Open-File Report

Analysis of the 2007 Post Season Recharge Using North Side Canal

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Abstract

Idaho Ground Water Appropriators and Idaho Dairymen's Association proposed diverting 29,500 ac-ft of water through the North Side Canal Co's (NSCC) canal system to recharge the Eastern Snake Plain Aquifer and mitigate for declines in flows at Blue Lakes and Clear Lake Springs. The planned recharge experiment took place after the 2007 irrigation season. Prior to the end of the irrigation season, NSCC and Idaho Department of Water Resources (IDWR) personnel worked together to select the canals most likely to benefit the injured springs. NSCC was able to divert about 27,360 ac-ft of water before freezing temperatures forced an end to the experiment on November 27.

IDWR collects water level measurements in wells on a bi-monthly basis in the Thousand Springs area and has transducers deployed in three wells along the North Side Main Canal. The United States Geological Survey (USGS) monitors flow at three springs in the area. During the recharge experiment NSCC personnel collected measurements at various checks and diversion points regularly, and IDWR conducted seepage runs along the main canal near the end of the experiment.

The continuous observations from the wells and springs were normalized and graphed using an annual Julian date to enable overlaying the hydrographs. The resulting plots show a positive impact from the recharge experiment when compared with previous years. A comparison of post irrigation season water levels from 2006 with 2007 data also indicates a positive impact.

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Introduction

With an increase in overall ground water pumping from the Eastern Snake Plain Aquifer (ESPA) beginning in the 50s and extending through the 80s, compounded by climate and water management changes, users of spring water in the discharge area of the aquifer known as the Thousand Springs area, have experienced reduced spring flows. These Diminished spring flows threaten area businesses and livelihoods, most notably fish farming and other aquaculture enterprises.

In accordance with the Idaho Constitution and statutes, and under the Idaho Department of Water Resources (IDWR) Rules for Conjunctive Management of Surface and Ground Water Sources, the Department Director is empowered to issue curtailment orders when water delivery deficiencies to senior appropriators can be demonstrated. In response to the diminished spring flows, spring users made water delivery calls in 2005, which resulted in curtailment orders issued by the IDWR Director requiring the junior water right holders to either mitigate the effects of their diversions or cease diverting ground water in order to enhance the senior rights.

In the North Snake Ground Water District and Magic Valley Ground Water District Joint Supplemental Replacement Water Plan (2007), the Idaho Ground Water Appropriators (IGWA) and the Idaho Dairymen's Association (IDA) agreed to purchase and make 29,500 ac-ft of water available for recharge to the aquifer. Among the irrigation canal systems fed by the Snake River, incidental recharge from the North Side Canal system was identified as having the most influence on spring flows in the Thousand Springs area (Figure 1). North Side Canal Company (NSCC) and IDWR personnel worked together to identify canals and laterals within the North Side system most likely to benefit the springs with active calls. Figure 2 shows the portion of the NSC system selected for use in the recharge experiment.

Beginning October 20, 2007, about seven days after irrigation diversions terminated, the NSCC provided the use of its canal system, manpower and equipment for late season recharge to the ESPA. The goal was to recharge the 29,500 ac-ft of Snake River water acquired by IGWA and IDA by late November or when freezing temperatures prevented continued flows. IDWR's role in this project was to facilitate efforts between IGWA, IDA and NSCC. IDWR Staff also assisted in measuring flows along specific reaches of the canal, and measured water levels in observation wells.

The post-irrigation season recharge added about 27,360 acre-feet of water to the aquifer to help compensate the senior spring users for their water delivery shortages. The project increased IDWR's understanding of the interaction between the canal network and incidental recharge to the aquifer. This effort will provide useful information for evaluating future aquifer recharge projects.

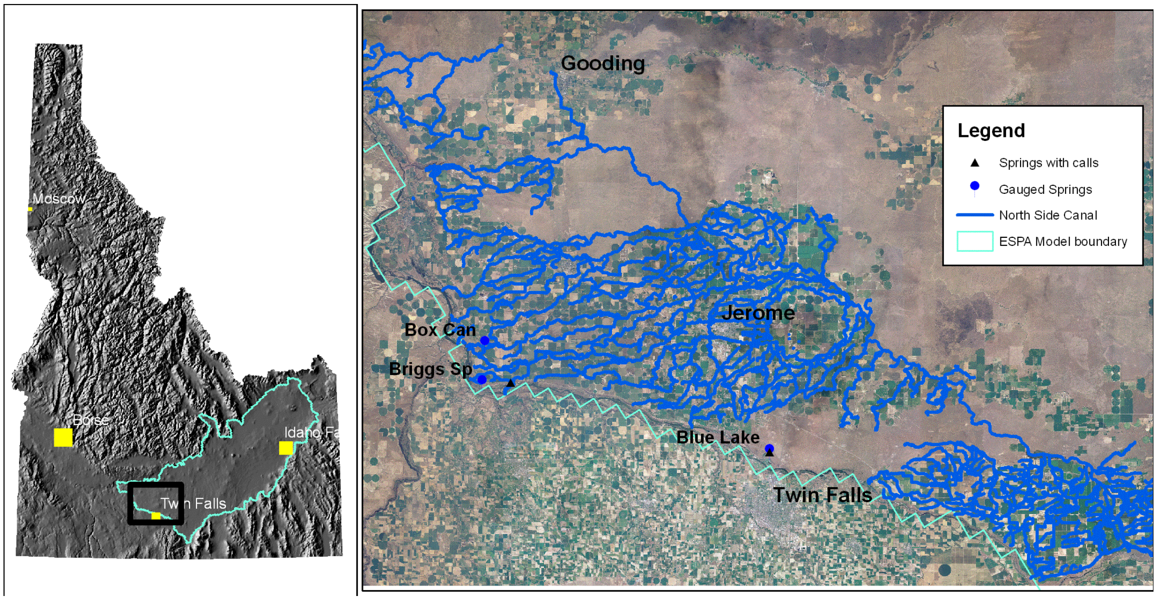


Figure 1. Location map.

Methods

Many measurements were collected to monitor the hydrologic impacts of the recharge event. These included manual water level measurements in wells collected by IDWR, by contractors to IDWR, and by the United States Geological Survey (USGS), continuous water level measurements in wells obtained using transducers deployed in wells by IDWR, flow measurements in the North Side Canal by NSCC and IDWR, and spring flow measurements by the USGS.

IDWR maintains a database of water levels collected from wells throughout the state (http://www.idwr.idaho.gov/hydrologic/info/obswell/). This database is populated with measurements collected by IDWR personnel, by contractors to IDWR and by the USGS. The contractor collects measurements on a bi-monthly basis in the area of the recharge experiment. IDWR also maintains transducers in three wells along the North Side Canal. Figure 2 shows the locations of wells with routine water levels and the wells with transducers.

NSCC ditch riders collected measurements along portions of the canal selected for use in the experiment as shown in Figure 2. The measurement locations are at weirs or rated sections normally used by the ditch riders to monitor water distribution during the irrigation season. The ditch riders filled out daily logs recording their observations at each location, resulting in approximately daily observations at 69 different locations between October 20 and November 27.

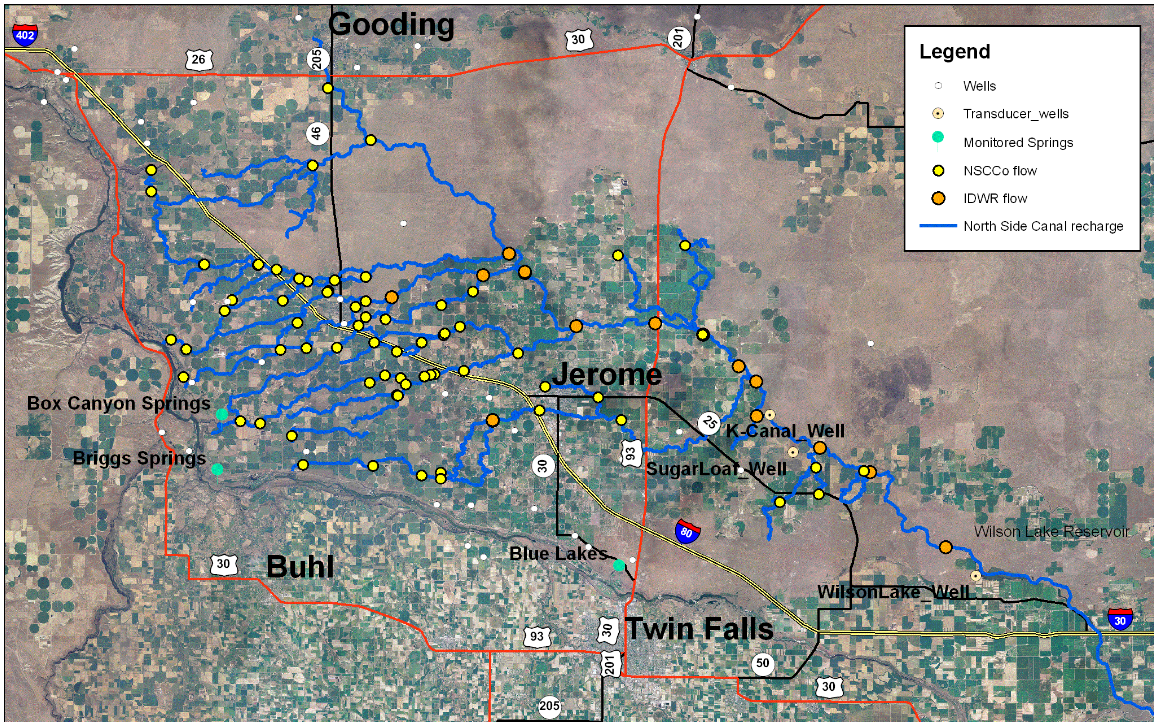


Figure 2. Canal and spring measurement locations and observation well locations.

IDWR personnel collected flow measurements along the main canal at various times during the recharge event and conducted seepage runs along the Main Canal, U Canal, and W Canal between October 20 and 28.

Two seepage runs were performed during the study. The first occurred on November 20 and involved streamflow measurements at seven locations in the reach between Wilson Lake and Highway 93 crossing below the R-lateral. The second seepage run was conducted November 27 and 28 and focused on the reach from the Highway 93 crossing to the head of the W-canal and down the W-canal to W-26 near Wendell. Before the start of the second seepage run measurements were repeated at the top (below Wilson Lake) and bottom (Highway 93 crossing) of the first seepage run to check for differences in discharge. Since the change in discharge was less than 1 % at both sites, the system was assumed to be in equilibrium and the data from both runs presumed comparable.

Discharge was measured with a StreamPro acoustic Doppler current profiler (ADCP) produced by Teledyne RDI. Measurements were either done from a bridge or on a temporary pulley system. To minimize measurement error, USGS standards were followed for all measurements. A coefficient of variation (COV) of less than 0.05 was obtained with the first four transects at most sites. Where the COV was greater than 0.05 for the first four transects, four additional transects were done and the average of all eight transects equaled the final discharge.

The USGS spring gauges in the area of interest include Blue Lakes, Briggs Springs, and Box Canyon Springs (Figure 2).

Results

The ability to observe the impact of recharge depends on establishing aquifer conditions prior to recharge. Thus analysis requires comparisons with previous years without recharge. Between 2000 and 2007 approved recharge activities took place in 2006 and 2007. Comparison of annual hydrographs from a continuous time series can be made by converting the time stamp (calendar date and time recorded by the transducer) into a Julian date and normalizing the observations. These changes are linear thus; although the scale is changed, the trend and the slope of the trend remain constant. Bi-monthly manual measurements were differenced to compute the water level change between November 2006 and November 2007.

Manual bi-monthly water level data

The manual bi-monthly water level data collected during the November 2007 recharge event were compared with data collected in the same wells during November 2006. The water level differences were interpolated using the kriging algorithm in the Spatial Analyst extension to ArcGIS. Figure 3 shows the interpolated water level change within the NSCC service area. Assuming all volume above the zero ft change contour interval is due to recharge, the inferred addition to the aquifer attributable to recharge is 1,824 ac-ft, or about 7% of the total recharge volume. The discrepancy between the 27,360 ac-ft diverted and the 1,824 ac-ft computed change in the aquifer can most likely be explained by two factors: 1) not all 2007 measurements were collected at the end of the recharge event after all the recharge water percolated down to the aquifer; and 2) an assumed floor of zero likely underestimates the calculated volume added to the aquifer. The following paragraphs address the under estimate of volume added to the aquifer provided by the water level change map.

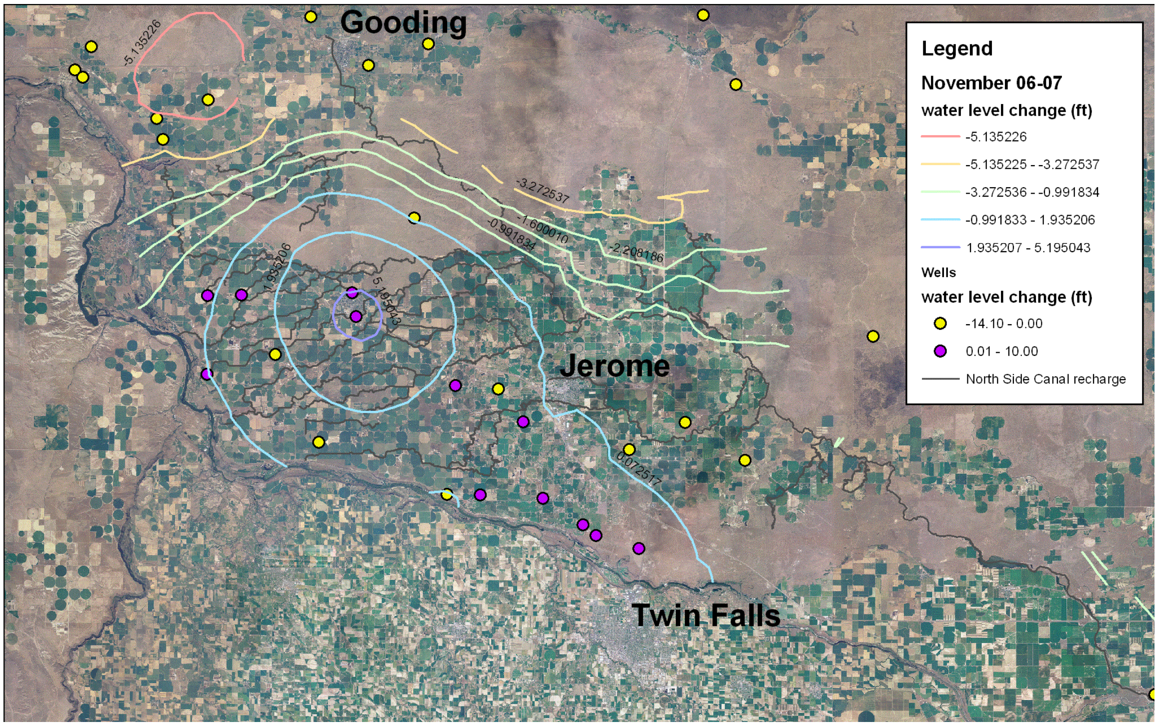


Figure 3. Water level change map for November 2006 - 2007.

The November 2007 water level collection in the Thousand Springs area did not coincide with the end of the recharge event. All water level measurements collected before the end of the recharge event tend to underestimate the water level change caused by the entire recharge event and hence, result in an underestimate of the volume of water added to the aquifer.

Many of the observed water level changes are less than zero, therefore the minimum value showing impact from recharge might actually be less than zero. The mean for all wells with changes less than zero is -3.78, perhaps a floor of -3.78 ft might be more appropriate.

Other factors affecting this analysis include: 1) Documented recharge activities took place in the area during 2006, and no attempt was made to correct for the impact of these actions. The impact of the 2006 recharge events would vary depending on where, when, and how much water was recharged. In general, these activities would tend to increase the 2006 water levels, lowering the difference between the 2006 and 2007 observations. 2) Some outflow likely occurred before all the recharge water entered the aquifer. 3) A storage coefficient must be assumed to calculate the volume within the contours.

Although quantifying the amount of water added by the recharge experiment is difficult, the water level change shows a positive impact directly below the portion of the canal system used during the recharge event.

Wells with transducers

IDWR has maintained three wells with transducers near the Main Canal since 2001. From east to west, these wells are the Wilson Lake Well, the Sugar Loaf Well, and the K-Canal Well. Figure 2 shows the locations and Figures 4 though 9 contain hydrographs produced using data from these wells. The transducers have been maintained from the spring of 2001 until present with varying degrees of success. These data are valuable for determining the impact of recharge, because they provide a means to compare a time series from years without recharge with years with recharge.

Wilson Lake Well

The Wilson Lake Well (Figure 2) is near Wilson Lake, a control structure on the North Side Canal. The record from this well provided the most continuous data set of the three wells, although data from May of 2005 through October 2007 are missing. Figure 4 is a hydrograph of the period of record with the Y axis recording feet above mean sea level (famsl). Flow records indicate that Wilson Lake leaked about 129 cfs during the recharge experiment. This data should provide clear evidence of the recharge event, yet it is difficult to observe the impact in Figure 4. Figure 5 is a hydrograph produced using the same data as Figure 4, but with the time stamp converted to a Julian date and the water table elevation converted to a normalized water level by dividing the observed water level with the average water level (H/H_avg). The gaps in each yearly time series between day 250 and 300 marks the end of irrigation diversions in North Side Canal. No gap exists in the 2007 time series because it starts at the end of the 2007 irrigation season. The effect of recharge is readily apparent in Figure 5 because the recession after the irrigation season is not as steep for 2007 as for any of the previous years.

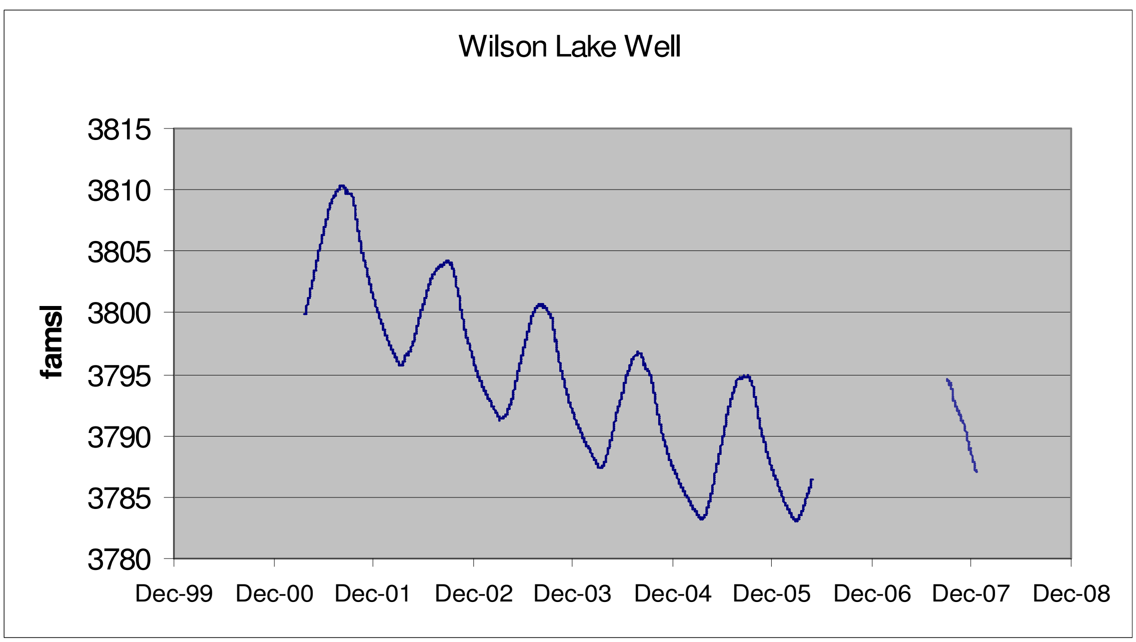


Figure 4. Wilson Lake Well hydrograph.

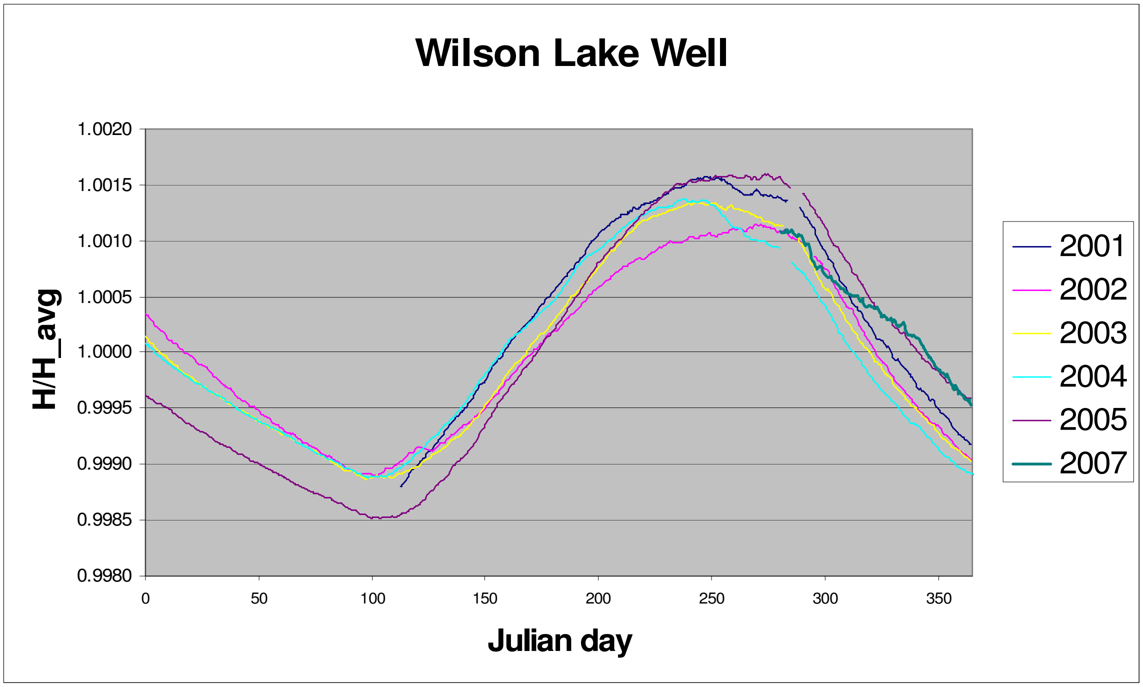


Figure 5. Normalized Wilson Lake Well hydrograph.

Sugar Loaf Well

The Sugar Loaf Well is west of the Wilson Lake Well (Figure 2). The well record is continuous from the spring of 2001 through October of 2003. Measurements were also taken between March 2006 and May 2007, and resumed again in October 2007. Figure 6 is a hydrograph for this well. Figure 7 is a hydrograph of much of the same data as Figure 6 but with the time stamp converted to a Julian date, the water levels normalized and the data from 2006 removed. To observe the impact of recharge in 2007 the hydrograph must be compared to years without recharge. Several recharge projects took place in the Thousand Springs area during 2006, so the 2006 data were removed. As in Figure 5, the gaps in each yearly time series between day 250 and 300 marks the end of irrigation diversions and the 2007 series commences at the end of irrigation diversions. The recession following the end of irrigation for 2007 is much more gradual than for 2001 or 2002. The more gradual decline is likely due to the recharge event.

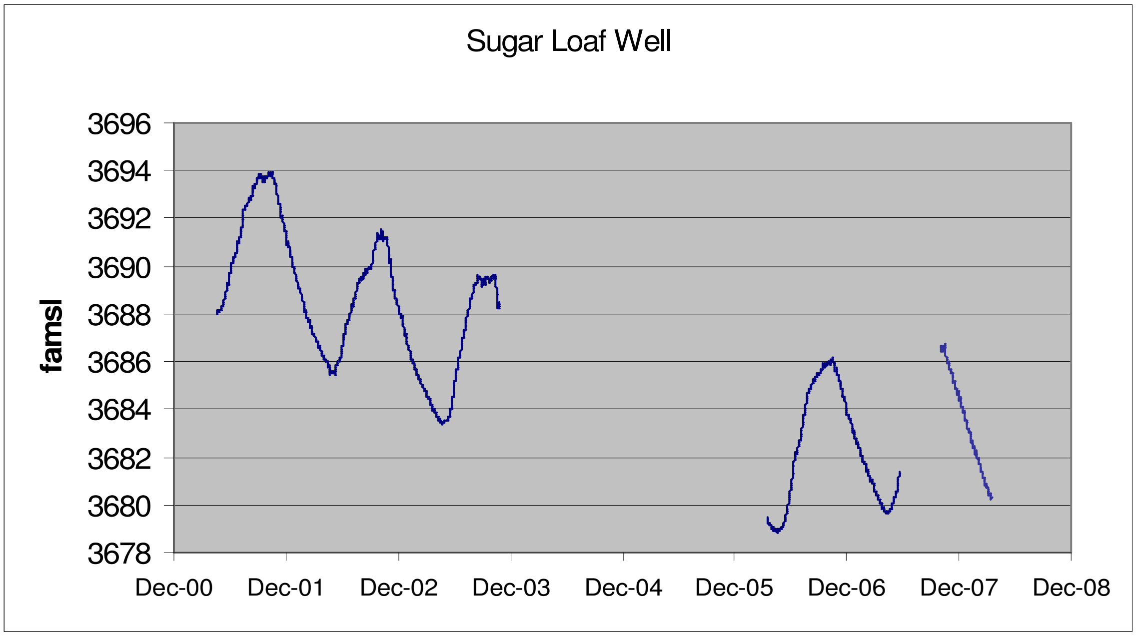


Figure 6. Sugar Loaf Well hydrograph.

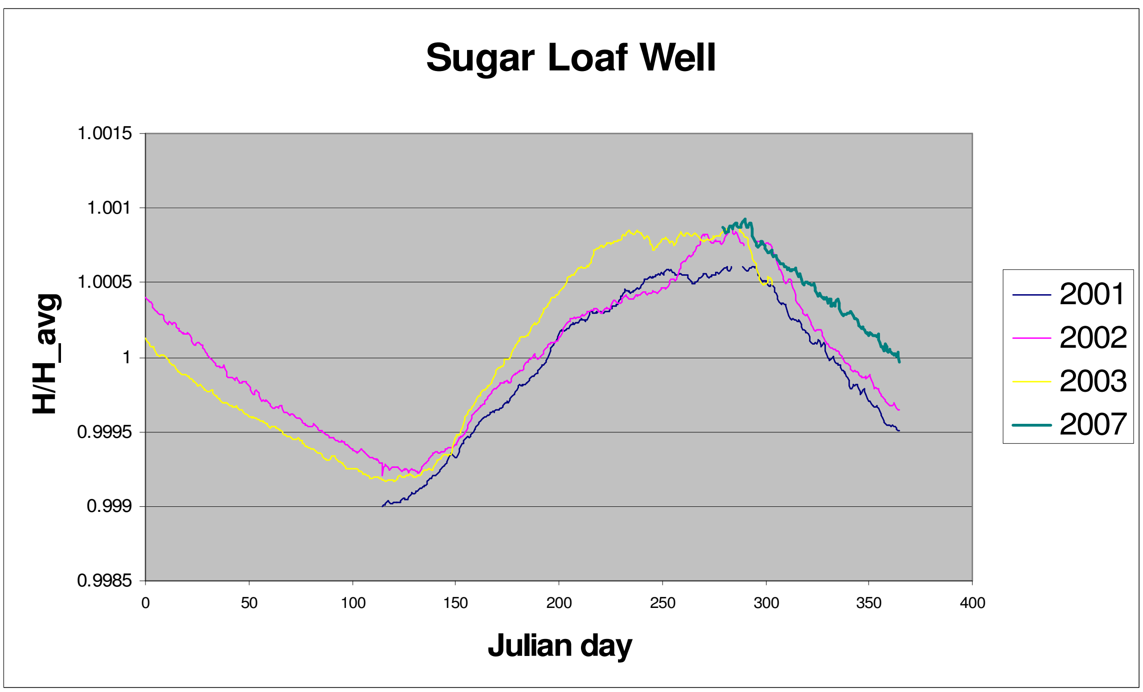


Figure 7. Normalized Sugar Loaf Well hydrograph.

K-Canal Well

The K-Canal Well is the farthest west transducer well in this analysis (Figure 2). The record for this well (Figure 8) is continuous from the spring of 2001 through November of 2002. The record picks up again in June of 2003 through October 2003. The record resumes in May of 2004 through March 2006, however, the time stamp for this portion of the record appears incorrect as it is not in general agreement with the regional trends in water level fluctuations in the area. The water levels in this segment rise in January, and recession begins in May and other wells in the area have water levels rising in May and declining in November (see, for example, Figures 4 and 6). The record resumes again, with a correct time stamp, in October of 2007. The data show abrupt increases and recessions in response to the onset and conclusion of the irrigation season. The abruptness of the response suggests that water is leaking out of the canal and cascading into the well. The flat portion of the hydrograph representing the non-irrigation season indicates that the water level is below the transducer. This well may not be completed in the aquifer but has a direct connection to the canal via a fracture or some other subsurface conduit. Figure 9 is a hydrograph of the same data as Figure 8 but with the time stamp converted to a Julian date, the water levels normalized and the data with the incorrect time stamp removed. As in Figure 5, the gaps in each yearly time series between day 250 and 300 marks the end of irrigation diversions and the 2007 series commences at the end of irrigation diversions. The recession following the end of irrigation for 2007 is abrupt like in the 2001 through 2003 hydrographs. However, water levels partially recover through the end of December, and the well empties shortly after the end of the recharge event.

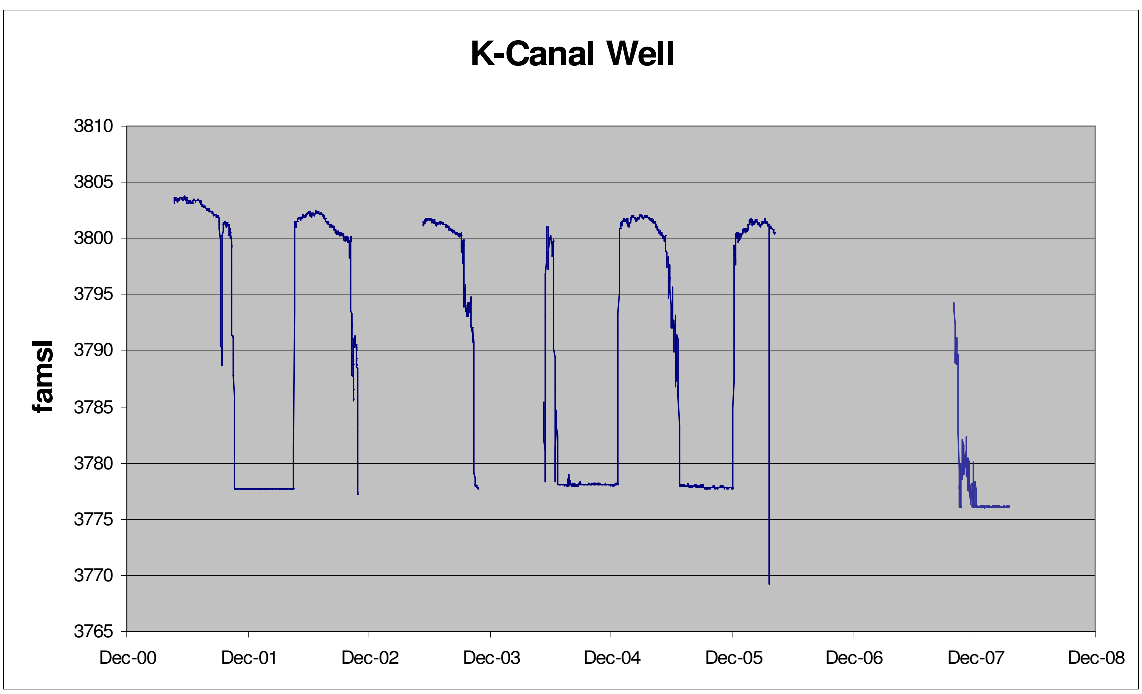


Figure 8. K-Canal Well hydrograph.

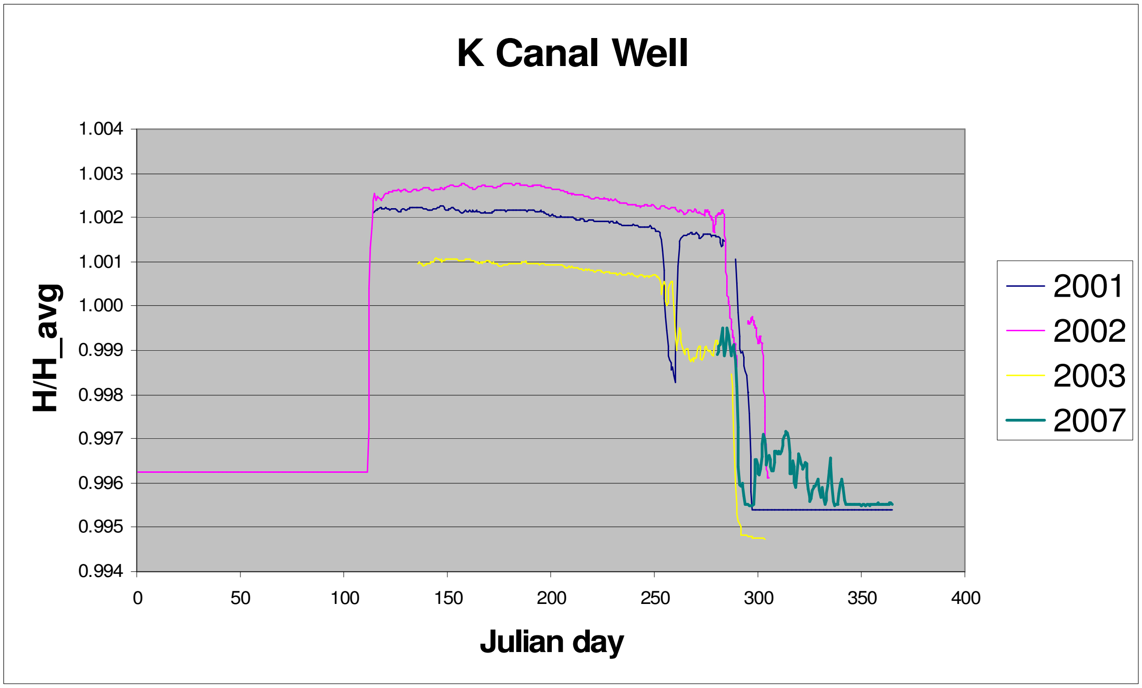


Figure 9. Normalized K-Canal Well hydrograph.

Springs

Springs discharge in response to the hydraulic head in the aquifer; thus, if the head in the aquifer increases, the discharge in the spring increases, and if the head in the aquifer decreases, spring discharge decreases. The USGS monitors three springs in the Thousand Springs area, Blue Lakes, Briggs Spring, and Box Canyon Springs (http://waterdata.usgs.gov/id/nwis/sw/). Figure 2 locates the three springs.

Blue Lakes

Blue Lakes is located north of Twin Falls, Idaho (Figure 2). At this time, data available from the USGS for Blue Lakes does not extend through the 2007 irrigation season. Figure 10 contains a hydrograph of the available Blue Lakes data. No analysis can be done with this data set until it is updated to December of 2007.

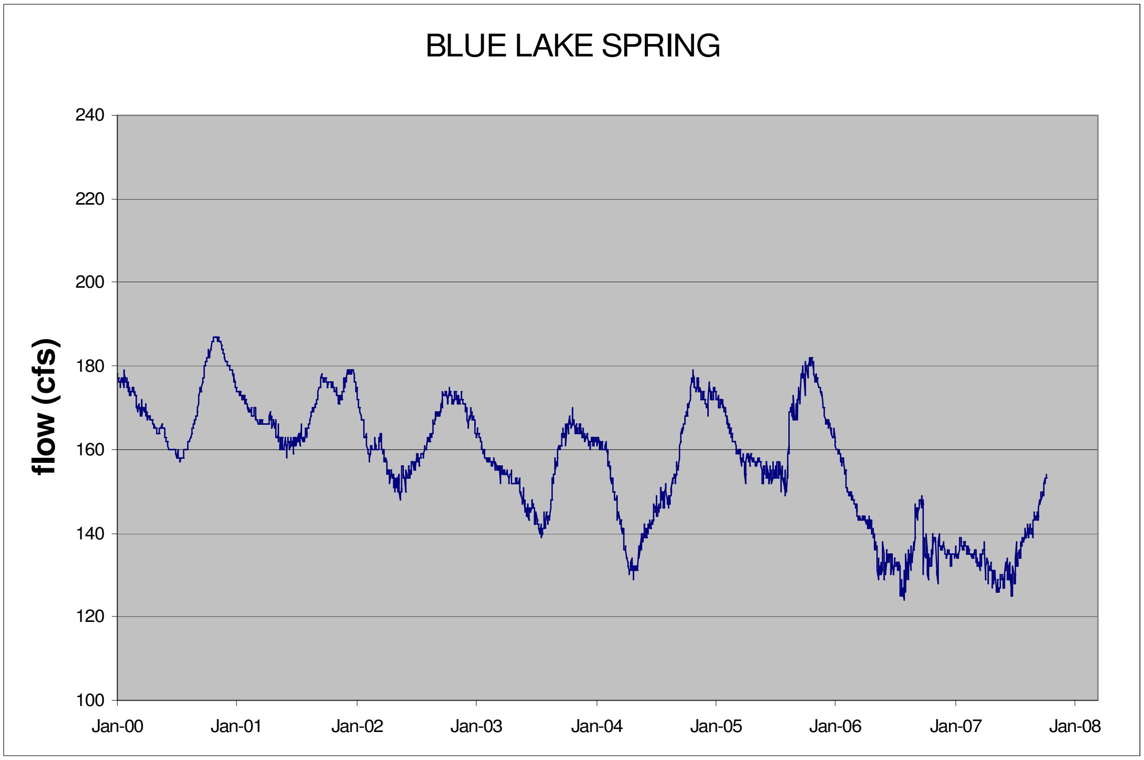


Figure 10. Blue Lakes hydrograph.

Briggs Spring

Briggs Spring is located northwest of Buhl, Idaho (Figure 2). The record for this spring is continuous from January of 2000 through present. Figure 11 is a hydrograph of the data from Briggs Spring. Figure 12 is a hydrograph of the same data as Figure 11 but with the time stamp converted to a Julian date, the spring discharge normalized and the data from 2006 removed. To observe the impact of recharge, the 2007 hydrograph must be compared to years without recharge. Several recharge projects took place in the Thousand Springs area during 2006, so these data were removed in Figure 12. As in Figure 5, the short gap in each yearly time series between day 250 and 300 marks the end of irrigation diversions. For the years between 2000 and 2005, the post season recession in discharge begins shortly after the conclusion of irrigation by NSCC; however, normalized discharge continues to climb after the 2007 irrigation season. The increase in discharge after the conclusion of the irrigation season is likely due to the 2007 recharge event.

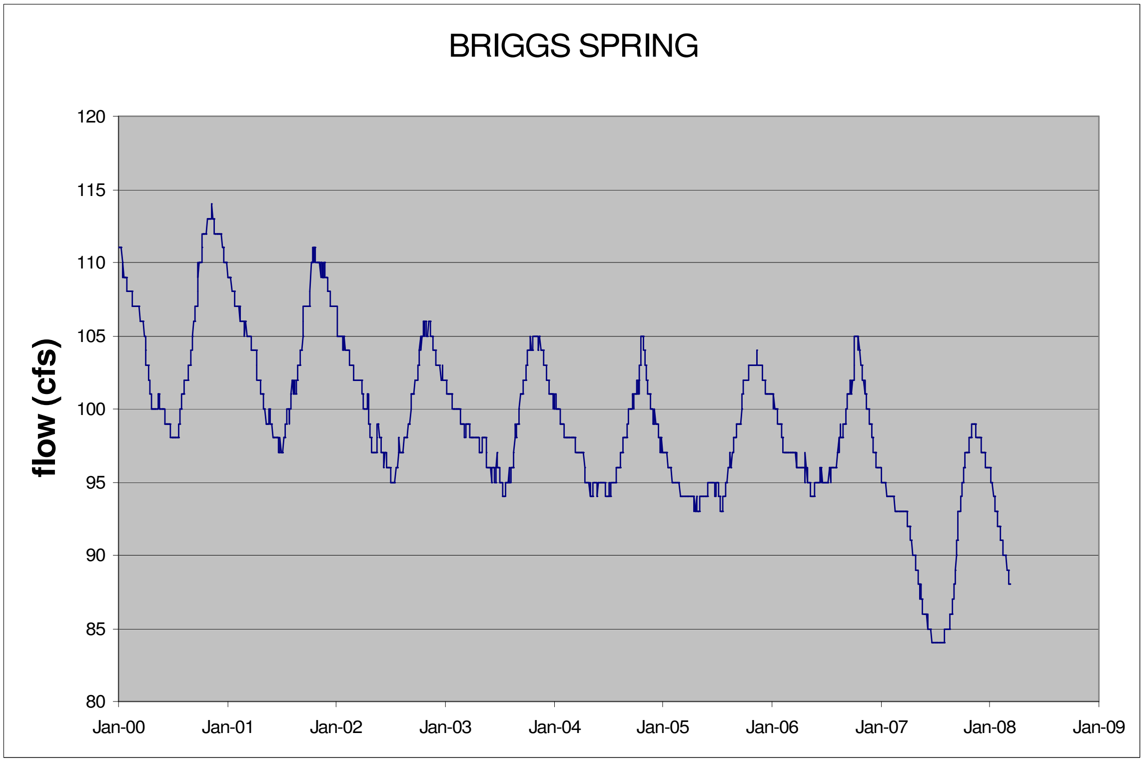


Figure 11. Briggs Spring hydrograph.

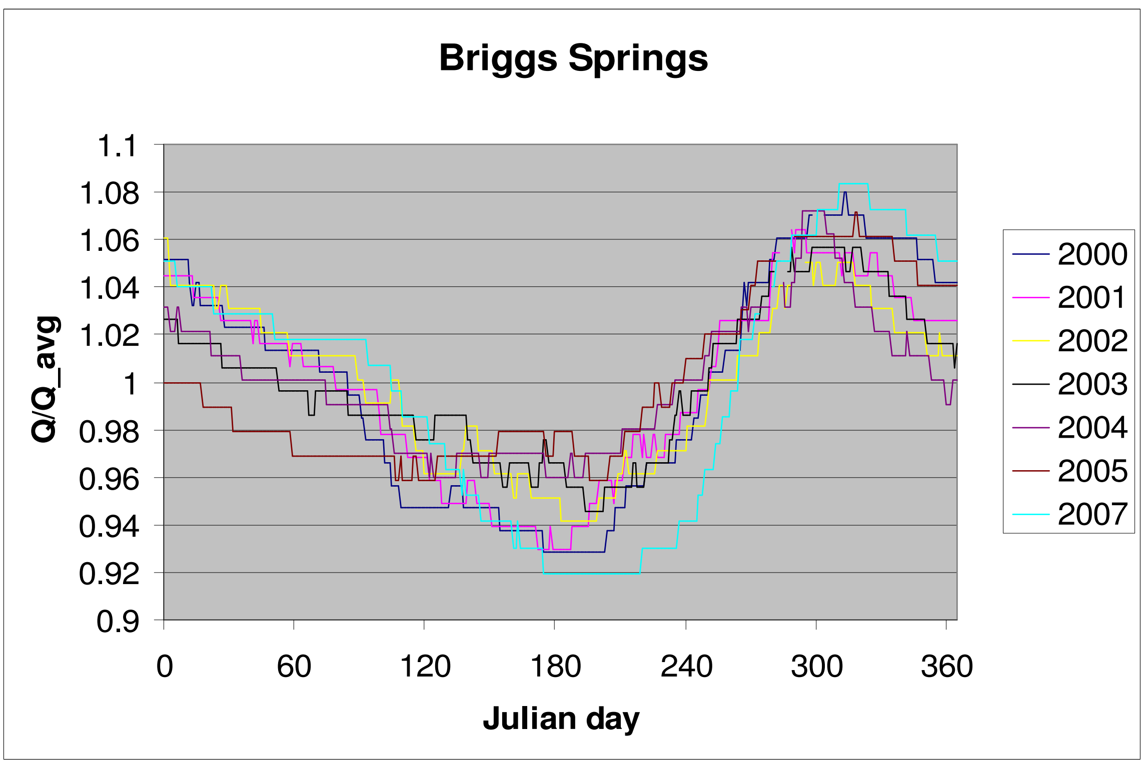


Figure 12. Normalized Briggs Springs hydrograph.

Box Canyon Springs

Box Canyon Springs is located north of Briggs Springs (Figure 2). The record for this spring is continuous from January of 2000 through present. Figure 13 is a hydrograph of the data from Box Canyon Springs. Figure 14 is a hydrograph of the same data as Figure 13 but with the time stamp converted to a Julian date, the spring discharge normalized and the data from 2006 removed. As with the Briggs Springs data, the 2006 data were removed to enable comparison between 2007 and hydrographs from years without recharge. The gaps in each yearly time series between day 250 and 300 marks the end of irrigation diversions. Typically the post season recession in discharge begins shortly after the conclusion of the irrigation season. However, discharge does not begin decreasing for several days after the 2007 irrigation season.

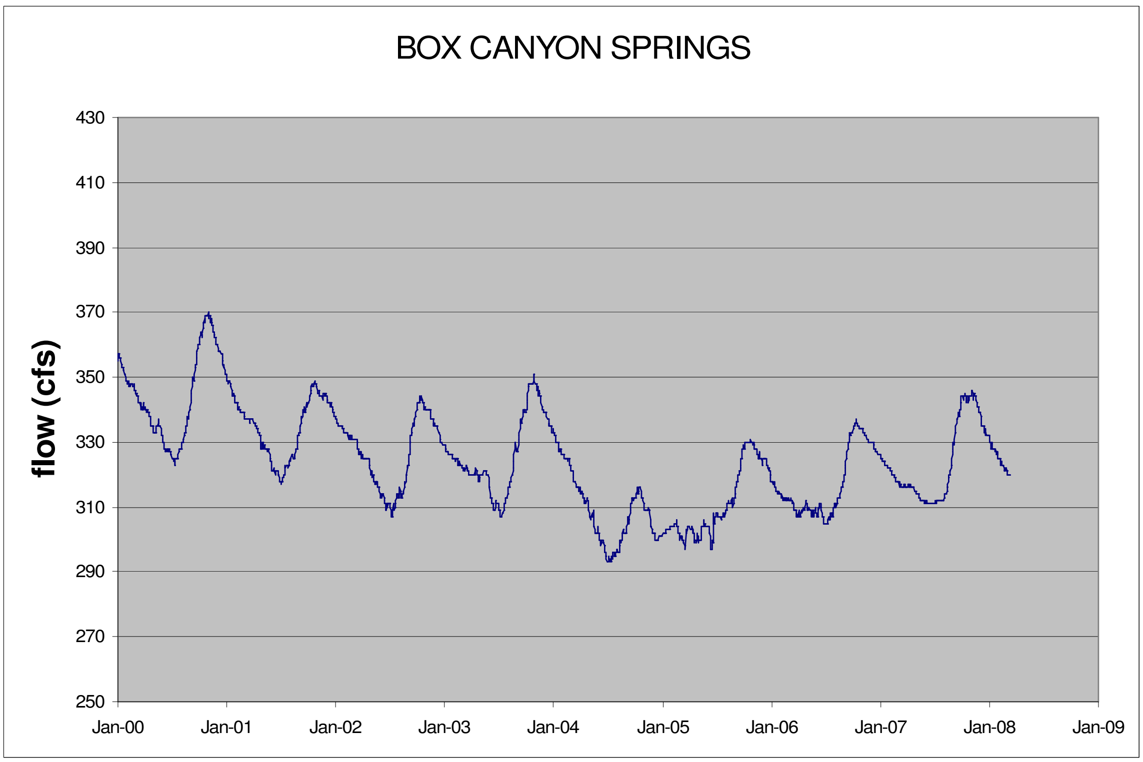


Figure 13. Box Canyon Springs hydrograph.

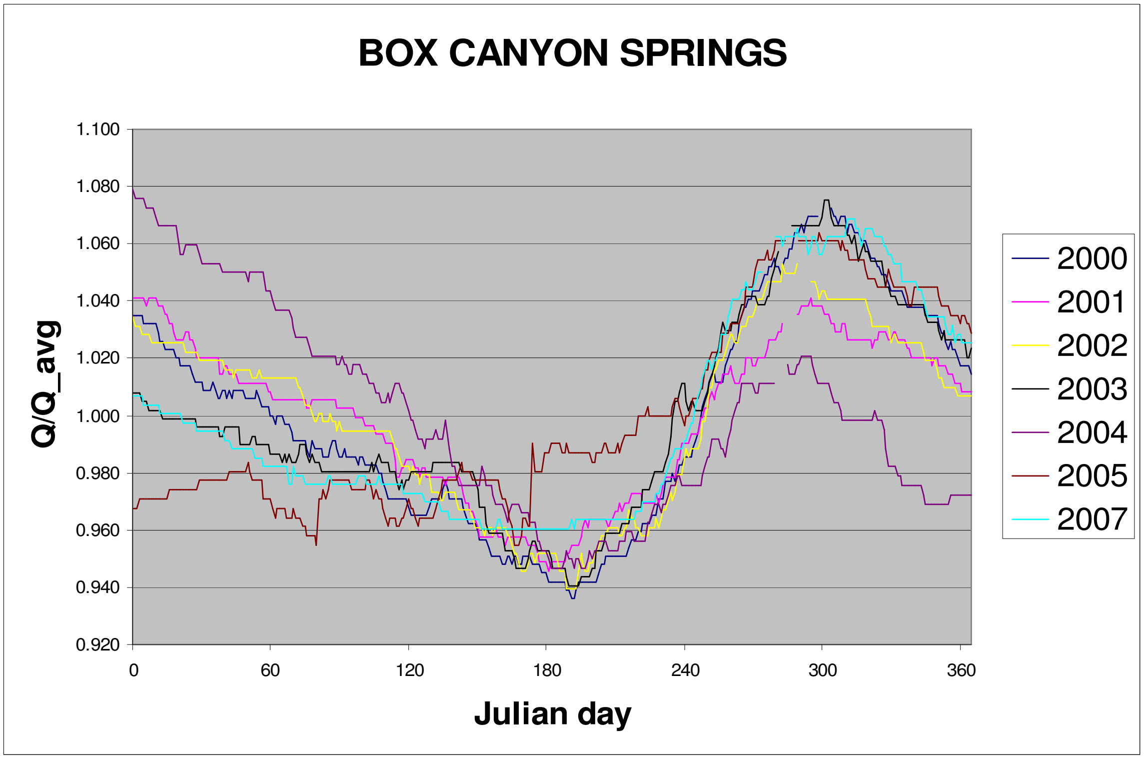


Figure 14. Normalized Box Canyon Springs hydrograph.

Spring Statistics

Table 1 contains a statistical comparison between 2007 and years without recharge as observed in Briggs Spring and Box Canyon Springs. The Max Q column contains the date of maximum discharge as determined using the USGS data. If the maximum discharge remained constant for several days, Max Q records the last day in the series. Days past shutoff is the difference between the last day of irrigation diversions and Max Q at the springs. In 2007, Max Q for Briggs Spring occurred 16 days later than for any year between 2000 and 2005, and for Box Canyon Springs Max Q occurred 20 days later than for any year between 2000 and 2005. The statistics near the bottom of Table 1 are for days past shutoff from the non-recharge years, 2000-2005; thus, the mean of 10.5 for Briggs Spring is the average number of days past canal shutoff before the maximum discharge is observed, stand dev is the standard deviation in the days past shutoff, and conf int is the 95% confidence interval for the days past shutoff. Ninety-five percent of the time Max Q occurs within 19.36 days past the end of the NSCC irrigation diversions for Briggs Spring and within 12.86 days for Box Canyon Springs. The fact that for 2007, Max Q occurs 47 and 37 days past shutoff for Briggs and Box Canyon Springs respectively, when the 95% confidence interval for the springs is 19.36 and 12.86 days respectively, implies that the post season recharge had a measureable positive impact.

Table 1. Maximum spring discharge statistics.

Briggs Spring		Box Canyon Springs	
Date of Max Q	days past shutoff	Date of Max Q	days past shutoff
11/9/2000	12	10/31/2000	3
10/16/2001	2	10/23/2001	9
10/21/2002	1	10/11/2002	-9
10/17/2003	5	10/29/2003	17
10/21/2004	12	10/10/2004	1
11/15/2005	31	10/27/2005	12
11/21/2007	47	11/11/2007	37
mean	10.50	mean	5.50
stand dev	11.11	stand dev	9.20
count	6	count	6
conf int	19.39	conf int	12.86

The Eastern Snake Plain Aquifer Model

The ESPA model version 1.1 (Cosgrove and others, 2006) provides a means for quantifying the impact of the 2007 recharge experiment. However, the ESPA model was calibrated using a six month stress period, and evaluating the impact of events with a time period that is less than the calibration stress period increases the uncertainty in the analysis.

The flow measurements collected by NSCC and IDWR at numerous locations were input into the ESPA model. Figure 15 shows the gauging stations and the computed seepage per model cell between stations. The flow measurements collected during the recharge experiment can be used to compute seepage between each upstream and downstream station by differencing the two stations. A comparison between total diversions and computed seepage along the Main Canal plus diversions down laterals resulted in less than 2% more water seeping into the aquifer than was diverted at the head of the canal. The overage was corrected for at the W45 diversion (Figure 15). Some uncertainty existed regarding the actual flow path of diversions along the S system. This was resolved by evenly dispersing the water along the S system (Figure 15).

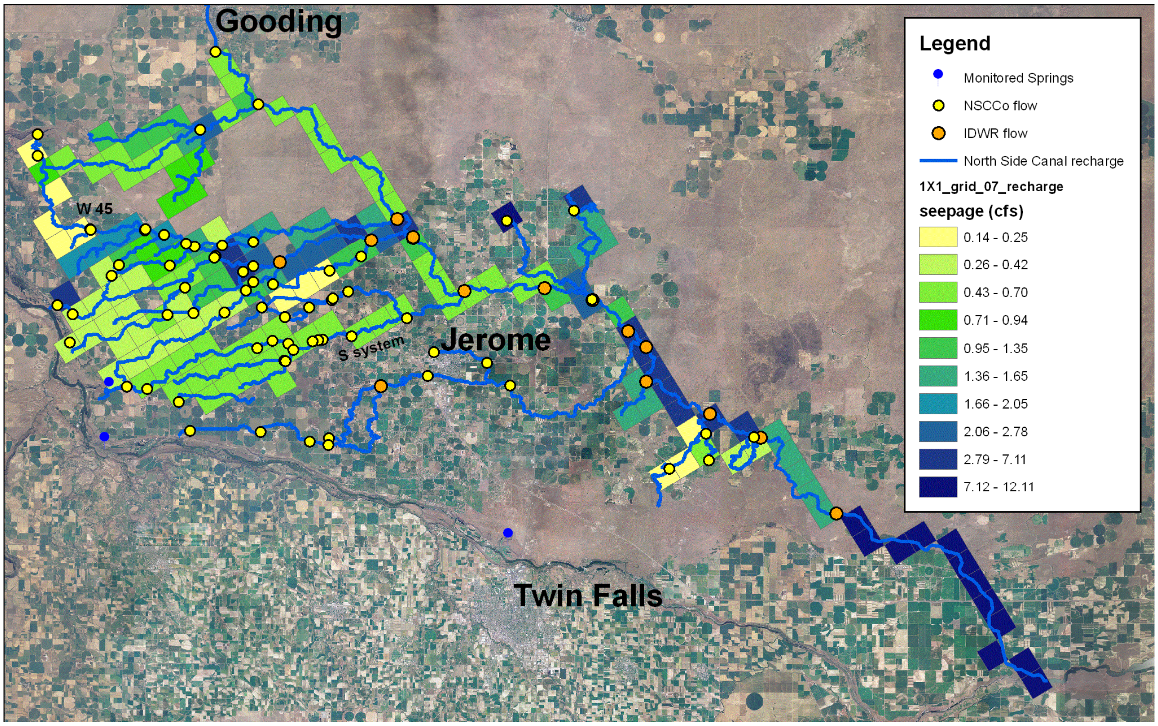


Figure 15. Computed seepage per model cell for November 27-28, 2007.

Once seepage from the canal system is assigned to model cells, the model can be used to predict the impact of recharge to the modeled river and spring reaches. Figures 16 and 17 show fraction of seepage the ESPA model predicts goes to the model reach containing Blue Lakes and the model reach containing Box Canyon Springs and Briggs Spring.

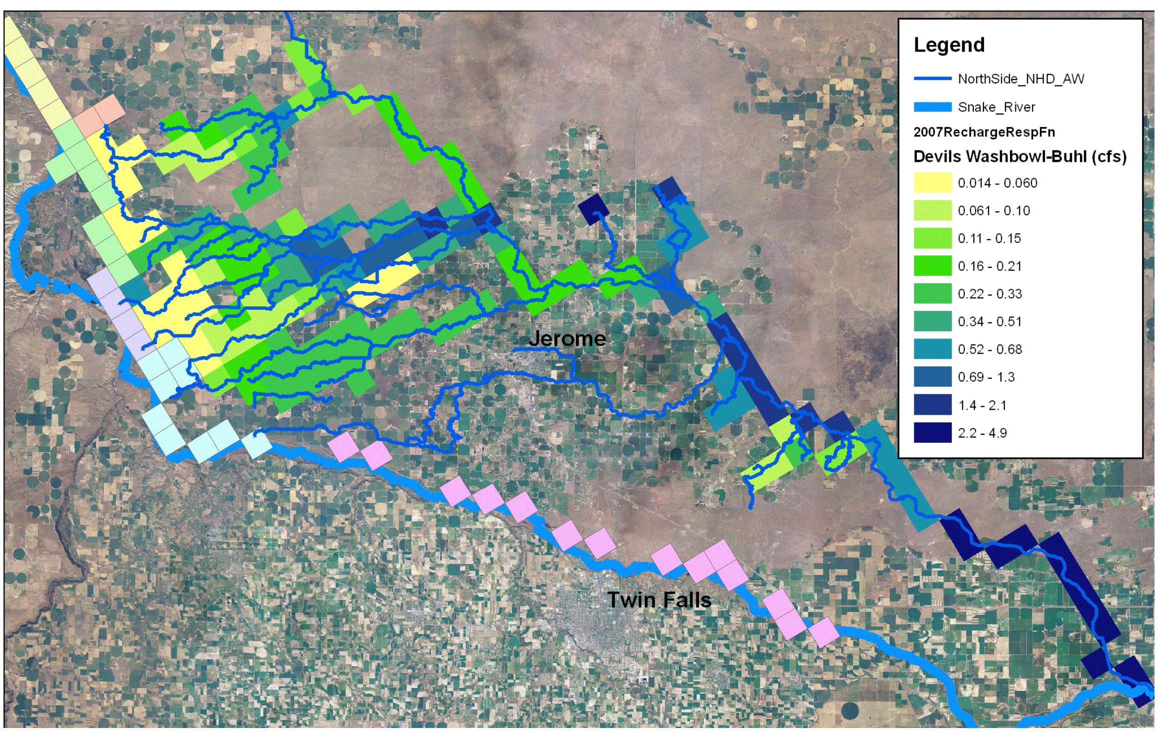


Figure 16. Seepage going to the model reach containing Blue Lakes (pink cells).

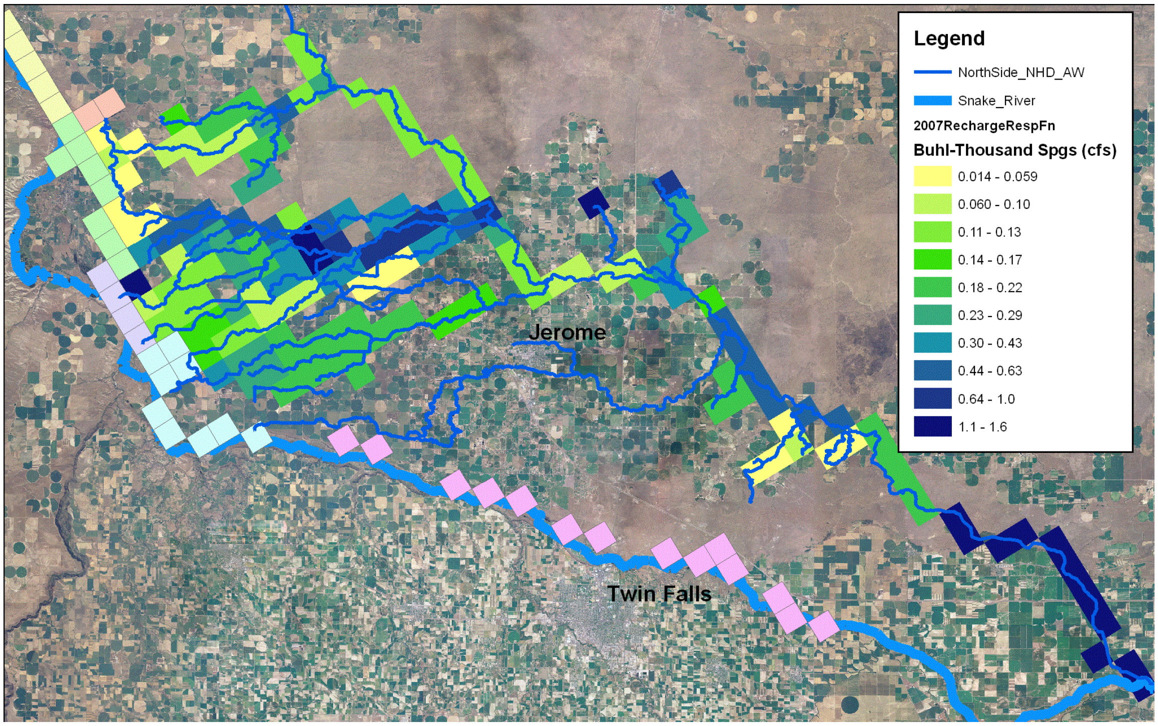


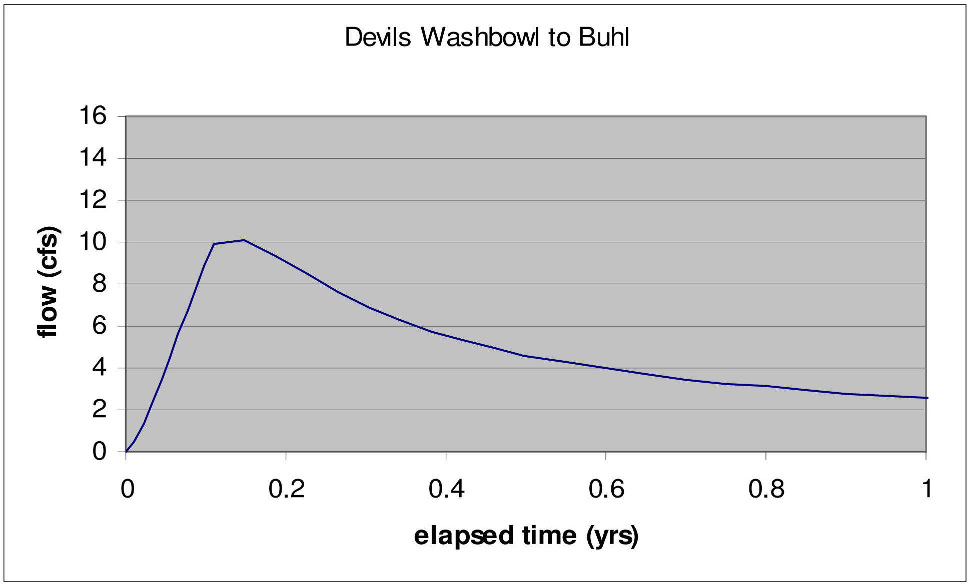
Figure 17. Seepage going to the model reach containing Briggs & Box Canyon Springs reach (powder blue cells).

Table 2 shows the percent of model-predicted impact that would arrive over time at each of the modeled reaches. Note that the two reaches benefiting the most from the recharge event are the targeted reaches.

Table 2. Modeled steady state impact from 2007 recharge.

Model Reach	% of recharge
Ashton-Rexburg	0.52%
Heise-Shelley	0.60%
Shelley-nr Blackfoot	4.44%
nr Blackfoot-Neeley	15.47%
Neeley-Minidoka	4.36%
Devils Washbowl-Buhl (Blue Lakes)	34.72%
Buhl-Thousand Spgs. (Briggs & Box Canyon Springs)	16.99%
Thousand Spgs.	12.67%
Thousand Spgs.-Malad	1.41%
Malad	8.50%
Malad-Bancroft	0.31%

Although the ESPA model should not be used to predict the benefit to individual springs, it can predict the benefit to the reach. Figure 18 shows the modeled transient benefit to the Devils Washbowl to Buhl and the Buhl to Thousand Springs reaches. The model indicates that the maximum benefit should be realized in the Devils Washbowl to Buhl reach about 54 days past the conclusion of the recharge event and in the Buhl to Thousand Springs reach about 40 days past the conclusion of the recharge event. The model also suggests that these benefits should be quite transitory, with around a two cfs or less benefit being realized in the reaches after one year.



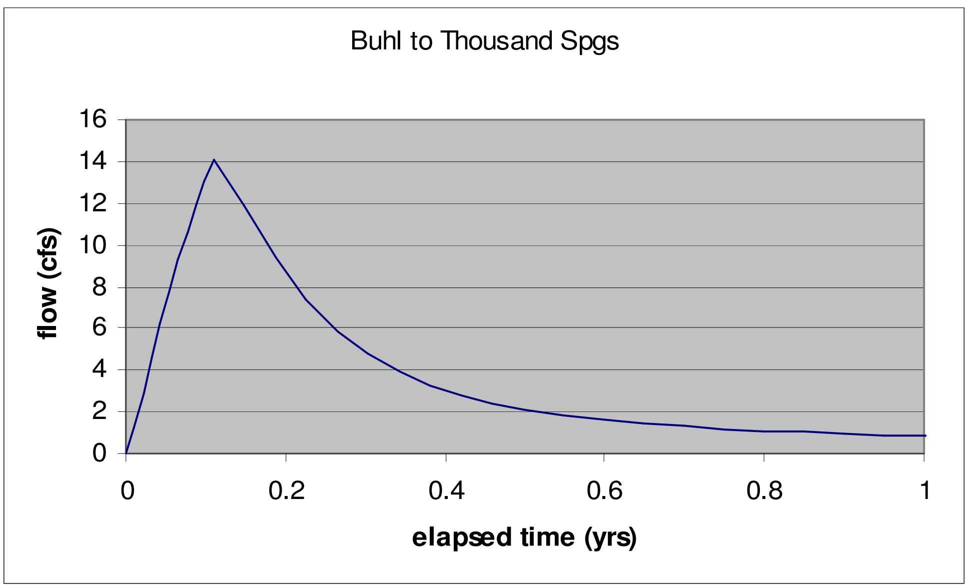


Figure 18. Modeled transient benefit for target reaches.

Conclusions

The 2007 post season recharge resulted in observable increases in aquifer water levels and spring flows. These benefits were only observable in springs and wells with a historical time series. Comparison of the historical time series to the data collected during the 2007 recharge event allowed the benefits from recharge to be more readily observed. Increased spring flows were observable in Briggs and Box Canon Springs monitored by the USGS. The ESPA model suggests that these observable benefits should diminish rapidly with time.

Acknowledgements

IGWA and IDA leased the water. NSCC accommodated the recharge experiment, provided personnel, and collected valuable flow measurements. Cindy Yenter and staff provided Boise IDWR staff with a tour of the canal system, and collected several flow measurements along the canal. IDWR acknowledges the special effort and cooperation that NSCC has generously provided in working with IGWA and IDA to help ensure the project's success.

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North Snake Ground Water District and Magic Valley Ground Water District Joint Supplemental Replacement Water Plan, 2007. In The Matter Of Distribution Of Water To Water Right Nos. 36-02356a, 36-07210, And 36-07427 (Blue Lakes Delivery Call) And In The Matter Of Distribution Of Water To Water Right Nos. 36-04013a, 36-04013b, And 36-07148 (Clear Springs Snake River Farm Delivery Call) Dated July 29, 2007.