Estimates of Tributary Basin Underflow for the Eastern Snake Plain Aquifer Model Version 2 – As Built

Prepared by Idaho Water Resources Research Institute

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ESPAM2 Design Document DDM-V2-13

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DESIGN DOCUMENT OVERVIEW

During calibration of the Eastern Snake Plain Aquifer Model Version 1.1 (ESPAM 1.1), a series of Design Documents were produced to document data sources, conceptual model decisions and calculation methods. These documents served two important purposes; they provided a vehicle to communicate decisions and solicit input from members of the Eastern Snake Hydrologic Modeling Committee (ESHMC) and other interested parties, and they provided far greater detail of particular aspects of the modeling process than would have been possible in a single final report. Many of the Design Documents were presented first in a draft form, then in revised form following input and discussion, and finally in an "as-built" form describing the actual implementation.

This report is a Design Document for the calibration of the Eastern Snake Plain Aquifer Model Version 2 (ESPAM2). Its goals are similar to the goals of Design Documents for ESPAM 1.1: To provide full transparency of modeling data, decisions and calibration; and to seek input from representatives of various stakeholders so that the resulting product can be the best possible technical representation of the physical system (given constraints of time, funding and personnel). It is anticipated that for some topics, a single Design Document will serve these purposes prior to issuance of a final report. For other topics, a draft document will be followed by one or more revisions and a final "as-built" Design Document. Superseded Design Documents will be maintained in a "superseded" file folder on the project Website, and successive versions will be maintained in a "current" folder. This will provide additional documentation of project history and the development of ideas.

INTRODUCTION

Tributary underflow is the discharge of subsurface water from a tributary basin into an area of interest, such as an aquifer. Tributary underflow to the Eastern Snake River Plain Aquifer is recognized in 22 surrounding basins. Because tributary underflow is flow beneath the surface, it is difficult to estimate yet it is an important component of recharge in the water budget for the Eastern Snake Plain Aquifer Model. The purpose of this design document is to briefly review how the values of tributary underflow were estimated in ESPAM1.1 and to explain how estimates were made for ESPAM2.

REVIEW OF ESPAM1.1

Estimates of underflow were based on Kjelstrom's (1986) estimates of underflow published in the Regional Aquifer-System Analysis (RASA) study performed by the USGS (Garabedian, 1992). Basin-yield equations were used to calculate average annual underflow rates from the tributary basins. The characteristics of the basins incorporated include drainage area, mean annual precipitation, and percentage of forest cover. As part of the water budget balancing process, all tributary underflow estimates were scaled by a factor of 0.97 (a net 3% reduction) in ESPAM 1.1. Tributary underflow varies seasonally and from year to year, so the average annual underflow values were scaled (dampened) using normalized values based on measured discharges at Silver Creek. Silver Creek was chosen as a proxy because it is almost entirely spring-fed and reflects temporal spring discharge from a basin similar to many of the Snake Plain tributary basins. At the July 2009 ESHMC meeting, Mike McVay reviewed the ESPAM 1.1 process of estimating tributary underflow. Figure 1 below shows how Silver Creek flux was dampened over time. Although this was chosen as the best method of estimating tributary underflow, this aspect of ESPAM 1.1 has a degree of limitation and uncertainty. One of three components of the aquifer budget for ESPAM 1.1 mentioned in the final report that has the greatest uncertainty is tributary underflow.

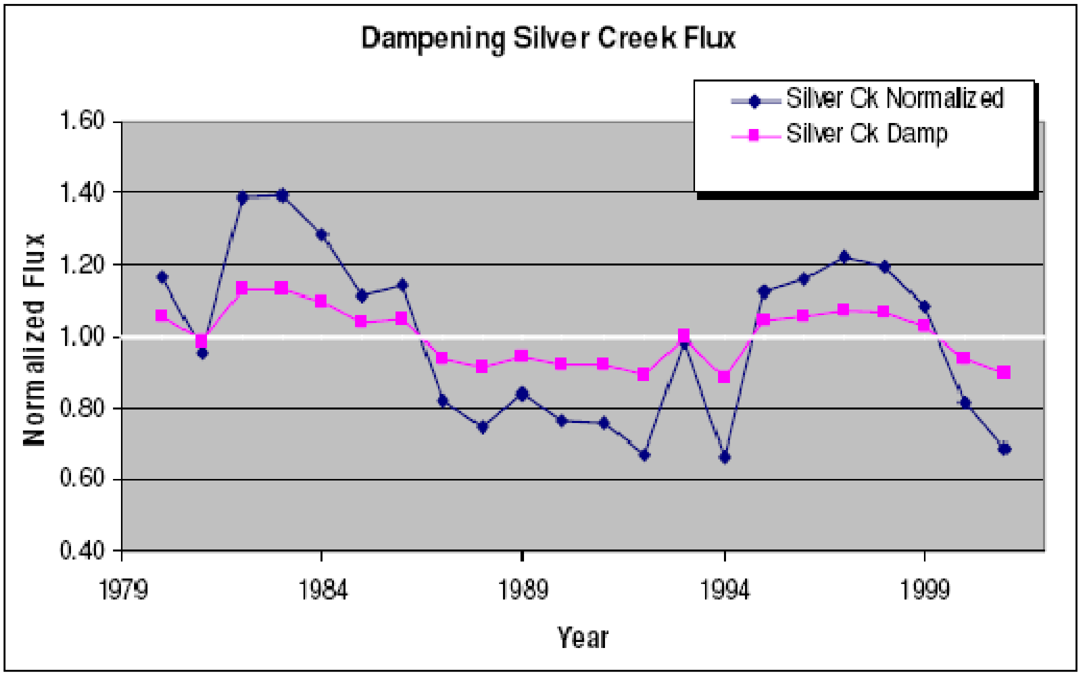

Figure 1. Silver Creek flux was normalized and dampened over time.

Adapted from Slide 6 of McVay (2009)

Figure 2 (adapted from Figure 22 of Cosgrove et al., 2006) shows the tributary basins that were recognized in ESPAM1.1. The highlighted squares (mostly red and some green) represent the individual model cells that were used to enter the specified flux for each tributary basin. The estimated flux for each tributary was evenly distributed across the model cells to that tributary in each stress period.

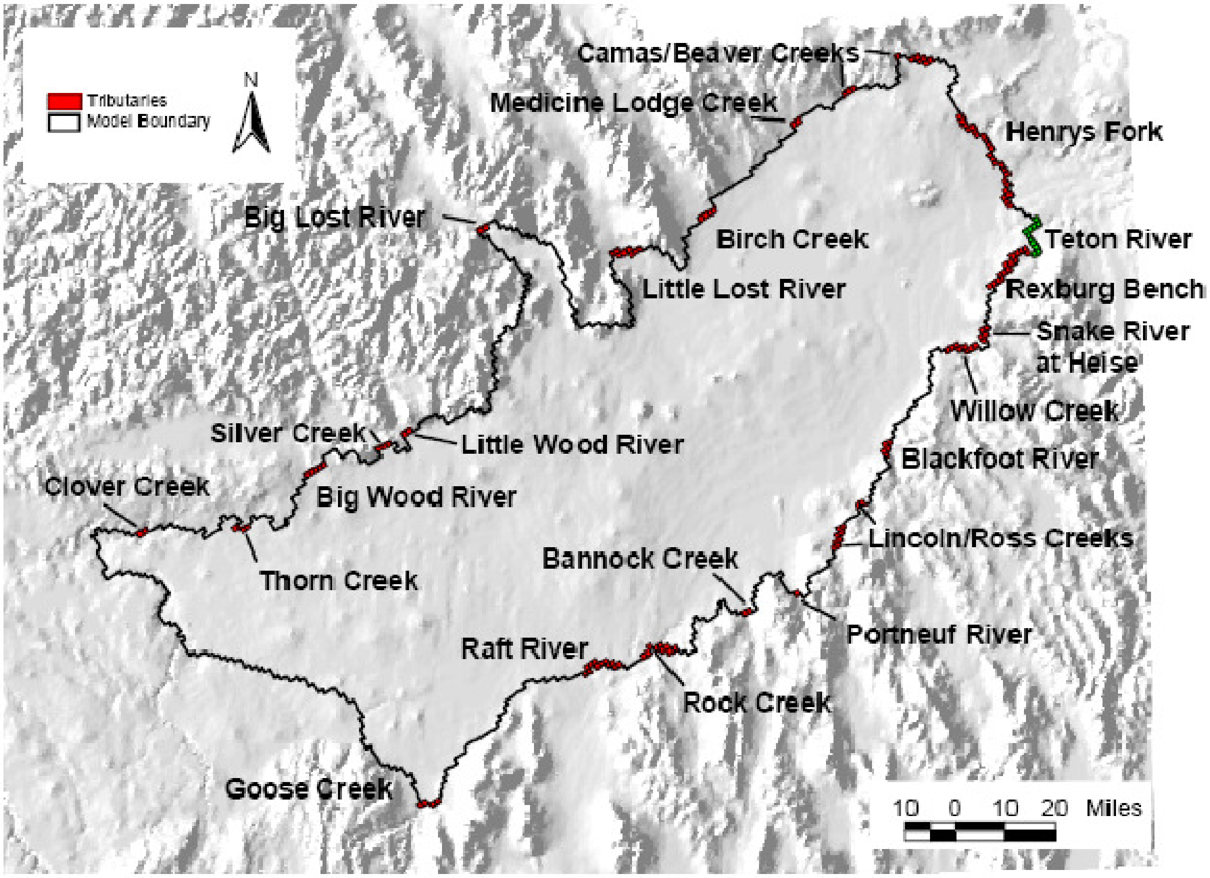

Figure 2. Tributary basins in ESPAM1.1

(adapted from Figure 22 of the final ESPAM1.1 report).

OVERVIEW OF ESPAM2

Time was not allotted to improve tributary underflow estimates for ESPAM2. Discharge measurements at Silver Creek were collected for 2002 through 2008 and tributary underflow estimates were calculated in the same fashion as they were in ESPAM1.1. The six-month stress period values of underflow used in ESPAM1.1 were adjusted to the one-month stress periods of ESPAM2. Monthly values were specifically calculated by dividing the value from ESPAM1.1 by the number of days in six months (182.625) and then multiplying by the number of days in the corresponding month (i.e. 31 days for January and 30 days for April).

Some changes were made to the tributary underflow shapefile since the model boundary has changed slightly since ESPAM1.1. The most notable change to the model boundary affecting the tributary underflow geometry is on the southeastern side of the Snake Plain as shown in Figure 3. In Figure 3, the blue cells represent active cells in ESPAM2 while the white cells were active cells that were included in ESPAM1.1 and no longer included as active cells in ESPAM2. Tributary underflow in ESPAM1.1 applied to all cells spanned by the black lines and the lines shown in blue are the changes that were made for ESPAM2.

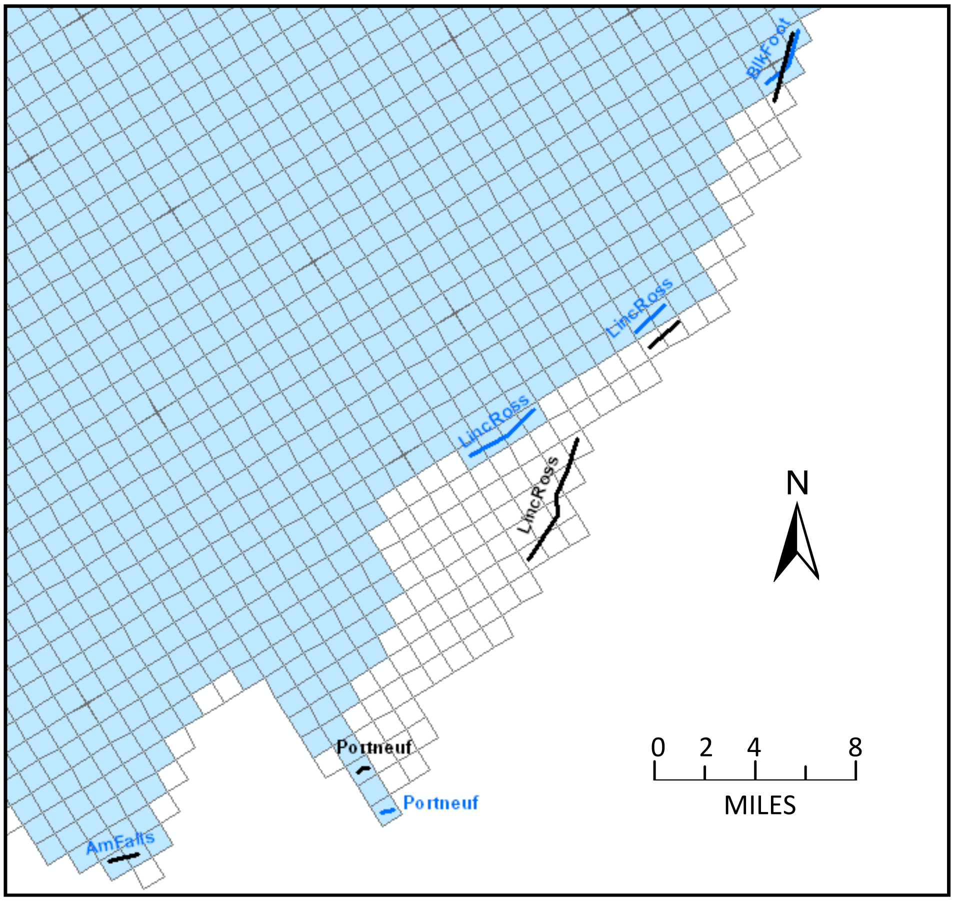

Figure 3. Southeastern edge of the ESPAM2 model boundary. Changes to the model boundary resulted in changes in the cells assigned flux from tributary underflow.

Figure 4 shows the active cells of the model in ESPAM2. The cells highlighted in red were assigned values of flux for underflow for the corresponding basin.

CHANGES IN THE PORTNEUF RIVER VALLEY

In the Portneuf River Valley, the model boundary was changed. This adjustment is shown in Figure 3. This is the only basin where changes were made to reflect different estimates of underflow for ESPAM2. In 2006, John Welhan released an updated study of the lower Portneuf River Valley. According to Welhan's report on the Portneuf basin, a value of 5.4 ± 0.1 billion gal/yr represents underflow from the Mink Creek, Gibson Jack Creek, and City-Cusick Creek watersheds through the Portneuf Gap. It is assumed that recharge from the eastern side of the basin is negligible. A value of 5.4×10^9 gal/yr was used as the underflow value for the Portneuf Basin for ESPAM2.

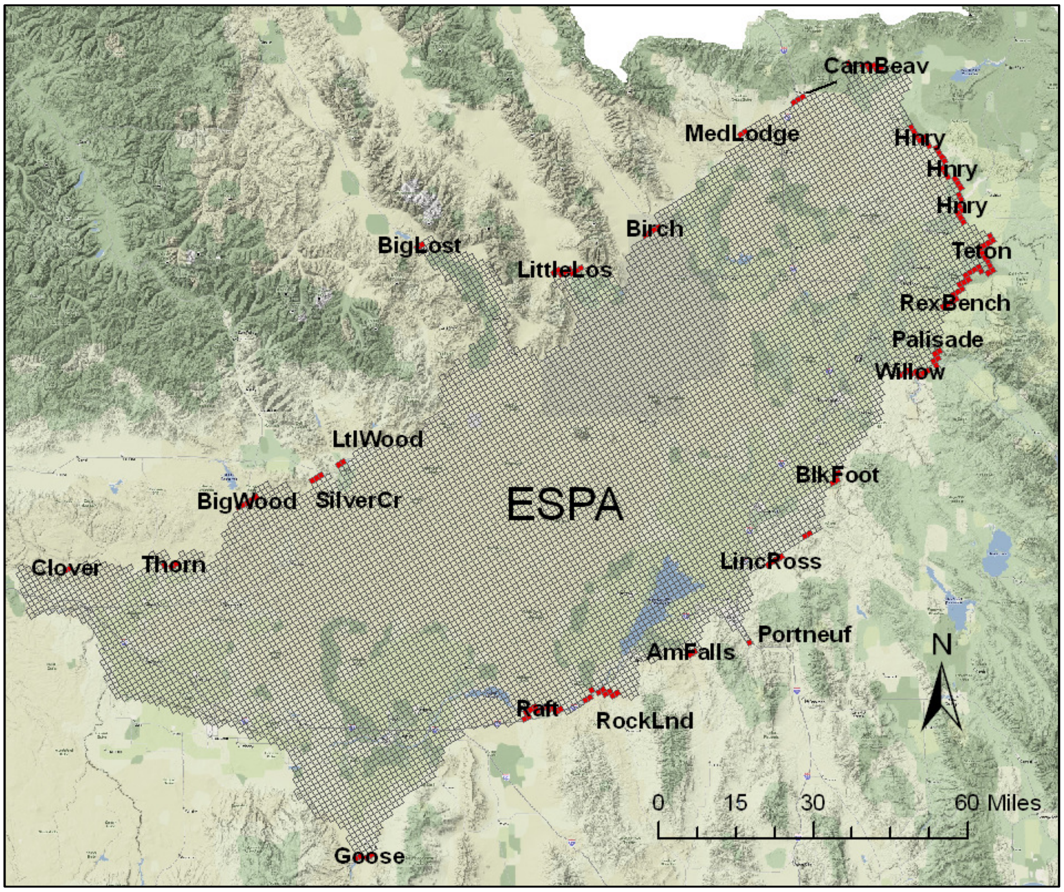

Figure 4. ESPAM2 cells assigned flux from tributary underflow.

CHECKING FOR ACCURACY

In July 2009, Mike McVay of the Idaho Department of Water Resources (IDWR) presented his work on tributary underflow estimates in the lower Portneuf River Valley. McVay discussed the use of Silver Creek gage measurements as a proxy to allow computation of underflow in basins where data are not available. He also showed that Silver Creek flow data reflects precipitation patterns in the Portneuf basin and concluded that, for the time being, Silver Creek may be a usable proxy for the temporal scaling of the Garabedian (1992) underflow estimates. Figure 5 below shows the result of dampening Silver Creek and the Portneuf River precipitation values.

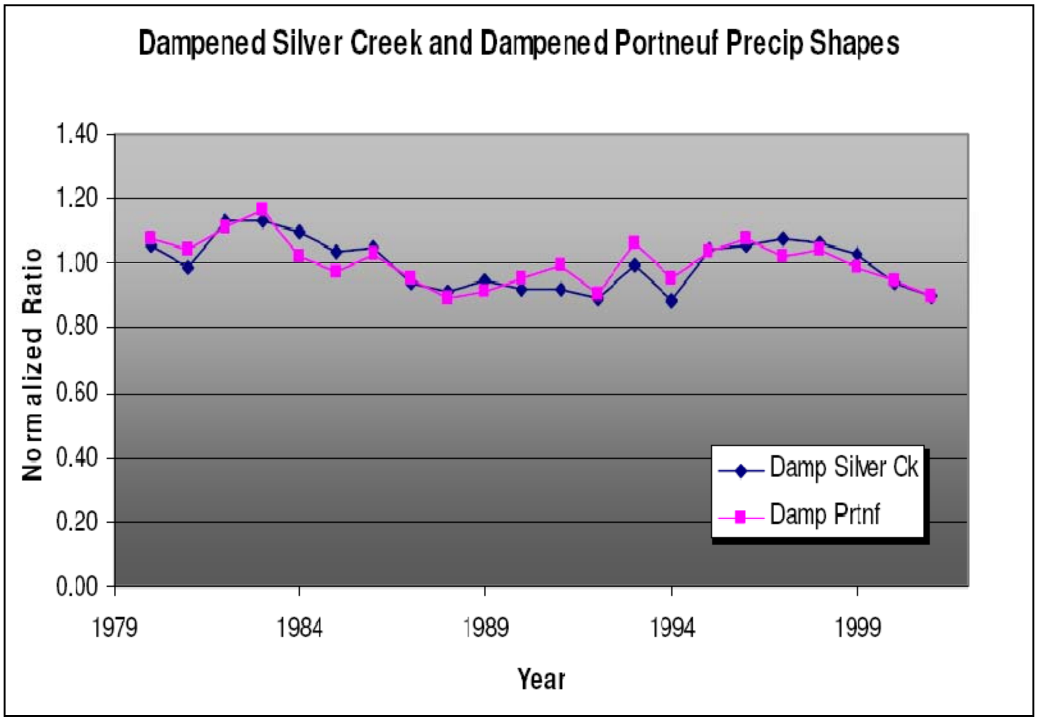

Figure 5. Comparing dampened precipitation values in the Silver Creek and Portneuf River basins.

(Adapted from Slide 11 of McVay (2009)).

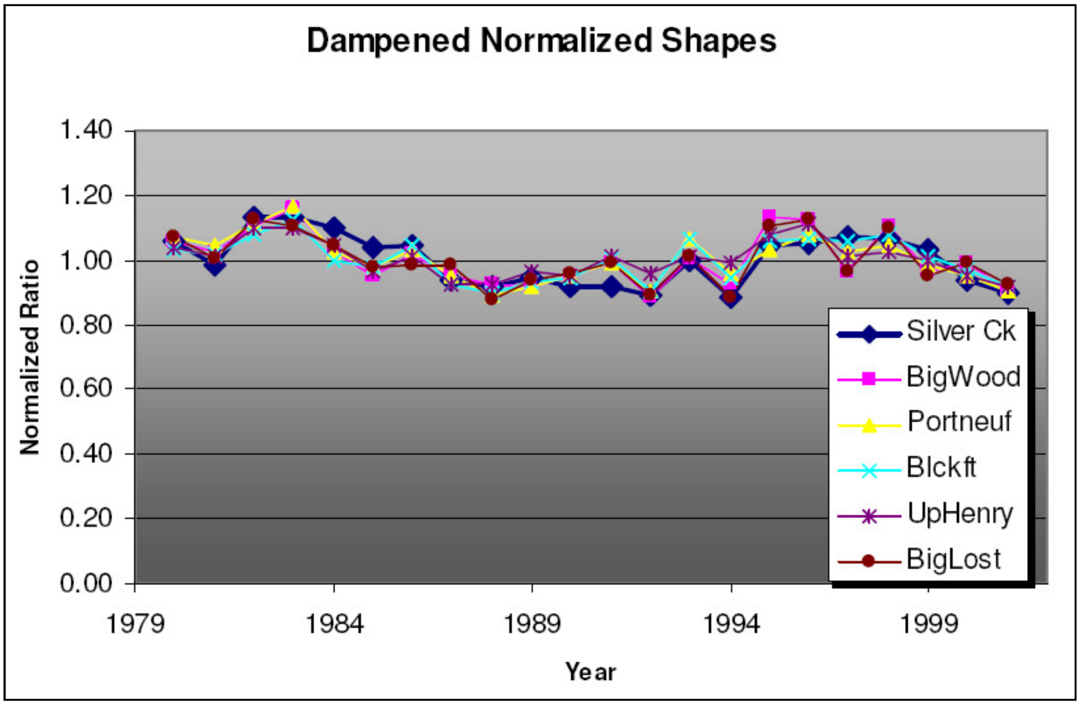

Figure 6. Comparing dampened precipitation values for several basins in the ESPA.

(Adapted from Slide 13 of McVay (2009)).

McVay also reviewed a Darcy approach to calculate tributary underflow. It is an appealing approach because of the simplicity of using the Darcy equation ($Q = -KA(dh/dl)$), but there are some drawbacks due to limited data and uncertainty in parameters. McVay also reviewed a mass balance approach for estimating tributary underflow, but concluded this seemingly simple procedure was truly complicated. The data needed to include basin boundaries, volume of applied surface water, total groundwater pumped, stream flow estimates, precipitation and evapotranspiration data, and basin data from other states. While some of these inputs are available, others are not making it difficult to estimate underflow with the mass balance approach. Both of these methods were applied in the Welhan (2006) study of the Portneuf basin. McVay performed calculations using Silver Creek for refining tributary underflow in the Portneuf basin and compared the estimates to the values in Welhan's report. McVay concluded the use of Silver Creek as a proxy was suitable for now when estimating tributary underflow and Welhan's estimates of underflow in the Portneuf basin would be appropriate for calculating tributary underflow for ESPAM2.

SUMMARY AND DESIGN DECISION

The ESPAM1.1 tributary underflow data were based on Kjelstrom's (1986) estimates of underflow found in the Regional Aquifer-System Analysis (RASA) study by the USGS (Garabedian, 1992). During the water budget balancing process, all tributary underflow estimates were scaled by a factor of 0.97 (a net 3% reduction) in ESPAM 1.1. Tributary underflow varies seasonally and from year to year, so the average annual underflow values were scaled using normalized values. Silver Creek was chosen as a proxy because it is mostly spring-fed and shows temporal spring discharge from a basin similar to several of the Snake Plain tributary basins. Although this was chosen as the best method of estimating tributary underflow, ESPAM 1.1 has a degree of limitation and uncertainty.

The ESPAM1.1 values were applied to ESPAM2 and new data was collected for performing the same calculations for underflow estimates for 2002 through 2008. Values of underflow for most basins were adjusted from the six-month stress periods to the one-month stress periods. Due to changes in the model boundary near the Portneuf River Valley and the Welhan (2006) study on the Portneuf River basin, more appropriate estimates of tributary underflow were applied. A preliminary investigation performed by Mike McVay of the IDWR indicated that Silver Creek may be an acceptable proxy for shaping underflow while using estimates of Welhan's study for underflow in the Portneuf basin.

Figure 7 displays the final estimates of tributary underflow for each stress period for ESPAM2. The names of the basins are provided on the right-hand side. Several of the names are abbreviated and these are the names provided in the actual file for the water budget. Refer to the appendix for the full name of these basins if any are unclear.

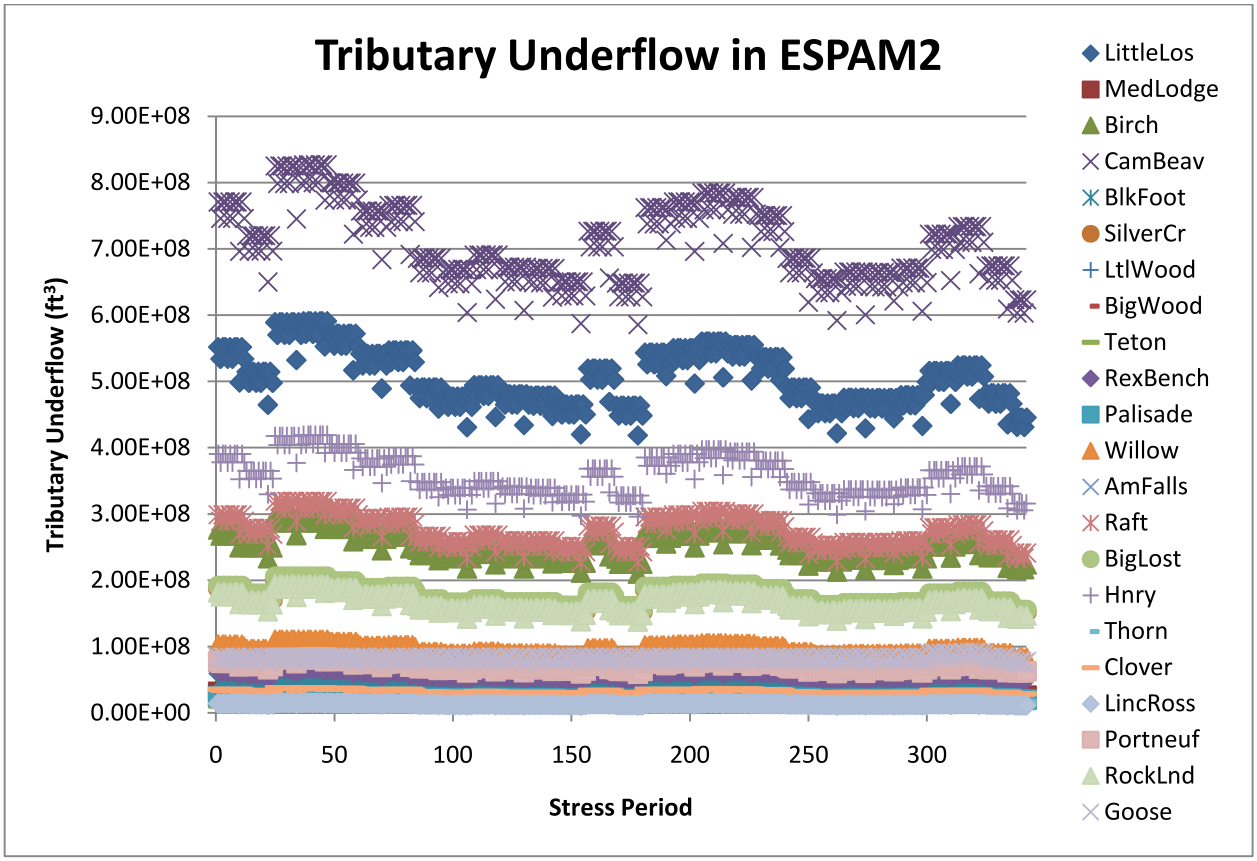

Figure 7. Estimates of tributary underflow per stress period for ESPAM2.

RECOMMENDATIONS

In Mike McVay's presentation to the ESHMC (2009), he also provided a list of recommendations to the committee to use in the future:

1. Perform a literature search.
2. Collect data for the individual tributary basins.
3. Rank the tributary basins based on data availability and model importance.
4. Perform Darcy calculations and/or mass balance calculations with available information.
5. Create a range or estimate error bars associated with tributary underflow values.

REFERENCES

Cosgrove, D.M., B.A. Contor, and G.S. Johnson. 2006. Enhanced Snake Plain Aquifer Model Final Report: Idaho Water Resources Research Institute Technical Report 06-002, Eastern Snake Plain Aquifer Model Enhancement Project Scenario Document Number DDM-019, 232 p.

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

Kjelstrom, L.C. 1986. Flow characteristics of the Snake River and Water Budget for the Snake River Plain, Idaho and eastern Oregon: U.S. Geol. Survey Hydrologic Investigations Atlas HA-680, scale 1:1,000,000, 2 sheets.

McVay, Mike. 2009. ESPA Tributary Basin Underflow Estimation – Preliminary Investigation Update. 8 July 2009. Presentation to the Eastern Snake Hydrologic Modeling Committee. <http://www.idwr.idaho.gov/Browse/WaterInfo/ESPAM/meetings/2009_ESHMC/7-8&9-2009/McVayl%20Tributary%20Groundwater%20Basins.pdf> Accessed 22 Oct 2010.

Welhan, J. 2006. Water Balance and Pumping Capacity of the Lower Portneuf River Valley Aquifer, Bannock County, Idaho; Idaho Geological Survey Staff Report 06-5.

APPENDIX

The following table provides the full names of the tributary basins abbreviated in several of the figures of this design document.

Abbreviated Name	Tributary Basin Name
LittleLos	Little Lost River
MedLodge	Medicine Lodge Creek
Birch	Birch Creek
CamBeav	Camas and Beaver Creek
BlkFoot	Blackfoot River
SilverCr	Silver Creek
LtlWood	Little Wood River
BigWood	Big Wood River
Teton	Teton River
RexBench	Rexburg Bench
Palisade	Palisade (Snake River)
Willow	Willow Creek
AmFalls	American Falls (Bannock Creek)
Raft	Raft River
BigLost	Big Lost River
Hnry	Henrys Fork
Thorn	Thorn Creek
Clover	Clover Creek
LincRoss	Lincoln Creek and Ross Creek
Portneuf	Portneuf River
RockLnd	Rock Creek
Goose	Goose Creek