Opportunities to Affect the Water Budget of the Eastern Snake Plain Aquifer of Idaho

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INTRODUCTION

The Idaho Water Resource Board has been tasked with preparing a framework for an Aquifer Management Plan for the Eastern Snake Plain Aquifer of Idaho. In support of this task, Idaho Water Resources Research Institute (IWRRI) has performed an analysis of the components of the water budget of the aquifer. This document reports on that work, assuming that "active aquifer management" means controlling the *amount* and *quality* of water going into (recharge) and out (discharge) of the aquifer.[1] This work has been reviewed by Idaho Department of Water Resources but not by the Eastern Snake Hydrologic Modeling Committee. Details of data, assumptions and calculations are contained in an accompanying appendix.

An aquifer water budget is an accounting of the sources of water to the aquifer and the discharges of water from the aquifer. The largest source of recharge to the Eastern Snake Plain Aquifer is incidental recharge from surface-water irrigation, both in-field percolation and canal seepage. The largest discharge from the aquifer is direct discharge to the Snake River and to springs along the canyon rim above the river. Ground-water pumping (mostly for irrigation) is another large discharge from the aquifer.

Some components of the water budget (recharge from precipitation, for instance) depend on natural processes and cannot be influenced by human activity. Other components (spring discharge and river gains) depend on aquifer water levels, which are influenced by both natural and human processes. Other components (such as ground-water pumping) may be directly controlled by human action.

This report considers only the physical ability to change recharge and discharge from the aquifer, without considering water quality, administrative, policy, or economic implications. The purpose of the report is to provide the Idaho Water Resource Board with a context of the relative impact of potential activities as it considers the policy and economic implications of actions that may be considered. Some of the possibilities presented here may require legislative action for implementation, or may not even be possible administratively.

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[1] A plan could also address efforts to influence the *timing* of aquifer discharges. Except for identifying the expected time delay for benefits to accrue, this report does not address changing the timing of aquifer discharges.

This report is focused on the aquifer. Other potential effects of activities (for instance, the aid that managed recharge may provide in management of the river hydrograph and flood control) are not considered. Similarly, all economic effects (positive or negative) are ignored in this report.

The values here are *potential maximum* values. It is expected that actual implementation will be less. For instance, the reported value for reducing ground-water pumping for irrigation is the expected effect if *all* ground-water irrigation were retired, and the reported value for reducing municipal and domestic use is the volume expected if *all* ground-water use for these purposes were retired; neither of these actions is likely. The rationale behind reporting the full potential benefit rather than some reduced amount is to avoid errors in calculating the reductions. Because all these activities are reported on the same basis, they are directly comparable.

This is a survey-level effort that depends on prior data, prior analyses, and some new analyses based on best-available data and estimates. As particular policy actions are considered for implementation, more refined analysis may be in order. This preliminary analysis suggests that the potential effect of individual actions ranges from 38,000 thousand acre feet to as much as 2,100,000 acre feet per year. There is some uncertainty in input data and modeling results, but the largest uncertainty in this process is uncertainty as to the extent of implementation that might eventually be adopted.

EASTERN SNAKE PLAIN AQUIFER WATER BUDGET

Components

The basic recharge components of the water budget are:

1. Recharge from surface-water irrigation
    a. In-field percolation
    b. Canal seepage
2. Seepage from rivers and streams
    a. The Snake River
    b. Streams tributary to the Snake River
    c. Streams that sink at the margins or on the surface of the Eastern Snake Plain
3. Underground inflow from tributary basins adjoining the plain
4. Percolation from precipitation

5. Managed recharge (when this occurs)

The basic discharge components of the water budget include:

1. Discharge to springs
2. Discharge directly to the bed of the Snake River (river gains)
3. Pumping for human use
   a. Agricultural irrigation
   b. Municipal
   c. Commercial and industrial
   d. Dairy and livestock production
   e. Rural domestic
4. Evapotranspiration by vegetation in areas where the water table intersects the root zone (Fort Hall Bottoms, for instance)

Physical Mechanisms to Influence Water Budget

Budget Components Beyond Human Control. Some components of the water budget are beyond human control. These include:

1. Seepage from perched reaches of rivers and streams.[2]
2. Recharge from precipitation, within the bounds of the aquifer.
3. Recharge from precipitation in tributary basins:
   a. Precipitation that becomes ground-water underflow into the regional aquifer.
   b. Precipitation that becomes flow in streams that sink into the regional aquifer.

Some other components are indirectly under human control (human activities affect aquifer water levels, which affect these components) but influencing these components will be the *outcomes* of a successful aquifer management plan, not actions that may be taken as *parts of* a management plan:

1. Seepage from hydraulically-connected losing reaches of the Snake River.
2. Aquifer discharge to gaining reaches of the Snake River.
3. Discharge to springs.

Negative Impacts. While the purpose of this report is to quantify *beneficial* (to the aquifer) actions that an aquifer management plan may consider, it is important to consider potential negative (to the aquifer) impacts that may be simultaneously

[2] To the extent that seepage is a function of stage, and to the extent that stage can be affected by diversions and storage releases, seepage from perched streams can be influenced by human activity.

undertaken by other parties, for other purposes. These are listed but not quantified. Some of these activities (such as canal lining or conversion to sprinklers) may even be currently taking place with state or federal funding or sponsorship. Potential negative actions include:

1. Lining of canals.
2. Conversion from gravity irrigation to sprinkler irrigation.
3. Increase in ground-water irrigated acreage.
4. Increase in surface-water irrigated acreage without a corresponding increase in surface-water diversions.
5. Change to more consumptive crops.
6. More intensive production of existing crops, resulting in increased consumptive use per acre.
7. Removing surface-water supplies from lands that are developed for residential or commercial purposes.
8. Increased reliance on ground water on mixed-source lands.
9. Decrease in surface-water irrigated acres with a corresponding reduction in surface-water diversions.

Positive Impacts. There are a number of activities that may be considered in an aquifer management plan that physically can cause more water to be stored in the aquifer than otherwise would have been. These can be activities that increase the supply of water to the aquifer, or activities that reduce the rate of extraction from the aquifer. Some of the activities would be undertaken within the geographic bounds of the aquifer itself, while others may also be undertaken in the valleys that are tributary to the aquifer. It is acknowledged that obstacles - administrative, economic, or social - may limit actual implementation of some of these actions. The purpose of this document is to identify and quantify the effect of possible actions, as an aid to the Idaho Water Resource Board as it contemplates the feasibility of undertaking these activities. Activities are presented without consideration of administrative authority, under the assumption that a plan could identify and call for beneficial activities that would be implemented by agencies other than the Idaho Water Resource Board.

The activities analyzed in this report are:

1. Reduction in acreage irrigated from ground water, within the aquifer boundaries.
2. Reduction in irrigation demand in basins tributary to the aquifer:
    a. Ground-water acreage in all basins.
    b. Surface-water acreage in basins whose streams eventually sink into the aquifer.

3. Reduction in commercial and industrial extraction (including dairies and livestock feeding operations).
4. Reduction in municipal and rural domestic extraction.
5. Managed aquifer recharge.
6. Conversion of irrigated lands to less-consumptive crops.
7. Conversion of ground-water irrigated lands to surface-water supplies:
    a. Permanent conversions.
    b. Temporary supplies of surface water to replace ground-water pumping on mixed-source lands.

At the most basic level, all these activities may be combined into two categories: 1) Activities that reduce consumptive use; 2) Activities that increase net delivery of surface water. These activities may take place on the lands overlying the aquifer or on lands in tributary basins. Any activity that does not perform one of these basic functions may be a redistribution of water but it is not a benefit to the aquifer as a whole. Even so, redistribution activities may be desirable; they may address current problems and serve to better meet the needs of water users. This report, however, is focused on activities that cause more water to be stored in the aquifer. All the activities presented influence the aquifer in one of the two ways discussed above. Other activities not discussed here (such as reduced irrigation from Snake River surface water) would be difficult to assess because they may simultaneously reduce consumptive use (benefit to the aquifer) and reduce net diversions (detriment to the aquifer).

DATA AND TOOLS

Data for the analyses are generally from the Eastern Snake Plain Aquifer Model (ESPAM) calibration data set or from the IDWR water-rights data. Some analyses were performed previously for modeling scenarios, and others were performed specifically for this document. One analysis uses the ESPAM itself, but most use tools previously developed by IWRRI that allow any user with a computer spreadsheet to perform specific analyses based upon the ESPAM. These tools are available at http://www.if.uidaho.edu/~johnson/ifiwrri/projects.html and include:

1. Water Rights Transfer Tool Version 2.1
2. Conversion and Replacement Steady State Spreadsheet (ESPAM v1.1)
3. Conversions Spreadsheet 1 (ESPAM v1.1)
4. Conversions Spreadsheet 2 (ESPAM v1.1)
5. Replacements Spreadsheet (ESPAM v1.1)
6. Managed Recharge Steady State Spreadsheet (ESPAM v1.1)
7. Lower Snake Managed Recharge Spreadsheet (ESPAM v1.1)

8. Upper Snake Managed Recharge Spreadsheet (ESPAM v1.1)
9. CREP Steady State Summary Spreadsheet (ESPAM v1.1)
10. CREP Transient Bannock to Cassia Spreadsheet (ESPAM v1.1)
11. CREP Transient Clark to Lincoln Spreadsheet (ESPAM v1.1)
12. CREP Transient Madison to Power Spreadsheet (ESPAM v1.1)
13. CREP Transient Summary Spreadsheet (ESPAM v1.1)

The Idaho Water Resource Board or other parties may wish to use these tools to evaluate specific proposals within each of these management-option categories. The tools are designed to allow the user to quickly apply hypothetical acreages, stresses, recharge volumes and participation levels and visualize the impact to the river and spring reaches. The tools produce graphs and tables that indicate the magnitude, timing and spatial distribution of the benefit of the activities tested.

Details of the assumptions, data sets used, and application of the above-described tools are outlined in an appendix to this report.

ANALYSES PERFORMED

Reduction in irrigated acreage. Discharge from the aquifer may be reduced by reducing the number of acres irrigated by direct ground-water extraction from the aquifer. Reducing acreage irrigated from ground water in tributary valleys increases recharge to the aquifer (via tributary valley underflow), and reducing acreage irrigated from streams that eventually sink into the aquifer also increases recharge to the aquifer (via percolation from stream beds).

Two earlier analyses (the Curtailment Scenario and the CREP spreadsheets) considered specific administrative actions that could reduce acreage irrigated by direct pumping from the aquifer, but these are not the only activities that could be used to reduce irrigated acreage. Regardless of the activity used, these two analyses indicate the range of benefits that could be expected from various levels of reduced pumpage. Based on the scenario data sets, reduction of irrigation pumping on the Eastern Snake Plain itself could provide an annual benefit ranging from 140,000 acre feet to 2,100,000 acre feet per year. Approximately 35 years are required for 90% of the benefit to be realized at the most-impacted reach, given the spatial location of the water-use changes described in the scenario. Approximately 58% of this benefit accrues above Milner.

The impact of irrigation in tributary basins can be estimated based on acreage derived from photos and remote sensing, and an assumed net consumptive use of two feet per year. Reducing ground-water irrigation in tributary basins, along with surface-water-irrigation in basins whose streams sink into the aquifer, could produce an additional benefit of 370,000 acre feet per year. Approximately 17 years are required for 75% of this benefit to be realized, and about 47 years for 90% to be realized. Most (approximately 88%) of this benefit is above Milner.

Reduction in Commercial, Industrial and Livestock Use. One potential reduction in consumptive use from the aquifer is to reduce commercial, industrial and livestock pumping from ground water. These water-right categories include nearly all dairy use.[3] Based on IDWR water rights, adjudication claims, and recommendations, the calculated maximum diversion volume for these rights, across the plain and tributary basins, is 221,000 acre feet per year. The contributions to this volume are:

1. Small stockwater rights (less than 0.25 cfs)	95,000 acre feet
2. Large stockwater rights	19,000 acre feet
3. Commercial rights	43,000 acre feet
4. Industrial rights	64,000 acre feet

As with all the potential actions described in this report, there is uncertainty in the administrative ability and desirability of reducing pumping under these rights. In addition, there is technical uncertainty in the potential maximum volumes reported above:

1. The potential benefit from retiring stockwater rights may be significantly over-estimated. One reason (for the small stockwater rights) is that decrees or licenses may have been issued at an administrative minimum rate that could be adequate for far more animals than actually are supplied with a given right.[4] Another reason (for all stockwater rights) is that some stockwater diversion rates are high enough to allow a full day's supply to be pumped in a few hours, to match historical beneficial use patterns. This may have caused an over-estimate of volume for rights without a listed volume, whose volume was calculated based on diversion rate.
2. These water uses may not be 100% consumptive; some percolation returns to the aquifer may occur.
3. Some of this water may offset ground-water irrigation through land application of waste water. Retiring this pumping therefore may induce increased pumping for irrigation, partially offsetting the reduction in commercial, industrial or stockwater pumping.

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[3] Very small dairies can operate under the 13,000 gallon-per-day limit of a domestic water right. However, larger dairies will hold both a stockwater right and a commercial right.

[4] One implication of this is that net extraction could potentially *increase* up to the water-right level, without any additional rights being issued.

Modeling indicates that within 12 years the benefit to the river will equal 75% of the reduced consumptive use and that within 36 years 90% of the benefit will be realized. The above-Milner benefit is 75% of the total.

Reduction in Municipal and Rural Domestic Consumptive Use. Municipal water rights and municipal pumping records indicate gross pumpage volume, some of which is percolation return to the aquifer. Many rural domestic water rights are not recorded in the IDWR water-rights data, since a water-right permit is not required to perfect a domestic right and the rights were deferrable in the Snake River Basin Adjudication. For these reasons, water-rights data and pumping data were not used to estimate the potential benefit of reducing consumptive use from municipal and domestic rights. Instead, impermeable-cover data (USGS 2001) were used with estimation methods from other studies (Contor 2006) to derive homes per square mile and water use per home. The net extraction was adjusted depending on whether it was expected that in-home use was discharged to a septic system that recharged the aquifer or to a public sewer system that discharges to a river or evaporation pond. This analysis indicates a potential maximum benefit of about 20,000 acre feet per year from reducing municipal extraction and an additional 18,000 acre feet from reducing rural domestic extraction, on the plain and in the tributary valleys. Within 11 years, 75% of this benefit is expected to be seen at the river, with 90% of the benefit occurring within 25 years. The above-Milner benefit is 84% of the total.

Managed Aquifer Recharge. The IWRRI Managed Recharge Scenario (Contor and others 2004) suggests that the potential benefit of managed aquifer recharge averages about 170,000 acre feet per year.[5] The scenario did not directly calculate the time for 75% and 90% of the benefit to accrue, but inspection of the figures suggests that the bulk of benefits accrue within ten or fewer years. The reader is referred to the scenario itself for discussion of the details of calculations, the range of possible recharge volumes, and the assumptions of the scenario.

The above-Milner benefit was 35% of the total, but the scenario purposely focused simulated recharge deliveries to lower-valley recharge sites. Neither the scenario nor this analysis addresses upper-valley recharge. Springtime recharge in the Aberdeen-Springfield area may benefit the Near Blackfoot to Milner reach during the critical mid-to-late summer period. Potentially, recharge in the fall or early spring in the Henrys Fork area could sustain early-summer and mid-

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5 A more conservative analysis suggests that 40,000 to 60,000 acre feet per year may be a more appropriate estimate (Idaho Water Resource Board Working Group meeting, Burley Idaho, 13 December 2006). However, the original scenario estimate is more consistent with other components discussed here, which are considered in terms of potential maximum levels.

summer diversions below Idaho Falls and above American Falls. This could have a secondary effect of delaying and reducing ground-water pumping from supplemental wells and increasing incidental recharge near American Falls, thereby also sustaining reach gains in the critical mid-to-late summer period for the Near Blackfoot to Minidoka reach. These possibilities warrant further study.

<u>Change to Less-consumptive Crops.</u> Crops such as corn, alfalfa and sugar beets consume more water per acre than crops such as beans, potatoes[6] and small grains. In the higher-elevation, northern counties a hypothetical rotation of two years barley, one year potatoes is possible. In the lower-elevation, southern counties, a rotation of barley, beans, potatoes is possible.[7] This low-consumptive crop regime would result in a reduction in consumptive use of approximately 950,000 acre feet per year, across the plain and tributary valleys. If there were *no corresponding reduction* in surface-water diversion volumes, this would all accrue to the benefit of the aquifer. Within 15 years, 75% of this benefit would be expressed at the springs and rivers, and 90% would be seen within 35 years. The above-Milner benefit is about 68% of the total. If surface water diversions *were* reduced, the only benefit to the aquifer would be the reduction of consumptive use on ground-water-irrigated acres. This would reduce the benefit by approximately half and would also likely change the timing and spatial distribution of benefits to some extent.

<u>Conversion of Ground-water Irrigated Lands to Surface-water Supplies.</u> Previous work by Contor and others (2005) indicates that potential conversion projects already identified by IDWR and the Idaho Water Resource Board could potentially benefit the aquifer by 120,000 acre feet per year.[8] The time-to-benefit was not explicitly calculated, but inspection of the figures indicates that most of the benefit will occur within only a few years, due to the proximity of conversion lands to the river. Approximately 41% of the benefit will accrue above Milner.

Additionally, temporary application of a full surface-water supply to the mixed-source lands (lands with both surface-water and ground-water rights) in districts or companies served by the Snake River could replace 230,000 acre feet of consumptive use from ground-water pumping and provide an additional 230,000 acre feet of incidental recharge from in-field percolation, for a total benefit of 460,000 acre feet per year. This benefit would accrue to the springs and rivers

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6 Potatoes must be irrigated very frequently and require careful irrigation management and constant water supplies. However, the actual annual consumptive use of potatoes *is* significantly less than for some other crops.

7 Contract, economic and market considerations are ignored in this analysis.

8 Technical staff for the Idaho Water Resource Board identified 100,000 acre feet per year of potential conversions as Strawman Proposal targets (Patton 2006). The higher value in the unpublished scenario came from lengthy discussions within the Eastern Snake Hydrologic Modeling Committee late in 2004 and early in 2005.

with 75% of the benefit seen in five years and 90% within 17 years. The above-Milner benefit is about 87% of the total.

DISCUSSION AND SUMMARY

Discussion

Implementation of Activities. If implementation of these activities is contemplated, several factors should be kept in mind:

1. The maximum potential benefits of these activities have been presented here. It is understood that the actual realized benefits would likely be less.
2. Some activities (managed recharge, for instance) are within the current scope of statute and policy, while others (changing crop mix) may not be. Both types of activities are presented in the spirit that a plan should contemplate and address *all* potentially beneficial activities, even if the plan adopted speaks only to the legislative or policy changes that would be necessary to adopt the activity.
3. A plan conceptually could include elements that are possible within existing policy or legislation, but under an authority other than the Idaho Water Resource Board. In this case, a plan could discuss and recommend the activity, even if other agencies would implement it.

Interrelationships between activities. Some of these activities are independent, but some are interrelated. The total ability to influence the aquifer is not simply the sum of the individual components presented here.

1. The estimates for reductions in ground-water irrigation are based on remote-sensing data that may effectively include much of the livestock and rural domestic consumptive use. Therefore, the potential benefits of reducing stockwater or rural domestic extraction may be "double counting" water already presented as a potential benefit of reducing ground-water irrigation.
2. Except as noted above, activities that reduce consumptive use can be conducted simultaneously, without hydrologic interference. Their benefits are additive.
3. Other activities are essentially mechanisms to increase net diversions from the Snake River. They compete for the same available supply and are therefore may not be additive.
4. Though competing for water supply, activities that increase diversion may still be complementary, due to different timing, policy or administrative implications. For instance, managed recharge and temporary delivery of surface water to offset ground-water pumping on mixed-source lands could be complementary: During some seasons, managed recharge

could be accomplished when irrigation was not authorized. During other periods, water could be delivered as irrigation water to offset ground-water pumping, when recharge might be subject to a water-right restriction.

Historical context. Current Snake River diversions are about 1,000,000 acre feet per year lower than 1950s levels. It is believed that irrigation water rights and diversion and delivery structures have not lost significant capacity since the 1950s.

Supply limitations. As noted, all activities that benefit the aquifer by increasing the net diversion of water from the Snake River necessarily compete for the same finite supply of water (with each other, and with other uses). An aquifer management plan could greatly benefit the aquifer by explicitly proposing activities to increase the availability of surface water for aquifer purposes, including purchase or lease of natural-flow and storage water or water rights.

Comparing potential activities. Because all these activities are presented on a maximum potential basis, they may be directly compared. There is some uncertainty in both the input data and analysis tools used. Again, though the magnitudes are somewhat uncertain, the components are on equal footing and may be directly compared. The uncertainty in the physical potential magnitudes of benefits is overshadowed by the larger uncertainty in the administrative, political and economic feasibility or desirability of implementing these actions. Actual implementation and benefits are likely to be at lower levels than the maximum potential values given here.

Summary

Table 1 presents the budget components that reduce consumptive use. Table 2 presents budget components that increase net diversions from the Snake River. Both tables give the maximum magnitude of benefits, the expected timing of these benefits being expressed at springs and river reaches, and the spatial distribution of benefits to reaches. The timing of benefits is generally based on the aggregate of all the reaches, which is dominated by reaches with high benefit fractions. Generally, reaches with high benefit fractions may see results slightly sooner, and reaches with low benefit fractions will see results considerably later than these average times.

Table 1
Potential Reductions in Consumptive Use
from the Eastern Snake Plain Aquifer and Tributary Valleys
(Note that the livestock and rural domestic components may duplicate effects included in the ground-water irrigation component.)

Activity	Reduce GW Irr. Acres, Plain	Reduce Irr. Acres, Tribs.	Reduce Commercial, Industrial, Livestock	Reduce Municipal and Domestic	Change Crop Mix
Acre ft/yr	2,100,000	370,000	221,000	38,000	950,000
Yrs to 75%	-	17	12	11	15
Yrs to 90%	35	47	36	25	35
Above Milner	58%	88%	75%	84%	68%
Below Milner	42%	12%	25%	16%	32%

Table 2
Potential Mechanisms to Increase Net Diversions
from the Snake River to the Eastern Snake Plain Aquifer
(Note that these activities are supply-limited and compete for the same supply.)

Activity	Managed Recharge	Permanent GW Conversions to SW Supply	Temporary Supply of SW to Offset GW Pumping on Mixed-source Lands
Acre ft/yr	170,000	120,000	460,000
Yrs to 75%	<10 (approx)	<10 (approx)	5
Yrs to 90%	-	-	17
Above Milner	35%	41%	87%
Below Milner	65%	59%	13%

Figure 1 illustrates the relative maximum volume of benefit from each of these potential activities.

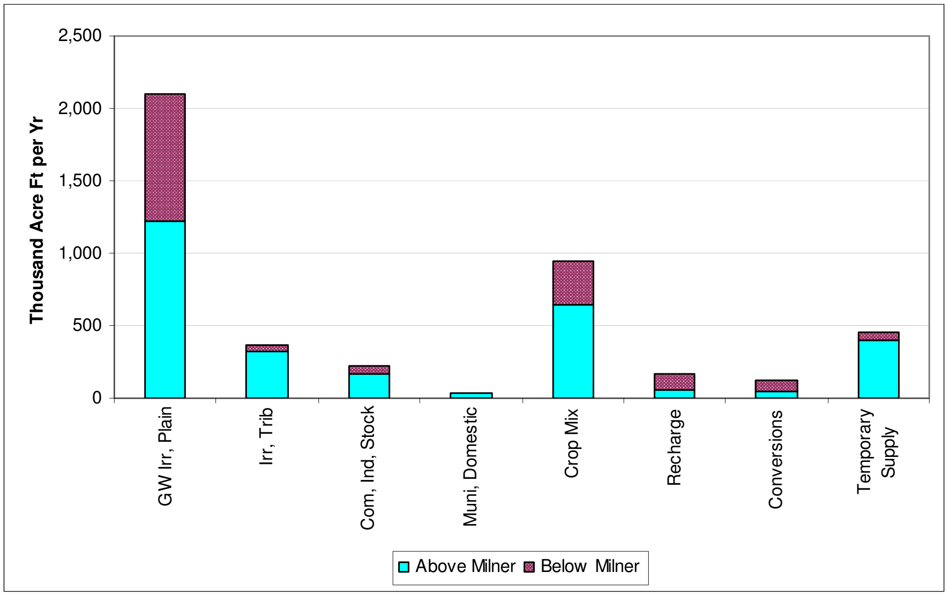

Figure 1. Relative magnitude of potential benefit to aquifer.

REFERENCES

Contor, B.A. 2006. Unpublished calculations from the Spokane Valley Rathdrum Prairie Interagency Aquifer Model Project.

Contor, B.A., D.M Cosgrove, G.S. Johnson. 2005. Snake River Plain Aquifer Model Scenario: Strawman Proposals: Conversion from Ground-water to Surface-water Irrigation "Conversion Scenario." Idaho Water Resources Research Institute unpublished draft report.

Contor, B.A., D.M. Cosgrove, G.S. Johnson, N. Rinehart and A. Wylie. 2004. Snake River Plain Aquifer Model Scenario: Managed Recharge in the Thousand Springs Area "Managed Recharge Scenario." Idaho Water Resources Research Institute Technical Report 04-002. Accessed 18 December 2006 at http://www.if.uidaho.edu/%7ejohnson/Recharge%20Report_Draft4.pdf

Patton, B.W. December 6, 2006. Memorandum to ESPA Modeling Committee re: ESPA Ground Water to Surface Water Conversions Projects.

U.S.G.S. 2001. National Land Cover Data Set (NLCD) Impermeable Cover 2001. Accessed November 2006 at http://seamless.usgs.gov/website/seamless/viewer.php