WATER BUDGET FOR THE TREASURE VALLEY AQUIFER SYSTEM

FOR THE YEARS 1996 AND 2000

Prepared by

Scott M. Urban

Idaho Department of Water Resources

Treasure Valley
Hydrologic Project

Executive Summary

This report presents water budgets for the Treasure Valley's shallow aquifer system for the calendar years 1996 and 2000. It also represents an updated version of the water budget previously published for the year 1996 (Urban and Petrich, 1998). While general comparisons can be made between the 1996 and 2000 water budgets, different methods were used to estimate some of the parameters. As a result, direct comparisons of some water budget components should not be made.

A water budget provides an estimate of the current balance between total aquifer withdrawals and discharge, aquifer recharge, and changes in aquifer storage. Specific objectives for these water budgets were to (1) define major water budget components, (2) estimate inflows and outflows for the Treasure Valley aquifer systems, (3) describe, where possible, the spatial characteristics of the water budget data, (4) create, where possible, GIS coverages of the water budget data, and (5) create input files (e.g., recharge, withdrawals and ET) for the Treasure Valley ground water flow model.

Inflows to the Treasure Valley aquifer system include:

1. Seepage from canals
2. Seepage from rivers and streams
3. Seepage from Lake Lowell
4. Underflow
5. Infiltration of precipitation and surface water
6. Seepage from rural domestic septic systems

Outflows include:

1. Municipal withdrawals
2. Industrial withdrawals
3. Irrigation withdrawals
4. Rural domestic withdrawals
5. Stock withdrawals
6. Discharge to canals, drains, and rivers
7. Evapotranspiration (ET)

Total inflow for 1996 is estimated at 1,020,300 acre-feet (af), while total outflow is estimated at 1,013,000 af. The net difference shows an apparent increase in aquifer storage of 7,300 af. This difference is less than 1% of the total recharge or discharge and is well within the estimated margin of error of 20% for some of the individual water budget component estimates. For the year 2000, total inflow was estimated to be 1,145,200 af, with an outflow

of 1,056,600 af, for a positive net difference of 88,600 af. At this time, the condition of ground water surplus is obscured by the error margin associated with some water budget components. Also, much of the difference between the 1996 and 2000 values may be attributed to differences in estimating components.

The largest source of ground water recharge appears to be seepage from the canal system, followed by seepage from flood irrigation and precipitation. The aggregate discharge to the Boise and Snake Rivers (through canals, drains, or to the rivers directly) is far greater than all withdrawals combined. On a valley-wide basis, the volume of ground water pumped during the year represents approximately 15 to 20% of the total ground water recharge.

Primary withdrawal areas and primary recharge areas do not coincide throughout the valley. The primary recharge areas are those with extensive canals and/or flood irrigation, while the greatest withdrawals occur in areas that are not flood irrigated. For example, agricultural irrigation withdrawals (non-supplemental) are concentrated in areas where surface water irrigation is unavailable, and municipal withdrawals are concentrated near the urban areas of Boise, Nampa, Caldwell, and Meridian. As a result, withdrawals may exceed recharge in local areas within the Treasure Valley, resulting in local water level declines. Water level increases were noted in areas where recharge exceeded local withdrawals.

The water budgets estimate the amount of water infiltrating to, and discharging from, the entire aquifer system. However, much of this water encounters the shallow aquifer only; recharge to the deeper aquifers is much less than to the shallow system.

The aggregate nature of the water budget masks the temporal characteristics of ground water recharge, withdrawals, and natural discharge. Infiltration from the surface water distribution system and irrigation occurs primarily in the summer. The actual aquifer recharge from irrigation activities lags the infiltration, so that water levels may be rising months after irrigation has ceased. Also, municipal withdrawals vary throughout the year and are greatest during the summer irrigation season.

Acknowledgements

Disclaimer

Some of the values and estimates provided in this report are changing on the basis of new information. For the latest estimates, please contact Scott Urban, Idaho Department of Water Resources, Boise, Idaho (email: surban@idwr.state.id.us, or telephone: 208-327-5441).

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1. INTRODUCTION

Water budgets have been used throughout the western United States to help understand, quantify, and manage surface and ground water supplies. A water budget provides an estimate of the current balance between total aquifer withdrawals and discharge, aquifer recharge, and changes in aquifer storage.

This report presents water budgets for the Treasure Valley aquifer system for the calendar years 1996 and 2000. The water budgets include estimates of recharge to the Treasure Valley aquifer system and estimates of ground water discharge. The water budgets estimate the amount of water infiltrating to, and discharging from, the entire aquifer system. However, much of this water encounters the shallow aquifer only; recharge to the deeper aquifers is much less than to the shallow system (Petrich, 2004). The report outlines specific water budget components and provides estimates of aquifer recharge and discharge rates. The water budget also provides data for the development of a numerical ground water flow model for the Treasure Valley aquifer system. (Note: model input files for 2000 were not created at the time of this report as the model was calibrated using 1996 data.)

While the updated 1996 water budget (Urban and Petrich, 1998) remains largely the same as before, some errors are corrected and revised estimates provided. In some cases, these updated data resulted in relatively large changes to specific parameters.

Due to improved technology, some water budget parameters for the years 1996 and 2000 were estimated using different methods. For example, evapotranspiration (ET) for 1996 was estimated using averaged AgriMet data, whereas ET for the year 2000 was estimated using Landsat imagery and the Surface Energy Balance Algorithm for Land (SEBAL) (see Section 2 for further discussion). Also, the 1996 water budget relied on land use interpretations using 1994 satellite imagery, while the 2000 water budget utilized imagery for the year 2000. Due to such variations in methodology, conclusions made from direct comparisons of the two years should be made with caution.

1.1. Purpose and Objectives

The purpose of the Treasure Valley water budget was to estimate recharge to and discharge from the Treasure Valley aquifers. Specific objectives for this water budget were to:

1. Define major water budget components.
2. Estimate inflows and outflows for the Treasure Valley aquifer system.
3. Describe, where possible, the spatial characteristics of the water budget data.
4. Create, where possible, GIS coverages of the water budget data.

5. Create input files (e.g., recharge and withdrawals) for the Treasure Valley ground water flow model.

1.2. Background

This section provides a review of water budgets for arid regions within the western United States. This review of water budget methods, applications, and results was conducted to help define Treasure Valley water budget components. Selected results from these water budgets are shown for the purpose of comparison. Results from these water budgets do not necessarily reflect conditions within the Treasure Valley.

Water budgets have been compiled for many areas, including Utah's Ogden Valley (Thomas, 1963), Las Vegas Valley (Patt, 1987), the Uinta Basin of Utah (Holmes, 1985), the Coconino Aquifer in Arizona (Mann, 1979), and California's San Joaquin Valley (Gronberg and Belitz, 1992). Newton (1991) and Kjelstrom (1995) prepared water budgets for the Western Snake River Plain (WSRP), which includes the Treasure Valley area. Garabedian (1992) completed a water budget for the eastern Snake River Plain. Newton's (1991) water budget was prepared in conjunction with a ground water model of the WSRP. However, the range of uncertainty associated with the water budget was large because some of the component values could not be well defined (Newton, 1991). For example, the amount of irrigation water that returns to canals and drains was not measured. As a result, the amount of return flow attributed to ground water discharge could not be defined.

Irrigation with surface water is intensive in the Boise and Payette River valleys, and along the Snake River. Newton (1991) estimated that 80% of ground water recharge resulted from surface water irrigation. Precipitation was shown to be a source of recharge, though on average, it was estimated only about 2% of total annual precipitation became ground water recharge for the WSRP. Recharge from precipitation on irrigated land was assumed to be equivalent to the average annual precipitation. Nearly 83% of ground water discharge was estimated to be to rivers and drains, the remainder was pumping withdrawals. Power-consumption records were used to estimate that about 300,000 af of ground water were pumped to irrigate about 130,000 acres on the western plain. The mean application rate was estimated to be about 2.2 feet/acre (ft/ac) (Newton, 1991).

Kjelstrom (1995) reported that changes in ground water storage were the net result of 100 successive years of irrigation on the entire Snake River Plain. During the 1930 to 1972 time period, ground water storage increased about 3 million af. From 1972 to 1980, storage generally decreased. Furthermore, from 1930 to 1980, several short-term cycles of gains and losses are evident. Kjelstrom attributed some cycles to periods of above and below normal precipitation. Sources of recharge, in order of decreasing magnitude, were infiltration of surface water irrigation and infiltration of precipitation. According to Kjelstrom (1995), precipitation for the WSRP contributes an average of

about 0.03 ft/ac of aquifer recharge per year. Most ground water discharge is to rivers and drains, primarily during the irrigation season (Kjelstrom, 1995).

Garabedian (1992) developed a numerical model for the eastern Snake River Plain. Ground water withdrawals were shown to be an important discharge component of the water budget. Withdrawals were estimated at about 1.8 million af for 1980 by using power billings for irrigation pumps. Some pumped water was returned to the aquifer from canal loss and field seepage. Therefore, withdrawals estimated from power-consumption were compared with estimated consumptive irrigation requirements; the smaller of the two estimates was used to determine net ground water withdrawals. For 1980, net ground water withdrawals were estimated at about 1.1 million af, or about two-thirds of total withdrawals as estimated from power data (Garabedian, 1992).

1.3. Physiography and Climate

This water budget focuses on the Treasure Valley of southwestern Idaho. The project area is shown in Figure 1. The term "Treasure Valley" refers to the lower Boise River watershed area. The lower Boise River begins where the Boise River exits the mountains near Lucky Peak Reservoir. From Lucky Peak Reservoir, the lower Boise River flows about 64 (river) miles northwestward through the Treasure Valley to its confluence with the Snake River. The valley is bounded to the northwest by the Boise Foothills. Topography within the valley can be described as generally flat with some rolling hills within the southern-most portion of the area. The project area extends to the southwest to the Snake River. This area was included in the study because some ground water originating in the lower Boise River area discharges to the Snake River.

Precipitation in the Treasure Valley ranges from about 8 to 14 inches/yr with a 30-year average of about 11 inches/yr. Figure 2 is a precipitation map of the Treasure Valley; Figure 3 shows the mean monthly precipitation at four sites. About 50% of the precipitation falls during the non-irrigation season. The average precipitation in the southern portion of the valley is about 10 inches/yr. The average precipitation for flood-irrigated lands during 1996 was 12.8 inches (based upon data for Deer Flat Dam, Boise, Caldwell, and Parma [NOAA, 1996]). The average for the year 2000 was 11.2 inches (Boise and Parma stations only [NOAA, 2000]). The mean annual temperature for the valley is about 51 degrees for the 30-year period.
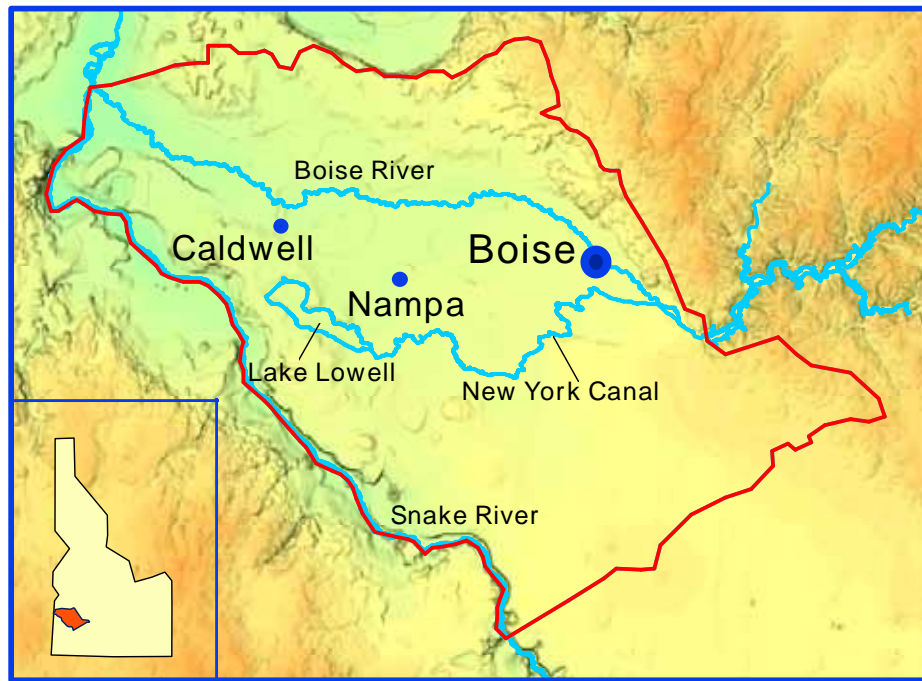
Figure 1: Project Area.
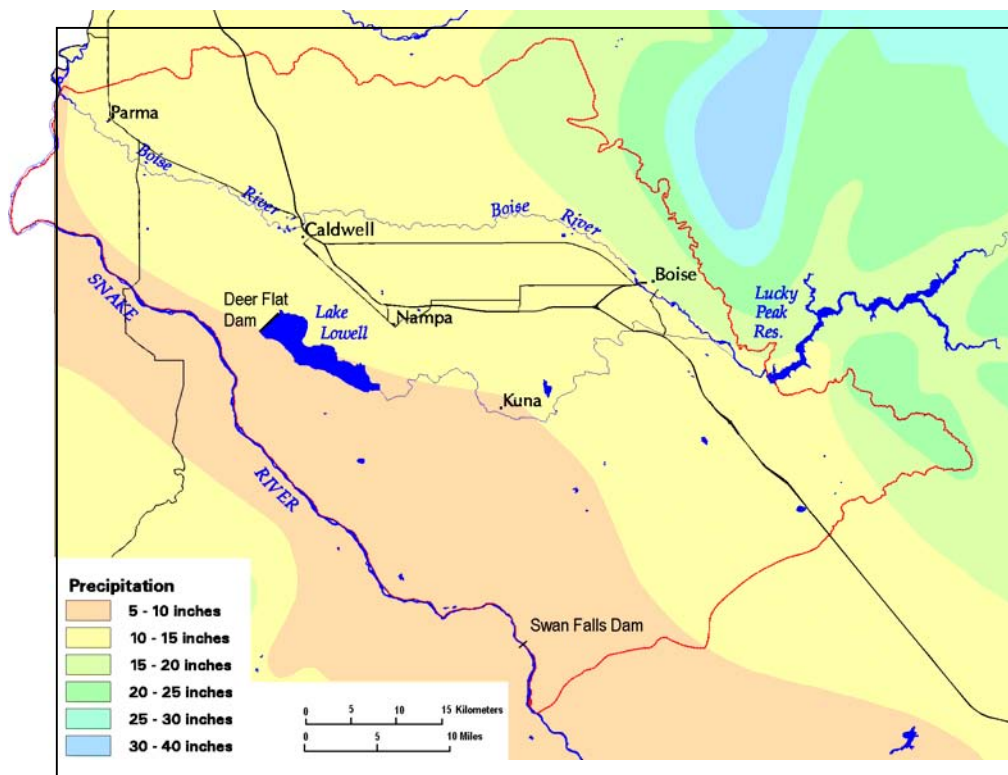
Figure 2: Precipitation map of the Treasure Valley.
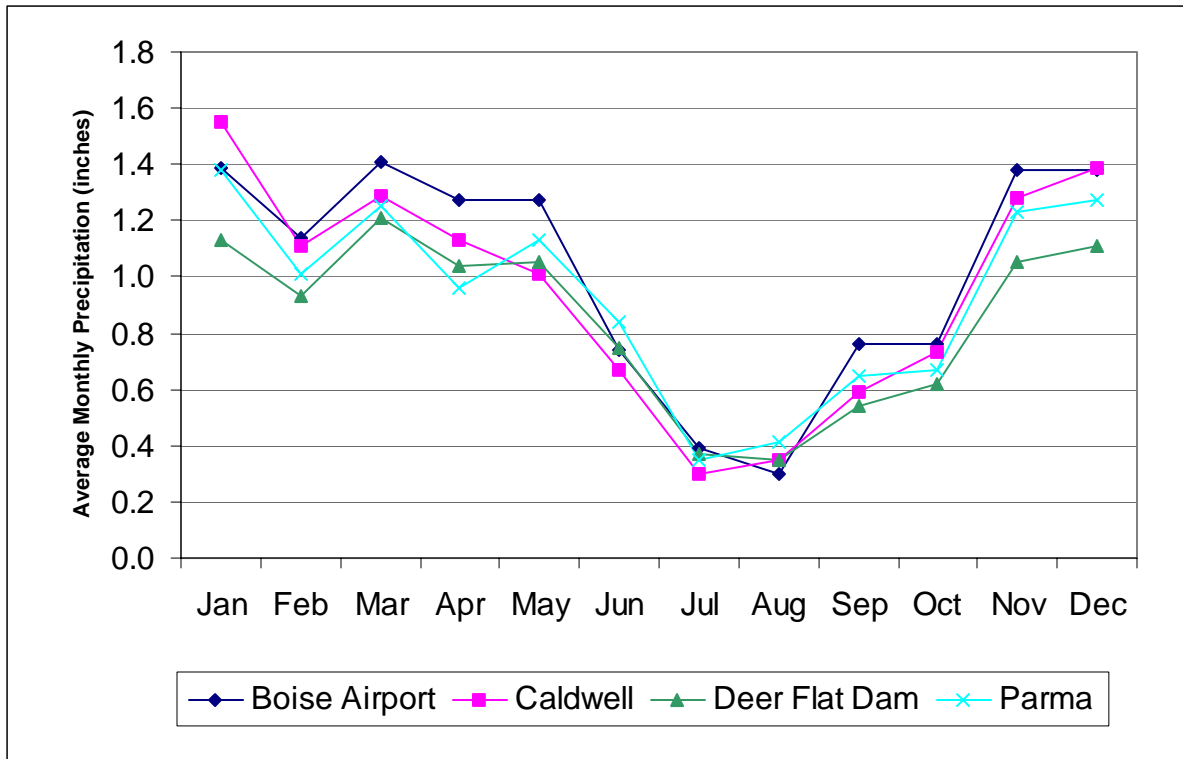
Figure 3: Average monthly precipitation for 1971-2000.

1.4. Water Budget Area and Time Frame

The water budget area corresponds with that of the Treasure Valley Hydrologic Project (TVHP) area (Figure 1). Water budgets can be constructed for an entire aquifer system, individual aquifers, or both. The Treasure Valley contains a deep, regional aquifer system (typically confined, with depths ranging from about 250 to more than 1,500 feet) and a shallow aquifer system (typically unconfined, generally less than about 250 feet in depth). The shallow system may contain local perched aquifers. This water budget focuses on the entire Treasure Valley aquifer system as a whole, although direct recharge is estimated for the shallow aquifer only.

Subsurface flow rates between the shallow and deeper regional aquifer systems have not been quantified. Percolating water from surface sources recharges shallow zones first. Recharge to the deeper regional system depends on local hydraulic gradients and on the hydraulic characteristics of aquifer materials. Recharge to the deep, regional aquifer system can only occur in areas with downward hydraulic gradient. Shallow system recharge can occur in areas of regional upward hydraulic gradient, although this "recharge" may quickly discharge into the nearest drain or canal (Figure 4). Vertical flow between aquifer systems has been evaluated with the help of the numerical model (Petrich, 2004).
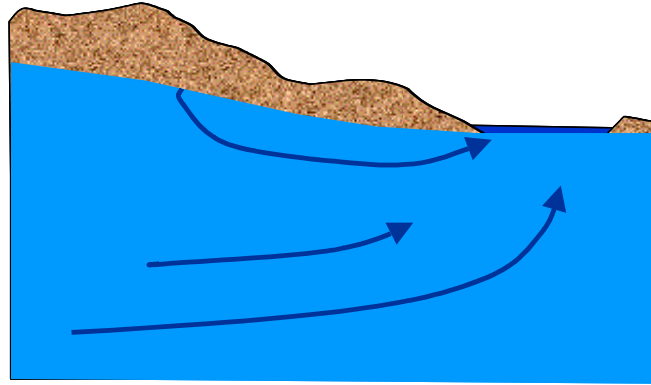
Figure 4: Schematic diagram showing recharge in a regional discharge area.

1.5. Water Budget Components

Water budget components include all significant sources of ground water inflows (recharge) and outflows (discharge) to the Treasure Valley aquifer system. In general,

Inflows – Outflows = Change in Aquifer Storage (Eqn 1)

Ground water recharge is defined (Driscoll, 1986) as the amount of water added to the saturated zone. Ground water discharge is the sum total of water leaving the saturated zone and can be in the form of aquifer discharge into canals, drains, or rivers, evapotranspiration (ET), and withdrawals from wells.

Inflows into the Treasure Valley aquifer system (Figure 5) include:

6. Seepage from canals
7. Seepage from rivers and streams
8. Seepage from Lake Lowell
9. Underflow
10. Infiltration of precipitation and surface water used for irrigation
11. Seepage from rural domestic septic systems

Outflows include:

1. Municipal withdrawals
2. Industrial withdrawals
3. Irrigation withdrawals
4. Rural domestic withdrawals
5. Stock withdrawals
6. Discharge to canals, drains, and rivers
7. Evapotranspiration (ET)

These inflows and outflows are related as shown in the following equation:

$$R_C + R_R + R_L + I_U + R_P + R_{FI} + R_{SI} + R_S$$
$$-P_M - P_{MI} - P_{IN} - P_{IR} - P_R - P_S - D_R - D_C - ET \qquad \text{(Eqn. 2)}$$
$$= \Delta S_{(S+R)}$$

where

R_C = recharge from canal seepage
R_R = the recharge from river seepage
R_L = the recharge from Lake Lowell seepage
I_U = subsurface inflow (underflow)
R_P = recharge from precipitation
R_{FI} = recharge from agricultural flood irrigation
R_{SI} = recharge from agricultural sprinkler irrigation
R_S = recharge from rural domestic septic systems
P_M = municipal domestic and commercial withdrawals
P_{MI} = municipal irrigation withdrawals
P_{IN} = industrial withdrawals
P_{IR} = agricultural irrigation withdrawals
P_R = rural domestic withdrawals
P_S = withdrawals for stock watering
D_R = discharge to rivers
D_C = discharge to canals
ET = loss to evapotranpsiration
$\Delta S_{(S+R)}$ = aggregate change in aquifer storage for the shallow and regional aquifers.
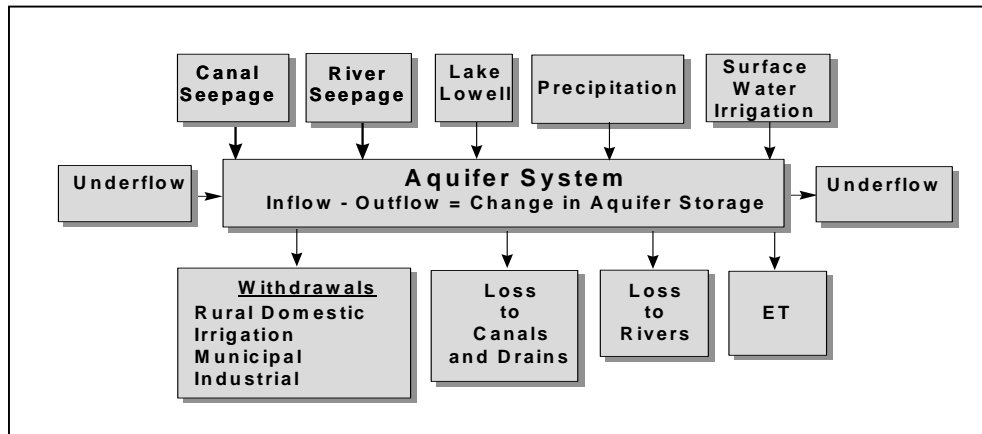
Figure 5: Generalized water budget schematic .

Equation 2 describes water budget components for the Treasure Valley ground water system as a whole. The Treasure Valley covers a large area (over 1,500 square miles),

and aggregate values for the water budget components may mask some of the spatial characteristics of individual water budget components. For instance, recharge and withdrawal areas may not coincide spatially or temporally, resulting in local changes in aquifer storage. The spatial distribution of inflows and outflows are also important to the numerical ground water flow model. The spatial distribution of individual water budget components is therefore provided whenever possible.

The following sections provide a discussion of individual water budget components. Included are descriptions of analysis methods and preliminary water budget results. Note that the 1996 water budget was completed in 1998 using data and technology available at that time. The 2000 water budget was completed in 2003 using improved data collection and analysis methods. As a result of these differing methods and data sets, it may be difficult to draw certain conclusions between the two water budget years.

1.6. Units

Data provided in this report are generally presented in the form of acre-feet per year (af/yr) or cubic feet per second (cfs). Managers of surface water supplies commonly use acre-feet when evaluating water volumes stored in reservoirs or when describing volumes allotted for irrigation. The unit of cubic feet per second is commonly used to describe flows in rivers and canals and is also used in water rights to specify the permitted rate of ground water withdrawals. It is important to note that all flow rates presented in this report are average annual rates, even though some flows are seasonally variable.

2.   ESTIMATES OF INFLOWS

The primary inflows to the Treasure Valley aquifer system include: Seepage from canals

1. Seepage from rivers and streams
2. Seepage from Lake Lowell
3. Underflow
4. Infiltration from precipitation and irrigation
5. Seepage from septic systems

Estimates of inflows from these sources are presented in the following sections.

2.1.   Canal Seepage

There are about 1,170 miles of major irrigation canals throughout the Treasure Valley (D. Palmer, IDWR, personal communication, 1997), and seepage from these is a major contribution to ground water recharge. These large and intermediate canals are shown in Figure 6. In addition to these larger canals, many miles of small canals and ditches exist within the valley. However, most of these smaller canals have not been mapped, and as a result, the total length and spatial distribution of such canals is unknown. Because the length and location of the smaller canals is unknown, estimates of seepage from these canals are not provided in this water budget. Rather, this water budget provides an estimate of total canal seepage and assigns the total seepage to the large and intermediate sized canals, which have been located spatially.

The total canal seepage was estimated using the following relationship:

$$C_{seep} = T_{div} \text{ - } Evap \text{ - } ET \text{ - } LL_{loss} + LL_{dS} \text{ -} F_A \qquad \text{(Eqn. 3)}$$

where

C_{seep} = total canal seepage

T_{div} = total amount of water diverted to the valley

$Evap$ = direct evaporation from the canal surface

ET = evapotranspiration from phreatophytes along the canals

LL_{loss} = amount of water lost from Lake Lowell (seepage plus evaporation)

LL_{dS} = change in storage at Lake Lowell

F_A = average amount of water delivered to the fields
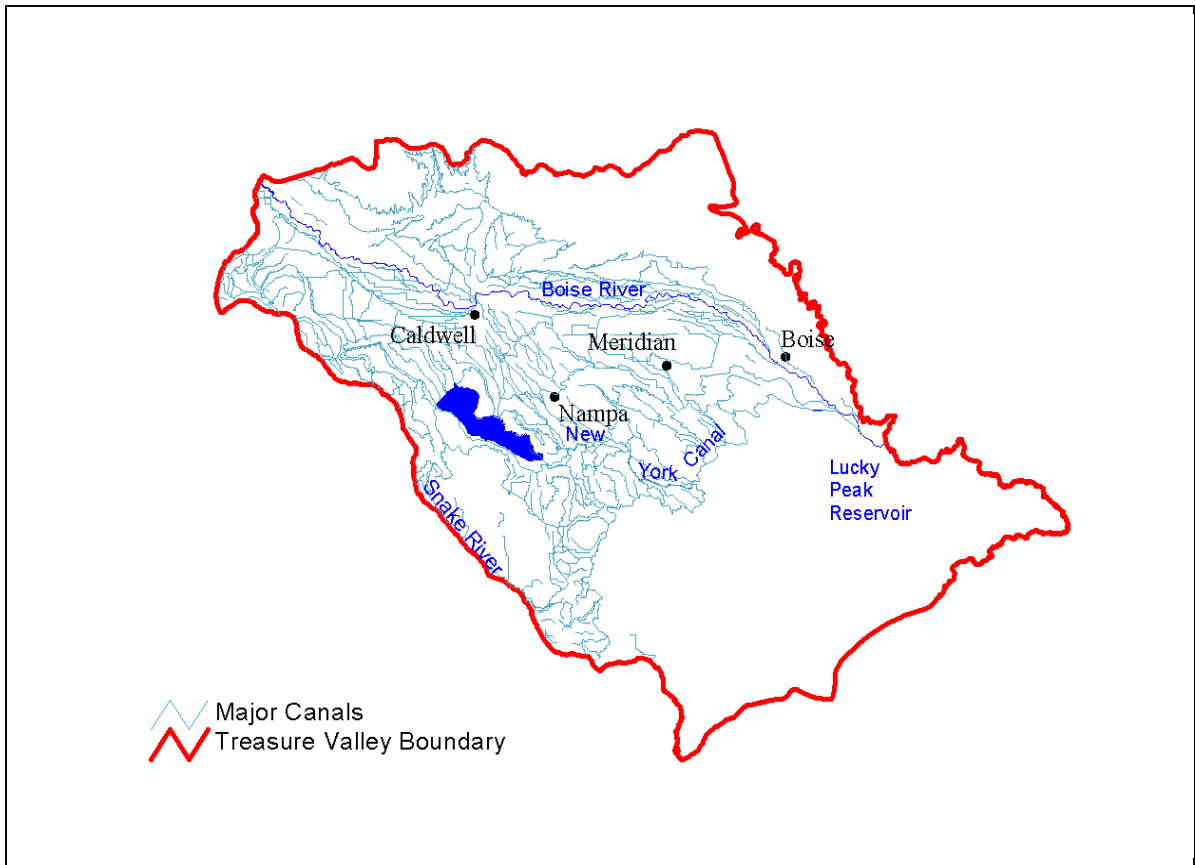
Figure 6: Distribution of major and intermediate canals and drains

In estimating canal seepage, it was assumed that none of the diverted water passes directly to the Boise or Snake Rivers (i.e., it was assumed that return flow to the river system consists only of runoff from the fields and ground water discharge to canals, drains, and rivers).

The total 1996 diversion (T_{div}) for all irrigation districts within the Treasure Valley was about 1,539,000 af during the irrigation season (April 15 through October 15). (Note: all water volumes presented in this report are totals for a calendar year period). About 1,351,000 af were diverted to the Boise Project and other districts from the Boise River (USGS, 1997), while approximately 188,000 af were diverted from the Payette River to irrigate farmland within the Black Canyon Irrigation District (Personal communication, Roy Orr, Black Canyon Irrigation District, 2003). Total diversion from the Boise River in 2000 was 1,327,000 af, with an additional 188,000 af imported from Black Canyon; total diversion to the valley was estimated at 1,515,000 af. Note that the Black Canyon water is provided via a pump station, and the pumps run at the same rate and for the same period of time each year, thus both 1996 and 2000 have the

same estimate (Personal communication, Roy Orr, Black Canyon Irrigation District, 2003).[1]

Total flood-irrigated area for 1996 was estimated to be about 252,000 acres using 1994 imagery (IDWR GIS data, 1997). Flood-irrigated acreage for 2000 was estimated at 269,000 acres using 2000 imagery (IDWR data). The increase in irrigated land was attributed to previously idle land being brought back into production.

Evaporation from canals (*Evap*) was estimated with the following assumptions: (1) total length of the canal system (major canals only) is about 1,170 miles (IDWR, 1996); (2) average canal width is 10 feet, and (3) the evaporation rate is about 33 inches/yr (see Section 2.3 for further discussion). Based upon these assumptions, about 3,600 af of canal water may be lost as evaporation. This is less than 1% of the total diversion of 1,539,000 af.

Evapotranspiration (ET) from phreatophytes along the canals was estimated based upon the following assumptions: (1) total canal length is about 1,170 miles; (2) average vegetated width is about 5 feet along each side of the canal; and (3) evapotranspiration is about 2.4 ft/yr (see Section 2.5 for further discussion). Based upon these assumptions, ET from phreatophytes along the canals was estimated to be about 3,600 af, which is less than 1% of the total diversion.

Water loss data (USGS, 1997) for Lake Lowell (Ll_{loss}) showed a total loss of about 46,300 af in 1996 (evaporation plus seepage) and 48,100 af in 2000 (BPBC annual report). Change in storage at Lake Lowell (LL_{dS}) was estimated at 224,000 af for 1996 and 218,500 af for 2000. This is the amount of water diverted from Lake Lowell during the irrigation season. Note that data for 2000 were not available, so the 2000 value is estimated from the below regression equation obtained by plotting total Boise River diversion data against lake Lowell outflow data for the calendar years 1980 through 1998. In comparing calculated outflow to recorded outflow, maximum error for this period of time was 19%, with an average error of 0.23%.

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[1] Note that the original water budget showed a value of 360,200 acre-feet; 360,200 is the total Payette River diversion, not the amount diverted to the Treasure Valley from the Payette River.
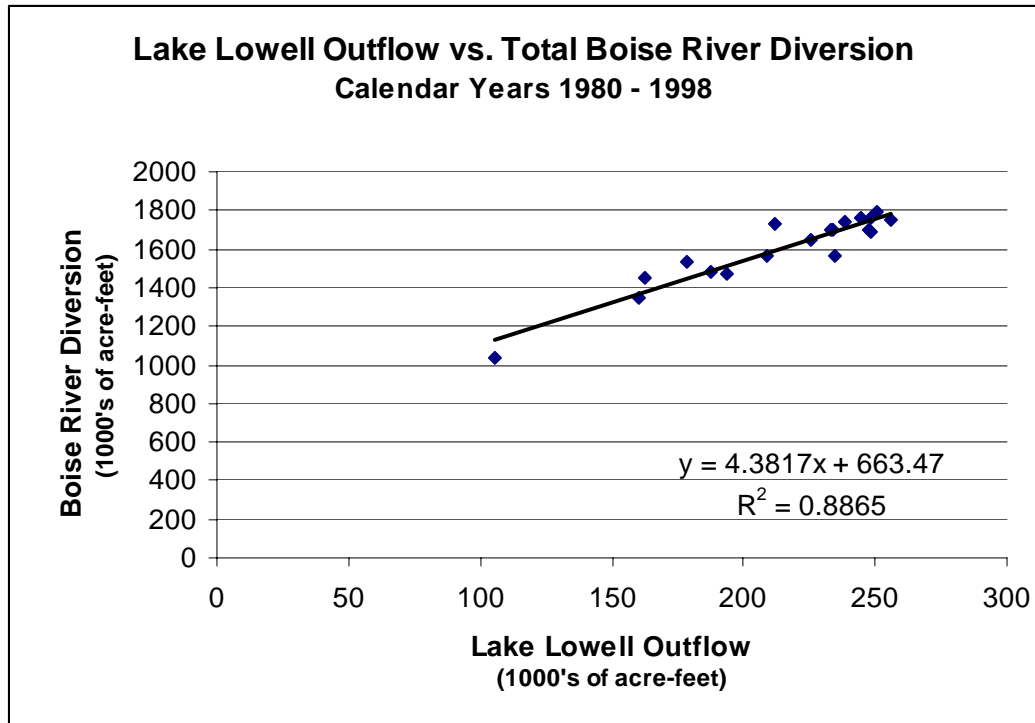
Figure 7: Lake Lowell Outflow Regression Plot

The average amount of water delivered to the fields (F_A) was estimated to be about 4.3 ft/ac (refer to Section 2.5 for additional discussion). Assuming a total flood-irrigated area of 252,000 acres, this is about 1,083,600 af for 1996, and 1,156,700 af in 2000 (applied to 269,000 acres).

Using these estimates, Treasure Valley canal seepage was estimated as follows:

$$C_{seep} = T_{div} - Evap - ET - LL_{loss} + LL_{dS} - F_A$$

$$= 1,539,000 - 3,600 - 3,600 - 46,300 + 224,000 - 1,083,600$$

$$= 625,000 \text{ acre-feet/year for 1996}$$

and

$$= 1,515,000 - 3,600 - 3,600 - 48,100 + 218,500 - 1,156,700$$

$$= 521,500 \text{ acre-feet/year for 2000}$$

This result suggests canal seepage for 1996 was greater than in 2000; total diversion for 1996 was also greater than 2000, but by a lesser percentage. Since the year 2000 had more irrigated lands than 1996, a greater volume of water was allotted to these fields during 2000, thus reducing the residual amount assumed to represent canal

seepage. In reality, less water is delivered on a per-acre basis during a low water year. The seepage equation used in this estimate assumes 4.3 ft/ac is applied to all fields, regardless of total diversion. Better data regarding actual delivery would improve this estimate.

These estimates were then compared to conveyance loss data from the Boise Project Board of Control and the Black Canyon Irrigation District. The Boise Project is an irrigation operations entity comprised of five irrigation districts: Big Bend, Boise-Kuna, Nampa and Meridian, New York, and Wilder. These districts comprise approximately 48% of Treasure Valley flood-irrigated acreage (about 137,700 acres). The Black Canyon Irrigation District irrigated about 45,300 acres of land within the northern portion of the valley (north and west of the City of Caldwell).

According to Board of Control annual reports (IDWR files), the average conveyance loss during the 1985-1990 period was about 49% of the amount diverted to the Boise Project area. About 3% of the conveyance loss was attributed to losses from Lake Lowell, while an additional 1% was lost through direct evaporation and ET along the canals. Using these estimates, conveyance loss attributed to canal seepage was estimated to be about 45% of the total diversion. The Black Canyon Irrigation District reported canal seepage losses of about 33% of the diversion for 1992 (USBR, 1997).

In addition to the above estimates, seepage measurements were taken by the USGS in 42 canal reaches throughout the Treasure Valley during the beginning and end of the 1996 irrigation season (Berenbrock, 1999). These data appear to be influenced by local hydraulic factors and do not necessarily reflect regional seepage patterns.

The USGS also measured seepage in the New York Canal during March 1997 (Berenbrock, 1999). The New York canal lost approximately 12% of the flow between the Boise River and Lake Lowell when approximately 430 cfs were being diverted at Diversion Dam. At a diversion rate of 870 cfs the canal lost approximately 17% of its flow over the same reach. Causes for the flow loss include channel loss (seepage) and evaporation. Evaporation at the March measuring time is considered to be minimal, so most of the loss was attributed to channel loss. These seepage tests were of relatively short duration, and it is possible that the measured seepage rate would decrease over time as the local soils became saturated and as shallow ground water levels rise in response to the seepage. For the purpose of this water budget, it was assumed that under equilibrium conditions New York Canal, seepage was approximately 13% of the total 1996 diversion during the irrigation season.

In conclusion, canal seepage rates will vary throughout the valley, depending on soil type and elevation of the water table. For the purpose of this water budget, total canal seepage for the valley was estimated to be about 625,900 af in 1996, or about 40% of the total diversion to the valley; seepage for 2000 was estimated at 521,500 af, which is about 34% of the total diversion for 2000. Assuming a total canal length of

1,170 miles (major and intermediate canals only), canal seepage occurs at an average rate of about 0.75 cfs/mile.

2.2. Recharge from Rivers and Streams

Additional sources of aquifer recharge include seepage from the Boise River and from small streams and drainages located within the Boise Foothills. Other streams within the valley are ephemeral in nature and are thought to contribute very little ground water recharge. Many serve as drains where they pass through flood-irrigated lands (B. Ondrechen, IDWR, personal communication, 1997).

Streams draining the Boise Foothills either discharge to the Boise River or provide seepage into the ground, which then enters the valley as underflow. Recharge within the Boise Foothills was treated as a source of underflow and is discussed further in Section 2.4 below.

The Boise River loses water to the aquifer system from the Lucky Peak Reservoir to Capitol Bridge reach (about 11 miles), while it gains water from the aquifer along the Capitol Bridge to Parma reach (based on stream gage data; USGS, 1996). Reach gain data indicate an annual average loss of about 15,000 af/yr along the Lucky Peak to Capitol Bridge reach during 1958-1996, a period of time reflecting a wide variety of river flow conditions following the construction of Lucky Peak Dam (B. Sutter, IDWR, personal communication, 1996). Data for 1996 suggests the Boise River lost about 15,500 af to the aquifer system along the Lucky Peak to Capitol Bridge reach (USGS, 1997). About 77,000 af were lost during 2000 (IDWR data, 2003).

2.3. Recharge from Lake Lowell

Lake Lowell is a 9,800-acre reservoir located in the southwest portion of the valley. Data for 1996 were not available at the time of this report. However, total loss during 1995 was about 46,000 af (IDWR data) and 48,100 af in 2000 (BPBC annual report), including evaporative losses from the lake surface. About 26,900 af are lost to evaporation each year, assuming a total surface area of 9,800 acres and a mean evaporative loss of 33 inches/yr (Dion, 1972). Net recharge to the shallow aquifer for 1995 was therefore estimated to be about 19,000 af. This value was used for the 1996 water budget. About 21,200 af were lost to seepage in 2000 (BPBC annual report).

2.4. Subsurface Inflow (Underflow)

Subsurface inflow (or underflow) is defined as the ground water that flows across the water budget boundary and can include both horizontal and vertical components of flow. There appears to be no evidence (on the basis of regional ground water contours [Newton, 1991]) of ground water flow across the northern boundary (the watershed divide between the Payette and Boise Rivers) or underneath the Snake River. There is

potential underflow across the northeast water budget boundary and across the east and southeast boundaries.

The magnitude of underflow across the northeast boundary was estimated by assuming all precipitation within the Boise Foothills, less ET and stream discharge, seeps into the rocks and sediments and ultimately flows across the northeastern boundary as ground water. The net precipitation was estimated using water yield maps (Rosa, 1968) and total drainage area (B. Ondrechen, IDWR, 1996). These maps correct for ET, thus allowing an estimate of water available for recharge and runoff. The total drainage area bounded by the valley floor and the hydrographic divide was estimated at 55.4 mi^2. This area includes Stuart Gulch, Crane Creek, Hulls Gulch, Freestone Creek, Cottonwood Creek, Warm Springs Creek, Squaw Creek, Maynard Gulch, Highland Creek, and other unnamed tributaries between Highland Creek and Lucky Peak Reservoir. Based on this approach, the average annual amount of water available for runoff and ground water recharge was estimated to be 7,600 af/year (2.6 area inches). Less than 1 area inch of recharge is estimated for the foothills area west of Stuart Gulch.

Total stream discharge from the Foothills was estimated to be about 4 cfs using published data (e.g., USGS, 1956). Total underflow across the northern and northeast boundaries was therefore estimated to be about 4,300 af.

The underflow across the eastern and southeastern project boundaries also appears to be very small. Ground water level maps drawn from spring and fall 1996 mass ground water level measurements indicate ground water flow lines somewhat parallel to the southeastern project boundary, indicating no-flow boundary conditions (see Berenbrock, 1999). Simulated ground water contours in deeper zones (Newton, 1991) also indicate minimal ground water flow across the southeastern project boundary. Newton's model (1991) was run to evaluate the possible magnitude of underflow across the southeastern project boundary. Calculations using transmissivity and head-difference values between rows 30 and 31 of layer 2 (which extends from 500 to 4,500 ft below ground surface) in the WSRP model (Newton, 1991) result in an estimate of approximately 5 cfs in the form of underflow across the eastern boundary. However, subsequent ground water modeling within the Treasure Valley (Petrich, 2004) suggests no underflow from this region. In summary, total underflow (as recharge) for the valley was estimated to be about 4,300 af. This represents less than 1% of the total aquifer recharge.

2.5. Recharge from Precipitation and Surface Water Irrigation

It is generally recognized that flood irrigation can be a significant source of recharge to Treasure Valley aquifers. Development of an extensive canal system, beginning in the 1880s, and associated irrigation using diverted surface water raised ground water levels in the shallow aquifers several tens of feet and has significantly increased the amount

of water held in storage (Dion, 1972). This section presents estimates of ground water recharge from precipitation and irrigation for several Treasure Valley land use types.

Precipitation and surface water irrigation are addressed together because precipitation and applied surface water jointly meet consumptive demands and a portion of each source may become aquifer recharge. For example, most of the precipitation is lost to ET in a low precipitation area. In an irrigated area, some of the soil moisture requirement is met by irrigation but some is also met by precipitation (especially in the spring and early summer months). Similarly, some precipitation may infiltrate to become aquifer recharge, and any excess water applied during the irrigation season may also become recharge.

The following sections provide estimates of ground water recharge for flood-irrigated lands using surface water (Section 2.5.1), sprinkle-irrigated lands using surface water, fallow land, rangeland, residential lands, and public lands, such as parks and greenways (Section 2.5.2).

2.5.1.   Recharge from Flood Irrigation and Precipitation

Recharge was estimated using the following relationship:

$$R_{FI} = F_A + P - ET - R_{off} - F_c \qquad\qquad \text{(Eqn. 4)}$$

where

R_{FI} = recharge from flood irrigation

F_A = amount of surface water applied

P = precipitation

ET = crop evapotranspiration

$Evap$ = evaporation from bare soils

R_{off} = total runoff (includes runoff from excess flood irrigation and precipitation into drains, and municipal discharges to the river)

Water application rates vary within the Treasure Valley, depending upon water availability, crop demand, and the efficiency of the irrigation district. The Boise Project, which includes most of the southern portion of the Treasure Valley, delivered an average of 2.5 ft/ac of water to the fields during the 1985-1990 time period. The Black Canyon Irrigation District (located in the northern portion of the valley) delivered about 5.2 ft/ac to fields during 1992 (USBR, 1997). Other districts within the valley delivered an unknown amount of water. According to Newton (1991), the USBR reported that farm delivery requirements for the Boise River valley averaged about 3.8 ft/ac. Lindgren (1982) evaluated average irrigation diversions for

29 subareas within the Treasure Valley. Net application ranged from less than 2 ft/ac to more than 8 ft/ac; the average was 4.3 ft/ac.

The actual amount diverted throughout the valley varies; the actual amount applied to a specific tract of land depends on crop demand and water availability. For this water budget, it was assumed that an average of 4.3 ft/ac was applied to 252,000 acres of flood-irrigated lands during 1996 (1,083,600 af). For the year 2000, it was also assumed the average application rate was 4.3 ft/ac, resulting in 1,156,700 af over 269,000 acres. It was also assumed that all precipitation, less ET, evaporation during the non-irrigation season, and direct runoff was available for recharge where land is used for flood irrigation because soil-moisture conditions are otherwise satisfied throughout much of the growing season (Newton, 1991). The mean annual precipitation for flood-irrigated land within the valley was about 12.8 inches (Section 1.3). This results in about 268,800 af of precipitation over a flood-irrigated area of 252,000 acres for 1996 and 251,000 af for 2000 (11.2 inches of precipitation applied to 269,000 acres).

Much of the total potential recharge from precipitation is lost to ET. For 1996, ET data for the Treasure Valley area were calculated for a variety of crops using the Kimberly-Penman equation, which incorporates variables representing local conditions (USBR, 1995). These variables include measured values for solar radiation, air temperature, relative humidity, and wind conditions. These variables are used to develop coefficients, which are updated yearly using water consumption data provided by local farmers. As a result, these data are considered by many to be most representative for this area (B. Ondrechen, IDWR, personal communication, 1996).

Typical crop rotations for 1995 (Idaho Agricultural Statistics Service, 1996) were examined and assumed to be relatively unchanged for 1996. Crop rotations and corresponding ET data are summarized in Table 1. Because crop types vary spatially, and ET varies by crop, a weighted average for ET was developed. This average takes into account the average crop acreage and ET for each crop type. As shown in Table 1, this approach resulted in a weighted average of about 29.1 inches (2.4 af/ac). This weighted average represented the average amount of water transpired for each acre of cropland within the Treasure Valley. Using this value, and a flood-irrigated area of 252,000 acres, total crop ET (consumptive use) was estimated to be 604,800 af/yr for 1996.

| Crop | 1995 Crop Acreages[a] | | Total Acreage[a] | Percent of Acreage in Normal Rotation | Average Consumptive Use for 1988-1994[b] (inches/acre) |
	Ada County	Canyon County			
Alfalfa Hay	26,400	33,500	59,900	23	38.8
Alfalfa Seed	1,900	18,100	20,000	8	29.9
Barley	2,300	13,900	16,200	6	24.3
Corn	4,900	22,800	17,700	10	25.7
Dry Beans	1,900	15,700	17,600	7	19.2
Mint	5,000	7,100	12,100	5	24.7
Oats	1,200	3,400	4,600	2	24.3
Onions	0	5,000	5,000	2	27.4
Potatoes	600	11,000	11,600	4	25.6
Sugar Beets	5,200	25,300	30,500	12	31.8
Wheat	7,300	49,700	57,000	22	24.3
Total	**56,700**	**205,500**	**262,200**	**101**	
				Weighted Average:	**29.1**

[a]1995 crop acreages from Idaho Agricultural Statistics Service (July 1996) EXCEPT data for alfalfa seed, mint and onions, which are 1992 values from USDA 1992 Census of Agriculture. For comparison, land use data for 1994 (IDWR, 1997) show about 258,370 acres of actively irrigated land in organized irrigation districts within the water budget area.

[b]Consumptive use data from Agricultural Water Use Summary, 1988-1994 (USBR, 1995). Consumptive use for alfalfa seed computed as 77 percent of alfalfa hay (Brockway and Allen, 1983)

Table 1: Estimates of irrigated acreage and consumptive use for 1995

For the year 2000, ET was estimated using SEBAL, a satellite image-processing model for computing ET data for large areas. SEBAL is comprised of computational steps that predict a complete radiation and energy balance for the earth's surface along with fluxes of sensible heat and ET. SEBAL uses digital image data collected by Landsat or other remote-sensing satellites measuring visible, near-infrared and thermal infrared radiation. ET is computed as a component of the energy balance on a pixel-by-pixel basis. Using year 2000 Landsat imagery, ET estimates were obtained for a variety of Treasure Valley land uses at the scale originally mapped by IDWR. For fields that were flood-irrigated with surface water, total ET for the 2000 irrigation season was estimated to be about 608,000 af, which is an average of 2.34 feet over 269,000 acres (Kramber, personal communication, 2003).

Data for evaporation from bare soils during the non-irrigation season (*Evap*) were not available for the valley, so this parameter was estimated using monthly values for reference ET (AgriMet data, USBR, 1997) and early season crop coefficients. During the early months of the growing season, crops such as peas and potatoes have relatively little foliage, thus most of the reported ET is from direct evaporation from the soils (B. Ondrechen, IDWR, personal communication, 1997). The early season crop coefficients for these plants suggested bare soil evaporation was about 25% of the reference ET. The total reference ET for the October-March period was about

10.2 inches during the 1996 calendar year (AgriMet data, USBR, 1997), and 10.6 inches in 2000. Using a crop coefficient of 25%, bare soil evaporation during the non-irrigation season was estimated to be about 2.5 inches for 1996 and 2.6 inches for 2000. This is equivalent to about 52,000 af of evaporation over a 252,000 acre area for 1996 and 58,200 af for 2000 (269,000 acres).

Run off of flood irrigation water and precipitation was estimated from reach gain data for the Boise River using the following relationship:

$$R_{off} = R_{gain} - GW_{disch} \qquad \text{(Eqn. 5)}$$

where

R_{off} = total runoff (flood irrigation and precipitation runoff)

R_{gain} = total gain

Gw_{disch} = estimated ground water discharge

Runoff represents excess flood-irrigation water and precipitation that has discharged to drains and canals that subsequently discharge to the Boise River. Reach gains represent the aggregate inflow along a particular reach and include ground water discharge and runoff from fields. Reach gains are determined using stream flow measurements at discrete points along the reach. Boise River stream flow data for Parma and Capitol Bridge were used for this estimate.

Reach gain data for the Boise River (IDWR data) showed a total gain of about 903,000 af during 1996 and 845,000 af for 2000. About 523,200 af of ground water were discharged to the Boise River during 1996, either directly, or through streams and canals (refer to Section 3.2). About 529,000 af were discharged in 2000. Based upon these estimates, total runoff (as drain discharge) to the Boise River was estimated to be about 379,800 af during 1996 and 315,000 af in 2000.

Reach gain data were not available for the Snake River for the year 1996. However, drain flow data from major canals and drains were available for 1992 and showed about 14,000 af of return flow to the Snake River (Section 3.2.3). This amount was assumed to represent total runoff (surface water plus precipitation) from the Treasure Valley to the Snake River during 1996; this same estimate was used for 2000 calculations total runoff from the Treasure Valley and was therefore estimated to be about 393,800 af for the year 1996. Spread over 252,000 acres of flood-irrigated land, this is equivalent to about 19 inches of runoff per acre. Runoff for 2000 is estimated to be about 329,000 af, or about 14 inches per acre. The actual amount of runoff may vary throughout the valley, ranging from about 3 to 30 inches/ac, depending on crop

and soil type, water availability, and method of application (T. Stieber, University of Idaho College of Agriculture, personal communication, 1997).

For comparison, an average of 11 inches/yr of runoff per acre was reported by the Natural Resource Conservation Service (NRCS) for farmlands within the Treasure Valley. The NRCS estimate is based on preliminary results from a computer model ("EPIC") that simulates field erosion. This preliminary estimate was thought to be a representative average for the valley; actual values vary depending upon soil types and field slopes (David Ferguson, NRCS, personal communication, 1997).

Based upon the above estimates, the net recharge to flood-irrigated land during 1996 was estimated as follows:

$R_{FI} = F_A + P - ET - Evap - R_{off}$

$\quad = 1,083,600 + 268,800 - 604,800 - 52,000 - 393,800$

$\quad = 301,800$ acre-feet/yr

$\quad = 1.2$ feet/acre of flood-irrigated land

For 2000, recharge was estimated to be :

$= 1,156,000 + 251,000 - 616,100 - 58,200 - 329,000$

$= 404,400$ acre-feet

$= 1.5$ feet/acre of flood-irrigated land

It was assumed that the estimated recharge is distributed proportionately over flood-irrigated areas. This assumption, and the estimated recharge value will be reviewed as more data become available.

2.5.2. Recharge from Precipitation for Other Land Uses

This section presents estimates of ground water recharge from precipitation and irrigation for non-flood-irrigated areas. Specifically, this subsection presents estimates of recharge from (1) sprinkler-irrigated land, (2) fallow lands, (3) rangeland, (4) residential land, and (5) public lands. Except where specifically noted, it was assumed that most of these lands use ground water for irrigation purposes.

Previous investigations in the WSRP provided estimates of recharge from precipitation. Kjelstrom (1995) assumed an average of 0.03 ft/yr for the WSRP. Newton (1991) estimated that the total average to all lands within the WSRP was 2% of the average annual precipitation (about 0.02 ft/yr assuming an average precipitation of 10 inches/yr). In developing this estimate, Newton assumed that no recharge occurs

through non-irrigated lands if precipitation is less than 9 inches (i.e., ET from native vegetation exceeds precipitation).

Recharge rates from precipitation were estimated on the basis of 1986 and 1994 land use data (IDWR). Recharge sources by land use included precipitation, and where applicable, irrigation practices. Recharge rates were estimated for individual land use types. The rates were approximated based upon recharge estimates from Newton (1991), Kjelstrom (1995), Drost, et. al.(1997), and communications with IDWR staff. Actual recharge rates vary widely throughout the study area and depend on variables such as soil type, vegetative cover, and water application.

Table 3 provides a summary of estimated recharge rates. These rates represent an approximation of potential recharge based upon major land use classifications. For lands occupied by buildings, pavement, and irrigable lawn (such as residential lands, public lands, and recreational lands), it was assumed that 50% of the land was not irrigable. Given these assumptions, it was estimated that precipitation contributed about 47,900 af of recharge to Treasure Valley aquifers for non-flood-irrigated land uses in 1996 and 65,700 af in 2000. As shown in Table 3, the amount of irrigated land area increased between 1994 and 2000. Using aerial photography, IDWR GIS analysts (Kramber and Wilkins, personal communication, 2003) determined that some farmland that was classified as idle in 1994 had since gone back into production. As a result, an increase in total recharge is observed.

Land Use	Recharge Rate[a] (ft/yr)	Total Acreage[b]		Recharge from Precipitation (af/yr)	
		1996	2000	1996	2000
Arid/Barren Lands	.02	483,800	360,100	9,700	7,200
Residential[c]	.25	57,200	77,200	14,300	19,300
Public/Recreation[c]	.25	7,900	10,300	2,000	2,600
Farmland, Sprinkle Irrigated (ground water)	.20	42,300	27,700	4,200	5,500
Farmland, Sprinkle Irrigated (surface water)	.45	58,700	68,900	17,600	31,000
Dairy/Feedlot	.02	4,300	6,300	100	130
Industrial/Commercial	0.0	17,200	14,300	0	0
			Total	47,900	65,700

[a]Recharge rates are estimated values based on previous investigations (eg., Newton, 1991, Kjelstrom, 1995, and Drost, et. al., 1997) and communications with IDWR staff. Additional recharge estimates from precipitation on flood-irrigated land are provided in Section 2.5.1.

[b]Acreages from 1986 and 1994 GIS land use coverage for 1996 data (IDWR, 1995, 1997), and 2000 imagery for year 2000. Note that year 2000 has a model grid that is about 117,000 acres smaller than the initial model domain, resulting in less arid/barren lands.

[c]"Residential" includes rural dwellings, farmsteads, and old urban and new subdivisions. "Public" includes parks, colleges, hospitals, schools, etc. "Recreation" includes golf courses, racetracks, campgrounds, stadiums, etc. Recharge rate for these land uses was estimated to be about 0.5 ft/yr but was reduced to 0.25 ft/yr to correct for assumption that about 50% of these lands are not irrigable.

Table 2: Recharge from precipitation by land use.

2.6. Recharge from Rural Domestic Septic Systems

Recharge from septic systems can be significant in some regions, particularly where water use is high and where rural housing is relatively dense. It was assumed that all septic discharge becomes ground water recharge. This recharge was estimated using census data for numbers of rural dwellings and an estimated per-capita discharge rate.

House count data were obtained using census tract data (Bureau of Census, 1992). This GIS database provided an approximate spatial distribution of houses in the Treasure Valley and showed approximately 28,700 rural domestic houses existed within the Treasure Valley during 1990. (Note: the Treasure Valley includes all lands within Ada and Canyon Counties and portions of Elmore and Payette Counties). Similar GIS census tract data were not available for 1995 or 1996. However, county census data showed the number of rural houses in Ada and Canyon Counties increased from a total of 22,775 to 27,000 from 1990 to 1995. This represents an increase of about 20%. To provide an approximation of the spatial distribution of rural domestic houses within the entire Treasure Valley during 1995, the 1990 GIS estimate was increased by 20%, resulting in about 34,400 rural domestic houses.

For 2000, Census data obtained from COMPASS (Goodell, personal communication, 2003) show about 33,500 rural dwellings, with about 31,950 homes being occupied. An average of 2.9 people/house were reported for Ada and Canyon Counties.

The U.S. Environmental Protection Agency reported typical septic discharge to be about 45 gallons per day per person (gpd/person) (EPA, 1980). Assuming three persons per household (Idaho State Department of Commerce, 1996), and 34,400 houses, total recharge from septic systems during 1996 was estimated to be about 1.7 billion gallons, or about 5,200 af. Septic recharge for 2000 was estimated at 4,600 af based upon estimated occupancy.

3. ESTIMATES OF GROUND WATER DISCHARGE

3.1. Ground Water Withdrawal

Ground water withdrawals are comprised of water that is pumped or flows under artesian pressure from municipal, industrial, agricultural and rural domestic water supply wells. The category includes water that is withdrawn from a variety of depths and aquifers. The following sections describe how withdrawal data were obtained and provide estimates of 1996 withdrawals. With the exception of industrial withdrawals, all estimates refer to a total volume of ground water withdrawn and do not necessarily reflect consumptive use (i.e., water permanently removed from the system). For many land uses, some of the ground water withdrawn seeps into the ground as recharge (e.g., irrigated and rural domestic lands; refer to Sections 2.5 and 2.6). For industrial land uses it was assumed that the estimated withdrawal was a measure of consumptive use (i.e., no subsequent aquifer recharge occurs).

3.1.1. Municipal Withdrawal

Municipal wells in the Treasure Valley supply water to a large number of domestic and commercial users. Domestic use refers to water used for individual homes, while commercial use refers to water used by restaurants, industries, apartment complexes, miscellaneous businesses, etc. In addition to these uses, water pumped by municipalities is used to irrigate public lands, such as parks and golf courses. This section provides estimates of withdrawals for each of these uses. Not included are geothermal withdrawals for heating purposes. Geothermal water is withdrawn from an aquifer system, which is below, and largely isolated from, the aquifer systems considered in the TVHP.

3.1.1.1. Domestic and Commercial Withdrawal

Data for municipal ground water withdrawals were obtained from UWI (serving Boise), and the cities of Caldwell, Eagle, Kuna, Meridian, Middleton, Nampa, Parma, and Star.

Municipal pumping rates for areas where actual data were not available were estimated on a per capita basis for 1996. Data from the city of Kuna were used to estimate per capita pumping rates because user population was well known, and these pumping data represent largely domestic uses with some commercial uses. Based on 1995 population and water use data, the citizens of Kuna use about 230 (gpd/person). This was the same value reported by Goodell (1988) for non-industrial public-supply for Ada and Canyon Counties during 1980. Table 3 compares Kuna withdrawals with other suppliers from which actual pumping data were obtained.

A recent IDWR investigation (unpublished revision of Cook, et. al., 2001) resulted in similar water use coefficients, with an estimated 225 gpd/person for single-family homes in Ada and Canyon counties. For mobile homes and apartments, an estimate of 176 gpd/person and 169 gpd/person was developed for Canyon and Ada Counties, respectively.

City	Population[a]		Average Commercial and Domestic Water Use (gpd/person) [b]	
Year	1995	2000	1996	2000
Boise[c]	146,000	185,800	240	236
Caldwell[d]	24,000	25,970	160	178
Kuna[e]	2,400	5,400	230	224 (279)[e]
Nampa[d]	35,300	51,900	140	116

[a]1996 census data unavailable at time of report.

[b]Does not include municipal irrigation of public lands, or self-supplied industrial/commercial use.

[c]Assumes UWI serves a population equivalent to the city of Boise. Assumes domestic irrigation is supplied by UWI.

[d]Does not include domestic irrigation from municipal irrigation wells.

[e]Domestic irrigation was provided by municipal wells in 1996 and is included in water use coefficient. In 2000, pressurized domestic irrigation (107,197,800 gallons) was provided by a separate well. The 224 gpd/person coefficient does not include irrigation, whereas the 279 gpd/person includes irrigation (water that is delivered between April 15 and October 15). Beginning in 2001, Kuna's pressurized irrigation system used surface water pumped from a pond (Personal communication, Jim Taylor, City of Kuna, 2003).

Table 3: Summary of selected municipal water consumption

Figure 8 summarizes municipal water use for 1996. Total municipal use (less municipal irrigation) for 1996 was estimated to be about 66,100 af. For comparison, municipal withdrawal for 1980 (Goodell, 1988) was about 51,300 af. Based upon municipal pumping data for 2000, about 76,800 af of ground water were pumped for domestic, commercial, and industrial uses.

Municipal Water Use
1996 and 2000
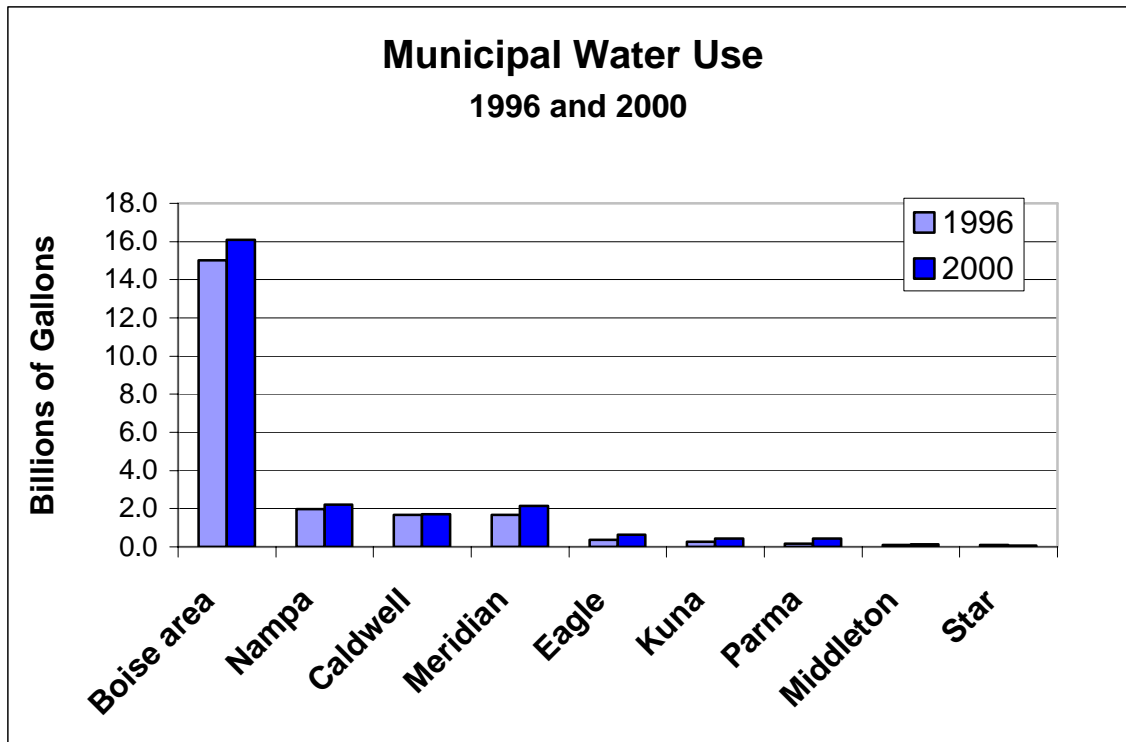
Figure 8: Municipal water use for 1996 and 2000

3.1.1.2. Municipal Irrigation of Public Lands

Most municipalities also use ground water to irrigate public areas such as parks, public golf courses, etc. The city of Nampa utilizes a dual-supply system, where culinary and irrigation water is supplied by two different distribution systems. Nampa used about 11,600 af for municipal irrigation of public and private lands from canals and irrigation wells during 1996 (T. Chavez, city of Nampa, personal communication, 1996).

The city of Boise irrigates about 435 acres of city parks and greenways using ground water and an additional 240 acres using surface water (L. Cody, personal communication, 1996). Most of Boise's irrigation wells lack flow meters, so estimates of ground water withdrawals for irrigating public lands were made using total acreage and ET data. A weather station located at Ann Morrison Park provided daily ET values, which were used to estimate lawn irrigation requirements. For 1995, total ET was estimated to be about 31 inches (2.6 feet). A minimum of 1,130 af were required to meet this demand. Assuming an irrigation efficiency of about 80% (T. Scanlan, Scanlan Engineering, personal communication, 1997), approximately 3.5 feet of water were required per acre. Total ground water withdrawal by the city of Boise for municipal irrigation was estimated to be about 1,500 af.

Total municipal irrigation of public lands throughout the valley was estimated using land use data (IDWR, 1997). These data show that the total area for public lands was about 7,900 acres (this includes public lands within the City of Boise). As discussed in

Section 2.5.2, it was assumed that approximately 50% of public lands were not irrigable, resulting in a revised irrigated acreage of about 3,950 acres. Assuming that 3.5 feet of water were applied (based on the above estimate for the city of Boise), total use of ground water for municipal irrigation was estimated to be about 13,800 af. However, some of this public land was irrigated with surface water. The city of Boise irrigated about 35% of its public lands with surface water, while the city of Nampa obtained about 24% of its irrigation water from surface sources. It was therefore assumed that 30% of the total municipal irrigation demand is satisfied with surface water sources.

In conclusion, it was assumed that about 70% of public lands are irrigated with ground water, resulting in about 9,700 af of ground water withdrawal. For the purpose of this valley-wide water budget, this estimate was assumed to represent both 1996 and 2000 conditions.

3.1.2. Self-Supplied Industrial

Industrial ground water use is difficult to quantify because many industries rely on different water sources, such as a combination of municipal supply and self-supplied water. Also, municipal suppliers usually do not distinguish between commercial and industrial use (i.e., the commercial category includes small businesses, multi-family housing, and industrial facilities).

Industrial pumping for 1996 was estimated from water use coefficients (USGS, 1997b) because actual pumping data were not available for most Treasure Valley industries. Water use coefficients relate average industrial water use, without regard to region or specific water conservation efforts, to the total number of employees for each industry. Actual water use for a specific industry may vary within a region depending on plant efficiency and/or the type of water conservation programs used (Burt, 1983). Goodell (1988) used this approach to estimate self-supplied industrial ground water withdrawal for 1980 and showed self-supplied industrial use was about 14,900 af for Canyon County and about 700 af for Ada County, or a total of about 15,600 af.

To estimate current self-supplied industrial withdrawal for the Treasure Valley, census data for industrial populations were obtained for 1995 (Idaho Department of Employment, 1997; 1996 data unavailable at time of report preparation). Industrial water use coefficients were obtained for industries typically found in the Treasure Valley (USGS, 1997b), assuming the majority of Treasure Valley industries are self-supplied.

Most industries within the Treasure Valley do not record or report water use. However, Micron Technology, Inc., of Boise provided estimates for 1995 water use and employee census. This allowed a water use coefficient to be calculated for the largest industrial employer in the Treasure Valley. In 1995, Micron employed about 7,000 persons and used about 2,650 af of water at its southeast Boise semiconductor facility. This resulted in a water use coefficient of about 340 gpd/employee. However,

about 960 af of the total used was purchased from UWI (M. Maupin, USGS, personal communication, 1997). Using this latter value yielded a water use coefficient of about 215 gpd/employee for the amount of water self-supplied by Micron (the balance of 960 af was included under total municipal withdrawal; refer to Section 3.1.1). Table 4 provides a summary of industry census data and water use coefficients.

Industry[a]	Numbers of Employees (1995)[a]		Water Use Coefficient[b] (gpd/person)	Self-Supplied Industrial Withdrawal by County (af/yr)		Total Self-Supplied Industrial Withdrawal (af/yr)
	Ada County	Canyon County		Ada County	Canyon County	
Agriculture[c]	400	3,000	15	10	50	60
Construction	10,300	2,500	390	4,480	1,070	5,550
Food Processing	2,400	3,900	1,287	3,470	5,710	9,180
Manufacturing[d]	10,000	4,700	204	2,240	1,070	3,310
Micron Technology[e]	7,000	0	215	1,690	0	1,690
Wood Products[f]	2,300	1,400	240	630	360	990
Total	**32,400**	**15,500**		**12,520**	**8,260**	**20,780**

[a]Industry categories and 1995 employee census data from Idaho Dept. of Employment, Research and Analysis, except for Micron Technology, Inc, which supplied its own population and water use data for 1995.

[b]Typical daily industrial water consumption (gpd/employee). Data from USGS website: http://h20.er.usgs.gov/public/wateruse. Exception for Micron Technology, which supplied specific water use and population estimates for 1995.

[c]Agriculture category refers to amount of water personally consumed by the employee; does not include irrigation water, livestock water, or other agricultural uses. Rate of 15 gpd/person obtained from Idaho Water Law Handbook, 1988, Appendix IV;value for "day camps, no lunch served."

[d]Manufacturing category includes electronics industries such as Hewlett-Packard (does not iclude Micron Technology, Inc., of Boise, which is considered separately).

[e]This rate reflects the amount of water pumped from Micron wells only; an additional 123 gpd/employee was purchased from UWI.

[f]Wood products category includes lumber and wood industries, such as lumber, plywood, and cabinet making. It does not include pulp and paper industries.

Table 4: Summary of self-supplied industrial ground water withdrawal for 1996

Approximately 12,500 af of self-supplied industrial ground water were self-supplied by industries in Ada County during 1995 (Table 5). About 8,300 af of self-supplied ground water were used by industries in Canyon County. Total self-supplied industrial ground water use for 1995 was estimated to be about 20,800 af based upon employee census data.

As discussed above, this approach assumes all major industries are self-supplied, except for Micron Technology, Inc.. The estimates of industrial withdrawal presented above may be higher than actual because some industries purchase an undefined amount of ground water from municipal suppliers. Also, with the exception of Micron Technology, Inc., the industrial water use estimates may contain some error because national water use coefficients were used, which may not accurately reflect local conditions (Burt, 1983). Despite these potential errors, total industrial ground water use is small relative to other water budget components.

For the year 2000, average annual industrial water use data were obtained from an IDWR project that investigated domestic, commercial, and industrial water demand for Ada and Canyon Counties (Cook, et. al., 2001). Two sets of data were used to calculate annual water demand coefficients. The first data, from the Idaho Department of Labor, contained monthly counts of employees for establishments covered by unemployment insurance during 1997 and 1998. The second data, from billing records of UWI, contained bimonthly water usage during 1997 and 1998 for all commercial, municipal, and industrial accounts in their service area. The two sets of data were matched and linked using business name and address. The composite data set contained a single record for establishments, with annual values for 1997 and 1998 on employees and water usage. Overall, the sample represented 58,200 (38%) of the estimated 151,560 employees in Ada County and 1,095 (8%) of the estimated 12,771 establishments. Results from this analysis suggested industrial water use was about 8,200 af for Ada and Canyon Counties. This value is less than the 1996 estimate of 20,800 af. This difference is likely the result of using different water use coefficients: the 1996 estimate used published national averages (from USGS, 1997b), whereas the 2000 estimate uses averaged coefficients developed for the local region (from Cook, et. al., 2001).

3.1.3. Irrigation Withdrawals

Significant portions of Treasure Valley agricultural lands are irrigated with ground water. Approximately 42,300 acres of farmland (primarily in the southern portion of the valley) utilize ground water exclusively (IDWR, 1997). In addition, many of the irrigators dependent on surface water supplies use supplemental irrigation wells during periods of drought.

There are three methods commonly used to estimate ground water pumping for irrigation wells (Collins, 1984; Frenzel, 1984; Bowman and Wilson, 1987; Morgan, 1988; Van Metre and Seevers, 1991). These methods include (1) direct readings from flow meters, (2) power billing records for the pump, and (3) consumptive use data and irrigated acreage. These methods are discussed below.

First, direct readings from flow meters require that a significant number of irrigation wells are fitted with totalizing flow meters. At this time, most wells within the Treasure Valley area are not metered.

Second, power consumption data are commonly used to estimate ground water withdrawal using the following relationship (Goodell, 1988):

$$Q = \frac{kWh}{K \times TH} \qquad \text{(Eqn. 6)}$$

where Q = total volume of water pumped (af/yr)

kWh = total power consumed in a year (kilowatt-hours)

K = number of kilowatt-hours required to lift 1 af of water 1 foot (kilowatt-hours/acre-feet-foot)

TH = total head, or pumping lift (feet)

Power consumption, as an indication of ground water pumping, is best suited to areas where pumping lifts are fairly constant throughout an irrigation season and where data are available for individual irrigation wells (Bowman and Wilson, 1987, Frenzel, 1984). Power billing data are available for Treasure Valley irrigation wells, but measurements of head are not available at this time. Consequently, errors in estimates of total head could be a major source of error with respect to calculating ground water use (Morgan, 1988).

The third approach is to use consumptive use and irrigated acreage data to estimate ground water withdrawals. This latter approach was used for the 1996 Treasure Valley water budget because of the limitations associated with the first and second approaches. Estimates of ground water withdrawal on a per-acre basis were obtained by multiplying the irrigated acreage by the average per-acre consumptive use for the valley. A consumptive use value of 29.1 inches/ac was used as described in Section 2.5.

The following assumptions were made in estimating agricultural ground water irrigation:

1. Because water pumping costs are high relative to flood irrigation costs, farmers will not over apply ground water used for irrigation.
2. With the exception of runoff, all precipitation goes into soil storage and is available to the crop.
3. The mean annual precipitation for areas irrigated with ground water was about 10 inches.
4. Topography in areas irrigated with ground water is relatively flat, and the soils are generally well-drained. Therefore, runoff from the fields was probably very low and was estimated to be about 1 inch/acre (B. Ondrechen, IDWR, 1996).

5. The amount of ground water withdrawn was estimated to be equivalent to the total consumptive use (ET), less the net precipitation.

The average ET throughout the valley was estimated in Section 2.5 to be about 29.1 inches/ac (2.42 ft), while the effective precipitation was estimated to be about 9 inches. Based upon these estimates, the amount of ground water required to meet crop consumptive use was estimated to be about 20 inches/ac (1.7 ft/ac). Multiplying this value by 42,300 acres (the total ground water irrigated acreage) resulted in about 71,900 af of ground water withdrawn for agricultural irrigation.

ET for 2000 was obtained using the SEBAL algorithm (Section 2.5.1). Results from this analysis showed about 9,300 acres of land were flood-irrigated with ground water, and about 27,700 acres were sprinkle-irrigated with ground water. Total ET for these lands was estimated at 20,600 af for the flood-irrigated land (2.21 ft/ac) and 66,800 af for the sprinkle-irrigated lands (2.41 ft/ac), for a total ET of about 87,400 af. Subtracting 11.2 inches of precipitation from the total ground water irrigated acreage (37,000 acres) yields a net pumping demand of about 53,000 af for the year 2000.

Pumpage from "supplemental" irrigation wells was not addressed in this water budget. Surface water irrigators frequently use supplemental wells during times when surface water supplies run short (such as during a drought period). Supplemental pumping was not addressed because it was judged to be relatively small given that surface water supplies were available throughout the growing season.

3.1.4. Rural Domestic Withdrawals

Rural domestic withdrawal refers to ground water used by rural residences located outside the boundaries of municipal distribution systems. This section describes estimates made for domestic use only; stock water use was described in Section 1.3.5.

Goodell (1988) assumed the average per-capita rural domestic use was about 98 gpd/person for a total rural population of 51,800 in 1980. The rural domestic ground water use for 1980 was therefore estimated to be about 5,600 af for Ada and Canyon Counties. The 98 gpd/person value used by Goodell was reported to be the average per-capita rural domestic use for 17 western states.

For the 1996 Treasure Valley water budget, rural domestic ground water use was estimated using census data for numbers of rural dwellings and occupants and an assumed per capita consumption rate. House count data were obtained using 1990 using census tract data (Bureau of the Census, 1992). This GIS database provided an approximate spatial distribution of houses and therefore ground water withdrawal (a more recent GIS database was not available). From this data set, the total number of rural domestic homes was estimated to be about 28,700 for the study area in 1990. As described in Section 2.6, 1995 census data were used to extrapolate a spatially distributed estimate for 1995. Results suggest that there were about 34,400 rural domestic houses in the Treasure Valley in 1995, and it was assumed that each house

had its own well. According to census records (Idaho Department of Commerce, 1996), each house is occupied by an average of 3 people. Total rural domestic population was therefore estimated to be about 103,200. Data for 2000 (Goodell, personal communication, 2003) suggests a total of 31,950 occupied homes (33,500 total), with 2.9 people/house, resulting in a total of 92,650 people. Note that the 1996 estimate is for total house, not "occupied" houses; using "total" houses for 2000 results in a population of 97,150. Note also that 2000 data may be more accurate than 1996 data.

In general, many rural houses occupy larger lot sizes (0.5 to 5 acres) than in urban areas. As a result, per capita water use may be higher in rural areas. However, many rural residences within the Treasure Valley have access to surface water supplies, which can be used for lawn and pasture irrigation, thus reducing overall ground water use during the irrigation season. As a result, overall per capita ground water use was assumed to be the same as for urban domestic use (230 gpd/person).

Based on the above, total rural domestic ground water withdrawal was estimated to be about 26,600 af during 1996 and 24,000 af in 2000 (2000 estimate based upon occupancy; amount increases to 25,000 af for total houses).

3.1.5. Livestock

Stock water refers to water used by livestock, such as cattle, horses, etc. Goodell (1988) reported 1980 stock ground water use in Ada and Canyon Counties to be about 2,100 af/yr, with an additional 900 af of surface water being used, or a total of about 3,000 af. This estimate was made using reported livestock populations and typical daily per animal water use.

Revised estimates of ground water consumption for stock watering were made for the 1996 Treasure Valley water budget using animal inventories (Table 5) as provided by the 1992 Census of Agriculture (U.S. Dept. of Commerce, 1994) and typical daily water consumption values (Idaho Water Law Handbook, 1988). Data for 1996 were not available at the time of the original report; data for 2000 were incomplete during this 2003 revision. This estimate was restricted to those animals using relatively large amounts of water (i.e., small animals were not included). It is not known how much surface water was used to augment stock ground water withdrawal during 1992. However, estimates previously provided by Goodell (1988) suggest about 30% of total stock demand is satisfied using surface water sources. Total stock water consumption for Ada and Canyon Counties for 1992 was estimated to be about 3.4 million gallons per day (MG/day) (about 3,800 af/yr). Assuming ground water comprises 70% of this total, it was estimated that ground water use was about 2,600 af.

| Animal | 1992 Census | | Daily Water Consumption (gallons) | Total Consumption (surface and ground water) | |
	Ada County	Canyon County		(gallons/day)	(af/yr)
Cattle/Calves	73,400	130,790	12	2,457,500	2,750
Dairy	9,430	14,010	35	820,600	920
Horses	2,910	2,840	12	69,000	70
Sheep	1,940	16,130	2	36,100	40
			Total	3,383,200	3,780

Table 5: Estimated stock water use.

3.1.6. Summary of Ground Water Pumping

In summary, total ground water withdrawal for 1996 was estimated to be about 197,700 af, with about 174,300 af pumped during 2000. Table 6 provides a summary of withdrawal estimates. Agricultural irrigation represents the largest amount of water pumped followed by municipal uses. Irrigation withdrawal is concentrated primarily within the southwestern portion of the valley.

Ground Water Pumping	Estimated Pumping for 1996 (ac/ft)	Estimated Pumping for 2000 (ac/ft)
Domestic and Industrial Withdrawal[a]	66,100	76,800
Municipal Irrigation	9,700	9,700
Self-Supplied Industrial	20,800	8,200
Agricultural Irrigation[b]	71,900	53,000
Rural Domestic Withdrawal	26,600	24,000
Stock Watering	2,600	2,600
Total	197,700	174,300

[a]Municipal pumping is concentrated in urban areas. The amount of water withdrawn for industrial use was considered to represent consumptive use (volume of water removed from the aquifer system). The volume estimates associated with the remaining water use classifications do not represent consumptive use because some ground water recharge was assumed to occur (from excess water applied for irrigation on these lands; refer to Section 2.5).

[b]According to IDWR land use data, there were 42,300 acres of farm land irrigated with ground water during 1996, and 37,000 acres in 2000.

Table 6: Summary of treasure valley ground water pumping for 1996

3.2. Discharge to Rivers and Drains

Discharge to rivers and drains refers to ground water that exits the valley by discharging into canals, drains, and rivers. According to Lindholm (1993), 83% of discharge from the WSRP is to rivers and drains, with the remaining 17% discharged via wells. Most discharge in the Treasure Valley occurs to the Boise River during the

irrigation season. The principal discharge area along the Boise River is the reach between the cities of Middleton and Parma (Kjelstrom, 1995). This reach represents the lower half of the valley, and it is along this reach that most of the drains (from the valley's extensive irrigation system) discharge to the river. Additional ground water discharge occurs to the Snake River between Murphy and Nyssa. The following sections provide estimates of ground water discharge to these reaches.

3.2.1. Previous Estimates

Newton (1991) estimated ground water discharge to the Boise River to be about 460,000 af for the year 1980. This estimate was based on river gain data for the non-irrigation season (October to April) and assumes all canal and drain flow to the river during this period was due to ground water discharge.

Thomas and Dion (1974) estimated ground water discharge directly to the Boise River to be about 3 cfs/mile (about 104,200 af) during 1971. This was determined by measuring river discharge at select points at a time when there were no releases from Lucky Peak Reservoir. Increases in river flow were attributed to ground water discharge.

Ground water discharge to the Snake River was estimated by Newton (1991) to be about 350,000 af for the year 1980 over the 101 mile reach between Murphy and Weiser. Gain measurements for the Snake River typically fall within the assumed 5% margin of error for gage measurements (Newton 1991), and as a result should be used with caution.

3.2.2. Boise River

For this water budget, ground water discharge to the Boise River was estimated by determining the mean monthly gain during the non-irrigation season and assuming the same discharge rate occurs during the irrigation season. With the exception of runoff from precipitation, it was assumed that this gain was from ground water discharge to canals and drains and ground water discharge directly to the river. Total gain during the non-irrigation season (e.g., October 15, 1995, through April 15, 1996) was estimated at 283,500 af, or an average of 47,175 af/month (data from USGS, 1996). However, about 3,600 af/month of the winter gain is from storm water and wastewater discharges from the cities of Boise, Caldwell, Meridian, and Nampa (DEQ, 1997). Subtracting this amount from the mean monthly gain results in about 43,600 af/month of ground water discharge for 1996; data for 2000 suggest a corrected monthly average of 44,100 af. Assuming these same rates of ground water discharge occurs during the irrigation season, a total of about 523,200 af of ground water were discharged during 1996 and about 529,200 af in 2000.

There are potential sources of error with this estimate. For example, the ground water discharge is not constant throughout the year. The discharge rate may be less than the

average winter flow at the start of the irrigation season and peak at an above-average value following the end of the irrigation season.

3.2.3. Snake River

Some ground water from the Treasure Valley also discharges to the Snake River. Reach gain data (USGS) for the 68-mile Murphy to Nyssa reach were examined to provide an updated estimate. This reach was coincident with much of the TVHP's southwestern boundary. Because the Snake River received discharge from sources outside the Treasure Valley, ground water discharge was estimated by subtracting estimates of these additional discharge sources from the total reach gain. The balance was assumed to represent ground water discharge and direct return flow from drains leaving the Treasure Valley project area. This approach was taken because data were not available for most drains along this reach.

Reach gain data for the Snake River were not available for 1995 or 1996, so the mean annual gain for the years 1976-1992 was used (period of record). The mean gain for the Murphy to Nyssa reach was estimated to be about 540,800 af. Of this total, about 250,000 af/yr was attributed to sources located south and west of the Snake River (e.g., the Owyhee River drainage, an area outside the TVHP; IDWR data). Subtracting this amount resulted in a net gain of about 290,800 af for 1996.

Discharge from drains was estimated using 1992 data from the Boise Project Board of Control. These data showed drain discharge was about 14,000 af. This amount was assumed to represent surface water runoff only. Subtracting this runoff amount from 290,800 af resulted in about 276,800 af of ground water discharge. Applying the same correction for 2000, about 352,600 af of ground water were discharged to the Snake River during that year.

In summary, ground water discharge to the Boise River during 1996 was estimated to be about 523,200 af, while discharge to the Snake River was estimated to be 290,800 af, for a total of 814,000 af. Data for 2000 suggest 529,000 af of discharge to the Boise River and 352,600 af to the Snake River, resulting in a total of 881,600 af.

Estimated Ground Water Discharge		
Reach	1996 (af)	2000 (af)
Boise River		
Lucky Peak to Boise	NA*	NA*
Boise to Parma	523,200	529,000
Snake River		
Murphy to Nyssa	276,800	352,600
Total	**814,000**	**881,600**

*Not applicable because river discharges to aquifer along this reach.

Table 7: Ground water discharge to rivers and drains.

3.3. Underflow

With the exception of ground water discharge to major rivers (Section 3.2), there appears to be no evidence of significant subsurface ground water flow leaving the project area. Based upon ground water contours for the region (Newton, 1991), the Snake River appears to be a major ground water divide along the downgradient southern and western project boundaries. Underflow from the project area is therefore considered to be negligible.

4. SPATIAL DISTRIBUTION OF RECHARGE AND PUMPING

The water budget results presented in the preceding sections focus on the Treasure Valley aquifer system as a whole. These aggregate values do not describe the spatial distribution of the water budget components. This section provides three maps describing the general spatial distribution of recharge to and withdrawals from the Treasure Valley aquifer system, as currently defined by the Treasure Valley water budget.

Maps shown in this section were created by kriging spatial data and interpolating the results to a grid with a one-mile cell size. This grid is the same as that used for the development of a Treasure Valley ground water flow model (Petrich, 2004).

4.1. Recharge

The estimated spatial distribution of 1996 ground water recharge in the Treasure Valley is presented in Figure 9. Recharge is concentrated in areas receiving flood irrigation and containing canals. Note that the ground water model uses recharge data compiled on a cell-by-cell basis. At the time of this report, the TVHP model utilized 1996 data for the purpose of calibration. As a result, cell-by-cell data sets were not compiled for 2000, and thus spatial plots for 2000 could not be created.

Some of the recharge is shown in areas of ground water discharge. Infiltration to shallow, local ground water flow systems may result in discharge to nearby canals and/or drains. The map does not distinguish between recharge entering local and regional ground water flow systems.

The spatial distribution of ground water recharge reflects the methods used for estimating recharge. For instance, recharge associated with flood-irrigated agriculture was estimated on the basis of land use; the spatial distribution of flood irrigation is therefore based on the estimated spatial distribution of flood-irrigated lands. Similarly, the recharge associated with canal seepage is distributed on the basis of aggregate canal length per unit area. The greatest canal seepage is therefore in areas having the greatest concentration of canals. A better method of distributing canal seepage throughout the canal system is not available because of the current lack of seepage data for individual canals (with the exception of the New York Canal).

Figure 9 shows significant recharge along the New York Canal. The New York Canal seepage estimate was based on measurements made during March 1997 (Berenbrock, 1999). The New York Canal was assumed to be leaking at a rate of 13% of the average irrigation season flow (refer to Section 2.1). This amount was subtracted from the general canal seepage estimate and was distributed evenly along the length of the New York Canal.
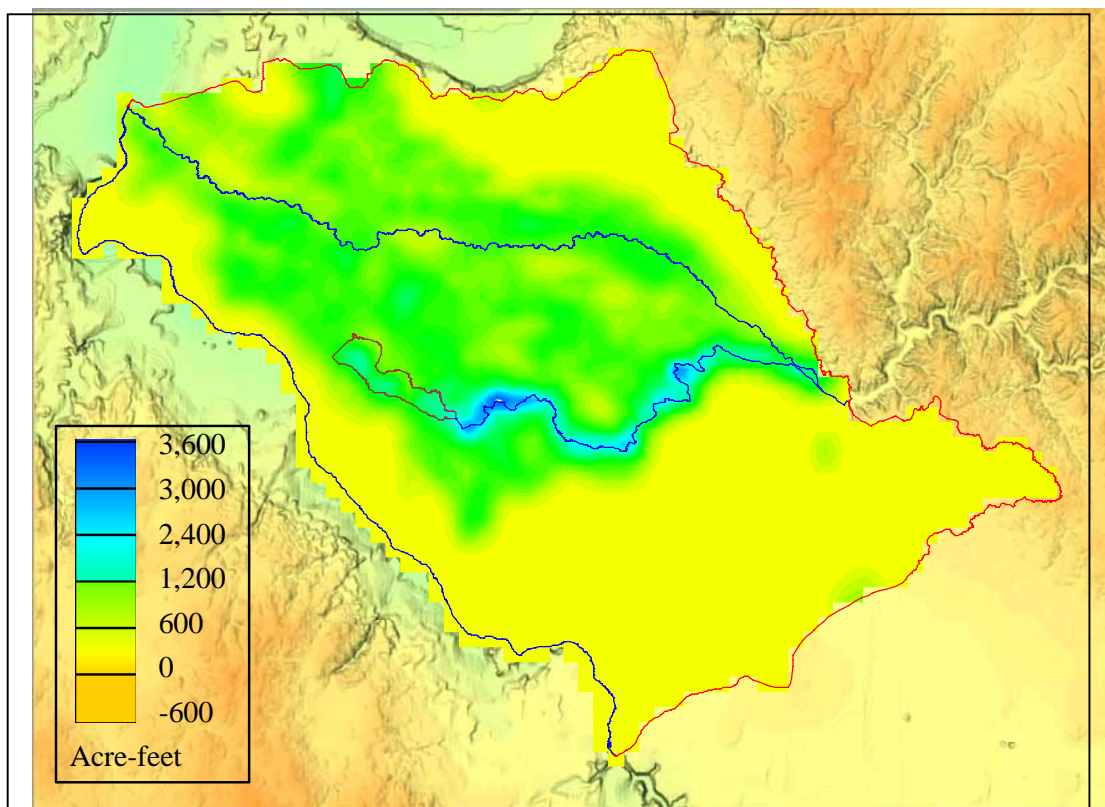
Figure 9: Estimated spatial distribution of 1996 ground water recharge.

4.2. Discharge

Ground water discharge from the Treasure Valley aquifer system consists of discharges to canals, drains, and rivers, and ground water pumping. Discharges to canals, drains, and rivers were estimated on the basis of river gains along Boise and Snake River reaches (Section 3.2). Ground water withdrawals were estimated for various water uses (municipal, irrigation, industrial, etc.).

The spatial distribution of ground water discharge to canals and drains cannot be determined using the aggregate reach gain measurements along the Boise and Snake Rivers. The spatial distribution of discharge to canals and drains will be made using the numerical ground water flow model currently under development.

The approximate spatial distribution of ground water withdrawals in the Treasure Valley is shown in Figure 10. The pumping distribution shows concentrated pumping in urban areas surrounding Boise, Nampa, and Caldwell, and in areas of significant irrigation use (e.g., south and southeast of Lake Lowell).

The distribution of ground water use shown in Figure 10 does not distinguish between source aquifers. Most rural domestic and some irrigation pumping occur from shallow aquifers; most of the municipal pumping occurs from deep, regional aquifers.
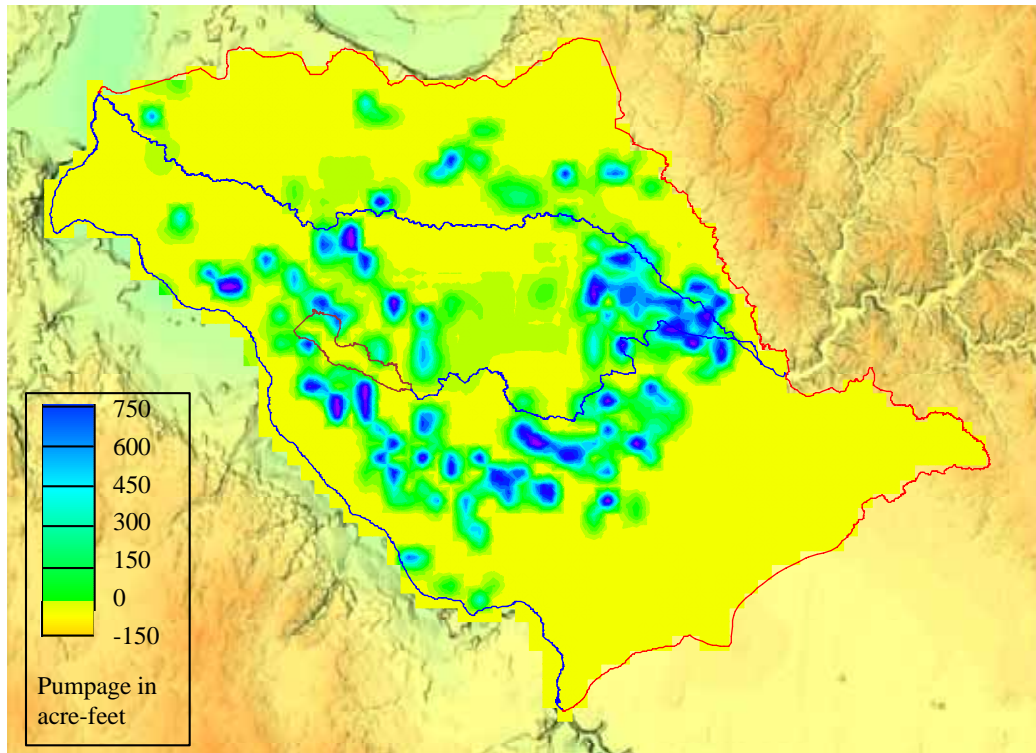
Figure 10: Estimated spatial distribution of 1996 withdrawals.

5. CHANGE IN AQUIFER STORAGE

A difference between net recharge and net discharge implies a change in aquifer storage. A net increase in aquifer storage of about 7,300 af was estimated on the basis of water budget results for 1996. For comparison, a change in regional ground water storage was estimated using water level data.

Water level measurements were compared from 72 Treasure Valley wells taken in March 1996 and March 1997. These measurements were part of monthly measurements in 74 Treasure Valley wells (Berenbrock, 1999). The 72 water level measurements were taken from wells completed at deep and shallow depths and from wells that may have been influenced by recent pumping. The time period of March 1996 to March 1997 does not fully coincide with that of the water budget, which was prepared for the 1996 calendar year; TVHP water level measurements did not begin until March 1996.

Water levels from the March 1996 measurement were subtracted from the March 1997 measurement and a surface map was prepared (using Surfer™) from the individual difference values (Figure 11). This method will produce similar values as subtracting one surface from another and is legitimate if the measurement points are the same (Davis, 1986). It was assumed that the increase in storage occurred in the uppermost aquifer and that this aquifer zone had an effective porosity of 0.30.

Based upon the above, an increase in aquifer storage of approximately 20,000 af was estimated using the 1996 and 1997 water level measurements. This was a preliminary estimate because it was based on water levels taken from a variety of wells (some of the water levels may have been influenced by pumping) completed in different aquifer zones.
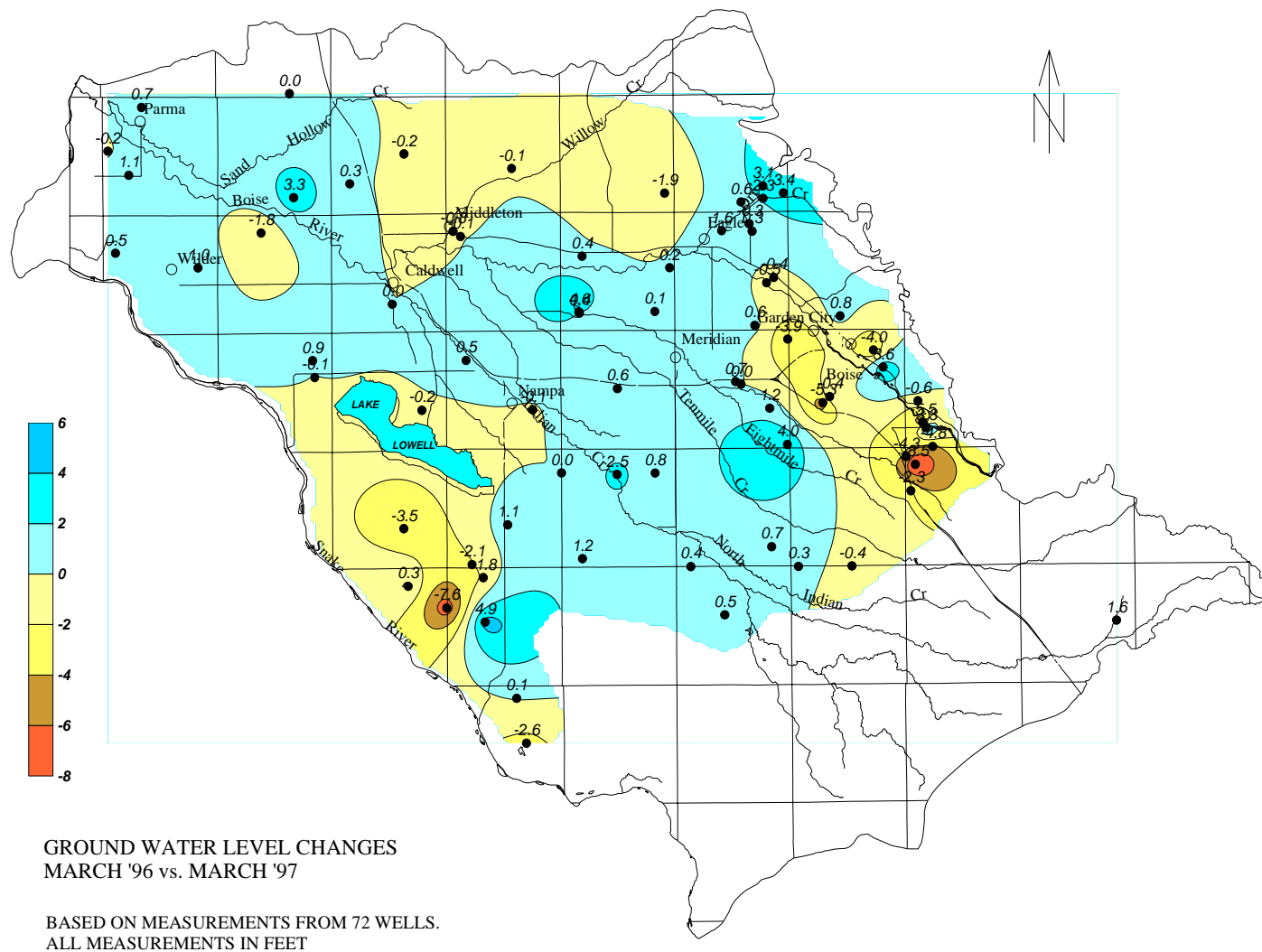
GROUND WATER LEVEL CHANGES
MARCH '96 vs. MARCH '97

BASED ON MEASUREMENTS FROM 72 WELLS.
ALL MEASUREMENTS IN FEET

Figure 11: Ground water level change map created by comparing water level elevations for March 1996 and March 1997.

6.   SUMMARY AND CONCLUSIONS

This section summarizes results presented in previous sections and provides a discussion of those results.   Conclusions drawn from the water budget data are summarized at the end of this section.

This water budget provides an initial regional accounting of inflows and outflows to the Treasure Valley aquifer system. Results from this water budget are summarized in Table 8 and in Figure 12. The largest source of ground water recharge was seepage from the canal system, followed by flood irrigation and precipitation. The aggregate discharge to the Boise and Snake Rivers (through canals, drains, or to the rivers themselves) is far greater than all withdrawals combined. On a valley-wide basis, ground water withdrawals represent approximately 20% of the total ground water recharge.

Error ranges are associated with all of the water budget estimates. Sources of error include all of the measurement and estimation methods for each water budget component. The impact of a relatively small error in a large component can have a significant impact on the water budget balance. For example, seepage from the canal system appears to be the largest recharge component, but the actual magnitude and the distribution of the leakage has not yet been well defined. Similarly, the aquifer discharge to the Snake and Boise Rivers and to Treasure Valley canals and drains is the largest discharge mechanism, and a small error in this estimate could have a significant effect on the overall water budget. The error associated with individual water budget component estimates is expected to decrease as more information becomes available.

The water budget addresses the Treasure Valley aquifer system as a whole. However, the aquifer system clearly consists of a series of shallow and regional aquifers interconnected to varying degrees. This water budget does not take into account ground water flow between different aquifer zones. The numerical ground water flow model can be used to help quantify inter-aquifer flows (Petrich, 2004).

Sources of Recharge and Discharge	Estimated Recharge and Discharge[a]			
	1996		2000	
	(af)	(% of total)	(af)	(% of total)
Recharge[b]				
Canal Seepage	626,000	62	521,500	50
Seepage from Rivers and Streams	16,000	1	77,000	7
Seepage from Lake Lowell	19,000	2	21,200	2
Underflow	4,300	<1	4,300	<1
Flood Irrigation and Precipitation[c]	302,000	29	404,400	35
Recharge by Other Land Uses[c]	48,000	5	65,700	6
Rural Domestic Septic Systems	5,000	<1	4,600	<1
Total Recharge[d]	**1,020,300**		**1,098,700**	
Discharge				
Domestic and Industrial Withdrawals	66,000	7	76,800	7
Municipal Irrigation	10,000	1	10,000	1
Self-Supplied Industrial	21,000	2	8,200	<1
Agricultural Irrigation	72,000	7	53,000	5
Rural Domestic Withdrawals	27,000	3	24,000	2
Stock Watering	3,000	<1	3,000	<1
Discharge to Rivers and Drains	814,000	82	881,600	83
Total Discharge	**1,013,000**		**1,056,600**	
Net Difference[e]	**+7,300**		**+42,100**	

[a]Because the two years used differing methods of estimation, or revised data sources, some parameters should not be compared directly (e.g., idustrial pumping and recharge from irrigation).

[b]See text for explanations; values shown in this table are rounded to the nearest 1,000 af.

[c]Includes recharge from precipitation and irrigation on flood-irrigated lands only.

[d]Includes recharge from precipitation by land use; does not include flood-irrigated land.

[e]Because of the error associated with the individual water budget components, a positive net difference does not necessarily indicate a positive change in aquifer storage. Likewise, the net difference between the years 1996 and 2000 may not be significant.

Table 8: Water budget summary.

The aggregate nature of the water budget masks the temporal characteristics of ground water recharge, withdrawals, and natural discharge. Infiltration from the surface water distribution system and irrigation occurs primarily in the summer. The actual recharge from irrigation activities lags the infiltration so that water levels may be rising months after irrigation has ceased. Also, municipal ground water use varies throughout the year and is greatest during the summer irrigation season.
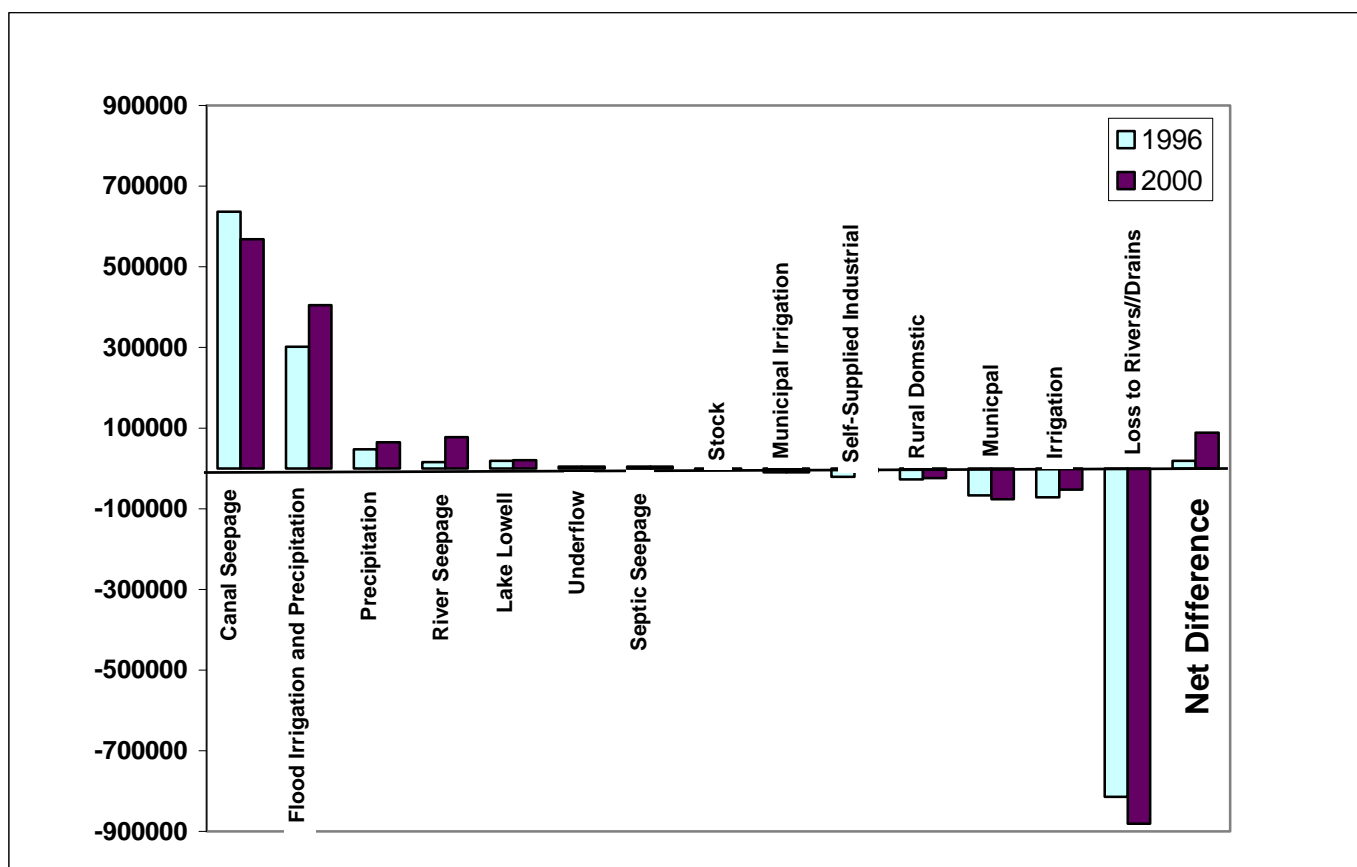
Figure 12: Graph showing water budget components.

The total estimated ground water recharge exceeded the estimated discharge by approximately 7,300 af during 1996 and 42,100 af in 2000. However, these positive net differences are less than 5% of the total recharge or discharge and are considered to be within the margin of error for the individual water budget component estimates. As a result, the net differences do not indicate conclusively that a condition of ground water surplus existed during the 1996 and 2000 calendar years.

Several general conclusions can be drawn from this water budget.

1. The largest components of aquifer recharge are seepage from the canal system and infiltration associated with irrigated agriculture.

2. Seepage to rivers, drains, and canals is the largest source of discharge from the Treasure Valley aquifer system.

3. Overall, total aquifer recharge to the Treasure Valley appears to exceed aquifer discharge. However, the net difference is well within the error range of the water budget components, and the system as a whole is considered to be in equilibrium. Recharge to the Treasure Valley aquifer

system is significantly influenced by land use (by the location of irrigation activities).

4. Evaluating water budgets for individual portions of the Treasure Valley aquifer system requires quantification of vertical and horizontal ground water movement between aquifer zones and the categorization of pumping data by aquifer zone.

7. RECOMMENDATIONS

The following recommendations are made on the basis of the water budget results:

1. Collect additional diversion and return flow data for all of the canal systems in the Treasure Valley to better define canal losses and gains. Some of these data are currently being developed by the USBR.

2. Measure seepage and gains in more intermediate-sized canals. These measurements should be conducted over longer reaches, with diversion and return flow measurements made along the measured reaches.

3. Evaluate the dynamics of canal seepage. This evaluation might be done by measuring directly the hydraulic conductivity of canal bottom sediments, installing piezometers near selected canal reaches and monitoring infiltration, or other means.

4. Separate pumping data by aquifer zone. The water budget could then be differentiated between shallow and regional portions of the aquifer system.

5. Evaluate withdrawals from irrigation wells by installing flow meters in selected wells (on a voluntary basis) and evaluating withdrawals data with electrical records, lift data, and crop type data.

6. Evaluate the impact of supplemental irrigation wells during typical normal and dry water years. This could be done by installing flow meters in selected wells (on a voluntary basis) in different parts of the valley, and evaluating withdrawals on acreage and crop-type basis.

7. The estimated recharge rates presented for some land use classifications may not reflect actual conditions. For example, the net recharge from domestic lawn irrigation may be much higher than 0.25 foot/yr in some areas, depending on soil type and efficiency of the irrigation system. In general, actual measurements of recharge rates for major land use classifications would improve the overall estimate of aquifer recharge.

8. Conduct a study to evaluate the hydrologic effects of land use changes, such as the conversion of irrigated lands to urban subdivisions.

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