Draft Design Document: Calculating Incidental Recharge and Groundwater Pumping Demand on Irrigated and Semi-Irrigated Lands

By Jennifer Sukow, IDWR

Table of Contents

List of Figures

List of Tables

Design document description and purpose

The U.S. Geological Survey (USGS), in collaboration with the Idaho Department of Water Resources (IDWR), is constructing a numerical groundwater-flow model of the Wood River Valley aquifer system in order to simulate potential anthropogenic and climatic effects on groundwater and surface-water resources. This model will serve as a tool for water-rights administration and water-resource management and planning. The study will be conducted over a 3-year period from late 2012 until model and report completion in 2015. One of the goals of the modeling study is to develop the model in an open and transparent manner. To this end, a Modeling Technical Advisory Committee (MTAC) was formed to provide for transparency in model development and to serve as a vehicle for stakeholder input. Technical representation was solicited by the IDWR and includes such interested parties as water-user groups and current USGS cooperating organizations in the Wood River Valley.

The design, construction, and calibration of a groundwater-flow model requires a number of decisions such as the number of layers, model cell size, or methodologies used to represent processes such as evapotranspiration or pumpage. While these decisions will be documented in a final USGS report, intermediate decision documents will be prepared in order to facilitate technical discussion and ease preparation of the report. These decision documents should be considered preliminary status reports and not final products.

Problem statement

In the Wood River Valley, surface water and groundwater are diverted to irrigate agricultural fields and landscaping. A portion of the water diverted is consumed by evapotranspiration (ET). Water not consumed by ET may be returned to the river or infiltrate into the subsurface and recharge the aquifer. Aquifer recharge may be the result of canal seepage, leakage from municipal delivery systems, and infiltration of excess water applied to fields and landscaping. Water may be returned to the river as surface returns from canal systems or as discharge from municipal wastewater treatment plants.

For this project, land use is classified as “irrigated” agricultural land, “semi-irrigated”, and “non-irrigated”. Semi-irrigated lands include non-agricultural developed lands in urban and suburban areas.

Semi-irrigated areas include irrigated landscaping, parks, and golf courses, as well as impervious areas such as roads, driveways, and buildings. The purpose of this design document is to discuss the calculation and spatial distribution of incidental recharge associated with water delivery and irrigation on irrigated and semi-irrigated lands. In semi-irrigated areas, evaporation from aesthetic ponds is also included in the water consumed by ET.

Historically, only a limited number of groundwater diversions have been measured and recorded by water districts or municipalities. The majority of groundwater diversions in the Wood River Valley were not measured or recorded prior to 2013, when the IDWR began requiring most non-domestic groundwater users in the valley to install measuring devices (IDWR, 2011). The unmeasured groundwater diversions must be estimated during the model calibration period (1995 through 2010) based on irrigation demand, surface water supply, and irrigation efficiency.

Data availability

The following data sources are available for use in calculating canal seepage, incidental recharge, and unmeasured groundwater diversions in the Wood River Valley.

Diversions

Diversions are defined as the use of water for something other than its natural fate. In the Wood River Valley the primary uses of water are agricultural irrigation, municipal and domestic irrigation, in home use, and industrial use.

Surface water diversions

1. Surface water diversions from the Big Wood River, Silver Creek, and some tributary streams have been recorded daily by Water District 37 and Water District 37M since 1920. IDWR compiled monthly diversion data for the model calibration period (1995 – 2010). Data are available for April through September. Although the irrigation season extends through October 31, these Water Districts do not record diversions that occur after September 30.
2. Monthly diversions of treated effluent from the Bellevue wastewater treatment plant to a land application site adjacent to the plant were available from the Idaho Department of Environmental Quality (IDEQ) for 1999 to 2012.

Groundwater diversions

1. A few groundwater diversions have been recorded by Water District 37 or 37M during all or part of the model calibration period. These groundwater diversions are regulated by the Water District because they are delivered through natural channels, or are mitigated by surface water rights and regulated in conjunction with surface water priority cuts on the Big Wood River or Silver Creek. Some diversions were recorded daily, others were recorded as total irrigation season use.
2. Groundwater diversion data for the Sun Valley Company's River Run snowmaking system are available from Brockway (2013). This memorandum provides total winter season diversion volumes from 1991 through 2012.
3. Monthly groundwater and spring diversions recorded by the City of Hailey municipal water system are available for the model calibration period.
4. Monthly groundwater diversions recorded by the Sun Valley Water and Sewer District (SVWSD) and the City of Ketchum municipal water systems are available for the model calibration period.
5. Monthly groundwater and spring diversions recorded by the City of Bellevue municipal water system are available for 2006 through 2013.
6. Surface water priority cut dates during the model calibration period are available from Water District 37 and Water District 37M[1]. IDWR compiled the priority cut date at the end of each month. Surface water priority cut dates are useful for determining when supplemental groundwater was needed to irrigate mixed source lands.

Surface return flow

Only a portion of water diverted by a canal company or municipal water system is consumed by evapotranspiration. While much of the unconsumed water recharges the aquifer through infiltration, some unconsumed water may be discharged directly to a river or creek as surface return flow. Accounting for these returns allows more accurate calculation of aquifer recharge.

1. There are few measured surface returns in the model area. Water District 37 has recorded surface discharge from the District canal system to the Loving Creek area. In recent years, Water District 37 began recording returns to the Big Wood River from canals that primarily

[1] Water District 37 oversees water distribution within the Big Wood River basin. Water District 37M oversees water distribution within the Silver Creek and Little Wood River basin. More information on water districts in Idaho can be found at http://www.idwr.idaho.gov/WaterManagement/WaterDistricts/default.htm.

deliver water for aesthetic, non-consumptive uses, such as the Gimlet and Rinker systems. The O Drain returns tailwater from the Iden Canal to Silver Creek downstream of the model boundary and is not measured. Based on personal communication with Watermaster Kevin Lakey (August 27, 2013), other unmeasured surface returns from irrigation canals are believed to be negligible in the model area.

2. Records of municipal wastewater treatment plant discharge are available for various years (1995-2012 for Ketchum and Sun Valley, 1996-2012 for Hailey, 1999-2012 for Bellevue, and 2000-2012 for The Meadows). Treated effluent from Ketchum and Sun Valley, Hailey, and The Meadows is returned to the Big Wood River. The City of Ketchum and SVWSD have separate public water systems, but are served by a common wastewater treatment plant. For purposes of calculating return flow from each water system, 51% of the recorded wastewater treatment plant discharge was apportioned to Ketchum and 49% was apportioned to SVWSD based on the average volume of diversions for each public water system during the non-irrigation season (November through March). The Ketchum/Sun Valley Wastewater Treatment Plant is currently permitted to provide up to 3.1 million gallons per day of recycled water for irrigation and snowmaking (City of Ketchum, 2013), but reuse did not occur during the model calibration period. The City of Bellevue's wastewater treatment plant was constructed in 1992 about four miles south of the city (Furber, 2004). Treated effluent from Bellevue is applied to fields adjacent to the treatment plant during the irrigation season and is discharged to infiltration ponds during the winter. Effluent discharge during periods of missing data (1995 for Hailey, 1995-1998 for Bellevue, and 1995-1999 for The Meadows) was assumed to be similar to the first year for which data were available.

3. Sun Valley Water and Sewer District diversions include water delivered to Dollar Mountain for snowmaking. Most of this water is assumed to return to Trail Creek as snowmelt in the spring. The water use is not consumptive, but the water does not infiltrate directly into the aquifer. Records of monthly deliveries to Dollar Mountain for snowmaking were provided by the Sun Valley Water and Sewer District from 1995 through 2010.

Canal seepage

In the Wood River Valley most canals are earthen ditches, which tend to leak. This leakage is commonly referred to as canal seepage.

1. Spatial delineation of canals in the model area is available from the USGS National Hydrography Dataset (NHD) and from IDWR's update of the NHD in the Big Wood River area. IDWR GIS analysts used 2009 NAIP imagery, historical maps, and input from Water District 37 to update the spatial delineation of canals in the model area.
2. Brockway and Grover (1978) measured canal losses in reaches of the District, Bypass, Baseline, Glendale, and Iden canals in 1975 and 1976. Measured reaches ranged from 0.5 mile to 3.4 miles in length. Measured losses ranged from 1% of flow per mile to 35% of flow per mile. These measurements only include some sections of canals and are not sufficient to quantify seepage losses throughout the canal systems. These measurements suggest relatively high losses in the District, Baseline, and Iden canals, and relatively low losses in the Glendale canal.
3. Bartolino (2009) estimated canal seepage loss as 12% of total flow for the Hiawatha, Cove, District, and Bannon canals based on the average of measurements reported by Brockway and Grover (1978) for selected reaches of the District Canal. Bartolino (2009) estimated canal seepage loss as 7% and 1% of total flow in the Baseline and Glendale canals, respectively, based on Brockway and Grover (1978) measurements of a 0.5-mile reach of each these canals. Because large portions of the canal systems were not measured, direct application of the Brockway and Grover (1978) measurements may underestimate canal losses.
4. Merritt (1997) documented a May 29, 1997 conversation with Jim Eakin, Wood River Valley Irrigation District #45 manager, regarding canal losses in the District canal system. Mr. Eakin indicated that the irrigation district assigns a 15% loss in the 1.4-mile section between the headgate and where the main canal splits into three branches. When the 1886 rights are being delivered, the district assigns an additional 5% loss per mile downstream of the split. When the 1886 rights are out of priority, the district cuts the amount being delivered to the field headgate by an additional 50%. For example, a water right delivered by the district to a point four miles below the split would be assigned a conveyance loss of 35% when the 1886 rights are being delivered and 67.5% when the 1886 rights are out of priority. The three branches of the canal system extend 5 to 9 miles below the split. The centroid of the 2006 irrigated lands in the district service area is located approximately 4 miles below the split.
5. In April 2008, Allen Merritt, P.E., IDWR, calculated conveyance loss in the Hiawatha Canal using the Worstell method to evaluate canal loss mitigation requirements for a water right transfer. The total seepage loss calculated for the canal was 25% of the diverted flow rate.

6. On August 28, 2012, the USGS (Bartolino, 2014) measured flow in the Bypass Canal at the point of diversion (52.0 cfs), at Alpine Kennels (44.0 cfs), and above the Bypass extension (35.5 cfs). There are no diversions from the Bypass Canal between the heading and Alpine Kennels. The Baseline Canal and Dittoe Ditch divert from the Bypass Canal between Alpine Kennels and the Bypass extension (Kevin Lakey, Watermaster, personal communication). Water District 37 records available for August 28, 2012 indicate that 7 cfs was diverted from the Bypass Canal between Alpine Kennels and the Bypass extension. Therefore, canal seepage on the Bypass Canal was 8 cfs in the 2.6-mile reach above Alpine Kennels and 1.5 cfs in the 0.7-mile reach below Alpine Kennels. The USGS (Bartolino, 2014) also measured flow in the Bypass Canal on October 23, 2014. Canal seepage was 11 cfs in the 2.6-mile reach above Alpine Kennels. Canal seepage cannot be determined for the 0.7-mile reach below Alpine Kennels because the Water District does not monitor diversions during October.

Crop irrigation requirement

In the Wood River Valley, precipitation is not sufficient to meet the water demand of agricultural crops. While some water is provided by precipitation, much of the crop water demand is provided by irrigation. Crop irrigation requirement (CIR) is the difference between ET and precipitation. Precipitation on irrigated lands is assumed to be used to satisfy crop water demand, and any shortfall will be provided by irrigation.

1. Monthly METRIC (Mapping EvapoTranspiration at High Resolution and Internalized Calibration) ET data are currently available for April through October of 1996, 2000, 2002, 2006, 2008, 2009, and 2010. These data consist of 30-meter by 30-meter rasters of the monthly ET depth (McVay, 2014b).
2. Monthly ET data have been developed for the nine other years in the model calibration period using Normalized Difference Vegetation Index (NDVI) and interpolation. These data also consist of 30-meter by 30-meter rasters of monthly ET depth (McVay, 2014b).
3. Precipitation data are available at Ketchum and Picabo for the model calibration period (1995-2010). Precipitation data are available at Hailey for 2005 through 2010. Precipitation at Hailey was estimated for 1995 through 2004 by correlation with precipitation data at Picabo (McVay, 2014a).

Irrigated lands and water source

The source of irrigation water is either groundwater, surface water or mixed (both surface water and groundwater). Surface water is diverted from the Big Wood River, Silver Creek, a tributary stream, or a spring. Groundwater is diverted from the Wood River Valley aquifer system.

1. Spatial delineation of irrigated, semi-irrigated, and non-irrigated lands is available for 1996, 2000, 2002, 2006, 2008, 2009, and 2010. Spatial delineation was performed by IDWR GIS analysts, who reviewed and refined USDA Common Land Unit (CLU) polygons using high resolution imagery available from the USDA National Agriculture Imagery Program (NAIP) and USGS Digital Orthophoto Quadrangles (DOQ). IDWR GIS analysts classified the irrigation status of CLU polygons for each year by reviewing Landsat imagery from multiple dates throughout the growing season.
2. Water right place of use data from the IDWR water permit, water right, and adjudication recommendation databases are available to classify the water source for irrigated and semi-irrigated lands as surface water only, groundwater only, or mixed source.

Calculation of recharge from canal seepage

Aquifer recharge from canal seepage will be applied to Layer 1 for canal systems delineated in the updated NHD. Canal seepage is represented as a percentage of water diverted to the canal headgate

Table 1) and is spatially distributed evenly across model cells intersected by the canal (Figure 1 and Figure 2). Relatively high seepage losses are assigned to the District, Baseline/Bypass, and Kilpatrick/Iden canal systems based on Brockway and Grover (1978) and Merritt (1997). A seepage loss of 25% is assigned to the Hiawatha canal system based on the analysis performed by Mr. Merritt in 2008. Other canals in the model area have shorter distribution systems and are assigned a seepage loss of 10%.

Canal System	Total Length (miles)	Seepage loss (% of diversion)
Comstock	1.0	10%
Old Comstock Ditch (Clear Creek)	2.4	10%
Rinker	2.3	10%
Mizer (Starweather)	1.3	10%
Hiawatha (includes Valley Club)	12.2	25%
Cove	3.0	10%
Broadford Slough	1.7	10%
District	34.5	60%
Bannon	3.1	10%
Glendale	5.7	10%
Bypass Baseline	17.0	60%
Graff	1.2	10%
Kilpatrick Iden	16.3	60%

Table 1. Canal seepage as a percentage of diversions.

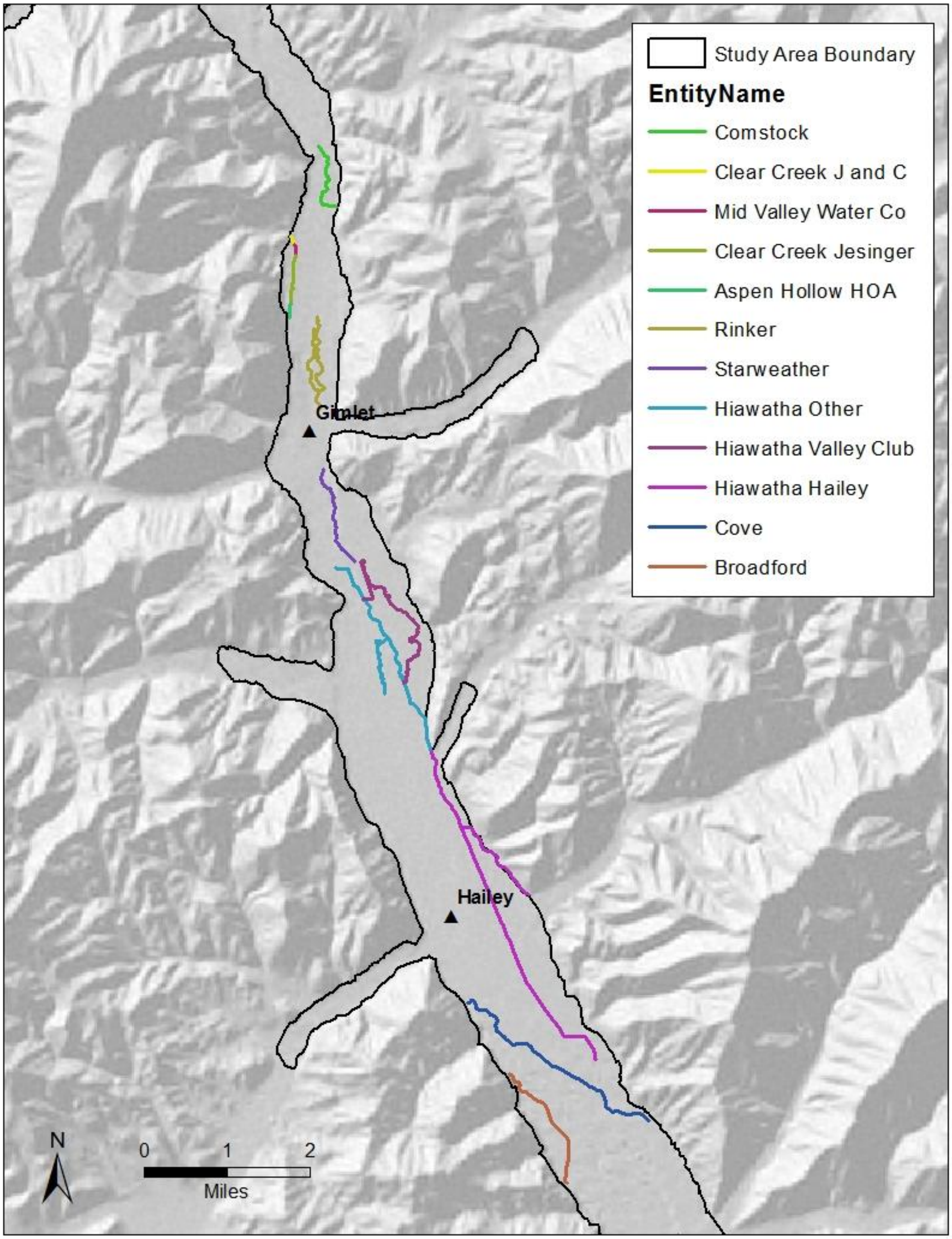

Figure 1. Spatial distribution of canals north of Bellevue.

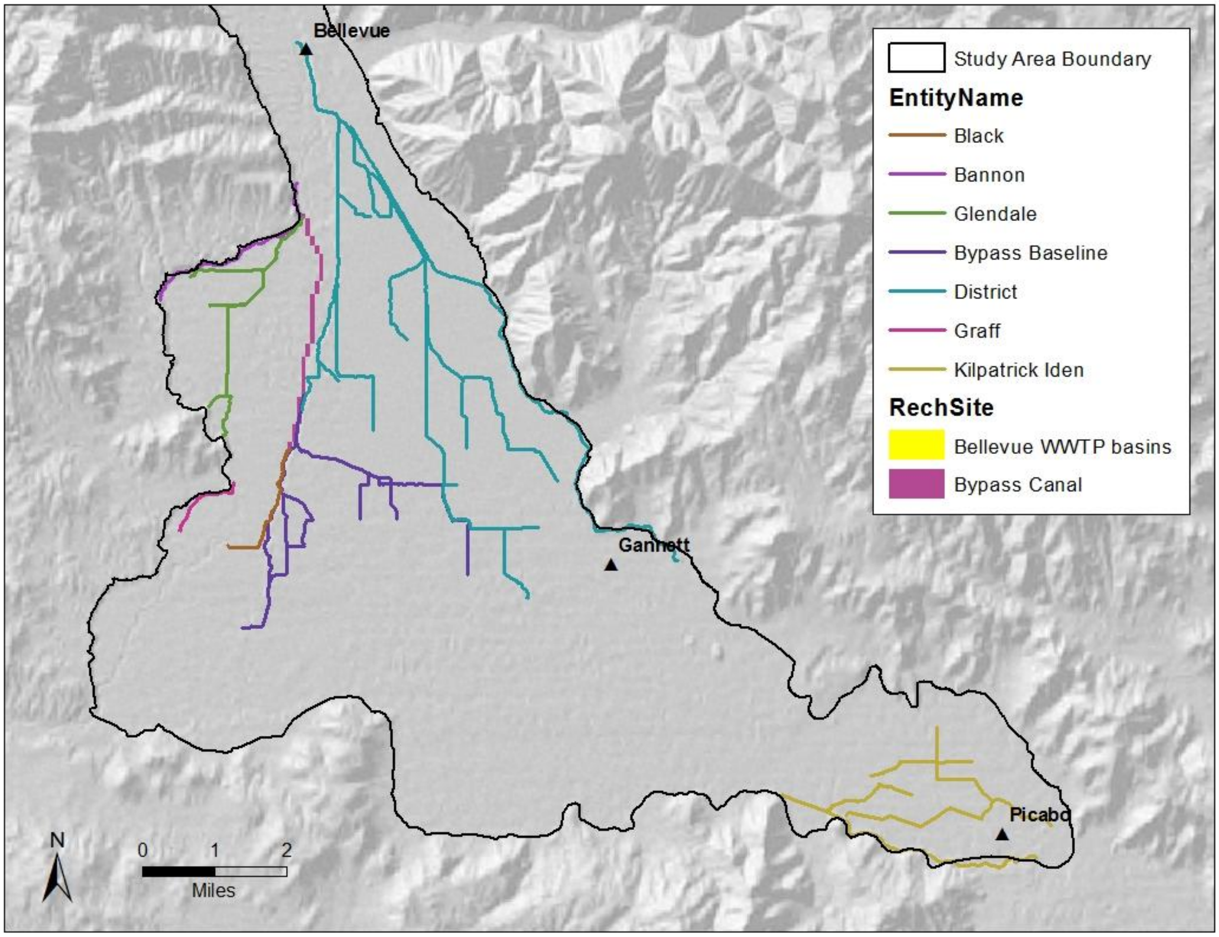

Figure 2. Spatial distribution of canals south of Bellevue.

Bypass Canal seepage

The Bypass Canal was constructed in 1920 to bypass the Dry Bed section of the Big Wood River to reduce river seepage losses and improve delivery of water to the lower valley (Chapman, 1921). The Bypass Canal carries irrigation water delivered to the Baseline Canal, Dittoe Ditch, and Bypass Extension Canal, and water returned to the Big Wood River. Water delivered to irrigation diversions is measured and recorded by Water District 37 from April through September. Water bypassing and returning to the Big Wood River is not measured by the Water District (Kevin Lakey, Watermaster, personal communication). The Bypass Canal begins carrying irrigation water in April or May. Later in the irrigation season until early November, the entire flow of the Big Wood River is routed through the Bypass Canal.

Because the volume of water in the Bypass Canal is unknown, seepage from the Bypass Canal is represented differently than seepage from the other canals. A constant seepage rate of 10 cfs is applied to the 3.3-mile Bypass Canal between the heading and the Bypass Extension, based on the measurements collected by the USGS in August and October 2012 (Bartolino, 2014). The seepage is applied to Layer 1 and is spatially distributed evenly across model cells intersected by the canal (Figure 2). The seepage is applied from the time of the first recorded diversion to the Bypass Canal, Dittoe Ditch, or Bypass Extension through the end of October.

Infiltration Basins

Water applied to infiltration basins at the City of Bellevue wastewater treatment plant is applied to Layer 1 and is spatially distributed evenly across model cells intersected by the basins (Figure 2). The recorded monthly volumes of water applied to the infiltration basins were used for 1999 through 2010. The monthly volumes from 1999 were applied to 1995 through 1998.

Calculation of recharge from infiltration of excess applied water

Aquifer recharge from infiltration of excess applied water is applied to Layer 1 at locations delineated as irrigated or semi-irrigated in the irrigated lands datasets. Irrigated lands data are available for seven years in the model calibration period (Figure 3 through Figure 9). Data from the closest year are used for years without data (Table 2). Wetlands are removed from the irrigated lands data by deleting areas delineated by the U.S. Fish and Wildlife Service National Wetlands Inventory (Cowardin et al. 1979). Some non-irrigated areas on public lands north of Bellevue were included in the semi-irrigated lands classification. These areas were removed from the semi-irrigated lands data by deleting areas delineated by tax lots owned by the U.S. Forest Service or U.S. Bureau of Land north of Bellevue.

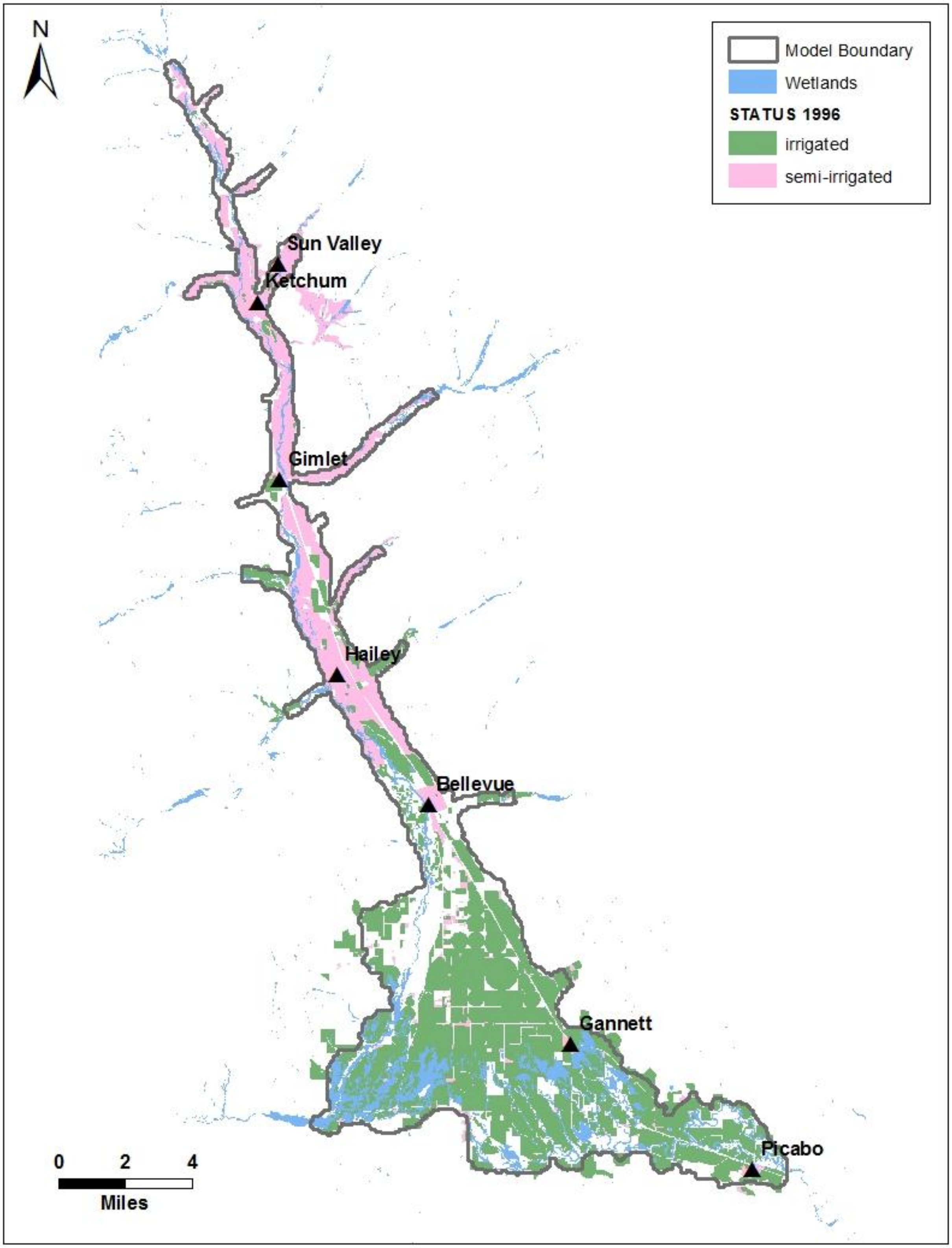

Figure 3. 1996 land status.

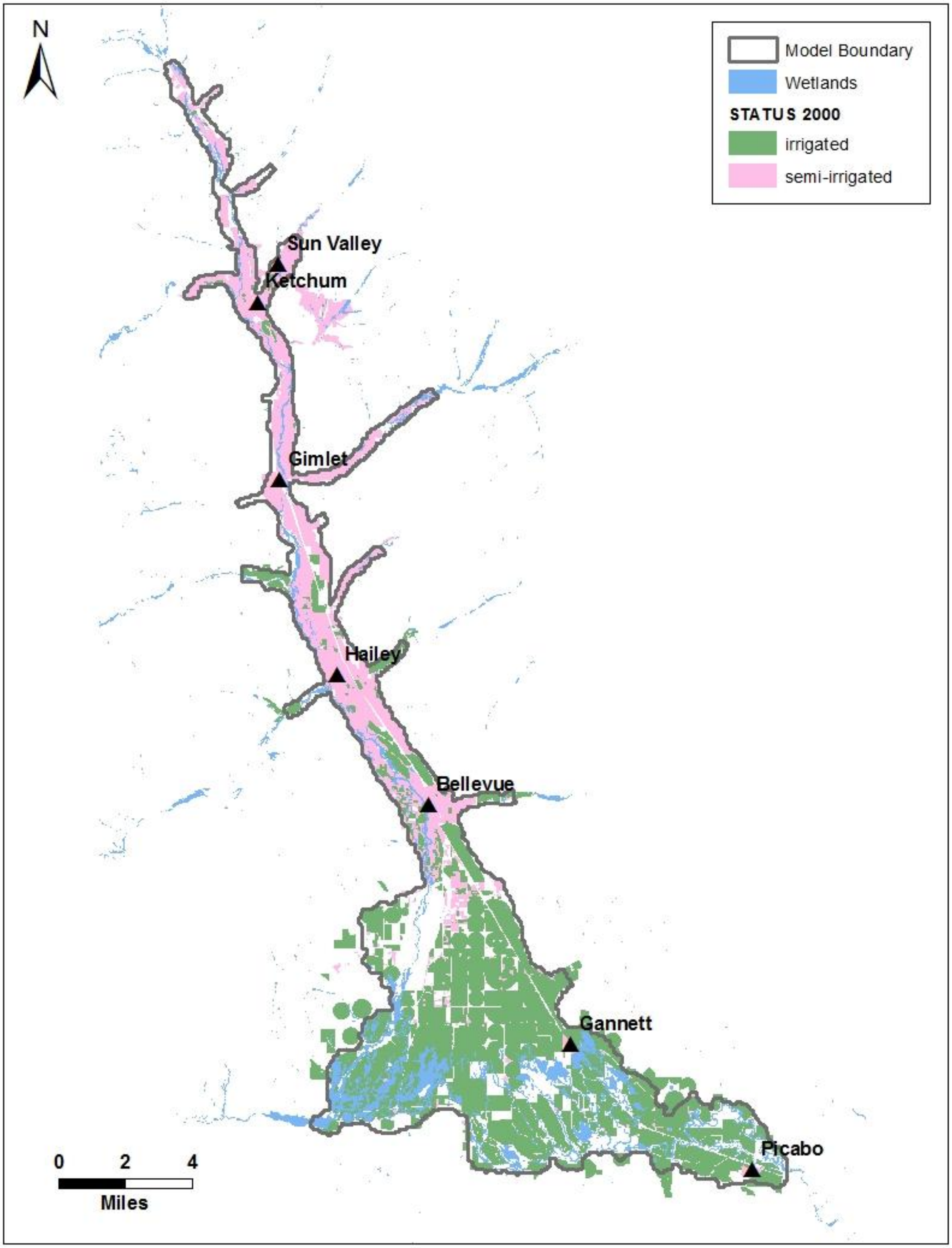

Figure 4. 2000 land status.

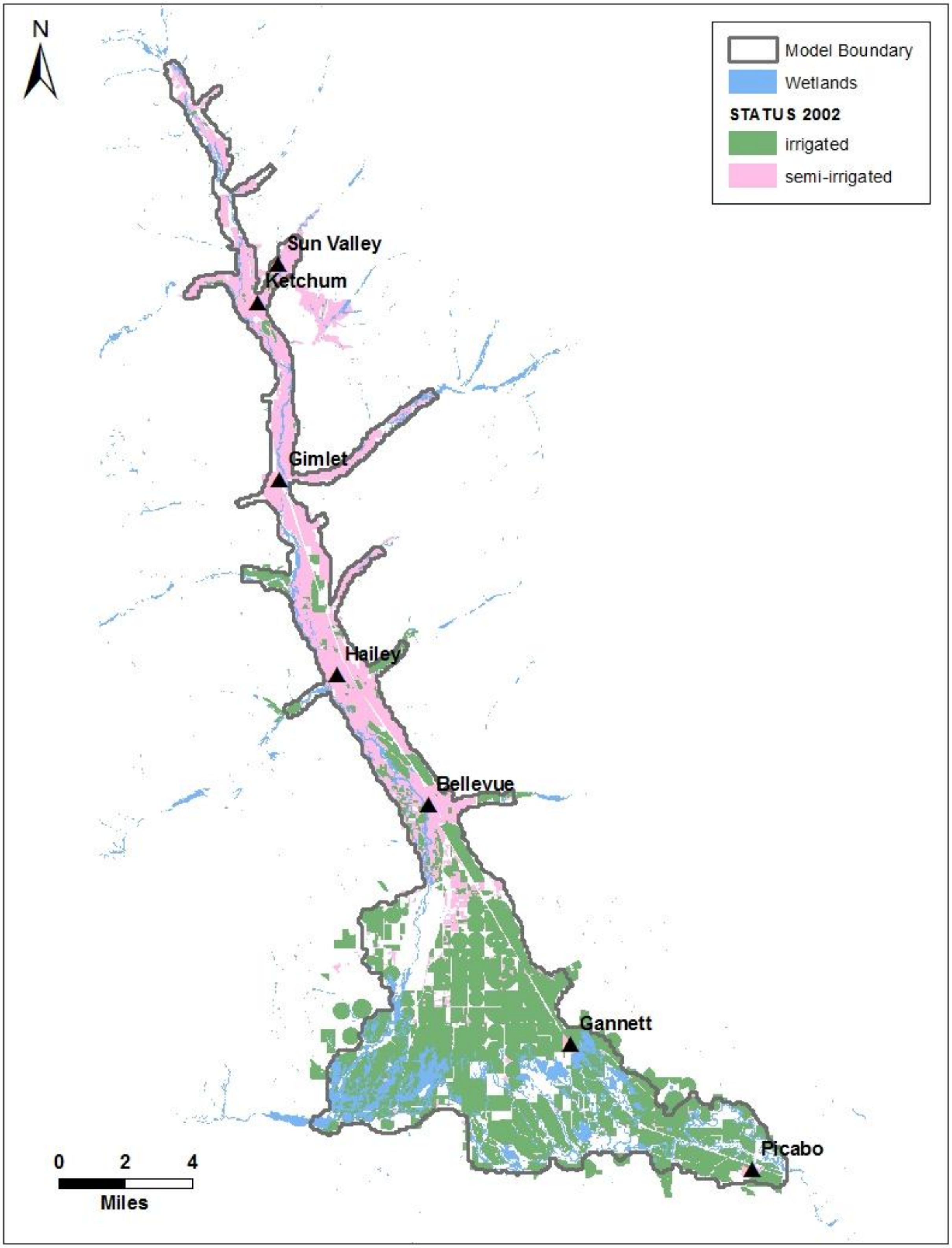

Figure 5. 2002 land status.

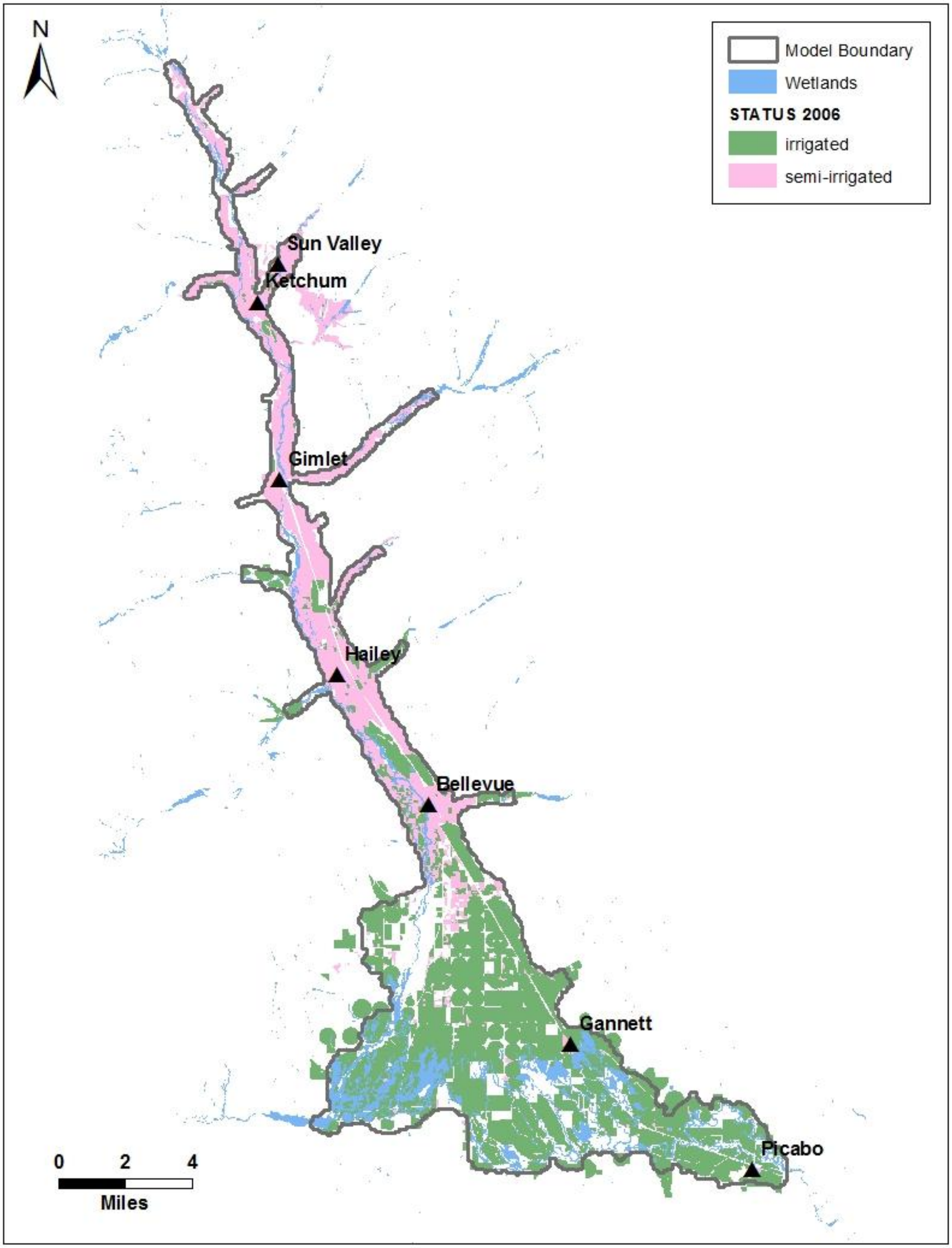

Figure 6. 2006 land status.

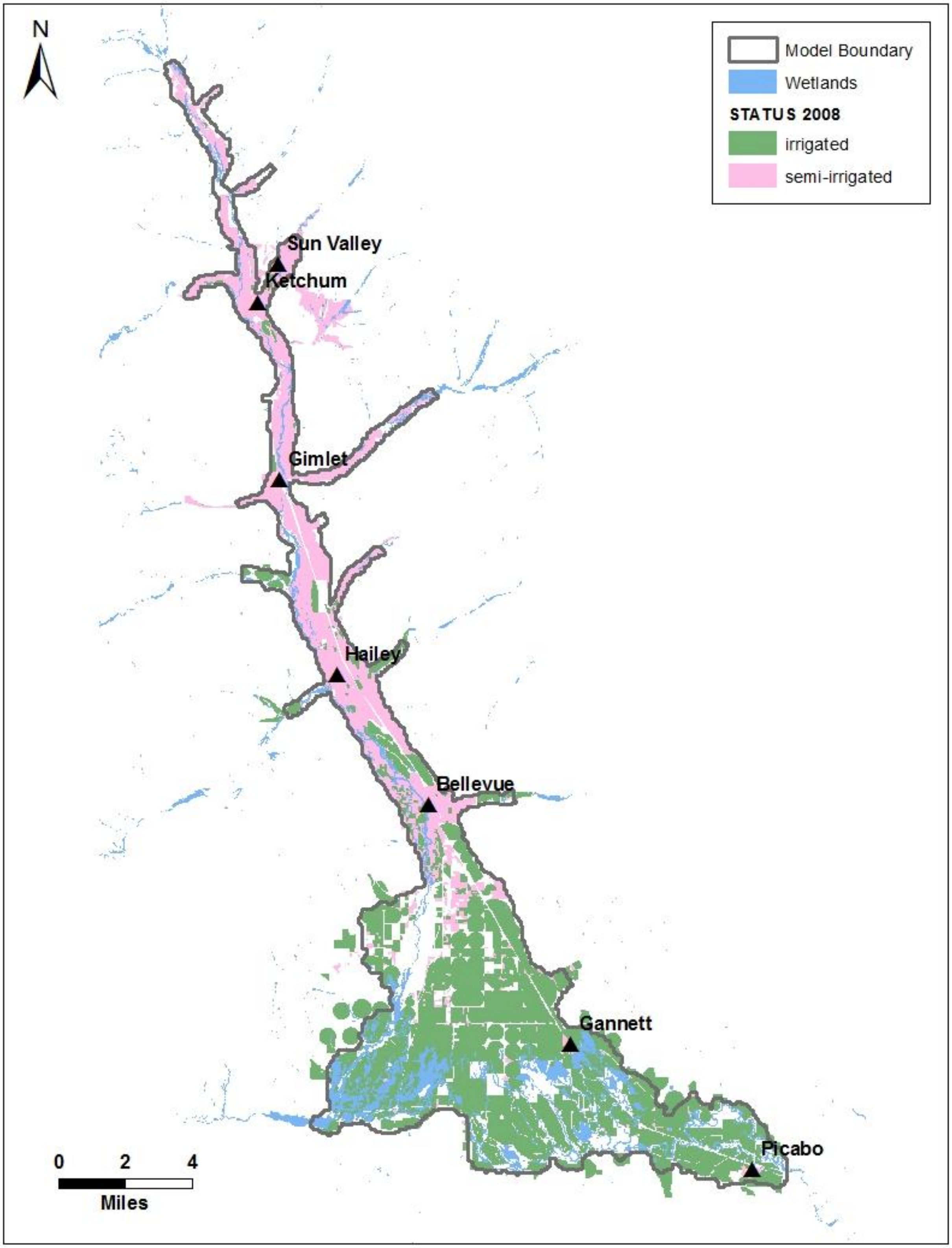

Figure 7. 2008 land status.

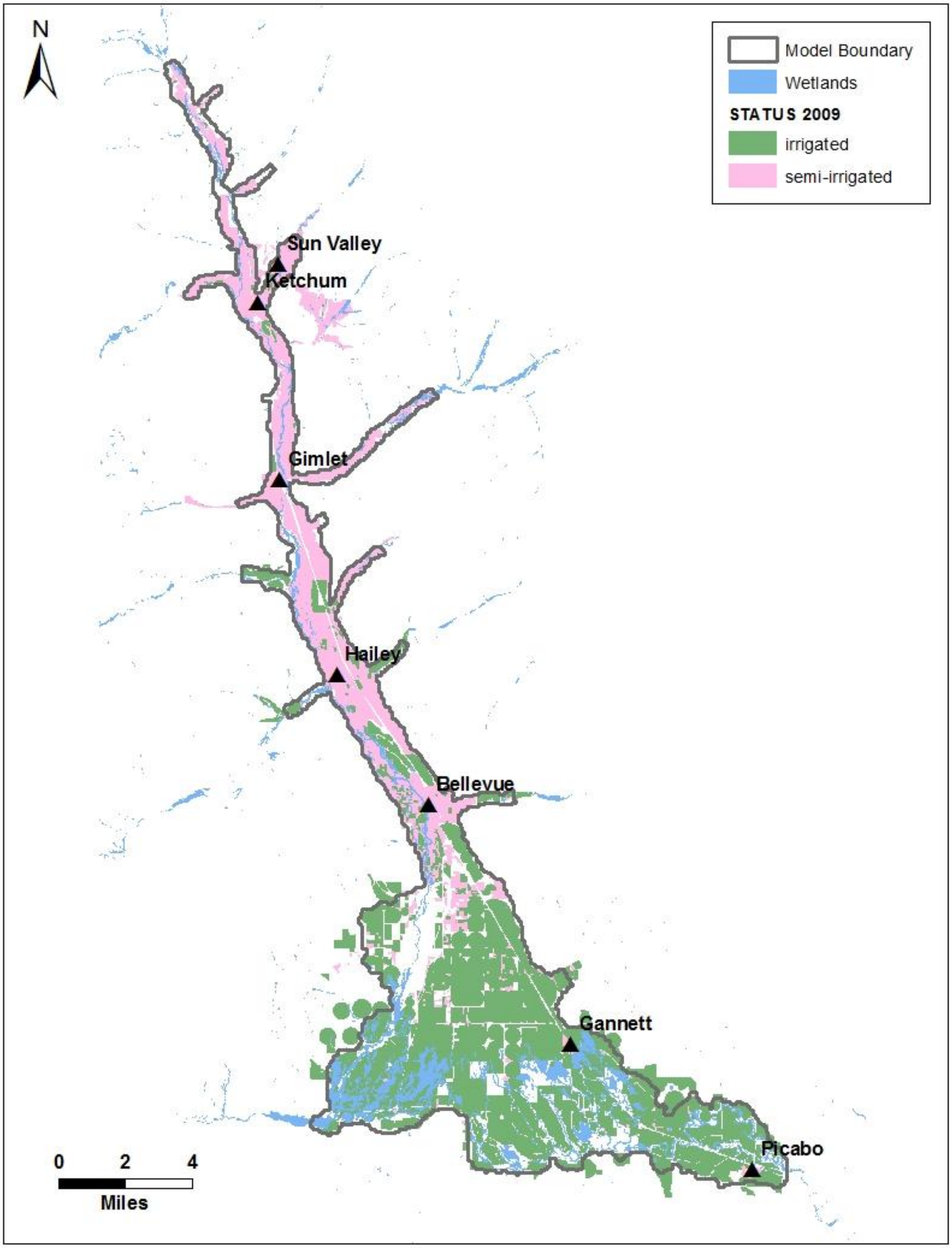

Figure 8. 2009 land status.

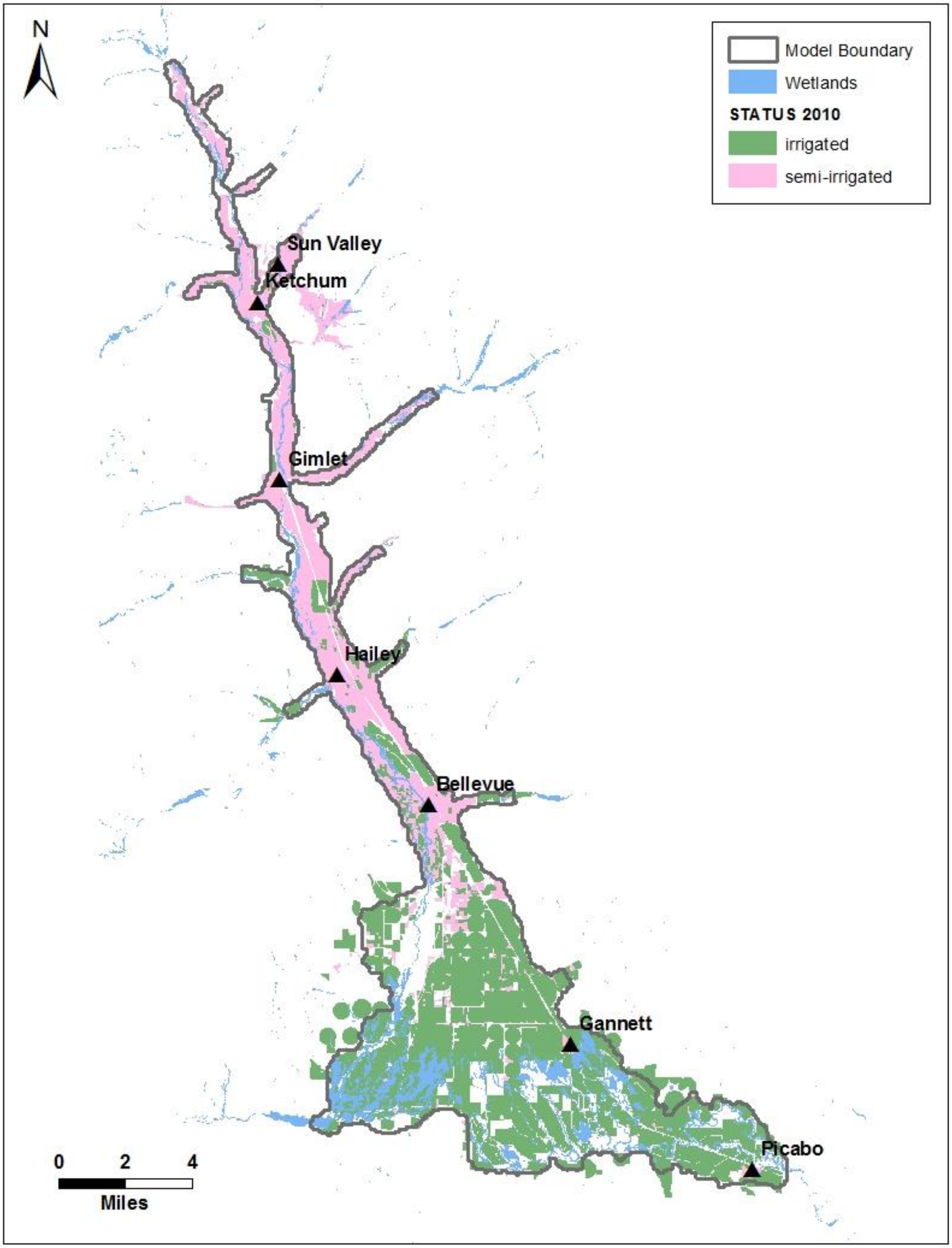

Figure 9. 2010 land status.

Irrigated Lands Delineation Year	Applied Years
1996	1995-1997
2000	1998-2000
2002	2001-2003
2006	2004-2006
2008	2007-2008
2009	2009
2010	2010

Table 2. Irrigated lands datasets.

Irrigated lands are grouped into 88 irrigation entities for calculation of monthly water supply, crop irrigation requirement, and incidental recharge. Irrigation entities are used in calculating recharge for the Wood River Valley model for several reasons.

1. Many surface water diversions in the Wood River Valley provide irrigation water to multiple water users within a canal service area. Surface water diversion data are generally recorded by Water District 37 and 37M at the canal heading. Field headgate deliveries to individual parcels are not available.
2. Some groundwater wells provide irrigation water within community water system service areas, or to multiple irrigated parcels.
3. Recorded water right shape delineations do not precisely match irrigated lands shape delineations, so the edges of irrigated parcels may fall outside of a delineated water right shape.
4. Some areas are irrigated by diversions from domestic wells without recorded water rights.

Classification of irrigation entities is shown in Figure 10 through Figure 14. Irrigation entities are further subdivided by water source, which may be surface water only, groundwater only, or mixed source (Figure 15).

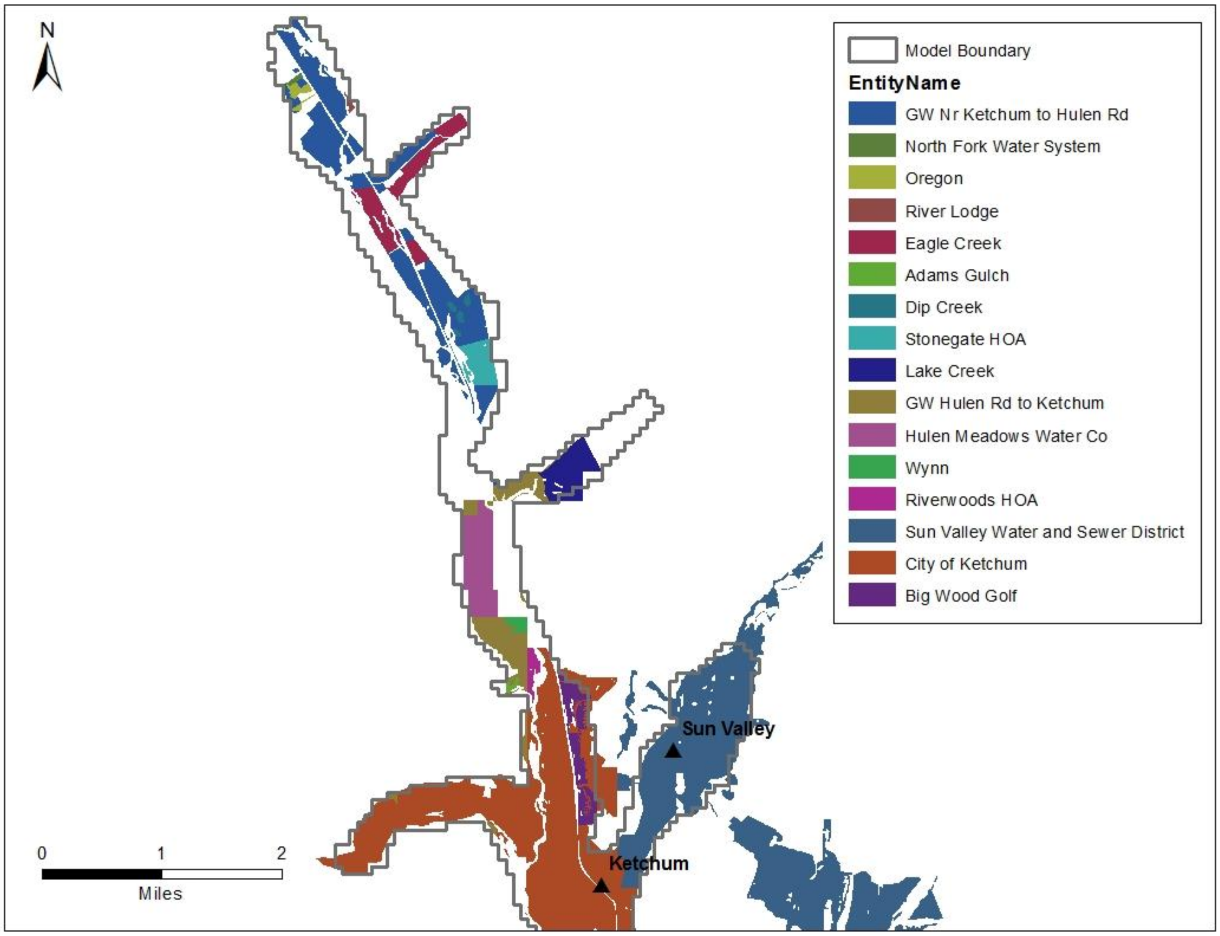

Figure 10. Irrigation entities north of Ketchum (2008 irrigated and semi-irrigated lands).

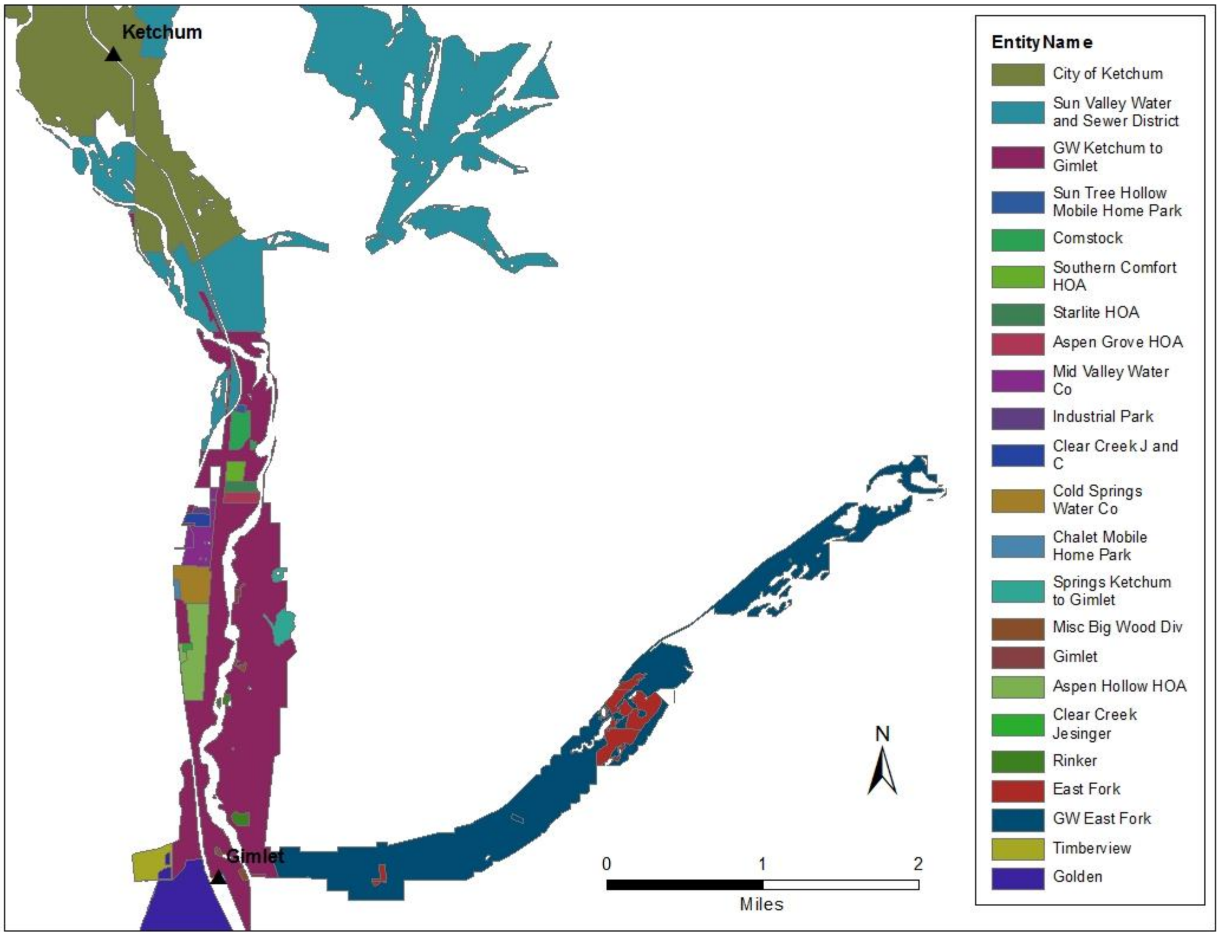

Figure 11. Irrigation entities between Ketchum and Gimlet (2008 irrigated and semi-irrigated lands).

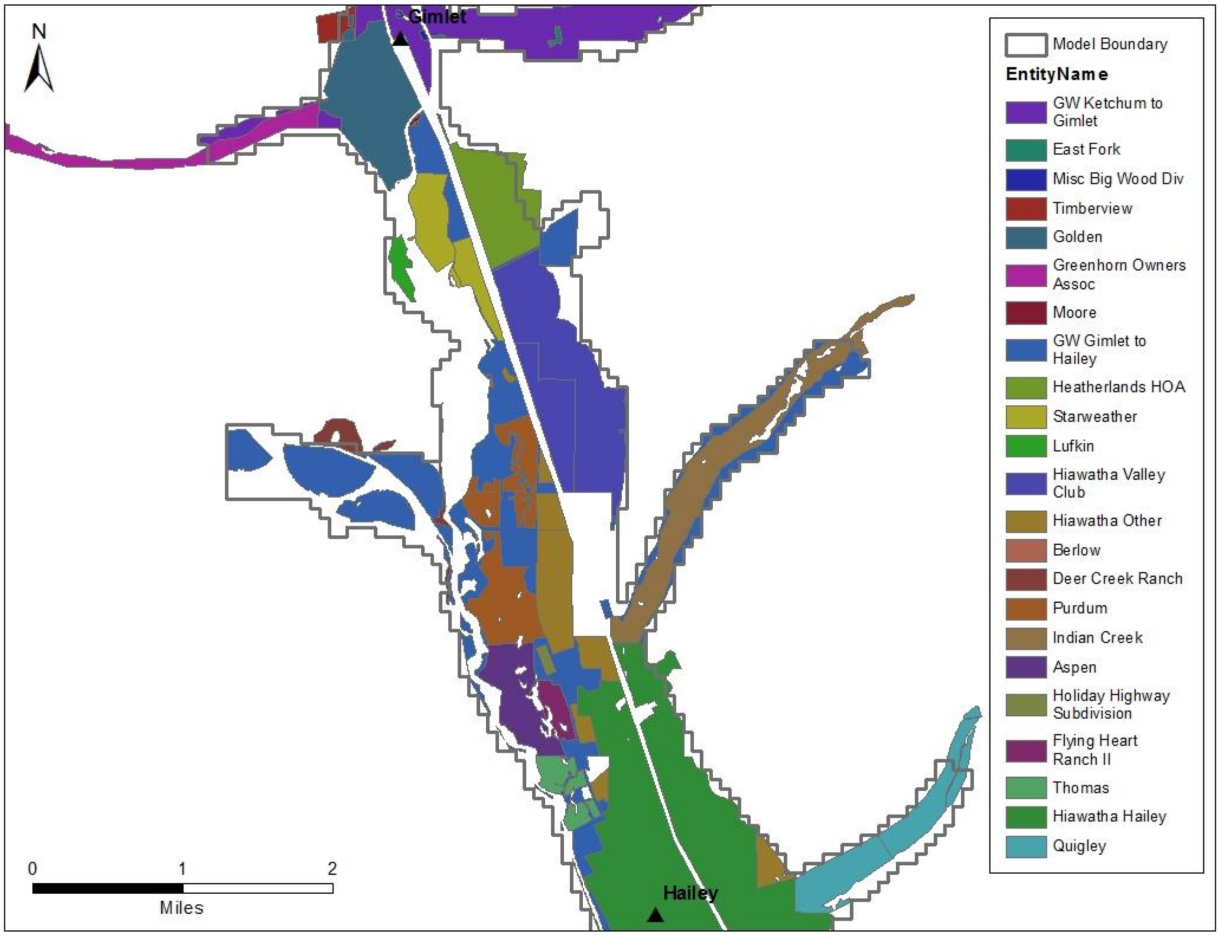

Figure 12. Irrigation entities between Gimlet and Hailey (2008 irrigated and semi-irrigated lands).

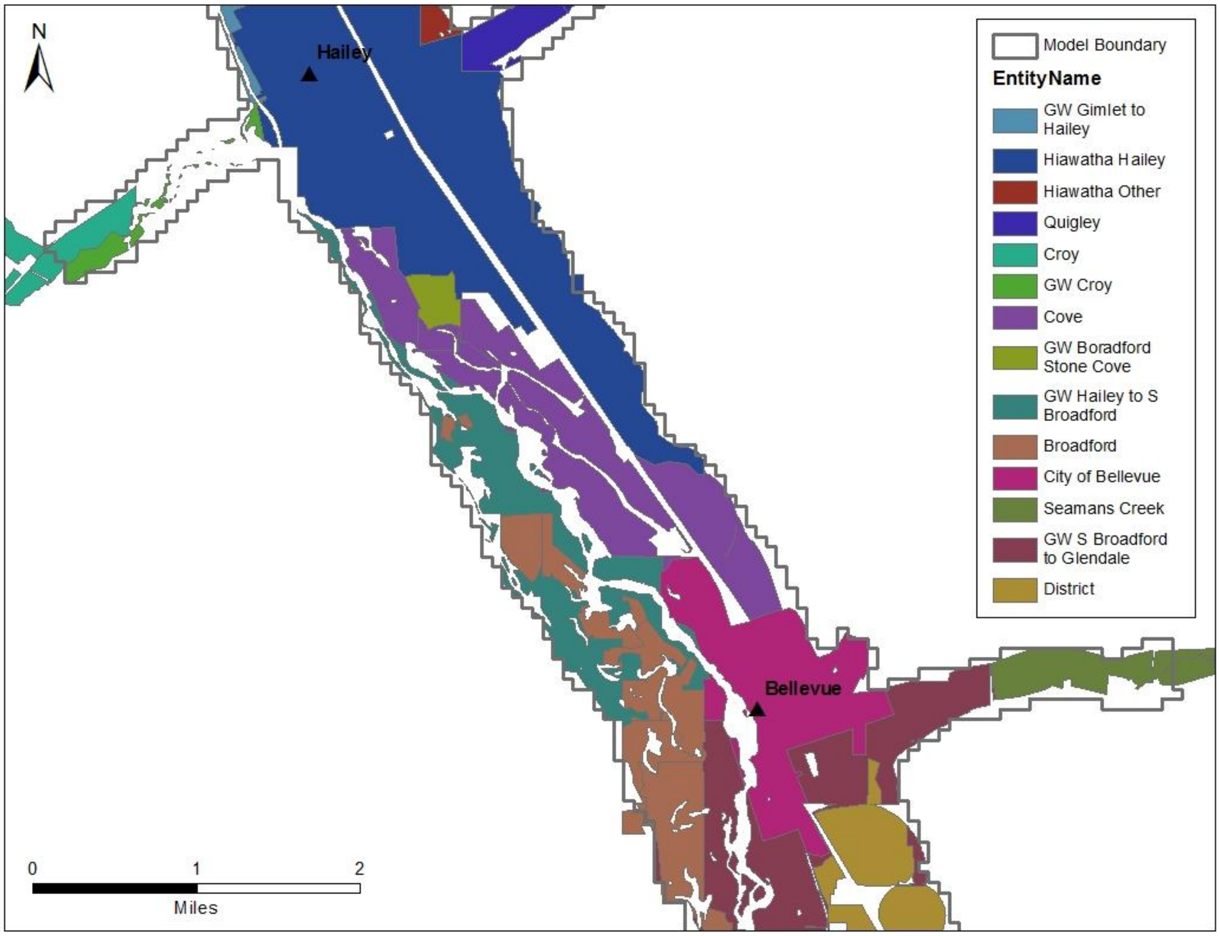

Figure 13. Irrigation entities between Hailey and Bellevue (2008 irrigated and semi-irrigated lands).

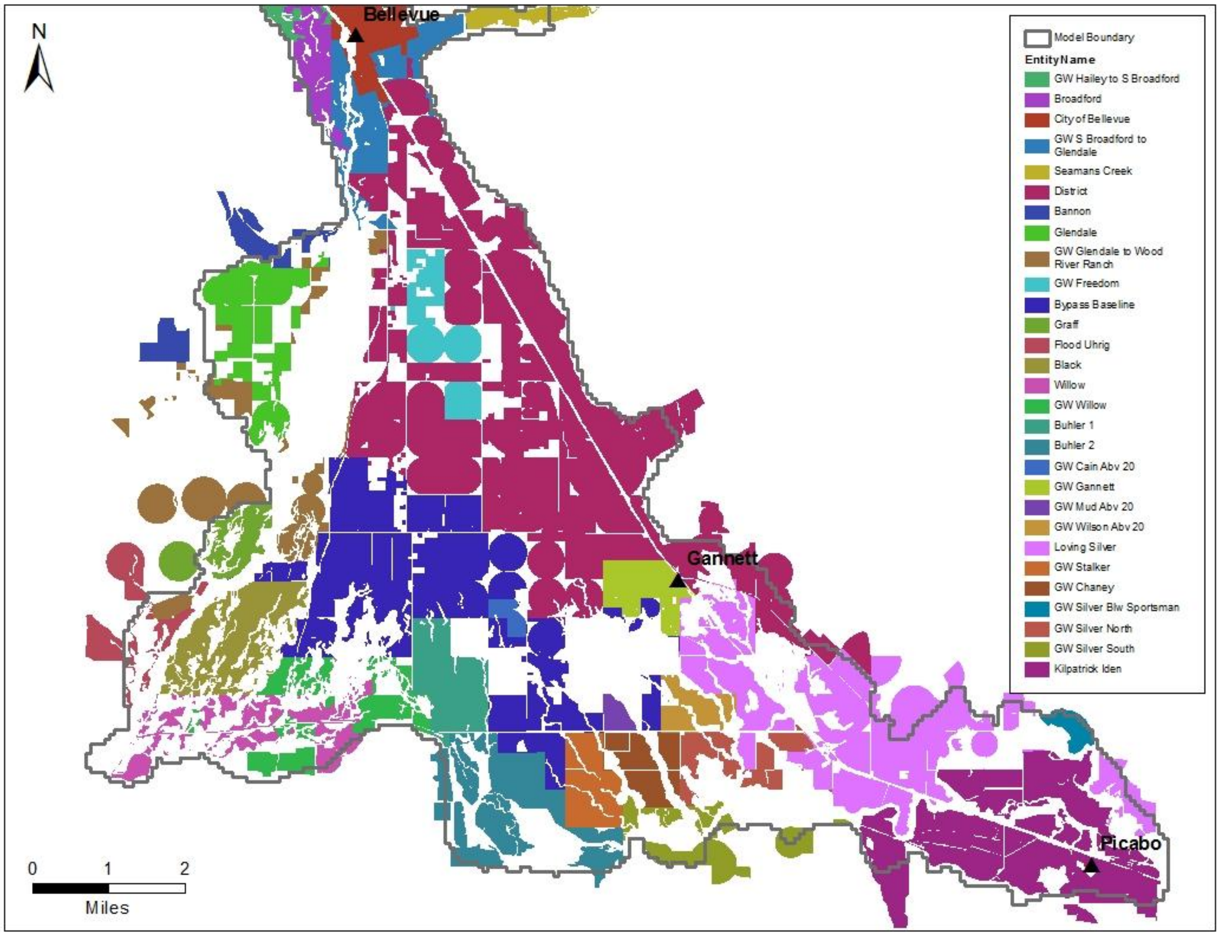

Figure 14. Irrigation entities south of Bellevue (2008 irrigated and semi-irrigated lands).

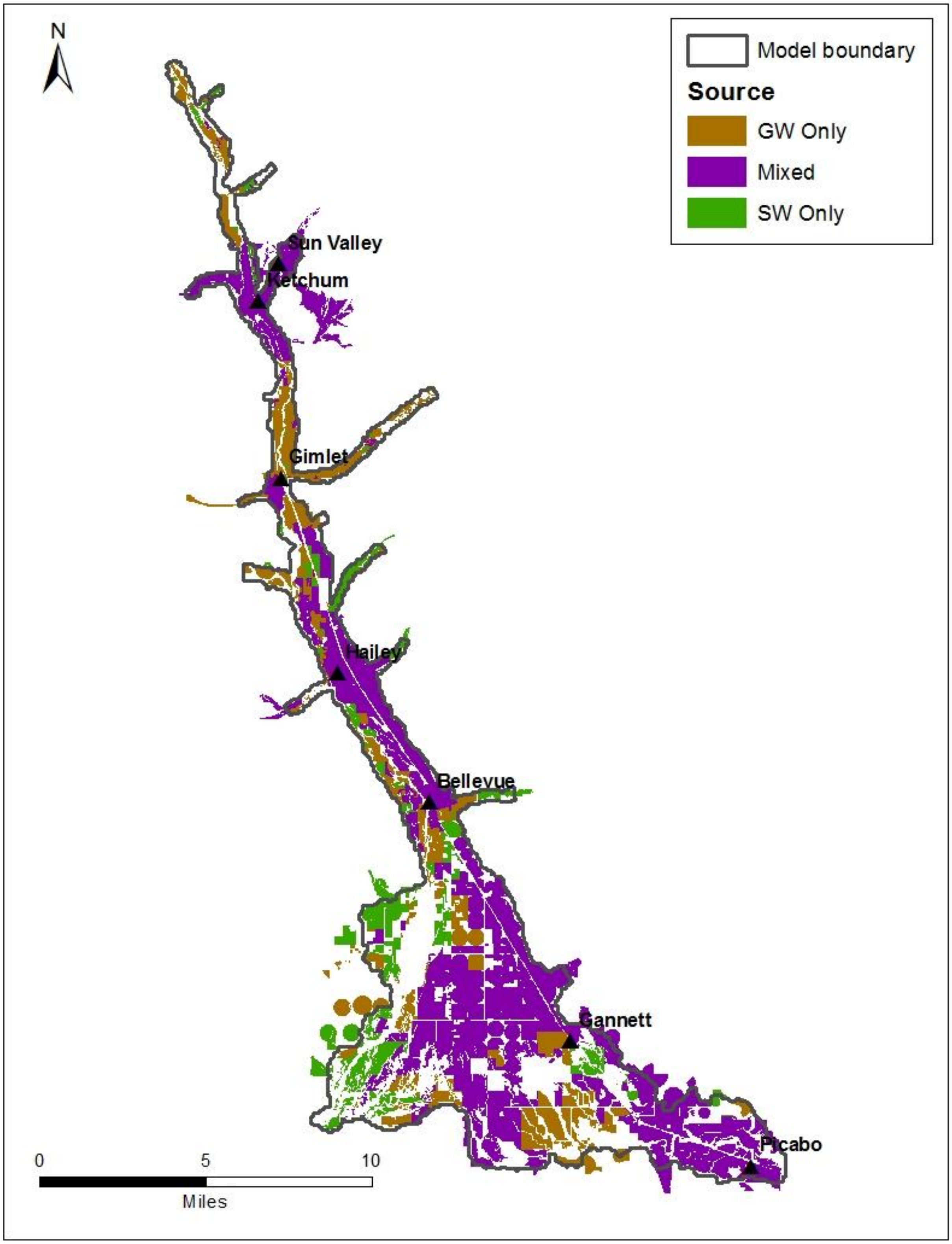

Figure 15. Irrigation water source (2008 irrigated and semi-irrigated lands).

For each irrigation entity, recharge from excess applied water is calculated using Equation 1.

[Rech] = [SWDiv] – [SWRet] – [CanalSeep] + [GWDiv] – [WWTP] – [CIR] Equation 1.

Where [Rech] = Incidental recharge from excess applied water [L^3]

[SWDiv] = Surface water diversions (includes municipal spring diversions) [L^3]

[SWRet] = Surface return flow [L^3]

[CanalSeep] = Canal seepage [L^3]

[GWDiv] = Groundwater diversions [L^3]

[WWTP] = Municipal wastewater treatment plant discharge [L^3]

[CIR] = Crop irrigation requirement [L^3]

Calculation of unmeasured groundwater diversions

Because groundwater diversion records in the Wood River Valley are limited, many of the groundwater diversions must be estimated. Estimated groundwater diversions are calculated from available irrigation diversion data, monthly CIR, and irrigation efficiency. Estimated groundwater diversions are equal to the water demand calculated from CIR and irrigation efficiency less the water supply available from surface water deliveries and recorded groundwater diversions. If recorded surface water and groundwater diversions are sufficient to meet the CIR after accounting for returns, delivery losses, and irrigation efficiency, then it is assumed that no additional groundwater was diverted.

[GWDivEst] = [CIRMixed]/[eff] + [CIRSW]/[eff] + [CIRGW]/[eff] – ([SWDiv] – [SWRet] – [CanalSeep]) – ([GWDivRec] – [WWTP]); for [GWDivEst] > 0 and [CIRSW]/[eff] – ([SWDiv] – [SWRet] – [CanalSeep]) > 0

Equation 2.

Where [GWDivEst] = Estimated groundwater diversions needed to meet crop irrigation requirement [L^3]

[CIRMixed] = Crop irrigation requirement on mixed source irrigated lands [L^3]

[CIRSW] = Crop irrigation requirement on surface water only irrigated lands [L^3]

[CIRGW] = Crop irrigation requirement on groundwater only irrigated lands [L^3]

[eff] = Irrigation efficiency

[SWDiv] = Surface water diversions (includes municipal spring diversions) [L^3]

[SWRet] = Surface return flow [L^3]

[CanalSeep] = Canal seepage [L^3]

[GWDivRec] = Recorded groundwater diversions [L^3]

[WWTP] = Municipal wastewater treatment plant discharge [L^3]

If [GWDivEst] < 0 or [CIRSW]/[eff] – ([SWDiv] – [SWRet] – [CanalSeep]) < 0, the CIR and surface water diversion data suggest that assumed values for irrigation efficiency and/or canal seepage are incorrect and need to be adjusted. This is discussed further in the following section.

Irrigation efficiency

Equation 2 requires an assumption of irrigation efficiency. An irrigation efficiency of 80% was proposed for these calculations in the October 2013 MTAC meeting. Committee members Dr. Christian Petrich and Dr. Erick Powell stated that they believed 80% was too high, and suggested that IDWR use a lower value supported by literature. The Food and Agriculture Organization of the United Nations (Brouwer et al, 1989) stated that average field application efficiency is approximately 60% for gravity irrigation, 75% for sprinkler irrigation, and 90% for drip irrigation. The U.S. Department of Agriculture (Howell, 2003) indicated that attainable field efficiencies ranged from 75% to 98% for various types of gravity, sprinkler, and center pivot systems, with average field efficiencies ranging from 65% to 95%. The University of Nebraska Extension (Irmak et al, 2011) indicated that typical application efficiencies for gravity, sprinkler, and center pivot systems range from 45% to 90%. The University of California Davis (Solis, 2013) evaluated application efficiency for ten agricultural regions in California for the 2010 irrigation season. Solis (2013) reported application efficiencies ranging from 50% to 95% for various types of gravity, sprinkler, and center pivot systems, with mean application efficiencies ranging from 68% to 83%. Mean application efficiencies within each of the ten regions ranged from 73.5% to 79.8%. Based on the referenced literature, an average efficiency of 75% will be used as the initial value in Equation 2 to estimate the volume of groundwater pumping needed to meet CIR.

If surface water supply is less than the calculated demand for surface water only irrigated lands within an irrigation entity, there will be no surface water available for irrigation of mixed source lands in the irrigation entity. This indicates either the initial irrigation efficiency estimate is too low, or input data (i.e. diversions, canal seepage, or ET) are incorrect. If surface water supply and measured groundwater diversions are greater than the calculated demand for surface water only and mixed source irrigation lands within an irrigation entity, estimated groundwater diversions will be zero. Unless the majority of groundwater diversions are measured, this indicates either the initial estimate of irrigation efficiency is too high, or input data (i.e. diversions, canal seepage, or ET) are incorrect. For irrigation entities where the data do not constrain the initial estimate of irrigation efficiency, the irrigation efficiency for each irrigation entity may be an adjustable parameter (within specified limits) during model calibration.

Ponds

Evaporation from ponds located within irrigated and developed areas is included in the ET values used to calculate CIR for Equation 1. Evaporation from wetlands and ponds located outside of irrigated and developed areas is included in ET values used to calculate groundwater recharge and discharge on non-irrigated lands (McVay, 2014b).

Surface water diversions to ponds may be recorded by the Watermaster as non-consumptive ("NCP") or as a measured diversion and measured return. Diversions recorded as non-consumptive were excluded from the surface water diversion data. Where both diversions and returns were measured, both were included in the surface water diversion and return data.

Municipalities

Equations 1 and 2 are suitable for calculating recharge and estimated groundwater diversions within municipal service areas. Municipal diversions from springs and surface water diversions for irrigation within municipal service areas are included in the surface water diversion data compiled from municipal and Water District 37 records. Groundwater diversions recorded by municipalities are included in the groundwater diversion data. Precipitation which falls within the service area is accounted for in the calculation of CIR. Water supplied to the service area may return to a wastewater treatment plant, be applied for irrigation, or infiltrate into the ground via leaky water distribution system piping or stormwater disposal facilities (Figure 16). For a given municipal service area, the volume of water available for infiltration into the aquifer equals the total water supply less ET and wastewater treatment plant returns. The Sun Valley Water and Sewer District delivers water to Dollar Mountain for snowmaking. This water is assumed to return to Trail Creek as snowmelt runoff and is also deducted from the volume of water available for infiltration. While all of the municipalities have provided diversion data, groundwater diversions for unmeasured non-municipal irrigation wells located within the municipal service areas must be estimated. Groundwater and spring diversions by the City of Bellevue prior to 2006 also must be estimated.

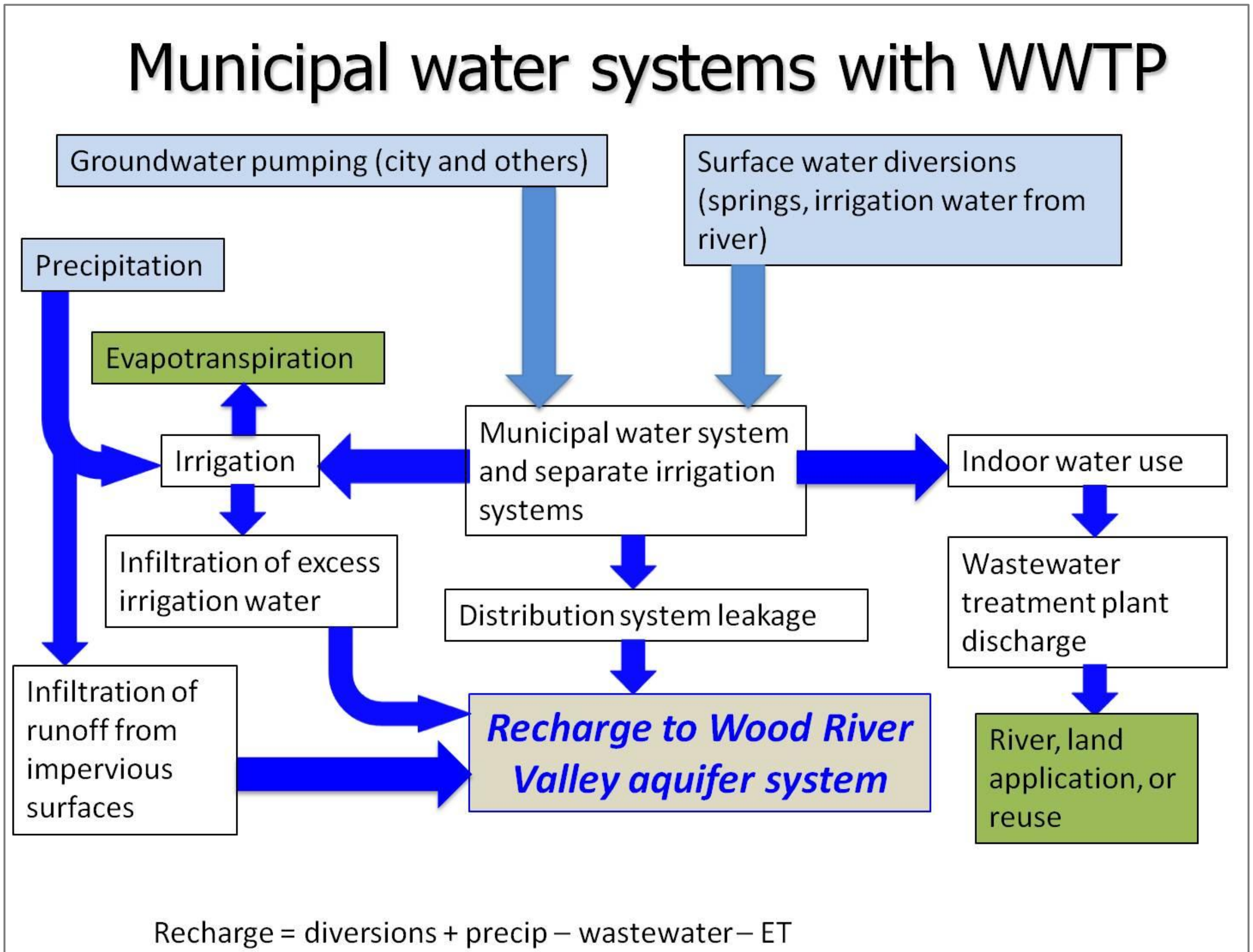

Figure 16. Water supply and fate of water in municipal areas.

Subdivisions with centralized water systems

Equations 1 and 2 are suitable for calculating recharge and estimated groundwater diversions within subdivisions with community water systems and on-site septic systems. Irrigation supplied by surface water is included in the surface water diversion data. Groundwater diversions are generally unmeasured. Precipitation which falls within the service area is accounted for in the calculation of CIR. Water supplied to the service area may be applied for irrigation, or infiltrate into the ground via leaky water distribution system piping, stormwater disposal facilities, or septic systems (Figure 17). For a given subdivision, the volume of water available for infiltration into the aquifer equals the total water supply less evapotranspiration.

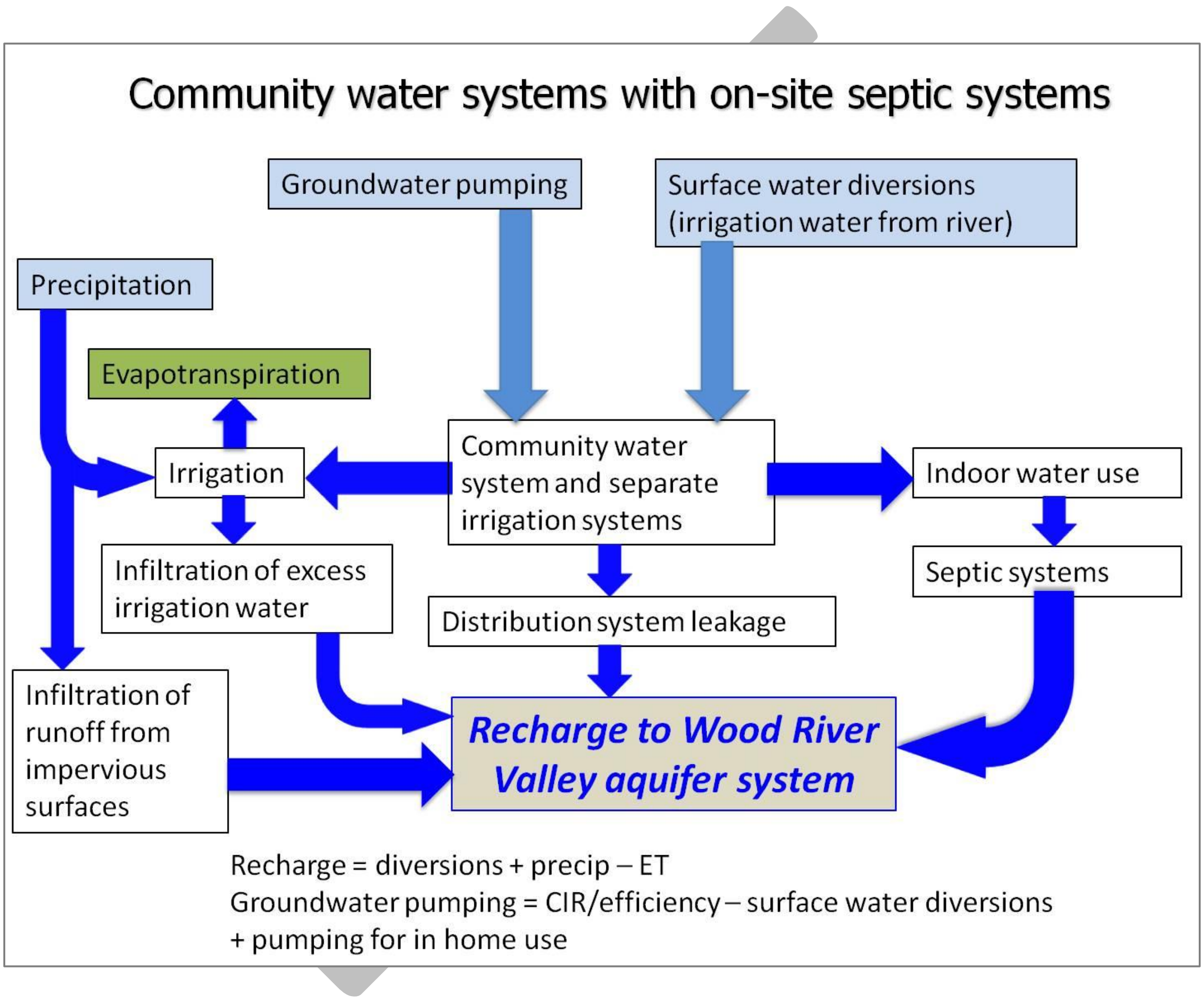

Figure 17. Water supply and fate of water within subdivisions with community water systems.

Single home domestic systems

Equations 1 and 2 are suitable for calculating recharge and estimated groundwater diversions for single home domestic systems located within subdivisions or agricultural areas. Groundwater diversions are generally unmeasured. Precipitation which falls within the service area is accounted for in the calculation of CIR. Water supplied to the service area may be applied for irrigation, or infiltrate into the ground via infiltration of stormwater runoff or septic systems (Figure 17). For a given municipal system, the volume of water available for infiltration into the aquifer equals the total water supply less evapotranspiration. Because most single home domestic wells pump water from Layer 1, water pumped for non-consumptive use generally returns to the same model layer in the same model cell via septic systems. Only consumptive water use, which is equal to ET less precipitation, needs to be calculated to estimate the net stress resulting from groundwater diversions in these areas.

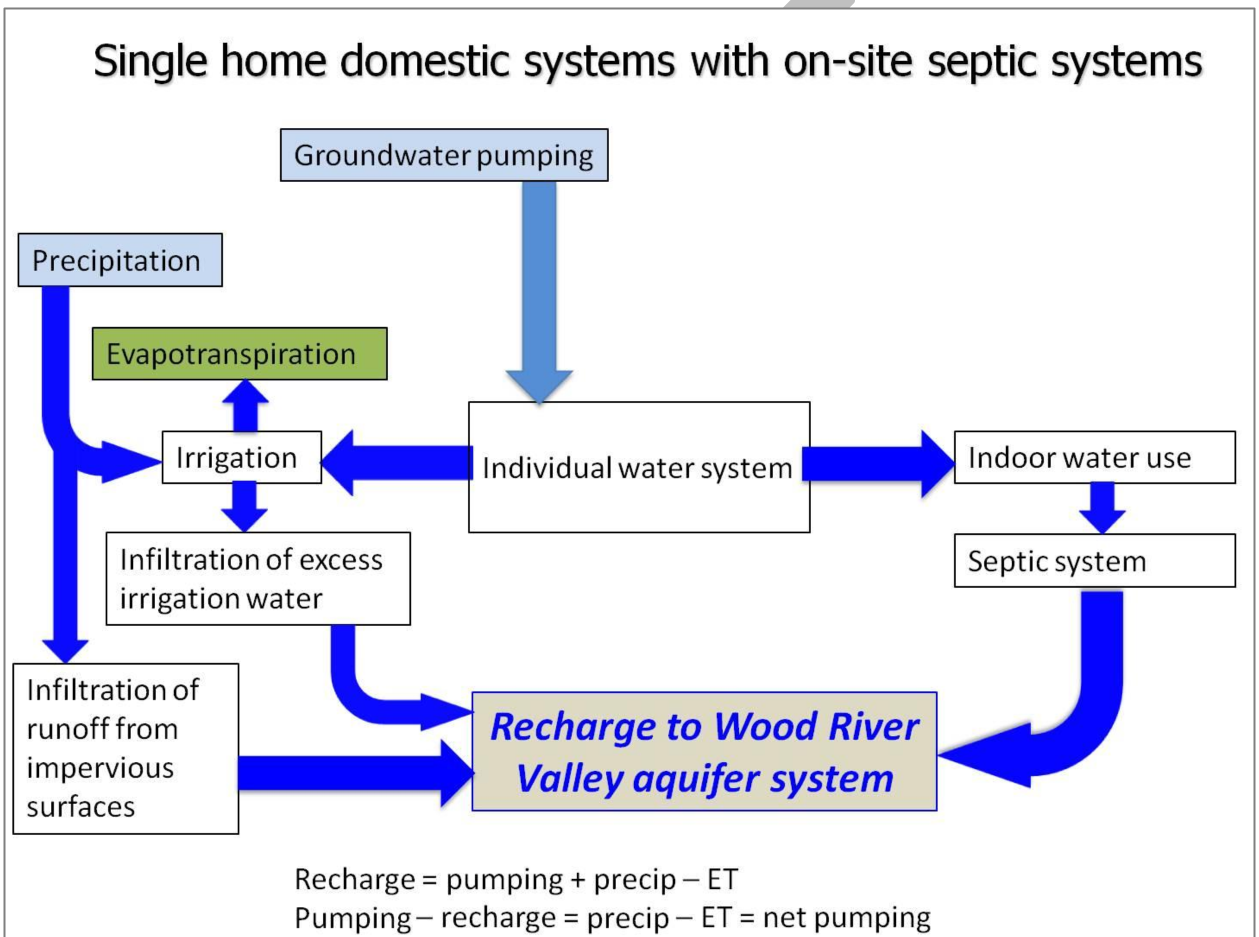

Figure 18. Water supply and fate of water within residential areas served by individual wells.

Apportioning unmeasured groundwater pumping to individual wells

Groundwater diversions reported by municipal providers and Water Districts 37 and 37M are modeled as a withdrawal in the model cell containing the appropriate well. Wells without measured diversions are grouped by irrigation entity and a portion of the remaining groundwater demand calculated using Equation 2 is modeled as a withdrawal in each model cell containing an unmeasured well. Figure 19 shows the locations of groundwater points of diversion with and without measured diversions. Points labeled as measured diversions in Figure 19 have diversion records for at least part of the model calibration period, but may not have diversion records for the entire calibration period. For stress periods without recorded diversions, diversions from these wells are estimated with the other unmeasured wells as described below.

Because a significant portion of groundwater rights in the Upper Wood River Valley are supplemental to surface water from the Big Wood River or Silver Creek, the MTAC requested that surface water availability and water right priority dates be accounted for in the method used to apportion groundwater pumping to individual wells. Surface water availability during each monthly stress period can be evaluated using annual reports prepared by Water District 37 and 37M, which list the watermaster's historic priority cut dates for each irrigation season.

Groundwater pumping calculated using Equation 2 is apportioned and assigned to unmeasured wells within each irrigation entity based on groundwater right diversion rates, the priority dates and diversion rates of any surface water rights that share combined limits with a given groundwater right, Water District 37 priority cut dates for the Big Wood River above Magic Reservoir, and Water District 37M priority cut dates for Silver Creek and the Little Wood River. Groundwater pumping within each irrigation entity is apportioned to individual wells using Equation 3.

[GWDivEstWellNum] = [GWRateWMISNum]/[SumGWRateEntity]*[GWDivEst] Equation 3.

Where [GWDivEstWellNum] = Portion of estimated groundwater diversions assigned to individual well [L^3]

[GWRateWellNum] = Sum of diversion rates for groundwater rights diverted from a given well that are not supplemental to surface water rights that were in priority at the end of the month [L^3/T]. For water rights diverted from multiple wells, the diversion rate is divided by the number of points of diversion. For groundwater rights that are supplemental to more than one surface water right, the diversion rate is multiplied by the fraction of surface water rights not in priority at the end of the month.

[SumGWRateEntity] = Sum of diversion rates for groundwater rights diverted within an irrigation entity that are not supplemental to surface water rights that were in priority at the end of the month [L^3/T]. For water rights diverted from multiple wells, the diversion rate is divided by the number of points of diversion. For groundwater rights that are supplemental to more than one surface water right, the diversion rate is multiplied by the fraction of surface water rights not in priority at the end of the month.

[GWDivEst] = Estimated groundwater diversions needed to meet CIR within irrigation entity [L^3]

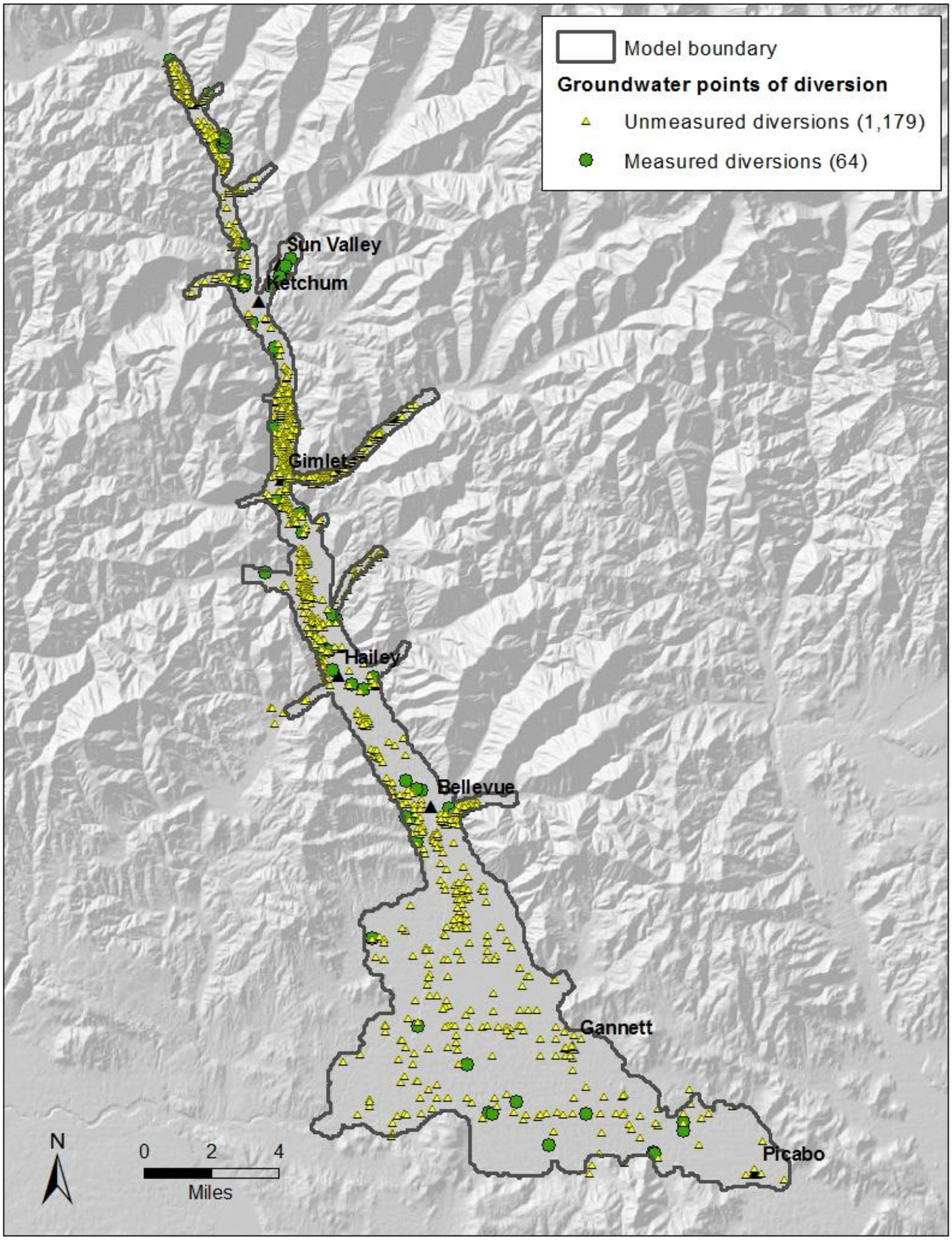

Figure 19. Groundwater points of diversion.

MODFLOW input files

Incidental recharge on irrigated and semi-irrigated lands is calculated by irrigation entity and is applied to model layer 1 in model cells intersecting the irrigation entity. Recharge from canal seepage is applied to model layer 1 in model cells intersecting the canal. Incidental recharge on irrigated and semi-irrigated lands and recharge from canal seepage are represented in MODFLOW using the well (WEL) package. Recharge from infiltration of precipitation on non-irrigated lands and discharge from ET in wetlands and riparian areas are also included in the MODFLOW WEL file. Recharge is assigned to model cells as a positive stress. The WEL file may have negative values for the net stress in some cells for some stress periods, if ET in wetlands or riparian areas exceeds recharge in the model cell, or if well pumping occurs in the model cell.

Groundwater diversions, both recorded and estimated, are represented in MODFLOW as a negative stress using the WEL package. For points of diversion with a well driller's log, pumping is assigned to one or more layers based on well construction. For points of diversion without a well driller's log, the pumping is assumed to occur in the same layer(s) as the nearest well with a driller's log (Wylie, 2014). For wells that pump from multiple layers, the stress applied to each layer is calculated based on hydraulic conductivity and thickness of the open interval.

References

Bartolino, J.R., 2009, *Ground-Water Budgets for the Wood River Valley Aquifer System, South-Central Idaho , 1995-2004*. Scientific Investigations Report 2009-5016, United States Geological Survey, 36 p.

Bartolino, J.F., 2014, *Stream Seepage and Groundwater Levels, Wood River Valley, South-Central Idaho, 2012-13*. Scientific Investigations Report 2014-5151, United States Geological Survey, 44 p.

Brockway, C.E., and K.P Grover, 1978, *Evaluation of Urbanization and Changes in Land Use on the Water Resources of Mountain Valleys*. Research Technical Completion Report Project B-038-IDA, Idaho Water Resources Research Institute, University of Idaho, Moscow, Idaho.

Brockway, C.G., 2013. *Analysis of Annual Water Usage for Snowmaking at River Run, Sun Valley Water Company, Water Permit 37-8575A*. Brockway Engineering, January 8, 2013, http://www.idwr.idaho.gov/apps/ExtSearch/DocsImages/j9f401_.pdf.

Brouwer, C., K. Prins, and M. Heibloem, 1989, *Irrigation Water Management: Irrigation Scheduling, Annex I: Irrigation Efficiencies*. FAO Training Manual No. 4, http://www.fao.org/docrep/t7202e/t7202e08.htm#annex i: irrigation efficiencies.

City of Ketchum, 2013. City of Ketchum website, http://ketchumidaho.org/index.aspx?NID=199, accessed on December 13, 2013.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe, 1979, *Classification of Wetlands and Deepwater Habitats of the United States*. U.S. Department of the Interior, Fish and Wildlife Service, FWS/OBS-79/31.

Furber, M., 2004, *Bellevue Water and Sewer Systems Reach Capacity*, Idaho Mountain Express, Ketchum Idaho, March 5, 2004, http://www.mtexpress.com/2004/04-03-05/04-03-05bvuewater.htm, accessed on April 24, 2014.

Howell, T.A., 2003, *Irrigation Efficiency* in *Encyclopedia of Water Science*, B.A. Stewart and T.A. Howell, eds. Marcel Dekker, Inc., New York, NY, pp. 467-472, http://www.cprl.ars.usda.gov/pdfs/Howell-Irrig%20Efficiency-Ency%20Water%20Sci.pdf.

IDWR, 2011, *Preliminary Order Creating a Water Measurement District for Groundwater Rights in the Upper Big Wood and Little Wood River Basins*, Idaho Department of Water Resources, 14 p., http://www.idwr.idaho.gov/WaterManagement/WaterRelatedDistricts/PDFs/Big_Wood_Water_Measurement_District_Order.pdf.

Irmak, S., L.O. Odhiambo, W.L. Krantz, and D.E. Eisenhauer, 2011, *Irrigation Efficiency and Uniformity, and Crop Water Use Efficiency*, University of Nebraska Lincoln Extension, EC732, 8 p., http://ianrpubs.unl.edu/live/ec732/build/ec732.pdf.

McVay, M., 2014a, *Draft Design Document: Estimating Precipitation*, Idaho Department of Water Resources, 6 p.

McVay, M., 2014b, *Draft Design Document: Calculating Evapotranspiration during the Growing Season*, Idaho Department of Water Resources, 19 p.

Merritt, A., 1997, *Review and Recommendation, Memorandum to Transfer File No. 4920 in the Name of Gregory Ranch, LLC*. Idaho Department of Water Resources, May 29, 1997.

Panday, S., C.D. Langevin, R.G. Niswonger, M. Ibaraki, and J.D. Hughes, 2013, *MODFLOW-USG Version 1: An Unstructured Grid Version of MODFLOW for Simulating Groundwater Flow and Tightly Coupled Processes Using a Control Volume Finite-Difference Formulation*, U.S. Geological Survey, Technique and Methods 6-A45, 66 p.

Solis, S.S., 2013, *Application Efficiency: Hydrologic Region 2010*. University of California Davis Water Management Group in cooperation with United States Geological Survey and California Department of Water Resources, http://watermanagement.ucdavis.edu/research/application-efficiency.

USGS, 2014, *MODFLOW-USG Version 1.2: Description of Model Input and Output*, U.S. Geological Survey, March 21, 2014, 128 p.

Water District 37 & 37M, 1995-2010, *Water Distribution and Hydrometric Works*.

Wylie, A., 2014, *Draft Design Document: Assigning Pumping to Model Layers*, Idaho Department of Water Resources, 5 p.