SNAKE RIVER PLAIN AQUIFER MODEL SCENARIO:

MANAGED RECHARGE IN THE THOUSAND SPRINGS AREA

"Managed Recharge Scenario"

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INTRODUCTION

This scenario, *Managed Recharge in the Thousand Springs Area* (also known as the Recharge Scenario), is one of many Snake River Plain aquifer model scenarios being developed to assist in resolution of conflicts among water users and guide future water management such as implementation of managed recharge. Water management should be guided by a collective perspective from many of the scenario evaluations rather than a single document. These scenarios are being prepared for use with the enhanced Snake Plain Aquifer (ESPA) Model.

The enhanced Snake River Plain aquifer model was developed with funding provided by the State of Idaho, Idaho Power Company, the U.S. Geological Survey, and the U.S. Bureau of Reclamation. The model was designed with the intent of evaluating the effects of land and water use on the exchange of water between the Snake River Plain aquifer and the Snake River. This evaluation is part of the application of the model towards this purpose.

The model was developed by the Idaho Water Resources Research Institute (IWRRI) under the guidance, and with the participation of, the Eastern Snake Hydrologic Modeling Committee (ESHMC). The effort was led by the Idaho Department of Water Resources (IDWR) and active participants in the Committee included Idaho Power Company, the U.S. Geological Survey, the U.S. Bureau of Reclamation, and IWRRI. The ESHMC has also served to guide and review the scenario evaluation process. Documentation of the model and related activities are available from the Idaho Department of Water Resources and the Idaho Water Resources Research Institute at the University of Idaho.

This "Recharge Scenario" is intended to answer the question "If we had been recharging in the Milner-Gooding and Northside Canal recharge sites during the past 22 years using all available water and canal capacity, what would be the expected increases in discharges to the river as a result of the managed recharge?" This scenario models one of the proposed managed recharge methods documented in "Draft Managed Aquifer Recharge Proposal, Thousand Springs Area, Idaho" (IDWR, 2004).

The underlying theory of this scenario is that if, during the period of 1980-2002, we had been able to conduct managed recharge using available water, there would have been an increase in spring discharges to the Snake River. This scenario models this managed recharge and assesses the resultant distribution of gains to the Snake River. It is important to recognize that even after cessation of managed recharge activities, there is a residual impact to river reaches due to previous years of managed recharge. The magnitude and timing of this residual impact can also be evaluated using these scenarios.

This scenario has been evaluated using a numerical superposition method. Using numerical superposition, the impacts of managed recharge can be assessed in isolation of all other recharge and discharge.

The purpose of this scenario evaluation is to determine and describe how spring discharges and river gains and losses would be affected by conducting managed recharge. The specific objectives of this evaluation are to:

1) Predict the increases in spring discharges and river gains over time for simulated managed recharge during the 1980-2002 period.
2) Determine the seasonal magnitude of the expected increases.
3) Determine the residual impacts to the river gains after cessation of managed recharge activities.
4) Determine the predicted impacts to aquifer water levels due to managed recharge activities.

BACKGROUND

Managed recharge has been identified as one potential part of the solution to the problem of declining spring discharges from the eastern Snake River plain aquifer. Declines in spring discharges have been attributed to a combined effect of ground water pumping, changes in surface water practices and drought. Managed recharge has garnered particular interest because it can, in some cases, be accomplished for a relatively low cost using existing infrastructure and may provide a mechanism for capitalizing on high water years to help to sustain flows during low water years.

Managed recharge is the diversion of water from the river onto the plain for the sole purpose evoking changes to the hydrology or chemistry of the aquifer. The goals of managed recharge are typically either to increase aquifer water levels and river gains or to alter the water chemistry via dilution. In the case of the Snake Plain, the goals of managed recharge would be to change the hydrology such that aquifer water levels and aquifer discharges to the river would be increased. Previous studies (Johnson and others, 19xx; Sullivan and Johnson, 19xx) have shown that the greatest potential for managed recharge on the eastern Snake River plain is through the use of the existing canal system. The canals have unused capacity during the non-growing season. Several of the canals on the eastern Snake Plain carry diverted water long distances from the point of diversion to the point of use. These canals are often leaky, losing much of the water which is being conveyed. Additionally, these canals typically traverse large tracts of public land comprised largely of open areas of fractured basalt. Some of these areas are considered suitable for managed recharge.

Several problems with using existing canals for managed recharge are that a) there is limited canal capacity available for managed recharge, b) during the non-irrigation season, the canals are frequently undergoing repairs and c) the recharge typically occurs relatively near to the river. The result is that much of the recharge water returns to the river (via the aquifer) within several years and does not contribute on a widespread basis to regional aquifer water levels. However, such recharge water does contribute to increased spring discharges to the river.

DESCRIPTION OF THE NUMERICAL SUPERPOSITION MODEL

The numerical superposition version of the ESPA model is very similar to the fully populated ESPA model with all recharge and discharge terms removed and with a zero initial gradient. The numerical superposition model uses the concepts of superposition as detailed in Reilly and others (1987). The fundamental basis of superposition theory is that, for a strictly linear system, a complex problem can be decomposed into more simple sub-problems. The sum of the solutions of the sub-problems will be the same as the solution to the whole, more complex problem. As previously stated, application of superposition concepts depends upon the system being linear.

The ESPA model is a confined representation of a generally unconfined aquifer system. Confined aquifer model representations are strictly linear; unconfined aquifer model representations are non-linear due to the fact that aquifer transmissivity changes as aquifer water levels change. In the eastern Snake River Plain, the changes in aquifer water levels are very small relative to the total saturated thickness, so these non-linearities are considered negligible. A comparison of the confined version of the ESPA model versus the unconfined version has been done by IWRRI and will be published in a forthcoming report. Similarly, a comparison of model results using the fully populated model versus the numerical superposition model has been done by IWRRI and will also be documented in a report. These results have been presented to the ESHM committee.

Model parameters, which represent physical traits of the aquifer system, are the same for the numerical superposition model and the fully populated model. These parameters include aquifer transmissivity and storativity and river and drain conductance. The numerical superposition model starts with zero hydraulic gradient, so initial aquifer head is uniformly set to zero. The Modflow (McDonald and Harbaugh, 1988) representation of drains (springs) only allows water to leave the aquifer. The Modflow representation of rivers allows water to leave or enter the aquifer. Otherwise, drain and river representations in Modflow are identical. For the numerical superposition model, all drain cells (which were used to represent spring discharge between Milner and King Hill) are converted to river cells. The initial elevation of the river cells is set to zero. This creates an initial condition where there is no flux between the aquifer and surface water features. All recharge and discharge terms are removed in the numerical superposition model except for the aquifer stress being evaluated. For example, simulation of an aquifer stress will induce flux from represented surface water features in an amount that is equal to the depletion of rivers and springs for the same stress in the fully populated model. The results from this simulation represent the impacts from the particular aquifer stress being evaluated in isolation of all other recharge and discharge.

A simple example would be evaluation of the impacts to river reaches due to pumping at a single well. Pumping at the well does not affect any of the other sources of recharge or discharge. For example, pumping will have no effect on precipitation or evapotranspiration. The cone of depression from the pumping well will propagate radially from the well until the resultant drawdown affects water levels near a river reach. At that time, the pumping will result in a reduction of the river gain or increase in river loss. By analyzing this stress using the numerical superposition model, all exchanges between the river and aquifer will be due to the ground water pumping being evaluated. Evaluation of the same pumping well using the fully populated model would require running the fully populated model with and without the pumping well and differencing results of the two model runs. The latter analysis is more cumbersome and more prone to analysis and numerical error.

Evaluation of the impacts of managed recharge was greatly facilitated by using the numerical superposition model. The numerical superposition model is not restricted to the 22-year period of the fully populated model and the effects of managed recharge can be evaluated in isolation of all other recharge and discharge, yielding an estimate of expected *changes* in river gains and spring discharges due to managed recharge. Evaluation of the results of this scenario using numerical superposition can be used to estimate expected impacts to river gains due to managed recharge and the expected residual impacts to river gains once managed recharge activity has ceased. Using superposition allows analysis of future impacts without requiring knowledge of other future conditions such as weather.

MANAGED RECHARGE ANALYSIS METHOD

IDWR conducted an analysis of the potential for conducting managed recharge using the Milner-Gooding and Northside Canals (IDWR, 2004). Figure 1 shows the location of these two canals relative to hydraulically connected reaches of the river, as represented in the Enhanced Snake Plain Aquifer Model. The draft IDWR Managed Recharge report (IDWR, 2004) advocates use of the existing canal system to deliver water to recharge sites during the non-irrigation season. Managed recharge would be accomplished both via conveyance losses from the canals as well as seepage at selected recharge sites. The draft IDWR Managed Recharge report identified six potential managed recharge sites along the Milner-Gooding and Northside Canals (figure 2). Limiting factors on conducting managed recharge in this manner include a) water availability, b) canal carrying capacity and c) estimated site seepage capacity.

The draft IDWR Managed Recharge Report assessed water availability on a year by year basis between 1982 and 2001. In order to better align with the model calibration period for which the components of recharge and discharge are reasonably well understood, IDWR extended the analysis to 1980-2002. Both in-stream flow and Rental Pool water were evaluated for availability. The base assumption was made that diversions of in-stream flow for managed recharge would not reduce the flow past Milner Dam below 750 ft^3/sec. Any in-stream water in excess of 750 ft^3/sec was presumed available for managed recharge.

For the purposes of this scenario evaluation, only water available from in-stream flow was considered. This decision was made by the ESHMC based on a question of whether Rental Pool water could legally be used for managed recharge. Figure 3 shows the estimated water available for recharge from in-stream flows by 6-month stress period. The water availability shown in figure 3 takes into account a) maintaining a 750 ft^3/sec flow past Milner and b) canal and recharge site capacity. Figure 3 shows that there is a great variation in water available for recharge from year to year. On average, 170,000 acre-feet were available annually for the modeled period. Water availability is a function of a) current year precipitation, b) reservoir carryover from the previous year and c) irrigation demands. The reader is referred to the draft IDWR Managed Recharge Report for more details.

It should be noted that it is impossible to predict future flows. By using the estimated amount of water available during the 1980-2002 period, we can get a reasonable indication of the occurrence of excess flow available for managed recharge.

Recharge values for 44 6-month stress periods were provided by IDWR. The recharge data were mapped to the model grid using geographical information system tools. The numerical superposition model was run for both the transient and the steady state cases. The steady state model was run using an average recharge for the 44 stress periods. The transient model was run using 100 6-month stress periods. The first 44 stress periods reflected the recharge data received from IDWR. In the subsequent 56 stress periods, no recharge was modeled, allowing analysis of impacts to the model river reaches after the cessation of managed recharge. Results were analyzed by aggregating the modeled river cells into sub-reaches. The addendum to this report details the data files and steps necessary for running this scenario.

MODEL RESULTS

Steady State Results

The steady state results reflect the impacts to each river sub-reach of applying the average of the 22 years of recharge for an infinitely long time. Table 1 summarizes the steady state results, listing the steady state impact to each of the sub-reaches of the Snake River which are represented in the model in ft^3/sec. Additionally, for each sub-reach, table 1 lists the percentage of the total sub-reach gain that this impact represents. Note that these percentages are based on the average sub-reach gain predicted by the 22-year calibrated model. These percentages were based on modeled average gains because measured gains are not available for the sub-reaches in the Thousand Springs area. Also note that these percentages are absolute values of the modeled reach gain or loss. The percentages are provided to give the reader an idea of the magnitude of the predicted impact of managed recharge relative to the predicted total reach gain.

Table 1. Summary of Steady State Reach Impacts.

Sub-Reach	**Recharge Impact (cfs)**	**Percent of SS Model Reach Gains**
Ashton-Rexburg	2.9	1.5
Heise-Shelley	2.0	0.4
Shelley-Near Blackfoot	10.7	0.4
Near Blackfoot-Neeley	46.7	2.1
Neeley-Minidoka	9.4	39.8
Sum of Upper Snake Sub-Reaches	**71.7**	**4.6**
Devil's Washbowl-Buhl	83.0	8.6
Buhl-Thousand Springs	30.8	1.9

Thousand Springs	18.5	1.0
Thousand Springs-Malad	1.7	2.2
Malad	17.5	1.5
Malad-Bancroft	0.3	0.3
Sum of Thousand Springs Sub-Reaches	**151.8**	**2.7**
TOTAL	**223.4**	**3.1**

Inspection of table 1 shows that the total predicted steady state river gain due to this managed recharge scenario is approximately 223 ft^3/sec. Of this total, approximately 72 ft^3/sec would impact the river above Milner and 152 ft^3/sec would impact the springs below Milner.

Impacts to the river above Milner would be the result of the effects of the managed recharge radiating in all directions from where the stress (managed recharge) is applied. Impacts do not follow flow paths, but radiate symmetrically from the point of the stress. The symmetry is altered by areas of higher or lower transmissivity or when the impacts reach a hydraulic boundary such as the river. Figure 4 shows a map of the transmissivity for the calibrated Enhanced Snake Plain Aquifer Model. The reader will note that there is an area of high transmissivity to the northeast of the Milner-Gooding Canal which would facilitate movement of the impacts to the Snake River above Milner. Additionally, some of the applied managed recharge water is to the east of the Devil's Washbowl to Buhl sub-reach. Recharge in this area would have an impact almost equally on the upper and lower Snake reaches.

Canal loss represented approximately half of the managed recharge represented in this scenario. The other half was recharged via the managed recharge sites. Table 2 lists the steady state recharge for each of the six recharge sites. The reader will note in figure 2 that four of the managed recharge sites are located in the eastern portion of the two canals, very close to the Devil's Washbowl to Buhl sub-reach. Inspection of table 1 shows that the Devil's Washbowl to Buhl sub-reach is predicted to gain 83 of the total 152 ft^3/sec gain in below Milner. Additionally, inspection of table 1 shows that the Thousand Springs to Malad sub-reach has a relatively small predicted gain of 2 ft^3/sec. The Thousand Springs to Malad sub-reach is a relatively small sub-reach flanked by two sub-reaches with very large discharge (Thousand Springs and Malad sub-reaches). Further inspection of table 1 shows that the predicted gain in the Thousand Spring and Malad sub-reaches are 19 and 18 ft^3/sec, respectively. The predicted magnitude of impact to these three sub-reaches underscores the difficulty of attempting to target specific springs with managed recharge. Although the Thousand Springs to Malad sub-reach contains springs with very senior water rights, it is flanked by larger springs with more junior water rights which capture most of the water in that vicinity.

Table 2. Steady state recharge applied at recharge sites.

Location	Average AF/yr
R1	22,182
R2	17,169
R3	8,079
R4	32,595
R5	27,332
R6	1,603
Total	**108,960**

Transient Results

A transient model predicts impacts as they occur over time. In the case of the Managed Recharge Scenario, the transient model is predicting impacts due to managed recharge activities to each of the eleven sub-reaches of the Snake River at 6-month intervals. River reaches which are close to the area of managed recharge will, in general, experience larger impacts earlier in time, tapering off quickly after cessation of managed recharge activity. River reaches which are more distant will experience a delay before realizing any impacts and the expected impacts will be lower in magnitude. However, the residual impacts after cessation of managed recharge activity will continue longer into the future for distant reaches than for reaches close to the recharge area.

The transient results will be discussed relative to the stated objectives of the Managed Recharge Scenario. As previously stated, the transient numerical superposition model was run using 100 6-month stress periods. The first 44 of the 6-month stress periods applied the recharge values as estimated by IDWR. No recharge was applied for the following 56 6-month stress periods. These stress periods were used to analyze recovery after cessation of managed recharge activity.

Description of Increases in Spring Discharges and River Gains over Time for Simulated Managed Recharge During the 1980-2002 Period (Objective 1)

Figures 5 through 15 show the predicted impacts due to the modeled managed recharge for the eleven sub-reaches of the Snake River. Each figure follows the same format, which will be described for figure 5. Time (in years) is displayed on the x-axis and recharge impact to the specific sub-reach (in ft^3/sec) is displayed on the y-axis. The reader will note the vertical red line on figure 5. This line marks the cessation of simulated managed recharge activity. Recharge is modeled for the first 22 years and recovery is modeled for the last 28 years. The reader will also note that the predicted steady state impact is noted on figure 5 with an X. This is the final expected sub-reach impact if the average of the 22 years of available water were recharged every year indefinitely.

To illustrate the difference in predicted magnitude of impact for reaches close to the recharge sites versus reaches distant from the recharge site, the reader is encouraged to compare the results shown in figure 5 and figure 12. Figure 5 shows the predicted gains in the Ashton to Rexburg sub-reach and figure 12 shows the predicted gains in the Thousand Springs sub-reach. Impacts to the Ashton to Rexburg sub-reach take a long time to propagate from the recharge site.

Inspection of figure 5 shows that the predicted impacts slowly build up, actually peaking several years after cessation of recharge activities. The maximum predicted impact in the Ashton to Rexburg sub-reach is approximately 1.7 ft^3/sec, occurring in approximately year 28. In contrast, figure 12 shows that the Thousand Springs sub-reach impacts are predicted to occur almost immediately (within 1 year) of the recharge activity and reflect the pattern of the applied recharge shown in figure 3. The maximum predicted impact to the Thousand Springs sub-reach is 30 ft^3/sec and occurs in year 20, after five years of available water for managed recharge. This illustrates that the impacts to sub-reaches close to the managed recharge areas will be experienced almost immediately and will not last long into the future. This implies that managed recharge which is conducted close to a river reach will have an almost immediate impact on the reach but will not serve to sustain spring flows for a long period of time.

Another way to interpret these graphs is to look at the predicted increases in each sub-reach at year 22 (where the vertical red line appears in figures 5-15). If we had been recharging during the period of 1980-2002, flows in the sub-reaches in 2002 would have been increased by the rate indicated on each graph at the 22-year mark. For example, for the Devil's Washbowl to Buhl sub-reach (figure 10), after 22 years of recharging, flows in this sub-reach would have been approximately 50 ft^3/sec higher than what actually occurred in 2002.

Description of the Seasonal Magnitude of the Expected Increases (Objective 2)

Figures 5 through 15 also demonstrate the predicted seasonality of impact to the river sub-reaches. Inspection of figure 5 (Ashton to Rexburg sub-reach) shows that there is almost no seasonal component to the predicted impacts. This is due to the fact that the impacts take a long time to propagate to the reach and are greatly attenuated over time, so the seasonality is smoothed out. In contrast, figure 12 shows that the Thousand Springs sub-reach, which is close to the area of managed recharge, has a very distinct seasonal component. In general, water for managed recharge is expected to be largely available during the non-irrigation season and less available during the irrigation season. The seasonal peaks are expected to occur in the spring at the end of the non-irrigation season.

The discharge at springs influenced by surface irrigation rises during the irrigation season, peaks at the end of the irrigation season and recovers during the non-irrigation season. For springs influenced by surface water irrigation, the seasonal nature of managed recharge conducted in the proposed manner will tend to offset the seasonality imposed by surface water irrigation activities, tending to even out the flows in these springs.

Description of the Residual Impacts to the River Gains After Cessation of Managed Recharge Activities (Objective 3)

Even after cessation of managed recharge activities, the effects of the managed recharge activities will propagate through the aquifer. Some residual effect will be realized at each sub-reach after cessation of managed recharge activities. The magnitude and timing of this residual impact will depend upon how close the sub-reach is to the managed recharge site. Again, inspection of figure 5 shows that the Ashton to Rexburg sub-reach is predicted to experience positive impacts from the modeled managed recharge activities for decades into the future.

These impacts will not be large in magnitude, but will continue long into the future. This can be seen in figure 5 as the portion of the graph to the right of the vertical red line.

Figure 12 shows that, for reaches close to the managed recharge activity, although there will be some residual impacts, these impacts will be small in magnitude and will quickly decline. In the case of the Thousand Springs sub-reach, the residual impacts are predicted to rapidly decline from an approximate level of 10 ft^3/sec.

<u>Description of the Predicted Impacts to Aquifer Water Levels Due to Managed Recharge Activities (Objective 4)</u>

Managed recharge activity is anticipated to have a positive impact to aquifer water levels. Figure 16 shows a predicted potentiometric surface map at steady state due to the modeled managed recharge. Figure 16 shows that the greatest predicted increase in aquifer water levels (22 ft) is located near the area of greatest recharge (the eastern end of the two canals, where four of the six recharge sites are located). Although the predicted impacts to aquifer water levels elsewhere on the Snake Plain are less than the maximum predicted impact of 22 ft, there is a predicted impact of 2 ft as far away as the American Falls area.

Figures 17 through 22 show predicted hydrographs for six selected locations on the plain. These hydrographs represent the predicted changes in aquifer water levels due to the modeled managed recharge activity. Figure 17 shows predicted changes in aquifer water levels in the Mud Lake area. Inspection of figure 17 shows that the Mud Lake area is expected to realize a maximum change in water level of approximately half a foot. Similar to the reach gains for reaches which are distant from the managed recharge site, the changes in aquifer water levels in the Mud Lake area are predicted to increase slowly and then to slowly decline after cessation of managed recharge activity.

In contrast, figure 22 shows predicted changes in aquifer water levels at a well very close to one of the recharge sites in the Thousand Springs area. The hydrograph for this well shows very rapid predicted response to the managed recharge activity, with seasonal swings of approximately 2 ft.

SUMMARY

Managed recharge has the potential for providing one means to help relieve water supply issues on the eastern Snake River plain. The ESPAM model was used to predict response to a managed recharge scenario designed by IDWR (2004) which uses the Milner-Gooding and Northside canals for conveyance to six managed recharge sites. The amount of water available for recharge was calculated based on excess in-stream flows determined from actual flow records. The predicted benefit to river sub-reaches varies depending upon proximity to the managed recharge site. Reaches close to the site will experience the greatest benefit from managed recharge, however the benefit will not be sustained long into the future. Reaches more distant from the site will receive less benefit, but the benefit will continue into the future long after cessation of managed recharge activity.

The predicted seasonality of the benefit will also depend on proximity of the reach to the managed recharge site. Reaches close to the managed recharge site will exhibit a high degree of seasonality, unlike more distant reaches.

It will be difficult to use managed recharge to target reach gains in a specific sub-reach or spring. The positive benefits will be spatially distributed among all hydraulically connected river reaches. Managed recharge is also expected to have a positive impact on aquifer water levels. As with increased flows, the greatest benefit to aquifer water levels will be realized in areas close to the recharge site.

One of the least expensive ways of conducting managed recharge is through the existing canal system. Unfortunately, the canals tend to be located close to the river reaches, so the recharge water at these sites tends to exit the aquifer rather quickly. However, managed recharge has a definite positive, stabilizing effect on river reaches. Even if the impacts of managed recharge are only sustained for two or three years, it is still viable as a method for helping to stabilize spring discharges.

REFERENCES

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