Estimating Perched River Seepage in the Big Wood River, Little Wood River, Big Lost River, Little Lost River, Birch Creek, Medicine Lodge Creek, Beaver Creek, and Camas Creek for Calibration of the Eastern Snake Plain Aquifer Model Version 2

Prepared by Idaho Water Resources Research Institute

In fulfillment of the Water-Budget Component – Perched River Seepage

of Contract # CON00803

for

The Idaho Department of Water Resources

University of Idaho

Idaho Water Resources Research Institute

Stacey L. Taylor

Greg L. Moore

August 2009

Idaho Water Resources Research Institute Technical Report 200905

ESPAM 2 Design Document DDW-V2-03

Estimating Perched River Seepage in the Big Wood River, Little Wood River, Big Lost River, Little Lost River, Birch Creek, Medicine Lodge Creek, Beaver Creek, and Camas Creek for Calibration of the Eastern Snake Plain Aquifer Model Version 2

DESIGN DOCUMENT OVERVIEW

During calibration of the Eastern Snake Plain Aquifer Model Version 1.1 (ESPAM 1.1), a series of Design Documents was 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 (ESPAM 2). 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 Superseded Design Documents will be maintained in a "superseded" file folder on the project Website, and successive versions will be maintained in a "current" folder.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

As discussed in analysis for ESPAM 1.1, Design Document DDW-024 (Erickson, Nelson, and Contor, 2004) some streams in the Snake River Plain that are perched are believed to be hydraulically contributing to the aquifer because of seepage. This design document describes perched river seepage from streams and other water bodies in the Eastern Snake Plain. Some surface water bodies that are represented in ESPAM 1.1 as perched are likely connected to the aquifer, which includes Mud Lake and parts of the Big Lost River and Camas Creek. These were not represented as hydraulically connected because simulating impacts to those water bodies was not part of the purpose of ESPAM 1.1. Because these are tributary to the regional aquifer, this doesn't change the water balance nor does it materially change the propagation of impacts to the Snake River or springs. These water bodies (Mud Lake, parts of the Big Lost River and Camas Creek, part of Twin Falls Canal, and Lake Murtaugh) will be simulated the same as they are in ESPAM 1.1 and will therefore not be discussed in this design document. Seepage from the Snake River is excluded from this discussion as it is simulated with the River Package as discussed in DDM-03 (Taylor and Moore, 2009).

Perched river seepage is represented in a GIS line data set (shapefile) and a data table. These two features are inputs to the GIS Recharge Tool. This design document outlines a proposal for the treatment of perched river seepage in the GIS Recharge Tool for ESPAM 2. It is based on discussions in January and March/April 2009 ESHMC meetings. The process of inducing temporal variation to adjust for the monthly stress periods of ESPAM 2 and predicting stream flow at ungaged sites will be discussed in this document. Certain diversions and returns will be used to estimate perched river seepage as are discussed in DDW-024 (Erickson, Nelson, and Contor, 2004).

REVIEW OF ESPAM 1.1 APPROACH

In ESPAM 1.1, perched river seepage (bed loss) was estimated by calculating gains through use of the following formula:

Upstream gage (cfs) – downstream gage (cfs) - diversions (cfs) = Gains (cfs) (Equation 1)

By using the above formula, available flow data from USGS gages and diversion data from watermaster reports were used to estimate gains. Based on the ESPAM 1.1 model boundary and data available during the model calibration period, adjustments were made to the data to estimate flow right at the model boundary, gages lacking flow data (ungaged sites) during the calibration period, and/or to estimate diversions that overlapped active and inactive cells of the model. For ESPAM 1.1, a linear regression was used to estimate flow for periods of time when data was lacking for the following streams in the Eastern Snake Plain:

(1) Big Wood River
(2) Little Wood River
(3) Big Lost River
(4) Little Lost River
(5) Birch Creek
(6) Medicine Lodge Creek
(7) Camas Creek

Along with the streams previously listed, perched river seepage is associated with flood control diversions and sites that extract water from these streams for non-irrigation purposes. These entities are as follows:

(1) Magic Reservoir Spill (Big Wood River)
(2) INL Flood Control (from the Big Lost River)

(3) Little Lost Flood Control
(4) Birch Creek Hydropower Plant (from Birch Creek)
(5) Basin 31 Flood Control (from Camas Creek)
(6) Camas National Wildlife Refuge (from Camas Creek)
(7) Lone Tree Flood Control (from Camas Creek)

As was discussed in ESPAM 1.1 Design Document DDW-024 (Erickson, Nelson, and Contor, 2004), nearly all of the irrigated lands supplied water by the Twin Falls Canal Company lie outside of the study area of the model. However, the leaky part of the Twin Falls Canal and part of Lake Murtaugh within the study area contribute large volumes of recharge relative to the fraction of diversions involved. As a result, these entities were not treated with the canal function of the GIS and FORTRAN recharge tools and were instead simulated in the model as perched river seepage.

In ESPAM 1.1, gaged stream flow near the model boundary or head of the stream less the diversions within the model boundary associated with the stream was the method used to calculate perched river seepage (Equation 1). In several cases, stream flow was not available for the entire calibration period in ESPAM 1.1 (1980-2001); therefore, linear regression was applied to estimate the flow. Linear regression was based on factors such as flow in other streams, known diversions, and precipitation attempting to get the best R^2 value possible for the regression. The methods associated with determining these estimates can be found in the design document DDW-024 (Erickson, Nelson, and Contor, 2006).

DISCUSSION OF TOPICS FOR ESPAM 2

In ESPAM 1.1, little data was available for ESPAM 1.1 to estimate perched river seepage for some streams, including data for stream flow and diversions. As a result, prediction methods using linear regression yielded small R^2 values and for ESPAM 2 we wanted to improve these estimates of perched river seepage. During ESHMC meetings four main questions were discussed:

(1) Should Beaver Creek be added as a perched river with seepage?
(2) What major changes will be made relative to the ESPAM 1.1 approach?
(3) What prediction methods are available for estimating perched river seepage?
(4) Which prediction method is best and why?

Addition of Beaver Creek

Perched river seepage in Beaver Creek was not included in ESPAM 1.1; however, data analysis has shown that it may be necessary to add. There are three gages on Beaver Creek that are within or near the ESPAM 2 model boundary: (1) at Spencer, (2) at Dubois, and (3) near Camas. Data was available at both the Spencer gage and the Dubois gage between 1936 and 1989. Figure 1 shows the difference between the daily data for the upstream gage (Spencer) and the downstream gage (Dubois).

Note that gaps in the data occur when data at both sites were not available. Based on Figure 1 below, it appears that Beaver Creek has gains as well as losses between Spencer and Dubois. The largest losses typically occur in April and May. The negative values (losses) seem to vary over the years and are not focused within one month. Figure 2 shows the difference between the daily data between the upstream gage (Dubois) and downstream gage (Camas). Beaver Creek has more losses than gains in this reach.

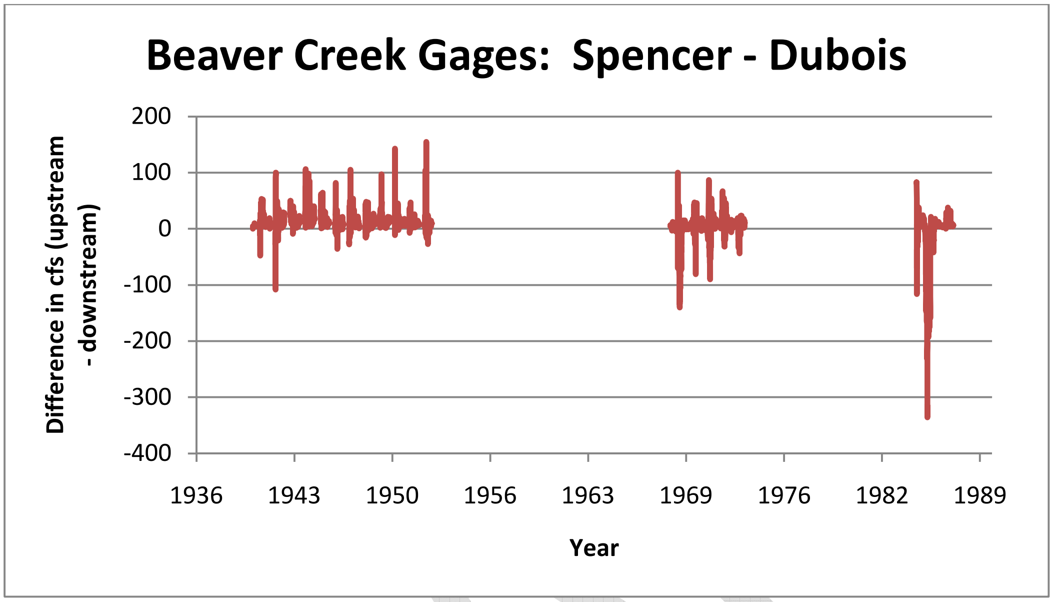

Figure 1. Gains (negative) and losses (positive) between Spencer and Dubois in Beaver Creek.

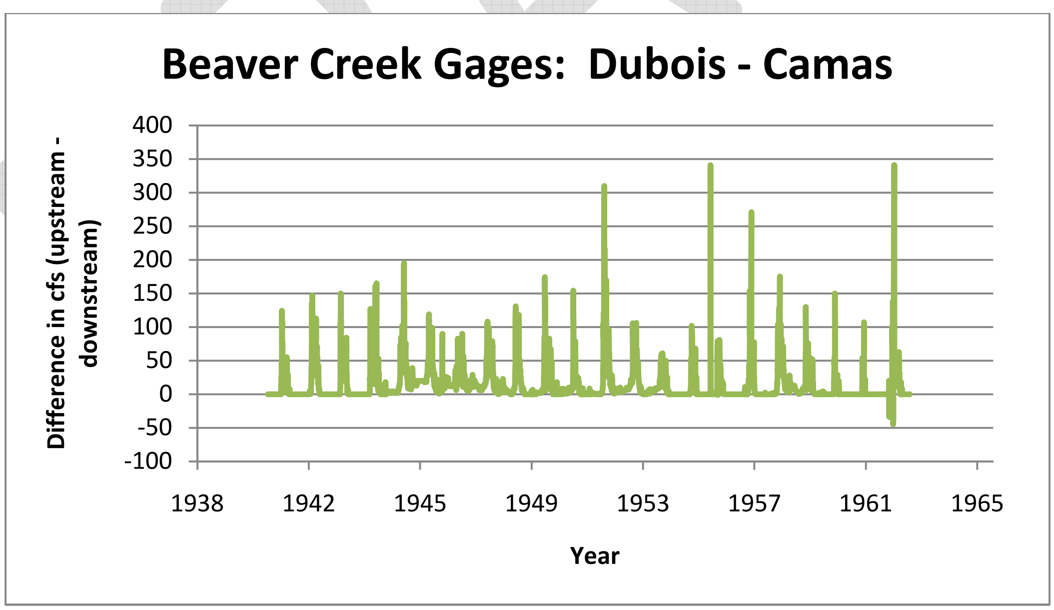

Figure 2. Gains (negative) and losses (positive) between Dubois and Camas in Beaver Creek.

Changes to the ESPAM 1.1 Approach

Data acquired for ESPAM 1.1 along with additional data acquired from IDWR, paper, and microfiche watermaster records, engineering firms, and other additional data were used in making calculations for ESPAM 2. In order to add more recent data, additional watermaster reports were acquired. Stream flow data were acquired from the US Geological Survey NWIS system and were summarized to a monthly format. Unfortunately, several necessary flow sites are lacking data essential to estimating perched river seepage. Table 1 is a list of USGS flow sites and monthly data available for use in calculating perched river seepage.

Table 1. Available data for USGS stream flow sites in the Eastern Snake Plain.

USGS Stream Flow Site needed to Estimate Seepage	Available Data during ESPAM 2 Calibration Period
Big Wood River below Magic nr Richfield	May 1980 – October 2008
Malad River near Gooding	May 1980 – October 2008
Malad River near Bliss	January 1985 – September 2007
Little Wood River near Carey	May 1980 – October 2008
Little Wood River near Richfield	None during calibration period
Little Wood River at Shoshone	None during calibration period
Big Lost River below Mackay near Mackay	May 1980 – October 2008
Big Lost River near Arco	May 1980 – October 1980; April 1981 – September 1981; May 1982 – October 2008
Big Lost River below INL Diversion near Arco	August 1984 – October 2008
Big Lost River at Lincoln Blvd Bridge near Atomic City	August 1984 – October 2008
Big Lost River above Big Lost River sinks near Howe	April 1996 – October 2008
Little Lost River near Howe	May 1980 – September 1981; May 1985 – September 1990
Birch Creek at 8 Mile Canyon Road near Reno	June 1980 – September 1980; April 1981 – September 1981; April 1984 – December 1984; April 1985 – August 1985
Medicine Lodge Creek near Small	June 1985 – October 2008
Beaver Creek at Spencer	May 1980 – May 1982; May 1985 – September 1993
Beaver Creek at Dubois	April 1983 – September 1983; April 1985 – September 1987
Beaver Creek near Camas	None available during calibration period
Camas Creek at Red Road near Kilgore	October 1986 – December 1991
Camas Creek at Camas	May 1983 – September 1986; May 1989 – June 1989; October 1989 – November 1989; April 1990 – October 2008

Figure 3 shows the sections of each stream in the model boundary that will be represented in ESPAM 2. Although the entire Big Wood River is shown in the figure, the dotted blue line section of the river will be represented with values of zero. This reach was placed in the shapefile for the GIS Recharge Tool as a placeholder in case it was desirable to add values for this reach in the future. Data analysis indicates that calculated gains and losses are always within the uncertainty of the underlying gage data. Beaver Creek, the newest addition to the shapefile, was divided in to two reaches based on gage locations.

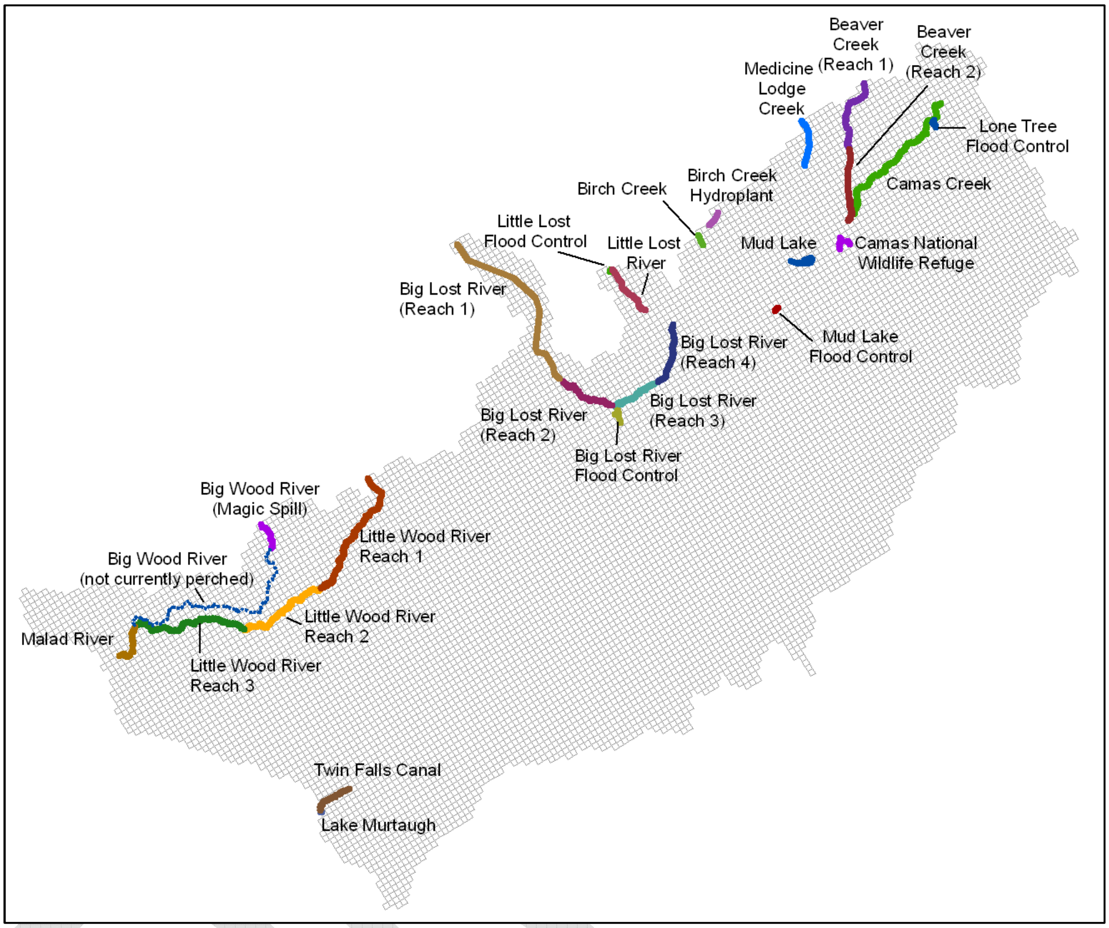

Figure 3. Reaches of streams representing perched river seepage in ESPAM 2.

As discussed earlier, linear regression was used to estimate stream flow based on various factors such as precipitation or diversions in ESPAM 1.1. Instead of using different types of data, the goal was to use one method and apply to all streams when estimating ungaged flow for ESPAM 2. The following section will discuss the methods explored prior to choosing one prediction method.

Prediction Methods for Ungaged Flow

Quillian and Harenberg (1982)

One method explored for use in predicting perched river seepage for ESPAM 2 was developed by Quillian and Harenberg (1982). They developed a Network Analysis for Regional Information (NARI) and a Cost-Effectiveness Procedure for testing stream-gaging networks in Idaho. Idaho was divided into nine regions and a multivariate regression equation was developed for each region. The form of the regression equation recommended for use is as follows:

$Y = b_0 x_1^{b1} x_2^{b2} \ldots x_k b^k$,

where Y is the stream flow characteristic of interest; x_1, x_2, …, x_k are the independent variables which are known characteristics of the drainage basin at the site being considered as a predictor; and b_0, b_1, b_2, …, and b_k are the regression coefficients. The independent variables used in this method include basin area, mean annual precipitation, percentage of forest cover, longitude of station, and mean basin elevation. Unfortunately, this method yielded an annual discharge value, which was not appropriate for the ESPAM 2 monthly stress periods.

Kjelstrom (1998) and Lipscomb (1998)

A second method explored for use in predicting stream flows to estimate perched river seepage was based on Kjelstrom (1998) and Lipscomb (1998). Kjelstrom (1998) developed a method for estimating the 20, 50, and 80 percent monthly exceedance discharge values for the Salmon and Clearwater River Basins in central Idaho. Kjelstrom (1998) created a technique to estimate mean monthly discharge values for the ungaged basin, but accuracy was not estimated. In this study, discharge data was collected at 73 gaging stations that were used to relate mean monthly discharge to daily mean discharges that were exceeded 20, 50, and 80 percent of the time. Estimates of the daily mean discharge at the three points on the flow-duration curve can be made by multiplying a factor by the mean monthly discharge. The factors can be used for ungaged drainage basins in the study area where discharge is not substantially affected by regulation or diversions and monthly mean discharge is known. Lipscomb (1998) estimated mean monthly discharges for each subbasin by apportioning mean annual discharges into the monthly increments on the basis of records from gage stations selected as being characteristics of the subbasin. Unfortunately, Kjelstrom's (1998) and Lipscomb's (1998) studies on the monthly mean discharges did not have a known accuracy and recommended method for use on non-regulated streams; therefore, this method was not explored further.

Hortness and Berenbrock (2001)

Another method by Hortness and Berenbrock (2001) was considered for estimating ungaged flow. The method was developed by using a multiple-regression analysis in which stream flow was related to various basin characteristics. The analysis resulted in equations used to estimate monthly exceedance and mean annual discharge values at ungaged sites. Nine basin characteristics were tested in the final analysis in which eight of these characteristics were used in one or more of the final estimating equations. Unfortunately, the equations developed by Hortness and Berenbrock (2001) were not applicable because (1) only mean annual discharges were predicted, (2) regulated streams were not applicable, and (3) equations tended to be more reliable for high stream flow statistics.

Idaho USGS StreamStats (2008)

StreamStats is a web-based GIS application created by the USGS that provides users with access to a variety of analytical tools useful for planning and management of water resources. It was based on three different reports, including Hortness and Berenbrock (2001). The following is a description of the StreamStats application from the website (http://water.usgs.gov/osw/streamstats/ ssinfo.html):

> StreamStats makes the process of computing stream flow statistics for ungaged sites much faster, more accurate, and more consistent than previously used manual methods. It also makes stream flow statistics for gaged sites available without the need to locate, obtain, and read the publications in which they were originally provided. Examples of stream flow statistics that can be provided by StreamStats include the 100-year flood, the mean annual flow, and the 7-day, 10-year low flow. Examples of basin characteristics include the drainage area, stream slope, mean annual precipitation and percentage of forested area. Basin characteristics are the physical factors that control delivery of water to a point on a stream.

The user interface of StreamStats allows the user to select the area of interest on a particular stream in which StreamStats then delineates a drainage-basin boundary for that particular point on the stream. As a result, statistics such as 100-year flood, the mean annual flow, 7-day low flow, and 10-year low flow are estimated by using regionalization. Regionalization is the same method used in those listed previously, in which it is the transfer of a flow record based on a linear regression using precipitation, diversions, or other similar basins. These data are helpful, yet the same problem continues to occur in which annual estimates are available and monthly values are not.

Horn (1988)

The Horn (1988) method was developed to assess the risk of drought in Idaho. At the time, about 400 stream flow gaging stations were available for testing the method; 124 of these stations were chosen for this study. The number of stations was narrowed from 400 to 124 because the author excluded data files that were of poor quality, short in record length, included upstream diversions and returns, or included sites with flowing water consisting mostly of groundwater. Chapter 2 of Horn (1988) discusses how a thoroughly tested data augmentation model developed by Yevjevich (1975) was used to estimate stream flow. Given the 124 stations, data from one station from was partially removed and compared to a similar station. Stations were paired based on location, elevation, drainage area, geology, and model constraints. Using the station with removed data points, referred to as the “subordinate” station (the station with a full period of record referred to as the “key” station), the series of equations based on Yevjevich’s (1975) model were used to estimate flow. The Horn method preserves the individual station characteristics and has strict parameters that allow for comparing one station to another. This method would provide reliable estimates of flow at ungaged sites, yet the analysis would take a considerable amount of time to complete and only yield long-term average monthly estimates of flow.

Linear Regression

Another method explored was linear regression. This method was not discussed at an ESHMC meeting, but it was initially used as a simple technique to evaluate predicted data through use of StreamStats. Linear regression involves comparing similar ungaged station locations to gaged locations where data is available. Linear regression would involve plotting two gages against each other and finding a prediction equation in the format of $y = ax + b$, where y is the gage in need of predicted data, a is the slope of the linear regression line, x is the gage which is similar to the ungaged station yet has data available to make a linear prediction, and b is the intercept of the linear regression line.

Moving Average

Since it was difficult to find a gaged flow site (with the appropriate period of data and similarity of characteristics) suited to predict data for another ungaged site, a moving average technique was applied. Like the linear regression method, this method was also not discussed at an ESHMC meeting because it was an easy method to employ. The moving average was calculated on a 12-month basis, meaning that the value for October 1996 would be an average of the values October 1995 through September 1996. This method was developed in an attempt to induce temporal variation at ungaged flow sites.

Three techniques involving a moving average were tested when attempting to predict ungaged flow. The techniques are similar yet use different statistics provided by StreamStats. The equation for the first moving average technique is as follows:

$$\textit{Predicted Flow at Month } n = (Q_a \textit{ of Ungaged Site}) * \frac{(\textit{Moving Average at gaged site})_n}{(\textit{Long-term Average at gaged site})}, \qquad \text{(Equation 2)}$$

where *Predicted Flow at Month n is* the estimated flow at an ungaged site for a specific month *n*, Q_a *of Ungaged Site* is the mean annual flow statistic for the ungaged site provided by StreamStats, *(Moving Average at gaged site)*$_n$ is the 12-month moving average at a gaged site for a specific month *n*, and *(Long-term Average at gaged site)* is the average value of the monthly data available for the gaged site. The second moving average technique is very similar to Equation 2 with the exception of two variables:

$$\textit{Predicted Flow at Month } n = (X \textit{ of Ungaged Site}) * \frac{(\textit{Moving Average at gaged site})_n}{(Q_a \textit{ of gaged site})}, \qquad \text{(Equation 3)}$$

where *X of Ungaged Site* is the mean monthly flow value for the months April through November. For the remaining months (December, January, February, and March) the 50% flow duration value was used for the variable *X of Ungaged Site* since the mean monthly flow value was not provided for these months. The third moving average technique is similar to Equation 3 except one variable is different:

$$\textit{Predicted Flow at Month } n = (Y \textit{ of Ungaged Site}) * \frac{(\textit{Moving Average at gaged site})_n}{(Q_a \textit{ of gaged site})}, \qquad \text{(Equation 4)}$$

where the variable, *Y of the Ungaged Site*, only uses the 50% flow duration statistics provided by StreamStats for all months without using the mean flow values.

Choosing a Method

At an ESHMC meeting earlier in 2009, the members agreed that USGS Idaho StreamStats would be the method of choice when predicting ungaged flow because it was a commonly used program and seemed to be a good predictor for sites lacking data. Other methods previously described seemed to either (1) not provide monthly flow averages, (2) take more time to compute than there was time to complete the task, or (3) not provide enough accuracy. At the time it was believed StreamStats provided monthly flow averages. In case that only annual average values could be used, the following formula could be used based on the statistics provided by StreamStats to estimate monthly flow:

$$Q_a \cdot \frac{(\text{Monthly } Q)}{(\text{Long-term } Q)} = \text{Predicted flow for a specific month at an ungaged stream flow site} \qquad \text{(Equation 5)}$$

where Q_a is the mean annual flow at an ungaged site predicted by StreamStats for a specific stream location or gage in cubic feet per second (cfs), *Monthly Q* is a known value (cfs) of flow for a gaged site that will be used as a predictor, and *Long-term Q* is an average of monthly flow (cfs) over the period in which data is available for the gaged site. The equation above yields a monthly prediction of flow at an ungaged stream flow site.

The above method was tested on several gages in the Snake Plain. One gage that was used was the Beaver Creek gage at Spencer. Estimates were predicted using several different predictors. Data are available at Beaver Creek at Spencer for 1985-1993; therefore, predictions were made at this gage during this time period to test the ability of different gages to predict flow.

In an attempt to show how well Equation 5 predicted data for the Spencer gage at Beaver Creek, a linear line was plotted through the points in a plot of predicted flow versus actual flow. This linear line is not to be confused with a later method discussed involving linear interpolation. It is simply used to as a technique to visually see how well the data was predicted relative to the actual data. Figure 4 shows the three different gages with data between 1985-1993 that were used to predict data at Beaver Creek, which were (1) Camas Creek at Red Road near Kilgore, (2) Big Lost River at Howell Ranch near Chilli, and (3) Little Wood River above High Five Creek near Carey. These gages were chosen based on site similarity, which including comparisons between drainage area, gage elevation, values of Q_a, and mean annual precipitation. The gages previously listed may not seem to be a good comparison relative to the site needing predicted data (Beaver Creek at Spencer); however, theses gages were the best given the data that was available during the ESPAM 2 calibration period. Based on Figure 4, the Little Wood gage appears to be the best predictor of flow at Beaver Creek relative to the actual flow data since it has the highest R^2 value and the slope of the line reveals that it is a fair 1:1 relationship.

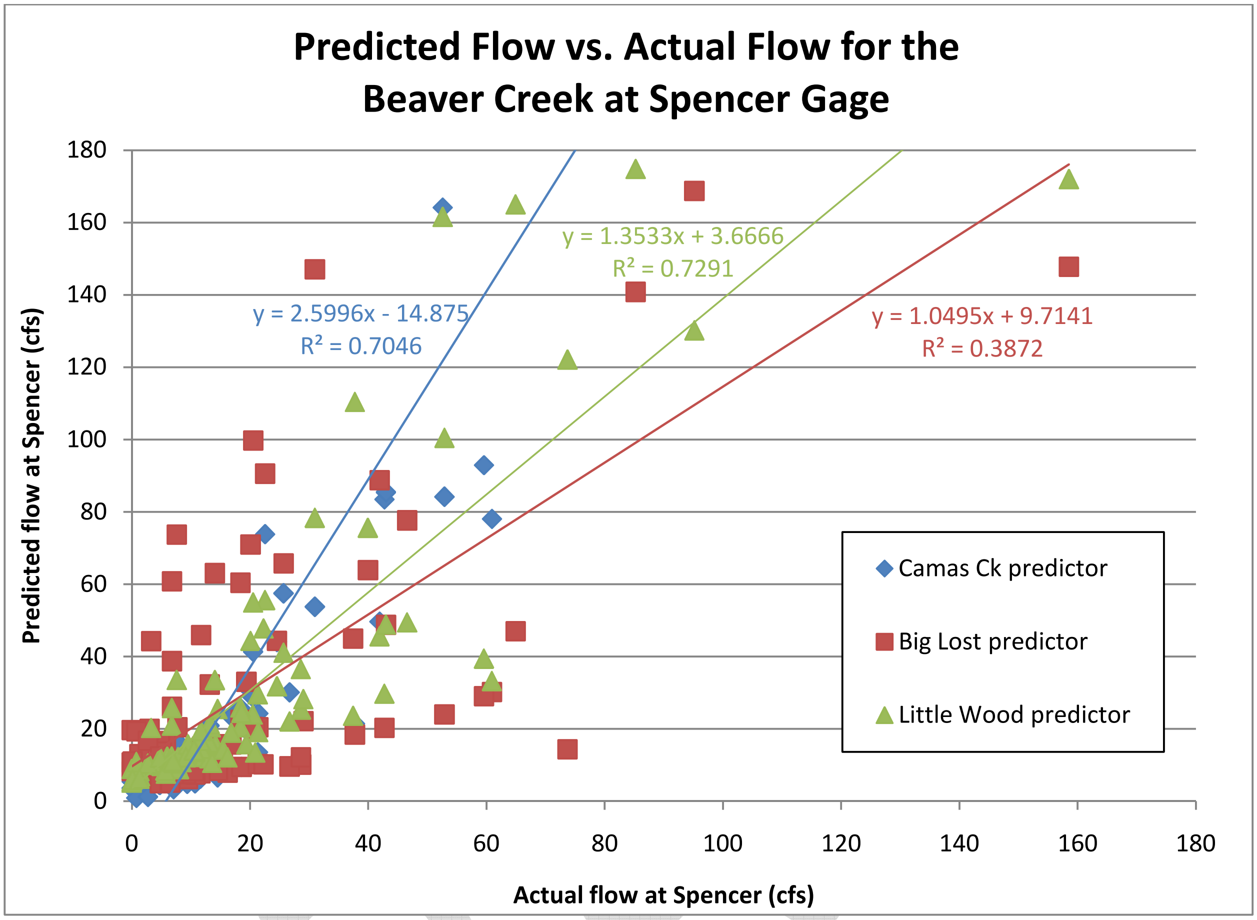

Figure 4. Predicted vs. Actual Flow for the Beaver Creek at Spencer Gage.

Given the results provided by StreamStats, other methods previously discussed were also tested. Figure 5 shows the results of testing different prediction methods on the Beaver Creek at Spencer gage and the results are plotted as predicted flow versus actual flow. Since the Little Wood proved to be the best at predicting flow based on using the StreamStats method (see Figure 4), this gage was used for further analysis with the other methods.

In Figure 5, the dotted blue line is the actual flow data for Beaver Creek at Spencer. The solid lines represent predicted data using different methods as indicated within the parentheses in the legend of Figure 4. The red line is data that was predicted using Equation 4 and StreamStats statistics. This method tends to overestimate flow in Beaver Creek at Spencer with the exception of reasonable estimates after October 1986 and February 1988. The green line is the flow predicted using a linear regression. This method is not flawless and sometimes tends to predict lower flow in Beaver Creek at Spencer. The remaining methods (purple, blue, and orange lines) use moving averages and statistics provided by StreamStats for both Beaver Creek at Spencer and the gage used to predict flow (Little Wood River above High Five Creek near Carey).

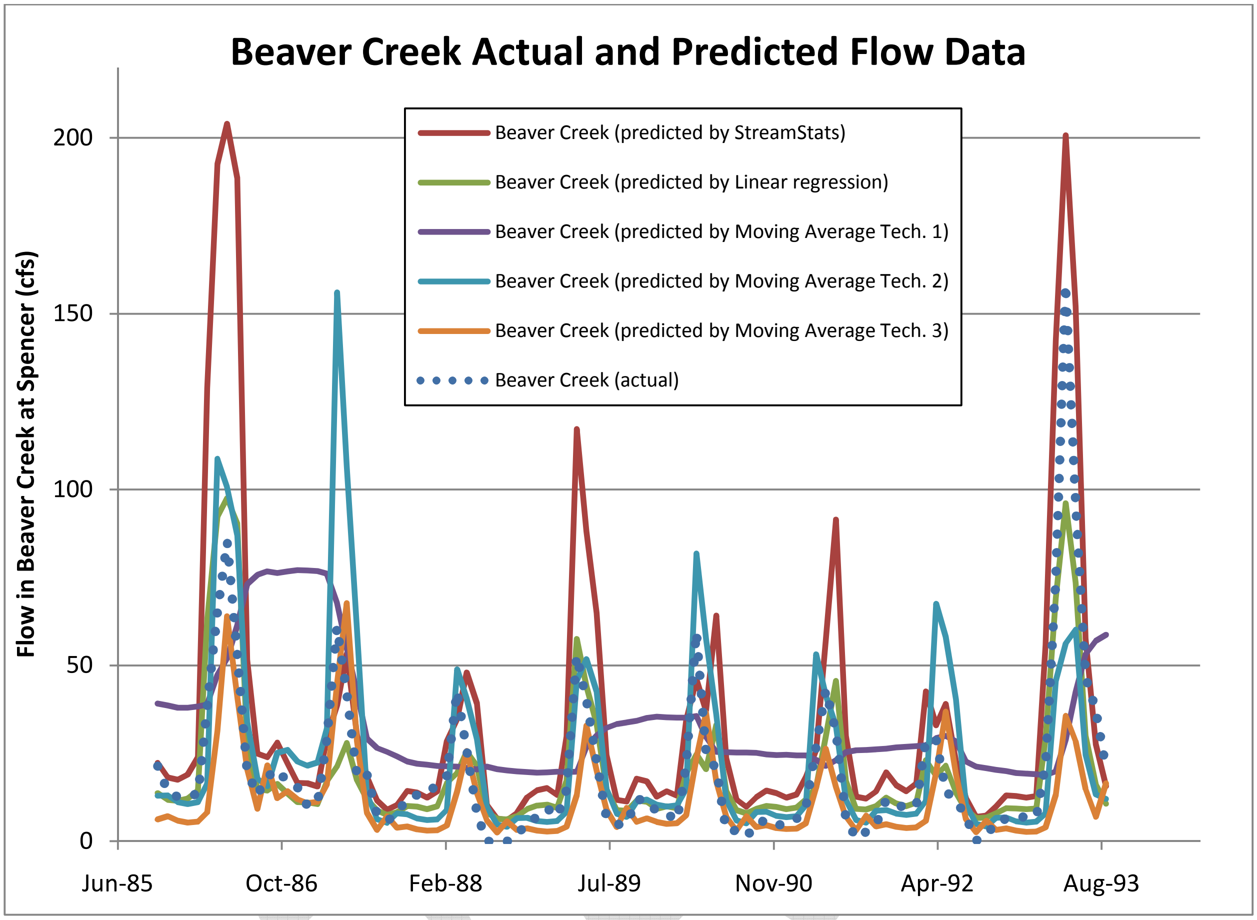

Figure 5. Predicted flow at Beaver Creek over time. The actual values of flow on Beaver Creek are shown by the dotted line.

Use of StreamStats technique (Equation 4) and the linear regression method seemed to provide the best results out of all five methods tested; however, the linear regression provided slightly better results. Figure 6 below shows the results of testing predicted values in Beaver Creek by plotting predicted flow versus actual flow and plotting a linear line through the points. As expected based on Figure 5 above, the moving average techniques have low r-squared values. The StreamStats method and linear regression method have higher R-squared values (which happen to be the same R-squared value for both methods) along with better prediction equations (since the trendlines for both are close to a 1:1 relationship) as shown in Figure 6. The StreamStats method and linear regression method have nearly the same value for R-squared; however, the linear regression method provides a trendline more similar to a 1:1 relationship relative to the StreamStats method. As a result, the linear regression equation represents a better method over all other equations because it has a trendline with a low R-squared value and a trendline that is closer to 1:1 than any of the other methods. The 1:1 line (where y = x) is shown by the dashed black line in Figure 6.

In order to avoid confusion of the linear regression method along with using a linear trendline plotted through the points in a plot of predicted flow versus actual flow, more clarification may be necessary. The linear regression method was developed using Little Wood as a predictor (i.e. as the independent or X variable) and Beaver Creek as the value to be predicted (i.e. as the dependent or Y variable). The equation was assembled as follows: Beaver Creek flow = $B_0 + B_1$ * (Little Wood flow). In Figure 4, the linear regression is used to test prediction equations. The actual value (during times of available data) was used as the independent (X) variable and various predicted values (from different methods) were used as the dependent (Y) variables. The resulting equation is of the form: Predicted = $B_0 + B_1$ * (Actual). If a prediction method were perfect, B_0 would be zero and B_1woudl be 1.0.

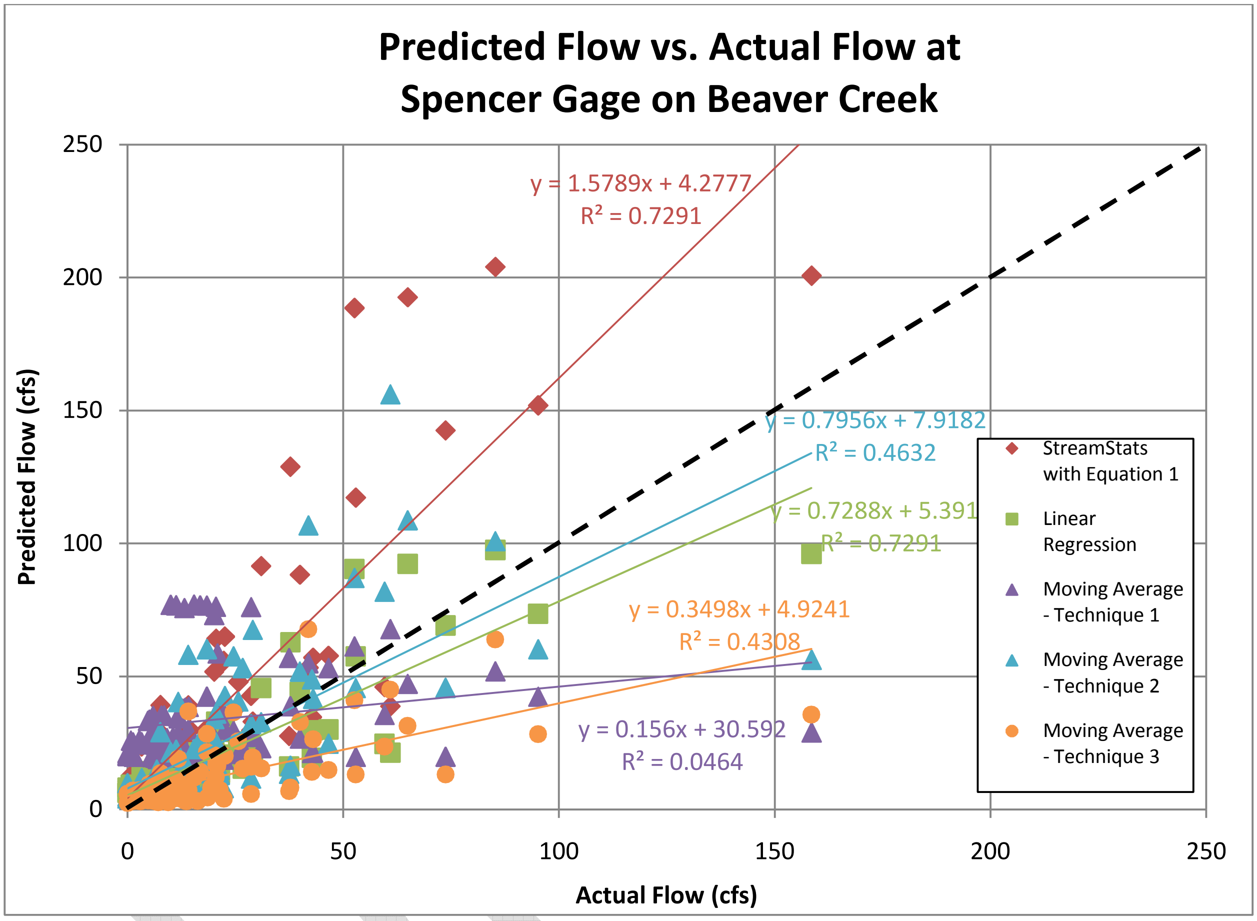

Figure 6. Methods used in predicting stream flow on Beaver Creek at Spencer.

SUMMARY AND CONCLUSIONS

Relative to the other five methods previously discussed, the linear regression proved to be simple yet provided reliable estimates of flow at Beaver Creek. This method was chosen to predict missing values in Beaver Creek along with the other streams in ESPAM 1.1 that were represented as being seeping perched rivers. The form of the equation would be:

$$\text{Predicted flow} = B_0 + B_1 * (\text{Actual flow}),$$

where an appropriate gage (as described in the section "Prediction Methods for Ungaged Flow" under *Linear Regression*) would be chosen to predict flow at an ungaged site. Along with Beaver Creek, the linear regression method will be applied to all other streams and bodies of water in which gaged flow is not available for the ESPAM 2 calibration period. When estimating the actual value of perched river seepage, the same techniques outlined for ESPAM 1.1 in the Water Budget Design Document DDW-024 (Erickson, Nelson, Contor, 2004) will be used. The following equation (Equation 1) was used in ESPAM 1.1 for estimating perched river seepage:

Upstream gage (cfs) – downstream gage (cfs) + diversions (cfs) = Gains (cfs).

REFERENCES

Erickson, N., Nelson, D., and Contor, B.A., 2006. Non-Snake River Diversions and Perched River Seepage. Idaho Water Resources Research Institute Technical Report 06-003.

Horn, D.R., 1988. Annual flow statistics for ungaged streams in Idaho: American Society of Civil Engineers, Journal of Irrigation and Drainage Engineering, v. 114, no. 3, p. 463-474.

Hortness, J.E., and Berenbrock, C., 2001. Estimating Monthly and Annual Streamflow Statistics at Ungaged Sites in Idaho: U.S.G.S. Open-File Report 01-4093, 34p.

Kjelstrom, L.C., 1998. Methods for estimating selected flow-duration and flood-frequency characteristics at ungaged sites in central Idaho: U.S.G.S Professional Paper 1604, 49p.

Quillian, E.W., and Harenberg, W.A., 1982. An evaluation of Idaho stream-gaging networks: U.S.G.S. Open-File Report 82-865, 57p.

StreamStats, 2008. <http://streamstats.usgs.gov>.

Taylor and Moore, 2009. Representation of MODFLOW-2000 River Cells for the Snake River above Milner Dam and American Falls Reservoir for Calibration of the Eastern Snake Plain Aquifer Model Version 2; As Built. Idaho Water Resources Research Institute Technical Report 200903.

Yevjevich, V., 1975. Generation of Hydrologic Samples, Case Study of the Great Lakes, Hydrol. Paper 72, Co. State University.