MEMORANDUM

To: Stacey Taylor
        Greg Moore
Fr: Bryce Contor
Date: 13 August 2009

Re: IESW005 Diversions and Perched Seepage in Big Lost
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        As you requested, I have reviewed the Diversions and Perched Seepage
data and calculations for the Big Lost . When we talked last, I had recalled:

1. In ESPAM1.1 we had calculated diversions for IESW005 as (Mackay gage -
    Arco gage) in the summer time, and zero in the winter.

2. BL1 (Big Lost River, Mackay to Arco) perched seepage was zero in the
    summer time and (Mackay gage - Arco gage) in the winter.

3. We had complete gage records for Big Lost River below the INL flood control
    diversion and at Lincoln Boulevard, for all periods when there would have
    been flow.

        This information did not always correspond to the ESPAM1.1 data files on
hand. Also, Greg downloaded available gage data and attempted to define
regressions to predict missing values, and the regressions had odd appearances
and low r^2 values.

        Based on our discussion of these issues, I looked at the ESPAM1.1
perched seepage & diversion files, the USGS gage files, and Greg's regression
files. I was looking at the following questions:

1. Why did some periods in ESPAM1.1 show negative seepage (i.e. reach
    gains) in reach BL1?

2. Why does ESPAM1.1 show non-zero BL1 seepage in some summertime
    periods?

3. Where are the data used in ESPAM1.1 for years prior to 1984, for gages
    below Arco?

4. How did we estimate missing data for Big Lost River gages below Arco in
    ESPAM1.1?

5. Why do Greg's regressions for Big Lost River gages show such odd patterns and low r^2 values?

6. How should we apportion ESPAM1.1 six-month data to one-month periods, if we elect to use the same values as ESPAM1.1 for 1980-2001?

I was able to find a draft write-up and the Big Lost spreadsheets from ESPAM1.1. It turns out I had remembered incorrectly:

1. For 1980 - 1996, we used actual watermaster diversion records for IESW005 (with a few missing months estimated from other years).

2. For 1997 on, we calculated diversions as I described above, because after 1996 the watermaster records also include groundwater pumpage, without differentiating water source.

3. For 1980 - 1996, we assumed that (Bed Loss) = (Mackay Gage - Arco Gage - Diversions). This explains both the appearance of non-zero values in summertime months and the appearance of negative values. We assumed that negative values were for periods when there were net gains in the Big Lost. We accepted this, knowing that there are gaining reaches in the Big Lost above Arco.

4. My assertion that we had all needed values for gages below Arco was incorrect. We did use linear regression with the Arco Gage as the predictor station, to fill in missing values. Values prior to 1984 were missing for all the gages below the Arco gage.

I didn't fully evaluate Greg's spreadsheets, but I believe there may have been a problem with summing daily values to monthly values. A number of Greg's monthly values were very small negative numbers, but when I acquired fresh downloads of USGS gage data, there were no negative flows in any of the daily records. Problems in summing could have contributed to the issues seen in the regressions.

In reviewing the data, I also noticed that the periods of low indicated seepage generally corresponded to periods of high flow. This did not seem reasonable; at high flows, river stage and therefore driving head ought to be greater, and seepage should increase. It appeared that in periods of high flow, the Arco Gage flow was higher relative to Big Lost at Mackay than in periods of low flow. A possible explanation is that there are additional tributaries between Mackay and Arco, not included in the ESPAM1.1 data. One known neglected tributary is Antelope Creek. Using data that were gathered in 1919 - 1922 (with significant winter-time data gaps), I was able to construct a reasonable prediction equation for Antelope Creek daily CFS using the Big Wood River near Hailey as predictor, as shown in Figure 1:
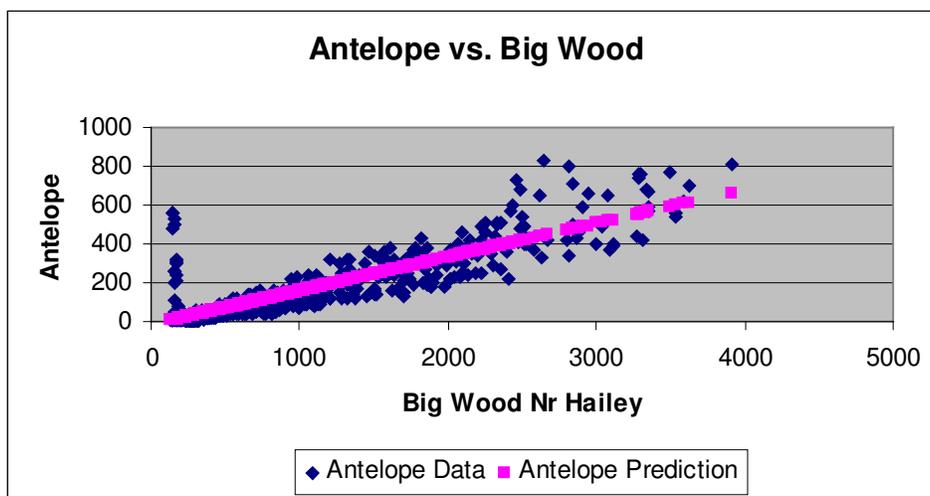
Figure 1. Prediction of Antelope Creek daily cfs using Big Wood River near Hailey. (Antelope) = -16.4552 + 0.173915 (Big Wood); r^2 = 0.79. Equation and all parameters are statistically significant at alpha = 0.05.

Adding predicted Antelope Creek flows to Big Lost River at Mackay reduced but did not eliminate the occurrence of very low (or negative) seepage during periods of high flow. Reasoning that this still represented a data deficiency rather than hydrologic fact, I determined to constrain the BL1 perched seepage calculation, as described later in the memo.

I also investigated prediction equations for the missing data at gage stations below Arco. Since there are no tributaries, and the river below Arco is perched high above the aquifer, all water passing a lower gage must come past a higher gage. Therefore, in each case I used the next-upstream gage as predictor. Figure 2 and Figure 3 show the results of this investigation.
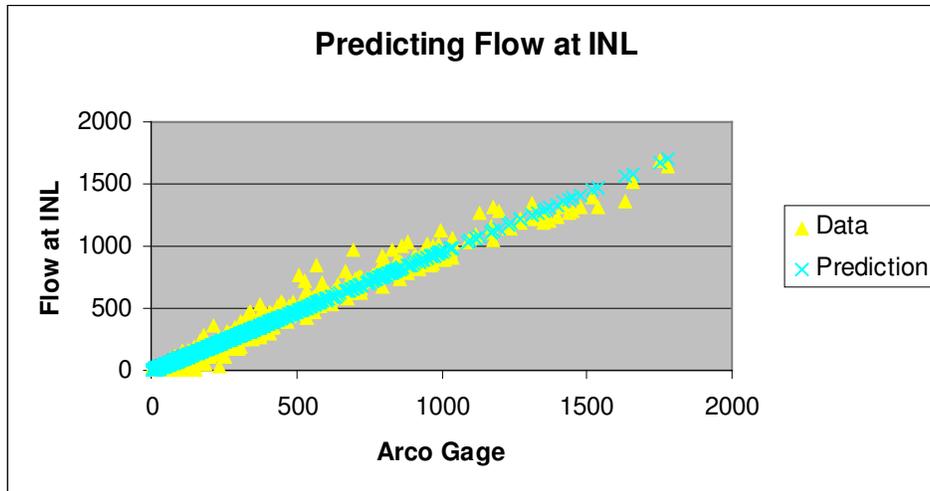
Predicting Flow at INL

Figure 2. Prediction equation for (INL Diversion plus flow below INL diversion): (INL + Below) = -4.82013 + 0.957603 (Arco); r2 = 0.98. Equation and all parameters are statistically significant at alpha = 0.05.
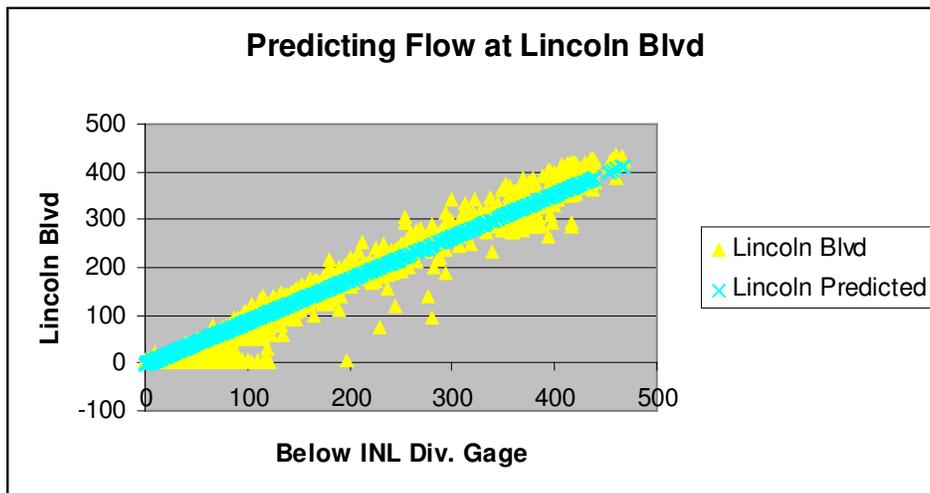
Predicting Flow at Lincoln Blvd

Figure 3. Prediction equation for flow at Lincoln Boulevard: (Lincoln Blvd) = -2.94064 + 0.887357 (Blw INL); r^2 = 0.97. Equation and all parameters are statistically significant at alpha = 0.05.

The flow at INL is partitioned between the INL flood-control diversion and flow below the INL diversion. My recollection from living in Howe in 1983 - 1997 is that there were no diversions to the flood-control basin prior to 1984. I believe that we confirmed this assumption during ESPAM1.1, and the ESPAM1.1 data have no diversions to INL flood control prior to 1984. Therefore, for ESPAM2 I assumed all estimated flows at INL prior to 1984 remained in the river channel.

Starting in July 1984 we have data for nearly the full period. The Mackay and INL Diversion records have a few short data gaps which I filled with prior-day values. The Arco gage is missing part of the winter of 1980/1981 and part of the winter of 1981/1982. I filled these with 1979/1980 values.

I used a small Visual Basic utility to sum values (in daily average CFS) by month, and convert to cubic feet per month. The resulting monthly values I imported to spreadsheet "Daily_Bryce_DataGaps_Filled.csv.out.xls," and performed further calculations. You can look at cell contents to see what I did. The important columns for IESW005 diversions and Big Lost River perched seepage are the following:

1. Column D, "IrrSeason." This contains zero (0) for winter months (November through March) and one (1) for summer months, based on months prior to 1997 when watermaster records show diversions.

2. Column E, "M + A." This is the sum of flows at Mackay and estimated Antelope Creek flows.

3. Column F, "Arco." This is the flow at the Arco gage.

4. Column G, "INL_Div." This is the recorded diversion to the INL flood control site. Prior to July 1984 it contains assumed values of zero (0).

5. Column H, "BLW_INL." This is flow in the Big Lost below the INL diversion.

6. Column I, "I + B." This is the flow in the Big Lost below the INL diversion plus the INL diversion. It represents total flow at the INL.

7. Column J, "Lincoln." This is flow at Lincoln Boulevard.

8. Column K, "Sinks(Howe)." This is the flow above the Howe sinks, estimated prior to 1996. Unless we further subdivide the Perched River shapefile, this column will not be needed.

9. Column L, "WaterM_Divs." This is the IESW005 diversion volume by month from ESPAM1.1, through 1996. These were based on watermaster records, with some estimates in the summer of 1980 and 1981.

10. Column M, "Min_B1." This represents the minimum expected value of seepage between Mackay and Arco. It is calculated as the minimum of 50 cfs (times the number of days in the month), or the sum of flow at Mackay and Antelope Creek. This calculation is made to avoid the very low or negative seepage that is indicated in periods of high flow, without ever exceeding the low-flow available supply. It could be argued that imposing this minimum is "creating water," but I assert that it is correcting for a data deficiency. The 50-cfs minimum is subjectively chosen based on looking at hydrographs of indicated seepage.

11. Column N, "IESW005." This is the column that represents diversions to use in the model, in units of ft³ per stress period. Column T contains the same values in units of 1000 acre feet per month. Worksheet "IESW005" contains the 1000-acre-feet value transposed into horizontal format, and is the source that should be used to populate the diversions spreadsheet. Use the ESPAM1.1 values for WY1979 and the first part of WY1980.

Through 1996 this column uses values from ESPAM1.1, which were based on watermaster records. After 1996 it is calculated from (Mackay + Antelope - Arco), using a regression based on watermaster records through 1996, irrigation-season values only. This regression is illustrated in Figure 4.
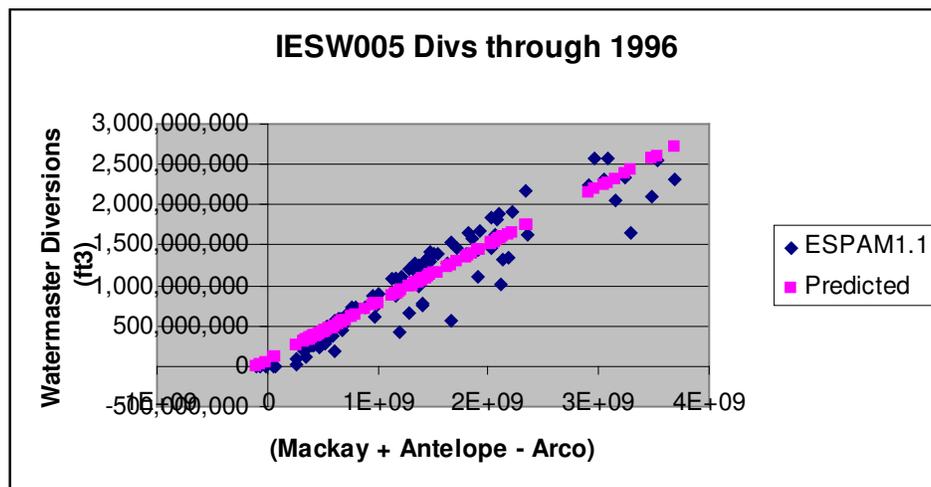

Figure 4. Prediction equation for monthly diversions (ft³/month):
(Diversions) = 61,116,502 + 0.7179959 (Mackay + Antelope - Arco); r^2 = 0.90. Equation and slope are statistically significant at alpha = 0.05; intercept is not statistically different from zero. Calculated using April - October data.

Due to the continuing issue of the Arco gage occasionally exceeding (Mackay + Antelope), diversions are limited to a minimum of zero. This limitation is invoked only a few times, always in April or October.

12. Column 0, "BL1." These are the values to use in Perched River Seepage for the Big Lost River, Mackay to Arco. It is the greater of the value in the "Min_B1" (minimum seepage, described above) and the value (Mackay + Antelope - Arco - Diversions).

13. Column P, "BL2." These are the values to use in Perched River Seepage for the Big Lost River, Arco to INL Diversion. It is the Arco gage minus (INL diversion + Flow below INL diversion). In a very few months, small negative values are replaced by zeroes.

14. Column Q, "BL_Flood." These are the values to use in Perched River Seepage for the Big Lost River Flood location. This is from the USGS record, assuming zero for all dates prior to July 1984. One date in 2008 I manually

filled using the prior-day value.

15. Column R, "BL3." These are the values to use in Perched River Seepage for the INL Diversion to Lincoln Boulevard reach. It is the Big Lost Below INL Diversion gage minus the Lincoln gage. In a very few months, small negative values are replaced by zeroes.

16. Column S, "BL4." These are the values to use in Perched River Seepage for the below-Lincoln Boulevard reach. It is the monthly sum of flow at Lincoln Boulevard. Prior to 1984 uses estimated values, as discussed above. After 1984 the data series was complete and no estimates are used.

17. Column T, "IESW005_1000af." This contains the diversion volumes from column N, converted to units of thousands of acre feet. This is the column to use in populating the "pink sheet" diversions spreadsheet.

The remaining columns were used to generate the test graphics that appear to the right of the data. All the time series appear reasonable to me.

The underlying data, VB utility and calculation worksheets will be archived on my "Snake August 2009" CD and on my computer in the "Snake August 2009" folder, in both cases in a subdirectory called "BigLost." "BigLost" also contains copies of the archived ESPAM1.1 files that I found.