Estimation of Ground Water Contribution from the South Side of the Snake River, Milner to King Hill

Eastern Snake Plain Aquifer Model Version 2

Idaho Department of Water Resources
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ESPAM2 Design Document DDW-V2-14

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Estimation of Ground Water Contribution from South Side of Snake River, Milner to King Hill, for Calibration of Eastern Snake Plain Aquifer Model Version 2

DESIGN DOCUMENT OVERVIEW

During calibration of the Eastern Snake Plain Aquifer Model Version 1.1 (ESPAM1.1), 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 ESPAM1.1: 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 Superseded Design Documents will be maintained in a "superseded" file folder on the project Website, and successive versions will be maintained in a "current" folder.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

In ESPAM2, transient gains in the Kimberly to King Hill reach and the Kimberly to Buhl, Buhl to Lower Salmon Falls, and Lower Salmon Falls to King Hill sub-reaches will be model calibration targets. These transient reach gain targets will replace steady-state spring-reach targets used in ESPAM1.1. Between Kimberly and Lower Salmon Falls, ground water discharges to the Snake River from both the ESPA and from the south side of river. Estimation of the contribution from ground water discharge on the south side of the river is necessary to develop reach gain targets that better represent ground water discharge from the ESPA. The estimated contribution from ground water discharge on the south side of the river will be deducted from the transient reach gains.

This Design Document provides an estimate of ground water discharge from the south side of the Snake River between Kimberly and Lower Salmon Falls. Components estimated include ground water discharge resulting from deep percolation of irrigation water supplied by the Twin Falls Canal Company, and tributary underflow from the Salmon Falls drainage area.

This design document describes generation of transient data sets representing the south side ground water contribution to the Kimberly to Buhl and Buhl to Lower Salmon Falls reaches. These data will be deducted from the groundwater reach gains to provide a representation of the ESPA contribution to these reaches. South side ground water discharge to the Milner to Lower Salmon Falls, Milner to Kimberly, and Kimberly to Lower Salmon Falls reaches are estimated as intermediate steps. The south side ground water contribution to the Lower Salmon Falls to King Hill reach is assumed to be zero.

This Design Document is based on ESHMC meeting discussions between September 2009 and December 2011, and supporting data analyses completed by IDWR staff.

Figure 1 shows the locations of the Twin Falls Canal Company, Salmon Falls Creek watershed, Salmon River Canal Company, and U.S. Geological Survey streamflow gaging stations between Milner and King Hill.

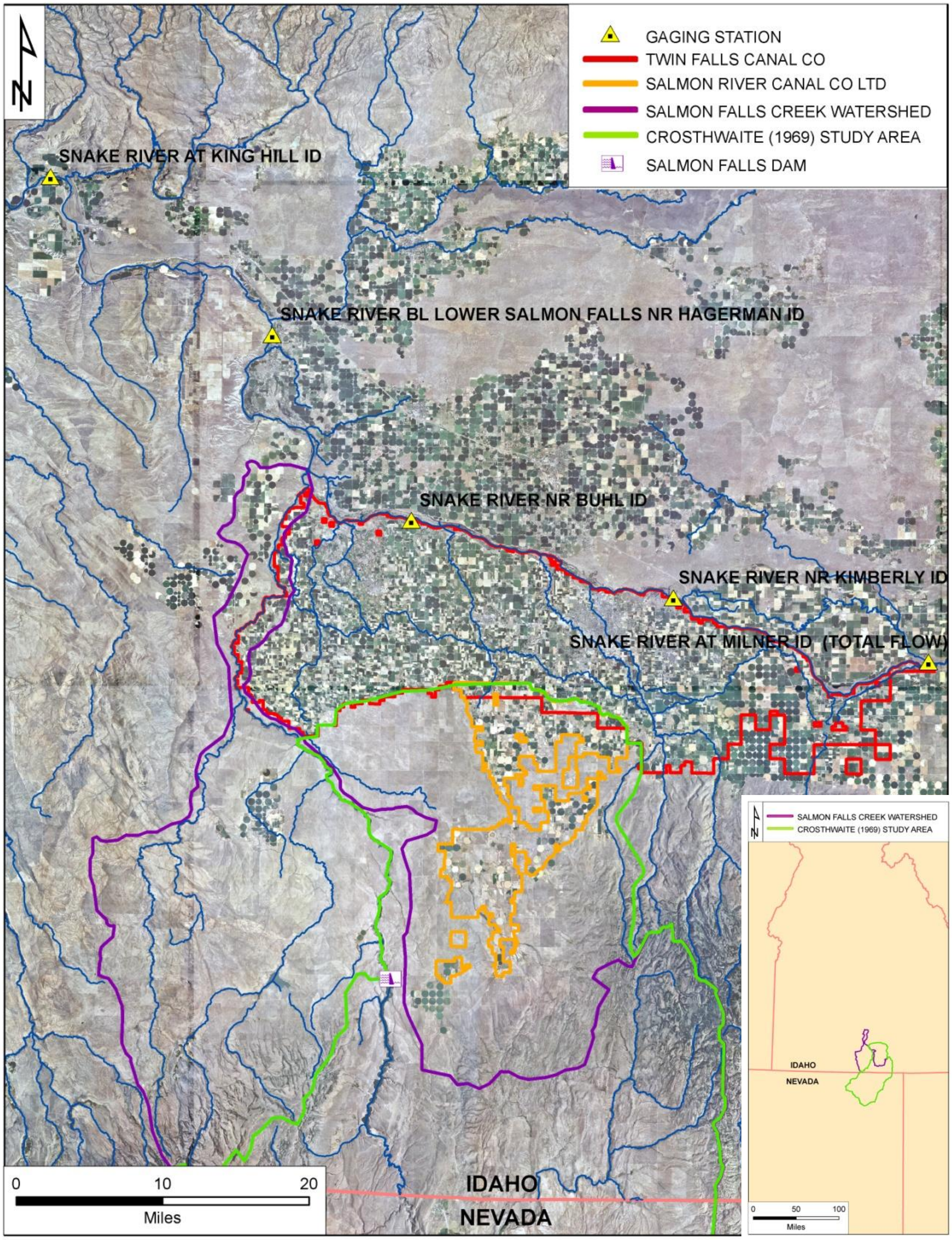

Figure 1. Vicinity Map, Milner to King Hill Reach

LITERATURE REVIEW

Thomas (1969) and Kjelstrom (1986, 1995) reviewed inflows and streamflow gains in the Snake River for four reaches between Milner and King Hill. Kjelstrom (1995) estimated the average annual south side ground water contribution to the Snake River between Milner and Hagerman was approximately 370,000 AFA between 1951 and 1980. Kjelstrom (1995) estimates for each reach are shown in Table 1. Kjelstrom's data indicate that approximately 9% of the total ground water contribution between Milner and King Hill was from the south side of the Snake River in 1980.

1. Milner to Kimberly. Between the gaging stations at Milner and near Kimberly, most of the inflow to the Snake River is from seeps and springs on the south bank (Thomas, 1969). In 1980, ground water seepage from the south side was estimated to be approximately 90% of the ground water inflow, with approximately 10% from north side springs (Kjelstrom, 1995).

2. Kimberly to Buhl. Between the gaging stations near Kimberly and near Buhl, inflow to the Snake River is from north side springs and south side irrigation return flows, and south side seeps and springs (Thomas, 1969). In 1980, ground water seepage from the south side was estimated to be approximately 8% of the ground water contribution, with approximately 92% from north side springs (Kjelstrom, 1995).

3. Buhl to Lower Salmon Falls (Hagerman). Between the gaging stations near Buhl and below Lower Salmon Falls (near Hagerman), inflow to the Snake River is from north side springs, south side waterways, and south side seeps (Thomas, 1969). In 1980, ground water seepage from the south side was estimated to be approximately 5% of the ground water contribution, with approximately 95% from north side springs (Kjelstrom, 1995).

4. Lower Salmon Falls (Hagerman) to King Hill. Between the gaging stations below Lower Salmon Falls (near Hagerman) and at King Hill, inflow to the Snake River is from Malad Springs and other north side springs. Ground water seepage from the south side of the river is not significant in this reach. (Thomas, 1969; Kjelstrom, 1969, 1995).

Reach	Milner to Kimberly	Kimberly to Buhl	Buhl to Hagerman	Hagerman to King Hill	Milner to King Hill
Estimated north side ground water contribution in 1980 (AFA)	20,000	810,000	2,510,000	1,020,000	4,360,000
Estimated south side ground water contribution in 1980 (AFA)	190,000	70,000	140,000	---	400,000
Estimated annual average south side ground water contribution 1951-1980 (AFA)	180,000	80,000	110,000	---	370,000

Table 1. Estimated ground water contribution to the Snake River (Kjelstrom, 1995).

Based on review of Thomas (1969) and Kjelstrom (1986, 1995), IDWR initially proposed attributing a constant percentage of the reach gains between Kimberly and Hagerman to ground water contribution from the south side of the Snake River. The ESHMC requested further analyses, including:

1. water balance calculations for estimation of annual recharge from surface water irrigation within Twin Falls Canal Company (TFCC) from 1980 to 2008;
2. review of Allen (2004) for applicability to TFCC water balance calculation; and
3. estimation of tributary underflow from the Salmon Falls Creek drainage based on Crosthwaite (1969).

Allen (2004) compared METRIC ET data available from March through October 2000 and April through August 2003 with TFCC diversions. Of the 261,000-acre Twin Falls tract, 231,000 acres were identified as “potentially irrigated lands”, with some unspecified potion of the area within the 231,000 acres being occupied by farmsteads, roads, canals, laterals, other infrastructure, dry fields, confined animal feeding operations, and dairies.

Allen (2004) evaluated evapotranspiration (ET) as a percentage of total diversions, and found that ET ranged from 46% to 55% of the diverted volume over the time periods evaluated. METRIC ET coverage for 2003 did not include a small part of the southwest portion of the irrigated tract. This area was also clipped from the 2000 coverage for this analysis. The METRIC ET for March through October 2000 was 585,000 AF for the 261,000-acre tract (including other land uses).

Fowler (1960) and Crosthwaite (1969) provided estimates of ground water recharge in the Salmon Falls area. Fowler (1960) estimated an average annual recharge of 95,000 AF, including approximately 20,000 AF from infiltration of precipitation and 75,000 AF from reservoir seepage, canal seepage, and deep percolation from surface water irrigated fields. Fowler (1960) acknowledged considerable uncertainty is this estimate, but was confident that the average annual recharge was likely between 70,000 and 160,000 AF. The study area extended approximately 4 miles south of Rogerson, and did not include the upper drainage basin in Nevada.

Crosthwaite (1969) provided estimates of recharge and ground water use in the Salmon Falls basin. Recharge estimates included infiltration of precipitation in the drainage basin upstream of Salmon Falls Dam, including the upper drainage basin in Nevada (Figure 1). Crosthwaite (1969) estimated infiltration of precipitation using two different methods, resulting in values of 50,000 AF and 214,000 AF. Average annual recharge associated with surface water storage, delivery, and irrigation within the Salmon River Canal Company was estimated at 65,000 AF using available data between 1912 and 1960. Crosthwaite (1969) recommended using the lower estimate of infiltration from precipitation (50,000 AF), and concluded that an average annual recharge of 115,000 AF was the best estimate that could be derived from available data. This value is higher than the estimate provided by Fowler (1960), who estimated infiltration from precipitation over a smaller area. For comparison, Garabedian (1992) used annual underflow estimates of 100,000 AF for the Salmon Falls Creek basin and 14,000 AF for the Cotttonwood, Rock, and Dry Creek basins.

Crosthwaite (1969) estimated the total annual withdrawals from wells in 1960 at 8,000 AF, of which approximately 6,000 AF were for irrigation use.

Cosgrove et al (1997) developed a steady state ground water model for the Twin Falls area, which included the Twin Falls Canal Company service area and a portion of the Salmon River Canal Company service area. Cosgrove et al (1997) estimated 202,000 acres were irrigated within the Twin Falls Canal Company service area, with 85 to 90% irrigated by gravity.

Cosgrove et al (1997) notes that the lower reaches of Salmon Falls Creek, Rock Creek, Deep Creek, Mud Creek, and Cedar Draw are incised in canyons and drain considerable amounts of ground water from the study area. Cosgrove et al (1997) also notes that ground water discharge to man-made drains occurs within the study area. The model water budget, which was developed using average data from 1973 to 1993, estimated total ground water discharge to streams, drains, and the Snake River at 640,000 AF per year. Approximately 380,000 AF of this total was estimated to occur as discharge to the lower reaches of Salmon Falls Creek, Rock Creek, Deep Creek, Mud Creek, Cedar Draw and man-made drains.

WATER BALANCE CALCULATIONS FOR TWIN FALLS CANAL COMPANY

Water balance data discussed in this section are provided in Appendix A and the spreadsheet SS_Contribution_Kimberly_Hagerman_12072011.xlsx.

Ground water recharge associated with surface water delivery and irrigation within the Twin Falls Canal Company (TFCC) was calculated using the following equation.

$$\text{Annual Recharge} = \text{Div} - \text{Ret} + P_{eff} - ET_{act}$$

where

Div = TFCC diversions[1], AF

Ret = TFCC returns[2], AF

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[1] Measured Twin Falls Canal Company diversions obtained from Snake River Planning Model.

[2] Twin Falls Canal Company returns based on measured return flow fractions between 2005 and 2008 and scaling up of partial measurement data from 2002 to 2004. Average return flow fraction was applied to estimate returns for 1980 through 2001.

P_{eff} = Annual effective precipitation on irrigated lands from ET_{Idaho} 2009 (Twin Falls WSO) weighted for County crop mix, AF

ET_{act} = "Actual" evapotranspiration on irrigated lands from ET_{Idaho} 2009 (Twin Falls WSO) weighted for County crop mix (Contor, 2009a), AF

ET data were obtained from the files ET_TO_COUNTIES_20090717_GIS*.ZIP. Generation of the ET data is described in detail by Contor (2009a). These files contain monthly ET data for May 1980 through October 2008. ET data were summed by water year (October through September) to be consistent with data obtained from the Snake River Planning Model.

ET and effective precipitation data were multiplied by the irrigated land acreage estimated from 1980, 1992, and 2006 irrigated lands files. Reduction factors described in MEMO_IrrLands_And_RED_20090814.doc (Contor, 2009b), which were developed for areas located within the ESPAM2 model boundary, appear to be too low to account for non-irrigated inclusions in the 1980 and 1992 irrigated lands files within the TFCC area. Hand drawn polygons based on Snake River Basin Adjudication imagery were compared to the 1980 and 1992 irrigated lands shapefiles in three test areas within the TFCC area (Figure 2). The three test areas, which included a total irrigated area of 34,150 acres, were selected in areas unaffected by urban growth. A reduction factor of 0.14 was estimated for both the 1980 and 1992 irrigated lands shapefiles based on comparison with the hand drawn polygons.

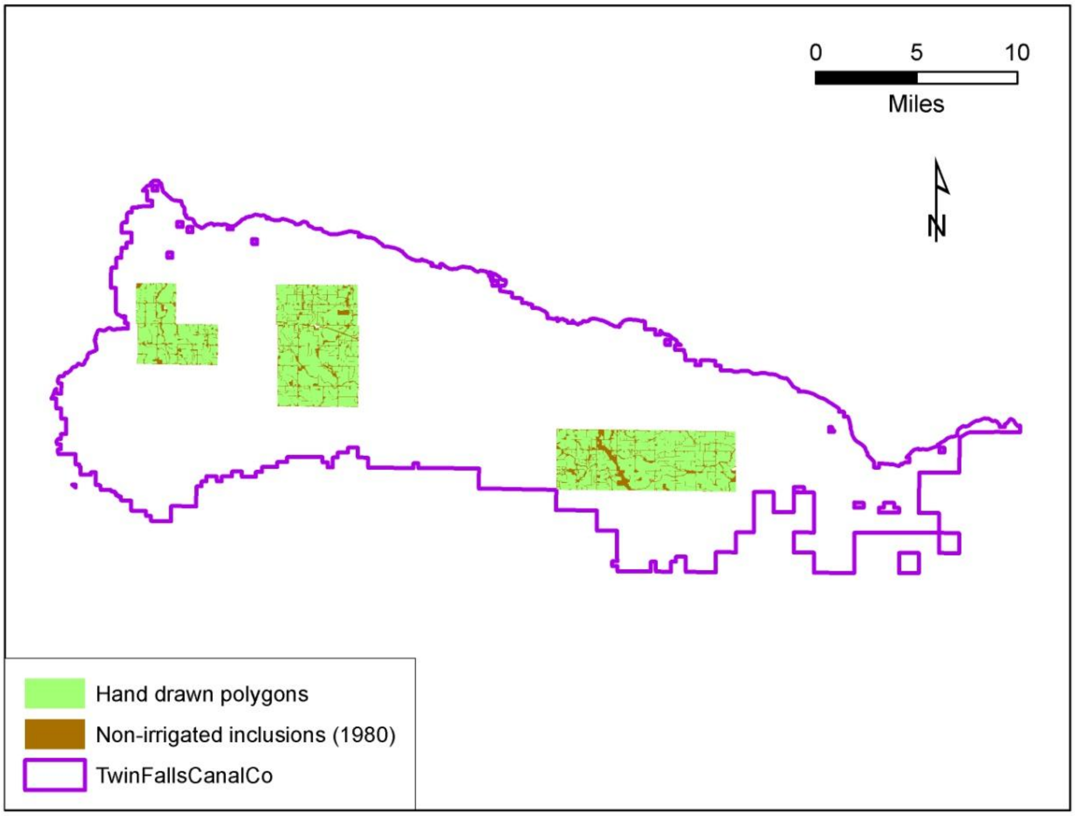

Figure 2. Test areas for calculation of irrigated lands reduction factors.

Irrigated lands files for 1986 and 2000 excluded the TFCC area. The adjusted irrigated acreages estimated from the available irrigated lands files decreased from 213,300 acres in 1980 to 209,800 acres in 1992 and 193,000 in 2006 (Figure 3). These estimates include agricultural lands irrigated by surface water and/or ground water within the Twin Falls tract. ET associated with ground water irrigation consumes water that would otherwise contribute to reach gains.

These values are also generally consistent with the Allen (2004) report, which described 231,000 acres of the 261,000-acre Twin Falls tract as “potentially irrigated lands” including non-irrigated inclusions, and the Cosgrove et al (1997) report which estimated 202,000 irrigated acres served by TFCC.

The irrigated lands files do not include landscape irrigation within urban areas. Urban growth in the Twin Falls area appears to be a significant factor in the reduction of irrigated acreage between 1980 and 2006. Irrigated acreage was assumed to decline linearly, and values for 1981 through 1991 and 1993 through 2005 were interpolated from the 1980, 1992, and 2006 values. The irrigated acreage in 2007 and 2008 was assumed to be the same as the 2006 value.

Resulting values of estimated ground water recharge associated with surface water irrigation within the Twin Falls Canal Company are provided in Appendix A and the spreadsheet SS_Contribution_Kimberly_Hagerman_12072011.xlsx. Estimated annual recharge between water year 1981 and water year 2008 ranged from 242,000 to 465,000 AF, with an average of 348,000 AF. This value is less than the 400,000 AF estimated by Kjelstrom (1995), but does not include tributary underflow from the Salmon Falls Creek drainage or Salmon Falls tract.

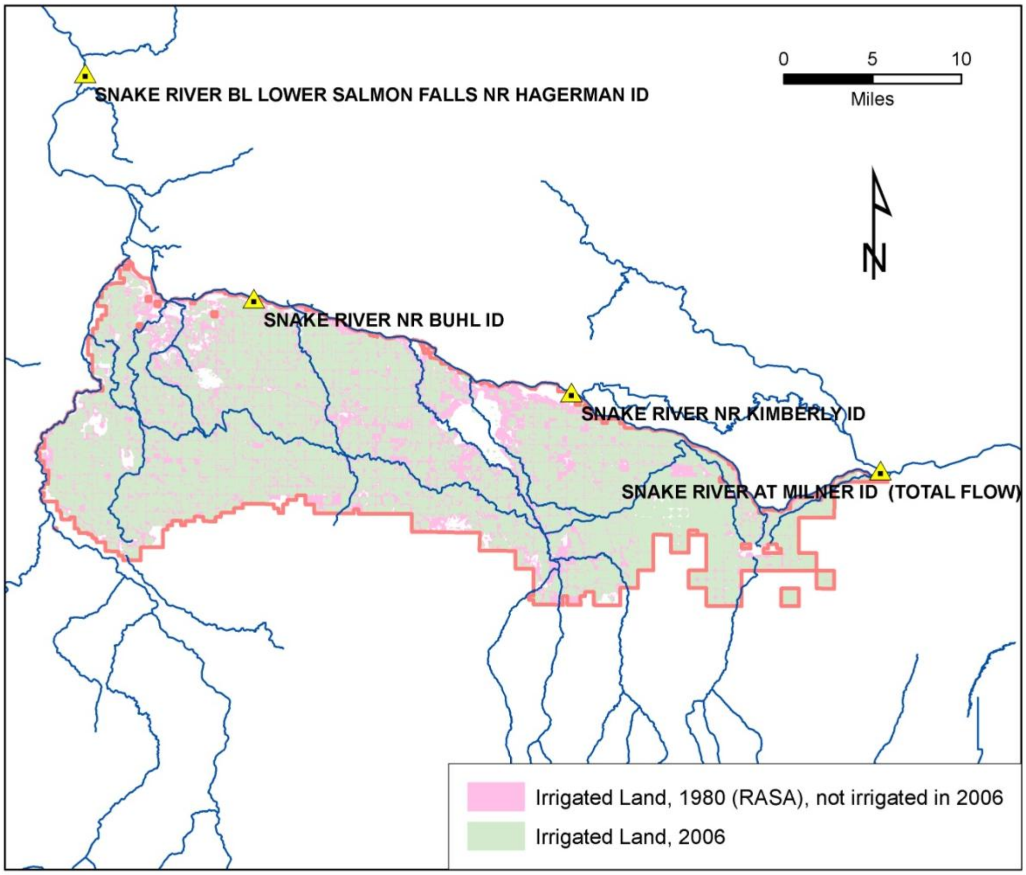

Figure 3. Change in irrigated lands in the Twin Falls tract between 1980 and 2006. Note that the 1980 shape file includes approximately 14% non-irrigated inclusions.

ESTIMATION OF TRIBUTARY UNDERFLOW FROM SALMON FALLS CREEK DRAINAGE BASIN

Values estimated by Crosthwaite (1969) were used as an estimate of the average annual tributary underflow from the Salmon Falls Creek drainage basin and Salmon Falls tract. An annual average tributary underflow of 111,000 AF was used. This value includes 65,000 AF of recharge associated with surface water irrigation within the Salmon River Canal Company, plus 50,000 AF of recharge associated with infiltration from precipitation, less 4,000 AF of assumed consumptive use associated with 6,000 AF of ground water pumped for irrigation use.

The assumed average annual value of 111,000 AF was scaled using normalized annual values based on measured discharges at Silver Creek as described in Cosgrove et al. (2006) and Taylor (2009). The monthly time series for Silver Creek for the period May 1980 to October 2008 was obtained from the file Trib_Underflow_V2_11_04_09.csv. Monthly tributary underflow estimates were summed by water year to obtain annual estimates. Data are provided in Appendix A and the spreadsheet SS_Contribution_Kimberly_Hagerman_12072011.xlsx.

Between water years 1981 and 2008, the estimated annual tributary underflow from the Salmon Falls Creek drainage basin (including irrigation within the Salmon River Canal Company) ranged from 102,000 to 129,000 AF.

The average annual value is similar to the underflow estimates used by Garabedian (1992) for the Salmon Falls, Cottonwood, Rock, and Dry Creek drainage basins, which totaled 114,000 AF per year.

REACH GAIN CALCULATIONS

The ground water contribution to reach gain between Milner and Kimberly is calculated as the difference between the Snake River near Kimberly and the Snake River at Milner gages less Group 1A[3] and Group 4A[4] return flows. Data

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[3] Group 1A measured returns from Northside Canal Company in the Milner to Kimberly reach include the Ehler/C33 drain and the McFarland drain.

are provided in Appendix A and the spreadsheet SS_Contribution_Kimberly_Hagerman_12072011.xlsx.

The ground water contribution to reach gain between Kimberly and Lower Salmon Falls was calculated as follows.

> Reach gain = Snake River blw Lower Salmon Falls – Snake River nr Kimberly + diversions – southside return flow (Group 4B[5]) – northside return flow (Group 1B[6]) – surface water component of Lower Salmon Falls Creek[7] - discharge Rock Creek at Highline*1.15[8].

The ground water contribution to reach gain between Kimberly and Buhl was calculated as follows.

> Reach gain = Snake River nr Buhl – Snake River nr Kimberly– southside return flow (Group 4B1[9]) – northside return flow (Group 1B1[10]) – surface water component of Lower Salmon Falls Creek - discharge Rock Creek at Highline*1.15.

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[4] Group 4A measured returns from Twin Falls Canal Company in the Milner to Kimberly reach include the A10 Coulee and Twin Falls Coulee.

[5] Group 4B includes 12 measured returns from Twin Falls Canal Company in the Kimberly to Lower Salmon Falls reach. Includes return flow components of Rock Creek, Mud Creek, Cedar Draw, and Deep Creek.

[6] Group 1B includes 7 measured returns from Northside Canal Company in the Kimberly to Lower Salmon Falls reach.

[7] Lower Salmon Falls Creek includes measured return flow Group 4C, Twin Falls Canal Company returns to Lower Salmon Falls Creek (N Coulee and L10 Power Plant).

[8] Rock Creek at Highline *1.15 represents surface runoff from the south hills to Rock Creek and its tributaries.

[9] Group 4B1 includes 10 measured returns from Twin Falls Canal Company in the Kimberly to Buhl reach. Includes non-baseflow components of Rock Creek and Cedar Draw.

[10] Group 1B1 includes 3 measured returns (K End, N30, N23) from Northside Canal Company in the Kimberly to Buhl reach.

The ground water contribution to reach gain between Buhl and Lower Salmon Falls was calculated as Kimberly to Lower Salmon Falls reach gain less the Kimberly to Buhl reach gain.

Streamflows, diversions, and return flows were obtained from the Snake River Planning Model and include both measured and estimated data. The ground water base flow component of Lower Salmon Falls Creek was estimated by assuming that measured flows occurring from December through March represent the average ground water baseflow for the water year. Streamflow in excess of the average ground water baseflow was assumed to be return flow or surface runoff.

The ground water contribution to reach gains between Kimberly and Buhl and Buhl to Lower Salmon Falls includes water contributed from both the ESPA and ground water on the south side of the Snake River. The ground water base flow components of Lower Salmon Falls Creek, Rock Creek, Mud Creek, Cedar Draw, Deep Creek, and other perennial channels are included in the reach gain. Data are provided in Appendix A and the spreadsheet SS_Contribution_Kimberly_Hagerman_12072011.xlsx.

ASSIGNMENT OF ESTIMATED SOUTH SIDE GROUND WATER CONTRIBUTION TO RIVER REACHES AND STRESS PERIODS

The estimated ground water contribution from the south side of the Snake River between Milner and Lower Salmon Falls is assumed to be the sum of the recharge from the Twin Falls tract and tributary underflow from the Salmon Falls Creek drainage basin (which includes recharge from the Salmon Falls tract). The contribution from recharge on non-irrigated lands outside of the Crosthwaite (1969) study area is assumed to be negligible, and is not included in the estimates. The annual ground water contribution from the south side is estimated to range from 350,000 to 584,000 AF, with an average of 460,000 AF (Figure 4). The average estimate is slightly higher than the 400,000 AF estimated by Kjelstrom (1995) for the year 1980.

Tributary underflow from the Salmon Falls Creek drainage comprises approximately 25% of the estimated contribution, with approximately 75% resulting from recharge associated with irrigation within the Twin Falls Canal Company (Figure 4).

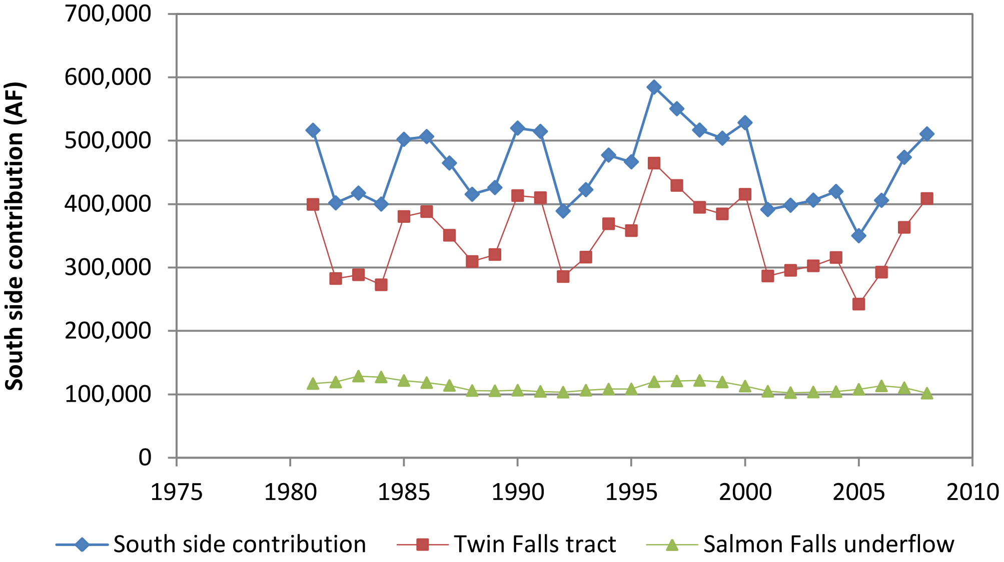

Figure 4. Components of estimated south side ground water discharge, Milner to Lower Salmon Falls.

The estimated contribution from the south side discharges to the Snake River between Milner and Lower Salmon Falls. For use in the ESPAM2 model, the portion of the estimated south side ground water discharge occurring between Kimberly and Buhl and between Buhl and Lower Salmon Falls needs to be quantified. Options considered for distributing the south side contribution by river reach included the following.

1) Distributing the south side contribution per Kjelstrom (1995) was considered. Kjelstrom (1995) estimated that 47.5% of the south side ground water discharge occurred between Milner and Kimberly, and 52.5% occurred between Kimberly and Lower Salmon Falls/Hagerman, based on 1980 water budget data.

2) Calculating the south side contribution from Kimberly to Lower Salmon Falls/Hagerman was attempted by deducting the unmeasured reach gain between Milner and Kimberly from the estimated south side ground water contribution. This method assumes that all reach gains between Milner

and Kimberly result from ground water seepage on the south side of the river. This method was unsuccessful because the magnitude of gage errors exceeds the magnitude of the reach gains during wet years (Figure 5), resulting in highly variable data during the period of interest (Figure 6).

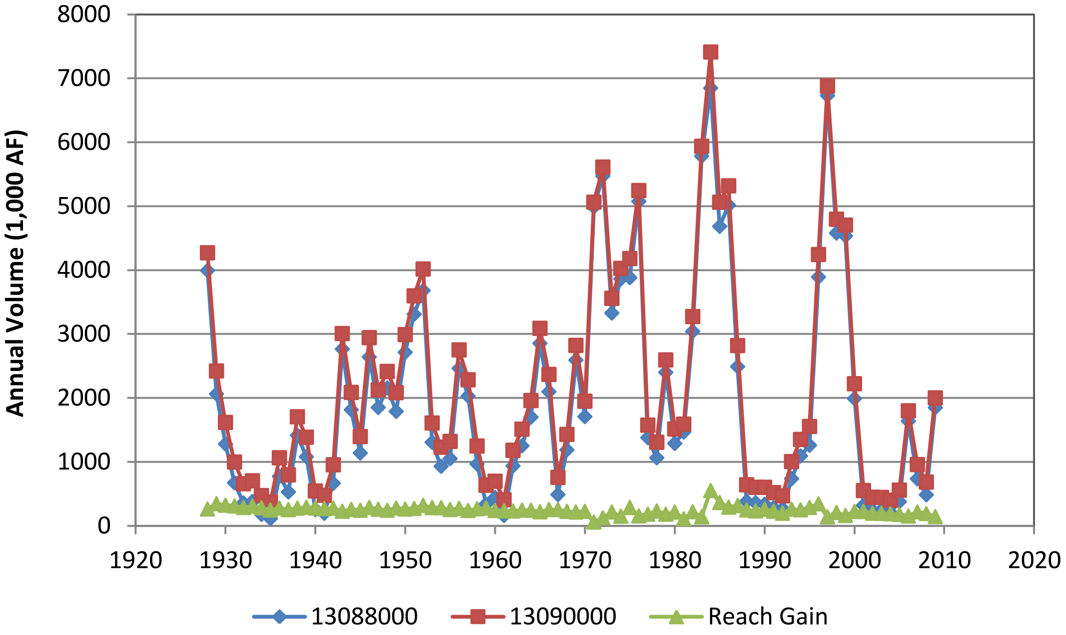

Figure 5. Milner to Kimberly reach gain and gaging station data.

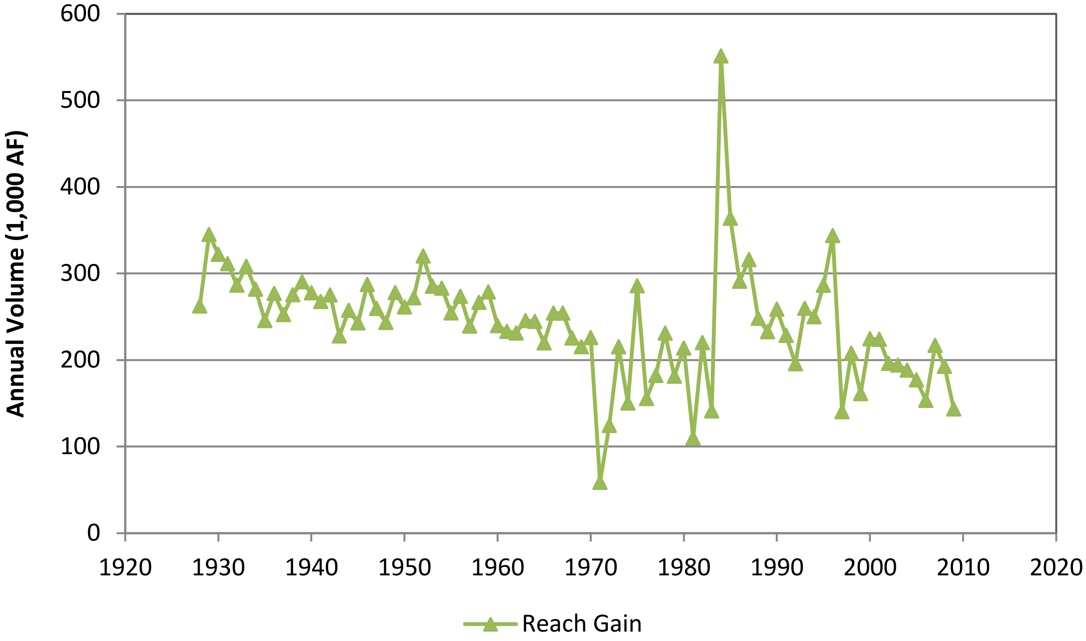

Figure 6. Variability in calculated reach gain, Milner to Kimberly.

3) Comparison of the calculated annual Milner to Kimberly reach gains with the estimated annual south side contributions indicates that the Milner to Kimberly reach gains average 52% of the south side contributions (Appendix A, page 3). Distributing 52% of the south side contributions to the Milner to Kimberly reach and 48% to the Kimberly to Lower Salmon Falls/Hagerman reach is proposed for use in the ESPAM2 model. This method also assumes that all reach gains between Milner and Kimberly result from ground water seepage on the south side of the river. South side contributions within the Kimberly to Lower Salmon Falls reach are further subdivided into the Kimberly to Buhl and Buhl to Lower Salmon Falls reaches using measured data from return flow sites and Lower Salmon Falls Creek.

With 48% of the estimated south side contribution assigned to the Kimberly to Lower Salmon Falls/Hagerman reach, the south side contribution accounts for 5% to 8% of the annual reach gain. The other 92 to 95% is assumed to be ground water contribution from the ESPA. The average estimated south side contribution (220,000 AF) is similar to Kjelstrom (1995) estimates for the year

1980, which estimated that 210,000 AF of the reach gains between Kimberly and Lower Salmon Falls were from ground water seepage on the south side of the river.

South side contributions between Kimberly and Lower Salmon Falls were subdivided based on the percentage of baseflow to measured creeks and drains upstream and downstream of the Buhl gage. Measurements of the south side creeks and drains were available from 2002 to 2008. The groundwater baseflow portion of these creeks and drains was estimated during analysis of measured return flow data. The average measured south side baseflow between Kimberly and Lower Salmon Falls (204,400 AF/year) was similar to the average south side contribution estimated from the water budget calculations (202,400 AF/year). This suggests that most of the ground water discharge from the south side downstream of Kimberly occurs in Lower Salmon Falls Creek and other incised creeks and drains. Based on data from Lower Salmon Falls Creek and measured return flow sites, approximately 42.5% of the south side discharge occurs between Kimberly and Buhl, and 57.5% occurs between Buhl and Lower Salmon Falls (Figure 7).

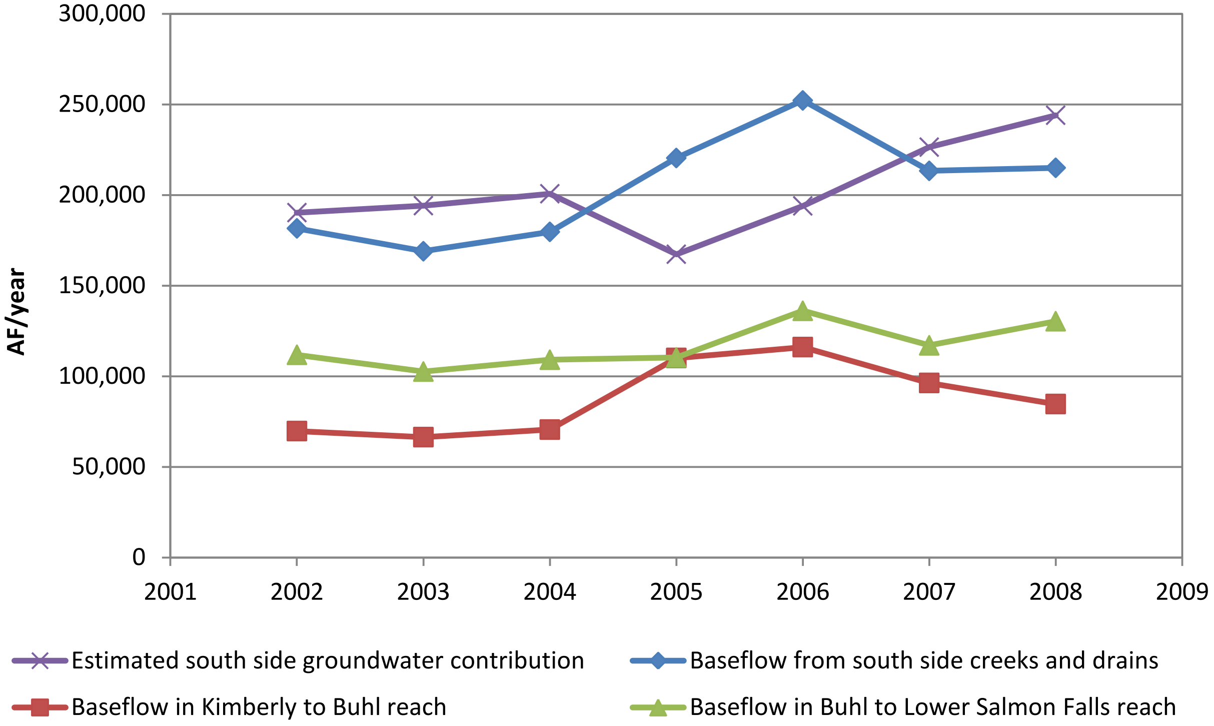

Figure 7. Kimberly to Lower Salmon Falls south side contribution estimated from water budget and baseflow from measured creeks and drains.

For use in the ESPAM2 model, which uses monthly stress periods, a flat distribution was assumed within each water year. Monthly values were estimated by dividing each annual value by the number of days per year and multiplying by the number of days per month. The average monthly value from the 1981 water year was assigned to the stress periods from May 1980 through September 1980. The average monthly value from the 2008 water year was assigned to October 2008.

The monthly values for estimated south side contribution to the Kimberly to Buhl and Buhl to Lower Salmon Falls reaches were deducted from the ground water reach gains. The adjusted reach gains, which represent ESPA contributions to these reaches, are proposed calibration targets for ESPAM2. Annual estimates are shown in Figure 8. Examples of data for monthly stress periods are shown for 1987 (Figure 9) and 2005 (Figure 10). The full data set is provided in

Appendix A, and the spreadsheet SS_Contribution_Kimberly_Hagerman_12072011.xlsx.

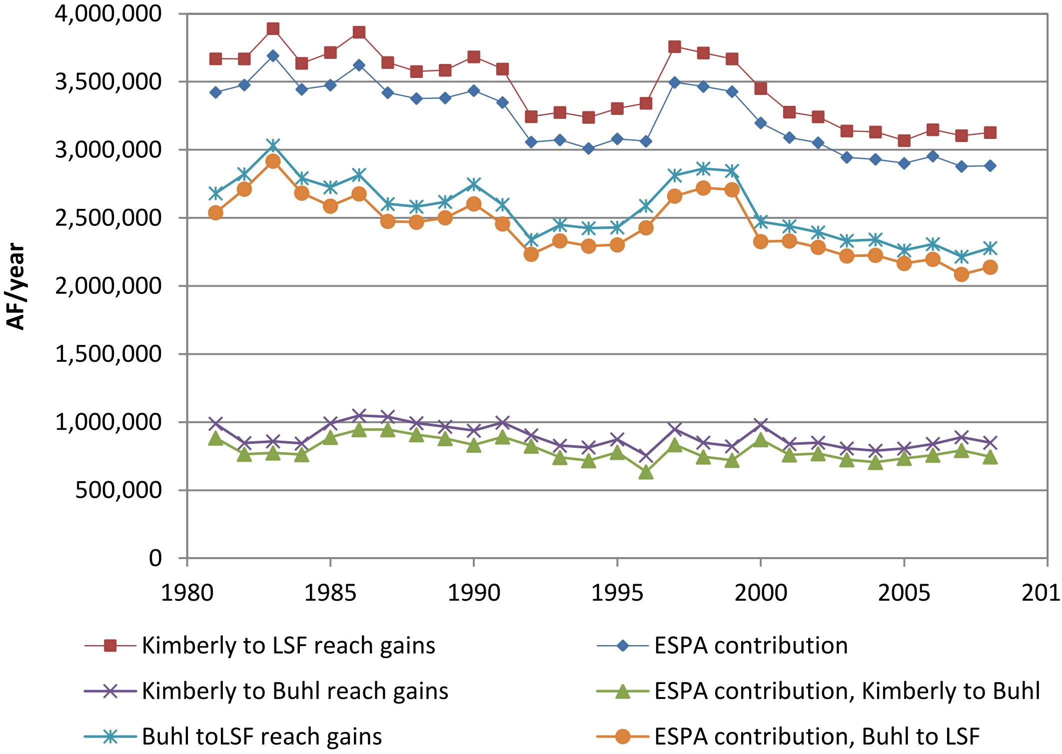

Figure 8. Estimated annual ESPA contribution to reach gains from Kimberly to Lower Salmon Falls.

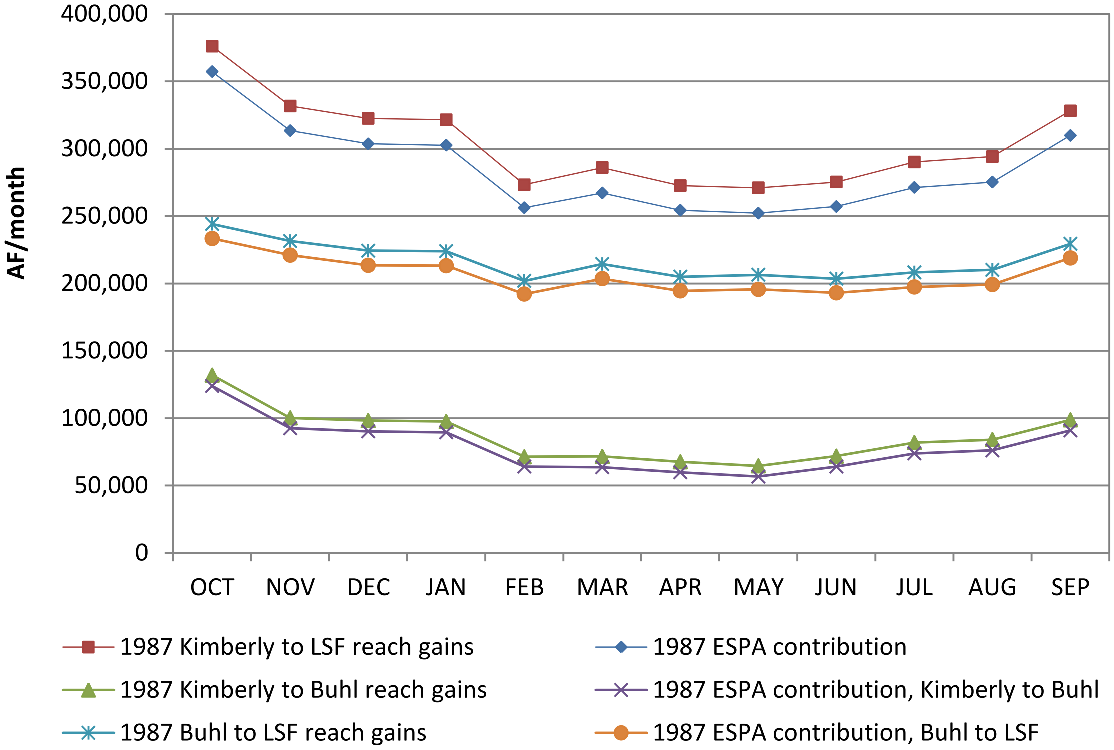

Figure 9. Estimated monthly ESPA contribution to reach gains from Kimberly to Lower Salmon Falls, water year 1987.

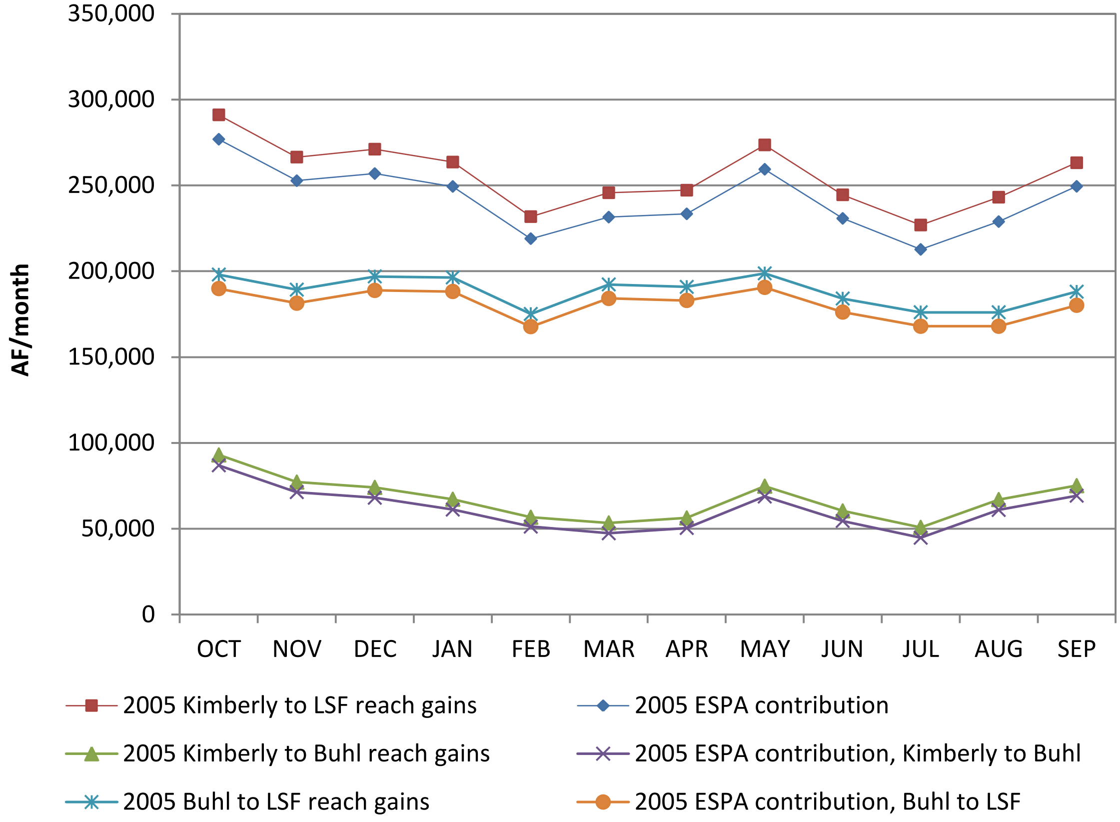

Figure 10. Estimated monthly ESPA contribution to reach gains from Kimberly to Lower Salmon Falls, water year 2005.

Reach gain targets representing ESPA discharge to the Snake River between Kimberly and King Hill are shown in Figure 11.

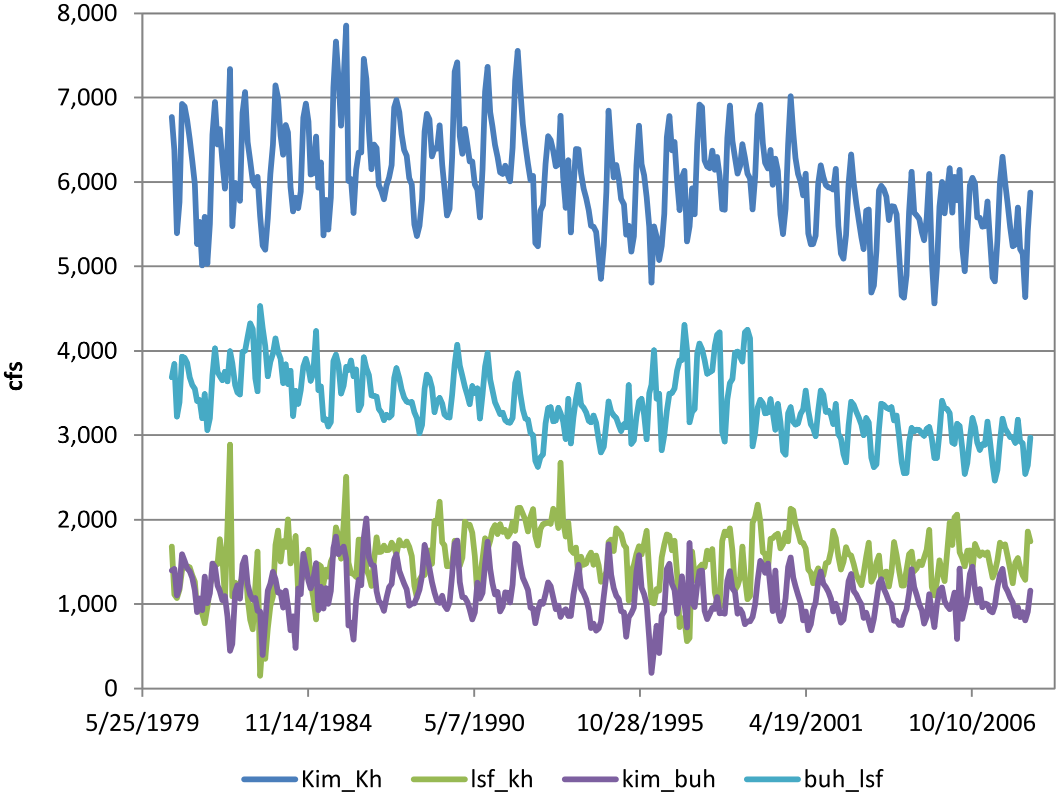

Figure 11. Reach gain targets for ESPAM2.0, Kimberly to King Hill.

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APPENDIX A.

ESTIMATION OF SOUTH SIDE GROUND WATER CONTRIBUTION TO KIMBERLY TO LOWER SALMON FALLS REACH

SS_Contribution_Kimberly_Hagerman_12072011.xlsx