Research Technical Completion Report

HYDROLOGIC EVALUATION OF THE BIG WOOD RIVER AND SILVER CREEK WATERSHEDS
PHASE II

submitted to
The Nature Conservancy

by

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This study was made possible by a very diverse and committed group of supporters. The study began in 1992 when The Nature Conservancy felt a strong need to assess the impacts of changing land uses on Silver Creek's hydrology. This turned into a 7-year long intensive research project to model Silver Creek's ground water system, and to assess current and future water resources of the Big Wood River and Silver Creek watersheds.

Although The Nature Conservancy spearheaded this effort, and raised and coordinated the necessary funding, many organizations and individuals were involved in the project's success. Indeed, this work is an excellent example of community-based cooperation. Fly fishermen, developers, irrigation canal companies, conservationists, and local county and city governments all came together, served on a steering committee, and gave this project direction and support.

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ABSTRACT

The complex hydrologic system and water resources of the Big Wood River-Silver Creek watershed located in Blaine County, Idaho, were examined in this study. Population growth, land use changes, and irrigation system modifications have altered this complex system resulting in concerns about future water availability, stream flows, and riparian habitat of Silver Creek and the Big Wood River. The USGS three dimensional ground water flow model, MODFLOW, was successfully applied to the aquifer system downstream of Hailey. Aquifer responses to changes in the water budget were quantified through use of the model. For the Big Wood River watershed above Hailey (the "Upper Valley"), the water yield, current water usage, and demand associated with population growth were estimated. For the remainder of this report, the phrase, "Upper Valley", is used to refer to that area and portion of the study.

The mean annual precipitation on the Upper Valley watershed was estimated in excess of 1.1 million acre-feet (af). The estimated annual water yield from the Upper Valley was 396,000 af. The Upper Valley mean annual surface and ground water diversions were estimated at 54,700 acre-feet per year (af/y), with an associated consumptive use of 18,300 af/y. For the lower system, the Big Wood River-Silver Creek aquifer area, the combined surface and ground water diversions were estimated at 192,000 af/y, with approximately 107,100 af/y consumptively used. For the entire area, municipal diversions were estimated at 10,000 af/y of the 246,700 af/y diverted.

Additional rural subdivision development from irrigated lands will have the least impact on consumptive use if the building density is high. Change in consumptive use is insensitive to building density for new rural subdivisions on non-irrigated lands where parcel areas are in excess of one-half acre. The relative impact on consumptive use in the Upper Valley through the conversion of irrigated ranch land to golf courses with turf irrigation is minimal.

Surface diversions for irrigation from the Big Wood River have been declining since the 1970's. Based on ground water flow model simulations, continued irrigation with surface diversions from the Big Wood River will be crucial in maintaining the Big Wood River-Silver Creek aquifer water table elevations and associated spring flows to the Big Wood River and Silver Creek. Managed recharge of the aquifer system from available Big Wood River flows have the potential for the largest positive impact on aquifer levels and Silver Creek flows of any water use changes simulated in this study.

INTRODUCTION

Continued population expansion and changes in irrigation technology, climate, environmental priorities, and land use have altered water resource needs and supplies in the Big Wood River-Silver Creek watersheds (Figure 1) over the last twenty years. Several droughts (1977 and 1987-1992) during which runoff averaged about 60 percent of normal on the Big Wood River, have further aggravated the delicate water situation. Consequently, Idaho's world famous Silver Creek has experienced decreased flows. This blue ribbon trout stream is known for its slow-moving, cold, crystal clear spring water which supports an abundance of aquatic and terrestrial life, such as rainbow and brown trout, bald and golden eagles, sandhill cranes, hawks, and deer. Low flows during hot summer days in 1992 caused elevated water temperatures and dissolved oxygen depletion resulting in a fish kill for the first time in recorded history.

Population growth in the Big Wood River Valley has called into question the available water supply. The Nature Conservancy and the irrigators in the Big Wood River-Silver Creek aquifer area have expressed their concern about the declining spring flows and water table levels. Local planning commissions and government officials would like better information regarding the quantity and quality of this valuable resource. Citizens of Blaine County, The Nature Conservancy, and irrigators in the area expressed a need for a hydrologic study to define the aquifer system interaction and responses to increased demand.

While geologic and hydrologic conditions in the Big Wood River and Silver Creek basin are complex, this basin has supplied water for domestic use and irrigation in this part of Blaine County since 1881 and helped to retain the quality of life in the Wood River valley for many years.

A hydrologic study for the Big Wood River-Silver Creek aquifer system was proposed in two phases by the University of Idaho under the auspices of The Nature Conservancy of Idaho and the Idaho Water Resources Research Institute. The purpose of the first phase (Kahlown and Brockway, 1994) was to collect hydrologic, geologic, meteorologic, and land use data associated with the Big Wood River-Silver Creek aquifer system south of Hailey and north of the Timmerman Hills (Figure 1). The second phase of the study was to develop a three dimensional ground water flow model for the multi-layer aquifer system, using the data collected in the first phase of the study. The developed ground water model would then be used to evaluate "what if" scenarios for better management of water resources.

Phase II of the study was a continuation of Phase I (Kahlown and Brockway, 1994) in which hydrologic data from the first phase were used to calibrate a numerical ground water flow simulation model for the Big Wood River-Silver Creek aquifer system. Also, data from the first phase were utilized to develop data sets for various hypothetical scenarios. The first portion of this report covers the calibration of the aquifer geohydrologic parameters and presents the results of different scenarios simulated with the calibrated ground water model. The actual study area in Phase II was expanded to include the Big Wood River watershed upstream of Hailey (Figure 1). The study objectives were also extended to answer questions with respect to water supply and demand in the upper valley, although the upper valley aquifer was not modeled. The last part of this report covers the findings on water supplies, uses, demands, and needs north of Hailey.

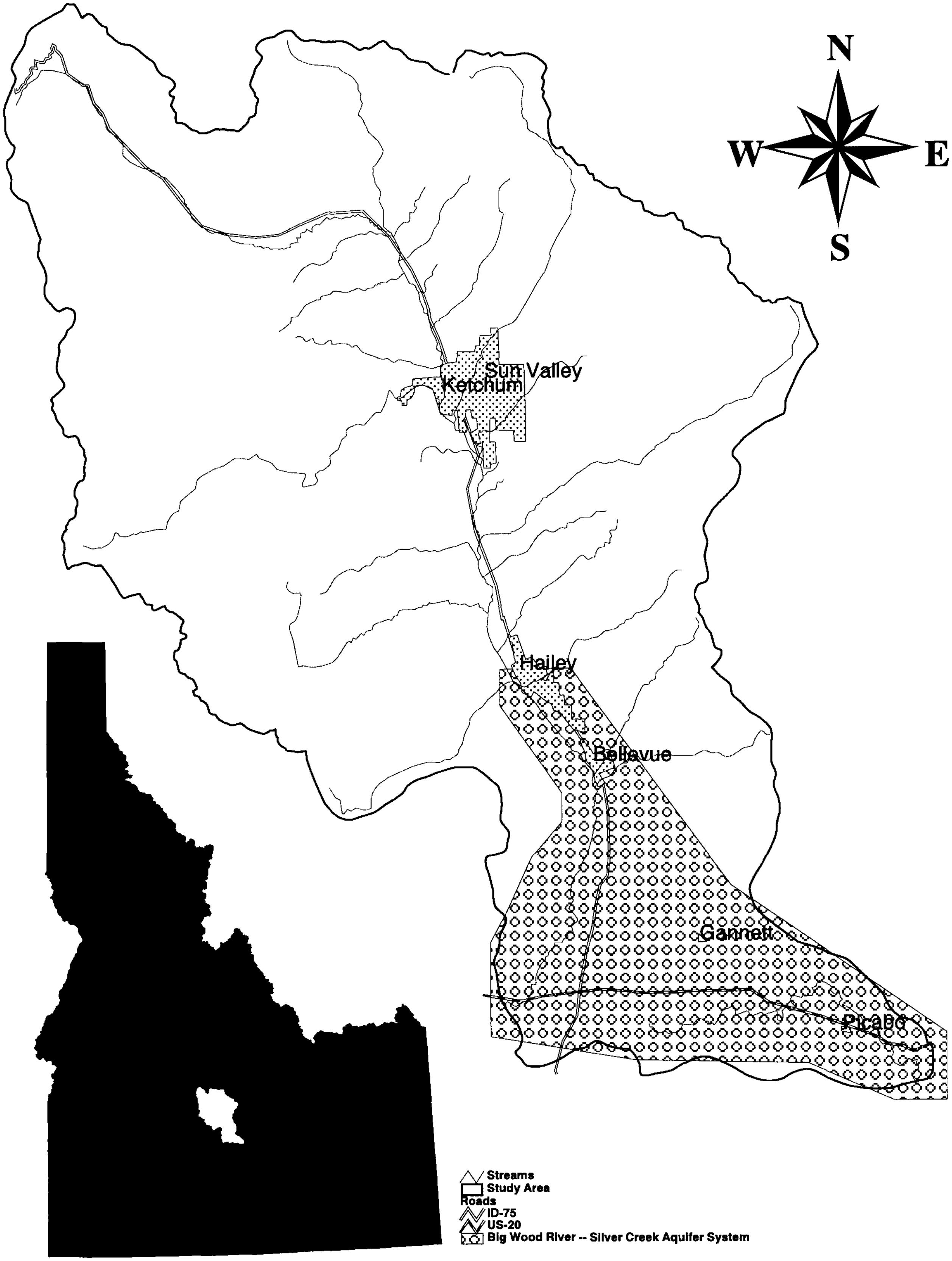


Figure 1. **General Study Area**

OBJECTIVES

The primary objectives of Phase II were to develop a ground water flow model using the hydrologic and land use data collected in the first phase and to utilize the model in understanding and evaluating the Big Wood River-Silver Creek aquifer system response to changes in land and water use. An additional objective was to evaluate the availability of ground and surface water resources in the Hailey-Sun Valley area of the Big Wood River relative to current and future land use and population growth.

The following study objectives and specific products and questions were identified by a citizens' steering committee, coordinated by The Nature Conservancy. These objectives are presented in no particular priority or chronology.

- Estimate the amount of water being withdrawn from the Big Wood River-Silver Creek watershed south of the Sawtooth National Recreation Area, including surface and ground water diversions and evaporation loss.
- Quantify the annual recharge of the Big Wood River-Silver Creek aquifer system.
- Estimate the underflow leaving the Big Wood River-Silver Creek aquifer system.
- Provide an analysis comparing water requirements associated with various land uses in the Big Wood River-Silver Creek watershed.
- Procure the three-dimensional ground water flow model code selected in Phase I.
- Develop and calibrate the ground water flow model for the Big Wood River-Silver Creek aquifer system.
- Predict the impact on future water supplies based on different land use scenarios in the Big Wood River-Silver Creek watershed.
- Simulate the response of the Big Wood River-Silver Creek aquifer system to potential climatic, land use, and man-induced changes.
- Procure and evaluate existing data and develop additional hydrologic, land use, and water use data in the Hailey-Sun Valley locale.
- Estimate the water resources and evaluate the impacts of future development on the water resources of the Hailey-Sun Valley locale.

PREVIOUS INVESTIGATIONS

There have been several investigations of water resources in the Big Wood River and Silver Creek watersheds. Some the earliest work was conducted by the United States Geological Survey (USGS) in the 1950s (Jones, 1952 and Smith, 1959). Castelin and Chapman (1972) studied the surface and ground water relationships in the lower part of the valley. Castelin and Winner (1975), Luttrell and Brockway (1982, 1984) and Frenzel (1989) evaluated the relationship between surface and ground water as well as the water quality. Their studies were conducted in the upper and lower regions of the valley.

The Big Wood River-Silver Creek aquifer system was previously modeled by Brockway and Grover (1978) using a two-dimensional ground water flow model. Upper (water table) and lower (confined) aquifers in the system were modeled separately in an iterative fashion with feedback between the separate models. The results from one model were used for input into the other, whose results were used for input to the first model, iteratively. Information on aquifer parameters and properties from that study served for comparing and contrasting the parameters and properties developed in this study.

METHODOLOGY

The phase II study was originally based on a plan of work developed prior to the phase I study. However, after the completion of phase I, the plan of work and study area were expanded. To facilitate the additional area and objectives, this study was split into two components which were addressed separately. The first component addresses objectives from the original plan of work on the Big Wood River-Silver Creek aquifer system south of Hailey. The second component addresses the additional objectives concerning the water supply of the Big Wood River watershed north of Hailey, or the Upper Valley.

BIG WOOD RIVER-SILVER CREEK AQUIFER SYSTEM GROUND WATER MODEL

GROUND WATER STUDY AREA

The ground water study area, known locally as "the Bellevue Triangle", includes portions of the Big Wood River and Silver Creek watersheds (Figure 2). The approximately 57,100 acre area is bounded by Hailey on the north, Stanton Crossing on the southwest, and Priest Road on the southeast. Mountains surround the entire valley. The cities of Hailey and Bellevue are in the northern part of the area, and two small communities, Gannett and Picabo, are situated in the southern part. Primary thoroughfares are U.S. Highway 75 and Idaho State Highway 20 which service the area in the north-south and east-west directions, respectively.

The modeled area is two miles wide at the apex of the triangle at Hailey and 15 miles wide at its widest point in the east-west direction, and approximately 17 miles long in the north-south direction. Land surface elevations in the valley vary from approximately 4,750 feet at Priest Road to 4,800 feet at Stanton Crossing to 5,300 feet at Hailey. The valley floor has an average slope of only 30 feet/mile in the north-south direction.

For purposes of this report, Stanton Crossing is commonly referred to as being the southwest boundary of the ground water model. The actual model boundary was located to include the mouth of Willow Creek at the Big Wood River (one mile west of this bridge). The USGS stream gaging station is 1/4 mile west and out of the study area, but the flow measurements of the Big Wood River exiting the area were assumed to occur at the model boundary. Hailey represents the northern boundary of the ground water model area, where the USGS operates a stream gage on the Big Wood River. Priest Road is commonly referred to as the southeast boundary of the model. A stilling well and continuous stage recorder were installed and operated by University of Idaho personnel on Silver Creek near the Swanson's Bridge and Priest Road bridge sites.

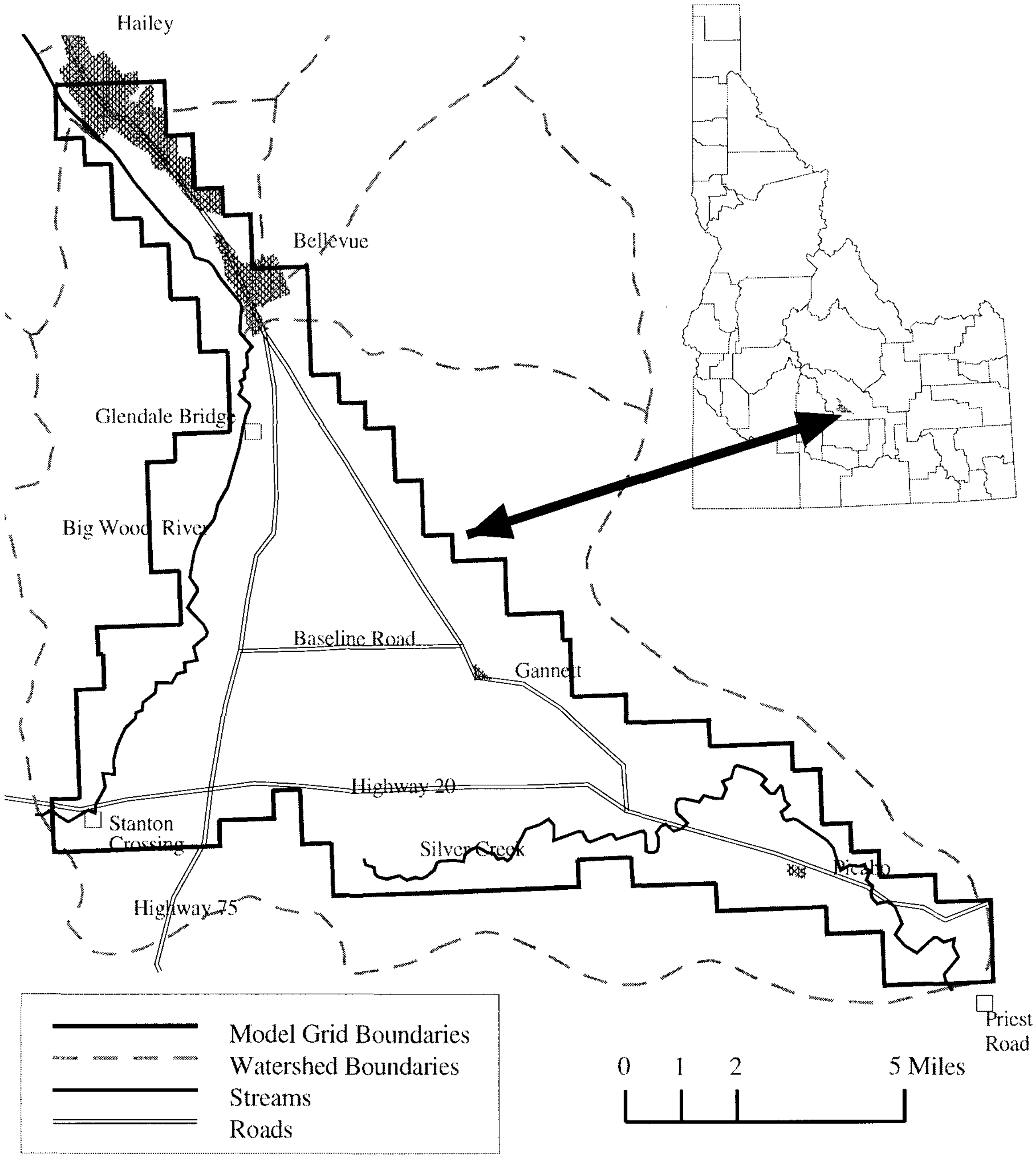


Figure 2. Big Wood River – Silver Creek Aquifer System

Geologic Framework

The Big Wood River-Silver Creek aquifer system is composed of Quaternary age alluvial deposits of gravel, sand, silt, and clay bounded by relatively impermeable mountains and basement complex formed by Tertiary and earlier aged sedimentary, volcanic, and granitic rocks. Based on prior geologic investigations and the interpretations of Smith (1959), Castelin and Chapman (1972), and Moreland (1977) Figure 3 generalizes the geologic formations associated with the area.

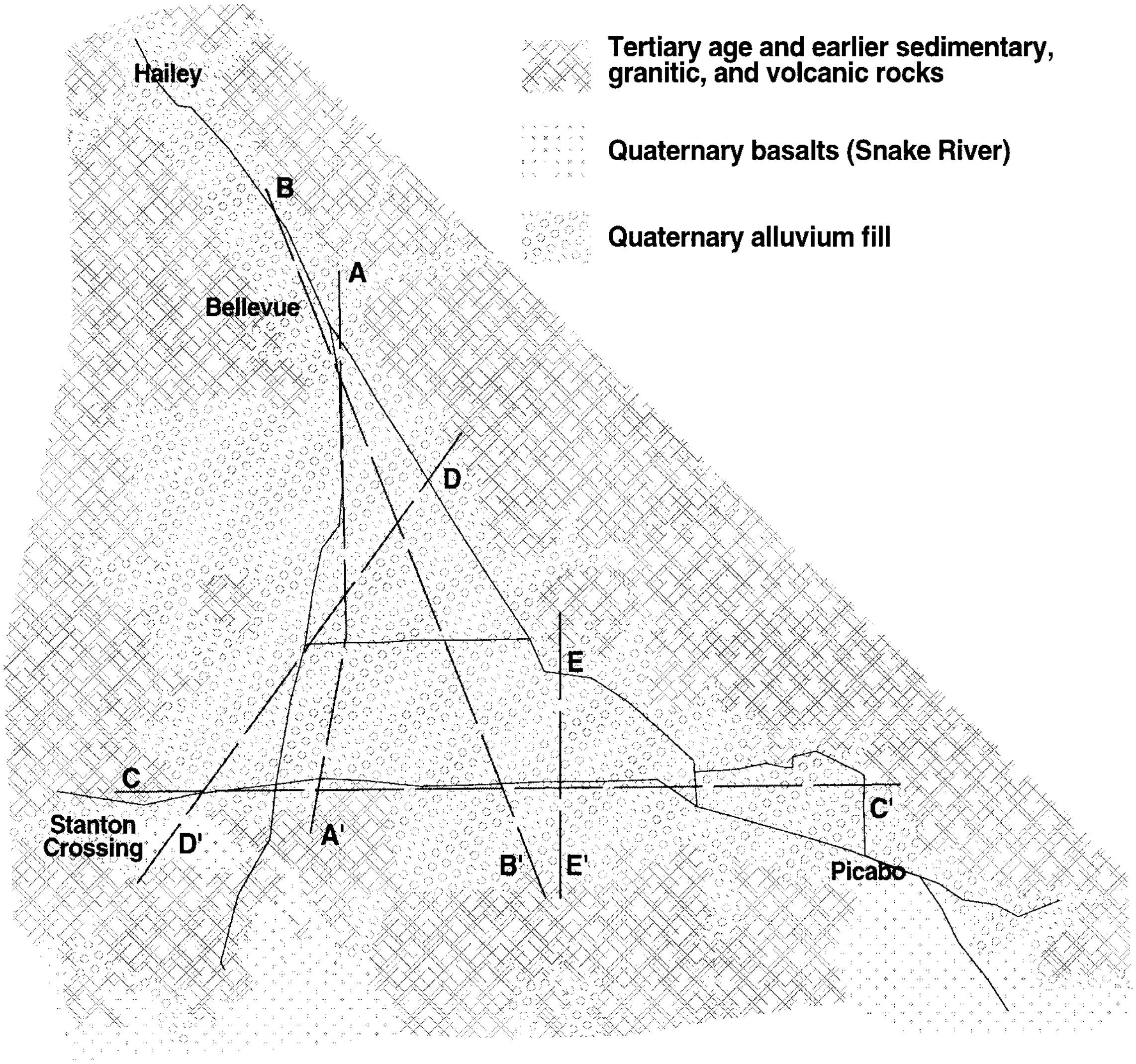


Figure 3. Generalized Geology of the Big Wood River -Silver Creek Area

The system is a result of repeated lake forming events between the three mountainous sides. It is generally believed that the original course of the Big Wood River was from Bellevue southeasterly to Picabo where it exited the valley. Basalt flows blocked the southeast exit causing a lake to form. As a result, gravel and other coarse-grained material was deposited in the upper, northern valley area, with silt and fined-grained material deposited in the southern part. Eventually, water levels rose sufficiently causing the river to exit via the southwest corner, in the Stanton Crossing area. Another basalt flow occurred blocking the southwest exit. The lake reformed and additional depositions occurred until the river found another exit. Over time, various basalt flows occurred blocking the river's exit and reforming the lake. Sometimes the blockage would result in the river changing its exit point from one corner to the other corner. Glacial events occurred several times during the lake forming period. The resulting glacial melt produced poorly sorted glacial outwash material deposits over the valley. The resulting valley surface is presently convex upwards and only a shallow surface-water divide separates the Big Wood River and Silver Creek drainages.

These events explain the heterogeneous nature of the alluvial deposits forming the valley fill and aquifer material. Cross sections of the valley fill presented in Figure 4 and referenced in Figure 3 simplify this complex lithology. The figures were based on material presented by Smith (1959), Castelin and Chapman (1972), and Moreland (1977). The relatively thick, fine-grained layers in the southern and westerly areas confine the aquifer. Thus, in the northern area, a single water table aquifer exists. This aquifer transitions into a confined aquifer and a water table aquifer to the south. The system transitions back into a single water table aquifer going to the southeast as the fine-grained sediment layers diminish and the valley alluvium shallows out with basalt basement intrusion.

Aquifer System

Brockway and Grover (1978, p. 15) stated, "It is difficult, if not impossible, to identify all the layers present in this alluvial system." A three layer model was selected to approximate the high degree of vertical stratification. Generally, north of Baseline Road, the system was assumed to be a single layer, water table aquifer consisting of larger grain material except for the southern and western side. Between Glendale Bridge and Baseline Road, the system transitions into a three layer system. The upper layer was assumed to be a water table (unconfined) aquifer and the lower layer was modeled as an artesian (confined) aquifer. These two aquifers are separated by an aquitard consisting of clay lenses with low permeability and varying thickness and spatial extent. This three layer

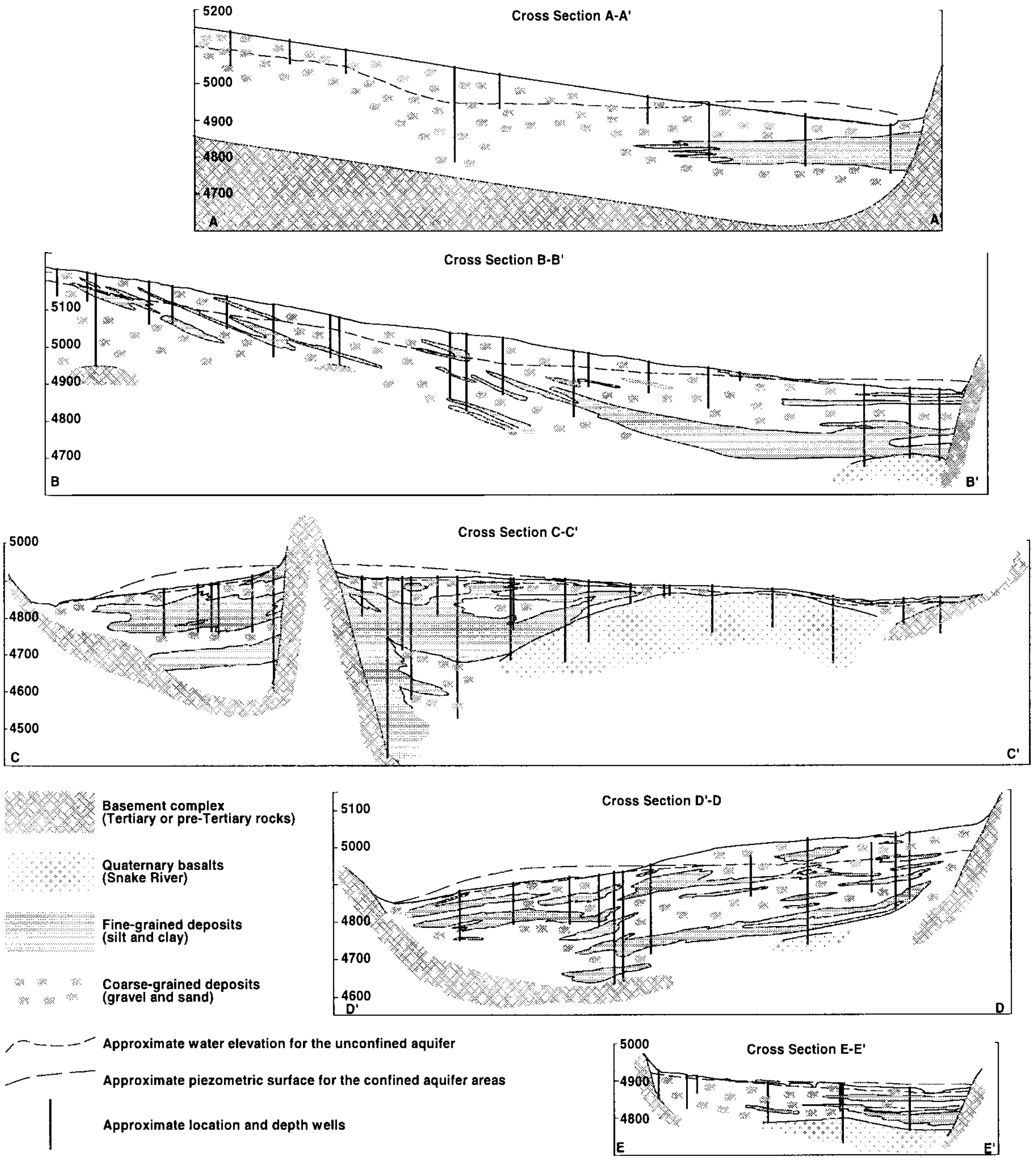


Figure 4. Geologic Cross Sections of the Big Wood River-Silver Creek Area.

system continues southward to Stanton Crossing and Picabo. The aquifer system transitions back into a single water table aquifer in the southeastern corner of the study area. A small, localized, perched aquifer overlays the water table aquifer north of Picabo.

Figure 5 shows the extent of these modeled aquifers and aquitard. In this study, the confined aquifer and associated aquitard was identified farther north than previously defined by Brockway and Grover (1978). This redefinition of boundaries was done to eliminate irregularities that develop at the boundaries while running the model and to allow unimpeded flow from the lower layer to the upper layer. Several cells were added in the southeast region (south of Picabo) to make the modeled area wider in this region to reduce the effects of boundary conditions.

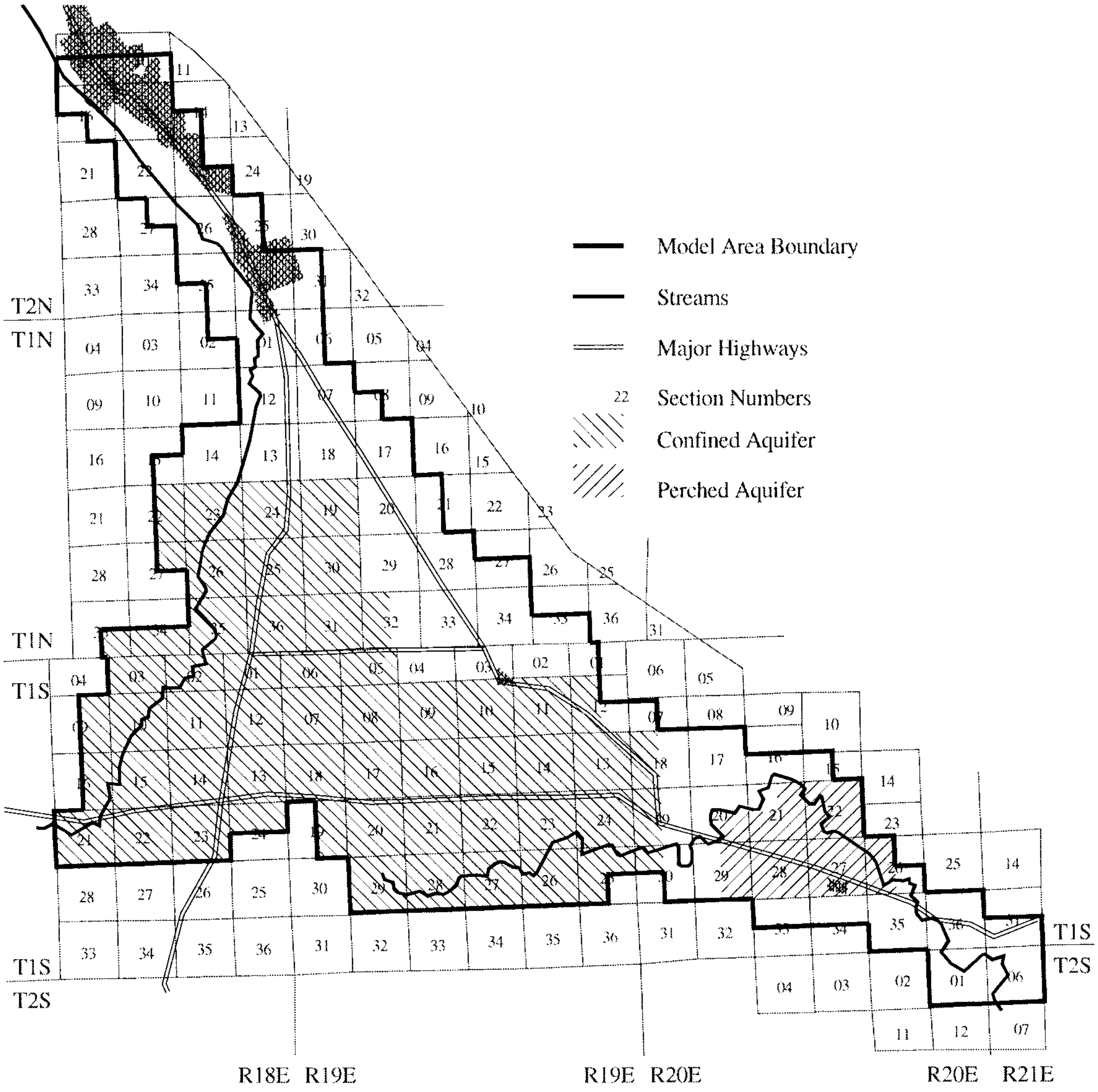


Figure 5. Approximate Extent of Aquifers

There is a ground water divide that runs approximately parallel to and east of State Highway 75 in both the confined and unconfined aquifers. Ground water flows from this divide either westerly towards Stanton Crossing or easterly towards Silver Creek and Priest Road.

SURFACE HYDROLOGY

The Big Wood River flows along the western side of the study area in a southerly direction from Hailey to below Stanton Crossing. The northern part of the channel is made up of highly permeable materials contributing to a large seepage loss of the Big Wood River in this portion. During the late summer months, the entire flow of the river is diverted for irrigation into major canals (Figure 6), leaving the riverbed dry from Glendale Bridge to below the Boise Baseline. In the southern part of the Big Wood River, springs appear in the channel and the river starts flowing again. Several springs emerge below the Baseline and develop into streams that also flow into the Big Wood River, increasing the flow at Stanton Crossing. Silver Creek is a meandering stream fed by numerous springs in the southern region. It flows in an east-southeast direction leaving the area below Picabo at Priest Road. Silver Creek is a gaining (aquifer discharges into it) stream above Swanson Bridge and a losing stream (recharges the aquifer) below Swanson Bridge (Figure 6).

Two separate water measurement districts regulate the surface water diversions in this area. Water District 37 controls the surface water that is diverted out of the Big Wood River and Water District 37M regulates the diversions out of Silver Creek and its tributaries. Both Water Districts are under the direction of the same watermaster in Shoshone, Idaho.

Underflow

Ground water underflow from the upper Big Wood River Valley enters the study area at Hailey (Figure 6). At the Priest Road vicinity (Figure 6), underflow discharges into the Snake River Plain aquifer. Ground water underflow to the west, at Stanton Crossing, is considered negligible due to geologic boundaries (Brockway and Grover, 1978). No significant overland flow or underflow was assumed to enter the study area from the surrounding hills.

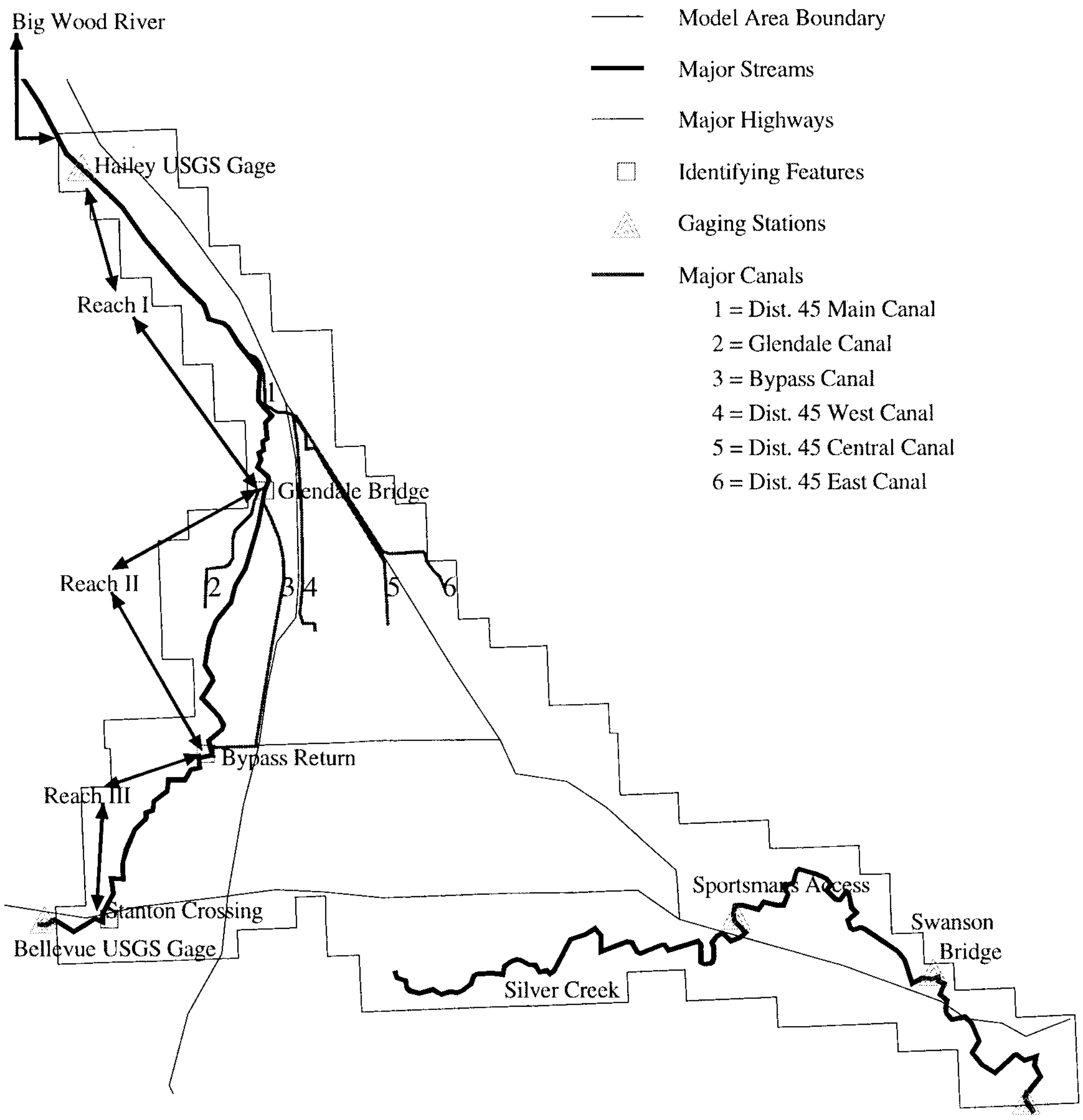


Figure 6. Hydrologic Features

MODEL DESCRIPTION

Numerical Simulation Code

The computer code used for simulating the aquifer system was the USGS modular three-dimensional, finite-difference, ground water flow model, MODFLOW, by McDonald and Harbaugh (1988). The modules used for this study include the BAS (basic), BCF (block-centered flow), WEL (well), RIV (river), DRN (drain), RCH (recharge), SIP (strongly implicit procedure), and OC (output control). Commercial pre- and post-processors were not used for developing, calibrating, or viewing the model.

The model is operated in either steady-state or transient mode. In steady-state mode, the inflow equals the outflow with no change in storage occurring and time is not considered. In a transient mode, the model considers change in storage over time. Transient simulations produce a set of heads and discharges for each time step, whereas steady-state simulations generate only one set of heads and discharges (Anderson, 1992). Transient simulations are more complicated to calibrate and operate than are steady-state simulations.

Model Spatialization

Temporally, the model used a time step of 15.2 days or approximately twice a month. The time steps were defined to be one per stress period in duration. The time step length determined the frequency for solving the finite-difference flow equations. The stress period length determined the frequency at which inflow (recharge) and outflow (discharge) stresses were applied or entered.

Areally, the aquifer area was divided into a grid of 34 columns, 35 rows, and three layers. The model grid was oriented in a north-south, east-west direction so that the cells approximate the Public Land Survey sections. The model grid and active cells are shown in Figure 7. The cell area was defined to be a fixed dimension of 160 acres, or 1/2 mile by1/2 mile except for the cells on the northern most tier of Township 1 South which was a correction section. These cells contained 215 acres.

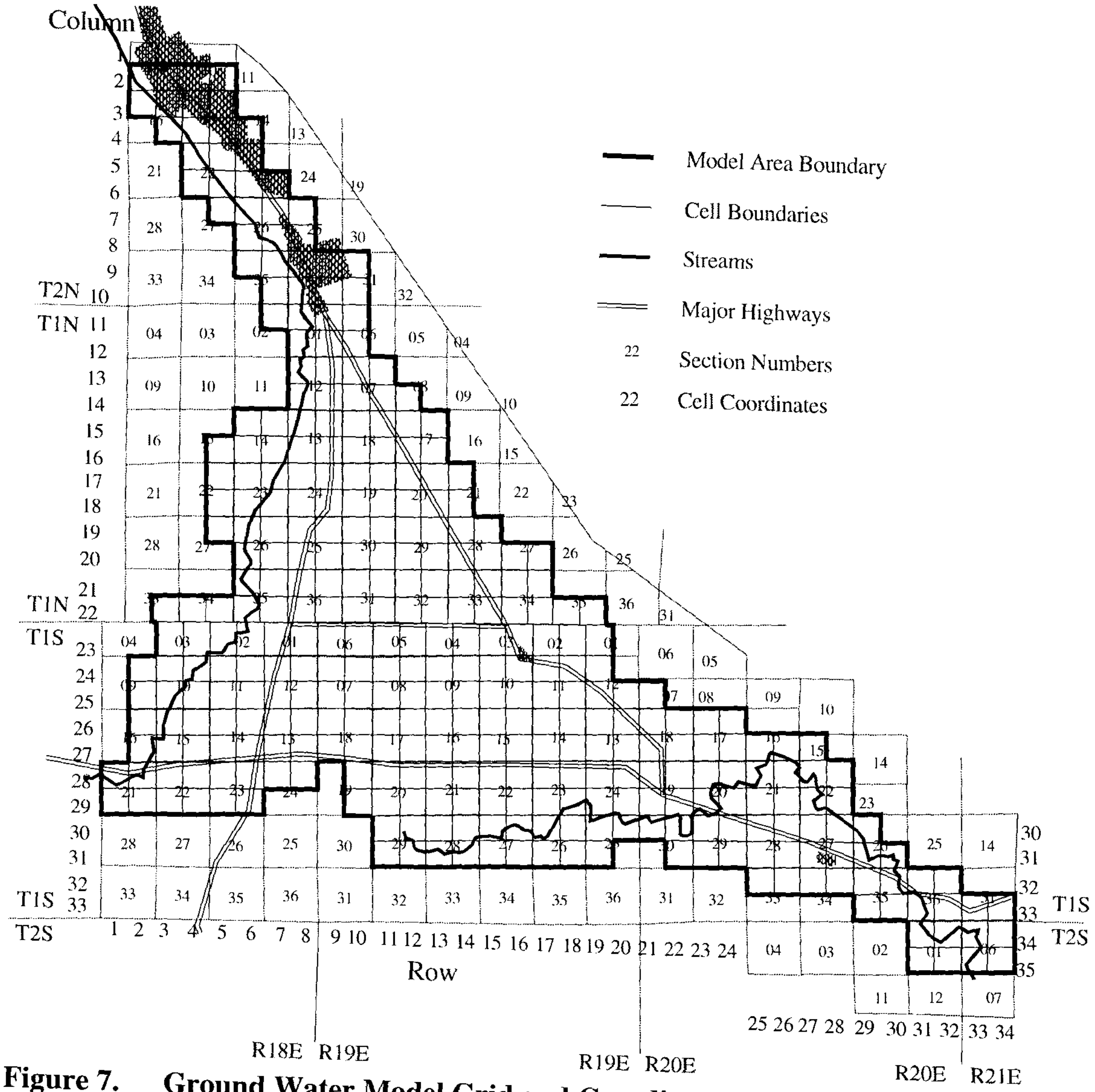


Figure 7. Ground Water Model Grid and Coordinates

The origin of the finite difference grid (cell 1,1) was defined as the northeast quarter of Section 8, Township 2 North, Range 18 East, near Hailey. Each cell was then defined by coordinates in a row-column fashion, with the origin of the model being at the top left (northwest) corner of the study area. The numbering system increased down (south) and to the right (east), which is the inverse in the north-south direction of standard Cartesian coordinate systems (Figure 5). There were 355 active cells in the model grid covering approximately 57,700 acres, or 90.2 square miles.

Well logs from approximately 1400 wells in the study area were evaluated to determine the top and bottom elevation of each aquifer layer. Initial estimates of hydraulic conductivity were made from the aquifer thickness and well drillers' descriptions of materials. Well drillers' descriptions of aquifer layers varied greatly, and significant interpretation was required to determine the aquifer interfaces. The unconfined aquifer ranged in depth from 150 feet at Hailey to 300 feet at Priest Road. Over the confined aquitard, the water table aquifer depth ranged from 10 feet to 150 feet. The middle layer, or aquitard, ranged from 0.0 feet to 50.0 feet thick. The confined aquifer varied in depth from 20 feet to 150 feet. Aquifer thicknesses and elevations were supplemented with values reported by Brockway and Grover (1978).

The water surface elevations were estimated from the mass measurements of the 80 observation wells obtained during the Phase I study. The monitoring network and observation well locations are fully described in the Phase I report. The water surface elevation and the elevation of the bottom of the aquifer were used to calculate the wetted thickness of the unconfined aquifer.

Boundaries

The limits of the model were assumed to coincide with the valley boundaries from Hailey south to Stanton Crossing and Priest Road. All the boundary cells were simulated as non-flow cells except for three cells at the Priest Road area. These three cells were simulated as constant head cells and were used to simulate the underflow across this boundary. The model boundary conditions and cells that were modeled as river and drain cells are shown in Figure 8 and Figure 9 for layers 3 and 1, respectively. The underflow at Hailey was simulated as a constant flow term entering the system.

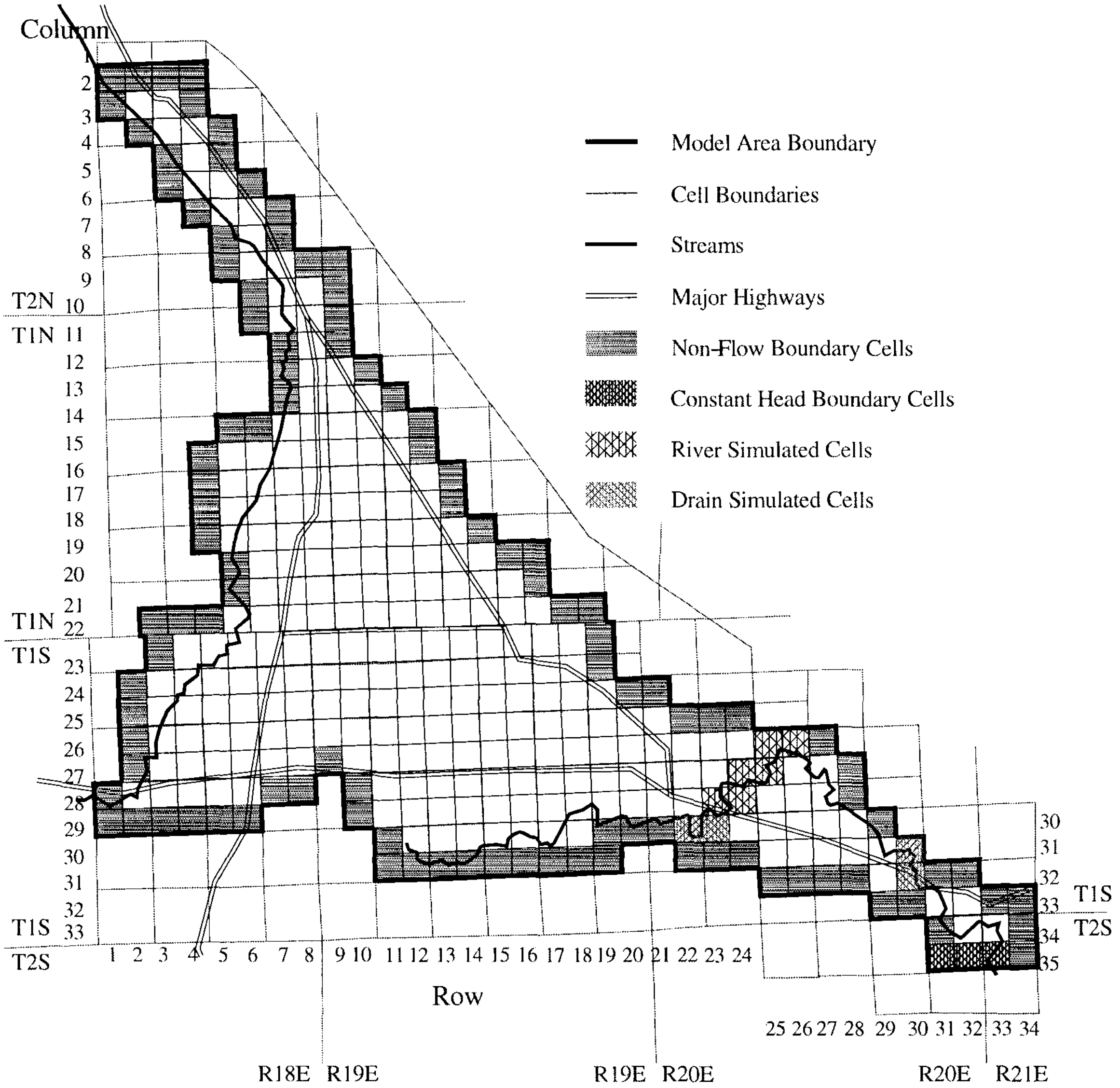


Figure 8. Boundary Conditions and River Simulated Cells, Layer 3

The northern boundary cells associated with layer 1 (Figure 9) are depicted as non-flow boundary. In formulating the numeric model, these boundary cells were positioned two nodes north of the estimated extent of the shallow unconfined aquifer. The vertical conductivity was adjusted and calibrated to allow free flow between the underlying (layer 3) nodes and these layer 1 boundary nodes.

The ground water flows orthogonal (perpendicular) to the water surface elevation contour lines as shown in Figures 10 through 15. Both the upper and lower aquifers show a gradient to the southwest in the southwest corner of the area. The lower aquifer piezometric head elevations (water elevation due to the pressure in a confined aquifer) are greater than the land surface in this region. Using the assumption that no underflow leaves the valley at the southwest corner and there are no wells in the area, a gradient in the lower confined aquifer signifies water discharges upwards through the clay lenses into the upper layer. Thus, the ground water in the lower aquifer leaves this portion of the study area by percolating upwards into the upper aquifer and then discharging into the Big Wood River through springs. The contours of both layers, which are approximately perpendicular

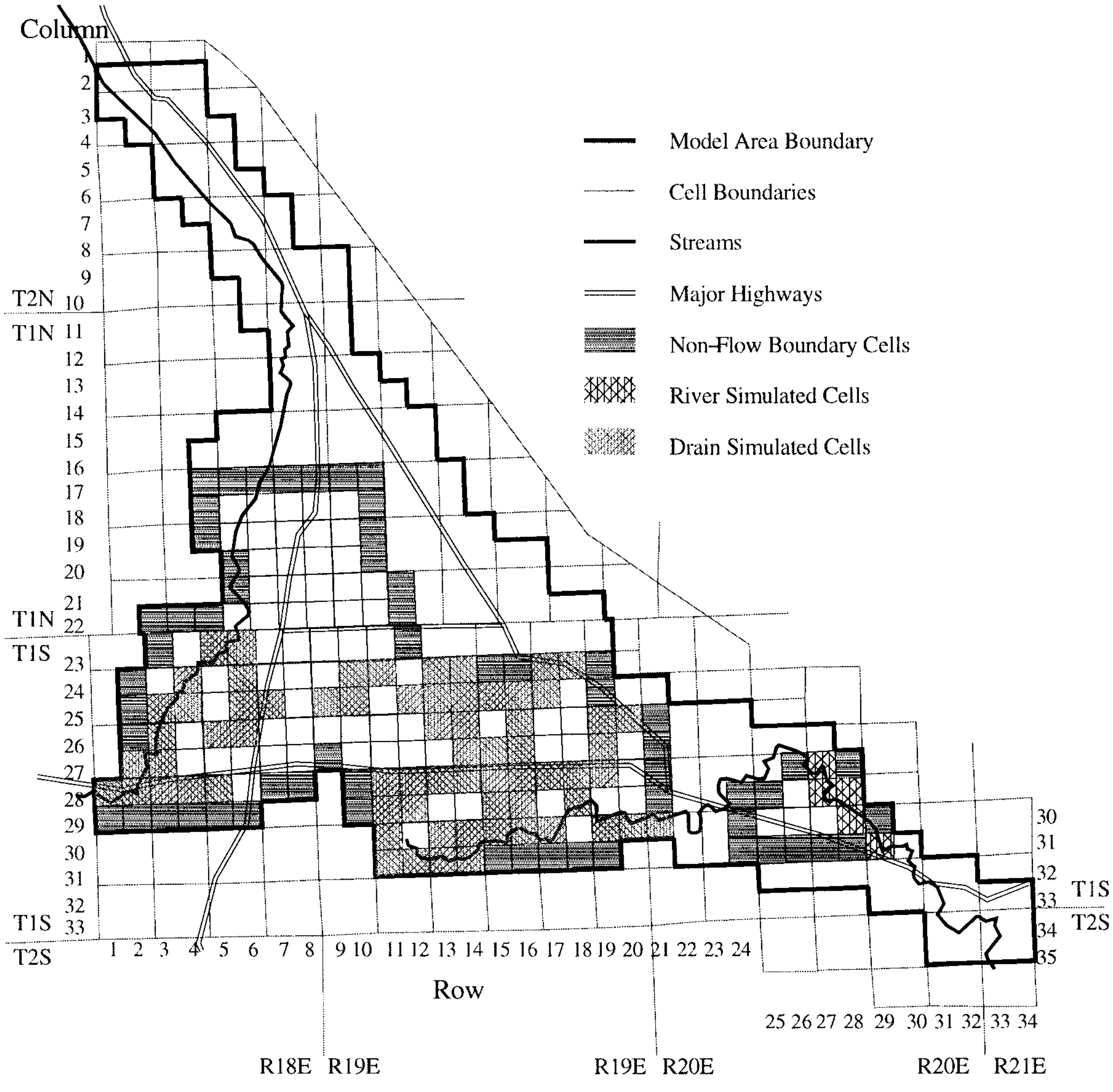


Figure 9. Boundary Conditions and River and Drain Simulated Cells, Layer 1

to the boundaries, show that underflow is insignificant along the boundaries other than the northern most boundary at Hailey and at Priest Road.

The ground water divide running approximately parallel to and east of State Highway 75 shifts with time of year and recharge conditions (Figures 10 and 11). West of the divide, ground water flows to springs tributary to the Big Wood River. East of the divide, ground water discharges via springs into Silver Creek or leaves the system as underflow into the Snake River Plain aquifer near Priest Road.

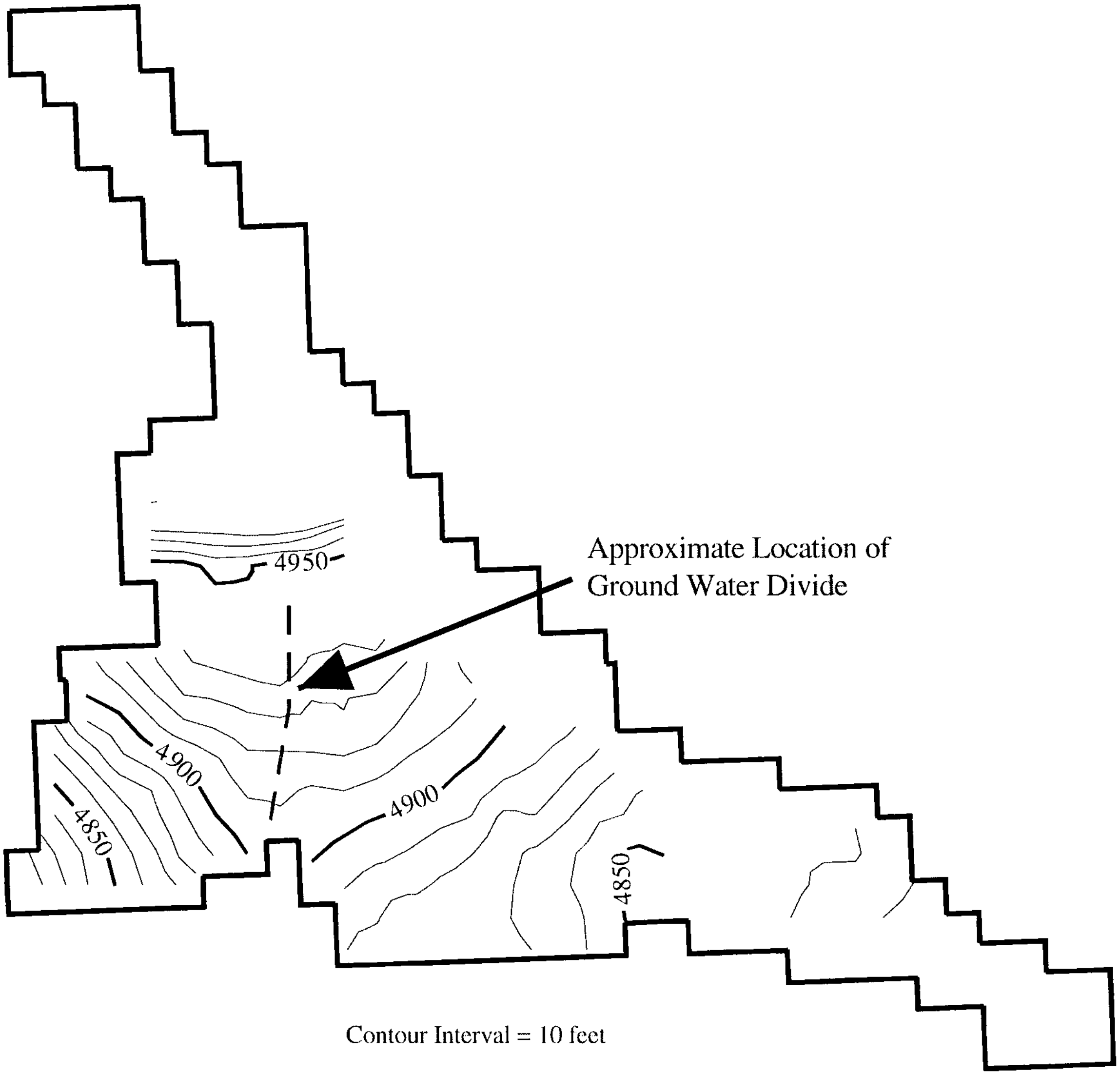


Figure 10. Layer 1 Spring 1993 Estimated Water Surface Elevation

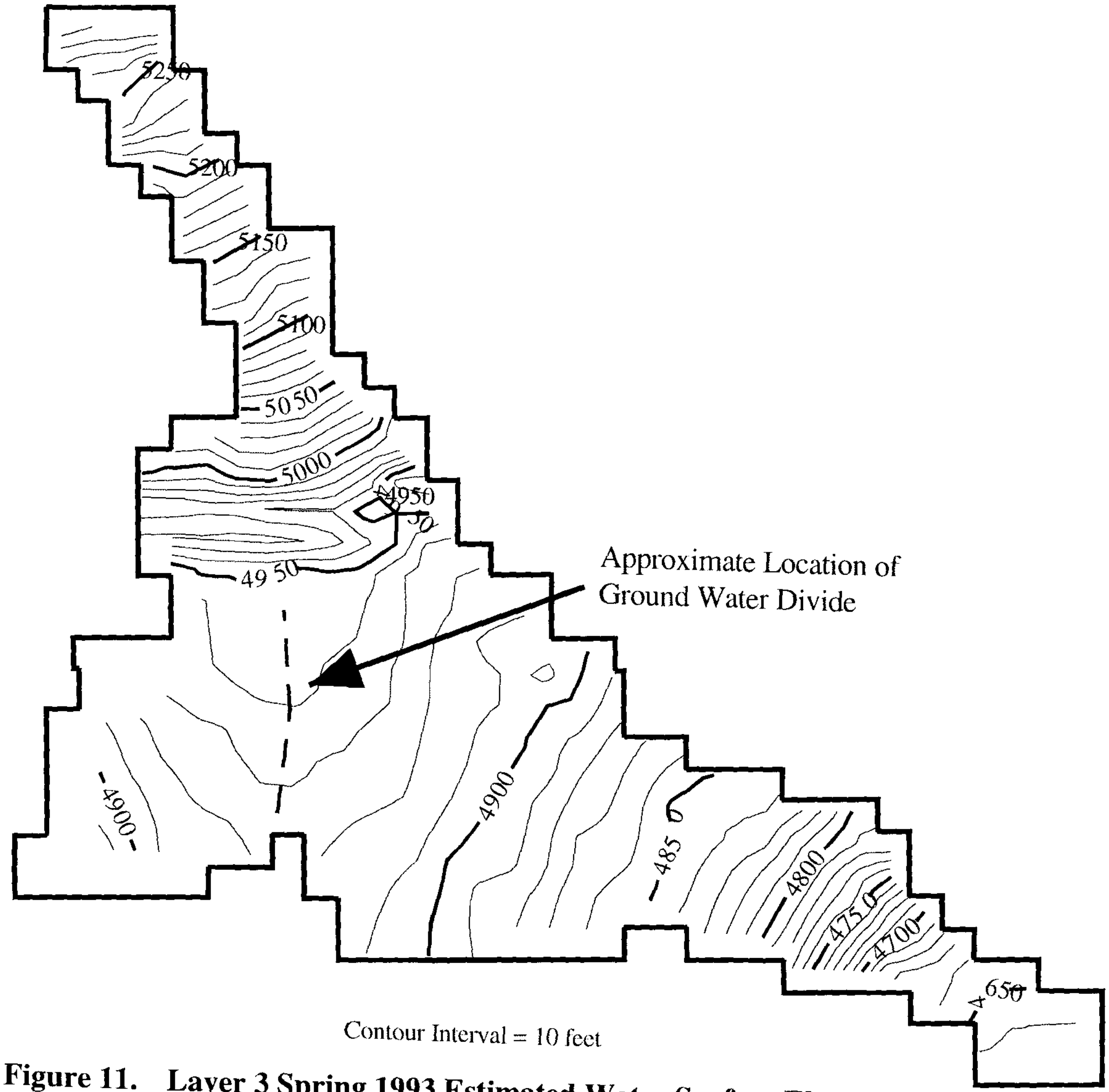


Figure 11. Layer 3 Spring 1993 Estimated Water Surface Elevation

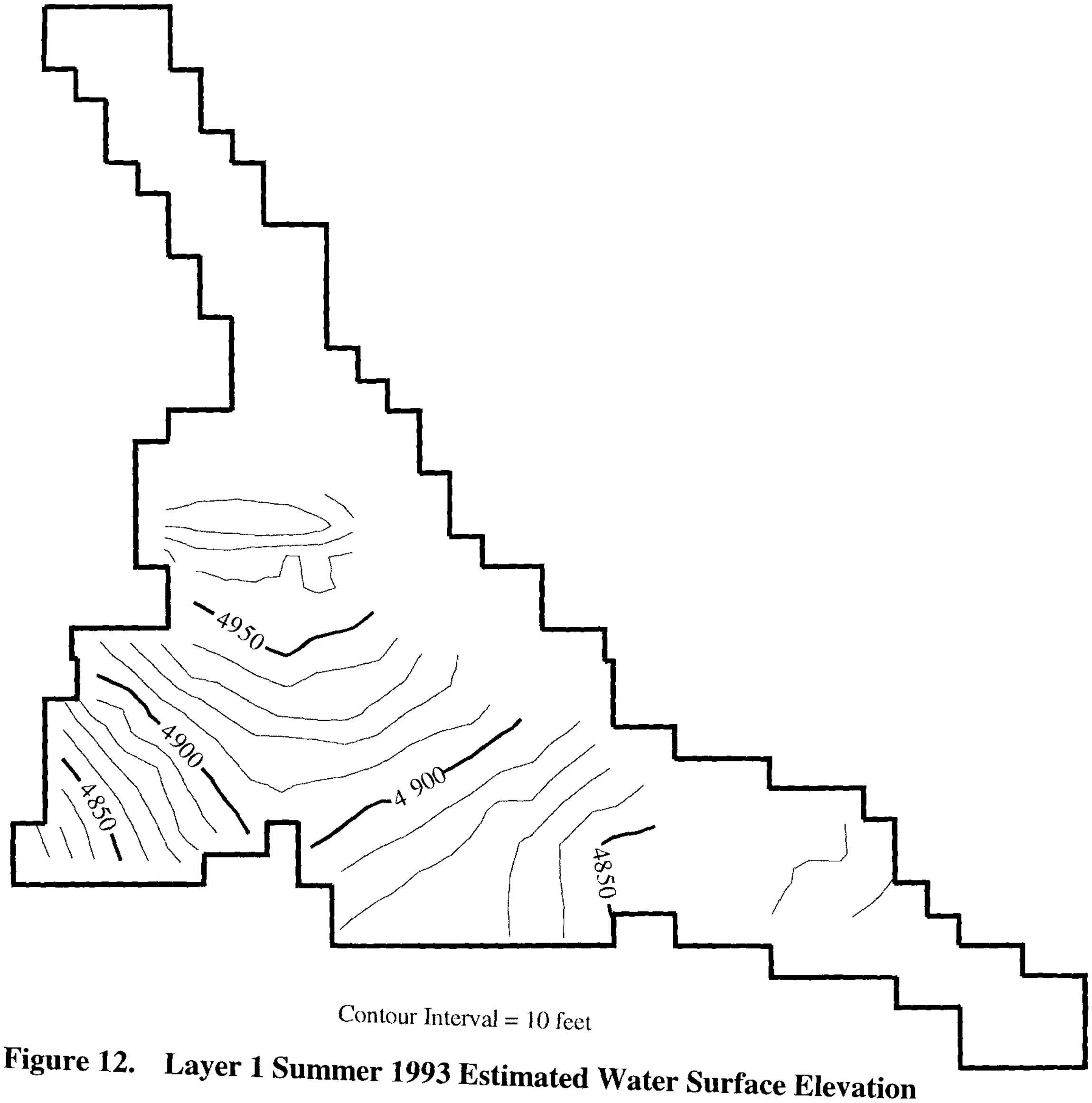


Figure 12. Layer 1 Summer 1993 Estimated Water Surface Elevation

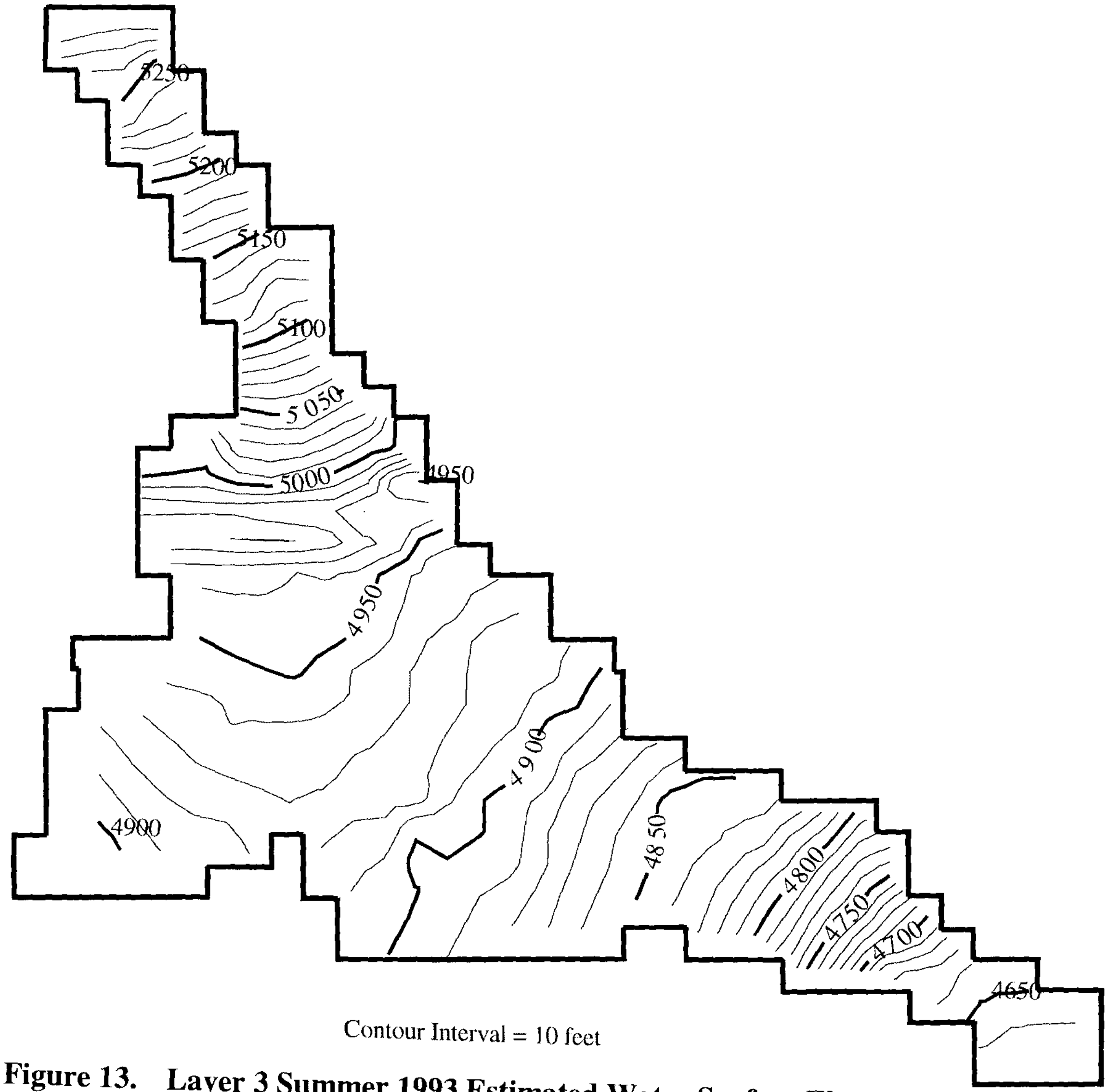


Figure 13. Layer 3 Summer 1993 Estimated Water Surface Elevation

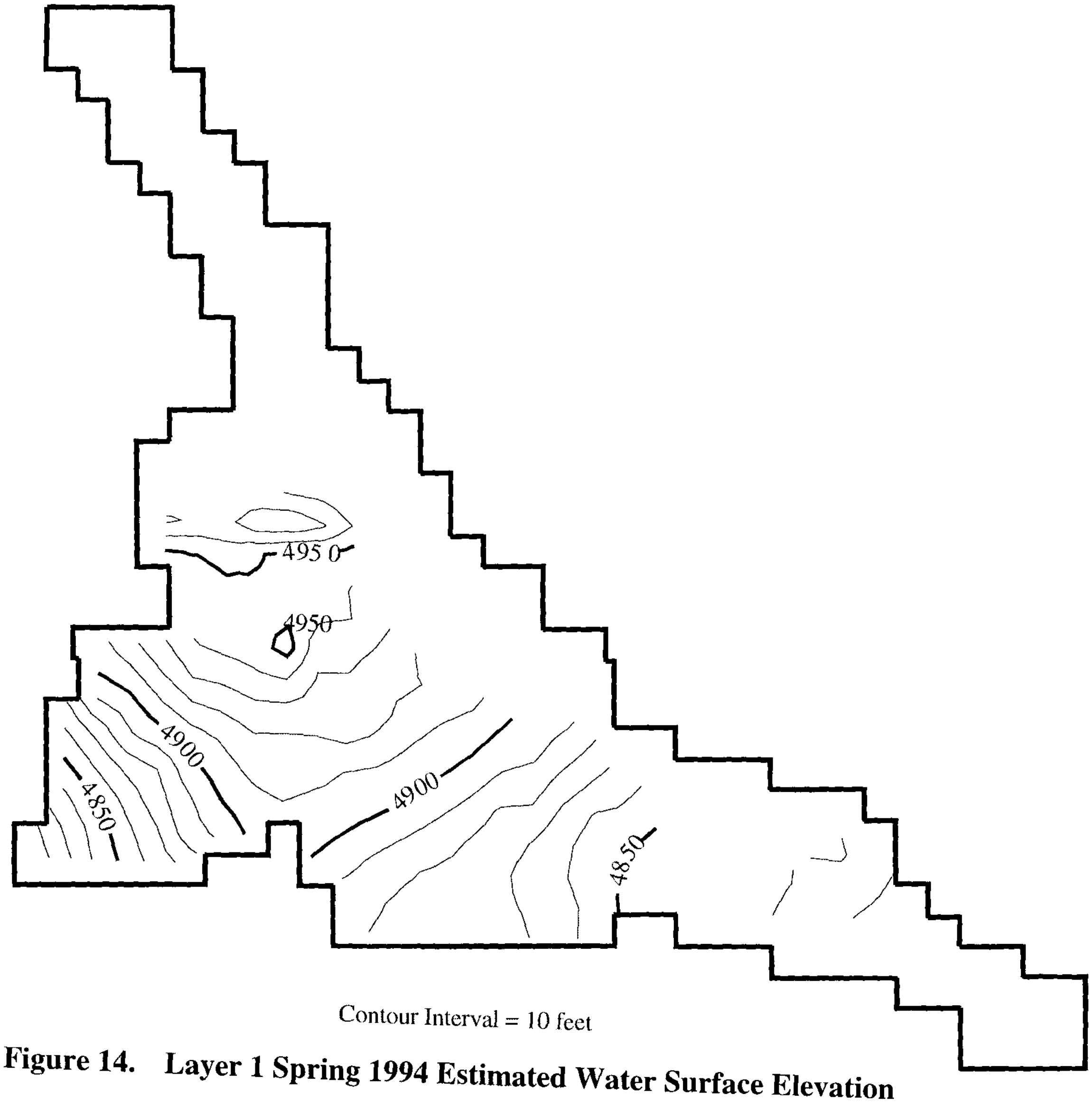
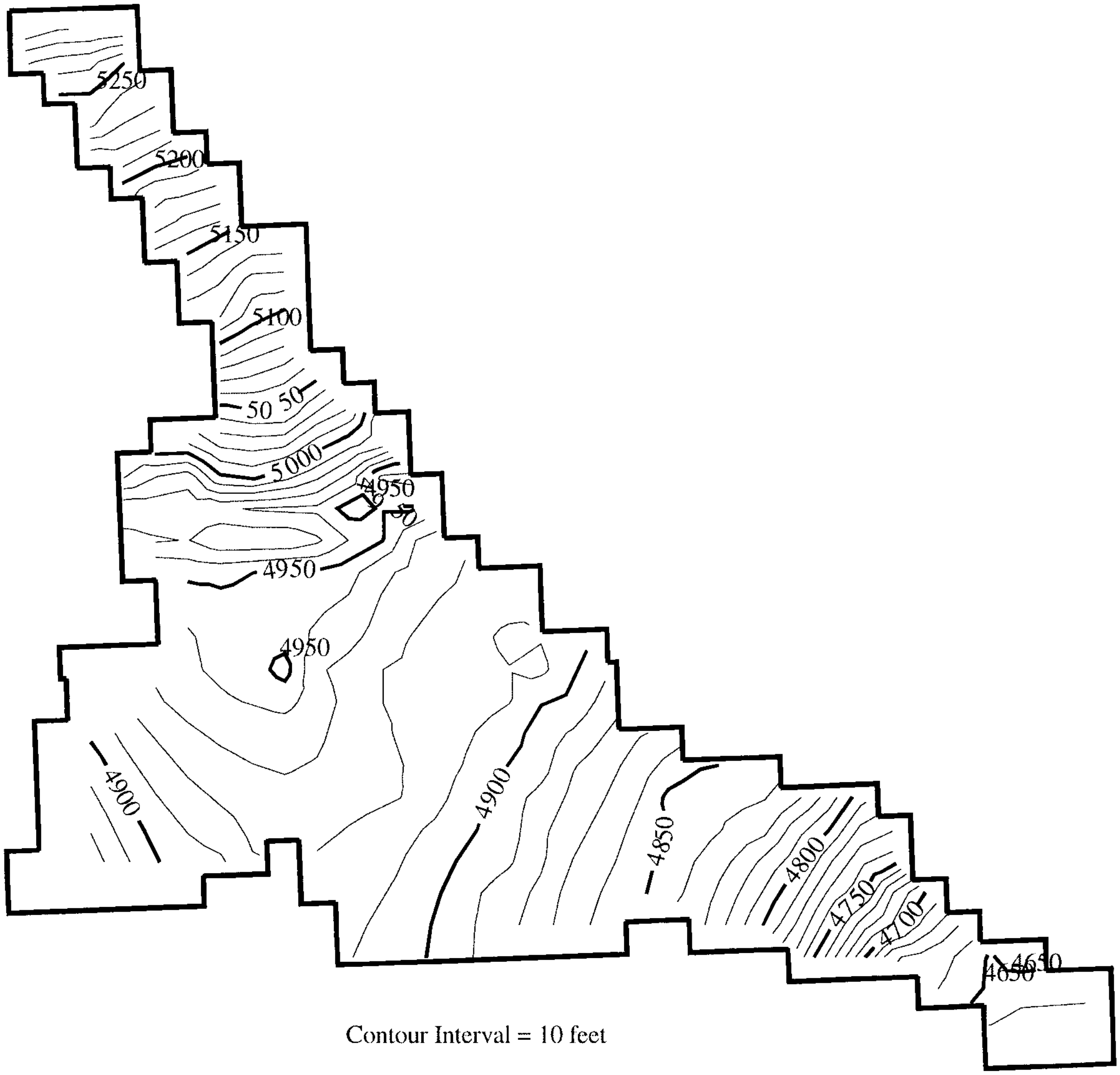


Figure 14. Layer 1 Spring 1994 Estimated Water Surface Elevation



Contour Interval = 10 feet

Figure 15. Layer 3 Spring 1994 Estimated Water Surface Elevation

MODEL CALIBRATION

Ground water model calibration generally has four objectives: minimize differences between measured (estimated) and simulated water surface elevations, minimize differences between measured and simulated ground water fluxes, maintain aquifer parameters within acceptable ranges for the geology of the area, and acceptable simulation mass balance errors – numerical stability. There are fixed guidelines for the first three objectives; however, it is generally accepted that simulation mass balance errors should be less than 1 percent. For this model, the maximum acceptable simulation mass balance error was 0.05 percent. The model calibration process involved generation of the water surface elevations (heads or hydraulic heads) during the four observation well mass measurement periods, and the top and bottom elevations of each aquifer in each active cell. Calibration also required development of a balanced water budget, installation of the data into the model, and adjustment of aquifer parameters to achieve the desired output for aquifer heads and outflows. The beginning period for the model calibration was April 16-30, 1993, coinciding with the first set of observation well measurements. The last period of the calibration, the 24th stress period, was for the period April 1-15, 1994. All the water movements in and out of each cell (flux) were averages for each time step. The fluxes were assumed constant for the time step and were applied at the center of each layer in the cell (node).

A table of the approximate dates corresponding to stress periods is presented in Table 1. This semi-monthly correlation was employed to calculate the average stress changes for each time step. However, for ease of data input, a constant 15.2 days (365 days/24 stress periods) per stress period was used. Some graphs presented in this report only have the stress period numbers shown on the horizontal axis and not the dates associated with these periods.

The length measurement units used in this model were feet, and the time units used were seconds. A standard discharge (flow) unit of cubic feet per second (ft^3/sec) was utilized for modeling.

The model was first calibrated in the steady state mode using specific average annual fluxes for inflows and outflows except for the underflow at Priest Road. The

Table 1. Approximate Stress Period Dates

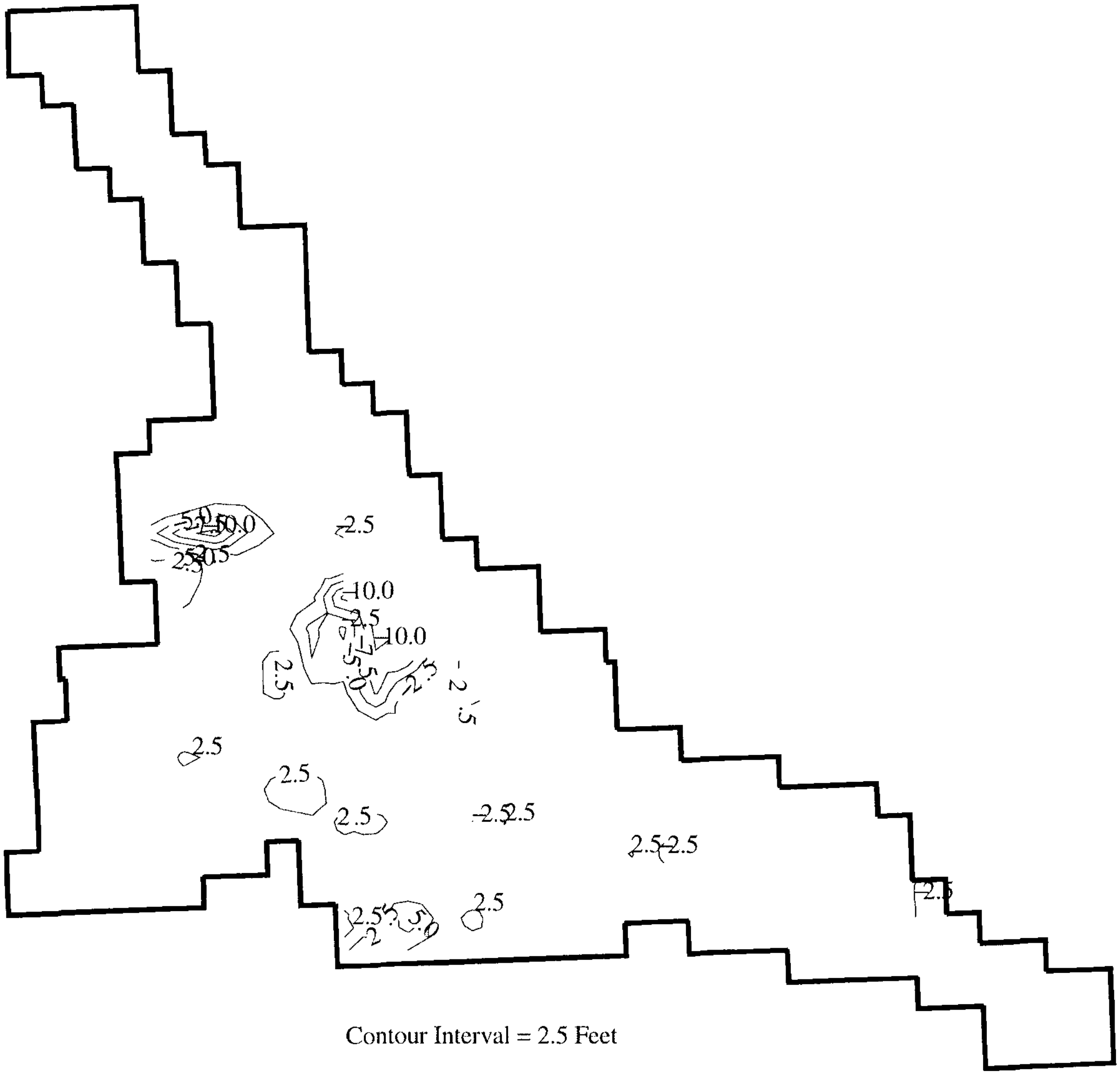
Stress Period Number	Dates
1	16-30 Apr.
2	1-15 May
3	16-31 May
4	1-15 Jun.
5	16-30 Jun.
6	1 -15 Jul.
7	16-31 Jul.
8	1-15 Aug.
9	16-31 Aug.
10	1-15 Sep.
11	16-30 Sep.
12	1-15 Oct
13	16-31 Oct
14	1-15 Nov.
15	16-30 Nov.
16	1 -15 Dec.
17	16-31 Dec.
18	1-15 Jan.
19	16-31 Jan.
20	1-14 Feb.
21	15-28 Feb.
22	1-15 Mar
23	16-31 Mar
24	1-15 Apr.

model boundary cells at Priest Road were simulated as constant head cells. The horizontal hydraulic conductivity and vertical conductance calibrated in this step were then used in the transient calibration. The parameters calibrated during the transient calibration were the storage coefficients for the unconfined and confined aquifer systems to match the change in water surface elevations. The drain and river elevations with their respective conductivities were adjusted to obtain the desired (measured) outflow hydrographs.

Water Surface Elevations

The water surface elevations measured in the observation wells during the four mass measurements from Phase I were used to develop the heads for each active cell with an inverse distance interpolation routine. The monitoring well network, well locations, and measurements are fully described in the Phase I report. On the basis of the interpolated values, additional control data points were incorporated in the data set to control the water surface elevation interpolation along the boundaries and at the spring discharge areas. These water surface elevations and piezometric heads were developed and contoured for the upper and lower layers. Figures 10 through 15 show the water table or piezometric head surfaces estimated for the confined and unconfined systems from the first, second, and fourth mass measurements. The heads for the third mass measurement collected in December 1993 produced contour and gradient patterns similar to the other three mass measurements. Figures 16 and 17 show the difference between spring 1993 and spring 1994 heads. An area of decline was observed in the southwest corner of the confined aquifer. The other changes are localized in a several cell area for both the upper and lower aquifers. These changes could be the results of the contouring method or localized conditions from well measurements.

In Phase I, the observation wells were assigned to the aquifer layer best represented by the well. The unconfined aquifer water surface was developed by combining the elevations of wells representing the water table, regardless of the physical location. The piezometric head of the confined system was developed using the wells representative of the confined aquifer where an aquitard was present and the water table wells located outside the area with an aquitard.



Contour Interval = 2.5 Feet

Figure 16. Layer 1 Difference Between Spring 1993 and Spring 1994

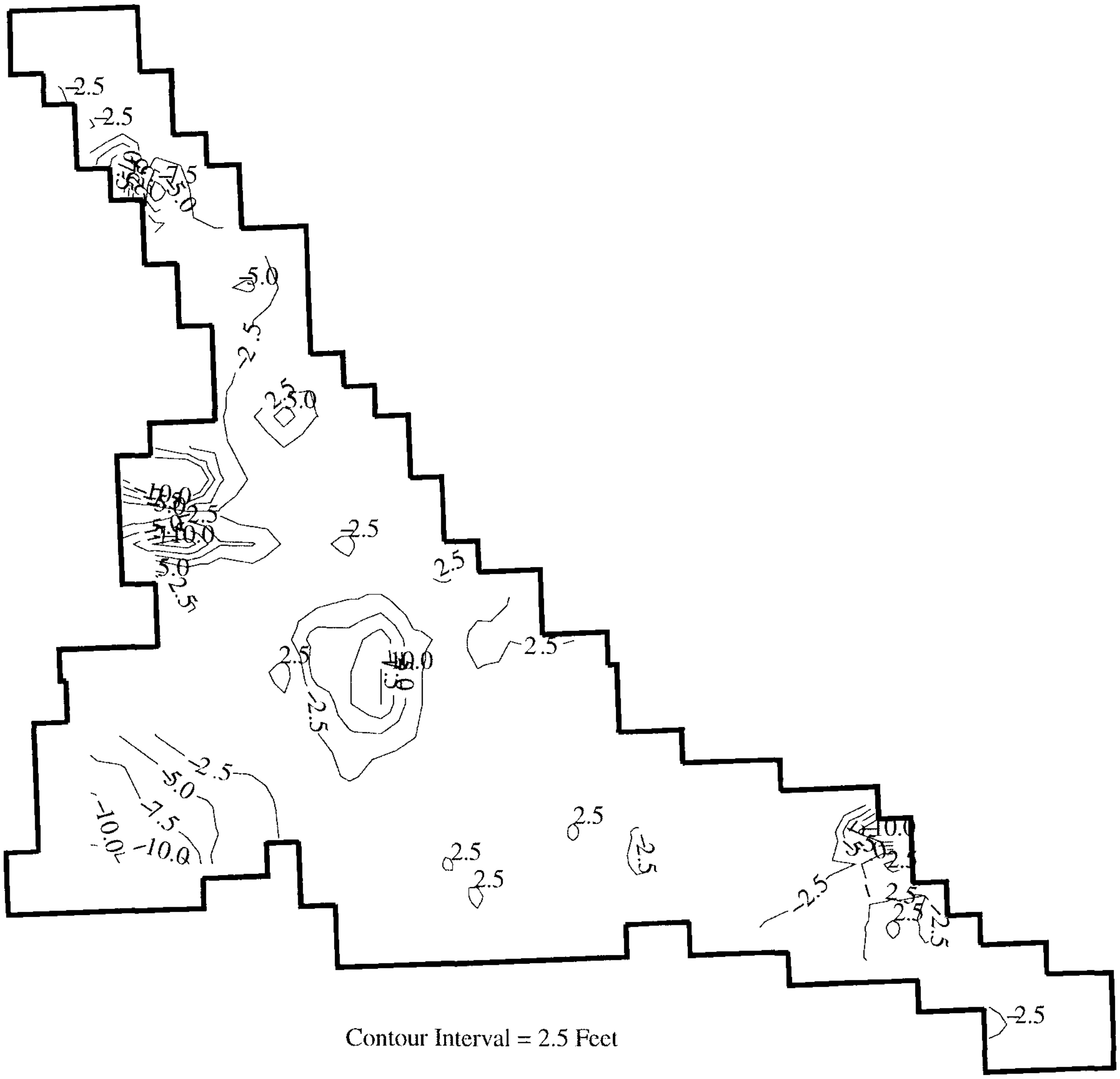


Figure 17. Layer 3 Difference Between Spring 1993 and Spring 1994

The beginning head values used for calibration in the steady state mode were the averages of the four observation well mass measurements. In steady-state mode, the beginning heads were also the ending heads and were the desired head values for the model to produce. The transient beginning heads were the values associated with the spring 1993 mass measurements. The target heads for transient simulations consisted of the values associated with the remaining three mass measurements. Seasonal variations of the water table elevation and piezometric head in the aquifers range from 5 to 20 feet as reported in

Phase I. These seasonal head changes also produced spring flow changes. The transient calibration objective was to simulate these measured aquifer responses and spring discharges.

Water Budget

A water budget was completed for 1993-1994 to define the recharge and discharge ground water components for this study period. A water budget includes all inflow and outflow components in the ground water system and can be defined as:

$$\text{inflow} - \text{outflow} = \text{change in aquifer storage}$$

There were differences between the beginning and ending water surface elevations for the calibration period as measured in the observation wells, but this difference was not deemed significant (Figures 16 and 17). Therefore, the calibration inflows and outflows for the period were assumed to be equal.

The major recharge (inflow) components for the ground water model included ground water underflow above Hailey, seepage from the Big Wood River, deep percolation from irrigation diversions, and precipitation. The discharge (outflow) from the system included ground water underflow at Priest Road, spring outflows to both the Big Wood River and Silver Creek, and evapotranspiration (ET) from crops.

The overall water budget, including surface and ground water for the modeled area, is presented in Figures 18 and 19. Figure 18 is a conceptual depiction of the study area and includes both surface water and ground water components. Inflow to and outflow from the modeled area are incorporated while distribution within the area is not. Figure 19 displays the magnitude of these flows in relationship to each other. The municipal ground water use was associated only with Hailey and Bellevue usage. Some municipal ground water originates from production wells and springs outside the study area in addition to water supplied from municipal deep wells within the study area.

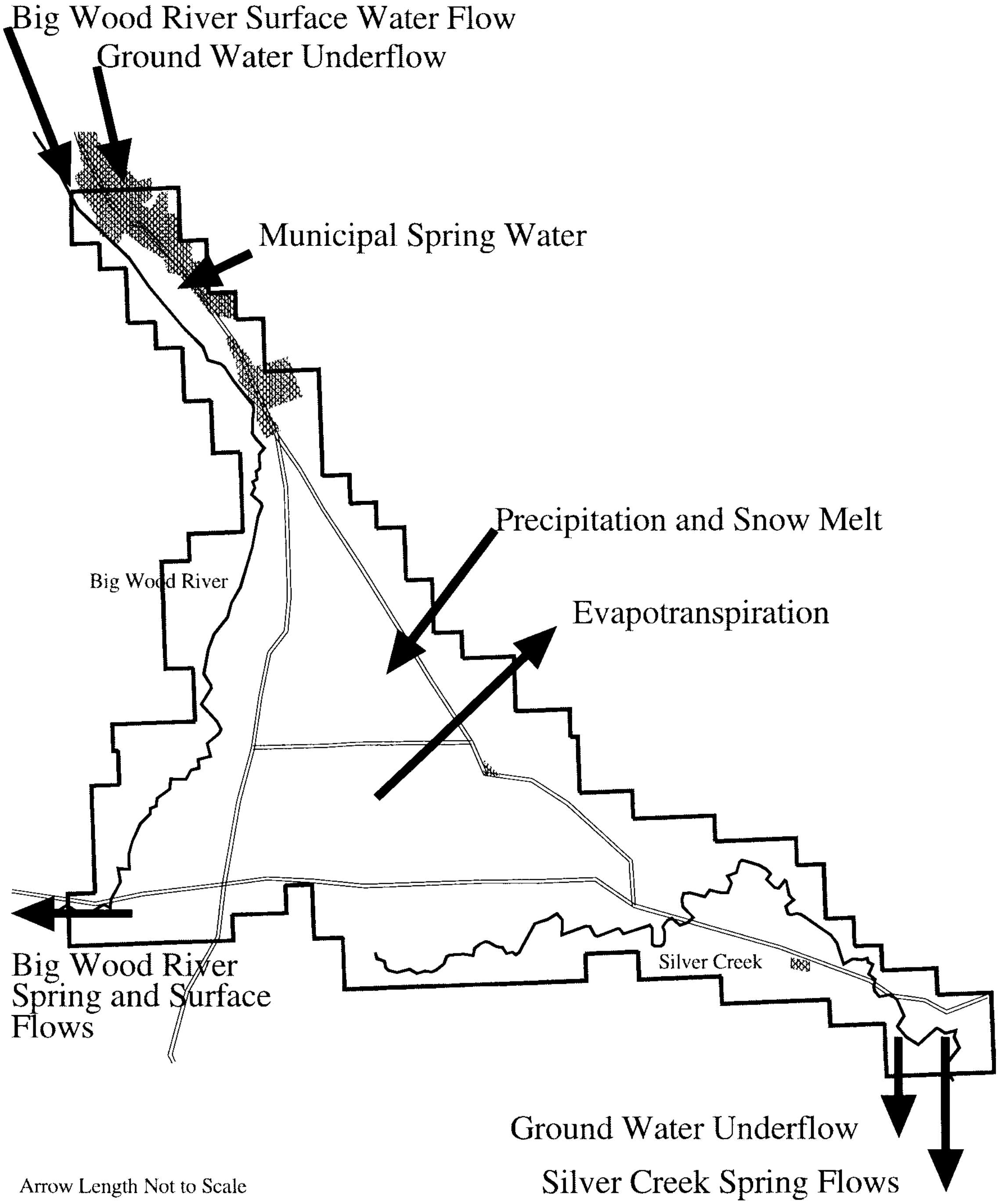


Figure 18. **Conceptual Big Wood River – Silver Creek Aquifer System Surface and Ground Water Budget**

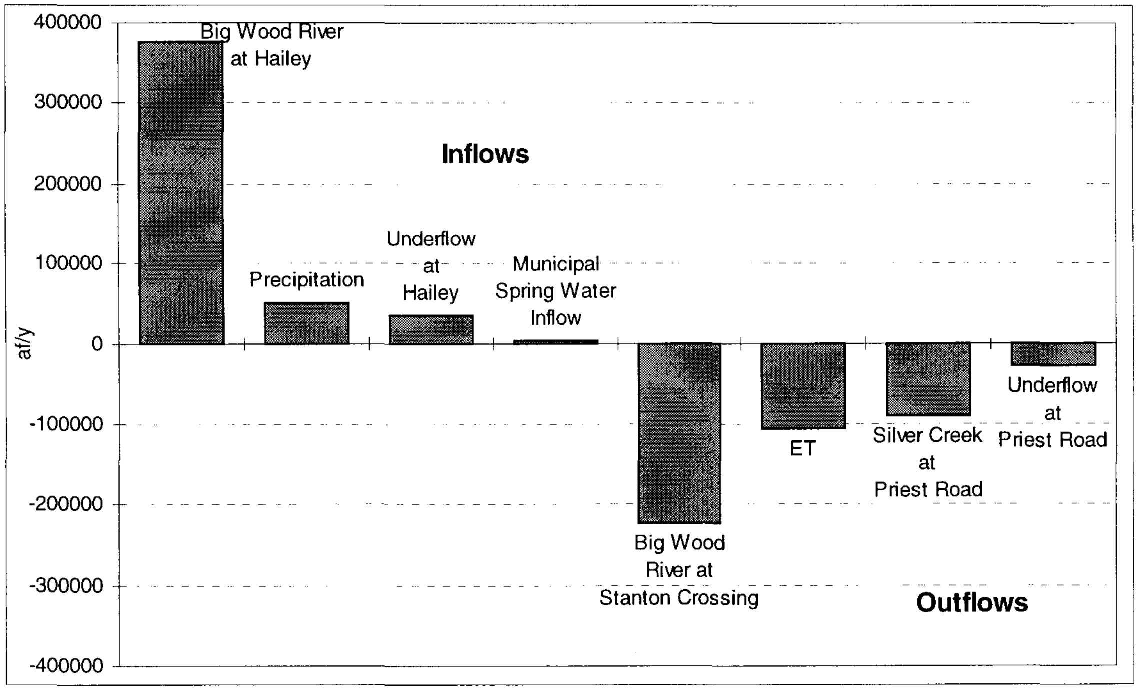


Figure 19. Big Wood River -- Silver Creek Aquifer System Surface and Ground Water Budget

Figure 20 represents the conceptual aquifer system ground water budget while Table 2 is the ground water budget for the study area. The outflow at Stanton Crossing includes only the ground water component produced by spring flows. The surface water inflow at Hailey was replaced with the seepage attributed to the Big Wood River and District 37 surface water diversions. The water supplied to the recharge pits was deducted from these diversions. The ground water irrigation diversions were included as both recharge and discharge to the system because many irrigated areas received water from multiple sources and consumptive use could not be associated with a single source. Thus, these diversion-related discharges and recharges were equal in magnitude. The consumptive use, a separate term, depletes the combined irrigation diversion and precipitation term. When the point of diversion was the same as the point of use, the net effect on the cell involved would be the crop consumptive use. When the point of diversion was not the point of use, one node experienced a recharge while another node experienced a discharge. The ground water irrigation diversions also included the year around flow of the Lucke and Stevenson artesian wells and the nonconsumptive water use of the Hayspur Fish Hatchery. Surface water irrigation diversions from Silver Creek were also both a recharge and discharge to the system as were the ground water irrigation diversions.

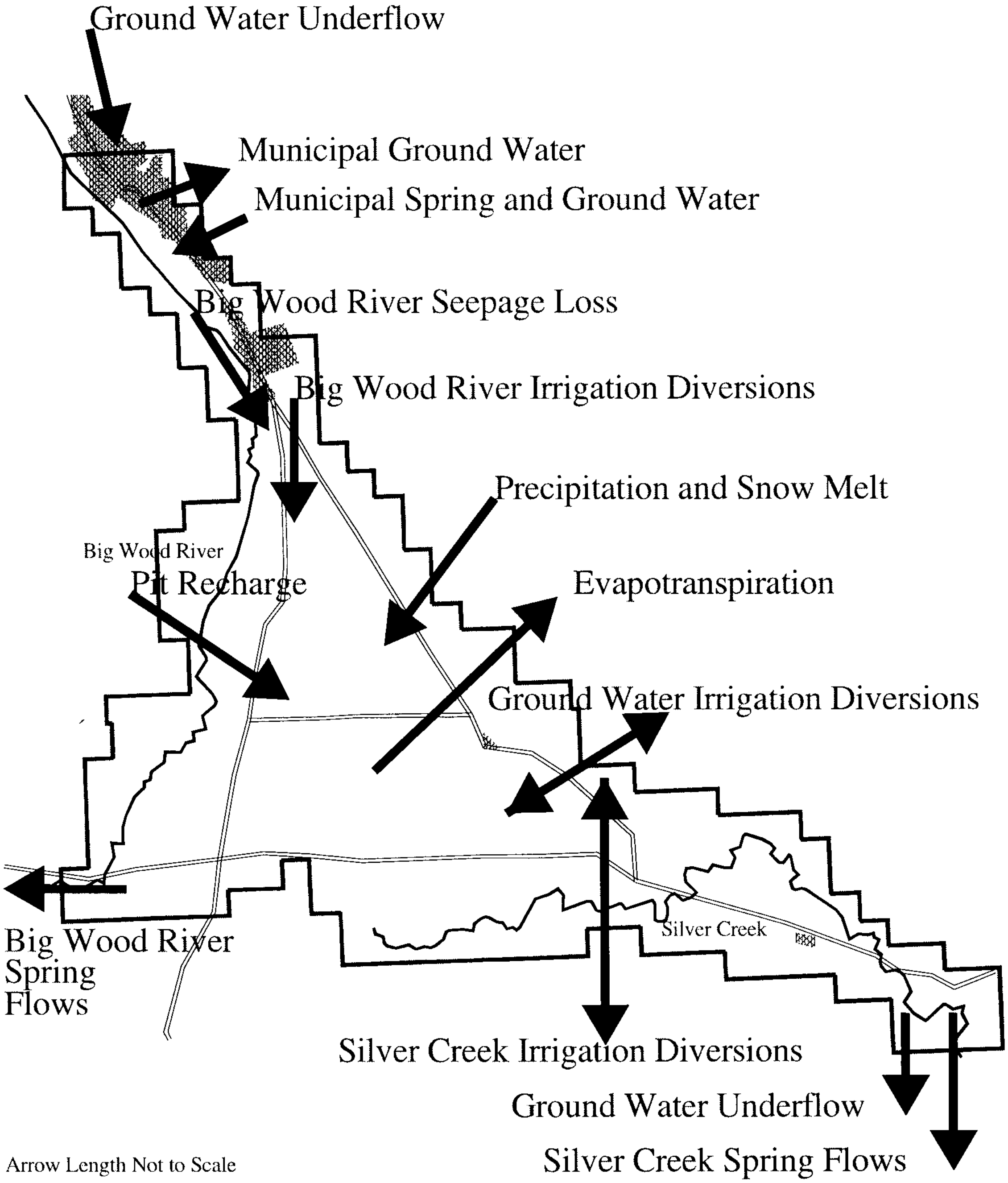


Figure 20. Conceptual Big Wood River – Silver Creek Aquifer System Ground Water Budget

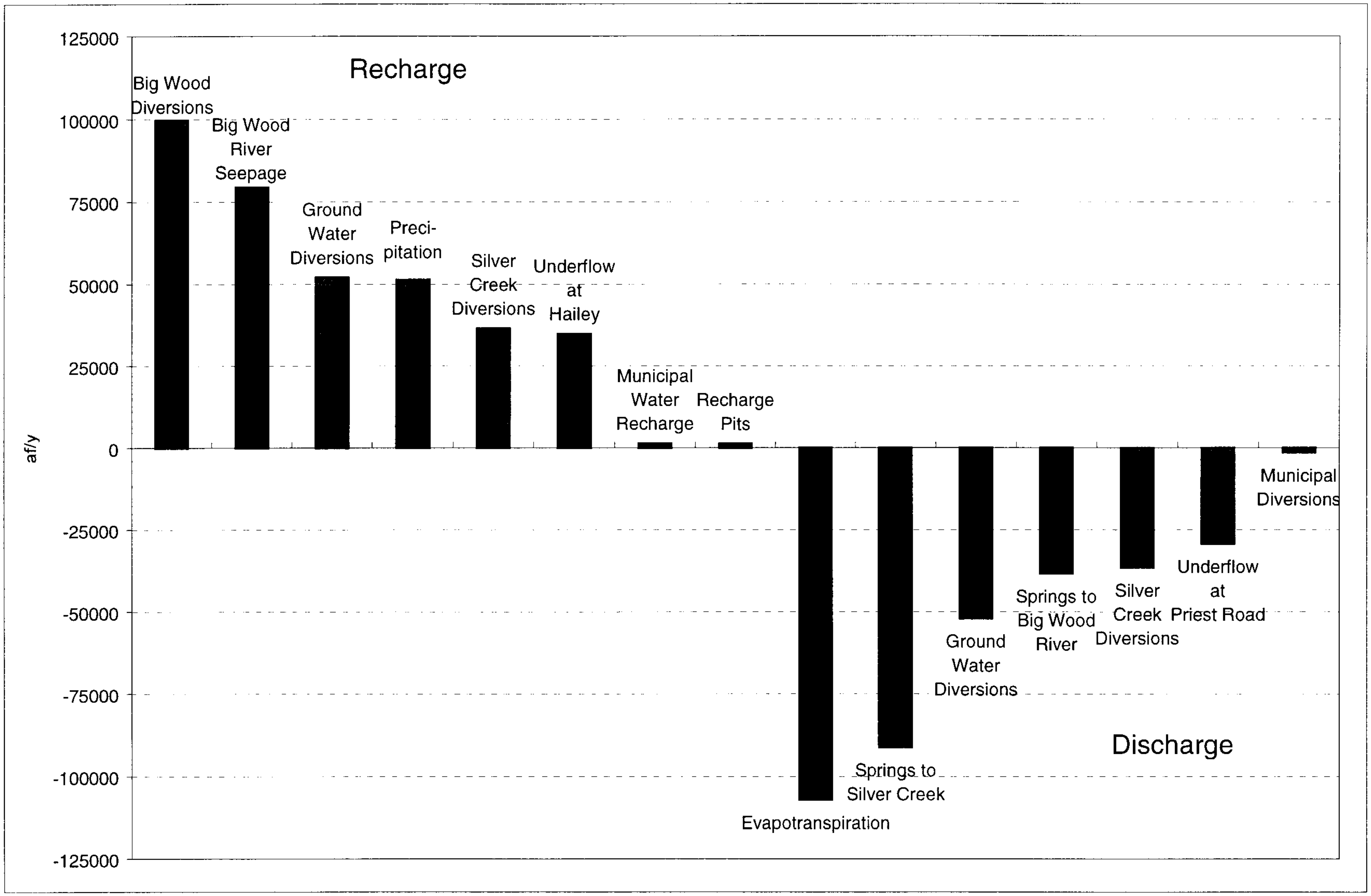
Table 2. Ground Water Budget

Source	Inflows (af/y)	Outflows (af/y)
Big Wood River Diversions	99700	
Big Wood River Reach I & II Seepage	79200	
Ground Water Irrigation	52000	
Precipitation	51300	
Silver Creek Diversions	36500	
Underflow at Hailey	34800	
Municipal Spring & Ground Water	2800	
Pit Recharge	1400	
Total Inflow	357700	
ET		107100
Silver Creek Springs		91100
Ground Water Irrigation		52000
Big Wood River Springs		38300
Silver Creek Diversions		36500
Underflow at Priest Road		29300
Municipal Ground Water		1400
Total Outflow		355700
Error		2000

The ground water budget was based on the water budget presented in Figure 16 of Phase I. The final ground water budget for Phase II, shown in Figure 21, was the result of additional data and analysis. (The differences among the data presented in the Phase I and Phase II reports are presented here and analyzed in later sections.) The largest change was in the Big Wood River seepage between Hailey and Glendale Bridge. Phase I listed 22,400 acre-feet per year (af/y) and Phase II uses 79,200 af/y for the calibration water budget. Underflow at Hailey (34,880 af/y), irrigation diversions (99,700 af/y), pit recharge (1,400 af/y), precipitation (51,300 af/y), and spring flows at Stanton Crossing (38,300 af/y) and Priest Road (91,100 af/y) remained approximately the same as reported in Phase I. Evapotranspiration was considerably higher, increasing from 66,500 in Phase 1 to 107,100 af/y in Phase II. The larger seepage loss for the Big Wood River required increasing the underflow from 11,800 to 29,300 af/y at Priest Road.

Phase I did not include the ground water irrigation diversions and the surface water irrigation diversions from Silver Creek in Water District 37M in the water budget. As explained earlier, both of these types of diversions were treated as a discharge and a recharge to the system. The other major differences were the unreported surface diversions

Figure 21. Big Wood River -- Silver Creek Aquifer System Ground Water Budget



that occurred after September 30 through mid-November. Other Phase I information extracted from Brockway and Grover (1978) did not always account for differences between the study areas.

Recharge

Underflow at Hailey

Significant boundary underflows of the Big Wood River-Silver Creek aquifer occur at two locations, Hailey and Priest Road. The underflow at Hailey recharges the system, while the underflow at Priest Road discharges the system. The underflow at Hailey was assumed to be a fixed inflow that was not affected by aquifer response to stresses.

Darcy's porous media flow equation was used to calculate underflow in the northern region of the study between Hailey and Bellevue. Darcy's equation relates aquifer flow to saturated flow area with hydraulic conductivity and ground water gradient. Several water surface elevation gradients were compared and averaged. The Big Wood River has a profile gradient of 0.008 ft/ft in this region, and Phase I measured ground water gradients associated with two wells in the area as 0.004 and 0.006 ft/ft. The average of the above three gradients was 0.006 ft/ft. The aquifer width for the northern area was approximately 1.5 miles; the estimated saturated thickness was 65 feet based on well drillers' logs and other investigations (Luttrell and Brockway, 1984; Frenzel, 1989; and Brockway and Grover, 1978). The hydraulic conductivity for gravel with fines was estimated at 0.025 ft/sec or 2160 ft/day (Das, 1994). Using this information and Darcy's equation, an estimated aquifer flow of 78 cfs was calculated for the aquifer system south of Hailey.

Big Wood River seepage between the northern boundary and up gradient of the underflow calculation area was estimated at 30 cfs. Therefore, the 78 cfs aquifer flow was reduced by 30 cfs, resulting in an estimated underflow at Hailey of 48 cfs (34,800 af/y). This underflow was distributed equally into the four northern most cells of the study area and was assumed to be constant throughout the year.

Other studies of the area have identified a range of underflow values. Smith (1959), Luttrell and Brockway (1984), and Frenzel (1989) estimate underflow at Hailey as 34,000, 40,000, and 13,000 af/y (47, 55, and 18 cfs) respectively. Brockway and Grover (1978) list a value of 59,200 af/y (82 cfs) as underflow at Bellevue, some 4.5 miles south of the current boundary. Phase I stated that, "The variation is due to the methodology of analysis and the values of hydraulic conductivity used." The 34,800 af/y used for this study was comparable to most of the other studies.

Big Wood River Seepage

A major contribution to the recharge of the aquifer was the seepage of the Big Wood River in the northern part of the valley between Hailey and the Glendale Bridge. These seepages and canal diversions were the two factors that accounted for the decrease in stream flow between the Hailey USGS gage and the Stanton Crossing USGS gage. The river was subdivided into three reaches for the study as shown in Figure 6. Reach I was from the Hailey gage to the Glendale Bridge; Reach II was from the Glendale Bridge to above the Bypass Canal return; and, Reach III was between the Bypass return and Stanton Crossing. Individual reach gains/losses were computed from diversion records and measured or known stream flows entering or leaving the reach. Reaches I and II were primarily losing reaches. The lower reach of the river, from Stanton Crossing upstream approximately five miles, was a gaining reach due to spring discharges from the aquifer.

During the late summer months, the entire flow of the river was diverted for irrigation through the District 45, Bypass, and other canals. These diversions left the riverbed dry from Glendale Bridge to below the Baseline Road as verified in the Watermaster's records. The reach gains/losses for Reaches I and III were initially estimated when the flow at Glendale Bridge was zero. The initial estimates for Reach II losses were based on periods with flow at Glendale Bridge and the other reach gain/loss estimates.

The Reach III gains during the summer months were calculated using a flow balance from Stanton Crossing upstream, while the losses in Reaches I and II were calculated using a balance from Hailey downstream, with the Glendale Bridge being the central point. During periods when the river was dry below Glendale Bridge, the Reach I losses (seepage) were calculated as the difference between the gage at Hailey and canal diversions. Reach II gains/losses plus Reach III gains and stream inflows equal the flow at Stanton Crossing plus Reach II canal diversions during this period. During the winter months when there were no diversions, Reach I and Reach II losses plus Reach III gains equal the difference between the gages at Hailey and Stanton Crossing. Several iterations were made to obtain average values that looked compatible for all three reaches. An increase in Reach III gain would also mean an increase in Reach I and II losses.

Reach I was calculated as being 81% of the total distance of Reach I and Reach II. These two reaches were then linked together when both reaches were losing at the same time, yielding the loss proportional to the length of the distance of the Big Wood River in each reach. The river loses 80% of its flow to seepage during the low flow periods (Table 3).

The estimated reach gain/loss from the above procedure was used in the initial phase of the steady-state calibration process. When the horizontal and vertical conductivities used to calibrate the steady-state model were utilized in the transient calibration, the model would not converge. The calculated heads of the northern region of the model area were either too high when compared to the mass measurement heads of the summer of 1993 or too low when compared with the winter of 1993 mass measurements. Because of the high volume of water estimated to be flowing as underflow in the narrow valley, horizontal conductivity values were increased to allow for ground water movement through the valley as well as to allow simulation of the higher summer heads. When the high seepage rates due to spring time river flows and percolation from excess irrigation water application where reduced or removed, the heads decreased below desired levels. With the high

Table 3. Big Wood River Gains and Losses by reach.

Period	Time Step	Flow @ Hailey Gage cfs	Diversions in Reach I cfs	Reach I Losses Percolation cfs	Flow @ Glendale Bridge cfs	Diversions in Reach II cfs	Reach II Losses Percolation [Top-Down - Bottom-Up] cfs	Flow @ Bypass Bottom-Up cfs	Reach III Gain cfs	Reach III Stream Inflow cfs	Flow @ Stanton Bridge cfs
16Apr-30Apr	1	526.8	37.4	171.3	318.1	15.3	40.2	262.6	54.0	36.4	353.0
1May-15May	2	1246.0	56.9	304.5	884.6	29.6	71.4	783.6	54.0	36.4	874.0
16May-31May	3	2574.5	352.0	348.1	1874.4	34.6	81.7	1758.2	54.0	38.8	1851.0
1Jun-15Jun	4	1898.1	294.8	167.1	1436.3	15.2	39.2	1382.0	54.0	48.1	1484.0
15Jun-30Jun	5	1738.5	375.1	200.7	1162.8	13.4	47.1	1102.3	54.0	45.8	1202.0
1Jul-15Jul	6	932.9	369.7	250.5	312.8	26.5	58.8	227.5	54.0	42.5	324.0
16Jul-31Jul	7	656.7	375.0	164.6	117.1	24.5	38.6	54.0	54.0	48.0	156.0
1Aug-15Aug	8	382.4	298.2	84.2	0.0	28.1	-28.9	0.8	103.0	48.2	152.0
15Aug-31Aug	9	224.2	233.5	-9.3	0.0	11.9	-12.1	0.2	57.6	49.2	107.0
1Sep-15Sep	10	202.8	139.8	63.0	0.0	10.1	-10.1	0.1	35.6	42.4	78.0
16Sep-30Sep	11	203.0	118.0	85.0	0.0	11.9	-12.0	0.1	30.0	46.9	77.0
1Oct-15Oct	12	202.5	118.0	84.5	0.0	11.9	-12.4	0.5	20.0	48.1	68.5
16Oct-31Oct	13	219.8	118.0	101.8	0.0	11.9	-11.9	0.0	28.0	48.7	76.7
1Nov-15Nov	14	175.3	118.0	57.3	0.0	11.9	-12.3	0.4	26.0	46.0	72.4
16Nov-30Nov	15	138.8	118.0	20.8	0.0	11.9	-12.1	0.2	20.0	45.3	65.5
1Dec-15Dec	16	156.6		126.2	30.4		29.6	0.8	18.0	40.3	59.1
16Dec-31Dec	17	149.3		120.9	28.4		28.4	0.0	13.6	34.9	48.5
1Jan-15Jan	18	148.8		117.3	31.5		27.5	4.0	15.5	22.3	41.8
16Jan-31Jan	19	145.5		110.1	35.3		25.8	9.5	11.7	16.9	38.1
1Feb-14Feb	20	114.2		90.4	23.8		21.2	2.6	12.6	18.1	33.2
15Feb-28Feb	21	124.3		100.7	23.6		23.6	0.0	8.9	23.9	32.8
1Mar-15Mar	22	150.2		121.6	28.6		28.5	0.0	11.4	33.6	45.0
16Mar-31Mar	23	178.2		143.9	34.3		33.8	0.5	14.0	22.8	37.3
1Apr-15Apr	24	173.1	6.2	160.7	6.1	1.9	37.7	0.7	14.0	22.7	37.3
Totals (af/y)		381750	94316	96048	191385	8156	15712	168544	24659	27311	220515

conductivity values used, the ground water moved through the region so rapidly that the model calculated heads were lower than desired with the lower flows. Variation of the horizontal and vertical conductivities would not produce convergence in transient mode. An adjustment in the flow stresses was required to obtain model convergence.

Adjusting the gage flows at Hailey and at Stanton Crossing by less than ±5% and the Watermaster records by less than ±10% allowed the model to converge in transient mode. The USGS rates the Hailey and Stanton Crossing records as "good" and "fair", respectively. The good and fair ratings indicate that 95% of the time the reported discharge was within 10 and 15% of the true value.

The computed flows were also adjusted at the Glendale Bridge. During August, the flow at Hailey was increased to account for the high Reach III gain. If the flow at the Hailey gage was not increased and the flow at the Glendale Bridge was set to 0.0 as per the Watermaster's records, the gain in Reach III would be significantly greater than the flows of Brock and Willow Creek. No other stress periods showed this trend. From these adjustments, a Reach III average gain of approximately 15 cfs was calculated. The seasonal variation of the gain was determined in part with measured seasonal variations of two spring fed streams, Brock Creek and Willow Creek. These two creeks are tributary to Reach III in the vicinity of Stanton Crossing. Castelin (1972) also estimated this gain at 15 cfs.

The equation used to calculate the reach loss/gain was therefore:

$$\text{Gage at Hailey} - \text{Gage at Stanton} - \text{Canal Diversions} = (\text{Reach I loss} + \text{Reach II loss} - \text{Reach III gain})$$

with Reach I equaling 81% and Reach II equaling 19% of the total losses when applicable.

The adjusted estimates of the reach gains/losses during the calibration period are given in Table 4. The Reach I Percolation column of this table shows the Big Wood River has an average seepage loss of 109 cfs. Reach I was seven miles long. The point of calculations used to define the underflow at Hailey was two miles downstream of the

Table 4. Adjusted Big Wood River Reach Gains/Loses

Period	Flow @ Hailey Gage cfs	Diversions in Reach I cfs	Reach I Losses Percolation Cfs	Flow @ Glendale Bridge cfs	Diversions in Reach IIa cfs	Reach II Losses Percolation [Top-Down - Bottom-up] cfs	Canal Water Return to BWR cfs	Flow @ Bypass Bottom-up cfs	Reach III Gain cfs	Reach III Stream Inflow cfs	Flow @ Stanton Bridge cfs
16Apr-30Apr	500.5	37.4	103.5	359.6	15.3	24.3		320.0	14.2	36.4	370.7
1May-15May	1186.6	62.6	181.7	942.3	32.6	42.6		867.1	14.2	36.4	917.7
16May-31May	2346.4	352.0	131.9	1862.6	34.6	30.9		1797.0	15.2	38.8	1851.0
1Jun-15Jun	1883.0	294.8	126.3	1461.9	15.2	29.6		1417.2	18.8	48.1	1484.0
15Jun-30Jun	1689.7	375.1	132.0	1182.7	13.4	31.0		1138.4	17.9	45.8	1202.0
1Jul-15Jul	886.3	406.6	137.2	342.4	29.1	32.2		281.1	16.6	42.5	340.2
16Jul-31Jul	617.1	375.0	97.7	144.4	24.5	22.9		97.0	18.8	48.0	163.8
1Aug-15Aug	521.9	328.0	99.2	94.7	30.9	-10.0		73.8	22.4	48.2	144.4
15Aug-31Aug	359.3	233.5	100.0	25.8	11.9	-19.2		33.1	19.4	49.2	101.7
1Sep-15Sep	224.7	139.8	84.9	0.0	10.1	-25.2		15.2	16.6	42.4	74.1
16Sep-30Sep	203.0	118.0	85.0	0.0	11.9	-17.4		5.4	20.8	46.9	73.2
1Oct-15Oct	202.9	118.0	85.0	0.0	11.9	-12.8		0.9	18.8	48.1	67.8
16Oct-31Oct	206.6	118.0	88.6	0.0	11.9	-14.5		2.6	21.6	48.7	72.9
1Nov-15Nov	175.7	118.0	57.8	0.0	11.9	-15.4		3.5	19.3	46.0	68.8
16Nov-30Nov	132.2		117.4	14.8		14.8		0.0	16.9	45.3	62.2
1Dec-15Dec	156.9		121.8	35.1		29.2		6.0	15.8	40.3	62.1
16Dec-31Dec	140.3		111.6	28.7		26.3		2.4	13.6	34.9	50.9
1Jan-15Jan	149.1		111.1	38.0		25.1		12.9	8.7	22.3	43.9
16Jan-31Jan	136.7		97.5	39.2		22.6		16.5	6.6	16.9	40.0
1Feb-14Feb	122.6		91.8	30.9		21.2		9.7	7.1	18.1	34.9
15Feb-28Feb	124.3		101.0	23.3		22.0		1.2	9.3	23.9	34.4
1Mar-15Mar	150.5		122.4	28.2		27.6		0.6	13.1	33.6	47.3
16Mar-31Mar	159.1		122.0	37.1		29.6		7.5	8.9	22.8	39.2
1Apr-15Apr	173.1	6.2	119.4	47.5	1.9	28.0		17.6	8.9	22.7	37.3
Totals (AF)	375761	93057	79283	203421	8061	10425	0	184935	10970	27344	223249

beginning of Reach I. Multiplying the total average seepage in Reach I by this 2/7's distance produced the 30 cfs that was utilized in the determination of the underflow at Hailey (previous section).

Phase I listed the Big Wood River seepage as 22,400 af/y, and attributed the estimate to Luttrell and Brockway (1984). However, the estimate appears to be based upon Brockway and Grover (1978). Their flow estimate was based on five flow measurements for Reach I, three measurements of Reach II, four measurements of Reach III, and one measurement of Reach I and Reach II in 1975-1976. These measured flow rates were then extrapolated to obtain a yearly flow volume for the three reaches. Luttrell and Brockway (1984) only report a Big Wood River stream loss between Hailey and Glendale Bridge of 57 cfs based on a late summer measurement. During this period, stream seepage is relatively low. This 57 cfs loss would indicate a minimum seepage value of 41,200 af/y.

The mass balance approach used in this phase, resulting in a seepage of 79,300 af/y, was considered to be more accurate than the current meter flow measurements because of the inability to measure the spring time high flows due to safety factors. The many large boulders in the river channel also made it difficult to locate a well-defined, cross section area in which to position a current meter. A semi-monthly mass balance for the year using the two USGS gages and Watermaster irrigation records calculated in Phase II does not account for a time lag factor that may occur in the ground water movement.

Irrigation Diversions

Surface Water Sources. There is a complex system of canals supplying irrigation water to different regions in the valley. The canals are not under the control of a single water district, adding to the complexity and cooperation required from the share holders of each system. Figure 6 shows the upper regions of the District 45, Glendale and Bypass Canals.

The volume of the surface water diversions for irrigation was defined in Phase I based on Watermaster records that indicate no surface water diversions after the end of

September. The Watermaster for Districts 37 and 37M (Peterson, personal communication) indicated that the ditch riders stop recording the flows for the diversions at the end of September, but the diversion gates are not closed and locked at that time. These late fall diversions supply stock water. A review of the Idaho Department of Water Resources water right filings for the region verified the filings for stock water in this region. Water continued to flow throughout the entire system until some unknown time. Diversions were assumed to flow until November 15 when ice started to block the canals. The diversion of these flows from the Big Wood River also agreed with the Watermaster's statement that the "Big Wood River is dry below Glendale Bridge until some time in November" (Peterson, personal communication). Diversions were assumed to be the same as in the last recorded period and were distributed proportionally throughout the entire area serviced by the diversion. The flow diverted from the District 45 canal to the gravel pits during this time was deducted from the total diversion to eliminate double accounting (Phase I report).

The model area was subdivided into irrigation diversion service areas as defined by Brockway and Grover (1978). Each surface water diversion was associated with at least one service area. Flows are evenly proportioned to irrigated lands within the irrigation system with the exception of the District 45 diversion. The District 45 canal system is comprised of three major laterals: East, Main, and West. At the head of each lateral, a Parshall flume is used to measure the discharge into the lateral. Thus, each lateral was treated as an individual surface diversion and assigned irrigation diversion service areas. The model assumed that all surface water diverted into a service area stayed within the area and was distributed proportionally to the irrigated acres associated with the diversion based on the method of irrigation. Sprinkler irrigated acres received 70% of the amount allocated to gravity irrigated acres. The 30% reduction was based on the assumption that sprinkler irrigation is more efficient and uniform with respect to supplying crop water requirements.

All irrigation water applied in excess of consumptive use was assumed to recharge the water table aquifer. No surface return flow or stream runoff was assumed to occur with excess irrigation water. A total of 101,100 af/y was assumed to be diverted out of the Big Wood River as surface irrigation water. Of this 101,100 af/y, 1,400 af/y was diverted into the recharge pits in the fall, and the remaining 99,700 af/y was attributed to surface irrigation (Table 2). This flow was measured by the Watermaster of District 37. The 36,500 af/y irrigation diversions from District 37M were listed as both a recharge and discharge to the system. These flows originated as spring flows in the southern region of the study area. Spring flows were associated with the water table aquifer. Typically, irrigated areas from these surface water diversions have the point of diversion within the area of use. When this occurred, the net impact on the water table aquifer was the consumptive use associated with the crop assuming no other source of water occurs. When the point of diversion was not located in the cell for which it provided irrigation water, the aquifer experienced a withdrawal equal to the diversion in that cell and a recharge in the cell with the point of application. The water table aquifer underneath the irrigated area was therefore recharged by the amount of diversion in excess of crop consumptive use. The assumption that no surface return flow occurred was also used here.

Canal seepage as a separate input was only defined for the Reach between the point of diversion of the District 45 Canal on the Big Wood River and the three Parshall flumes located at the heads of the three laterals. Seepage was estimated to be the difference between the Watermaster records of the District 45 Canal and the estimated flows using stage recorders on the three Parshall flumes. Brockway and Grover (1978) identified the seepage on selected reaches of canals and laterals in the study area based on the canal wetted areas that were determined by current metering. Canal and stream seepage information based on current metering was not collected during either the Phase I or the Phase II study. Brockway and Grover (1978) states, "The rate of seepage from a canal varies with the elevation of the water level in the canal and also varies seasonally with the filling of bank storage and siltation." Figure 17 in the Phase I study shows the reported Big

Wood River irrigation diversions to be 110,000 af/y during the Brockway and Grover (1978) study period. It also shows that the irrigation diversions during Phase I were approximately 97,500 af/y. (No canal seepage, other than in the District 45 main canal, was used in the ground water budget developed in Phase II.)

Ground Water Sources. Irrigation with ground water in the Big Wood River-Silver Creek area encompassed three possible scenarios that affect water budget development. The first scenario involved the vertical location of irrigation wells within the water table aquifer (upper layer) combined with the location within the irrigated surface area. The net impact on the water table aquifer was the crop consumptive use. A second scenario occurred when the well (point of diversion) was not located within its irrigated area. The aquifer where the well is developed experiences a withdrawal equal to the pumped diversion, and the water table aquifer underneath the irrigated area experiences recharge equal to the amount of diversion in excess of crop consumptive use. The last scenario involved irrigation wells developed in a lower aquifer of a multiple layer system regardless of the well's location with respect to the irrigated area. The lower aquifer where the well is located experiences a withdrawal equal to the entire diversion from the well, and the water table aquifer underneath the irrigated area experiences recharge equal to the diversion amount in excess of crop consumptive use. Thus, the development of the ground water irrigation portion of water budget for the study area was based on identification of the ground water irrigated areas and the well(s) servicing those areas.

The Phase I study reported the survey results of landowners and operators concerning ground water irrigation. This information identified the volume pumped, location of the production well, period of application, and the location of irrigated acres serviced by the well. This water was taken out of the aquifer layer and then reapplied where the ground water was used for irrigation. Some of the irrigation wells were developed in both the upper and lower layers. Therefore, an approximation of the horizontal and vertical point of diversion (well) and place of use was made for all wells.

An estimate of 52,000 af/y was assumed to be the volume of water discharged from the aquifer system by irrigation pumps. This volume of water was also used as a recharge to the system as applied irrigation water.

Pit Recharge

Waste or surplus canal flows were diverted into ponds or recharge pits through the existing canal systems. This excess water was used for recharge to the aquifer. Phase I described the location of the recharge pits and the volumes supplied to these pits. This flow usually occurred in the fall after crop irrigation demand was no longer needed. The 1,400 af/y diverted was deducted from the total 101,100 af/y that was estimated for Water District 37 diversions from the Big Wood River.

Precipitation

All moisture from precipitation was assumed to be available for consumptive use or recharge. Antecedent soil moisture and other variables needed to adjust for effective precipitation were not available; therefore, all moisture was assumed to be effective. Precipitation as well as irrigation applications in excess of evapotranspiration were assumed to recharge the water table aquifer without any contribution to overland flow or surface runoff. The springtime increase in discharge of Silver Creek at the first period in March, which was during the 22nd stress period (Figure 24), could probably be attributed to overland flows and streams reacting to a precipitation or snowmelt recharge event. If the increased spring time discharge at Priest Road were attributed to surface runoff from a rain storm or snowmelt, the volume of precipitation that effectively recharged the water table aquifer would have to be decreased by this amount to maintain a balanced water budget. For this study, this increase in stream flow was modeled as an increase in spring flow.

A review of the precipitation records (Table 5 and Table 6) showed more precipitation at the Hailey NOAA station than at the Picabo NOAA weather station for the thirty-year period prior to the study period. However, the values from the Picabo

Table 5. 1961-1990 Precipitation (inches/month) at the Hailey NOAA Station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	0.32	1.44	0.86	0.54	1.48	0.72	0.03	1.08	1.32	2.00	0.90	1.70	12.39
1962	1.18	4.52	1.40	1.00	2.78	0.73	1.15	0.42	0.37	0.30	1.40	1.67	16.92
1963	0.85	3.35	0.91	2.46	1.56	4.78	0.03	0.62	1.45	0.48	3.86	1.13	21.48
1964	2.36	0.06	2.43	1.52	1.12	3.15	0.44	0.10	0.04	0.39	2.49	11.30	25.40
1965	3.85	0.31	0.30	2.08	1.58	1.66	0.60	4.20	0.35	0.00	1.92	1.94	18.79
1966	3.91	0.56	1.30	0.73	0.67	0.39	0.06	0.17	0.88	0.11	1.84	3.30	13.92
1967	6.15	0.29	1.88	1.95	0.58	5.59	0.41	0.27	0.20	1.48	1.66	1.45	21.91
1968	2.65	1.21	0.42	0.35	1.88	2.53	0.92	3.37	0.33	0.55	1.26	3.01	18.48
1969	8.16	4.16	0.18	0.44	0.03	2.35	0.70	0.00	1.24	0.13	0.16	2.82	20.37
1970	4.88	0.34	1.54	1.08	1.35	2.93	1.51	0.43	0.77	1.62	3.32	5.14	24.91
1971	3.49	1.38	2.25	0.47	1.36	2.01	0.65	0.19	0.86	0.74	1.12	3.65	18.17
1972	2.01	0.50	0.38	0.69	1.35	1.15	0.22	0.94	0.90	1.31	1.41	1.63	12.49
1973	2.95	1.46	0.80	0.63	0.17	0.83	1.67	0.00	0.33	0.40	4.33	2.40	15.97
1974	2.80	0.79	2.84	0.25	0.07	0.00	0.34	0.26	0.00	1.46	0.38	1.98	11.17
1975	1.15	4.36	2.71	1.12	0.89	1.26	0.31	0.45	0.03	1.84	1.45	1.15	16.72
1976	0.96	2.74	0.43	0.63	0.44	0.64	0.28	2.06	2.44	0.22	0.01	0.00	10.85
1977	0.28	0.60	0.43	0.00	3.70	0.91	0.99	1.20	0.77	0.12	1.36	4.17	14.53
1978	3.75	3.39	1.08	3.72	1.24	0.59	0.47	0.05	2.68	0.00	0.31	0.67	17.95
1979	1.34	2.90	1.56	1.01	1.13	0.04	0.39	1.29	0.19	1.88	0.69	1.84	14.26
1980	3.82	2.03	0.79	0.88	3.35	0.72	0.70	0.76	1.69	0.37	1.08	0.17	16.36
1981	1.10	0.10	1.04	2.08	0.95	0.61	0.18	0.32	0.24	1.48	3.88	3.00	14.98
1982	1.50	1.73	3.20	2.07	1.03	1.01	1.49	0.13	1.39	2.38	1.35	4.60	21.88
1983	2.58	3.54	2.95	0.69	0.32	1.61	0.77	3.09	1.17	1.53	4.23	4.14	26.62
1984	0.59	1.99	1.17	0.59	0.96	2.57	3.37	1.60	0.40	0.43	3.15	1.29	18.11
1985	0.57	2.53	0.76	0.24	1.34	0.28	0.85	0.12	2.25	1.44	1.25	2.59	14.22
1986	2.10	4.79	1.51	0.67	2.41	0.57	0.78	0.48	1.87	0.04	0.26	0.07	15.55
1987	1.46	1.35	1.57	0.00	5.29	2.22	1.44	0.14	0.00	0.17	2.00	1.26	16.90
1988	1.42	0.29	0.56	1.24	2.27	0.34	0.00	0.00	0.20	0.00	6.43	2.18	14.93
1989	1.42	1.24	1.74	0.25	1.68	0.18	0.35	0.80	0.72	2.25	0.76	0.00	11.39
1990	2.20	1.55	0.62	1.60	2.23	1.13	0.10	0.44	0.28	0.33	0.91	0.91	12.30

Table 6. 1961-1990 Precipitation (inches/month) at the Picabo NOAA Station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	0.34	0.90	0.62	0.63	0.80	0.63	0.33	0.19	2.00	1.08	0.70	1.06	9.28
1962	1.00	2.75	1.71	0.61	3.83	0.66	0.54	0.47	0.35	0.66	0.81	0.83	14.22
1963	0.78	3.05	0.53	2.56	1.53	3.45	0.00	0.58	1.11	0.45	2.53	0.66	17.23
1964	1.96	0.00	1.88	0.87	1.28	1.99	0.09	0.12	0.03	0.56	2.24	7.96	18.98
1965	1.62	0.18	0.25	1.87	1.83	1.07	0.10	2.16	0.44	0.00	1.58	1.21	12.31
1966	1.38	0.17	1.11	0.59	0.59	0.11	0.11	0.00	0.22	0.54	1.36	1.90	8.08
1967	4.07	0.23	1.06	0.79	0.36	4.20	0.22	0.00	0.08	1.20	2.02	0.90	15.13
1968	1.00	1.01	0.68	0.26	1.47	3.59	0.00	3.48	0.43	0.22	1.52	3.25	16.91
1969	6.63	1.68	0.19	0.29	0.11	1.77	0.22	0.00	1.43	0.16	0.45	2.04	14.97
1970	3.32	0.55	1.46	0.86	0.89	2.35	0.26	0.30	1.24	1.10	3.26	4.03	19.62
1971	3.31	0.57	1.75	1.05	0.62	1.52	0.21	0.31	0.56	0.90	1.68	2.62	15.10
1972	2.35	0.75	0.93	0.80	0.84	0.90	0.00	0.38	1.53	1.11	1.53	1.46	12.58
1973	1.57	1.01	1.03	0.49	0.46	0.28	0.71	0.51	0.34	0.43	3.78	2.00	12.61
1974	2.14	0.58	2.32	0.31	0.11	0.00	0.21	0.08	0.00	1.31	0.41	1.28	8.75
1975	1.34	3.17	2.87	1.69	1.07	0.67	0.25	0.41	0.03	1.73	0.95	0.98	15.16
1976	1.69	2.06	1.13	1.77	0.62	0.48	0.05	1.19	1.21	0.55	0.00	0.10	10.85
1977	1.10	0.52	0.48	0.10	2.09	0.64	0.80	0.14	0.57	0.35	1.33	3.11	11.23
1978	2.10	1.86	0.88	2.15	0.65	0.55	0.35	0.30	1.82	0.01	0.72	0.60	11.99
1979	1.32	1.38	1.05	0.50	1.15	0.59	0.35	1.03	0.14	1.51	0.82	0.73	10.57
1980	3.57	1.55	0.45	0.72	3.15	0.76	0.61	0.65	1.62	0.35	0.83	2.01	16.27
1981	0.85	0.88	1.08	1.76	0.83	0.59	0.06	0.05	0.00	1.52	2.55	2.60	12.77
1982	1.72	1.54	1.99	1.29	1.18	0.85	1.38	0.10	1.70	1.17	1.95	3.50	18.37
1983	0.41	2.62	2.79	0.75	0.89	1.78	0.65	1.44	0.83	0.77	3.98	3.15	20.06
1984	0.00	1.73	1.00	0.74	0.48	1.78	0.96	0.78	0.22	0.83	2.86	0.00	11.38
1985	0.60	2.38	0.92	0.10	0.96	0.10	2.32	0.00	1.80	0.75	0.93	1.97	12.83
1986	1.62	4.55	1.36	0.67	1.75	0.75	0.25	0.33	1.42	0.44	0.15	0.22	13.51
1987	1.08	0.50	1.12	0.00	2.69	0.71	1.42	0.15	0.00	0.20	1.32	1.02	10.21
1988	0.91	0.25	0.50	1.11	1.65	0.05	0.00	0.00	0.30	0.00	5.61	1.80	12.18
1989	1.40	0.50	1.56	0.21	1.22	0.15	0.15	0.53	0.80	2.09	0.58	0.00	9.19
1990	1.85	1.40	0.56	1.62	1.62	1.25	0.05	0.53	0.15	0.30	0.80	0.75	10.88

Table 7. 1993-1994 Picabo AGRIMET Station Precipitation (inches/day)

DAY	Apr-93	May-93	Jun-93	Jul-93	Aug-93	Sep-93	Oct-93	Nov-93	Dec-93	Jan-94	Feb-94	Mar-94	Apr-94
1		0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.064	0.058	0.047	0.000	0.023
2		0.023	0.220	0.010	0.000	0.000	0.000	0.000	0.029	0.006	0.000	0.006	0.000
3		0.413	0.279	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.105
4		0.087	0.000	0.122	0.000	0.000	0.006	0.000	0.099	0.285	0.000	0.000	0.006
5		0.105	0.256	0.030	0.000	0.000	0.012	0.000	0.000	0.058	-0.006	0.000	-0.017
6		0.012	1.465	0.000	0.006	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.157
7		0.000	0.512	0.000	0.087	0.000	0.134	0.000	0.006	0.000	0.140	0.000	0.035
8		0.000	0.000	0.006	0.000	0.000	0.116	0.000	0.517	0.140	0.064	0.000	0.000
9		0.000	0.000	0.041	0.000	0.000	-0.006	-0.006	0.017	0.035	0.052	0.000	0.000
10		0.000	0.250	0.000	0.064	0.000	-0.006	0.023	0.006	0.105	0.064	0.000	0.081
11		0.000	0.087	0.006	0.017	0.029	-0.006	0.000	0.006	0.000	0.273	0.081	-0.006
12		0.000	0.000	0.000	0.000	0.029	0.000	0.000	0.006	0.000	0.000	0.000	0.012
13		0.000	0.000	0.000	0.000	0.000	0.023	0.000	-0.006	0.000	0.006	0.000	0.000
14		0.000	0.000	0.000	0.017	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000
15		0.076	0.041	0.000	0.000	0.000	0.087	0.000	0.000	0.000	0.000	0.000	0.000
16	-0.006	0.000	0.000	0.000	0.000	0.000	0.169	0.000	0.000	0.000	0.010	0.000	
17	0.006	0.020	0.000	0.000	0.012	0.023	0.023	0.000	0.012	0.006	0.326	0.000	
18	0.116	0.000	0.000	0.000	0.000	0.221	0.017	0.000	0.006	0.000	0.047	0.000	
19	0.006	0.000	0.000	0.000	0.006	0.012	0.087	0.000	0.000	0.000	0.006	0.000	
20	-0.122	0.000	0.000	0.000	0.000	0.017	-0.006	0.000	0.000	0.000	0.029	0.000	
21	0.349	0.023	0.029	0.000	0.314	0.000	0.000	0.000	0.000	0.000	0.017	0.000	
22	0.070	0.006	0.017	0.000	0.000	0.000	0.000	0.070	0.006	0.000	0.052	0.000	
23	0.017	0.000	0.000	0.300	0.000	0.000	0.000	0.006	0.000	0.000	0.122	0.000	
24	0.000	0.000	0.000	0.081	0.010	0.000	0.000	0.012	-0.006	0.000	0.000	0.000	
25	0.000	0.000	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000	
26	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000	
27	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.012	0.000	-0.012	0.035	0.000	
28	0.000	0.000	0.000	0.041	0.000	0.000	0.012	0.000	0.006	0.000	0.029	0.000	
29	0.326	0.000	0.000	0.000	0.000	0.000	-0.012	0.006	0.000	0.000		0.000	
30	0.006	0.012	0.000	0.000	0.000	0.000	0.000	0.023	0.000	0.017		0.000	
31		0.017		0.000	0.000		0.000		0.000	0.017		0.006	
TOTAL	0.780	0.793	3.156	0.666	0.533	0.331	0.657	0.145	0.773	0.733	1.318	0.093	0.396
Total = 10.4 inches per year													

AGRIMET station were used uniformly throughout the study area. Table 7 shows that the Picabo AGRIMET station reported a total of 10.4 inches of precipitation for the calibration period.

The total precipitation (inches per time step) was applied uniformly to each cell based on the surface area. Precipitation was assumed to be immediately available for consumptive use or recharge to the water table aquifer, except during the wintertime when it fell as snow. A total precipitation recharge of 51,300 af/y was used as a model stress. This stress was a combination of moisture from rainfall events and snow melt.

Snow. Snow pack accumulation and melt has an effect on the timing of the recharge to the water table aquifer from precipitation. The study area was divided into four areas as shown in Figure 22 with a snow course station in each area. The snow pack at the four snow courses was measured five times during the calibration period. A snow pillow continuously monitored the snow pack at the AGRIMET station near the Silver Creek Preserve Manager's house. The snow pillow was in the same area as the snow course near the Manager's house, and the hydrographs are very similar with the difference being attributed to blowing and drifting snow (Figure 23).

The accumulated water content in the snow pack at the four snow courses, total accumulated precipitation, and snow pillow accumulated moisture are shown in Figure 23. The plot of accumulated precipitation and accumulated moisture at the snow pillow shows that there was very little infiltration or loss of water content until the final melt period. This figure also shows the total accumulated snow pack increased the farther north the snow course was located. The Picabo course recorded the least accumulation, and the Gannet Road snow course recorded the highest accumulation.

The methodology used for applying the snowmelt was to accumulate, or hold, the measured precipitation at the snow courses and then apply this volume of moisture during the melt period. The melt period was defined as the falling limb in the hydrograph of the snow pillow accumulated water content in Figure 23. The interpolated values between the measured values for each snow course were determined from the accumulated precipitation or snow pillow hydrographs produced at the AGRIMET station.

The snow melt period shown in the snow course data coincided with the rise shown in the hydrographs (Figure 24) at Sportsman's Landing, Swanson Bridge, and at Priest Road (Figure 1). The stress period numbers are displayed on the horizontal axis of Figure 24, while dates are displayed on the horizontal axis of Figure 23. (Table 1 correlates the stress period numbers and dates.) This volume of increased stream flow from snow melt and runoff was considered as gain from ground water.

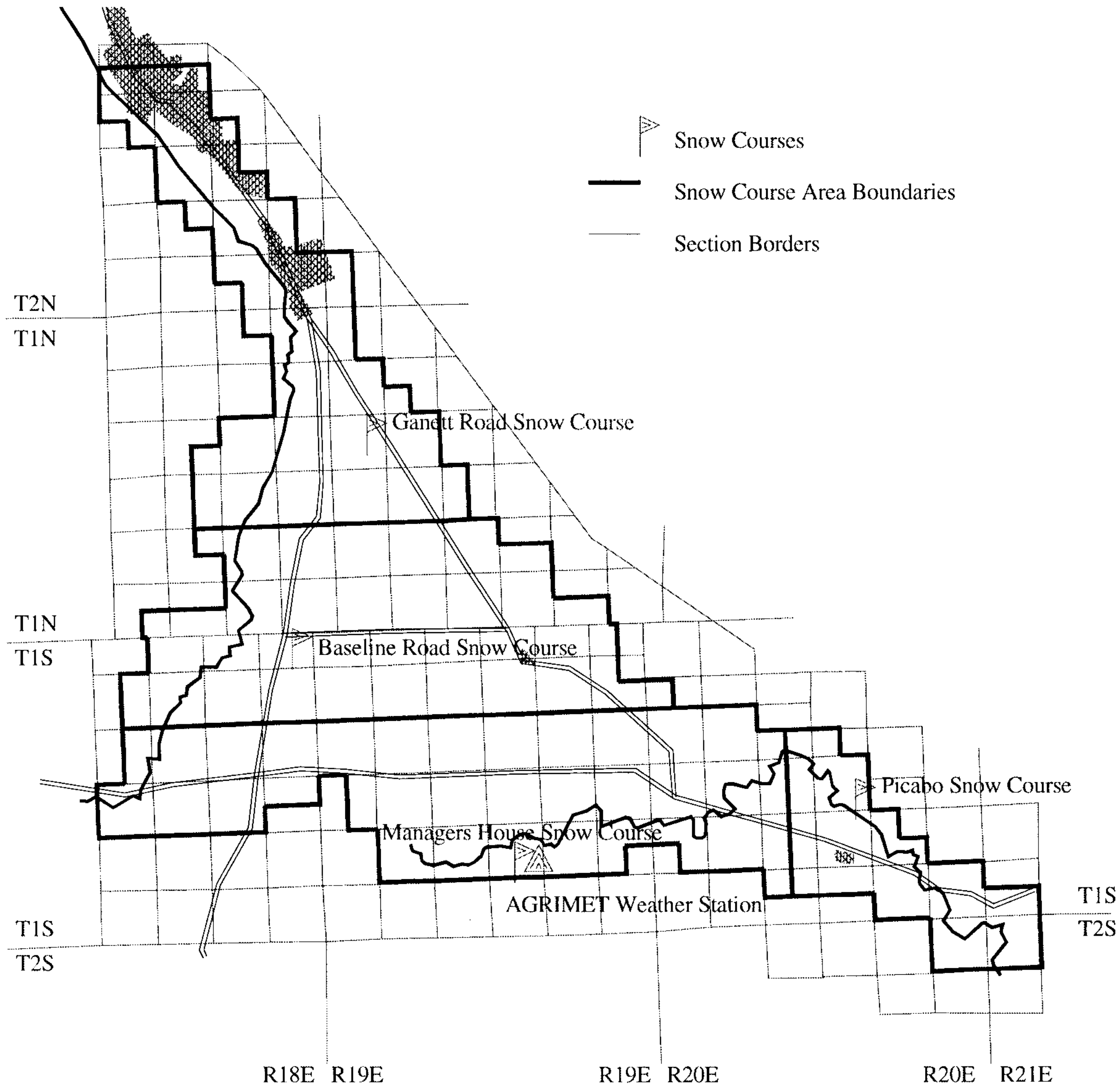


Figure 22. Snow Course Areas

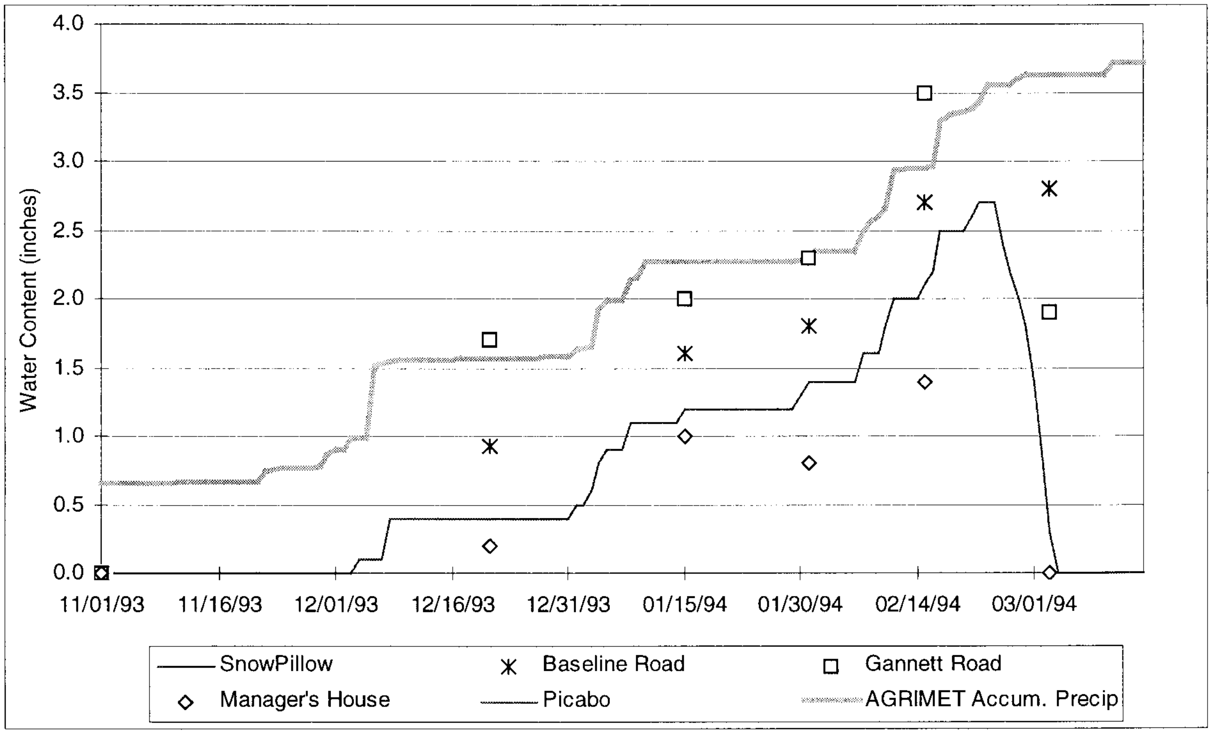


Figure 23. Snow Course-Snow Pillow Accumulated Snow Pack

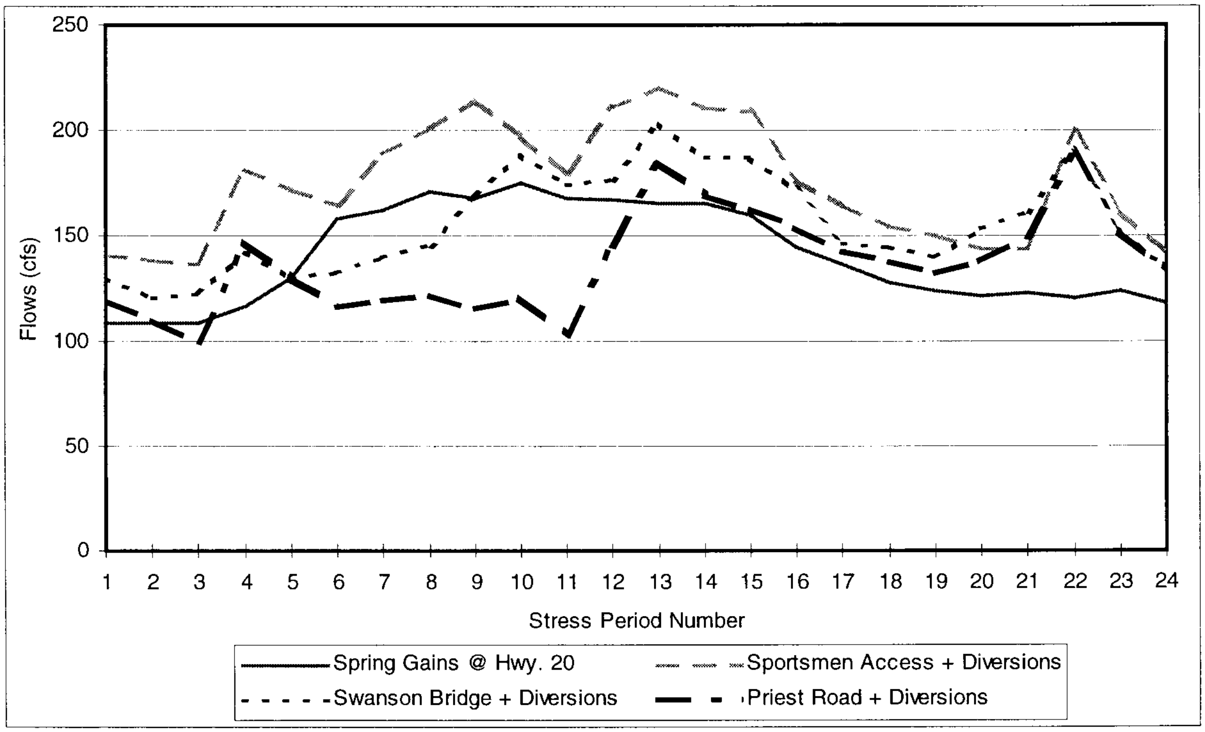


Figure 24. Silver Creek Stream Flow and Diversions.

Municipal Water Recharge

Municipal water inflows. Bellevue and a portion of Hailey are within the study area. Their water supply is derived from wells and springs inside and outside the study area. The City of Hailey receives its water from the River Street, 3rd Avenue, and Woodside wells and from Indian Springs. The City of Bellevue obtains its water from wells and one spring. The water supplied by springs and wells outside the study area was listed as a recharge component to the water balance. This water, combined with water from production wells within the modeled area, was available for irrigation and municipal consumptive and nonconsumptive use. The water supplied by the production wells within the model area was listed as both a recharge and discharge to the water balance similar to the irrigation production wells. The usage associated with the evapotranspiration for cities was extracted from the total water supply. The remainder was assumed to be waste treatment plant inflow or deep percolation.

Waste Water Treatment Plants. Wastewater from the municipalities' treatment plants was included as a recharge term for the modeled area through the municipal water term in the budget. The City of Hailey has two treatment plants. The Riverside Treatment Plant discharges treated water into the Big Wood River, and the Woodside Treatment Plant uses leach fields as a method of disposal. The city of Bellevue uses lagoons in the Poverty Flats area to dispose of its wastewater. All municipal water inflow not used by ET or municipal consumptive use is converted to waste water treatment plant outflow.

This recharge component had a minor impact because of its relative size compared to the major components. The combined flow of Hailey and Bellevue treatment plants was approximately 2 cfs yearly average (Table 17) as compared to 48 cfs for the underflow at Hailey and 118 cfs for the yearly average seepage from the Big Wood River. The waste water from the Ketchum-Sun Valley plant was not included in this water balance. It discharged into the Big Wood River at Ketchum.

Discharge

Underflow at Priest Road

The underflow at Priest Road was calculated from the 1993 water budget shown in Figure 21 (29,300 af/y). This volume of water was a target value used in the calibration process. The model should produce this value when it computes a mass balance, given the cells at the boundary of the model were designated as constant head cells. The 29,300 af/y value was calculated as a mass balance for the entire system. Applying Darcy's equation using the water table elevation difference between wells at 2S-20E-01ACC2 and 1S-20E-26CDC1, saturated aquifer area between the two wells and hydraulic conductivity for fractured basalt produced similar results. Smith (1959) and Castelin and Chapman (1972) both reported underflow at Priest Road of 38,000 af/y. This 8,700 af/y difference, as well as the underflow differences at Hailey, was due to the method of analysis and was considered insignificant when compared to the entire ground water budget of 355,700 af/y (Table 2).

Spring Discharges

Springs from the Big Wood River-Silver Creek aquifer were classified as either tributary to the Big Wood River or tributary to Silver Creek.

Tributary to Big Wood River. The hydrology of the Big Wood River and the west side of the valley were presented in the Big Wood River Seepage section. Flow in the lower reach of the Big Wood River, Reach III, was comprised seasonally of spring flows and sometimes surface flows. Spring flows also enter the Big Wood River via Willow Creek and Brock Creek. Table 4 shows the gain in Reach III as 11,000 af/y and the spring flows that produced Willow Creek and Brock Creek as 27,300 af/y. The combined total spring discharge that flowed out of the valley at Stanton Crossing was 38,300 af/y.

Tributary to Silver Creek. Springs that originate in the center and on the eastern side of the valley form creeks that combine to form Silver Creek. The spring fed tributary creeks feeding Silver Creek were measured along Highway 20 during the Phase I study.

The flows associated with these creeks were summed into a gross tributary spring flow value. The stream flow in Silver Creek was measured at three gauging sites: Sportsman's Access, Swanson Bridge, and Priest Road (Figure 6). From the above measurements, Silver Creek was determined to be a gaining stream above Sportsman's Access; it can be a gaining or losing reach between Sportsman's Access and Swanson Bridge; and it loses water below Swanson Bridge to Priest Road (Table 8). The reach gains or losses were distributed to each cell proportional to the length of Silver Creek in each cell.

Surface irrigation diversions from the creeks and from Silver Creek influence computed reach gains and/or losses. These diversions were determined from District 37M measurements reported in Phase I and included in the water budget even though they originated and were distributed within the model. Their significance was similar to the ground water irrigation diversions, as they were both a recharge and a discharge to the system.

Figure 24 shows the relationship between the summation of the stream flow from the tributary springs as measured at Highway 20 and the flow measurement gages at Sportsmen Access, Swanson Bridge, and Priest Road (Table 8). The flow at Priest Road was less than the flow at Swanson Bridge showing recharge from Silver Creek to the aquifer in this reach. The southern edge of the perched aquifer in the Picabo region terminates below the Swanson Bridge causing the aquifer system to transition back into a single water table aquifer. The depth from the ground surface to the water table in the aquifer increased to the point where the aquifer is no longer hydraulically connected to Silver Creek.

There was an increase in Silver Creek discharge for two time steps (22 and 23) associated with springtime snowmelt and rainfall that was seen at the three measurement gages on Silver Creek but not at the spring flows measured along Highway 20. Therefore, this increased flow in Silver Creek could be attributed to runoff from snowmelt, but, as stated in the Snow section, it is assumed that all Silver Creek flow was attributed to spring

Table 8. Silver Creek flows at three locations.

Time Step	Above Sportman's Access				Sportsman's Access to Swanson's Bridge				Swanson's Bridge to Priest Road			
	TOTAL Spring Gains	TOTAL Diversions	Sportsman Access	Reach Gains	Sportsman Access	Total Diversions	Swanson Bridge	Reach Gain	Swanson Bridge	Total Diversions	Priest Road	Reach Gain
1	108.7	0.3	140.5	32.1	140.5	0.0	130.0	-10.53	130.0	0.0	120.0	-10.0
2	108.7	13.2	124.7	29.2	124.7	0.3	120.0	-4.4	120.0	0.0	110.0	-10.0
3	108.9	42.8	93.8	27.7	93.8	6.6	115.2	28.09	115.2	0.3	99.0	-16.5
4	116.8	46.5	135.2	64.9	135.2	7.2	135.2	7.24	135.2	6.6	140.9	-0.9
5	130.4	42.5	129.7	41.8	129.7	7.9	122.1	0.35	122.1	4.3	126.0	-0.5
6	158.2	54.3	110.9	7.0	110.9	19.1	113.3	21.44	113.3	11.6	104.9	-19.9
7	162.4	54.5	134.6	26.7	134.6	12.9	126.9	5.14	126.9	9.6	110.3	-26.2
8	170.8	58.6	142.3	30.1	142.3	18.1	127.4	3.2	127.4	10.1	112.5	-24.9
9	167.9	44.9	170.1	47.1	170.1	17.8	150.7	-1.59	150.7	7.6	108.3	-50.0
10	175.6	50.5	147.5	22.4	147.5	22.4	166.6	41.42	166.6	8.4	112.4	-62.6
11	168.4	47.1	132.7	11.4	132.7	23.4	151.3	42.04	151.3	7.6	95.1	-63.8
12	167.4	44.3	166.4	43.3	166.4	13.5	162.9	10.05	162.9	3.6	142.2	-24.3
13	165.4	40.6	180.0	55.2	180.0	13.5	189.6	23.09	189.6	2.3	182.3	-9.6
14	166.0	40.0	170.6	44.6	170.6	13.5	174.0	16.91	174.0	2.3	166.9	-9.4
15	160.0	40.0	168.7	48.7	168.7	13.5	173.4	18.23	173.4	2.3	161.1	-14.7
16	144.4	4.2	172.8	32.6	172.8	12.8	159.4	-0.66	159.4	2.3	152.0	-9.7
17	136.7	4.2	160.9	28.5	160.9	0.0	146.3	-14.64	146.3	0.8	142.3	-4.8
18	128.2	0.0	154.4	26.2	154.4	0.0	144.8	-9.58	144.8	0.0	138.1	-6.8
19	123.7	0.0	150.3	26.6	150.3	0.0	139.9	-10.33	139.9	0.0	132.3	-7.6
20	121.5	0.0	143.7	22.2	143.7	0.0	153.9	10.13	153.9	0.0	138.4	-15.5
21	123.1	0.0	144.1	21.0	144.1	0.0	162.0	17.9	162.0	0.0	149.6	-12.4
22	120.8	0.0	199.5	78.8	199.5	0.0	190.5	-9.08	190.5	0.0	189.0	-1.5
23	124.0	0.0	161.9	38.0	161.9	0.0	152.3	-9.62	152.3	0.0	152.0	-0.4
24	118.6	0.0	142.0	23.5	142.0	0.0	134.6	-7.4	134.6	0.0	133.4	-1.2
Sum	3376.3	628.4	3577.5	829.6	3577.5	202.7	3542.2	167.43	3542.2	79.6	3218.7	-403.1
Avg.	140.7	26.2	149.1	34.6	149.1	8.4	147.6	7.0	147.6	3.3	134.1	-16.8

flow in the model.

Evapotranspiration

The Phase I study reported evapotranspiration (ET) data for the Picabo AGRIMET climate station that was based on the Wright-Penman approach for calculating evapotranspiration from climatic data. The Wright-Penman reference evapotranspiration (ET_{ref}) was based on alfalfa as the reference crop. The ET_{ref} value was multiplied by a crop coefficient, K_{cm}, for a given crop (Jensen, et al, 1990). Crop coefficients for trees and rangeland that were not listed by Jensen were provided by Dr. James L. Wright (personal communication). The evapotranspiration associated with rangeland approximates the precipitation in the area, with cottonwood trees using the most water of any plant listed (Table 9). These ET values were associated with the growing season which was from April 1 to October 31. Commercial and residential areas were given 60% of the values that irrigated pasture received. The reasoning was that 40% of the lot was covered with roofs and/or pavements. This 60-40 % relationship would change with dwelling unit lot size, but the magnitude of water changes associated with this decision would be small when referenced to the entire ground water budget.

During the non-growing season, some evaporation could occur if the soil surface was moist and there was no snow cover. The snow course data showed the ground was snow covered from December through March for most of the area. Evaporation could occur during November and March but was assumed to be zero because of uncertainty and the probable magnitude.

Table 14 in Phase I lists pasture, barley, alfalfa, potatoes, oats, wheat, and canola as 42%, 30%, 20%, 4%, 2%, 1% and 1% of the total crop distribution, respectively. It was from those acres that evapotranspiration was calculated in the Phase 1 study. The evapotranspiration for non-agricultural lands was not included in the 66,500 af/yr reported. The non-agricultural land in the study area accounts for approximately 45 percent of the study area. The evapotranspiration from the non-agricultural lands accounts for most of the

Table 9. Evaportanspiration (ET) for the Study Area

		Agrimet	Alfalfa & Canola		Spring Grains		Pasture		Potatoes		Dryland		Cottonwood Trees		Residential
	Time	Ref. ET		Time		Time		Time		Time		Time		Time	Time Step ET
Period	Step		Kcm	Step ET	Kcm	Step ET	Kcm	Step ET	Kcm	Step ET	Kcm	Step ET	Kcm	Step ET	is .6 of
		(in/day)		(in/day)		(in/day)		(in/day)		(in/day)		(in/day)		(in/day)	Pasture ET
16Apr-30Apr	1	0.15	0.82	0.12	0.20	0.03	0.60	0.09	0.25	0.04	0.65	0.10	0.98	0.15	0.05
1May-15May	2	0.19	0.82	0.16	0.35	0.07	0.70	0.13	0.25	0.05	0.67	0.13	0.98	0.19	0.08
16May-31May	3	0.27	0.82	0.22	0.50	0.14	0.75	0.20	0.21	0.06	0.50	0.14	0.98	0.27	0.12
1Jun-15Jun	4	0.18	0.82	0.15	0.75	0.14	0.75	0.14	0.22	0.04	0.52	0.09	0.98	0.18	0.08
15Jun-30Jun	5	0.27	0.82	0.22	0.92	0.25	0.75	0.20	0.25	0.07	0.10	0.03	0.98	0.27	0.12
1Jul-15Jul	6	0.27	0.82	0.22	1.00	0.27	0.75	0.20	0.40	0.11	0.10	0.03	0.98	0.27	0.12
16Jul-31Jul	7	0.26	0.82	0.21	1.00	0.26	0.75	0.20	0.60	0.16	0.10	0.03	0.98	0.26	0.12
1Aug-15Aug	8	0.24	0.82	0.20	1.00	0.24	0.75	0.18	0.75	0.18	0.10	0.02	0.98	0.24	0.11
15Aug-31Aug	9	0.24	0.82	0.20	0.70	0.17	0.75	0.18	0.90	0.22	0.10	0.02	0.98	0.24	0.11
1Sep-15Sep	10	0.21	0.82	0.17	0.30	0.06	0.75	0.16	0.78	0.16	0.10	0.02	0.98	0.21	0.09
16Sep-30Sep	11	0.14	0.82	0.11	0.15	0.02	0.75	0.11	0.60	0.08	0.10	0.01	0.98	0.14	0.06
1Oct-15Oct	12	0.13	0.82	0.11	0.10	0.01	0.75	0.10	0.50	0.07	0.10	0.01	0.98	0.13	0.06
16Oct-31Oct	13	0.10	0.82	0.08	0.10	0.01	0.75	0.08	0.40	0.04	0.10	0.01	0.98	0.10	0.05
1Nov-15Nov	14	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16Nov-30Nov	15	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1Dec-15Dec	16	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16Dec-31Dec	17	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1Jan-15Jan	18	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16Jan-31Jan	19	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1Feb-14Feb	20	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15Feb-28Feb	21	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1Mar-15Mar	22	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16Mar-31Mar	23	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1Apr-15Apr	24	0.13	0.82	0.11	0.20	0.03	0.50	0.07	0.25	0.03	0.60	0.08	0.98	0.13	0.07
TOTALS (in/year)		50.01		34.65		25.63		30.71		19.67		10.90		41.58	18.82

Kcm = crop coefficient and Time Step ET = Agrimet Reference ET * Kcm.

increase evapotranspiration used in Phase II (107,100 af/y). The evapotranspiration for each node by time step as was determined from the vegetation within each node and the associated rates shown in Table 9.

Production Wells

Irrigation Production Wells. Some of the irrigation water demands were met by production wells that withdraw water from the aquifer system. This topic was discussed earlier under the recharge section of ground water sources for irrigation diversions.

Municipal Water Wells. The two cities within the ground water model area have municipal water supplies that are derived from surface springs as well as developed wells. Some of these sources were located outside the model boundaries, and for Hailey, a portion of the delivery area was located outside the model boundaries. Both cities reported total water use, and both estimated that one half of the total was derived from spring sources.

Bellevue reported estimated summer and winter flows of 800 and 390 gallons per day per capita, respectively. Based on 630 service connections with an average of 3.2 persons per connection, the Bellevue water system had a usage of 1,200 af/y.

The Hailey water supply system production was based on 3,200 af/y reported production. For the population of Hailey (5,800), this results in a summer and winter consumption of 620 and 268 gallons per day per capita, respectively. Because half of the city was outside model boundaries, the 3,200 af/y production was reduced to 1,600 af/y.

Combined municipal ground water production was estimated at 2,800 af/y (Table 2) with half from spring sources.

Aquifer Parameter Calibration

The aquifer parameters for the ground water model were calibrated in several stages. The hydraulic conductivity, horizontal and vertical, were the first set of parameters calibrated, followed by aquifer storage parameters and parameters describing spring and river conductances. These calibration steps required readjusting the estimates for the parameters determined in the prior step. The first stage was a steady state simulation with all three layers modeled as confined, and all the fluxes were modeled as discrete values that were not head dependent. Modeling the layers as confined eliminated the cell dewatering problem that occurred when the layers were unconfined. The second stage was a steady state simulation with the three layers modeled as either unconfined or confined based on the conceptual model. During the third stage, the model was run under transient conditions. The last stage was to introduce the head dependent nature of the drain and river packages to the transient simulation.

Steady State

All stress period fluxes were summed for the yearly study period and divided by 24 to achieve an average yearly recharge value. The stress period in steady-state was defined as one year, or 365 days, in length. Precipitation, evapotranspiration, irrigation application from surface and ground water sources, and gravel pit recharge flux values per node were placed into the model using the recharge package. The Big Wood River gains and losses, Silver Creek gains and losses, production wells outflow, and the underflow at Hailey were modeled as discrete values in the well package. The values used in the recharge and well modules were yearly averages. The beginning heads were the same as the target head values, which were the averages of the four mass measurements.

Transmissivity values given in Brockway and Grover (1978) were utilized as initial estimates for layers 1 and 3. Layer 2 was given a very small value to minimize horizontal movement of water within the layer. A trial and error process was employed for calibration until the model converged and produced output. Smoothing and parameter estimation routines were utilized to adjust the transmissivity and vertical conductance values for each cell to achieve a greater match between the simulated and target hydraulic heads and gradients.

Horizontal hydraulic conductivity for the unconfined layers was calculated as transmissivity divided by the aquifer thickness. This horizontal conductivity value was placed into the model and the layer classification was changed from confined to confined/unconfined status for the second set of steady state calibration runs.

Vertical conductance placed at the interface between layers was computed as a function of horizontal conductivity:

$$VC_{u\text{-}l} = 1/((AT_u/HY_u)+(AT_l/HY_l))$$

where: $VC_{u\text{-}l}$ was vertical conductance at the interface between the upper layer and lower layer,

AT was aquifer thickness of the upper and lower layers and,

HY was horizontal conductivity of the upper and lower layers.

The model simulations were repeated, and the horizontal conductivity values were adjusted until the differences between the simulated heads (gradients) and the target heads (gradients) were reduced to acceptable levels. The vertical conductance was recalculated each time the horizontal conductivity was altered.

This model was time consuming to calibrate because of the ground water divide. A small change in the horizontal conductivity values on the east side of the divide in either layer would cause the heads on the west side to change rapidly. The west side of the artesian aquifer below Gannett did not have an exit or discharge point other than upwards through the aquitard. Excess inflows placed into the area during calibration caused the heads to rise rapidly in the southwesterly-most cells. A change in flow to either layer 1 or 3 also would have a dynamic effect on the head in the other layer. The perched aquifer near Picabo was also difficult to model. When the water table in the lower aquifer decreased, the gradient in the perched aquifer would reverse with slope to the north instead of to the south.

A root mean square error (RMS) value less than 5.0 feet was achieved between the simulated and target heads for the steady state calibration.

Transient Analysis

Once the steady state simulation was completed, the transient simulation was begun. The fixed fluxes used in the well and recharge modules were the average flow for each of the 15.2 day stress periods rather than the yearly average. The beginning head values were the values of the mass measurement taken in the spring of 1993 instead of the averages of the four stress periods that were used to calibrate the steady state mode. The target water surface elevations were the water surface elevations from the summer 1993, winter 1993, and spring 1994 mass measurements corresponding to time steps 8, 16, and 24, respectively.

To keep the model from dewatering a cell during calibration, a minimum thickness of 50 feet for each layer was assumed. During calibration of the transient simulations, horizontal hydraulic conductivity was adjusted. The model calculates transmissivity, which is hydraulic conductivity times aquifer thickness. Therefore, a smaller hydraulic conductivity value will offset a greater aquifer thickness to achieve the desired transmissivity.

The horizontal hydraulic conductivities and vertical conductances used in the steady state simulation served as initial estimates for the transient simulation. The aquifer storage coefficients were the next parameters adjusted to achieve the desired head values. As stated earlier, the recharge fluxes for the Big Wood River were lowered for the northern region and raised for the southern region to achieve desired heads. The model would not simulate the cycles that the real system demonstrated until these changes were made. The response produced by the model in the northern region was satisfactory but the cycle desired in the southern region was not obtained. The maximum storage coefficient was limited to 0.3, which was supported by Brockway and Grover (1978). The desired head differences were obtained by adjusting the storage coefficients while also readjusting the hydraulic conductivity values. Root mean square (RMS) error values of 5, 4, and 5 feet for the 8th, 16th, and 24th stress periods were achieved between the simulated and target heads for this part of the calibration.

Next, the drain and river packages were implemented in the transient simulation to let the model start producing the output fluxes. The cells that represent Silver Creek between

Sportsman's Access and Swanson Bridge were modeled with the river package while the remainder of Silver Creek, the springs in the center of the model, and the springs tributary to the Big Wood River were modeled with the drain package. The river module added water to the aquifer when the calculated head would fall below a target value. This process kept cells in the perched aquifer below Sportsman's Bridge from dewatering. The drain module would only withdraw water from the model layer to which it is connected. The simulated flows from these two modules were combined into two terms, spring flow tributary to the Big Wood River and spring flow tributary to Silver Creek.

The drain elevation, drain hydraulic conductivity, stage in the river, river bottom, and river hydraulic conductivity were the parameters adjusted in these modules. The previously calibrated parameters also were readjusted to obtain the desired hydraulic head elevations and flow rates. The differences (feet) between the target head values and the simulated head values for the transient simulation with the drain and river modules operating were calculated and are shown in Figures 25 through 30. Root mean square (RMS) error values of 5.1, 4.6, and 5.3 feet for the 8th, 16th, and 24th stress periods were achieved between the modeled heads and the target heads (Table 10). The target versus simulated water surface elevations for 20 cells are given in Figure 31. The largest difference between the target and simulated heads occurs in the southern region of layer three. The simulated head hydrographs all show a noticeable drop in the artesian aquifer (layer 3) during the irrigating season. The remainder of the cells show a close correlation between the target and simulated hydraulic heads. Three wells were also measured by the

Table 10. RMS Differences Between Target and Simulated Heads

Stress Period	RMS	Maximum Drawdown		Maximum Rise	
		(ft)	Location (Row, Col., Layer)	(ft)	Location (Row, Col., Layer)
8	5.13	19.78	24-3-3	12.74	27-21-3
16	4.6	12.18	24-3-3	13.27	22-19-3
25	5.32	17.86	22-9-1	17.49	29-3-3

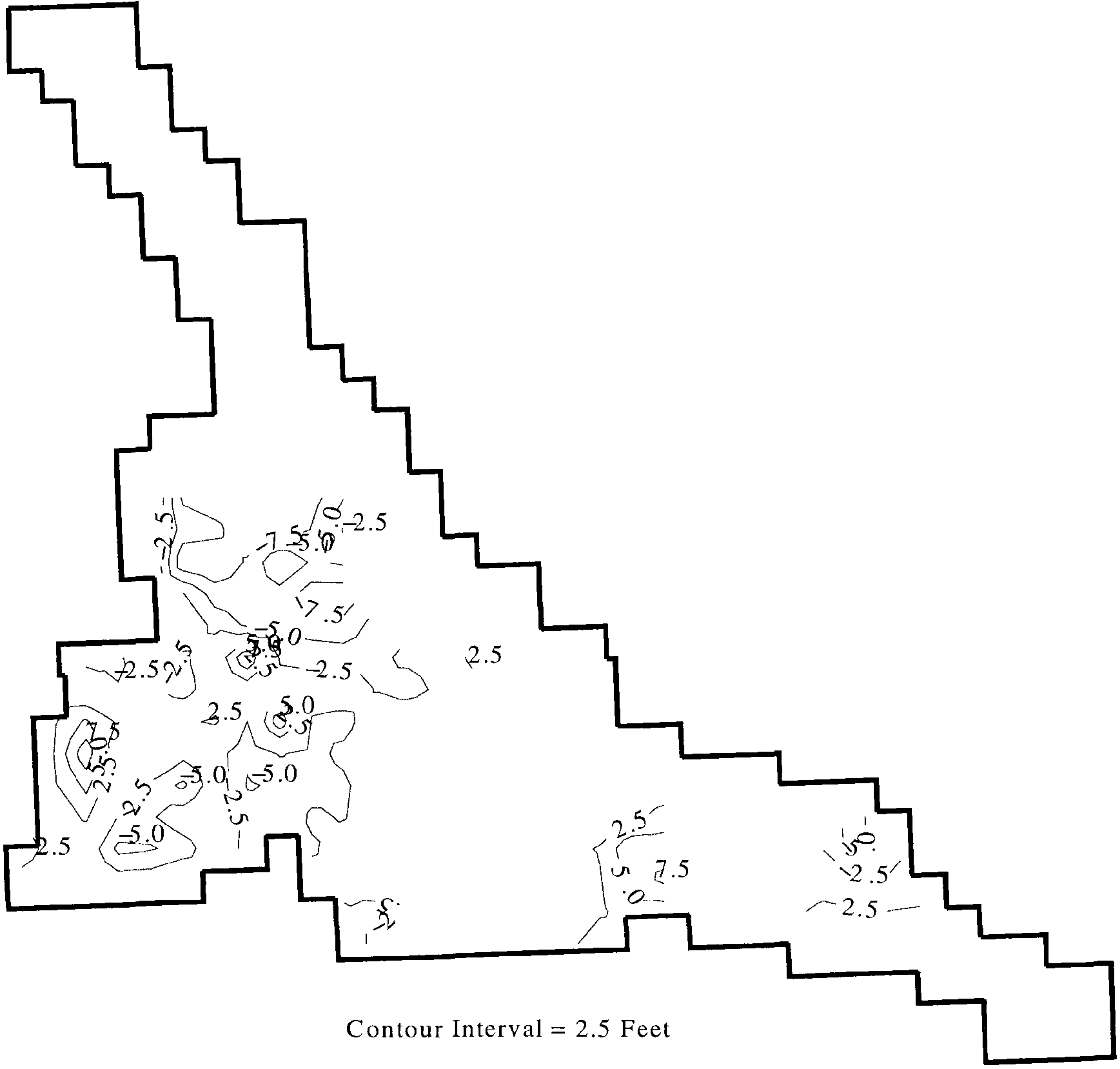
USGS during this time. A difference between the target heads and USGS measured heads can be observed in Figure 31. The USGS head is measured at a specific site, whereas the target heads are heads calculated at the center of the cell in which the well resides. The target head being under the influence of neighboring wells can explain this difference.

The final transmissivity values are shown in Figures 32 and 33. An area near Gannett shows values greater than 300,000 ft^2/day in both layers 1 and 3. Moreland (1977) also shows a similar distribution transmissivity values in this area. Smith (1956) reported on five aquifer tests made in the area. Those tests would indicate tranmissivities between 100,000 to 430,000 ft^2/day. Moreland (1977) evaluated pump tests conducted in the area and concluded that for the alluvial system transmissivities generally range between 7,000 to 300,000 ft^2/day. He also indicated that locally the aquifer transmissivity may be much lower or higher. The valley between Hailey and Bellevue also has high values. The transmissivity values assigned to layers 1 and 3 ranged from 14 to 449,000 ft^2/day with the lowest values occurring on the west boundary. Transmissivities in layer 2 were less than 100 ft^2/day except at the northern most boundary of layers 1 and 2 and the edges of the perched aquifer at Picabo.

The target flows versus simulated flows are shown in Table 11 and Figures 34, 35, and 36 for each of the drain flow areas. The target flows are a combination of flows produced by the drain and river modules for each area. The model simulates the seasonal response but does not adequately simulate the magnitude of either the maximum or the minimum flows. Adjusting each one of the model parameters while holding the other parameters constant or adjusting several parameters simultaneously did not produce the desired flows. These hydrographs show a marked increase in flow for the 4th period which can be attributed to high precipitation during this period. A noticeable increase in flow out of the aquifer is also visible during the 22nd and 23rd periods and may correspond to a runoff event. The simulated hydrographs show the trends desired but not the magnitudes.

The transient calibration output has an average of 2.1 cfs per year more water coming out towards Big Wood River and 1.14 cfs less water coming out to Silver Creek than the target response as shown in Table 11. Further adjustments to the model parameters could reduce these differences, but the error associated with other measurements and parameters exceeds this error.

The model produced an underflow of 26,900 af/year for the 3 cells designated as constant head cells in the Priest Road area which is 8% lower than the target value of 29,300 af/year. This small difference adds credibility to the accuracy of the stress data sets input into the model.



Contour Interval = 2.5 Feet

Figure 25. Differences between Estimated and Simulated Water Surface for Stress Period 8 in Layer 1

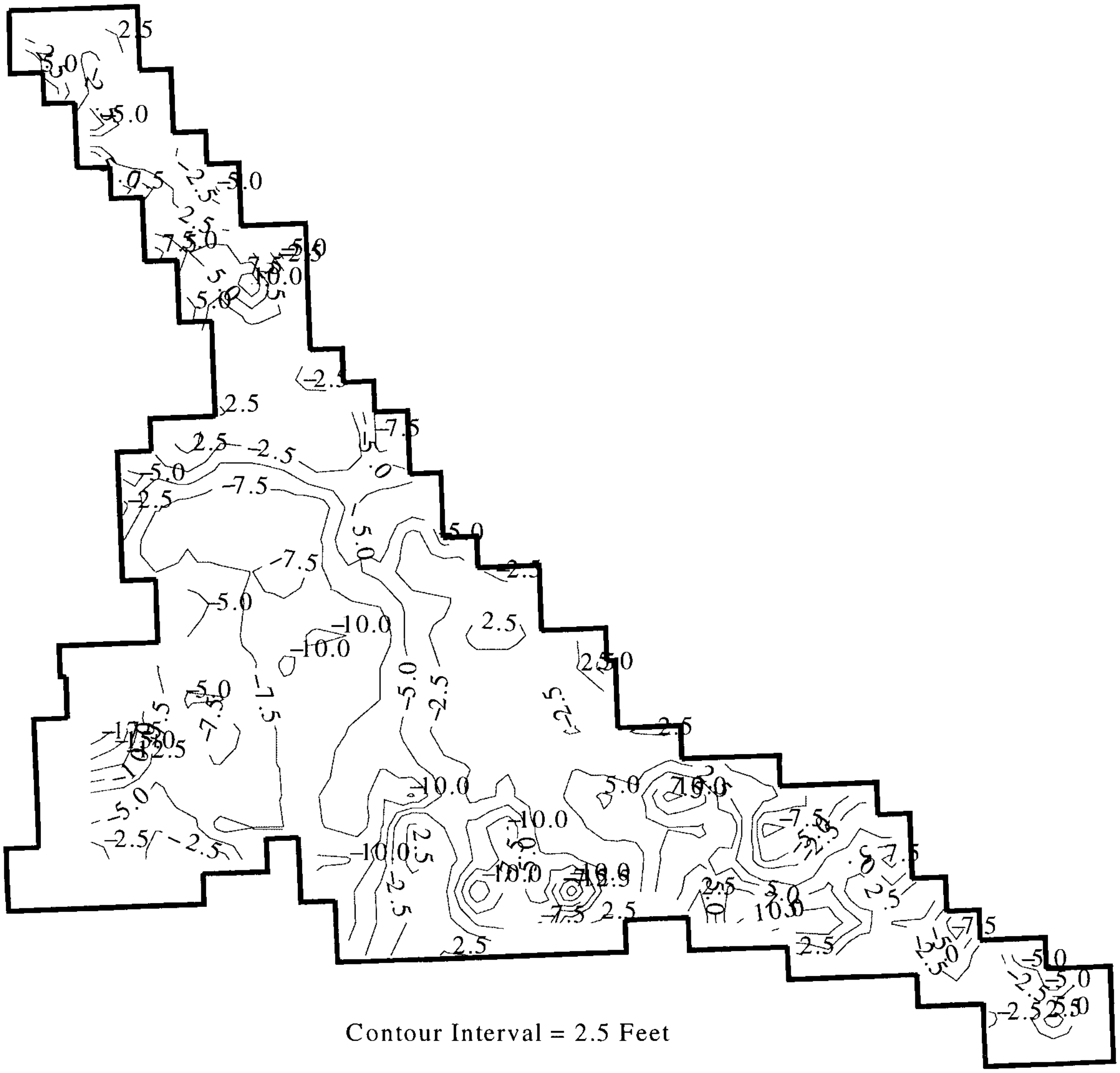


Figure 26. **Differences between Estimated and Simulated Water Surface for Stress Period 8 in Layer 3**

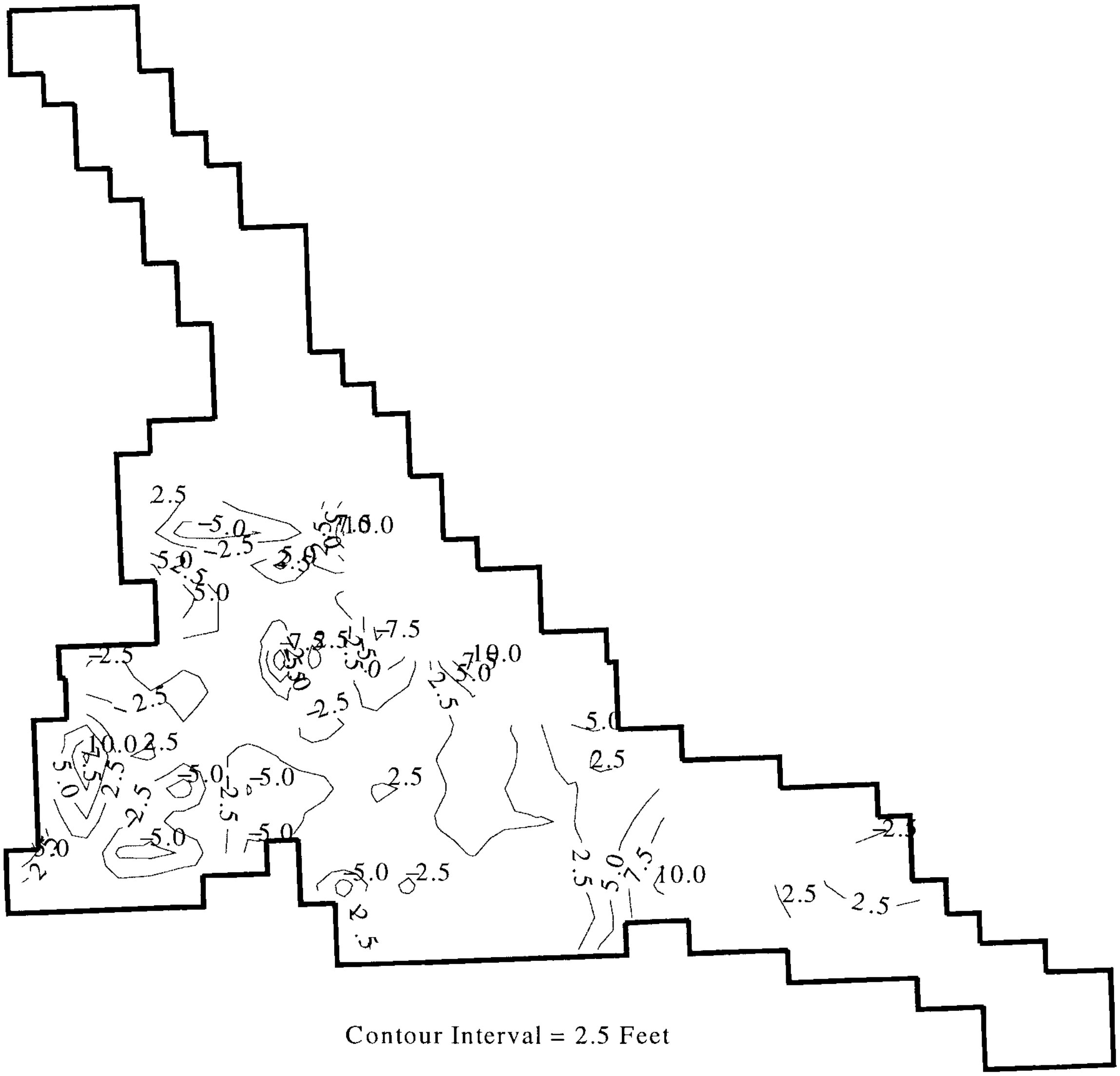


Figure 27. Differences between Estimated and Simulated Water Surface for Stress Period 16 in Layer 1

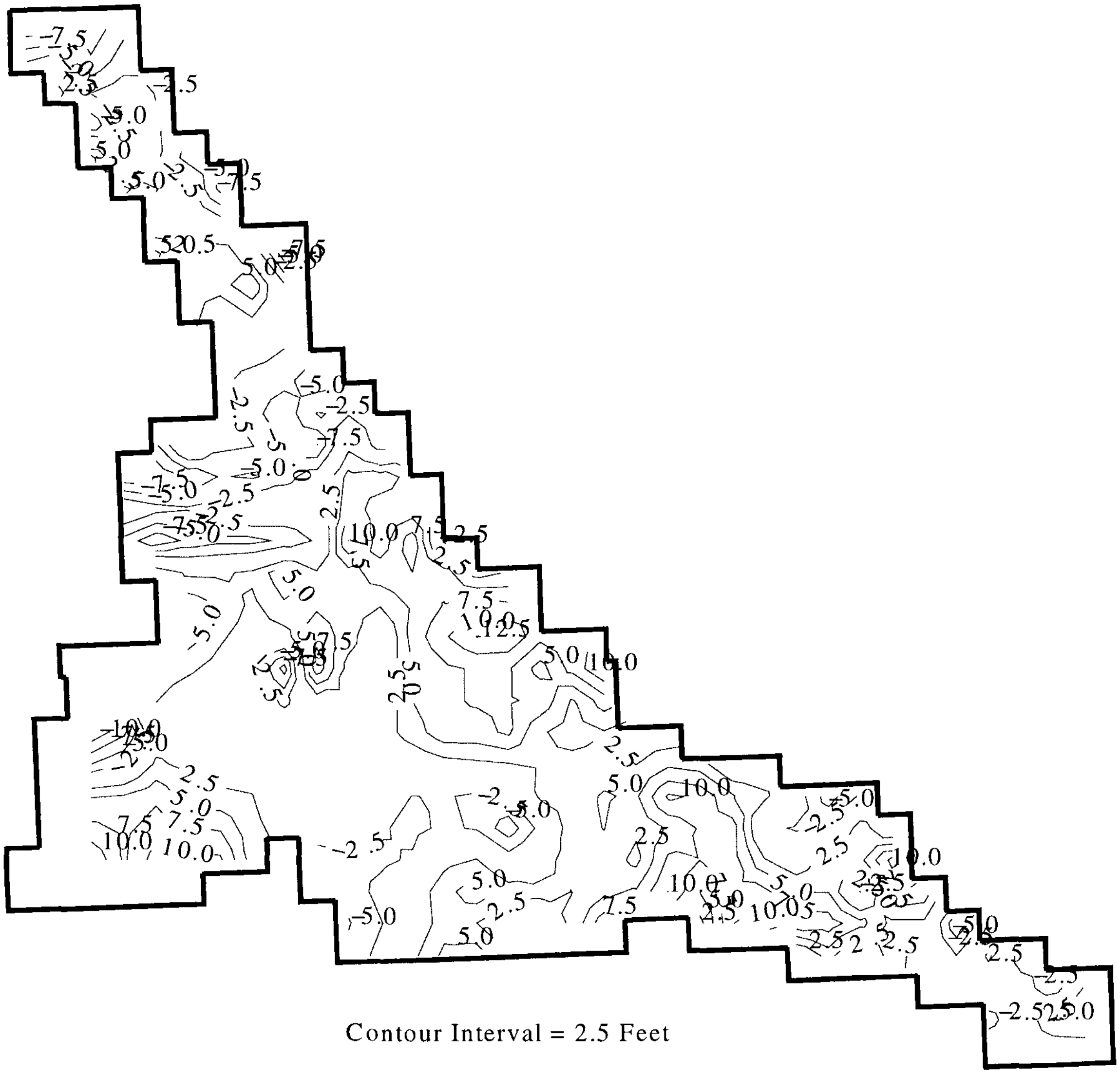


Figure 28. **Differences between Estimated and Simulated Water Surface for Stress Period 16 in Layer 3**

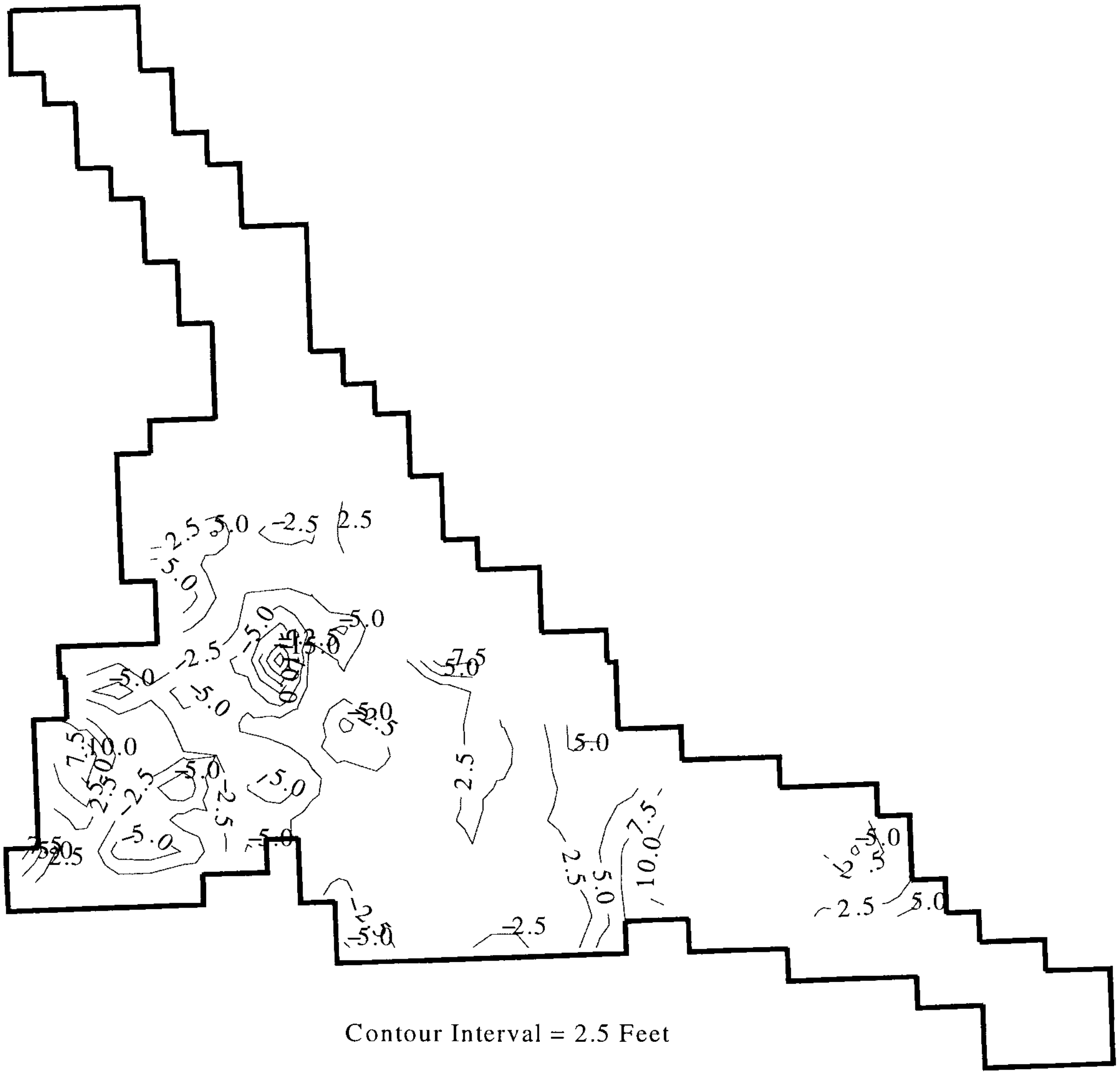


Figure 29. **Differences between Estimated and Simulated Water Surface for Stress Period 24 in Layer 1**

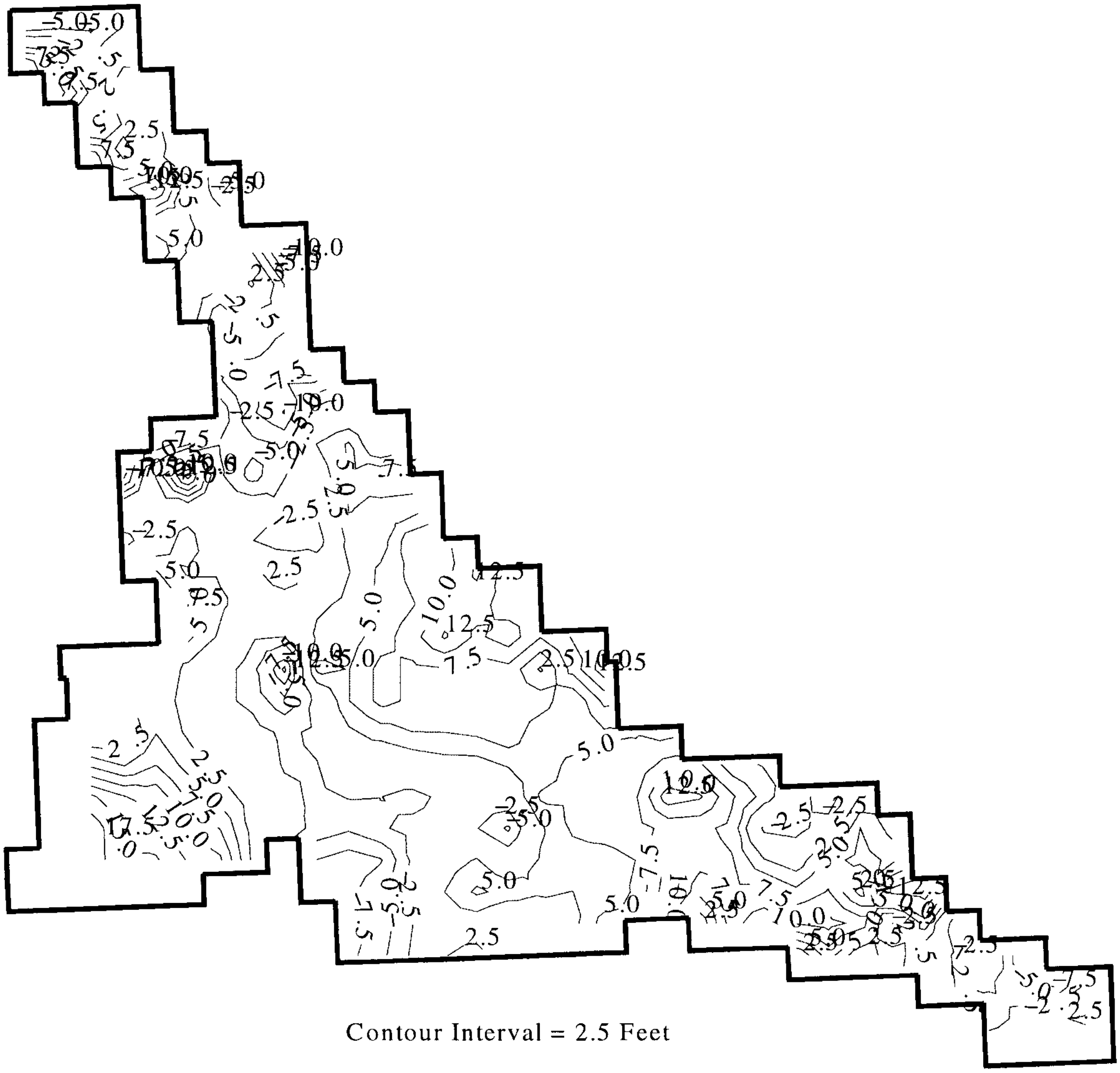


Figure 30. Differences between Estimated and Simulated Water Surface for Stress Period 24 in Layer 3

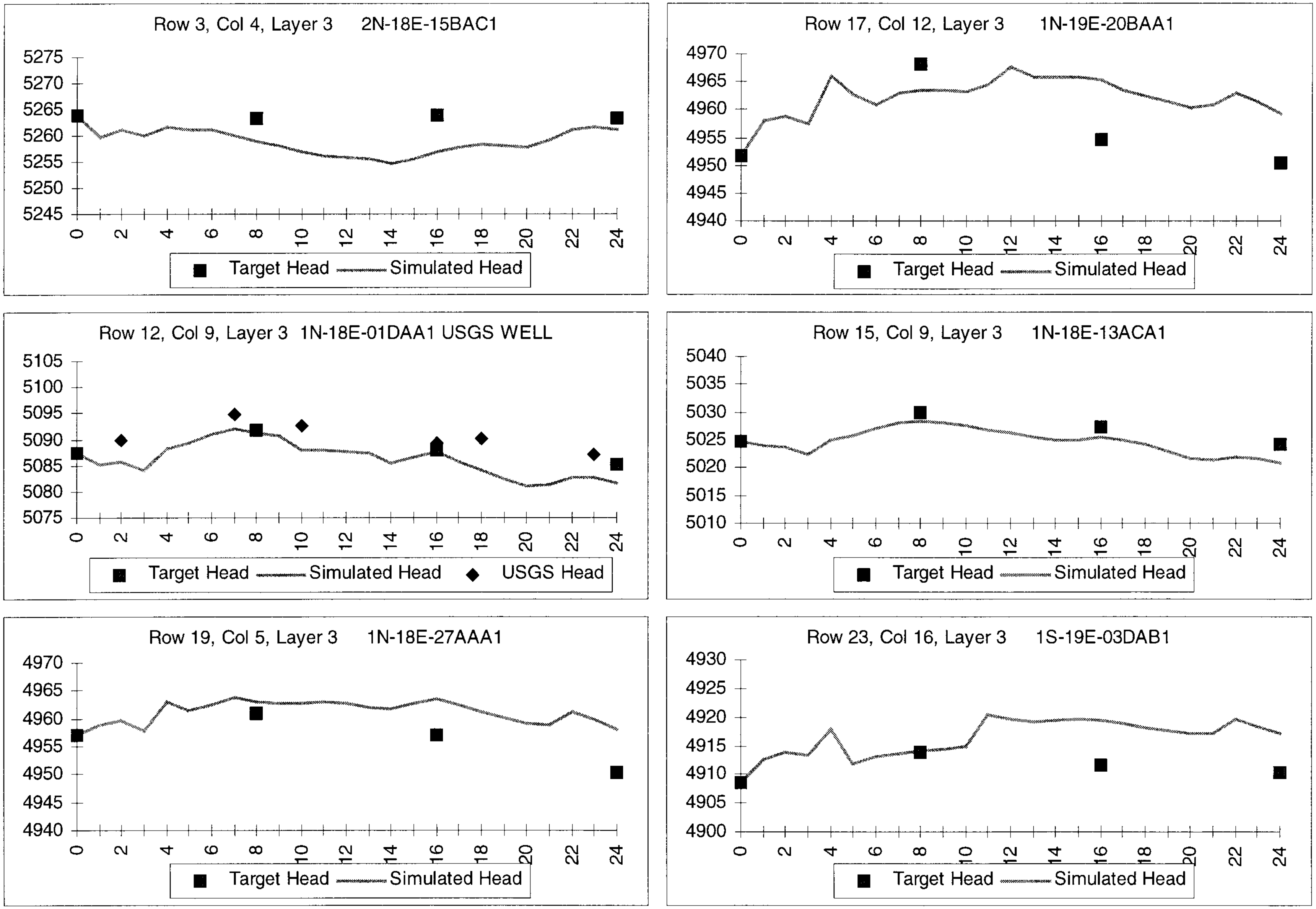


Figure 31. **Target versus Simulated Head Responses**

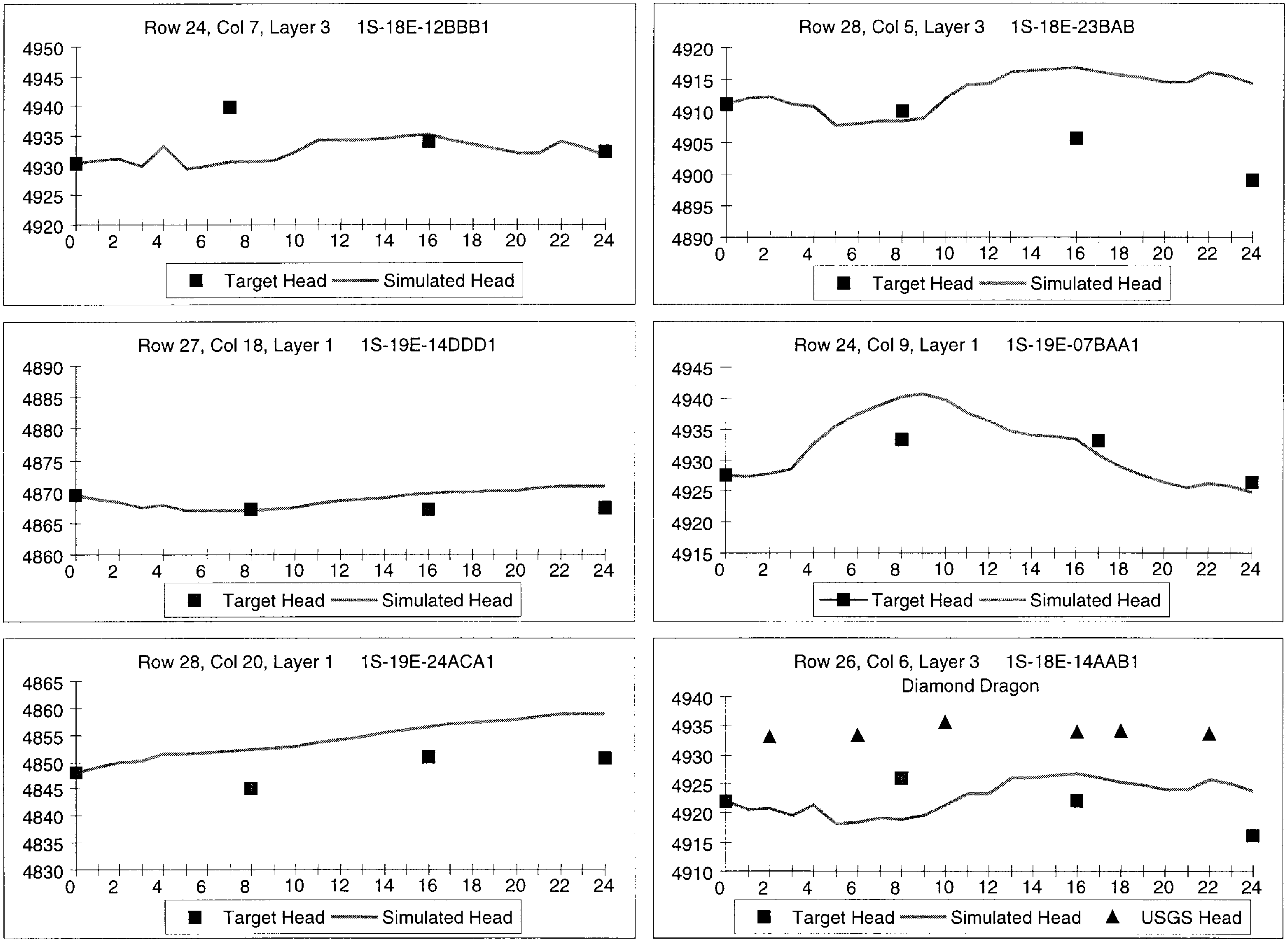


Figure 31. Target versus Simulated Head Responses (continued)

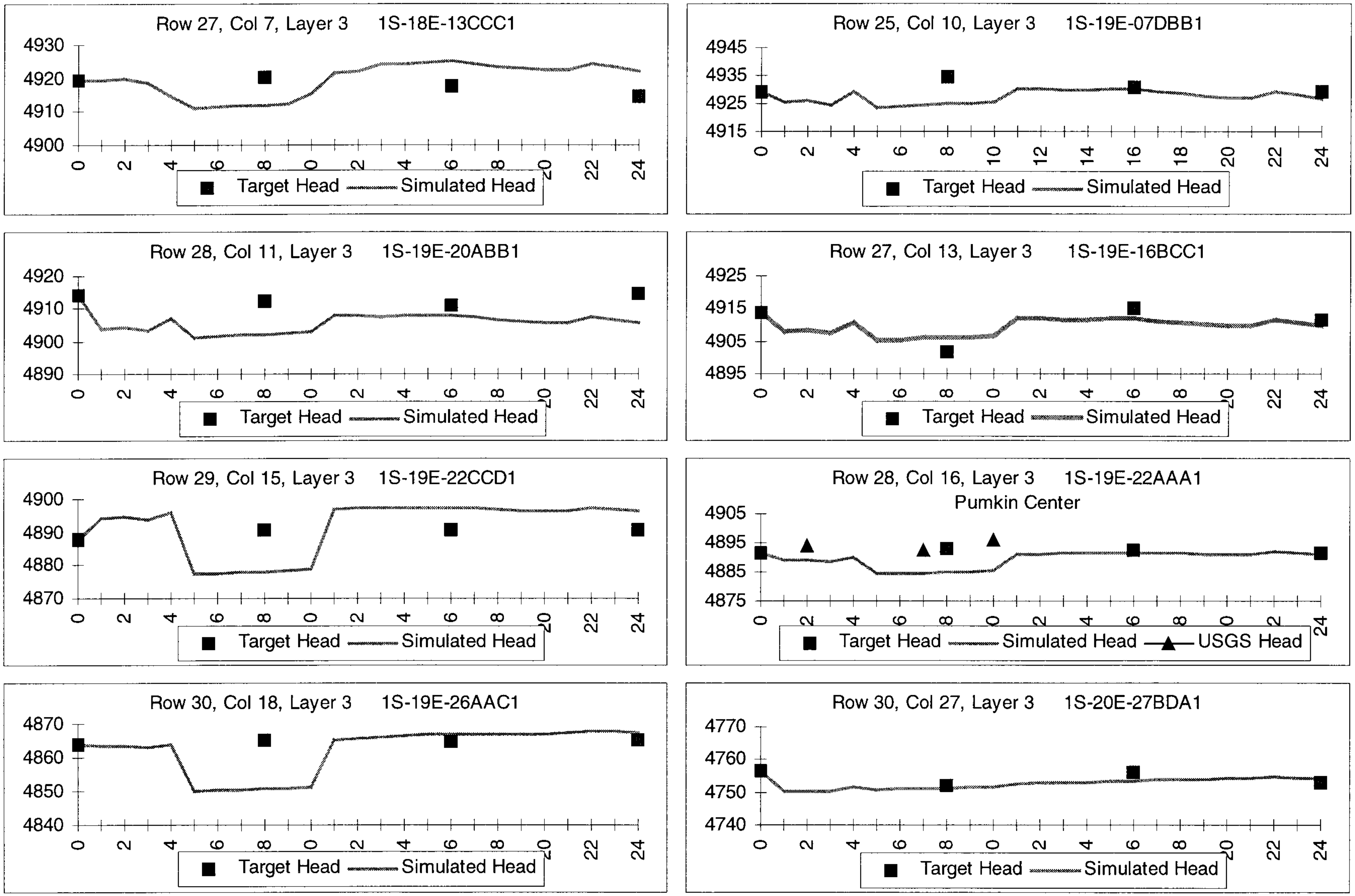
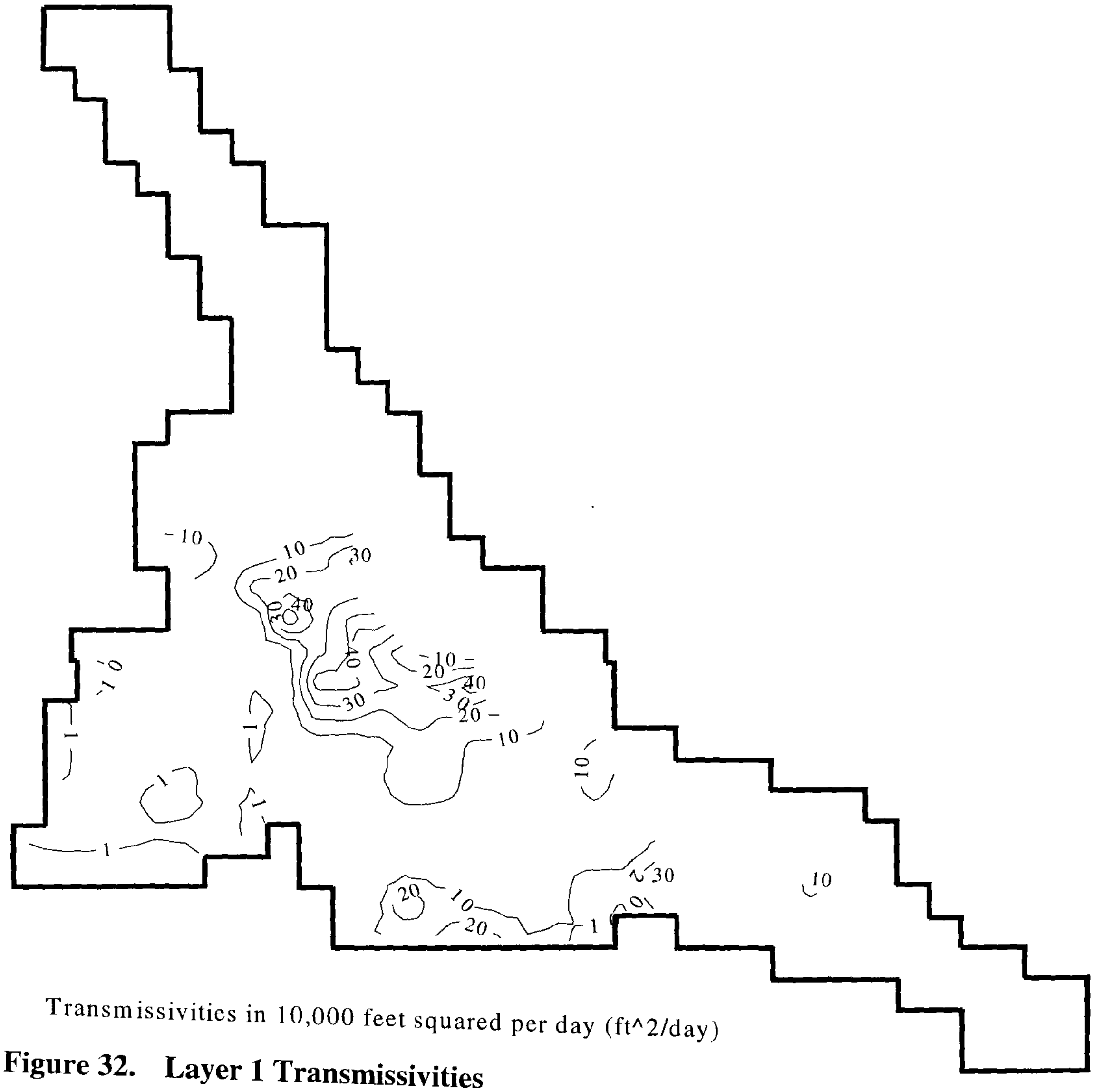
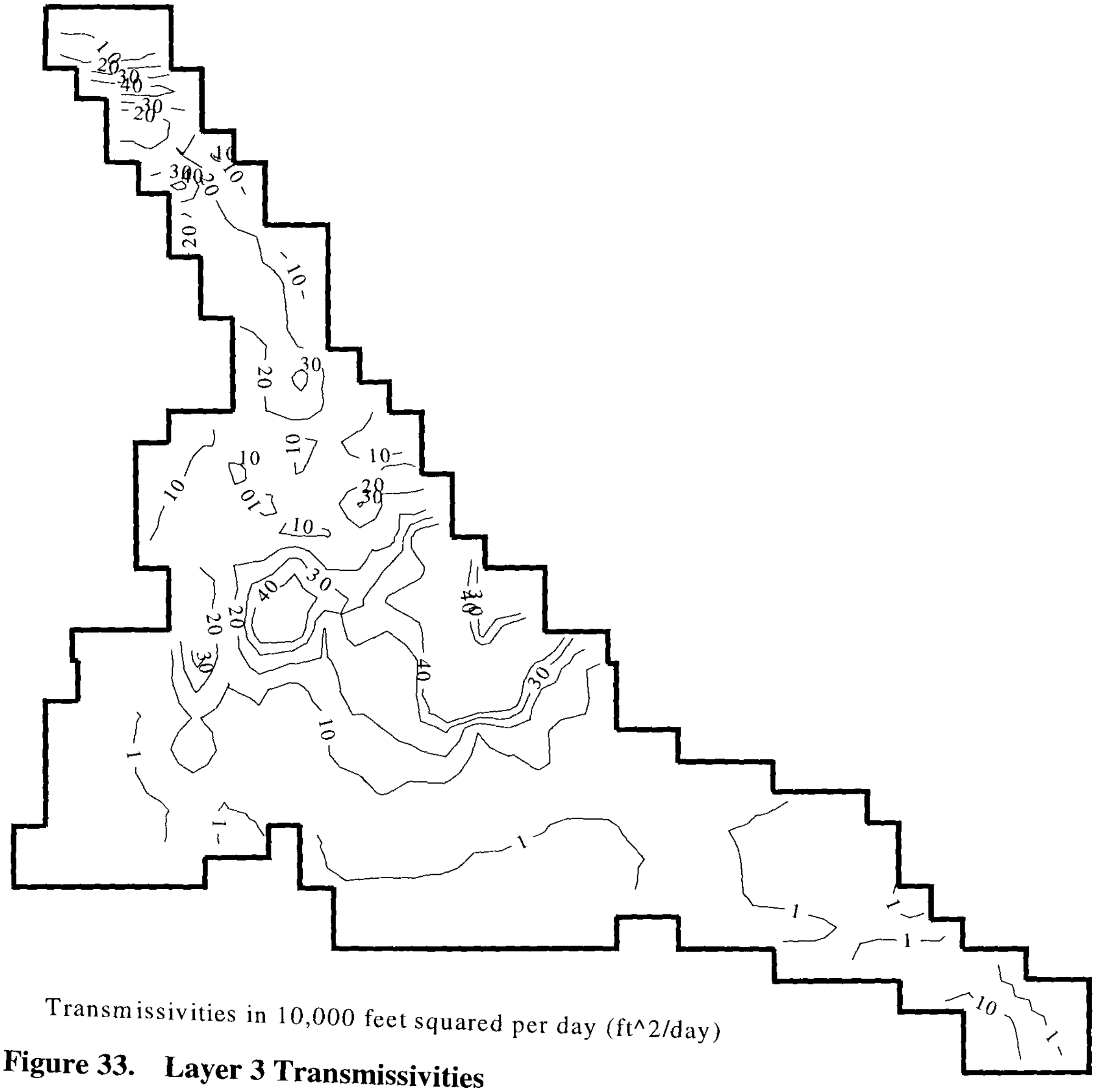


Figure 31. Target versus Simulated Head Responses (continued)



Transmissivities in 10,000 feet squared per day (ft^2/day)

Figure 32. Layer 1 Transmissivities



Transmissivities in 10,000 feet squared per day (ft^2/day)

Figure 33. Layer 3 Transmissivities

Table 11. Target versus Simulated Drain Flows for the Modeled Area.

	Total Big Wood River Reach and Springs Gains				Total Spring Flow Tributary to Silver Creek				Total flows for Silver Creek above Swanson Bridge			
Per	Modflow	Target	Diff.	% Diff.	Modflow	Target	Diff.	% Diff.	Modflow	Target	Diff.	% Diff.
6	-65.77	-50.60	-15.17	-30%	-119.18	-108.9	-10.33	-9%	-36.98	-21.51	-15.47	-72%
2	-56.79	-50.60	-6.19	-12%	-119.01	-109	-9.97	-9%	-33.98	-24.65	-9.33	-38%
3	-47.99	-56.33	8.34	15%	-109.37	-117.2	7.79	7%	-29	-55.39	26.39	48%
4	-61.07	-70.62	9.55	14%	-137.84	-135	-2.88	-2%	-37.84	-71.71	33.87	47%
5	-59.86	-79.86	20.00	25%	-117.1	-148.9	31.75	21%	-30.68	-41.85	11.17	27%
6	-60.84	-68.54	7.70	11%	-123	-170.8	47.84	28%	-30.04	-28.25	-1.79	-6%
7	-63.2	-69.35	6.15	9%	-130.43	-174.5	44.04	25%	-30.63	-31.7	1.07	3%
8	-65.5	-83.32	17.82	21%	-135.22	-183.6	48.37	26%	-30.68	-33.02	2.34	7%
9	-66.53	-77.26	10.73	14%	-139.99	-176.9	36.94	21%	-31.69	-45.25	13.56	30%
10	-66.93	-74.29	7.36	10%	-143.14	-182.6	39.46	22%	-33.76	-63.48	29.72	47%
11	-65.38	-70.53	5.15	7%	-164.61	-176.2	11.54	7%	-38.51	-53.07	14.56	27%
12	-64.5	-76.14	11.64	15%	-162.04	-167.4	5.32	3%	-41.55	-53.02	11.47	22%
13	-63.51	-75.79	12.28	16%	-159.69	-165.4	5.7	3%	-44.13	-77.77	33.64	43%
14	-63.73	-73.16	9.43	13%	-161.09	-166	4.86	3%	-46.34	-61.11	14.77	24%
15	-64.65	-69.16	4.51	7%	-162.53	-160	-2.55	-2%	-48.82	-66.59	17.77	27%
16	-65.32	-63.94	-1.38	-2%	-162.54	-144.4	-18.12	-13%	-49.62	-31.75	-17.87	-56%
17	-61.32	-52.97	-8.35	-16%	-158.34	-136.7	-21.67	-16%	-48.27	-13.82	-34.45	-249%
18	-58.17	-43.20	-14.97	-35%	-153.66	-128.2	-25.47	-20%	-47.68	-16.5	-31.18	-189%
19	-55.62	-28.49	-27.14	-95%	-149.34	-123.7	-25.68	-21%	-47.28	-16.13	-31.15	-193%
20	-53.46	-23.77	-29.69	-125%	-145.38	-121.5	-23.86	-20%	-47.12	-32.09	-15.03	-47%
21	-53.48	-27.49	-25.99	-95%	-145.04	-123.1	-21.95	-18%	-49.13	-38.71	-10.42	-27%
22	-60.92	-37.31	-23.61	-63%	-162.32	-120.8	-41.56	-34%	-52.35	-69.29	16.94	24%
23	-57.58	-41.23	-16.35	-40%	-155.76	-124	-31.78	-26%	-50.16	-28.22	-21.94	-78%
24	-52.69	-40.61	-12.08	-30%	-146.23	-118.6	-27.68	-23%	-47.04	-15.96	-31.08	-195%
Average Flows												
	-60.62	-58.52	-2.10		-144.29	-145.14			-40.97	-41.29		
Total BWR, Silver Creek Springs, and Silver Creek Channel Modflow									-245.87			
Total BWR, Silver Creek Springs, and Silver Creek Channel Target									-244.95			
Total BWR, Silver Creek Springs, and Silver Creek Channel Difference									-2.44			
Total BWR, Silver Creek Springs, and Silver Creek Channel % Difference									-0.38%			

All flows in cfs or % and negative flows indicate flow out of the aquifer.

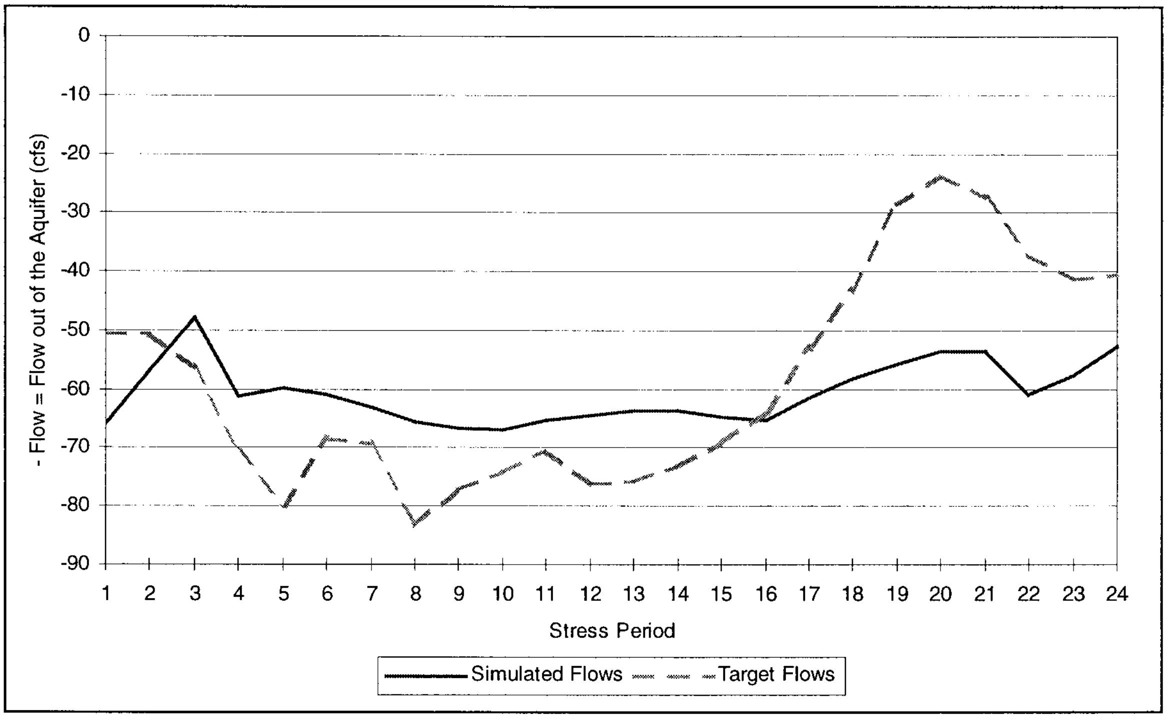


Figure 34. 1993 Target vs Simulated Spring Flows for Big Wood River Area

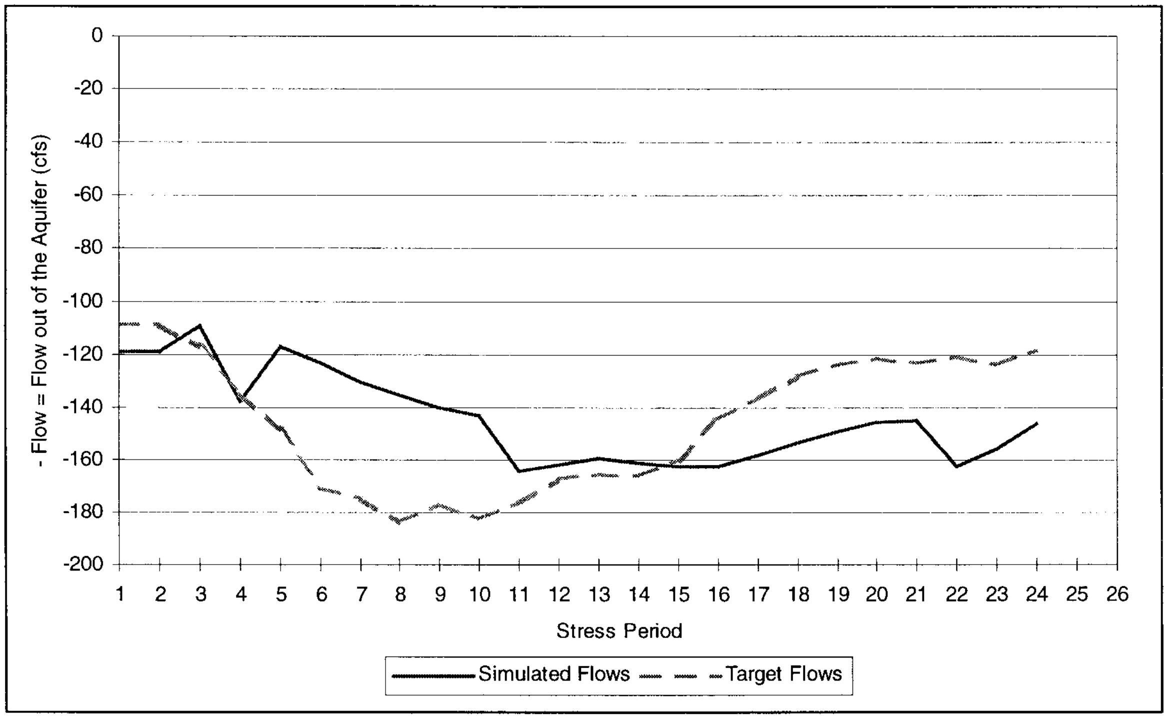


Figure 35. 1993 Target vs Simulated Flows for Springs Tributary to Silver Creek

Figure 36. 1993 Target vs Simulated Flows for Silver Creek above Swanson Bridge

Model Limitations and Needs for Further Study

The range of uncertainty associated with the components of the water budget is large. The estimates of the Big Wood River seepage used for this study vary considerably from the values used in other reports. A semi-monthly mass balance using the two USGS gages and Watermaster irrigation records does not account for a time lag factor that may occur in the ground water movement. This estimate for the seepage of the Big Wood River is therefore only fair (page 41). Ground water pumpage estimates are considered fair because of the method of collection. Relying on the owners' estimate of the number of days the pumps operated and the flow produced can be a large source of error. The flow rates for the surface water irrigation diversions were based on Watermaster daily records. Estimates on the annual precipitation are considered good because of the agreement of the long term records with the 1993-1994 values. Estimates of the consumptive use were calculated with recognized standard methods and are considered good. Underflow across the boundary at Priest Road was computed as the difference between the total recharge and total discharge of the system. An error in the determination of any of the other stresses would have an effect on this variable. Underflow at Hailey is considered good by the agreement with other studies. The flows measured at Priest Road and Stanton Crossing are considered good, but the assumption of 100% infiltration for irrigation water and precipitation with no surface return flows to the system was not totally verified.

Several areas related to the calibration data sets also need to be addressed. Measured flows of the Big Wood River at Glendale Bridge would have been beneficial for model calibration. The Watermaster's statement that the Big Wood River is dry until "sometime in November" was not specific enough. Additional monitoring is needed on the irrigation diversions both before and after the official irrigation season. Phase I stated that the irrigation diversions have decreased since 1972. Even though the diversions are dependent on the flow of the Big Wood River, the higher flows of the Big Wood River during the middle 1980's did not result in higher flows for the irrigation diversions. The Phase I report verified this lack of correlation. This also supports the hypothesis that the irrigators have converted to sprinklers and/or developed additional ground water irrigation resulting in decreased surface diversions.

A data collection period longer than one year would have allowed calibration of the model for more than one annual cycle. The beginning and ending water surface elevations for some of the observation wells were different (Figures 16 and 17). This difference indicates that aquifer levels were not in equilibrium and that an assumption of zero net change in aquifer storage may not be totally valid.

At the Stanton Crossing gage, the stream channel would change at times because of sediment deposition and channel scour. Therefore, some of the difficulties calculating the seepage losses of Reaches I and II could be associated with stream channel variation at the gage site.

Three wells were also measured by the USGS: one near Bellevue, an artesian well at the Diamond Dragon Ranch, and the Pumpkin Center artesian well. The Pumpkin Center well was dropped from the USGS network half way through the Phase I measurement period.

GROUND WATER MODEL APPLICATION

The ground water flow model developed for the Big Wood River-Silver Creek aquifer is capable of answering questions in terms of differences. These head and flow differences are in a relative rather than an absolute sense. The procedure was to develop an aquifer long range or period of record stress data set consisting of reference recharge and discharge fluxes. Then the model was used to simulate a reference aquifer response over a period of time. The reference simulation is typically run until there is minimum change in storage on an annual basis. The resulting head distributions are used as starting heads for any "what if" scenarios. Also this reference head distribution and associated spring outflows spatially and temporally provide the base to which to compare the "what if" simulation results. “Because the model grossly simplifies a complex hydrologic system, results of the model should be used with caution” (Newton, 1991).

Reference Simulation

A reference transient aquifer stress data set was developed and an aquifer response was simulated for comparison with responses resulting from land use and water use changes. Simulated hydraulic heads for each cell and output fluxes generated by the drain and river modules were compared. (The basis of the data for the reference simulation is the period of record for the USGS gauging stations, surface diversions, and climatic data with current land use, ground water diversions, and cropping patterns.)

Aquifer Stress Data Set

The 1916-1994 average Big Wood River flows at Hailey and Stanton Crossing and canal diversions were used to develop the seepage loss of the Big Wood River in Reaches I and II. Canal diversions were changed for all the diversions in both District 37 and 37M by the ratios of Period of Record (POR) average and 1993 flows given in Table 12. These relationships were developed from Phase I data.

Average flows at Hailey are lower than for the calibration year (1993-1994); the surface diversions are lower for some periods and higher for some; and, the average flows at Stanton Crossing are lower for the spring time flows and higher for the rest of the year (Table 13).

The assumption that the Big Wood River is dry at Glendale during the late summer months was made for the reference simulation. During this time frame, the Reach I loss was the difference between Hailey gage and diversions. For the other times of the year, the Reach I loss was calculated from the flow at Hailey by using the formula developed when comparing the Hailey gage and Reach I losses for 1993. Two functions were used to calculate the seepage losses as a function of stream discharge: one for the spring and summer periods when flows were greatest and there were canal diversions; and the other function was used for wintertime flows. Figure 37 shows the calculated seepage versus the expected seepage calculated with the formulas used to develop the expected flows.

The length of Reach II was 19% of the combined length of Reach I and Reach II. This ratio was used to calculate the Reach II seepage when the seepage in Reach I was known. This process was employed earlier when calculating the Reach II losses for 1993 and was used again for this reference simulation except for the periods when Reach II was a gaining reach. During this time the gains were the same for the reference simulation year as for 1993.

Table 12. Reference Scenario Canal Diversions

Month	1993 Volume (kaf)[a]	Avg. Voilume (kaf)[b]
3	0	0.06
4	2.37	2.6
5	16.6	18.28
6	23.3	26.93
7	26.2	19.37
8	18.8	11.5
9	9.2	7.71
10	0	0

[a] 1993 Canal Diversions as defined in Phase I Report (kaf).

[b] Avg. Flows are for Period of Record (POR) reported in Phase I.

Underflow at Hailey, ET, recharge in the gravel pits, and the pumpage for production wells remained the same for the reference stress data set as the calibration year.

Table 13. Big Wood River Reach Gains/Losses for Reference Scenario

Period	Time Step	93 Adj. Flow Hailey Gage cfs	POR Flow Hailey Gage cfs	Reach I				Reach II				93 Reach III Gain cfs	93 Reach III Stream Inflow cfs	93 Adj. Flow Stanton Bridge cfs	POR Flow Stanton Bridge cfs
				Diversions		Losses		Diversions		Losses					
				1993	Avg.	1993	Baseline	1993	Avg.	1993	Baseline				
				cfs		cfs		cfs		cfs					
16Apr-30Apr	1	500.5	650.2	37.4	41.2	103.5	103.7	15.3	16.8	24.3	24.3	14.2	36.4	370.7	598.0
1May-15May	2	1186.6	1001.5	62.6	62.7	181.7	114.2	29.6	32.6	42.6	26.8	14.2	36.4	917.7	800.2
16May-31May	3	2346.4	1400.7	352.0	387.6	131.9	126.2	34.6	38.1	30.9	29.6	15.2	38.8	1851.0	1050.4
1Jun-15Jun	4	1883.0	1488.1	294.8	340.7	126.3	128.8	15.2	17.5	29.6	30.2	18.8	48.1	1484.0	1123.7
15Jun-30Jun	5	1689.7	1229.3	375.1	433.5	132.0	121.1	13.4	15.5	31.0	28.4	17.9	45.7	1202.0	966.2
1Jul-15Jul	6	886.3	781.7	406.6	273.3	137.2	107.6	26.5	19.6	32.2	25.3	16.6	42.5	340.2	566.0
16Jul-31Jul	7	617.1	408.7	375.0	277.2	97.7	96.4	24.5	18.1	22.9	22.6	18.8	48.0	163.8	222.2
1Aug-15Aug	8	521.9	245.1	328.0	187.2	99.2	58.0	28.1	17.7	-10.0	-10.0	22.4	57.3	144.4	121.4
15Aug-31Aug	9	359.3	199.8	233.5	146.6	100.0	53.2	11.9	7.5	-19.2	-19.2	19.4	49.5	101.7	103.6
1Sep-15Sep	10	224.7	163.0	139.8	117.2	84.9	45.8	10.1	8.4	-25.2	-25.2	16.6	42.3	74.1	100.2
16Sep-30Sep	11	203.0	154.2	118.0	98.9	85.0	55.4	11.9	10.0	-17.4	-17.4	20.8	53.1	73.2	96.5
1Oct-15Oct	12	202.9	147.4	118.0	98.9	85.0	48.6	11.9	10.0	-12.8	-12.8	18.8	48.1	67.8	98.2
16Oct-31Oct	13	206.6	146.4	118.0	98.9	88.6	47.6	11.9	10.0	-14.5	-14.5	21.6	55.2	72.9	104.5
1Nov-15Nov	14	175.7	138.1	118.0	98.9	57.8	39.2	11.9	10.0	-15.4	-15.4	19.3	49.4	68.8	110.2
16Nov-30Nov	15	132.2	120.8			117.4	99.0			14.8	23.2	16.9	43.3	62.2	110.1
1Dec-15Dec	16	156.9	108.3			121.8	92.4			29.2	21.7	15.8	40.3	62.1	95.8
16Dec-31Dec	17	140.3	110.0			111.6	93.3			26.3	21.9	13.6	34.9	50.9	83.7
1Jan-15Jan	18	149.1	108.8			111.1	92.7			25.1	21.7	8.7	22.3	43.9	72.8
16Jan-31Jan	19	136.7	115.0			97.5	95.9			22.6	22.5	6.6	16.9	40.0	69.2
1Feb-14Feb	20	122.6	105.0			91.8	90.7			21.2	21.3	7.1	18.1	34.9	73.3
15Feb-28Feb	21	124.3	104.5			101.0	90.4			22.0	21.2	9.3	23.9	34.4	81.1
1Mar-15Mar	22	150.5	113.7			122.4	95.3			27.6	22.3	13.1	33.6	47.3	100.1
16Mar-31Mar	23	159.1	153.3			122.0	98.2			29.6	23.0	8.9	22.8	39.2	140.4
1Apr-15Apr	24	173.1	303.4	6.2	6.8	119.4	93.3	1.9	2.1	28.0	26.2	8.9	22.7	37.3	296.5
Totals (AF)		375306	286317	92945	80478	79187	62915	7797	7048	10412	8978	10970	28016	222894	216604
Avg. Flow (cfs)		518.7	395.7	128.5	111.2	109.4	87.0	10.8	9.7	14.4	12.4	15.1	38.7	307.7	299.4

Base Year Flows = Average for Period of Record (POR) of 1916-1994

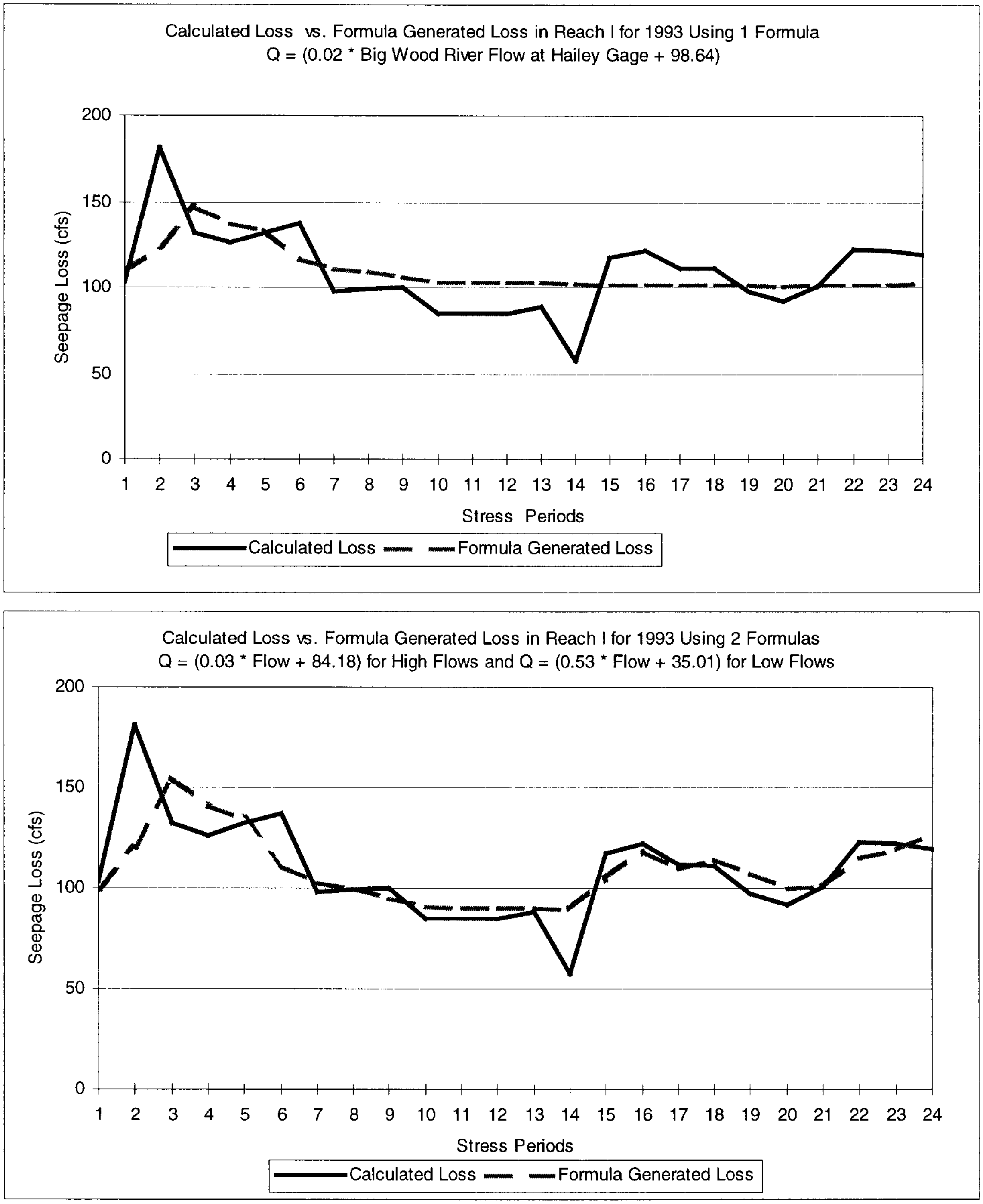


Figure 37. Formulas to Calculate Big Wood River Seepage Losses.

The average precipitation is 13.3 in/year, while the 1993 precipitation was 10.4 in/year; therefore, the 1993 precipitation was adjusted uniformly by 13.3/10.4 to produce the precipitation input for the reference scenario. The precipitation term was adjusted by this ratio for the water content derived from the snowmelt as well as from rain events.

The beginning head values for the reference simulation were the heads obtained from the spring 1993 mass measurement of the observation wells. All the aquifer parameters calibrated from the 1993-1994 period were used for the reference simulation. The model was then run for 20 years or 480 stress periods. These generated output heads were used as the beginning heads and the model was run for another 20 years. After this second simulation cycle, there were 4 cells with head changes greater than 0.5 feet. The model was run again with the same procedure using the 20-year generated heads as starting heads. After this simulation cycle, there were no head change variations greater than 0.05 feet between the last two simulated years. These final simulated head values serve as the starting water surfaces for all scenarios.

The reference scenario was run for another 40 year period to develop a set of head and flow values to compare with other scenarios. Each scenario was run for a 40 year time period to develop an "equilibrium" situation. The comparison time frame values included the 24 stress periods from the 39th year and the first stress period of the 40th year. This provided 25 stress periods for comparison. The first stress period of each simulated year should have identical head values for individual cells if the simulation has reached equilibrium.

Sensitivity Analysis of Model Parameters

A sensitivity analysis was conducted using the reference scenario stress data sets to identify the degree of change in modeled output associated with uncertainty in aquifer parameters. By changing a single parameter while fixing the other parameters, the degree of uncertainty associated with the single parameter can be evaluated. A uniform global change of ±10% was executed on the aquifer parameter in question because a change in a single cell will not significantly affect any results.

Changes in Horizontal Hydraulic Conductivity

Water level and spring flow changes that occurred in response to ±10% changes in the horizontal hydraulic conductivity are shown in Table 14 and Figure 38. A 10%

increase or decrease in horizontal conductivity produced a change of only ±3 cfs in spring flows to both the Big Wood River and Silver Creek, while head changes of up to 9 feet in the northern region of the study resulted from this change. The model experienced a decrease in underflow at Priest Road of 344 af/year (1.2%) from the decrease in hydraulic conductivity, and no change in underflow was observed for the increased hydraulic conductivity values.

Changes in Vertical Conductance

The model failed to converge in the 32nd stress period when vertical conductance was by changed by ±10%. Cells that dewater in the perched aquifer near Picabo caused this failure. Cells below this perched aquifer experienced head decreases of up to 60 feet, while other cells in layer three near Stanton Crossing had piezometric head declines of 50 feet. The model is very sensitive to a change in vertical conductance.

Vertical conductance between layers was calculated at the interface of two layers. It was intended to be function of the horizontal conductivity of the layer above and layer below the interface. Making a ±10% change in this parameter would violate this relationship. The vertical conductance parameter could be calibrated as a unique variable, but for this study it was assumed to be related to the horizontal conductivity.

Changes in the Drain and River Conductances

A change of ±10% in the drain and river hydraulic conductances caused a flow difference of ±2 cfs in flows to both the Big Wood River and Silver Creek (Figure 39). No head changes greater than two feet resulted from this change. Underflow changes of a decrease in 290 af/year were observed with a 10% increase in drain and river conductances (Table 14).

Table 14. Changes in Heads and Flows During Model Parameter Sensitivity Analysis

	Horizontal Hydraulic Conductivity				Drain & River Hydraulic Conductivity				Specific Yield Storage Coefficient- sf1			
	110%		90%		110%		90%		110%		90%	
Cells *	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
Maximum Head Changes (ft)												
3 4 3	-5.55	-6.14	6.58	5.50	-0.01	-0.01	0.01	0.01	0.42	-0.38	0.45	-0.46
12 9 3	-9.00	-9.54	8.87	7.96	-0.15	-0.16	0.19	0.18	0.56	-0.69	0.86	-0.54
19 5 3	-3.91	-4.12	3.79	3.52	-0.35	-0.36	0.43	0.42	1.69	-0.70	1.99	-2.14
17 12 3	-3.44	-3.84	5.01	4.62	-0.36	-0.38	0.45	0.43	0.82	-0.48	1.38	-1.18
15 9 3	-7.95	-8.29	7.58	7.04	-0.27	-0.28	0.33	0.32	0.29	-0.46	0.86	-0.59
23 16 3	-0.69	-1.04	1.28	0.89	-0.45	-0.51	0.61	0.55	0.13	-0.10	0.29	-0.55
24 7 3	-1.47	-1.71	1.59	1.31	-0.38	-0.40	0.47	0.45	0.81	-0.59	0.64	-1.14
27 18 1	0.58	0.44	-0.48	-0.66	-0.66	-0.75	0.95	0.85	0.29	-0.16	0.08	-0.08
28 20 1	0.75	0.68	-0.73	-0.80	-0.85	-0.90	1.25	1.17	0.31	-0.21	0.08	-0.08
28 5 3	0.29	-0.22	-0.08	-0.65	-0.39	-0.41	0.48	0.46	0.51	-0.37	0.67	-0.51
24 9 1	-1.54	-1.82	1.93	1.62	-0.39	-0.42	0.50	0.47	0.79	-0.52	1.09	-1.08
26 6 3	-0.50	-1.00	0.80	0.22	-0.39	-0.41	0.48	0.46	0.64	-0.49	0.83	-0.98
27 7 3	0.08	-0.89	0.72	-0.42	-0.39	-0.40	0.48	0.46	0.59	-0.26	0.79	-0.53
28 11 3	0.47	0.16	-0.30	-0.61	-0.44	-0.49	0.58	0.53	0.39	-0.14	0.58	-0.66
29 15 3	1.82	0.37	-0.47	-2.14	-0.52	-0.60	0.70	0.62	0.15	-0.07	0.23	-0.36
30 18 3	1.70	0.68	-0.72	-1.91	-0.72	-0.77	0.99	0.93	0.15	-0.10	0.05	-0.06
25 10 3	-1.16	-1.48	1.63	1.23	-0.41	-0.44	0.53	0.49	0.64	-0.41	0.92	-0.93
27 13 3	-0.02	-0.34	0.35	-0.01	-0.47	-0.53	0.63	0.57	0.16	-0.17	0.46	-0.57
28 16 3	0.87	0.48	-0.59	-1.01	-0.59	-0.67	0.79	0.70	0.14	-0.06	0.16	-0.25
30 27 3	-0.45	-0.48	0.64	0.60	-0.41	-0.47	0.85	0.70	0.74	-0.69	0.64	-0.59
Average	-1.46	-1.91	1.87	1.32	-0.43	-0.47	0.59	0.54	0.51	-0.35	0.65	-0.66
Maximum	1.82	0.68	8.87	7.96	-0.01	-0.01	1.25	1.17	1.69	-0.06	1.99	-0.06
Minimum	-9.00	-9.54	-0.73	-2.14	-0.85	-0.90	0.01	0.01	0.13	-0.70	0.05	-2.14
Maximum Flow Changes (cfs)												
Big Wood River	-0.74	-2.35	1.55	0.36	-0.10	-0.53	0.61	0.10	0.42	-0.63	1.08	2.91
Silver Creek	1.23	-0.39	-2.62	-2.88	1.94	-2.04	2.29	-2.39	2.65	-1.81	-1.96	-4.32
Underflow Changes (af/year)												
		0		-344	100			-135		0		0

* (Cells are defined by row, column, and layer)

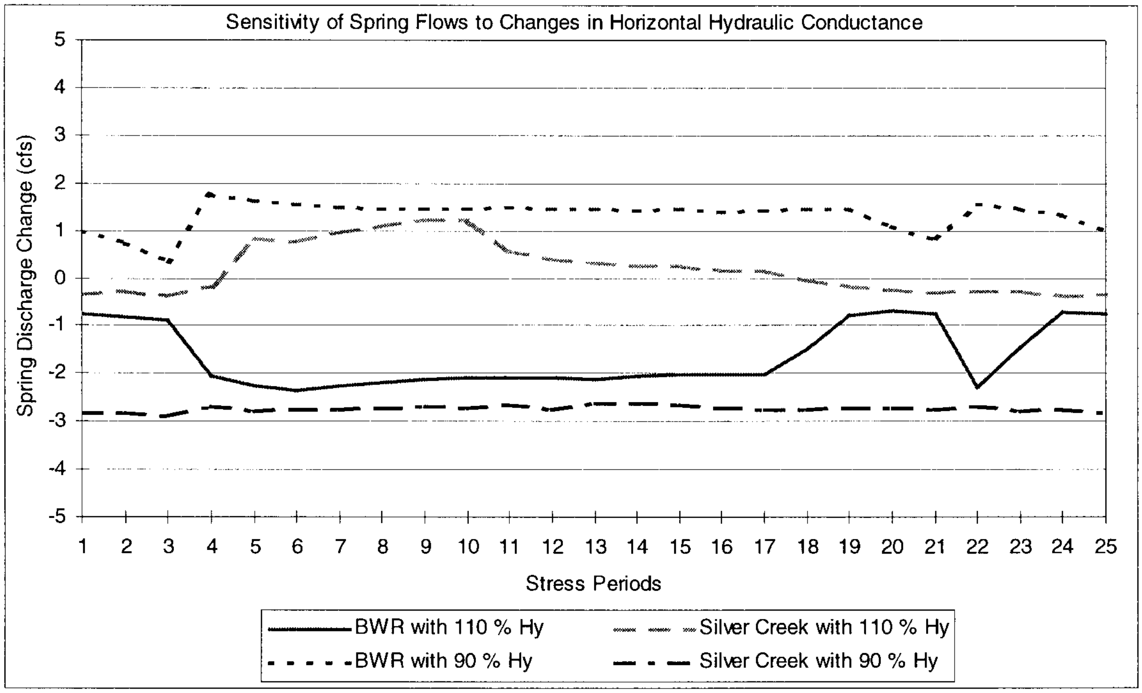


Figure 38. Flow Sensitivity to Changes in Hydraulic Conductivity.

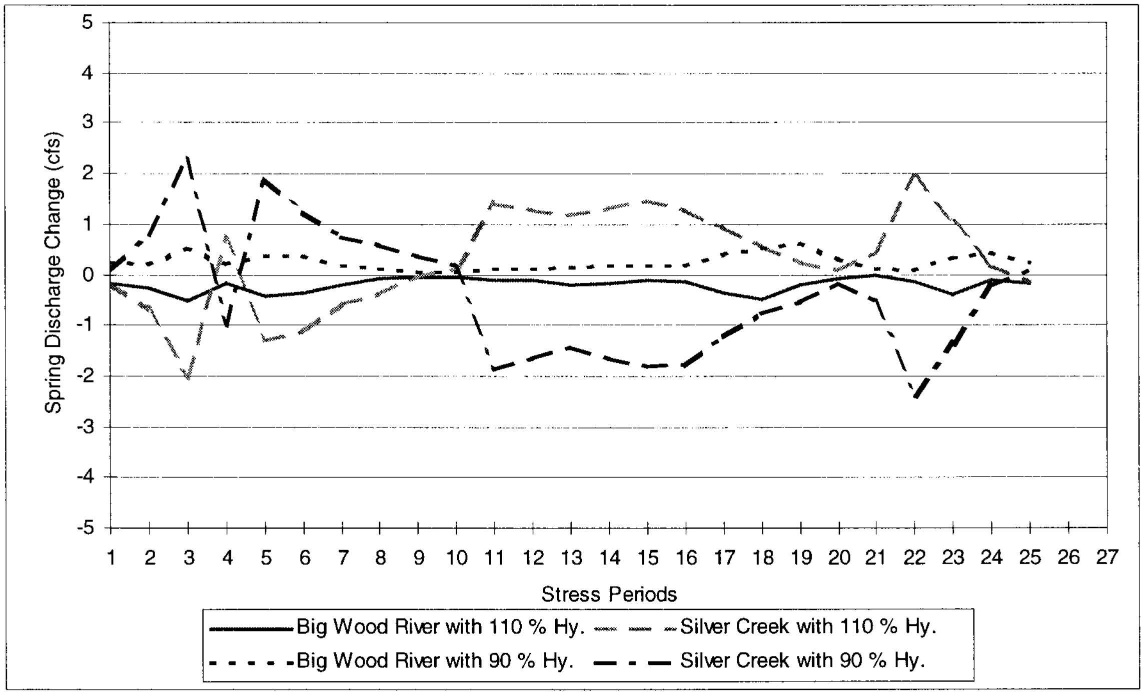


Figure 39. Flow Sensitivity to Changes in Drain and River Hydraulic Conductivity

Changes in the Storage Coefficients

A 10% decrease in the unconfined storage coefficient (specific yield) produced a decline of 4 cfs for Silver Creek in the 3rd stress period (Table 14 and Figure 40). A 10% increase in this variable did not result in as large a change. The model is, therefore, more sensitive to a reduced value of specific yield. The spring flow change was very erratic, showing the sensitivity of this parameter.

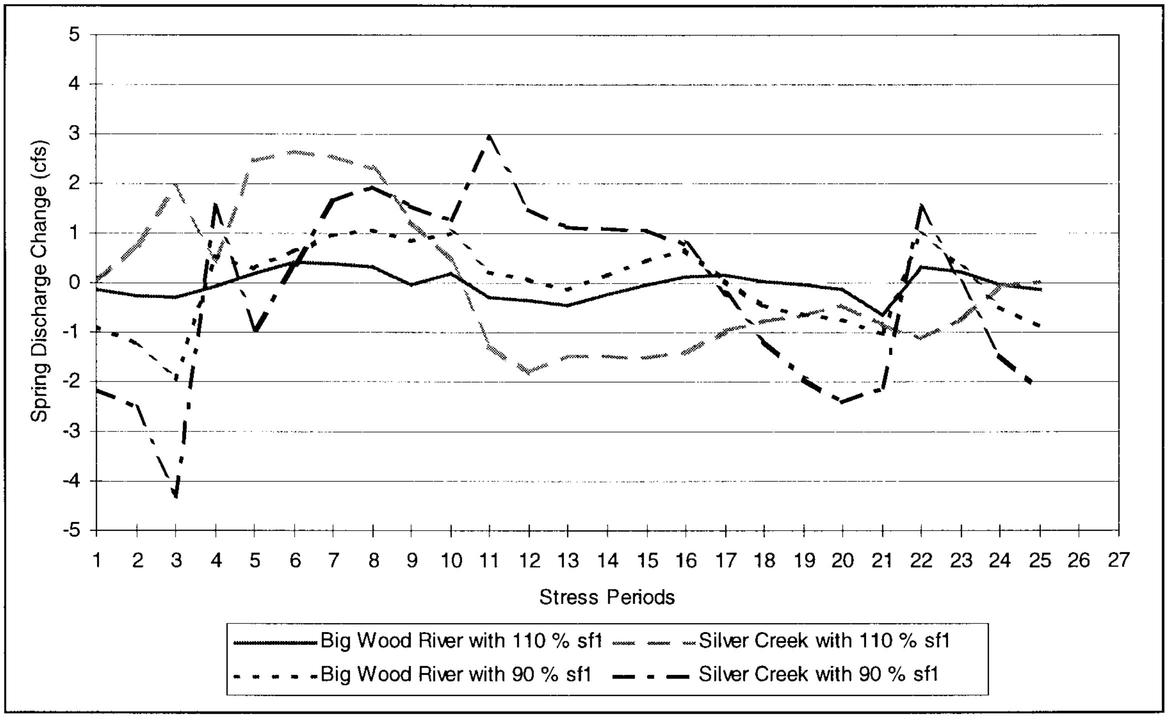


Figure 40. Flow Sensitivity to Changes in Specific Yield Storage Coefficient

The specific yield in the model ranged from 0.05 to 0.3 while the confined storage coefficient ranged from 0.000001 to 0.00002. There were no noticeable changes in the head differences with changes to this variable. No change in underflow was observed with either an increase or decrease in specific yield. A change of ±10% in the confined storage coefficient produced no observable change in flow, heads, or underflow.

Sensitivity Analysis Conclusions

This model is most sensitive to changes in the vertical conductance. This sensitivity was due to hydrologic connections that allow water movement between the layers. Ground water moves up and down between the top and bottom layers in this system. Changes in vertical direction of flow can occur seasonally or with stress changes. This circulation of water between the aquifer layers is not totally understood. In this valley, the vertical movement of water is less understood than the horizontal movement, and the model is most sensitive to the parameter that controls the vertical movement of water when solving the flow equations.

Some of the observation wells used in development of the calibration data sets were not fully cased, and the water levels could be a composite of the heads in several aquifers. Further investigations should include observation wells that have identifiable water levels associated with aquifer layers and the gradients between layers.

Besides the uncertainty associated with calibrated physical aquifer parameters, there is also uncertainty about future hydrologic stresses. Anderson and Woessner (1992) wrote, "Even though the set of calibrated parameters may give close agreement during calibration and verification, the model may not accurately reflect system behavior when the model is stressed in some new way."

A ±10% systematic global change on the model hydrologic stresses was not simulated. The following simulated scenarios addressing changes with water use give insight to sensitivity of the model to hydrologic components.

WATER AND LAND USE CHANGE SCENARIOS

Pre-Irrigation Scenario

This scenario simulated the water levels and spring flows prior to irrigation development (pre 1860) in the modeled area.

Stress Changes

- All irrigation diversions from the Big Wood River from Hailey to Stanton Crossing and Silver Creek were removed.
- All irrigation wells were removed from the ground water model area.
- Crop consumptive use was replaced with range land consumptive use north of Gannett and with marsh (wetland) consumptive use south of Gannett.

- Diverted water remained in the Big Wood River and was available for seepage below Glendale Bridge year around.
- Underflow entering the model area at Hailey was not changed.
- Precipitation remained the same as in the reference scenario.
- No new stresses to the system were encountered.

The losses from the Big Wood River to the aquifer system in Reaches I and II and the Reach III spring flow gains were readjusted (Table 15), because the extra water that was being diverted into the irrigation canals now remains in the channel. The reach losses and gains were calculated using the same assumptions as defined in the previous section and using the same formulas.

Response Changes

The spring flow differences between the reference scenario and the pre-irrigation scenario are shown in Figure 41. The simulation showed that spring discharge to the Big Wood River decreased by 40 cfs and discharge from Silver Creek decreased by 120 cfs. Both sets of spring discharges reduced to one third of the reference according to the simulation. These comparative differences and the remainder of the scenarios differences or response changes are relative change values and are not meant to be taken in an absolute sense. The differences are not referenced to the head and flow values used in the 1993-1994 calibration period but to the values associated with the reference simulation.

Some cells above Baseline Road experienced head changes of up to a 20 foot drop. The cells in the center of the model experienced an average of a 10 foot drop, and the cells in the southwest portion experienced a 10 foot head rise for several periods due to increased seepage in the lower reach of the Big Wood River.

Underflow at Priest Road was 4,000 af/year (13.7%) less for this scenario because there is more surface water staying in the Big Wood River in addition to more ground water coming out of the springs on the west side of the valley.

Table 15. Big Wood River Seepage for Pre-Irrigation Scenario

				Reach I			Reach II					Reach III + Stream Inflow		
Stress Period	1993 Adj. Flow @ Hailey Gage cfs	1916-94 Flow @ Hailey Gage cfs	Avg. Canal Div. cfs	1993 Losses cfs	Baseline Losses cfs	Pre-Irr Hailey + Div. * Formula cfs	1993 Losses cfs	Avg. Losses cfs	Pre-Irrig. Losses cfs	Stanton 1993 Adj. cfs	Stanton Avg. cfs	1993 cfs	Avg. cfs	Pre-Irr cfs
				81% of I and II			19% of I and II							
16Apr-30Apr	500.46	650.20	41.21	103.46	103.69	104.92	24.29	24.32	24.61	370.65	598.04	50.62	117.06	77.37
1May-15May	1186.55	1001.52	62.66	181.70	114.23	116.11	42.63	26.79	27.23	917.70	800.19	50.62	2.35	-57.99
16May-31May	2346.43	1400.69	387.6	131.90	126.20	137.83	30.93	29.60	32.33	1851.00	1050.39	53.96	193.10	-180.14
1Jun-15Jun	1882.98	1488.14	340.7	126.26	128.82	139.05	29.62	30.22	32.62	1484.00	1123.71	66.84	135.31	-192.77
15Jun-30Jun	1689.74	1229.26	433.5	131.95	121.06	134.06	30.95	28.40	31.45	1202.00	966.21	63.63	319.89	-97.54
1Jul-15Jul	886.25	781.71	273.3	137.23	107.63	115.83	32.19	25.25	27.17	340.20	566.03	59.12	190.48	-72.69
16Jul-31Jul	617.12	408.65	277.2	97.72	96.44	104.76	22.92	22.62	24.57	163.80	222.23	66.76	209.86	-57.09
1Aug-15Aug	521.91	245.11	187.2	99.18	57.95	97.15	-10.00	-10.00	22.79	144.40	121.41	79.68	111.41	-3.76
15Aug-31Aug	359.30	199.79	146.6	100.00	53.22	94.57	-19.20	-19.20	22.18	101.65	103.60	68.86	84.41	20.56
1Sep-15Sep	224.73	163.02	117.2	84.91	45.84	92.59	-25.24	-25.24	21.72	74.10	100.19	58.90	74.94	51.47
16Sep-30Sep	203.00	154.23	98.87	85.02	55.36	91.77	-17.35	-17.35	21.53	73.15	96.53	73.91	79.19	55.61
1Oct-15Oct	202.93	147.42	98.87	84.96	48.55	91.57	-12.84	-12.84	21.48	67.76	98.20	66.84	85.36	63.83
16Oct-31Oct	206.56	146.42	98.87	88.58	47.55	91.54	-14.48	-14.48	21.47	72.87	104.54	76.83	90.06	71.13
1Nov-15Nov	175.73	138.05	98.87	57.75	39.18	91.29	-15.37	-15.37	21.41	68.78	110.20	68.72	94.83	84.85
16Nov-30Nov	132.17	120.76		117.40	99.01	92.00	14.77	23.23	21.58	62.23	110.13	60.18	111.61	102.95
1Dec-15Dec	156.93	108.30		121.80	92.41	92.41	29.15	21.68	21.68	62.06	95.83	56.06	101.62	101.62
16Dec-31Dec	140.31	110.00		111.60	93.31	93.31	26.29	21.89	21.89	50.93	83.67	48.48	88.87	88.87
1Jan-15Jan	149.13	108.75		111.10	92.65	92.65	25.12	21.73	21.73	43.89	72.79	30.98	78.42	78.42
16Jan-31Jan	136.67	114.95		97.50	95.93	95.93	22.63	22.50	22.50	40.01	69.21	23.48	72.69	72.69
1Feb-14Feb	122.64	105.01		91.76	90.66	90.66	21.16	21.27	21.27	34.86	73.31	25.15	80.24	80.24
15Feb-28Feb	124.27	104.52		101.01	90.40	90.40	22.02	21.21	21.21	34.44	81.05	33.19	88.14	88.14
1Mar-15Mar	150.53	113.65		122.38	95.25	92.25	27.60	22.34	21.64	47.25	100.11	46.70	104.05	100.35
16Mar-31Mar	159.07	153.28		122.00	98.20	92.00	29.58	23.03	21.58	39.17	140.42	31.66	108.37	100.72
1Apr-15Apr	173.06	303.39	6.83	119.38	93.28	98.00	28.00	26.20	22.99	37.33	296.52	31.52	119.44	114.11
Totals (AF)	375306	286317	80478	79187	62915	73341	10412	8978	17203	222625	216604	38973	82658	20832
Avg. Flow (cfs)	518.69	395.70	111.22	109.44	86.95	101.36	14.39	12.41	23.78	307.68	299.35	53.86	114.24	28.79

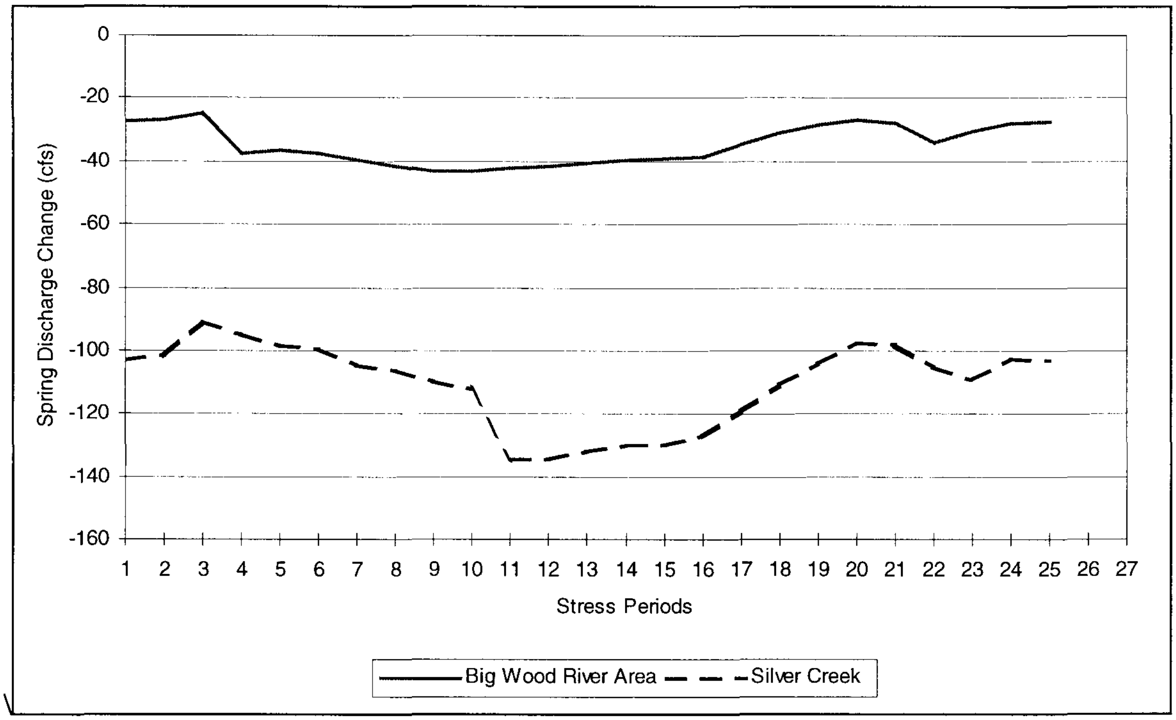


Figure 41. **Reference Scenario vs Pre-Irrigation Spring Flows**

The model predicted reduced flows for Silver Creek, but Silver Creek did not quit flowing at any time during the running of this scenario. During this scenario, the northern part of the valley above Gannett was assumed to be range land and the southern end of the valley was marsh. Silver Creek was assumed to always be a natural flowing stream that received its water from the marshland. The area is almost all farmed now, but some of the area south of Highway 20 was marsh and not farmable before the 1960s (Brockway).

The model-predicted responses for this scenario are indicative of expected change in outflows. However, the degree of hydrologic stress difference between this scenario and the reference scenario is large and the results should be used with caution.

Selective Well Removal

This scenario evaluated the impact of removing a group of wells and their associated irrigated area on water levels and spring flows.

Stress Changes

- Six selected wells located in sections 22, 26, and 25 in the vicinity of the Nature Conservancy Manager's house were removed (Table 16).

Table 16. Wells Removed in the Selective Well Removal Scenario

Owner's Name	Location Row - Col.	Location PLS Description	Days Flowing	Flow Rate (cfs)	Total Diversion (af)
Molyneaux	30 - 20	T1S-R19E-25ACC1	80	3.00	476
TNC	30 - 18	T1S-R19E-26AAC1	60	0.75	89
Prinz	29 - 15	T1S-R19E-22CCD1	60	2.00	238
Stinson	29 - 15	T1S-R19E-26CAA1	21	1.06	44
Gardner	31 - 18	T1S-R19E-26ACC	60	1.75	208
Gardner	31 - 17	T1S-R19E-26CDA	60	3.00	357

- Any crop consumptive use associated with irrigation from the wells was replaced with range or marsh consumptive use based on location.
- The other stresses remained the same.

Response Changes

Silver Creek simulated flow increased by a maximum of 4.5 cfs during the 10th stress period (1-15 Sep.). The stream flow ranged from 1 cfs during the first part of June, to 4.5 cfs during the first part of September as shown in Figure 42. The model did not predict a significant change in the spring flow of the Big Wood River.

No head differences were observed except in rows 28, 29, and 30 of layer 3. There was a 15 foot rise observed in the cells close to the area of well removal. No change in underflow at Priest Road was observed in this scenario.

Combined Waste Water Treatment Plant with Disposal Fields

This scenario evaluated the impact of a combined waste water treatment plant (WWTP) using disposal fields located in the northern part of the model area on water levels and spring flows in the Big Wood River and Silver Creek.

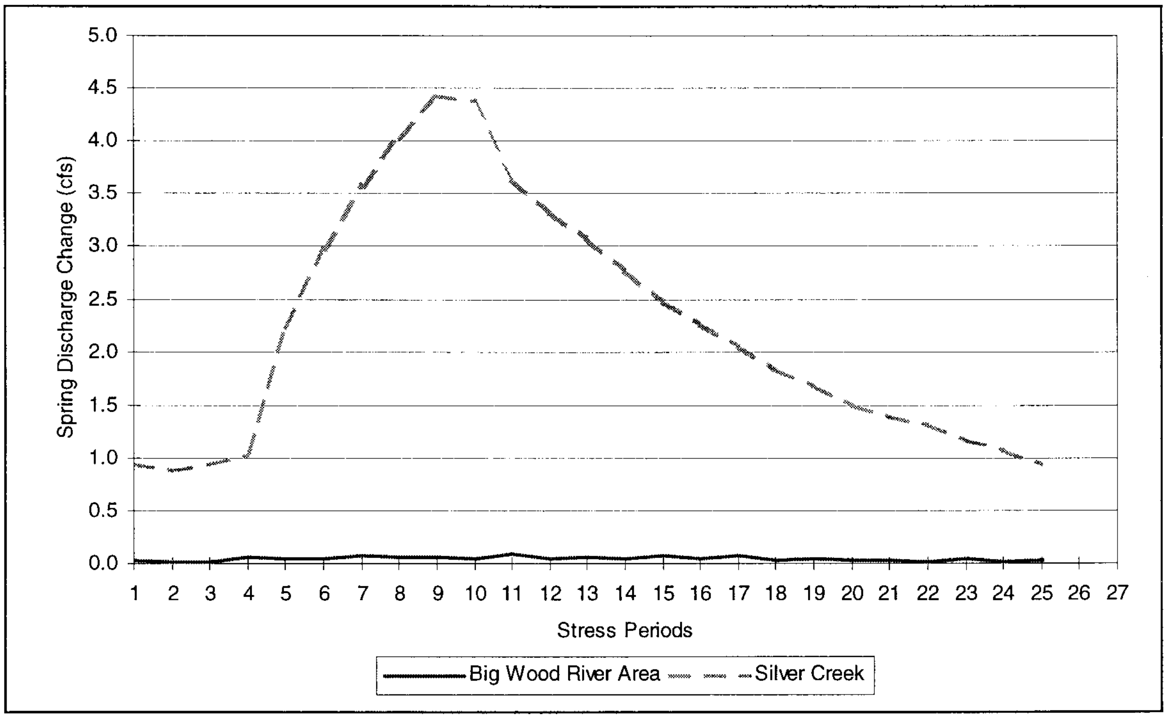


Figure 42. Reference Scenario vs Selected Well Removal Scenario Spring Flows

Stress Changes

- Flows were based on the reported average sewage flows from Sun Valley, Ketchum, Hailey, and Bellevue for the period of record (Table 17).
- Two separate evaluations of effluent recharge from disposal fields were conducted in this scenario. One evaluation considered expansion of Bellevue's present facility in cell 16-7. The other evaluation considered a new facility between Bellevue and Gannett in cell 18-12.
- The flow of the Big Wood River at Hailey was reduced by the reported flows from the Sun Valley-Ketchum WWTP. This reduced recharge to the aquifer from the Big Wood River seepage. The effluent flows from the treatment plants in Hailey and Bellevue are already recharge terms to the model.

Response Changes

This scenario produced insignificant changes in both the spring flows and hydraulic heads as shown in Figure 43 due to a maximum recharge of 5.00 cfs from sewage effluent. Simulated water level responses are not consistent with expected results. Simulated water level changes are generally small (<0.03 ft) and negative; however, some negative changes in the northern part of the aquifer are significant (Table 21). This simulated response is believed to be a result of the change in recharge location, changes in river seepage, and numerical rounding errors within MODFLOW.

Table 17. Municipal Waste Water Treatment Plant Flows

Stress Period	Dates	Ketchum-Sun Valley 1992-96 Avg. Flow (cfs)	Hailey 1992-95 Avg. Flow (cfs)	Bellevue 1994 Flow (cfs)	Total (cfs)
1	16-30 Apr.	2.87	0.86	0.97	4.70
2	1-15 May	2.87	0.80	0.97	4.64
3	16-31 May	2.87	0.87	0.97	4.71
4	1-15 Jun.	2.97	0.92	0.97	4.86
5	16-30 Jun.	2.97	0.90	0.97	4.84
6	1 -15 Jul.	3.10	0.87	0.97	4.94
7	16-31 Jul.	3.10	0.84	0.97	4.91
8	1-15 Aug.	2.85	0.78	0.97	4.60
9	16-31 Aug.	2.85	0.84	0.97	4.66
10	1-15 Sep.	2.23	0.86	0.97	4.06
11	16-30 Sep.	2.23	0.86	0.97	4.06
12	1-15 Oct	2.06	0.90	0.97	3.93
13	16-31 Oct	2.06	0.90	0.97	3.93
14	1-15 Nov.	1.90	0.92	0.97	3.79
15	16-30 Nov.	1.90	0.96	0.97	3.83
16	1 -15 Dec.	2.42	1.00	0.97	4.39
17	16-31 Dec.	2.42	1.00	0.97	4.39
18	1-15 Jan.	2.40	0.95	0.97	4.32
19	16-31 Jan.	2.40	0.94	0.97	4.31
20	1-14 Feb.	2.36	0.92	0.97	4.25
21	15-28 Feb.	2.36	0.92	0.97	4.25
22	1-15 Mar	3.12	0.95	0.97	5.04
23	16-31 Mar	3.12	0.96	0.97	5.05
24	1-15 Apr.	2.87	0.89	0.97	4.73

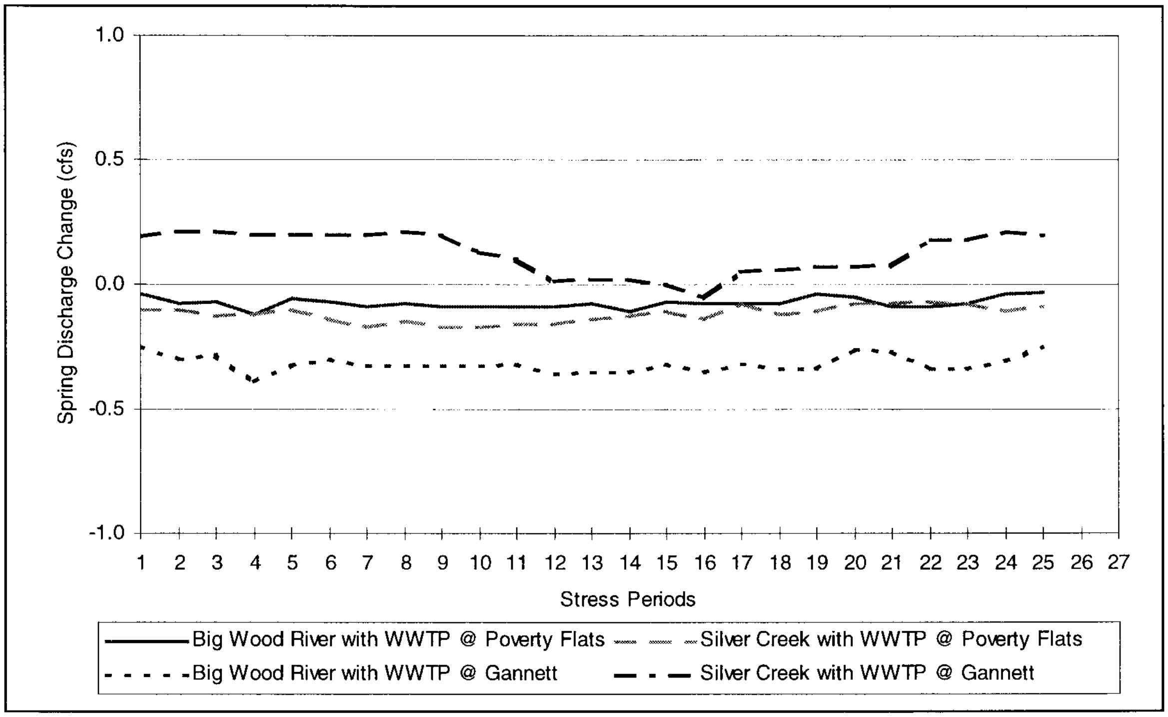


Figure 43. Reference Scenario vs Combined Waste Water Treatment Plant Scenario Spring Flows

Artificial Recharge Using Excess Big Wood River Flows

The next two scenarios evaluated the impact of recharge to six pits using flood flows from the Big Wood River on water levels and spring flows in the Big Wood River and Silver Creek.

Recharge Utilizing Average Flows for Period of Record

Stress Changes and Assumptions

- Recharge location was dependent upon using the present canal system and recharge pits were located primarily along Baseline Road.
- Excess flow available for recharge was estimated based on the filling potential of Magic Reservoir and was only deliverable between April 1 and June 30.
- Maximum canal capacity (Peterson, personal communication): District 45- 400 cfs, Baseline Canal - 100 cfs, and Glendale Canal 50 cfs.
- Magic Reservoir is 1/4 full at end of irrigation season.
- No flows from Camas Creek will be utilized; these flows will satisfy other diversions.

- Any flows at Stanton Crossing greater than 75% of the 191,000 AF capacity of Magic Reservoir during Oct-Apr. period are available for recharge.

- The canals are capable of diverting an additional 70,000 af/y during the period from April to June as shown in Table 18. Records indicate that an additional diversion of 29,000 af/y can be diverted from Big Wood River flood flows on average (Table 19).

- A constant canal seepage flux of 2 cfs per cell was specified for the cells of the District 45, Baseline, and Glendale canals during this time of extra recharge. (No other simulation has used this line recharge for canal seepage.) An additional 6 cfs was distributed to the cells between the point of diversion from the Big Wood River and the three Parshall Flumes on the District 45 Main Canal. The remainder of the flow not attributed to canal seepage was distributed equally into the 6 recharge pits. Five pits that were defined in Phase I were located in cells 16-8, 18-10, 18-12, 22-12, and 24-12. An additional recharge pit was placed in cell 16-6 (near the Bellevue Waste Water Treatment Plant) with recharge water from the Glendale Canal. The flows in the Big Wood River were decreased by the additional flow diverted during the recharge period thereby reducing the seepage loss in the river.

Response Changes

The model simulated an increase of 20 to 45 cfs (15 to 25%) in spring discharge to Silver Creek with the minimum increase in March and the maximum in June (Figure 44). The Big Wood River flow was predicted to gain 5 to 12 cfs from springs. An underflow increase at Priest Road of 600 af/year was simulated by the model. The cells from Hailey downstream to the Glendale Bridge experienced increased heads as much as 15 feet. The northern end of Layer 1 near Baseline Road, above the artesian aquifer, showed a water table rise of five feet, and the artesian aquifer piezometric heads rose between 2 and 5 feet.

One Year Response Using Maximum Diverted Flow

This simulation evaluated the length of time a recharge volume of 70,000 af during the April to June period for only one year would affect spring flows.

Stress Changes

The maximum volume the irrigation canals can handle minus the volume of irrigation water already in the canal was diverted into the recharge pits (Table 18) between April 1 and June 30 for this simulation.

Table 18. Maximum Canal Capacities Available for Transportation of Excess Big Wood River Flows

Period	Time Step	Flows at Hailey Gage		Diversions Reach I		1993 Dist 45 Canal Flow (cfs)	1993 Baseline Canal Flow (cfs)	1993 Glendale Canal Flow (cfs)	Dist 45 Canal Capacity Available (cfs)	Baseline Canal Capacity Available (cfs)	Glendale Canal Capacity Available (cfs)	Total Canal Flow Available (cfs)	Total Canal Vol. Available (af)
		1993 Adjusted (cfs)	POR Avg. (cfs)	1993 (cfs)	POR Avg. (cfs)								
16Apr-30Apr	1	500.5	65	37.4	41.2	14.3	22.7	0.0	385.7	77.3	50.0	513.0	15466
1May-15May	2	1186.6	1001	62.6	62.7	12.6	29.2	5.1	387.4	70.8	44.9	503.1	15167
16May-31May	3	2346.4	1400	352.0	387.6	229.0	57.7	22.4	171.0	42.3	27.6	240.9	7263
1Jun-15Jun	4	1883.0	1488	294.8	340.7	162.6	72.7	16.4	237.4	27.3	33.6	298.3	8992
15Jun-30Jun	5	1689.7	1229	375.1	433.5	220.5	72.4	34.0	179.5	27.6	16.0	223.1	6726
1Jul-15Jul	6	886.3	78	406.6	273.3	212.9	75.5	35.5	187.1	24.5	14.5		
16Jul-31Jul	7	617.1	40	375.0	277.2	193.4	77.4	31.8	206.6	22.6	18.2		
1Aug-15Aug	8	521.9	24	328.0	187.2	156.0	65.2	37.4	244.0	34.8	12.6		
15Aug-31Aug	9	359.3	19	233.5	146.6	112.0	45.9	30.0	288.0	54.1	20.0		
1Sep-15Sep	10	224.7	16	139.8	117.2	82.7	21.1	14.4	317.3	78.9	35.6		
16Sep-30Sep	11	203.0	15	118.0	98.9	71.1	22.7	8.7	328.9	77.3	41.3		
1Oct-15Oct	12	202.9	14	118.0	98.9	71.1	22.7	8.7	328.9	77.3	41.3		
16Oct-31Oct	13	206.6	14	118.0	98.9	71.1	22.7	8.7	328.9	77.3	41.3		
1Nov-15Nov	14	175.7	13	118.0	98.9	71.1	22.7	8.7	328.9	77.3	41.3		
16Nov-30Nov	15	132.2	12										
1Dec-15Dec	16	156.9	10										
16Dec-31Dec	17	140.3	11										
1Jan-15Jan	18	149.1	10										
16Jan-31Jan	19	136.7	11										
1Feb-14Feb	20	122.6	10										
15Feb-28Feb	21	124.3	10										
1Mar-15Mar	22	150.5	11										
16Mar-31Mar	23	159.1	15										
1Apr-15Apr	24	173.1	30	6.2	6.8	0.0	0.0	0.0	400.0	100.0	50.0	550.0	16582
Totals (AF)		375306	286317	92945	80478								70196
Maximum Canal Capacity (cfs)						400	100	50					

Table 19. Excess Big Wood River Flows Used for Artificial Recharge

Water Year	Stanton Crossing Total Flow Oct-Jun (af)	Volume of Water Available (Total Flow - 75% Cap.)[b] (af)	Volume of Water Diverted For Recharge[a] (af)	Water Year	Stanton Crossing Total Flow Oct-Jun (af)	Volume of Water Available (Total Flow - 75% Cap.)[b] (af)	Volume of Water Diverted For Recharge[a] (af)	Water Year	Stanton Crossing Total Flow Oct-Jun (af)	Volume of Water Available (Total Flow - 75% Cap.)[b] (af)	Volume of Water Diverted For Recharge[a] (af)
WY16	217202	73577	70196	WY58	268573	124948	70196	WY77	34619		
WY22	243591	99966	70196	WY59	74289			WY78	189559	45934	45934
WY40	112034			WY60	81975			WY79	82570		
WY41	137028			WY61	43638			WY80	198647	55022	55022
WY43	311812	168187	70196	WY62	143244			WY81	181311	37686	37686
WY44	129584			WY63	140041			WY82	311409	167784	70196
WY45	99525			WY64	135277			WY83	425020	281395	70196
WY46	181795	38170	38170	WY65	378353	234728	70196	WY84	345075	201450	70196
WY47	157635	14010	14010	WY66	130923			WY85	145051	1426	1426
WY48	128644			WY67	243989	100364	70196	WY86	334872	191247	70196
WY49	122521			WY68	98497			WY87	74156		
WY50	136311			WY69	391404	247779	70196	WY88	50862		
WY51	234633	91008	70196	WY70	177827	34202	34202	WY89	98337		
WY52	333219	189594	70196	WY71	328697	185072	70196	WY90	63773		
WY53	149289	5664	5664	WY72	235383	91758	70196	WY91	59129		
WY54	132226			WY73	94379			WY92	29377		
WY55	84369			WY74	352671	209046	70196	WY93	193688	50063	50063
WY56	298445	154820	70196	WY75	182031	38406	38406	WY94			
WY57	207860	64235	64235	WY76	175295	31670	31670	WY95			
								WY96	216754	73129	70196

Average Volume for POR	56937	28966
Avg. Volume for Years that had Flow	110078	56000

[a] Volume of water diverted for recharge is the lesser of volume of water available or total canal capacity available from Table 18 of 70,196 af/y

[b] 75% capacity of Magic Reservoir's 191,000 af is 143,625 af.

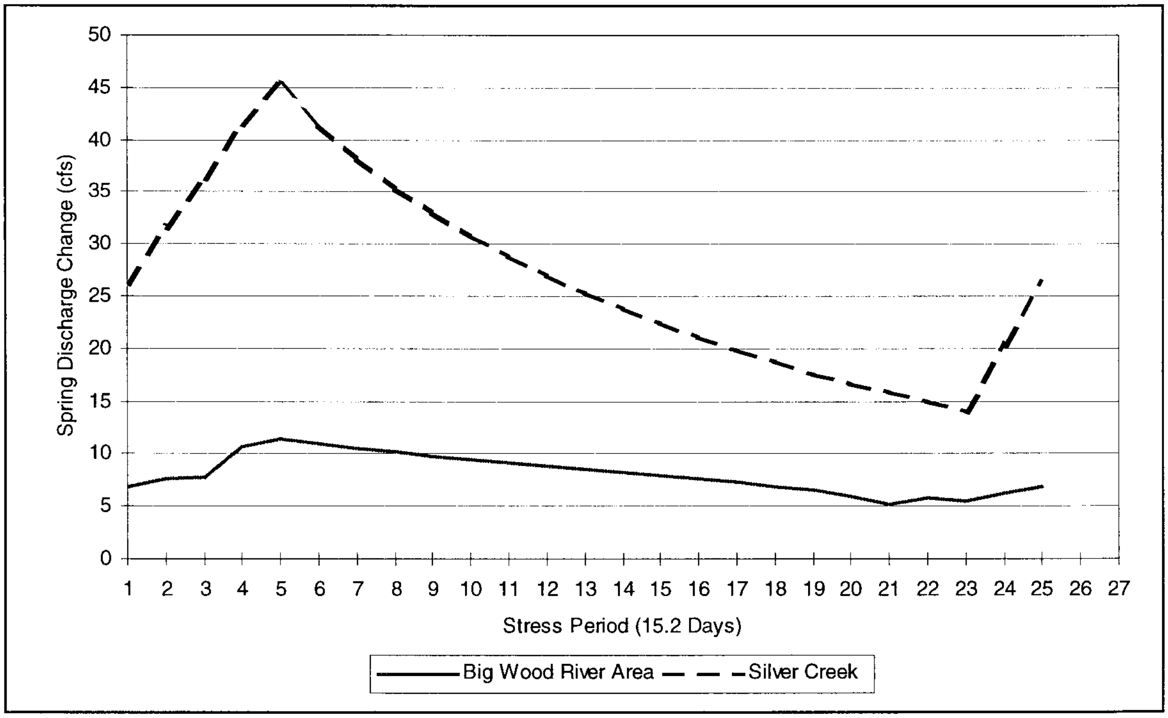


Figure 44. Reference Scenario vs Recharge with Excess Yearly Average Big Wood River Flows Scenario Spring Flows

The canals were assumed to supply the recharge pits as follows:

- Glendale Canal- Pit in cell 16-6.
- Baseline Canal - Pits in cells 22-12 and 24-12
- District 45 Canal- Pits in cells 16-8,18-10,18-12,22-12, and 24-12. (Recharge pits in cells 22-12 and 24-12 are serviced by both the Baseline and District 45 Canals.)
- A constant canal seepage of 2 cfs per cell was used for the cells of the three above mentioned canals in April to June. The cells between the point of diversion from the Big Wood River and the three Parshall Flumes on the District 45 Main Canal were assigned a 10 cfs increase in seepage. The remainder of the flow of each canal after irrigation deliveries and seepage was taken out was distributed equally into the recharge pits serviced by these canals.

Response Changes

The model simulated a maximum increase of 77 cfs in the 16-30 June period for Silver Creek at Swanson's Bridge. The model predicted a maximum increase of 15 cfs in Big Wood River springs during this same period (Figure 45). The flow increase declines rapidly for Silver Creek after this peak and reaches near base level flows by the end of three years. After one year, about 30 cfs increase remains. A small increase of flow occurs in the spring of the second year even though no extra flow has been added to the system. The spring flow increase for the Big Wood River decreases at a more gradual rate than the Silver Creek springs. No hydraulic head or underflow differences at Priest Road were evaluated.

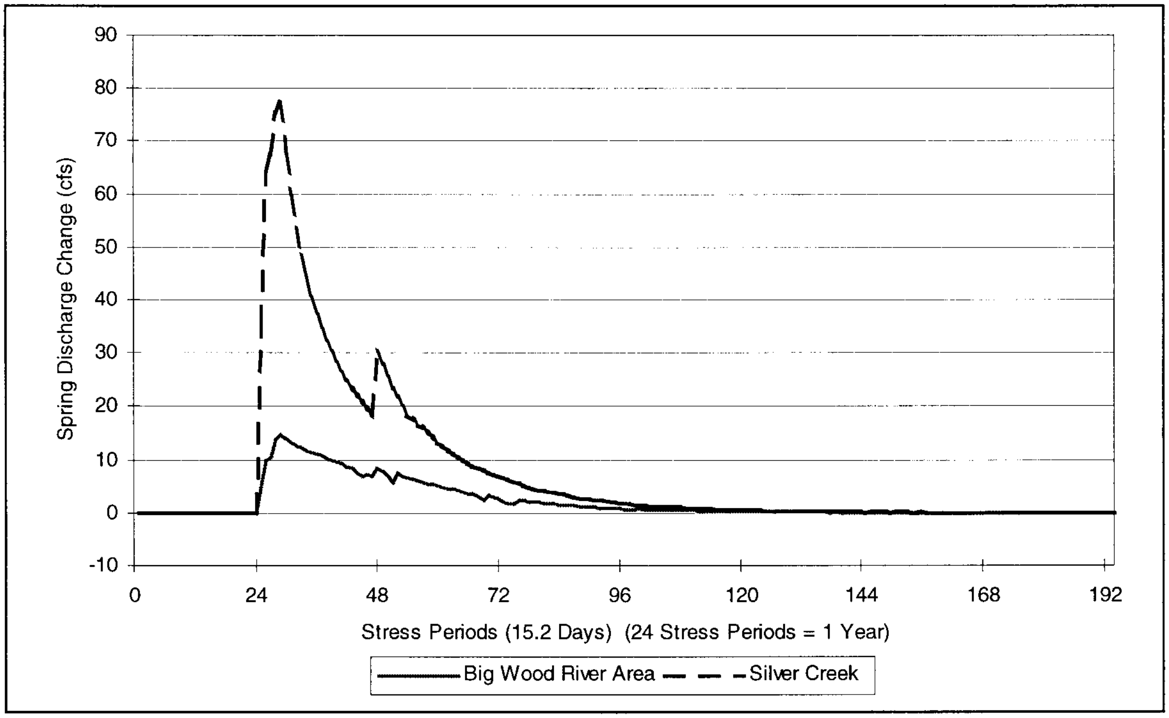


Figure 45. Reference Scenario vs Recharge with Maximum Excess Big Wood River Flows Scenario Spring Flows

Artificial Recharge Using Irrigation Diversions

The next two scenarios evaluated changes in water levels and spring flows in the Big Wood River and Silver Creek utilizing five recharge pits supplied with 10 cfs from either existing diversions within the study area or from water imported from outside the study area.

Conversion of a 10 cfs Irrigation Diversion to Recharge

This scenario evaluated the impact on water levels and spring flows associated with conversion of an existing irrigation diversion within the modeled area to supply water to the recharge pits described in the pervious scenario.

Stress Changes

- Conversion of a 10 cfs irrigation diversion within the modeled area supplied the recharge water. The consumptive use and deep percolation was removed from the irrigated area and replaced with rangeland consumptive use.

The 10 cfs maximum diversion came from removal of irrigated areas in cells 17-12, 18-12, and 24-11, and ET for rangeland was specified for these 3 cells. This diversion was determined using 1 cfs (50 miner's inches) with one acre receiving one miner's inch of water. The 480 acres in the 3 cells would require 480 inches, approximately 10 cfs, of surface irrigation water. The Watermaster records list only the total water diverted into the canal and not the amount diverted per owner or acre. Therefore, three cells were arbitrarily chosen to supply the needed diversion. The three cells did not experience a combined constant 10 cfs flow, but the flow was distributed according to District 45 seasonal distribution as listed in Table 20.

Table 20. Canal Flows Associated with an Existing 10 cfs Water Right

Stress Period	Flow (cfs)
1	1.50
2	1.82
3	3.00
4	10.70
5	8.17
24	3.31

The flow that had been specified as diversion to the three cells was equally divided among the five recharge pits.

Response Changes

Simulated Silver Creek flow experienced an increase of 3.2 cfs during the last period in August and an increase of 1.5 cfs for the remainder of the year. The Big Wood River

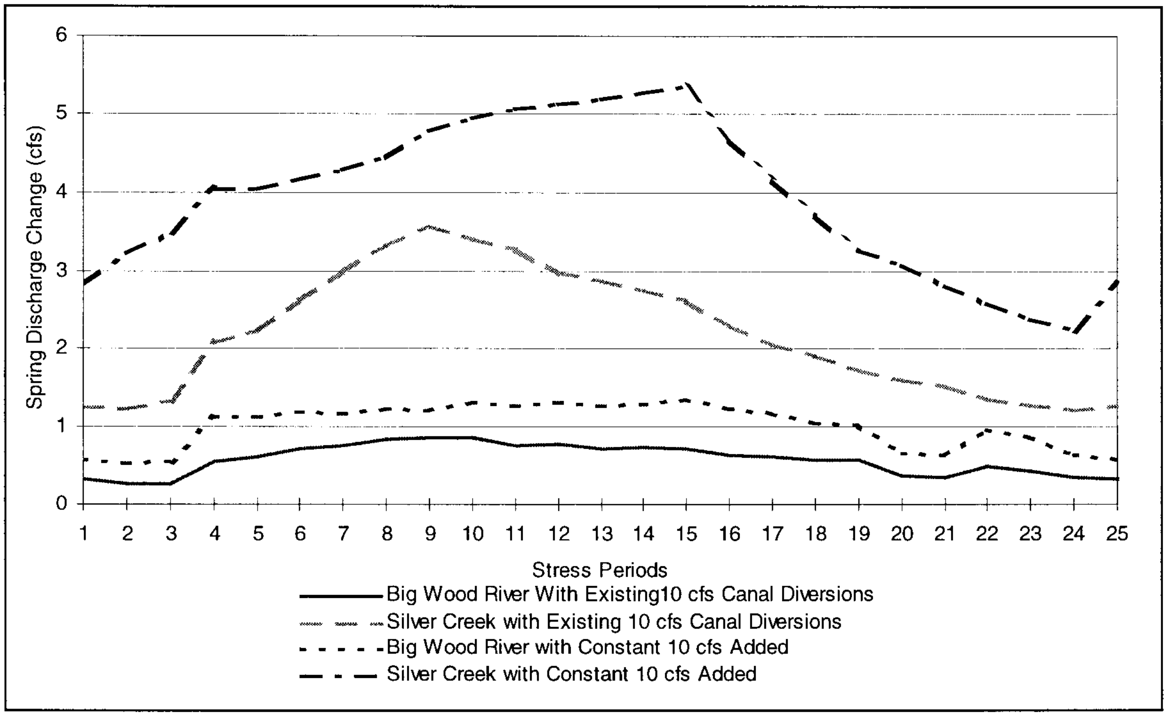


Figure 46. Reference Scenario vs Recharge with Canal Diversion Scenario Spring Flows

produced an almost constant increase of 0.5 cfs (Figure 46). No significant underflow difference at Priest Road was observed for this scenario. Maximum hydraulic head increased 0.4 feet due to the recharge of a maximum of 10 cfs.

Conversion of a 10 cfs Diversion Outside the Modeled Area to Recharge

This scenario evaluated the impact on water levels and spring flows associated with conversion of constant surface water 10 cfs diversion outside the modeled area into the 5 recharge pits used in the previous scenario.

Stress Changes

- Two cfs was added to each of the five recharge pits from the 15th of April until the 30th of November.
- All other stresses used in the reference scenario data set remained unchanged.

Response Changes

The model simulated a spring discharge increase of 5.0 cfs to Silver Creek during the last period in November. These spring discharges had a constant increase of 3.0 cfs at the first stress period to the maximum of 5.0 cfs, and then an almost constant decline back to 3.0 cfs. For the Big Wood River, the model simulated a maximum increase of 3.3 cfs at the end of August, with a beginning and ending increased flow of 1.2 cfs for the period (Figure 46). A maximum hydraulic head rise of 1.0 feet occurred in cell 15-9 (Figure 47 a-c), and the underflow at Priest Road increased by 200 af/year.

Summary of Response Changes for Water and Land Use Change Scenarios

Table 21 summarizes the response of aquifer water level and spring flows to the various simulated water use changes. The largest increased flow to Silver Creek is simulated to occur when managed recharge is performed with excess Big Wood River flows. Silver Creek flow could increase by as much as 45 cfs with a consistent recharge of available river flows. However, recharge with 10 cfs of either internally generated flow or external imported flow is less effective but still results in significant increase of spring flows (0.5 to 3.5 cfs).

The magnitude of waste water treatment plant effluent (<5 cfs) for aquifer recharge is small compared to the total recharge. Simulated water level responses are not consistent with expected results. Simulated water level changes are generally small (<0.03 ft) and negative; however, some negative changes in the northern part of the aquifer are significant (Table 21). This simulated response is believed to be a result of the change in recharge location, changes in river seepage, and numerical rounding errors within MODFLOW.

The simulated changes in the aquifer response in the pre-irrigation scenario are large and point out the necessity for preservation of irrigation and associated recharge in the area. A reduction in the Silver Creek spring flows of 90 to 130 cfs would decrease Silver Creek flows to approximately 70 cfs compared to the present flow of 160 to 200 cfs. Similarly, spring flows and Reach III gains in the Big Wood River would decrease to about half of present day gains. However, early season surface flows in the river would be enhanced.

The simulated changes in underflow leaving the area for all scenarios except the pre-irrigation scenario are less than 600 af/y. For the pre-irrigation scenario, the simulated 4,000 acre foot per year decrease in underflow from the area is about 10 percent of the reference outflow, and average change in water levels of 3 to 11 feet are significant. The magnitudes of simulated aquifer response for the pre irrigation scenario are large and may be approaching limits for which the model can be expected to simulate accurately. The numerical mass balance error (numerical stability) associated with all the simulations were less than 0.01%. This would indicate that the numerical solutions are acceptable and the model is functioning properly. The larger question would be in the assumptions and changes in the water budget associated with a simulation. For example, in the pre-irrigation scenario, the amount and location of marsh areas was an estimate. To assess the sensitivity of the assumption, several additional simulations could be performed varying the amount of marshes.

Table 21. Summary of Simulated Changes in Heads and Flows For Scenario Simulations

	Pre-Irrigation		Selective Well Removal		Combined WWTP				Recharge With Excess BWR Flows		Recharge With Canal Diversions			
					Poverty Flats		Gannett				10 cfs within area		10 cfs imported in	
Cells *	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
Maximum Head Changes (ft)														
3 4 3	8.67	-2.96	0.00	0.00	-0.14	-0.83	-0.17	-0.91	0.27	-0.37	0.01	0.01	0.02	0.02
12 9 3	-5.68	-19.69	0.01	0.01	-0.75	-1.03	-1.10	-1.35	12.05	3.03	0.29	0.18	0.52	0.36
19 5 3	-14.69	-18.64	0.04	0.02	0.18	0.16	-0.46	-0.50	9.37	3.80	0.53	0.26	0.89	0.51
17 12 3	-12.15	-21.18	0.05	0.02	-0.10	-0.15	0.31	0.13	10.81	3.10	0.61	0.23	0.91	0.44
15 9 3	-12.96	-21.47	0.02	0.02	-0.30	-0.42	-0.95	-1.09	14.48	4.33	0.60	0.29	1.00	0.57
23 16 3	-6.20	-12.28	0.07	0.02	-0.01	-0.02	0.07	0.02	4.88	1.44	0.34	0.11	0.49	0.22
24 7 3	-8.97	-13.44	0.06	0.01	0.01	-0.01	-0.13	-0.16	5.97	2.06	0.38	0.16	0.58	0.30
27 18 1	-2.27	-5.27	0.27	0.05	0.00	-0.01	0.02	0.01	1.43	0.62	0.10	0.05	0.17	0.09
28 20 1	-4.93	-6.39	0.62	0.14	0.00	0.00	0.01	0.01	0.70	0.47	0.05	0.04	0.09	0.07
28 5 3	-2.97	-11.03	0.05	0.01	0.00	-0.01	-0.09	-0.11	4.16	1.60	0.27	0.12	0.41	0.22
24 9 1	-8.53	-13.88	0.09	0.01	0.00	-0.01	-0.06	-0.10	6.23	2.08	0.43	0.16	0.64	0.31
26 6 3	-4.66	-12.44	0.05	0.01	0.00	-0.01	-0.11	-0.13	4.93	1.76	0.31	0.14	0.49	0.26
27 7 3	1.00	-12.21	0.07	0.01	0.00	-0.01	-0.08	-0.11	4.93	1.71	0.32	0.13	0.49	0.25
28 11 3	5.01	-0.89	0.57	0.02	0.00	-0.02	0.00	-0.03	4.54	1.39	0.31	0.11	0.45	0.21
29 15 3	13.49	-5.31	14.49	0.03	0.00	-0.01	0.02	0.00	2.51	0.82	0.18	0.07	0.27	0.13
30 18 3	8.86	-5.31	13.83	0.15	0.00	0.00	0.01	0.00	0.56	0.36	0.04	0.03	0.07	0.05
25 10 3	-6.95	-12.88	0.13	0.01	0.00	-0.02	-0.01	-0.05	6.17	1.87	0.40	0.15	0.59	0.27
27 13 3	-1.85	-7.59	0.54	0.02	-0.01	-0.02	0.02	-0.01	3.85	1.23	0.28	0.00	0.41	0.18
28 16 3	1.12	-4.77	1.47	0.03	0.00	-0.01	0.01	0.01	1.85	0.65	0.14	0.05	0.21	0.11
30 27 3	-7.71	-9.07	0.09	0.05	0.00	-0.01	0.00	0.00	0.08	0.07	0.01	0.01	0.01	0.01
Average	-3.12	-10.84	1.63	0.03	-0.06	-0.12	-0.13	-0.22	4.99	1.60	0.28	0.12	0.44	0.23
Maximum	13.49	-0.89	14.49	0.15	0.18	0.16	0.31	0.13	14.48	4.33	0.61	0.29	1.00	0.57
Minimum	-14.69	-21.47	0.00	0.00	-0.75	-1.03	-1.10	-1.35	0.08	-0.37	0.01	0.00	0.01	0.01
Maximum Flow Changes (cfs)														
Big Wood River	-24.66	-43.21	-0.09	0.01	-0.03	-0.11	-0.25	-0.39	11.37	5.25	-0.86	0.26	5.35	1.36
Silver Creek	-91.44	-134.4	4.43	-0.29	-0.08	-0.17	0.21	-0.05	45.23	14.04	3.57	1.21	2.24	0.53
Underflow Changes (af/year)														
		-4120		< 100		< 100		< 100	600			< 100		< 100

UPPER BIG WOOD RIVER WATER RESOURCE

Part of the Phase II study was an evaluation of water supply and demands north of Hailey, the Upper Big Wood River Valley (Upper Valley). The water supply in the Upper Valley is dependent on precipitation falling on the watershed. The primary water use in this part of the watershed consists of plant evapotranspiration and evaporation from water surfaces. Transport of excess water out of the valley occurs either as surface flow in the Big Wood River or through the alluvial aquifer underling the Big Wood River. This underflow supplies the Big Wood – Silver Creek aquifer system south of Hailey.

Figure 47 shows the watershed and sub watersheds associated with the Upper Big Wood River valley and the Big Wood River – Silver Creek area. Upstream of Hailey the Big Wood River valley floor is generally narrow with widths up to 2 miles. Tributary valley floor widths are typically between 1/8- to 1/2-mile wide. Steep mountains surround the valley and the tributary valleys. Elevation of the Upper Valley watershed ranges from 5,295 ft to mountain peaks exceeding 10,000 ft with an average elevation being 7,620 ft. Drainage area of the Upper Valley above the USGS Hailey gaging station is 640 square miles according to the USGS (Brennan, 1994); however, this study estimated the area at 626 square miles. Table 22 lists sub watersheds that are tributary to the Upper Valley with associated areas and average elevations. Primary tributaries to the Big Wood River in the Upper Valley are Deer Creek, East Fork, North Fork, Trail Creek, and Warm Springs Creek.

The Upper Valley climate consists of cold, wet winters and short, warm, dry summers. The monthly average temperature at Hailey ranges from 20°F to 67°F in January and July, respectively. The mean annual precipitation at the Hailey observation station is 16.5 inches. The bulk of the precipitation occurs from November through March (9.6 inches). At Galena, the average monthly minimum and maximum temperatures are 3°F and 35°F, respectively, and the mean annual precipitation is 25 inches. The average frost free period during the summer is 85 days in the valleys (Hailey) and 13 days in the mountains

(Galena). The precipitation received by the mountains is as high 50 inches in some areas (Abramovich, et al, 1998).

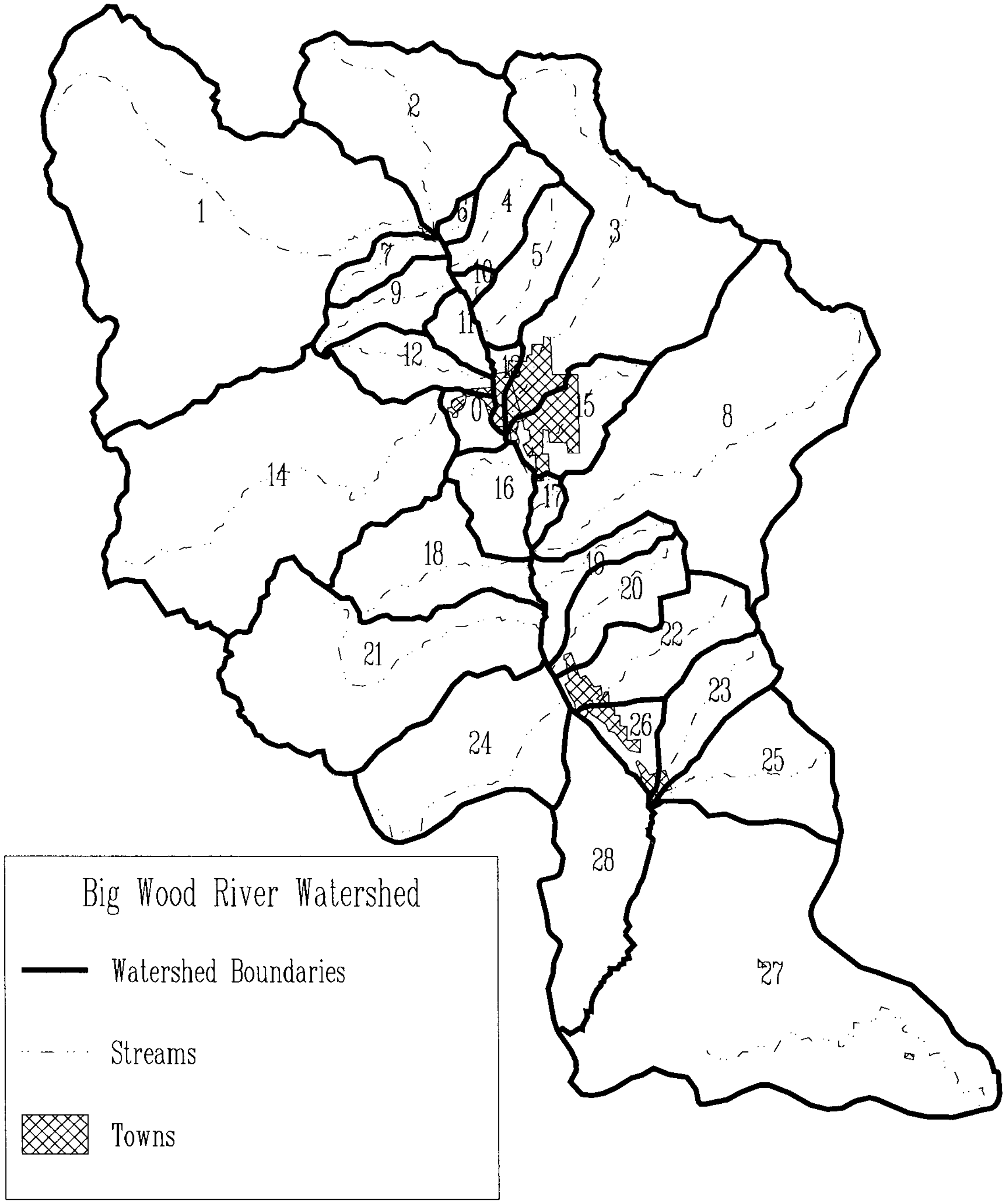


Figure 47. Big Wood River -- Silver Creek Watersheds

Table 22. Upper Valley Subwatersheds

ID	Name -- Description	Area sq-mi	Tributary to Hailey Gage	Percent Area Above Hailey	Mean Elevation ft-msl
1	Above North Fork	137	Yes	21.9%	8350
2	North Fork	41	Yes	6.6%	8618
3	Trail Creek	64	Yes	10.2%	8242
4	Eagle Creek	11	Yes	1.8%	7889
5	Lake Creek	15	Yes	2.4%	7602
6	Leroux Creek	1.8	Yes	0.3%	7487
7	Oregon Gulch	6.1	Yes	1.0%	7289
8	East Fork	86	Yes	13.7%	7928
9	Fox Creek	9.8	Yes	1.6%	7351
10	Dip Creek	1.4	Yes	0.2%	6592
11	No Name	4.9	Yes	0.8%	6892
12	Adams Gulch	12	Yes	1.9%	7456
13	No Name	2.5	Yes	0.4%	6254
14	Warm Springs Creek	98	Yes	15.7%	7704
15	Elkhorn Gulch	15	Yes	2.4%	6835
16	West Gimlet Area	11	Yes	1.8%	6853
17	East Gimlet Area	2.9	Yes	0.5%	6323
18	Greenhorn Gulch	24	Yes	3.8%	6896
19	Ohio Gulch	9.5	Yes	1.5%	6898
20	Indian Creek	14	Yes	2.2%	6709
21	Deer Creek	59	Yes	9.4%	7010
**	Above Hailey Gage:	626			7789
22	Quigley Creek	20	No		6649
23	Slaughtor House	14	No		6715
24	Croy Creek	36	No		6469
25	Seamans Creek	24	No		6558
26	Woodside Area	7	No		6172
27	East Side of Big Wood	120	No		5736
28	West Side of Big Wood	34	No		5633

** Summation of sub watersheds and area weighted average of sub watersheds.

The surface and ground water of the Upper Valley are closely linked. The Big Wood River and its tributaries exchange water with underlying aquifers, depending on the location and time of year. The underlying aquifers generally consist of glacial and alluvial deposits of gravels and sediments. These aquifers rest on volcanic and granitic consolidated rock formations (Luttrel and Brockway, 1984). The consolidated materials generally have very low hydraulic conductivities while the unconsolidated materials have high hydraulic conductivities.

PROCEDURE

The procedure for evaluating the water resource availability and use of the Upper Valley consisted of the following components:

- Estimation of the mean yearly precipitation volume in the Upper Valley watersheds.
- Estimation of the mean yearly volume of water evaporated from water surfaces and vegetation evapotranspiration.
- Estimation of annual underflow estimates for selected tributary valleys.
- Estimation of mean annual stream flow for gaging stations within the study area.
- Estimation of current and future water use, domestic and residential, within the study area.

PRECIPITATION VOLUME

The mean yearly volume of precipitation intercepted by the watershed was estimated by overlaying the Mean Annual Precipitation (1961-90) map for Idaho (Molnau, 1995) as shown in Figure 48. The areas between the isolines were treated as areas receiving uniform precipitation amounts equal to the middle of the contour interval. By overlaying the sub watershed areas with the mean annual precipitation bands, the mean annual precipitation intercepted by each sub watershed was estimated. The Upper Valley receives 1.1 million acre-feet of precipitation or an average of 33 inches per year. Table 23 lists the mean average precipitation volume and depth for each sub watershed. Frenzel (1989) reported mean annual precipitation values for selected sub watersheds in the Upper Valley and for the watershed above Hailey. The values presented by Frenzel are lower than those listed in Table 23. For the area upstream of Hailey, Frenzel reported a mean annual precipitation of 28 inches per year or approximately 85 percent of that shown in Table 23. The largest variation in values was for the Warm Springs Creek drainage where the Frenzel value was 70% of that listed in Table 23. Some of these differences are due to the use of different mean annual precipitation map versions.

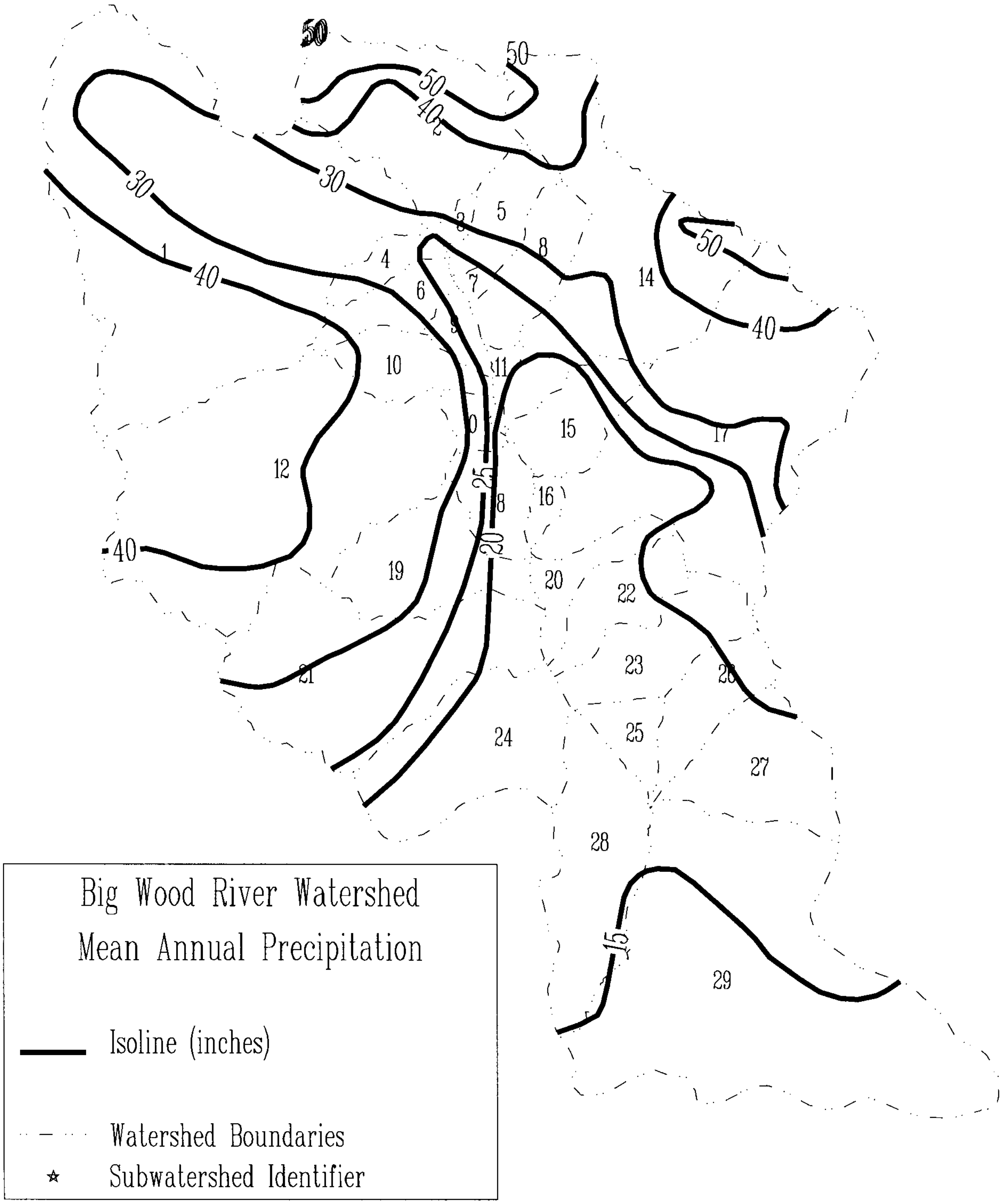


Figure 48. Mean Annual Precipitation, 1961-90

Table 23. Mean Annual Precipitation Volumes.

		Mean	Annual	Precipitation
ID	Name -- Description	inches	acre-feet	% of Gage
1	Above North Fork	36	261315	23.5%
2	North Fork	43	93957	8.5%
3	Trail Creek	37	124921	11.2%
4	Eagle Creek	34	19718	1.8%
5	Lake Creek	28	22553	2.0%
6	Leroux Creek	31	2983	0.3%
7	Oregon Gulch	29	9378	0.8%
8	East Fork	30	135561	12.2%
9	Fox Creek	32	16785	1.5%
10	Dip Creek	23	1720	0.2%
11	No Name	25	6661	0.6%
12	Adams Gulch	34	21945	2.0%
13	No Name	22	2872	0.3%
14	Warm Springs Creek	40	210649	18.9%
15	Elkhorn Gulch	19	15502	1.4%
16	West Gimlet Area	22	12861	1.2%
17	East Gimlet Area	17	2673	0.2%
18	Greenhorn Gulch	31	39296	3.5%
19	Ohio Gulch	18	9058	0.8%
20	Indian Creek	19	13836	1.2%
21	Deer Creek	28	87403	7.9%
**	Above Hailey Gage:	33	1111647	
22	Quigley Creek	19	20582	
23	Slaughtor House	19	14116	
24	Croy Creek	18	35410	
25	Seamans Creek	18	22929	
26	Woodside Area	17	6499	
27	East Side of Big Wood	14	88662	
28	West Side of Big Wood	17	31195	

** Summation of sub watersheds and area weighted average of sub watersheds.

STREAM FLOW RECORDS

Three USGS gaging stations have operated in the upper Big Wood River watershed and have significant periods of record. These gages are named the Big Wood River near Ketchum, Warm Springs Creek at Guyer Hot Springs near Ketchum, and the Big Wood River at Hailey, and are shown in Figure 49.

Big Wood River near Ketchum was located on the Big Wood River upstream of the confluence with the North Fork. The period of record for this gaging station was from 1949 to 1971. During the period of operation, the minimum, mean, and maximum annual discharge was 86, 167, and 270 cfs, respectively. The precipitation for the corresponding period was approximately 97% of the mean annual precipitation for 1961-90 period, with the yearly range between 48% and 170%.

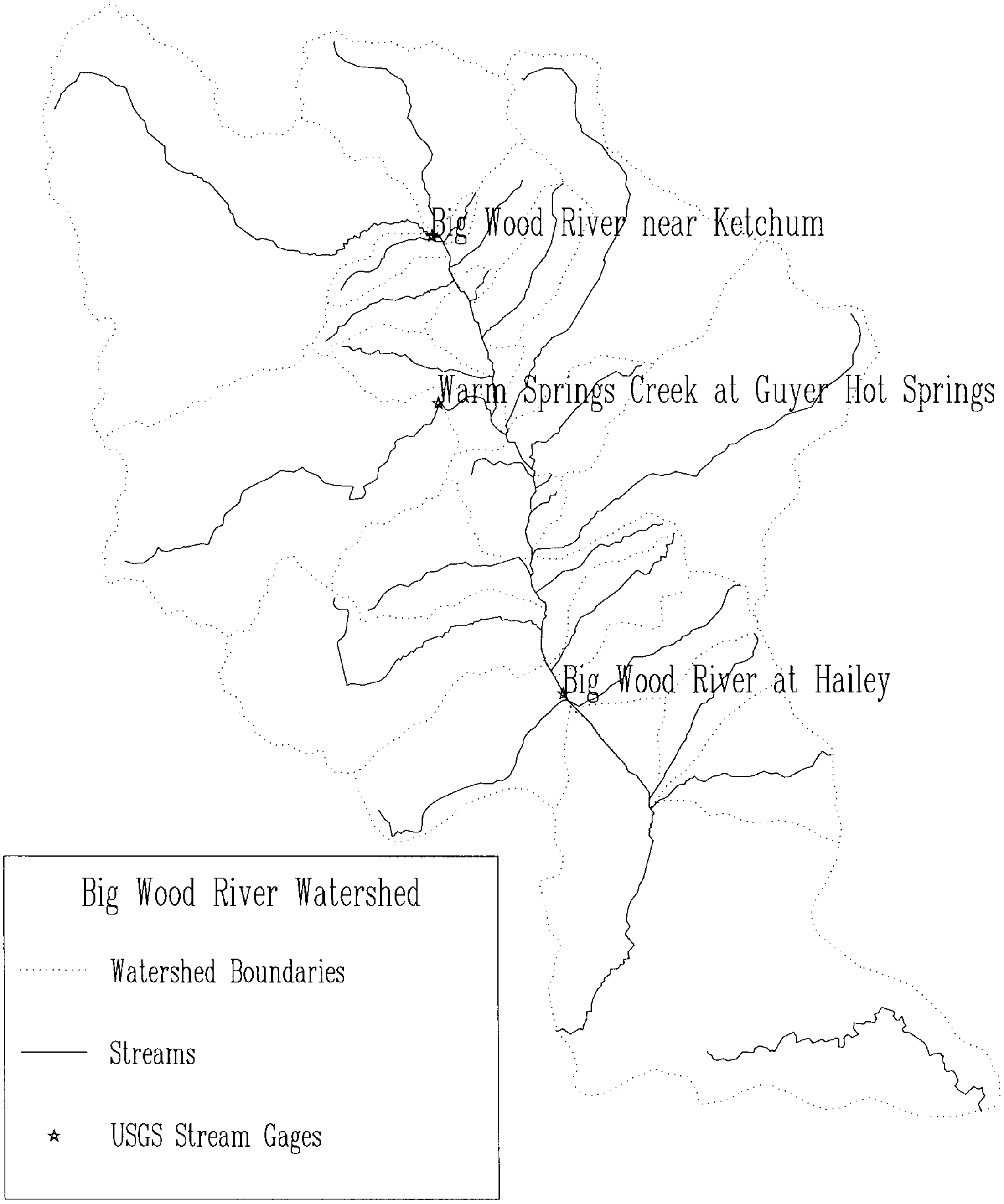


Figure 49. Upper Valley USGS Gaging Stations with Significant Record

Warm Springs Creek at Guyer Hot Springs near Ketchum was located approximately 2 1/8 miles upstream of the mouth. The gaging station measurement did not include discharge from the hot springs. The USGS reports the drainage associated with this gage as 96 square miles. The period of record for this station was from 1940 through 1958. The minimum, mean, and maximum annual discharge of Warm Springs Creek was 55, 89, and 117 cfs, respectively. The average annual precipitation for the same period was approximately 85% of the 1961 - 1990 mean, with the yearly range between 48 and 130 percent.

The Big Wood River at Hailey is located upstream of the county road bridge crossing approximately 1/2 mile upstream of the mouth of Croy Creek. The gage has been in operation since 1915. The minimum, mean, and maximum annual discharge for this period of record is 170, 448, and 842 cfs, respectively. For the period 1949 through 1958 corresponding to the intersection with the Warm Springs Creek gage period of record, the minimum, mean, and maximum annual flows were 316, 507, and 714 cfs, respectively. For the period of record corresponding with the Big Wood River near Ketchum gage the minimum, mean, and maximum annual discharge was 235, 490, and 841 cfs, respectively.

UPPER VALLEY AND TRIBUTARY VALLEY UNDERFLOW ESTIMATES

The valley underflow at the Big Wood River near Ketchum gage was estimated by Smith (1960) as approximately 10% of the annual yield at the gage and approximately 10% at any section downstream to Hailey. Smith also reported that the underflow passing the Warm Springs Creek gage was negligible and less than 1% of the annual yield. Jones commented on the underflow from the Trail Creek drainage as "moderate in amount but is believed to be an appreciable percentage of the water yield of the Trail Creek drainage area".

Driller's records for wells drilled in the various tributaries were examined. From those records and estimates of the water surface gradients, annual underflow was estimated using Darcy's Law for the tributaries as listed in Table 24. The estimate for Warm Springs

Creek is higher than 1% of the watershed yield, which is higher than that reported by Smith (1960).

Table 24. Tributary Valley Underflow Estimates

ID	Location	Estimated Underflow af/y
1	Above North Fork	16,300
14	Warm Springs	2,900
3	Trail Creek	15,900
8	East Fork	19,000
21	Deer Creek	19,600
	Hailey Gage	34,800

Along the Upper Valley, the aquifer saturated flow area perpendicular to the flow increases from North Fork to Hailey by a factor of 10. Frenzel (1989) reported cross-sectional areas of 100,000, 150,000, and 820,000 ft^2 near Adams Gulch, Gimlet, and Hailey.

WATER YIELD

The annual water yield from a watershed is the amount of precipitation intercepted minus evaporation and transpiration from vegetation and the soil surface and the change in soil moisture. The change in soil moisture or aquifer storage buffers the outflows from yearly changes in precipitation and evaporation. Over time, changes in storage can be assumed to be zero. Methods of computing water yield range from empirical to water-budget methods. The water budget method consists of performing a mass balance on the watershed according to the following equations.

$$WY = WP - WE = WS + WG$$

where:

WY is the water yield,
WP is the intercepted precipitation,
WE is the volume evaporated,
WS is the volume of surface runoff, and
WG is the volume of ground water underflow.

Johnson (1982) reports and documents an empirical method devised by the USGS for estimating average annual total water yield from a basin that was based on known water yields in southern Idaho. The same equation was utilized by Luttrel and Brockway (1984) in their study of the Big Wood River Valley and was presented as:

$$Q = 0.000903(A^{0.90})(P^{1.83})(F^{0.29})$$

where:

Q is the yield, cfs
A is the watershed area, square miles
P is the average annual precipitation, inches, and
F is the percentage of the watershed forested.

Hawley and McCuen (1982) presented a series of linear equations and a series of logarithmic equations for estimating water yield for the western United States. The linear equation for the Idaho area is:

$$Y = -12.1721 + 0.91756(P)$$

where:

Y is the water yield, inches
P is the average annual precipitation, inches

For some of the methods, it was necessary to determine the vegetation associated with each of the sub watersheds. The USDA Forest Service provided a geographical information system data set for vegetation within the Sawtooth National Recreation Area that encompassed forested areas. The USDI Bureau of Land Management (BLM) staff provided vegetation cover information for a portion of the watershed.

The USFS and BLM vegetation information were combined into a single set. Based on that vegetation information and information concerning soils, precipitation, land elevation, and aspect, a classification tree was developed to classify the remaining areas into forest and 'brush/grass' vegetation types. The vegetation classifications for the study area and sub watershed is shown in Figure 50 and tabulated in Table 25.

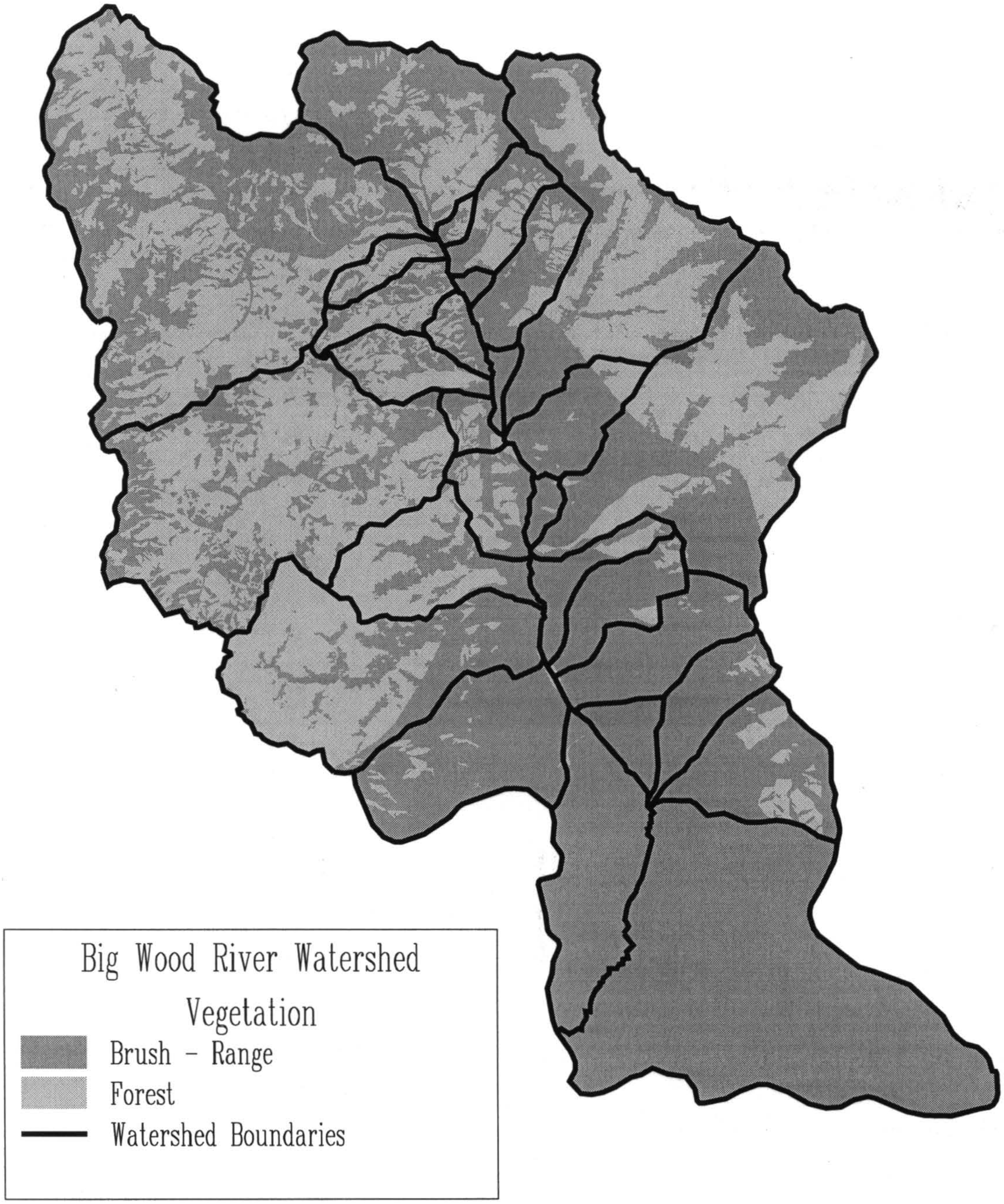


Figure 50. Forested and Rangeland Areas

Table 25. Sub Watershed Vegetation Classification

ID	Name -- Description	Forested Area	Brush or Grass Area
1	Above North Fork	47.1%	52.9%
2	North Fork	29.8%	70.2%
3	Trail Creek	47.5%	52.5%
4	Eagle Creek	39.1%	60.9%
5	Lake Creek	27.4%	72.6%
6	Leroux Creek	37.3%	62.7%
7	Oregon Gulch	53.6%	46.4%
8	East Fork	41.8%	58.2%
9	Fox Creek	51.0%	49.0%
10	Dip Creek	3.2%	96.8%
11	No Name	28.3%	71.7%
12	Adams Gulch	49.7%	50.3%
13	No Name	1.7%	98.3%
14	Warm Springs Creek	60.2%	39.8%
15	Elkhorn Gulch	17.8%	82.2%
16	West Gimlet Area	39.8%	60.2%
17	East Gimlet Area	2.9%	97.1%
18	Greenhorn Gulch	59.5%	40.5%
19	Ohio Gulch	14.2%	85.8%
20	Indian Creek	9.5%	90.5%
21	Deer Creek	56.7%	43.3%
**	Above Hailey Gage:	44.8%	55.2%
22	Quigley Creek	2.2%	97.8%
23	Slaughtor House	4.2%	95.8%
24	Croy Creek	5.7%	94.3%
25	Seamans Creek	17.5%	82.5%
26	Woodside Area	0.0%	100.0%
27	East Side of Big Wood	0.0%	100.0%
28	West Side of Big Wood	0.2%	99.8%

** Based on summation of sub watershed areas.

The consumptive use of the watershed vegetation was estimated based on reported values from Johns, et al (1989), shown in Table 26. For the forest classification estimated water use was 25 inches per year, and for the Brush-Grass classification it was 12 inches per year. Table 27 shows the estimated sub watershed natural vegetation evapotranspiration (water use) with an Upper Valley evapotranspiration of 699,000 acre feet per year.

Table 26. Natural Vegetation Water Use

		Annual	Use --	inches
	Vegetation	min	max	mid
Brush/Grass	Grass -- Cheat	3	12	8
Brush/Grass	Grass -- Meadow	5	36	21
Brush/Grass	Grass -- Wheatgrass	5	30	18
Brush/Grass	Shrub (Mixed)	9	9	9
Brush/Grass	Rabbitbrush	2	26	14
Brush/Grass	Sagebrush and Cheatgrass	3	12	8
Brush/Grass	Sagebrush - Big	4	12	8
Brush/Grass	Classification Average	4	20	12
Forest	Aspen	10	24	17
Forest	Cottonwood	36	60	48
Forest	Fir - Douglas	12	20	16
Forest	Forest (General)	15	21	18
Forest	Spuce	15	15	15
Forest	Willow	13	48	31
Forest	Pine	19	46	33
Forest	Juniper	14	26	20
Forest	Classification Average	17	33	25

To evaluate the three different methods, the above North Fork and Warm Springs Creek sub watershed yields were determined using adjusted annual precipitation for the stream gage's period of record. Table 28 shows the watershed yield estimation methods and their application to these sub watersheds. All the methods overestimated the yield from the Warm Springs Creek drainage compared to measured surface and estimated underflows. The water budget provided the best estimate of yield for Warm Springs Creek. The Hawley linear equation estimated a yield of 173 cfs compared to 93 cfs based on the stream flow and estimated underflow. For the above North Fork watershed, the water budget method and Johnson-USGS equation underestimated the target by 50 and 27 cfs, respectively. The Hawley equation overestimated the target by 21 cfs.

Individual sub watershed mean annual water yields are presented in Table 29. The estimated yield, by these different methods for the Upper Valley were 412,000, 396,000, and 614,000 acre feet per year. This compares to an estimated yield of 400,000 af/y by Frenzel and 369,000 af/y by Luttrell and Brockway. The yields for the sub watersheds of the Upper Valley (Trail Creek, Warm Springs, and East Fork) identified by Frenzel were

Table 27. Estimated Sub Watershed Natural Evapotranspiration, af/y

ID	Name -- Description	Total	Forest	Brush/Grass
1	Above North Fork	152402	98446	53956
2	North Fork	41361	19233	22127
3	Trail Creek	75072	48819	26253
4	Eagle Creek	12904	7333	5571
5	Lake Creek	14788	6453	8335
6	Leroux Creek	2360	1298	1062
7	Oregon Gulch	7527	5295	2232
8	East Fork	94680	56436	38244
9	Fox Creek	11666	7948	3718
10	Dip Creek	1460	92	1368
11	No Name	5579	2500	3079
12	Adams Gulch	13758	9219	4539
13	No Name	2987	102	2885
14	Warm Springs Creek	110290	83392	26898
15	Elkhorn Gulch	13657	4200	9457
16	West Gimlet Area	13150	7566	5585
17	East Gimlet Area	2642	151	2491
18	Greenhorn Gulch	31312	23503	7809
19	Ohio Gulch	9932	2513	7419
20	Indian Creek	12316	2174	10142
21	Deer Creek	69370	50547	18822
**	Above Hailey Gage:	699214	437220	261994
22	Quigley Creek	17731	768	16962
23	Slaughtor House	13112	1085	12027
24	Croy Creek	28653	3178	25476
25	Seamans Creek	21641	6548	15092
26	Woodside Area	7600	0	7600
27	East Side of Big Wood	120864	23	120841
28	West Side of Big Wood	37341	135	37207

Table 28. Water Yield Estimation Method Evaluation

	Above North Fork		Warm Springs Creek	
	acre-ft/yr	cfs	acre-ft/yr	cfs
Water Budget Approach:				
Precipitation	253500	350	179000	247
Forest Water Use	98400	136	83400	115
Brush/Grass Use	54000	75	26900	37
Yield Estimate	101100	140	68700	95
Outflow Estimate	137200	190	67300	93
Difference	-36100	-50	1400	2
Johnson--USGS Equation:				
Yield Estimate	117900	163	111500	154
Outflow Estimate	137200	190	67300	93
Difference	-19300	-27	44200	61
Hawley Linear Equation:				
Yield Estimate	152400	211	125600	173
Outflow Estimate	137200	190	67300	93
Difference	15200	21	58300	81

Table 29. Average Annual Water Yield (af/y)

ID	Name -- Description	Water Budget	Johnson-USGS	Hawley-Linear
1	Above North Fork	108913	116505	150835
2	North Fork	52596	48184	59595
3	Trail Creek	49849	61438	73075
4	Eagle Creek	6814	10180	10951
5	Lake Creek	7765	8801	10956
6	Leroux Creek	623	1707	1569
7	Oregon Gulch	1851	4956	4645
8	East Fork	40881	52234	68556
9	Fox Creek	5119	9120	9039
10	Dip Creek	260	386	669
11	No Name	1082	2700	2931
12	Adams Gulch	8187	12248	12346
13	No Name	-115	478	1012
14	Warm Springs Creek	100359	115159	129664
15	Elkhorn Gulch	1845	3910	4486
16	West Gimlet Area	-289	4681	4660
17	East Gimlet Area	31	426	570
18	Greenhorn Gulch	7984	19660	20476
19	Ohio Gulch	-874	2094	2144
20	Indian Creek	1520	2819	3607
21	Deer Creek	18033	36275	41896
*	Above Hailey Gage	412433	513959	613682
**	Above Hailey Gage	412433	395712	613682
22	Quigley Creek	2851	2727	5902
23	Slaughtor House	1004	2313	3864
24	Croy Creek	6757	5655	9120
25	Seamans Creek	1288	5141	5458
26	Woodside Area	-1101	0	1419
27	East Side of Big Wood	-32202	1534	3451
28	West Side of Big Wood	-6146	1723	6551

* Summation of sub watershed estimated water yield.

** Based on application of estimation equation to integrated watershed parameters above Hailey gage.

estimated for this study at 50,000 to 73,000, 100,000 to 130,000, and 41,000 to 69,000 af/y, respectively. Frenzel estimated 50,000, 60,000, and 50,000 af/y for these drainages, respectively. Summation of the sub watershed estimated yield by the Johnson-USGS method for the areas above Hailey is 118,000 af/y higher than that determined using integrated Upper Valley parameters.

SURFACE WATER -- GROUND WATER INTERACTION

The surface and ground water systems are interconnected in the Upper Valley. The Big Wood River either gains or loses water with respect to the aquifer. The aquifer discharges to the river in locations when the water table elevation exceeds the elevation of the stream and is recharged by the river in locations when the river water surface elevation exceeds the water table surface elevation. The elevation fluctuations in the water table surface and river water surface vary over time and location. Luttrell and Brockway (1984) reported that the water table surface approximates the river surface elevation from North Fork to Bellevue with areas where it is higher and lower than the river elevation. Based on seepage studies in the same area conducted during 1983 and 1986 (Luttrell and Brockway, 1984, and Frenzel, 1989), the river gained overall. The river gain and loss determined by the seepage measurements correlated to the difference between the aquifer water table surface and river surface elevations.

USE OF WATER

There are two basic uses of water: consumptive and non consumptive. Non consumptive use (i.e., aesthetic, recreational, and minimum stream flows) does not deplete the overall basin water supply while consumptive use does deplete the water supply of the Upper Valley. Moreover, consumptive use is that amount of water changed from a liquid or solid state into water vapor by evaporation processes and is typically expressed as a depth of water per unit area similar to precipitation. The major consumptive use in the Upper Valley is evapotranspiration by naturally occurring and cultivated (irrigated) vegetation.

Naturally occurring vegetation is limited to species for which evapotranspiration is satisfied by precipitation during the growing season and soil water holding capacities. Earlier, the consumptive use of the brush-rangeland and forest landscapes was estimated as 12 and 25 inches, respectively. With development of the Upper Valley, a portion of the water supply that historically left the Upper Valley was utilized to irrigate vegetation which had a consumptive use requirement greater than summer precipitation plus soil water holding capacity during the growing season. Three vegetation classes are currently associated with irrigation in the Upper Valley: landscape (turf), alfalfa, and pasture.

In a report to the Idaho Department of Water Resources, Allen and Brockway (1983) estimated consumptive use and irrigation requirements for the major crops grown in Idaho. Table 30 contains consumptive use estimates for alfalfa and pasture grown in the Hailey area and the adjusted consumptive use for Ketchum area. The consumptive use estimation method was based on temperatures. The mean temperature in the Ketchum-Sun Valley area is approximately 5°F lower than the Hailey area (Table 30). This results in an approximate 8 to 9 percent reduction in the consumptive use estimates for the Upper Valley (Table 30).

Table 30. Upper Valley Consumptive Use Estimates

	May	June	July	Aug	Sep	Annual
Hailey Area						
Reference Evapotranspiration*	0.24	0.30	0.30	0.25	0.19	38
Alfalfa*, in/day and in/year	0.14	0.27	0.25	0.19	0.09	28
Pasture*, in/day and in/year	0.17	0.23	0.23	0.19	0.15	29
ETra to ETrg Coefficient	0.87	0.87	0.87	0.87	0.87	
Blue Grass, in/day and in/year	0.21	0.26	0.26	0.22	0.17	33
Hailey Temperature, °F**	50.8	58.7	66.7	65.6	56.3	
Ketchum Temperature, °F**	46.2	54.4	61.6	59.3	51.5	
Temperature Difference, °F	4.6	4.3	5.1	6.3	4.8	
Hailey to Ketchum Adjustment	0.9085	0.9225	0.9206	0.9065	0.9087	
Ketchum Area						
Reference Evapotranspiration	0.22	0.27	0.28	0.23	0.18	35
Alfalfa, in/day and in/year	0.13	0.25	0.23	0.17	0.08	26
Pasture, in/day and in/year	0.16	0.21	0.22	0.18	0.14	27
Blue Grass, in/day and in/year	0.19	0.24	0.24	0.20	0.15	30

* Allen and Brockway (1983)
**Abramovich, Molnau, and Craine (1998)

Landscaping vegetation evapotranspiration was not estimated by Allen and Brockway in their report. Borrelli, et al (1981), presented measured evapotranspiration for various turf grasses in the western United States and coefficients for estimating the consumptive use using the USDA-NRCS (SCS) Blaney-Criddle method. Hartgreaves (1982), in discussion of the Borrelli paper, indicated that the annual crop coefficient for the bluegrass would be in the range of 0.96 to 1.06 for "grass-based" reference evapotranspiration method. The reference evapotranspiration utilized in the Allen and Brockway report was "alfalfa-based". In discussion of the various methods of calculating reference evapotranspiration, Jensen, Burman, and Allen (1990) indicated that reference evapotranspiration from grass-based methods may be converted to an alfalfa based reference by multiplying by 1.15. Application of this information to the alfalfa-based reference resulted in an estimated evaporation for bluegrass, turf, of 33 and 30 inches per year for Hailey and Ketchum, respectively (Table 30).

Rural Water Use

Water use by individuals (in-house, domestic) was considered to be non consumptive. The consumptive water use is associated with vegetation: In the determination of water yield, brush -- range grass consumptive use was estimated at 12 inches. When the vegetation is changed from brush -- range grass to an irrigated vegetation, the consumptive use of the irrigated area increases to between 26 and 33 inches (Table 30). Table 31 shows the application of estimated consumptive use values to rural parcel irrigated landscape, irrigated pasture, and irrigated alfalfa areas. From Table 31, the consumptive use associated with land parcels varying in size between 0.5 to 160 acres ranges between 19 and 28 inches per year. The lowest consumptive use per gross area was associated with small residential lots and the largest was associated with 5 acre parcels, small ranchettes.

Table 31. Rural Parcel Consumptive Use Estimates

	Small	Medium	Large	Ranchettes	Ranch	Golf Course
Parcel Size, acres	0.5	0.7	1.0	5.0	160.0	160.0
Buildings and roads, acres	0.2	0.2	0.2	0.2	5.0	20.0
Irrigated Landscape, acres	0.3	0.5	0.8	0.8	1.0	130.0
Irrigated Pasture, acres	0.0	0.0	0.0	4.0	75.0	0.0
Irrigated Alfalfa, acres	0.0	0.0	0.0	0.0	75.0	0.0
Non Irrigated, acres	0.0	0.0	0.0	0.0	4.0	10.0
Consumptive Use, inches	19.1	22.7	25.5	27.5	26.3	26.6

Municipal Water Use

Table 32 shows municipal water production by the Cities of Ketchum, Sun Valley and Hailey for the recent past, 1992 through 1997. On an average annual basis, these municipalities pump approximately 7.8 million gallons per day (8,800 acre-feet per year) or

482 gallons per day per person. This production is higher than the United States average of 159 gallons per day (Heathcote, 1998). The table shows a difference between the summer and winter production that can be associated with irrigation. These values compare to the City of Bellevue reported summer and winter production per capita of 800 and 400 gallons per day, respectively. The per capita production was based on total production reported by the municipality and the number of dwelling units and population per dwelling unit from land capacity (buildout) studies conducted for planning agencies. These studies indicate a higher population than the census. However, the crucial element in the use of water is the vegetative consumptive use, which can be derived from the summer versus winter production and dwelling units.

Based on the differences between summer and winter and assuming a landscape irrigation efficiency between 65 and 85 percent, the combined consumptive use for the three cities, Ketchum, Sun Valley, and Hailey, was estimated between 1,500 and 1,730 acre feet per year (Table 32).

Table 32. Municipal Water Production and Use

	Production, thousand gallons per day		
	Annual	Summer	Winter
Ketchum	2330	3070	1540
Sun Valley	2850	3940	1610
Hailey	2680	3680	1590
Total	7860	10690	4740
	Production, gallons per day per person*		
	Annual	Summer	Winter
Ketchum	388	511	256
Sun Valley	651	900	368
Hailey	452	620	268
Total	482	655	290
	Landscape Area and Consumptive Use		
Irrigation Efficiency	65%	75%	85%
Ketchum	0.06	0.07	0.08
Sun Valley	0.14	0.16	0.18
Hailey	0.10	0.11	0.13
Average	0.09	0.07	0.08
Total	668	516	584
Consumptive Use, af/y	1726	1332	1509

*Based on Buildout and Land Capacity reported population densities.

CURRENT WATER USE AND DEMANDS

Upper Valley surface diversions from the Big Wood River, East Fork, and Trail Creek for the period between 1920 and 1997 were examined (Figure 51). The average annual diversion for 1992 and 1997 was 36,200 acre-feet according to Water District 37 records. This compares to an annual average of 42,250 acre-feet from 1920 to present. Municipal ground water diversions are 8,800 acre-feet per year (Table 32, 7.86 million gallons per day).

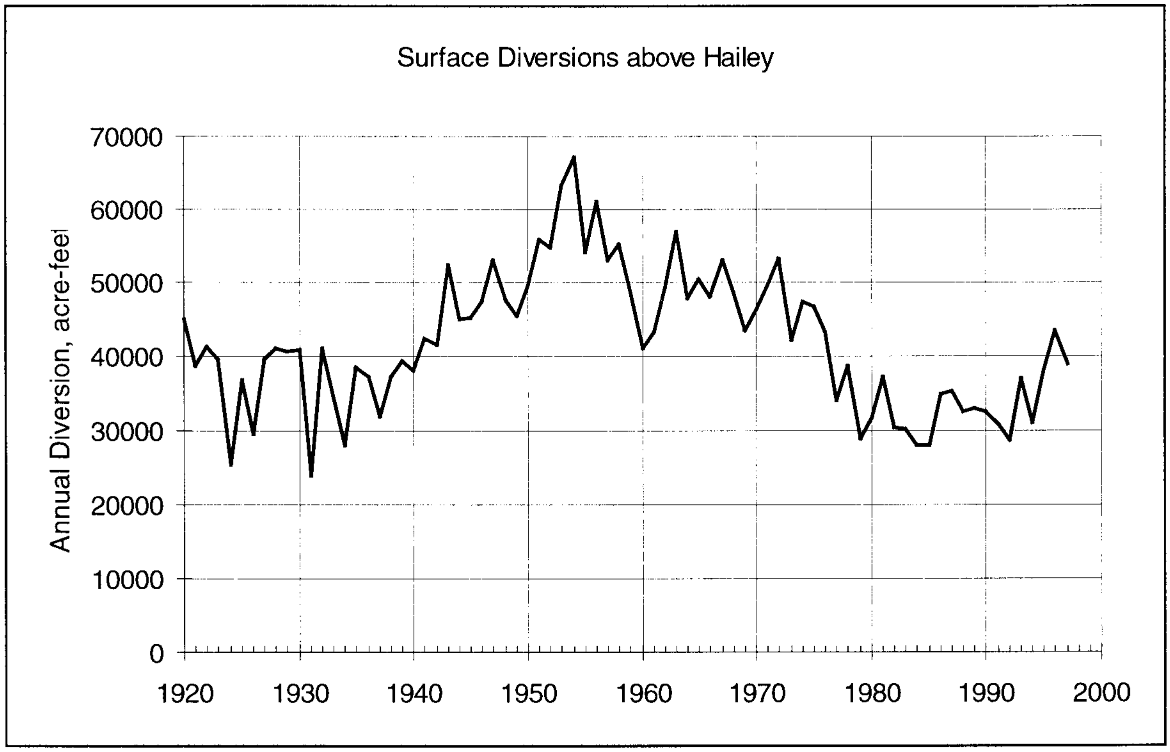


Figure 51. Upper Valley Historical Surface Diversions, 1921-97

Irrigated area

Jones (1952) reported the irrigated area above Hailey to be approximately 9,405 acres based on diversion permits. The USGS Water Resources Data for Idaho: Volume 1 reports an irrigated area of 8,800 acres above Hailey based on a 1966 determination. Luttrell and Brockway (1984) indicated that the potential irrigated area above Hailey was 7,500 acres based on city boundaries and valley floors. As of 1996 the Idaho Department of Water Resources (IDWR) had permits associated with irrigation for 10,500 acres. Some of the permits are supplemental irrigation permits which cannot be readily differentiated in their data base and could greatly reduce their record of irrigated acres. Assuming that the parcels with claimed irrigated areas in excess of the 40 acre parcel size only have 40 irrigated acres, an irrigated area of 6,400 is estimated from the IDWR records. Figure 52 shows the estimated change in irrigated area in the Upper Valley. Utilizing an annual evapotranspiration of 27 acre-inches per acre, the annual consumptive use for the these acreages was estimated at 21,100 af/y for Jones, 19,800 af/y for USGS, 16,800 af/y for Luttrell, and 11,400 af/yr for IDWR.

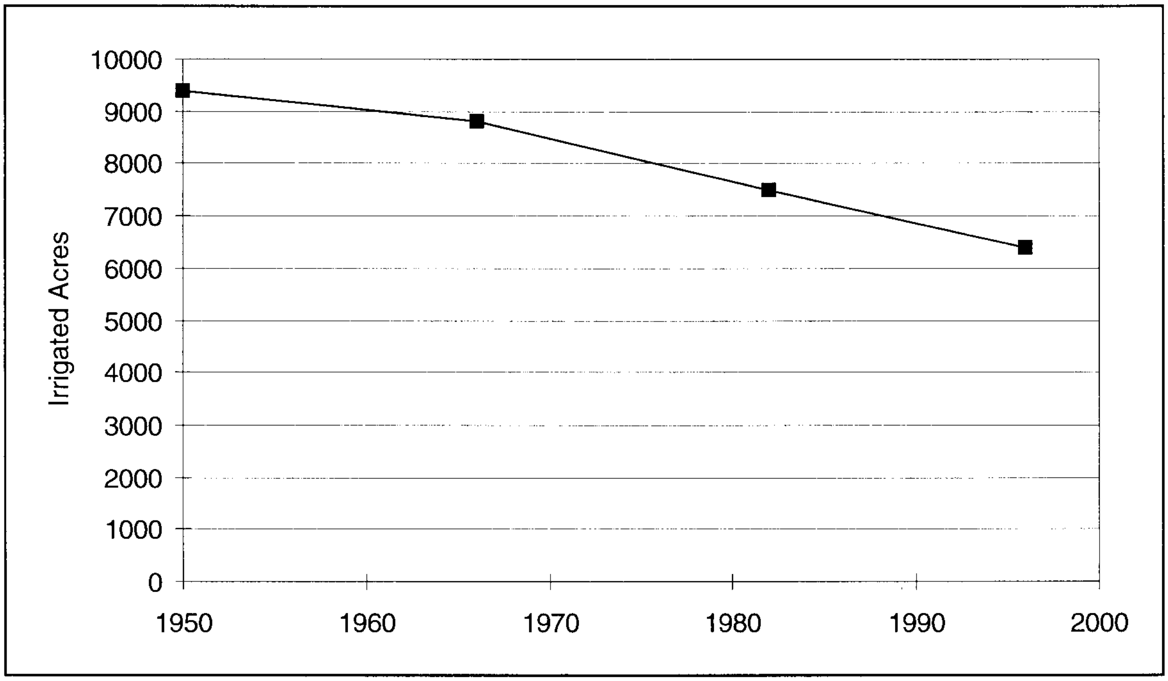


Figure 52. Upper Valley Historical Estimated Irrigated Area

Approximately 25 percent of the acreage associated with irrigation claims was identified as irrigated with ground water. Thus, the ground water irrigated area was estimated to be 1,600 acres out of the 6,400 acres. The ground water diversion requirement for these acres was estimated at 4,900 af/y based on an assumed irrigation efficiency of 70 to 75 percent. This amounts to a ground water diversion rate of 3 af/y per acre.

The current rural buildout for the Upper Valley, subarea A and subarea B, shown in Figure 52, was reported to be 1,366 dwelling units with 2.67 persons per dwelling unit. As of 1996, IDWR had approximately 790 domestic ground water claims. Of these permits approximately 5 to 10 percent had an associated irrigation and or stock water claim.

Assuming that 10 percent of the existing rural dwelling units (137) have an irrigation water permit and the average dwelling unit is best represented by the small parcel (Table 31), the ground water diversion requirement and consumptive use was estimated at 260 and 100 af/y, respectively. The demand is based on 290 gallons per day per capita (Table 32) and 75% efficiency for landscape irrigation. For the remaining 1,229 units, the large parcel (1 acre, Table 31) was assumed to have the same 2.67 people per dwelling unit and 290 gallons per day demand per person which resulted in 4,500 af/y diversion and 2,580 af/y consumptive use.

Table 33 summarizes the current diversions and consumptive use for the Upper Valley. The total diversion was estimated at 54,700 af/y with an associated consumptive use of 18,300 af/y. The municipal diversion is 16% of the total diversion. The surface and sub-surface return flows from the total diversion is approximately 66 percent. Rural parcel diversion and consumptive use cannot be differentiated since small subdivisions are irrigated from specific irrigation water rights, not under domestic rights.

Table 33. Current Water Diversion and Consumptive Use

	Diversion		Consumptive Use	Return Flows
	Surface	Ground		
Municipalities	0	8800	1300	7500
Irrigation and Non consumptive Use	36200	4900	14300	26800
Rural Residential				
With irrigation Right	**	264	109	155
Without Irrigation Right	0	4544	2609	1936
Total	36200	18509	18318	36391

** Accounted for in irrigation uses.

The total consumptive use associated with human activities in the Upper Valley is 18,300 af/y or 2.6% of the total natural vegetation water use (699,000 af/y, Table 27). Similarly, this consumptive use is 4.6% of the minimum estimated basin yield (396,000 af/y (Table 29). The municipal depletion, 1300 af/y, is a small percentage of the total basin yield. The 36,400 af/y estimated surface and subsurface return flow from all diversions is 95% of the estimated aquifer underflow at Hailey.

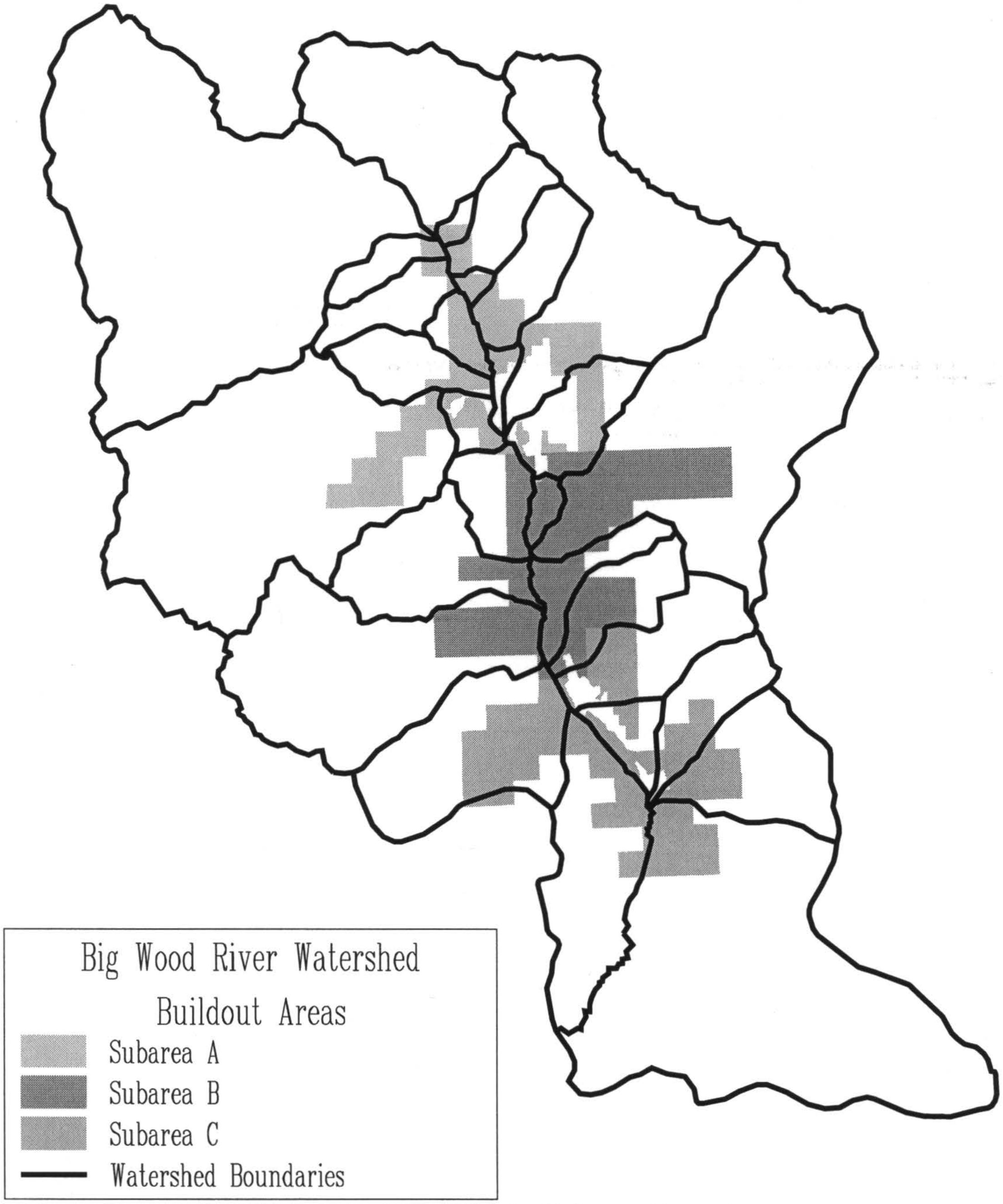


Figure 53. Blaine County Buildout Study Subarea Locations

FUTURE IMPACTS

Local government entities in Blaine County have recently conducted a buildout study. Based on these studies, the Upper Valley has the potential for 2,422 additional rural dwelling units in subareas A and B (Figure 53) an increase of 77 percent. The buildout study did not identify the average land area associated with these future dwelling units or the percent of units replacing irrigated lands. To assess future impacts from these additional dwelling units, two subdivision scenarios (presented in Table 34) were identified for various lot sizes: subdivision of an irrigated 160 tract; and, subdivision of a non irrigated 160 acre tract.

Table 34. Future Buildout Assessment of 160 Acre Tracts

Conversion of Irrigated Lands

	Before	After		
		Small	Medium	Large
Parcels	1	156	31	15
Parcel Size	160.0	1	5	10
Buildings and roads, acres	5.0	31.2	6.2	3
Irrigated Landscape, acres	1.0	124.8	24.8	12
Irrigated Pasture, acres	75.0	0.0	124.0	135
Irrigated Alfalfa, acres	75.0	0.0	0.0	0.0
Non Irrigated, acres	4.0	4.0	5.0	10.0
Consumptive Use, ac-in/ac	26.3	25.1	27.1	26.8
Change in consumptive use ac-in/parcel/yr		-1.2	3.7	5.0

Conversion of Non Irrigated Lands

	Before	After		
		Small	Medium	Large
Parcels	1	156	31	15
Parcel Size	160.0	1	5	10
Buildings and roads, acres	0.0	31.2	6.2	3
Irrigated Landscape, acres	0.0	78.0	15.5	7.5
Irrigated Pasture, acres	0.0	0.0	0.0	0.0
Irrigated Alfalfa, acres	0.0	0.0	0.0	0.0
Non Irrigated, acres	160.0	50.8	138.3	149.5
Consumptive Use, inches	12.0	19.3	13.5	12.7
Change in consumptive ac-in/parcel/yr		7.5	7.5	7.5

The first scenario in Table 34 shows the impact of subdividing a 160 acre, irrigated area into small, medium, and large lots (1, 5, and 10 acres). The large parcel and ranchette configurations shown in Table 31 served as the basis for these parcels. Existing irrigation diversions associated with each parcel are assumed to remain in place. The maximum density (one-acre lots) resulted in a decrease of the annual consumptive use by 1.2 acre-inches per parcel; whereas, the large parcel increased annual consumptive use by 5.0 acre-inches per parcel above previous irrigated conditions.

The second scenario was development of a 160 acre, non-irrigated tract. It was patterned after the irrigated tract scenario with the exception that only 0.5 acres of landscape could be irrigated. The per parcel increase in annual consumptive use is constant regardless of lot size, 7.5 acre-inches per parcel.

SUMMARY AND CONCLUSIONS

The Big Wood River-Silver Creek aquifer is a complex system because of the ground water divide that divides the ground water flow westerly towards springs that feed the Big Wood River or easterly towards springs that feed Silver Creek. There are multiple aquifers in this system which also complicates understanding the hydrologic interactions between the surface water and ground water in this area.

During this phase II study, a 3 layer ground water flow model of the Big Wood River-Silver Creek aquifer was developed using the USGS quasi 3-D flow model, MODFLOW. A transient calibration was completed using water measurements collected during 1993 to 1994. A water budget for the 1993-1994 period was completed to provide the recharge and discharge volumes of water necessary to calibrate the model. The aquifer system is recharged from underflow at Hailey, seepage from the Big Wood River, irrigation diversions, and precipitation. The respective values are 34,800, 79,300, 101,100, and 51,300 af/y. Discharge from the system occurs from springs that are tributary to either the Big Wood River, 39,000 af/y, or Silver Creek, 91,100 af/y, evapotranspiration, 107,100 af/y, and underflow at Priest Road, 29,300 af/y.

Model parameters were calibrated to achieve the desired hydraulic heads and spring flows. The transmissivity values assigned to layers 1 and 3 varied from 14 to 449,000 ft^2/d. The largest values were in an area near Gannett. Layer 2 transmissivity values were less than 100 ft^2/d except along its northern most boundary and the edges of the perched aquifer at Picabo. The specific yield in the model ranges from 0.05 to 0.3, while the confined storage coefficient had values between 0.000001 and 0.00002.

A root mean square (RMS) value between 4.6 and 5.3 was achieved between the simulated and measured water levels for the mass measurement periods. The simulated outflows for springs supplying both the Big Wood River and Silver Creek were within 4% of the target values. A sensitivity analysis was completed on the model aquifer parameters to identify the degree of change in modeled output associated with changes in parameters. A global change of ±10% was executed on the variable in question because a change in a single cell would not significantly affect any results. Changes in the vertical conductance produced the greatest differences, signifying the model is most sensitive to this parameter. The model would not converge when this parameter was changed by 10%. A change in the specific yield also produced a noticeable change.

The ground water flow model developed for the Big Wood River-Silver Creek aquifer is capable of answering questions in terms of differences. A reference transient aquifer stress data set was developed and aquifer response simulated to compare "what if" scenarios. Five scenarios were simulated with the calibrated ground water flow model. These include pre-irrigation, selective well removal, combined waste water treatment plant, artificial recharge using excess Big Wood River flows, and artificial recharge using irrigation diversions.

The greatest differences resulted from the pre-irrigation scenario. A maximum decline of 120 cfs for Silver Creek and 40 cfs for the springs that feed the Big Wood River were simulated. Water table elevations fell 21 feet in the region close to the Glendale Bridge. Results of this scenario show the necessity of continuing irrigation on the triangle area.

The removal of 6 deep irrigation wells (11 cfs) close to the Silver Creek Preserve increased Silver Creek flows by 4.4 cfs during August, and the artesian aquifer head rose 14 feet in the vicinity of the removed wells. The Big Wood River did not experience changes from this scenario.

The scenario recharging the combined waste water treatment plant flows in different locations produced insignificant change in spring flows and water surface elevations in the model area.

The maximum increase to flows for the scenario utilizing excess Big Wood River flows for recharge were 45 cfs to Silver Creek and 10 cfs to the Big Wood River. The Glendale Bridge area experienced a rise in the water table elevation of 14 feet.

Recharging with canal diversions produced a maximum increase of 5.4 cfs to Silver Creek when 10 cfs was imported into the study area, and a maximum increase of 3.3 cfs when 10 cfs within the study area was converted from irrigation to recharge. The springs feeding the Big Wood River increased 3.3 and 0.5 cfs for the same scenarios. Several cells experienced a water surface elevation rise of only one foot for these two scenarios.

Upper Valley surface water diversions from the Big Wood River are documented by Water District 37 for period 1920 through 1997. These diversions have been decreasing since the mid 1950s and are currently 36,200 acre-feet per year. The ground water diversions for municipal, rural residential, and irrigation were estimated at 18,500 acre-feet per year. The consumptive use, evaporation, from these diversions is 18,300 acre-feet per year, approximately 33 percent of the total diversions. The consumptive use is approximately 5 percent of the minimum estimated basin yield. Ground water and surface water return flows are therefore about 36,400 acre-feet per year or 67 percent of the total diversion.

An analysis of consumptive use or evapotranspiration for the Hailey-Ketchum area shows that the water use for turf is approximately 31 inches in the Hailey-Ketchum area compared to 27 inches for alfalfa and 28 inches for pasture. Conversion of an irrigated ranch to a golf course with associated buildings, roads, parking lots, and recreational facilities can result in similar consumptive use for the gross area. Conversion of irrigated areas to one acre residential lots or smaller results in a net decrease in consumptive use.

The county buildout study did not address dwelling unit lots size or location relative to irrigated areas. Therefore, an estimate of the change in total consumptive use from development of the potential buildout is not possible. However, an estimate of per dwelling unit consumptive use change was made based on a range of lot sizes and pre-development land use. In general, on irrigated lands, more dense development results in decreased consumptive use. Development on non-irrigated lands always results in an increase of consumptive use compared to historical vegetation.

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