Modeling the Impact of New Groundwater Pumping in Basin 36, on Groundwater Levels in the A&B Irrigation District

DRAFT

US Bureau of Reclamation, Pacific Northwest Region

Modeling the Impact of New Groundwater Pumping in Basin 36, on Groundwater Levels in the A&B Irrigation District

RD Schmidt and Tim Miller
US Bureau of Reclamation, Pacific Northwest Region

12/3/03

Contents

Figures

Tables

Modeling the Impact of New Groundwater Pumping in Basin 36, on Groundwater Levels in the A&B Irrigation District

Modeling Objective

The A&B area groundwater model was developed for the purpose of evaluating the impact of proposed new groundwater pumping in Administrative Basin 36, on groundwater levels beneath the A&B Irrigation District. The model focuses on pending application 36-16125 (the Delis application), which involves three proposed wells located about a mile north and west of the A&B Irrigation District in T8SR22E Sec. 14, 15, and 22. However, the cumulative effects of twenty-three other pending well applications in Basin 36, with earlier priority dates then the Delis application are also evaluated using the model.

The A&B area groundwater model is centered on the A&B Irrigation District, and includes about 175 square miles of the surrounding Eastern Snake River Plain. (Although certain far-field hydrologic boundaries outside this area are also part of the model). Results of recent hydrologic investigations by the Idaho Department of Water Resources (IDWR), the Idaho Water Resources Research Institute (IWRRI), and the US Geologic Survey (USGS) were used in conceptual development, parameterization, and calibration of the A&B area model.

The A&B Irrigation District

The A&B Irrigation District encompasses 77,650 acres of irrigable land in southern Minidoka County, and consists of two units, a 64,000 acre groundwater irrigated unit (Unit-B), and a 13,650 acre surface water irrigated unit (Unit-A) (Figure 1). The District is located within Administrative Basin 36, and is bounded on the south by the Minidoka

Irrigation District and the Snake River, and on the north and west by approximately 110,000 acres of private groundwater irrigated land. During water year 2002, 225,368 acre-feet of water was delivered to farms within the District. Of this, 41,986 acre-feet came from Snake River diversions and 183,381 acre-feet came from groundwater withdrawals (Temple, 2003).

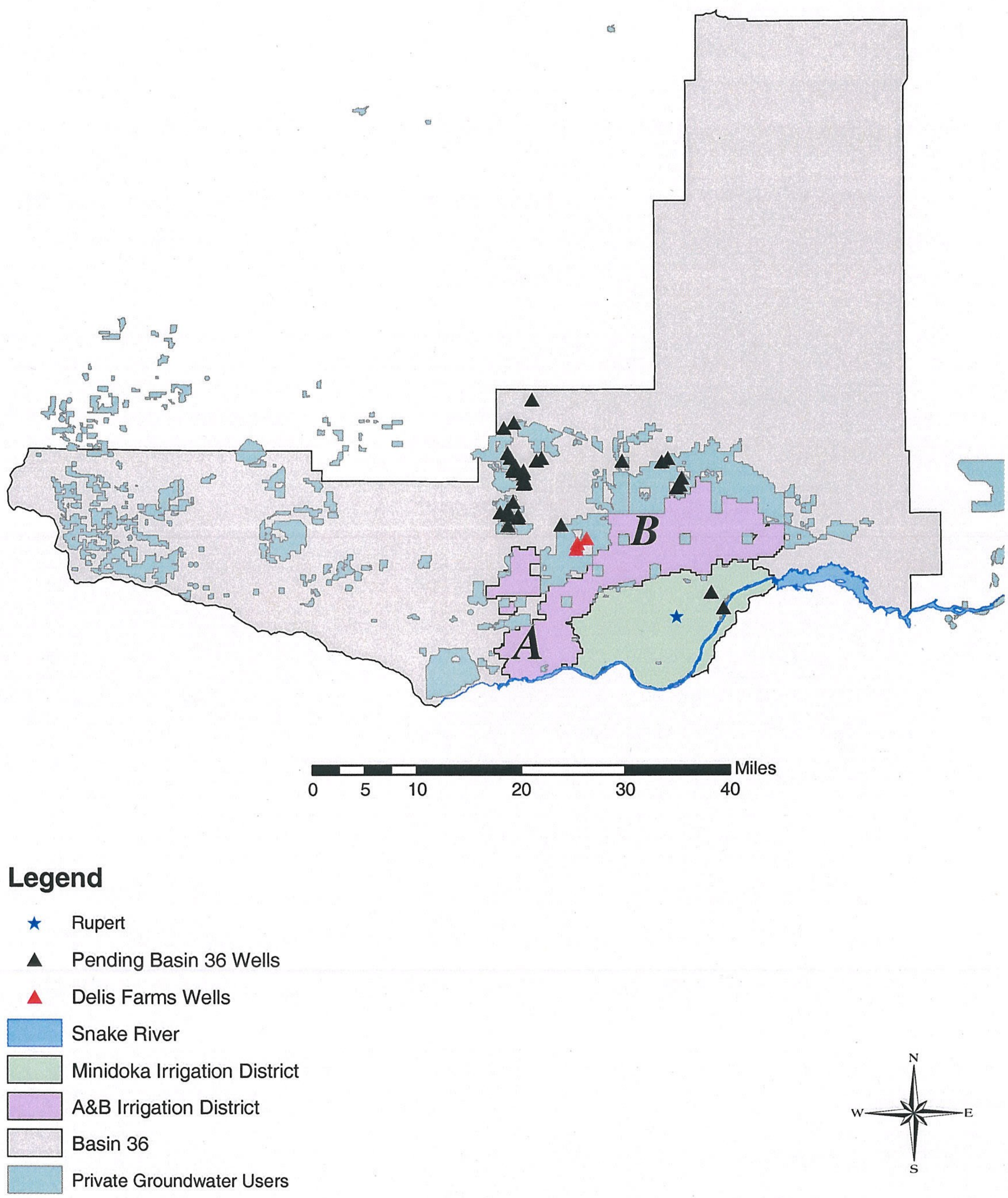

Figure 1. A&B Irrigation District area of interest.

Hydrogeology of Southern Minidoka County

The Quaternary Age, Snake River basalt formation underlies most of the Eastern Snake River Plain and all of Minidoka County. The formation consists of multiple basalt flow sheets ranging from 10 to 75 feet thick and totaling more than 4,000 feet thick in the middle of the plain. The basalt formation is the principal aquifer in Minidoka County and throughout most of the Plain. The most permeable zones within the formation are the contacts between flow sheets, where irregular surfaces, granulation and brecciation have resulted in a concentration of connected void spaces that convey large volumes of groundwater. Open vertical cracks and joints in some flow sheets impart high vertical permeability. Although groundwater travels a sometimes tortuous path within and between basalt flow sheets, on a regional scale groundwater flow in the formation is mainly horizontal (Whitehead, 1992).

In southern Minidoka County, the Snake River basalt formation is overlain by up to 650 feet of alluvial sediments and lake deposits consisting of clays, silts, sands, and fine gravels, intercalated with basalt flows. Younger alluvium in the area overlies a basalt flow referred to as the Minidoka Basalt, which is exposed along the north shore of Lake Walcott. The Minidoka Basalt overlies a layer of older alluvium which in turn overlies the lake sediments known as the Burley Lakebeds. The Burley Lakebeds consist of about 450 feet of compacted clay and silt with small amounts of sand and fine gravel.

At one time the Snake River occupied a wide deep valley in southern Minidoka County and adjacent areas. A lake which covered the extreme southern part of the county was impounded behind a lava dam. The lake basin gradually filled with sediments and then drained as the Snake River cut an outlet through the dam. Afterwards the Snake River deposited a sheet of alluvium on the former lake bed.

The old lake bed forms a relatively flat stream terrace that is referred to as the Rupert Terrace (Figure 2). The terrace is a local feature that is aligned, more-or-less, with the Minidoka Irrigation District. It is bounded on the north and west by an escarpment 50 to

75 feet high, marking the edge of a lava bench which may at one time have dammed the Snake River. To the south, the terrace is bounded by the Snake River (Crosthwaite and Scott, 1956).

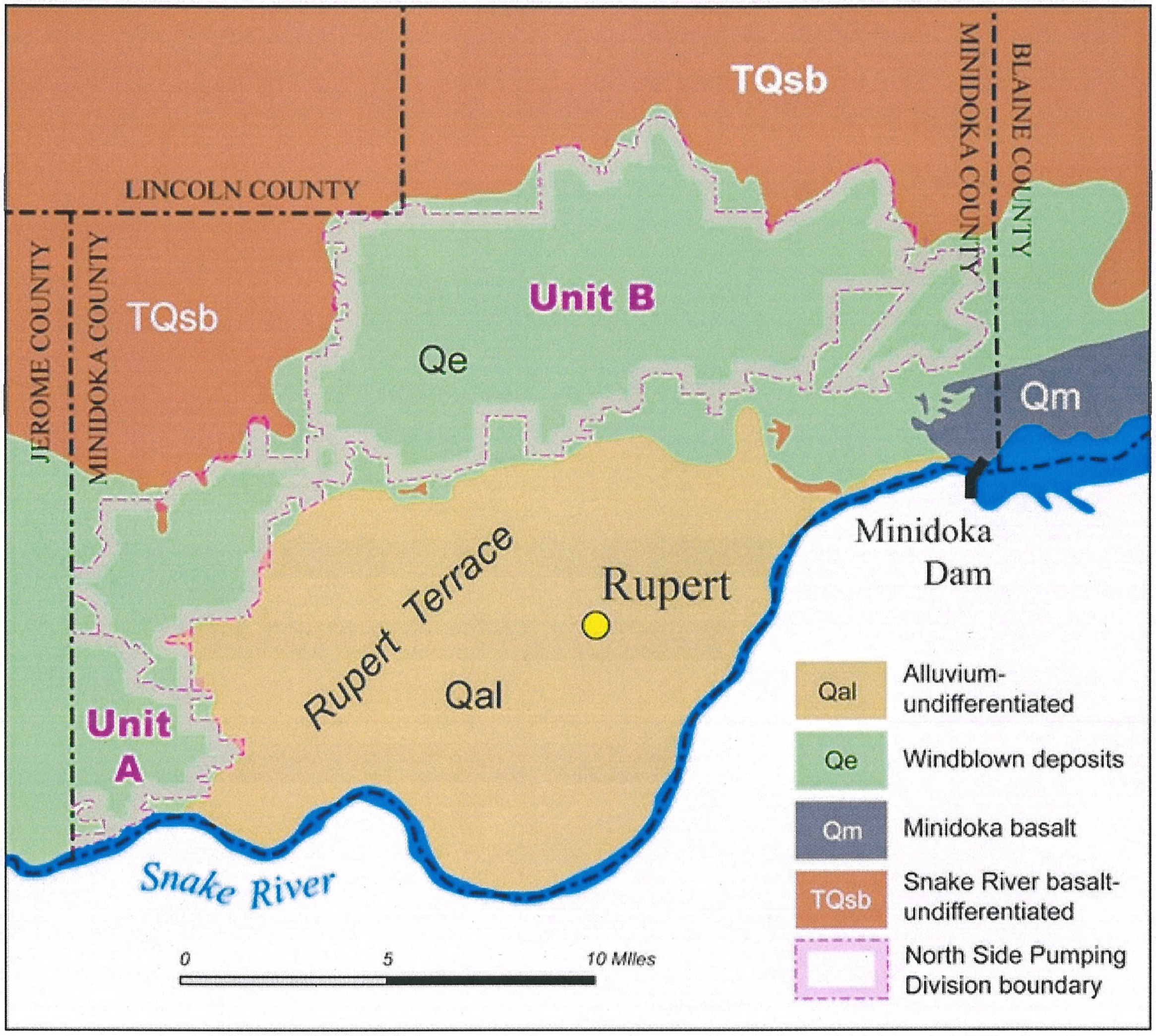

Figure 2. Geologic map of southern Minidoka County (from Crosthwaite and Scott, 1956).

A shallow perched aquifer is encountered on the Rupert Terrace at a depth of 15 to 50 feet, although because of its limited aerial extent and thickness it is not a significant source of groundwater. The perched aquifer is recharged mainly by infiltrating irrigation water from the Minidoka Irrigation District. Several drains located on the terrace collect irrigation waste water, and discharge it to the Snake River. Some of the waste water also recharges the underlying regional aquifer. Reclamation constructed three piezometer nests on the Rupert Terrace in 2001, in order to monitor groundwater levels in the perched zone and in the underlying regional aquifer.

The A and B Units of the A&B District are located on the lava bench, north and west of the escarpment which bounds the Rupert Terrace. Up to 50 feet of windblown silt and fine sand mantle the lava flow in this area and create a gently rolling terrain. A few rounded volcanic hills are located directly north of Unit-A and west of Unit-B, the largest being Kimama Butte.

Permeabilities in the upper 100 to 200 feet of the Snake River Basalt formation are very high, as much as 48,000 ft/day. The sand and gravel deposits which overlie the Snake River basalts in southern Minidoka County are also permeable, and yield moderate amounts of groundwater, however the overlying clay and silt beds are very low in permeability (Garabedian, 1992 and Lindholm, 1996).

Groundwater Levels in the A&B Irrigation District Area

USGS Observation Well Data

Since the late 1940's numerous USGS observation wells have been used to monitor changes in regional groundwater levels in the area of the A&B Irrigation District (although the wells have varying periods of record). The locations of 60 observation wells that are now regularly monitored by the USGS are shown in Figure 3.

Hydrographs for the five observation wells having the longest and most continuous periods of record are shown in Figure 4. Although groundwater levels in these wells fluctuate from year to year, the overall trend is downward. Since the mid 1950's the well levels have declined 0.51 feet per year, on average. During the past three years the average decline has been 1.89 feet per year.

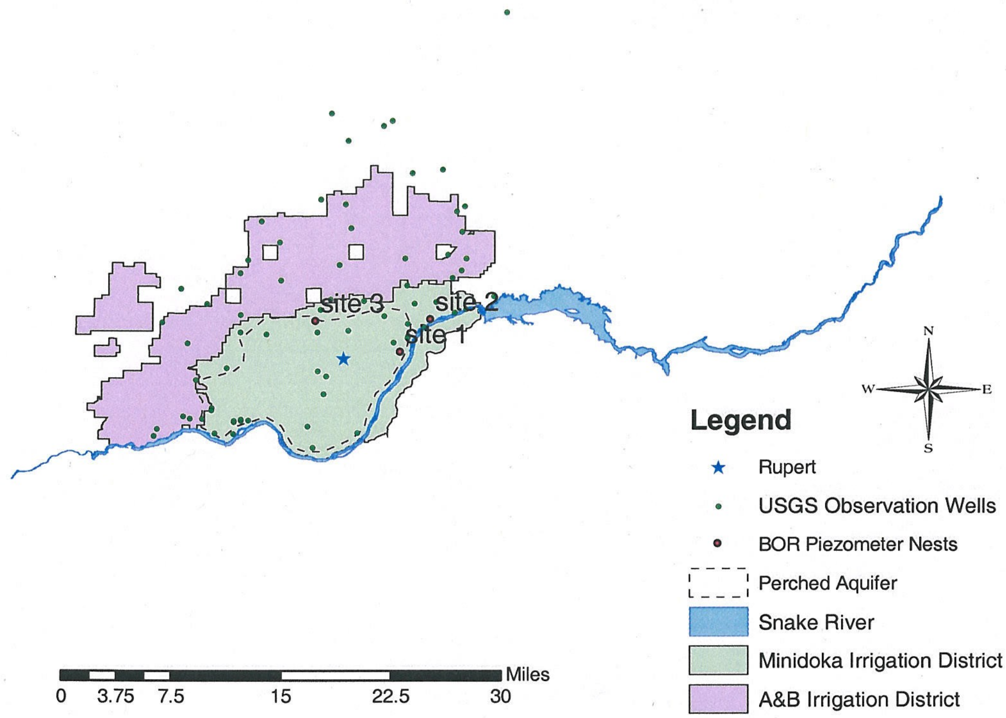

Figure 3. USGS and BOR well locations and approximate boundary of perched aquifer conditions in southern Minidoka County(based on Crosthwaite and Scott, 1956).

A&B Irrigation District Low Pumping Depth

Irrigation wells within the A&B District have also registered groundwater level declines. Figure 5 shows the average annual low pumping depth in 107 A&B District irrigation wells, between 1960 and 2002. Low pumping depth is a measure of the maximum drawdown that occurs in a well while it is being pumped. Since 1960, the average low pumping depth in A&B irrigation wells has declined by 17 feet.

Reclamation Piezometer Nests

Reclamation constructed three piezometer nests on the Rupert Terrace, in 2001. The locations of these piezometer nests are shown in Figure 3. Piezometer nest 1 is located about five miles east of Minidoka Dam and about 0.6 miles from the Snake River and has two piezometer wells. The shallow piezometer is 37 feet deep and the deep piezometer is 119 feet deep. Piezometer nest 2 is located three miles east of Minidoka Dam and within

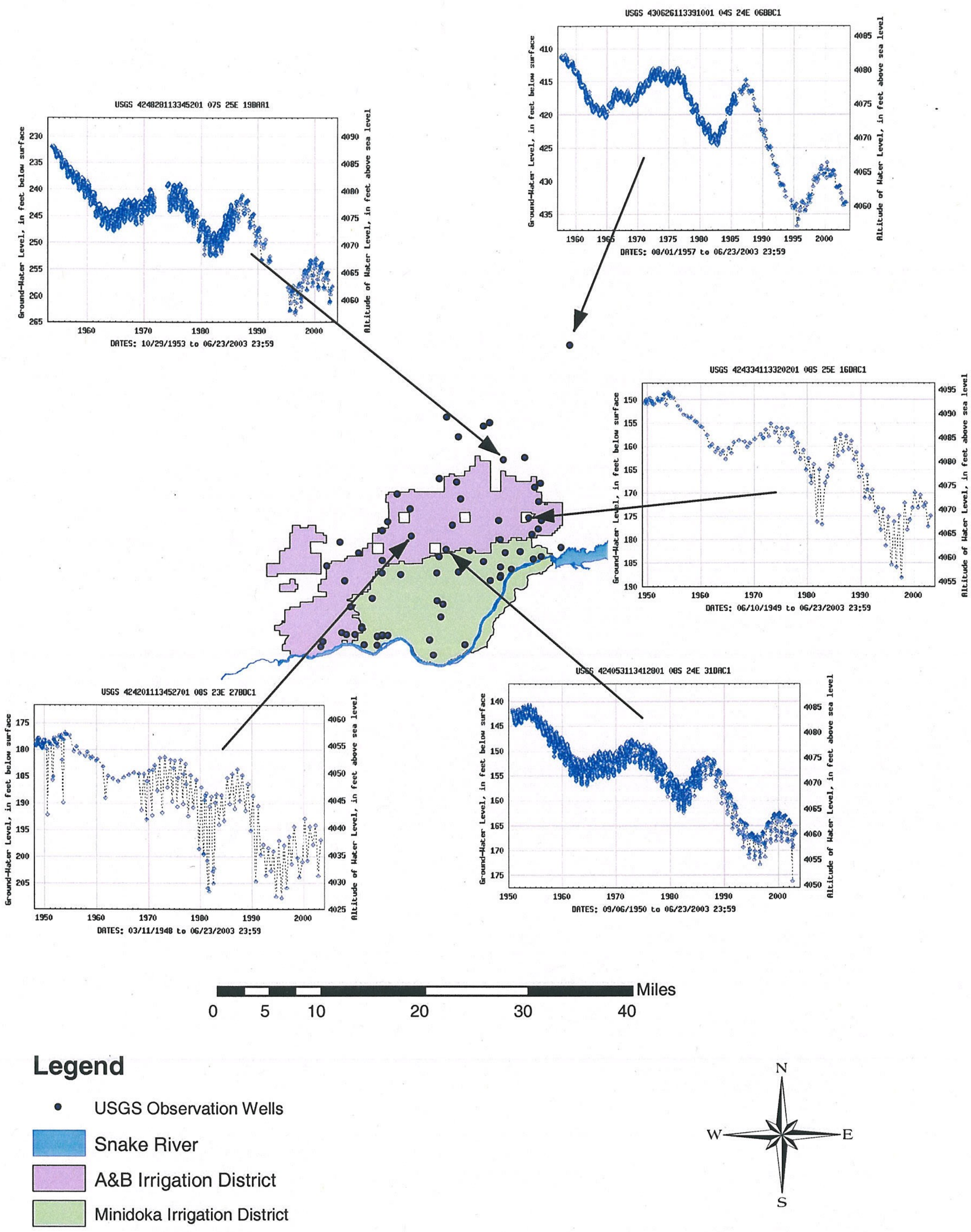

Figure 4. Groundwater elevation changes since the late 1940's in and around the A&B District.

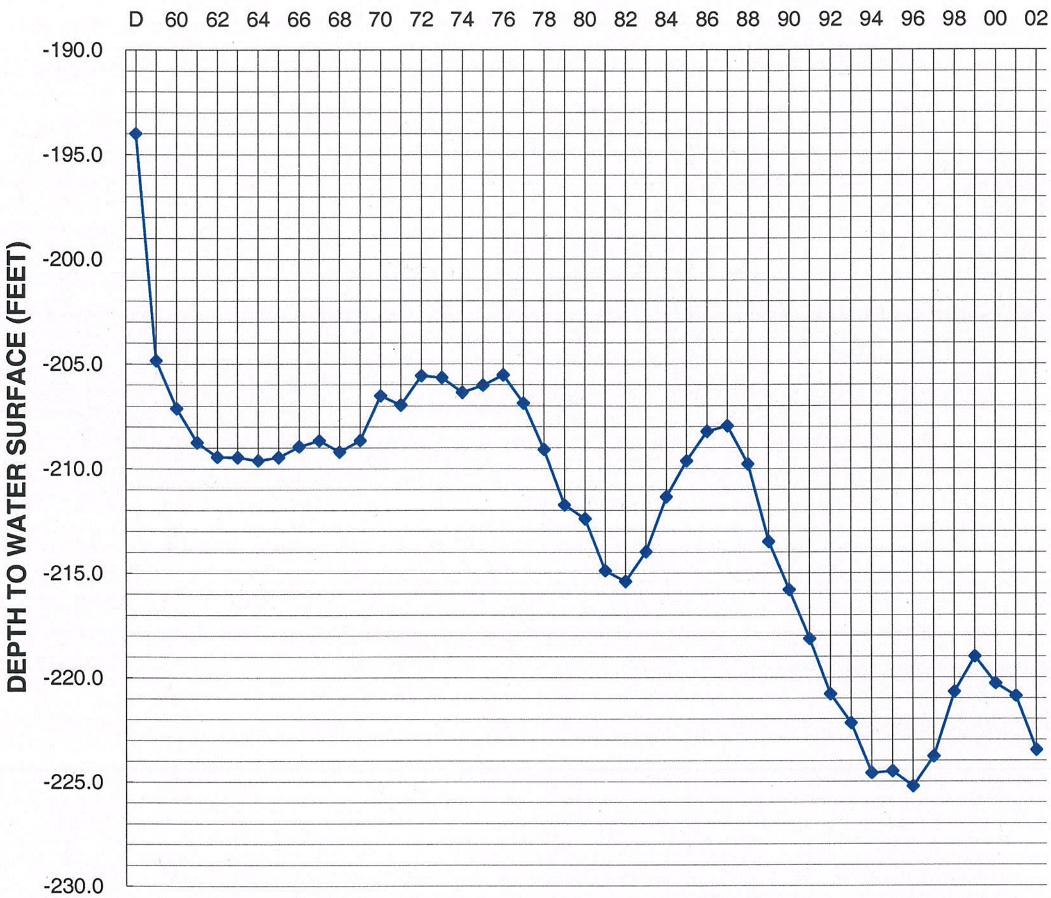

Figure 5. Average low pumping depth for 107 wells in A&B Irrigation District.

1,000 feet of the Snake River. It has two piezometer wells also. The shallow piezometer is 41 feet deep, and the deep piezometer is 134 feet deep. Piezometer nest 3 is the closest of the three to the A&B Irrigation District. It is located about 11 miles west of Minidoka Dam and about 6.5 miles north of the Snake River, a little over a mile south of the Unit-B. This piezometer nest has three wells. The shallow piezometer at this location is 44 feet deep. An intermediate piezometer is 95 feet deep, and the deep piezometer is 147 feet deep.

Lithologic logs based on drill cuttings (figure 6), indicate that the four shallow piezometers were completed in sand, silt, and clay sediments that are up to 135 feet thick. The three deep piezometers are completed in basalt.

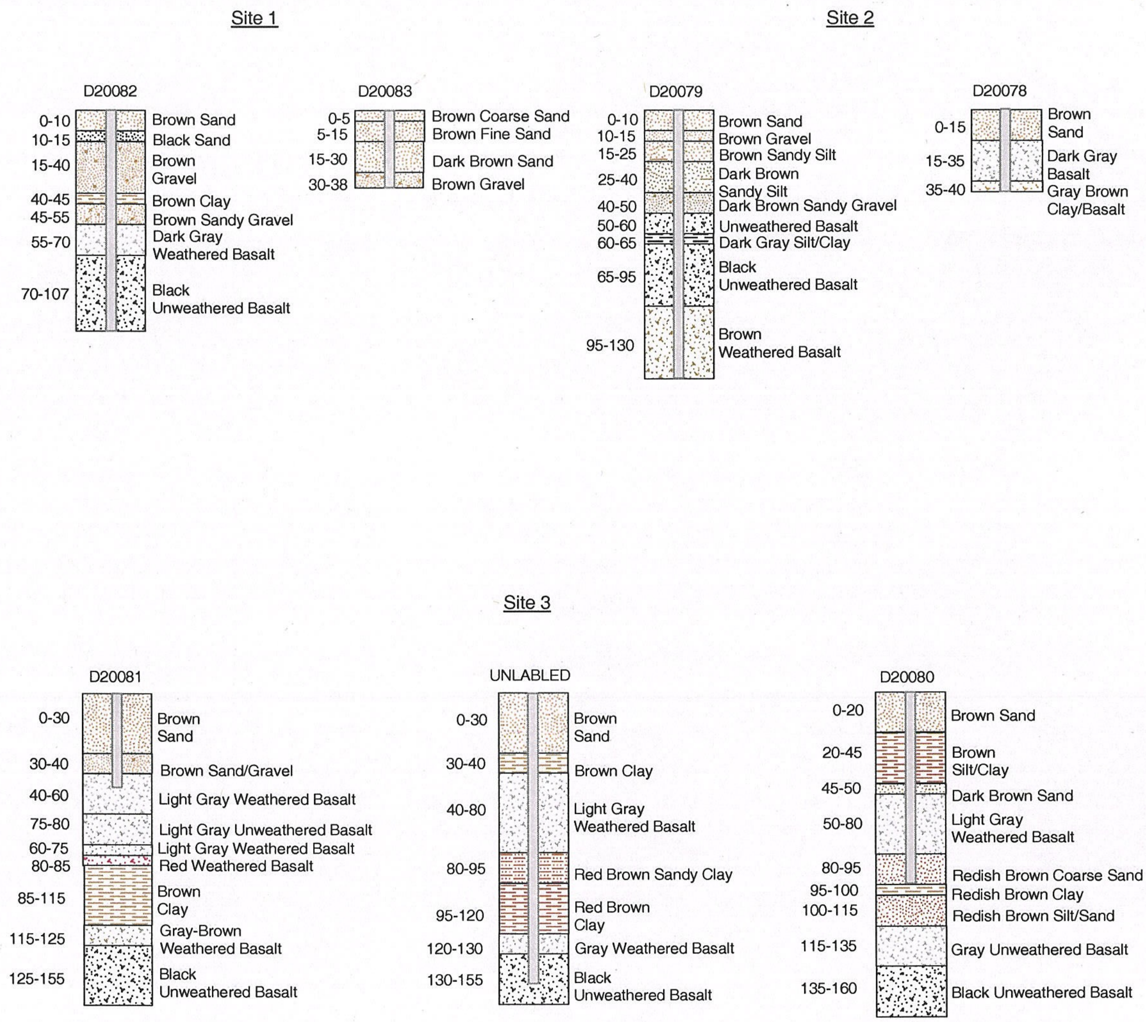

Figure 6. Lithologic logs from Reclamation piezometer wells. Depth is feet below ground surface.

Continuous water level recorders were installed in the piezometer wells in March of 2001, and the resulting hydrgraphs (Figures 7, and 8) confirm that perched aquifer conditions exist at piezometer sites 1 and 3. The shallow piezometer water level at these two locations is 25 to 50 feet higher then the deep piezometer water level. And, the deep piezometer water level is below the perching layer, which is a 5 to 10 foot thick, brown clay layer (probably a lakebed deposit) encountered at a depth of between 38 and 40 feet.

Note that the shallow piezometer at site 3 (Figure 8) is dry at the start of the irrigation season. As mentioned earlier, while the perched aquifer contains groundwater at a shallow depth, because of its dependence on infiltration from surface water irrigation, it is not a reliable source of groundwater.

Seasonal water level fluctuation in both shallow and deep piezometers at sites 1 and 2 (Figures 7 and 9) indicates that not only the shallow perched aquifer, but also the deep regional aquifer, responds to infiltration from surface water irrigation. At site 3 (Figure 8), which is closest to Unit-B, the regional aquifer responds mainly to groundwater pumping during the irrigation season.

The well hydrograph from site 2 (Figure 9) does not indicate the presence of perched aquifer conditions. This may be due to the absence of the perching layer at this location, or simply the close proximity of this piezometer nest to the Snake River.

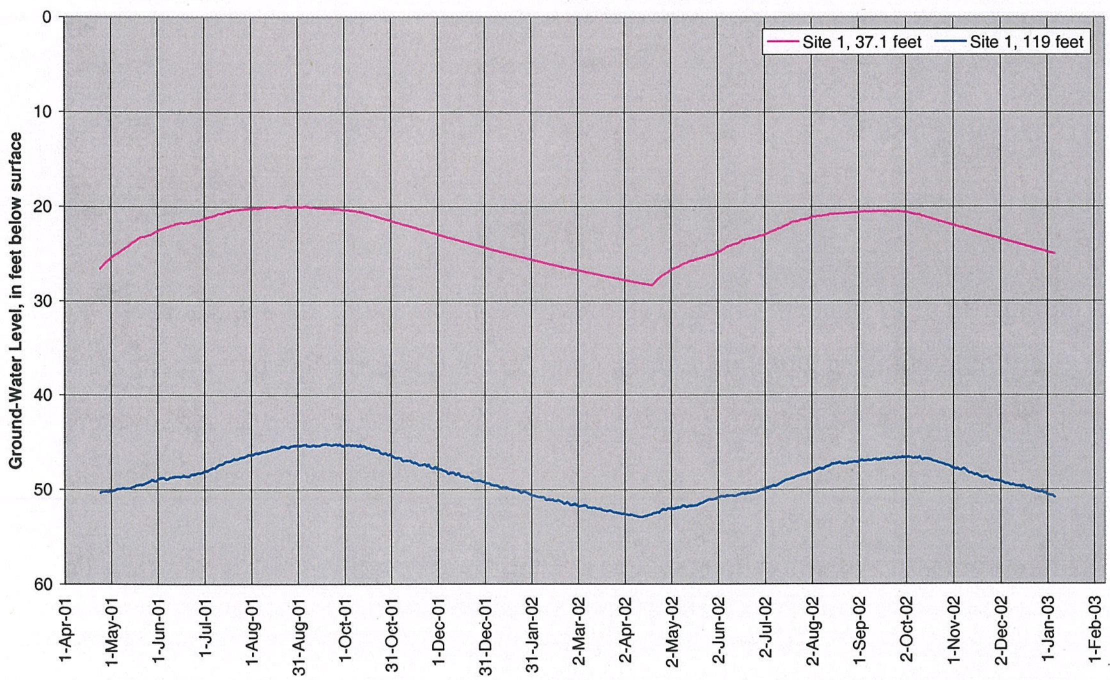

Figure 7. Water table elevations in piezometers at site 1.

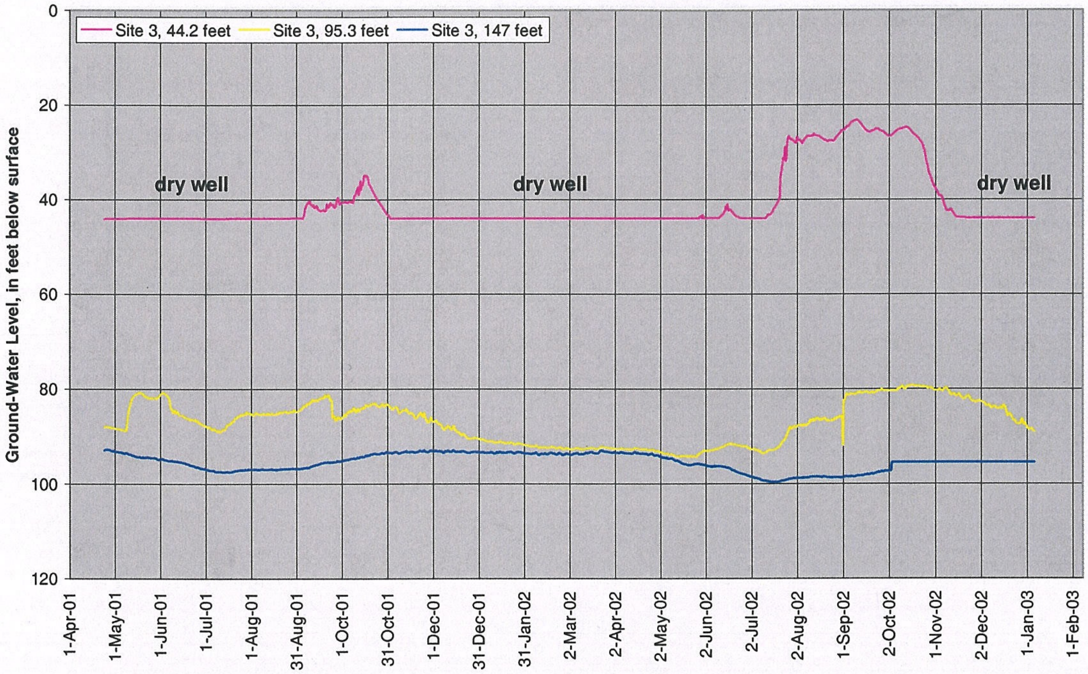

Figure 8. Water table elevations in piezometers at site 3.

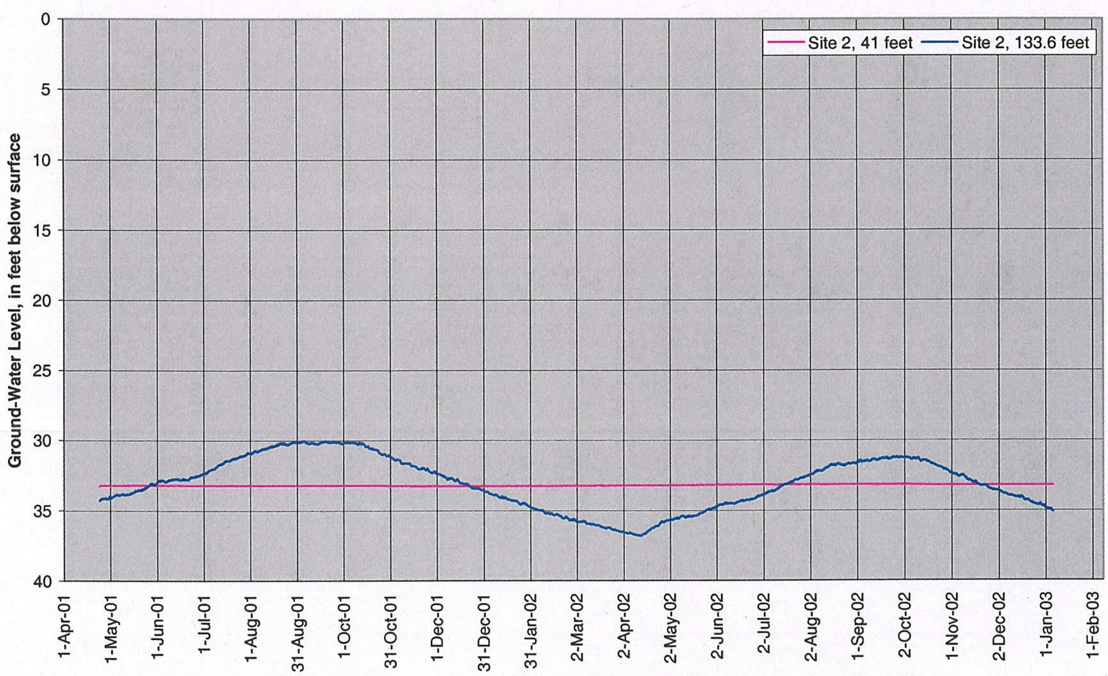

Figure 9. Water table elevations in piezometers at site 2.

The A&B Area Groundwater Model

The impact of proposed new groundwater pumping on groundwater levels beneath the A&B Irrigation District was estimated using the A&B area groundwater model. Model inputs, including net aquifer recharge and discharge on A&B District lands are based on records of diversion and groundwater pumping. Other model inputs, such as aquifer permeability, and net aquifer recharge and discharge on lands outside the District, are based on studies conducted by IWRRI as part of the ESPA model enhancement. Model calibration targets, which include 2002 groundwater levels and Snake River gains and losses, are based on USGS observation well data, and a recently completed Snake River seepage study.

<u>Net Aquifer Recharge and Discharge</u>

Net aquifer recharge or discharge expressions were developed by IWRRI for the Eastern Snake Plain groundwater model enhancement project. Positive numbers denote net aquifer recharge and negative numbers denote net aquifer discharge.

For surface water irrigated lands:

Net Recharge/Discharge (surface) = Diversion + Precipitation – Canal Seepage – Return Flows – (ET*Adjustment Factor)

For groundwater irrigated lands:

Net Recharge/Discharge (ground) = Precipitation – (ET*Adjustment Factor)

In 2000, ET in the Eastern Snake River Plain was computed and mapped using the Surface Energy Balance for Land (SEBAL). SEBAL is an image processing model that uses Landsat TM7 data which provides instantaneous ET at a resolution of 30 meters. The instantaneous SEBAL ET was extended to the surrounding 24 hour period using hourly lysimeter data and daily reference ET. Seasonal ET is estimated by expanding the 24 hour ET proportionally to a reference ET derived from meteorological measurements at local weather stations.

Figures 10 is a colorized raster image showing total ET between April 15 and Oct 15, 2000. lands in the A&B area in July 2001 and March 2002, respectively (Contor, 2003). For modeling purposes, figure 10 is considered representative of irrigation season net aquifer recharge and discharge conditions, and figure 11 is considered representative of non-irrigation season conditions.

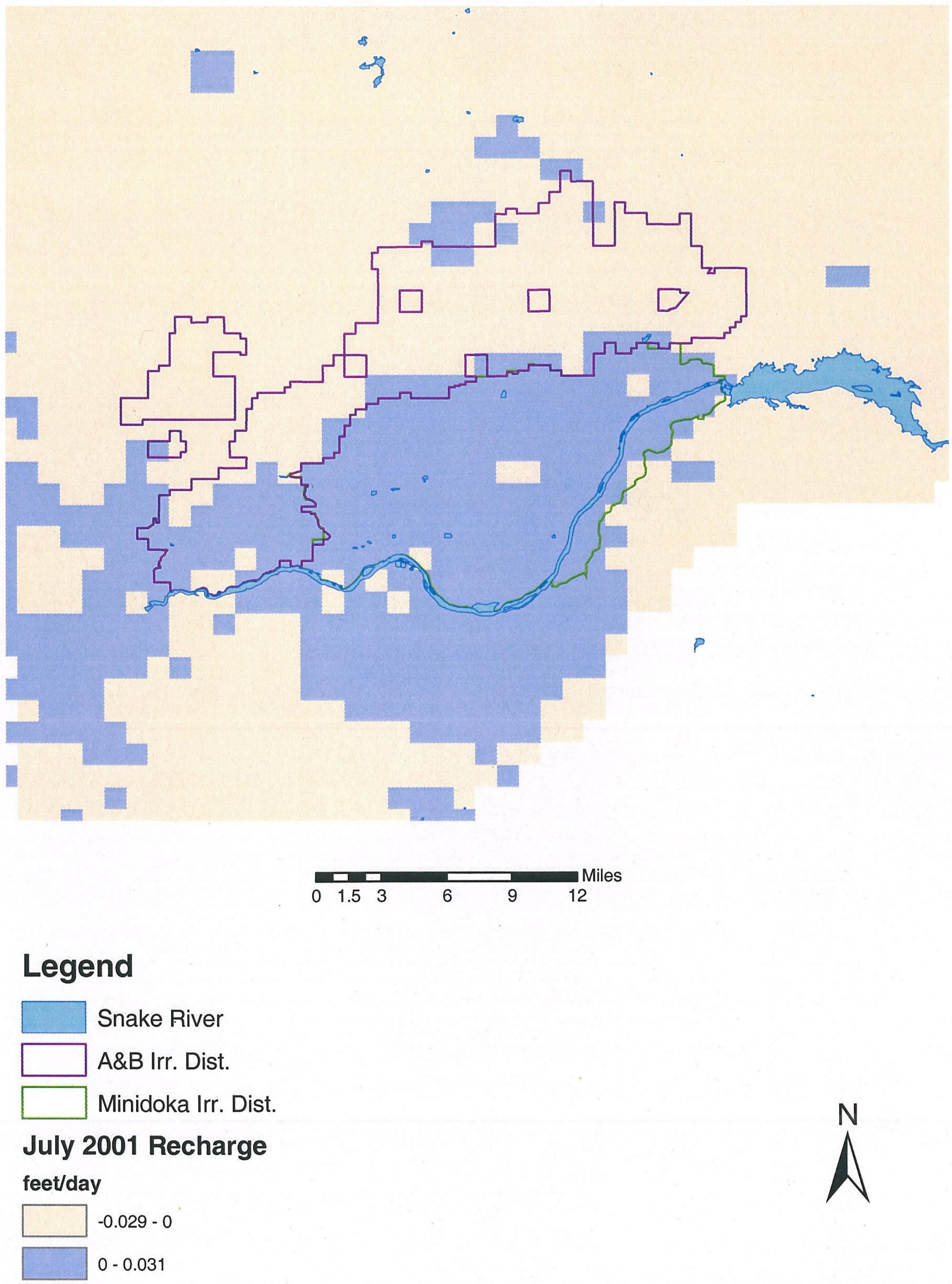

Figure 10. Spatial distribution of net aquifer recharge on irrigated lands in Central Idaho during the irrigation season months.

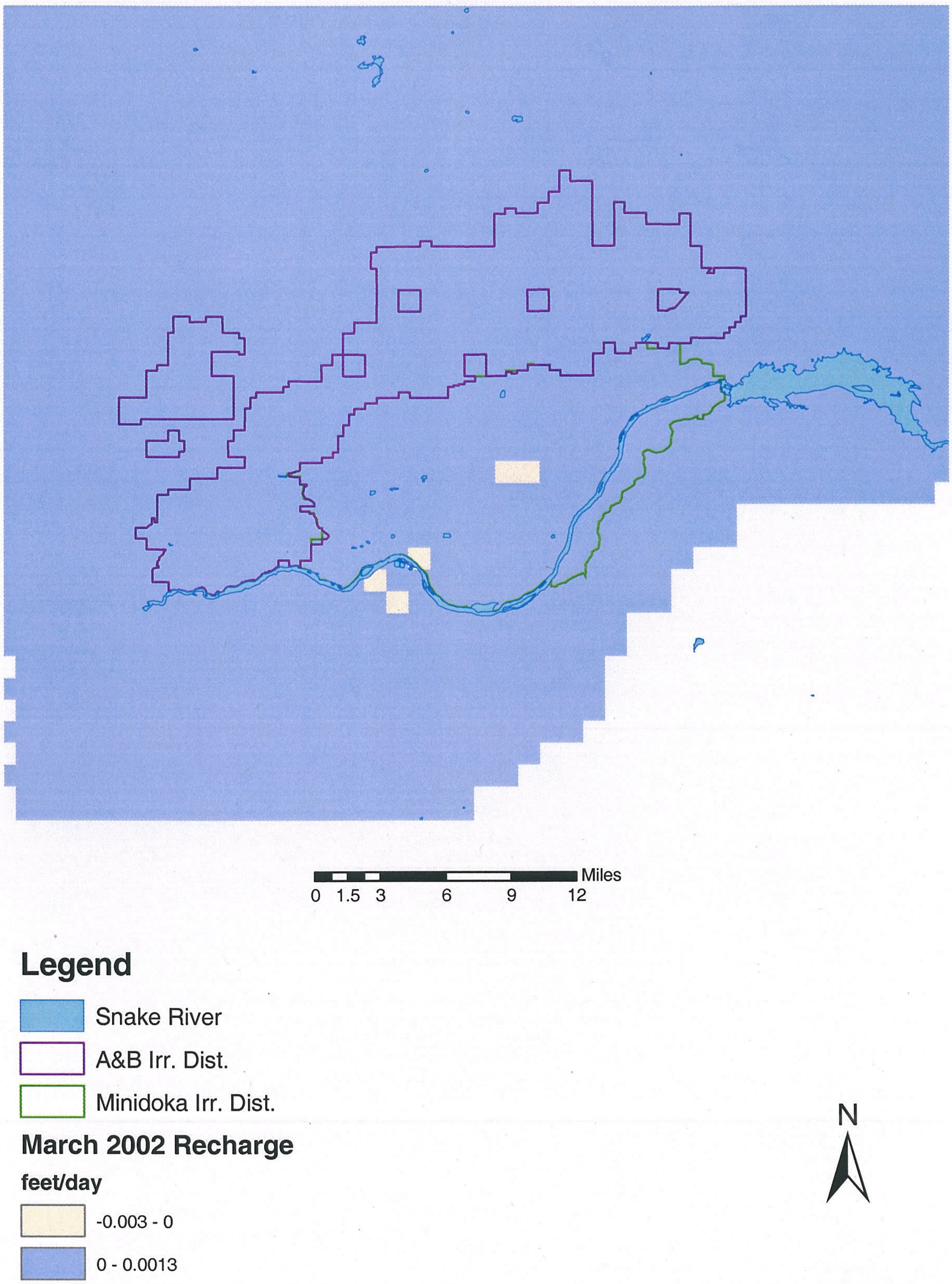

Figure 11. Spatial distribution of net aquifer recharge on irrigated lands in Central Idaho during the non-irrigation season months.

Figure 10 shows net aquifer recharge of up to 0.031 feet/day occurring on surface water irrigated lands, and net aquifer discharge of up to 0.029 feet/day occurring on groundwater irrigated lands. Net recharge on surface water lands is due to canal seepage and on-farm infiltration, net discharge on groundwater lands is due to pumping. Figure 11 shows net aquifer recharge of up to 0.0013 feet/day occurring over nearly all of southern Minidoka County. Aquifer recharge at this time of year is due to higher precipitation and a lower evapotranspiration rate.

Groundwater Elevations in 2002

Groundwater elevations in the regional aquifer, in southern Minidoka County, during the spring of 2002, (Figure 12) were contoured using data from 60 USGS observation wells and three Reclamation piezometer nests. Shallow piezometer wells completed in the perched aquifer were excluded from the data set used to generate this map. Control elevations along the boundaries of the contour map are based on data from Garabedian (1992).

The contour map indicates that some of the highest groundwater elevations in the area (4140-4080 feet msl) are along the Snake River, beneath the Minidoka Irrigation District. Groundwater elevations are lower (4080-4020 feet msl) beneath Unit-B of the A&B District, and beneath the private groundwater lands just to the north of Unit-B. Some of the lowest elevations in the area (4020-3840 feet msl) are found beneath Unit-A.

Arrows were superimposed on the elevation contour map to show the general direction of groundwater flow in the area. South of Unit-B in the Minidoka Irrigation District, the direction of groundwater flow is to the north, the flow gradient gradually bends around to the west as the groundwater moves beneath Unit-B. Groundwater flow beneath Unit-A is, for the most part, directly west. The dense concentration of contour lines along the eastern boundary of Unit-A indicates a steep hydraulic gradient in this area. The steep gradient follows the escarpment which marks the western boundary of the Rupert Terrace, and is attributed to a localized low permeability zone in this area that impedes the east to west flow of groundwater.

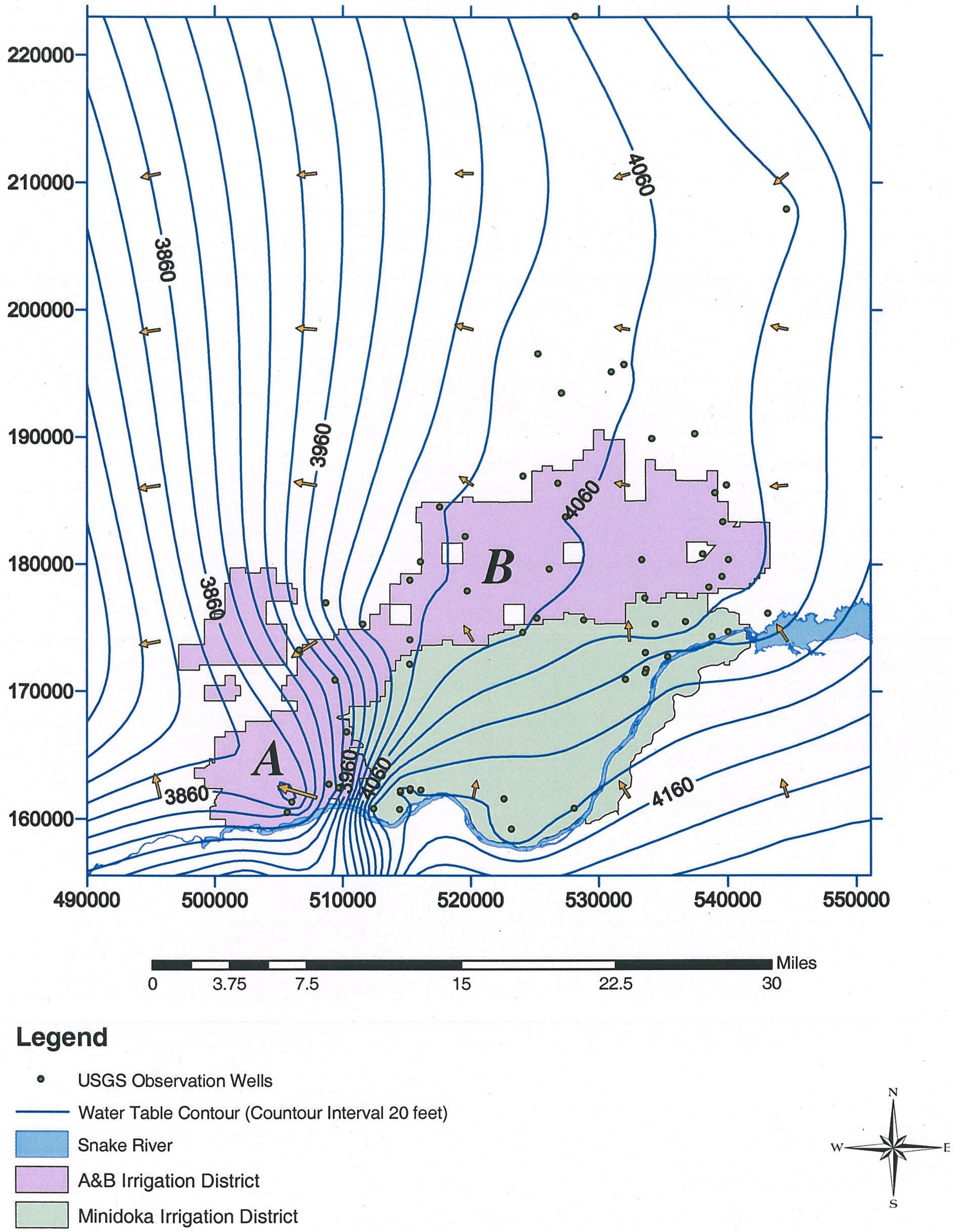

Figure 12. Contour plot of groundwater elevations in the ESPA, based on USGS and Reclamation observation well data from spring of 2002.

Snake River Gains/Losses

Estimates of Snake River gains and losses to groundwater in the reach between Minidoka Dam and Milner Dam were estimated using a recently completed Snake River seepage study conducted by USGS and Idaho Power Co. (Hortness and Vidmar, 2003). This study was also part of the Eastern Snake Plain groundwater model enhancement project.

As part of the seepage study, an Acoustic Doppler Current Profiler (ADCP) was used to measure Snake River discharge at various locations. Measurements were made on five occasions, March 2001, November 2001, March 2002, July 2002, and November 2002. The ADCP measurements, combined with river gage data, canal diversion data, and drain return data, were then used to estimate river gains and losses to groundwater.
For the seepage study, the river reach between Minidoka Dam and Milner Dam was divided into three sub-reaches designated L1-L2, L2-L3, and L3-L4 (Figure 13). The groundwater gains and losses for each of these three sub-reaches, and for the entire Minidoka Dam to Milner Dam river reach, are presented in Table 1. Positive numbers in this table denote river gains (groundwater losses) and negative numbers denote river losses (groundwater gains).

The data in Table 1 is also split into what are considered irrigation season and non-irrigation season data. The March 2001 and March 2002 data is considered representative of non-irrigation season river gain and loss conditions, while the November 2001, July 2002, and November 2002 data is considered more representative of irrigation season conditions. The November data is included in the irrigation season, because the effect of irrigation activity on river/groundwater interaction could be expected to lag behind the irrigation season by a month or two.

As Table 1 shows, the Minidoka Dam to Milner Dam reach of the river is, on average, a losing reach during the irrigation season and a gaining reach during the non-irrigation season. The average loss during the irrigation season is 102 cfs, and the average gain during the non-irrigation season is 39 cfs. This is a somewhat surprising result, since the river reach between Minidoka Dam and Milner Dam has in the past been considered,

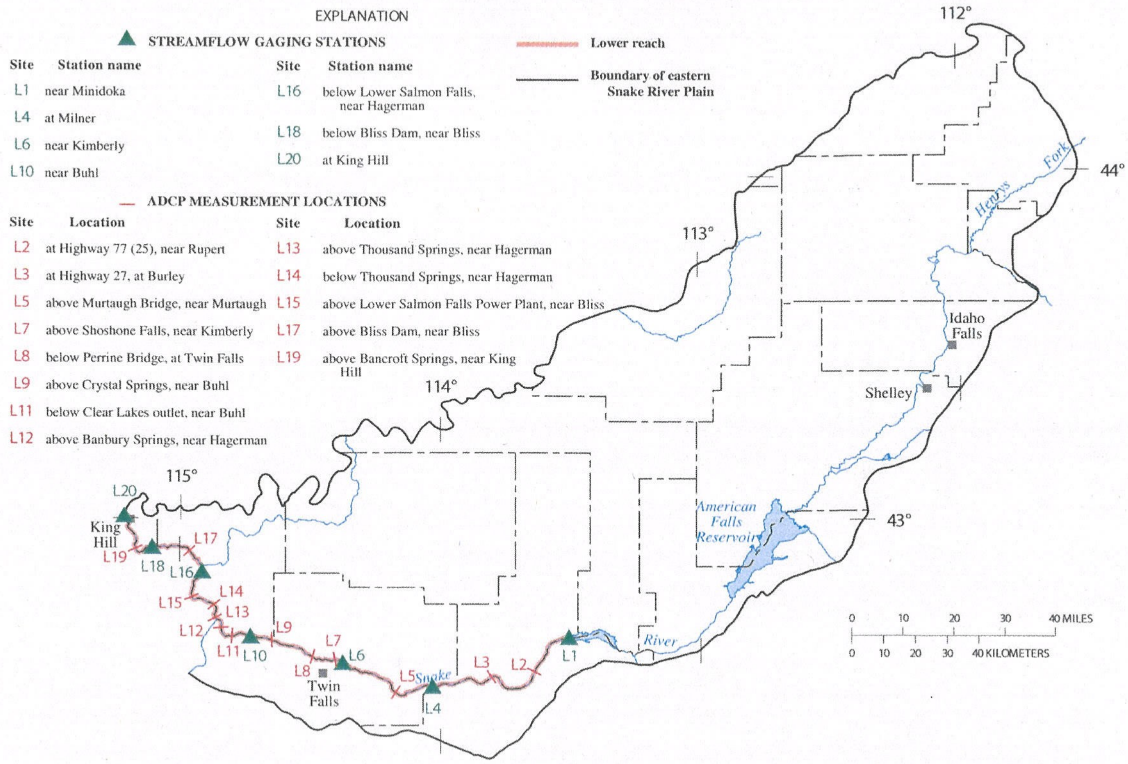

Figure 13. Location of stream flow gaging stations and ADCP flow measurement sites (Hortness and Vidmar, 2003).

Table 1. River reach gains (+) and losses (-) to groundwater between Minidoka Dam and Milner Dam (Hortness and Vidmar, 2003).

	L1-L2 (cfs)	L2-L3 (cfs)	L3-L4 (cfs)	Minidoka Dam – Milner Dam (cfs)
March 2001	--	--	44	44
November 2001	4	31	5	40
March 2002	0	--	-5	-5
July 2002	-354	191	54	-109
November 2002	-89	-57	-92	-238
Irrigation season average	-146	55	-11	-102
Non-Irrigation season average	0	0	39	39

-- indicates no data

overall, to be gaining groundwater (Johnson and Cosgrove, 2003). The seepage study results are, however, consistent with recent USGS observation well data, which show a general decline in groundwater elevations on both sides of the river between Minidoka Dam and Milner Dam, during the last three or four years.

The Analytic Element Modeling Method

The modeling methodology used to develop the A&B area model is referred to as analytic elements. The analytic element method (AEM) has its origins at the University of Delft (De Josselin De Jong, 1969), (Verruijt, 1982). But it was primarily developed at the University of Minnesota in the 1980's (Strack, 1989). Analytic element models have become a standard with many consulting firms, universities, and government agencies because they are able to solve steady-state groundwater flow problems more efficiently than numerical models such as Modflow (McDonald and Harbaugh, 1988).

In Idaho, analytic element models have been used to address a wide variety of groundwater flow problems. An AEM model was used by the Washington Group International to delineate wellhead protections zones for communities in Minidoka and Jerome Counties (Washington Group International, 2001). An AEM model was also used by IDEQ to delineate wellhead protection zones for 549 municipal wells in the Treasure Valley (IDEQ, 2001). More recently, an AEM model was used by Reclamation to assess the impact of proposed groundwater pumping on Reclamation facilities in the Dry Lake area of Canyon County, Idaho (Schmidt, 2003).

The analytic element modeling method is based on the superposition of analytic functions (elements), representing a wide variety of surface and subsurface hydrologic features that influence groundwater flow. Each analytic element satisfies the governing linear differential equation for steady-state, two-dimensional groundwater flow (the Poisson equation). Point source-sink elements are used to represent individual wells. Strings of line source-sink elements are used to represent rivers, canals and drains. Doublet elements bound areas with differing aquifer permeability. Area recharge/discharge elements enclose areas with differing net aquifer recharge and discharge rates. A boundary condition (either a fixed head or a fixed flow rate) is required for each analytic element. Analytic elements with a fixed head are referred to as head-specified elements, elements with a fixed flow are referred to as flow-specified elements.

Individual analytic element solutions to the governing linear differential equation can be superimposed on one another, in order to generate a comprehensive solution for a groundwater flow problem that involves many different analytic element boundaries.

AEM Software

Analytic element modeling software commonly used by consultants, universities and government agencies include WHAEM (USEPA, 1987) and Gflow (Haitjema, 1995). Both programs have been thoroughly tested. Gflow, which was developed at Indiana University by the same team that developed the WHAEM for the USEPA, was selected for this application. Although Gflow is primarily a steady-state groundwater flow model, it is capable of simulating the time-dependent effects of well pumping.

Analytic Elements in the A&B Area Model

The A&B area groundwater model was developed for the specific purpose of estimating the effects of increased groundwater pumping north of the District, on groundwater levels beneath the District. As such, the model includes only those hydrologic features that are important locally. The local hydrologic features that are considered important include: Lake Walcott, the Snake River between Minidoka Dam and Milner Dam, on-farm infiltration on surface water irrigated lands of the Minidoka District and Unit-A of the A&B District, groundwater pumping (consumptive use) on groundwater irrigated lands of Unit-B and on private groundwater lands located just north of Unit-B, and major aquifer heterogeneities located near the A&B District. Since the shallow perched aquifer beneath the Rupert Terrace has no direct influence on regional groundwater flow conditions in the A&B area, it is not explicitly represented in the model.

Figure 14 shows the distribution of analytic elements that make up the A&B area model. Line source/sink elements are used to represent Lake Walcott, and a portion of the Snake

River. Area recharge and discharge elements represent the spatial distribution of on-farm infiltration on surface water irrigated lands, and the consumptive use of groundwater on groundwater irrigated lands. Doublet elements represent variations in permeability in the regional aquifer. Lastly, the model contains 42 point-sink elements, which are used to represent 42 proposed wells located north of the District.

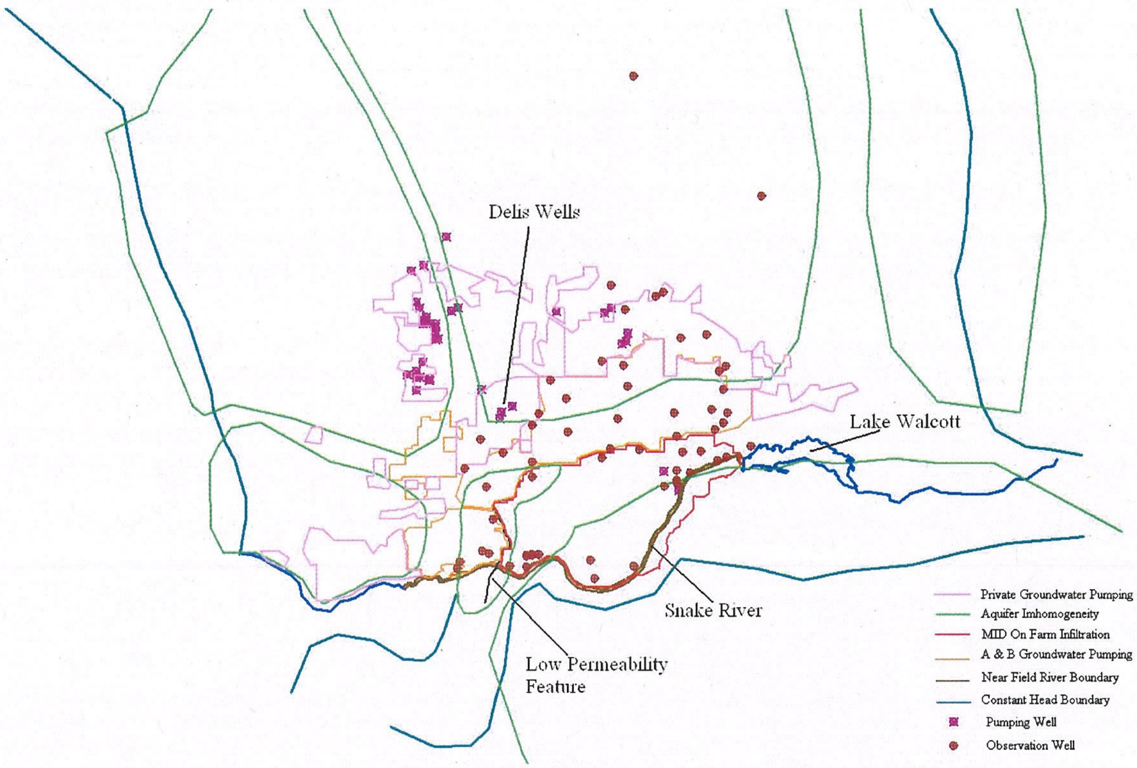

Figure 14. Analytic elements in the A&B Area model.

Both flow-specified and head-specified analytic elements are used in the A&B area model. The proposed wells are all flow-specified. Also the area recharge and discharge elements that represent existing irrigation activity in the Minidoka District, the A&B District, and private groundwater lands are all flow specified.

Head-specified elements are used to represent Lake Walcott and the Snake River. The head-specified river and lake elements require input of a river or lake elevation, and a river bed or lake bed conductance. River and lake elevations were obtained from Hydromet records, and bed conductances were estimated through model calibration.

Other analytic elements, termed far-field constant head boundaries, are also part of the model. These elements represent aquifer head conditions on the fringes of the model area of interest, 20 to 30 miles from the A&B District. The far-field boundaries are based on previous ESPA model results (Johnson, Brockway, et al, 1985).

A&B Area Model Calibration

The calibration parameters for the A&B area model are aquifer transmissivity (aquifer permeability multiplied by aquifer thickness), and river and lake bed conductances. Targets for calibration are groundwater elevations in up to 60 USGS observation wells, and groundwater gains and losses in the Snake River between Minidoka Dam and Milner Dam. All calibration is with respect to aquifer conditions during the years 2001 and 2002. Calibration was conducted using both irrigation season and non-irrigation season conditions of aquifer recharge and discharge. The calibration targets are representative of irrigation season and non-irrigation season groundwater levels, and river gain and loss conditions.

Regional aquifer thickness in the A&B area model is assumed to be 1,500 feet. Aquifer transmissivities (which are the same in both models) range from 7.5×10^3 ft^2/day to 7.5×10^6 ft^2/day, although most of the A&B area is modeled with a transmissivity of 6.0 $\times 10^5$ ft^2/day. This range of transmissivities is consistent with results of recent Eastern Snake Plain model calibration studies (Wylie, 2003).

Snake River bed conductances between Minidoka Dam and Milner Dam vary. They range from 1×10^{-4} to essentially an infinite conductance. The LakeWalcott bed conductance is 1×10^{-3}. (Bed conductance takes bed thickness into account, thus the units for conductance are feet per day per foot of bed thickness, or 1/days).

<u>The Irrigation Season Model</u>

Records indicate that the A&B District pumped 196,367 acre-feet of groundwater to irrigate lands in Unit-B in 2001, and 182,635 acre-feet in 2002, on average about 3.0

acre-feet per acre. The District also diverted 41,986 acre-feet from the Snake River to Unit-A in 2002, on average about 3.1 acre-feet per acre. Therefore, in the irrigation season model, net discharge from the regional aquifer beneath Unit-B is assumed to be 3.0 acre-feet per acre. Net recharge of the regional aquifer beneath Unit-A is assumed to be 0.2 acre-feet per acre.

Stearns (1938) estimated that subsurface losses from the Minidoka Irrigation District were about 233,000 acre-feet per year (about 3.1 acre feet per acre). The net recharge rate input to the irrigation season model is about half of this (1.8 acre-feet per acre). The more conservative estimate takes into account increased irrigation efficiency since 1938, as well as the moderating influence of the shallow perched aquifer, which overlies the regional aquifer beneath much of the Minidoka District.

Net aquifer discharge on private groundwater irrigated lands north of the A&B District is assumed to be the same as that of Unit-B, i.e. 3.0 acre-feet per acre during the irrigation season.

Figure 15 shows the calibration results for the irrigation season model. The irrigation season model was calibrated using 60 USGS observation wells. Water level measurements made in these wells at the end of the irrigation season in 2001 range from 3,832 feet msl to 4,152 feet msl. The average difference between observed and modeled head in the calibrated irrigation season model is 4.7 feet, and the root mean square difference is 12.3 feet. The model deviation from observed head is 4.3 percent of the total range in head.

Based on Table 1, the calibration target for Snake River loss (aquifer gain) between Minidoka Dam and Milner Dam in the irrigation season model is 102 cfs. In the calibrated model, the Snake River loss between Minidoka Dam and Milner Dam is 98 cfs, which is within 4 percent of the target.

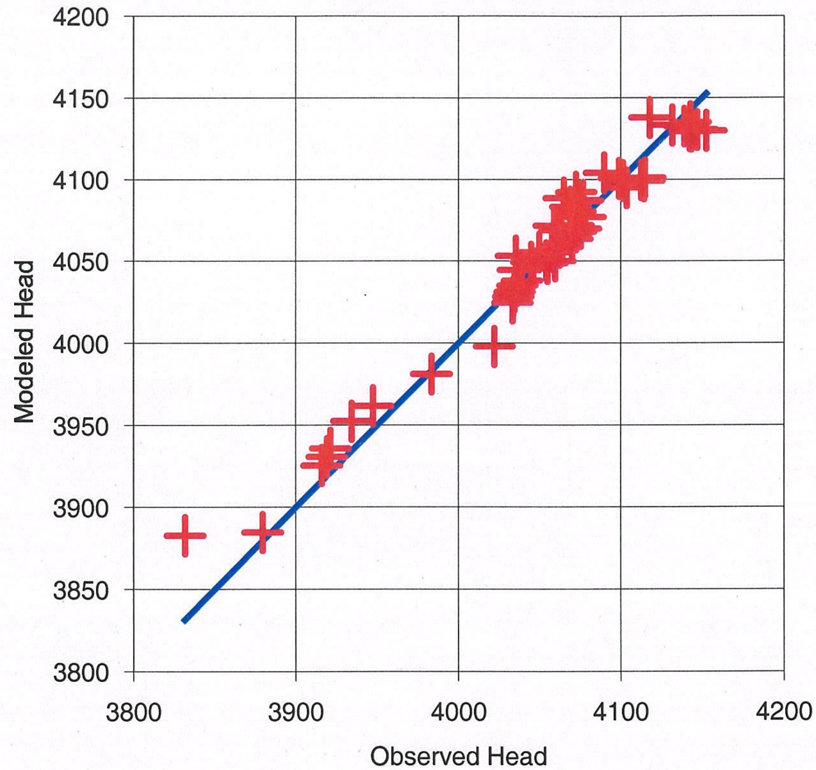

Figure 15. Model calibration with respect to observation well heads during the irrigation season.

The Non-Irrigation Season Model

All of the irrigation season recharge and discharge conditions are removed from the non-irrigation season model. In addition, the head specification for Lake Walcott is lowered by five feet, and the far-field constant head boundary south of the Snake River is raised by four feet. A net aquifer recharge, representing infiltration from precipitation, is imposed uniformly over the entire model area. Based on Figure 11, the net recharge rate from precipitation is assumed to be 0.23 acre-feet per acre.

Figure 16 shows calibration results for the non-irrigation season model which was also calibrated using 60 USGS observation wells. Water level measurements made in these wells just before the start of the irrigation season in 2002, range from 3,830 feet msl to 4,150 feet msl. The average difference between observed and simulated well head in the calibrated model is 2.6 feet, and the root mean square difference is 12.5 feet. The model deviation from observed head is 4 percent of the total range in head.

The calibration target for Snake River gain (aquifer loss) between Minidoka Dam and Milner Dam during the non-irrigation season is 39 cfs (Table 1). The modeled reach gain is 46 cfs, a deviation from the target of about 18 percent.

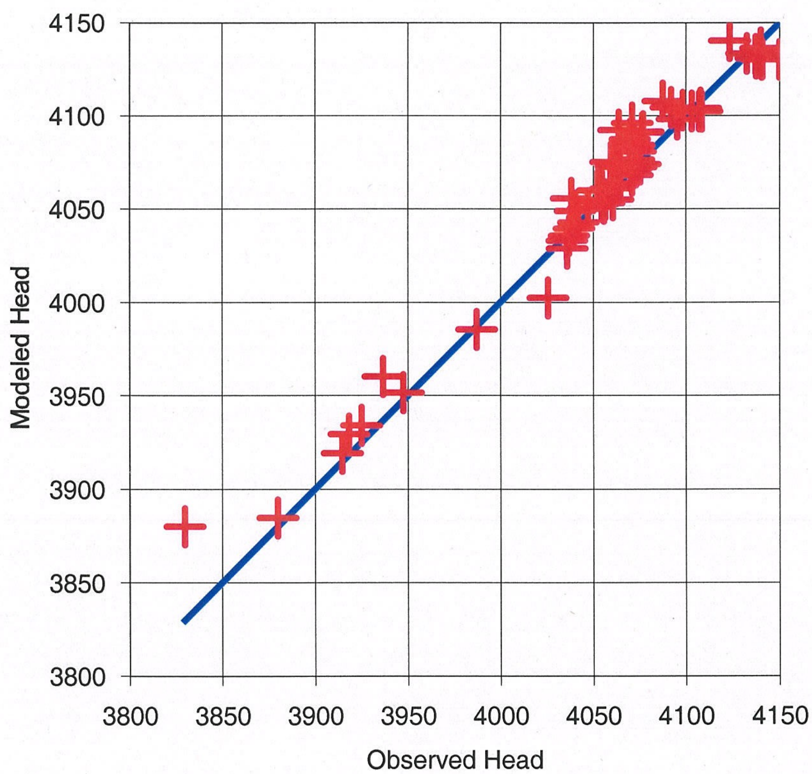

Figure 16. Model calibration with respect to observation well heads during the non-irrigation season.

A&B Area Model Results

Model results, in the form of irrigation season and non-irrigation season groundwater level contour maps, are presented in Figures 17 and 18. A comparison with Figure 12 reveals that these model results correspond closely to observed groundwater elevations in the A&B area. In particular, the steep hydraulic gradient that exists at the boundary between the Minidoka Irrigation District and Unit-A is reproduced in both irrigation season and non-irrigation season models. The presence in the model of a semi-permeable barrier feature at this location is essential for good calibration of the A&B area model.

While the groundwater contours appear to be about the same in both Figures 17 and 18, there are some important differences. The irrigation season water table is slightly higher on surface water irrigated lands and slightly lower on groundwater irrigated lands than the non-irrigation season water table. In Unit-B for instance, the water table elevations of the irrigation season model are about 2 feet lower than those of the non-irrigation season model. In the Minidoka Irrigation District, the water table elevations of the irrigation season model are 2 to 8 feet higher then those of the non-irrigation season model. This seasonal pattern of water table fluctuation is consistent with BOR piezometer data (refer to the deep piezometers in Figures 7 – 9) and USGS observation well data.

Estimating Aquifer Depletion Due to Proposed New Groundwater Pumping

The impact of proposed new pumping on groundwater levels in the A&B area is estimated by comparative analysis. The steady-state A&B area model is first run with the present irrigation season inputs, and then with the irrigation season inputs that include the proposed wells. The difference in groundwater elevations between the two runs is an indication of the maximum aquifer depletion (additional drawdown) that could be expected in the area of the A&B District as a result of the proposed new pumping.

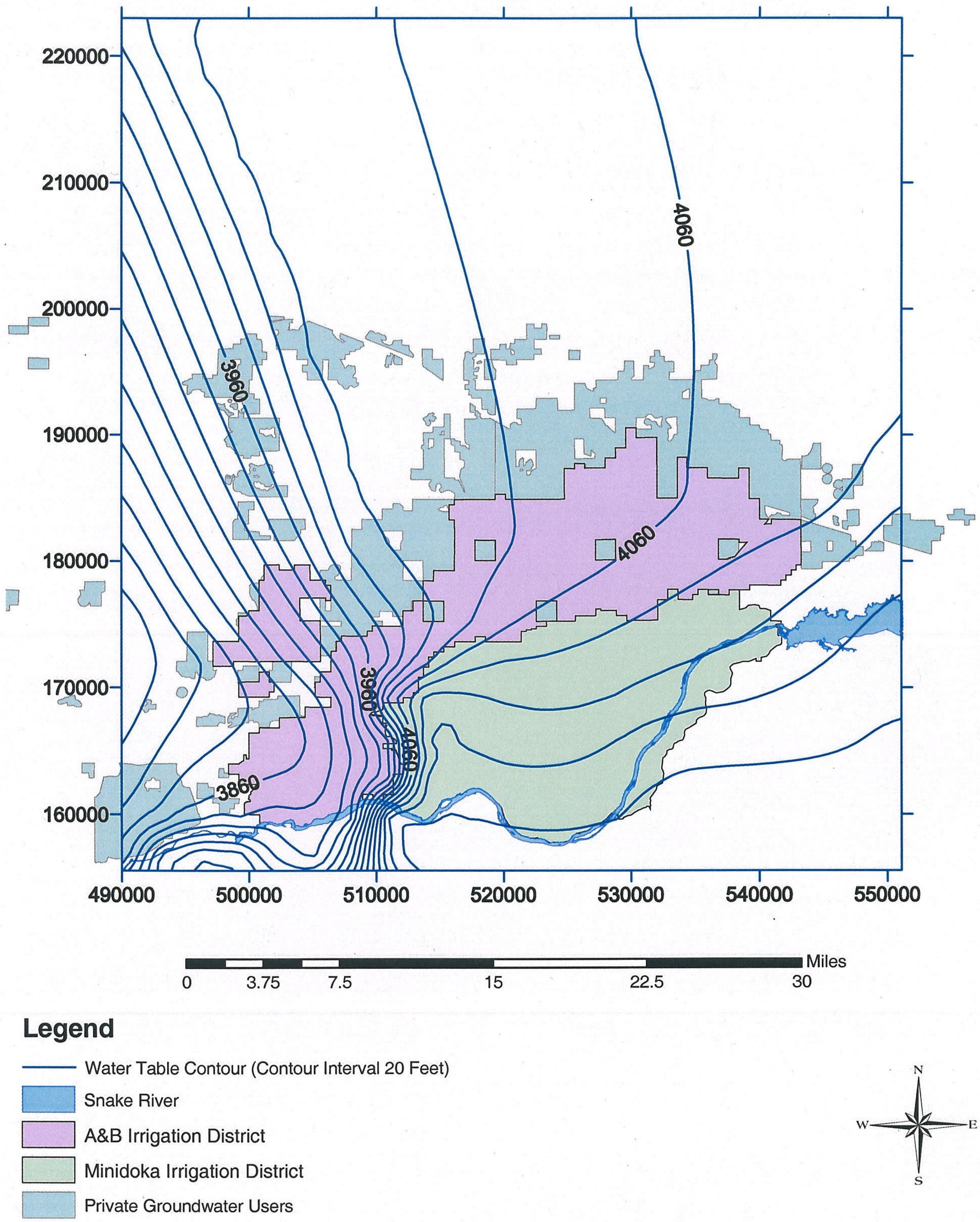

Figure 17. Modeled irrigation season groundwater elevations in the A&B Irrigation District area.

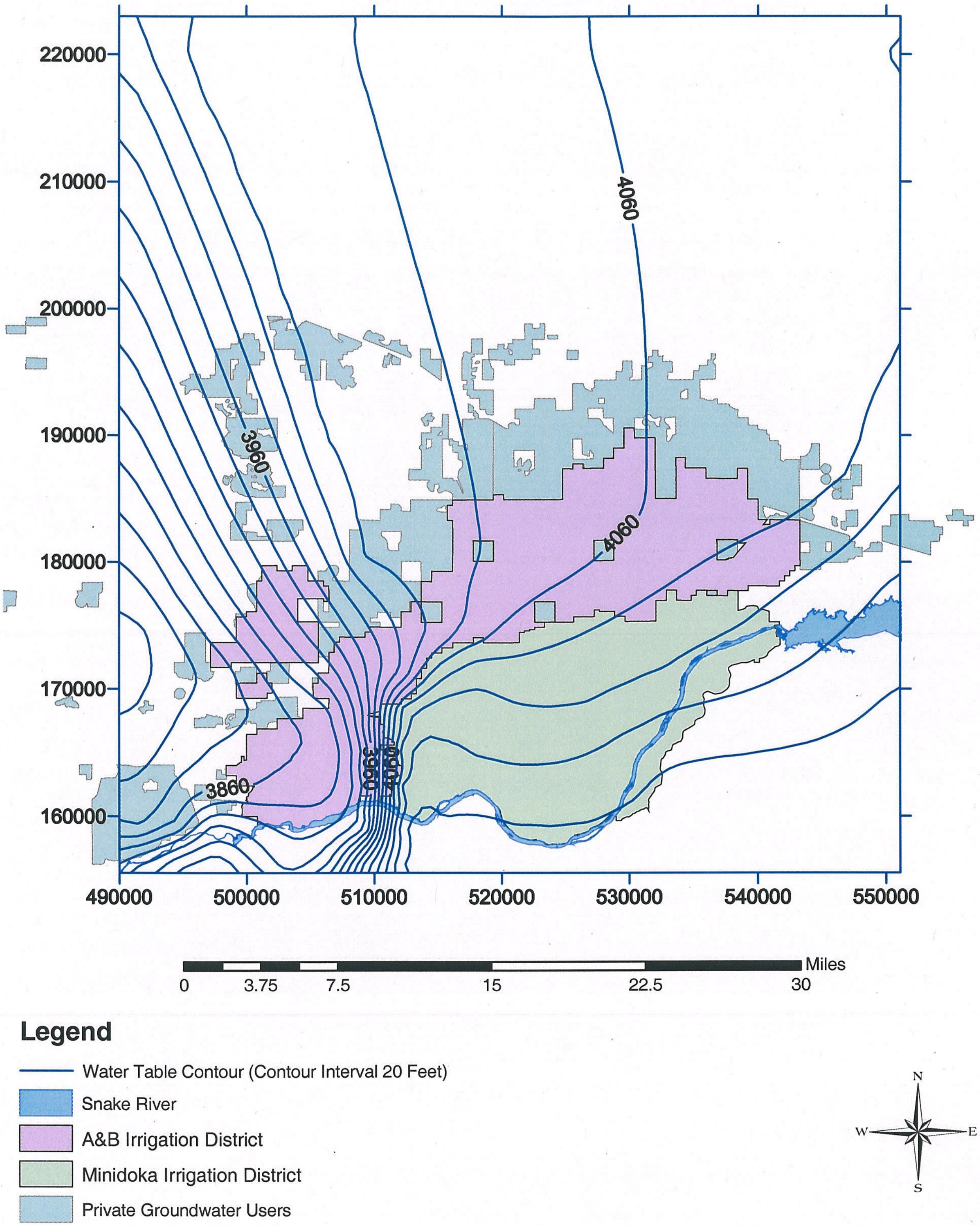

Figure 18. Modeled non-irrigation season groundwater elevations in the A&B Irrigation District area.

The Delis Well Model

The Delis Well model is the A&B area model (with the irrigation season inputs), and the addition of the three proposed Delis wells. The specified pumping rates for these wells are assumed to be the maximum annual withdrawal indicated in the water-right applications. Therefore, the irrigation season model is run with each of the Delis wells pumping at a constant rate of 0.783 cfs, which is one third of the maximum diversion rate of 2.35 cfs described in the water right application.

Model results show the maximum aquifer depletion (increased drawdown) that could be expected to occur as a result of the new pumping from these three wells. The model results are presented in the form of a groundwater level change map (Figure 19). As this figure shows, the additional drawdown due to new pumping is extremely small, not more than 3 to 5 hundredths of a foot in most of the A&B Irrigation District.

The Cumulative Effects Model

The Delis application is being considered out of priority; therefore it is reasonable to expect that if this application were approved, 23 other pending well applications in the A&B area with dates earlier then the Delis application would also be approved. The cumulative effects analysis is conducted in order to estimate the aquifer depletion that could be expected if these additional wells were also permitted. Table 2 provides some details of these other pending applications, including maximum annual withdrawal rates. The cumulative withdrawal rate for these 23 applications (a total of 39 wells) is about 30 times greater then that of the Delis wells alone.

The maximum depletion that could be expected to occur as a result of pumping from all 23 applications pending in Basin 36 is again presented in the form of a groundwater level change map (Figure 20). The depletion is significantly greater than what would result from pumping the Delis wells alone. About 3.5 feet of additional aquifer drawdown could be expected to occur just to the north of the A&B District. Drawdown directly beneath the District could be expected to range from 0.2 to 2.8 feet, and average about

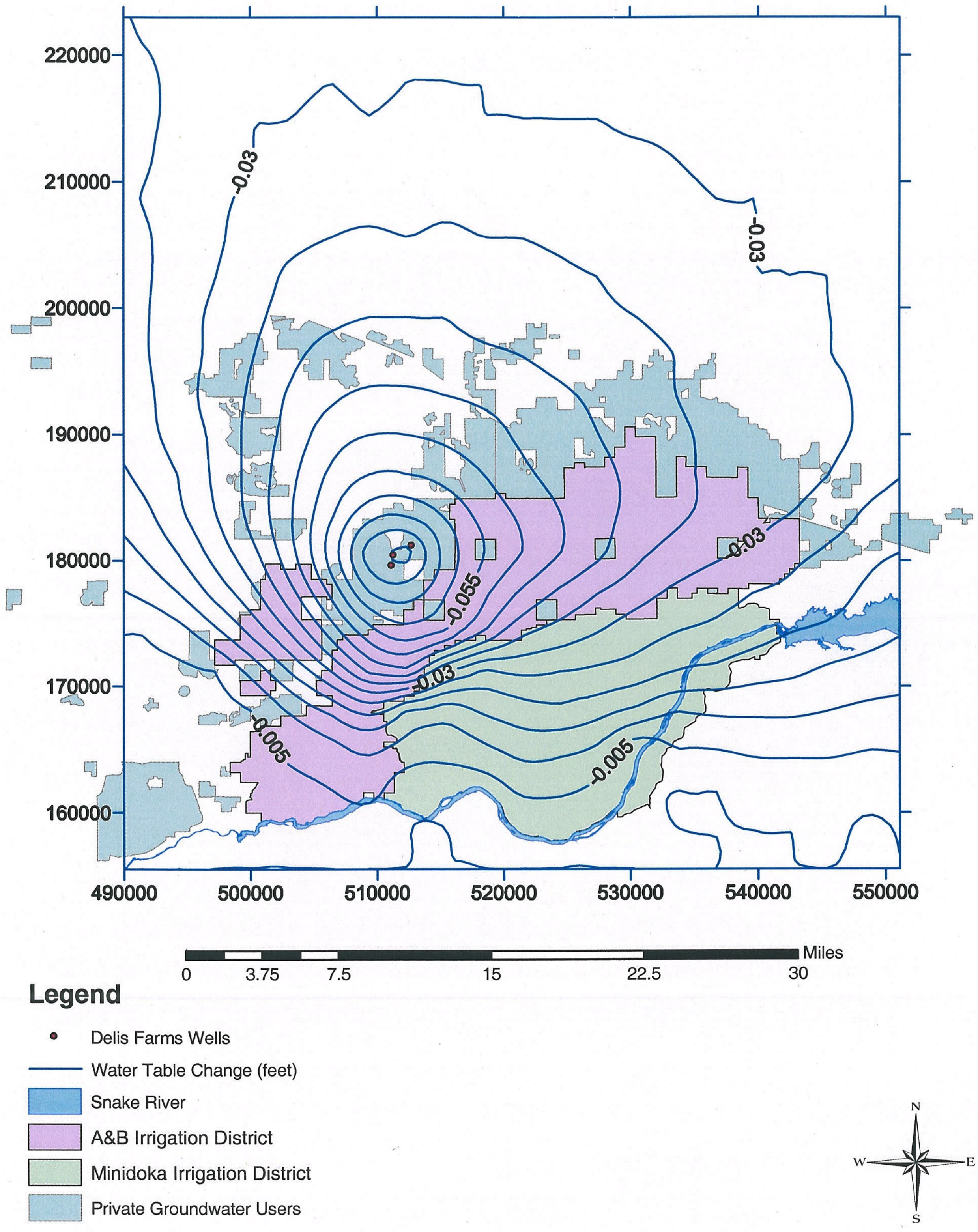

Figure 19. Delis effects modeled results. Contour lines represent feet of drawdown.

Table 2. Twenty-three pending groundwater applications in Basin 36. Note some of the applications include multiple points of diversion. (IDWR, 2003)

Water Right Number	Priority Date	Beneficial Use	Season of Use	Rate CFS
36-8663	5/15/1992	Irrigation	3/15-11/15	2.37
36-8664	5/15/1992	Irrigation	3/15-11/15	5.72
36-8309	4/25/1986	Irrigation	3/15-11/15	4.34
36-8642	12/31/1991	Irrigation	3/15-11/15	1.26
36-8565	9/27/1990	Irrigation	4/01-11/01	4.8
36-8647	3/17/1992	Irrigation	3/15-11/15	6.4
36-8703	12/29/1992	Irrigation	4/01-10/31	1.07
36-8690	11/17/1992	Commercial	1/01-12/31	1.02
36-8635	11/15/1991	Irrigation	3/15-11/15	0.2
36-8646	3/17/1992	Irrigation	3/15-11/15	6.4
36-7979A	4/14/1981	Irrigation	4/10-11/01	12.8
36-7979B	4/14/1981	Irrigation	4/01-11/01	6.4
36-7979C	4/14/1981	Irrigation	4/01-11/01	6.4
36-7979D	4/14/1981	Irrigation	4/01-11/01	6.4
36-7979E	4/14/1981	Irrigation	4/01-11/01	6.4
36-7979F	4/14/1981	Irrigation	4/01-11/01	3.2
36-7979G	4/14/1981	Irrigation	4/01-11/01	6.4
36-7979H	4/14/1981	Irrigation	4/01-11/01	6.4
36-7978A	4/14/1981	Irrigation	4/01-11/01	12.8
36-7978B	4/14/1981	Irrigation	4/01-11/01	6.4
36-7978C	4/14/1981	Irrigation	4/01-11/01	6.4
36-7978D	4/14/1981	Irrigation	4/01-11/01	3.2
36-7980	4/27/1981	Irrigation	4/01-11/01	25.6

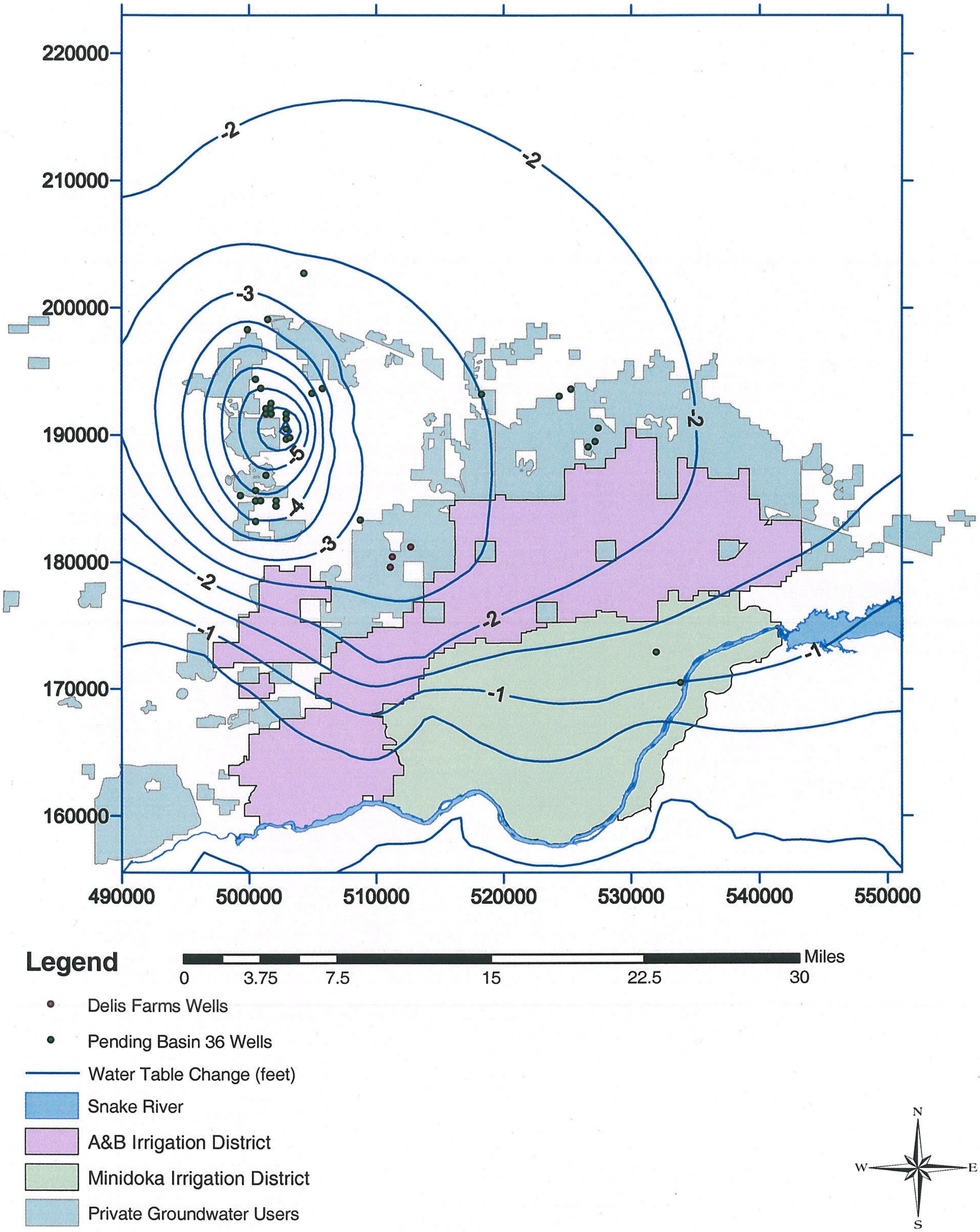

Figure 20. Cumulative effects modeled results. Contour lines represent feet of drawdown.

2.0 feet. This drawdown would be in addition to the already observed annual water table decline represented in Figures 4 and 5.

Steady-State versus Time-Dependent Impacts of New Pumping

Groundwater depletions due to pumping at the start of the irrigation season are mostly aquifer storage. In an unconfined aquifer, storage water comes mainly from gravity drainage of the aquifer. Over time however, as pumping continues, less water comes from gravity drainage of the aquifer, and more water comes from hydrologic boundaries such as rivers or reservoirs. Steady-state hydrologic conditions are present once the water table depression around the well is no longer expanding, gravity drainage of the aquifer is no longer occurring, and all pumped water is coming from hydrologic boundaries.

The analytic element model for the A&B Irrigation District is primarily a steady-state model, which means that it predicts the aquifer depletion (as well as the river and reservoir depletion) that could be expected to occur over the long-term, as a result of new groundwater withdrawals. However, the Gflow software also incorporates an analytic element that can be used to model the time-dependent effects of well pumping. Replacing the steady-state wells in the present model with transient (Theis) wells (Freeze and Cherry, 1979) enables the model to estimate the time required for steady-state conditions to develop following the onset of new groundwater pumping.

Superposition of time-dependent and steady-state elements in an AEM model is appropriate as long as the transient elements (the time-dependent wells) do not unduly influence other head-specified steady-state boundary conditions, such as the Snake River or Lake Walcott boundaries. In the A&B area model, the proposed wells are far enough away from these boundaries such that this is the case.

The time-dependent model results indicate that three to five years would be required for the steady-state aquifer depletions shown in Figures 16 and 17 to occur. A more complete time-dependent analysis of proposed pumping would require application of a fully transient flow model such as Modflow (McDonald Harbaugh, 1988) or TOUGH II (Berkeley Lab, 1999). Development and calibration of a transient flow model would require additional hydrologic data, and substantial additional effort which is not justified at this time.

Summary and Conclusions

Previously presented USGS observation well data and A&B Irrigation District records (Figures 4 and 5) have demonstrated that on average, since the late 1940's the groundwater table in southern Minidoka County has been declining at a rate of about 0.51 feet per year. In the last 3 years the water table has declined an average of 1.89 feet per year. New groundwater pumping north of the A&B Irrigation District could be expected to intensify this decline.

A groundwater model of the A&B area was developed in order to predict the impact of proposed new pumping north and west of the A&B District, on groundwater elevations beneath the District. Model inputs, including aquifer transmissivity, and net aquifer recharge and discharge rates were taken from recent Eastern Snake Plain hydrologic investigations by IWRRI and USGS, and from A&B Irrigation District records. The A&B area model was calibrated using observation well data and river gain and loss data.

The A&B area model indicates that the maximum impact of the Delis wells on groundwater elevations in the A&B District could be expected to be very small, generally less than 5 hundredths of a foot of drawdown. This magnitude of depletion would probably not be measurable using groundwater instrumentation that is in general use today.

It is not the object of this modeling study to argue whether this small depletion constitutes a significant impact to groundwater resources of the A&B District. However, basic hydrodynamic principles guarantee that pumping from the Delis wells will bring about some amount of additional drawdown in the aquifer. The best estimate of the A&B area model, 0.05 feet of drawdown, is therefore not simply an approximation of zero.

The recognition that some drawdown (however small) must occur as a result of pumping from each new well is important justification for considering the cumulative impacts of permitting many new wells. The cumulative effects model estimates that pumping from all the proposed Basin 36 wells (a total of 42 wells, 3 Delis and 39 other) located north of the A&B District would ultimately result in additional water table declines beneath the A&B District of from 0.2 to 2.8 feet, depending on location in the District. This additional water table decline could be expected to occur within three to five years following the onset of new pumping.

References

Berkeley Laboratory, http://esd.lbl.gov/TOUGH2/, 1999.

Contor, B., Percolation, Runoff, and Deficit Irrigation, Idaho Water Resources Research Institute, Design Document Number DDW-002, 2002.

Crosthwaite E. G., and Scott R. C., Ground Water in the North Side Pumping Division, Minidoka Project Minidoka County, U.S. Geological Survey Circular 371, 1956.

De Josselin De Jong G., Generating Functions in the Theory of Flow through Porous Media, Chapter 9 in Flow through Porous Media, ed. R. DeWiest, Academic Press, 1969.

Freeze R. A., and Cherry J. A., Groundwater, Prentice-Hall, 1979.

Garabedian, S.P., Hydrology and Digital Simulation of the Regional Aquifer System, Eastern Snake River Plain, Idaho, U.S. Geological Survey Professional Paper 1408-F, 1992.

Haitjema H. M., Analytic Element Modeling of Groundwater flow, Academic Press, 1995.

Hortness, J., and Vidmar P., Seepage Study on the Heneys Fork and Snake River, Idaho, U.S. Geological Survey, 2003.

IDEQ, Delineation of Public Drinking Water Sources for the Source Water Assessment Program; Boise Valley and Mountain Home Plateau, 2001.

IDWR Website, http://www.idwr.state.id.us, 2003.

Johnson G., Brockway C., and Lindgren J., Calibration of the Snake Plain aquifer groundwater flow model, IWRRI Technical Completion Report G839-06, 1985.

Johnson J., and Cosgove D., personal communication, October, 2003,

Lindholm, G.F., Summary of the Snake River Plain Regional Aquifer-System Analysis in Idaho and Eastern Oregon, U.S. Geological Survey professional Paper 1408-A, 1996.

McDonald M. G., and Harbaugh A. W., A Modular Three Dimensional Finite-Difference Groundwater Flow Model, U.S. Geological Survey Techniques of Water Resource Investigation, Book 6, 1988.

Schmidt R.D., Analysis of Hydrologic Impacts of New Groundwater Pumping in the Dry Lake Area of Canyon County, Idaho, U.S. Bureau of Reclamation, 2003.

Stearns H.T, Crandall, L, and Steward W.G., Geology and Groundwater Resources of the Snake River Plain in southwestern Idaho, USGS Water Supply Paper 774, 1938.

Strack ODL, Groundwater Mechanics, Prentice Hall, 1989.

Temple D., Personal Communication, 2003.

USEPA, Guidelines for Delineation of Wellhead Protection Areas, Technical Report, Office of Groundwater Protection, 1987.

Verruijt A.:, Theory of Groundwater Flow, Macmillan, 1982.

Washington Group International, Source Area Delineation Report: Southwest Margin of the Eastern Snake River Plain Hydrologic Province, 2001.

Water District 130, Jerome Meeting Minutes, February 2003

Whitehead R.L., Geohydrologic Framework of the Snake River Plain Regional Aquifer System, Idaho and Eastern Oregon, U.S. Geological Survey professional Paper 1408-B, 1992.

Wylie A., Personal Communication, 2003.