SNAKE RIVER PLAIN AQUIFER
MODEL SCENARIO:

THE SOURCES OF DRAWDOWN AT A&B

"A&B Scenario"

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By
Allan Wylie
Idaho Department of Water Resources

With guidance from the
Eastern Snake Hydrologic Modeling Committee

INTRODUCTION

This scenario, *Sources of Drawdown Beneath the A&B Irrigation District* (also known as the A&B Scenario), is one of many Snake River Plain aquifer model scenarios being developed to provide technical information that will be useful in resolution of conflicts among water users and in future water administration. A collective perspective involving analysis of many scenarios will guide water management. These scenarios are being evaluated using the enhanced Snake Plain Aquifer (ESPA) Model.

The present version of the Snake Plain aquifer model (version 1.1) 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 Plain aquifer and the Snake River.

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 Idaho Department of Water Resources (IDWR) led the effort and active participants in the Committee included Idaho Power Company, the U.S. Geological Survey, the U.S. Bureau of Reclamation, IWRRI and technical experts representing affected users. The ESHMC also provided guidance while conceptually developing this scenario and reviewed this scenario upon completion. Documentation of the model and related activities are available from the IDWR.

This “A&B Scenario” is intended to answer the question “Is the drawdown observed beneath A&B primarily due to ground water use at A&B, or is it largely due to other ground water use?” This analysis approaches this question by making two model runs that include:

1. Ground water irrigation from within the A&B service area only
2. Ground water irrigation from within the model, but outside the A&B service area.

The underlying theory of these two model runs (scenarios) is that if the ground water declines observed at A&B are due primarily to A&B, then pumping from within the A&B service area (scenario 1) will show more drawdown beneath A&B than the other scenario. If others are more responsible for the ground water declines observed at A&B, then the scenario with no pumping from within the A&B service area (scenario 2) will show more drawdown beneath A&B than the scenario with pumping from within the A&B service area.

Koreny (2005) claims that A&B does not serve about 13,000 ground water irrigated acres within the boundary of the A&B service area. The IDWR has not substantiated this claim.

The scenarios were evaluated using a numerical superposition method (IWRRI, 2004). Using numerical superposition, the impacts of the various groups of ground water pumpers can be assessed in isolation of all other recharge and discharge.

The purpose of these scenario evaluations is to determine whether or not ground water pumping within the A&B service area or other ground water pumpers are contributing more to the ground water declines at A&B. The specific objectives of these evaluations include:

1. Determine the steady state drawdown at A&B due to ground water irrigation pumping from within the A&B service area,
2. Determine the steady state drawdown at A&B due to all ground water irrigation pumping on the Eastern Snake Plain except within the A&B service area.

Background

Since the onset of ground water irrigation on the Eastern Snake Plain, ground water withdrawals have impacted aquifer water levels and river gains and losses. Initially, ground water pumping removes water from aquifer storage, causing a localized cone of depression. As pumping continues over a long period of time, the effects propagate away from the source of pumping until they reach a hydraulic boundary. Once that boundary is reached, the hydraulic boundary starts to act as a source, or as a barrier. A hydraulically connected river is an example of a source, the relationship between river stage and aquifer water level will affect the flux between the aquifer and river. For a gaining river reach, a decrease in aquifer water level will result in a decrease in the rate of water discharging into the river.

Sources of recharge and discharge on the Eastern Snake Plain include precipitation, recharge incidental to surface water irrigation, ground water withdrawals, evapotranspiration, tributary valley underflow, and river gains and losses. Of these sources of recharge and discharge, only the Snake River gains and losses are head dependent.

As ground water levels decline due to pumping on the Eastern Snake Plain and propagate throughout the aquifer system, less of the pumped water is coming out of storage and more is coming from the river, either in the form of reduced spring discharges, decreased aquifer discharges to the river, or increased losses from the river. These sources of water must necessarily balance pumping, and ground water declines must increase to steepen the gradient and hence the flux between the river and the aquifer.

Description of the Numerical Superposition Model

The numerical superposition version of the ESPA model is similar to the fully populated model with all recharge and discharge terms removed and 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 ESPA model is a confined representation of a generally unconfined aquifer system. Confined aquifer models are strictly linear; unconfined aquifer models are non-linear due to the fact that aquifer transmissivity changes as aquifer water levels change. In the Eastern Snake Plain aquifer, the changes in aquifer water levels are small relative to the total saturated thickness, so these non-linearities are considered negligible (Wylie, 2005).

Model parameters representing physical traits of the aquifer system, are the same for the numerical superposition model and the fully populated model. These parameters include aquifer transmissivity, 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 (Harbaugh et al, 2000) representation of rivers allows water to move from the aquifer into the river and to move from the river into the aquifer. The drain representation allows only water movement from the aquifer to the drain; otherwise, drain and river representations 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 with no flux between the aquifer and surface water features. All recharge and discharge terms are removed except for the aquifer stress in question. Thus, simulation of an aquifer stress will induce a water level change, and ultimately alter flux from the represented surface water features. Because all other aquifer stress (recharge and discharge) is ignored in a superposition analysis, these results generally do not compare directly with field observations.

Method

These scenarios were evaluated using the following general steps:

1. Clip the model irrigated lands GIS coverage to include:
    a. Only ground water irrigated acres within the A&B service area
    b. All ground water irrigated acres outside of the A&B service area
2. Apply average (1961-1990) values of precipitation and average (1980-2001) evapotranspiration to this new irrigated lands coverage to estimate net consumptive use for the lands identified. IWRRI (2004) includes plots showing how precipitation and evapotranspiration vary over time in the Model Recharge Re-cap section of the manual.
3. Run the numerical superposition version of the ground water model using the MODFLOW input file created in step 2.
4. Determine the drawdown at A&B due to ground water pumping.

A detailed step-by-step procedure used to compute ground water irrigated area and evapotranspiration mentioned in steps 1 and 2 above is provided in Practicum Three found in the Recharge Tool Practicums section of the IWRRI (2004) *Scenario Generation Training Manual.*

Modeling Analyses

Factors other than pumping contribute to water level declines in the aquifer. Conversions from flood irrigation to sprinklers improve irrigation efficiency but reduce deep percolation. This factor is investigated in the *"No Changes to Surface Water Practices Scenario"* (Contor et al, 2004). Drought also contributes to ground water declines and this factor was investigated in the *"Drought Scenario"* (Contor et al, 2005).

This scenario investigates the effects ground water pumping has on aquifer declines at A&B. Thus, all other factors are ignored and only the effects of ground water pumping are explored. Ground water pumping generates drawdown in the aquifer to stimulate flow toward the pumping well. This drawdown is eventually propagated throughout the aquifer, although miniscule in areas remote from the pumping well. The principles of superposition indicate that the effects of numerous pumping wells are additive. Thus, if enough pumping wells are distributed throughout the aquifer, drawdown will not be trivial. Figure 1 shows the location of the ground water irrigated acres for these scenarios. The drawdown associated with the ground water irrigated acres shown for the scenarios illustrated in Figure 1 was determined using the numerical superposition model.

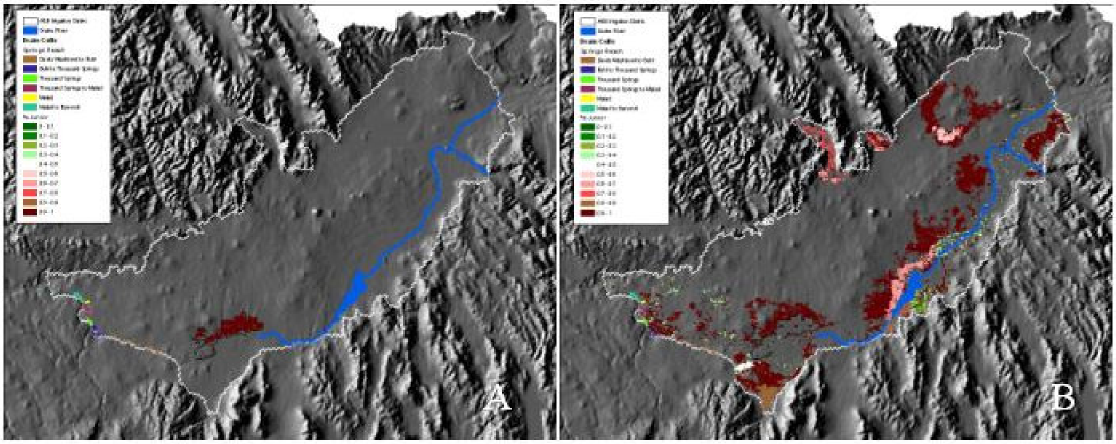

Figure 1. Ground water irrigated acres used in: a) A&B pumping only; b) all ground water irrigated acres except A&B.

A&B Pumping

This scenario predicts the drawdown at A&B due to ground water pumping within the A&B service area as illustrated in Figure 1 A. The analysis indicates that there are about 64,000 ground water irrigated acres within the service area, with a depletion of about 2.21 ft per acre (143,000 ac-ft/yr). The drawdown analysis is presented in Table 1 and shown in Figure 2. The steady state results indicate that the average drawdown at A&B due to pumping within the A&B service area is about 19 ft. Note that for this scenario drawdowns are focused beneath A&B and disperse outward away from A&B.

Recall that Koreny claimed about 13,000 groundwater-irrigated acres within the service area of A&B is not part of the irrigation district. This is about 20% of the ground water irrigated acres within the A&B service area. Using the principals of superposition this should reduce the average drawdown by about 20%, or from 19 ft to about 15 ft.

Table 1. Computed drawdown at A&B due to A&B pumping.

Max Drawdown (ft)	Min Drawdown (ft)	Range	Average
29	13	16	19

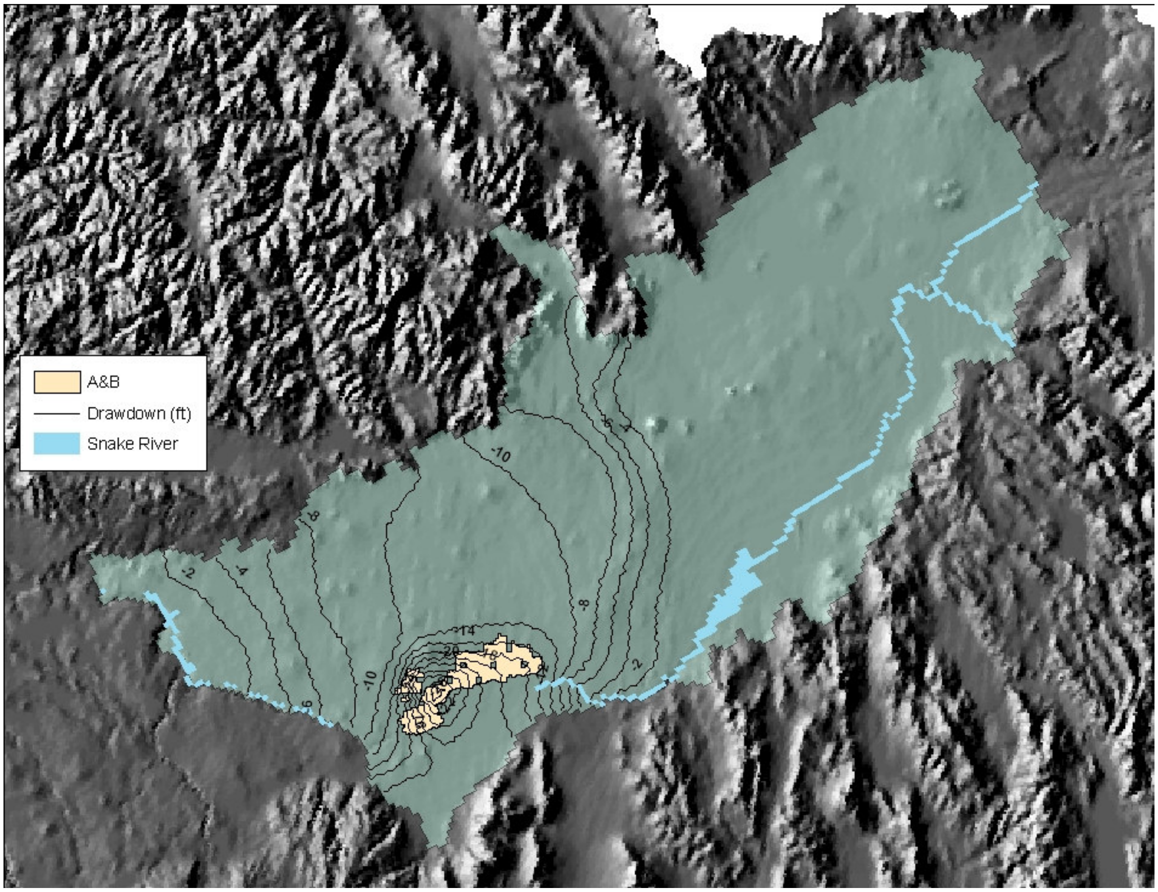

Figure 2. Drawdown at A&B due to pumping within the A&B service area only.

Ground Water Irrigation From Everyone but A&B

This scenario predicts the drawdown at A&B due to all ground water irrigation not within the A&B service area as illustrated in Figure 1 B. The analysis indicates that there are about 911,000 ground water irrigated acres outside of A&B, with a depletion of about 2.01 ft per acre (1,830,000 ac-ft/yr). The drawdown analysis is presented in Table 2 and shown in Figure 3. The steady state results indicate that the average drawdown at A&B due to all other ground water irrigation is about 77 ft.

Using the principals of superposition, if the 13,000 acres within the service area of A&B is not part of the A&B Irrigation District, the drawdown associated with these acres could be added back onto the 77 ft of average drawdown associated pumping outside the A&B service area. This drawdown is about 4 ft (19 ft – 15 ft). Thus, including the 13,000 acres would increase the total average drawdown from others to about 81 ft.

Table 2. Computed drawdown at A&B due to all other pumping.

Max Drawdown (ft)	Min Drawdown (ft)	Range	Average
162	51	112	77

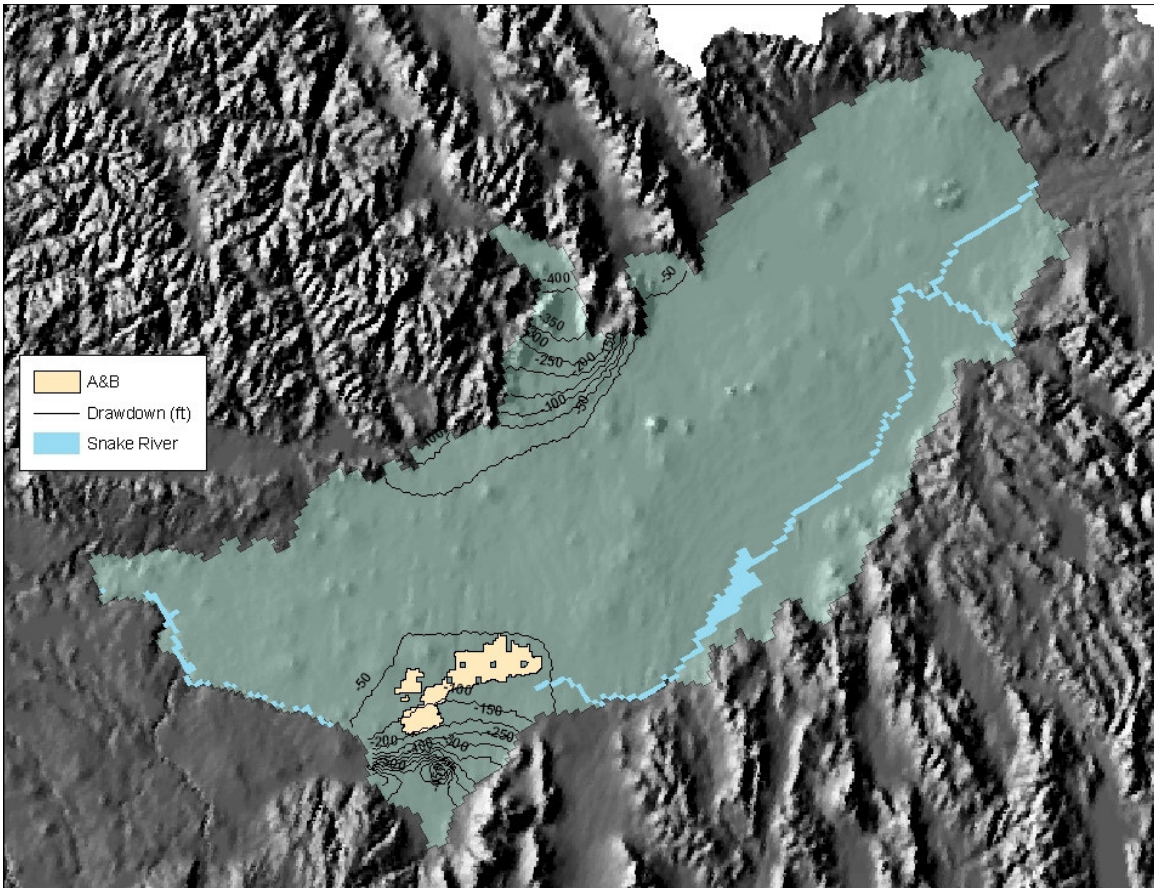

Figure 3. Drawdown at A&B due to all other ground water irrigation.

An examination of Figure 3 indicates that drawdown is focused in the Oakley area. The hills surrounding the Oakley Fan are composed of less permeable rocks, so this contact is represented in the model as a no flow boundary. This effect results in increased drawdown because the only source of water to satisfy the pumping demand is from the aquifer to the north. The Big Lost River and Little Lost River Valleys suffer from similar boundary effects.

Summary

Other factors not included in this analysis affect water levels in the aquifer. Some serve to mitigate the drawdown due to pumping such as incidental recharge from surface water irrigation, precipitation recharge, and river leakage. Others contribute to aquifer declines such as drought and conversions from flood irrigation to sprinkler irrigation. Thus, these results should not be interpreted as absolute changes in aquifer water levels; however, this analysis indicates that between 80 and 84% of the ground water declines experienced at A&B are due to the effects of ground water pumping from others. This result is consistent with by an unpublished analysis by Schmidt and Miller (2003) who modeled the impact of 23 pending well applications in the A&B area and indicated that permitting the new wells would significantly increase ground water declines at A&B.

References

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Harbaugh, A.W., E.R. Banta, M.C. Hill, and M.G. McDonald, 2000. MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process. U.S. Geological Survey Open-File Report 00-92.

IWRRI, 2004. Snake River Plain Aquifer Model: Scenario Generation Training. May 11-14, 2004.

Koreny, J.S., 2005. Letter to Rick Raymondi dated September 9, 2005 titled Re: Comments on A&B Scenario.

Reilly, T.E., O.L. Franke, and G.D. Bennett, 1987. The Principle Of Superposition And Its Application In Ground-Water Hydraulics: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter B6.

Schmidt, R.S. and T. Miller, 2003. Modeling the Impact of New Groundwater Pumping in Basin 36, on Groundwater Levels in the A&B Irrigation District. Unpublished U.S. Bureau of Reclamation Report.

Wylie, A.W., 2005. Comparison of Unconfined and Confined Aquifer Representation. Idaho Water Resources Research Institute, University of Idaho, DDM-019.

Appendix 1 HDR Comments

<u>Comment 1</u>
Please remove the following sentence from the introduction, "The ESHMC also served to guide and review the scenario evaluation process." The ESHMC did not "guide and review" this scenario; instead, the ESHMC was provided the opportunity to review some of the results after the scenario was completed and to submit comments on the draft report. Please reference our letter to IDWR on this subject dated July 26, 2005.

> Decline. Because the full ESHMC discussed the initial scenario conceptualization in a forum where all participants had an opportunity to provide input to scenario development, the ESHMC did offer guidance. Also the ESHMC was allowed to review a draft of this report, all model and recharge tool files, and results presented at the September 3 and 4 meeting.

<u>Comment 2</u>
Please remove the phrase, "and the IWRRI at the University of Idaho" from paragraph 3 in the introduction, because IWRRI representative have recently stated that IWRRI will no longer be available for data or questions concerning the model and IDWR has indicated that this information must be obtained through IDWR.

> Accept.

<u>Comment 3</u>
A portion of the land within the irrigation boundary of Unit B is not served by the District. Of the area within the Unit B irrigation boundary, approximately 13,000 acres are not served by the District. The breakdown of these 13,000 acres of non-District lands includes: 5,000 acres in distinct "school sections" and 8,000 acres in other land.

> Accept. I will add a paragraph to that effect in the Introduction. The IDWR will not check these claims at this time, so I will reference this letter as the source for the claim and address the 13,000 acres in each scenario.

<u>Comment 4</u>
The "Methods" section of the report should be expanded to include information and the process used to develop estimates of ground water pumping and consumptive use. We request that, as appropriate, the information be included as both graphs and GIS maps to identify the time-and spatial-varying nature of the data.

We appreciate that significant information is contained in the Scenario Generation Training manual. However, the information is generalized and does not detail the procedures used for the analysis described in this report. We recommend removing the statement, *"IWRRI (2004) provides a detailed discussion of the procedure used to compute irrigated area and evaportranspiration…"* and replacing it with a citation to the Training Manual with more-detailed information on the procedures used to develop the dataset for this scenario.

Partial Accept the first paragraph. Graphs showing the time varying nature of precipitation and evapotranspiration are available in the Model Recharge Re-cap section of the Training Manual.

Decline second paragraph. We followed the procedures outlined in Practicum Three as presented in the Recharge Tool Practicums section of the Training Manual. We will add appropriate references and clarifications.

Comment 5

Information should be included in the "Modeling Analysis" section to discuss the implications of using super-position to evaluate drawdown from ground water pumping. Please provide appropriate guidance on the use of the model results from this super-position analysis in the context of predicting ground water levels resulting from ground water pumping and other factors that influence ground water levels (i.e. changes in irrigation practices, climate, etc).

Accept.

Comment 6

The statistic of 13 feet in the text under the A&B Pumping section des not match the statistic in Table 1.

Accept.

Comment 7

The scenario results in Figure 3 seem to show boundary effects in the Oakley Fan and Big Lost River area. Please explain.

Accept. We will add a paragraph to that effect in the "others" scenario.

Comment 8

We understand that drains are not included in the super-position analysis. If this is the case, please remove the drain cells from Figures 2 to 4.

Accept.

Comment 9

The predicted drawdown shown in Figures 2 to 4 exceeds the observed drawdown in the aquifer at areas near A&B Irrigation District and south of the District. Please explain these results.

Accept. I will add an explanation to the summary section.

Comment 10

We suggest removing the statement, "*This result is supported by…*" when referencing Schmidt and Miller (2003) in the Summary section.

Partial Accept. We will explain how their results are consistent with this analysis.

<u>e-mail (in italics) from John Koreny dated 9/12/2005</u>

REPORT CITATION

Page 3 of the report states:

"Sources of recharge and discharge on the Eastern Snake Plain include precipitation, recharge incidental to surface water irrigation, ground water withdrawals, evapotranspiration, tributary valley underflow, and river gains and losses. Of these sources of recharge and discharge, only the Snake River gains and losses are hydraulically connected sources."

COMMENT

I think I understand what you meant by this statement- but the terminology needs clarification.

In this case- all of the sources cited ARE hydraulically connected (in some degree more or less). The standard nomenclature for the word, "hydraulically connected" requires asking the question- "does the source of recharge/discharge influence ground water in the aquifer (i.e., ground water levels, recharge, discharge, storage, etc.)?"

So- let's ask that question for some of the specific sources cited in the report:

1) Q: Does ground water pumping effect the aquifer? A: Most folks would agree that ground water pumping effects water levels, flux, storage, etc. in the aquifer (1 gallon pumped is 1 gallon removed from the aquifer with some amount going back into the aquifer).

2) Q: Does tributary underflow effect the aquifer? A: Again- I think most would agree- tributary underflow effects water levels, flux, storage, etc. in the aquifer- i.e., 1 gallon of tributary underflow leaving a tributary or tributary reach x-section is 1 gallon of flow entering the aquifer.

3) Q: Are some canals connected. A: Again- yes.

4) Q: Is precip., surface water recharge and other sources of incidental recharge connected? A: These sources are a specified flux- and recharge rate is not governed by drawdown (in most cases). However, even though these are not head-dependent flux boundaries- they are still "hydraulically connected".

Maybe what is meant by the paragraph is, "are these sources head-dependent flux boundaries or specified flux boundaries"?

This comment applies to all of the other scenario reports where the citation is mentioned.

Accept with regard to this scenario.