ENHANCED SNAKE PLAIN AQUIFER MODEL FINAL REPORT

July, 2006

By
D. M. Cosgrove, B. A. Contor,
G. S. Johnson
Idaho Water Resources Research Institute,
University of Idaho

for the
Idaho Department of Water Resources

with guidance from the
Eastern Snake Hydrologic Modeling Committee

Idaho Water Resources Research Institute
Technical Report 06-002

Eastern Snake Plain Aquifer Model Enhancement Project
Scenario Document Number DDM-019

Idaho
Legislature

Abstract

The development of ground-water and surface-water irrigation on the eastern Snake River Plain has necessitated conjunctive management of the ground and surface water resources. To facilitate this management approach, the Idaho Department of Water Resources (IDWR) has placed a strong emphasis on the development, use and refinement of scientific tools which help quantify the impacts of changing water use practices on ground water and surface water supplies on the eastern Snake River Plain. Recognizing the importance of the ground-water model as a water management tool, the IDWR, the State Legislature and the water user community agreed to embark on a model reformulation process.

Model reformulation was funded as a joint effort between the State of Idaho, Idaho Power, the U.S. Bureau of Reclamation and the U.S. Geological Survey. The reformulation was overseen by the Eastern Snake Hydrologic Modeling Committee (ESHMC), a collection of scientists and engineers representing the above-identified agencies and private water user groups. The actual modeling was accomplished by the Idaho Water Resources Research Institute (IWRRI) at the University of Idaho. Major design alternatives were presented to ESHMC members for discussion and guidance. The model development was accomplished in an open environment, with acceptance of design input from all committee members, in an attempt to allay concerns regarding technical bias.

The technical effort was initiated in 1999 and involved data collection for a 22-year calibration period (Spring, 1980 through Spring, 2002), establishing a new model grid and boundary conditions and an exhaustive calibration of the new model. The 22-

year calibration period was broken into 44 6-month stress periods. The calibration was accomplished using version 9.0 of PEST (Doherty, 2005), a non-linear parameter estimation program for data interpretation, model calibration and predictive analysis. The model was calibrated to approximately 11,000 aquifer water level and river gain/loss observations. The resulting model, the Enhanced Snake River Plain Aquifer Model (ESPAM), is a single layer, confined model with 104 rows and 209 columns. Each model grid cell is 1 mile x 1 mile. The model contains 11,451 active cells.

This report documents the enhancement (i.e. design and calibration) of the ESPAM. As design decisions were made during the life of the project, a series of thirty-five reports called Design Documents were written and circulated among ESHMC members for review and comment. The Design Documents contain further details including design alternatives which were considered and the rationale for selecting a specific design option. This report details the accounting of recharge and discharge for the 22-year calibration period, the technical tools used to develop the model, the observations used for model calibration and comparison of the model-predicted aquifer water levels and river gains with observed data. The report cites the various Design Documents for the reader who is interested in more detail.

As with any model of a complex physical system the ESPAM has limitations and uncertainties. The ESPAM is a regional-scale model and is best applied for regional-scale predictions. Additionally, some of the water budget elements and measured observations are known with greater certainty than others. Further discussion about model limitations can be found in the section entitled Model Limitations.

The ESPAM will be used to quantify the impacts of ground-water use on surface water resources. No attempt is made in this report to address the topic of injury to senior water rights.

Introduction

Background and Study Objectives

Ground water and surface water are highly interconnected on the eastern Snake River Plain. This report documents the design, development and calibration of the Enhanced Snake Plain Aquifer Model (ESPAM). The ESPAM will be used by the Idaho Department of Water Resources to estimate impacts between ground water use and surface water resources to support water management decisions.

This project was initiated as a joint effort overseen by groups of eastern Snake River Plain (ESRP) water interests. The study was funded jointly by the State of Idaho, Idaho Power, the U.S. Bureau of Reclamation, with in-kind services from the U.S. Geological Survey (USGS). Technical oversight and input from representatives of these entities andd water user groups were incorporated in the model development to create the best possible technical tool for management of ground-water resources on the eastern Snake River Plain and to which all involved parties could agree is an unbiased representation of the complex aquifer system. The process, which was established for allowing oversight and technical input from the interested parties, is described in a later section.

The ESPAM project had several other objectives in addition to creating a model which all interested parties could agree to and support. These objectives are: a) to create a numerical ground-water model of the eastern Snake River Plain aquifer which is calibrated to a sufficient time period to represent a wide range of aquifer stresses, b) to improve the model representation of river/aquifer interaction, c) to fully document the new model including major design decisions and data, and d) to create the model using state of the art model development methods.

Project Scope

The scope of this project was limited to the reformulation and re-calibration of the ground-water model used for water management on the eastern Snake River Plain. This entails the accurate accounting of aquifer recharge and discharge for the modeled period, an accurate assessment of water use on the eastern Snake River Plain, and creation and calibration of a numerical model to represent the Snake River Plain aquifer. The scope of the project was limited to model creation and calibration and did not entail generation of water management scenarios.

The Role of the Eastern Snake Hydrologic Modeling Committee

The ESPAM was created with extensive review and input from the Eastern Snake Hydrologic Modeling Committee (ESHMC) during the period from 1999 through June, 2005. The ESHMC is comprised of professionals working on water issues on the eastern Snake River Plain. Regular members include agency representatives (Idaho Department of Water Resources, U.S. Bureau of Reclamation, U.S. Geological Survey, U.S. Fish and Wildlife Service), industry representatives (Idaho Power), researchers (University of Idaho, Idaho Water Resources Research Institute) and private consultants representing water users on the eastern Snake River Plain. The ESHMC was formed in 1998 and was a follow-on to the previous Idaho Technical Committee on Hydrology (ITCH) which had a similar function. The ESHMC was originally formed to allow researchers and water users a forum for discussing water issues and research on the eastern Snake River Plain and is chaired by the Idaho Department of Water Resources.

Shortly after its formation, the ESHMC was tasked to identify the most critical research needs on the eastern Snake River Plain. The reformulation of the ground-water model was a high priority identified by the ESHMC. Model reformulation was funded jointly by the State of Idaho, Idaho Power and the U.S. Bureau of Reclamation, with in-kind services provided by the U.S. Geological Survey. Model development was contracted by IDWR to IWRRI. Program management for the model reformulation was provided by IDWR. However, realizing the contentious nature of water disputes on the eastern Snake River Plain and, in an effort to temper future disagreement, IDWR elected to have the model design, construction and calibration overseen by the ESHMC. IDWR's goal was to provide insight and input into the model design so that all parties could attest to the facts that a) the model was created with as little bias as possible and b) the model was as accurate a representation of the physical system as possible, given the available data. IDWR further stated the goal that future water disputes on the eastern Snake River Plain should be focused on policy and not on the science. It was understood that not every decision would attain complete agreement from all members of the ESHMC.

IWRRI held approximately quarterly meetings to present project status and proposed design choices to the ESHMC. The design choices were documented in a series of technical reports that are called Design Documents. The Design Documents were distributed to ESHMC members in draft form prior to all design review meetings. During the design reviews, the ESHMC members received presentations of various design options. These options would often be discussed at length. Once either consensus (but not necessarily unanimous agreement) was reached or there was no further discussion, the final design decision was documented in a final version of the relevant Design Document. Many fundamental design decisions were modified specifically in response to ESHMC guidance. Realizing that the group was being presented with an extraordinary volume of information and detail during the design reviews, the ESHMC members were encouraged to provide written comments on specific Design Documents or on specific design issues as well as oral comments during meetings.

If, in the course of model development or calibration, the technical team determined that a design decision needed to be changed or required more extensive Committee review, either a memorandum or a revised version of the Design Document was distributed to the ESHMC. At every juncture, the ESHMC committee members were kept apprised of model design options and decisions.

Recognizing that multiple (often disparate) viewpoints were represented at ESHMC meetings, it was understood that not all design decisions could be made with unanimous agreement. All major design decisions, however, were discussed at length and consensus on the design approach was reached among the present parties. Throughout this report, major design decisions made by the ESHMC members are noted. The authors recognize that this is an extraordinary approach for ground-water model documentation; however, the authors feel that the method of model development, including and soliciting input from interested parties from the very beginning of model design, was a unique approach aimed at gaining consensus on a potentially contentious model.

ESPAM Version

During the preparation of this final project report, some data entry errors were discovered in the original model calibration, requiring model re-calibration. The data entry errors were centered around the calibration targets used for the river reaches in the upper Snake River. The most significant data entry errors were that the measured irrigation return flow percentages had not been integrated into the model calibration targets and there was a mismatch in reach integration between the model-predicted and observed values for the Shelley to Near Blackfoot and Near Blackfoot to Neeley reaches. These data entry errors were corrected and the model was re-calibrated in May, 2005, resulting in the release of ESPAM Version 1.1, which is described in this report. These data entry errors did not significantly affect results of the model simulation.

Study Area Description

The Snake River Plain extends in an arcuate shape across most of southern Idaho and into eastern Oregon. The plain is divided into eastern and western regions based primarily on ground-water hydrology. The eastern Snake River Plain is the focus of this report and entails an area of about 10,000 square miles extending from Ashton, Idaho in the northeast, southwest to King Hill, Idaho (Figure 1). The boundaries of the plain, shown in Figure 1, were originally defined by the U.S. Geological Survey's Regional Aquifer- System Analysis (RASA) program (Lindholm, 1993) and were modified for this study (see Geographic Boundary Conditions section). The model boundary shown in Figure 1 is the modified boundary used for this study. Elevation of the eastern plain varies from about 2600 feet above sea level in the southwest to over 5000 feet in the northeast.

Population within the plain is generally sparse, with most of the population residing along the eastern and southern margins of the plain in an agriculturally productive band near the Snake River. Much of the remainder of the plain is federal land managed primarily by the U.S. Bureau of Land Management. Extensive portions of the plain are covered by rugged basalt outcroppings that include the Craters of the Moon National Monument.

The Snake River Plain enjoys an arid to semi-arid temperate climate. Precipitation ranges from about 8 to 14 inches per year, falling predominantly in the colder months. Irrigation is required for agricultural production. The crops grown vary with location; the major crops throughout the plain include potatoes, wheat, barley, alfalfa, and sugar beets. Dry edible beans, corn and peas are grown in the southwestern part of the valley.

Irrigation on the eastern Snake River Plain began in the late 1800s using water from the Snake River and its tributaries. Garabedian (1992) describes changes in surface-water and ground-water irrigated areas on the eastern Snake River Plain that are shown graphically in Figure 2. Acreage irrigated by surface water has been declining since the mid-1940s. Since the onset of ground-water irrigation in the 1950s, the number of acres irrigated by ground water increased steadily until the early 1990s.

Irrigation practices are continually changing in response to technology and economic factors. Furrow, flood, and sub-irrigation were the dominant methods of water application into the second half of the twentieth century. In the 1980s and 1990s sprinkler systems have commonly replaced surface application methods, with a resulting decrease in the amount of water diverted per acre of agricultural land.

Significant legal developments in the 1990s have dramatically affected water use on the Snake River Plain. A basin-wide adjudication of water rights was initiated in 1987 (Idaho Water Resources Board, 1996). The Idaho State legislature enacted legislation affecting the adjudication, including recognition of enlargements in irrigated acreage that occurred before 1987. A moratorium on expansion of irrigated acreage has been in effect for the Snake River Basin since 1992. The moratorium includes both surface and ground water irrigated lands within the basin (Idaho Water Resource Board, 1996). Conjunctive management rules were adopted by the Idaho Department of Water Resources (IDWR) in 1994, essentially linking administration of ground- and surface-water rights. Water measurement districts were established in 1996 to provide records of ground-water pumpage for irrigation. Managed recharge of the Snake River Plain aquifer has also been supported by the Idaho legislature. Estimates for managed recharge, which has occurred at various locations through existing irrigation facilities, are listed in Table 1.

The onset of drought conditions in 2000 caused multiple legal actions to be initiated accelerating the conjunctive administration of surface- and ground-water resources. It was widely agreed that the old numerical model of the eastern Snake River Plain was not sufficiently documented to support conjunctive management decisions.

Model History

Numerical ground-water flow models of the Snake River Plain aquifer have been developed and applied by state and federal agencies, universities, and private interests. The models vary in purpose, extent, and the computer code employed. The first numerical model of the aquifer was developed by the University of Idaho for IDWR and the U.S. Bureau of Reclamation (deSonneville, 1974). The original IDWR/UI model has undergone multiple revisions and improvements, described below.

The finite-difference model code developed by the University of Idaho and evolved by the University and the IDWR will be referred to as the IDWR/UI Ground Water Flow Model Code. The application of this code to the Snake River Plain aquifer will be referred to as the IDWR/UI Ground Water Flow Model, following the convention established by the IDWR (IDWR, 1997a). The IDWR has applied various versions of this model as a planning and management tool for over two decades.

In the early 1980s, the IDWR/UI Ground Water Flow Model was re-calibrated to 1980-1981 conditions. This re-calibration was able to capitalize on the extensive data collection effort which the USGS did in support of the Regional Aquifer-System Analysis (RASA) study of the Snake River plain during that period. In the early 1980s, the USGS also created a model of the eastern Snake River Plain aquifer for scientific investigations (Garabedian, 1992).

In 1999, the IDWR/UI Ground Water Flow Model was converted to use one of the most widely used and accepted ground-water modeling codes, MODFLOW (McDonald and Harbaugh, 1988). The conversion to MODFLOW was not intended to create a new model, but to develop an equivalent model using a different code. Model representation of physical properties such as aquifer transmissivity, storage and streambed conductance were preserved in this conversion of the IDWR/UI Ground Water Flow Model to the MODFLOW code. The 1999 MODFLOW application to the Snake River Plain aquifer will be referred to as the Snake River Plain Aquifer Model (SRPAM), with the most recent version being SRPAM1.1. There were several benefits gained from conversion to the MODFLOW code including: a) the MODFLOW code is accepted as an industry standard, b) MODFLOW includes algorithms that simulate physical processes and have been verified against analytical solutions, c) MODFLOW is more familiar to a wider group of scientists and engineers, d) numerous user interfaces have been developed for MODFLOW, e) MODFLOW capabilities are continuously increasing, f) MODFLOW has a significant capability for treating more advanced features such as three-dimensional flow and variable grid spacing, and g) the MODFLOW code is well documented.

In addition to conversion of the IDWR/UI Ground Water Flow Model to the MODFLOW code, the model was modified to improve model representation of the physical system. This was achieved primarily by expansion of the model domain to include segments of the Snake River and tributaries in the northeast portion of the plain that were not previously simulated. Additionally, model documentation was significantly enhanced (Cosgrove and others, 1999; Johnson and others, 1999).

With the potential for rising conflict between surface water and ground water users on the eastern Snake River Plain, in 2000, IDWR embarked upon a full reformulation and re-calibration of the ground water model. This effort resulted in the model which is documented in this report. The resulting model is called the Enhanced Snake Plain Aquifer Model (ESPAM).

Hydrogeology

Geologic Framework

The surface of the Snake River Plain consists primarily of volcanic rocks, which, in most areas, are covered by a veneer of windblown or fluvial sediments. Sediment deposits overlying the basalt vary in thickness from zero to tens of feet. Exposed volcanic rocks are predominantly basalt, which in places such as the Craters of the Moon National Monument, cover expansive areas.

The eastern Snake River Plain is composed of a series of relatively thin basalt flows and interbedded sediments. Flows range in thickness from a few feet to tens of feet. Welhan and Funderberg (1997) report median flow thickness near the Idaho National Laboratory ranging from about 7 to 25 feet. Individual flows typically have a rubble or clinker zone at the top and bottom with a more massive interior containing fewer vesicles. Vertical fractures in the flow interiors form columnar basalt in some locations (Garabedian, 1992). Individual basalt flows generally are not extensive (Welhan and Funderberg, 1997). The collective thickness of basalt flows of the eastern Snake River Plain is estimated to exceed several thousand feet in places (Whitehead, 1986). More detailed descriptions of the geology of the eastern Snake River Plain are provided by Anderson (1991), Whitehead (1986), and Kuntz and others (1992).

The eastern plain is bounded structurally by faulting on the northwest and downwarping and faulting on the southeast (Whitehead, 1986). The plain is bounded by Yellowstone Group rhyolite in the northeast and Idavada volcanics in the southwest. Granitic rocks of the Idaho batholith, along with pre-Cretaceous sedimentary and metamorphic rocks, border the plain to the northwest (Garabedian, 1992).

Surface-Water Hydrology

The Snake River passes along the southern margin of the eastern Snake River Plain and is the exclusive surface water discharge mechanism for the eastern plain. Ground water underflow from the eastern plain into the western plain is assumed to be minimal, due to the more extensive low hydraulic conductivity sedimentary deposits of the western plain. Consequently, flow of the Snake River at King Hill is widely considered to be the equivalent of basin discharge, excluding evaporation. Annual discharge of the Snake River at King Hill is shown in Figure 3. The cumulative discharge line in Figure 3 shows little long-term change in slope. This indicates that despite significant changes in water use during the last several decades, there has been little change in basin outflow. A possible reason for the stability of the slope of the cumulative graph in Figure 3 is that human activities have apparently had a greater temporary impact on aquifer storage than on basin outflow.

The Snake River is intensively managed for irrigation and hydropower generation. The average annual flow, major inflows and diversions at different points within the system are illustrated by river width in Figure 4. The flow in the Snake River is noticeably depleted at Milner Dam where substantial diversions are made for irrigation. A gradual increase in river flow below Milner Dam is due largely to aquifer discharge in the form of springs emitting from the wall of the Snake River canyon. North of Idaho Falls, in the eastern part of the plain, the Henrys Fork (locally referred to as the North Fork) joins the Snake River, locally referred to as the South Fork, shortly downstream from Lorenzo, Idaho. The origin of the Henrys Fork is in the Island Park area to the northeast of the Snake River Plain. Headwaters of the Snake River (South Fork) are in Yellowstone Park in Wyoming. On average, flow of the Snake River at Lorenzo is about triple the flow of the Henrys Fork near Rexburg.

Several reservoirs have been constructed on the Snake River and its tributaries for the purposes of irrigation, flood control, hydropower generation, and recreation. In some years, spring snowmelt exceeds system storage capacity and irrigation demands and water is spilled past Milner Dam. On average, about two million AF of water are discharged annually past Milner Dam (Figure 5).

Direct tributaries to the Snake River occur primarily from the east and south sides of the basin. Several streams along the northern margin disappear through seepage before flows can reach the Snake River (Figure 4). Only flows of the Big and Little Wood Rivers, Silver Creek (not shown in Figure 4, but tributary to the Big Wood River), and Camas Creek may eventually reach the Snake River from the northern margin of the plain. Other streams on the northern margin of the plain, such as the Big and Little Lost Rivers, contribute recharge to the Snake River Plain aquifer, but do not directly discharge to the Snake River.

An extensive network of irrigation canals provides water for approximately 1.0 million acres of surface-water irrigated land on the eastern Snake River Plain. Technical reports provide different estimates of surface water irrigated land due to: 1) differences in the area being evaluated, 2) difficulties discriminating between ground-water and surface-water irrigated land in some locations, and 3) the application of adjustments for non-productive lands (e.g. homesteads, roads, ditches) within an area that appears irrigated in satellite images. In 1980, the U.S. Geological Survey reported 2.1 million acres of irrigated land (both surface- and ground-water) on the eastern Snake River Plain (Garabedian, 1992) within the RASA aquifer boundary. For the current study, it was estimated that there are 1.0 million acres irrigated by surface water and 1.1 million acres irrigated by ground water, for a total of 2.1 million irrigated acres.

Irrigation diversions consume a large proportion of the flow of the Snake River during irrigation season. Diversions of surface water for irrigation in the eastern Snake

River Plain (including all tributaries) have diminished by about 20 percent from the nearly eight million AF/yr diverted in the early 1970s (IDWR, 1997a). Irrigation diversions both deplete and affect the timing of flows in the river, with some of the diverted water returning to the river as either surface or ground water return flows. In addition, surface water diverted for irrigation also has a major effect on recharge of the Snake River Plain aquifer as will be discussed in the following section.

Extensive ground water irrigation across the plain also impacts the surface water resources. Due to the interconnection between the aquifer and the river, water withdrawn from the aquifer to supply the approximately 1.1 million acres of ground-water irrigated land either diminishes aquifer discharge to the river or increases river losses to the aquifer.

Ground-Water Hydrology

The Snake River Plain aquifer underlies the eastern Snake River Plain. This highly productive aquifer is hosted in fractured basalts and interbedded sediments. The primary conduit for ground-water flow appears to be the highly permeable rubble zones that formed at the tops of the numerous basalt flows which comprise the Snake River Plain. Garabedian (1992) reports median specific capacity on a county basis for 176 wells across the eastern plain. The median values ranged from 4 to 950 gallons per minute per foot of drawdown, with the largest values occurring in counties near the center of the plain where Quaternary basalts are thickest. The lower values were found near the margins of the plain where Tertiary basalts and sediments predominate.

Although the collective thickness of the basalt flows may be in excess of several thousand feet in places, the active portion of the aquifer often is thought to be limited to the upper several hundred feet of saturated thickness. Robertson (1974) states that "Although the real aquifer system is probably more than 1,000 feet thick, a thickness of 250 feet is used in this study based on the apparent layering effects of the aquifer." Based on the presence of low permeability sedimentary layers encountered in a well drilled on the Idaho National Laboratory, Mann (1986) suggests that the aquifer is 450-800 feet thick. Model studies by the U.S. Geological Survey (Garabedian, 1992) represent the aquifer as four layers with a collective thickness ranging from 500 to over 3,000 feet. Modeling by the IDWR and the University of Idaho (deSonneville, 1974; Newton, 1978; IDWR, 1997a; Cosgrove and others, 1999) represents the aquifer as a single layer ranging from 200 to 1,700 feet thick.

The Snake River Plain aquifer generally is considered unconfined; however, in some locations and under certain conditions the aquifer responds as a confined system. In some areas, low permeability lakebed sediments create local confining layers (Spinazola, 1994). The layered basalts and interbedded sediments also may produce conditions that appear locally confined, at least when subjected to short duration stress (Frederick and Johnson, 1996).

The Snake River Plain aquifer is recharged by irrigation percolation; canal, stream, and river losses; subsurface flow from tributary valleys; and precipitation directly on the plain. The aquifer discharges to the Snake River, springs along the Snake River and to ground-water pumping, primarily for irrigation. Figure 6 shows a conceptual model of recharge and discharge to the Snake River Plain aquifer. The relative magnitudes of the recharge and discharge components were evaluated by the USGS (Garabedian, 1992) and, more recently, for this study. Estimates from the USGS represent conditions in 1980 for the entire Snake River Plain (Figure 7). Estimates from the current study represent an average of 1980 through 2001 conditions (Figure 8). The USGS estimates of water budget components include portions of the plain not included in the current estimate due to differences in model boundaries (model extent is discussed in a later section).

Incidental aquifer recharge from irrigation is a significant component of the water budget and has varied as irrigation practices have evolved. The 1980 water budget of the USGS (Garabedian, 1992), shown in Figure 7, shows that surface water irrigation contributes more than 50 percent of the total recharge to the aquifer. Historically, recharge from surface water irrigation increased as more land was brought into production up to the 1970s. Since the 1970s, a gradual conversion to sprinkler irrigation methods reduced the amount of incidental recharge from irrigation.

Natural discharge from the Snake River Plain aquifer is primarily to the Snake River along two reaches: Kimberly to King Hill, and Near Blackfoot to Neeley. These reaches are defined by gaging stations shown in Figure 1. Spring discharge has varied in response to changes in precipitation, irrigated acreage, and irrigation practices. Overall, discharge in the Kimberly to King Hill reach appears to have been impacted more than in the Near Blackfoot to Neeley reach (Figure 9), although the Near Blackfoot to Neeley reach shows more seasonal variation since approximately 1970. The effects of weather variation and irrigation recharge are apparent from the short-term variation of spring discharge. Maximum discharge occurs around October, near the end of the irrigation season. The seasonal variation in the Blackfoot to Neeley and Milner to King Hill reaches is about 15 and 20 percent of the respective maximum reach gains (from interpretation of Kjelstrom, 1995a).

Historically, aquifer water levels and corresponding discharges to the Snake River rose significantly at the onset of surface water irrigation. This is particularly apparent in the historic discharge in the Milner to King Hill reach shown in Figure 9. Aquifer water levels peaked around 1950 and have been declining since that time. The declines are attributed to the onset of ground-water irrigation, more efficient surface water irrigation practices such as conversion to sprinkler irrigation and canal lining, and the recent seven years of drought. Historic discharge in the Near Blackfoot to Neeley reach shows a less dramatic response to historic changes in irrigation practices, however the reach does exhibit more dramatic seasonal variation since the 1950s.

Other reaches of the Snake River also are hydraulically connected to the aquifer. In these segments, the river may gain or lose water, depending on river stage and the water level in the aquifer. The Neeley to Minidoka reach both gains and loses water, with gains generally exceeding losses. Further upstream, between Heise and Lorenzo, the South Fork of the Snake River is a seasonally losing stream (Kjelstrom, 1995a). Average annual loss of this reach was 150 ft^3/sec in the 1980 water year. During that same period, the Lorenzo to Lewisville reach of the main stem of the Snake River and the lower Henrys Fork reach were estimated to have gained 290 and 120 ft^3/sec, respectively (Garabedian, 1992).

Contours of the potentiometric surface indicate that ground-water flow direction generally is parallel to the axis of the plain (Figure 10). Steep hydraulic gradients are apparent near the margins of the plain due to tributary valley inflow and lower transmissivity relative to the center of the plain. Steep gradients also are apparent near the Kimberly to King Hill discharge area due to convergence of flow lines and probable aquifer thinning. Near the center of the plain and near Mud Lake, steeper gradients presumably result from decreased transmissivity due to the volcanic rift zone and thick sediment deposits, respectively. Garabedian (1992) used transmissivities ranging from $4x10^3$ to $1x10^7$ ft^2/day. The SRPAM model had transmissivities which ranged from $2x10^4$ to $5x10^6$ ft^2/day. These ranges of values are consistent with published values for fractured basalt.

Aquifer storage in the eastern Snake River Plain aquifer is reasonably high due to the highly fractured nature of the system. Garabedian (1992) used specific yield values ranging from .05 to .2 (unitless ratio). Specific yield values used in the SRPAM model were higher, ranging from .08 to .26. The specific yield values used by Garabedian and the SRPAM model are consistent with published specific yield values for fractured basalts in unconfined systems, although many of the SRPAM values are at the upper limits of published values.

Aquifer water levels have changed significantly over the past several decades in response to changes in irrigation and variations in weather. Figure 11 shows the water level changes on the eastern Snake River Plain for the period from spring, 1980 to spring, 2002. This change in water level corresponds approximately to the change in aquifer storage shown in Figure 8 (Figure 8 shows the change in storage up through 2001). During that period, water levels across the plain generally declined between 5 and 15 feet, with some areas experiencing declines as great as 20-25 feet. The greatest changes in water level appear in a band traversing the south-central portion of the plain. Figure

12 shows water level declines between spring, 2001 and spring, 2002, the last year of the period shown in Figure 11. The reader will note that water level declines shown in Figure 12 are almost half of the total decline in the 1980-2002 period, reflecting a rapid aquifer response to the drought conditions of the year 2001-2002. This suggests that under long-term, average conditions (1980-2001), water use on the eastern Snake River Plain was reasonably in balance with use slightly exceeding supply. The rapid decline in the 2001-2002 year indicates that water level declines occur rapidly under drought conditions. This general decline in water level is consistent with observed declines in aquifer discharge to the Snake River.

Model Description

Governing Equations and Model Code

The mathematical equations governing unconfined flow are non-linear due to the fact that saturated thickness and, therefore, transmissivity, change with time. In confined systems, saturated thickness is constant, therefore the mathematical representation is linear.

The ESPAM is a confined representation of the eastern Snake River Plain aquifer. This decision was made by the ESHM Committee and was consistent with field observations of the propagation of pumping impacts through the aquifer (Frederick and Johnson, 1996). Additionally, the deep saturated thickness (Whitehead, 1986) supports the representation of a generally unconfined aquifer as confined since drawdowns in the highly transmissive aquifer will be less than 10% of total saturated thickness in most management applications (Anderson and Woessner, 1992). The confined representation of the eastern Snake River Plain aquifer allows a more stable numerical simulation of the aquifer during automated model calibration. ESPAM Design Document DDM-019 discusses the confined representation of the ESPAM. The thickness of the aquifer is discussed further in the section on Geographic Boundary Conditions.

The general equation governing confined, steady state, anisotripic, heterogeneous flow in two dimensions is:

$$\frac{\partial}{\partial \mathrm{x}}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial \mathrm{y}}\left(K_{yy}\frac{\partial h}{\partial y}\right)=0 \qquad \text{(Eq. 1)}$$

where:

K_{xx} is hydraulic conductivity in the x-dimension (ft/d)

K_{yy} is hydraulic conductivity in the y-dimension (ft/d)

h is aquifer head (ft)

The general equation governing confined, transient, anisotropic, heterogeneous flow in two dimensions is:

$$\frac{\partial}{\partial \mathrm{x}}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial \mathrm{y}}\left(K_{yy}\frac{\partial h}{\partial y}\right)-W=S_s\frac{\partial h}{\partial t} \quad \text{(Eq. 2)}$$

where:

K_{xx} is hydraulic conductivity in the x-dimension (ft/day)

K_{yy} is hydraulic conductivity in the y-dimension (ft/day)

h is aquifer head (ft)

W is the rate of aquifer recharge (1/day)

S_s is specific storage (1/ft)

t is time (days)

The ESPAM comprises both a steady state and transient, two-dimensional, isotropic representation of the eastern Snake River Plain aquifer. The isotropic representation means that $K_{xx} = K_{yy}$. In a numerical model, individual model cells are homogeneous. Heterogeneity is represented by the spatial variation of properties such as transmissivity, on a cell by cell basis. Therefore, the governing equations for a numerical model are the same as for a homogeneous system. Multiplying Equations 1 and 2 by b/T, where b is saturated thickness (ft) and T is aquifer transmissivity (ft^2/day), yields the following:

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} - W\frac{b}{T} = 0 \quad \text{(Eq. 3)}$$

and

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} - W\frac{b}{T} = \frac{S}{T}\frac{\partial h}{\partial t} \quad \text{(Eq. 4)}$$

where:

T is aquifer transmissivity (ft^2/day)

h is aquifer head (ft)

W is the rate of aquifer recharge (1/day)

S is storativity (dimensionless)

t is time (days)

b is aquifer thickness (ft)

Equations 3 and 4 represent the governing equations used for representing groundwater flow in the ESPAM steady state and transient models, respectively.

Flow between the aquifer and river or drain cells is governed by equations which are based on Darcy’s law. Darcy’s law is:

$$Q = -KA\frac{dh}{dl} \quad \text{(Eq. 5)}$$

where:

Q = discharge (ft^3/day)

A = cross-sectional area (ft^2)

K = hydraulic conductivity (ft/day)

dh/dl = hydraulic gradient (dimensionless)

In a numerical model, for both river and drain cells, the hydraulic conductivity term represents the conductivity of the river-bed or drain sediments which controls the flow between the river/drain and the aquifer. The gradient (dh/dl) represents the head differential between river stage (or drain elevation) and aquifer level.

In a finite-difference model, the ground-water flow equation is solved for each individual model cell and river or drain cell, preserving the mass balance of water. Each model cell can have individual properties representing aquifer transmissivity and storage. Similarly, all river and drain cells can have individual properties representing river/drain elevation and conductance. At every time step of the model, the equations are solved simultaneously using a numerical solver.

The ESPAM was constructed using MODFLOW2000, a finite-difference code widely used for ground-water modeling which was created by the U.S. Geological Survey (McDonald and Harbaugh, 1988, Harbaugh and others, 2000). The ESPAM was constructed using the Link-Module Gradient (LMG) solver (Mehl and Hill, 2000), however, the model can also be run using the Pre-Conjugate Gradient solver (Hill, 1990). With the LMG solver, the water budget closure criterion is .00001 and the dampening parameter is 1.0. The parameter estimation code, PEST version 8.3 (Doherty, 2004) was used to assist with model calibration.

MODFLOW2000 was selected because it is considered an industry standard for finite difference ground-water models. PEST was selected because of adaptability to the complexity of the model calibration where model results were compared with thousands of aquifer measurements during the calibration process.

Discretization

Finite difference modeling consists of breaking a large physical area into small volumes, which are called model cells, and simultaneously solving the numerical problem (Equations 3, 4 and 5) for each model cell. Additionally, if the model is transient, the total simulation time is also broken down into smaller time periods and the problem is solved at the end of each time period. In the case of ground-water modeling, the problem is being solved to determine aquifer head at each of the model cells and flux to drains and to/from rivers. This process of breaking the larger pieces down into smaller pieces is referred to as discretization.

For a uniform grid, the estimated aquifer head for each model cell represents the head at the center of the cell. If the cells are very large and the gradient is steep, interpolating head at locations other than at the center of the cell can introduce significant error.

Spatial Discretization

The spatial discretization of the model study area is the representation of the eastern Snake River Plain aquifer system in small volumes. The study area was overlain by a uniform 1 mile x 1 mile grid. The grid was intersected with the model boundary. Any cell within the model boundary is considered an active cell, or a cell for which aquifer head would be computed using the model. Any cell outside of the model boundary is considered an inactive model cell and not part of the calculation of aquifer head.

Model Grid

The ESPAM grid consists of 104 rows and 209 columns. The grid rows are numbered with row 1 at the top of the grid. The grid columns are numbered from west to east, with column 1 being the west-most column. The grid origin is at the outside corner of model cell (1,1), the most northwest point of the model grid, and is at Idaho Transverse Mercator (IDTM) coordinates x=378,416.2 m and y=233,007.2 m (in feet: x=1,241,523 and y=764,459.2, latitude = 43.118806°, longitude=-115.49619 °). The reader should note that these IDTM coordinates are in the original IDTM system (IDTM 27) and not the IDTM83 system which was adopted in 2004. For more information on IDTM coordinates, the reader is encouraged to contact IDWR.

The model grid is rotated 31.4° counter-clockwise relative to an east-weat orientation. The rotation is selected to minimize the number of inactive model cells. Figure 13 shows the model grid, the origin and the orientation. The grid is comprised of model cells which are 1 mile x 1 mile square cells (5,280 ft x 5,280 ft). There are 11,451 active model cells. Selection of the 1 mile x 1 mile grid size was consistent with the density of data available for the study area and the steepness of gradients in the Snake River Plain aquifer. Figure 14 shows a close-up of the model grid in the Thousand Springs area (between the Kimberly and King Hill gages) and the density of observation wells in that area. This gives the reader a sense of the density of available data relative to the model grid size. Details of the model grid design are available in ESPAM Design Document DDM-015.

Model Layers

The ESPAM of the eastern Snake River Plain aquifer is a single-layer model. Previous models of the aquifer have contained both single (Cosgrove and others, 1999) and multiple (Garabedian, 1992) layers. It is generally agreed that the regional eastern Snake River Plain aquifer resides in a single large stratigraphic unit, consistent with a single layer model (Whitehead, 1986).

There are localized lenses of sediments in some locations on the plain (the Rigby Fan and the Burley-Rupert area), which may contain locally elevated water levels. When the ESPAM was being designed, it was agreed among the ESHMC that the option of adding a top layer to represent the sedimentary units would be explored only if time permitted and data were available. Investigation showed that there are little data available to support calibration of separate layers representing these locally elevated zones and ESHM Committee members agreed that a single layer model was sufficient. More information on the choice of using a single layer representation is available in ESPAM Design Document DDM-003.

Temporal Discretization

The ESPAM includes both a steady state and a transient model. Steady state simulation does not involve a time factor (Eq. 3). For a transient model, it is necessary to select a) the total time span for the model calibration period, b) the model stress period interval and c) the number of time steps in each stress period for which aquifer head and river gains will be calculated. Decisions on model calibration time span and temporal discretization were made by the ESHM Committee.

The criteria used to select the model calibration period included a) the period should represent a wide range of recharge and discharge, b) reliable data should be available for the period, c) the period should be long enough to allow the ground-water model to adequately predict long-term aquifer trends and d) the period should reflect current land use and irrigation practices. The ESHM Committee selected a model calibration period of 22 years, from May, 1980 through April, 2002. The starting date was selected to coincide with the extensive data collection effort on the eastern Snake River Plain which was done by the USGS as part of the RASA project. The end date was originally set one year earlier (April, 2001); however, since the 2001-2002 water year was an extreme drought year, the choice was made to extend the model end period by one year to include the 2001-2002 water year. This decision had the added benefit of allowing the modelers to use field measurements from the 2001-2002 water year. The period of May, 1980 through April, 2002 includes the wettest year on record (1997), early drought years (1987-1990) and the starting years of the current drought period (2000-2002). A calibration period with a wide variation of recharge and discharge results in calibration targets (river gains, spring discharges and aquifer water levels) which provide a better constraint on the calibrated model parameters (aquifer transmissivity and aquifer storage and riverbed conductance).

In a MODFLOW model, a stress period is the length of time during which aquifer recharge and discharge (aquifer stresses) are held constant. In the ESPAM, because the hydrology is dominated by irrigated agriculture, 6-month stress periods (182 days during the irrigation season and 183 days during the non-irrigation season) were selected. The irrigation season stress period starts on May 1 and ends on October 31 and the non-irrigation season starts on November 1 and ends on April 30. The ESHM Committee agreed that, if calibration were successful with the 44 6-month stress periods, an attempt would be made to calibrate with 6-month stress periods representing the first 21 years and twelve 1-month stress periods representing the last year. This was attempted during model calibration; however, there was insufficient resolution in many components of the recharge and discharge data to support the 1-month stress periods. Hence, the final calibrated ESPAM transient model has 44 6-month stress periods. Table 2 lists the dates represented by each of the 44 transient stress periods.

In ground-water modeling using MODFLOW the stress period is subdivided into time steps. The ground-water flow equations are solved at every time step. Even though the same aquifer stress is being applied during the whole stress period, aquifer water levels and river gains are changing throughout the stress period (the aquifer water levels and river gains are responding to the applied stress). By further discretizing time using time steps, the model predicts these intermediate aquifer water levels and river gains, allowing comparison of predicted water levels and river gains with measured values and reducing uncertainty in model predictions. For ESPAM calibration, 10 time steps of equal length (18.2 days during the irrigation season and 18.3 days during the non-irrigation season) are used for each model stress period. Since each time step is 18.2 or 18.3 days in length, the net result is that aquifer water levels and river gains are estimated by the model every 18.2 or 18.3 days during the 22-year calibration period.

Model Boundary Conditions

In a numerical ground-water model, the boundary conditions can exert a great amount of control on the model solutions, particularly for steady state solutions. The selection of boundary conditions is a critical element of the conceptual design of any ground-water model.

The ESPAM employs several types of numerical model boundary conditions. No-flow boundaries are used around most of the perimeter of the model, simulating the physical contact between the aquifer and impermeable geologic formations. Specified flux boundaries are used to represent tributary underflow, non-Snake River reaches, wells where water is not locally applied for irrigation, recharge from precipitation on non-irrigated lands, irrigation conveyance loss and net recharge/discharge from surface- and ground-water irrigation. Head-dependent boundaries, where the rate of discharge to or from the aquifer is driven by a head differential between the aquifer and a hydraulically connected water body (such as a river reach or spring), are employed to represent some reaches of the Snake River and springs immediately tributary to the Snake River.

Geographic Boundary Conditions

The ESPAM boundary is based on the SRPAM and RASA aquifer boundaries, with some modifications. Figure 15 shows the ESPAM boundary, the RASA boundary, the SRPAM model boundary and irrigated areas. Because the ESPAM is intended for the conjunctive management of ground- and surface-water resources, the SRPAM and RASA boundaries were evaluated based on inclusion of irrigated areas. Modifications were made to expand the original aquifer boundaries to include irrigated acreage in the Kilgore, Rexburg Bench, American Falls and Oakley Fan areas (Figure 15). The Twin Falls tract, which is within the RASA boundary but not the SRPAM boundary, was excluded since the Snake River is deeply incised between Kimberly and King Hill, so there is no communication between the aquifers on the north and south sides of the Snake River.

In the King Hill area, the RASA boundary extends several miles further to the west than the SRPAM boundary. The decision was made to include that area in the ESPAM boundary, allowing inclusion of the King Hill gage on the Snake River. The model boundary was extended up the Big Lost River drainage to Mackay Dam in order to simplify the estimate of tributary underflow in that drainage. A result of the expansion of the model grid (beyond SRPAM) was the inclusion of approximately 294,000 acres of irrigated lands, which had a significant impact on the model water budget (addressed in a later section). The ESHM Committee felt, however, that this was necessary to support the need for model use for conjunctive management of surface- and ground-water resources.

In addition to the areal extent of the study area, an analysis was done of the bottom of the aquifer. In hydrogeology, the aquifer transmissivity (T) is equal to the saturated thickness (b) multiplied by the aquifer hydraulic conductivity (K). Since the bottom of the aquifer is unknowable in many locations, the imperfect understanding of the saturated thickness is compensated for by adjustments to K during model calibration. Stating this another way, it is the combined parameter, transmissivity ($T=K*b$) which is critical to understanding the movement of water in the aquifer. Neither the hydraulic conductivity nor the saturated thickness must be individually well understood. Although not overtly necessary to calibration of a model, knowledge of the bottom of the aquifer is of interest when interpreting modeling results. An estimate of the bottom of the aquifer allows the modelers to determine an estimate of hydraulic conductivity based on T and b. Additionally, when analyzing the potential non-linearities in an aquifer system, an understanding of the magnitude of saturated thickness relative to aquifer drawdown is critical.

Whitehead (1986) published basalt thickness maps for the eastern Snake River Plain. The maps were based on borehole logs and geophysics at a limited number of locations. The ESHM Committee agreed that a delineation of the bottom of the eastern Snake River Plain aquifer which was based on Whitehead's work with an assumption of a minimum aquifer thickness at the aquifer margins of 200 ft was a reasonable approach. Figure 16 shows the kriged surface of the bottom of the aquifer assumed for the current study. Because there are very few data points available for delineation of the bottom of the aquifer, Whitehead used some presumed data points to delineate the bottom of the aquifer. For this model, some of Whitehead's presumed data points were used, some were modified and several points were established in the Thousand Springs region to establish the minimum aquifer thickness of 200ft. The locations of these data points are all shown in Figure 16. Figure 17 shows the locations at the aquifer margin where the aquifer thickness was set to 200 ft. More details about the determination of the bottom of the aquifer can be obtained in ESPAM Design Document DDM-012.

Hydrologic Boundary Conditions

Hydrologic boundary conditions are used to represent the interaction of the aquifer with rivers, streams, lakes and springs. Strictly speaking, the representation of aquifer recharge and discharge is also a hydrologic boundary condition. The following sections discuss how rivers, streams and springs are represented in the ESPAM. As previously mentioned, some reaches of the Snake River and some springs discharging to the Snake River are represented as head-dependent flux boundaries. Tributary underflow, non-Snake River streams and rivers, and irrigation conveyance loss are represented as specified flux boundaries. All other components of aquifer recharge and discharge (e.g. wells and net recharge/discharge from surface- and ground-water irrigation) are represented as a specified flux in each model cell. Estimation of aquifer recharge and discharge is discussed in the section on Model Water Budget.

MODFLOW Representation of Head-Dependent Boundaries

Head-dependent boundaries are boundaries where the rate of flux between the surface water body and the aquifer is dependent upon the head gradient between the surface water body and the aquifer. Head-dependent boundaries are used to represent surface water bodies which are hydraulically connected to the aquifer. These surface water bodies can be either gaining water from or losing water to the aquifer. In the case of springs, the model representation is strictly a discharge out of the aquifer through the spring.

The flow between the aquifer and a hydraulically connected surface water body is governed by Equation 5. In the MODFLOW River Package, Equation 5 is implemented in terms of a) stage of the surface water body, b) aquifer water level and c) a conductance term describing the hydraulic conductivity of the riverbed (or spring) sediments and the wetted areas of the riverbed. The user specifies river stage, elevation of the bottom of the river sediments and conductance of the riverbed sediments. As long as the water level in the aquifer is above the elevation of the bottom of the river sediments, the discharge to (or from) the river is calculated as:

$$Q_{riv} = C_{riv}(h_{riv} - h_{aq}) \quad \text{(Eq. 6)}$$

where:

Q_{riv} is the discharge to or from the river (ft^3/day)

C_{riv} is the riverbed conductance (ft^2/day)

h_{riv} is the head in the river (ft)

h_{aq} is the head in the aquifer (ft)

Figure 18 shows conceptually how river leakage is calculated in MODFLOW. As long as the aquifer head is above river bottom, the discharge to or from the river is calculated based on the head differential. When the aquifer water level drops below the bottom of the riverbed sediments, the river becomes perched and leaks at a constant rate.

Springs in the ESPAM are represented using the MODFLOW Drain Package. The Drain Package is identical to the River Package with one important distinction: the drain package only allows water to exit the aquifer. When the aquifer water level drops below the drain (spring) elevation, the drain or spring shuts off until the aquifer water level recovers. The equation governing aquifer discharge to drains in MODFLOW is:

$$Q_{drn} = C_{drn}(h_{aq} - el_{drn}) \quad \text{(Eq. 7)}$$

where:

Q_{drn} is the discharge to the drain (ft^3/day)

C_{drn} is the drain conductance (ft^2/day)

h_{aq} is the head in the aquifer (ft)

el_{drn} is the drain elevation (ft)

ESPAM Head-Dependent River Boundaries

Head-dependent river boundaries are used in the ESPAM to represent most of the Snake River above Milner Dam. Two hundred and thirty river cells were established to represent the Snake River above Milner Dam. Since riverbed conductance is a lumped parameter (ie. it represents multiple physical attributes) and impossible to measure, it is commonly estimated during model calibration. Figure 19 shows the ESPAM head-dependent river cells and the aggregation into reaches. Water balance calculations (accomplished using the IDWR Reach Gain and Loss program) indicate that there is virtually no leakage in the reach between Minidoka and Milner, so the reach is not represented in the model. Table 3 lists the model cells used in the MODFLOW River Package and the assigned reach.

The MODFLOW River package requires river stage, elevation of the river bottom and riverbed conductance for each river cell. Determination of river stage and river bottom elevation will be discussed in this section. The estimation of riverbed conductance will be discussed in the section on model calibration. River stage (or elevation of the river surface) was determined by projecting a GIS coverage of the Snake River onto the 10 meter digital elevation models (DEMs) available from the USGS. Once this projection was accomplished, the river elevation was digitized from the DEMs. The 95% confidence interval on deriving elevations using 10 m DEMs is estimated at 1.21 ft +/- 1.17 ft (ESPAM Design Document DDM-010).

Elevation of the river bottom is important, particularly in reaches which may transition between hydraulically connected and perched. Estimation of the river bottom elevation carries a high degree of uncertainty, as it is difficult to measure and may vary greatly at different locations. Elevation of the river bottom is typically only known at gaging stations. The ESHM Committee decided that the best approach for estimating the elevation of the river bottom was to interpolate river bottom depth between the known points at gaging stations. Using this method, the differential between river stage and the bottom of the riverbed ranged between 33 feet and 63 feet. For more information on estimation of river stage or the elevation of the bottom of the riverbed, the reader is referred to ESPAM Design Document DDM-010.

Head-Dependent Spring Representation

In the ESPAM, springs discharging to the Snake River in the Thousand Springs region (between the gaging stations at Kimberly and King Hill) are represented using the MODFLOW Drain Package. As previously discussed, the Drain Package is very similar to the River Package in that discharge from the aquifer through the drain is calculated based on the head differential between the aquifer water level and the drain elevation. If the aquifer water levels drop below the drain elevation, discharge from the drain ceases until the aquifer water levels recover. In the Thousand Springs region, the Snake River flows through a deeply incised canyon, allowing little opportunity for water to discharge from the river to the aquifer. Therefore, selection of the Drain Package is consistent with the physical system.

Forty-five drain cells were used to represent spring discharge in the Thousand Springs area. Unlike the river cells which represent the upper reaches of the Snake River, the drain cells are not contiguous along the Thousand Springs area. The drain cells were sited by mapping springs with significant discharge from the Covington and Weaver (1990) maps published by the USGS. The Covington and Weaver maps were also used to establish initial drain elevations; however, drain elevations were modified during calibration (see the section on model calibration). Table 4 lists the model cells represented with the MODFLOW Drain Package.

Discharge of individual springs or individual drain cells is difficult to represent with a regional scale model. Consequently, the ESHMC agreed that drain cells should be aggregated into reaches that were more consistent with the scale of the model. Aggregation of the drain cells into reaches was accomplished based on an analysis of a) discharge of individual groups of springs and b) cumulative discharge of springs along the entire Thousand Springs reach. Figure 20 shows the cumulative spring discharge along the Thousand Springs reach starting at Devils Washbowl (near Milner dam). Inspection of Figure 20 shows that there are some natural changes in the slope of cumulative discharge which supported aggregation of groups of springs into reaches. In Figure 20, it can be seen that cumulative discharge progresses at a fairly constant slope between Devils Washbowl and Buhl. At approximately the Buhl gage, the slope of the cumulative discharge curve increases until the springs at the Thousand Springs power plant. The springs at the power plant have extremely high discharge, causing a dramatic rise in cumulative discharge. The slope of the cumulative discharge is lower between Thousand Springs and Malad, where the cumulative discharge curve has a second dramatic rise. Between Malad and Bancroft, the cumulative discharge curve again has a lower slope. Analysis of Figure 20 resulted in the springs being aggregated into the following six reaches, shown in Figure 21: Devils Washbowl to Buhl, Buhl to Thousand Springs, Thousand Springs, Thousand Springs to Malad, Malad, and Malad to Bancroft. The color-coded squares in Figure 21 represent individual model cells where MODFLOW drains are used to represent spring reaches.

Initial values of drain conductance for the drain cells along a spring reach were estimated based on the discharge for the group of springs and the estimated head differential between the aquifer and the spring elevation. Drain conductances were calibrated during model parameterization. This will be discussed further in the model calibration section. More details on the location of drain cells, aggregation of the spring reaches and estimation of initial drain conductance can be found in ESPAM Design Document DDM-018.

Specified Flux Boundaries

Specified flux boundaries are used to represent flow to or from the aquifer which occurs at an estimated rate and is not driven by a head differential. Specified flux boundaries are typically used to represent the interface between the aquifer and a water supply which is not hydraulically connected. In the ESPAM, tributary basin underflow, percolation from irrigation and precipitation on non-irrigated lands, seepage from perched rivers and irrigation conveyance losses are represented using specified flux boundaries. This section describes the specified flux boundaries. The rate of specified flux used in the ESPAM, including pumping, will be discussed in the Water Budget section.

Underflow from Tributary Basins

Tributary underflow represents the subsurface discharge of water from a tributary basin into the eastern Snake River Plain aquifer. Because tributary underflow is subsurface flow, it is difficult to estimate.   Underflow from 22 tributaries is represented in the ESPAM. Table 5 lists the tributary basins, for which underflow is represented in the ESPAM. Figure 22 shows the location of each of the tributary basins on the Snake Plain. In Figure 22, the individual model cells which are used to enter the specified flux are highlighted. Appendix A contains a table listing the model cells associated with each tributary (Table A-1). The estimated flux for each tributary is evenly distributed across the model cells assigned to that tributary in each stress period. Estimation of the rate of tributary underflow discharge is discussed in the water budget section.

Perched River Seepage

The ESPAM has 12 locations at which perched river seepage is represented. These reaches represent surface water bodies other than the Snake River. Perched reaches of the Snake River (other than the previously mentioned reach between Minidoka and Milner) are represented using the MODFLOW River Package. Table 6 lists the non-Snake River perched reaches. Strictly speaking, not all of the perched reaches are river reaches. Several flood control sites are represented in the same manner as perched river reaches. Figure 23 shows the location of each perched reach. The model cells in which perched seepage is represented are highlighted in Figure 23. Appendix A contains a table listing the model cells associated with each perched reach (Table A-2). The estimated flux for each perched reach is evenly distributed across the model cells assigned to that perched reach in each stress period. Estimation of the rate of perched seepage is discussed in the water budget section.

Irrigation Conveyance Loss

As irrigation water is delivered to fields, there is leakage from the canals and laterals. This is referred to as irrigation conveyance loss or canal leakage. The eastern Snake River Plain has approximately 1,000,000 acres of land irrigated by surface water which is delivered by canals and laterals. It would be impossible to characterize leakage from all of the canals and laterals, so leakage is only explicitly represented from the largest of the canals and canals where the seepage was determined to affect simulation of spring discharges. Other canal leakage is assumed to have approximately the same spatial distribution as incidental recharge from irrigation and is implicitly included in the irrigation recharge calculation. Canal leakage rates are estimated as a percentage of surface water diversions and are discussed in the water budget section.

Leakage from the larger canals is represented in the ESPAM as specified flux boundaries. The ESPAM has 5 locations at which irrigation conveyance loss is represented. Table 7 lists the represented canals. Figure 24 shows the location of each leaky canal and the model cells in which canal seepage is represented. Appendix A contains a table listing the model cells associated with each canal (Table A-3). The estimated flux for each canal is evenly distributed across the model cells assigned to that canal in each stress period.

Model Initial Conditions

Estimates of aquifer head for each model cell at the beginning of a simulation form the initial model conditions. Of primary concern are initial aquifer water levels or starting heads for the transient simulation. For the steady state ESPAM, the starting heads are set at an arbitrary initial value of 7000 ft. Because a steady state simulation is run until there are no further changes in aquifer water levels, the starting heads are not important. The simulation will continue running and balancing the water flow between each model cell until the system reaches equilibrium and there are no further changes in water levels.

For the transient ESPAM, the starting water levels are the ending heads from the steady state model. In the physical system, water levels fluctuate with location and with season, largely in response to irrigation practices. It is very difficult to accurately estimate the water levels throughout the aquifer at an instantaneous point in time, so the ESHM Committee agreed that using the ending heads from the steady state simulation was a reasonable point for starting heads for the transient simulation. The ending steady state heads will represent an average water level condition—high in some locations and low in others. As the transient model progresses in time, the water levels will be driven by the recharge and discharge and the physical aquifer properties (transmissivity, aquifer storage and riverbed conductance). This means that changes in aquifer water levels during the first few years of transient simulation are less meaningful than the later years, after the initial head conditions have been overcome.

Model Water Budget

The model water budget is one of the most important elements of a ground-water model. The water budget comprises the accounting of all recharge and discharge to the aquifer both for the steady state period and for each model stress period. By definition, steady state means that there are no changes in aquifer water levels (which equates to no change in aquifer storage). Therefore, for steady state, the inflows must balance with the outflows (Eq. 3). For each transient stress period, the inflows minus the outflows must balance with the change in aquifer storage (Eq. 4).

Water use, and therefore the hydrology, on the eastern Snake River Plain is dominated by irrigated agriculture. The major sources of recharge to the aquifer are incidental recharge from surface water irrigation, tributary underflow, leakage from canals and rivers and recharge from precipitation on non-irrigated lands. The major sources of discharge from the aquifer are evapotranspiration and spring discharges to the Snake River (Figure 8). There is a lot of natural variation in water supply from year to year. Several large reservoirs on the Snake River help to buffer the water supply available for irrigation, but supply is still limited in some years.

Estimation of the water budget for the ESPAM required estimation of all of the above-mentioned components. Estimation of some of these components entailed multiple steps. In addition to the major components of the water budget, there are several smaller components which were also estimated and are discussed below.

Land Use

One of the first steps in evaluating water use for a study area is an evaluation of land use. Recharge to the aquifer can vary greatly among different land uses. For example, on land irrigated with surface water, the amount of irrigation water applied generally exceeds the consumptive use, so there is a net recharge to the aquifer. On the other hand, on lands irrigated with groundwater and on wetlands, there is a net extraction from the aquifer to meet consumptive use. Identifying land use is an important part of estimating the water budget, particularly in an area where the water use is dominated by irrigated agriculture, such as in the eastern Snake River Plain.

To evaluate irrigated areas for the ESPAM, multiple sources of data were evaluated. One of the problems with using land use analyses from different sources is that it is difficult to discern whether changes in land use reflect actual changes over time or different analysis techniques. The modeling team did an exhaustive job of comparing data from multiple sources and ground-truthing the land use analyses, as documented in ESPAM Design Document DDW-015. Initially, the ESHM Committee decided to employ land use analyses based on imagery from 1980, 1992 and 2000. The 1980 (RASA80LC, IDWR, 1980) analysis is a land classification of LANDSAT data performed by the Idaho Image Analysis Facility of IDWR (IDWR, 1982), using the "thematic mapper" LANDSAT sensor and Vicker's classification algorithms, which are not directly comparable with later LANDSAT data and methods (Morse, 2001). The 1992 (SNAKLC92, IDWR, 1997b) analysis is based on 1987 aerial photography and extensive field work. The 2000 (ESPAC2000, IDWR, 2002a) classification was performed by IDWR specifically for this project, using classification of multiple LANDSAT images, with a two-week to one-month image frequency. These three land use analyses were initially selected to represent the changes in irrigated area between 1980 and 2002.

During model calibration, comparison of the water budget with the aquifer water levels and spring discharges indicated that the slight trend of decreasing irrigated acreage over time, as evidenced by the land use analyses of these three sets of imagery, was inconsistent with trends in measured modeling targets. Inspection suggested that the differences in spatial distribution between the three land-cover data sets were minor and the differences were distant from river or spring reaches of concern. The decision was made by the ESHM Committee that the final model calibration would use the irrigated lands analysis which was based on the SNAKLC92 data set for the entire calibration period. The extensive ground-truthing which was done for the SNAKLC92 data set provided the highest confidence in the land use analysis.

The location of wetlands was derived from a 1991 analysis of LANDSAT imagery done by IDWR (SRBAS91LU, IDWR, 1994). Some of the available land use analyses did not identify wetlands. For the land use analyses which did identify wetlands, known wetland locations were ground-truthed. The SRBAS91LU coverage had the most reliable identification of wetlands.

Identification of cities was compared among the available land use analyses. 2000 LANDSAT images of the City of Idaho Falls were compared with the analyses which did identify cities. The ESHM Committee agreed that the SRBAS91LU (IDWR, 1994) analysis provided the most accurate delineation of cities. For further details on the delineation of wetlands and cities, the reader is referred to ESPAM Design Document DDW-015.

Figure 25 shows a composite coverage of irrigated lands, wetlands, cities and soil types on non-irrigated lands (to be discussed in a later section). Figure 25 reflects the land use which was used in compiling the ESPAM recharge and discharge.

Estimation of Recharge/Discharge

Estimation of aquifer recharge and discharge includes estimation of many intermediate variables which are used to calculate the net recharge to the aquifer. For example, even though precipitation contributes to aquifer recharge, it is actually used as an intermediate variable for estimating recharge on surface-water irrigated lands, discharge from ground-water irrigated lands and recharge on non-irrigated lands. The reason it is treated as an intermediate variable is that some estimate must be made of the amount of precipitation which evaporates versus the amount which is available to recharge the aquifer. Similarly, evapotranspiration on irrigated lands, canal seepage, irrigation return flows (irrigation water returning to the surface water system which includes end of canal spills and surface run-off), off-site pumping and crop mix are used as intermediate variables in the estimation of aquifer recharge and discharge associated with irrigation. The next sections will discuss how these variables are used in the estimation of net aquifer recharge as well as how these variables are estimated.

Other components of aquifer recharge and discharge are estimated directly. These include tributary basin underflow, perched river seepage, pumping for surface water replacement and recharge on non-irrigated lands.

The following sections describe a) the estimation of all of the components of the water budget including both intermediate variables and directly estimated components and b) how the various components are used in the water budget estimation.

Recharge on Irrigated Lands

Irrigated agriculture can result in a net recharge to the aquifer (surface-water irrigation) or a net discharge from the aquifer (ground-water irrigation). The land use analysis described above identified irrigated agriculture, but a separate analysis was required to delineate surface-water irrigated lands from ground-water irrigated lands.

Estimation of net recharge to the aquifer from surface-water irrigated lands requires surface water diversion, irrigation return flow, canal leakage, precipitation and evapotranspiration data. The calculation is as follows:

Field Delivery = Diversions - Canal Leakage - Return Flows (Eq. 8)

Net Recharge (surface) = (Field Delivery + Precipitation) –
(ET x Adjustment Factor) (Eq. 9)

Ground-water pumping rates have only been measured since the mid-1990s on the ESRP. The measurement methods are not consistent throughout the plain, so measurement data is not yet reliable. Additionally, the data that do exist record gross pumpage and not net extraction. The lack of historical ground-water pumping measurement data and the lack of consistency in the measured data required an alternative method of estimating net discharge from ground-water irrigation. Net discharge from the aquifer from ground-water irrigated lands is estimated using evapotranspiration, offset by available precipitation. The rationale behind this method of estimation is that any ground water which is pumped in excess of crop demand (ET) will infiltrate back into the aquifer. The calculation is as follows:

Discharge from aquifer = Precipitation - (ET x Adjustment Factor) (Eq. 10)

By agreement, the ESHM Committee and modeling team decided that surface runoff was negligibly small and could be disregarded for this calculation. Similarly, because precipitation and ET were estimated for the full year, it was agreed that soil moisture content could also be neglected.

When the precipitation exceeds the demand, there will be a net recharge to the aquifer on ground-water irrigated lands. When demand exceeds precipitation, there will be a net discharge.

Precipitation

Precipitation for the study period was estimated using PRISM (Parameter-elevation Regressions on Independent Slopes Model) maps produced by the Oregon Climate Service and the Spatial Climate Analysis Service (Daly and Taylor, 1998). PRISM uses point data, a digital elevation model, and other spatial data sets to generate gridded estimates of several spatial and temporal climatic parameters, including precipitation. A summary of the steps taken to estimate precipitation is provided below. For more detailed information on the estimation of precipitation for the ESPAM, the reader is referred to ESPAM Design Document DDW-011.

PRISM distributes point measurements of monthly, seasonal, and annual precipitation to a geographic grid of four kilometers by four kilometers. By use of a resampling algorithm, two-kilometer by two-kilometer resolution grids can be estimated. These grids are produced in a GIS-compatible latitude-longitude grid or a gridded map projection.

Monthly PRISM maps for the study area for 1980 through 1997 were obtained from the Spatial Climate Analysis Service. As of the estimation of the ESPAM water budget, maps were not available for 1998 through 2002. For consistency in precipitation data estimation, a method was devised, with the concurrence of the ESHM Committee, to interpolate precipitation data between weather stations for the years 1998-2002. The method is described below.

Precipitation data for the years 1998 to 2002 were purchased from NOAA (http://lwf.ncdc.noaa.gov/oa/ncdc.html) for all NOAA stations on the eastern Snake River Plain. These data series include precipitation values, in inches, and the departure from normal values, in inches.

In order to maintain precipitation data consistency over the entire 22-year study period, 1998 to 2002 NOAA data were processed with 30-year average PRISM data to achieve consistent data formatting with the PRISM two-kilometer by two-kilometer grids for each monthly precipitation map. This 1998 to 2002 NOAA processed dataset was then used to supplement the 1980 to 1997 PRISM dataset. A detailed description of the NOAA data processing follows.

Using the NOAA departures from normal values and the NOAA monthly actual precipitation values, a normal for each NOAA station was calculated. Then, actual precipitation as a fraction of the normal was calculated for each NOAA station. This resulted in a multiplier which, when multiplied by the normal value, gave the actual NOAA precipitation value. A set of multipliers was calculated for each month for the period of January 1998 to April 2002. Using ArcView3.2, the point-value multipliers were interpolated to a raster surface of NOAA multipliers. The NOAA multipliers were applied to the PRISM 30-year average monthly precipitation data using ArcView 3.2. The multiplier datasets were applied to the 30-year average PRISM rasters to produce monthly precipitation rasters for the 1998-2002 period.

Once monthly precipitation maps were generated for the full model period, the monthly rasters were summed into the same time periods as the ESPAM stress periods. Figure 26 shows example PRISM precipitation maps for average precipitation for the 22-year model period, for both the irrigation season and the non-irrigation season. Inspection of Figure 26 shows the great difference between irrigation season and non-irrigation season precipitation on the ESRP. Figure 27 shows the annual total precipitation for each year of the study period. Inspection of Figure 27 shows that there is a great degree of annual variation in precipitation.

Crop Mix

Knowledge of the mix of grown crops is necessary for the estimation of evapotranspiration. Differences in crop mix can change average ET by as much as ten percent, which translates into 1.7×10^{10} ft^3 (400,000 AF), or approximately seven percent of the aquifer water budget, assuming two feet of ET on 2,000,000 irrigated acres and a 6,000,000 acre-foot aquifer budget. The final crop mix used for the ESPAM was calculated based on data from several sources of crop statistics data, as discussed below.

The primary data source is the National Agricultural Statistics Service (NASS) crop report data, which are based on county-wide surveys of farm operators. These data are available in three formats for the study area. These are the Published Estimates Data Base On Line (USDA, 2000), the US Agricultural Census (USDA, 1992, 1997) and the Idaho Agricultural Statistics (Idaho Department of Agriculture, 1981 - 2002) reports. The Published Estimates Data Base On Line (PEDB) version provides county-wide acres planted and harvested, by crop. These reports do not include alfalfa hay for the earlier years of the study, so 1982 and 1987 values from the US Agricultural Census (Ag Census) version of the NASS data for alfalfa were used. The Idaho Agricultural Statistics (IAS) report was used to fill in gaps in the PEDB potato data. The Agricultural Census reports provide more detailed results, including details of irrigated and non-irrigated acreage by county, for the years 1982, 1987, 1992, and 1997. The IAS report is compiled from NASS data and includes yearly values for irrigated and non-irrigated acreage, by county, for major crops. As of the time of this study, the IAS data were available for years 1980 through 2001. Many of the county agents interviewed recommended the NASS/IAS data.

About half of the counties in the study area have farmed land both inside and outside the study area (Figure 28). It is possible that the crop mix outside the study area is different than the mix inside. The potential errors associated with these crop differences were first assessed by estimating a “reasonable” and “extreme” crop mix for lands inside the study area, and calculating volume of ET for each. The analysis was performed for Bonneville and Cassia Counties. The result of the analysis was that “irrigated only” crop report data provided a better representation of the study area than did county-wide data. Therefore, whenever possible, "irrigated only" (agricultural census or IAS) data were used.

The final data compilation uses the published Idaho Agricultural Statistics (Idaho Department of Agriculture 1981 - 2002) data with some refinements, as detailed in ESPAM Design Document DDW-001. Final crop mix fractions by year and county are listed in Table A-4 in Appendix A. The crop evapotranspiration estimates compiled from crop mix data and reference evapotranspiration data indicated that year-to-year variation in total crop consumptive use is very small. A more detailed description of the evaluation of crop mix for the ESPAM can also be found in ESPAM Design Document DDW-001.

Evapotranspiration

One of the largest components of discharge on the ESRP is evapotranspiration, a combined variable encompassing evaporation and plant transpiration. Evapotranspiration is controlled by climate as well as crop and soil characteristics. Climate affects the evaporative power of the atmosphere, reflecting the energy available to drive evapotranspiration and the capacity of air to accept evapotranspired water. Soil and plant characteristics control the crop's ability to extract water from the soil, and biological characteristics of the crop control the transpiration response to evaporative power. Soil texture, surface wetness and condition and shading by plants control the soil's response to evaporative power. Although far more water evapotranspires during the growing season, there is still measurable evapotranspiration during the non-growing season. For the ESPAM, growing season ET was estimated separately from non-growing season ET.

Growing season evapotranspiration was estimated primarily using an alfalfa reference ET scaled by crop coefficients. The alfalfa reference ET is available for each

NOAA weather station within the ESRP. Allen (2002) evaluated five different ET calculation methods. The Kimberly-Penman Alfalfa Reference method was chosen as most suitable for the modeling application (Allen, 2003). This method was developed with Idaho empirical data and of the five methods is the most directly comparable to the reference ET reported in Estimating Consumptive Irrigation Requirements for Crops in Idaho (Allen and Brockway, 1983) data and to Agrimet (U.S. Bureau of Reclamation, 2003) estimates.

The selected data series provides only reference ET, but calculation of crop ET also requires crop coefficients (Kc values). Coefficients for individual crops were extracted from the original Allen and Brockway (1983) data by dividing individual crop ET by reference ET, for each weather station each month. The original data only include typically grown crops for each location. To avoid calculating zero ET if an atypical crop is grown, Kc values for all crops were assigned to all weather stations. Missing values were supplied from nearby stations. The variation of Kc between weather stations for any given crop is low (Allen, 2003). Because the data for each county include values for all typically grown crops, missing values represent rarely-grown crops. Therefore, this substitution will affect only a few acres within any stress period and has a very low potential of introducing error. An average Kc value was determined for each county which was an average, weighted according to the proportion of crops, from the nearest NOAA station data. This was performed for each model stress period.

ET estimation for this project included a remote sensing analysis of ET using the METRIC algorithm (Allen and others, 2002; Allen and others, 2005; Morse and others, 2000) for the 2001 growing season. METRIC results were used to calculate ET adjustment factors. ET adjustment factors allow adjustment of ET to account for deviations from a perfectly managed crop such as a) water shortage, b) crop disease or c) post-harvest watering. ET adjustment factors may also reflect differences in ET due to source of irrigation water or method of application. Unique ET adjustment factors were evaluated for a) sprinkler or furrow application, b) ground water or surface water source and c) irrigation entity. The METRIC analysis indicated that the Kimberly-Penman estimates of ET are consistent with crops which are furrow-irrigated, but that crops irrigated with sprinklers have approximately 5% higher ET. For the ESPAM calibration, ET adjustment factors were set at 1.0 for all furrow application and at 1.05 for all sprinkler application. For more information regarding ET adjustment factors, the reader is referred to ESPAM Design Document DDW-021.

Though crops do not actively transpire in the winter time, evaporation and sublimation continue. For the ESPAM, winter-time ET is based on experiment data collected over several years at Kimberly, Idaho (Wright, 1993). The average winter ET from the Wright study is reported in Table 8.

Except for February, these values should generally be representative of the entire study area. The February value is representative of the lower-elevation portions of the study area, but February ET for higher elevation areas that are still snow covered in February is probably closer to the January average from Kimberly (personal communication, Wright, 2003). Snow increases the reflection of solar radiation back into the atmosphere, reducing the energy available to drive evaporation or sublimation. To adjust for differences in snow cover, February ET was scaled by elevation. February ET at Twin Falls (elev. 3770 feet) was set to 1.0 mm/day, and at Rexburg (4920 feet) to 0.6

mm/day. ET at other locations was adjusted using linear interpolation between the elevations at Rexburg and Twin Falls according to the equation:

$$ET\ (mm/day) = -0.0003478 \times Elevation\ (feet) + 2.3112 \qquad (Eq.\ 11)$$

For stations higher in elevation than Rexburg, December and January ET were adjusted to be no higher than the elevation-adjusted February value. November ET was adjusted to be no higher than 120% of the adjusted February value. Table 9 lists the resulting winter-time ET values for all stations, converted to feet per month.

Figure 27 shows the annual total evapotranspiration for each year of the study period. Inspection of Figure 27 shows that there is some degree of annual variation in evapotranspiration, however, ET is relatively constant.

Source of Irrigation Water

Net recharge from surface-water irrigation is the largest component of the water budget. The second-largest component of the water budget is net withdrawal (calculated as consumptive use, or evapotranspiration) due to ground-water irrigation. The source of water for individual parcels must be identified so that diverted volumes of surface water are applied to the appropriate spatial locations. In the ESRP, aquifer water levels respond to surface-water irrigation by rising during the irrigation season and declining during the non-irrigation season. Aquifer response to ground-water irrigation is exactly opposite.

The source of irrigation water also affects the calculation of consumptive use, which depends in part on evapotranspiration (ET) adjustment factors, application method (sprinkler or gravity), and the reduction factor for non-irrigated inclusions within irrigated lands. For an individual parcel, the ET adjustment factor and sprinkler percentage from the local surface-water irrigation entity or the local ground-water irrigation polygon are applied, depending on the water source identified for the parcel. The source of irrigation water by parcel is also required for model scenarios; for example, a hypothetical scenario might represent curtailment of a specific source of irrigation.

Water rights data provide the best information regarding source of irrigation water for each parcel of land. Many irrigated lands are either 100% surface-water irrigated or 100% ground-water irrigated. However, some irrigated lands have mixed ground water and surface water sources. This has typically occurred where surface water sources were inadequate, and supplemental ground water sources have been developed. The following sections describe the method used to determine the source of irrigation water and the method used to calculate recharge on mixed-source lands. A more detailed description of the assignment of irrigation source may be found in ESPAM Design Document DDW-017.

Geographic Information Systems (GIS) technology and Water Measurement District and Ground Water District records of actual well diversion volumes have recently become available. These sources were used for determining the source of irrigation water, in conjunction with Snake River Basin Adjudication data base records, which reflect varying degrees of resolution in the adjudication process. The adjudication data reflect accomplished changes not shown in water rights data. The adjudication data also represent legitimate "beneficial use" rights perfected before the statutory requirement to obtain a state permit for a water right. Adjudication claims are the users' representations of water use, and exist for the entire plain. Recommendations are Idaho Department of Water Resources' findings from investigation of claims. As of the time of this study, recommendations existed for about 2/3 of the study area. The court's determination of the adjudicated water right is called a partial decree. At the time of this study, partial decrees existed for a much smaller portion of the study area. Not all the partial decree data were available for automated electronic querying.

The map identifying water source by 40-acre quarter-quarter section is compiled from IDWR adjudication data with manual adjustments. Using GIS, the map identifying water source is combined with the map of irrigated lands (Figure 25) to identify irrigation water source for all irrigated lands. Figure 29 shows the GIS map of water source used in model calibration.

There are some limitations to the available water rights data. The ground-water diversion volume data only cover the years 1997 through 2002, and may have missing values, especially for the earlier years. These data were used to verify irrigation water source assignment which was based on adjudication data. The adjudication claims are uninvestigated representations of water users. Recommendations and partial decrees reflect the legal authorization to use water, not necessarily the actual practice. Because of the common occurrence of overlapping water rights, the ratio of ground-water to surface-water rights in a quarter-quarter section is not useful for determining the mix ratio on mixed-source lands.

Potential errors in the mix ratio apply only to the 13% of the quarter-quarter sections identified as mixed-source in the adjudication data. The modeling team, in conjunction with the ESHM Committee, developed a method for apportioning the mixed-source lands to either ground-water or surface-water irrigation. Consumptive use for mixed-source irrigated lands was evaluated for each irrigation entity. Assuming a requirement of 4 feet of delivered water (to meet consumptive use, conveyance loss and irrigation inefficiencies), the team estimated how many acres could be satisfied by the recorded diversions. The balance of the irrigated acres was assigned to ground-water source. It was acknowledged that the actual split may change from irrigation season to irrigation season depending upon the surface water supply and that no record is kept of supplemental ground water use. This analysis resulted in approximately 63% of mixed-source lands within the study area being assigned to a ground-water source (ESPAM Design Document DDW-017).

The operation of the Fortran recharge tool implicitly adjusts for changes in ground-water use on mixed-source lands, by the process used to calculate net recharge. Within the tool, full irrigation requirement (consumptive use minus precipitation) is applied to all irrigated lands as an aquifer extraction. On lands with surface-water supplies, net surface-water application is applied as aquifer recharge, offsetting the required irrigation extraction. For each stress period and each surface-water irrigation entity, the net depth of surface-water application is calculated based on the diversion and return data for that stress period. The application depth is based on the full acreage of surface-water only parcels and a portion of the acreage (based on the source fraction described above) of mixed-source parcels. Then, within each model cell, the stress-period-specific application depth is applied as an aquifer recharge. The applied water is pro-rated to mixed-source and surface-water-only parcels based on the source fraction. Where application exceeds irrigation requirement (surface-water-only parcels) a net recharge is inferred. Where irrigation requirement exceeds application (mixed-source parcels) a net withdrawal is inferred. On mixed-source parcels, in years with high surface-water supplies, the difference between irrigation requirement and surface-water supply is small and small amounts of net ground-water pumping on these mixed lands are represented in the model water budget. When surface-water supplies are low, the difference is large and large amounts of ground-water pumping are represented.

Reduction for Non-Irrigated Inclusions

The irrigated lands shown in Figure 25 represent the spatial extent of irrigated areas. However, some portion of these areas is actually non-irrigated areas such as roads, homes, rock piles and canal banks. During the estimation of recharge and discharge, the actual square footage of irrigated area in each model cell is reduced by a factor which accounts for these non-irrigated inclusions. For the ESPAM calibration period, irrigated areas were reduced by 12%. The reduction factor was determined using a GIS analysis of individual parcels mapped by IDWR as part of the Snake River Basin Adjudication (Norquest, 2002). ESHM Committee members agreed that 12% was a reasonable estimate for reduction in irrigated area.

In the GIS/Fortran Recharge Tool (described in Appendix B), the capability exists to specify a reduction factor for each model stress period by application method. This enables the user to reflect a potential different reduction factor for sprinkler versus gravity irrigation for each time period. For the ESPAM calibration, the consensus of the ESHM Committee members was that the estimate of non-irrigated inclusions derived from IDWR GIS data, which showed no statistically-significant difference between sprinkler and gravity application, represented the best available estimate for the irrigated lands reduction factor.

Aggregation of Canal Companies into Surface Water Entities

There are more than 100 surface water irrigation companies and numerous private surface water irrigators within the ESPAM boundary. Many of these irrigation companies share common acreage. In order to treat all surface water irrigated areas in a consistent manner, these surface water irrigation companies are aggregated into a smaller number of 'irrigation entities.' The aggregated irrigation entities more accurately reflect the delivery of surface water to the irrigated areas by maintaining a level of resolution consistent with available diversion and return flow data.

A similar surface water irrigation company aggregation was performed for the original UI/IDWR SRPAM model. Because GIS software was not available at that time, the irrigation company aggregation was a more difficult process and took much longer to complete. The earlier aggregation resulted in approximately 172,000 acres throughout the plain being assigned to an un-named surface-water entity.

For the current study, the process of aggregating surface water irrigation companies entailed evaluating each irrigation company to identify the point of diversion from the river and the likely corresponding irrigation return flow location. Adjacent irrigation companies were then examined for similar characteristics, including irrigation practice, points of diversion, common conveyance, location of irrigation return flow, soil type, water right priorities, common drainage area, and previous aggregation in the earlier UI/IDWR SRPAM model. If adjacent irrigation companies did not have any significant differences from one another, they were aggregated into the same irrigation entity to maintain a level of irrigation company resolution consistent with the resolution of the diversion and return flow data.

Most private water rights within the model boundary were aggregated with the organized irrigation companies. The private rights that were not aggregated with adjoining entities are: Camas and Beaver Creek (Basin 31), Birch Creek and Medicine Lodge Creek (Basin 32), and Little Lost River (Basin 33). The private rights in these three basins were aggregated separately from each other and from the irrigation companies because of different practices and water supply than the organized companies. Source of irrigation water was determined from IDWR adjudication data (see ESPAM Design Document DDW-017).

Three irrigation companies in the Mud Lake area, including Jefferson Irrigation Company, Monteview Canal Company Incorporated, and Producers Irrigation Company, do not use surface water for irrigation. These companies use off-site ground water pumping and were aggregated as a surface water irrigation entity for model purposes. With ordinary ground water irrigation, it is assumed for modeling that the pumping and the recharge occur within the same model cell. This is not the case for the aforementioned canal companies. The wells used to obtain water are miles from the place of use and conveyed by a canal. Therefore, in the model, the pumping and recharge would occur in different model cells. Because many irrigation companies that use off-site ground water pumping co-mingle the pumped ground water with the surface water in the canals, the ground water withdrawal was treated as a point extraction assigned to the model cell. This withdrawal, or volume extracted, was added to the surface water diversions for the respective irrigation entity. When water master records were not available to determine the amount of ground water pumped, estimates were made. For the three companies mentioned, the surface-water component is set to zero, since there is no surface-water supply.

The aggregation process resulted in 43 irrigation entities (Table 10). These 43 entities were assigned an identification number (for use by the GIS/Fortran Recharge Tool) and a descriptive name. Descriptive names were created by choosing the largest (by area) organized irrigation company in the entity, and adding on to that name the number of organized companies aggregated to create that entity. For example, aggregated entity IESW16, named “Egin 2”, consists of two organized companies, Egin Bench Canals Inc. and St. Anthony Union Canal Company, of which Egin Bench Canals Inc. is the larger (by area), of the two companies. (Note that a mid-project recombination of some of the entities to correspond to new return-flow data resulted in some entities whose names may violate the “biggest company” naming convention.) Figure 30 shows the final set of irrigation entities. For a more detailed description of the aggregation of canal companies into irrigation entities, the reader is referred to ESPAM Design Document DDW-008.

Delineation of Ground Water Irrigation Polygons

This section describes the designation of portions of the study area into “Ground Water Irrigation Polygons” for the purpose of recharge calculation. The withdrawals associated with irrigation from ground water are a negative recharge and are calculated based on adjusted ET and precipitation. The ET adjustment factor is applied according to the geographic location of the irrigated land being calculated and the method used to apply irrigation water. ET adjustment factor and application method parameters for irrigation from ground water are carried as attributes of the ground water irrigation polygon map.

The goals in constructing the ground water irrigation polygon map were to adequately represent known differences between geographical areas and management practice and to minimize the number of unique ground water polygons (to reduce data management concerns and recharge tool run times). Because these ground water irrigation polygons are only used for assigning ET adjustment and application method parameters for recharge calculation, no requirement was made that polygons be contiguous areas. Similarly, the ground water irrigation polygons assigned for recharge calculation are not based on current ground water management areas or measurement districts, nor is it contemplated that these polygons would form the basis for any administrative boundaries or decisions.

Because both ET adjustment factor and percent sprinkler application are driven largely by cost of water, and because the primary cost of ground water is the energy cost for lifting water out of the ground, depth-to-water was used as the basis for delineation of the polygons. Relative to the range of depths on the plain, water level changes since 1980 are minor, so a single water table map was deemed adequate for the delineation. Figure 31 shows the depth-to-water map used for the analysis, digitized from a paper map created by Lindholm and others (1988).

Pumping lift was hypothesized to influence the cost of water and crop production and consequently the intensity of management. Regional variations in cropping patterns and climate throughout the Snake Plain were also considered to be factors in management intensity. Intensively managed crops are expected to approach the ideal values of crop coefficients. Poorly managed crops are expected to exhibit less evapotranspiration. Depth to water (pumping lift) provided a basis for dividing the Snake River Plain into GIS polygons. These polygons were then subdivided based on location within the plain. That is, if a single polygon represented a depth to water of 100 to 200 feet, this polygon would be divided into two units if this depth range existed in both the southwest and northeast portions of the plain. The final GIS polygons are presented in Figure 32. The central portion of the plain is absent of irrigation which is identified as polygon IEGW600 in Figure 32.

The Mud Lake area and the U.S. Bureau of Reclamation project known as the “A & B Irrigation District” were the first large-scale applications of ground water on the plain (Goodell, 1988). These developments pre-dated the widespread use of sprinklers, while most other ground water development post-dated the use of sprinklers. Field observations show that the Mud Lake area still has a different mix of application method relative to other ground-water areas. The same is true of the A & B Irrigation District (Temple, 2002). For this reason, these two areas were partitioned into their own, unique ground water irrigation polygons.

Method of Irrigation Application

An analysis was done to identify what percentage of irrigated areas has been irrigated by sprinkler versus furrow irrigation throughout the simulation period. Because actual evapotranspiration may be affected by the type of application system used (as well as other factors), and because changes in application system type (e.g. conversion from gravity to sprinkler) have occurred during the period of the study, a method for identifying application method and describing changes was required. Identification of the method of irrigation application on each parcel of land allows application of ET adjustment factors for deviations from predicted ET which are associated with sprinkler or furrow irrigation.

Previous modeling efforts have not included an ET adjustment factor, so there has not been a need to identify application method. Neither Garabedian (1992) nor IDWR (1997a) explicitly referred to consideration of application method in irrigation calculations. Goodell (1988) used application method to derive discharge pressure parameters for pumpage calculations, but not for recharge or ET calculations. IDWR (1997a) adjusted for non-irrigated inclusions based on a distinction between ground water and surface water, but examination of maps indicates that it is likely the difference is actually driven by application method, and water source was used as a surrogate.

Available data included Geographic Information Systems (GIS) electronic maps that delineate the irrigated lands in the study area in 1982 and 1992 as sprinkler or gravity irrigated (IDWR 1982, 1992). The Natural Resource Conservation Service National Resource Inventory (NRI) includes a report of a statistical sample indicating percent of irrigated acres using pressurized (sprinkler) systems by 8-digit Hydrologic Unit Code area or by Major Land Resource Area (MLRA) (NRCS, 1997). NRCS also classifies drip irrigation as a pressurized system but this is such a minor practice within the current calibration period that it is neglected here.

Since the 1982 and 1992 GIS maps represent the most certain data, and the data with the best spatial resolution, these maps were used as the primary data source. The NRI data are statistically-based, and quantify percentages, so they were used to establish overall percentages for 1987 and 1997.

Initial tables of sprinkler percentage for each irrigation entity or polygon were constructed for 1982 and 1992, using GIS and the 1982 and 1992 maps. From the irrigation entity and water source maps (Figures 29, 30 and 32), all ground-water-irrigated and mixed-source lands in each ground water polygon, and all surface-water-irrigated and mixed-source lands in each surface-water entity were identified using GIS software. These maps were intersected with the application method maps to produce maps of irrigated lands with appropriate water source, by application method, by ground water polygon or irrigation entity. The total area of each method, within each entity, was used to calculate a sprinkler percentage for each entity or polygon. This process was done for both 1982 and 1992. The result was a table of values, having a unique sprinkler percentage for each irrigation entity or polygon, for the break-point years 1982 and 1992.

The NRI data were used as a secondary source, to determine sprinkler percentages for 1980, 1987, 1997 and 2000. Sprinkler percentages for other years were linearly interpolated between these values. Table 11 lists the ratio of area under sprinkler application for each ground-water and surface-water entity for each of the years for which data were available.

The complete table used in model calibration includes values for each stress period and is presented in Appendix A, Table A-5. Figures 33 and 34 show the spatial distribution of the sprinkler fractions for the years 1980 and 2000 by surface water irrigation entity and by ground water polygon, respectively.

Surface Water Irrigation

Net recharge incidental to surface irrigation occurs when more irrigation water is applied and remains on the field than the crop demands. As noted in Equation 8, field delivery is the volume of water diverted minus canal leakage and irrigation return flows. Net recharge to the aquifer is estimated as the field delivery plus precipitation, less adjusted ET (Eq. 9). Precipitation and adjusted ET have been discussed in previous sections. The following sections discuss estimation of irrigation diversions, return flows conveyance loss and the estimation of net recharge due to surface water irrigation.

Irrigation Diversions

In order to effectively and accurately estimate percolation to the aquifer due to surface water irrigation, irrigation diversions from the river must be estimated with the highest possible degree of accuracy. Irrigation return flows to the river and evapotranspiration are also components of calculating percolation from surface water irrigation.

For Snake River diversions, two sources of data were considered for use in estimating surface water irrigation diversions. The first source is irrigation diversion and return flow ‘raw’ daily data from the water districts, and the second source is ‘processed’ monthly data that is used in the IDWR Reach Gain/Loss Program. For consistency with the IDWR Reach Gain/Loss Program estimates of reach gains that were used for model calibration, the ‘processed’ monthly data were used to estimate irrigation diversions.

The diversion data which are used as input to the IDWR Reach Gain/Loss Program were assigned to appropriate canal companies. The diversion data for each canal company were aggregated into the appropriate surface irrigation entity by use of a Microsoft Excel spreadsheet, described below. More information about the estimation of Snake River surface irrigation diversions is available in ESPAM Design Document DDW-012.

Data for surface water diversions from sources other than the Snake River were primarily available from watermaster records. The actual data were obtained from various sources, including electronic files from Idaho Department of Water Resources (2001), paper and microfiche watermaster records (IDWR, 2002b), and other sources. In the case of watermaster reports, data were generally available as annual summaries. Monthly fractions were determined by hand calculation from a sample of microfiche or paper copies of daily watermaster records, and applied to annual data. The irrigation entities which use some non-Snake River diversions are IESW005, IESW007, IESW008, IESW025, IESW029, IESW037, IESW051, IESW052 and IESW054 (see Table 10). A complete description of the non-Snake River diversion data is available in ESPAM Design Document DDW-024.

Using both the Snake River and non-Snake River diversions and the aggregated surface water irrigation entities, a spreadsheet was created in Microsoft Excel to estimate surface water irrigation diversions for each surface water irrigation entity. This spreadsheet was also used to perform the calculations to estimate irrigation return flows to the Snake River, using monthly diversion data and return flow percentages (see section on Irrigation Return Flows).

The spreadsheet contains separate worksheets for each irrigation entity. Each worksheet contains the diversion data and return flow factors for all of the irrigation companies and private irrigators which comprise the associated irrigation entity.

Irrigation return flow factors (discussed in the following section) are applied to the respective diversion data on each worksheet of the spreadsheet file. The monthly diversions and returns for each canal company and private irrigator are summed to yield the monthly diversions and returns for the irrigation entity. Table A-6 lists the diversion volume for each irrigation entity for each stress period.

Irrigation Return Flows

Forty-six irrigation returns were measured as part of this study. The sites were selected and measured in a joint effort between Idaho Power and the U.S. Geological Survey, with oversight from the ESHM Committee. Irrigation return flow locations on the Snake River below American Falls Reservoir were suggested by IDWR to match the sites used in a study conducted in 1985-86. For the upper Snake River, candidate sites were identified from a video taken during a helicopter flight over the Snake River above American Falls and the Henrys Fork.

The site selection was verified through field work. Each selected site was assigned a standard eight digit USGS gage identification number. Pressure transducers with data loggers were installed at each site and irrigation return flow data were collected for the 2002 and 2003 irrigation seasons. The reader should note that both 2002 and 2003 were extraordinarily dry years, so the measured return flows from these two seasons may not be representative of other years. However, very little measured return flow data exist for the ESRP. Table 12 lists the site name, location (lat/long) and USGS identification number for each measured site. Maps of site locations above and below American Falls are included in Figures 35 and 36, respectively.

Each return flow was assigned to an appropriate irrigation entity as defined in ESPAM Design Document DDW-008.   The assignment was accomplished using the maps of irrigation entities (Figure 30) and return flow locations (Figures 35 and 36). The assignment was made based on location, land elevations and canal locations. Some of the returns on the Henrys Fork serviced more than one irrigation entity. The number of return sites per entity ranged from as many as ten for IESW032 (Twin Falls Southside) to one site shared by three irrigation entities on the Henrys Fork of the Snake River. Several entities were grouped together for the purpose of return flow calculation rather than try to parse the amount diverted from a single diversion between two or more entities. This procedure resulted in aggregating the returns and diversions into ten unique groups that were used to calculate the return flow lag factors. Table 13 lists the grouping of irrigation entities used to estimate return flow percentages. Diversions were summed for each of the return flow groups. Using measured return flows and an estimate of the volume of un-measured return flows for each group, a total percentage of irrigation return flow was estimated. This percentage was used to reduce the total diversion by the fraction of return flow to estimate how much water to apply to lands irrigated with surface water. Figure 37 shows the net irrigation diversions (minus return flows) and return flows for each year.

It should be noted that the Milner-Gooding Canal is used to deliver Snake River water directly to irrigation and also to deliver Snake River water into the Big Wood River, for downstream re-diversion by other canals. The data in their native format include this water as a Snake River diversion to the Milner-Gooding Canal and also as a Big Wood River diversion to other canals. To prevent this from causing double-counting of surface water applied to land surface, deliveries from the Milner-Gooding Canal directly into the Big Wood River were treated as return flows in the net-diversion calculations for entity IESW007. Due to this adjustment, the variability of the return-flow values shown in Figure 37 is somewhat dampened and the magnitude is somewhat amplified.

Irrigation diversions and return flows are also used for the estimation of river gains and losses, which are discussed in a later section. In addition to the return percentage, the measured return flow data were also used to calculate the lag time of return flows in support of the estimation of river gains and losses. Examination of typical hydrographs of surface water returns versus diversion records indicates that there is a time lag between the timing of the diversions and the timing of the returns. A typical return flow hydrograph shows an increase as the irrigation season progresses. The diversions will remain constant or actually decrease during this same time period. The increase is likely due to increased returns as the fields and canals become saturated.

This phenomenon was dealt with by applying the concept of lag factors. Lag factors are the portion of the diverted water which returns to the river in each month following diversion. The lag factors are a time series of ratios. For example, a typical lag factor series might be (.01, .03, .07, .02, .01). Applied to a single month's diversion, this would mean that 1% of the diverted water returns in the first month, 3% in the second month, 7% in the third month, etc. By applying the lag factor series to the monthly diversions, the net diversion and return flow for each model stress period can be calculated. The sum of the lagged factors equals the total return percentage used in calculating net diversions.

Up to twelve lag factors could be used but more than five were never needed to obtain a "best fit" to the measured return flow data. The lags were estimated using an Excel spreadsheet. Measured return flow hydrographs were compared with predicted return flow hydrographs. The return flow lag factors used to generate the predicted return flow hydrographs were adjusted until a reasonable match was obtained between predicted and measured hydrographs. This process was repeated for each of the ten groups of irrigation entities. Table 14 shows the final return flow lag factors for each of the ten groups of irrigation entities. ESPAM Design Document DDW-005 describes the estimation of return flow lag factors in detail. ESPAM Design Document DDF-007-2002 summarizes the measured return flow data for the 2002 season.

Irrigation entities for which there were no measured return flows were correlated with one of the ten groups of entities based on a) magnitude of diversions, b) method of irrigation application, c) regional similarity and d) similar crop mix. The return flow lag factors for the correlated entity were applied to the entity for which there were no measured return flows. These lag factors were entered into the input data sets for the IDWR Reach Gain/Loss Program which is used to estimate monthly Snake River gains and losses.

During model calibration, comparison of net model recharge with measured hydrographs indicated that there was too much water being applied to the model in the latter ten years of the calibration period. Inspection of the data indicated that the first ten years of simulation showed generally high water levels, corresponding to wet hydrologic conditions and high rates of recharge. This was followed by a decline in simulated water levels and then by a return to the high levels simulated for the first wet period. Observed water levels showed this same general trend, but in the second ten-year period, water levels did not quite return to the levels observed during the first ten-year period. The discrepancy between these two temporal patterns suggested that estimated net recharge was too high during the latter part of the calibration period. After much discussion, the ESHM Committee agreed that applying an increase in irrigation returns would serve the purpose of reducing the net recharge. This adjustment was made to help balance the water budget and did not imply any knowledge of the trends of irrigation return flows over time. Irrigation return flows have largely been un-measured on the ESRP despite the fact that return flows are such an important element of the water budget. The current study was limited to using measurements from the 2001 irrigation season and some limited measurements which were made in the 1985-1986 seasons. Efforts to measure return flows on the ESRP should be continued into the future so that the return flows can be better characterized and the new information can be incorporated in future modeling and calibration efforts. Table A-7 lists the return flow volume for each irrigation entity for each model stress period.

Conveyance Loss

Some of the water lost from irrigation is seepage from canals and ditches. This water is not available for irrigation and therefore neither available for crop evapotranspiration (ET) nor for recharge associated with irrigated agricultural fields. However, the leakage is still a component of recharge associated with irrigation activity. Seepage from canals can be an important source of aquifer recharge. Long canals in porous soils can lose 40% or more of the water diverted from the source (Chavez-Morales, 1985). In Idaho’s climate, virtually all of this loss is associated with leakage to the aquifer (Dreher and Tuthill, 1999). Canal leakage can be represented by explicitly identifying leakage rates and locations. Or, a simplified approach can be taken by assuming that canal leakage is spatially distributed across the irrigated lands served by the canal.

Most canal systems have a large main canal or canals, supplying secondary laterals. These in turn supply individual farm ditches. Because size, construction, and maintenance of laterals and farm ditches are highly variable, estimating leakage on these secondary conveyances is difficult. Alternate wetting and drying can damage the “skin of sediment and biological slime” that helps seal canals. Smaller channels have more frequent drying cycles, and have more wetted perimeter relative to total flow capacity, so losses in these ditches are often higher than in main canals (Hubble, 1991). These laterals and farm ditches are widely distributed across irrigated areas. For these reasons, the simplified approach often closely reflects reality.

In prior Eastern Snake Plain models, a mixed approach has been taken. Garabedian (1992) treated three canals - Aberdeen-Springfield (95,000 AF/year), Milner-Gooding (97,000 AF/year), and Reservation (11,000 AF/year) - as leaky. IDWR (1997a) treated only the Milner-Gooding Canal as leaky and attributed 146,000 AF of annual leakage to that canal. In both models, all other canal leakage was assumed to have spatial distribution similar to the spatial distribution of irrigated lands.

In the ESPAM, Northside, Milner-Gooding and Aberdeen-Springfield canals are represented as leaky. These are high-volume canals with significant leakage along reaches that do not correspond with the irrigated places of use. Figure 24 shows a map of the canals which are represented as leaky in the ESPAM. Some of the canal reaches shown in Figure 24 are sub-reaches of the three canals mentioned above.

Seepage is a function of the hydraulic conductivity of the bed material, the wetted perimeter, and the head (depth of water) in the canal. Because wetted perimeter and head can vary with flow, there is conceptual justification for using a percentage of flow to describe leakage. This is sometimes done in irrigation system assessment (Hubble, 1991) and has been used in aquifer modeling (Booker and others, 1990). Canal leakage can also be represented as a specified rate (volume per time), which has also been used in ground-water modeling efforts (Garabedian, 1992).

Because both specified-rate and percentage-based leakage rates are supported in the literature and can be justified conceptually, either was a candidate for use in the ESPAM. Since a diversion rate partially controls seepage (apparent from the Chavez-Morales (1985) data), and since a percentage calculation guarantees that there will never be leakage calculated in a period without diversions, a percentage-based method was selected for the ESPAM. Canal leakage was applied to linear GIS features representing leaky sections of canal. The GIS/Fortran Recharge Tool accommodates multiple leaky canal sections per irrigation entity, each with a unique leakage rate. The leakage rate can also be varied with time. Locations and leakage rates were assigned based on interviews with canal company personnel and results of previous studies. Some laterals of the Northside Canal were added in response to comparisons between model-predicted hydrographs and observed hydrographs at some wells, during early stages of calibration. For the Northside and Milner-Gooding canals, a constant leakage rate was used throughout the study period. For the Aberdeen-Springfield canal, unique values were assigned to each stress period based on canal-company data (Howser, 2002).

Varying canal seepage within a season may allow a better fit to measured heads in wells. While it is acknowledged that intra-season variation in canal leakage may occur, and that these differences may propagate into aquifer heads, data were not available to adequately represent these conditions for the calibration period. Leakage rates were based on interviews with canal personnel and checked against values published by Garabedian (1992) and IDWR (1997a). Because imprecision in calculating canal leakage affects only the spatial distribution and not the total amount of recharge, and because of the danger of introducing error by synthesizing data, canal leakage for the model calibration period was estimated as a constant percentage of diversion volume within each irrigation season. To allow for future testing of various scenarios, the GIS and Fortran components of the recharge tool allow unique canal leakage percentages to be applied to each stress period. The data available from the Aberdeen-Springfield Canal Company are annual volume totals, so the fractions calculated were based upon annual volumes. Table A-8 lists the canals, the assigned irrigation entities and the seepage percentages used during the simulation for each of the canals.

Net Recharge from Surface Irrigation

Net recharge due to surface irrigation is calculated in the GIS/Fortran Recharge Tool (Appendix B). The GIS component of the tool prepares text data files containing a) a mapping of surface water entities to model cells within each entity's service area, b) reduction factors for non-irrigated inclusions, c) ET and precipitation for each model cell for each stress period, d) ET adjustment factors, e) diversion data, return flow percentages, canal leakage percentages and sprinkler proportion for each model stress period for each surface water irrigation entity and f) off-site pumping volume delivered for irrigation.

For each model cell, for each stress period, the GIS/Fortran Recharge Tool calculates the net recharge due to surface water irrigation according to Equations 8 and 9. The net recharge from surface water irrigation is added to other estimated recharge and discharge (for example, ground-water withdrawals in the same model cell). Figure 37 shows the net recharge due to surface water irrigation for every year of the calibration period. Inspection of Figure 37 shows that there is approximately a 2 million-acre-ft variation in net recharge due to surface water irrigation between the highest and lowest years of the 22-year calibration period. This reflects the great variation in natural water supply. This also reflects the important role that incidental recharge to the aquifer from surface water irrigation plays in aquifer recharge.

Ground Water Irrigation

Net discharge from ground-water irrigation is estimated as consumptive use (ET) offset by available precipitation (Eq. 10). ET adjustment factors are applied to the estimated evapotranspiration based on source of irrigation water and method of application. No difference was found between ET for ground-water or surface-water irrigation. Sprinkler irrigation was determined to consume approximately 5% more water than furrow irrigation (see ESPAM Design Document DDW-021). Figure 37 shows the net extraction due to ground-water irrigation. As can be seen in Figure 37, a relatively constant 2 million AF annually is applied to approximately 1.1 million acres of ground-water irrigated land. This reflects the relatively constant rate of ET (see Figure 27). Much of the variation in net extraction due to ground-water irrigation (a variation of approximately 900,000 AF) is arguably driven by variation in precipitation (approximately 1,200,000 AF variation). Figure 38 shows the spatial distribution of the net extraction due to ground-water irrigation averaged for the 22-year model calibration period.

Tributary Underflow

Groundwater contributions from tributary basins, or tributary underflows, were estimated for the new model based on tributary underflow estimates published in Garabedian (1992). The Garabedian estimates were adjusted in tributary basins where the ESPAM aquifer boundary differed from the Garabedian aquifer boundary. As part of the water budget balancing process, all of the tributary underflow estimates were scaled by a factor of .97 (a net 3% reduction). Table 5 lists the average annual tributary underflow values used for ESPAM.

Recognizing that tributary underflow varies seasonally and from year to year, the average annual ESPAM tributary underflow values were scaled using normalized annual values based on measured discharges at Silver Creek. Silver Creek was selected because a) it is almost entirely spring-fed and sits on bedrock, b) there is a long-term gage on Silver Creek and c) the flows in Silver Creek reflect spring discharge from a basin which is similar to many of the Snake Plain aquifer tributary basins from the standpoint of land use, precipitation, and elevation. It is believed that flow of Silver Creek is more seasonally variable than underflow in the tributary valley. Therefore, the variation of Silver Creek discharge was dampened by 2/3 to decrease the amplitude of variation. Table 15 lists the non-dampened and dampened normalized flows for Silver Creek for each year of the ESPAM calibration period. The average annual tributary underflow discharge for each tributary basin was multiplied by the dampened Silver Creek normalized flow for each time period, yielding the contribution from each tributary to the ground water model for each stress period. While it is acknowledged that there will be intra-year variations in flow, lack of knowledge about the basin-to-basin differences in the timing of peak flow dictated shaping underflow on a year-by-year basis (Table 5). ESPAM Design Document DDW-004 describes the estimation of tributary underflow for the ESPAM in more detail.

Recharge on Non-Irrigated Lands

This section discusses calculation of two spatially-distributed components of the aquifer water budget; recharge from precipitation on non-developed lands and spatially-distributed recharge and discharge from land uses that comprise a small fraction of the study area. These minor-use areas are dry farms, cities, and wetlands.

Precipitation on the plain is approximately 6.7 million AF per year, with 80% of this falling on non-developed lands. Garabedian (1992) estimates that precipitation on non-developed lands produces 700,000 AF of recharge per year, which equals approximately 15% of the magnitude of irrigation recharge. It is the component of recharge to which Garabedian assigns the most uncertainty. The other land uses, dry farms, cities, and wetlands, represent minor components of the water budget, with a combined net effect of about 160,000 AF per year (calculated from data reported by Goodell, 1988).

Recharge on Non-Developed Lands. A method was developed for estimating recharge from precipitation using GIS grid maps of monthly precipitation (Daly and others, 1998) and thickness and texture of soil coverage (Figure 25). The developed method is suggested by Rich (1951). Rich studied basins which, unlike the Eastern Snake Plain, had a component of surface discharge. His relationship actually described total basin yield, but it is simplified here to represent recharge, since runoff that does occur on the plain collects in depressions where it also recharges the aquifer. The equation is:

$$\text{Recharge} = K * (\text{Precipitation})^{N} \qquad \text{(Eq. 12)}$$

where K is an empirical slope parameter and N is an empirical exponent that introduces curvature into the relationship.

Rich applied this formula to annual precipitation. The formula presumes that with less precipitation, most of the precipitation is intercepted by various mechanisms (leaf interception, depression storage, soil moisture storage, evaporation, etc.) and that with increasing precipitation, more of the precipitation is available for infiltration. Parameters K and N can be adjusted to shape the calculated recharge curves. However, knowing the actual recharge from precipitation on non-irrigated arid lands is very difficult (Gee, 1988). Attempts to use a water balance to determine the non-irrigated recharge are frustrated by the fact that another large component of recharge, tributary basin underflow, is also poorly defined. Consequently, parameters K and N were initially calibrated to match previous results. ESPAM Design Document DDW-003 contains a detailed explanation of the estimation of recharge on non-irrigated lands.

Estimates of recharge depth from Equation 12 were performed for three soil classifications based largely on soil thickness. These calculations employed monthly estimates of precipitation. Precipitation during November through February was summed into the February value to represent snowmelt. These calculations were performed external to the GIS component of the recharge program but were input to the Fortran component of the recharge program as monthly recharge depths. A fourth soil classification was used to represent the minor land uses (cities, wetlands and dry farms).

Within the Fortran component of the recharge program, the recharge depths from non-developed land were multiplied by the non-irrigated land in each cell. Non-irrigated land was determined as the difference between the area of a cell and the irrigated area within the cell. Monthly non-irrigated recharge values were summed to estimate recharge in each stress period. Figure 39 illustrates the areal distribution of non-irrigated recharge averaged for the 22-year calibration period.

Recharge on Minor Land Use Types. Several minor land use types were identified and recharge on these areas was handled separately. The categories of minor land uses which were identified were: dry farm, water and wetlands and cities and industrial areas. Table 16 lists the minor land use types, the acres represented by these types and the recharge rate. On dry farms, the recharge rate was presumed to be zero. Discharge on wetlands was presumed to be three feet, less precipitation. Discharge for cities and industrial areas, which is attributable to parks and lawn watering, was presumed to be 1.2 feet/year. The discharge from wetlands and cities is represented in Figure 39 as negative recharge. These minor land uses are discussed further in Contor (2002).

Fixed Point Pumping

Fixed point pumping (or recharge) represents an impact that occurs at a single point and does not enter into any other recharge calculation. Negative values are applied directly as an extraction from the model cell that contains the point, and positive values are applied as a direct injection. Fixed point pumping was used to represent the following practices: a) pumping where the pumped water is added to a natural water body to augment the surface water supply and the same water is counted as a diversion from that surface water body, b) recharge corrections for deficit irrigation on the Richfield tract and c) recharge correction for wetlands. Table A-9 lists the model cells where fixed pumping is represented.

Irrigation Wells. In the ESPAM, certain irrigation wells are treated as fixed-point pumping because the pumped water is delivered to a natural water body and is included in the water master reported diversion volume of water diverted for irrigation from the water body. One group includes wells known as “exchange wells,” which pump water into the Teton River or the Snake River. Their volumes are included as diversions within the diversion data files from the IDWR planning model (see ESPAM Design Document DDW-012). The other group of fixed-point wells includes the wells that deliver water into Mud Lake or Camas Creek in Jefferson County, for diversion to irrigation entity IESW029. The volume of water pumped from these wells is included within the diversion volumes reported by Water District 31 (see ESPAM Design Document DDW-025).

The spatial location of the “exchange wells” class of fixed points was obtained from GPS data or public land survey legal descriptions supplied by Water District 01 (Madsen, 2000; Olenichak, 2003). Figure 40 shows the location of these exchange wells.

The GIS points for the Mud Lake fixed points and the offsite ground-water pumping wells were placed to represent groups of physical wells within small local areas. The actual locations of the physical wells were obtained from IDWR GPS data (IDWR,

1999) and aerial photography. Figure 41 shows the fixed points in the Mud Lake area, relative to the model grid, observation wells, and physical pumping wells.

Pumping volume for the "exchange wells" fixed points was obtained from Water District 01 annual reports (Water Distrtict 01, 2003). These data are complete for the entire calibration period. The annual reports include monthly pumpage volume for each well that is active in a given year. The gross pumping volume for the "Mud Lake" fixed points was obtained from Water District 31 data, as described in ESPAM Design Document DDW-025. To apportion the Mud Lake volume to individual points, the number of wells per model cell was adjusted to better reflect field observations of relative production of individual well groups. The fraction of the total volume assigned to each point was apportioned to the adjusted number of wells, as shown in Table 17. Any uncertainty in apportionment represents imprecision in the spatial distribution of discharge, but not an uncertainty in the water budget.

<u>Richfield Tract Recharge Adjustment</u>. An adjustment was made on the Richfield tract to account for deficit irrigation conditions. Because most irrigated areas with limited surface-water supplies have supplemental wells, the GIS/Fortran Recharge Tool automatically presumes supplemental ground-water pumping whenever surface-water supplies are inadequate to meet consumptive use demand. For some stress periods this is an inappropriate calculation for irrigation entity IESW007 (in the Richfield area), since deficit irrigation occurs without the opportunity for supplemental ground-water pumping. This is corrected by applying an offsetting volume to a deficit-irrigation class of fixed points, in those cells where deficit irrigation occurs without supplemental ground water. This correction is explained in further detail in ESPAM Design Document DDW-003.

Deficit irrigation correction volumes were determined by identifying cells without groundwater where net irrigation from surface-water irrigation was zero or negative. Using a spreadsheet, a correction volume was calculated to offset the indicated negative recharge.

Wetlands Correction. During model calibration, the need for a correction for wetlands became apparent. As described in ESPAM Design Document DDW-003, Recharge on Non-irrigated Lands, a correction was required for model cells that contained both wetlands and irrigated lands. The GIS/Fortran Recharge Tool applies the cell-average non-irrigated recharge rate to the non-irrigated lands within each model cell. When part of the cell is irrigated and part is wetlands, the cell-average rate is biased by the non-irrigated-recharge rate associated with the soil type on the irrigated lands. This bias was corrected by applying an offsetting volume to a wetlands class of fixed point pumping in those cells containing both irrigation and wetlands. Wetlands correction point volumes were determined by calculating the correct non-irrigated recharge in individual cells with both wetlands and irrigation, and comparing the volumes to the volumes calculated by the GIS/Fortran Recharge Tool.

Figure 42 illustrates fixed points used to represent the wetlands and deficit-irrigation correction points. Table 18 lists the total adjustment to recharge for each stress period for each category of fixed point well.

Off-Site Ground Water Pumping

Offsite ground water pumping refers to irrigation pumping that is conveyed to a distant location for application to irrigated lands. It must be accounted as a withdrawal from the model cell that contains the well and as applied irrigation water to the model cells that contain the irrigated lands. While physically this is the same process that is represented by fixed-point pumping for the exchange wells and Mud Lake wells described above, the accounting difference is that offsite-pumping volumes have not been included in a water-master reported diversion volume. They must be added to diversions within the recharge calculations. In this modeling effort, wells in Jefferson County that supply water to irrigation entity IESW044 are represented as offsite ground water pumping. While irrigation entities IESW001 (A & B Irrigation District) and IESW018 (Falls Irrigation District) also pump ground water into canals for conveyance to places of use, their wells are distributed approximately uniformly across the irrigated service area, similar to other ground-water irrigated areas within the study area. There is not a need to spatially separate the extraction and recharge associated with irrigation.

In the Fortran component of the recharge tool, the pumped volume from the offsite ground water pumping wells is removed from the cells in which the wells are located, and added to diversions for IESW044. The entire pumped volume is included in the irrigated-lands recharge calculation as a contribution towards recharge. Volume-for-volume, any over-estimate in pumping becomes an over-estimate in irrigated-lands recharge, and any under-estimate in pumping becomes an under-estimate in recharge. The inaccuracies balance, so that the only consequence of an inaccuracy in estimating pumping volume is an inaccuracy in spatial distribution of discharge and recharge. The region in which this practice occurs is distant from the Snake River so these potential inaccuracies have a low impact to predictions near the river.

An initial pumping estimate of 4 AF/ac/yr comes from experience of the North Water Measurement District for water years 1997 through 1999. This appears reasonable considering ET, precipitation rates and irrigation and conveyance efficiency.

The lands in IESW044 are aggregated from three irrigation companies; Jefferson Irrigation, Monteview, and Producers Canal Companies. Three of the offsite points are associated with the Jefferson lands, three with the Monteview lands, and two with the Producers lands. Figure 43 shows the location of the off-site wells. Based on the original GIS shapefiles (see ESPAM Design Document DDW-008), the 2000 irrigated lands map was clipped to show irrigated lands in each of the three companies. The acreage of these lands was multiplied by four feet to determine a gross pumpage volume for each company, then divided by the number of represented off-site wells to obtain an annual volume per well. The annual volume was distributed among the months according to a crop-weighted average monthly ET from U.S. Bureau of Reclamation (2003) Agrimet data for 2000.

To scale pumpage to reflect year-to-year differences in ET, an index was constructed for each year 1980 through 2000 using revised ET values (Allen, 2002) for Hamer, Idaho (the nearest weather station with a full record). The ET index is a factor that relates ET for each given year to the long-term average ET. It is multiplied by the derived average monthly pumpage to give a monthly pumpage adjusted for the individual year's climatic regime.

Because the Monteview AGRIMET station did not start operation until 1997, the Hamer NOAA station was used to calculate the index for years up through 2000. For each of those years, the index was estimated as the ETr for the specific year divided by the average ETr. Because the revised ETr for the Hamer NOAA station did not include a value for 2001, the 2001 index was derived from Monteview AGRIMET data. The results are summarized in Table 19. ESPAM Design Document DDW-026 contains more details regarding the estimation of off-site ground-water pumping. Table 20 lists the represented pumping in each model stress period for the off-site wells.

Perched River Seepage

Perched seepage, or bed loss, represents seepage from a creek or river which is above the water table. The seepage rate is independent of the nearby aquifer water levels; that is, the reach is not hydraulically connected to the aquifer. All perched seepage is entered into the model as a line source. The estimated seepage is distributed among the model cells associated with each perched reach. This information is prepared as input to the Fortran component of the recharge tool, which applies the perched seepage in the estimation of net recharge.

Perched river seepage for rivers and creeks other than the Snake River was estimated from a water balance using gage and diversion data. The same data were often used for both diversion (see section on surface water diversions) and seepage calculations. Figure 23 shows the primary perched reaches. Some of the less significant represented perched reaches (for example, the Birch Creek hydropower discharge) were represented in the model but are not shown on Figure 23. Table 6 contains a complete listing of the represented perched reaches. Table A-2 lists the model cells associated with each of the perched reaches.

Data were not always available for every gage for every year. The following section summarizes how the seepage from each perched reach was estimated. For a complete description, the reader is referred to ESPAM Design Document DDW-024.

Camas Creek and Lone Tree. Flood-control diversion volumes (USGS, 2002) were applied as a line source at the Lone Tree spreading location. Camas Creek perched-river seepage (bed loss) was based on the difference in flow between two gaging stations at Camas Creek. The upper gaging station is Camas Creek at Red Road near Kilgore and the lower is Camas Creek near Camas. Corrections were made for diversions at Lone Tree and irrigation diversions between the two gages (Shenton, 2002).

The Red Road gage data series (the north end of the losing reach) was incomplete. Thus, the final perched seepage values used in model calibration were based on gage data for all periods where data were available and estimated seepage where Red Road gage data were not available.

Medicine Lodge Creek. Medicine Lodge Creek lies partially inside and partially outside the model study area. GIS analysis shows that 45% of District 32-c irrigated lands are within the study area. Medicine Lodge Creek sinks into the Snake River Plain south of the irrigated lands. Bed loss was calculated by subtracting the inside-study-area diversions from the gaged flow of Medicine Lodge near Small, Idaho. The gaging station for Medicine Lodge began to function during the summer of 1985; records were not kept prior to that date. For years after 1985, the "Big Lost River Below Mackay Reservoir" gaging station was compared with Medicine Lodge creek gage records using linear regression. This produced a reasonable relationship, which was applied to the years before 1985. For all years before 1985, the predicted Medicine Lodge gage record was used with actual diversions in calculating bed loss. Actual data were used to calculate bed loss for all years after 1985.

Birch Creek and Birch Creek Hydropower Plant. The bed loss and diversion calculations for Birch Creek are divided into two different time periods. Before 1987, water was delivered to Reno Ranch through a ditch with an estimated 50% bed loss. After 1987, water was diverted into a lined canal and pipeline and delivered to the Birch Creek hydroelectric plant before being used by the Reno Ranch (Sorenson Engineering, 2002).

Prior to 1987, Birch Creek was measured at the USGS gage station “Birch Creek at Eight-mile Canyon Road Near Reno Idaho.” Water measured by this gage station was then diverted into the old Reno Ranch ditch during summer months. Excess water (and all water during winter months) was allowed to continue downstream and flow out onto the desert.

For months when the Eight-mile gage station was not active, gage records were predicted using regression based on Birch Creek diversions. Prior to 1987, half of the reported diversions were applied as diversions to irrigation entity IESW037. The Eight-mile gage record, minus diversions applied to IESW037, was applied as perched river seepage (bed loss) in the natural channel of Birch Creek within the study area. This actually applied the 50% ditch loss from the old ditch to the natural channel of Birch Creek, but since the old ditch is outside the model study area, seepage from the ditch actually enters the model domain as sub-surface flow in the model cells near the creek channel.

During the summer of 1987, the Birch Creek hydroelectric plant began to operate and the Eight-mile gage was discontinued. The entire flow of Birch Creek is delivered to the plant through a lined canal and pipe system. Outflow from the plant is applied to irrigation of the Reno Ranch or delivered to a channel where it infiltrates into the subsurface. Discharge records were obtained from the Birch Creek hydroelectric plant for use in calculating bed loss (Sorenson Engineering, 2002), in combination with watermaster diversion records.

Camas National Wildlife Refuge and Mud Lake.   For the wildlife refuge, surface-water delivery volumes are recorded by the watermaster. These volumes are applied to a GIS line feature along the axis of the wetland.

Camas Creek inflows to Mud Lake. In some years, particularly during the winter, Camas Creek supplies water to Mud Lake. In the perched river seepage data set, Camas Creek inflows are applied as perched river seepage (recharge to the aquifer) to a GIS line feature that occupies the same model cells as the lake. Summertime values are obtained from watermaster records (Shenton, 2002). Wintertime inflows are not recorded directly, but are computed from a mass-balance calculation of October and May lake contents, winter-time pumping to the lake, and estimates of winter-time ET and precipitation, using watermaster-supplied data.

Mud Lake Flood Control. In high water years, water is pumped from Mud Lake to the desert south of the farm lands as a flood control measure. Data are obtained from watermaster records. No irrigation diversions are associated with this perched river seepage site.

Little Lost River and Little Lost River Flood Control. Because the Little Lost River infiltrates to the aquifer a short distance beyond the irrigated lands, perched river seepage is calculated as the difference between flow at the Little Lost River gage (very near the model boundary) and diversion volume.

When annual diversion volumes were interpolated to monthly values based on percentages from 2001 daily records, many negative bed loss values were generated. To correct this condition, annual diversion volumes were distributed temporally according to summer gaging station temporal patterns. This gave a more reasonable distribution without causing negative bed loss values.

The gaging station at "Little Lost near Howe" was decommissioned in 1991. A number of prediction options were explored to estimate gaging records for the last years of the model calibration period. A linear regression based on precipitation at the Howe gage was the selected method.

Using the predicted yearly gage station record for years after 1991, yearly diversions were subtracted to give a total bed loss for each year. Annual values were interpolated to monthly results using percentages from the pre-1991 data. To smooth the time series, months were grouped together and averaged. The groups were April-Oct, Nov-Feb, and March.

In 1985, a flood-control spreading area was developed up-river of Little Lost River diversions. During winter months water is diverted to the spreading area to prevent icing and local flooding. Another line source was developed to show this location as a point of recharge during winter months. Prior to 1985, wintertime bed loss is applied to the channel of the Little Lost River below the gage. For 1985 and later years, it is applied to the spreading area. Summertime bed loss is always applied to the river channel.

Big Lost River. The entire irrigated area of the Big Lost Valley that is included within the model area is bounded between two gages on the Big Lost River. The river flows through irrigated lands throughout this area, and there is a fairly dense network of diversion canals and laterals throughout the irrigated area. The gage data were complete for the entire calibration period. Therefore, the recharge associated with surface water irrigation, canal leakage and perched river seepage was all lumped into the surface-water irrigation calculation. For summer months, the entire difference between the upstream gage (Mackay Dam) and the downstream gage (Near Arco) was applied as a diversion to irrigation entity IESW005. In the winter months, the entire difference was applied as bed loss (perched river seepage) to the line feature representing the riverbed, illustrated in Figure 23. This resulted in some wintertime negative values, which could be consistent with the processes of periodically gaining reaches and of lagged return flows. These are both physical possibilities, so the negative values were retained in the data. Three gages below Arco and records of diversions to a flood-control spreading ground at the Idaho National Laboratory were used to spatially distribute any water discharging past the Near Arco gage to the spreading ground and lower reaches of the river.

Big Wood River and Little Wood River. Most of the Big Wood River was represented with no perched seepage because the bed loss calculated from gage data oscillated about zero, with a very small magnitude relative to stream discharge. Upstream and downstream gage data (adjusting for diversions and returns) were used to calculate bed loss in the Little Wood River, the lower reach of the Big Wood River, and the reach of the Big Wood River identified in Table 6 as the "Below Magic Reservoir" reach, just below the reservoir.

Twin Falls Canal and Lake Murtaugh. Because nearly all of the Twin Falls Canal Company lands lie outside the study area, the diversions applied to irrigation entity IESW041 were discounted substantially. However, the leaky portion of the canal within the study area and a part of Lake Murtaugh within the study area contribute recharge to the aquifer based on total diversions. Because of the large volume of recharge relative to the small fraction of diversions applied to the model, these leaky features were not treated with the leaky canal function of the GIS/Fortran Recharge Tool. Instead, recharge for these locations was calculated in a spreadsheet using the full diversion volume, and applied in recharge calculations as perched river seepage to the location illustrated in Figure 23. Leakage calculations relied upon data from Twin Falls Canal Company (circa 1955).

Table 6 lists the average perched seepage for each reach. Both average stress period seepage and average annual seepage are listed in Table 6.

Steady-State Model Water Budget

During compilation of water level data, it became apparent that there was an 18.5-year period (May 1, 1982 to October 31, 2000) during the 22-year model calibration period where aquifer water levels across the eastern Snake River Plain started and ended at approximately the same levels. This suggests that during that period, there was no net change in aquifer storage or, stated otherwise, that on the average during that period the inflows were equal to the outflows. This period was selected as the steady state period for the ESPAM. To generate the recharge for the steady state model, each component of recharge was averaged for that period. Figure 44 shows a bar graph of the elements of the steady state recharge. River gains in Figure 44 represent the net of Snake River and Henrys Fork gains and losses above Minidoka and spring discharges in the Milner to King Hill reach. Figure 45 shows a map of the areal distribution of steady state recharge.

Transient Model Water Budget

All of the components of recharge described above were estimated for each of the 44 transient model stress periods and were processed through the GIS/Fortran Recharge Tool. The output of the Fortran component of the recharge tool is the MODFLOW-formatted well file or recharge array which contains the net recharge or discharge for every model cell for every stress period. Figure 46 shows a graph of the annual net recharge for the 22-year period, graphed along with precipitation for the same period. There are several striking features to note in Figure 46. The amount of net aquifer recharge is highly correlated to the amount of precipitation. Precipitation contributes to net aquifer recharge in three ways: precipitation is the basis for the water supply for surface water irrigation, high summer precipitation reduces the requirement for ground-water pumping and precipitation contributes directly to aquifer recharge via recharge on non-irrigated lands. Additionally, in a high precipitation year, carryover water will be left in the reservoirs for use in the following season, helping to sustain the supply of water available for aquifer recharge in the following year. Another striking feature from Figure 46 is that there is a 4.7 million acre-foot variation in estimated annual recharge to the aquifer, ranging from a high in 1984 of approximately 7.5 million AF to a low in 1989 of approximately 2.8 million AF. These dramatic variations in net aquifer recharge will cause dramatic variations in aquifer water levels.

Figures 47 and 48 show the spatial distribution of transient recharge for the irrigation season and the non-irrigation season, respectively, for 1980-1981. Comparison of Figures 47 and 48 shows that irrigated agriculture plays a significant role in net aquifer recharge.

Model Calibration

The ESPAM was calibrated using automated parameter estimation tools. The goal of model calibration was to adjust model parameters (transmissivity, aquifer storage, riverbed conductance and drain conductance and elevation) until model-predicted values of aquifer water levels and discharges to the river matched observed values. The calibration was done in two steps. An initial steady state calibration was done to establish initial aquifer transmissivity and riverbed and drain conductance. After the initial steady state calibration, a coupled steady state and transient calibration was done. During the coupled steady state and transient calibration, the parameter estimation software would adjust aquifer storage and drain elevation during the transient portion, followed by a check of the steady state model fit. This forced the transient calibration to not only provide a 'best fit' to the transient data but to also honor the steady state observations. Changes to the transmissivity field and riverbed and drain conductance were allowed during the coupled steady state/transient calibration.

The following sections describe the parameter estimation tools used for ESPAM calibration, the collection of aquifer observation data used during model calibration and the initial steady state and final coupled steady state/transient calibrations. Final model parameters and a comparison between model-predicted values and observed values are presented in the section describing the coupled steady state/transient calibration.

Parameter Estimation Tools

PEST, a nonlinear, least-squares inverse modeling program developed by Doherty (2004) was used to calibrate the model. (PEST is available for download on the web at *www.sspa.com/pest*.) During calibration, PEST runs the MODFLOW model thousands of times, comparing model-predicted results with observations. After each model run, the objective function is analyzed to determine whether the model run was an improvement over the previous run. After each model run, PEST evaluates each adjusted parameter to determine the next best adjustment to that parameter. PEST then prepares the input data set for the next model run with the adjusted parameters, runs the model and re-evaluates the output. The goal is a weighted, least-squares optimization of the fit between the model-predicted values and the observations.

A key to success at using parameter estimation tools is to have a greater number of observations than parameters being estimated. With previous parameter estimation packages (including previous versions of PEST), this was accomplished by establishing zones of transmissivity and aquifer storage. The parameter estimation software would be tasked to calibrate a single parameter value for each zone, thus greatly reducing the number of parameters being estimated for the entire model. The delineation of the zones was subjective and the calibrated model had abrupt changes in parameter values at zone boundaries.

PEST allows an option of using “pilot points” where parameter values are estimated at user-specified points. PEST interpolates model parameter values between the pilot points using kriging or some other spatial interpolation scheme. For example, during ESPAM calibration using PEST, transmissivity was estimated at 169 pilot points. The transmissivity at these 169 points was interpolated to the entire grid of 11,000 active model cells. Similarly, aquifer storage, which has a much lower degree of variation than transmissivity, was estimated at 28 pilot points and interpolated to the whole grid. Doherty (2003) provides a more rigorous description of pilot points and how the process works. Additionally, PEST was instructed to calibrate riverbed conductance at the five reaches of the upper Snake River and drain conductance and elevation at the six spring reaches in the lower Snake River. At each calibration run, PEST minimized the difference between observed and model-predicted aquifer water levels and river gains.

River Gain/Loss Calibration Targets

For the upper Snake River, the river gain/loss calibration targets were estimated using the IDWR Reach Gain/Loss Program. The Reach Gain/Loss Program uses gaged reach inflows and outflows, measured diversions and estimated irrigation returns and reservoir storage and evaporation to calculate a water balance for the reach. The residual of the water balance is the estimated river reach gain from or loss to the aquifer. More information on the IDWR Reach Gain/Loss Program can be obtained directly from IDWR. Inputs to the Reach Gain/Loss Program include measured diversions, gaged river flows, reservoir stage and irrigation return flow lag factors (described above). For the purposes of the ESPAM modeling, the newly calculated return flow lag factors were entered into the Reach Gain/Loss Program input files.

Figures 49 through 53 show the estimated monthly reach gain for the five reaches of the upper Snake River (Ashton to Rexburg, Heise to Shelley, Shelley to Near Blackfoot, Near Blackfoot to Neeley and Neeley to Minidoka). As can be seen in Figures 49-53, there is a lot of noise in the monthly data. Prior to use as calibration targets, the monthly reach gains/losses were filtered to eliminate some of the noise (see transient calibration section).

The streamflow gages on the Snake River are maintained by the USGS and are assigned a rating of “excellent,” ”good” or ”fair,” with associated uncertainty bands of ± 5%, ± 10% and ± 15%, respectively. Each of the upstream gages for the five reaches of interest is rated “good.” Given the “good” rating, the uncertainty on the inflows for each reach is approximately ± 10%. In general, assuming that there is no systematic error introduced at a gage, the ± 10% uncertainty is for an instantaneous measurement. Assuming no systematic error, the uncertainty in the river discharge should be reduced as single day measurements are aggregated into weekly or monthly measurements.

The uncertainty in the estimated river gain or loss is driven by a) uncertainty in both the upstream and downstream gages, b) uncertainty in measured diversions, c) uncertainty in estimated irrigation return flows and d) uncertainty in reservoir storage and evaporative losses. The estimated reach gain or loss cannot be more accurate than the least accurate component. In order to provide a sense of the magnitude of the estimated river gain or loss relative to gage uncertainty, Figures 49 through 53 also show an uncertainty band of ± 5% of the upstream gage. This is not a statement of the true uncertainty of the estimated reach gain or loss but is provided as a guideline for the magnitude of the gain or loss relative to a conservative uncertainty band on the gaged inflow.

If the estimated reach gain or loss is approximately the same magnitude as the ± 5% band, then there is low confidence that the reach is gaining or losing. Figure 53 shows that the magnitude of the Neeley to Minidoka estimated reach gain is almost always within this ± 5% band; hence, there is significant uncertainty that this reach is gaining or losing. In contrast, Figure 52 shows that the magnitude of the Near Blackfoot to Neeley estimated reach gain is significantly greater than the ± 5% band; hence there is more confidence that this reach is gaining. The estimation of river gain and loss calibration targets is further discussed in ESPAM Design Document DDM-017.

Spring Discharge Calibration Targets

Spring discharge calibration targets proved to be something of a challenge for the ESPAM project. Very few of the springs in the Thousand Springs region are measured with any regularity or accuracy. For many of the springs in the region, it is difficult to discern the discharge point of the spring. Many of the springs have complex plumbing which routes the collected water to various users, making measurement difficult.

The USGS estimates the total annual spring discharge from the regional eastern Snake River Plain aquifer (excluding spring discharge from the Twin Falls area on the south side of the river) based on a regression equation developed by Kjelstrom (1995b). The regression equation uses measured flow at several index springs. However, the Kjelstrom method addresses neither seasonal nor spatial variation in spring discharge. Table 21 lists the annual estimated reach gain from the north side in the Milner to King Hill reach for the calibration period.

In order to compensate for this lack of data, the ESPAM modeling team and the ESHM Committee agreed to try to spatially distribute the total reach gains as predicted by the Kjelstrom method according the magnitude of the springs recorded by Covington and Weaver (1990). For each of the spring sub-reaches shown in Figure 21, the relative magnitude of spring discharge in the sub-reach to spring discharge in the whole reach was estimated. These estimates were based on the Covington and Weaver (1990) estimates. Table 22 lists the relative magnitude of the six spring sub-reaches from Milner to King Hill and the percent of the total reach gain that each represents. Temporal discretization was done using the seasonal variation in measured springs such as Blue Lakes, Crystal and Box Canyon, which were deemed representative of the springs in the whole reach. This was the method initially used to generate spring calibration targets in the Thousand Springs reach. This method was successful for generating average spring reach calibration targets for steady state calibration. During transient model calibration, however, it became apparent that springs varied markedly in their temporal discharge patterns. Thus the initial method of generating spring targets was unsuccessful for use in the transient calibration.

The second approach, which ultimately was successful for transient calibration, was to use actual spring measurements for the springs for which measurements exist. Initially, the springs for which long-term measurements existed were: Devils Washbowl, Devils Corral, Blue Lakes, Crystal Springs, Clear Lakes, Briggs Springs and Box Canyon Springs. The two springs with the greatest magnitude of discharge, Thousand Springs Power Plant and Malad Gorge Power Plant, did not have discharge measurement records.

At the request of the modeling team, Idaho Power used power generation records at the two plants to estimate spring discharge for Malad and Thousand Springs. Although not obtained through direct measurement, these turned out to be reasonable proxies for measurements of the springs at Malad and Thousand Springs. Once those hydrographs were obtained, transient model calibration was successful. Figure 54 shows the location of the individual springs used as calibration targets. Hydrographs of the measured (and estimated) springs will be presented in figures in the discussion of transient model calibration. Table 23 lists the model cells representing the springs used as transient calibration targets. Table 24 lists the number of observations and the date range of the observations for each of the calibration target springs. In addition to using monthly spring measurements, the mean discharge and standard deviation of each spring were also used as calibration targets. The annual Kjelstrom estimate of total spring discharge for the entire Milner to King Hill reach as well as the estimated sub-reaches were used to help evaluate the model fit. The estimation of spring discharge calibration targets is further discussed in ESPAM Design Documents DDM-018 and DDM-008.

Aquifer Water Level Calibration Targets

Aquifer water level calibration targets were obtained from the IDWR data base of Idaho aquifer water level measurements using the program WellLog. The WellLog data base includes measurements from the USGS, IDWR, Idaho Power and private consulting firms contracted by the agencies to conduct water level measurements. More information about WellLog can be obtained in the WellLog user's manual (IDWR, 1997c).

Several synoptic measurements (mass measurements) of aquifer water levels were done in 1980-1981 as part of the USGS Regional Aquifer-Systems Analysis effort on the eastern Snake River Plain. This entails measuring as many wells as possible throughout the study area in a short period of time in order to estimate a regional potentiometric surface. As part of the current study, three additional synoptic measurements were done; in Spring, 2001, Fall, 2001 and Spring, 2002. This provided mass measurements at the beginning and ending of the model calibration period.

WellLog was queried for all depth to water measurements within the study area within the calibration period. Depth to water measurements which were documented to be in aquifers other than the regional aquifer, such as locally perched zones, were excluded. Similarly, depth to water measurements which appeared flawed (perhaps an error in recording or a measurement taken shortly after a well was pumped) were discarded. If neighboring water level measurements corroborated a seemingly spurious measurement, the measurement was retained.

Wellhead elevations were estimated using USGS 10 meter digital elevation maps (DEMs) intersected with the IDTM position of each well. This was done using GIS software. An analysis of the accuracy of this technique was done by comparing the elevation determined using 10 meter DEMs versus surveyed elevations where they existed. It was found that, on the average, the elevation determined from the DEMs was within 1.21 ft of the surveyed elevation. This was considered acceptable accuracy by the ESHM Committee. More detail on the use of DEMs for estimating wellhead elevation can be found in ESPAM Design Document DDM-011.

Using the estimated wellhead elevations and the measured depth to water, water table elevations were calculated for each measurement. Figure 10 illustrates water table contours from the Fall 2001 mass measurement. More detail on the collection of aquifer water level data can be found in ESPAM Design Document DDW-014.

Initial Steady State Calibration

Steady-State Calibration Data

Although true steady state conditions rarely exist in natural aquifers, most ground water modeling efforts include a steady state analysis because the transmissivity distribution tends to be more sensitive to steady state water levels than transient water levels. As previously stated, the net change in aquifer storage, as indicated by water levels between May 1, 1982 and October 31, 2000 was small, so the period was selected as the steady state period. At steady state, the recharge and discharge for an aquifer system are balanced and no water is entering or leaving aquifer storage.

Steady state calibration water level targets were generated by averaging water level measurements for this period. Wells with only one observation during this time period were not used as targets. A total of 1009 steady state aquifer water level observations were used. Figure 55 shows the locations of the wells used as observations for steady state calibration. Figure 55 also shows the location of the river and spring reaches. The reader will note in Figure 55 that many of the wells used for steady state calibration targets are located reasonably close to the river and spring reaches. This helps to control the certainty of the calibrated parameters in these areas of high interest. In areas with few observation wells, the calibration parameters are less certain.

Steady state river gain targets were estimated by averaging the transient river gains for each of the five sub-reaches for the steady state period. Similarly, steady state spring calibration targets were estimated by averaging the transient spring reach targets for the steady state period. Table 25 lists the steady state river and spring calibration targets.

Steady-State Calibration Procedure

During steady state calibration, the model parameters of aquifer transmissivity and riverbed and drain conductance were estimated. The steady state calibration was accomplished using 1020 observations and 180 adjustable parameters. The observations include 1009 aquifer water level observations, five river reach gain/loss observations, and six spring reach observations. The adjustable parameters include 169 pilot points used to adjust the transmissivity distribution, five river parameters to adjust riverbed conductance for the five river reaches, and six drain parameters to adjust drain conductance for the six spring reaches. Figure 56 shows the location of the pilot points used for calibration of aquifer transmissivity.

The steady state calibration was accomplished by minimizing the difference between model-predicted steady state aquifer water levels and Snake River gains and losses and the averaged observed water levels and averaged estimated Snake River gains and losses and spring discharges. The steady state calibration was done using PEST parameter estimation tools. During the steady state calibration, model-predicted aquifer water levels, which are generated for the center of each model cell, were interpolated to the actual location of each observation well prior to comparison.

The same steady state calibration targets and calibration procedure were used during the initial steady state calibration and during the coupled steady state/transient calibration. The product of the initial steady state calibration is an intermediate product. The ending steady state heads and aquifer transmissivity and riverbed conductance became the starting values for the coupled steady state/transient calibration. The coupled steady state/transient calibration yielded both calibrated steady state and transient versions of the ESPAM.

Coupled Steady State/Transient Calibration

Transient Calibration Data

The transient calibration data include aquifer water level observations, monthly Snake River gains and losses, and spring discharge observations. Transient calibrations are undertaken primarily to determine specific yield. Changes in aquifer water level are a function of aquifer storage or specific yield; hence transient model water level targets are changes in water levels, not the absolute measured water levels. Modeled aquifer water levels were also converted to changes in water levels for comparison with the targets. For the ESPAM calibration, three different types of transient aquifer water level data were used as calibration targets: 1) seasonal wells - wells with long time series consisting of frequent observations (9548 total observations in 39 wells over a maximum of 17 years), 2) mass measurement wells - water level observations collected between spring 2001 and spring 2002 as part of this project (1766 total observations in 601 wells), and 3) trend wells - wells with regular spring-time observations (1403 observations in 173 wells). Figure 57 shows the locations of the transient aquifer water level observation wells.

As during the steady state calibration, model-predicted aquifer water levels are interpolated from the center of the model cell to the actual location of the observation wells. For the transient part of the calibration, a similar interpolation was also done in time. The model-predicted water levels are generated at every model time step (in the case of the ESPAM calibration, every 18.2 or 18.3 days). During calibration, the PEST software interpolated model-predicted water levels to times which match the actual dates of aquifer water level observations.

The monthly gains and losses for the five river reaches above Milner Dam which were computed using the IDWR Reach Gain/Loss Program proved to contain significant measurement noise, so the data were filtered in a computer program called TSPROC (Doherty and Johnston, 2003) prior to their use as calibration targets. TSPROC uses a 1-stage, low passButterworth filter to remove excessive noise in time series data sets. For the ESPAM application, the cutoff frequency was 5.48e-4. Model-predicted river gains were filtered using TSPROC and matched with the filtered observations.

Measured discharge data from Devils Washbowl, Devils Coral, Blue Lakes, Crystal Springs, Clear Lakes, Briggs Springs and Box Canyon Springs were used as calibration targets, as were the spring discharge estimates for Thousand Springs and Malad which were estimated from power records. In general, these spring discharge data were not as noisy as the river gain and loss estimates from upstream reaches and therefore were not filtered. Model-predicted spring discharge at the model cells noted in Table 23 were interpolated in time and then compared with the measured spring discharges. Despite the fact that these individual springs were explicitly modeled, the ESPAM is a regional model and is not intended for predictions of impacts to individual springs. A regional model is limited to replicating broad-scale heterogeneity in the physical system and cannot replicate localized heterogeneities.

Coupled Steady State/Transient Calibration Procedure

The coupled steady state/transient calibration was done using PEST parameter estimation software. During the transient part of the calibration, aquifer specific yield was calibrated at 28 pilot points (see Figure 56), spring (drain) elevation was estimated at the model cells representing the springs used as calibration targets and spring (drain) conductance was estimated at the six spring reaches and the nine drains used as calibration targets. The steady state portion of the calibration was as described above. The ending heads from steady state were used as starting heads for the transient calibration. During the coupled steady state/transient component of each calibration model run, PEST was allowed to modify aquifer transmissivity and river and drain conductance as well as establish aquifer specific yield and spring elevations. After each pair of steady state and transient model runs, the model-predicted aquifer water levels and river and spring discharges were compared with the thousands of calibration target values. The coupling of the steady state and transient models during transient model calibration forced the calibrated transient model to match both the steady state and transient calibration targets, ensuring that there was minimal degradation in the match to the steady state data caused by the transient calibration.

The objective of the transient part of the model calibration was to minimize the difference between observed river gains and losses, spring discharges and water level changes between May 1, 1985 and April 30, 2002. The transient model required a warm-up period of about five years because observations during the initial 1980-1985 period are partly dependent on events that occurred years prior to 1980. By using the ending steady state heads as the transient starting heads, the impacts of recharge and discharge in the years prior to 1980 were approximated. When the model was allowed to run with estimated recharge and discharge data from 1980 to 1984, by 1985 the model was responding appropriately based on comparison with measured values (river gains and losses and aquifer water levels).

The coupled steady state/transient calibration utilizes about 16,600 observations and 225 adjustable parameters. The observations include 12,700 aquifer water level change observations, 1300 Snake River gain/loss observations, 1500 spring discharge observations and the previously mentioned steady state observations. The adjustable parameters include 169 pilot points to adjust the transmissivity distribution, 28 pilot points to adjust the specific yield distribution, 5 river parameters to adjust riverbed conductance for the five river reaches, and 9 drain conductance parameters and 9 drain elevation parameters at model cells with spring records.

When data entry errors in the calibration targets were discovered in ESPAM Version 1.0, the coupled steady state/transient calibration was re-run using the corrected reach aggregations and upper Snake River calibration targets. Keeping all initial estimates of calibration parameters and the overall calibration methodology the same as were used for Version 1.0, making only the changes required for correcting the data entry errors in the previous calibration, the PEST calibration was re-run to generate ESPAM Version 1.1. The statistics and parameters discussed below are for ESPAM Version 1.1. These data entry errors, however, did not significantly affect results of the model simulation.

Steady State Calibration Model Fit

Model residuals (the difference between model-predicted and observed values) are generated by the PEST software, providing an indication of how well the model-predicted values match the observed values. Model statistics for the steady state calibration indicate an overall R^2 between measured and modeled aquifer water level observations of 0.9943. The standard error for the aquifer water level estimates is 17.84

ft indicating that about 95 percent of the modeled aquifer water levels are within about 35.6 ft of observed values, which represents less than 2% of the head change in the aquifer between St. Anthony and King Hill, Idaho. Figure 58 shows a scatter plot of model-predicted versus observed aquifer water levels. Figure 58 shows an excellent match between the predicted and observed aquifer water levels. A regression line for the data indicates a slope of .9936 and an intercept of 28.618. With a perfect match, each point in Figure 58 would fall on a line with a slope of 1 and an intercept of 0. Relative to the range of values on either axis, 28.618 is very nearly zero. Figure 59 shows a map with water level contours for both the model-predicted and observed aquifer potentiometric surface. Figure 59 also shows an excellent fit between the model and the steady state observations.

Steady state model-predicted versus observed discharge to river and springs is shown in a scatter plot in Figure 60. Figure 60 shows an excellent fit between model-predicted and observed discharges to the river, with an R^2 value of .9878. The regression line which fits the data in Figure 60 has a slope of 1.0107 and a y-intercept of 679,326. Table 25 lists the model-predicted and observed steady state river and spring discharges.

Transient Calibration Model Fit

Comparison of Simulated and Observed Transient Heads

One of the measures of a transient calibration is how well the model simulates measured aquifer water levels over time. Figures 61 through 65 show transient model-predicted versus observed water levels. On Figures 61 through 65, the transient comparisons are sited on maps of the study area with pointers to the location of each hydrograph. In each of these figures, the pink line represents the model-predicted values.

Wells with multiple measurements each year for a long period were selected to calibrate the ESPAM's model ability to replicate the seasonal changes in aquifer water level. Figures 61 and 62 show eight selected wells with seasonal fits. The ability of the model to replicate seasonal aquifer water level changes is a function of aquifer storage and transmissivity as well as the model recharge and discharge. Figures 61 and 62 show that the ESPAM does a very good job of matching seasonal aquifer water level data. The standard error for the seasonal aquifer water level ovservations is 1.84 ft.

Wells with a spring observation for each of many years were selected to test the ESPAM's ability to replicate the long-term trend of aquifer water levels for the calibration period. Figures 63 and 64 show model-predicted versus observed aquifer water level trend data. Similar to the seasonal data, a model's ability to match trend data is a function of aquifer storage, transmissivity and model recharge and discharge. Figures 63 and 64 show that the fit to trend data was very good. The standard error for the trend data is 5.83 ft.

Figure 65 shows the model's fit to the mass measurement data which was collected for three periods at the end of the calibration period. Figure 65 also shows a reasonable fit to the mass measurement data. The standard error for the mass measurement data is 5.17 ft.

Comparison of Simulated and Observed River Reach Gains

Figures 66 through 70 show the filtered modeled gains in the upper Snake River versus the filtered observed gains. Figures 71 through 75 show the same data, without the filtering. Figures 66 through 70 and 71 through 75 represent reach gains in the Ashton to Rexburg, Heise to Shelley, Shelley to Near Blackfoot, Near Blackfoot to

Neeley and Neeley to Minidoka reaches, respectively. The pink line in Figures 66 through 70 represents the model-predicted values. The observation data shown in Figures 66 through 70 is the filtered data shown in Figures 49 through 53, as previously discussed. In each river reach, no attempt was made to match the first five years of data due to the transient model warm-up period. As can be seen in Figures 66 through 70, the model does a reasonable job of predicting reach gains in each reach of the upper Snake River. For the Neeley to Minidoka reach, the measured data shows that the reach gain is somewhat erratic, year to year, but is a slight gain on the average. The model predicts an almost constant modest gain for Neeley to Minidoka. Inspection of Figure 53, the raw monthly reach gain observation data versus gage uncertainty for the Neeley to Minidoka reach, shows that this reach effectively, on the average, has a slight gain. Hence, the model-predicted value was considered reasonable.

Figures 71 through 75, the comparison of unfiltered model-predicted versus measured river gains, show the seasonal variation of both the measured and predicted river gains. The model generally under-predicts the month to month variation of the measured data; however, inspection of the unfiltered measured reach gains shows a significant amount of noise in the data, reflecting uncertainty in instantaneous river gage measurements.

Comparison of Simulated and Observed Spring Discharges

Figures 76 through 84 show the model-predicted versus observed spring discharges for the following springs: Devils Washbowl, Devils Corral, Blue Lakes, Crystal, Clear Lakes, Briggs, Box Canyon, Thousand Springs and Malad. As with previous transient hydrographs, the pink line represents the model-predicted values in

Figures 76 through 84. As can be seen in Figures 76 through 84, the model does an excellent job of predicting the magnitude of the spring discharge for each spring. The model underestimates the seasonal amplitude of spring discharge for Crystal, Briggs, Box Canyon, Thousand Springs and Malad. The measured seasonal amplitude for these springs is approximately 20% and the model-predicted seasonal amplitude is approximately 9%.

Calibrated Model Parameters

Aquifer Transmissivity

Simulation results indicate a wide range in transmissivity from about 125 to 4.9×10^7 ft^2/day (Figure 85). Riverbed and drain conductance ranges from 10.3 to 1.57×10^7 ft/day/ft. Final values for riverbed and drain conductance can be found in Tables 3 and 4, respectively. Figure 86 shows the ratio of the final ESPAM transmissivity to the preliminary steady state transmissivity. As can be seen in Figure 86, the preliminary steady state transmissivities were scaled by as much as an order of magnitude during the coupled steady state/transient calibration. This represents the amount of change required in the initial steady state transmissivity field in order to accommodate the transient data.

The map of the calibrated model transmissivity (Figure 85) shows that estimated transmissivity values tend to be lower along the margins of the plain and higher towards the center. Two major exceptions to this generalization include the Mud Lake barrier and the Great Rift. The Mud Lake barrier extends east to west across the aquifer from the Bitterroot Mountains to just south of the confluence of the Henrys Fork and the South Fork of the Snake River. The Great Rift extends north to south across the plain from the Big Lost River Valley to just west of American Falls Reservoir. The transmissivity of both of these features is lower and impedes ground water flow as evidenced by the more tightly spaced equipotential lines in these areas. These features in the calibrated transmissivity distribution match our current understanding of the aquifer.

Aquifer Storage

The transient component of a model calibration is primarily used to calibrate aquifer storage (storativity or specific yield). In the case of the ESPAM, the confined representation of the physically unconfined system uses aquifer storativity (rather than the unconfined parameter of specific yield). However, unlike a truly confined system, the storativity values expected for the ESPAM would be in the range of .001 to .3, a range much more typical of specific yield. For a truly confined aquifer, storativity values would be several orders of magnitude smaller.

During the coupled steady state/transient calibration, aquifer storage was calibrated at 28 pilot points (Figure 56) and interpolated to every model cell. Aquifer storage has a much lower degree of spatial variation, so fewer pilot points are required for calibration. The aquifer storage distribution ranges from 5.2×10^{-3} to 0.280 (Figure 87).

Drain Elevation

After the coupled steady state/transient calibration, drain elevations, which were modified as part of the calibration, were assessed relative to the ending steady state heads. It was noted that some of the ending drain elevations were within a few feet of the ending steady state heads. The ESHMC discussed the fact that the ending drain elevations were high relative to the ending steady state aquifer levels, with the potential result that drains would shut off with minor declines in aquifer water level. It was agreed that the true elevations of the drains are unknown but that an absolute discontinuation of major portions of spring discharge due to a minor change in aquifer water level would be unreasonable.

As previously noted, Equation 7 is the governing equation for aquifer discharge through a drain. Inspection of Equation 7 shows that discharge is directly proportional to the conductance of the drain as well as to the elevation differential between the aquifer level and the drain elevation. The ESHMC discussed the fact that drain elevations could be changed with a corresponding change in drain conductance to alleviate this concern without changing the calibration or any major functionality of the model. To achieve this modification, all drain elevations were checked against the ending aquifer water levels in the same model cell. Any drain elevation which was within 30 feet of the ending steady state aquifer water level was adjusted to an elevation 30 feet lower than the ending state aquifer water level at the drain location. A corresponding adjustment was made to the drain conductance in that model cell to keep the drain discharge the same. Table 4 lists the final values for drain conductance and drain elevation for each model cell representing a drain.

This modification was deemed a reasonable representation of the physical system of springs. In the ESPAM, all model cells, including drain cells, are 1-mile square. A model cell representing a drain should not be considered to represent an individual spring but rather the collective spring discharge along a 1-mile segment of the canyon wall. In the physical system, springs at high elevations will shut off with significant water level declines. This will still be represented in the model as a decline in the spring discharge represented in a model cell. However, it was deemed that the total discharge of a 1-mile segment was more likely to be reduced than to be eliminated by a realistic change in aquifer water level. Clearly, really significant changes (30 ft or more) in aquifer water levels from the steady state ending heads would result in the wholesale discontinuation of spring discharge in a model cell.

Model Limitations

As with any model of a natural system, the ESPAM has a degree of limitation and uncertainty. Simplifying assumptions must be made to model complex, natural systems. Components of the aquifer water budget which have the least certainty are irrigation return flows, recharge on non-irrigated lands and tributary underflow. As discussed in the Water Budget section, these elements were estimated based on the collective professional judgement of the modeling team and the ESHMC using existing published material. As previously discussed, there is a shortage of data on spring discharges and irrigation return flows. The ESPAM calibration would have been enhanced by the existence of additional measured or estimated spring discharge data and irrigation return flow measurements.

The ESPAM is a regional ground-water model. For this reason, the model is best used for broad-scale predictions. As previously noted, the user should avoid the temptation to model localized impacts, such as impacts to a specific spring.

A primary objective of the model development and calibration was the characterization of the interaction between the aquifer and the river. Although thousands of aquifer water level observations were used during the model calibration the model was optimized for prediction of impacts to the river due to water use on the plain. The model can be used to provide a general sense of ground-water to ground-water impacts, however, the model is best used for prediction of impacts to surface water resources at a regional scale due to ground-water use.

Despite these noted limitations, the ESPAM is the most thoroughly calibrated model in existence of the eastern Snake River Plain Aquifer. The extensive use of model calibration tools and the prevalence of available data yielded an excellent model calibration.

Related Reports

During ESPAM design and development, a total of thirty-five design documents were written to document important model and water budget decisions. Each design document chronicled the design alternatives, the final design and the rationale for selecting the final design. The design documents were distributed in draft form to the ESHMC for review and feedback. Many of the design documents went through multiple iterations as a result of feedback from ESHMC members either during or after design reviews. Throughout the ESPAM project, draft and final design documents were made available to the ESHMC via the IWRRI web site. If, in the course of final model development or calibration, the documented final design had to be changed, an 'as-built' version of the pertinent design document was released to document the change. Table 26 lists the ESPAM design documents and their status as of this writing.

Summary and Conclusions

This report documents the successful reformulation and calibration of the numerical ground-water model used for water management on the eastern Snake River Plain. The ESPAM was calibrated to 22 years of recharge and discharge data, as compared with the previous SRPAM model, which was calibrated to only one year of data. Calibration to a long span of years which include some of the driest and wettest years on record ensures that the model is capable of accurately simulating the response of the river/aquifer system to a broader spectrum of stresses.

The ESPAM was calibrated using the PEST suite of parameter estimation tools. Using PEST enabled the modeling team to optimize the fit of the model to thousands of observed aquifer water levels and streamflow measurements. The final calibrated ESPAM shows a significantly better fit to observed data than the previous SRPAM model.

A significant aspect of the ESPAM reformulation and calibration was the involvement of the ESHMC. The ESHMC, comprised of interested parties representing agencies, private industry and water user groups, oversaw the ESPAM reformulation and calibration process. Although the collaborative process used to develop the ESPAM took more time than the more streamlined, conventional model development process, it allowed ESHMC members an active voice in model design and implementation decisions and helped to eliminate bias. By including a broad spectrum of interested parties in the model reformulation and calibration, the committee members were able to gain a better understanding of model design details. The ultimate goal of the process was to allow discussions about future aquifer management decisions to center on policy interpretation and not on the scientific tools used in support of those decisions.

The outcome of any ground-water modeling effort is enhanced insight into the hydrologic processes being modeled. This was also true for the ESPAM reformulation and calibration. Development of the ESPAM underscored several significant gaps in either data or our understanding of the underlying hydrologic processes.

Recommendations for further work include:

a) Long-term collection of spring discharge data in the Thousand Springs area and in the Near Blackfoot to Neeley reach
b) Long-term collection of irrigation return flow data and development of numerical relationships between the collected data and measured surface irrigation diversion data
c) Continued refinement of estimates of evapotranspiration
d) Improved estimates of river gains and losses, including the use of new technology such as acoustic Doppler-based stream gaging instruments
e) Further research on the interaction between the river and the aquifer, particularly in the Thousand Springs and American Falls areas
f) Improved estimates of the contribution to the aquifer from tributary basins

Although every model represents a simplification of complex processes, with the ESPAM being no exception, the ESPAM is the best available tool for understanding the interaction between ground water and surface water on the eastern Snake River Plain. The science underlying the reformulation and calibration of the ESPAM reflects the best knowledge of the aquifer system available at this time. The ESPAM was calibrated to approximately 11,000 observed aquifer water levels and river gain and loss estimates. Calibration parameters indicate an excellent fit to the observed data, providing confidence that the ESPAM provides an excellent representation of the complex hydrologic system of the eastern Snake River Plain.

Complex water management decisions on the eastern Snake River Plain will be greatly enhanced by use of the ESPAM. The participation of the ESHMC members in the model design and calibration process provided members with unprecedented insight into the details of this complex numerical ground-water model, allowing committee members to make informed judgements regarding how the model is applied to aquifer management.

References

Allen, R.G. and C.E. Brockway. 1983. Estimating Consumptive Irrigation Requirements for Crops In Idaho. Idaho Water and Energy Resources Research Institute.

Allen, R.G. 2002. Draft revision of Estimating Consumptive Irrigation Requirements for Crops In Idaho, preliminary electronic data. University of Idaho.

Allen, R.G., M. Tasumi and R. Trezza. 2002. Crop-year 2000 SEBAL (METRIC) Estimates of Evapotranspriation, Snake River Plain, Idaho. Electronic data. University of Idaho.

Allen, R.G. 2003. Personal communication.

Allen, R.G., M. Tasumi and A. Morse. 2005. Satellite-based Evapotranspiration by METRIC and LANDSAT for Western States Water Management. U.S. Bureau of Reclamation Evapotranspiration Workshop, February 8-10, Ft. Collins, Colorado.

Anderson, M.P. and W. W. Woessner. 1992. "Applied groundwater modeling." Academic Press, San Diego, CA., 381p.

Anderson, S. R., 1991, Stratigraphy of the unsaturated zone and uppermost part of the Snake River Plain aquifer at the Idaho Chemical Processing Plant and Test Reactors Area, Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 91-4010, 71 p.

Booker, J., R.A. Young, C. M. Zhang, and H.J. Morel-Seytoux. 1990. HELM: An Integrated Model Applied to the South Platte Stream-Aquifer System, in Conference Proceedings: Groundwater Engineering and Management Conference. Colorado Water Resources Research Institute and The Office of the State Engineer.

Chavez-Morales, J. 1985. An Optimization and Simulation Methodology for Irrigation Planning. University of California, Davis.

Contor, B.A. 2002. Non-irrigated recharge for minor land use types, memorandum to Eastern Snake Plain Aquifer Model Enhancement Project Technical Committee.

Cosgrove, D.M., G.S. Johnson, S. Laney, and J. Lindgren, 1999, Description of the IDWR/UI Snake River Plain Aquifer Model: Idaho Water Resources Research Institute, University of Idaho, Moscow, ID, 120 p.

Covington, H.R. and J.N. Weaver, 1990, Geologic map and profile of the north wall of the Snake River Canyon. U.S. Geological Survey Miscellaneous Investigation Series, Maps I-1947A through I-1947E.

Daly, C. and G. Taylor, 1998. PRISM Briefing Book and Questionnaire, A Description of the PRISM Model for Spatially Distributing Observed Precipitation. Natural Resources Conservation Service Water and Climate Center and Oregon Climate Service, Oregon State University. (http://www.ocs.orst.edu/prism/nrcs_brief.html)

Daly, C., G.H. Taylor, W.P. Gibson, T. Parzybok, G.L. Johnson, and P.A. Pasteris, 1998. Development of High-Quality Spatial Climate Datasets for the United States. Presented at First International Conference on Geospatial Information in Agriculture and Forestry, Lake Buena Vista, FL, June 1-3, 1998b.

de Sonneville, J.L.J., 1974, Development of a digital ground-water model with application to aquifers in Idaho: University of Idaho unpublished thesis, Moscow, ID, 227 p.

Doherty, J. 2004. PEST Model-Independent Parameter Estimation Users Manual, Watermark Numerical Computing, 336 Cliveden Avenue, Corinda 4075, Brisbane, Australia

Doherty, J. 2003. Ground water model calibration using pilot points and regularization, Ground Water, vol. 41, no. 2, 170-177.

Doherty, J., and J.M. Johnston, 2003. Methodologies For Calibration And Predictive Analysis Of A Watershed Model. J. American Water Resources Association, vol 39, no 2, p 251-265.

Dreher, K. J., and D.R. Tuthill. 1999. Report regarding evaluation of irrigation diversion rates. Idaho Department of Water Resources Adjudication Bureau, report to the Snake River Basin Adjudication District Court.

Frederick, D. B. and G. S. Johnson. 1996. Estimation of hydraulic properties and development of a layered conceptual model for the Snake River Plain aquifer at the Idaho National Engineering Laboratory, Idaho: Idaho Water Resources Research Institute, University of Idaho, Moscow, ID, 80 p.

Garabedian, S.P. 1992. Hydrology and digital simulation of the regional aquifer system, eastern Snake River Plain, Idaho. USGS Professional Paper 1408. F.

Gee, G.W. 1988. Groundwater recharge in arid regions: review and critique of estimation methods, Hydrological Processes vol. 2, 255-266.

Goodell, S.A. 1988. Water use on the Snake River Plain, Idaho and Eastern Oregon. USGS.

Harbaugh, A.W., E.R. Banta, M.C. Hill, and M.G. McDonald, 2000. MODFLOW-2000, the U.S. Geological Survey modular ground-water model-user guide to modularization concepts and the ground-water flow process. USGS Open-File Report 00-92.

Hill, M.C. 1990. Preconditioned conjugate-gradient 2 (PCG2), a computer program for solving ground-water flow equations: U.S. Geological Survey Water-Resources Investigations Report 90-4048, 43 p.

Howser, S. 2002. General Manager, Aberdeen-Springfield Canal Company. Personal communication.

Hubble Engineering, Inc. and Associated Earth Sciences. 1991. Guidelines for the Evaluation of Irrigation Diversion Rates. Prepared for the State of Idaho Department of Water Resources.

Idaho Department of Agriculture. 1981 - 2002. Idaho Agricultural Statistics.

Idaho Department of Water Resources. 1980. RASA80LC. GIS shapefile and attribute tables of LANDSAT land cover classification.

Idaho Department of Water Resources. 1982. 1980 Inventory of Irrigated Cropland on the Snake River Plain. Idaho Image Analysis Facility.

Idaho Department of Water Resources. 1994. SRBAS91LU. GIS shapefile of land cover.

Idaho Department of Water Resources. 1997a. Upper Snake Basin Study.

Idaho Department of Water Resources. 1997b. SNAKLC92. GIS shapefile of land cover.

Idaho Department of Water Resources. 1997c. WellLog users manual.

Idaho Department of Water Resources. 1999. GIS point file, GPS locations of Mud Lake-area wells.

Idaho Department of Water Resources. 2001. Electronic data files containing surface water diversion (from the Reach Gain and Loss Program data set).

Idaho Department of Water Resources. 2002a. ESPAC2000. GIS shapefile of land cover.

Idaho Department of Water Resources. 2002b. Watermaster records available on microfiche and in paper files.

Idaho Water Resources Board. State of Idaho, State Water Plan. 1996.

Johnson, G.S., D.M. Cosgrove, S. Laney, and J. Lindgren, 1999, Conversion of the IDWR/UI ground water flow model to MODFLOW: the Snake River Plain aquifer model. Idaho Water Resources Research Institute, University of Idaho, Moscow, ID, 42 p.

Kjelstrom, L.C.. 1995a. Streamflow gains and losses in the Snake River and ground-water budgets for the Snake River Plain, Idaho and eastern Oregon: U.S. Geological Survey Professional Paper 1408-C, 47p.

Kjelstrom, L.C.. 1995b. Methods to estimate annual mean spring discharge to the Snake River between Milner Dam and King Hill, Idaho. U.S. Geological Survey Water Resources Investigations Report 95-4055.

Kuntz, M.A., H.R. Covington, and L.J. Schorr. 1992. An overview of basaltic volcanism of the eastern Snake River Plain, Idaho: in Regional Geology of eastern Idaho and Western Montana, eds. P.K. Link, M.A. Kuntz, and L.B. Platt, Geological Society America Memoir 179, pp. 227-267.

Lindholm, G.F., S.P. Garabedian, G.D. Newton, and R.L. Whitehead. 1988. Configuration of the Water Table and Depth to Water, Spring 1980, Water Level Fluctuations, and Water Movement in the Snake River Plain Regional Aquifer System, Idaho and Eastern Oregon. Map. USGS. Hydrologic Investigations Atlas HA-703.

Madsen, R. 2000. GIS point file, GPS location of Water District 01 measurement and diversion locations.

Mann, L., 1986. Hydraulic Properties Of Rock Units And Chemical Quality Of Water For INELl-1: A 10,365-Foot Deep Test Hole Drilled At The Idaho National Engineering Laboratory, Idaho. Idaho Falls, Idaho: U.S. Geological Survey

McDonald, M. G. and A.W. Harbaugh. 1988. A modular three-dimensional finite-difference ground-water flow model. U.S. Geological Survey Techniques of Water-Resources Investigations, Book 6, Chapter A1.

Mehl, S.W. and M.C. Hill, MODFLOW-2000. 2001. the U.S. Geological Survey Modular Ground-water model—user guide to the Link-AMG (LMG) package for solving matrix equations using an algebraic multigrid solver. U.S. Geological Survey Open-File Report 01-177.

Morse, A., M. Tasumi, R.G. Allen., W.J. Kramber. 2000. Final Report. Application of the SEBAL (METRIC) Methodology for Estimating Consumptive Use of Water and Streamflow Depletion in the Bear River Basin of Idaho Through Remote Sensing. Idaho Department of Water Resources and University of Idaho.

Morse, A. 2001. IDWR GIS Supervisor. Personal communication.

Newton, G.D., 1978, Application of a simulation model to the Snake Plain aquifer: University of Idaho unpublished thesis, Moscow, Idaho.

Norquest, E. 2002. Unpublished GIS shapefiles of irrigated lands within service areas. IDWR Adjudication Bureau.

Natural Resource Conservation Service. 1997. Natural Resource Inventory. Electronic data received via nri@rid8.nhq.nrcs.usda.gov.

Olenichak, T. 2003. Water District 01. Personal communication.

Rich, L.R. 1951. Forest and Range Vegetation. Transactions - American Society of Civil Engineers. Proceedings - Separate, No. 90.

Robertson, J. B., 1974, Digital modeling of radioactive and chemical waste transport in the Snake River Plain aquifer at the National Reactor Testing Station, Idaho: U.S. Geological Survey Open-File Report 74-1089, 41 p.

Shenton, G. 2002. Watermaster, Water District 31. Personal communication and unpublished paper water district records.

Sorenson Engineering. 2002. Unpublished electronic spreadsheet of power-plant discharge volumes.

Spinazola, J.M., 1994, Geohydrology and simulation of flow and water levels in the Mud Lake area of the eastern Snake River Plain, eastern Idaho: U.S. Geological Survey Water-Resources Investigations Report 93-4227, Boise, ID, 78 p.

Temple, D. 2002. A & B Irrigation District. Personal communication.

Twin Falls Canal Company. Circa 1955. Unpublished seepage study.

United States Bureau of Reclamation. 2003. Agrimet: The Pacific Northwest Cooperative Agricultural Weather Network. Internet website http://mac1.pn.usbr.gov/agrimet/h2ouse.html

U.S. Department of Agriculture, National Agricultural Statistics Service (NASS), 1992 and 1997. US Census of Agriculture. Electronic data on compact disk.

U.S. Department of Agriculture, National Agricultural Statistics Service (NASS), 2000. Published Estimates Data Base On Line. (http://www.nass.usda.gov:81/ipedb/front/html)

U.S. Geological Survey. 2002. Gauge station data. http://nwis.waterdata.usgs.gov/usa/nwis/discharge

Water District 01. 2003. Annual Reports 1980 - 2001.

Welhan, J. and T. Funderberg, 1997, Stochastic modeling of hydraulic conductivity in the Snake River Plain aquifer: 1. Hydrogeologic constraints and conceptual approach: Proceedings of the 32nd Symposium on Engineering Geology and Geotechnical Engineering, Boise, ID, March 26-28, 1997, pp. 75-91.

Whitehead, R.L., 1986. Geohydrologic Framework of the Snake River Plain, Idaho and Eastern Oregon. Atlas HA-681.

Wright, J.L. 1993. Nongrowing Season ET from Irrigated Fields, in Management of Irrigation and Drainage Systems. Conference proceedings, Irrigation and Drainage Division, American Society of Civil Engineers.

Tables in main document.

Table 1. Managed recharge volumes for eastern Snake River Plain.

Year	Volume (ac-ft)
1995	180,000
1996	169,000
1997	230,000
1998	201,000
1999	153,000
2000	70,000
2001 and later	none

Table 2. Start and end date for model stress periods. Irrigation season stress periods start on May 1 and end on October 31 of the same year. Non-irrigation season stress periods start on November 1 and end on April 30 of the following year.

Period	Start Month	End Month	Length (days)	Period	Start Month	End Month	Length (days)
SP001	May, 1980	Oct, 1980	182	SP023	May, 1991	Oct, 1991	182
SP002	Nov, 1980	April, 1981	183	SP024	Nov, 1991	April, 1992	183
SP003	May, 1981	Oct, 1981	182	SP025	May, 1992	Oct, 1992	182
SP004	Nov, 1981	April, 1982	183	SP026	Nov, 1992	April, 1993	183
SP005	May, 1982	Oct, 1982	182	SP027	May, 1993	Oct, 1993	182
SP006	Nov, 1982	April, 1983	183	SP028	Nov, 1993	April, 1994	183
SP007	May,1983	Oct, 1983	182	SP029	May, 1994	Oct, 1994	182
SP008	Nov, 1983	April, 1984	183	SP030	Nov, 1994	April, 1995	183
SP009	May, 1984	Oct, 1984	182	SP031	May, 1995	Oct, 1995	182
SP010	Nov, 1984	April, 1985	183	SP032	Nov, 1995	April, 1996	183
SP011	May, 1985	Oct, 1985	182	SP033	May, 1996	Oct, 1996	182
SP012	Nov, 1985	April, 1986	183	SP034	Nov, 1996	April, 1997	183
SP013	May, 1986	Oct, 1986	182	SP035	May, 1997	Oct, 1997	182
SP014	Nov, 1986	April, 1987	183	SP036	Nov, 1997	April, 1998	183
SP015	May, 1987	Oct, 1987	182	SP037	May, 1998.	Oct, 1998	182
SP016	Nov, 1987	April, 1988	183	SP038	Nov, 1998	April, 1999	183
SP017	May, 1988	Oct, 1988	182	SP039	May, 1999	Oct, 1999	182
SP018	Nov, 1988	April, 1989	183	SP040	Nov, 1999	April, 2000	183
SP019	May, 1989	Oct, 1989	182	SP041	May, 2000	Oct, 2000	182
SP020	Nov, 1989	April, 1990	183	SP042	Nov, 2000	April, 2001	183
SP021	May, 1990	Oct, 1990	182	SP043	May, 2001	Oct, 2001	182
SP022	Nov, 1990	April, 1991	183	SP044	Nov, 2001	April, 2002	183

Table 3. List of model cells containing river cells representing the Snake River.

Row	Column	Stage (ft)	Riverbed Conductance (ft^2/day)	River Bottom Elevation (ft)	Reach
52	200	5059.56	1.01E+06	5020.45	Ashton to Rexburg
52	201	5072.45	1.01E+06	5034.25	Ashton to Rexburg
53	197	5018.37	1.01E+06	4977.65	Ashton to Rexburg
53	198	5034.22	1.01E+06	4993.48	Ashton to Rexburg
53	199	5045.92	1.01E+06	5005.63	Ashton to Rexburg
54	182	4826.99	1.01E+06	4790.52	Ashton to Rexburg
54	183	4828.79	1.01E+06	4792.48	Ashton to Rexburg
54	184	4836.26	1.01E+06	4800.14	Ashton to Rexburg
54	185	4840.07	1.01E+06	4803.99	Ashton to Rexburg
54	186	4848.72	1.01E+06	4812.76	Ashton to Rexburg
54	187	4859.43	1.01E+06	4823.79	Ashton to Rexburg
54	188	4866.33	1.01E+06	4831.1	Ashton to Rexburg
54	189	4876.77	1.01E+06	4842.16	Ashton to Rexburg
54	190	4901.92	1.01E+06	4867.95	Ashton to Rexburg
54	191	4914.41	1.01E+06	4880.7	Ashton to Rexburg
54	192	4945.66	1.01E+06	4912.51	Ashton to Rexburg
54	193	4963.37	1.01E+06	4928.95	Ashton to Rexburg
54	194	4980.06	1.01E+06	4942.81	Ashton to Rexburg
54	195	4994.97	1.01E+06	4954.97	Ashton to Rexburg
54	196	5007.84	1.01E+06	4967.19	Ashton to Rexburg
55	180	4818.69	1.01E+06	4781.67	Ashton to Rexburg
55	181	4823.2	1.01E+06	4786.41	Ashton to Rexburg
56	178	4814.93	1.01E+06	4777.38	Ashton to Rexburg
56	179	4816.46	1.01E+06	4779.12	Ashton to Rexburg
56	168	4770.82	1.10E+05	4730.46	Heise to Shelley
56	169	4775.57	1.10E+05	4735.15	Heise to Shelley
56	170	4779.76	1.10E+05	4739.28	Heise to Shelley
57	166	4763.71	1.10E+05	4723.57	Heise to Shelley
57	167	4766.42	1.10E+05	4726.23	Heise to Shelley
57	170	4784.37	1.10E+05	4743.82	Heise to Shelley
57	177	4813.42	1.10E+05	4775.62	Heise to Shelley
58	166	4764.36	1.10E+05	4724.34	Heise to Shelley
58	167	4764.85	1.10E+05	4724.8	Heise to Shelley
58	171	4790.95	1.10E+05	4750.3	Heise to Shelley
58	174	4807.07	1.10E+05	4766.88	Heise to Shelley
58	175	4809.3	1.10E+05	4769.74	Heise to Shelley
58	176	4810.94	1.10E+05	4772.55	Heise to Shelley
59	165	4762.48	1.10E+05	4722.56	Heise to Shelley
59	166	4764.36	1.10E+05	4724.4	Heise to Shelley
59	171	4794.72	1.10E+05	4754.03	Heise to Shelley
59	174	4807.5	1.10E+05	4774.5	Heise to Shelley
60	164	4759.23	1.10E+05	4719.36	Heise to Shelley
60	172	4797.76	1.10E+05	4757.04	Heise to Shelley

Table 3 (contd.). List of model cells containing river cells representing the Snake River.

Row	Column	Stage (ft)	Riverbed Conductance (ft^2/day)	River Bottom Elevation (ft)	Reach
60	173	4802.84	1.10E+05	4762.07	Heise to Shelley
60	174	4811.5	1.10E+05	4778.5	Heise to Shelley
61	164	4758.28	1.10E+05	4718.46	Heise to Shelley
61	175	4830	1.10E+05	4797	Heise to Shelley
62	164	4755.48	1.10E+05	4715.76	Heise to Shelley
62	175	4837.5	1.10E+05	4804.5	Heise to Shelley
63	164	4753.39	1.10E+05	4713.72	Heise to Shelley
63	175	4844.5	1.10E+05	4811.5	Heise to Shelley
64	164	4749.19	1.10E+05	4709.61	Heise to Shelley
64	176	4865.5	1.10E+05	4832.5	Heise to Shelley
65	164	4744.68	1.10E+05	4705.43	Heise to Shelley
65	176	4873.5	1.10E+05	4840.5	Heise to Shelley
65	177	4884	1.10E+05	4851	Heise to Shelley
66	163	4739.41	1.10E+05	4700.6	Heise to Shelley
66	177	4896.5	1.10E+05	4863.5	Heise to Shelley
67	163	4737.56	1.10E+05	4699.08	Heise to Shelley
67	178	4912.5	1.10E+05	4879.5	Heise to Shelley
68	163	4735.39	1.10E+05	4697.22	Heise to Shelley
68	178	4926.5	1.10E+05	4893.5	Heise to Shelley
69	162	4720.53	1.10E+05	4682.79	Heise to Shelley
69	178	4788.82	1.10E+05	4755.82	Heise to Shelley
70	161	4707.02	1.10E+05	4669.82	Heise to Shelley
70	179	4770.5	1.10E+05	4737.5	Heise to Shelley
71	161	4701.45	1.10E+05	4664.52	Heise to Shelley
71	180	4786	1.10E+05	4753	Heise to Shelley
72	161	4690.55	1.10E+05	4654.02	Heise to Shelley
72	180	4797	1.10E+05	4764	Heise to Shelley
73	160	4677.21	1.10E+05	4641.1	Heise to Shelley
73	180	4809	1.10E+05	4776	Heise to Shelley
74	157	4647.71	1.10E+05	4612.6	Heise to Shelley
74	158	4658.3	1.10E+05	4622.86	Heise to Shelley
74	159	4665.72	1.10E+05	4630.04	Heise to Shelley
74	180	4816	1.10E+05	4783	Heise to Shelley
74	181	4818	1.10E+05	4785	Heise to Shelley
75	153	4606.84	1.10E+05	4572.26	Heise to Shelley
75	156	4629.01	1.10E+05	4594.46	Heise to Shelley
75	181	4818	1.10E+05	4785	Heise to Shelley
76	154	4610.81	1.10E+05	4576.84	Heise to Shelley
76	155	4617.41	1.10E+05	4583.2	Heise to Shelley
76	181	4818	1.10E+05	4785	Heise to Shelley
76	152	4598.48	1.57E+05	4561.11	Shelley to Near Blackfoot
77	151	4589.92	1.57E+05	4548.08	Shelley to Near Blackfoot
77	152	4595.78	1.57E+05	4556.51	Shelley to Near Blackfoot

Table 3 (contd.). List of model cells containing river cells representing the Snake River.

Row	Column	Stage (ft)	Riverbed Conductance (ft^2/day)	River Bottom Elevation (ft)	Reach
78	150	4575.03	1.57E+05	4532.01	Shelley to Near Blackfoot
79	149	4569.54	1.57E+05	4526.38	Shelley to Near Blackfoot
80	147	4553.89	1.57E+05	4510.25	Shelley to Near Blackfoot
80	148	4560.89	1.57E+05	4517.62	Shelley to Near Blackfoot
81	139	4491.97	1.57E+05	4453.9	Shelley to Near Blackfoot
81	140	4501.35	1.57E+05	4461.96	Shelley to Near Blackfoot
81	141	4513.71	1.57E+05	4472.78	Shelley to Near Blackfoot
81	142	4521.68	1.57E+05	4478.88	Shelley to Near Blackfoot
81	143	4527.72	1.57E+05	4484.18	Shelley to Near Blackfoot
81	144	4535.9	1.57E+05	4491.21	Shelley to Near Blackfoot
81	145	4541.93	1.57E+05	4497.1	Shelley to Near Blackfoot
81	146	4547.91	1.57E+05	4503.68	Shelley to Near Blackfoot
82	128	4418.1	1.57E+05	4383.03	Shelley to Near Blackfoot
82	129	4423.53	1.57E+05	4388.8	Shelley to Near Blackfoot
82	130	4431.3	1.57E+05	4396.07	Shelley to Near Blackfoot
82	131	4435.75	1.57E+05	4400.34	Shelley to Near Blackfoot
82	132	4442.82	1.57E+05	4407.11	Shelley to Near Blackfoot
82	133	4448.35	1.57E+05	4412.2	Shelley to Near Blackfoot
82	134	4456.59	1.57E+05	4419.38	Shelley to Near Blackfoot
82	135	4464.03	1.57E+05	4425.76	Shelley to Near Blackfoot
82	136	4472.21	1.57E+05	4433.43	Shelley to Near Blackfoot
82	137	4477.15	1.57E+05	4438.74	Shelley to Near Blackfoot
82	138	4485.21	1.57E+05	4447.49	Shelley to Near Blackfoot
83	127	4408.11	1.57E+05	4372.24	Shelley to Near Blackfoot
83	115	4354.09	9.90E+04	4314.81	Near Blackfoot to Neeley
83	116	4357.37	9.90E+04	4318.34	Near Blackfoot to Neeley
83	126	4402.41	9.90E+04	4365.84	Near Blackfoot to Neeley
84	114	4353.66	9.90E+04	4314.18	Near Blackfoot to Neeley
84	115	4354.09	9.90E+04	4314.81	Near Blackfoot to Neeley
84	116	4357.37	9.90E+04	4318.34	Near Blackfoot to Neeley
84	125	4393.24	9.90E+04	4354.98	Near Blackfoot to Neeley
84	126	4399.29	9.90E+04	4361.92	Near Blackfoot to Neeley
85	112	4353.76	9.90E+04	4313.88	Near Blackfoot to Neeley
85	113	4353.66	9.90E+04	4314.01	Near Blackfoot to Neeley
85	114	4353.66	9.90E+04	4314.18	Near Blackfoot to Neeley
85	115	4354.09	9.90E+04	4314.81	Near Blackfoot to Neeley
85	116	4357.37	9.90E+04	4318.34	Near Blackfoot to Neeley
85	122	4378.63	9.90E+04	4336.98	Near Blackfoot to Neeley
85	123	4382.95	9.90E+04	4342.12	Near Blackfoot to Neeley
85	124	4387.28	9.90E+04	4347.59	Near Blackfoot to Neeley
86	112	4353.76	9.90E+04	4313.88	Near Blackfoot to Neeley
86	113	4353.66	9.90E+04	4314.01	Near Blackfoot to Neeley
86	114	4353.66	9.90E+04	4314.18	Near Blackfoot to Neeley

Table 3 (contd.). List of model cells containing river cells representing the Snake River.

Row	Column	Stage (ft)	Riverbed Conductance (ft^2/day)	River Bottom Elevation (ft)	Reach
86	115	4353.66	9.90E+04	4314.27	Near Blackfoot to Neeley
86	116	4357.37	9.90E+04	4318.34	Near Blackfoot to Neeley
86	117	4359.68	9.90E+04	4320.81	Near Blackfoot to Neeley
86	118	4360.26	9.90E+04	4320.66	Near Blackfoot to Neeley
86	119	4363.43	9.90E+04	4323.18	Near Blackfoot to Neeley
86	120	4365.87	9.90E+04	4325.32	Near Blackfoot to Neeley
86	121	4373.64	9.90E+04	4332.18	Near Blackfoot to Neeley
87	111	4353.66	9.90E+04	4313.61	Near Blackfoot to Neeley
87	112	4353.76	9.90E+04	4313.88	Near Blackfoot to Neeley
87	113	4353.66	9.90E+04	4314.01	Near Blackfoot to Neeley
87	114	4353.66	9.90E+04	4314.18	Near Blackfoot to Neeley
88	107	4353.56	9.90E+04	4311.31	Near Blackfoot to Neeley
88	109	4353.67	9.90E+04	4313.3	Near Blackfoot to Neeley
88	110	4353.66	9.90E+04	4313.41	Near Blackfoot to Neeley
88	111	4353.66	9.90E+04	4313.61	Near Blackfoot to Neeley
88	112	4353.7	9.90E+04	4313.73	Near Blackfoot to Neeley
88	113	4353.66	9.90E+04	4314.01	Near Blackfoot to Neeley
88	114	4353.66	9.90E+04	4314.18	Near Blackfoot to Neeley
88	115	4353.66	9.90E+04	4314.18	Near Blackfoot to Neeley
89	106	4353.18	9.90E+04	4310.06	Near Blackfoot to Neeley
89	107	4353.56	9.90E+04	4311.31	Near Blackfoot to Neeley
89	108	4353.66	9.90E+04	4312.48	Near Blackfoot to Neeley
89	109	4353.67	9.90E+04	4313.3	Near Blackfoot to Neeley
89	110	4353.66	9.90E+04	4313.41	Near Blackfoot to Neeley
89	111	4353.66	9.90E+04	4313.61	Near Blackfoot to Neeley
89	112	4353.7	9.90E+04	4313.73	Near Blackfoot to Neeley
89	113	4353.66	9.90E+04	4314.01	Near Blackfoot to Neeley
89	114	4353.66	9.90E+04	4314.18	Near Blackfoot to Neeley
89	115	4353.66	9.90E+04	4314.18	Near Blackfoot to Neeley
90	104	4353.12	9.90E+04	4308.02	Near Blackfoot to Neeley
90	105	4352.87	9.90E+04	4308.82	Near Blackfoot to Neeley
90	106	4353.18	9.90E+04	4310.06	Near Blackfoot to Neeley
90	107	4353.56	9.90E+04	4311.31	Near Blackfoot to Neeley
90	108	4353.66	9.90E+04	4312.48	Near Blackfoot to Neeley
90	109	4353.67	9.90E+04	4313.16	Near Blackfoot to Neeley
90	110	4353.66	9.90E+04	4313.41	Near Blackfoot to Neeley
90	111	4353.66	9.90E+04	4313.61	Near Blackfoot to Neeley
90	112	4353.7	9.90E+04	4313.73	Near Blackfoot to Neeley
90	113	4353.66	9.90E+04	4314.01	Near Blackfoot to Neeley
90	114	4353.66	9.90E+04	4314.18	Near Blackfoot to Neeley
90	115	4353.66	9.90E+04	4314.18	Near Blackfoot to Neeley
91	103	4352.68	9.90E+04	4306.46	Near Blackfoot to Neeley
91	104	4353.12	9.90E+04	4308.02	Near Blackfoot to Neeley

Table 3 (contd.). List of model cells containing river cells representing the Snake River.

Row	Column	Stage (ft)	Riverbed Conductance (ft^2/day)	River Bottom Elevation (ft)	Reach
91	105	4353.29	9.90E+04	4308.74	Near Blackfoot to Neeley
91	106	4353.18	9.90E+04	4310.06	Near Blackfoot to Neeley
91	107	4353.56	9.90E+04	4311.31	Near Blackfoot to Neeley
91	108	4353.66	9.90E+04	4312.48	Near Blackfoot to Neeley
91	109	4353.67	9.90E+04	4313.16	Near Blackfoot to Neeley
91	110	4353.66	9.90E+04	4313.41	Near Blackfoot to Neeley
92	100	4348.82	9.90E+04	4299.47	Near Blackfoot to Neeley
92	101	4350.99	9.90E+04	4302.4	Near Blackfoot to Neeley
92	102	4352.79	9.90E+04	4305.13	Near Blackfoot to Neeley
92	103	4352.77	9.90E+04	4306.06	Near Blackfoot to Neeley
92	104	4353.12	9.90E+04	4308.02	Near Blackfoot to Neeley
92	105	4353.29	9.90E+04	4308.74	Near Blackfoot to Neeley
92	106	4353.18	9.90E+04	4310.06	Near Blackfoot to Neeley
92	107	4353.56	9.90E+04	4311.31	Near Blackfoot to Neeley
92	108	4353.66	9.90E+04	4312.48	Near Blackfoot to Neeley
92	109	4353.67	9.90E+04	4313.16	Near Blackfoot to Neeley
93	99	4327.91	9.90E+04	4277.3	Near Blackfoot to Neeley
93	100	4348.46	9.90E+04	4298.4	Near Blackfoot to Neeley
93	101	4350.99	9.90E+04	4302.4	Near Blackfoot to Neeley
93	102	4352.79	9.90E+04	4305.13	Near Blackfoot to Neeley
93	103	4352.77	9.90E+04	4306.06	Near Blackfoot to Neeley
94	99	4273.49	9.90E+04	4222.01	Near Blackfoot to Neeley
95	98	4240.65	9.90E+04	4188	Near Blackfoot to Neeley
95	99	4248.08	9.90E+04	4196.01	Near Blackfoot to Neeley
85	68	4172.75	3.51E+04	4123.2	Neeley to Minidoka
85	69	4190.45	3.51E+04	4140.28	Neeley to Minidoka
85	70	4192.86	3.51E+04	4141.68	Neeley to Minidoka
86	71	4195.25	3.51E+04	4142.87	Neeley to Minidoka
86	72	4195.28	3.51E+04	4141.95	Neeley to Minidoka
86	73	4195.02	3.51E+04	4141.09	Neeley to Minidoka
87	74	4195.44	3.51E+04	4140.29	Neeley to Minidoka
88	74	4196.01	3.51E+04	4140.01	Neeley to Minidoka
89	75	4195.99	3.51E+04	4138.93	Neeley to Minidoka
90	75	4196.08	3.51E+04	4138.09	Neeley to Minidoka
91	75	4195.54	3.51E+04	4136.65	Neeley to Minidoka
92	75	4195.62	3.51E+04	4135.82	Neeley to Minidoka
93	76	4196.07	3.51E+04	4134.87	Neeley to Minidoka
93	78	4196.18	3.51E+04	4133.16	Neeley to Minidoka
94	77	4195.92	3.51E+04	4132.94	Neeley to Minidoka
94	79	4196.18	3.51E+04	4133.16	Neeley to Minidoka
94	80	4196.18	3.51E+04	4133.49	Neeley to Minidoka
95	81	4196.18	3.51E+04	4134.13	Neeley to Minidoka
95	95	4196.6	3.51E+04	4140.24	Neeley to Minidoka

Table 3 (concluded). List of model cells containing river cells representing the Snake River.

Row	Column	Stage (ft)	Riverbed Conductance (ft^2/day)	River Bottom Elevation (ft)	Reach
95	96	4202.58	3.51E+04	4147.47	Neeley to Minidoka
95	97	4217.18	3.51E+04	4163.29	Neeley to Minidoka
96	82	4196.17	3.51E+04	4134.81	Neeley to Minidoka
96	83	4196.18	3.51E+04	4135.79	Neeley to Minidoka
96	90	4195.04	3.51E+04	4133.79	Neeley to Minidoka
96	93	4194.75	3.51E+04	4135.54	Neeley to Minidoka
96	94	4195.68	3.51E+04	4137.93	Neeley to Minidoka
97	84	4196.18	3.51E+04	4135.79	Neeley to Minidoka
97	85	4196.18	3.51E+04	4136.22	Neeley to Minidoka
97	86	4196.18	3.51E+04	4136.67	Neeley to Minidoka
97	87	4196.18	3.51E+04	4137.15	Neeley to Minidoka
97	88	4196.18	3.51E+04	4137.5	Neeley to Minidoka
97	89	4196.11	3.51E+04	4137.54	Neeley to Minidoka
97	91	4195.04	3.51E+04	4133.79	Neeley to Minidoka
97	92	4195.87	3.51E+04	4135.33	Neeley to Minidoka

Table 4. List of model cells containing drains representing springs in the Thousand Springs region.

Row	Column	Drain Elevation (ft) Elevation (ft)	Drain Conductance (ft^2/d)	Reach
70	30	3693.77	87.56523	Devils Washbowl to Buhl
69	29	3682	10.34861	Devils Washbowl to Buhl
68	29	3661	68.46006	Devils Washbowl to Buhl
66	28	3645.97	31711.91	Devils Washbowl to Buhl
65	28	3622.07	72169.5	Devils Washbowl to Buhl
65	27	3608.07	7904.277	Devils Washbowl to Buhl
64	26	3591	1273.676	Devils Washbowl to Buhl
62	24	3540.61	453546.3	Devils Washbowl to Buhl
61	23	3506	3502.608	Devils Washbowl to Buhl
59	22	3455	278.6165	Devils Washbowl to Buhl
58	21	3419.59	1512.49	Devils Washbowl to Buhl
57	20	3372	604.996	Devils Washbowl to Buhl
54	18	3250.03	941722.4	Devils Washbowl to Buhl
53	17	3241.2	103486.1	Devils Washbowl to Buhl
51	14	3180	254.8987	Buhl to Thousand Springs
50	13	3150.01	185533.5	Buhl to Thousand Springs
50	12	3128.01	456229.9	Buhl to Thousand Springs
49	11	3100.02	189105	Buhl to Thousand Springs
48	11	3100	1058810	Buhl to Thousand Springs
47	13	3128.27	149180.1	Buhl to Thousand Springs
47	12	3107.83	641034.8	Buhl to Thousand Springs
46	13	3115.92	179172.9	Buhl to Thousand Springs
46	12	3094.06	307529.7	Buhl to Thousand Springs
45	12	3075	404081.1	Thousand Springs
44	12	3059.08	15649154	Thousand Springs
43	12	3050	500578.1	Thousand Springs
42	12	3072.47	29734.38	Thousand Springs
42	13	3096.3	24060.39	Thousand Springs to Malad
41	13	3098.59	2168.47	Thousand Springs to Malad
40	13	3095.04	944.3784	Thousand Springs to Malad
39	14	3074.71	33836.27	Thousand Springs to Malad
38	14	3072.87	949.0182	Thousand Springs to Malad
37	14	3047	11480.96	Thousand Springs to Malad
37	13	3058	34838.79	Thousand Springs to Malad
36	14	3016	9501.488	Thousand Springs to Malad
36	16	3072.35	1118337	Malad
36	15	2998.77	1158866	Malad
35	14	3007	19541.74	Malad to Bancroft
34	14	2978.97	78008.92	Malad to Bancroft
33	14	2949.78	21851.87	Malad to Bancroft
32	14	2931.01	14574.1	Malad to Bancroft
31	14	2939.88	6660.319	Malad to Bancroft
31	13	2923.55	12483.49	Malad to Bancroft
30	13	2957.8	1236.11	Malad to Bancroft
25	6	2787	75081.41	Malad to Bancroft

Table 5. List of tributary basins.

Basin	Average Annual Tributary Valley Underflow for ESPAM Model (acre feet)	Average Annual Tributary Valley Underflow for ESPAM Model (ft^3)	Average Tributary Valley Underflow for ESPAM Model (ft^3/stress period)
American Falls	20,000	8.51E+08	4.25E+08
Big Lost River	48,000	2.09E+09	1.04E+09
Big Wood River	8,900	3.87E+08	1.93E+08
Birch Creek	69,000	3.02E+09	1.51E+09
Blackfoot River	12,000	5.03E+08	2.51E+08
Camas/Beaver Creeks	193,000	8.39E+09	4.20E+09
Clover Creek	8,900	3.87E+08	1.93E+08
Goose Creek	24,000	1.04E+09	5.22E+08
Henrys Fork	98,000	4.25E+09	2.13E+09
Lincoln/Ross Creeks	3,600	1.55E+08	7.73E+07
Little Lost River	138,000	5.99E+09	3.00E+09
Little Wood River	21,000	9.28E+08	4.64E+08
Medicine Lodge Creek	8,000	3.48E+08	1.74E+08
Palisades	6,200	2.71E+08	1.35E+08
Portneuf River	56,000	2.44E+09	1.22E+09
Raft River	75,000	3.25E+09	1.62E+09
Rexburg Bench	16,000	6.96E+08	3.48E+08
Rock Creek	45,000	1.97E+09	9.86E+08
Silver Creek	47,000	2.05E+09	1.02E+09
Teton River	2,700	1.16E+08	5.80E+07
Thorn Creek	5,300	2.32E+08	1.16E+08
Willow Creek	26,000	1.12E+09	5.61E+08

Table 6. List of perched non-Snake River reaches.

Reach	Acre Feet/Stress Period	Acre Feet/Year
Basin 31 Flood Control	1,929	3,857
Below Magic Reservoir	41,023	82,046
Big Lost River 1	7,279	14,557
Big Lost River 2	3,651	7,302
Big Lost River 3	4,511	9,022
Big Lost River 4	2,084	4,168
Big Lost River Flood Control	6,435	12,870
Big Wood River Below Gooding	3,493	6,985
Birch Creek	4,144	8,288
Birch Creek Hydropower Discharge	6,227	12,455
Camas Creek	13,827	27,654
Camas National Wildlife Refuge	3,712	7,425
Little Lost River	3,088	6,175
Little Lost River Flood Control	3,723	7,446
Little Wood River 1	2,436	4,873
Little Wood River 2	1,095	2,190
Little Wood River 3	1,699	3,397
Lone Tree Flood Control (Camas Creek)	3,079	6,157
Medicine Lodge Creek	16,202	32,404
Milner-Pickets (TFCC)	1,408	2,815
Mud Lake	4,514	9,028
Murtaugh Lake	1,675	3,351
Total	137,233	274,466

Table 7. List of canals represented with specified flux.

Canal Name
Northside Main
Northside Wilson Lake
Milner-Gooding
Aberdeen-Springfield
Northside Laterals above Rim

Table 8. Six-year average of measured lysimeter winter ET for Kimberly, Idaho.

Month	Average ET, mm/day	Average ET, ft/month
November	0.7	0.069
December	0.4	0.041
January	0.6	0.061
February	1.0	0.093

Table 9. Calculated Winter-Time ET Rates, Feet Per Month

Station	County	ID	Elev (ft)	Nov ET (ft)	Dec ET (ft)	Jan ET (ft)	Feb ET (ft)
Aberdeen Exp	Bingham	100010	4400	0.069	0.041	0.061	0.072
American Falls 3 NW	Power	100227	4320	0.069	0.041	0.061	0.075
Arco 3 SW	Butte	100375	5330	0.050	0.041	0.042	0.042
Ashton	Fremont	100470	5110	0.059	0.041	0.049	0.049
Blackfoot Fire Dept	Bingham	100915	4320	0.069	0.041	0.061	0.075
Bliss	Gooding	101002	3270	0.069	0.041	0.061	0.109
Burley FAA AP	Cassia	101303	4160	0.069	0.041	0.061	0.080
Dubois Exp	Clark	102707	5460	0.046	0.038	0.038	0.038
Fort Hall Indian Age	Bingham	103297	4500	0.069	0.041	0.061	0.069
Hamer 4 NW	Jefferson	103964	4800	0.069	0.041	0.060	0.060
Hazelton	Jerome	104140	3770	0.069	0.041	0.061	0.093
IF 16 SE	Bonneville	104456	5720	0.036	0.030	0.030	0.030
IF FAA AP	Bonneville	104457	4740	0.069	0.041	0.061	0.061
Jerome	Jerome	104670	3770	0.069	0.041	0.061	0.093
MacKay Ranger St	Custer	105462	5910	0.029	0.024	0.024	0.024
Minidoka Dam	Minidoka	105980	4210	0.069	0.041	0.061	0.079
Paul	Minidoka	106877	4150	0.069	0.041	0.061	0.080
Picabo	Blaine	107040	4880	0.068	0.041	0.057	0.057
Poc WB AP	Bannock	107211	4770	0.069	0.041	0.060	0.060
Richfield	Lincoln	107673	4310	0.069	0.041	0.061	0.075
Shoshone	Lincoln	108380	3970	0.069	0.041	0.061	0.086
St Anthony	Fremont	108022	4970	0.065	0.041	0.054	0.054

Table 10. Irrigation Entity Table

Entity ID	Entity Name	Irrigation Company(ies) Included in Entity
IESW01	A & B 1	A & B Irrigation District
IESW02	Aberdeen Springfield 1	Aberdeen Springfield Canal Co
IESW03	Arcadia 1	Arcadia Reservoir & Canal Co Ltd
IESW04	Bell Rapids 1	Bell Rapids Mutual Irrigation Co
IESW05	Big Lost River 3	Big Lost River Irrigation District
		Moore Water Users Association
		Darlington Land & Irrigation Co
IESW06	Big Spring 3	Banbury Pipe Company Inc
		Big Spring Water Users Assn
		Hagerman Water Users Association
IESW07	Big Wood 4	Justice Ditch Co
		Thorpe Ditch Co
		Big Wood Canal Company
		Mullins Canal & Reservoir Co
IESW08	Blaine 1	Blaine County Canal Co
IESW09	Burgess 5	Burgess Canal & Irrigating Co
		North Rigby Irrigation & Canal Co Inc
		Parks & Lewisville Irrigation Co Inc
		Rigby Canal & Irrigation Co
		Clark & Edwards Canal Company
IESW10	Burley 1	Burley Irrigation District
IESW11	Butte and Market 1	Butte & Market Lake Canal Co
IESW12	Canyon Creek 3	Enterprise Irrigation District
		Canyon Creek Lateral Ditch Assn
		Canyon Creek Canal Co Inc
IESW13	Consolidated Farmers 4	Roxana Canal Co
		Consolidated Farmers Canal Co Ltd
		Saurey-Sommer Ditch
		Island Ward Canal Co

Entity ID	Entity Name	Irrigation Company(ies) Included in Entity
IESW14	Corbett 4	Corbett Slough Ditch Company
		Eastern Idaho Water Co
		Little Butte Irrigation Co Ltd
		Younie Ditch Co
IESW15	Dewey 1	Dewey Canal Co
IESW16	Egin 2	Egin Bench Canals Inc
		St Anthony Union Canal Co
IESW17	Fall River 1	Fall River Irrigation Co
IESW18	Falls 3	Falls Irrigation District
		Warm Creek Irrigation Co
		Fort Hall Indian Reservation
IESW20	Harrison 5	Rudy Irrigation Canal Co Ltd
		Harrison Canal & Irrigation Co
		Kite And Nord Ditch
		Enterprise Canal Co Ltd
		Butler Island Canal Co
IESW21	Heise 1	Heise Canal
IESW22	Idaho 2	Snake River Valley Irrigation District
		Idaho Irrigation District
IESW23	Independent 6	Lowder Slough Canal Co
		West Labelle Irrigation Co Ltd
		Dilts Irrigation Company
		Ellis-Bramwell Ditch C0
		Independent Irrigation Co
		Labelle Irrigating Co
IESW24	Island 1	Island Irrigation Co
IESW25	Little Wood 2	Fish Creek Reservoir Company Inc
		Little Wood River Canal Co
IESW26	Long Island 1	Long Island Irrigation Co
IESW27	Milner 1	Milner Irrigation District
IESW28	Minidoka 1	Minidoka Irrigation District
		Owsley Canal Company
		Holley Water Users Assn
Entity ID	**Entity Name**	**Irrigation Company(ies) Included in Entity**
IESW29	Mud Lake 4	Level Canal Co Inc
		Mud Lake Water Users Inc
IESW30	New Sweden 7	Smith-Maxwell Ditch Co
		New Sweden Irrigation District
		Shattuck Irrigation Co.
		Stattuck Irrigation Co
		Long Island Canal Co
		Blackfoot Irrigation Co
		Woodville Canal Co
IESW31	North Fremont 1	North Fremont Canal Systems Inc
IESW32	North Side 4	King Hill Irrigation District
		North Side Canal Company Ltd
		American Falls Reservoir Dist #2
		Dba Bs Farms & Irrigation Co
IESW33	Osgood 4	Owners Mutual Irrigation Co
		Osgood Canal Co Inc

		H & W Water Users Association
		Bear Island Water Assn
IESW34	Peoples 8	Watson Slough Ditch And Irrigation Companies
		Peoples Canal & Irrigation Co
		Parsons Ditch Co
		Wearyrick Ditch Co
		Trego Ditch Co
		Danskin Ditch Company
		New Lavaside Ditch Company Limited
		Riverside Canal Co
IESW35	Progressive 2	Poplar Irrigation District
		Progressive Irrigation District
IESW36	Reid 6	Consolidated Feeder Canal Co
		Liberty Park Irrigation Co Inc
		Texas Slough Irrigating Canal Co
		Reid Canal Co
		Lenroot Canal Co
		Sunnydell Irrigation District

Entity ID	Entity Name	Irrigation Company(ies) Included in Entity
IESW37	Reno 1	Reno Ditch Company Inc
IESW38	Rexburg 1	Rexburg Irrigation Co C/O Keith Erikson
IESW39	Silky 2	Silky Lateral Ditch Water Users Assn
		Silky Irrigation District
IESW40	Southwest 2	Oakley Canal Co
		Southwest Irrigation District
IESW41	Twin Falls 1	Twin Falls Canal Co
IESW42	Twin Groves 6	Wilford Irrigation And Mfg Co
		Pioneer Ditch Co Ltd
		Twin Groves Irrigation & Manufacturing
		Salem Union Canal Co Ltd
		Farmers Friend Irrigation Co Ltd
		North Salem Agr & Mill Canal Inc
IESW43	Woodmansee Johnson 6	Woodmansee-Johnson Canal Company
		Teton Irrigation And Manufacturing Co
		Pincock Garner Ditch Association
		Pincock-Byington Ditch Co
		Wolf Ditch Company
		Teton Island Feeder Canal Co
IESW44	Jefferson 3	Jefferson Irrigation Co
		Producers Irrigation Co
		Monteview Canal Co Inc
		Monteview Canal Co Inc

Table 11. Sprinkler ratios used for interpolation between specific years.

ENTITY_ID	May-80	May-82	May-87	May-92	May-97	Oct-00
IEGW501	0.150	0.254	0.520	0.686	0.710	0.720
IEGW502	0.200	0.230	0.310	0.389	0.500	0.550
IEGW503	0.875	0.885	0.910	0.934	0.960	0.975
IEGW504	0.981	0.982	0.986	0.989	0.992	0.994
IEGW505	0.983	0.986	0.992	0.997	0.999	1.000
IEGW506	0.770	0.803	0.880	0.917	0.945	0.960
IEGW507	0.580	0.657	0.830	0.904	0.920	0.930
IEGW508	0.530	0.617	0.840	0.940	0.963	0.970
IEGW509	0.640	0.692	0.810	0.864	0.880	0.890
IEGW600	1.000	1.000	1.000	1.000	1.000	1.000
IESW000	0.333	0.373	0.499	0.555	0.610	0.634
IESW001	0.150	0.311	0.520	0.676	0.710	0.720
IESW002	0.825	0.847	0.900	0.919	0.930	0.936
IESW005	0.700	0.731	0.810	0.880	0.934	0.970
IESW007	0.147	0.165	0.215	0.239	0.263	0.276
IESW008	0.540	0.570	0.650	0.729	0.800	0.840
IESW009	0.015	0.050	0.130	0.185	0.220	0.250
IESW010	0.010	0.150	0.600	0.733	0.850	0.910
IESW011	0.440	0.467	0.530	0.560	0.590	0.610
IESW012	0.867	0.870	0.875	0.879	0.897	0.897
IESW014	0.210	0.286	0.450	0.545	0.640	0.700
IESW015	0.000	0.000	0.010	0.015	0.025	0.030
IESW016	0.050	0.136	0.750	0.808	0.860	0.890
IESW018	1.000	1.000	1.000	1.000	1.000	1.000
IESW019	1.000	1.000	1.000	1.000	1.000	1.000
IESW020	0.050	0.082	0.190	0.226	0.260	0.280
IESW022	0.250	0.384	0.650	0.763	0.850	0.900
IESW025	0.210	0.318	0.600	0.700	0.800	0.860
IESW027	0.000	0.000	0.230	0.307	0.360	0.380
IESW028	0.130	0.219	0.550	0.714	0.800	0.840
IESW029	0.035	0.068	0.150	0.240	0.320	0.420
IESW030	0.180	0.292	0.630	0.801	0.910	0.960
IESW031	0.950	0.961	0.980	0.998	1.000	1.000
IESW032	0.000	0.000	0.600	0.750	0.840	0.900
IESW033	0.970	0.976	0.990	0.996	1.000	1.000
IESW034	0.540	0.582	0.690	0.741	0.800	0.830
IESW035	0.020	0.056	0.190	0.278	0.360	0.410
IESW036	0.020	0.049	0.120	0.149	0.180	0.195
IESW037	0.145	0.229	0.420	0.608	1.000	1.000
IESW038	0.251	0.286	0.251	0.216	0.251	0.251
IESW039	0.270	0.296	0.270	0.243	0.270	0.270
IESW040	0.400	0.528	0.800	0.921	1.000	1.000
IESW041	0.000	0.017	0.120	0.188	0.250	0.285
IESW044	0.020	0.041	0.100	0.161	0.300	0.370
IESW051	0.000	0.000	0.000	0.000	0.040	0.070

IESW052	0.000	0.000	0.000	0.000	0.040	0.070
IESW053	0.530	0.560	0.610	0.630	0.645	0.660
IESW054	0.319	0.359	0.467	0.510	0.560	0.588
IESW055	0.000	0.007	0.026	0.041	0.059	0.072
IESW056	0.451	0.468	0.507	0.536	0.571	0.584
IESW057	0.648	0.676	0.767	0.813	0.813	0.813

Table 12. Measured Return Flow Sites.

Site #	Station #	Site Name	Location	
Henry's Fork River basin:				
1	13055300	Farmers Own Canal - Black Spring	Lat. 44 02'59"	Long. 111 32'20"
2	13055337	Rexburg Canal drain nr Thornton	Lat. 43 48'55"	Long. 111 53'15"
3	13050543	Independent Canal drain		
4	13056550	Texas Slough Canal nr Thornton	Lat. 43 47' 58"	Long. 111 54' 49"
5	13056600	Texas Slough nr Rexburg	Lat. 43 47'17"	Long. 111 53'45.
6	13056650	Liberty Park Canal	Lat. 43 47'24"	Long. 111 55'27"
7	13056850	Bannock Jim Spring Slough	Lat. 43 46'30"	Long. 111 56'11"
Snake River to American Falls Reservoir:				
8	13057000	Scott's Slough	Lat. 42 44'32"	Long. 111 58'20"
9	13057020	Dry Bed	Lat. 43 42'11"	Long. 112 04'13"
10	13057030	South Parks	Lat. 43 41'19"	Long. 112 03'47"
11	13057045	Butte Market Lake Canal	Lat. 43 39'20"	Long. 112 05'27"
12	13057100	Burgess drain nr Idaho Falls	Lat. 43 36'60"	Long. 112 03'03"
Near to and just below American Falls Reservoir:				
13	13069548	Sterling Waste	Lat. 43 01'49"	Long. 112 43'40"
14	13069565	Aberdeen Waste Drain	Lat.	Long.
15	13076210	Tartar Waste	Lat. 42 52'40"	Long. 112 51'23"
16	13077650	Rock Creek nr American Falls	Lat. 42 39'10"	Long. 113 01'00"

Table 12 (continued). Measured Return Flow Sites.

Site #	Station #	Site Name	Location	
Below American Falls Reservoir to King Hill:				
17	13082060	F drain nr Declo	Lat. 42 32' 48"	Long. 113 37' 14"
18	13082032	D-3 drain	Lat. 42 36'49"	Long. 113 36'10"
19	13082062	D-5 drain nr Rupert	Lat. 42 33'15"	Long. 113 38'38"
20	13082064	D-4 drain nr Rupert	Lat. 42 34'15"	Long. 113 38'25"
21	13082320	Marsh Creek nr Declo	Lat. 42 31'26"	Long. 113 40'02"
22	13082330	Spring Creek nr Declo	Lat. 42 31'01"	Long. 113 41'03"
23	13084705	D-16 drain nr Heyburn	Lat. 42 32'30"	Long. 113 45'24"
24	13084707	B drain nr Heyburn	Lat. 42 33'33"	Long. 113 47'01"
25	13085060	D-17 drain nr Heyburn	Lat. 42 32'53"	Long. 113 50'51"
26	13085065	Main drain North nr Heyburn	Lat. 42 33'02"	Long. 113 51'59"
27	13085070	G drain nr Burley	Lat. 42 31'56"	Long. 113 53'12"
28	13085080	J drain nr Burley	Lat. 42 31'53"	Long. 113 53'29"
29	13089690	Irr drain nr Hansen	Lat.	Long.
30	13089695	Twin Falls Coulee	Lat. 42 34'11"	Long. 114 20'32"
31	13090370	Fish Hatchery Waste 0	Lat. 42 35'29"	Long. 114 26'03"
32	13090460	Perrine Coulee nr Twin Falls	Lat. 42 35'53"	Long. 114 28'20"
33	13091733	Jerome Golf Course Drain 1	Lat. 42 38 03"	Long. 114 31'03"
34	13093150	Sonnickson drain	Lat. 42 38'40"	Long. 114 33'26"
35	13093190	Sucker Flat drain nr Filer (LSLQ)	Lat. 42 38'25"	Long. 114 35'30"
36	13093550	Cedar Draw nr Filer	Lat. 42 39'13"	Long. 114 39'15"
37	13093900	Waste I nr Buhl	Lat. 42 39'33"	Long. 114 41'28"
38	13094050	J8 at Rivers Edge	Lat. 42 40'27"	Long. 114 44'27"
39	13094700	Mud Creek nr Buhl	Lat. 42 39'33"	Long. 114 47'20"
40	13095060	Fish Hatchery drain upper	Lat. 42 32'60"	Long. 114 49'21"
41	13095061	Fish Hatchery drain lower	Lat. 42 40'01"	Long. 114 48' 60
42	13095360	S. Coulee (Cedar Draw)	Lat. 42 41'46	Long. 114 48'19"
43	13095490	Irr Ditch to Blind Canyon	Lat. 42 42'28"	Long. 114 4730"
44	13133785	Drain nr Bickel Springs	Lat. 42 45'28"	Long. 114 50'48"
45	13152450	Irr Ditch nr Bliss	Lat. 42 55'56"	Long. 115 00'19"
46	13152895	W. drain nr Tuttle (Drain to Malad River)	Lat. 42 51'50"	Long. 114 51' 58"

Table 13. Assignment of return flows, diversions to surface water entities.

Below American Falls:

Group	Irr. Entity	Assigned Return flows		Water Supply: Historic Diversions
1	IESW032	13152450	Irr. Ditch nr Bliss	13087000 T. F. Northside
		13152895	W. Dr. nr Tuttle (to Malad)	13086510 'A' Lateral in Gooding
		13133785	Drain nr Bickel Srings	13086520 N. Side Cross-cut
		13094050	J8 at Rivers Edge	
		13095490	Irr. Drain to Blind Canyon	
		13095360	S. Coulee(Ceder Draw)	
		13093150	Sonnickson drain	
		13091733	Jerome Golf drain	
2	IESW028	13085060	D-17 drain nr Heyburn	13080000 Minidoka Northside
		13085065	Main drain North nr Heyburn	
		13084707	B drain nr Heyburn	
		13084705	D-16 drain nr Heyburn	
		13082064	D-4 drain nr Rupert	
		13082062	D-5 drain nr Rupert	
		13082032	D-3 drain	
3	IESW010	13082060	F drain nr Declo	Minidoka South (13080500)
		13082320	Marsh Creek nr Declo	
		13082330	Spring Creek nr Declo	
		13085070	G drain nr Burley	
		13085080	J drain nr Burley	
4	IESW041	13089690	Irr drain nr Hansen	13087500 Twin Falls Southside Canal
		13089695	Twin Falls Coulee	
		13090370	Fish Hatchery Waste 0	
		13090460	Perrine Coulee nr Twin Falls	
		13093190	Sucker Flat drain nr Filer (LSLQ)	
		13093550	Cedar Draw nr Filer	
		13093900	Waste I nr Buhl	
		13094700	Mud Creek nr Buhl	
		13095061	Fish Hatchery drain lower	
		13095060	Fish Hatchery drain upper	

Table 13(continued). Assignment of return flows, diversions to surface water entities.

Above American Falls

Group	Irr. Entity	Assigned Return flows	Water Supply: Historic Diversions
5	IESW002	13069548 Sterling Waste 13069565 Aberdeen Waste Drain 13076210 Tartar Waste	13061610 Aberdeen Springfield Canal
6	IESW031	13055300 Farmers Own Canal - Black Spring	13047575 Farmers Own 13047305 Yellowstone 13047415 Marysville
7	IESW016	13050543 Independent Canal drain (Ave. of 1989-90 USGS Data)	13049725 St Anthony Canal 13049550 Last Chance 13050525 Egin Canal 13050530 St Anthony Union Fdr 13050535 Independant Canal
8	IESW011	13057045 Butte Market Lake Canal	13057025 Butte Market Lake
9	IESW036	13056550 Texas Slough Canal nr Thornton 13056650 Liberty Park Canal 13056850 Bannock Jim Spring Slough 13056600 Texas Slough nr Rexburg	13038392 Sunnydell Canal 13038426 Lenroot Canal 13038431 Reid Canal 13038435 Bannock Jim 13038436 Hill Pitinger 13038437 Nelson Cory 13038434 Texas Feeder 13055323 Rexburg Canal 13055334 Rexburg Irr.

Table 13(concluded). Assignment of return flows, diversions to surface water entities.

Above American Falls

Group	Irr. Entity	Assigned Return flows	Water Supply: Historic Diversions
10	IESW009	13057000 Scott's Slough	13038110 Burgess
	IESW020	13057020 Dry Bed	13038115 Clark & Edwards
	IESW023	13057030 South Parks	13038180 Rigby Canal
	IESW024	13057100 Burgess drain nr Idaho Falls	13037975 Eagle Rock
	IESW026		13037977 Eagle Rock ab Will Cr
			13037985 Enterprise
			13038025 Butler Island
`			13038030 Ross and Rand
			13038050 Steele Canal
			13038055 Harrison Canal
			13038065 Cheny Canal
			13038080 Butler Island #2
			13038095 Boomer Canal
			13038098 Kite & Nord
			13038145 Croft Pump
			13038387 Nelson Canal
			13038388 Mattson Creg
			1303838150 East Labelle
			13038205 Dilts Canal
			13038225 W. Labelle Long Is
			13038340 White Canal
			13038360 Bramwell
			13038362 Ellis Canal
			13038210 Island Canal

Table 14. Estimated return flow lags for the ten groups of surface irrigation entities.

Group	Irr. Entity	Results: Ann. Return and Lags					
1	IESW032	Total Annual Returned (%) =>		4.6			
		Month =>	1	2	3	4	5
		Lag. Ret. (%) =>	3	1.6	0	0	0
2	IESW028	Total Annual Returned (%) =>		4.80			
		Month =>	1	2	3	4	5
		Lag. Ret. (%) =>	2	1	1	1	0
3	IESW010	Total Annual Returned (%) =>		10.0			
		Month =>	1	2	3	4	5
		Lag. Ret. (%) =>	4	3	3	0	0
4	IESW041	Total Annual Returned (%) =>		6.4			
		Month =>	1	2	3	4	5
		Lag. Ret. (%) =>	3	2	1.5	0	0
5	IESW002	Total Annual Returned (%) =>		5.9			
		Month =>	1	2	3	4	5
		Lag. Ret. (%) =>	3	2	1	0	0
6	IESW031	Total Annual Returned (%) =>		19.5			
		Month =>	1	2	3	4	5
		Lag. Ret. (%) =>	7	4	3	3	2
7	IESW016	Total Annual Returned (%) =>		1.6			
		Month =>	1	2	3	4	5
		Lag. Ret. (%) =>	1	0.6	0	0	0
8	IESW011	Total Annual Returned (%) =>		1.8			
		Month =>	1	2	3	4	5
		Lag. Ret. (%) =>	1.8	0	0	0	0
9	IESW036	Total Annual Returned (%) =>		29.2			
	IESW038	Month =>	1	2	3	4	5
		Lag. Ret. (%) =>	12	10	5	2	1
10	IESW009	Total Annual Returned (%) =>		27.2			
	IESW020	Month =>	1	2	3	4	5
	IESW023	Lag. Ret. (%) =>	11	7	4	4	0
	IESW024						
	IESW026						

Table 15. Normalized annual Silver Creek flows.

Year	Annual (ac-ft)	Normalized Flux	Dampened Normalized Flux
1980/81	32383	1.17	1.06
1981/82	26539	0.96	0.99
1982/83	38543	1.39	1.13
1983/84	38628	1.39	1.13
1984/85	35633	1.29	1.1
1985/86	30812	1.11	1.04
1986/87	31684	1.14	1.05
1987/88	22700	0.82	0.94
1988/89	20691	0.75	0.92
1989/90	23278	0.84	0.95
1990/91	21075	0.76	0.92
1991/92	20976	0.76	0.92
1992/93	18595	0.67	0.89
1993/94	27301	0.99	1
1994/95	18327	0.66	0.89
1995/96	31272	1.13	1.04
1996/97	32242	1.16	1.05
1997/98	33892	1.22	1.07
1998/99	33167	1.2	1.07
1999/00	30072	1.09	1.03
2000/01	22677	0.82	0.94
2001/02	19090	0.69	0.9
Av Annual	27708	1	1

Table 16. Minor land use types.

Classification	**Acres**	**Percent of Study Area**	**Recharge Rate**
Dry Farm	95,000	1.3%	zero
Water and Wetlands	65,000	0.9%	Precipitation minus three feet/year
Cities and Industrial Areas	48,000	0.7%	Negative 1.2 feet/year

Table 17. Apportionment of Mud Lake fixed point pumpage.

Fixed Point	No. Wells	Adjusted No. Wells	Percent of Total Volume
Buck Springs	7	7	18%
Bybee	13	14	35%
Holley	6	8	21%
North Lake, East	12	7	18%
North Lake, West	3	3	8%

Table 18. Fixed point pumpage by stress period (ac-ft/stress period).

Stress Period	Snake/Teton Exchange Wells	Mud Lake Exchange Wells	Recharge Adjustment	Wetlands Adjustment
S1	-6,590	-76,926	0	-11,241
S2	0	-34,089	0	-5,294
S3	-13,082	-73,313	0	-11,241
S4	0	-17,936	0	-5,294
S5	-1,437	-57,902	0	-11,241
S6	0	0	0	-5,294
S7	-914	-23,598	0	-11,241
S8	0	0	0	-5,294
S9	-687	-15,563	0	-11,241
S10	0	0	0	-5,294
S11	-5,800	-69,008	0	-11,241
S12	0	0	0	-5,294
S13	-1,786	-60,730	0	-11,241
S14	0	0	0	-5,294
S15	-2,045	-112,847	0	-11,241
S16	0	0	417	-5,294
S17	-22,395	-167,982	12,933	-11,241
S18	0	-21,792	8,344	-5,294
S19	-7,379	-145,601	0	-11,241
S20	0	-42,358	0	-5,294
S21	-3,709	-159,949	626	-11,241
S22	-9,177	-52,773	8,344	-5,294
S23	-18,657	-145,528	12,725	-11,241
S24	-3,098	-40,742	8,344	-5,294
S25	-47,842	-163,418	30,246	-11,241
S26	0	-36,997	8,344	-5,294
S27	-998	-77,893	0	-11,241
S28	0	-49,972	0	-5,294
S29	-19,020	-156,706	0	-11,241
S30	0	0	0	-5,294
S31	-253	-34,435	0	-11,241
S32	0	-33,359	7,092	-5,294
S33	-448	-149,394	0	-11,241
S34	0	0	417	-5,294
S35	-103	-87,188	0	-11,241
S36	0	-14,917	1,669	-5,294
S37	-281	-52,254	0	-11,241
S38	0	0	0	-5,294
S39	-345	-62,114	0	-11,241
S40	0	0	0	-5,294
S41	-6,774	-166,460	0	-11,241
S42	-434	-43,060	0	-5,294
S43	-51,473	-175,595	37,963	-8,267
S44	0	0	12,308	-8,267
Average	-5,107	-59,600	3,404	-8,268
Annual Average	-10,215	-119,200	6,808	-16,535

Table 19. Evapotranspiration-indexed scale used to vary off-site pumping rates.

Year	Index	Year	Index
1980	0.94	1991	1.03
1981	0.98	1992	1.11
1982	0.97	1993	0.94
1983	0.96	1994	1.09
1984	0.94	1995	0.94
1985	1.01	1996	0.97
1986	1.03	1997	0.94
1987	1.07	1998	0.93
1988	1.10	1999	0.96
1989	1.03	2000	1.01

Table 20. Off-site well pumping for each model stress period (acre-ft per stress period).

Well ID	Location Name	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
1	Jefferson	-12,709	-410	-13,248	-405	-13,115	-401	-12,980	-393	-12,709	-422
2	Jefferson	-12,709	-410	-13,248	-405	-13,115	-401	-12,980	-393	-12,709	-422
3	Jefferson	-12,709	-410	-13,248	-405	-13,115	-401	-12,980	-393	-12,709	-422
4	Monteview	-6,338	-204	-6,609	-202	-6,540	-200	-6,474	-196	-6,338	-211
5	Monteview	-6,338	-204	-6,609	-202	-6,540	-200	-6,474	-196	-6,338	-211
6	Monteview	-6,338	-204	-6,609	-202	-6,540	-200	-6,474	-196	-6,338	-211
7	Producers	-1,479	-48	-1,542	-47	-1,526	-47	-1,510	-46	-1,479	-49
8	Producers	-1,479	-48	-1,542	-47	-1,526	-47	-1,510	-46	-1,479	-49

Well ID	Location Name	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
1	Jefferson	-13,655	-431	-13,926	-447	-14,465	-460	-14,874	-431	-13,926	-447
2	Jefferson	-13,655	-431	-13,926	-447	-14,465	-460	-14,874	-431	-13,926	-447
3	Jefferson	-13,655	-431	-13,926	-447	-14,465	-460	-14,874	-431	-13,926	-447
4	Monteview	-6,811	-215	-6,947	-223	-7,218	-229	-7,420	-215	-6,947	-223
5	Monteview	-6,811	-215	-6,947	-223	-7,218	-229	-7,420	-215	-6,947	-223
6	Monteview	-6,811	-215	-6,947	-223	-7,218	-229	-7,420	-215	-6,947	-223
7	Producers	-1,589	-50	-1,620	-52	-1,683	-54	-1,730	-50	-1,620	-52
8	Producers	-1,589	-50	-1,620	-52	-1,683	-54	-1,730	-50	-1,620	-52

Well ID	Location Name	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
1	Jefferson	-14,465	-431	-13,926	-464	-15,009	-393	-12,709	-456	-14,736	-393
2	Jefferson	-14,465	-431	-13,926	-464	-15,009	-393	-12,709	-456	-14,736	-393
3	Jefferson	-14,465	-431	-13,926	-464	-15,009	-393	-12,709	-456	-14,736	-393
4	Monteview	-7,218	-215	-6,947	-232	-7,484	-196	-6,338	-227	-7,353	-196
5	Monteview	-7,218	-215	-6,947	-232	-7,484	-196	-6,338	-227	-7,353	-196
6	Monteview	-7,218	-215	-6,947	-232	-7,484	-196	-6,338	-227	-7,353	-196
7	Producers	-1,683	-50	-1,620	-54	-1,746	-46	-1,479	-53	-1,715	-46
8	Producers	-1,683	-50	-1,620	-54	-1,746	-46	-1,479	-53	-1,715	-46

Well ID	Location Name	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40
1	Jefferson	-12,709	-405	-13,115	-393	-12,709	-389	-12,573	-401	-12,980	-422
2	Jefferson	-12,709	-405	-13,115	-393	-12,709	-389	-12,573	-401	-12,980	-422
3	Jefferson	-12,709	-405	-13,115	-393	-12,709	-389	-12,573	-401	-12,980	-422
4	Monteview	-6,338	-202	-6,540	-196	-6,338	-194	-6,274	-200	-6,474	-211
5	Monteview	-6,338	-202	-6,540	-196	-6,338	-194	-6,274	-200	-6,474	-211
6	Monteview	-6,338	-202	-6,540	-196	-6,338	-194	-6,274	-200	-6,474	-211
7	Producers	-1,479	-47	-1,526	-46	-1,479	-45	-1,463	-47	-1,510	-49
8	Producers	-1,479	-47	-1,526	-46	-1,479	-45	-1,463	-47	-1,510	-49

Well ID	Location Name	S41	S42	S43	S44
1	Jefferson	-13,655	-464	-15,009	-418
2	Jefferson	-13,655	-464	-15,009	-418
3	Jefferson	-13,655	-464	-15,009	-418
4	Monteview	-6,811	-232	-7,484	-209
5	Monteview	-6,811	-232	-7,484	-209
6	Monteview	-6,811	-232	-7,484	-209
7	Producers	-1,589	-54	-1,746	-49
8	Producers	-1,589	-54	-1,746	-49

Table 21. Annual spring discharge (north side only) in the Milner to King Hill reach.

Water Year	Discharge (cfs)
1980	6110
1981	5860
1982	5760
1983	5690
1984	6030
1985	5830
1986	6350
1987	6260
1988	5960
1989	5820
1990	5610
1991	5460
1992	5190
1993	5090
1994	5320
1995	5120
1996	5040
1997	5430
1998	5870
1999	5660
2000	5830
2001	5870
2002	5440

Table 22. Estimated spring discharge by sub-reach in the Milner to King Hill reach.

Subreach Name	Number of Model Cells	Total Discharge (cfs)	Subreach Proportion of Milner to King Hill Discharge
Devil’s Washbowl to Buhl Gage	17	1075	0.17
Buhl Gage to Thousand Springs	12	1700	0.28
Thousand Springs	4	1879	0.31
Billingsley Creek	10	204	0.03
Malad Gorge	2	1199	0.19
Malad Gorge to Bancroft Springs	10	97	0.02

Table 23. Model cells representing individually measured or estimated springs.

Spring	Row	Column
Devils Washbowl	66	28
Devils Corral	65	28
Blue Lakes	62	24
Crystal	54	18
Clear Lakes	50	12
	50	13
Briggs	49	11
Box	47	12
	47	13
Thousand Springs	44	12
Malad	36	15
	36	16

Table 24. Summary of spring discharge calibration target data.

Spring Name	Number of Observations	Start Date	End Date
Devils Washbowl	5657	4/6/85	9/30/00
Devils Corral	35	11/6/80	3/6/01
Blue Lakes	7470	5/1/80	9/15/02
Crystal	1802	6/3/85	2/18/02
Clear Lakes	56	10/13/82	1/16/02
Briggs	3462	5/19/80	9/30/98
Box	7458	5/1/80	9/30/00
Malad	217	12/1/84	12/1/02
Thousand Springs	236	5/1/80	12/1/02

Table 25. Steady state river gain and spring calibration targets and model predictions.

Spring or Reach Name	Steady State Target Discharge (ft^3/d)	Steady State Discharge (ft^3/d)
Ashton to Rexburg	2.72E+07	2.67E+07
Heise to Shelley	-5.14E+07	-5.19E+07
Shelley to Near Blackfoot	-6.43E+07	-6.35E+07
Near Blackfoot to Neeley	2.27E+08	2.28E+08
Neeley to Minidoka	7.08E+06	6.97E+06
Devils Washbowl to Buhl	8.66E+07	6.24E+07
Buhl to Thousand Springs	1.37E+08	1.32E+08
Thousand Ssprings	1.51E+08	1.70E+08
Thousand Springs to Malad	6.63E+06	5.34E+06
Malad	9.65E+07	1.04E+08
Malad to Bancroft	7.84E+06	1.14E+07

Table 26. Eastern Snake Plain Aquifer Model Enhancement Design Document Topics

Revised May, 2006

Model Design and Calibration Topic	Author	ESPAM Project Document Number	IWRRI Document Number	Status
Model Design Objectives	Paul Castelin, Donna Cosgrove	DDM-001		Final
Model Boundary	Allan Wylie	DDM-002	IWRRI04-016	Final
Model Layers	Allan Wylie	DDM-003	IWRRI04-019	Final
Model River Representation	Allan Wylie	DDM-010	IWRRI04-017	Final
Estimating Elevation of Wellheads and River Surface	Allan Wylie	DDM-011	IWRRI04-021	Final
Delineating the Bottom of the Aquifer	Allan Wylie	DDM-012	IWRRI04-015	Final
Steady State Response Functions	Donna Cosgrove, Gary Johnson	DDM-013		In Preparation
Transient Response Functions	Donna Cosgrove, Gary Johnson	DDM-014		In Preparation
Model Grid and Grid Orientation	Allan Wylie	DDM-015	IWRRI04-018	Final
Confined vs. Unconfined Aquifer Representation	Allan Wylie	DDM-016	IWRRI04-020	Final

Estimating Reach Gains in the Ashton/Heise to Milner Reach	Brenda Gilliland	DDM-017	IWRRI04-011	Final
Estimating Reach Gains in the Milner to King Hill Reach	Gary Johnson	DDM-018		In Revision
ESPAM Final Report	Donna Cosgrove	DDM-019	IWRRI06-002	Final

Recharge Calculation Topic	Author	ESPAM Project Document Number	IWRRI Document Number	Status
Determination of Crop Mix	Bryce Contor	DDW-001	IWRRI04-025	Final
Percolation, Runoff and Deficit Irrigation	Bryce Contor	DDW-002	IWRRI04-004	Final
Recharge from Precipitation on Non-Irrigated Lands	Bryce Contor	DDW-003	IWRRI04-006	Final
Tributary Underflow	Allan Wylie	DDW-004	IWRRI06-004	Final
Calculating Return Flow Lag Factors	Dick Lutz	DDW-005	N/A	Final
Aggregating Surface Water Canal Companies into Surface Water Irrigation Entities	Brenda Gilliland	DDW-008	IWRRI04-014	Final
Ground Water Irrigation Entities for Recharge Calculation	Bryce Contor	DDW-009	IWRRI04-026	Final
Traditional Evapotranspiration Calculation	Bryce Contor	DDW-010	IWRRI04-009	Final
PRISM Precipitation Maps	Brenda Gilliland	DDW-011	IWRRI04-013	Final
Estimating Irrigation Entity Diversions—Snake	Brenda Gilliland	DDW-012	IWRRI04-012	Final
Historical Gaging Station Locations	Brenda Gilliland	DDW-013	IWRRI04-022	Final

Historical Water Level Measurements	Suzy Shaub	DDW-014	Not assigned	Final
Land Use	Bryce Contor	DDW-015	IWRRI04-007	Final
Estimating ET Using SEBAL	Rick Allen	DDW-016		
Determining Source of Irrigation Water	Bryce Contor	DDW-017	IWRRI04-010	Final
Irrigation Conveyance Losses	Bryce Contor	DDW-020	IWRRI04-008	Final
ET Adjustment Factors	Bryce Contor	DDW-021	IWRRI06-005	Final
Discerning Method of Irrigation Water Application	Bryce Contor	DDW-022	IWRRI04-005	As-Built Version
Non-Snake Perched River Reach Seepage Estimates and Irrigation Diversions	Nathan Erickson	DDW-024	IWRRI06-003	Final
Fixed Point Pumping	Bryce Contor	DDW-026	IWRRI04-027	Final

Recharge Program Topic	Author	ESPAM Project Document Number	IWRRI Document Number	Status
GIS-Based Recharge Program Component Design	Jim Oakleaf	DDR-001	N/A	Final (incorporated in Recharge Tool as help files)
Preparing GIS Recharge Component Inputs	Bryce Contor	DDR-002	N/A	Available as May, 2004 training notes
Fortran-Based Recharge Program Component User's Guide	Donna Cosgrove	DDR-003		In preparation

Field Work Topic	Author	ESPAM Project Document Number	IWRRI Document Number	Status
ADCP Reach Gain Measurement Report—Spring/Fall, 2001	Idaho Power/USGS	DDF-001	N/A	Final
ADCP Reach Gain Measurement Final Report	Idaho Power/USGS	DDF-005	N/A	Final
Return Flow Measurement Plan	Idaho Power	DDF-006	N/A	Final
Return Flow Measurement Data Report—Year 1	Idaho Power	DDF-007	N/A	Final
Return Flow Measurement Data Report—Year 2	Idaho Power	DDF-008	N/A	Final

Scenario Topic	Author	ESPAM Project Document Number	IWRRI Document Number	Status
Base Case Scenario	IWRRI	DDS-001	IWRRI04-001	Final
Curtailment Scenario	IWRRI	DDS-004	IWRRI04-023	Final
No Changes in Surface Water Practices Scenario	IWRRI	DDS-003	IWRRI04-003	Final
Managed Recharge Scenario	IWRRI	DDS-002	IWRRI04-002	Final
Drought Scenario	IWRRI	DDS-005	IWRRI04-024	In preparation
Strawman Scenario	IWRRI	DDS-006	IWRRI05-003	In preparation
A&B Irrigation District Scenario	IWRRI	DDS-007		

Notes:

Web site for obtaining documents:

http://www.if.uidaho.edu/~johnson/ifiwrri/srpmrpts/index.html

DDM-nnn document number for model design documents

DDW-nnn document number for water budget design documents

DDR-nnn document number for recharge program design documents

DDF-nnn document number for field work design documents

DDS-nnn document number for scenario documents

Appendix A—Appendix Tables

Tables in Appendix

Table A-1. List of tributary basins and associated model cells.

Tributary	Model Row	Model Column	Tributary	Model Row	Model Column
Bannock Creek	100	110	Little Wood River	33	71
Bannock Creek	100	111	Little Wood River	33	72
Big Lost River	5	106	Medicine Lodge Cr.	19	171
Big Lost River	5	107	Medicine Lodge Cr.	19	172
Big Wood River	30	50	Palisades	75	181
Big Wood River	30	51	Palisades	75	182
Big Wood River	30	52	Palisades	76	180
Big Wood River	30	53	Palisades	76	181
Big Wood River	30	54	Palisades	77	180
Birch Creek	26	145	Portneuf River	102	121
Birch Creek	26	146	Raft River	93	77
Birch Creek	26	147	Raft River	93	78
Birch Creek	26	148	Raft River	93	79
Blackfoot River	85	152	Raft River	94	76
Blackfoot River	85	153	Raft River	94	77
Blackfoot River	86	151	Raft River	94	79
Blackfoot River	86	152	Raft River	94	80
Blackfoot River	87	151	Raft River	94	81
Camas/Beaver Creeks	19	183	Raft River	95	81
Camas/Beaver Creeks	19	184	Raft River	95	82
Camas/Beaver Creeks	19	185	Raft River	96	82
Camas/Beaver Creeks	20	198	Raft River	96	83
Camas/Beaver Creeks	20	199	Rexburg Bench	65	194
Camas/Beaver Creeks	21	199	Rexburg Bench	65	195
Camas/Beaver Creeks	21	200	Rexburg Bench	65	196
Camas/Beaver Creeks	22	200	Rexburg Bench	65	197
Camas/Beaver Creeks	22	201	Rexburg Bench	66	192
Clover Creek	23	15	Rexburg Bench	66	193
Clover Creek	23	16	Rexburg Bench	66	194
Goose Creek	100	34	Rexburg Bench	66	197
Goose Creek	100	35	Rexburg Bench	67	190
Goose Creek	101	36	Rexburg Bench	67	191
Goose Creek	101	37	Rexburg Bench	67	192
Henrys Fork	35	200	Rexburg Bench	68	187
Henrys Fork	36	200	Rexburg Bench	68	188
Henrys Fork	37	200	Rexburg Bench	68	189
Henrys Fork	38	200	Rexburg Bench	68	190
Henrys Fork	38	201	Rock Creek	96	90
Henrys Fork	39	201	Rock Creek	97	88

Tributary	Model Row	Model Column	Tributary	Model Row	Model Column
Henrys Fork	40	201	Silver Creek	33	65
Henrys Fork	41	202	Silver Creek	33	66
Henrys Fork	42	202	Silver Creek	33	67
Henrys Fork	43	202	Teton River	61	202
Henrys Fork	44	202	Teton River	62	199
Henrys Fork	45	201	Teton River	62	200
Henrys Fork	46	201	Teton River	62	201
Henrys Fork	47	201	Teton River	62	202
Henrys Fork	48	202	Teton River	63	199
Henrys Fork	49	202	Teton River	64	199
Henrys Fork	50	202	Teton River	65	199
Henrys Fork	51	201	Teton River	66	199
Henrys Fork	52	201	Teton River	67	198
Henrys Fork	53	200	Teton River	67	199
Henrys Fork	54	199	Thorn Creek	61	202
Henrys Fork	54	200	Thorn Creek	62	199
Henrys Fork	55	199	Thorn Creek	62	200
Henrys Fork	56	199	Thorn Creek	62	201
Lincoln/Ross Creeks	93	141	Thorn Creek	62	202
Lincoln/Ross Creeks	93	142	Thorn Creek	63	199
Lincoln/Ross Creeks	95	135	Thorn Creek	64	199
Lincoln/Ross Creeks	95	136	Thorn Creek	65	199
Lincoln/Ross Creeks	96	134	Thorn Creek	66	199
Lincoln/Ross Creeks	96	135	Thorn Creek	67	198
Lincoln/Ross Creeks	97	133	Thorn Creek	67	199
Lincoln/Ross Creeks	97	134	Thorn Creek	32	32
Lincoln/Ross Creeks	98	132	Thorn Creek	33	33
Lincoln/Ross Creeks	98	133	Thorn Creek	33	34
Little Lost River	23	126	Willow Creek	76	175
Little Lost River	23	127	Willow Creek	76	176
Little Lost River	24	127	Willow Creek	77	176
Little Lost River	24	128	Willow Creek	77	177
Little Lost River	24	129	Willow Creek	77	178
Little Lost River	25	129	Willow Creek	75	173
Little Lost River	25	130	Willow Creek	75	174
Little Lost River	25	131	Willow Creek	75	175
Rock Creek	97	89			
Rock Creek	97	91			
Rock Creek	97	92			
Rock Creek	98	92			
Rock Creek	98	93			
Rock Creek	99	93			
Rock Creek	99	94			

Table A-2. List of Perched reaches and associated model cells.

Tributary Name	Row	Column	Tributary Name	Row	Column
Basin 31 Flood Control	45	149	Basin 31 Flood Control	45	149
Basin 31 Flood Control	45	150	Basin 31 Flood Control	45	150
Below Magic Reservoir	34	50	Below Magic Reservoir	34	50
Below Magic Reservoir	30	50	Below Magic Reservoir	30	50
Below Magic Reservoir	31	50	Below Magic Reservoir	31	50
Below Magic Reservoir	31	51	Below Magic Reservoir	31	51
Below Magic Reservoir	33	51	Below Magic Reservoir	33	51
Below Magic Reservoir	32	51	Below Magic Reservoir	32	51
Below Magic Reservoir	34	51	Below Magic Reservoir	34	51
Big Lost River 1	24	112	Big Lost River 1	24	112
Big Lost River 1	24	113	Big Lost River 1	24	113
Big Lost River 1	26	111	Big Lost River 1	26	111
Big Lost River 1	5	107	Big Lost River 1	5	107
Big Lost River 1	8	107	Big Lost River 1	8	107
Big Lost River 1	33	110	Big Lost River 1	33	110
Big Lost River 1	18	113	Big Lost River 1	18	113
Big Lost River 1	22	113	Big Lost River 1	22	113
Big Lost River 1	22	114	Big Lost River 1	22	114
Big Lost River 1	6	107	Big Lost River 1	6	107
Big Lost River 1	7	107	Big Lost River 1	7	107
Big Lost River 1	9	107	Big Lost River 1	9	107
Big Lost River 1	9	108	Big Lost River 1	9	108
Big Lost River 1	10	108	Big Lost River 1	10	108
Big Lost River 1	11	108	Big Lost River 1	11	108
Big Lost River 1	11	109	Big Lost River 1	11	109
Big Lost River 1	12	109	Big Lost River 1	12	109
Big Lost River 1	12	110	Big Lost River 1	12	110
Big Lost River 1	13	110	Big Lost River 1	13	110
Big Lost River 1	13	111	Big Lost River 1	13	111
Big Lost River 1	15	111	Big Lost River 1	15	111
Big Lost River 1	15	112	Big Lost River 1	15	112
Big Lost River 1	14	111	Big Lost River 1	14	111
Big Lost River 1	29	109	Big Lost River 1	29	109
Big Lost River 1	16	112	Big Lost River 1	16	112
Big Lost River 1	17	112	Big Lost River 1	17	112
Big Lost River 1	17	113	Big Lost River 1	17	113
Big Lost River 1	19	113	Big Lost River 1	19	113
Big Lost River 1	20	113	Big Lost River 1	20	113
Big Lost River 1	20	114	Big Lost River 1	20	114
Big Lost River 1	21	114	Big Lost River 1	21	114
Big Lost River 1	23	113	Big Lost River 1	23	113
Big Lost River 1	25	111	Big Lost River 1	25	111
Big Lost River 1	25	112	Big Lost River 1	25	112
Big Lost River 1	30	109	Big Lost River 1	30	109
Big Lost River 1	30	110	Big Lost River 1	30	110
Big Lost River 1	27	110	Big Lost River 1	27	110
Big Lost River 1	27	111	Big Lost River 1	27	111
Big Lost River 1	28	109	Big Lost River 1	28	109
Big Lost River 1	28	110	Big Lost River 1	28	110
Big Lost River 1	31	110	Big Lost River 1	31	110

Table A-2 (continued). List of Perched reaches and associated model cells.

Tributary Name	Row	Column	Tributary Name	Row	Column
Big Lost River 1	32	110	Big Wood River Below Gooding	37	17
Big Lost River 1	34	109	Big Wood River Below Gooding	37	18
Big Lost River 1	34	110	Big Wood River Below Gooding	37	19
Big Lost River 1	35	110	Big Wood River Below Gooding	36	19
Big Lost River 2	38	110	Big Wood River Below Gooding	36	20
Big Lost River 2	38	111	Big Wood River Below Gooding	35	20
Big Lost River 2	42	112	Big Wood River Below Gooding	38	17
Big Lost River 2	42	113	Big Wood River Below Gooding	38	18
Big Lost River 2	42	114	Birch Creek	27	144
Big Lost River 2	39	111	Birch Creek	27	145
Big Lost River 2	39	112	Birch Creek	26	145
Big Lost River 2	36	110	Birch Creek	28	144
Big Lost River 2	37	110	Birch Creek Hydropower Discharge	25	149
Big Lost River 2	40	111	Birch Creek Hydropower Discharge	25	150
Big Lost River 2	40	112	Birch Creek Hydropower Discharge	26	147
Big Lost River 2	41	112	Birch Creek Hydropower Discharge	26	148
Big Lost River 2	43	115	Birch Creek Hydropower Discharge	26	149
Big Lost River 2	43	114	Camas Creek	29	193
Big Lost River 2	44	115	Camas Creek	29	194
Big Lost River 3	45	116	Camas Creek	33	180
Big Lost River 3	45	117	Camas Creek	33	181
Big Lost River 3	45	118	Camas Creek	33	182
Big Lost River 3	45	119	Camas Creek	33	183
Big Lost River 3	45	120	Camas Creek	33	184
Big Lost River 3	45	121	Camas Creek	35	172
Big Lost River 3	45	122	Camas Creek	35	173
Big Lost River 3	45	123	Camas Creek	35	174
Big Lost River 3	45	124	Camas Creek	35	175
Big Lost River 4	39	131	Camas Creek	30	190
Big Lost River 4	39	132	Camas Creek	30	191
Big Lost River 4	42	129	Camas Creek	30	192
Big Lost River 4	42	130	Camas Creek	30	193
Big Lost River 4	38	132	Camas Creek	31	189
Big Lost River 4	41	130	Camas Creek	31	190
Big Lost River 4	41	131	Camas Creek	31	191
Big Lost River 4	40	131	Camas Creek	31	192
Big Lost River 4	43	128	Camas Creek	32	184
Big Lost River 4	43	129	Camas Creek	32	185
Big Lost River 4	44	127	Camas Creek	32	186
Big Lost River 4	44	128	Camas Creek	32	187
Big Lost River 4	45	125	Camas Creek	32	188
Big Lost River 4	45	126	Camas Creek	32	189
Big Lost River 4	45	127	Camas Creek	34	173
Big Lost River Flood Control	48	115	Camas Creek	34	174
Big Lost River Flood Control	47	115	Camas Creek	34	175
Big Lost River Flood Control	46	115	Camas Creek	34	176
Big Lost River Flood Control	46	116	Camas Creek	34	177
Big Wood River Below Gooding	34	20	Camas Creek	34	178
Big Wood River Below Gooding	34	21	Camas Creek	34	179
Big Wood River Below Gooding	37	16	Camas Creek	34	180

Table A-2 (continued). List of Perched reaches and associated model cells.

Tributary Name	Row	Column	Tributary Name	Row	Column
Camas Creek	34	181	Little Wood River 1	43	59
Camas Creek	36	172	Little Wood River 1	43	60
Camas Creek	37	171	Little Wood River 1	44	57
Camas Creek	37	172	Little Wood River 1	44	58
Camas Creek	38	170	Little Wood River 1	44	59
Camas Creek	38	171	Little Wood River 1	45	54
Camas National Wildlife Refuge	41	165	Little Wood River 1	45	55
Camas National Wildlife Refuge	41	166	Little Wood River 1	45	56
Camas National Wildlife Refuge	41	167	Little Wood River 1	45	57
Camas National Wildlife Refuge	40	166	Little Wood River 2	45	53
Camas National Wildlife Refuge	42	165	Little Wood River 2	46	41
Camas National Wildlife Refuge	42	167	Little Wood River 2	46	42
Little Lost River	24	128	Little Wood River 2	46	43
Little Lost River	29	128	Little Wood River 2	44	39
Little Lost River	29	129	Little Wood River 2	44	48
Little Lost River	25	128	Little Wood River 2	45	38
Little Lost River	26	128	Little Wood River 2	45	39
Little Lost River	27	128	Little Wood River 2	45	40
Little Lost River	28	128	Little Wood River 2	45	41
Little Lost River	30	129	Little Wood River 2	45	43
Little Lost River	31	129	Little Wood River 2	45	44
Little Lost River	33	129	Little Wood River 2	45	45
Little Lost River	32	129	Little Wood River 2	45	46
Little Lost River Flood Control	24	128	Little Wood River 2	45	47
Little Wood River 1	35	71	Little Wood River 2	45	48
Little Wood River 1	39	65	Little Wood River 2	45	49
Little Wood River 1	39	66	Little Wood River 2	45	50
Little Wood River 1	39	67	Little Wood River 2	45	51
Little Wood River 1	39	68	Little Wood River 2	45	52
Little Wood River 1	33	71	Little Wood River 2	45	53
Little Wood River 1	34	71	Little Wood River 3	44	38
Little Wood River 1	36	71	Little Wood River 3	34	22
Little Wood River 1	36	72	Little Wood River 3	34	23
Little Wood River 1	37	71	Little Wood River 3	34	24
Little Wood River 1	37	72	Little Wood River 3	39	31
Little Wood River 1	38	67	Little Wood River 3	39	32
Little Wood River 1	38	68	Little Wood River 3	39	33
Little Wood River 1	38	69	Little Wood River 3	39	34
Little Wood River 1	38	70	Little Wood River 3	41	35
Little Wood River 1	38	71	Little Wood River 3	41	36
Little Wood River 1	40	62	Little Wood River 3	35	24
Little Wood River 1	40	63	Little Wood River 3	42	36
Little Wood River 1	40	64	Little Wood River 3	42	37
Little Wood River 1	40	65	Little Wood River 3	36	24
Little Wood River 1	41	60	Little Wood River 3	36	25
Little Wood River 1	41	61	Little Wood River 3	36	26
Little Wood River 1	41	62	Little Wood River 3	37	26
Little Wood River 1	41	63	Little Wood River 3	37	27
Little Wood River 1	42	60	Little Wood River 3	38	27
Little Wood River 1	42	61	Little Wood River 3	38	28

Table A-2 (concluded). List of Perched reaches and associated model cells.

Tributary Name	Row	Column
Little Wood River 3	38	29
Little Wood River 3	38	30
Little Wood River 3	38	31
Little Wood River 3	40	33
Little Wood River 3	40	34
Little Wood River 3	40	35
Little Wood River 3	43	37
Little Wood River 3	43	38
Little Wood River 3	44	38
Lone Tree Flood Control (Camas Cree	31	191
Lone Tree Flood Control (Camas Cree	32	191
Medicine Lodge Creek	22	170
Medicine Lodge Creek	22	171
Medicine Lodge Creek	21	171
Medicine Lodge Creek	19	171
Medicine Lodge Creek	20	171
Medicine Lodge Creek	23	169
Medicine Lodge Creek	23	170
Medicine Lodge Creek	24	169
Medicine Lodge Creek	25	167
Medicine Lodge Creek	25	168
Medicine Lodge Creek	25	169
Medicine Lodge Creek	26	167
Milner-Pickets (TFCC)	79	33
Milner-Pickets (TFCC)	79	39
Milner-Pickets (TFCC)	78	34
Milner-Pickets (TFCC)	78	35
Milner-Pickets (TFCC)	78	36
Milner-Pickets (TFCC)	78	37
Milner-Pickets (TFCC)	78	38
Mud Lake	39	156
Mud Lake	39	157
Mud Lake	41	158
Mud Lake	41	159
Mud Lake	41	160
Mud Lake	40	157
Mud Lake	40	158
Mud Lake	40	159
Mud Lake	40	160
Murtaugh Lake	79	33
Murtaugh Lake	80	33

Table A-3. List of canals and associated model cells.

Canal Name	Row	Column	Canal Name	Row	Column
Northside Main	54	31	Milner Gooding	58	38
Northside Main	54	32	Milner Gooding	60	39
Northside Main	41	25	Milner Gooding	60	40
Northside Main	41	26	Milner Gooding	59	38
Northside Main	42	26	Milner Gooding	59	39
Northside Main	46	27	Milner Gooding	61	40
Northside Main	40	24	Milner Gooding	61	41
Northside Main	40	25	Milner Gooding	62	41
Northside Main	43	26	Milner Gooding	63	41
Northside Main	44	26	Milner Gooding	63	42
Northside Main	44	27	Milner Gooding	64	40
Northside Main	45	27	Milner Gooding	64	41
Northside Main	69	37	Milner Gooding	65	40
Northside Main	47	27	Milner Gooding	73	43
Northside Main	53	31	Milner Gooding	73	44
Northside Main	55	32	Milner Gooding	74	42
Northside Main	55	33	Milner Gooding	74	43
Northside Main	56	33	Milner Gooding	75	43
Northside Main	57	33	Aberdeen Springfield	79	115
Northside Main	60	33	Aberdeen Springfield	79	116
Northside Main	60	34	Aberdeen Springfield	79	117
Northside Main	59	33	Aberdeen Springfield	79	126
Northside Main	61	34	Aberdeen Springfield	78	127
Northside Main	62	34	Aberdeen Springfield	78	128
Northside Main	62	35	Aberdeen Springfield	78	129
Northside Main	63	35	Aberdeen Springfield	78	130
Northside Main	63	36	Aberdeen Springfield	78	131
Northside Main	64	36	Aberdeen Springfield	78	132
Northside Main	65	36	Aberdeen Springfield	78	133
Northside Main	66	35	Aberdeen Springfield	78	134
Northside Main	66	36	Aberdeen Springfield	78	135
Northside Main	67	35	Aberdeen Springfield	78	136
Northside Main	67	36	Aberdeen Springfield	78	137
Northside Main	68	36	Aberdeen Springfield	78	138
Northside Main	68	37	Aberdeen Springfield	79	139
Northside Wilson Lake	72	39	Aberdeen Springfield	79	140
Northside Wilson Lake	70	37	Aberdeen Springfield	79	141
Northside Wilson Lake	70	38	Aberdeen Springfield	80	118
Northside Wilson Lake	71	38	Aberdeen Springfield	80	119
Northside Wilson Lake	71	39	Aberdeen Springfield	80	120
Milner Gooding	54	40	Aberdeen Springfield	80	121
Milner Gooding	54	41	Aberdeen Springfield	80	124
Milner Gooding	53	41	Aberdeen Springfield	80	125
Milner Gooding	55	39	Aberdeen Springfield	80	142
Milner Gooding	55	40	Aberdeen Springfield	80	143
Milner Gooding	56	39	Aberdeen Springfield	80	144
Milner Gooding	56	40	Aberdeen Springfield	80	145
Milner Gooding	57	38	Aberdeen Springfield	81	122
Milner Gooding	57	39	Aberdeen Springfield	81	123

Table A-3 (concluded). List of canals and associated model cells.

Canal Name	Row	Column
Northside Laterals Above Rim	48	14
Northside Laterals Above Rim	48	15
Northside Laterals Above Rim	48	25
Northside Laterals Above Rim	48	26
Northside Laterals Above Rim	41	15
Northside Laterals Above Rim	41	16
Northside Laterals Above Rim	41	17
Northside Laterals Above Rim	42	17
Northside Laterals Above Rim	46	21
Northside Laterals Above Rim	49	15
Northside Laterals Above Rim	49	16
Northside Laterals Above Rim	49	17
Northside Laterals Above Rim	49	18
Northside Laterals Above Rim	39	18
Northside Laterals Above Rim	40	18
Northside Laterals Above Rim	40	19
Northside Laterals Above Rim	40	22
Northside Laterals Above Rim	40	23
Northside Main	40	24
Northside Laterals Above Rim	45	13
Northside Laterals Above Rim	45	14
Northside Laterals Above Rim	43	14
Northside Laterals Above Rim	43	17
Northside Laterals Above Rim	43	18
Northside Laterals Above Rim	44	13
Northside Laterals Above Rim	44	14
Northside Laterals Above Rim	46	14
Northside Laterals Above Rim	46	15
Northside Laterals Above Rim	50	14
Northside Laterals Above Rim	50	18
Northside Laterals Above Rim	50	19
Northside Laterals Above Rim	50	20
Northside Laterals Above Rim	47	15
Northside Laterals Above Rim	47	16
Northside Laterals Above Rim	47	17
Northside Laterals Above Rim	47	21
Northside Laterals Above Rim	47	22
Northside Laterals Above Rim	47	23
Northside Laterals Above Rim	47	24
Northside Laterals Above Rim	47	25
Northside Laterals Above Rim	51	15
Northside Laterals Above Rim	51	16
Northside Laterals Above Rim	51	20
Northside Laterals Above Rim	52	16
Northside Laterals Above Rim	52	17
Northside Laterals Above Rim	52	18
Northside Laterals Above Rim	52	19
Northside Laterals Above Rim	53	19

Table A-4. Crop Mix Fractions for Irrigated Crops in the Eastern Snake Plain Aquifer Model Enhancement Project

Study Area.

County	Year	Alfalfa	Barley	DrBean	GrCorn	SilCorn	Oats	Potatoes	SugBeet	SprWht	WinWht
Bannock	1980	0.12	0.23	0.000	0.000	0.000	0.006	0.036	0.000	0.21	0.40
Bingham	1980	0.15	0.11	0.000	0.001	0.013	0.007	0.185	0.024	0.34	0.17
Blaine	1980	0.51	0.34	0.000	0.000	0.000	0.026	0.000	0.000	0.09	0.03
Bonneville	1980	0.12	0.26	0.000	0.001	0.005	0.005	0.167	0.000	0.19	0.25
Butte	1980	0.52	0.29	0.000	0.000	0.000	0.023	0.053	0.000	0.09	0.02
Cassia	1980	0.17	0.15	0.024	0.002	0.032	0.005	0.097	0.087	0.12	0.31
Clark	1980	0.42	0.18	0.000	0.000	0.000	0.000	0.093	0.000	0.10	0.20
Fremont	1980	0.08	0.55	0.000	0.000	0.000	0.008	0.185	0.000	0.14	0.04
Gooding	1980	0.36	0.07	0.033	0.093	0.083	0.009	0.104	0.015	0.10	0.12
Jefferson	1980	0.40	0.24	0.000	0.000	0.015	0.008	0.109	0.000	0.22	0.00
Jerome	1980	0.30	0.08	0.091	0.024	0.027	0.004	0.088	0.044	0.25	0.09
Lincoln	1980	0.39	0.16	0.004	0.016	0.054	0.009	0.061	0.075	0.18	0.06
Madison	1980	0.09	0.36	0.000	0.000	0.014	0.006	0.201	0.000	0.22	0.11
Minidoka	1980	0.12	0.19	0.043	0.004	0.035	0.004	0.088	0.209	0.25	0.05
Power	1980	0.04	0.04	0.000	0.000	0.000	0.002	0.084	0.040	0.32	0.47
Twin Falls	1980	0.28	0.10	0.205	0.039	0.036	0.005	0.061	0.044	0.10	0.13
Bannock	1981	0.13	0.27	0.000	0.000	0.000	0.010	0.040	0.000	0.15	0.40
Bingham	1981	0.14	0.14	0.000	0.001	0.010	0.006	0.199	0.027	0.31	0.16
Blaine	1981	0.50	0.38	0.000	0.000	0.000	0.018	0.000	0.000	0.08	0.03
Bonneville	1981	0.12	0.28	0.000	0.000	0.001	0.006	0.183	0.000	0.11	0.30
Butte	1981	0.52	0.32	0.000	0.000	0.000	0.023	0.054	0.000	0.06	0.02
Cassia	1981	0.17	0.15	0.025	0.002	0.028	0.005	0.109	0.084	0.10	0.31
Clark	1981	0.41	0.22	0.000	0.000	0.000	0.000	0.109	0.000	0.10	0.16
Fremont	1981	0.08	0.58	0.000	0.000	0.000	0.007	0.185	0.000	0.13	0.03
Gooding	1981	0.40	0.06	0.036	0.096	0.081	0.012	0.122	0.018	0.09	0.09
Jefferson	1981	0.39	0.28	0.000	0.001	0.016	0.008	0.120	0.000	0.18	0.00
Jerome	1981	0.30	0.12	0.090	0.028	0.022	0.004	0.099	0.041	0.21	0.09

County	Year	Alfalfa	Barley	DrBean	GrCorn	SilCorn	Oats	Potatoes	SugBeet	SprWht	WinWht
Lincoln	1981	0.38	0.21	0.004	0.012	0.051	0.008	0.064	0.056	0.17	0.05
Madison	1981	0.08	0.43	0.000	0.000	0.009	0.005	0.200	0.000	0.16	0.12
Minidoka	1981	0.13	0.21	0.044	0.002	0.029	0.002	0.097	0.208	0.23	0.06
Power	1981	0.04	0.05	0.000	0.000	0.000	0.002	0.095	0.030	0.31	0.47
Twin Falls	1981	0.28	0.12	0.200	0.050	0.031	0.004	0.065	0.053	0.08	0.12
Bannock	1982	0.12	0.30	0.000	0.000	0.000	0.010	0.041	0.000	0.17	0.36
Bingham	1982	0.15	0.14	0.000	0.000	0.010	0.006	0.214	0.022	0.30	0.16
Blaine	1982	0.50	0.40	0.000	0.000	0.000	0.014	0.000	0.000	0.07	0.03
Bonneville	1982	0.11	0.32	0.000	0.000	0.002	0.007	0.181	0.000	0.11	0.27
Butte	1982	0.52	0.31	0.000	0.000	0.000	0.020	0.057	0.000	0.07	0.02
Cassia	1982	0.16	0.15	0.022	0.001	0.023	0.004	0.101	0.071	0.16	0.31
Clark	1982	0.34	0.23	0.000	0.000	0.000	0.000	0.091	0.000	0.24	0.10
Fremont	1982	0.08	0.60	0.000	0.000	0.000	0.006	0.196	0.000	0.09	0.02
Gooding	1982	0.39	0.10	0.035	0.085	0.066	0.014	0.121	0.021	0.06	0.11
Jefferson	1982	0.38	0.28	0.000	0.001	0.019	0.009	0.121	0.000	0.18	0.00
Jerome	1982	0.29	0.12	0.089	0.032	0.019	0.004	0.099	0.037	0.20	0.10
Lincoln	1982	0.36	0.20	0.004	0.013	0.043	0.008	0.062	0.068	0.17	0.07
Madison	1982	0.07	0.46	0.000	0.000	0.005	0.003	0.181	0.000	0.19	0.09
Minidoka	1982	0.12	0.22	0.043	0.002	0.025	0.001	0.096	0.191	0.23	0.07
Power	1982	0.04	0.09	0.000	0.000	0.000	0.002	0.095	0.034	0.30	0.44
Twin Falls	1982	0.27	0.12	0.195	0.061	0.025	0.004	0.066	0.054	0.09	0.12
Bannock	1983	0.14	0.35	0.000	0.000	0.000	0.010	0.026	0.000	0.11	0.36
Bingham	1983	0.17	0.14	0.000	0.001	0.014	0.013	0.223	0.025	0.24	0.17
Blaine	1983	0.51	0.35	0.000	0.000	0.000	0.014	0.000	0.000	0.10	0.03
Bonneville	1983	0.12	0.30	0.000	0.000	0.004	0.004	0.174	0.000	0.11	0.29
Butte	1983	0.54	0.29	0.000	0.000	0.000	0.027	0.048	0.000	0.07	0.02
Cassia	1983	0.17	0.13	0.024	0.001	0.036	0.004	0.116	0.073	0.17	0.28
Clark	1983	0.34	0.25	0.000	0.000	0.000	0.000	0.034	0.000	0.27	0.11
Fremont	1983	0.08	0.58	0.000	0.000	0.000	0.005	0.213	0.000	0.09	0.03
Gooding	1983	0.43	0.08	0.038	0.094	0.062	0.006	0.098	0.024	0.08	0.09
Jefferson	1983	0.40	0.27	0.000	0.000	0.023	0.008	0.106	0.000	0.19	0.01
Jerome	1983	0.31	0.12	0.094	0.035	0.024	0.004	0.093	0.040	0.18	0.10
Lincoln	1983	0.40	0.18	0.005	0.014	0.049	0.009	0.069	0.065	0.15	0.06
Madison	1983	0.07	0.48	0.000	0.000	0.011	0.012	0.219	0.000	0.11	0.10
Minidoka	1983	0.14	0.19	0.048	0.003	0.023	0.006	0.070	0.221	0.23	0.07

County	Year	Alfalfa	Barley	DrBean	GrCorn	SilCorn	Oats	Potatoes	SugBeet	SprWht	WinWht
Power	1983	0.05	0.15	0.001	0.000	0.000	0.004	0.096	0.039	0.23	0.43
Twin Falls	1983	0.29	0.10	0.208	0.053	0.020	0.002	0.046	0.073	0.09	0.12
Bannock	1984	0.21	0.55	0.000	0.000	0.000	0.023	0.033	0.000	0.12	0.06
Bingham	1984	0.15	0.19	0.000	0.000	0.006	0.006	0.208	0.022	0.23	0.18
Blaine	1984	0.44	0.49	0.000	0.000	0.000	0.020	0.000	0.000	0.04	0.01
Bonneville	1984	0.13	0.54	0.000	0.001	0.004	0.007	0.189	0.000	0.08	0.05
Butte	1984	0.47	0.41	0.000	0.000	0.000	0.019	0.045	0.000	0.06	0.00
Cassia	1984	0.18	0.25	0.025	0.002	0.023	0.005	0.129	0.083	0.11	0.20
Clark	1984	0.43	0.23	0.000	0.000	0.000	0.000	0.043	0.000	0.19	0.10
Fremont	1984	0.08	0.61	0.000	0.000	0.000	0.007	0.224	0.000	0.06	0.01
Gooding	1984	0.42	0.11	0.038	0.109	0.066	0.018	0.096	0.026	0.03	0.08
Jefferson	1984	0.39	0.32	0.000	0.001	0.028	0.010	0.112	0.000	0.13	0.01
Jerome	1984	0.31	0.16	0.093	0.026	0.027	0.004	0.092	0.042	0.13	0.11
Lincoln	1984	0.38	0.26	0.004	0.014	0.041	0.010	0.059	0.081	0.08	0.07
Madison	1984	0.08	0.51	0.000	0.000	0.006	0.004	0.249	0.000	0.11	0.04
Minidoka	1984	0.13	0.26	0.045	0.002	0.027	0.002	0.070	0.197	0.14	0.12
Power	1984	0.06	0.34	0.001	0.000	0.000	0.000	0.130	0.051	0.23	0.19
Twin Falls	1984	0.26	0.18	0.192	0.067	0.028	0.005	0.045	0.060	0.05	0.11
Bannock	1985	0.26	0.49	0.000	0.000	0.000	0.022	0.039	0.000	0.15	0.04
Bingham	1985	0.17	0.15	0.000	0.001	0.007	0.006	0.242	0.023	0.25	0.15
Blaine	1985	0.39	0.49	0.000	0.000	0.000	0.022	0.000	0.000	0.08	0.01
Bonneville	1985	0.14	0.47	0.000	0.001	0.002	0.008	0.214	0.000	0.10	0.07
Butte	1985	0.48	0.35	0.000	0.000	0.000	0.022	0.047	0.000	0.11	0.00
Cassia	1985	0.17	0.25	0.026	0.002	0.026	0.004	0.139	0.099	0.11	0.18
Clark	1985	0.44	0.26	0.000	0.000	0.000	0.000	0.034	0.000	0.18	0.09
Fremont	1985	0.08	0.62	0.000	0.000	0.000	0.006	0.227	0.000	0.06	0.00
Gooding	1985	0.38	0.07	0.042	0.121	0.071	0.017	0.145	0.030	0.06	0.06
Jefferson	1985	0.36	0.31	0.000	0.002	0.027	0.010	0.112	0.000	0.18	0.00
Jerome	1985	0.24	0.17	0.096	0.031	0.036	0.003	0.100	0.052	0.19	0.08
Lincoln	1985	0.31	0.26	0.005	0.022	0.051	0.009	0.069	0.078	0.14	0.05
Madison	1985	0.08	0.45	0.000	0.000	0.003	0.003	0.246	0.000	0.19	0.03
Minidoka	1985	0.10	0.27	0.044	0.002	0.021	0.001	0.076	0.214	0.17	0.10
Power	1985	0.05	0.34	0.001	0.000	0.000	0.000	0.161	0.054	0.24	0.15
Twin Falls	1985	0.27	0.14	0.201	0.073	0.031	0.004	0.048	0.062	0.08	0.09
Bannock	1986	0.27	0.49	0.000	0.000	0.000	0.016	0.040	0.000	0.14	0.04

County	Year	Alfalfa	Barley	DrBean	GrCorn	SilCorn	Oats	Potatoes	SugBeet	SprWht	WinWht
Bingham	1986	0.17	0.16	0.000	0.000	0.004	0.005	0.228	0.026	0.23	0.18
Blaine	1986	0.41	0.46	0.000	0.000	0.000	0.013	0.000	0.000	0.09	0.02
Bonneville	1986	0.13	0.51	0.000	0.001	0.003	0.011	0.182	0.000	0.09	0.07
Butte	1986	0.50	0.33	0.000	0.000	0.000	0.014	0.066	0.000	0.09	0.01
Cassia	1986	0.19	0.24	0.030	0.004	0.020	0.004	0.098	0.112	0.12	0.19
Clark	1986	0.48	0.22	0.000	0.000	0.000	0.002	0.039	0.000	0.21	0.05
Fremont	1986	0.09	0.62	0.000	0.000	0.000	0.002	0.217	0.000	0.07	0.00
Gooding	1986	0.40	0.07	0.044	0.080	0.060	0.010	0.143	0.033	0.08	0.08
Jefferson	1986	0.39	0.29	0.000	0.000	0.021	0.006	0.109	0.000	0.18	0.01
Jerome	1986	0.24	0.13	0.094	0.027	0.023	0.005	0.130	0.062	0.18	0.11
Lincoln	1986	0.34	0.25	0.005	0.016	0.043	0.016	0.039	0.071	0.16	0.06
Madison	1986	0.10	0.40	0.000	0.000	0.000	0.002	0.273	0.000	0.20	0.04
Minidoka	1986	0.10	0.25	0.045	0.001	0.016	0.001	0.077	0.232	0.17	0.11
Power	1986	0.06	0.30	0.001	0.005	0.005	0.002	0.187	0.058	0.24	0.14
Twin Falls	1986	0.27	0.14	0.203	0.059	0.021	0.004	0.048	0.068	0.08	0.10
Bannock	1987	0.31	0.43	0.000	0.000	0.000	0.020	0.053	0.000	0.14	0.05
Bingham	1987	0.18	0.13	0.000	0.000	0.003	0.008	0.247	0.027	0.21	0.19
Blaine	1987	0.50	0.40	0.000	0.000	0.000	0.016	0.000	0.000	0.06	0.02
Bonneville	1987	0.15	0.46	0.000	0.000	0.000	0.016	0.209	0.000	0.08	0.08
Butte	1987	0.55	0.27	0.000	0.000	0.000	0.039	0.076	0.000	0.05	0.01
Cassia	1987	0.21	0.17	0.033	0.003	0.014	0.006	0.148	0.124	0.09	0.20
Clark	1987	0.53	0.20	0.000	0.000	0.000	0.004	0.044	0.000	0.15	0.07
Fremont	1987	0.10	0.57	0.000	0.000	0.000	0.004	0.268	0.000	0.06	0.00
Gooding	1987	0.44	0.07	0.048	0.063	0.063	0.005	0.162	0.035	0.05	0.07
Jefferson	1987	0.43	0.23	0.000	0.000	0.012	0.013	0.139	0.000	0.17	0.01
Jerome	1987	0.26	0.11	0.103	0.022	0.025	0.007	0.168	0.068	0.14	0.10
Lincoln	1987	0.36	0.21	0.005	0.004	0.037	0.021	0.083	0.079	0.13	0.06
Madison	1987	0.11	0.33	0.000	0.000	0.000	0.011	0.341	0.000	0.16	0.04
Minidoka	1987	0.11	0.22	0.050	0.001	0.012	0.001	0.094	0.259	0.13	0.12
Power	1987	0.07	0.20	0.001	0.000	0.000	0.007	0.240	0.068	0.26	0.16
Twin Falls	1987	0.30	0.11	0.223	0.050	0.022	0.004	0.054	0.085	0.07	0.08
Bannock	1988	0.45	0.14	0.000	0.000	0.000	0.020	0.086	0.000	0.22	0.09
Bingham	1988	0.16	0.12	0.000	0.000	0.004	0.008	0.247	0.026	0.21	0.22
Blaine	1988	0.51	0.39	0.000	0.000	0.000	0.007	0.000	0.000	0.07	0.02
Bonneville	1988	0.19	0.34	0.000	0.000	0.004	0.029	0.255	0.000	0.11	0.08

County	Year	Alfalfa	Barley	DrBean	GrCorn	SilCorn	Oats	Potatoes	SugBeet	SprWht	WinWht
Butte	1988	0.55	0.24	0.000	0.000	0.000	0.045	0.066	0.000	0.09	0.00
Cassia	1988	0.19	0.16	0.034	0.006	0.013	0.005	0.169	0.128	0.07	0.23
Clark	1988	0.45	0.14	0.000	0.000	0.000	0.002	0.128	0.000	0.21	0.07
Fremont	1988	0.14	0.41	0.000	0.000	0.000	0.019	0.311	0.000	0.11	0.00
Gooding	1988	0.38	0.07	0.044	0.078	0.072	0.006	0.159	0.041	0.08	0.06
Jefferson	1988	0.40	0.23	0.000	0.000	0.014	0.013	0.138	0.000	0.20	0.01
Jerome	1988	0.22	0.13	0.094	0.013	0.042	0.002	0.170	0.069	0.16	0.09
Lincoln	1988	0.38	0.21	0.006	0.009	0.028	0.019	0.097	0.071	0.15	0.03
Madison	1988	0.12	0.31	0.000	0.000	0.000	0.012	0.332	0.000	0.18	0.05
Minidoka	1988	0.11	0.21	0.048	0.001	0.018	0.003	0.091	0.254	0.13	0.13
Power	1988	0.11	0.04	0.001	0.000	0.000	0.003	0.251	0.079	0.32	0.19
Twin Falls	1988	0.26	0.13	0.220	0.053	0.031	0.008	0.063	0.081	0.07	0.08
Bannock	1989	0.45	0.14	0.000	0.000	0.000	0.013	0.078	0.000	0.25	0.06
Bingham	1989	0.15	0.11	0.000	0.000	0.005	0.012	0.217	0.025	0.23	0.26
Blaine	1989	0.47	0.37	0.000	0.000	0.000	0.037	0.000	0.000	0.09	0.03
Bonneville	1989	0.19	0.31	0.000	0.000	0.004	0.027	0.255	0.000	0.15	0.06
Butte	1989	0.49	0.22	0.000	0.000	0.000	0.033	0.073	0.000	0.18	0.00
Cassia	1989	0.19	0.14	0.030	0.002	0.013	0.008	0.165	0.124	0.07	0.25
Clark	1989	0.39	0.14	0.000	0.000	0.000	0.002	0.183	0.000	0.22	0.07
Fremont	1989	0.13	0.38	0.000	0.000	0.000	0.031	0.261	0.000	0.19	0.00
Gooding	1989	0.39	0.06	0.040	0.060	0.103	0.013	0.143	0.047	0.07	0.07
Jefferson	1989	0.37	0.24	0.000	0.001	0.018	0.018	0.132	0.000	0.21	0.01
Jerome	1989	0.21	0.12	0.088	0.009	0.055	0.006	0.173	0.064	0.17	0.10
Lincoln	1989	0.34	0.21	0.005	0.008	0.051	0.022	0.082	0.092	0.15	0.04
Madison	1989	0.12	0.36	0.000	0.000	0.000	0.005	0.316	0.000	0.16	0.04
Minidoka	1989	0.11	0.18	0.043	0.000	0.017	0.004	0.104	0.235	0.19	0.12
Power	1989	0.10	0.03	0.001	0.000	0.000	0.006	0.251	0.076	0.40	0.13
Twin Falls	1989	0.27	0.12	0.220	0.050	0.039	0.006	0.043	0.086	0.07	0.11
Bannock	1990	0.46	0.15	0.000	0.000	0.000	0.012	0.094	0.000	0.23	0.06
Bingham	1990	0.13	0.08	0.000	0.000	0.003	0.002	0.259	0.036	0.21	0.27
Blaine	1990	0.52	0.43	0.000	0.000	0.000	0.010	0.000	0.000	0.03	0.01
Bonneville	1990	0.19	0.31	0.000	0.000	0.004	0.018	0.301	0.000	0.12	0.06
Butte	1990	0.54	0.25	0.000	0.000	0.000	0.017	0.062	0.000	0.13	0.00
Cassia	1990	0.19	0.11	0.028	0.001	0.010	0.002	0.154	0.118	0.15	0.24
Clark	1990	0.27	0.14	0.000	0.000	0.000	0.002	0.293	0.000	0.28	0.01

County	Year	Alfalfa	Barley	DrBean	GrCorn	SilCorn	Oats	Potatoes	SugBeet	SprWht	WinWht
Fremont	1990	0.12	0.42	0.000	0.000	0.000	0.009	0.312	0.000	0.14	0.00
Gooding	1990	0.41	0.05	0.036	0.043	0.094	0.005	0.155	0.052	0.08	0.07
Jefferson	1990	0.39	0.24	0.000	0.000	0.017	0.004	0.137	0.000	0.18	0.03
Jerome	1990	0.21	0.12	0.089	0.017	0.062	0.003	0.196	0.074	0.13	0.11
Lincoln	1990	0.37	0.20	0.005	0.002	0.034	0.004	0.093	0.099	0.14	0.05
Madison	1990	0.13	0.30	0.000	0.000	0.004	0.001	0.349	0.000	0.17	0.05
Minidoka	1990	0.11	0.18	0.043	0.000	0.010	0.002	0.100	0.257	0.17	0.13
Power	1990	0.05	0.03	0.001	0.000	0.000	0.003	0.290	0.070	0.22	0.33
Twin Falls	1990	0.30	0.11	0.212	0.026	0.024	0.001	0.062	0.076	0.04	0.15
Bannock	1991	0.51	0.14	0.000	0.000	0.000	0.017	0.093	0.000	0.10	0.14
Bingham	1991	0.13	0.09	0.000	0.000	0.003	0.004	0.239	0.031	0.30	0.21
Blaine	1991	0.53	0.44	0.000	0.000	0.000	0.011	0.000	0.000	0.02	0.00
Bonneville	1991	0.21	0.32	0.000	0.000	0.005	0.014	0.249	0.000	0.16	0.04
Butte	1991	0.62	0.23	0.000	0.000	0.000	0.023	0.051	0.000	0.08	0.00
Cassia	1991	0.22	0.12	0.029	0.000	0.015	0.004	0.155	0.136	0.11	0.21
Clark	1991	0.24	0.11	0.000	0.000	0.000	0.012	0.333	0.000	0.29	0.01
Fremont	1991	0.14	0.41	0.000	0.000	0.000	0.010	0.312	0.000	0.13	0.00
Gooding	1991	0.43	0.05	0.034	0.086	0.089	0.011	0.135	0.046	0.06	0.05
Jefferson	1991	0.38	0.25	0.000	0.000	0.021	0.010	0.152	0.000	0.16	0.02
Jerome	1991	0.29	0.10	0.107	0.056	0.055	0.006	0.132	0.104	0.06	0.09
Lincoln	1991	0.44	0.12	0.005	0.034	0.061	0.013	0.084	0.109	0.09	0.05
Madison	1991	0.11	0.30	0.000	0.000	0.005	0.002	0.277	0.000	0.13	0.18
Minidoka	1991	0.12	0.21	0.039	0.000	0.010	0.007	0.143	0.239	0.14	0.10
Power	1991	0.08	0.03	0.001	0.000	0.000	0.007	0.293	0.076	0.26	0.24
Twin Falls	1991	0.31	0.14	0.218	0.039	0.019	0.004	0.057	0.081	0.05	0.09
Bannock	1992	0.41	0.14	0.000	0.000	0.000	0.006	0.089	0.000	0.19	0.17
Bingham	1992	0.13	0.09	0.000	0.000	0.002	0.002	0.232	0.036	0.24	0.26
Blaine	1992	0.48	0.48	0.000	0.000	0.000	0.008	0.000	0.000	0.03	0.01
Bonneville	1992	0.16	0.23	0.000	0.000	0.000	0.003	0.266	0.000	0.30	0.05
Butte	1992	0.52	0.21	0.000	0.000	0.000	0.008	0.064	0.000	0.20	0.00
Cassia	1992	0.17	0.11	0.026	0.000	0.012	0.002	0.134	0.135	0.22	0.19
Clark	1992	0.37	0.08	0.000	0.000	0.000	0.011	0.229	0.000	0.29	0.02
Fremont	1992	0.12	0.33	0.000	0.000	0.000	0.005	0.272	0.000	0.23	0.04
Gooding	1992	0.41	0.05	0.033	0.033	0.097	0.011	0.141	0.051	0.10	0.06
Jefferson	1992	0.35	0.19	0.000	0.000	0.012	0.004	0.117	0.000	0.25	0.08

County	Year	Alfalfa	Barley	DrBean	GrCorn	SilCorn	Oats	Potatoes	SugBeet	SprWht	WinWht
Jerome	1992	0.19	0.13	0.082	0.032	0.048	0.001	0.127	0.087	0.21	0.09
Lincoln	1992	0.30	0.14	0.004	0.000	0.066	0.005	0.086	0.125	0.17	0.11
Madison	1992	0.10	0.27	0.000	0.000	0.003	0.003	0.298	0.000	0.17	0.15
Minidoka	1992	0.09	0.20	0.039	0.000	0.007	0.002	0.122	0.230	0.21	0.10
Power	1992	0.06	0.02	0.001	0.000	0.000	0.001	0.246	0.072	0.35	0.24
Twin Falls	1992	0.22	0.13	0.221	0.027	0.021	0.002	0.051	0.087	0.08	0.16
Bannock	1993	0.43	0.14	0.000	0.000	0.000	0.011	0.094	0.000	0.14	0.20
Bingham	1993	0.15	0.08	0.000	0.000	0.002	0.001	0.227	0.044	0.24	0.26
Blaine	1993	0.49	0.41	0.000	0.000	0.000	0.007	0.000	0.059	0.02	0.01
Bonneville	1993	0.18	0.25	0.000	0.000	0.000	0.004	0.266	0.000	0.25	0.05
Butte	1993	0.55	0.22	0.000	0.000	0.000	0.008	0.058	0.000	0.17	0.00
Cassia	1993	0.21	0.11	0.034	0.001	0.017	0.003	0.133	0.131	0.15	0.21
Clark	1993	0.39	0.10	0.000	0.000	0.000	0.002	0.255	0.000	0.24	0.02
Fremont	1993	0.17	0.32	0.000	0.000	0.000	0.008	0.309	0.000	0.20	0.01
Gooding	1993	0.47	0.05	0.042	0.048	0.111	0.004	0.099	0.039	0.06	0.08
Jefferson	1993	0.46	0.20	0.000	0.000	0.020	0.002	0.122	0.000	0.19	0.01
Jerome	1993	0.20	0.14	0.121	0.018	0.058	0.001	0.102	0.097	0.16	0.10
Lincoln	1993	0.29	0.14	0.025	0.014	0.087	0.011	0.078	0.131	0.15	0.08
Madison	1993	0.11	0.31	0.000	0.000	0.003	0.003	0.320	0.000	0.10	0.14
Minidoka	1993	0.09	0.20	0.056	0.002	0.007	0.002	0.137	0.228	0.19	0.09
Power	1993	0.07	0.02	0.000	0.000	0.000	0.002	0.281	0.080	0.23	0.31
Twin Falls	1993	0.23	0.12	0.253	0.024	0.029	0.001	0.062	0.082	0.07	0.13
Bannock	1994	0.41	0.13	0.000	0.000	0.000	0.014	0.096	0.000	0.15	0.20
Bingham	1994	0.16	0.08	0.000	0.000	0.001	0.001	0.238	0.041	0.28	0.19
Blaine	1994	0.45	0.40	0.000	0.000	0.000	0.016	0.040	0.059	0.03	0.01
Bonneville	1994	0.17	0.29	0.000	0.000	0.000	0.005	0.247	0.000	0.24	0.04
Butte	1994	0.54	0.23	0.000	0.000	0.000	0.008	0.065	0.000	0.15	0.01
Cassia	1994	0.20	0.12	0.039	0.002	0.017	0.002	0.135	0.127	0.19	0.17
Clark	1994	0.35	0.10	0.000	0.000	0.000	0.002	0.259	0.000	0.27	0.02
Fremont	1994	0.14	0.31	0.000	0.000	0.000	0.011	0.314	0.000	0.23	0.00
Gooding	1994	0.45	0.04	0.079	0.032	0.091	0.001	0.130	0.042	0.07	0.06
Jefferson	1994	0.43	0.23	0.000	0.000	0.013	0.004	0.122	0.000	0.19	0.01
Jerome	1994	0.23	0.10	0.134	0.019	0.047	0.001	0.132	0.091	0.15	0.09
Lincoln	1994	0.36	0.14	0.017	0.006	0.043	0.011	0.092	0.142	0.16	0.02
Madison	1994	0.13	0.32	0.000	0.000	0.000	0.002	0.320	0.000	0.21	0.02

County	Year	Alfalfa	Barley	DrBean	GrCorn	SilCorn	Oats	Potatoes	SugBeet	SprWht	WinWht
Minidoka	1994	0.10	0.20	0.057	0.001	0.006	0.001	0.135	0.217	0.19	0.09
Power	1994	0.06	0.03	0.000	0.000	0.000	0.000	0.280	0.079	0.34	0.21
Twin Falls	1994	0.22	0.13	0.257	0.019	0.028	0.001	0.068	0.079	0.06	0.13
Bannock	1995	0.41	0.13	0.000	0.000	0.000	0.013	0.107	0.000	0.13	0.21
Bingham	1995	0.18	0.09	0.000	0.000	0.000	0.002	0.226	0.041	0.23	0.23
Blaine	1995	0.44	0.40	0.000	0.000	0.000	0.011	0.045	0.061	0.02	0.03
Bonneville	1995	0.20	0.31	0.000	0.000	0.000	0.003	0.241	0.000	0.21	0.04
Butte	1995	0.53	0.26	0.000	0.000	0.000	0.008	0.065	0.000	0.13	0.01
Cassia	1995	0.22	0.10	0.026	0.000	0.019	0.002	0.137	0.133	0.15	0.21
Clark	1995	0.38	0.02	0.000	0.000	0.000	0.005	0.343	0.000	0.22	0.02
Fremont	1995	0.15	0.34	0.000	0.000	0.000	0.005	0.299	0.000	0.20	0.01
Gooding	1995	0.46	0.04	0.034	0.045	0.082	0.005	0.134	0.038	0.07	0.09
Jefferson	1995	0.43	0.23	0.000	0.000	0.007	0.004	0.125	0.000	0.20	0.01
Jerome	1995	0.28	0.12	0.110	0.017	0.038	0.001	0.130	0.093	0.11	0.10
Lincoln	1995	0.35	0.16	0.000	0.010	0.051	0.010	0.087	0.119	0.18	0.03
Madison	1995	0.14	0.38	0.000	0.000	0.000	0.000	0.281	0.000	0.18	0.02
Minidoka	1995	0.11	0.22	0.040	0.000	0.008	0.001	0.129	0.220	0.16	0.11
Power	1995	0.07	0.02	0.000	0.000	0.000	0.003	0.273	0.086	0.28	0.27
Twin Falls	1995	0.24	0.15	0.206	0.021	0.030	0.002	0.069	0.077	0.05	0.15
Bannock	1996	0.31	0.12	0.000	0.000	0.000	0.026	0.143	0.000	0.18	0.22
Bingham	1996	0.14	0.08	0.000	0.000	0.000	0.002	0.226	0.048	0.22	0.28
Blaine	1996	0.41	0.41	0.000	0.000	0.000	0.010	0.051	0.068	0.04	0.01
Bonneville	1996	0.16	0.30	0.000	0.000	0.000	0.004	0.254	0.000	0.23	0.04
Butte	1996	0.44	0.25	0.000	0.000	0.000	0.023	0.049	0.000	0.21	0.02
Cassia	1996	0.20	0.10	0.017	0.002	0.012	0.003	0.151	0.130	0.21	0.18
Clark	1996	0.29	0.04	0.000	0.000	0.000	0.002	0.343	0.000	0.31	0.01
Fremont	1996	0.12	0.25	0.000	0.000	0.000	0.004	0.277	0.000	0.34	0.01
Gooding	1996	0.38	0.06	0.034	0.054	0.084	0.005	0.148	0.044	0.10	0.09
Jefferson	1996	0.43	0.20	0.000	0.000	0.000	0.003	0.131	0.000	0.24	0.01
Jerome	1996	0.26	0.10	0.074	0.013	0.060	0.001	0.135	0.087	0.18	0.09
Lincoln	1996	0.27	0.13	0.000	0.008	0.051	0.008	0.057	0.135	0.31	0.03
Madison	1996	0.13	0.26	0.000	0.000	0.000	0.000	0.301	0.000	0.29	0.03
Minidoka	1996	0.10	0.21	0.030	0.000	0.007	0.002	0.138	0.221	0.18	0.11
Power	1996	0.05	0.03	0.000	0.000	0.000	0.000	0.269	0.075	0.32	0.25
Twin Falls	1996	0.23	0.13	0.190	0.021	0.032	0.001	0.070	0.071	0.10	0.15

County	Year	Alfalfa	Barley	DrBean	GrCorn	SilCorn	Oats	Potatoes	SugBeet	SprWht	WinWht
Bannock	1997	0.40	0.13	0.000	0.000	0.000	0.026	0.103	0.000	0.14	0.21
Bingham	1997	0.19	0.07	0.000	0.000	0.000	0.001	0.218	0.073	0.20	0.24
Blaine	1997	0.39	0.50	0.000	0.000	0.000	0.009	0.043	0.026	0.03	0.00
Bonneville	1997	0.16	0.33	0.000	0.000	0.000	0.004	0.226	0.000	0.23	0.05
Butte	1997	0.49	0.26	0.000	0.000	0.000	0.008	0.038	0.000	0.19	0.01
Cassia	1997	0.20	0.12	0.020	0.003	0.019	0.002	0.131	0.151	0.14	0.22
Clark	1997	0.36	0.06	0.000	0.000	0.000	0.000	0.242	0.000	0.27	0.07
Fremont	1997	0.12	0.32	0.000	0.000	0.000	0.003	0.300	0.000	0.25	0.01
Gooding	1997	0.42	0.05	0.037	0.028	0.104	0.000	0.156	0.057	0.06	0.09
Jefferson	1997	0.39	0.21	0.000	0.000	0.011	0.004	0.142	0.000	0.24	0.01
Jerome	1997	0.31	0.12	0.000	0.010	0.083	0.002	0.140	0.115	0.12	0.10
Lincoln	1997	0.30	0.14	0.000	0.009	0.063	0.005	0.076	0.168	0.17	0.08
Madison	1997	0.11	0.28	0.000	0.000	0.000	0.000	0.319	0.000	0.26	0.03
Minidoka	1997	0.11	0.21	0.034	0.000	0.007	0.000	0.129	0.222	0.17	0.11
Power	1997	0.06	0.02	0.000	0.000	0.000	0.000	0.266	0.116	0.29	0.24
Twin Falls	1997	0.24	0.16	0.199	0.028	0.038	0.000	0.081	0.071	0.04	0.15
Bannock	1998	0.41	0.14	0.000	0.000	0.000	0.041	0.131	0.000	0.09	0.19
Bingham	1998	0.19	0.07	0.000	0.000	0.000	0.002	0.222	0.072	0.21	0.23
Blaine	1998	0.38	0.47	0.000	0.000	0.000	0.020	0.050	0.040	0.04	0.00
Bonneville	1998	0.16	0.34	0.000	0.000	0.000	0.006	0.223	0.000	0.23	0.04
Butte	1998	0.51	0.34	0.000	0.000	0.000	0.017	0.035	0.000	0.11	0.00
Cassia	1998	0.23	0.11	0.020	0.001	0.033	0.002	0.141	0.152	0.11	0.20
Clark	1998	0.41	0.05	0.000	0.000	0.000	0.000	0.276	0.000	0.24	0.02
Fremont	1998	0.14	0.33	0.000	0.000	0.000	0.004	0.290	0.000	0.23	0.00
Gooding	1998	0.39	0.04	0.018	0.076	0.170	0.000	0.145	0.054	0.06	0.05
Jefferson	1998	0.41	0.21	0.000	0.000	0.013	0.004	0.132	0.000	0.22	0.01
Jerome	1998	0.31	0.09	0.095	0.021	0.092	0.001	0.116	0.110	0.08	0.08
Lincoln	1998	0.30	0.18	0.000	0.009	0.063	0.009	0.087	0.144	0.17	0.04
Madison	1998	0.12	0.33	0.000	0.000	0.000	0.003	0.300	0.000	0.22	0.03
Minidoka	1998	0.15	0.18	0.042	0.000	0.009	0.001	0.135	0.235	0.15	0.10
Power	1998	0.07	0.03	0.000	0.000	0.000	0.000	0.301	0.136	0.24	0.23
Twin Falls	1998	0.29	0.13	0.172	0.033	0.058	0.002	0.080	0.073	0.03	0.13
Bannock	1999	0.39	0.13	0.000	0.000	0.000	0.033	0.125	0.000	0.12	0.20
Bingham	1999	0.20	0.07	0.000	0.000	0.000	0.003	0.217	0.078	0.20	0.23
Blaine	1999	0.43	0.46	0.000	0.000	0.000	0.010	0.049	0.000	0.05	0.00

County	Year	Alfalfa	Barley	DrBean	GrCorn	SilCorn	Oats	Potatoes	SugBeet	SprWht	WinWht
Bonneville	1999	0.19	0.30	0.000	0.000	0.000	0.007	0.214	0.000	0.25	0.05
Butte	1999	0.50	0.28	0.000	0.000	0.000	0.005	0.043	0.000	0.15	0.02
Cassia	1999	0.22	0.11	0.029	0.002	0.035	0.002	0.138	0.152	0.15	0.16
Clark	1999	0.37	0.03	0.000	0.000	0.000	0.000	0.127	0.000	0.45	0.02
Fremont	1999	0.14	0.29	0.000	0.000	0.000	0.006	0.303	0.000	0.26	0.00
Gooding	1999	0.47	0.03	0.024	0.064	0.191	0.003	0.093	0.048	0.05	0.03
Jefferson	1999	0.41	0.18	0.000	0.000	0.012	0.003	0.130	0.000	0.25	0.01
Jerome	1999	0.33	0.09	0.093	0.013	0.121	0.001	0.106	0.110	0.08	0.06
Lincoln	1999	0.31	0.16	0.000	0.005	0.075	0.005	0.098	0.150	0.17	0.03
Madison	1999	0.12	0.30	0.000	0.000	0.000	0.003	0.281	0.000	0.26	0.03
Minidoka	1999	0.14	0.16	0.041	0.000	0.012	0.001	0.141	0.226	0.22	0.06
Power	1999	0.07	0.02	0.000	0.000	0.000	0.000	0.275	0.115	0.35	0.17
Twin Falls	1999	0.29	0.14	0.162	0.037	0.070	0.001	0.072	0.083	0.04	0.11
Bannock	2000	0.35	0.13	0.000	0.000	0.000	0.027	0.142	0.000	0.14	0.20
Bingham	2000	0.17	0.08	0.000	0.001	0.006	0.002	0.227	0.074	0.22	0.23
Blaine	2000	0.43	0.46	0.000	0.000	0.000	0.010	0.051	0.000	0.05	0.01
Bonneville	2000	0.17	0.33	0.000	0.000	0.000	0.005	0.211	0.000	0.23	0.05
Butte	2000	0.53	0.30	0.000	0.000	0.000	0.004	0.049	0.000	0.12	0.01
Cassia	2000	0.19	0.10	0.018	0.001	0.052	0.001	0.148	0.145	0.15	0.19
Clark	2000	0.39	0.05	0.000	0.000	0.000	0.002	0.154	0.000	0.40	0.00
Fremont	2000	0.15	0.33	0.000	0.000	0.000	0.003	0.313	0.000	0.20	0.00
Gooding	2000	0.45	0.04	0.011	0.038	0.193	0.002	0.103	0.053	0.05	0.05
Jefferson	2000	0.45	0.22	0.000	0.000	0.016	0.002	0.141	0.000	0.16	0.01
Jerome	2000	0.33	0.12	0.057	0.019	0.155	0.001	0.107	0.085	0.05	0.07
Lincoln	2000	0.30	0.18	0.000	0.010	0.088	0.008	0.100	0.115	0.16	0.04
Madison	2000	0.13	0.32	0.000	0.000	0.000	0.003	0.273	0.000	0.25	0.02
Minidoka	2000	0.13	0.21	0.027	0.000	0.018	0.001	0.159	0.218	0.17	0.07
Power	2000	0.06	0.02	0.008	0.000	0.000	0.000	0.306	0.106	0.32	0.18
Twin Falls	2000	0.29	0.16	0.127	0.037	0.082	0.001	0.082	0.066	0.04	0.12
Bannock	2001	0.38	0.08	0.000	0.000	0.000	0.024	0.110	0.000	0.13	0.27
Bingham	2001	0.19	0.07	0.000	0.000	0.008	0.002	0.207	0.080	0.18	0.26
Blaine	2001	0.56	0.36	0.000	0.000	0.000	0.013	0.041	0.000	0.02	0.01
Bonneville	2001	0.18	0.36	0.000	0.001	0.013	0.007	0.211	0.000	0.20	0.03
Butte	2001	0.61	0.23	0.000	0.000	0.000	0.022	0.033	0.000	0.11	0.00
Cassia	2001	0.22	0.11	0.018	0.006	0.047	0.001	0.129	0.145	0.12	0.20

County	Year	Alfalfa	Barley	DrBean	GrCorn	SilCorn	Oats	Potatoes	SugBeet	SprWht	WinWht
Clark	2001	0.44	0.05	0.000	0.000	0.000	0.022	0.131	0.000	0.35	0.00
Fremont	2001	0.16	0.33	0.000	0.000	0.000	0.005	0.277	0.000	0.23	0.00
Gooding	2001	0.44	0.02	0.006	0.058	0.264	0.004	0.064	0.064	0.04	0.04
Jefferson	2001	0.45	0.21	0.000	0.000	0.017	0.013	0.149	0.000	0.15	0.01
Jerome	2001	0.35	0.13	0.052	0.023	0.169	0.000	0.082	0.104	0.04	0.04
Lincoln	2001	0.38	0.12	0.000	0.011	0.077	0.007	0.034	0.152	0.12	0.10
Madison	2001	0.15	0.30	0.000	0.000	0.000	0.003	0.261	0.000	0.26	0.03
Minidoka	2001	0.15	0.23	0.025	0.000	0.017	0.002	0.176	0.237	0.11	0.05
Power	2001	0.08	0.03	0.000	0.024	0.001	0.002	0.282	0.120	0.23	0.23
Twin Falls	2001	0.33	0.18	0.090	0.032	0.088	0.003	0.071	0.074	0.02	0.12

Table A-5. Sprinkler Fraction by Model Stress Period

ENTITY_ID	SP001	SP002	SP003	SP004	SP005	SP006	SP007	SP008	SP009	SP010
Start Date	May-80	Oct-80	May-81	Oct-81	May-82	Oct-82	May-83	Oct-83	May-84	Oct-84
IEGW501	0.150	0.150	0.202	0.202	0.254	0.254	0.307	0.307	0.360	0.360
IEGW502	0.200	0.200	0.215	0.215	0.230	0.230	0.246	0.246	0.262	0.262
IEGW503	0.875	0.875	0.880	0.880	0.885	0.885	0.890	0.890	0.895	0.895
IEGW504	0.981	0.981	0.981	0.981	0.982	0.982	0.983	0.983	0.983	0.983
IEGW505	0.983	0.983	0.984	0.984	0.986	0.986	0.987	0.987	0.988	0.988
IEGW506	0.770	0.770	0.786	0.786	0.803	0.803	0.818	0.818	0.834	0.834
IEGW507	0.580	0.580	0.619	0.619	0.657	0.657	0.692	0.692	0.726	0.726
IEGW508	0.530	0.530	0.573	0.573	0.617	0.617	0.661	0.661	0.706	0.706
IEGW509	0.640	0.640	0.666	0.666	0.692	0.692	0.715	0.715	0.739	0.739
IEGW600	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
IESW000	0.333	0.333	0.353	0.353	0.373	0.373	0.399	0.399	0.424	0.424
IESW001	0.150	0.150	0.230	0.230	0.311	0.311	0.353	0.353	0.394	0.394
IESW002	0.825	0.825	0.836	0.836	0.847	0.847	0.858	0.858	0.868	0.868
IESW005	0.700	0.700	0.716	0.716	0.731	0.731	0.747	0.747	0.763	0.763
IESW007	0.147	0.147	0.156	0.156	0.165	0.165	0.175	0.175	0.185	0.185
IESW008	0.540	0.540	0.555	0.555	0.570	0.570	0.586	0.586	0.602	0.602
IESW009	0.015	0.015	0.033	0.033	0.050	0.050	0.066	0.066	0.082	0.082
IESW010	0.010	0.010	0.080	0.080	0.150	0.150	0.240	0.240	0.330	0.330
IESW011	0.440	0.440	0.454	0.454	0.467	0.467	0.480	0.480	0.492	0.492
IESW012	0.867	0.867	0.868	0.868	0.870	0.870	0.871	0.871	0.872	0.872
IESW014	0.210	0.210	0.248	0.248	0.286	0.286	0.319	0.319	0.352	0.352
IESW015	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.004	0.004
IESW016	0.050	0.050	0.093	0.093	0.136	0.136	0.258	0.258	0.381	0.381
IESW018	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
IESW019	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
IESW020	0.050	0.050	0.066	0.066	0.082	0.082	0.104	0.104	0.125	0.125
IESW022	0.250	0.250	0.317	0.317	0.384	0.384	0.437	0.437	0.490	0.490

ENTITY_ID	SP001	SP002	SP003	SP004	SP005	SP006	SP007	SP008	SP009	SP010
Start Date	May-80	Oct-80	May-81	Oct-81	May-82	Oct-82	May-83	Oct-83	May-84	Oct-84
IESW025	0.210	0.210	0.264	0.264	0.318	0.318	0.374	0.374	0.431	0.431
IESW027	0.000	0.000	0.000	0.000	0.000	0.000	0.046	0.046	0.092	0.092
IESW028	0.130	0.130	0.174	0.174	0.219	0.219	0.285	0.285	0.351	0.351
IESW029	0.035	0.035	0.052	0.052	0.068	0.068	0.085	0.085	0.101	0.101
IESW030	0.180	0.180	0.236	0.236	0.292	0.292	0.360	0.360	0.427	0.427
IESW031	0.950	0.950	0.955	0.955	0.961	0.961	0.965	0.965	0.968	0.968
IESW032	0.000	0.000	0.000	0.000	0.000	0.000	0.120	0.120	0.240	0.240
IESW033	0.970	0.970	0.973	0.973	0.976	0.976	0.979	0.979	0.982	0.982
IESW034	0.540	0.540	0.561	0.561	0.582	0.582	0.603	0.603	0.625	0.625
IESW035	0.020	0.020	0.038	0.038	0.056	0.056	0.083	0.083	0.110	0.110
IESW036	0.020	0.020	0.034	0.034	0.049	0.049	0.063	0.063	0.077	0.077
IESW037	0.145	0.145	0.187	0.187	0.229	0.229	0.267	0.267	0.305	0.305
IESW038	0.251	0.251	0.269	0.269	0.286	0.286	0.279	0.279	0.272	0.272
IESW039	0.270	0.270	0.283	0.283	0.296	0.296	0.291	0.291	0.285	0.285
IESW040	0.400	0.400	0.464	0.464	0.528	0.528	0.582	0.582	0.637	0.637
IESW041	0.000	0.000	0.008	0.008	0.017	0.017	0.038	0.038	0.058	0.058
IESW044	0.020	0.020	0.030	0.030	0.041	0.041	0.052	0.052	0.064	0.064
IESW051	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IESW052	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IESW053	0.530	0.530	0.545	0.545	0.560	0.560	0.570	0.570	0.580	0.580
IESW054	0.319	0.319	0.339	0.339	0.359	0.359	0.381	0.381	0.402	0.402
IESW055	0.000	0.000	0.004	0.004	0.007	0.007	0.011	0.011	0.015	0.015
IESW056	0.451	0.451	0.460	0.460	0.468	0.468	0.476	0.476	0.484	0.484
IESW057	0.648	0.648	0.662	0.662	0.676	0.676	0.694	0.694	0.712	0.712

ENTITY_ID	SP011	SP012	SP013	SP014	SP015	SP016	SP017	SP018	SP019	SP020
Start Date	May-85	Oct-85	May-86	Oct-86	May-87	Oct-87	May-88	Oct-88	May-89	Oct-89
IEGW501	0.414	0.414	0.467	0.467	0.520	0.520	0.553	0.553	0.586	0.586
IEGW502	0.278	0.278	0.294	0.294	0.310	0.310	0.326	0.326	0.341	0.341
IEGW503	0.900	0.900	0.905	0.905	0.910	0.910	0.915	0.915	0.920	0.920

ENTITY_ID	SP011	SP012	SP013	SP014	SP015	SP016	SP017	SP018	SP019	SP020
Start Date	May-85	Oct-85	May-86	Oct-86	May-87	Oct-87	May-88	Oct-88	May-89	Oct-89
IEGW504	0.984	0.984	0.985	0.985	0.986	0.986	0.986	0.986	0.987	0.987
IEGW505	0.990	0.990	0.991	0.991	0.992	0.992	0.993	0.993	0.994	0.994
IEGW506	0.849	0.849	0.865	0.865	0.880	0.880	0.887	0.887	0.895	0.895
IEGW507	0.761	0.761	0.795	0.795	0.830	0.830	0.845	0.845	0.860	0.860
IEGW508	0.751	0.751	0.795	0.795	0.840	0.840	0.860	0.860	0.880	0.880
IEGW509	0.763	0.763	0.786	0.786	0.810	0.810	0.821	0.821	0.832	0.832
IEGW600	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
IESW000	0.449	0.449	0.474	0.474	0.499	0.499	0.511	0.511	0.522	0.522
IESW001	0.436	0.436	0.478	0.478	0.520	0.520	0.551	0.551	0.583	0.583
IESW002	0.879	0.879	0.889	0.889	0.900	0.900	0.904	0.904	0.907	0.907
IESW005	0.779	0.779	0.794	0.794	0.810	0.810	0.824	0.824	0.838	0.838
IESW007	0.195	0.195	0.205	0.205	0.215	0.215	0.220	0.220	0.225	0.225
IESW008	0.618	0.618	0.634	0.634	0.650	0.650	0.666	0.666	0.681	0.681
IESW009	0.098	0.098	0.114	0.114	0.130	0.130	0.141	0.141	0.152	0.152
IESW010	0.420	0.420	0.510	0.510	0.600	0.600	0.627	0.627	0.653	0.653
IESW011	0.505	0.505	0.517	0.517	0.530	0.530	0.536	0.536	0.542	0.542
IESW012	0.873	0.873	0.874	0.874	0.875	0.875	0.875	0.875	0.876	0.876
IESW014	0.385	0.385	0.417	0.417	0.450	0.450	0.469	0.469	0.488	0.488
IESW015	0.006	0.006	0.008	0.008	0.010	0.010	0.011	0.011	0.012	0.012
IESW016	0.504	0.504	0.627	0.627	0.750	0.750	0.762	0.762	0.773	0.773
IESW018	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
IESW019	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
IESW020	0.147	0.147	0.168	0.168	0.190	0.190	0.197	0.197	0.204	0.204
IESW022	0.543	0.543	0.597	0.597	0.650	0.650	0.673	0.673	0.695	0.695
IESW025	0.487	0.487	0.544	0.544	0.600	0.600	0.620	0.620	0.640	0.640
IESW027	0.138	0.138	0.184	0.184	0.230	0.230	0.245	0.245	0.261	0.261
IESW028	0.417	0.417	0.484	0.484	0.550	0.550	0.583	0.583	0.616	0.616
IESW029	0.117	0.117	0.134	0.134	0.150	0.150	0.168	0.168	0.186	0.186
IESW030	0.495	0.495	0.562	0.562	0.630	0.630	0.664	0.664	0.698	0.698
IESW031	0.972	0.972	0.976	0.976	0.980	0.980	0.984	0.984	0.987	0.987
IESW032	0.360	0.360	0.480	0.480	0.600	0.600	0.630	0.630	0.660	0.660
IESW033	0.985	0.985	0.987	0.987	0.990	0.990	0.991	0.991	0.992	0.992

ENTITY_ID	SP011	SP012	SP013	SP014	SP015	SP016	SP017	SP018	SP019	SP020
Start Date	May-85	Oct-85	May-86	Oct-86	May-87	Oct-87	May-88	Oct-88	May-89	Oct-89
IESW034	0.647	0.647	0.668	0.668	0.690	0.690	0.700	0.700	0.710	0.710
IESW035	0.136	0.136	0.163	0.163	0.190	0.190	0.208	0.208	0.225	0.225
IESW036	0.092	0.092	0.106	0.106	0.120	0.120	0.126	0.126	0.132	0.132
IESW037	0.344	0.344	0.382	0.382	0.420	0.420	0.458	0.458	0.495	0.495
IESW038	0.265	0.265	0.258	0.258	0.251	0.251	0.244	0.244	0.237	0.237
IESW039	0.280	0.280	0.275	0.275	0.270	0.270	0.265	0.265	0.259	0.259
IESW040	0.691	0.691	0.746	0.746	0.800	0.800	0.824	0.824	0.849	0.849
IESW041	0.079	0.079	0.099	0.099	0.120	0.120	0.134	0.134	0.147	0.147
IESW044	0.076	0.076	0.088	0.088	0.100	0.100	0.112	0.112	0.124	0.124
IESW051	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IESW052	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IESW053	0.590	0.590	0.600	0.600	0.610	0.610	0.614	0.614	0.618	0.618
IESW054	0.424	0.424	0.446	0.446	0.467	0.467	0.476	0.476	0.484	0.484
IESW055	0.018	0.018	0.022	0.022	0.026	0.026	0.029	0.029	0.032	0.032
IESW056	0.491	0.491	0.499	0.499	0.507	0.507	0.512	0.512	0.518	0.518
IESW057	0.730	0.730	0.749	0.749	0.767	0.767	0.776	0.776	0.785	0.785

ENTITY_ID	SP021	SP022	SP023	SP024	SP025	SP026	SP027	SP028	SP029	SP030
Start Date	May-90	Oct-90	May-91	Oct-91	May-92	Oct-92	May-93	Oct-93	May-94	Oct-94
IEGW501	0.620	0.620	0.653	0.653	0.686	0.686	0.691	0.691	0.696	0.696
IEGW502	0.357	0.357	0.373	0.373	0.389	0.389	0.411	0.411	0.433	0.433
IEGW503	0.924	0.924	0.929	0.929	0.934	0.934	0.939	0.939	0.944	0.944
IEGW504	0.987	0.987	0.988	0.988	0.989	0.989	0.989	0.989	0.990	0.990
IEGW505	0.995	0.995	0.996	0.996	0.997	0.997	0.997	0.997	0.998	0.998
IEGW506	0.902	0.902	0.909	0.909	0.917	0.917	0.922	0.922	0.928	0.928
IEGW507	0.874	0.874	0.889	0.889	0.904	0.904	0.907	0.907	0.910	0.910
IEGW508	0.900	0.900	0.920	0.920	0.940	0.940	0.944	0.944	0.949	0.949
IEGW509	0.842	0.842	0.853	0.853	0.864	0.864	0.867	0.867	0.870	0.870
IEGW600	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
IESW000	0.533	0.533	0.544	0.544	0.555	0.555	0.566	0.566	0.577	0.577
IESW001	0.614	0.614	0.645	0.645	0.676	0.676	0.683	0.683	0.690	0.690
IESW002	0.911	0.911	0.915	0.915	0.919	0.919	0.921	0.921	0.923	0.923
IESW005	0.852	0.852	0.866	0.866	0.880	0.880	0.891	0.891	0.902	0.902
IESW007	0.229	0.229	0.234	0.234	0.239	0.239	0.244	0.244	0.248	0.248
IESW008	0.697	0.697	0.713	0.713	0.729	0.729	0.743	0.743	0.757	0.757
IESW009	0.163	0.163	0.174	0.174	0.185	0.185	0.192	0.192	0.199	0.199
IESW010	0.680	0.680	0.707	0.707	0.733	0.733	0.757	0.757	0.780	0.780
IESW011	0.548	0.548	0.554	0.554	0.560	0.560	0.566	0.566	0.572	0.572
IESW012	0.877	0.877	0.878	0.878	0.879	0.879	0.883	0.883	0.886	0.886
IESW014	0.507	0.507	0.526	0.526	0.545	0.545	0.564	0.564	0.583	0.583
IESW015	0.013	0.013	0.014	0.014	0.015	0.015	0.017	0.017	0.019	0.019
IESW016	0.785	0.785	0.797	0.797	0.808	0.808	0.819	0.819	0.829	0.829
IESW018	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
IESW019	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
IESW020	0.211	0.211	0.219	0.219	0.226	0.226	0.233	0.233	0.239	0.239
IESW022	0.718	0.718	0.740	0.740	0.763	0.763	0.780	0.780	0.798	0.798
IESW025	0.660	0.660	0.680	0.680	0.700	0.700	0.720	0.720	0.740	0.740
IESW027	0.276	0.276	0.292	0.292	0.307	0.307	0.318	0.318	0.328	0.328

ENTITY_ID	SP021	SP022	SP023	SP024	SP025	SP026	SP027	SP028	SP029	SP030
Start Date	May-90	Oct-90	May-91	Oct-91	May-92	Oct-92	May-93	Oct-93	May-94	Oct-94
IESW028	0.648	0.648	0.681	0.681	0.714	0.714	0.731	0.731	0.748	0.748
IESW029	0.204	0.204	0.222	0.222	0.240	0.240	0.256	0.256	0.272	0.272
IESW030	0.733	0.733	0.767	0.767	0.801	0.801	0.823	0.823	0.845	0.845
IESW031	0.991	0.991	0.994	0.994	0.998	0.998	0.998	0.998	0.999	0.999
IESW032	0.690	0.690	0.720	0.720	0.750	0.750	0.768	0.768	0.786	0.786
IESW033	0.994	0.994	0.995	0.995	0.996	0.996	0.997	0.997	0.998	0.998
IESW034	0.721	0.721	0.731	0.731	0.741	0.741	0.753	0.753	0.765	0.765
IESW035	0.243	0.243	0.260	0.260	0.278	0.278	0.294	0.294	0.311	0.311
IESW036	0.137	0.137	0.143	0.143	0.149	0.149	0.155	0.155	0.161	0.161
IESW037	0.533	0.533	0.570	0.570	0.608	0.608	0.686	0.686	0.765	0.765
IESW038	0.230	0.230	0.223	0.223	0.216	0.216	0.223	0.223	0.230	0.230
IESW039	0.254	0.254	0.249	0.249	0.243	0.243	0.249	0.249	0.254	0.254
IESW040	0.873	0.873	0.897	0.897	0.921	0.921	0.937	0.937	0.953	0.953
IESW041	0.161	0.161	0.175	0.175	0.188	0.188	0.201	0.201	0.213	0.213
IESW044	0.137	0.137	0.149	0.149	0.161	0.161	0.189	0.189	0.217	0.217
IESW051	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.008	0.016	0.016
IESW052	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.008	0.016	0.016
IESW053	0.622	0.622	0.626	0.626	0.630	0.630	0.633	0.633	0.636	0.636
IESW054	0.493	0.493	0.501	0.501	0.510	0.510	0.520	0.520	0.530	0.530
IESW055	0.035	0.035	0.038	0.038	0.041	0.041	0.045	0.045	0.048	0.048
IESW056	0.524	0.524	0.530	0.530	0.536	0.536	0.543	0.543	0.550	0.550
IESW057	0.795	0.795	0.804	0.804	0.813	0.813	0.813	0.813	0.813	0.813

ENTITY_ID	SP031	SP032	SP033	SP034	SP035	SP036	SP037	SP038	SP039	SP040
Start Date	May-95	Oct-95	May-96	Oct-96	May-97	Oct-97	May-98	Oct-98	May-99	Oct-99
IEGW501	0.700	0.700	0.705	0.705	0.710	0.710	0.713	0.713	0.717	0.717
IEGW502	0.455	0.455	0.478	0.478	0.500	0.500	0.517	0.517	0.533	0.533
IEGW503	0.950	0.950	0.955	0.955	0.960	0.960	0.965	0.965	0.970	0.970
IEGW504	0.991	0.991	0.991	0.991	0.992	0.992	0.993	0.993	0.993	0.993
IEGW505	0.998	0.998	0.999	0.999	0.999	0.999	0.999	0.999	1.000	1.000
IEGW506	0.934	0.934	0.939	0.939	0.945	0.945	0.950	0.950	0.955	0.955
IEGW507	0.914	0.914	0.917	0.917	0.920	0.920	0.923	0.923	0.927	0.927
IEGW508	0.954	0.954	0.958	0.958	0.963	0.963	0.965	0.965	0.968	0.968
IEGW509	0.874	0.874	0.877	0.877	0.880	0.880	0.883	0.883	0.887	0.887
IEGW600	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
IESW000	0.588	0.588	0.599	0.599	0.610	0.610	0.618	0.618	0.626	0.626
IESW001	0.697	0.697	0.703	0.703	0.710	0.710	0.713	0.713	0.717	0.717
IESW002	0.925	0.925	0.928	0.928	0.930	0.930	0.932	0.932	0.934	0.934
IESW005	0.912	0.912	0.923	0.923	0.934	0.934	0.946	0.946	0.958	0.958
IESW007	0.253	0.253	0.258	0.258	0.263	0.263	0.267	0.267	0.271	0.271
IESW008	0.771	0.771	0.786	0.786	0.800	0.800	0.813	0.813	0.827	0.827
IESW009	0.206	0.206	0.213	0.213	0.220	0.220	0.230	0.230	0.240	0.240
IESW010	0.803	0.803	0.827	0.827	0.850	0.850	0.870	0.870	0.890	0.890
IESW011	0.578	0.578	0.584	0.584	0.590	0.590	0.597	0.597	0.603	0.603
IESW012	0.890	0.890	0.894	0.894	0.897	0.897	0.897	0.897	0.897	0.897
IESW014	0.602	0.602	0.621	0.621	0.640	0.640	0.660	0.660	0.680	0.680
IESW015	0.021	0.021	0.023	0.023	0.025	0.025	0.027	0.027	0.028	0.028
IESW016	0.839	0.839	0.850	0.850	0.860	0.860	0.870	0.870	0.880	0.880
IESW018	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
IESW019	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
IESW020	0.246	0.246	0.253	0.253	0.260	0.260	0.267	0.267	0.273	0.273
IESW022	0.815	0.815	0.833	0.833	0.850	0.850	0.867	0.867	0.883	0.883
IESW025	0.760	0.760	0.780	0.780	0.800	0.800	0.820	0.820	0.840	0.840
IESW027	0.339	0.339	0.349	0.349	0.360	0.360	0.367	0.367	0.373	0.373

ENTITY_ID	SP031	SP032	SP033	SP034	SP035	SP036	SP037	SP038	SP039	SP040
Start Date	May-95	Oct-95	May-96	Oct-96	May-97	Oct-97	May-98	Oct-98	May-99	Oct-99
IESW028	0.766	0.766	0.783	0.783	0.800	0.800	0.813	0.813	0.827	0.827
IESW029	0.288	0.288	0.304	0.304	0.320	0.320	0.353	0.353	0.387	0.387
IESW030	0.866	0.866	0.888	0.888	0.910	0.910	0.927	0.927	0.943	0.943
IESW031	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
IESW032	0.804	0.804	0.822	0.822	0.840	0.840	0.860	0.860	0.880	0.880
IESW033	0.998	0.998	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000
IESW034	0.776	0.776	0.788	0.788	0.800	0.800	0.810	0.810	0.820	0.820
IESW035	0.327	0.327	0.344	0.344	0.360	0.360	0.377	0.377	0.393	0.393
IESW036	0.168	0.168	0.174	0.174	0.180	0.180	0.185	0.185	0.190	0.190
IESW037	0.843	0.843	0.922	0.922	1.000	1.000	1.000	1.000	1.000	1.000
IESW038	0.237	0.237	0.244	0.244	0.251	0.251	0.251	0.251	0.251	0.251
IESW039	0.259	0.259	0.265	0.265	0.270	0.270	0.270	0.270	0.270	0.270
IESW040	0.969	0.969	0.984	0.984	1.000	1.000	1.000	1.000	1.000	1.000
IESW041	0.225	0.225	0.238	0.238	0.250	0.250	0.262	0.262	0.273	0.273
IESW044	0.244	0.244	0.272	0.272	0.300	0.300	0.323	0.323	0.347	0.347
IESW051	0.024	0.024	0.032	0.032	0.040	0.040	0.050	0.050	0.060	0.060
IESW052	0.024	0.024	0.032	0.032	0.040	0.040	0.050	0.050	0.060	0.060
IESW053	0.639	0.639	0.642	0.642	0.645	0.645	0.650	0.650	0.655	0.655
IESW054	0.540	0.540	0.550	0.550	0.560	0.560	0.569	0.569	0.579	0.579
IESW055	0.052	0.052	0.056	0.056	0.059	0.059	0.064	0.064	0.068	0.068
IESW056	0.557	0.557	0.564	0.564	0.571	0.571	0.575	0.575	0.580	0.580
IESW057	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.813

ENTITY_ID	SP041	SP042	SP043	SP044
Start Date	May-00	Oct-00	May-01	Oct-01
IEGW501	0.720	0.720	0.723	0.723
IEGW502	0.550	0.550	0.567	0.567
IEGW503	0.975	0.975	0.980	0.980
IEGW504	0.994	0.994	0.995	0.995
IEGW505	1.000	1.000	1.000	1.000
IEGW506	0.960	0.960	0.965	0.965
IEGW507	0.930	0.930	0.933	0.933
IEGW508	0.970	0.970	0.972	0.972
IEGW509	0.890	0.890	0.893	0.893
IEGW600	1.000	1.000	1.000	1.000
IESW000	0.634	0.634	0.642	0.642
IESW001	0.720	0.720	0.723	0.723
IESW002	0.936	0.936	0.938	0.938
IESW005	0.970	0.970	0.982	0.982
IESW007	0.276	0.276	0.280	0.280
IESW008	0.840	0.840	0.853	0.853
IESW009	0.250	0.250	0.260	0.260
IESW010	0.910	0.910	0.930	0.930
IESW011	0.610	0.610	0.617	0.617
IESW012	0.897	0.897	0.897	0.897
IESW014	0.700	0.700	0.720	0.720
IESW015	0.030	0.030	0.032	0.032
IESW016	0.890	0.890	0.900	0.900
IESW018	1.000	1.000	1.000	1.000
IESW019	1.000	1.000	1.000	1.000
IESW020	0.280	0.280	0.287	0.287
IESW022	0.900	0.900	0.917	0.917
IESW025	0.860	0.860	0.880	0.880
IESW027	0.380	0.380	0.387	0.387

ENTITY_ID	SP041	SP042	SP043	SP044
Start Date	May-00	Oct-00	May-01	Oct-01
IESW028	0.840	0.840	0.853	0.853
IESW029	0.420	0.420	0.453	0.453
IESW030	0.960	0.960	0.977	0.977
IESW031	1.000	1.000	1.000	1.000
IESW032	0.900	0.900	0.920	0.920
IESW033	1.000	1.000	1.000	1.000
IESW034	0.830	0.830	0.840	0.840
IESW035	0.410	0.410	0.427	0.427
IESW036	0.195	0.195	0.200	0.200
IESW037	1.000	1.000	1.000	1.000
IESW038	0.251	0.251	0.251	0.251
IESW039	0.270	0.270	0.270	0.270
IESW040	1.000	1.000	1.000	1.000
IESW041	0.285	0.285	0.297	0.297
IESW044	0.370	0.370	0.393	0.393
IESW051	0.070	0.070	0.080	0.080
IESW052	0.070	0.070	0.080	0.080
IESW053	0.660	0.660	0.665	0.665
IESW054	0.588	0.588	0.597	0.597
IESW055	0.072	0.072	0.077	0.077
IESW056	0.584	0.584	0.589	0.589
IESW057	0.813	0.813	0.813	0.813

Table A-6. Diversion volumes by irrigation entity for each model stress period (acre-feet).

Entity	Stress Per 1	Stress Per 2	Stress Per 3	Stress Per 4	Stress Per 5	Stress Per 6	Stress Per 7	Stress Per 8	Stress Per 9	Stress Per 10
IESW000	162,902	0	162,902	0	162,902	0	162,902	0	162,902	0
IESW001	50,482	0	56,933	0	44,835	0	46,327	0	43,457	0
IESW002	304,408	0	316,804	99	280,762	0	287,420	0	264,463	0
IESW005	200,115	0	193,549	0	169,467	0	93,205	0	107,874	0
IESW007	871,442	12,103	903,122	0	846,878	12,002	830,579	13,193	853,765	5,457
IESW008	11,508	0	11,616	0	17,163	0	25,666	0	19,839	0
IESW009	523,646	23,806	447,888	10,712	489,669	24,105	479,109	19,839	456,152	19,146
IESW010	315,427	0	348,714	0	305,326	0	314,509	0	308,310	0
IESW011	72,498	0	76,492	0	67,447	0	68,641	0	61,295	694
IESW012	25,000	794	24,013	99	23,714	496	28,558	298	27,181	0
IESW014	50,689	0	50,184	0	44,444	1,091	47,704	0	42,952	1,190
IESW015	42,264	1,587	103,168	13,294	67,562	5,457	61,501	20,436	38,384	4,465
IESW016	372,819	121,924	380,624	104,959	346,878	111,593	331,726	124,495	348,485	42,769
IESW018	23,301	0	24,793	0	21,428	0	17,957	0	17,261	0
IESW019	246,556	0	188,476	0	206,428	0	239,440	0	243,113	0
IESW020	720,615	18,648	682,736	6,846	671,717	12,202	667,815	14,185	591,827	13,193
IESW022	595,730	7,640	621,442	5,259	521,350	13,689	493,802	17,360	441,001	18,352
IESW025	81,841	7,241	81,841	7,241	81,841	7,241	81,841	7,241	81,841	7,241
IESW027	60,308	0	49,288	0	58,930	0	50,872	0	51,286	0
IESW028	382,461	0	404,500	0	358,815	0	371,901	0	364,096	0
IESW029	65,358	0	91,529	0	81,313	0	82,185	0	70,523	0
IESW030	339,302	2,578	327,365	6,745	334,252	9,522	339,991	9,920	306,933	9,621
IESW031	1,992	104	2,316	209	1,950	93	1,710	101	1,706	116
IESW032	1,082,415	31,244	1,049,816	298	1,028,926	33,540	1,016,299	41,070	963,728	37,190
IESW033	13,393	0	17,557	0	15,078	0	15,675	0	13,294	0
IESW034	306,244	1,686	321,625	1,289	300,275	1,786	291,781	2,879	275,941	2,083

Table A-6 (cont'd). Diversion volumes by irrigation entity for each model stress period (acre-feet).

Entity	Stress Per 1	Stress Per 2	Stress Per 3	Stress Per 4	Stress Per 5	Stress Per 6	Stress Per 7	Stress Per 8	Stress Per 9	Stress Per 10
IESW035	221,304	3,967	283,287	5,753	227,273	15,872	209,298	1,885	255,051	5,852
IESW036	237,144	6,249	213,590	2,182	227,663	15,078	231,175	9,125	220,317	15,774
IESW037	9,066	0	10,546	0	4,442	0	6,846	0	7,365	0
IESW038	50,275	893	62,879	2,775	59,320	5,358	46,028	5,654	43,365	4,068
IESW039	17,957	1,984	19,047	2,381	17,656	1,190	16,368	2,083	18,848	1,190
IESW040	63,315	2,709	40,680	2,567	38,499	2,757	41,391	9,380	140,680	2,925
IESW041	48,875	183	52,066	0	46,281	59	48,095	0	44,835	0
IESW044	0	0	0	0	0	0	0	0	0	0
IESW051	37,741	0	28,489	0	41,896	0	40,932	0	49,357	0
IESW052	21,809	0	15,831	0	20,039	0	20,296	0	16,320	0
IESW053	27,663	0	28,398	0	28,168	0	24,656	0	43,251	0
IESW054	158,035	0	145,340	0	161,983	0	159,206	0	158,930	0
IESW055	251,607	11,607	230,257	8,331	238,292	8,331	228,650	12,401	217,241	17,062
IESW056	484,160	120,523	505,510	132,530	546,373	126,171	518,136	141,047	498,393	81,244
IESW057	323,691	0	268,136	0	296,143	0	318,641	0	314,279	0

Table A-6 (cont'd). Diversion volumes by irrigation entity for each model stress period (acre-feet).

Entity	Stress Per 11	Stress Per 12	Stress Per 13	Stress Per 14	Stress Per 15	Stress Per 16	Stress Per 17	Stress Per 18	Stress Per 19	Stress Per 20
IESW000	162,902	0	162,902	0	161,134	0	127,755	0	127,755	0
IESW001	48,508	0	49,105	0	51,882	0	53,375	0	53,972	0
IESW002	294,536	0	280,762	0	326,676	0	315,427	1,190	323,232	0
IESW005	140,955	0	157,828	0	136,983	0	106,451	0	112,511	0
IESW007	877,410	4,465	936,410	47,521	870,753	0	759,871	0	876,492	9,920
IESW008	8,336	0	16,490	0	10,976	0	7,677	0	9,238	0
IESW009	462,121	11,607	475,436	25,184	465,335	2,182	422,176	99	503,444	12,895
IESW010	336,777	0	320,248	0	337,236	0	322,544	0	314,968	0
IESW011	63,590	0	64,187	1,289	71,120	0	88,292	0	73,898	99
IESW012	24,105	0	27,273	0	29,959	99	29,362	0	29,775	0
IESW014	49,977	1,190	49,587	99	53,880	496	56,244	0	56,451	298
IESW015	84,114	4,860	64,004	5,950	114,968	3,076	128,466	5,057	93,044	7,739
IESW016	338,154	88,682	346,878	66,667	347,337	35,009	357,897	23,209	336,547	57,140
IESW018	20,535	0	20,930	0	22,617	0	28,168	0	26,171	0
IESW019	237,144	0	246,097	0	258,724	0	250,000	0	256,198	0
IESW020	705,234	9,325	751,377	18,749	712,580	3,671	687,787	496	811,754	6,846
IESW022	550,964	6,350	458,907	26,584	663,682	0	627,640	397	639,807	6,350
IESW025	81,841	7,241	81,841	7,241	81,841	7,241	81,841	7,241	81,841	7,241
IESW027	63,085	0	59,619	0	64,394	0	65,978	0	58,815	0
IESW028	348,026	0	361,341	0	375,115	0	379,477	2,182	364,555	99
IESW029	77,089	0	75,000	0	83,861	0	89,761	0	77,020	0
IESW030	318,641	8,331	327,824	4,465	365,243	0	331,497	0	358,127	397
IESW031	1,675	74	1,989	0	1,741	8	1,153	0	1,138	0
IESW032	1,006,428	21,527	1,000,000	36,800	1,003,903	893	971,993	1,289	1,062,213	10,813
IESW033	15,576	0	15,675	0	17,163	0	17,163	0	14,681	0
IESW034	285,583	198	317,034	893	331,038	1,091	308,081	298	306,703	595

Table A-6 (cont'd). Diversion volumes by irrigation entity for each model stress period (acre-feet).

Entity	Stress Per 11	Stress Per 12	Stress Per 13	Stress Per 14	Stress Per 15	Stress Per 16	Stress Per 17	Stress Per 18	Stress Per 19	Stress Per 20
IESW035	226,676	2,677	249,770	5,753	280,073	99	261,478	0	255,739	496
IESW036	192,746	5,852	218,044	12,300	203,168	595	186,295	0	229,155	6,646
IESW037	7,052	0	7,241	0	13,147	0	15,216	0	14,330	0
IESW038	52,296	2,677	56,749	3,671	51,377	2,083	57,828	1,190	59,022	3,770
IESW039	16,864	893	21,329	1,488	21,127	397	17,557	198	18,648	992
IESW040	43,871	4,688	70,294	2,452	36,777	1,391	20,863	1,793	26,882	1,356
IESW041	50,413	780	51,469	602	49,725	61	29,293	94	31,428	283
IESW044	0	0	0	0	0	0	0	0	0	0
IESW051	39,807	0	46,212	0	41,368	0	20,585	0	33,379	0
IESW052	10,494	0	17,778	0	12,704	0	9,839	0	11,033	0
IESW053	24,679	0	27,479	0	28,352	0	24,839	0	26,194	0
IESW054	155,464	0	176,860	0	128,168	0	56,336	0	148,600	0
IESW055	213,292	5,950	217,355	15,177	236,685	794	244,031	496	245,409	7,241
IESW056	468,320	60,514	505,051	55,647	491,965	23,118	466,713	18,253	509,412	57,828
IESW057	312,443	0	325,298	0	339,302	0	332,874	0	335,399	0

Table A-6 (cont'd). Diversion volumes by irrigation entity for each model stress period (acre-feet).

Entity	Stress Per 21	Stress Per 22	Stress Per 23	Stress Per 24	Stress Per 25	Stress Per 26	Stress Per 27	Stress Per 28	Stress Per 29	Stress Per 30
IESW000	127,755	0	127,755	0	127,755	0	127,755	0	127,755	0
IESW001	59,619	0	54,362	0	61,685	0	49,403	0	57,828	0
IESW002	336,088	0	310,606	0	282,599	0	268,595	0	345,271	0
IESW005	125,528	0	140,381	0	98,416	0	184,252	0	111,685	0
IESW007	832,874	0	754,591	8,928	599,403	0	793,618	8,632	757,576	0
IESW008	9,828	0	8,044	0	3,365	0	13,122	0	2,149	0
IESW009	430,670	8,730	440,771	3,770	348,485	0	425,849	17,360	391,414	397
IESW010	317,723	0	291,552	0	294,536	0	275,482	0	292,700	0
IESW011	82,323	99	68,756	99	75,505	0	57,645	198	76,584	99
IESW012	31,451	0	28,650	0	21,527	0	24,105	0	28,788	0
IESW014	65,381	0	48,003	0	47,612	0	56,451	0	50,781	0
IESW015	127,571	8,134	100,000	8,432	123,209	6,547	79,270	38,085	150,781	10,317
IESW016	354,913	1,389	335,859	27,365	319,559	6,249	280,992	47,016	331,038	14,881
IESW018	27,181	0	24,702	0	27,273	0	19,047	0	27,571	0
IESW019	253,903	0	209,894	0	180,051	0	204,545	0	249,082	0
IESW020	772,039	694	705,464	298	698,347	0	626,033	3,274	761,478	198
IESW022	622,360	397	544,077	397	530,303	0	514,463	4,663	604,454	0
IESW025	81,841	7,241	81,841	7,241	81,841	7,241	81,841	7,241	81,841	7,241
IESW027	64,187	0	56,451	0	59,619	0	52,594	0	58,815	0
IESW028	382,002	0	339,073	0	332,415	0	285,583	0	334,711	0
IESW029	84,894	0	76,699	0	82,920	0	57,461	0	77,732	0
IESW030	369,835	0	293,618	298	267,447	0	271,579	2,879	279,844	0
IESW031	1,194	0	1,001	0	691	0	918	0	1,155	0
IESW032	1,128,788	595	1,062,443	496	966,253	0	1,078,053	18,154	1,101,010	7,837
IESW033	18,154	0	13,788	0	16,963	0	12,103	0	17,856	0
IESW034	321,166	198	263,774	198	280,533	0	237,603	794	286,731	0

Table A-6 (cont'd). Diversion volumes by irrigation entity for each model stress period (acre-feet).

Entity	**Stress Per 21**	**Stress Per 22**	**Stress Per 23**	**Stress Per 24**	**Stress Per 25**	**Stress Per 26**	**Stress Per 27**	**Stress Per 28**	**Stress Per 29**	**Stress Per 30**
IESW035	258,035	0	204,545	0	200,872	0	204,660	0	213,981	0
IESW036	218,044	496	200,069	2,381	180,142	0	184,711	2,182	188,567	893
IESW037	14,451	0	9,596	0	12,794	0	13,811	0	15,510	0
IESW038	59,022	1,885	50,987	992	52,181	397	45,638	2,182	53,581	99
IESW039	19,543	595	18,253	694	16,368	1,190	14,881	992	14,385	694
IESW040	20,344	1,584	23,760	1,084	16,270	2,118	31,772	1,339	20,083	2,143
IESW041	32,691	286	31,474	81	27,158	0	29,362	150	29,477	0
IESW044	0	0	0	0	0	0	0	0	0	0
IESW051	19,881	0	20,441	0	13,891	0	22,649	0	13,611	0
IESW052	12,392	0	10,916	0	7,229	0	19,869	0	6,814	0
IESW053	30,624	0	22,369	0	19,814	0	27,571	0	19,711	0
IESW054	71,419	0	51,997	0	27,870	0	167,355	0	84,711	0
IESW055	238,751	1,587	200,275	4,959	232,782	0	218,825	9,325	221,602	794
IESW056	505,280	21,228	490,129	42,172	394,399	20,634	484,848	56,543	418,503	20,634
IESW057	327,824	0	272,268	0	227,571	0	259,412	0	310,147	0

Table A-6 (cont'd). Diversion volumes by irrigation entity for each model stress period (acre-feet).

Entity	Stress Per 31	Stress Per 32	Stress Per 33	Stress Per 34	Stress Per 35	Stress Per 36	Stress Per 37	Stress Per 38	Stress Per 39	Stress Per 40
IESW000	127,755	0	128,076	0	134,343	0	134,343	0	134,343	0
IESW001	49,587	0	56,152	0	51,171	0	50,482	0	53,076	0
IESW002	316,804	0	342,287	0	316,804	0	336,547	0	354,454	0
IESW005	204,339	0	181,267	0	161,501	0	143,411	0	146,878	0
IESW007	827,365	5,950	930,900	10,317	907,254	20,436	909,550	12,895	916,208	0
IESW008	17,133	0	10,565	0	14,263	0	12,172	0	11,616	0
IESW009	466,024	29,775	484,848	29,568	476,584	6,449	466,942	8,829	471,074	8,432
IESW010	252,296	0	283,517	1,686	275,712	0	258,953	595	273,416	0
IESW011	62,397	99	76,791	0	61,387	0	62,489	0	57,438	198
IESW012	27,755	0	30,073	0	30,073	0	29,959	0	35,308	99
IESW014	48,393	397	59,114	1,488	47,406	1,885	58,035	1,488	62,787	1,686
IESW015	88,682	13,590	91,850	11,309	64,486	12,599	70,041	18,648	79,063	15,872
IESW016	300,735	32,438	329,660	34,320	309,917	51,079	300,964	56,933	314,050	40,680
IESW018	21,921	0	25,184	0	22,220	0	22,817	0	24,311	0
IESW019	203,558	0	231,635	0	220,317	0	221,993	0	221,901	0
IESW020	775,023	15,774	799,357	15,576	718,549	8,432	743,572	7,837	772,039	6,547
IESW022	547,291	4,167	564,968	198	476,354	4,860	467,860	1,389	494,261	3,967
IESW025	81,841	7,241	81,841	7,241	81,841	7,241	81,841	7,241	81,841	7,241
IESW027	50,390	0	58,724	0	59,022	0	53,375	0	55,464	0
IESW028	279,385	0	325,987	0	314,738	0	300,964	99	302,571	0
IESW029	58,333	0	81,084	0	89,302	0	82,622	0	83,333	0
IESW030	286,731	595	327,824	198	296,373	0	320,018	1,686	319,559	893
IESW031	996	5	1,328	0	1,019	0	1,021	0	1,179	3
IESW032	974,747	27,571	1,060,147	45,638	1,060,376	24,197	1,037,649	4,663	1,064,509	893
IESW033	13,590	0	18,154	0	15,177	0	15,576	0	13,294	0
IESW034	261,478	595	292,470	0	274,105	1,488	271,809	595	275,712	694

Table A-6 (cont'd). Diversion volumes by irrigation entity for each model stress period (acre-feet).

Entity	Stress Per 31	Stress Per 32	Stress Per 33	Stress Per 34	Stress Per 35	Stress Per 36	Stress Per 37	Stress Per 38	Stress Per 39	Stress Per 40
IESW035	209,596	0	255,051	1,786	232,094	298	202,961	397	218,526	198
IESW036	197,016	7,539	205,533	4,959	197,016	3,274	194,330	3,868	199,679	4,465
IESW037	16,129	0	14,387	0	12,741	0	9,832	0	21,490	0
IESW038	51,997	992	48,990	3,372	50,574	3,471	32,943	694	49,495	2,083
IESW039	15,275	1,190	20,037	1,389	17,459	1,984	16,566	1,389	17,261	1,786
IESW040	32,140	2,553	38,315	2,736	41,047	3,281	49,219	3,563	53,444	2,702
IESW041	29,890	380	32,300	958	30,808	1,736	28,512	1,586	30,556	139
IESW044	0	0	0	0	0	0	0	0	0	0
IESW051	37,902	0	27,732	0	26,676	0	28,788	0	33,930	0
IESW052	16,722	0	10,647	0	13,898	0	17,950	0	20,009	0
IESW053	30,831	0	24,885	0	27,250	0	27,663	0	25,298	0
IESW054	163,085	0	169,146	0	168,251	0	153,857	0	189,463	0
IESW055	206,635	6,745	213,981	8,432	210,882	9,325	207,415	9,027	213,292	7,043
IESW056	491,736	42,470	498,163	51,079	493,802	54,270	460,514	47,314	492,883	72,498
IESW057	256,887	0	290,634	0	275,253	0	275,482	0	276,171	0

Table A-6 (concluded). Diversion volumes by irrigation entity for each model stress period (acre-feet).

Entity	Stress Per 41	Stress Per 42	Stress Per 43	Stress Per 44
IESW000	134,343	0	134,343	0
IESW001	61,983	0	62,580	0
IESW002	382,002	0	258,035	0
IESW005	127,112	0	101,377	0
IESW007	937,098	0	737,374	8,124
IESW008	13,184	0	5,002	0
IESW009	469,927	0	366,621	0
IESW010	318,871	0	260,790	0
IESW011	81,841	0	65,588	0
IESW012	33,425	0	24,311	0
IESW014	56,152	0	40,771	0
IESW015	115,657	8,232	92,952	8,035
IESW016	312,443	60,399	267,447	0
IESW018	27,181	0	25,482	0
IESW019	269,284	0	231,405	0
IESW020	886,134	1,389	677,916	0
IESW022	579,890	0	490,588	0
IESW025	81,841	7,241	81,841	7,241

Entity	Stress Per 41	Stress Per 42	Stress Per 43	Stress Per 44
IESW027	66,873	0	63,797	0
IESW028	358,356	0	331,956	0
IESW029	96,281	0	95,271	0
IESW030	329,660	0	235,308	0
IESW031	1,094	0	722	0
IESW032	1,108,127	1,587	972,222	0
IESW033	17,957	0	15,576	0
IESW034	291,781	0	264,004	0
IESW035	235,767	0	186,180	0
IESW036	214,761	99	166,873	0
IESW037	22,555	0	22,257	0
IESW038	52,686	0	52,686	99
IESW039	16,664	1,091	13,887	893
IESW040	40,565	1,963	29,454	2,785
IESW041	32,231	0	28,099	0
IESW044	0	0	0	0
IESW051	17,410	0	12,408	0
IESW052	10,140	0	8,372	0
IESW053	31,061	0	23,508	0
IESW054	188,567	0	56,635	0
IESW055	221,006	1,190	212,672	0
IESW056	462,580	17,856	318,871	11,012
IESW057	340,680	0	260,331	0

Table A-7. Return flow volumes by irrigation entity for each model stress period.

Entity	Stress Per 1	Stress Per 2	Stress Per 3	Stress Per 4	Stress Per 5	Stress Per 6	Stress Per 7	Stress Per 8	Stress Per 9	Stress Per 10
IESW000	0	0	0	0	0	0	0	0	0	0
IESW001	0	0	0	0	0	0	0	0	0	0
IESW002	23,049	0	24,059	8	21,391	0	21,958	0	20,259	0
IESW005	0	0	0	0	0	0	0	0	0	0
IESW007	299,816	0	270,891	0	261,938	0	234,389	0	273,646	0
IESW008	0	0	0	0	0	0	0	0	0	0
IESW009	81,382	3,912	73,898	1,868	85,836	4,447	88,866	3,859	89,233	3,916
IESW010	17,534	0	20,847	0	19,534	0	21,465	0	22,383	0
IESW011	1,206	0	1,282	0	1,140	0	1,169	0	1,052	12
IESW012	0	0	0	0	0	0	0	0	0	0
IESW014	9,910	0	10,117	0	9,242	233	10,216	0	9,467	269
IESW015	0	0	0	0	0	0	0	0	0	0
IESW016	3,540	1,230	3,852	1,124	3,721	1,265	3,763	1,488	4,176	538
IESW018	0	0	0	0	0	0	0	0	0	0
IESW019	30,693	0	22,096	0	24,518	0	29,936	0	30,831	0
IESW020	127,732	3,441	126,194	1,317	129,454	2,445	134,022	2,957	123,646	2,851
IESW022	114,853	1,517	123,737	1,078	107,071	2,897	104,729	3,783	96,373	4,121
IESW025	0	0	0	0	0	0	0	0	0	0
IESW027	3,287	0	2,904	0	3,714	0	3,432	0	3,687	0
IESW028	12,736	0	14,093	0	13,085	0	14,155	0	14,449	0
IESW029	0	0	0	0	0	0	0	0	0	0
IESW030	60,675	480	61,019	1,307	64,922	1,920	68,733	2,077	64,463	2,090
IESW031	3	0	3	0	3	0	1	0	2	0
IESW032	31,979	991	33,425	10	35,193	1,220	37,144	1,591	37,511	1,528
IESW033	3,457	0	4,536	0	3,898	0	4,056	0	3,441	0
IESW034	71,786	399	76,171	309	71,809	431	70,523	702	67,424	513

Table A-7 (cont'd). Return flow volumes by irrigation entity for each model stress period.

Entity	Stress Per 1	Stress Per 2	Stress Per 3	Stress Per 4	Stress Per 5	Stress Per 6	Stress Per 7	Stress Per 8	Stress Per 9	Stress Per 10
IESW035	33,815	644	46,166	993	39,325	2,902	38,338	364	49,449	1,190
IESW036	44,766	1,241	42,470	457	47,865	3,317	51,033	2,105	51,079	3,806
IESW037	0	0	0	0	0	0	0	0	0	0
IESW038	15,087	268	18,866	833	17,796	1,607	13,809	1,696	13,005	1,220
IESW039	5,388	595	5,714	714	5,298	357	4,910	625	5,654	357
IESW040	0	0	0	0	0	0	0	0	0	0
IESW041	2,110	8	2,424	0	2,314	3	2,571	0	2,551	0
IESW044	0	0	0	0	0	0	0	0	0	0
IESW051	0	0	0	0	0	0	0	0	0	0
IESW052	0	0	0	0	0	0	0	0	0	0
IESW053	0	0	0	0	0	0	0	0	0	0
IESW054	58,632	0	64,187	0	45,432	0	61,593	0	65,680	0
IESW055	35,836	1,771	35,308	1,366	39,233	1,460	40,243	2,312	40,771	3,375
IESW056	8,193	2,051	8,602	2,269	9,355	2,173	8,923	2,443	8,639	1,416
IESW057	0	0	0	0	0	0	0	0	0	0

Table A-7 (cont'd). Return flow volumes by irrigation entity for each model stress period.

Entity	Stress Per 11	Stress Per 12	Stress Per 13	Stress Per 14	Stress Per 15	Stress Per 16	Stress Per 17	Stress Per 18	Stress Per 19	Stress Per 20
IESW000	0	0	0	0	0	0	0	0	0	0
IESW001	0	0	0	0	0	0	0	0	0	0
IESW002	22,624	0	21,635	0	25,230	0	24,426	92	25,092	0
IESW005	0	0	0	0	0	0	0	0	0	0
IESW007	278,007	0	279,155	0	281,221	0	254,132	0	270,202	0
IESW008	0	0	0	0	0	0	0	0	0	0
IESW009	94,972	2,491	102,548	5,663	104,913	512	99,541	24	123,921	3,287
IESW010	25,849	0	25,941	0	28,788	0	28,903	0	29,568	0
IESW011	1,099	0	1,118	23	1,248	0	1,561	0	1,316	2
IESW012	0	0	0	0	0	0	0	0	0	0
IESW014	11,327	276	11,552	24	12,874	121	13,786	0	14,183	76
IESW015	0	0	0	0	0	0	0	0	0	0
IESW016	4,256	1,171	4,589	921	4,809	506	5,179	350	5,083	896
IESW018	0	0	0	0	0	0	0	0	0	0
IESW019	28,696	0	30,877	0	31,244	0	29,660	0	30,831	0
IESW020	152,755	2,091	168,779	4,353	165,794	881	165,565	123	202,043	1,752
IESW022	123,875	1,466	106,152	6,311	157,759	0	153,214	99	160,354	1,630
IESW025	0	0	0	0	0	0	0	0	0	0
IESW027	4,805	0	4,800	0	5,466	0	5,891	0	5,503	0
IESW028	14,357	0	15,491	0	16,683	0	17,489	104	17,381	5
IESW029	0	0	0	0	0	0	0	0	0	0
IESW030	69,330	1,874	73,898	1,039	85,170	0	79,821	0	89,187	102
IESW031	2	0	1	0	1	0	0	0	1	0
IESW032	41,483	935	43,572	1,685	46,051	43	46,901	65	53,811	571
IESW033	4,036	0	4,063	0	4,451	0	4,456	0	3,813	0
IESW034	70,432	49	78,994	224	83,264	277	78,260	76	78,627	154

Table A-7 (cont'd). Return flow volumes by irrigation entity for each model stress period.

Entity	Stress Per 11	Stress Per 12	Stress Per 13	Stress Per 14	Stress Per 15	Stress Per 16	Stress Per 17	Stress Per 18	Stress Per 19	Stress Per 20
IESW035	46,235	572	53,489	1,289	62,833	23	61,387	0	62,672	126
IESW036	46,556	1,475	55,073	3,230	53,489	163	50,987	0	65,358	1,958
IESW037	0	0	0	0	0	0	0	0	0	0
IESW038	15,684	803	17,022	1,101	15,416	625	17,348	357	17,707	1,131
IESW039	5,057	268	6,400	447	6,341	119	5,269	60	5,595	298
IESW040	0	0	0	0	0	0	0	0	0	0
IESW041	3,044	50	3,283	40	3,338	4	2,068	7	2,328	22
IESW044	0	0	0	0	0	0	0	0	0	0
IESW051	0	0	0	0	0	0	0	0	0	0
IESW052	0	0	0	0	0	0	0	0	0	0
IESW053	0	0	0	0	0	0	0	0	0	0
IESW054	64,486	0	59,711	0	47,704	0	21,921	0	54,752	0
IESW055	42,332	1,245	45,684	3,345	52,388	184	56,864	121	59,894	1,842
IESW056	8,163	1,061	8,861	982	8,685	410	8,283	326	9,098	1,038
IESW057	0	0	0	0	0	0	0	0	0	0

Table A-7 (cont'd). Return flow volumes by irrigation entity for each model stress period.

Entity	Stress Per 21	Stress Per 22	Stress Per 23	Stress Per 24	Stress Per 25	Stress Per 26	Stress Per 27	Stress Per 28	Stress Per 29	Stress Per 30
IESW000	0	0	0	0	0	0	0	0	0	0
IESW001	0	0	0	0	0	0	0	0	0	0
IESW002	26,171	0	24,265	0	22,144	0	21,102	0	27,181	0
IESW005	0	0	0	0	0	0	0	0	0	0
IESW007	258,724	0	258,264	0	202,571	0	238,751	0	271,579	0
IESW008	0	0	0	0	0	0	0	0	0	0
IESW009	110,078	2,314	117,332	1,037	95,960	0	121,993	5,124	115,725	121
IESW010	31,175	0	29,867	0	31,382	0	30,601	0	33,655	0
IESW011	1,477	2	1,243	2	1,374	0	1,057	4	1,414	2
IESW012	0	0	0	0	0	0	0	0	0	0
IESW014	16,827	0	12,668	0	12,837	0	15,595	0	14,320	0
IESW015	0	0	0	0	0	0	0	0	0	0
IESW016	5,579	23	5,494	463	5,425	110	4,952	855	6,026	280
IESW018	0	0	0	0	0	0	0	0	0	0
IESW019	31,061	0	25,872	0	21,887	0	25,161	0	30,601	0
IESW020	198,003	183	186,846	81	190,129	0	175,689	942	219,399	59
IESW022	160,078	104	143,457	107	143,044	0	142,424	1,317	170,983	0
IESW025	0	0	0	0	0	0	0	0	0	0
IESW027	6,286	0	5,774	0	6,359	0	5,838	0	6,777	0
IESW028	18,822	0	17,254	0	17,427	0	15,452	0	18,620	0
IESW029	0	0	0	0	0	0	0	0	0	0
IESW030	94,858	0	77,663	81	72,727	0	76,194	826	80,441	0
IESW031	1	0	1	0	0	0	2	0	0	0
IESW032	59,780	33	58,770	29	55,693	0	64,761	1,129	68,641	506
IESW033	4,718	0	3,586	0	4,415	0	3,152	0	4,653	0
IESW034	83,173	52	68,985	52	74,059	0	63,338	213	77,089	0

Table A-7 (cont'd). Return flow volumes by irrigation entity for each model stress period.

Entity	Stress Per 21	Stress Per 22	Stress Per 23	Stress Per 24	Stress Per 25	Stress Per 26	Stress Per 27	Stress Per 28	Stress Per 29	Stress Per 30
IESW035	65,909	0	54,408	0	55,395	0	58,655	0	63,453	0
IESW036	64,417	151	61,341	753	57,002	0	60,514	736	63,682	311
IESW037	0	0	0	0	0	0	0	0	0	0
IESW038	17,707	565	15,296	298	15,654	119	13,689	655	16,070	30
IESW039	5,863	179	5,475	208	4,910	357	4,465	298	4,316	208
IESW040	0	0	0	0	0	0	0	0	0	0
IESW041	2,534	23	2,546	7	2,292	0	2,578	14	2,686	0
IESW044	0	0	0	0	0	0	0	0	0	0
IESW051	0	0	0	0	0	0	0	0	0	0
IESW052	0	0	0	0	0	0	0	0	0	0
IESW053	0	0	0	0	0	0	0	0	0	0
IESW054	24,403	0	16,963	0	10,317	0	70,041	0	27,571	0
IESW055	60,904	422	53,466	1,374	64,738	0	63,384	2,792	66,529	247
IESW056	9,073	383	8,852	766	7,163	377	8,859	1,038	7,684	381
IESW057	0	0	0	0	0	0	0	0	0	0

Table A-7 (cont'd). Return flow volumes by irrigation entity for each model stress period.

Entity	Stress Per 31	Stress Per 32	Stress Per 33	Stress Per 34	Stress Per 35	Stress Per 36	Stress Per 37	Stress Per 38	Stress Per 39	Stress Per 40
IESW000	0	0	0	0	0	0	0	0	0	0
IESW001	0	0	0	0	0	0	0	0	0	0
IESW002	25,023	0	27,112	0	25,138	0	26,791	0	28,306	0
IESW005	0	0	0	0	0	0	0	0	0	0
IESW007	210,698	0	278,696	0	240,817	0	262,856	0	270,661	0
IESW008	0	0	0	0	0	0	0	0	0	0
IESW009	142,769	9,385	153,398	9,621	155,601	2,163	157,071	3,051	163,338	3,000
IESW010	30,119	0	35,078	215	35,262	0	34,206	81	37,305	0
IESW011	1,160	2	1,438	0	1,158	0	1,187	0	1,098	4
IESW012	0	0	0	0	0	0	0	0	0	0
IESW014	13,960	117	17,431	447	14,256	578	17,819	465	19,667	538
IESW015	0	0	0	0	0	0	0	0	0	0
IESW016	5,668	630	6,421	688	6,228	1,056	6,233	1,212	6,706	891
IESW018	0	0	0	0	0	0	0	0	0	0
IESW019	25,046	0	27,709	0	26,446	0	26,033	0	26,263	0
IESW020	229,798	4,791	243,343	4,853	224,449	2,695	238,062	2,567	253,444	2,197
IESW022	158,471	1,231	167,287	60	144,146	1,499	144,559	437	156,038	1,275
IESW025	0	0	0	0	0	0	0	0	0	0
IESW027	6,033	0	7,289	0	7,578	0	7,082	0	7,603	0
IESW028	15,999	0	19,199	0	19,022	0	18,664	6	19,263	0
IESW029	0	0	0	0	0	0	0	0	0	0
IESW030	84,826	180	99,518	62	92,218	0	102,089	550	104,454	298
IESW031	1	0	1	0	1	0	1	0	2	0
IESW032	63,154	1,845	71,120	3,161	73,669	1,733	74,518	345	78,926	68
IESW033	3,545	0	4,736	0	3,962	0	4,070	0	3,476	0
IESW034	70,983	163	80,028	0	75,712	414	75,758	167	77,571	197

Table A-7 (cont'd). Return flow volumes by irrigation entity for each model stress period.

Entity	Stress Per 31	Stress Per 32	Stress Per 33	Stress Per 34	Stress Per 35	Stress Per 36	Stress Per 37	Stress Per 38	Stress Per 39	Stress Per 40
IESW035	64,348	0	80,877	584	76,033	100	68,572	138	76,148	71
IESW036	68,733	2,704	73,852	1,832	72,865	1,244	73,990	1,511	78,168	1,792
IESW037	0	0	0	0	0	0	0	0	0	0
IESW038	15,595	298	14,702	1,012	15,177	1,042	9,881	208	14,851	625
IESW039	4,582	357	6,010	417	5,239	595	4,970	417	5,179	536
IESW040	0	0	0	0	0	0	0	0	0	0
IESW041	2,831	37	3,173	97	3,129	182	2,996	172	3,315	16
IESW044	0	0	0	0	0	0	0	0	0	0
IESW051	0	0	0	0	0	0	0	0	0	0
IESW052	0	0	0	0	0	0	0	0	0	0
IESW053	0	0	0	0	0	0	0	0	0	0
IESW054	64,187	0	71,120	0	67,447	0	70,225	0	70,523	0
IESW055	64,486	2,173	69,146	2,810	70,546	3,216	71,694	3,214	76,217	2,587
IESW056	9,086	789	9,256	954	9,226	1,019	8,650	893	9,311	1,377
IESW057	0	0	0	0	0	0	0	0	0	0

Table A-7 (concluded). Return flow volumes by irrigation entity for each model stress period.

Entity	Stress Per 41	Stress Per 42	Stress Per 43	Stress Per 44
IESW000	0	0	0	0
IESW001	0	0	0	0
IESW002	30,601	0	20,714	0
IESW005	0	0	0	0
IESW007	151,676	0	122,314	0
IESW008	0	0	0	0
IESW009	167,585	0	134,229	0
IESW010	44,835	0	37,764	0
IESW011	1,576	0	1,270	0
IESW012	0	0	0	0
IESW014	17,943	0	13,260	0
IESW015	0	0	0	0
IESW016	6,857	1,361	6,038	0
IESW018	0	0	0	0
IESW019	32,966	0	28,145	0
IESW020	297,980	477	233,012	0
IESW022	186,639	0	160,904	0
IESW025	0	0	0	0

Entity	Stress Per 41	Stress Per 42	Stress Per 43	Stress Per 44
IESW027	9,456	0	9,298	0
IESW028	23,393	0	22,179	0
IESW029	0	0	0	0
IESW030	110,216	0	80,418	0
IESW031	0	0	0	0
IESW032	84,711	125	76,584	0
IESW033	4,697	0	4,079	0
IESW034	82,691	0	75,528	0
IESW035	84,527	0	68,572	0
IESW036	86,341	41	68,825	0
IESW037	0	0	0	0
IESW038	15,803	0	15,803	30
IESW039	4,998	327	4,167	268
IESW040	0	0	0	0
IESW041	3,604	0	3,242	0
IESW044	0	0	0	0
IESW051	0	0	0	0
IESW052	0	0	0	0
IESW053	0	0	0	0
IESW054	73,301	0	20,436	0
IESW055	81,428	451	80,693	0
IESW056	8,786	341	6,088	211
IESW057	0	0	0	0

Table A-8. Leakage Fraction Applied to Diversion Volume, By Stress Period

CANAL_ID	Name	SP001	SP002	SP003	SP004	SP005	SP006	SP007	SP008	SP009	SP010
	Start Month	May-80	Oct-80	May-81	Oct-81	May-82	Oct-82	May-83	Oct-83	May-84	Oct-84
007-Canal	Milner-Gooding	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
032-Canal	Northside Main	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
032-Lake	Wilson Lake	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
002-Canal	Aberdeen-Springfield	0.26	0.40	0.42	0.37	0.39	0.31	0.33	0.33	0.30	0.30
032-Rim	Northside Laterals	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

CANAL_ID	Name	SP011	SP012	SP013	SP014	SP015	SP016	SP017	SP018	SP019	SP020
	Start Month	May-85	Oct-85	May-86	Oct-86	May-87	Oct-87	May-88	Oct-88	May-89	Oct-89
007-Canal	Milner-Gooding	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
032-Canal	Northside Main	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
032-Lake	Wilson Lake	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
002-Canal	Aberdeen-Springfield	0.36	0.36	0.26	0.26	0.40	0.40	0.42	0.42	0.37	0.37
032-Rim	Northside Laterals	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

CANAL_ID	Name	SP021	SP022	SP023	SP024	SP025	SP026	SP027	SP028	SP029	SP030
	Start Month	May-90	Oct-90	May-91	Oct-91	May-92	Oct-92	May-93	Oct-93	May-94	Oct-94
007-Canal	Milner-Gooding	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
032-Canal	Northside Main	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
032-Lake	Wilson Lake	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
002-Canal	Aberdeen-Springfield	0.39	0.39	0.31	0.31	0.51	0.51	0.43	0.43	0.47	0.47
032-Rim	Northside Laterals	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

CANAL_ID	Name	SP031	SP032	SP033	SP034	SP035	SP036	SP037	SP038	SP039	SP040
	Start Month	May-95	Oct-95	May-96	Oct-96	May-97	Oct-97	May-98	Oct-98	May-99	Oct-99
007-Canal	Milner-Gooding	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
032-Canal	Northside Main	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
032-Lake	Wilson Lake	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
002-Canal	Aberdeen-Springfield	0.43	0.43	0.41	0.41	0.38	0.38	0.39	0.39	0.39	0.39
032-Rim	Northside Laterals	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

CANAL_ID	Name	SP041	SP042	SP043	SP044						
	Start Month	May-00	Oct-00	May-01	Oct-01						
007-Canal	Milner-Gooding	0.15	0.15	0.15	0.15						
032-Canal	Northside Main	0.05	0.05	0.05	0.05						
032-Lake	Wilson Lake	0.05	0.05	0.05	0.05						
002-Canal	Aberdeen-Springfield	0.42	0.42	0.49	0.49						
032-Rim	Northside Laterals	0.10	0.10	0.10	0.10						

Table A-9. Model cells with fixed pumping represented.

Row	Column	Type of Fixed Point
58	190	Exchange Wells
58	191	Exchange Wells
58	192	Exchange Wells
54	182	Exchange Wells
54	186	Exchange Wells
55	199	Exchange Wells
56	177	Exchange Wells
59	185	Exchange Wells
59	186	Exchange Wells
58	182	Exchange Wells
59	188	Exchange Wells
60	186	Exchange Wells
67	198	Exchange Wells
71	179	Exchange Wells
38	159	Mud Lake Wells
40	164	Mud Lake Wells
42	163	Mud Lake Wells
38	160	Mud Lake Wells
35	48	Richfield Recharge Adjustment
35	49	Richfield Recharge Adjustment
35	50	Richfield Recharge Adjustment
35	51	Richfield Recharge Adjustment
33	51	Richfield Recharge Adjustment
34	48	Richfield Recharge Adjustment
34	49	Richfield Recharge Adjustment
34	50	Richfield Recharge Adjustment
34	51	Richfield Recharge Adjustment
36	53	Richfield Recharge Adjustment
36	54	Richfield Recharge Adjustment
37	51	Richfield Recharge Adjustment
37	52	Richfield Recharge Adjustment
37	53	Richfield Recharge Adjustment
37	54	Richfield Recharge Adjustment
37	55	Richfield Recharge Adjustment
37	56	Richfield Recharge Adjustment
38	50	Richfield Recharge Adjustment
38	51	Richfield Recharge Adjustment
38	54	Richfield Recharge Adjustment
38	55	Richfield Recharge Adjustment
38	56	Richfield Recharge Adjustment
38	57	Richfield Recharge Adjustment
39	50	Richfield Recharge Adjustment
39	51	Richfield Recharge Adjustment
39	52	Richfield Recharge Adjustment
39	55	Richfield Recharge Adjustment
39	56	Richfield Recharge Adjustment
39	57	Richfield Recharge Adjustment

Row	Column	Type of Fixed Point
40	50	Richfield Recharge Adjustment
40	51	Richfield Recharge Adjustment
40	52	Richfield Recharge Adjustment
40	55	Richfield Recharge Adjustment
40	56	Richfield Recharge Adjustment
40	57	Richfield Recharge Adjustment
41	50	Richfield Recharge Adjustment
41	51	Richfield Recharge Adjustment
41	52	Richfield Recharge Adjustment
41	53	Richfield Recharge Adjustment
41	54	Richfield Recharge Adjustment
41	55	Richfield Recharge Adjustment
41	56	Richfield Recharge Adjustment
41	57	Richfield Recharge Adjustment
42	48	Richfield Recharge Adjustment
42	49	Richfield Recharge Adjustment
42	50	Richfield Recharge Adjustment
42	51	Richfield Recharge Adjustment
42	52	Richfield Recharge Adjustment
42	53	Richfield Recharge Adjustment
42	54	Richfield Recharge Adjustment
42	55	Richfield Recharge Adjustment
42	56	Richfield Recharge Adjustment
42	57	Richfield Recharge Adjustment
43	48	Richfield Recharge Adjustment
43	49	Richfield Recharge Adjustment
43	50	Richfield Recharge Adjustment
43	51	Richfield Recharge Adjustment
43	52	Richfield Recharge Adjustment
43	53	Richfield Recharge Adjustment
43	54	Richfield Recharge Adjustment
43	55	Richfield Recharge Adjustment
43	56	Richfield Recharge Adjustment
44	48	Richfield Recharge Adjustment
44	49	Richfield Recharge Adjustment
44	50	Richfield Recharge Adjustment
44	51	Richfield Recharge Adjustment
44	52	Richfield Recharge Adjustment
44	53	Richfield Recharge Adjustment
44	54	Richfield Recharge Adjustment
44	55	Richfield Recharge Adjustment
44	56	Richfield Recharge Adjustment
45	45	Richfield Recharge Adjustment
45	47	Richfield Recharge Adjustment
45	48	Richfield Recharge Adjustment
45	50	Richfield Recharge Adjustment
45	51	Richfield Recharge Adjustment
45	54	Richfield Recharge Adjustment
46	47	Richfield Recharge Adjustment

Table A-9 (continued). Model cells with fixed pumping represented.

Row	Column	Type of Fixed Point	Row	Column	Type of Fixed Point
10	107	Wetland Adjustment	32	157	Wetland Adjustment
10	108	Wetland Adjustment	33	23	Wetland Adjustment
11	108	Wetland Adjustment	33	110	Wetland Adjustment
11	109	Wetland Adjustment	33	156	Wetland Adjustment
12	108	Wetland Adjustment	33	157	Wetland Adjustment
12	109	Wetland Adjustment	34	14	Wetland Adjustment
12	110	Wetland Adjustment	34	73	Wetland Adjustment
13	110	Wetland Adjustment	34	78	Wetland Adjustment
13	111	Wetland Adjustment	34	79	Wetland Adjustment
14	110	Wetland Adjustment	34	156	Wetland Adjustment
14	111	Wetland Adjustment	35	95	Wetland Adjustment
14	112	Wetland Adjustment	35	94	Wetland Adjustment
15	112	Wetland Adjustment	35	93	Wetland Adjustment
15	113	Wetland Adjustment	35	92	Wetland Adjustment
16	112	Wetland Adjustment	35	91	Wetland Adjustment
16	113	Wetland Adjustment	36	90	Wetland Adjustment
16	116	Wetland Adjustment	36	89	Wetland Adjustment
17	113	Wetland Adjustment	36	87	Wetland Adjustment
18	113	Wetland Adjustment	36	86	Wetland Adjustment
18	114	Wetland Adjustment	36	85	Wetland Adjustment
20	114	Wetland Adjustment	37	84	Wetland Adjustment
20	196	Wetland Adjustment	37	83	Wetland Adjustment
21	113	Wetland Adjustment	37	82	Wetland Adjustment
21	114	Wetland Adjustment	37	81	Wetland Adjustment
22	113	Wetland Adjustment	37	80	Wetland Adjustment
22	114	Wetland Adjustment	38	79	Wetland Adjustment
23	12	Wetland Adjustment	38	78	Wetland Adjustment
23	16	Wetland Adjustment	38	77	Wetland Adjustment
24	12	Wetland Adjustment	38	76	Wetland Adjustment
24	14	Wetland Adjustment	38	75	Wetland Adjustment
24	15	Wetland Adjustment	39	74	Wetland Adjustment
25	12	Wetland Adjustment	39	73	Wetland Adjustment
25	13	Wetland Adjustment	39	72	Wetland Adjustment
25	14	Wetland Adjustment	39	71	Wetland Adjustment
25	170	Wetland Adjustment	39	70	Wetland Adjustment
26	12	Wetland Adjustment	40	69	Wetland Adjustment
26	167	Wetland Adjustment	40	68	Wetland Adjustment
26	170	Wetland Adjustment	40	67	Wetland Adjustment
26	171	Wetland Adjustment	40	66	Wetland Adjustment
27	167	Wetland Adjustment	41	65	Wetland Adjustment
28	10	Wetland Adjustment	41	64	Wetland Adjustment
29	10	Wetland Adjustment	41	63	Wetland Adjustment
29	11	Wetland Adjustment	41	62	Wetland Adjustment
30	50	Wetland Adjustment	41	61	Wetland Adjustment
30	51	Wetland Adjustment	42	60	Wetland Adjustment
31	51	Wetland Adjustment	42	59	Wetland Adjustment
31	157	Wetland Adjustment	42	58	Wetland Adjustment
31	158	Wetland Adjustment	42	57	Wetland Adjustment
32	23	Wetland Adjustment	42	56	Wetland Adjustment
32	156	Wetland Adjustment	42	164	Wetland Adjustment

Table A-9 (continued). Model cells with fixed pumping represented.

Row	Column	Type of Fixed Point	Row	Column	Type of Fixed Point
42	166	Wetland Adjustment	68	176	Wetland Adjustment
42	167	Wetland Adjustment	68	177	Wetland Adjustment
42	168	Wetland Adjustment	69	177	Wetland Adjustment
43	38	Wetland Adjustment	70	177	Wetland Adjustment
43	164	Wetland Adjustment	70	178	Wetland Adjustment
43	165	Wetland Adjustment	71	178	Wetland Adjustment
43	166	Wetland Adjustment	73	175	Wetland Adjustment
45	46	Wetland Adjustment	73	181	Wetland Adjustment
45	53	Wetland Adjustment	74	175	Wetland Adjustment
51	200	Wetland Adjustment	74	176	Wetland Adjustment
51	201	Wetland Adjustment	78	114	Wetland Adjustment
52	25	Wetland Adjustment	78	115	Wetland Adjustment
52	26	Wetland Adjustment	79	115	Wetland Adjustment
53	181	Wetland Adjustment	80	123	Wetland Adjustment
53	182	Wetland Adjustment	81	112	Wetland Adjustment
53	195	Wetland Adjustment	81	123	Wetland Adjustment
54	27	Wetland Adjustment	81	129	Wetland Adjustment
55	169	Wetland Adjustment	81	141	Wetland Adjustment
55	170	Wetland Adjustment	82	111	Wetland Adjustment
55	182	Wetland Adjustment	82	112	Wetland Adjustment
56	180	Wetland Adjustment	82	113	Wetland Adjustment
57	179	Wetland Adjustment	82	118	Wetland Adjustment
58	180	Wetland Adjustment	82	127	Wetland Adjustment
58	181	Wetland Adjustment	83	118	Wetland Adjustment
59	175	Wetland Adjustment	84	50	Wetland Adjustment
60	173	Wetland Adjustment	84	110	Wetland Adjustment
60	197	Wetland Adjustment	85	110	Wetland Adjustment
60	198	Wetland Adjustment	85	111	Wetland Adjustment
60	199	Wetland Adjustment	85	125	Wetland Adjustment
61	195	Wetland Adjustment	85	126	Wetland Adjustment
61	196	Wetland Adjustment	85	127	Wetland Adjustment
61	198	Wetland Adjustment	85	137	Wetland Adjustment
61	199	Wetland Adjustment	85	140	Wetland Adjustment
62	171	Wetland Adjustment	85	141	Wetland Adjustment
62	172	Wetland Adjustment	85	142	Wetland Adjustment
62	175	Wetland Adjustment	86	123	Wetland Adjustment
62	200	Wetland Adjustment	86	126	Wetland Adjustment
63	35	Wetland Adjustment	86	137	Wetland Adjustment
63	172	Wetland Adjustment	86	141	Wetland Adjustment
63	199	Wetland Adjustment	86	144	Wetland Adjustment
64	35	Wetland Adjustment	87	124	Wetland Adjustment
64	199	Wetland Adjustment	87	125	Wetland Adjustment
65	174	Wetland Adjustment	88	58	Wetland Adjustment
65	175	Wetland Adjustment	88	122	Wetland Adjustment
65	176	Wetland Adjustment	88	123	Wetland Adjustment
65	199	Wetland Adjustment	88	124	Wetland Adjustment
66	175	Wetland Adjustment	89	121	Wetland Adjustment
66	198	Wetland Adjustment	90	121	Wetland Adjustment
67	176	Wetland Adjustment	90	122	Wetland Adjustment
67	177	Wetland Adjustment	90	123	Wetland Adjustment

Table A-9 (concluded). Model cells with fixed pumping represented.

Row	Column	Type of Fixed Point
90	124	Wetland Adjustment
90	125	Wetland Adjustment
90	126	Wetland Adjustment
90	127	Wetland Adjustment
91	120	Wetland Adjustment
91	123	Wetland Adjustment
91	124	Wetland Adjustment
91	125	Wetland Adjustment
91	127	Wetland Adjustment
92	105	Wetland Adjustment
92	112	Wetland Adjustment
92	118	Wetland Adjustment
92	119	Wetland Adjustment
93	88	Wetland Adjustment
93	96	Wetland Adjustment
93	104	Wetland Adjustment
93	111	Wetland Adjustment
93	112	Wetland Adjustment
93	113	Wetland Adjustment
93	119	Wetland Adjustment
94	96	Wetland Adjustment
94	98	Wetland Adjustment
94	100	Wetland Adjustment
94	101	Wetland Adjustment
94	102	Wetland Adjustment
94	104	Wetland Adjustment
94	113	Wetland Adjustment
94	114	Wetland Adjustment
94	119	Wetland Adjustment
95	119	Wetland Adjustment
95	124	Wetland Adjustment
95	125	Wetland Adjustment
96	97	Wetland Adjustment
96	119	Wetland Adjustment
96	120	Wetland Adjustment
98	120	Wetland Adjustment
99	110	Wetland Adjustment
99	111	Wetland Adjustment
100	110	Wetland Adjustment
100	111	Wetland Adjustment

Appendix B—Description of the GIS/Fortran Recharge Tool

As part of the ESPAM upgrade, the Idaho Water Resources Research Institute at University of Idaho developed a tool for calculating recharge and discharge for MODFLOW ground water models using spatial data. The GIS/Fortran Recharge Tool uses a combination of geographical information system (GIS) technology and a Fortran program to process spatial data to calculate recharge and discharge to each model cell for a ground water model.

The GIS Recharge Tool is independent of model grid or aquifer basin. The tool was designed for use in basins with arid irrigation; however, the tool can easily be adapted to basins with no irrigation. Spatial data inputs to the tool include the model grid, precipitation, evapotranspiration, recharge on non-irrigated lands, land use, soil type and irrigation. Additionally, line source and point source data such as canal seepage, river seepage, tributary underflow and municipal pumping are entered as spatial data. The GIS component of the tool intersects each component of data with the model grid and generates ASCII output files which are input to the Fortran program. Figure B-1 shows schematically how the GIS component of the tool functions.

The Fortran program uses the cell-by-cell information to calculate net aquifer recharge/discharge for each model cell for each stress period and generates the MODFLOW input files. Figure B-2 shows conceptually the individual components of aquifer recharge and discharge which are accounted for by the GIS Recharge Tool.

The tool was developed primarily for use with the Enhanced Snake Plain Aquifer Model but was designed to be applied in other basins as well. The tool design divides functionality between spatial data analysis (the GIS component) and background computer processing (the Fortran component). This split of functionality allows the analyst maximum flexibility in the processing of the aquifer recharge/discharge. By segregating the background computer processing into a separate Fortran program, the GIS/Fortran Recharge Tool can be used with a parameter estimation package such as PEST enabling dual calibration of aquifer model parameters (transmissivity and storativity) with model recharge.

GIS Component

The GIS component of the recharge tool allows creation of a new simulation and scenario or creation of a simulation based on an existing simulation. Figure B-3 shows the user interface for the GIS component of the tool. As the user builds a recharge data set, the GIS component provides the user with pull-down menus for selection of desired data files or data fields within a file. Figure B-4 shows the user interface for the GIS component of the tool.

The GIS component of the recharge tool allows creation of a new simulation and scenario or creation of a simulation based on an existing simulation. As the user begins building a recharge data set, the GIS component provides the user with pull-down menus for selection of desired data components. Figure B-3 shows the user interface for the GIS component of the tool. Figure B-4 shows the selection of recharge components which the user can choose to analyze. After selecting the recharge component to be analyzed, the user is guided through selecting data files and fields within each file to be used for the analysis. Figure B-5 shows a sample navigation window for locating a data file.

Figure B-6 shows a sample of the data components from the selected file available for analysis. After identifying the data sources, the user selects the

RunAnalysis button and the GIS component processes the selected data, generating the input files for the Fortran component.

The GIS component is designed in a modular fashion, so that part of a recharge data set can be built or modified independently of the rest of the data set. The user can build part of a data set, close the tool, and resume processing of the same data set at a later time. The tool also allows easy modification of an existing data set, for scenario generation. The tool was built for maximum flexibility in generation of model recharge/discharge data.

Fortran Component

The Fortran component calculates recharge and discharge for each individual ground water model cell for each stress period, based on the input data from the GIS component. The Fortran component reads all of the data files created by the GIS component which contain recharge and discharge information for each model grid cell. Outputs of the Fortran component include the MODFLOW Well File or Recharge File, in either binary or ASCII format, (for direct input to the ground water model) as well as output of intermediate recharge variables such as evapotranspiration, precipitation, or applied irrigation water for each model cell for each stress period, which can be viewed using GIS software. This allows the analyst to graph the components of recharge spatially or to graph totals through time, enabling full analysis of the recharge data for error-checking as well as for hydrological analysis.

The Fortran component can be run solely to calculate recharge and discharge values for a single model scenario, or it can be run in conjunction with parameter estimation sofware such as PEST. Figure B-7 shows a flow diagram of how the

GIS/Fortran Recharge Tool would be used for generation of recharge/discharge for a single model scenario.

The recharge tool has also been designed to be run along with the model during parameter estimation. Figure B-8 shows how the Fortran component would be included in a parameter estimation loop using PEST. Inclusion in a parameter estimation loop enables the user to estimate model recharge parameters such as tributary underflow, percentage of canal leakage or aquifer recharge on non-irrigated lands along with the traditional model parameters of transmissivity and storativity.

Tool Use

The GIS Recharge Tool provides an analyst with a powerful tool for generation of model scenarios and different conceptual representations of aquifer recharge and discharge. The feature of the tool which allows a scenario to be based on an existing scenario enables the user to retain most of the input variables constant, varying only selected items, in order to test different conceptual models of recharge and discharge. This allows rapid generation of complex recharge/discharge scenarios for a ground water model, which is particularly useful during both model parameterization and model use.

In addition to generation of recharge and discharge for ground water models, the GIS Recharge Tool can be used to estimate the impacts to a regional aquifer from large-scale changes such as climate changes or changes in land use. By modifying the spatial inputs to the GIS Component, the user can create scenarios which represent significant changes in land use or natural precipitation or evaporation, then linking with the Fortran Component to predict the changes to aquifer recharge/discharge caused by these basin changes. This makes the GIS Recharge Tool a powerful tool for assessing natural and management changes of a groundwater basin.