are available for six of the wells. These six wells are located along the axis of the valley between Gate Creek and Goat Creek (Figure 1). These six wells were used to determine annual water-level fluctuations and water-table gradients. The wells are designated by section and quarter-section as follows:

Designation	Well Name
20/31R	Devin-IC EW1
20/30N	EW18-DRD 8
19/23P	Early Winters Ranger Station
19/22Q	CH2M Piezometer 3B
19/22B	Devin-Rattlesnake 4
19/15L	Devin-Schaeffer 7

Annual groundwater-level fluctuations measured in the wells range up to 25 feet (Appendix B), although most wells show water-level fluctuations of ten feet or less. A hydrograph of groundwater elevations in the six wells between

February 1988 and April 1989 is shown on Figure 4. Figure 5 shows groundwater-level fluctuations in well 19/22B which is typical of many of the wells presented on Figure 4. There is a seasonal trend in groundwater levels with rapidly increasing water levels during the spring and declining levels through the remainder of the year. The groundwater response to spring run-off is rapid, generally taking place over one to two weeks in March or April. Groundwater levels then decline steadily throughout the summer, and then may rise slightly during the early fall in response to increased run-off. During the late fall and winter, groundwater levels again decline steadily due to reduced recharge.

The seasonal fluctuations in groundwater levels are due to the distribution of recharge throughout the year. Recharge to the aquifer takes place from the infiltration of surface-water run-off and direct precipitation, although the latter is probably only a minor component of recharge. Surface-water run-off is transmitted to the aquifer via the bed of the Methow River. The coarse nature of the surficial materials, the lack of low permeability sediments in the upper valley, and the rapid response between surface-water flows and groundwater levels indicate that the Methow River is in direct hydraulic communication with the aquifer. The interaction between the surface water and groundwater system of the Methow valley results in a highly dynamic system with large seasonal fluctuations in groundwater levels and flow reversals such that the groundwater system is recharged in the early summer by the Methow River which in turn is sustained by groundwater discharge in the late summer, early fall and mid-winter months. During the early summer, the river is therefore described as "losing" flow to the aquifer; conversely, the river is "gaining" flow from the aquifer during the middle of the year when surface-water inflows to the valley are reduced.

2.2.4 Water-Table Gradient

Despite the seasonal fluctuations in groundwater levels, the water-table gradient along the upper Methow Valley remains nearly constant. This is because of the high transmissivity of the aquifer, which allows rapid adjustments in groundwater levels along the length of the valley in response to changes in aquifer recharge. Statistical analysis of the water-table gradient along the upper valley (based on five of the six surveyed wells) indicates an average hydraulic gradient of 35 feet/mile between each well throughout the year, with a standard deviation for all observations of 3.5 feet/mile or ten percent. The hydraulic gradient between wells 19/22Q and 19/23P was not included because the gradient is transverse to the axis of the Methow valley and may be influenced by Early Winters Creek.

2.2.5 Downvalley Groundwater Flow

The downvalley groundwater flow has been estimated based on available hydrogeologic data. These data indicate that downvalley groundwater flow probably remains relatively constant throughout the year since a near constant hydraulic gradient and saturated aquifer thickness are maintained. Assuming that the aquifer is a minimum of 100 feet in thickness, and that annual water-level fluctuations are ten feet or less, the aquifer transmissivity could vary from 190,000 ft^2/day to 210,000 ft^2/day (i.e., ± five per cent of the estimated value of 200,000 ft^2/day. Thus, by maintaining a constant hydraulic gradient and near constant transmissivity, the aquifer remains in a quasi-steady state condition where downvalley groundwater flow remains relatively constant year round.

Based on an aquifer transmissivity of 200,000 ft^2/day, an aquifer width of one mile, and a hydraulic gradient of 35 ft/mile, the estimated downvalley groundwater flow is about 80 cfs. In view of the potential seasonal variation in the transmissivity value, this estimate could vary by ± five percent. In addition, the transmissivity estimate is based on testing at one location; further testing in different parts of the valley could produce differing transmissivity values and hence alter the estimate of downvalley flows. The estimate of downvalley groundwater flow presented above is somewhat higher than the 45 cfs surface-water loss indicated between Lost River and Mazama

Bridge. However, water released from storage in the Upper Methow valley aquifer could amount to an additional 30 cfs or greater depending on the specific yield of the aquifer. Therefore, downvalley groundwater flow may be at least 45 cfs and possibly as much as 70 to 100 cfs. Additional hydrologic data including detailed surface-water gaging, drilling to identify the thickness and extent of the aquifer, and pump testing to determine the hydraulic properties of the aquifer would be required to better define the downvalley groundwater flow.

3. GROUNDWATER MODELING

3.1 Introduction

The USGS finite-difference groundwater flow model MODFLOW (McDonald and Harbaugh, 1984) was used to simulate groundwater flow, stream depletion and aquifer drawdown in the upper Methow Valley resulting from the proposed groundwater development for the Early Winters Resort Project. MODFLOW is a general-purpose model that, in addition to solving basic groundwater flow problems, will simulate aquifer/river interaction, pumpage, drains, recharge, and evapotranspiration. Modeling of the Early Winters area used only the RIVER and WELL packages, in addition to the basic groundwater flow package.

3.2 Model Parameters

A rectangular finite difference grid was constructed to describe the aquifer geometry shown in Figure 6. The grid (Figure 7) is 18 rows by 48 columns and extends 12 miles in the column direction (NW-SE) and 2 miles in the row direction (SW-NE). Node spacing is constant in each direction with cell dimensions of 1,250 feet (column-wise) by 500 feet (row-wise). Cells located above the valley on bedrock were designated inactive no-flow cells and describe the approximate north-west and south-east valley boundaries shown in Figure 6.

The boundary conditions at the north-east and south-west model boundaries were chosen based on the groundwater elevations measured during 1988 and 1989. These boundaries were designated as constant head (groundwater elevation) cells with values of 2,400 and 1,930 feet respectively. Two cells at the head of the fan on Early Winters Creek were assigned a constant head of 2,170 feet. The constant-head boundaries were justified based on the observed groundwater levels near Early Winters fan and the likely large groundwater inflows from Early Winters and Upper Methow drainages. The constant head values for the northwest and southeast boundaries are close to ground surface elevations and produce a constant hydraulic gradient of 40 feet/mile across the length of the model. This gradient is steeper than the gradient calculated from the water-level data presented earlier. The water-level data presented in section 2.2.4 appears to be from an area of flatter hydraulic gradient possibly because of a wider, deeper or more permeable section of the aquifer. No-flow boundaries were assigned for the remaining boundaries to reflect the low permeability bedrock which forms the valley sides.

The aquifer was simulated as an unconfined aquifer with a constant transmissivity. A constant transmissivity was justified because the estimated aquifer thickness is much greater than the observed water-level fluctuations. Assuming a minimum aquifer thickness of 100 feet, the potential maximum error in the transmissivity value is five percent based on an annual water-level fluctuation of ten feet. A constant transmissivity was also chosen because trial runs of the model applying a strictly unconfined aquifer with constant hydraulic conductivity and varying transmissivity (as a function of saturated aquifer thickness) resulted in mathematical instability in the solution of the groundwater flow equations.

For the simulations presented in this report, transmissivity was set at either 200,000 ft^2/day to 100,000 ft^2/day and storativity was set at either 10 or 30 percent (0.1 to 0.3). These values were considered the most appropriate hydraulic parameters for the aquifer based on the available data.

In addition to the boundary conditions and aquifer geometry, external conditions were applied to the model using the RIVER and WELL packages available in MODFLOW. River reaches were specified for the cells indicated on Figure 7. These river reaches were activated and de-activated to simulate seasonal fluctuations in river stage. Wells were positioned at three cells in two configurations (designated A and B) as shown in Figure 7 to simulate the anticipated distribution of water supply wells for the Early Winters Resort.

3.3 Flow Simulation

The transient nature of groundwater and surface water flow in the upper Methow Valley made it necessary to break the simulation into time steps and stress periods. Four stress periods were defined to simulate the cycle of high and low river flow in the Methow River. Each stress period was six months long to approximate the March to August high-flow period and the September to February low-flow period. During the high-flow stress periods, all of the river reaches were active allowing flow between the aquifer and the river. During the low-flow stress period, all river reaches upstream of Mazama Bridge (Cell 31) were in-active and there was no flow between the aquifer and the river upstream of Mazama Bridge.

Within each six-month stress period, ten time steps were defined to provide mathematical stability in the solution of the groundwater flow equations, and to allow calculation of groundwater head, aquifer drawdown, and river leakage throughout the simulation. Only results from the last time step of each stress period were plotted or contoured for display.

The initial heads input to the model were taken from a steady-state run performed with all river nodes active and no wells pumping.

3.4 River Simulation

A total of 48 river nodes, or reaches, were designated along the entire length of the model as shown in Figure 7. River simulation is accomplished in MODFLOW by specifying the dimensions and hydraulic conductance of the river bed for each river reach, as well as the head in the river for that reach. The head input for each river reach simulated a linear decline in river stage with a gradient of 40 feet/mile. River stage at each end of the model was set equal to the boundary head. Flow into or out of the river is then calculated from the head difference between the river and the aquifer, controlled by the conductance of the river bed. The river was assumed to fully penetrate the aquifer with the hydraulic conductivity of the river bed equal to that of the aquifer and a width of 50 feet.

The primary limitation of the RIVER package is that the head in the river remains constant for any given stress period and cannot be determined or modified by the resulting aquifer heads from a previous time step or stress period. Therefore, leakage through the river bed is always calculated from a constant user-input value. This complicated the analysis and comparison of river leakage under pumping and non-pumping conditions and additional post-processing had to be performed to describe the effect of pumping on leakage through the river bed (see Section 3.6)

3.5 Well Simulation

Two potential well configurations (designated A and B) were simulated as shown in Figure 7. Each well was assigned a pumping rate of 2.3 cfs, for a total withdrawal of 6.9 cfs (3,100 gpm). The wells were pumped continuously throughout the entire simulation.

3.6 Output and Data Reduction

MODFLOW can potentially produce an enormous amount of output, and manipulation of the output was necessary to produce interpretable results. Because of the complex aquifer geometry, the distribution of constant-head boundary conditions, the changing aquifer/river interaction for each stress period, and the limitations of the MODFLOW river simulation package, it was difficult to input starting heads and river heads for a given set of aquifer conditions that represented quasi steady-state conditions prior to pumping. Therefore, a base case transient simulation was run without pumping wells to produce a datum for the overall volumetric budget, cell-by-cell river leakage and groundwater head. Output from the simulation of pumping wells, under the same boundary and initial conditions, were then subtracted from the base-case datum to produce a net result (aquifer drawdown, river leakage, and changes in the volumetric budget of the model). This processing was performed outside of MODFLOW using simple BASIC programming and LOTUS 123. Groundwater heads were then contoured along lines of equal elevation (equipotentials) or equal aquifer drawdown by a commercial contouring package SURFER.

4. GROUNDWATER MODELING RESULTS

4.1 Overview

The model simulations are summarized in Table 2. Simulations were performed using a transmissivity of either 200,000 ft^2/day or 100,000 ft^2/day and storativity of either 0.3 or 0.1. Based on the hydrologic data available, we believe that the parameters that best represent the actual conditions are: transmissivity 100,000 ft^2/day and storativity 0.3. The simulations indicated that, for the parameters selected and based on the proposed well locations (configuration A), there was generally little difference between the amount of water derived from the Methow River (leakage), and that in all cases the amount of leakage downstream of Mazama Bridge was less than 20 percent of the total quantity of water pumped. The simulations presented are worst-case conditions, since the model did not consider the recharge of treated wastewater from the Project which will be allowed to seep into the aquifer near Mazama Bridge. The disposal of effluent in this area will significantly reduce the hydrologic effects described in the following sections.

4.2 Base-Case Simulations

Initially, base-case simulations were run to define the "background" conditions. Each simulation was performed over four stress periods each of six months in length. The results are presented for the last time step of each stress period. The stress periods are designated 1, 2, 3 and 4 on the figures, representing simulated conditions after 6, 12, 18 and 24 months. The results of 6 and 18 months and the 12 and 24 month simulations are generally identical. This is because the aquifer is fully recharged by the Methow River at the end of the six month period when the Methow River is active. It is therefore not necessary to simulate the aquifer response over many years since, unless recharge decreases substantially, the results will be identical to those presented for the end of six and twelve months.

4.2.1 Groundwater-Head Distribution

The resulting groundwater heads for each run described in Table 2 are quite similar, and differences between cases are not easily seen from a contoured equipotential plot. The resulting head distribution for case 1 (T=200,000 ft^2/day, S=0.3) is shown in Figure 8a and 8b. In general, the equipotentials are perpendicular to the axis of the valley, with a slight distortion around the Early Winters Creek fan due to inflow from this feature, and the widening of the valley in this area. This pattern is observed for all stress periods. The magnitude of head produced by the model approximates the observed heads to within about 10 feet, and groundwater-level fluctuations of up to eight feet are produced during periods of low river flow, when river reaches 1 through 30 are inactive.

4.2.2 River Leakage

River leakage for the base-case simulations indicates that the river alternates from losing to gaining conditions along the length of the valley. These changes are due in part to the choice of river head input to the model. As discussed previously, a constant gradient was input for the river stage with river heads equal to boundary heads at either end of the model. The fluctuations in river leakage produced by the base case represent the difference between an assumed linear decline in river head and the non-linear decline in aquifer head caused by the boundary conditions.

Figure 9 shows negative river leakage (flow from the aquifer to the river) where the Early Winters Creek fan intersects the Methow Valley. This is due to the constant head boundary which supplies water to the model at a rate proportional to the head differences between the boundary head, and the simulated aquifer head along this boundary. Part of this flow is then transmitted to the river based on the head difference between river stage and simulated aquifer head near the river.

Between nodes 19 and 21, river leakage is also negative, probably due to the narrowing of the valley near Goat Wall, and the simulated meander in the river. Groundwater heads tend to build up slightly near Goat Wall, which results in flow to the river because of its proximity to Goat Wall. Widening of the aquifer up-valley and down-valley of the Early Winters Creek constant head nodes causes head in the aquifer to decline slightly, and the river loses water to the aquifer (positive leakage).

Figure 9 also shows that aquifer/river interaction under non-pumping conditions is not sensitive to aquifer storage, but is sensitive to transmissivity. Peak river leakage decreases proportionally with decreased transmissivity, but the distribution of leakage along the various reaches of the Methow does not change.

4.2.3 Volumetric Water Budget

The volumetric water balance of inputs and outputs to the model is a good indicator of the accuracy of the resultant head distribution. Additionally, the relative magnitude of the flow components (storage, river leakage, and constant head boundary flows) is useful in determining the sources and sinks of groundwater in the model. Groundwater enters the model via the constant head boundary at Lost River and Early Winters Creek (QCH_{in}). Groundwater leaves the model at the constant head boundary at Weeman Bridge (QCH_{out}). Additional flow into or out of the model occurs along the river (QRIV) and from changes in aquifer storage (QS). The volumetric budget from each stress period for each run is included in Appendix B.

The downvalley flow (QCH_{out}) indicated by the model is 138 cfs for a transmissivity of 200,000 ft^2/day. This flow is reduced to 69 cfs for a transmissivity of 100,000 ft^2/day. The lower transmissivity appears to generate more reasonable downvalley groundwater flows when compared with the available data. The groundwater inflow into the model (QCH_{in}), based on the lower transmissivity is about 78 cfs. This is higher than the surface-water loss presented in Section 2.2.1, however the difference could easily be made up by water released from storage and groundwater inflow via Early Winters fan and the alluvial deposits of the upper Methow Valley. The balance of flows out of the model are produced by the river, and changes in storage cause by the fluctuation in the distribution of river reaches. Each stress period has less than one percent error in the volumetric budget. The cumulative volume budget has a discrepancy of up to five percent, which is caused by the inability of the river to remove water from the model during stress periods two and four when the river is inactive above Mazama Bridge.

4.2.4 Summary of Base-Case Simulations

In general, the base-case simulations indicate that the model performs adequately and responds correctly to the conditions imposed on it. As discussed previously, the base-case simulations do not represent fully calibrated simulations. However, we believe that for the purpose of determining the relative impact of groundwater development on the hydrologic system, the base case provides a reasonable means for comparison.

4.3 Pumping-Well Simulations

Simulations were repeated using the same stress periods and time steps as in the corresponding base cases. Then simulations of pumping conditions were included using the presently proposed well locations (configuration A). In addition, one simulation was performed using alternate well locations (configuration B). Pumping wells were simulated at nodes (19,9), (24,15) and (26,14) at 2.3 cfs each, for a total of 6.9 cfs. Output from the pumping-well simulations was subtracted from the corresponding output from the base-case simulation to determine the effect of pumping on head distribution (drawdown), river leakage, and volumetric water budget. The sequence of pumping-well simulations is presented in Table 2.

4.3.1 Drawdown

Case 1A: $T = 200{,}000\ ft^2/day$ $S = 0.3$

The resulting head distribution is similar to base case (Case 1). Figure 10a and 10b shows the resulting distribution of drawdown produce by pumping under well configuration A.

Step 1 (t = 6 months): All river reaches are active and three cones of depression are produced with a maximum drawdown of 1.0 feet at PW-1. Aquifer drawdown extends approximately one mile up valley from PW-1 and one mile downvalley of PW-3. Less than 0.1 feet of drawdown is observed at Mazama Bridge.

Step 2 (t = 12 months): All river reaches up-stream of Mazama Bridge are inactive, and the resulting cone of depression spreads across the valley because of the lack of induced infiltration from the river. The maximum drawdown is 1.6 feet at the pumping wells. The cone of depression extends up valley approximately two miles from PW-1 and two miles downvalley from PW-3. Approximately 0.2 feet of drawdown is observed at Mazama Bridge.

Step 3 (t = 18 months): All river reaches are active, and the cone of depression returns to the configuration observed in Step 1.

Step 4 (t = 24 months): River reaches upstream of Mazama Bridge are inactive, and the cone of depression expands to the same configuration predicted in Step 2.

Case 2A: T = 100,000 ft^2/day S = 0.3

The contoured head distribution is similar to the base case. Figure 11 shows the resulting distribution of drawdown produced by pumping under these conditions.

Step 1 (t = 6 months): All river reaches are active and three cones of depression are produced with a maximum drawdown of 1.5 feet at PW-1. Drawdown extends approximately one mile up valley from PW-1 and one mile downvalley from PW-3. Less than 0.1 feet of drawdown is observed at Mazama Bridge.

Step 2 (t = 12 months): All river reaches up-stream of Mazama Bridge are inactive, and the resulting cone of depression spreads across the valley because of the lack of induced infiltration from the river. The maximum drawdown is 2.8 feet at the pumping wells. The cone of depression extends up valley approximately two miles from PW-1 and two miles downvalley of PW-3. About 0.3 feet of drawdown is observed at Mazama Bridge.

Step 3 (t = 18 months): All river reaches are active, and the cone of depression returns to the configuration observed in Step 1.

Step 4 (t = 24 months): River reaches upstream of Mazama Bridge are inactive, and the cone of depression expands to the same configuration predicted in Step 2.

Case 3A: T = 100,000 ft^2/day S = 0.1

The resulting head distribution is similar to base case (Case 1, and Case 2). The drawdown for this case is nearly identical to that from Case 2A, and has not been included in this report. Reducing storativity does not appear to significantly influence the resulting cone of depression.

4.3.2 River Leakage

Case 1A: T = 200,000 ft^2/day S = 0.3

River leakage is presented in Figure 12a and 12b in terms of individual reach leakage and cumulative net leakage along the length of the river. Net leakage is the difference in leakage between the base-case simulations and the simulations including the pumping wells (Section 3.6). Cumulative net river leakage is also presented on Table 3.

Steps 1 and 3: All river reaches are active. Figure 12a shows that peak leakages of about 0.6 and 0.5 cfs respectively are observed at node 19 (adjacent to PW-1) and node 26 (adjacent to PW-2 and PW-3) during Steps 1 and 3 when the entire river is active. Lower leakage is observed at reach 26 because of the constant head boundary at Early Winters Creek, which supplies a portion of the water pumped by the wells. Cumulative river leakage (Figure 12b) is between 5.2 and 5.5 cfs, or about 77 percent of total pumpage, and is achieved up valley of Mazama Bridge.

Steps 2 and 4: Reaches upstream of Mazama Bridge are inactive. Figure 12a shows a peak leakage of 0.3 cfs at Mazama Bridge. Cumulative river leakage (Figure 12b) is 1.4 cfs, or 20 percent of total pumpage and is achieved about one mile downstream of Mazama Bridge.

Case 2A: T = 100,000 ft^2/day S = 0.3

River leakage is presented in Figure 13a and 13b in terms of individual reach leakage and cumulative leakage along the length of the river. Cumulative net river leakage is also tabulated on Table 3.

Steps 1 and 3: All river reaches are active. Figure 13a shows that peak leakages of about 0.6 and 0.5 cfs respectively are observed at node 19 (adjacent to PW-1) and node 26 (adjacent to PW-2 and PW-3) during Steps 1 and 3 when the entire river is active. Cumulative river leakage (Figure 13b) for step 1 is about 5.2 cfs, or 75 percent of total pumpage, and is achieved up valley of Mazama Bridge.

Steps 2 and 4: Reaches upstream of Mazama Bridge are inactive. Figure 13a shows a peak leakage of 0.2 cfs at Mazama Bridge. Cumulative river leakage (Figure 13b) is 1.07 cfs or 15 percent of total pumpage and is achieved about one mile downstream of Mazama Bridge.

Case 3A: T = 100,000 ft^2/day S = 0.1

River leakage under these conditions is nearly identical to Case 2A (Table 3).

4.3.3 Volumetric Budget

The volumetric budgets for the pumping-well simulations are presented in Appendix B. The water-budget discrepancies calculated for the individual stress periods are less than two percent, and cumulative discrepancies are less than three percent. Table 4 summarizes the changes in volumetric flows into and out of the model between the base case and pumping-well simulations.

Case 1A: T = 200,000 ft^2/day S = 0.3

When all river nodes are active (Step 1), 5.26 cfs is derived from river leakage, less than 0.1 cfs is derived from storage, and 1.59 cfs is derived from the constant-head boundaries at Lost River and Early Winters Creek. The sum of these flows is nearly identical to the pumping rate of 6.9 cfs. When the river dries up above Mazama Bridge (Step 2), 1.43 cfs is derived from river leakage below Mazama Bridge, 2.39 cfs is derived from storage, and 3.06 cfs is derived from the constant-head boundaries. The flow derived from the constant-head boundaries is small in relation to the total downvalley groundwater flow and is therefore acceptable.

Case 2A: T = 100,000 ft^2/day S = 0.3

At the end of Step 1, 5.23 cfs is derived from river leakage, 0.08 cfs is derived from storage, and 1.58 cfs is derived from the constant-head boundaries at Lost River and Early Winters Creek. During Step 2 (when the Methow River is assumed to be dry above Mazama Bridge), 1.07 cfs is derived from river leakage, 3.07 cfs from storage, and 2.78 cfs from the constant-head boundaries. Storage losses are higher because of the lower transmissivity, and constant head and river inflows decrease in response to the lower transmissivity.

Case 3A: T = 100,000 ft^2/day S = 0.1

At the end of Step 1, 5.30 cfs is derived from river leakage, less than 0.08 cfs is derived from storage, and 1.58 cfs is derived from the constant-head boundaries at Lost River and Early Winters Creek. The sum of these flow is nearly identical to the pumping rate of 6.9 cfs. At the end of Step 2, 1.04 cfs is derived from river leakage below Mazama Bridge, 2.83 cfs from storage and 3.00 cfs from the constant-head boundaries.

4.3.5 Alternate Well Configuration

A final set of simulations were performed assuming that the wells were located further up valley than in configuration A. The alternate well configuration (configuration B) involved pumping wells at nodes (9,16), (11,21), and (15,24). Pumping rates and total pumpage remained the same as in configuration A. The parameters chosen were those considered to be the most representative of the overall aquifer conditions.

Case 1B: T = 100,000 ft^2/day S = 0.3

The drawdown distribution (Figure 14) shows that, when all river nodes are active, the maximum drawdown is 0.7 feet at the pumping wells, and the cone extends less than one mile up-valley of PW-3. Drawdown is not observed down-valley of the Early Winters fan. During the inactive river period, the cone extends up valley, reaching the model boundary. Very little expansion of the cone is observed downvalley, and no drawdown is observed at Mazama Bridge.

Peak river leakage (Figure 14a) of about 0.65 cfs is observed adjacent to PW-1 and PW-2 during the active river periods, but PW-3, in the Early Winters fan, has little impact on leakage from the Methow River. Cumulative river leakage (Figure 14b) is similar to well configuration A at about 5.3 cfs, which is expected since the total pumping rate is the same. However, the leakage of 5.3 cfs is achieved around node 25, farther up valley than well configuration A.

During the inactive river periods, there is no leakage from the active reach (downstream of Mazama Bridge). This is due in part, to boundary effects caused by the expansion of the cone of depression to the up valley constant-head boundary. The effect of impacting this boundary can also be seen in the response at stress period 3 (Figure 14 and Table 3). More leakage is observed because the constant-head boundary supplies most of the water for the up-valley side of the cone of depression.

The volumetric budget for the alternate well configuration is not presented.

4.4 Summary of Modeling

The results of the modeling exercise can be summarized as follows:

Base-case simulations under non-pumping conditions indicate that the model responds appropriately to the imposed boundary conditions and approximates the observed distribution of head in the aquifer. The distribution of river leakage is affected by the aquifer geometry, boundary conditions and linear river stage gradient input to the model, but is not unreasonable to use as a datum for comparison to pumping conditions.

Simulation of three pumping wells for a total withdrawal of 6.9 cfs produces a cone of depression in the aquifer that responds to the presence or absence of active river reaches along the length of the model. Drawdown is intensified during periods of inactive river reaches, but the drawdown downvalley of Mazama Bridge is 0.5 feet or less.

Pumpage of the aquifer at 6.9 cfs changes the magnitude and distribution of flow between the river and the aquifer when compared to the base case. During the active river period, up to 70 percent of the pumped quantity is derived from the Methow river above Mazama Bridge. The remaining quantities are derived from aquifer storage or from the model boundaries. During inactive river periods, less than 20 percent of pumpage is derived from the active down-valley river reaches below Mazama Bridge, and the remaining quantities are derived from increased losses in aquifer storage and flow from the model boundaries.

The model is sensitive to the estimates of transmissivity and storage, but the distribution and magnitude of leakage from the river is not significantly affected by the aquifer properties selected for the present study. It should be noted that all of the modeled leakage distributions show a slight discrepancy between the leakage at the end of Step 1 and the beginning of Step 3 (Table 3). In reality, the river leakages determined at the end of these two steps should be identical since a full year has passed and the aquifer has been recharged by the intervening spring runoff. The reason for the discrepancy in the model calculated leakages is probably due to accumulating round-off errors and boundary conditions.

If the proposed wells are located further up valley, there may be little to no leakage (i.e., depletion in flow) from the Methow river below Mazama Bridge. However, because cone of depression produced by pumping impacted the upriver model boundary, there are some inaccuracies in this simulation.

4.5 Groundwater Modeling Limitations

The interaction between groundwater and surface-water systems is often complex and standard analytical or numerical techniques are not always well suited to describing the dynamic interaction between the two systems. Typical analyses treat surface-water bodies as constant-head sources or sinks within the groundwater system, subject to "leakage" through an intervening layer of differing hydraulic properties. In many cases however, the surface and groundwater systems are not static, and have transient effects on each other, which in turn impact the interaction between the two systems. The groundwater/surface-water system in the upper Methow Valley exhibits this complex behavior and the modeling work presented in this report necessarily contains simplifications and limitations inherent in the present ability to simulate these conditions.

A complete calibration of the groundwater flow model with observed groundwater levels and river stage has not been carried out because of the limited data available. However, the groundwater elevations simulated by the model approximately describe observed levels in the upper Methow Valley during 1988/89 (see section 4), and thus we believe that the model is a good tool to provide a preliminary assessment of the potential hydrologic impacts of groundwater development in the Early Winters area.

Complete calibration of the model to observed groundwater levels and river flows would involve the collection of much data over many years and could be extremely difficult given the complex nature of groundwater/surface water interaction in the upper Methow Valley.

5. SUMMARY AND CONCLUSIONS

A groundwater flow model based on the USGS finite-difference MODFLOW code has been developed to evaluate the potential hydrologic effects of groundwater development for the Early Winters Resort Project. The Project plans to use between 1,000 and 3,100 gpm of groundwater on a year-round basis. Water used for residential and commercial purposes will be treated and used to recharge the aquifer.

The Project plans to use groundwater from the Methow Valley Aquifer. The aquifer is contained within a glacial valley carved from sedimentary, metamorphic and igneous bedrock. The valley is believed to be infilled with at least 100 feet, and possibly several hundred feet of highly permeable coarse sands and gravels. The aquifer is recharged by direct infiltration from the Methow river and, to a minor extent by direct precipitation. Groundwater and surface water within the valley are in good hydraulic communication. Infiltration from the Methow River and tributary creeks recharges the aquifer principally in the spring and early summer months, although the alluvial aquifer is also recharged by minor runoff over the remainder of the year. During periods of low flow in the upper Methow valley, the Methow River downvalley of Mazama Bridge is sustained by groundwater discharge from the aquifer as storage is depleted by declining groundwater levels.

Available hydrologic data has been used to develop a numerical groundwater flow model for the upper Methow valley. The model has been used to determine the hydrologic effects of groundwater abstraction for the Project. Ecology has indicated that the removal of groundwater to supply the Project may reduce flows in the Mazama river at critical times of the year when minimum flow criteria are in effect. During the period of minimum flows Ecology have indicated that, if more than 50 percent of the total pumpage at the time of minimum flows is derived from streamflow, then the well(s) would not be permitted to operate unless and exemption is issued. The reach of the Methow river where the minimum instream flows would be applied by Ecology is that reach below Mazama Bridge, since the Methow is dry for much of the year above this point.

Model simulations based on the estimated aquifer parameters indicates that, under worst-case conditions, the removal of groundwater for the Project would not significantly impact river flows downstream of Mazama Bridge. During the period when the Methow is flowing above Mazama Bridge, at least 70 percent of the water pumped could be derived from the Methow river up valley of Mazama Bridge. The remainder would be derived from the constant-head boundaries, with a minor proportion from storage. This means that flow in the Methow river (upriver of Mazama Bridge) could be decreased by five cfs during this period, if 6.9 cfs is continually pumped by the Early Winters wells. This amount of river depletion is minor when compared with the river flow which is often in excess of 1,000 cfs.

During the assumed six-month period when the Methow River is dry above Mazama Bridge, between 15 and 20 percent of the water pumped could be derived from the Methow River downstream of Mazama Bridge. The remainder could be drawn from storage within the aquifer and from the constant-head boundaries. This means that flow in the Methow river (downstream of Mazama Bridge) could be decreased by between 1.07 and 1.4 cfs, if the Early Winters wells pumped 6.9 cfs continuously. This depletive effect would take place over a reach of the river of several miles and thus would not be detectable.

The results presented above are worst-case conditions. This is because the pumping rates used in the model assume a year round, 24-hour a day pumpage of 6.9 cfs or 3,100 gpm. The actual average year round pumpage is estimated to be between 1,500 and 2,000 gpm which, although not decreasing the percentage of pumped water derived from the river, would lessen the actual amount of river depletion. In addition, at least 90 percent and possibly as much as 95 percent of the water used for residential and commercial purposes (i.e., 1,000 to 1,500 gpm) will be returned to the aquifer as treated effluent by ground disposal means. This water will recharge the aquifer and thus mitigate much of the limited river depletion downstream of Mazama Bridge.

6. REFERENCES

✓ CH2M Hill, 1976. Analysis of Geohydrologic Data Related to Water Supply and Land Disposal of Domestic Effluent. Early Winters Valley, Near Mazama, Washington.

✓ Milhous, R.T., Sorlie, G. and Richardson, D., 1976. The Water Resources of the Methow Basin. Department of Ecology Office Report No. 56, 54 pp.

✓ MacDonald, M.G. and Harbaugh A W., 1984. A Modular Three-Dimensional Finite Difference Ground-Water Flow Model. U.S. Geological Survey 500pp.

TABLES

TABLE 1

DISCHARGE MEASUREMENTS IN THE UPPER METHOW RIVER BASIN
AUGUST 25, 1989 ? 1971

Gaging Station		Discharge (cfs)
Methow above Robinson Creek		49.6
Robinson Creek		9.9
Lost River		95.2
Gate Creek		1.0
Goat Wall Creek		0.0
Early Winters Creek		34.4
	TOTAL	190.4 cfs
Methow River at Mazama Bridge		145.0 cfs
Surface Water Loss		45.4 cfs

Source: Milhous et al., 1976

TABLE 2

MODEL SIMULATION SEQUENCE AND OUTPUT

Base-Case Simulations: No Wells Pumping

Case 1:	T=200,000 ft^2/day, S=0.3	Figure 8 and 9
Case 2:	T=100,000 ft^2/day, S=0.3	Figure 9
Case 3:	T=100,000 ft^2/day, S=0.1	Figure 9

Pumping-Well Simulations

Case 1A:	T=200,000 ft^2/day, S=0.3.	Well Config. A	Figure 10 and 12
Case 2A:	T=100,000 ft^2/day, S=0.3.	Well Config. A	Figure 11 and 13
Case 3A:	T=100,000 ft^2/day, S=0.1.	Well Config. A	Not Presented
Case 2B:	T=100,000 ft^2/day, S=0.3.	Well Config. B	Figure 14 and 15

Where T is transmissivity and S is Storativity.

TABLE 3

CUMULATIVE RIVER LEAKAGE

Stress Period	Cumulative River Leakage (cfs) Case 1A	Case 2A	Case 3A	Case 2B
1	5.26	5.23	5.29	5.63
2	1.43	1.07	1.04	-0.22
3	5.48	5.67	5.57	6.22
4	1.41	1.08	1.04	-0.20

Where:

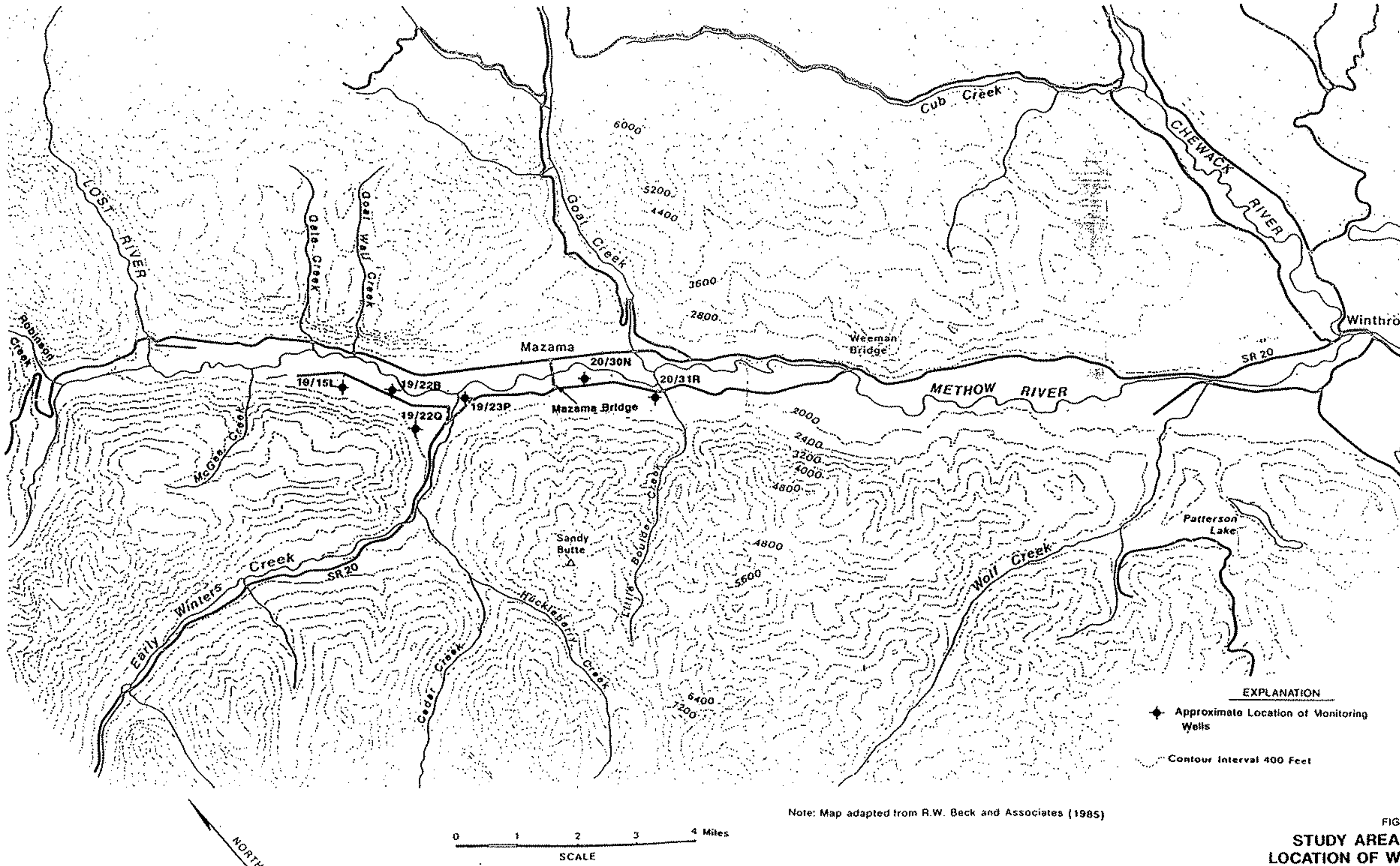
Case 1A: $T=200,000\ ft^2/day$, $S=0.3$
Case 2A: $T=100,000\ ft^2/day$, $S=0.3$
Case 3A: $T=100,000\ ft^2/day$, $S=0.1$
Case 2B: $T=100,000\ ft^2/day$, $S=0.3$

TABLE 4

VOLUMETRIC BUDGET - PUMPING WELL SIMULATIONS

	Change in River (cfs)	Change in Storage (cfs)	Change in Gradient (cfs)	Total Flow Change (cfs)	Pumping Rate (cfs)	Percent Error
Case 1A						
Step 1	5.26	0.07	1.59	6.92	6.9	-0.28
Step 2	1.43	2.39	3.06	6.88	6.9	0.34
Step 3	5.48	-0.17	1.59	6.90	6.9	-0.03
Step 4	1.41	2.36	3.04	6.82	6.9	1.20
Case 2A						
Step 1	5.23	0.08	1.58	6.89	6.9	0.21
Step 2	1.07	3.07	2.78	6.92	6.9	-0.25
Step 3	5.67	-0.30	1.60	6.97	6.9	-0.98
Step 4	1.08	3.05	2.78	6.91	6.9	-0.20
Case 3A						
Step 1	5.30	0.08	1.58	6.96	6.9	-0.90
Step 2	1.04	2.83	3.00	6.87	6.9	0.40
Step 3	5.57	-0.22	1.62	6.98	6.9	-1.11
Step 4	1.04	2.84	2.89	6.77	6.9	1.90

For definition of Cases 1A, 2A, and 3A, see Table 3.



Note: Map adapted from R.W. Beck and Associates (1985)

FIGURE 1
STUDY AREA AND LOCATION OF WELLS
EARLY WINTERS/GROUNDWATER MODEL

PROJECT NO 893-1169 DWG NO 20460 DATE 11/6/89 DRAWN DC APPROVED

Golder Associates

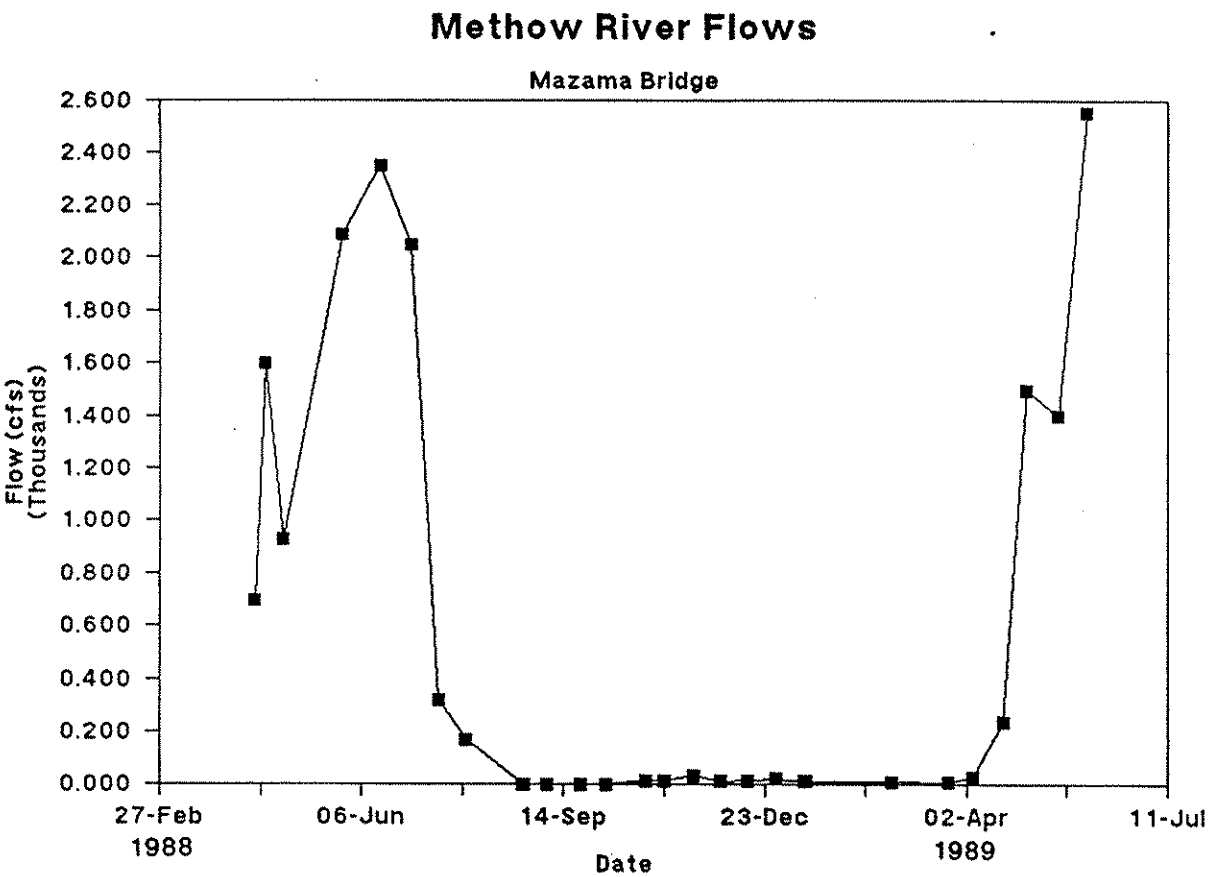


FIGURE 2
METHOW RIVER HYDROGRAPH
APRIL 1988 - MAY 1989
EARLY WINTERS/GROUNDWATER MODEL

PROJECT NO. 893-1169 DWG. NO. 20440 DATE 11/6/89 DRAWN TK APPROVED

Golder Associates

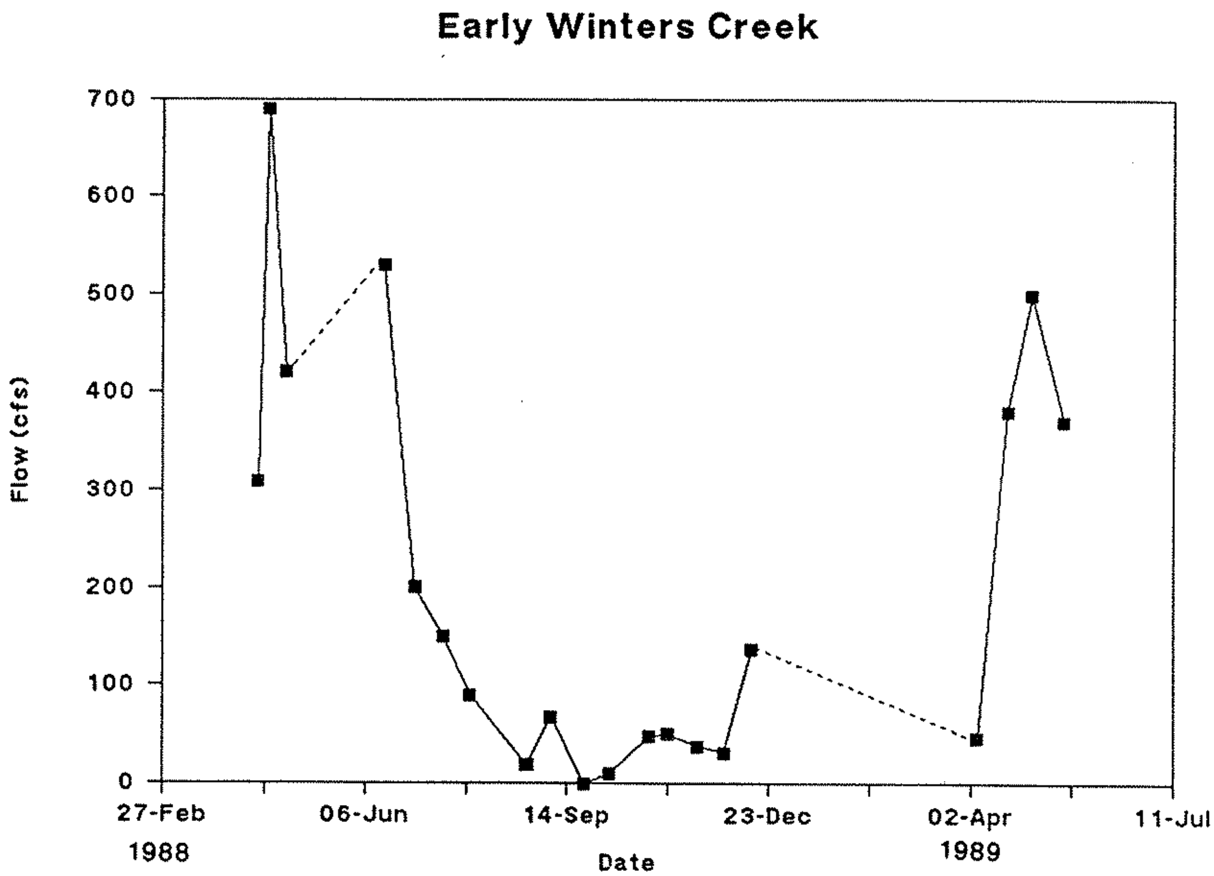


FIGURE 3

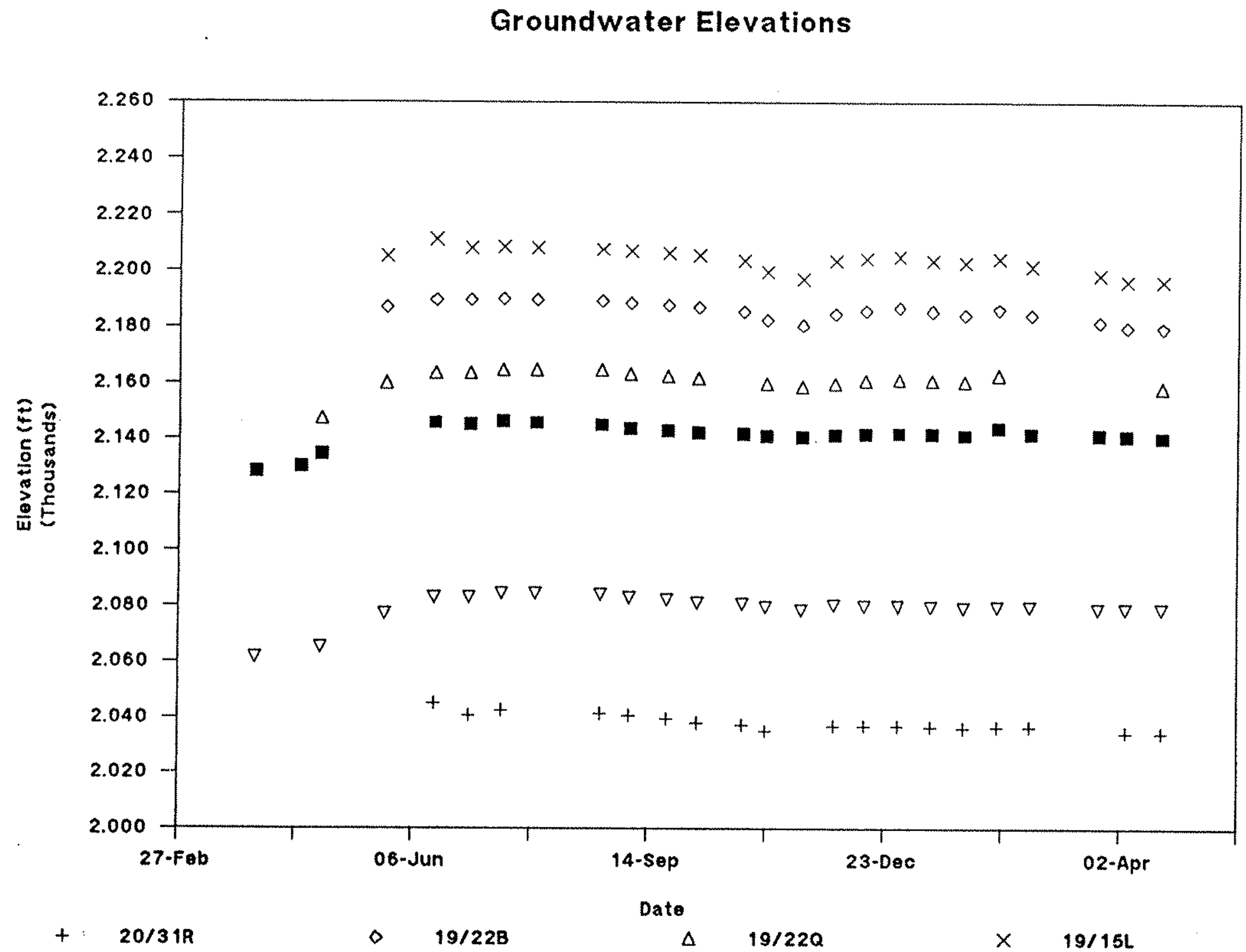
EARLY WINTERS CIRCLE HYDROGRAPH

APRIL 1988 - MAY 1989

EARLY WINTERS/GROUNDWATER MODEL

PROJECT NO. 893-1169 DWG. NO. 20441 DATE 11/6/89 DRAWN TK APPROVED

Golder Associates



(See Figure 1 for well locations)

FIGURE 4

GROUNDWATER ELEVATIONS
UPPER METHOW VALLEY
APRIL 1988 - MAY 1989

EARLY WINTERS/GROUNDWATER MODEL

PROJECT NO. 893-1169 DWG. NO. 20448 DATE 11/6/89 DRAWN TK APPROVED

Golder Associates

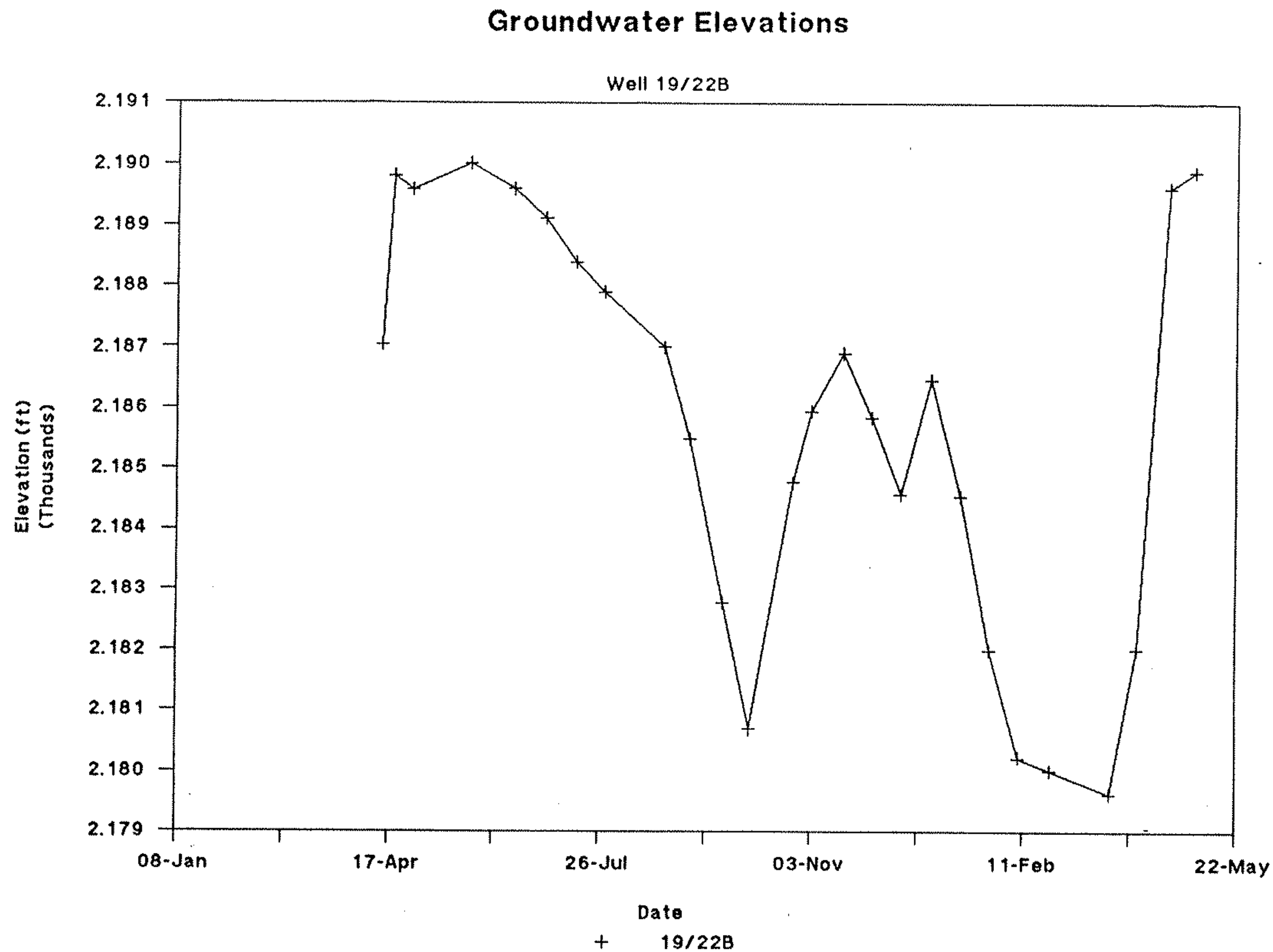


FIGURE **5**

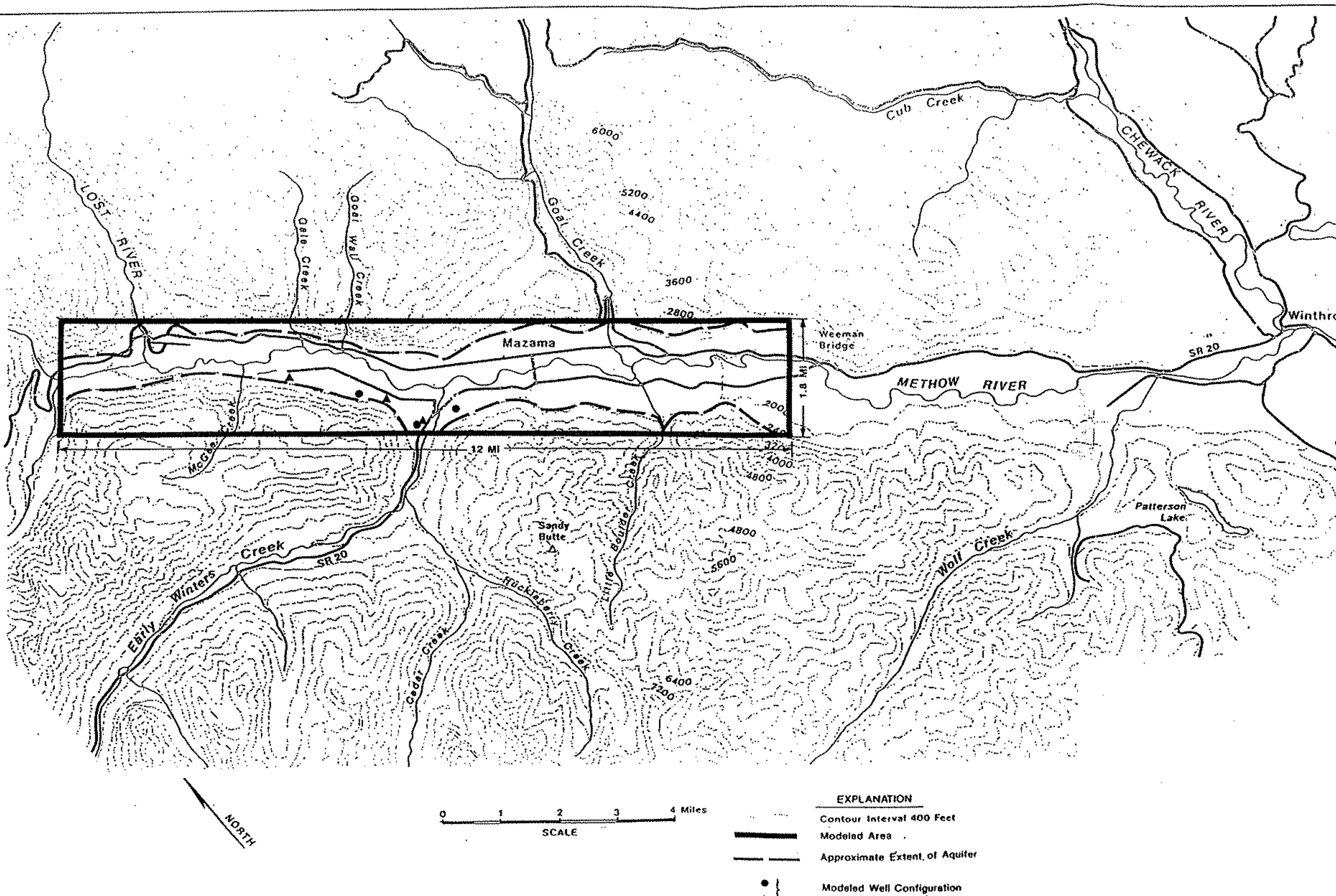
WELL HYDROGRAPH - WELL 19/22B

APRIL 1988 - MAY 1989

EARLY WINTERS/ GROUNDWATER MODEL

PROJECT NO. 893-1169 DWG. NO. 20447 DATE 11/6/89 DRAWN TK APPROVED

Golder Associates



Note: Map adapted from R.W. Beck and Associates (1985)

FIGURE 6

GROUNDWATER FLOW MODEL AREA

EARLY WINTERS/GROUNDWATER MODEL

PROJECT NO 893-1169 DWG NO 20461 DATE 11/16/89 DRAWN DC APPROVED

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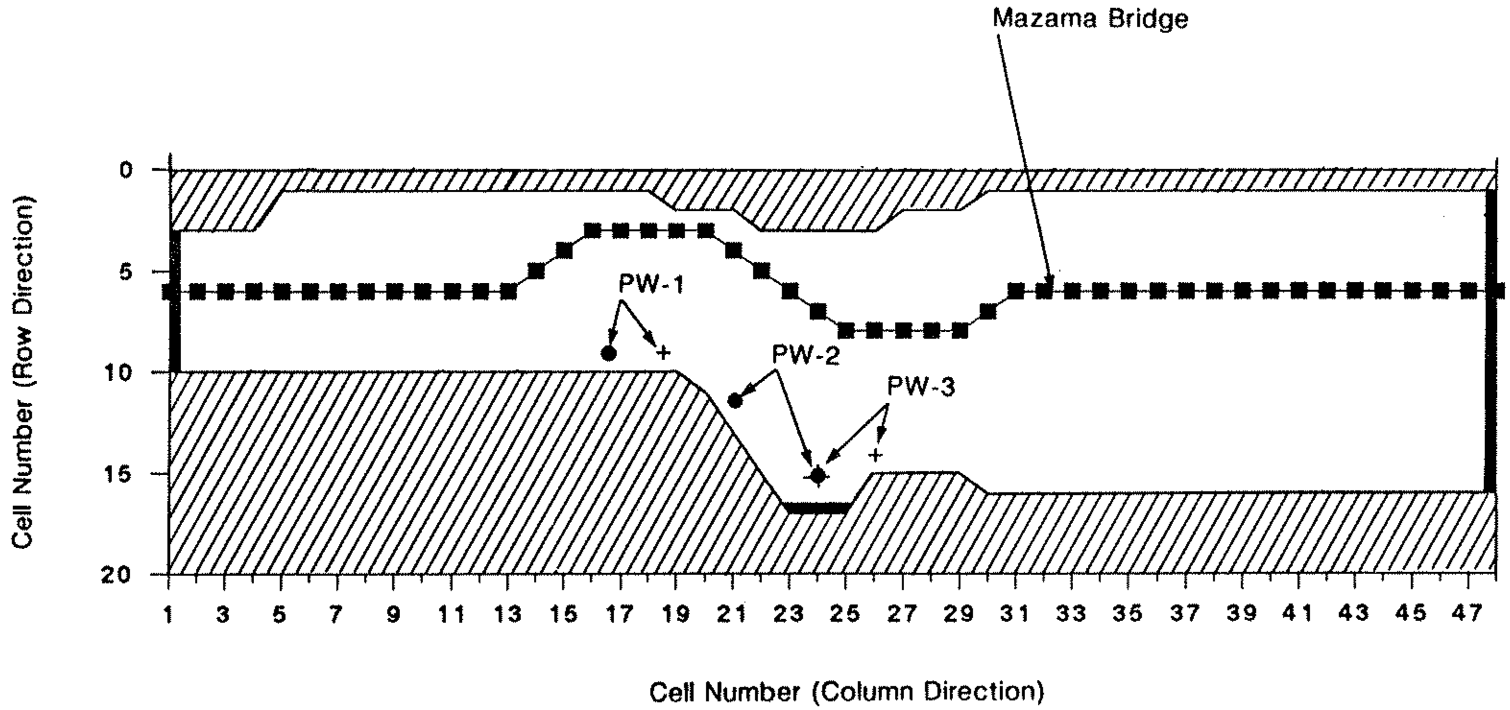
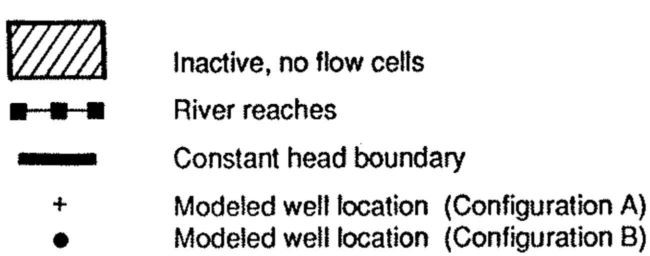




Note: 1 column = 1250 feet
1 row = 500 feet

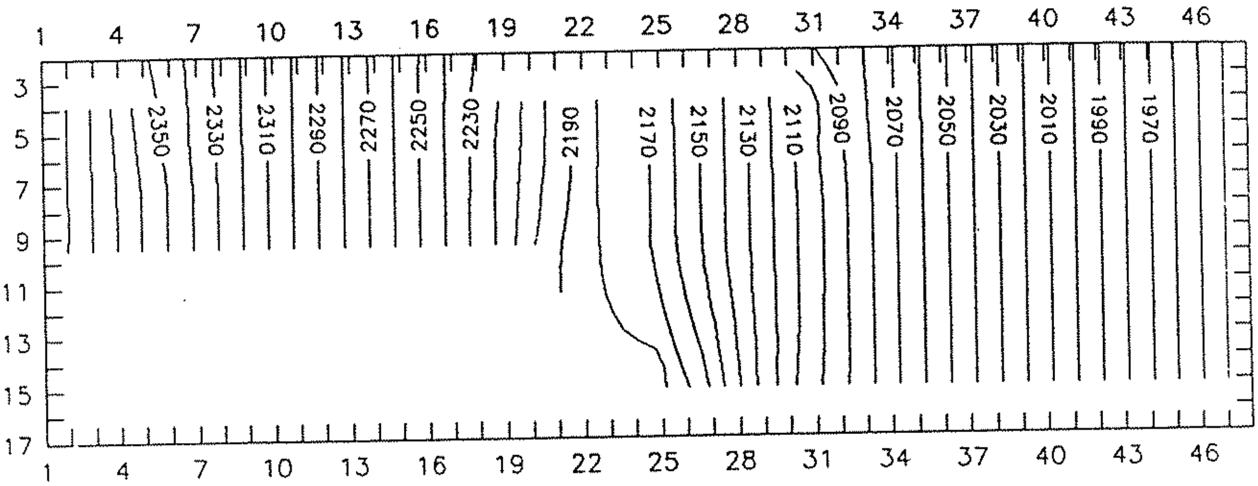
FIGURE 7

MODEL GRID

EARLY WINTERS/ GROUNDWATER MODEL

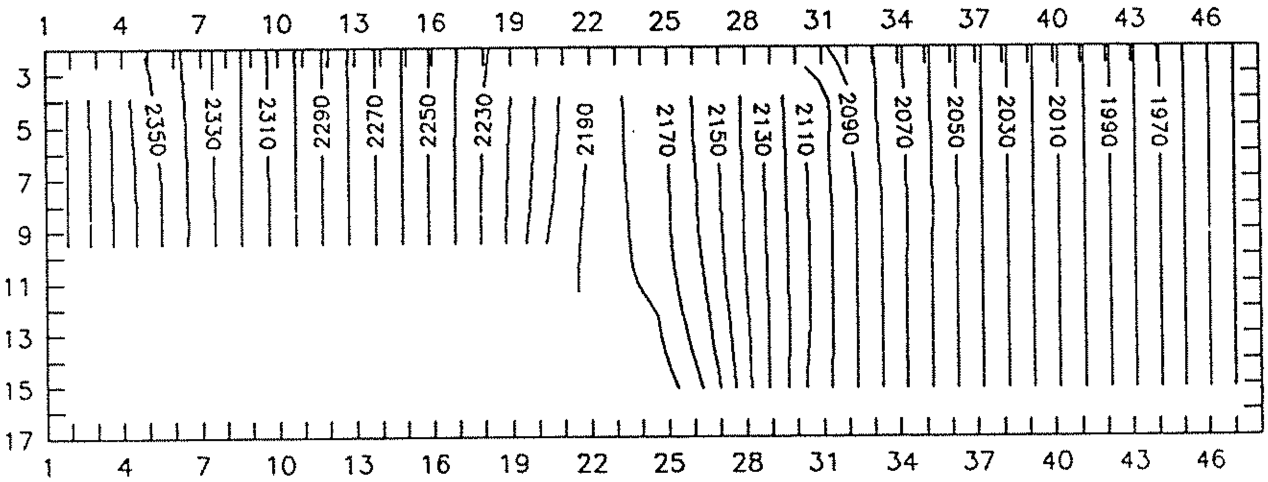
PROJECT NO. 893-1169 DWG. NO. 20448 DATE 11/6/89 DRAWN TK APPROVED

Golder Associates



Step 1: T = 6 months
All river reaches active

T = 200,000 ft^2/day
S = 0.3



Step 2: T = 12 months
River reaches 31-48 active

FIGURE **8A**

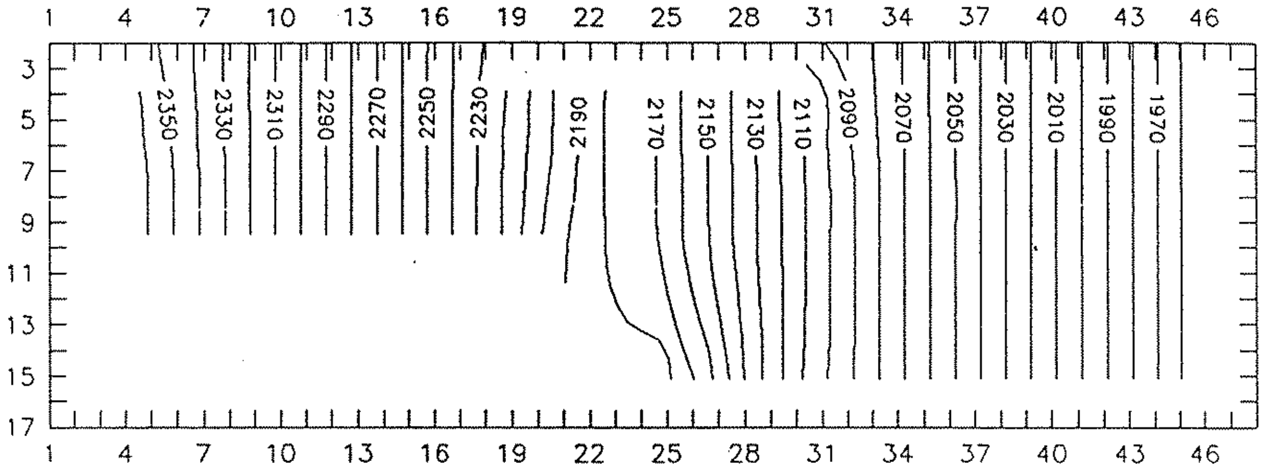
BASE CASE GROUNDWATER HEAD

CASE 1

EARLY WINTERS/GROUNDWATER MODEL

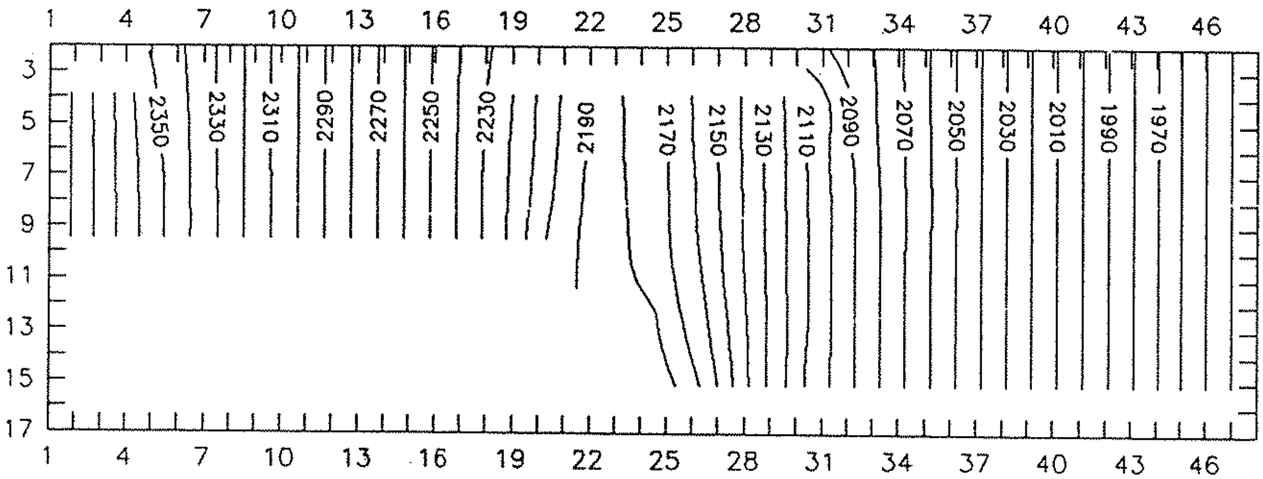
PROJECT NO. 893-1169 DWG. NO. 20454 DATE 11/6/89 DRAWN TK APPROVED

Golder Associates



Step 3: T = 18 months
All river reaches active

T = 200,000 ft^2/day
S = 0.3



Step 4: T = 24 months
River reaches 31-48 active

FIGURE **8B**

BASE CASE GROUNDWATER HEAD

CASE 1

EARLY WINTERS/GROUNDWATER MODEL

PROJECT NO. 893-1169 DWG. NO. 20455 DATE 11/6/89 DRAWN TK APPROVED

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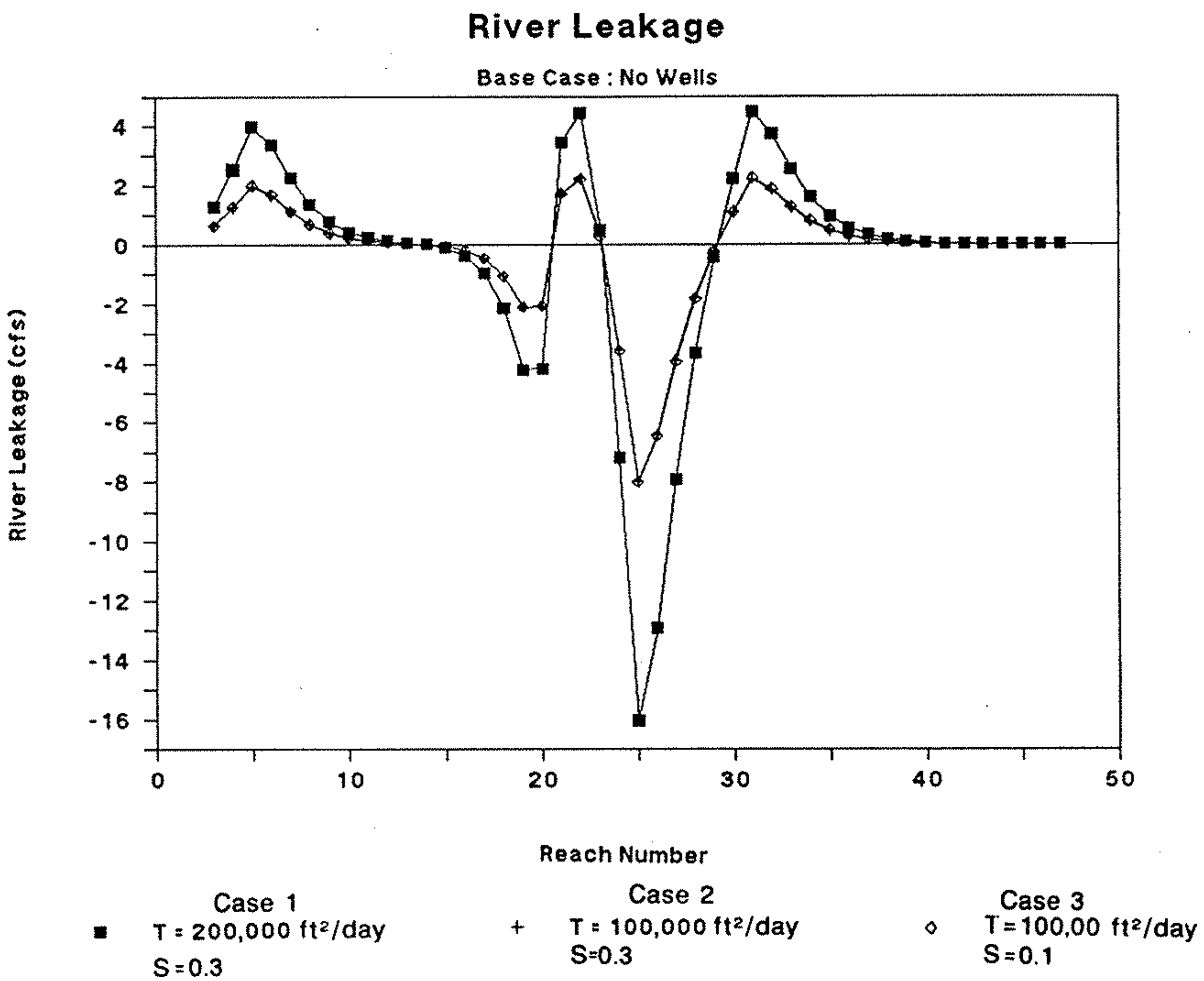


FIGURE 9
BASE CASE RIVER LEAKAGE
CASE 1, 2, &3
EARLY WINTERS/GROUNDWATER MODEL

PROJECT NO. 893-1169 DWG. NO. 20442 DATE 11/6/89 DRAWN TK APPROVED

Golder Associates

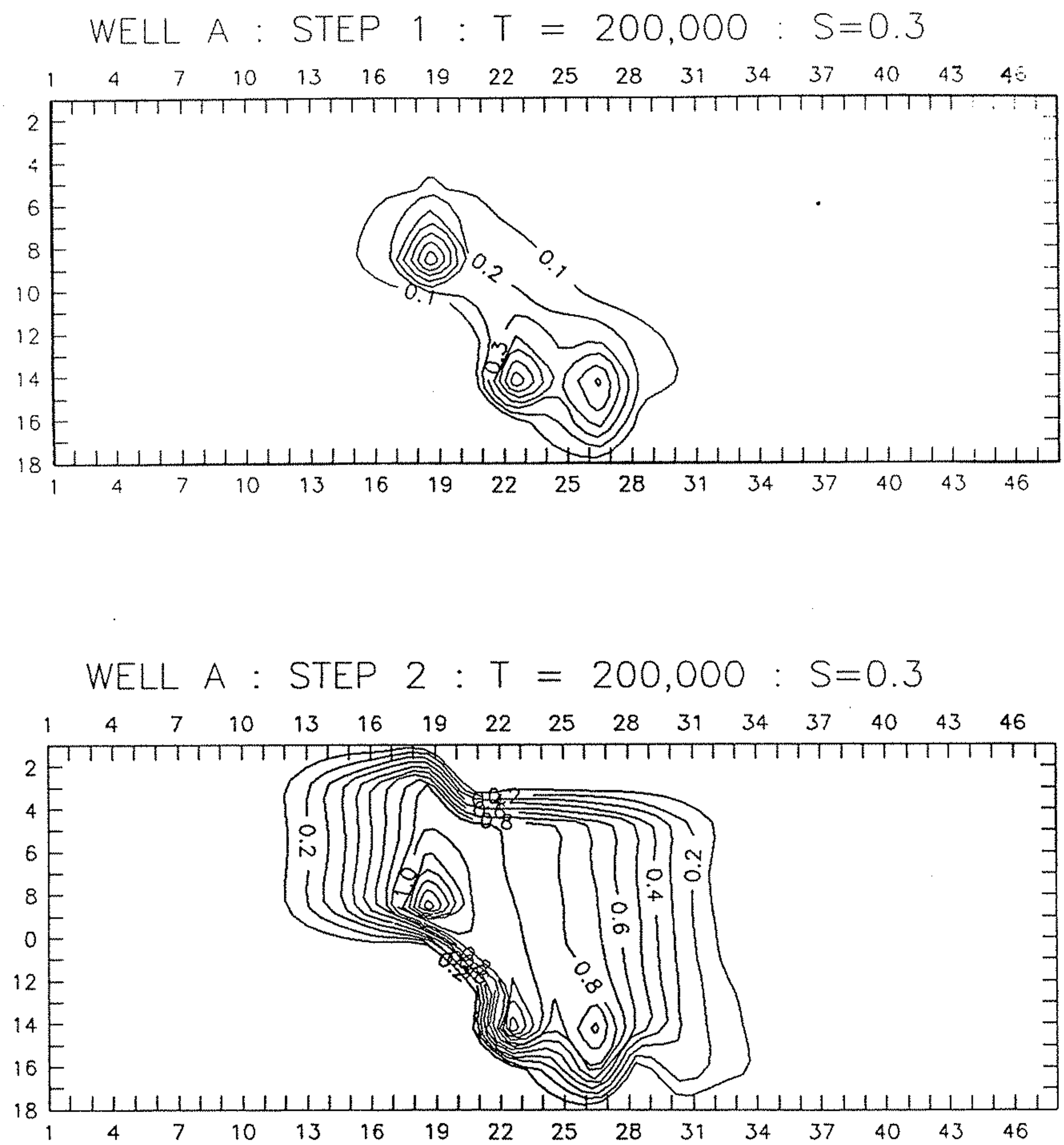


FIGURE **10A**

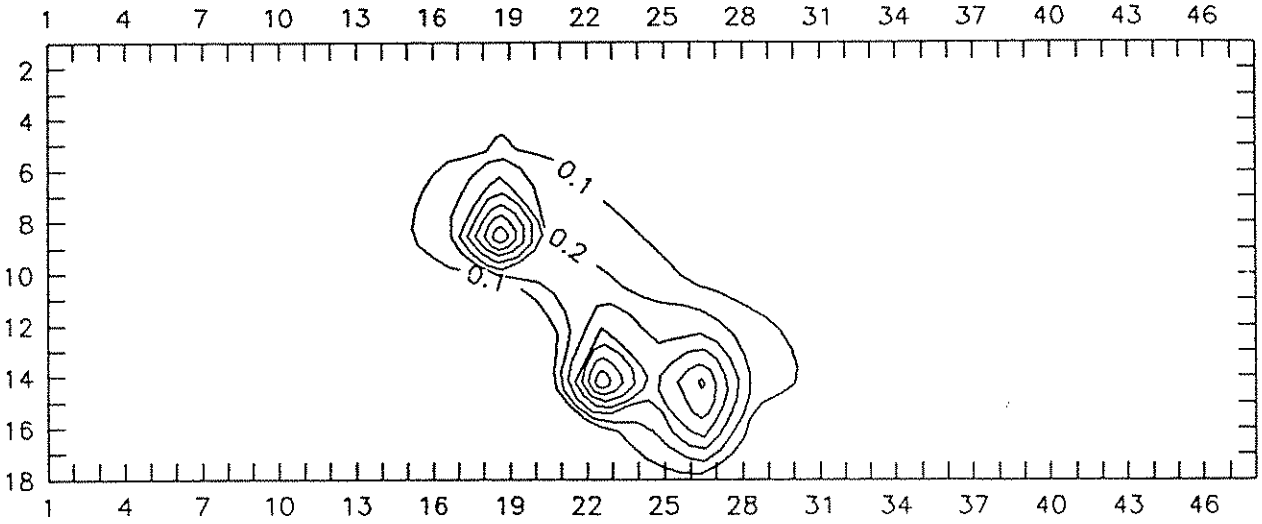
DRAWDOWN, CASE 1A

EARLY WINTERS/GROUNDWATER MODEL

PROJECT NO. 893-1169 DWG. NO. 20456 DATE 11/6/89 DRAWN TK APPROVED

Golder Associates

WELL A : STEP 3 : T = 200,000 : S=0.3



WELL A : STEP 4 : T = 200,000 : S=0.3

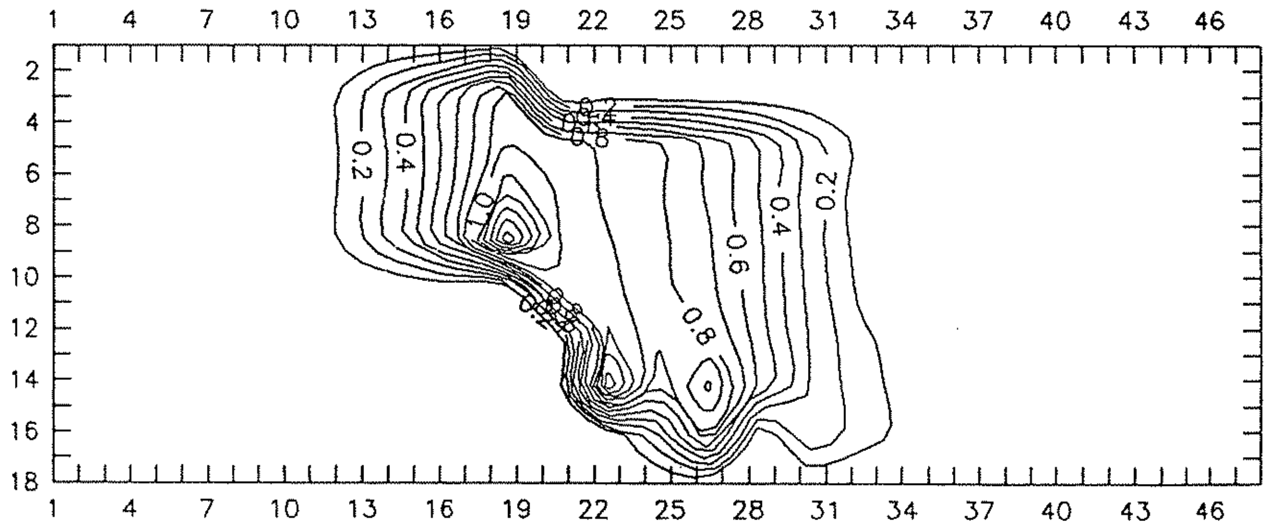


FIGURE **10B**

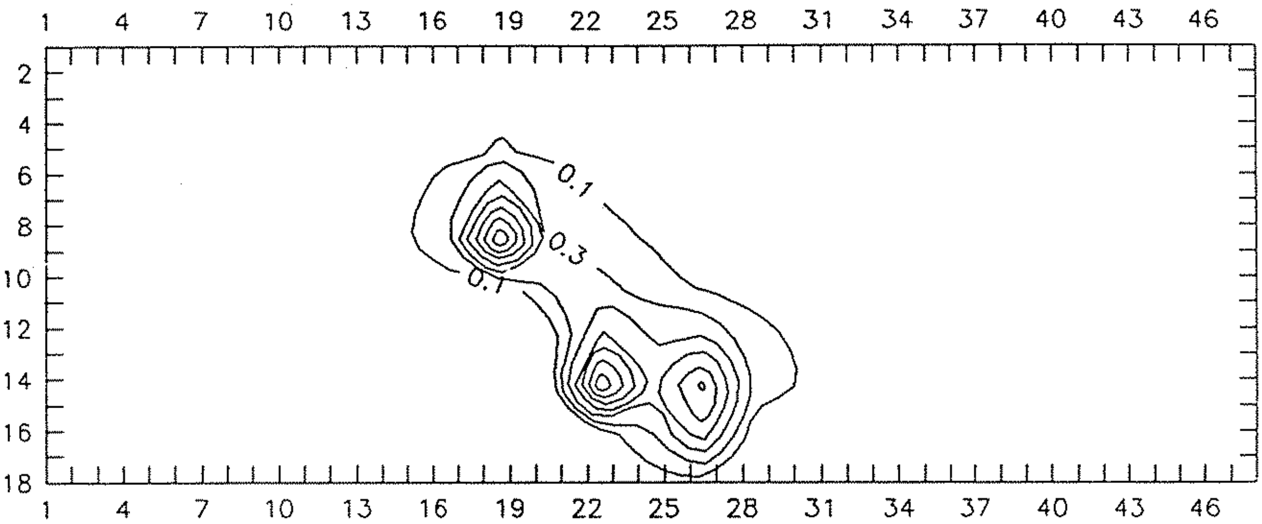
DRAWDOWN, CASE 1A

EARLY WINTERS/GROUNDWATER MODEL

PROJECT NO. 893-1169 DWG. NO. 20457 DATE 11/6/89 DRAWN TK APPROVED

Golder Associates

WELL A : STEP 1 : T = 100,000 : S = 0.3



WELL A : STEP 2 : T = 100,000 : S = 0.3

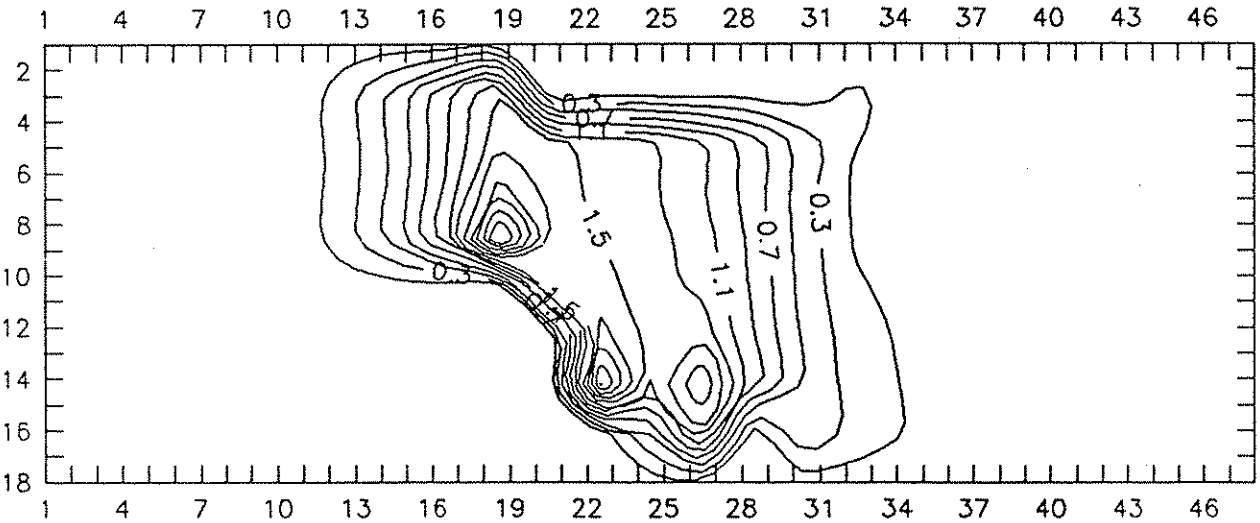


FIGURE **11**

DRAWDOWN, CASE 2A

EARLY WINTERS/GROUNDWATER MODEL

PROJECT NO. 893-1169 DWG. NO. 20458 DATE 11/6/89 DRAWN TK APPROVED

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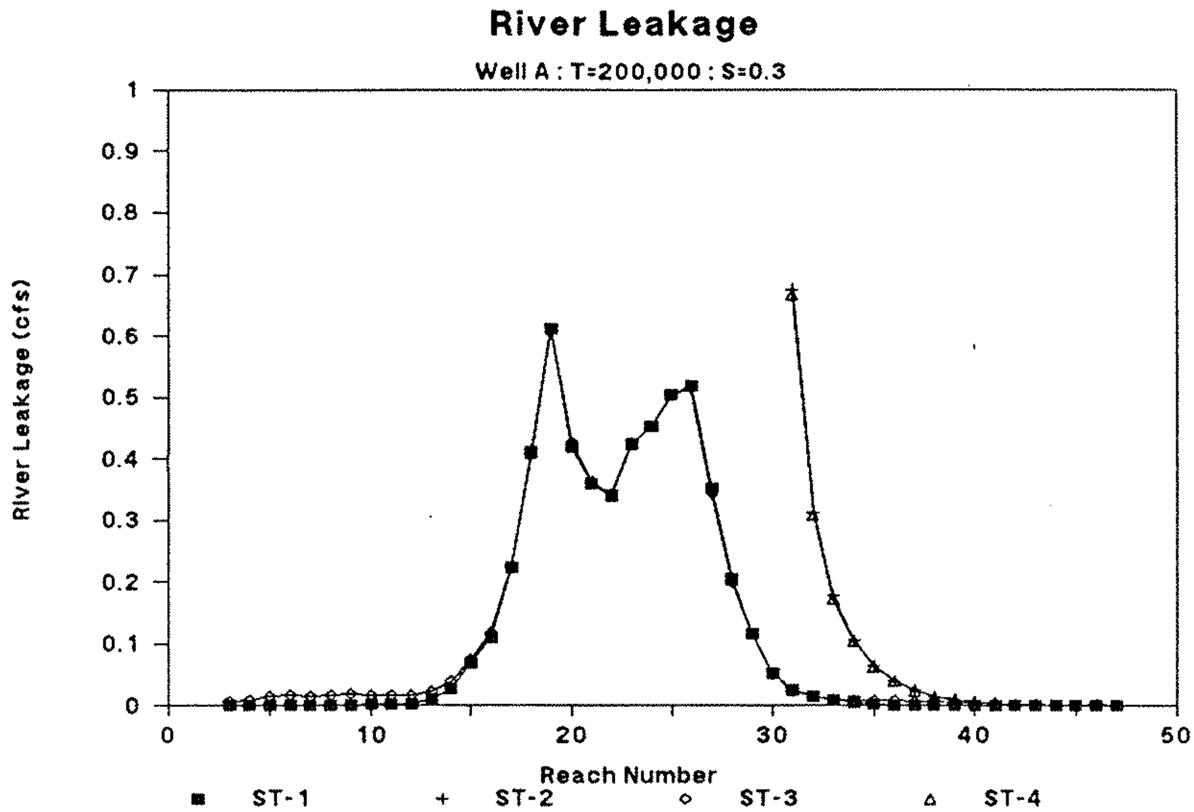
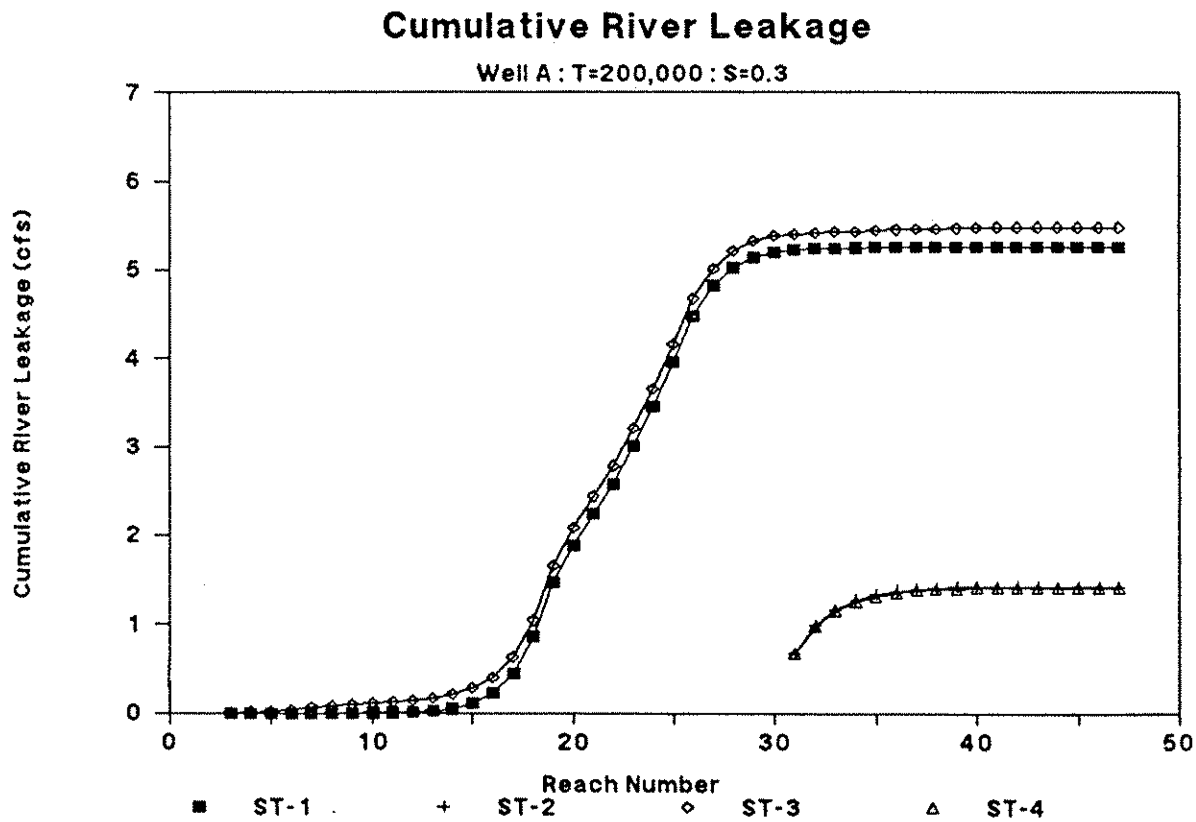




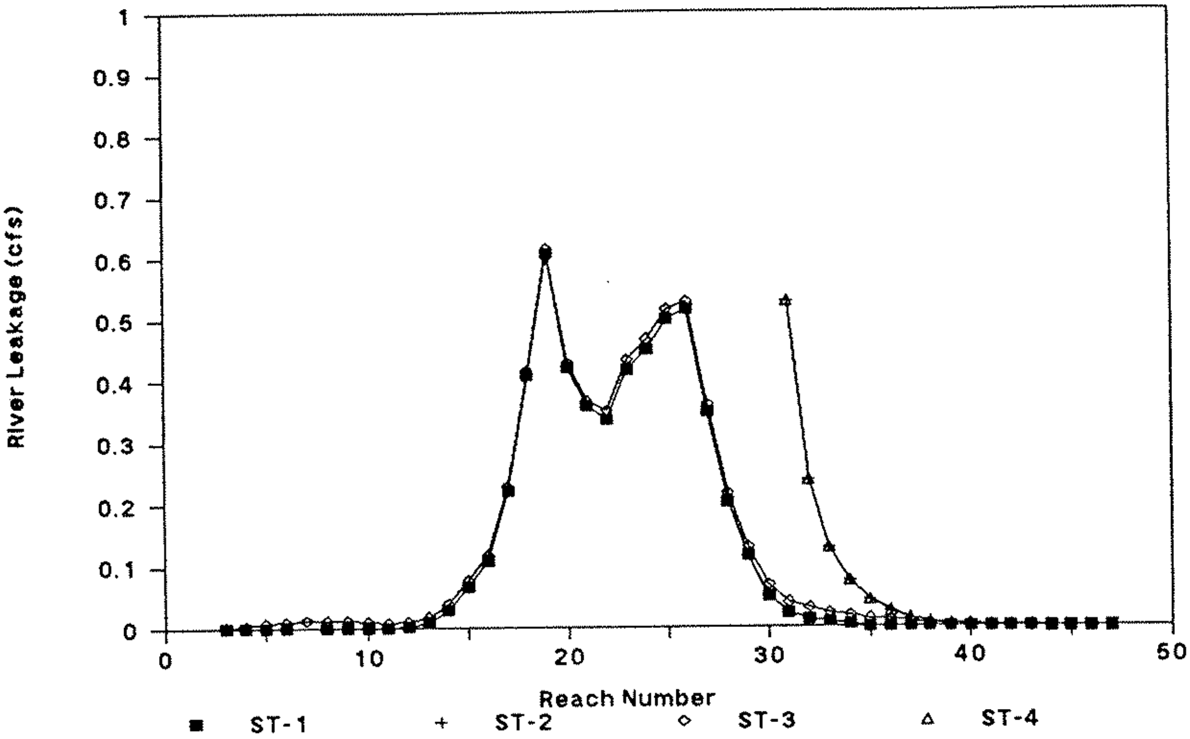
T=200,000 ft^2/day
S=0.3

FIGURE **12**

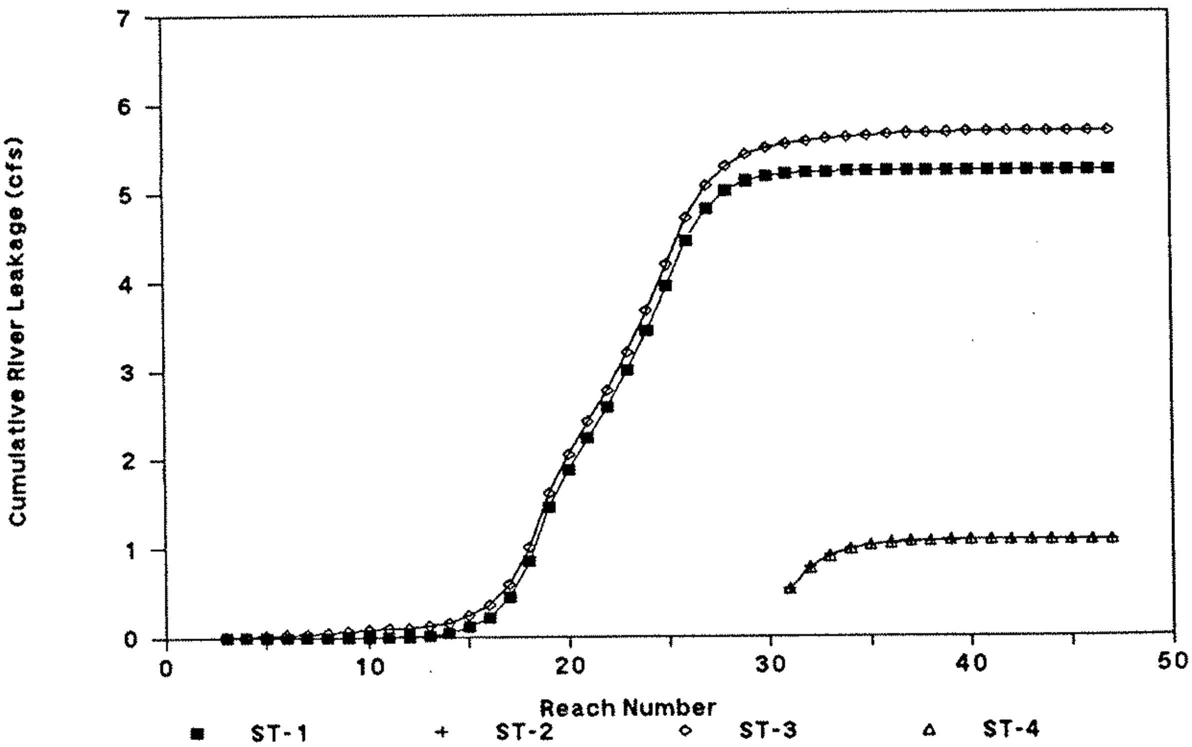
NET RIVER LEAKAGE CASE 1A

EARLY WINTERS/GROUNDWATER MODEL

River Leakage



Cumulative River Leakage



T = 100,000 ft²/day
S = 0.3

FIGURE 13
RIVER LEAKAGE CASE 2A
EARLY WINTERS/GROUNDWATER MODEL

PROJECT NO. 893-1169 DWG. NO. 20444 DATE 11/6/89 DRAWN TK APPROVED

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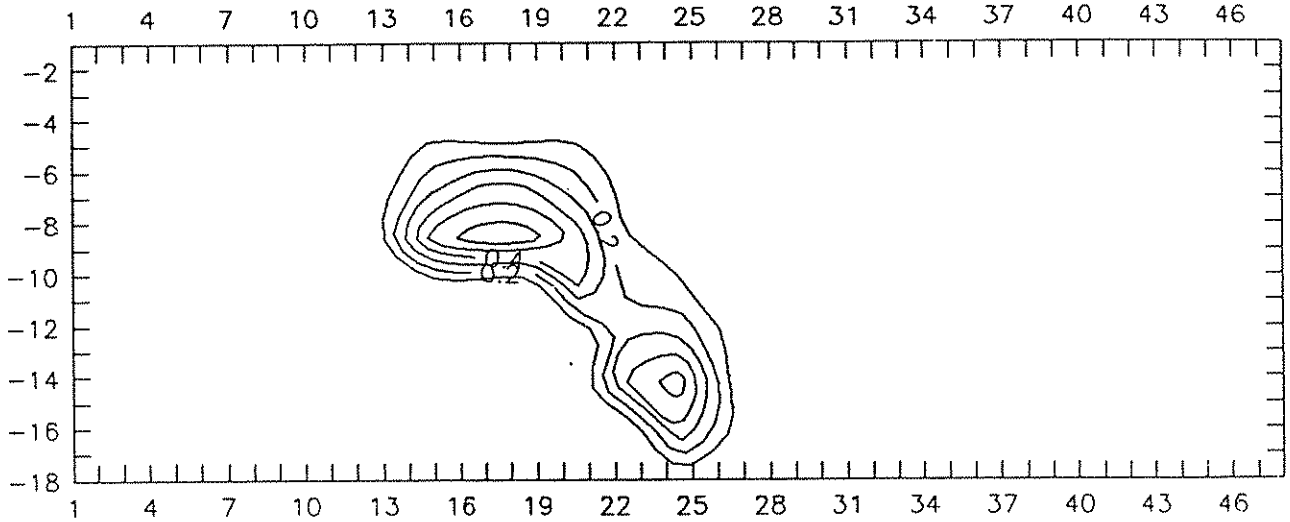
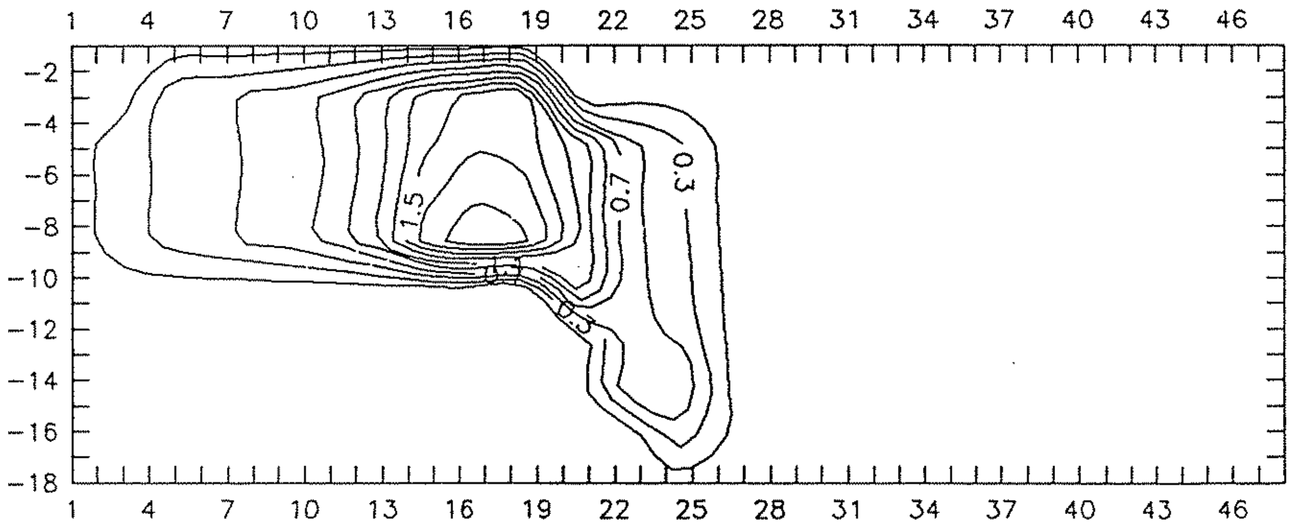
WELL B : STEP 1 : T=100,000



WELL B : STEP 2 : T=100,000

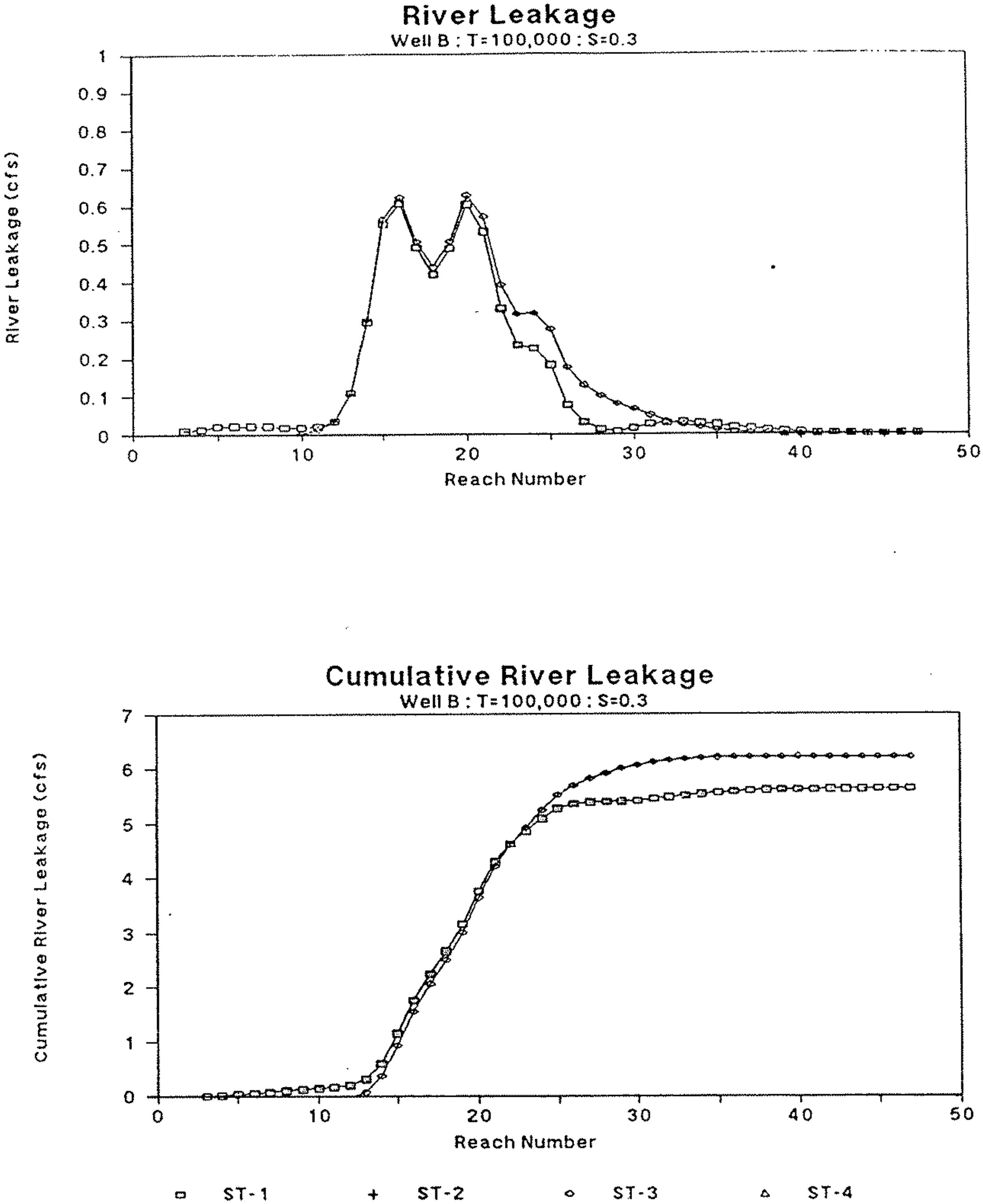


T = 100,000
S = 0.3
Well configuration B

FIGURE **14**

DRAWDOWN, CASE 2A

EARLY WINTERS/GROUNDWATER MODEL



T = 100,000 ft^2/day
S = 0.3
Well Configuration B

FIGURE **15**

NET RIVER LEAKAGE CASE 2B

EARLY WINTERS/GROUNDWATER MODEL

PROJECT NO. 893-1169 DWG. NO. 20445 DATE 11/6/89 DRAWN TK APPROVED

Golder Associates

APPENDIX A

WATER LEVEL MONITORING DATA

Appendix A

Table 1 : Water Level Data

EW Ranger Stn 36/19/23P

Completion @ 50 ft.

Elev. = 2160.8

Date	W.L	Elev.
18-Feb-88	32.56	2128.24
03-Mar-88	32.29	2128.51
17-Mar-88	30.77	2130.03
31-Mar-88	26.30	2134.50
19-Apr-88	15.18	2145.62
28-Apr-88	15.82	2144.98
25-May-88	14.61	2146.19
15-Jun-88	15.12	2145.68
30-Jun-88	15.94	2144.86
14-Jul-88	17.23	2143.57
28-Jul-88	17.82	2142.98
25-Aug-88	18.61	2142.19
06-Sep-88	18.92	2141.88
22-Sep-88	19.73	2141.07
05-Oct-88	20.03	2140.77
24-Oct-88	19.37	2141.43
03-Nov-88	19.06	2141.74
18-Nov-88	18.88	2141.92
02-Dec-88	19.15	2141.65
15-Dec-88	19.51	2141.29
29-Dec-88	16.92	2143.88
12-Jan-89	19.18	2141.62
26-Jan-89	19.43	2141.37
09-Feb-89	19.69	2141.11
23-Feb-89	20.23	2140.57
24-Mar-89		
05-Apr-89	20.21	2140.59
20-Apr-89		

Max	2146.19	2146.19
Min	2128.24	2140.57
Mean	2140.70	2142.59
Range	17.95	5.62

CH2M Piezometer 36/19/22Q

Completion @ 26 ft

Elev. = 2183.83

Date	W.L	Elev.
18-Feb-88		
03-Mar-88		
17-Mar-88		
31-Mar-88	36.62	2147.21
14-Apr-88	23.58	2160.25
19-Apr-88	20.27	2163.56
28-Apr-88	20.00	2163.83
25-May-88	18.91	2164.92
15-Jun-88	19.26	2164.57
30-Jun-88	19.08	2164.75
14-Jul-88	20.58	2163.25
28-Jul-88	21.16	2162.67
25-Aug-88	22.04	2161.79
06-Sep-88		
22-Sep-88	23.85	2159.98
05-Oct-88	24.80	2159.03
25-Oct-88	23.72	2160.11
03-Nov-88	22.70	2161.13
18-Nov-88	22.27	2161.56
01-Dec-88	22.59	2161.24
15-Dec-88	23.21	2160.62
29-Dec-88	20.62	2163.21
12-Jan-89		
26-Jan-89		
05-Feb-89		
24-Feb-89	25.38	2158.45
24-Mar-89	26.65	2157.18
05-Apr-89	24.46	2159.37
20-Apr-89		

Max	2164.92	2164.92
Min	2147.21	2157.18
Mean	2160.89	2161.57
Range	17.71	7.74

Devin-IC EW1 36/20/31R

Completion @ 20 ft

Elev. = 2052.8

Date	W.L	Elev.
18-Feb-88		
03-Mar-88		
17-Mar-88		
31-Mar-88		
14-Apr-88		
19-Apr-88	7.70	2045.10
28-Apr-88	12.10	2040.70
25-May-88	10.45	2042.35
15-Jun-88		
30-Jun-88	11.51	2041.29
14-Jul-88	12.14	2040.66
28-Jul-88	13.15	2039.65
25-Aug-88	14.66	2038.14
06-Sep-88	15.53	2037.27
22-Sep-88	17.67	2035.13
05-Oct-88		
25-Oct-88	15.86	2036.94
03-Nov-88	15.76	2037.04
18-Nov-88	15.75	2037.05
01-Dec-88	16.25	2036.55
15-Dec-88	16.49	2036.31
29-Dec-88	16.31	2036.49
12-Jan-89	16.28	2036.52
26-Jan-89		
09-Feb-89	18.24	2034.56
24-Feb-89	18.31	2034.49
24-Mar-89	17.59	2035.21
05-Apr-89	15.56	2037.24
20-Apr-89	11.9	2040.90
02-May-89	11.26	2041.54

Max		2045.1
Min		2034.49
Mean		2038.23
Range		10.61

Appendix A

Table 1 : Water Level Data

Devin-Rattlesnake 4 36/19/22B
Completion @ 0? ft
Elev. = 2213.5

Date	w.l	Elev.
18-Feb-88		
03-Mar-88		
17-Mar-88		
31-Mar-88		
14-Apr-88	26.45	2187.05
19-Apr-88	23.69	2189.81
28-Apr-88	23.91	2189.59
25-May-88	23.49	2190.01
15-Jun-88	23.90	2189.60
30-Jun-88	24.38	2189.12
14-Jul-88	25.11	2188.39
28-Jul-88	25.59	2187.91
25-Aug-88	26.50	2187.00
06-Sep-88	28.00	2185.50
22-Sep-88	30.72	2182.78
05-Oct-88	32.80	2180.70
25-Oct-88	28.72	2184.78
03-Nov-88	27.55	2185.95
18-Nov-88	26.59	2186.91
01-Dec-88	27.66	2185.84
15-Dec-88	28.92	2184.58
29-Dec-88	27.03	2186.47
12-Jan-89	28.95	2184.55
26-Jan-89	31.49	2182.01
09-Feb-89	33.27	2180.23
24-Feb-89	33.49	2180.01
24-Mar-89	33.88	2179.62
05-Apr-89	31.47	2182.03
20-Apr-89	23.87	2189.63
02-May-89	23.61	2189.89
Max		2190.01
Min		2179.62
Mean		2185.77
Range		10.39

Devin-Schaeffer 7 36/19/15L
Completion @ 46 ft
Elev. = 2219.6

Date	w.l	Elev.
18-Feb-88		
03-Mar-88		
17-Mar-88		
31-Mar-88		
14-Apr-88	14.07	2205.53
19-Apr-88	8.31	2211.29
28-Apr-88	11.52	2208.08
25-May-88	10.99	2208.61
15-Jun-88	11.38	2208.22
30-Jun-88	11.87	2207.73
14-Jul-88	12.51	2207.09
28-Jul-88	13.05	2206.55
25-Aug-88	13.95	2205.65
06-Sep-88	15.69	2203.91
22-Sep-88	19.59	2200.01
05-Oct-88	22.17	2197.43
25-Oct-88	15.53	2204.07
03-Nov-88	14.95	2204.65
18-Nov-88	14.22	2205.38
01-Dec-88	15.55	2204.05
15-Dec-88	16.62	2202.98
29-Dec-88	15.17	2204.43
12-Jan-89	17.75	2201.85
26-Jan-89	20.96	2198.64
09-Feb-89	22.98	2196.62
24-Feb-89	23.00	2196.60
24-Mar-89	23.90	2195.70
05-Apr-89	20.11	2199.49
20-Apr-89	11.92	2207.68
02-May-89	11.53	2208.07
Max		2211.29
Min		2195.7
Mean		2203.86
Range		15.59

EW18 DRD 8 36/20/30N
Completion @ ?? ft
Elev. = 2096.6

Date	w.l	Elev.
18-Feb-88	35.23	2061.37
03-Mar-88	36.11	2060.49
17-Mar-88		
31-Mar-88	31.44	2065.16
14-Apr-88	19.5	2077.10
19-Apr-88	13.55	2083.05
28-Apr-88	13.42	2083.18
25-May-88	12.22	2084.38
15-Jun-88	11.98	2084.62
30-Jun-88	12.50	2084.10
14-Jul-88	13.58	2083.02
28-Jul-88	14.39	2082.21
25-Aug-88	15.48	2081.12
06-Sep-88	15.79	2080.81
22-Sep-88	16.82	2079.78
05-Oct-88	17.89	2078.71
25-Oct-88	16.19	2080.41
03-Nov-88	16.45	2080.15
18-Nov-88	16.65	2079.95
01-Dec-88	16.91	2079.69
15-Dec-88	17.09	2079.51
29-Dec-88	16.97	2079.63
12-Jan-89	17.06	2079.54
26-Jan-89	17.53	2079.07
09-Feb-89	17.63	2078.97
24-Feb-89	17.79	2078.81
24-Mar-89	17.40	2079.20
05-Apr-89	16.71	2079.89
20-Apr-89	13.52	2083.08
02-May-89	13.06	2083.54
Max	2084.62	2084.62
Min	2060.49	2077.1
Mean	2078.98	2080.90
Range	24.13	7.52

Appendix A

Table 1A : River Flow Data

Methow River Flows Mazama Bridge			Early Winters Creek Flows Hwy 20		
Date	Gage	Flow	Date	Gage	Flow
18-Feb-88			18-Feb-88		
03-Mar-88			03-Mar-88		
17-Mar-88			17-Mar-88		
31-Mar-88			31-Mar-88		
14-Apr-88	9.14	695.00	14-Apr-88	7.52	308.00
19-Apr-88	9.88	1600.00	19-Apr-88	8.50	690.00
28-Apr-88	9.32	928.00	28-Apr-88	7.82	420.00
27-May-88	10.24	2090.00	27-May-88		
15-Jun-88	10.44	2350.00	15-Jun-88	8.41	530.00
30-Jun-88	10.33	2050.00	30-Jun-88	7.41	200.00
14-Jul-88	8.81	320.00	14-Jul-88	7.19	150.00
28-Jul-88	8.56	170.00	28-Jul-88	6.85	90.00
25-Aug-88	7.65	0.00	25-Aug-88	6.15	19.00
06-Sep-88	7.65	0.00	06-Sep-88	5.88	68.00
22-Sep-88	7.65	0.00	22-Sep-88	5.35	0.00
05-Oct-88	7.65	0.00	05-Oct-88	5.97	10.00
25-Oct-88	7.76	16.00	25-Oct-88	6.51	48.00
03-Nov-88	7.77	16.50	03-Nov-88	6.53	50.00
18-Nov-88	7.95	33.00	18-Nov-88	6.40	38.00
01-Dec-88	7.69	13.00	01-Dec-88	6.32	31.00
15-Dec-88	7.73	16.50	15-Dec-88	7.15	137.00
29-Dec-88	7.82	22.00	29-Dec-88		
12-Jan-89	7.64	12.00	12-Jan-89		
24-Feb-89	7.61	9.60	24-Feb-89		
24-Mar-89	7.52	6.60	24-Mar-89		
05-Apr-89	7.93	29.50	05-Apr-89	6.50	47.00
20-Apr-89	8.64	235.00	20-Apr-89	8.00	380.00
02-May-89	9.99	1500.00	02-May-89	8.28	500.00
18-May-89		1400	18-May-89		370.00
01-Jun-89		2550			
Max		2350	Max		690
Min		0	Min		0
Mean		617.80	Mean		204.30
Range		2350	Range		690

Appendix A

Table 2 : Hydraulic Gradient Analysis

Wells:	19/15L 19/22B	19/22B 19/22Q	19/23P 20/30N	20/30N 20/31R	19/22Q 19/23P
Del x (miles)	0.5	0.8	1.8	1.1	1.3
Date	Gradient (ft/mile)				
18-Feb-88					
03-Mar-88					
17-Mar-88					
31-Mar-88					
14-Apr-88	37.0	33.5			
19-Apr-88	43.0	32.8			
28-Apr-88	37.0	32.2			
25-May-88	37.2	31.4			
15-Jun-88	37.2	31.3	33.9		14.5
30-Jun-88	37.2	30.5	33.8	38.9	15.3
14-Jul-88	37.4	31.4	33.6	38.5	15.1
28-Jul-88	37.3	31.5	33.8	38.7	15.1
25-Aug-88	37.3	31.5	33.9	39.1	15.1
06-Sep-88	36.8		33.9	39.6	
22-Sep-88	34.5	28.5	34.1	40.6	14.5
05-Oct-88	33.5	27.1	34.5		14.0
25-Oct-88	38.6	30.8	33.9	39.5	14.4
03-Nov-88	37.4	31.0	34.2	39.2	14.9
18-Nov-88	36.9	31.7	34.4	39.0	15.1
01-Dec-88	36.4	30.8	34.4	39.2	15.1
15-Dec-88	36.8	30.0	34.3	39.3	14.9
29-Dec-88	35.9	29.1	35.7	39.2	14.9
12-Jan-89	34.6		34.5	39.1	
26-Jan-89	33.3		34.6		
09-Feb-89	32.8		34.5	40.4	
24-Feb-89	33.2	27.0	34.3	40.3	13.8
24-Mar-89	32.2	28.1		40.0	
05-Apr-89	34.9	28.3	33.7	38.8	14.4
20-Apr-89	36.1			38.3	
02-May-89	36.4			38.2	
Avg	36.18	30.42	34.22	39.26	14.75
Std Dev	1.78	1.59	0.45	0.68	0.43

Average Gradient 35.0 ft/mi

Std. Deviation 3.5

APPENDIX B

GROUNDWATER-MODEL OUTPUT

ELL CONFIGURATION A

Pumping Case 1A : T = 200,000
S = 0.3

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 1

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.41372E+08	STORAGE =	.13192E+06
CONSTANT HEAD =	.25211E+10	CONSTANT HEAD =	.13622E+08
WELLS =	.00000	WELLS =	.00000
RIVER LEAKAGE =	.62943E+09	RIVER LEAKAGE =	.37483E+07
TOTAL IN =	.31919E+10	TOTAL IN =	.17502E+08
OUT:		OUT:	
STORAGE =	.55742E+08	STORAGE =	53994.
CONSTANT HEAD =	.21960E+10	CONSTANT HEAD =	.12000E+08
WELLS =	.10980E+09	WELLS =	.60000E+06
RIVER LEAKAGE =	.84415E+09	RIVER LEAKAGE =	.48578E+07
TOTAL OUT =	.32057E+10	TOTAL OUT =	.17512E+08
IN - OUT =	-.13812E+08	IN - OUT =	-10118.
PERCENT DISCREPANCY =	-.43	PERCENT DISCREPANCY =	-.06

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 2

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.78702E+08	STORAGE =	.64780E+06
CONSTANT HEAD =	.49283E+10	CONSTANT HEAD =	.13035E+08
WELLS =	.00000	WELLS =	.00000
RIVER LEAKAGE =	.80733E+09	RIVER LEAKAGE =	.74780E+06
TOTAL IN =	.58143E+10	TOTAL IN =	.14431E+08
OUT:		OUT:	
STORAGE =	.15315E+09	STORAGE =	.17955E+07
CONSTANT HEAD =	.43919E+10	CONSTANT HEAD =	.11999E+08
WELLS =	.21960E+09	WELLS =	.60000E+06
RIVER LEAKAGE =	.84415E+09	RIVER LEAKAGE =	.00000
TOTAL OUT =	.56088E+10	TOTAL OUT =	.14395E+08
IN - OUT =	.20552E+09	IN - OUT =	35919.
PERCENT DISCREPANCY =	3.60	PERCENT DISCREPANCY =	.25

umpingase 1A : T = 200,000
S = 0.3

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 3

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.17427E+09	STORAGE =	.28341E+06
CONSTANT HEAD =	.74043E+10	CONSTANT HEAD =	.13602E+08
WELLS =	.00000	WELLS =	.00000
RIVER LEAKAGE =	.15053E+10	RIVER LEAKAGE =	.37939E+07
TOTAL IN =	.90838E+10	TOTAL IN =	.17680E+08
OUT:		OUT:	
STORAGE =	.18949E+09	STORAGE =	96857.
CONSTANT HEAD =	.65877E+10	CONSTANT HEAD =	.12000E+08
WELLS =	.32940E+09	WELLS =	.60000E+06
RIVER LEAKAGE =	.18908E+10	RIVER LEAKAGE =	.50027E+07
TOTAL OUT =	.89975E+10	TOTAL OUT =	.17699E+08
IN - OUT =	.86362E+08	IN - OUT =	-19234.
PERCENT DISCREPANCY =	.96	PERCENT DISCREPANCY =	-.11

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 4

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.21113E+09	STORAGE =	.64000E+06
CONSTANT HEAD =	.98109E+10	CONSTANT HEAD =	.13033E+08
WELLS =	.00000	WELLS =	.00000
RIVER LEAKAGE =	.16804E+10	RIVER LEAKAGE =	.73755E+06
TOTAL IN =	.11702E+11	TOTAL IN =	.14411E+08
OUT:		OUT:	
STORAGE =	.28558E+09	STORAGE =	.17766E+07
CONSTANT HEAD =	.87836E+10	CONSTANT HEAD =	.11999E+08
WELLS =	.43920E+09	WELLS =	.60000E+06
RIVER LEAKAGE =	.18908E+10	RIVER LEAKAGE =	.00000
TOTAL OUT =	.11399E+11	TOTAL OUT =	.14376E+08
IN - OUT =	.30319E+09	IN - OUT =	35025.
PERCENT DISCREPANCY =	2.62	PERCENT DISCREPANCY =	.24

PumpingCase 2A : T = 100,000
S = 0.3

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 1

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.42335E+08	STORAGE =	88285.
CONSTANT HEAD =	.12818E+10	CONSTANT HEAD =	.68811E+07
WELLS =	.00000	WELLS =	.00000
RIVER LEAKAGE =	.31369E+09	RIVER LEAKAGE =	.19100E+07
TOTAL IN =	.16379E+10	TOTAL IN =	.88794E+07
OUT:		OUT:	
STORAGE =	.53496E+08	STORAGE =	40944.
CONSTANT HEAD =	.10980E+10	CONSTANT HEAD =	.60001E+07
WELLS =	.10980E+09	WELLS =	.60000E+06
RIVER LEAKAGE =	.38476E+09	RIVER LEAKAGE =	.22514E+07
TOTAL OUT =	.16460E+10	TOTAL OUT =	.88924E+07
IN - OUT =	-.81908E+07	IN - OUT =	-13034.
PERCENT DISCREPANCY =	-.50	PERCENT DISCREPANCY =	-.15

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 2

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.74945E+08	STORAGE =	.41609E+06
CONSTANT HEAD =	.25094E+10	CONSTANT HEAD =	.66598E+07
WELLS =	.00000	WELLS =	.00000
RIVER LEAKAGE =	.41553E+09	RIVER LEAKAGE =	.46875E+06
TOTAL IN =	.29999E+10	TOTAL IN =	.75447E+07
OUT:		OUT:	
STORAGE =	.12544E+09	STORAGE =	.94157E+06
CONSTANT HEAD =	.21960E+10	CONSTANT HEAD =	.59998E+07
WELLS =	.21960E+09	WELLS =	.60000E+06
RIVER LEAKAGE =	.38476E+09	RIVER LEAKAGE =	.00000
TOTAL OUT =	.29257E+10	TOTAL OUT =	.75413E+07
IN - OUT =	.74150E+08	IN - OUT =	3347.0
PERCENT DISCREPANCY =	2.50	PERCENT DISCREPANCY =	.04

umpin@ase 2A : T = 100,000
S = 0.3

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 3

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.14446E+09	STORAGE =	.18489E+06
CONSTANT HEAD =	.37596E+10	CONSTANT HEAD =	.68669E+07
WELLS =	.00000	WELLS =	.00000
RIVER LEAKAGE =	.78648E+09	RIVER LEAKAGE =	.19651E+07
TOTAL IN =	.46906E+10	TOTAL IN =	.90168E+07
OUT:		OUT:	
STORAGE =	.15635E+09	STORAGE =	71907.
CONSTANT HEAD =	.32939E+10	CONSTANT HEAD =	.59997E+07
WELLS =	.32940E+09	WELLS =	.60000E+06
RIVER LEAKAGE =	.87930E+09	RIVER LEAKAGE =	.23531E+07
TOTAL OUT =	.46589E+10	TOTAL OUT =	.90248E+07
IN - OUT =	.31663E+08	IN - OUT =	-7952.0
PERCENT DISCREPANCY =	.68	PERCENT DISCREPANCY =	-.09

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 4

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.17638E+09	STORAGE =	.40982E+06
CONSTANT HEAD =	.49867E+10	CONSTANT HEAD =	.66583E+07
WELLS =	.00000	WELLS =	.00000
RIVER LEAKAGE =	.88678E+09	RIVER LEAKAGE =	.46173E+06
TOTAL IN =	.60499E+10	TOTAL IN =	.75299E+07
OUT:		OUT:	
STORAGE =	.22691E+09	STORAGE =	.92712E+06
CONSTANT HEAD =	.43918E+10	CONSTANT HEAD =	.59997E+07
WELLS =	.43920E+09	WELLS =	.60000E+06
RIVER LEAKAGE =	.87930E+09	RIVER LEAKAGE =	.00000
TOTAL OUT =	.59372E+10	TOTAL OUT =	.75268E+07
IN - OUT =	.11268E+09	IN - OUT =	3041.5
PERCENT DISCREPANCY =	1.88	PERCENT DISCREPANCY =	.04

PumpingCase 3A : T = 100,000^2/day
S = 0.1

0

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 1

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.14318E+08	STORAGE =	52288.
CONSTANT HEAD =	.12691E+10	CONSTANT HEAD =	.68779E+07
WELLS =	.00000	WELLS =	.00000
RIVER LEAKAGE =	.32840E+09	RIVER LEAKAGE =	.19424E+07
TOTAL IN =	.16118E+10	TOTAL IN =	.88726E+07
OUT:		OUT:	
STORAGE =	.17904E+08	STORAGE =	14458.
CONSTANT HEAD =	.10980E+10	CONSTANT HEAD =	.60000E+07
WELLS =	.10980E+09	WELLS =	.60000E+06
RIVER LEAKAGE =	.39604E+09	RIVER LEAKAGE =	.22605E+07
TOTAL OUT =	.16217E+10	TOTAL OUT =	.88749E+07
IN - OUT =	-.99621E+07	IN - OUT =	-2328.0
PERCENT DISCREPANCY =	-.62	PERCENT DISCREPANCY =	-.03

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 2

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.27597E+08	STORAGE =	.32188E+06
CONSTANT HEAD =	.24904E+10	CONSTANT HEAD =	.66243E+07
WELLS =	.00000	WELLS =	.00000
RIVER LEAKAGE =	.41925E+09	RIVER LEAKAGE =	.38281E+06
TOTAL IN =	.29373E+10	TOTAL IN =	.73290E+07
OUT:		OUT:	
STORAGE =	.47318E+08	STORAGE =	.70632E+06
CONSTANT HEAD =	.21959E+10	CONSTANT HEAD =	.59996E+07
WELLS =	.21960E+09	WELLS =	.60000E+06
RIVER LEAKAGE =	.39604E+09	RIVER LEAKAGE =	.00000
TOTAL OUT =	.28589E+10	TOTAL OUT =	.73059E+07
IN - OUT =	.78381E+08	IN - OUT =	23095.
PERCENT DISCREPANCY =	2.70	PERCENT DISCREPANCY =	.32

P pingCase 3A : T = 100,000
S = 0.1

0

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 3

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.56392E+08	STORAGE =	.13814E+06
CONSTANT HEAD =	.37418E+10	CONSTANT HEAD =	.68704E+07
WELLS =	.00000	WELLS =	.00000
RIVER LEAKAGE =	.78117E+09	RIVER LEAKAGE =	.19653E+07
TOTAL IN =	.45793E+10	TOTAL IN =	.89739E+07
OUT:		OUT:	
STORAGE =	.60246E+08	STORAGE =	53013.
CONSTANT HEAD =	.32939E+10	CONSTANT HEAD =	.59997E+07
WELLS =	.32940E+09	WELLS =	.60000E+06
RIVER LEAKAGE =	.87568E+09	RIVER LEAKAGE =	.23270E+07
TOTAL OUT =	.45592E+10	TOTAL OUT =	.89797E+07
IN - OUT =	.20122E+08	IN - OUT =	-5857.0
PERCENT DISCREPANCY =	.44	PERCENT DISCREPANCY =	-.07

0

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 4

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.69526E+08	STORAGE =	.31893E+06
CONSTANT HEAD =	.49629E+10	CONSTANT HEAD =	.66238E+07
WELLS =	.00000	WELLS =	.00000
RIVER LEAKAGE =	.87066E+09	RIVER LEAKAGE =	.37817E+06
TOTAL IN =	.59031E+10	TOTAL IN =	.73209E+07
OUT:		OUT:	
STORAGE =	.89210E+08	STORAGE =	.69809E+06
CONSTANT HEAD =	.43918E+10	CONSTANT HEAD =	.59996E+07
WELLS =	.43920E+09	WELLS =	.60000E+06
RIVER LEAKAGE =	.87568E+09	RIVER LEAKAGE =	.00000
TOTAL OUT =	.57959E+10	TOTAL OUT =	.72977E+07
IN - OUT =	.10720E+09	IN - OUT =	23220.
PERCENT DISCREPANCY =	1.83	PERCENT DISCREPANCY =	.32

WELLCONFIGURATION B

'umping Case 2B : T = 100,000
S = 0.3

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 1

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.43169E+08	STORAGE =	88541.
CONSTANT HEAD =	.12811E+10	CONSTANT HEAD =	.68726E+07
WELLS =	.00000	WELLS =	.00000
RIVER LEAKAGE =	.33239E+09	RIVER LEAKAGE =	.20149E+07
TOTAL IN =	.16566E+10	TOTAL IN =	.89760E+07
OUT:		OUT:	
STORAGE =	.55904E+08	STORAGE =	44526.
CONSTANT HEAD =	.10980E+10	CONSTANT HEAD =	.60001E+07
WELLS =	.10980E+09	WELLS =	.60000E+06
RIVER LEAKAGE =	.39924E+09	RIVER LEAKAGE =	.23417E+07
TOTAL OUT =	.16629E+10	TOTAL OUT =	.89863E+07
IN - OUT =	-.63171E+07	IN - OUT =	-10324.
PERCENT DISCREPANCY =	-.38	PERCENT DISCREPANCY =	-.11

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 2

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.81201E+08	STORAGE =	.47264E+06
CONSTANT HEAD =	.25021E+10	CONSTANT HEAD =	.66130E+07
WELLS =	.00000	WELLS =	.00000
RIVER LEAKAGE =	.42932E+09	RIVER LEAKAGE =	.42035E+06
TOTAL IN =	.30126E+10	TOTAL IN =	.75060E+07
OUT:		OUT:	
STORAGE =	.13185E+09	STORAGE =	.90357E+06
CONSTANT HEAD =	.21960E+10	CONSTANT HEAD =	.59998E+07
WELLS =	.21960E+09	WELLS =	.60000E+06
RIVER LEAKAGE =	.39924E+09	RIVER LEAKAGE =	.00000
TOTAL OUT =	.29466E+10	TOTAL OUT =	.75033E+07
IN - OUT =	.65961E+08	IN - OUT =	2670.0
PERCENT DISCREPANCY =	2.21	PERCENT DISCREPANCY =	.04

PumpinCase 2B : T = 100,000
S = 0.1

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 3

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.15422E+09	STORAGE =	.20510E+06
CONSTANT HEAD =	.37497E+10	CONSTANT HEAD =	.68566E+07
WELLS =	.00000	WELLS =	.00000
RIVER LEAKAGE =	.82571E+09	RIVER LEAKAGE =	.20701E+07
TOTAL IN =	.47296E+10	TOTAL IN =	.91318E+07
OUT:		OUT:	
STORAGE =	.16795E+09	STORAGE =	84446.
CONSTANT HEAD =	.32939E+10	CONSTANT HEAD =	.59998E+07
WELLS =	.32940E+09	WELLS =	.60000E+06
RIVER LEAKAGE =	.91638E+09	RIVER LEAKAGE =	.24554E+07
TOTAL OUT =	.47076E+10	TOTAL OUT =	.91396E+07
IN - OUT =	.21990E+08	IN - OUT =	-7836.0
PERCENT DISCREPANCY =	.47	PERCENT DISCREPANCY =	-.09

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 4

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.19160E+09	STORAGE =	.46433E+06
CONSTANT HEAD =	.49701E+10	CONSTANT HEAD =	.66114E+07
WELLS =	.00000	WELLS =	.00000
RIVER LEAKAGE =	.92051E+09	RIVER LEAKAGE =	.41211E+06
TOTAL IN =	.60822E+10	TOTAL IN =	.74878E+07
OUT:		OUT:	
STORAGE =	.24226E+09	STORAGE =	.88515E+06
CONSTANT HEAD =	.43918E+10	CONSTANT HEAD =	.59997E+07
WELLS =	.43920E+09	WELLS =	.60000E+06
RIVER LEAKAGE =	.91638E+09	RIVER LEAKAGE =	.00000
TOTAL OUT =	.59896E+10	TOTAL OUT =	.74849E+07
IN - OUT =	.92582E+08	IN - OUT =	2918.0
PERCENT DISCREPANCY =	1.53	PERCENT DISCREPANCY =	.04

BASECASE :NO WELLS

ase Case 1 : T = 200,000
S = 0.3

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 1

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.40166E+08	STORAGE =	.12833E+06
CONSTANT HEAD =	.24971E+10	CONSTANT HEAD =	.13485E+08
RIVER LEAKAGE =	.61187E+09	RIVER LEAKAGE =	.36389E+07
TOTAL IN =	.31492E+10	TOTAL IN =	.17252E+08
OUT:		OUT:	
STORAGE =	.57996E+08	STORAGE =	56809.
CONSTANT HEAD =	.21960E+10	CONSTANT HEAD =	.12000E+08
RIVER LEAKAGE =	.90346E+09	RIVER LEAKAGE =	.52028E+07
TOTAL OUT =	.31574E+10	TOTAL OUT =	.17260E+08
IN - OUT =	-.82765E+07	IN - OUT =	-7536.0
PERCENT DISCREPANCY =	-.26	PERCENT DISCREPANCY =	-.04

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 2

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.78832E+08	STORAGE =	.55747E+06
CONSTANT HEAD =	.48628E+10	CONSTANT HEAD =	.12771E+08
RIVER LEAKAGE =	.77575E+09	RIVER LEAKAGE =	.62439E+06
TOTAL IN =	.57174E+10	TOTAL IN =	.13952E+08
OUT:		OUT:	
STORAGE =	.17543E+09	STORAGE =	.19119E+07
CONSTANT HEAD =	.43919E+10	CONSTANT HEAD =	.11999E+08
RIVER LEAKAGE =	.90346E+09	RIVER LEAKAGE =	.00000
TOTAL OUT =	.54708E+10	TOTAL OUT =	.13911E+08
IN - OUT =	.24662E+09	IN - OUT =	41078.
PERCENT DISCREPANCY =	4.41	PERCENT DISCREPANCY =	.29

BasBase 1 : T = 200,000
S = 0.3

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 3

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.19435E+09	STORAGE =	.28085E+06
CONSTANT HEAD =	.73142E+10	CONSTANT HEAD =	.13465E+08
RIVER LEAKAGE =	.14455E+10	RIVER LEAKAGE =	.36652E+07
TOTAL IN =	.89541E+10	TOTAL IN =	.17411E+08
OUT:		OUT:	
STORAGE =	.21317E+09	STORAGE =	79712.
CONSTANT HEAD =	.65878E+10	CONSTANT HEAD =	.12000E+08
RIVER LEAKAGE =	.20190E+10	RIVER LEAKAGE =	.53479E+07
TOTAL OUT =	.88200E+10	TOTAL OUT =	.17427E+08
IN - OUT =	.13408E+09	IN - OUT =	-15916.
PERCENT DISCREPANCY =	1.51	PERCENT DISCREPANCY =	-.09

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 4

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.23258E+09	STORAGE =	.54928E+06
CONSTANT HEAD =	.96793E+10	CONSTANT HEAD =	.12769E+08
RIVER LEAKAGE =	.16066E+10	RIVER LEAKAGE =	.61548E+06
TOTAL IN =	.11518E+11	TOTAL IN =	.13933E+08
OUT:		OUT:	
STORAGE =	.32923E+09	STORAGE =	.18898E+07
CONSTANT HEAD =	.87836E+10	CONSTANT HEAD =	.11999E+08
RIVER LEAKAGE =	.20190E+10	RIVER LEAKAGE =	.00000
TOTAL OUT =	.11132E+11	TOTAL OUT =	.13889E+08
IN - OUT =	.38658E+09	IN - OUT =	44237.
PERCENT DISCREPANCY =	3.41	PERCENT DISCREPANCY =	.32

BaseCase 2 : T = 100,000
S = 0.3

```
0

                VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD  1
                ------------------------------------------------------------------------------
     CUMULATIVE VOLUMES      L**3                             RATES FOR THIS TIME STEP      L**3/T
     ------------------                                       ------------------------

           IN:                                                       IN:
           ---                                                       ---
             STORAGE =   .39780E+08                                   STORAGE =   88157.
       CONSTANT HEAD =   .12584E+10                             CONSTANT HEAD =   .67450E+07
       RIVER LEAKAGE =   .29640E+09                             RIVER LEAKAGE =   .18013E+07
0           TOTAL IN =   .15946E+10                                  TOTAL IN =   .86345E+07
          OUT:                                                     OUT:
          ----                                                     ----
             STORAGE =   .57817E+08                                   STORAGE =   47597.
       CONSTANT HEAD =   .10980E+10                             CONSTANT HEAD =   .60001E+07
       RIVER LEAKAGE =   .44225E+09                             RIVER LEAKAGE =   .25947E+07
           TOTAL OUT =   .15981E+10                                 TOTAL OUT =   .86423E+07
            IN - OUT =  -.34738E+07                                  IN - OUT =  -7837.0
0 PERCENT DISCREPANCY =               -.22              PERCENT DISCREPANCY =                -.09

0

                VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD  2
                ------------------------------------------------------------------------------
0    CUMULATIVE VOLUMES      L**3                             RATES FOR THIS TIME STEP      L**3/T
     ------------------                                       ------------------------

           IN:                                                       IN:
           ---                                                       ---
             STORAGE =   .74376E+08                                   STORAGE =   .33932E+06
       CONSTANT HEAD =   .24485E+10                             CONSTANT HEAD =   .64198E+07
       RIVER LEAKAGE =   .38893E+09                             RIVER LEAKAGE =   .37640E+06
0           TOTAL IN =   .29118E+10                                  TOTAL IN =   .71356E+07
          OUT:                                                     OUT:
          ----                                                     ----
             STORAGE =   .16140E+09                                   STORAGE =   .11302E+07
       CONSTANT HEAD =   .21959E+10                             CONSTANT HEAD =   .59997E+07
       RIVER LEAKAGE =   .44225E+09                             RIVER LEAKAGE =   .00000
           TOTAL OUT =   .27996E+10                                 TOTAL OUT =   .71299E+07
            IN - OUT =   .11222E+09                                  IN - OUT =   5634.0
0 PERCENT DISCREPANCY =               3.93              PERCENT DISCREPANCY =                 .08
```

BaseCase 2 : T = 100,000
S = 0.3

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 3

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.17529E+09	STORAGE =	.19806E+06
CONSTANT HEAD =	.36714E+10	CONSTANT HEAD =	.67291E+07
RIVER LEAKAGE =	.73056E+09	RIVER LEAKAGE =	.18284E+07
TOTAL IN =	.45772E+10	TOTAL IN =	.87556E+07
OUT:		OUT:	
STORAGE =	.19464E+09	STORAGE =	59368.
CONSTANT HEAD =	.32939E+10	CONSTANT HEAD =	.59998E+07
RIVER LEAKAGE =	.10334E+10	RIVER LEAKAGE =	.27062E+07
TOTAL OUT =	.45219E+10	TOTAL OUT =	.87653E+07
IN - OUT =	.55341E+08	IN - OUT =	-9772.0
PERCENT DISCREPANCY =	1.22	PERCENT DISCREPANCY =	-.11

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 4

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.20928E+09	STORAGE =	.33382E+06
CONSTANT HEAD =	.48609E+10	CONSTANT HEAD =	.64178E+07
RIVER LEAKAGE =	.82113E+09	RIVER LEAKAGE =	.36853E+06
TOTAL IN =	.58913E+10	TOTAL IN =	.71202E+07
OUT:		OUT:	
STORAGE =	.29654E+09	STORAGE =	.11149E+07
CONSTANT HEAD =	.43918E+10	CONSTANT HEAD =	.59997E+07
RIVER LEAKAGE =	.10334E+10	RIVER LEAKAGE =	.00000
TOTAL OUT =	.57217E+10	TOTAL OUT =	.71147E+07
IN - OUT =	.16952E+09	IN - OUT =	5516.0
PERCENT DISCREPANCY =	2.92	PERCENT DISCREPANCY =	.08

BaseCase 3 : T = 100,000
S = 0.1

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 1

CUMULATIVE VOLUMES	L**3		RATES FOR THIS TIME STEP	L**3/T	
IN:			IN:		
STORAGE =	.13467E+08		STORAGE =	50071.	
CONSTANT HEAD =	.12449E+10		CONSTANT HEAD =	.67411E+07	
RIVER LEAKAGE =	.31026E+09		RIVER LEAKAGE =	.18303E+07	
TOTAL IN =	.15686E+10		TOTAL IN =	.86215E+07	
OUT:			OUT:		
STORAGE =	.19368E+08		STORAGE =	19448.	
CONSTANT HEAD =	.10980E+10		CONSTANT HEAD =	.60000E+07	
RIVER LEAKAGE =	.45590E+09		RIVER LEAKAGE =	.26056E+07	
TOTAL OUT =	.15733E+10		TOTAL OUT =	.86250E+07	
IN - OUT =	-.46267E+07		IN - OUT =	-3519.0	
PERCENT DISCREPANCY =		-.29	PERCENT DISCREPANCY =		-.04

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 2

CUMULATIVE VOLUMES	L**3		RATES FOR THIS TIME STEP	L**3/T	
IN:			IN:		
STORAGE =	.26738E+08		STORAGE =	.25624E+06	
CONSTANT HEAD =	.24241E+10		CONSTANT HEAD =	.63750E+07	
RIVER LEAKAGE =	.38635E+09		RIVER LEAKAGE =	.29309E+06	
TOTAL IN =	.28372E+10		TOTAL IN =	.69243E+07	
OUT:			OUT:		
STORAGE =	.59907E+08		STORAGE =	.88545E+06	
CONSTANT HEAD =	.21959E+10		CONSTANT HEAD =	.59996E+07	
RIVER LEAKAGE =	.45590E+09		RIVER LEAKAGE =	.00000	
TOTAL OUT =	.27117E+10		TOTAL OUT =	.68851E+07	
IN - OUT =	.12550E+09		IN - OUT =	39226.	
PERCENT DISCREPANCY =		4.52	PERCENT DISCREPANCY =		.57

BaseCase 3 : T = 100,000
S = 0.1

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 3

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.66611E+08	STORAGE =	.14416E+06
CONSTANT HEAD =	.36501E+10	CONSTANT HEAD =	.67327E+07
RIVER LEAKAGE =	.71869E+09	RIVER LEAKAGE =	.18326E+07
TOTAL IN =	.44354E+10	TOTAL IN =	.87094E+07
OUT:		OUT:	
STORAGE =	.72906E+08	STORAGE =	40133.
CONSTANT HEAD =	.32939E+10	CONSTANT HEAD =	.59997E+07
RIVER LEAKAGE =	.10095E+10	RIVER LEAKAGE =	.26757E+07
TOTAL OUT =	.43762E+10	TOTAL OUT =	.87155E+07
IN - OUT =	.59125E+08	IN - OUT =	-6127.0
PERCENT DISCREPANCY =	1.34	PERCENT DISCREPANCY =	-.07

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 4

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	.79756E+08	STORAGE =	.25236E+06
CONSTANT HEAD =	.48290E+10	CONSTANT HEAD =	.63741E+07
RIVER LEAKAGE =	.79340E+09	RIVER LEAKAGE =	.28839E+06
TOTAL IN =	.57022E+10	TOTAL IN =	.69149E+07
OUT:		OUT:	
STORAGE =	.11294E+09	STORAGE =	.87688E+06
CONSTANT HEAD =	.43918E+10	CONSTANT HEAD =	.59996E+07
RIVER LEAKAGE =	.10095E+10	RIVER LEAKAGE =	.00000
TOTAL OUT =	.55142E+10	TOTAL OUT =	.68765E+07
IN - OUT =	.18795E+09	IN - OUT =	38358.
PERCENT DISCREPANCY =	3.35	PERCENT DISCREPANCY =	.56