MEMO

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Date:	12 January 2012
To:	ESHMC
From:	Allan Wylie AW
cc:	Sean Vincent, Rick Raymondi
Subject:	Magic Valley Underflow

Introduction

During the 12 December 2011 meeting, the Eastern Snake Hydrologic Modeling Committee (ESHMC) decided to include underflow as an explicit target for the Eastern Snake Plane Aquifer Model version 2 (ESPAM2). Prior to this point the model was asked to match the springs with transient targets (Class A&B springs), the total reach gains in the Snake River from the ESPA, and a ratio involving ranking of the discharge from Class C springs (springs without transient targets). Ranking the Class C springs prevented any conflict between matching Magic Valley river gains and spring discharge, however, as the ESHMC converted more Class C springs into Class A&B springs, the ungaged discharge (including underflow) entering the Snake River from the ESPA was forced into fewer Class C springs. Although the match between modeled and calculated rankings was good (Figure 1), the modeled discharge from the Class C springs became roughly four times higher than the inferred discharge. Figure 2 shows the relationship between modeled discharge and inferred discharge for a typical Class C spring.

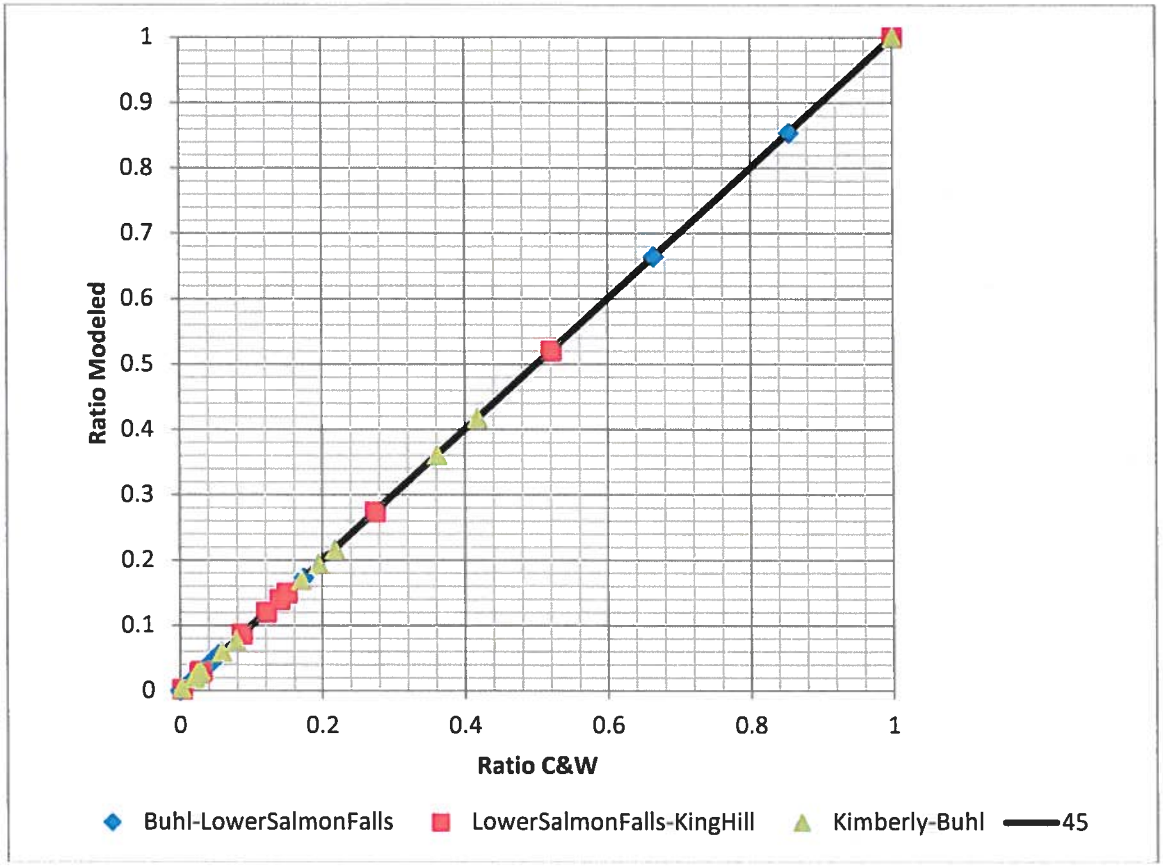

Figure 1. Comparison between modeled and calculated ranking for Class C springs.

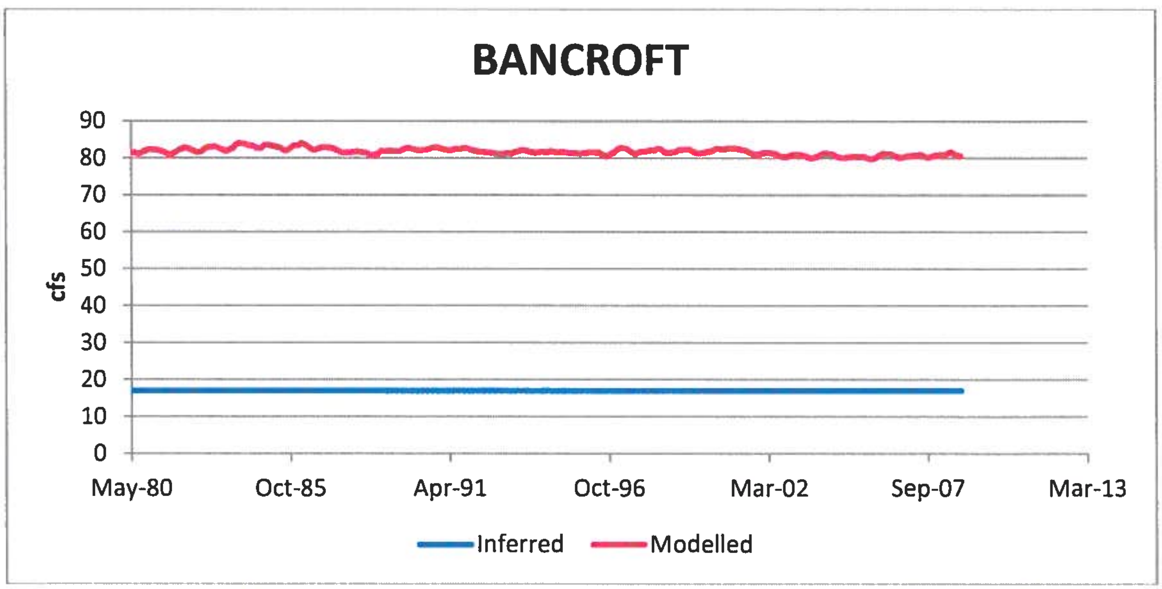

Figure 2. Comparison between modeled and inferred discharge for Class C Bancroft Spring.

The most likely explanation for the discrepancy between modeled and inferred Class C spring discharge is that a significant volume of water enters the Snake River without any surface expression. Examples of locations where gaging indicates that underflow enters the Snake River include Crystal Spring, Thousand & Magic Springs, and Blue Heart

Spring. In March 2011, the USGS gaged the Snake River both above and below Crystal Springs with a computed gain of 450 ± 45 ft^3/sec. Figure 3 shows the locations where the USGS collected the upstream and downstream measurements. Typical Crystal Springs March discharge is between 299 to 370 ft^3/sec, and the computed underflow by difference is 116 ft^3/sec (Appendix A). The USGS gaged the Snake River above the Thousand Springs Power Plant and below Magic Springs 14 times when calibration data exist for both springs (Appendix B). Figure 4 shows the locations of the upstream and downstream gaging locations. The calculated underflow at Thousand and Magic ranges from 224 to 765 ft^3/sec with an average of 494 ft^3/sec. Blue Heart Spring discharges downstream from Box Canyon (Figure 5) at the edge of the Snake River and has been measured five times by the USGS since 1917, most recently in 1995 at 63.3 ft^3/sec (Appendix C).

Figure 3. Crystal Springs measurement locations.

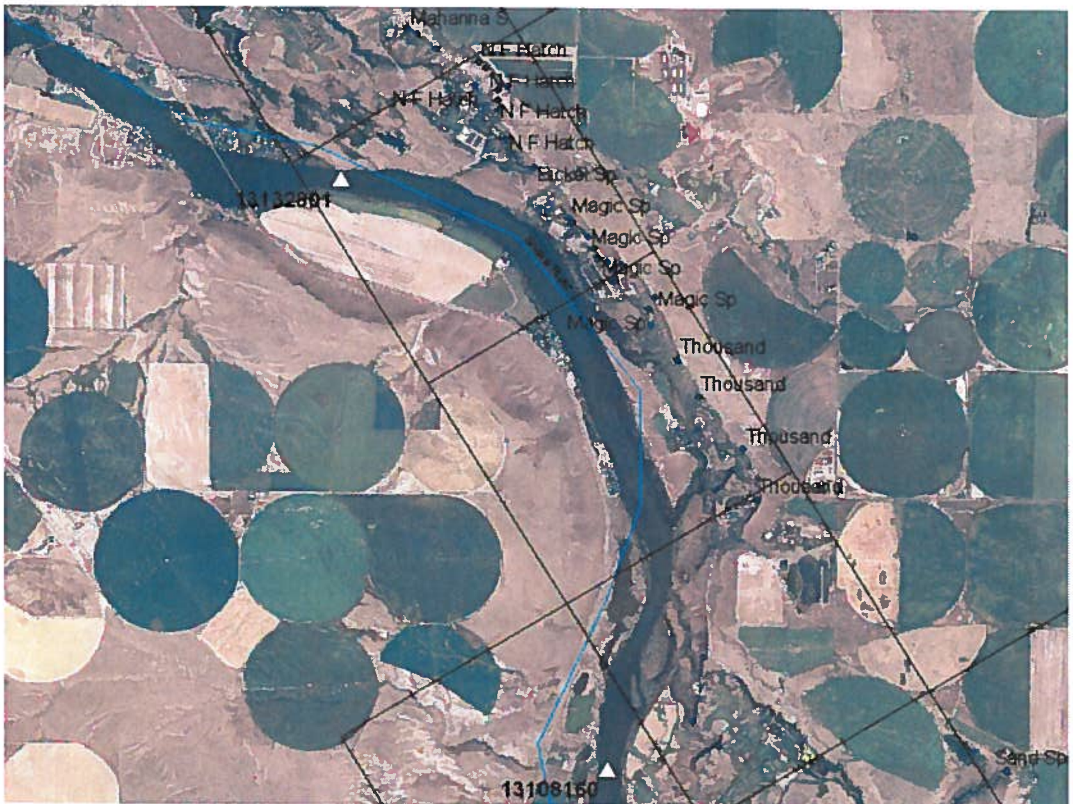

Figure 4. Thousand Springs measurement locations.

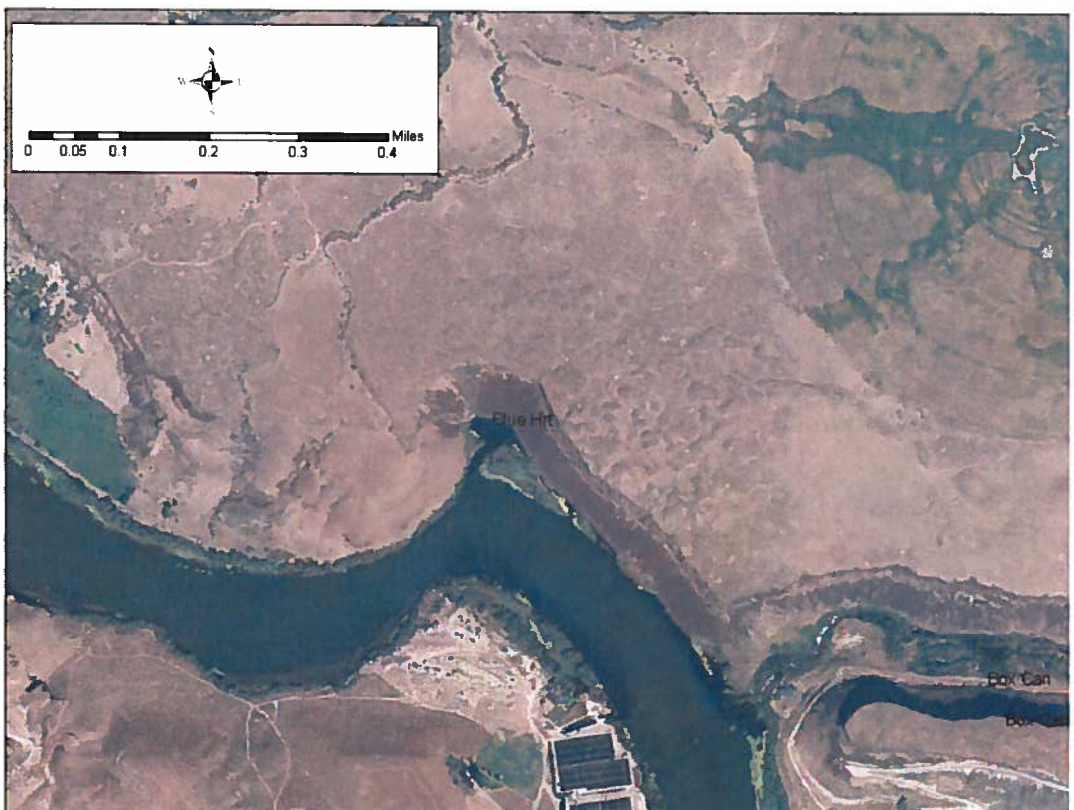

Figure 5. Location of Blue Heart Spring.

Proposal
I propose calculating the underflow targets by subtracting average spring discharge from average reach gain for the three Magic Valley reaches, Kimberly to Buhl, Buhl to Lower Salmon Falls, and Lower Salmon Falls to King Hill (Figure 6) using the following equation:

$$Average\ Underflow = Average\ Reach\ Gain - Average\ Spring\ Discharge$$

Where:
Average Reach Gain = gain between river gages with Northside and Southside returns removed and the Southside underflow subtracted out (Sukow, 2011).

Average Spring Discharge = average discharge of the Class A&B springs in the reach and the sum of the Covington and Weaver (1990) discharge for the Class C springs in the reach.

Thus the underflow targets will be average underflow for the model period (1980-2008) for three river reaches, Kimberly to Buhl, Buhl to Lower Salmon Falls, and Lower Salmon Falls to King Hill. These will be simulated using the MODFLOW General Head Boundary (GHB) package (Harbaugh and others, 2000) and identified as a separate line item in the model water budget. Appendix D shows the calculations for three Magic Valley river reach underflow targets and Appendix E contains a MODFLOW GHB file.

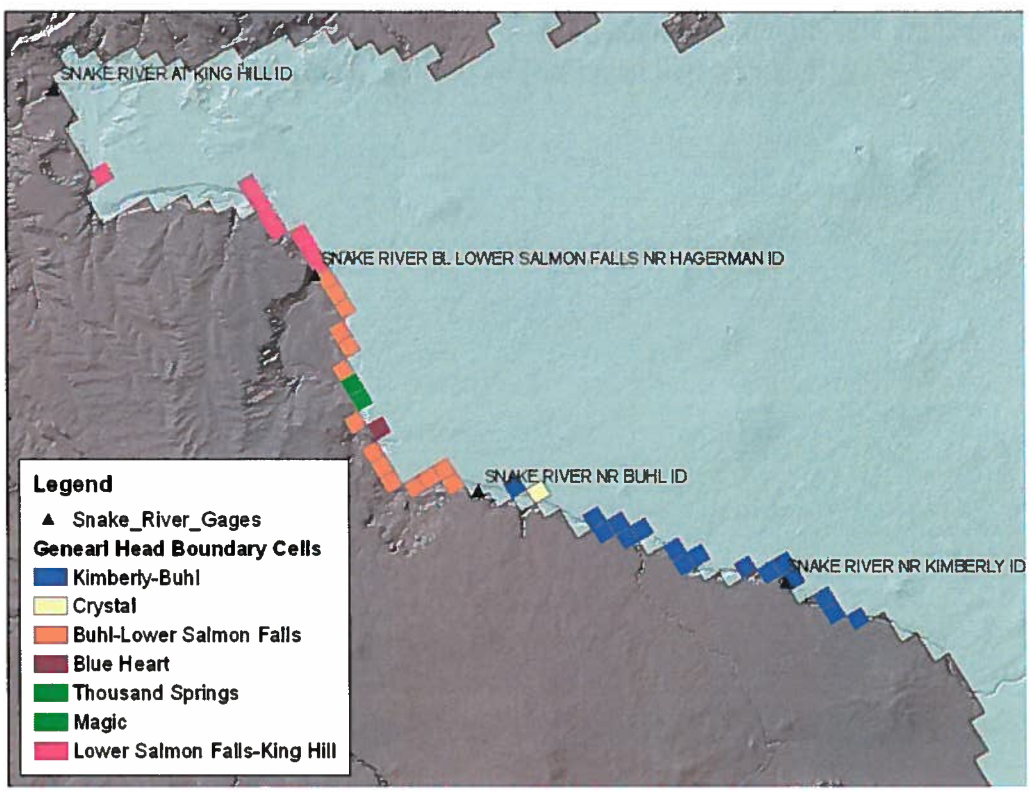

Figure 6. Location of Magic Valley gages and general head boundary cells.

The ability exists to spatially refine the underflow targets at Crystal Springs, Blue Heart Spring and Thousand & Magic Springs. This is an ability that should be exploited to improve the representation of underflow in those specific cells. The calibration targets will be computed as outlined above and shown in Appendix A – C. Thus the proposed underflow targets consist of:

1) Kimberly to Buhl underflow – 265 ft^3/sec average (includes 116 ft^3/sec average at Crystal)
2) Buhl to Lower Salmon Falls underflow – 907 ft^3/sec average (includes 63 ft^3/sec average at Blue Heart and 494 ft^3/sec average at Thousand & Magic)
3) Lower Salmon Falls to King Hill underflow – 365 ft^3/sec average
4) Crystal underflow – 116 ft^3/sec average
5) Blue Heart underflow – 63 average ft^3/sec
6) Thousand & Magic underflow – 494 average ft^3/sec

Figure 6 shows the location of the GHB cells, the underflow reaches and the specific underflow cells. Figure 7 shows the total reach gains and the underflow targets for the three reaches. Note that Crystal, Blue Heart, and Thousand & Magic underflow will be included in the underflow calculations for the three reaches.

Appendix E contains an annotated MODFLOW GHB file. Each GHB cell must be assigned a model layer, row, column, boundary elevation, and boundary conductance. The boundary head is the head at the point of discharge, and the conductance is the conductance of the interface between the aquifer and the boundary. The boundary head will be assigned the elevation of the Snake River as determined by the 10 m NED (ned10m12), and the conductance will be a PEST adjustable parameter.

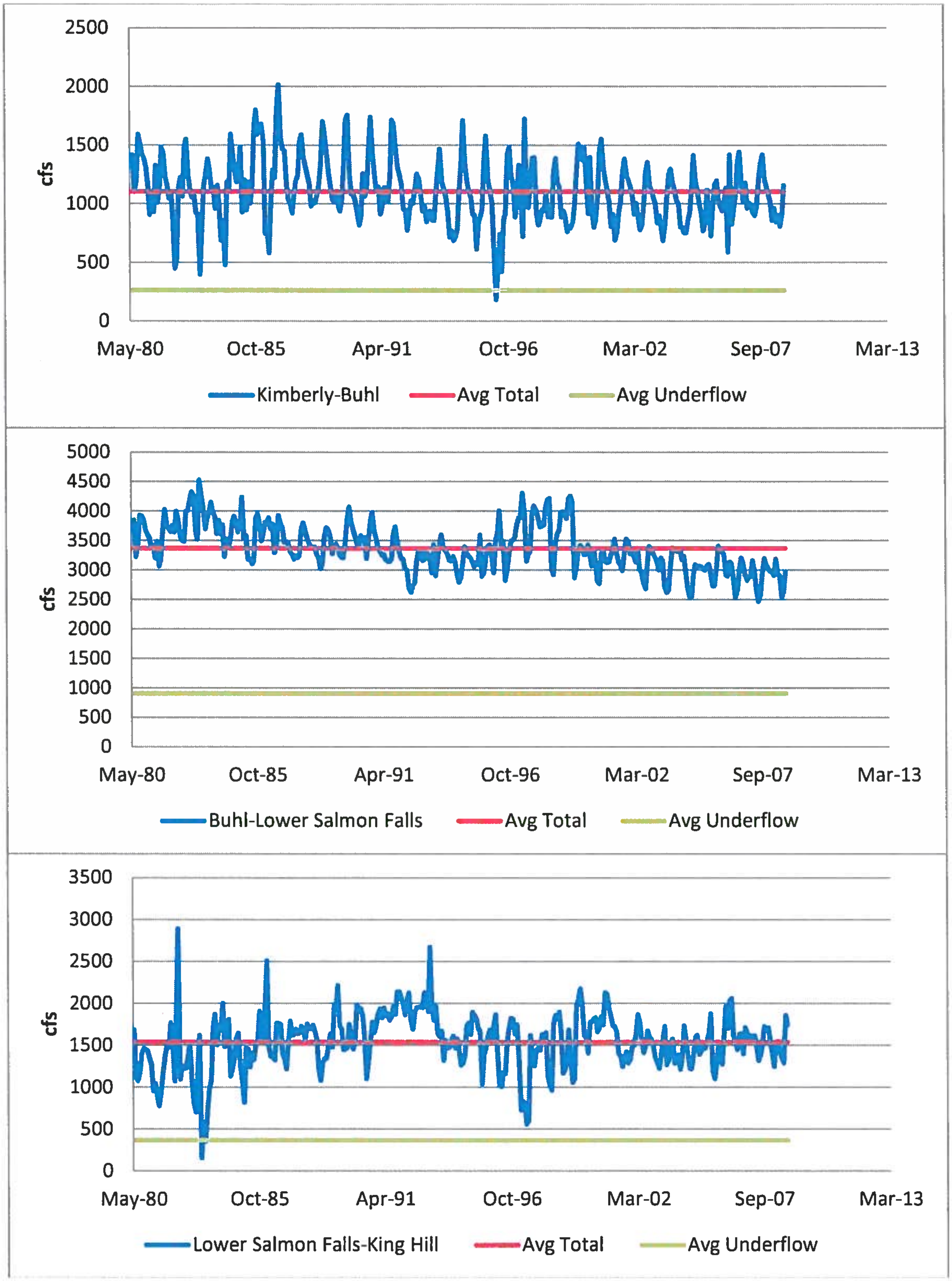

Figure 7. Observed reach gains, average total gains and calculated underflow.

Summary

The Class C springs were discharging, on average, about four times as much water as expected. The most probable cause is that unmeasured ESPA water directly enters the Snake River without first emerging as surface springs. The proposed solution is to simulate the underflow using MODFLOW's GHB package. This will result in the underflow targets having a separate line item in the model water budget.

The underflow targets will be calculated by subtracting the average of the Class A&B springs and the Class C springs from the Northside gains using the following equation:

$$Average\ Underflow = Average\ Reach\ Gain - Average\ Spring\ Discharge$$

The above calculation will be applied to three reaches in the Magic Valley, Kimberly to Buhl, Buhl to Lower Salmon Falls, and Lower Salmon Falls to King Hill. More Specific information exists at Crystal Springs, Blue Heart Spring, and Thousand & Magic Springs. The resulting underflow targets consist of:

1) Kimberly to Buhl – 265 ft^3/sec average (includes 116 ft^3/sec average at Crystal)
2) Buhl to Lower Salmon Falls – 907 ft^3/sec average (includes 63 ft^3/sec average at Blue Heart and 494 ft^3/sec average at Thousand & Magic)
3) Lower Salmon Falls to King Hill – 365 ft^3/sec average
4) Crystal – 116 ft^3/sec average
5) Blue Heart – 63 average ft^3/sec
6) Thousand & Magic – 494 average ft^3/sec

References

Sukow, J.S. 2011. Estimation of ground water contribution from the south side of the Snake River, Milner to King Hill. ESPAM2 Design Document DDW-V2-10.

Covington, H.R. and J.N. Weaver, 1990. Geologic map and profile of the north wall of the Snake River Canyon. U.S. Geological Survey Miscellaneous Investigation Series, Maps I-1947A through I-1947E.

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. USGS Open-File Report 00-92.

Appendix A

Crystal Springs Underflow Calculations

Date	Crystal Sp Discharge ft^3/sec
3/15/1995	356
3/15/1996	370
3/15/1997	367
3/15/1998	369
3/15/1999	356
3/15/2000	355
3/15/2001	349
3/15/2002	336
3/15/2003	327
3/15/2004	320
3/15/2005	307
3/15/2006	299
3/15/2007	312
3/15/2008	311
Average	338
Max	370
Min	299
Centroid	334
USGS Mar 2011	450
Underflow	116

The centroid was chosen because it is lower than the average and the overall trend of the time series is downward.

Appendix B
Thousand and Magic Springs

Date	USGS reach gain 13132800 (ft^3/sec)	Covington & Weaver discharge for Cell 1045012 (ft^3/sec)	Group B Target for Thousand Springs Cell (ft^3/sec)	Magic Springs Portion of Group B Target for NFH Cell (ft^3/sec)	Thousand Springs Power Plant from Sand Springs (ft^3/sec)	Estimated reach gain from underflow (ft^3/sec)
3/10/1998	1,510	5.0	613.60	86.50	73.75	731
11/16/1998	1,020	5.0	628.61	85.75	76.88	224
3/16/1999	1,480	5.0	562.06	85.13	62.83	765
11/15/1999	1,320	5.0	629.06	87.27	57.30	541
3/13/2000	1,110	5.0	548.21	86.20	51.38	419
11/16/2000	1,160	5.0	575.43	89.57	85.88	404
3/5/2001	1,290	5.0	620.79	82.34	55.12	527
3/12/2002	1,190	5.0	552.01	81.69	64.70	487
3/10/2003	1,089	5.0	551.86	78.63	45.58	408
3/16/2004	1,140	5.0	554.07	78.63	49.97	452
3/14/2005	1,080	5.0	537.32	77.88	41.96	418
3/13/2006	1,330	5.0	547.36	78.63	48.00	651
3/8/2007	1,140	5.0	536.77	78.63	51.20	468
3/19/2008	1,110	5.0	556.43	79.85	46.75	422
					Average underflow	494

Appendix C
Blue Heart Spring

USGS Measurements of
Blue Heart Springs

Date	Discharge (ft^3/sec)
4/1902	48.5
10/13/1917	61.5
9/19/1919	61
10/6/1931	65.6
3/27/1968	62.8
4/11/1995	63.3

Appendix D
Reach Underflow Calculations

Reach	Average Reach Gain ft^3/sec	Average A&B ft^3/sec	Sum of C ft^3/sec	Reach Underflow ft^3/sec
Kimberly-Buhl	1104.54	813.49	26.48	265
Buhl-Lower Salmon Falls	3370.39	2101.42	361.53	907
Lower Salmon Falls-King Hill	1538.74	1070.46	102.82	365
Total	6013.67	3985.37	490.83	1537.47

Appendix E

Annotated General Head Boundary file

42	*50*					Max no ghb, unit no for output
42						no ghb this stress period
1	*25*	*6*	*2522.66*	*9579.089*	*Lsf_Kh*	lay row col elev cond reach
1	*30*	*13*	*2650.94*	*9579.089*	*Lsf_Kh*	lay row col elev cond reach
1	*31*	*13*	*2650.94*	*9579.089*	*Lsf_Kh*	lay row col elev cond reach
1	*32*	*13*	*2650.94*	*9579.089*	*Lsf_Kh*	lay row col elev cond reach
1	*33*	*13*	*2650.94*	*9579.089*	*Lsf_Kh*	lay row col elev cond reach
1	*34*	*14*	*2650.94*	*9579.089*	*Lsf_Kh*	lay row col elev cond reach
1	*35*	*14*	*2650.94*	*9579.089*	*Lsf_Kh*	lay row col elev cond reach
1	*36*	*14*	*2650.94*	*9579.089*	*Lsf_Kh*	lay row col elev cond reach
1	*37*	*14*	*2808.29*	*7726.724*	*Bul_Lsf*	lay row col elev cond reach
1	*38*	*14*	*2808.36*	*7726.724*	*Bul_Lsf*	lay row col elev cond reach
1	*39*	*14*	*2808.36*	*7726.724*	*Bul_Lsf*	lay row col elev cond reach
1	*40*	*13*	*2808.36*	*7726.724*	*Bul_Lsf*	lay row col elev cond reach
1	*41*	*13*	*2808.36*	*7726.724*	*Bul_Lsf*	lay row col elev cond reach
1	*42*	*12*	*2877.35*	*7726.724*	*Bul_Lsf*	lay row col elev cond reach
1	*43*	*12*	*2877.35*	*96301.75*	*Magic*	lay row col elev cond reach
1	*44*	*12*	*2877.42*	*96301.75*	*Ksp*	lay row col elev cond reach
1	*45*	*11*	*2877.42*	*7726.724*	*Bul_Lsf*	lay row col elev cond reach
1	*46*	*12*	*2877.75*	*19715.28*	*BluHrt*	lay row col elev cond reach
1	*47*	*11*	*2877.42*	*7726.724*	*Bul_Lsf*	lay row col elev cond reach
1	*48*	*11*	*2877.75*	*7726.724*	*Bul_Lsf*	lay row col elev cond reach
1	*49*	*11*	*2880.54*	*7726.724*	*Bul_Lsf*	lay row col elev cond reach
1	*50*	*12*	*2912.66*	*7726.724*	*Bul_Lsf*	lay row col elev cond reach
1	*50*	*13*	*2922.17*	*7726.724*	*Bul_Lsf*	lay row col elev cond reach
1	*50*	*14*	*2937.49*	*7726.724*	*Bul_Lsf*	lay row col elev cond reach
1	*51*	*14*	*2937.49*	*7726.724*	*Bul_Lsf*	lay row col elev cond reach
1	*53*	*17*	*2973.91*	*2501.846*	*Kim_Bul*	lay row col elev cond reach
1	*54*	*18*	*2973.91*	*48228.56*	*Crystal*	lay row col elev cond reach
1	*57*	*20*	*2982.57*	*2501.846*	*Kim_Bul*	lay row col elev cond reach
1	*58*	*20*	*2982.57*	*2501.846*	*Kim_Bul*	lay row col elev cond reach
1	*58*	*21*	*2982.7*	*2501.846*	*Kim_Bul*	lay row col elev cond reach
1	*59*	*21*	*2982.77*	*2501.846*	*Kim_Bul*	lay row col elev cond reach
1	*59*	*22*	*2982.77*	*2501.846*	*Kim_Bul*	lay row col elev cond reach
1	*61*	*23*	*3116.62*	*2501.846*	*Kim_Bul*	lay row col elev cond reach
1	*62*	*23*	*3122.6*	*2501.846*	*Kim_Bul*	lay row col elev cond reach
1	*62*	*24*	*3143.95*	*2501.846*	*Kim_Bul*	lay row col elev cond reach
1	*64*	*26*	*3143.95*	*2501.846*	*Kim_Bul*	lay row col elev cond reach
1	*65*	*27*	*3339.26*	*2501.846*	*Kim_Bul*	lay row col elev cond reach
1	*65*	*28*	*3365.41*	*2501.846*	*Kim_Bul*	lay row col elev cond reach
1	*66*	*28*	*3365.41*	*2501.846*	*Kim_Bul*	lay row col elev cond reach
1	*68*	*29*	*3535.82*	*2501.846*	*Kim_Bul*	lay row col elev cond reach
1	*69*	*29*	*3554.16*	*2501.846*	*Kim_Bul*	lay row col elev cond reach
1	*70*	*30*	*3598.91*	*2501.846*	*Kim_Bul*	lay row col elev cond reach