**PRELIMINARY DRAFT**

# CALCULATION OF AGRICULTURAL RETURN FLOWS AND LAG FACTORS

**Idaho Department of Water Resources**

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Eastern Snake Plain Aquifer Model Enhancement Project
Scenario Document Number DDW-005

## Site Selection

The selection of drains and returns included in the study was a joint effort of the Department of Water Resources and the Idaho Power Company. The returns on the Snake River below American Falls Reservoir were suggested by IDWR to match the ones used in a study conducted in 1985- 86. Idaho Power created a video taken from a helicopter over flight of the Snake above American falls and the Henry's Fork, which was used to help select obvious returns to the river. A standard eight digit USGS gage identification number was assigned to each site selected.

See Table 1 for site name, location (lat/long) and USGS Identification number. Maps of site locations above and below American Falls are included in Figures 1 and 2 respectively.

## Results of Field Data

The over-all results of the first year's field measurements were very good. Sporadic gage failure of five to ten days was seen at some sites. Linear interpolation between the last and beginning data point filled in any missing data (cfs/day). On a monthly volume basis (ac-ft per month) any error induced by this process would have very little effect on the total water returned.

# Table 1: Selected site identification and location

| Site # | Station # | Site Name | Location | |
|---|---|---|---|---|
| **Henry's Fork River basin:** | | | | |
| 1 | 13055300 | Farmers Own Canal - Black Spring | Lat. 44 02'59" | Long. 111 32'20" |
| 2 | 13055337 | Rexburg Canal drain nr Thornton | Lat. 43 48'55" | Long. 111 53'15" |
| 3 | 13050543 | Independent Canal drain | | |
| 4 | 13056550 | Texas Slough Canal nr Thornton | Lat. 43 47' 58" | Long. 111 54' 49" |
| 5 | 13056600 | Texas Slough nr Rexburg | Lat. 43 47'17" | Long. 111 53'45. |
| 6 | 13056650 | Liberty Park Canal | Lat. 43 47'24" | Long. 111 55'27" |
| 7 | 13056850 | Bannock Jim Spring Slough | Lat. 43 46'30" | Long. 111 56'11" |
| **Snake River to American Falls Reservoir:** | | | | |
| 8 | 13057000 | Scott's Slough | Lat. 42 44'32" | Long. 111 58'20" |
| 9 | 13057020 | Dry Bed | Lat. 43 42'11" | Long. 112 04'13" |
| 10 | 13057030 | South Parks | Lat. 43 41'19" | Long. 112 03'47" |
| 11 | 13057045 | Butte Market Lake Canal | Lat. 43 39'20" | Long. 112 05'27" |
| 12 | 13057100 | Burgess drain nr Idaho Falls | Lat. 43 36'60" | Long. 112 03'03" |
| **Near to and just below American Falls Reservoir:** | | | | |
| 13 | 13069548 | Sterling Waste | Lat. 43 01'49" | Long. 112 43'40" |
| 14 | 13069565 | Aberdeen Waste Drain | Lat. | Long. |
| 15 | 13076210 | Tartar Waste | Lat. 42 52'40" | Long. 112 51'23" |
| 16 | 13077650 | Rock Creek nr American Falls | Lat. 42 39'10" | Long. 113 01'00" |
| **Below American Falls Reservoir to King Hill:** | | | | |
| 17 | 13082060 | F drain nr Declo | Lat. 42 32' 48" | Long. 113 37' 14" |
| 18 | 13082032 | D-3 drain | Lat. 42 36'49" | Long. 113 36'10" |
| 19 | 13082062 | D-5 drain nr Rupert | Lat. 42 33'15" | Long. 113 38'38" |
| 20 | 13082064 | D-4 drain nr Rupert | Lat. 42 34'15" | Long. 113 38'25" |
| 21 | 13082320 | Marsh Creek nr Declo | Lat. 42 31'26" | Long. 113 40'02" |
| 22 | 13082330 | Spring Creek nr Declo | Lat. 42 31'01" | Long. 113 41'03" |
| 23 | 13084705 | D-16 drain nr Heyburn | Lat. 42 32'30" | Long. 113 45'24" |
| 24 | 13084707 | B drain nr Heyburn | Lat. 42 33'33" | Long. 113 47'01" |
| 25 | 13085060 | D-17 drain nr Heyburn | Lat. 42 32'53" | Long. 113 50'51" |
| 26 | 13085065 | Main drain North nr Heyburn | Lat. 42 33'02" | Long. 113 51'59" |
| 27 | 13085070 | G drain nr Burley | Lat. 42 31'56" | Long. 113 53'12" |
| 28 | 13085080 | J drain nr Burley | Lat. 42 31'53" | Long. 113 53'29" |
| 29 | 13089690 | Irr drain nr Hansen | Lat. | Long. |
| 30 | 13089695 | Twin Falls Coulee | Lat. 42 34'11" | Long. 114 20'32" |
| 31 | 13090370 | Fish Hatchery Waste 0 | Lat. 42 35'29" | Long. 114 26'03" |
| 32 | 13090460 | Perrine Coulee nr Twin Falls | Lat. 42 35'53" | Long. 114 28'20" |
| 33 | 13091733 | Jerome Golf Course Drain 1 | Lat. 42 38 03" | Long. 114 31'03" |
| 34 | 13093150 | Sonnickson drain | Lat. 42 38'40" | Long. 114 33'26" |
| 35 | 13093190 | Sucker Flat drain nr Filer (LSLQ) | Lat. 42 38'25" | Long. 114 35'30" |
| 36 | 13093550 | Cedar Draw nr Filer | Lat. 42 39'13" | Long. 114 39'15" |
| 37 | 13093900 | Waste I nr Buhl | Lat. 42 39'33" | Long. 114 41'28" |
| 38 | 13094050 | J8 at Rivers Edge | Lat. 42 40'27" | Long. 114 44'27" |
| 39 | 13094700 | Mud Creek nr Buhl | Lat. 42 39'33" | Long. 114 47'20" |
| 40 | 13095060 | Fish Hatchery drain upper | Lat. 42 32'60" | Long. 114 49'21" |
| 41 | 13095061 | Fish Hatchery drain lower | Lat. 42 40'01" | Long. 114 48' 60 |
| 42 | 13095360 | S. Coulee (Cedar Draw) | Lat. 42 41'46 | Long. 114 48'19" |
| 43 | 13095490 | Irr Ditch to Blind Canyon | Lat. 42 42'28" | Long. 114 4730" |
| 44 | 13133785 | Drain nr Bickel Springs | Lat. 42 45'28" | Long. 114 50'48" |
| 45 | 13152450 | Irr Ditch nr Bliss | Lat. 42 55'56" | Long. 115 00'19" |

| | | | | |
|---|---|---|---|---|
| 46 | 13152895W. drain nr Tuttle (Drain to Malad River) | Lat. 42 51'50" | Long. 114 51' 58" | |

**Figure 1: Return flow gage sites from Ashton to American Falls**

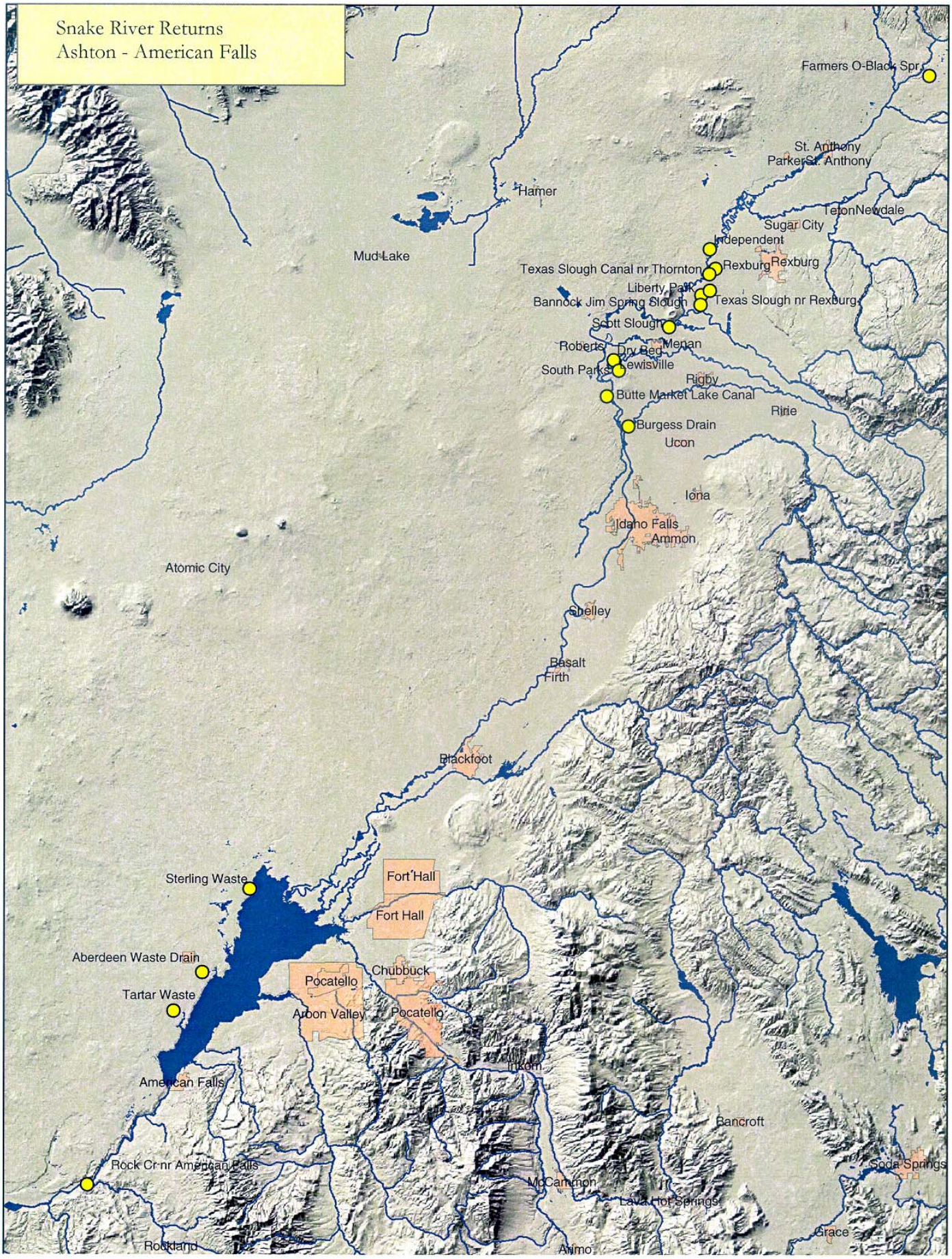
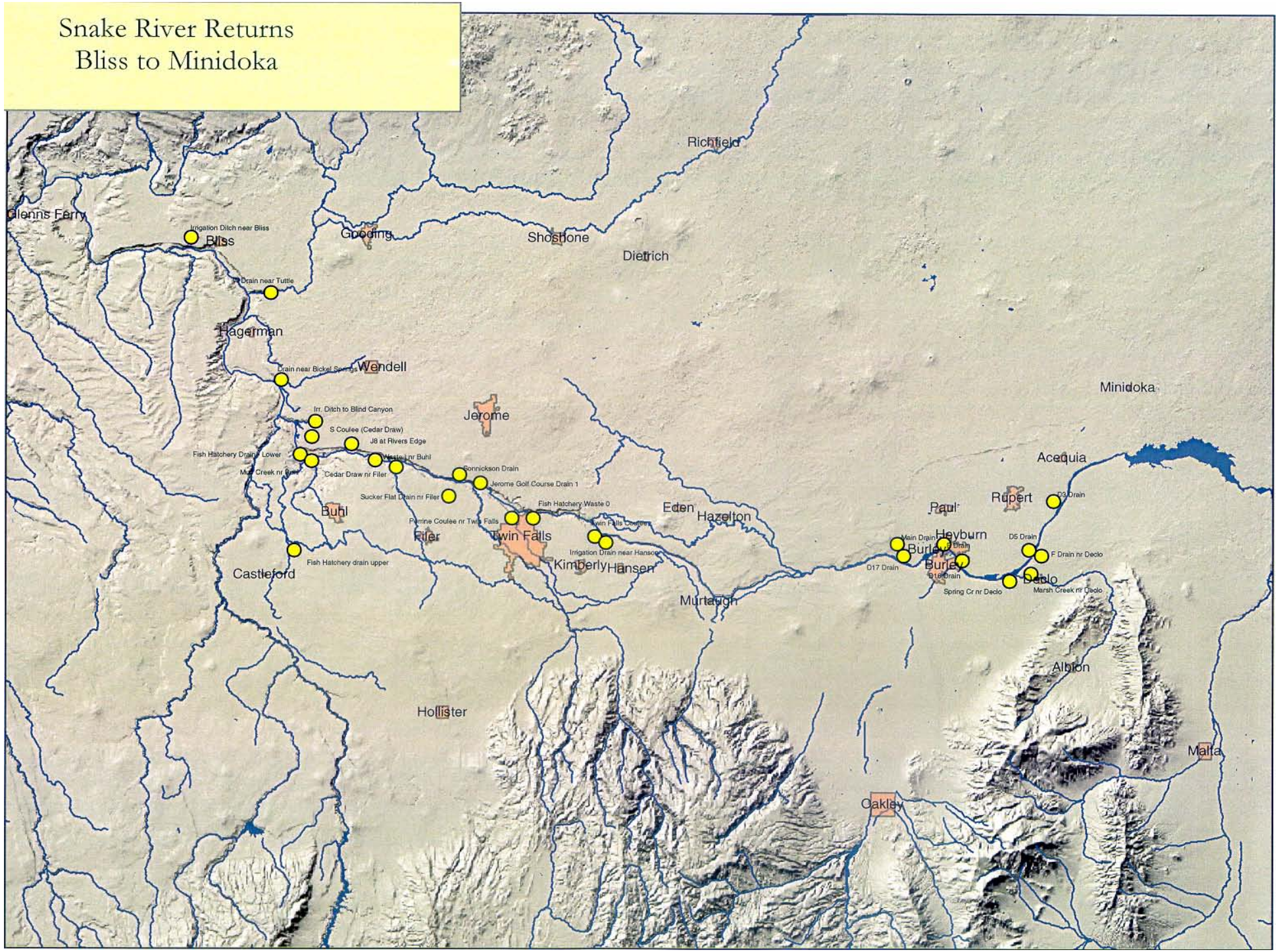


**Figure 2: Return flow Gage sites from Bliss to Minidoka**



**Assignment of Return Flows to Irrigations Entities**

Each return flow was assigned to an appropriate Irrigation Entity as defined in Design Document DDW-008 "Aggregation of Surface Water Canal Companies into Surface Water Irrigation Entities". A straightforward procedure was followed using the entity maps included in the above referenced document and the drain locations from Figures 1 & 2. The number of returns per entity ranged from as many as ten for IESW032 (Twin Falls Southside) to one for three entities on the Henry's Fork. On close examination of the entity maps including the land elevations, canals, and return flows, it became clear that some of the returns on the Henrys Fork serviced more than one irrigation entity. It was decided to group several entities together for the purpose of return flow calculation rather than try to parse the amount diverted from a single diversion between two or more entities. This procedure resulted in aggregating the returns and diversions into ten unique groups that were used to calculate the surface water returns.

The determination of water supplied to each entity (input) was the simple sum of each diversion referenced for that entity in DDW-008. The Idaho Department of Water Resource's historic database supplied these diversions values as acre feet per month..

This procedure resulted in aggregating the returns and diversions into ten unique groups that were used to calculate the surface water returns. Table 2 contains a complete listing of groups with entities, return flows, and diversions defined.

## Table 2: Assignment of return flows, diversions to entities.

**Below American Falls**:

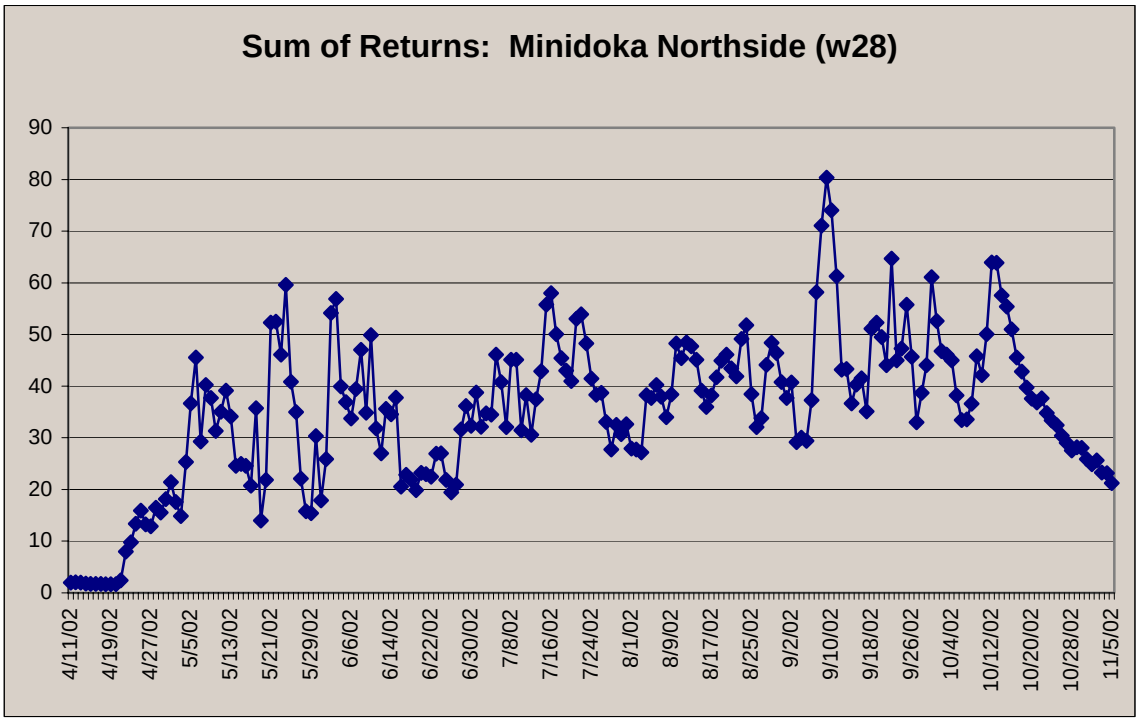
| Group | Irr. Entity | Assigned Return flows | | Water Supply: Historic Diversions |
|---|---|---|---|---|
| 1 | IESW032 | 13152450 | Irr. Ditch nr Bliss | 13087000 T. F. Northside |
| | | 13152895 | W. Dr. Nr Tuttle (to Malad) | 13086510 'A' Lateral in Gooding |
| | | 13133785 | Drain Nr Bickel Srings | 13086520 N. Side Cross-cut |
| | | 13094050 | J8 at Rivers Edge | |
| | | 13095490 | Irr. Drain to Blind Canyon | |
| | | 13095360 | S. Coulee(Ceder Draw) | |
| | | 13093150 | Sonnickson drain | |
| | | 13091733 | Jerome Golf drain | |
| 2 | IESW028 | 13085060 | D-17 drain nr Heyburn | 13080000 Minidoka Northside |
| | | 13085065 | Main drain North nr Heyburn | |
| | | 13084707 | B drain nr Heyburn | |
| | | 13084705 | D-16 drain nr Heyburn | |
| | | 13082064 | D-4 drain nr Rupert | |
| | | 13082062 | D-5 drain nr Rupert | |
| | | 13082032 | D-3 drain | |
| 3 | IESW010 | 13082060 | F drain nr Declo | Minidoka South (13080500) |
| | | 13082320 | Marsh Creek nr Declo | |
| | | 13082330 | Spring Creek nr Declo | |
| | | 13085070 | G drain nr Burley | |
| | | 13085080 | J drain nr Burley | |
| 4 | IESW041 | 13089690 | Irr drain nr Hansen | 13087500 Twin Falls Southside Ca. |
| | | 13089695 | Twin Falls Coulee | |
| | | 13090370 | Fish Hatchery Waste 0 | |
| | | 13090460 | Perrine Coulee nr Twin Falls | |
| | | 13093190 | Sucker Flat drain nr Filer (LSLQ) | |
| | | 13093550 | Cedar Draw nr Filer | |
| | | 13093900 | Waste I nr Buhl | |
| | | 13094700 | Mud Creek nr Buhl | |
| | | 13095061 | Fish Hatchery drain lower | |
| | | 13095060 | Fish Hatchery drain upper | |

Table 2: (continued) Above **American Falls**

| Group | Irr. Entity | Assigned Return flows | Water Supply: Historic Diversions | |
|---|---|---|---|---|
| 5 | IESW002 | 13069548 Sterling Waste | 13061610 Aberdeen Springfield Ca. | |
| | | 13069565 Aberdeen Waste Drain | | |
| | | 13076210 Tartar Waste | | |
| 6 | IESW031 | 13055300 Farmers Own Canal - Black Spring | 13047575 Farmers Own | |
| | | | 13047305 Yellowstone | |
| | | | 13047415 Marysville | |
| 7 | IESW016 | 13050543 Independent Canal drain | 13049725 St Anthony canal | |
| | | | 13049550 Last Chance | |
| | | (Ave. of 1989-90 USGS Data) | 13050525 Egin Canal | |
| | | | 13050530 St Anthony Union Fdr | |
| | | | 13050535 Independant Canal | |
| 8 | IESW011 | 13057045 Butte Market Lake Canal | 13057025 Butte Market Lake | |
| 9 | IESW036 | 13056550 Texas Slough Canal nr Thornton | 13038392 Sunnydell Ca | 36 |
| | IESW038 | 13056650 Liberty Park Canal | 13038398 Arnsberger | 36 |
| | | 13056850 Bannock Jim Spring Slough | 13038426 Lenroot Ca | 36 |
| | | 13055337 Rexburg Canal drain nr Thornton | 13038431 Reid Canal | 36 |
| | | 13056600 Texas Slough nr Rexburg | 13038435 Bannock Jim | 36 |
| | | | 13038436 Hill Pitinger | 36 |
| | | | 13038437 Nelson Cory | 36 |
| | | | 13038434 Texas Feeder | 36 |
| | | | 13055323 Rexburg canal | 38 |
| | | | 13055334 Rexburg Irr. | 38 |
| 10 | IESW009 | 13057000 Scott's Slough | 13038110 Burgess | 9 |
| | IESW020 | 13057020 Dry Bed | 13038115 Clark & Edwards | 9 |
| | IESW023 | 13057030 South Parks | 13038180 Rigby Ca | 9 |
| | IESW024 | 13057100 Burgess drain nr Idaho Falls | 13037975 Eagle Rock | 20 |
| | IESW026 | | 13037977 Eagle Rock ab Will Cr | 20 |
| | | | 13037985 Enterprise | 20 |
| | | | 13038025 Butler Island | 20 |
| ` | | | 13038030 Ross and Rand | 20 |
| | | | 13038050 Steele Ca. | 20 |
| | | | 13038055 Harrison Ca. | 20 |
| | | | 13038065 Cheny Ca | 20 |
| | | | 13038080 Butler Island #2 | 20 |
| | | | 13038095 Boomer Ca | 20 |
| | | | 13038098 Kite & Nord | 20 |
| | | | 13038145 Croft Pump | 20 |
| | | | 13038387 Nelson Ca | 20 |
| | | | 13038388 Mattson Creg | 20 |
| | | | 1303838150 East Labelle | 23 |
| | | | 13038205 Dilts Ca | 23 |
| | | | 13038225 W. Labelle Long Is | 23 |
| | | | 13038340 White Ca | 23 |
| | | | 13038360 Bramwell | 23 |
| | | | 13038362 Ellis Ca | 23 |
| | | | 13038210 Island Ca | 24 |

## Calculating per cent returned and development of Lag Factors

Upon examining typical hydrographs of surface water returns it is evident that a time delay is involved. The sum of the returns from the Minidoka South Side Canal shown below indicates a general increase as the irrigations season progresses. The actual diversions will remain constant or actually decrease during this same time period.




This phenomenon was dealt with by developing an algorithm that included the concept of lag factors. Lag factors are the portion of total annual percentage of water returned in the current and each successive month.

That is:

Lag Factor 1 ($LF_1$) = percent returned the same month diverted.
Lag Factor 2 ($LF_2$) = percent returned one month after diverted.
Lag Factor 3 ($LF_3$) = " " two months after diverted.
Etc. - - - - - - - - - -

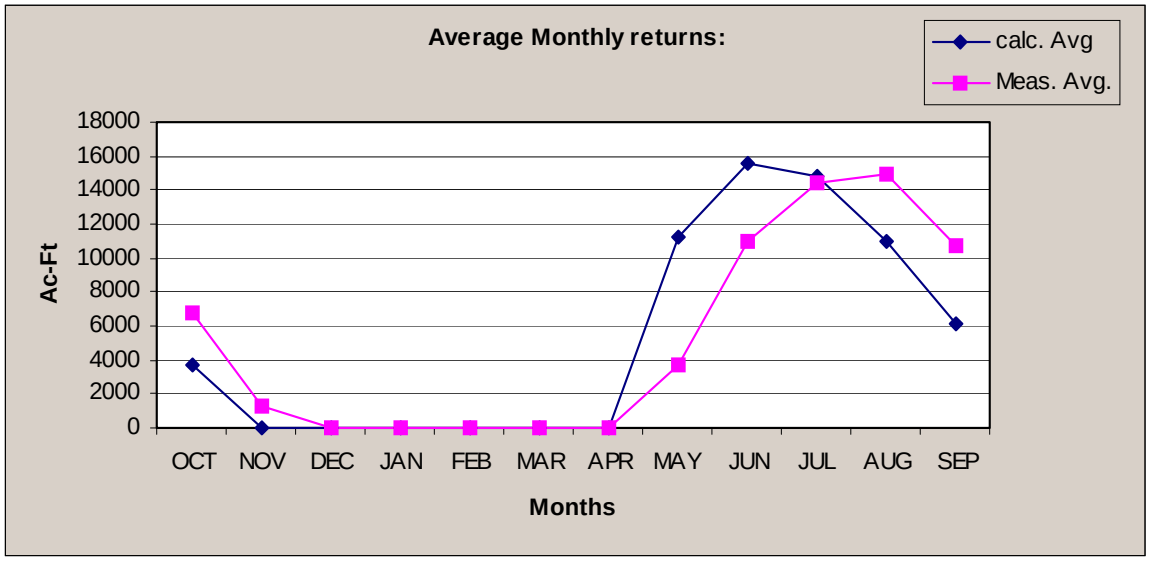
Up to twelve lag factors could be used but never more than five were needed to obtain a "best fit". Each monthly diversion would be returned per the following time profile.

Assume June Diversion: Returned in June = $Div_J (LF_1)$
" " July = $Div_J (LF_2)$
" " Aug = $Div_J (LF_3)$
" " $Mth_{m+n}=Div_m(LF_{n+1})$

With the constructs above an algebraic expression defining the water returned in any month as a function of water diverted can be written as:

$$Ret_{(m)} = Div_{(m)}(LF_1) + Div_{(m-1)}(LF_2) + Div_{(m-2)}(LF_3) \ldots Div_{(m-n)}(LFn)$$

This formula was programmed into an Excel spreadsheet and used to estimate the monthly return flow for each irrigation entity. These calculated values were graphically compared to the actual measured returns and the number and value of lag factors varied until a "best fit" was found. Below are the graphical plots of Group 9 comparing the measured and calculated returns. The improvement in fit of calculated values with measured values is clear with the introduction of lag factors




Above : No lag factors – 29% returned same month a diverted.

Below: Lag Factors used - $LF_1$=.12, $LF_2$=.10, $LF_3$=.05, $LF_4$=.02, $LF_5$=01

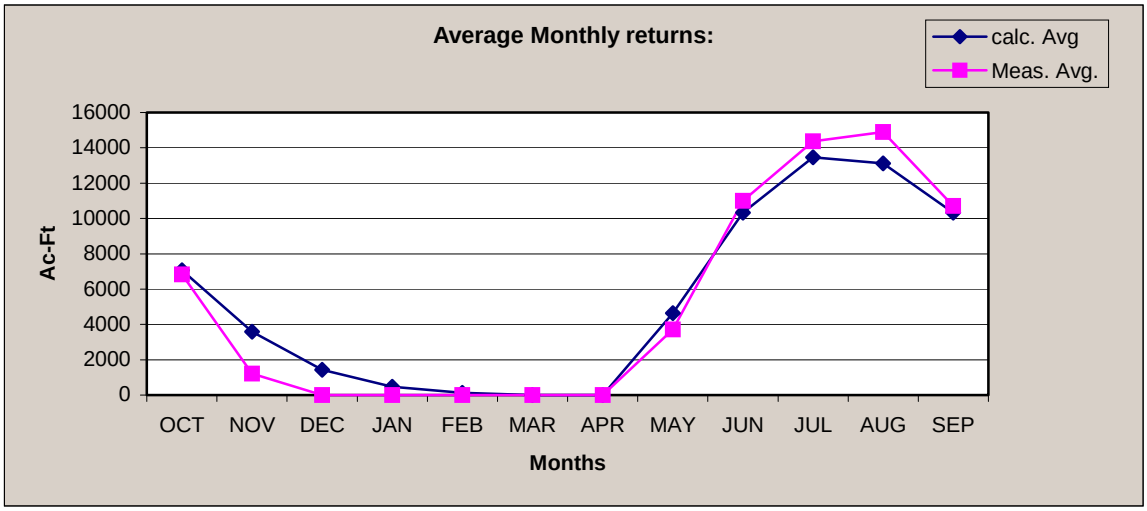


**Figure Three:** Example of Spreadsheet used to calculate lag factors

| | | | | | | |
|---|---|---|---|---|---|---|
| | | **Total Annual Returned (%) =>** | | | | **29.2** |
| **Group 9** | | **Month =>** | **1** | **2** | **3** | **4** | **5** |
| **Irrigation Entity: IESW036 & IESW038** | | **Lag. Ret. (%) =>** | **12** | **10** | **5** | **2** | **1** |

Recorded Diversions: Middle Henry's fork (Sum of 10 Div) [Ac-Ft] Ratio Returned = 0.2917

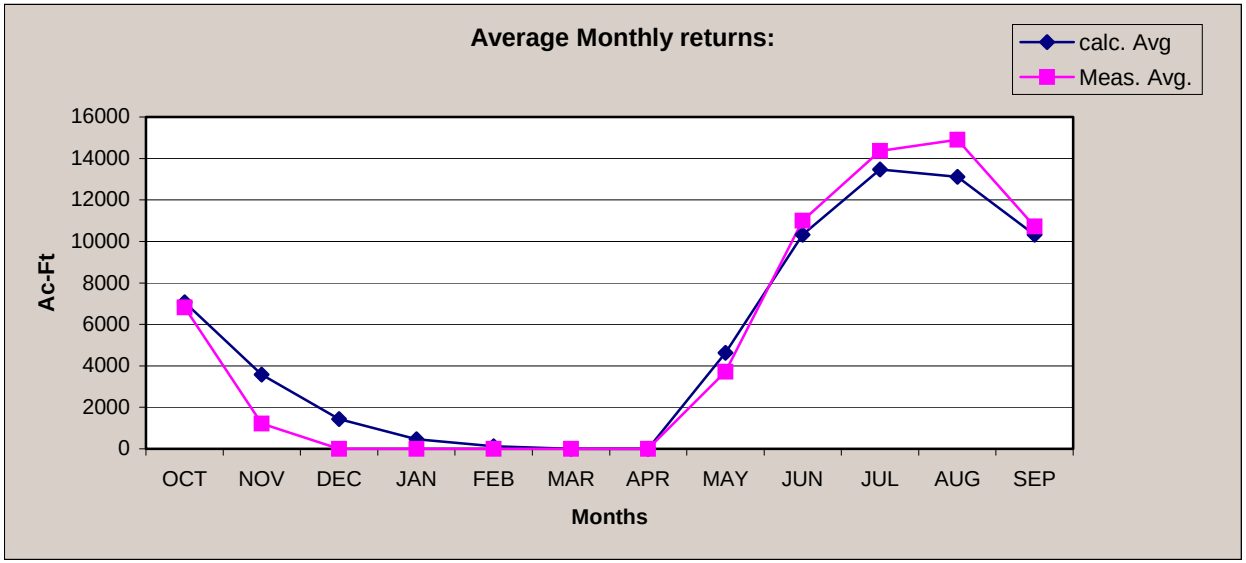
| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | ANNUAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Total |
| 2002 | | 0 | 0 | 0 | 0 | 0 | 0 | 38600 | 53900 | 51200 | 37700 | 21100 | 202500 | |
| 2003 | 12600 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 0 | 215100 |
| Time Lag(months) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | |
| Return Lags Factor | 0.120 | 0.100 | 0.050 | 0.020 | 0.010 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.300 |

Calculated Returns [Ac-Ft]

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | ANNUAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2002 | | | 0 | 0 | 0 | 0 | 0 | 0 | 4632 | 10328 | 13464 | 13111 | 10326 | 51861 |
| 2003 | 7070 | 3581 | 1429 | 463 | 126 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12669 |
| plot | 7070 | 3581 | 1429 | 463 | 126 | 0 | 0 | 4632 | 10328 | 13464 | 13111 | 10326 | | |

Measured Return Flows: [Ac-Ft]

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | ANNUAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2002 | | | | | | | | 0 | 3712 | 10994 | 14370 | 14901 | 10717 | 54694 | |
| 2003 | 6825 | 1218 | | | | | | | | | | | 8043 | 62738 |
| plot | 6825 | 1218 | 0 | 0 | 0 | 0 | 0 | 3712 | 10994 | 14370 | 14901 | 10717 | | |



## A summary of the results for all ten groups follows:

| Group | Irr. Entity | Results: Ann. Return and Lags | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | IESW032 | Total Annual Returned (%) => | | 4.6 | | | |
| | | Month => | 1 | 2 | 3 | 4 | 5 |
| | | Lag. Ret. (%) => | 3 | 1.6 | 0 | 0 | 0 |
| 2 | IESW028 | Total Annual Returned (%) => | | 4.80 | | | |
| | | Month => | 1 | 2 | 3 | 4 | 5 |
| | | Lag. Ret. (%) => | 2 | 1 | 1 | 1 | 0 |
| 3 | IESW010 | Total Annual Returned (%) => | | 10.0 | | | |
| | | Month => | 1 | 2 | 3 | 4 | 5 |
| | | Lag. Ret. (%) => | 4 | 3 | 3 | 0 | 0 |
| 4 | IESW041 | Total Annual Returned (%) => | | 6.4 | | | |
| | | Month => | 1 | 2 | 3 | 4 | 5 |
| | | Lag. Ret. (%) => | 3 | 2 | 1.5 | 0 | 0 |
| 5 | IESW002 | Total Annual Returned (%) => | | 5.9 | | | |
| | | Month => | 1 | 2 | 3 | 4 | 5 |
| | | Lag. Ret. (%) => | 3 | 2 | 1 | 0 | 0 |
| 6 | IESW031 | Total Annual Returned (%) => | | 19.5 | | | |
| | | Month => | 1 | 2 | 3 | 4 | 5 |
| | | Lag. Ret. (%) => | 7 | 4 | 3 | 3 | 2 |
| 7 | IESW016 | Total Annual Returned (%) => | | 1.6 | | | |
| | | Month => | 1 | 2 | 3 | 4 | 5 |
| | | Lag. Ret. (%) => | 1 | 0.6 | 0 | 0 | 0 |
| 8 | IESW011 | Total Annual Returned (%) => | | 1.8 | | | |
| | | Month => | 1 | 2 | 3 | 4 | 5 |
| | | Lag. Ret. (%) => | 1.8 | 0 | 0 | 0 | 0 |
| 9 | IESW036 | Total Annual Returned (%) => | | 29.2 | | | |
| | IESW038 | Month => | 1 | 2 | 3 | 4 | 5 |
| | | Lag. Ret. (%) => | 12 | 10 | 5 | 2 | 1 |
| 10 | IESW009 | Total Annual Returned (%) => | | 27.2 | | | |
| | IESW020 | Month => | 1 | 2 | 3 | 4 | 5 |
| | IESW023 | Lag. Ret. (%) => | 11 | 7 | 4 | 4 | 0 |
| | IESW024 | | | | | | |
| | IESW026 | | | | | | |

## General Discussion of Results

It is evident, upon examining the summary of results listed on the following page that the amount of water returned on the Snake River (Groups 1- 5) is less than is returned on the Henry's Fork. This seems to be explained by the difference in depth of water applied to each group. Bryce Condor has conducted an extensive examination of this phenomenon. In fact, the extrapolation of "percent returned" to entities without data used the depth of water applied as a guide.

The amount percentage (1.8%) of water returned for Irrigation entity IESW11 (Butte Market Lake) was not reasonable. The hydrograph of the field returns was not consistent with a typical return flow profile. Flow was high and inconsistent in May and June and receded to near zero in August and September.

The amount returned for entity IESW016 (Group7 – Independent drain) was also very low. Since the irrigation district refused access to the gage, an average of 1989-90 data from the USGS was used. Hopefully this data will be able to be collected in the 2003 irrigation season and current data will improve the results.

The 2002 water year was a relatively dry year the irrigation practices and availability of water would have skewed the overall results. It would seem logical that the average returns for a low year would be lower than for a normal or wet year. Although the study will continue into water year 2003 it appears that it also will be a low year.