# FINAL TECHNICAL MEMORANDUM

SUBJECT:         Green River Basin Plan
                 *Surface Water Data Synthesis and Spreadsheet Model Development*

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## Introduction

The Wyoming Water Development Commission has undertaken statewide water basin planning efforts in selected river basins. The purpose of the statewide planning process is to provide decision-makers with current, defensible data to allow them to manage water resources for the benefit of all the state's citizens. Under Task 3B, spreadsheet models were developed to determine average monthly streamflow in the basin during normal, wet, and dry years. The purpose of these models was to validate existing basin uses, assist in the determining timing and location of water available for future development, and help to assess impacts of future water supply alternatives,

Task 3B encompassed creating twelve spreadsheet workbooks, one for each of three hydrologic conditions and four distinct sub-basins:

• Upper Green River Basin from the Green River headwaters to Flaming Gorge

• Blacks Fork River Basin from the Blacks Fork and Smiths Fork headwaters to Flaming Gorge

• Henrys Fork River Basin from the Henrys Fork headwaters to Flaming Gorge, and

• Little Snake River Basin from the Little Snake headwaters to the USGS stream gaging station Little Snake River near Lily, CO.

The three workbooks for each sub-basin are yoked together with a simple menu-driven graphical user interface (GUI), effectively creating four sub-basin models.

This memorandum is intended to be both a user's guide and engineering documentation of the models. After a section describing the models in general terms, the document's organization follows the organization of worksheets in the model. The subsection "Model structure and components" describes the types of worksheets and the format of the worksheet documentation which follows. Engineering details of particular length or complexity have been placed in appendices, with "pointers" to them in the appropriate worksheet descriptions. The remainder of this memorandum comprises the following sections and subsections:

**Spreadsheet Models**
*Model overview*
*Model development*
*Model structure and components*

**The Navigation Worksheets**
*The central navigation worksheet*
*The basin map*
*The results navigator*

**The Input Worksheets**
*Master List of Nodes*
*Gage data*
*Diversion data*
*Import and export data*
*Options tables*

**The Computation Worksheets**
*Irrigation returns*
*Evaporative losses*
*Reach gain/loss*

**The Reach/Node Worksheets**
*Upper Green notes*
*Blacks Fork notes*
*Henrys Fork notes*
*Little Snake notes*

**The Results Worksheets**
*Outflows*
*Diversions*

**Spreadsheet Models**

*Model Overview*

For each Green River sub-basin, three models were developed, reflecting each of three hydrologic conditions: dry, normal, and wet year water supply. The spreadsheets each represent one calendar year of flows, on a monthly time step. The modelers relied on historical gage data from 1971 to 1998 to identify the hydrologic conditions for each year in the study period, as discussed in the technical memorandum for ***Task 3A Surface Water Data Collection and Study Period Selection.*** Streamflow, consumptive use, diversions, irrigation returns, and reservoir conditions are the basic input data to the model. For all of these data, average values drawn from the dry, normal, or wet subset of the study period were computed for use in the spreadsheets. The models do not explicitly account for water rights, appropriations, or compact allocations nor is the model operated based on these legal constraints. It is assumed that the historical data reflect effects of any limitations that may have been placed upon water users by water rights restrictions.

To mathematically represent each sub-basin system, the river system was divided into reaches based primarily upon the location of major tributary confluences. Each reach was then sub-divided by identifying a series of individual nodes representing diversions, reservoirs, tributary confluences, gages, or other significant water resources features. The resulting network is the simplification of the real world which the model represents. **Figures 1** through **4** present node diagrams of the models developed for the Green River. Each numbered node in the figure is a node in the model.

Natural or virgin flow for each month is supplied to the model by specifying flow at every headwater node, and incremental stream gains and losses within each downstream reach. Where available, upper basin gages were selected as headwater nodes; in their absence, flow at the ungaged headwater point was estimated outside the spreadsheet. For each reach, incremental stream gains (e.g., ungaged tributaries, groundwater inflow, and inflow resulting from human-caused but unmodeled processes) and losses (e.g. seepage, evaporation, and unspecified diversions) are computed by the spreadsheet. These are calculated by adding net modeled effects (diversions and increases in storage less return flows and decreases in storage) within the reach back into the difference between the upstream and downstream historical gage flows. Stream gains are input at the top of a reach to be available for diversion throughout the reach and losses are subtracted at the bottom of each reach.

At each node, a water budget computation is completed to determine the amount of water that flows downstream out of the node. At non-storage nodes, the difference between inflow, including upstream inflows, return flows, imports and reach gains, and outflows, including diversions, reach losses and exports, is the amount of flow available to the next node downstream. For storage nodes, an additional loss calculation for evaporation and the change in storage is evaluated.  Also at storage nodes, any uncontrolled spill that occurs is added to the scheduled release to get total outflow. Diverted amounts at diversion nodes are the minimum of demand (the historical or estimated historical diversion at the structure) and physically available streamflow. Mass balance, or water budget calculations, are repeated for all nodes in a reach.

Model output includes the diversion demand and simulated diversions at each of the diversion points, and streamflow at each of the Green River Basin nodes. Estimates of impacts associated with various water projects can be analyzed by changing input data, as decreases in available streamflow or as changes to diversions occur.  New storage projects that alter the timing of streamflows or shortages may also be evaluated.
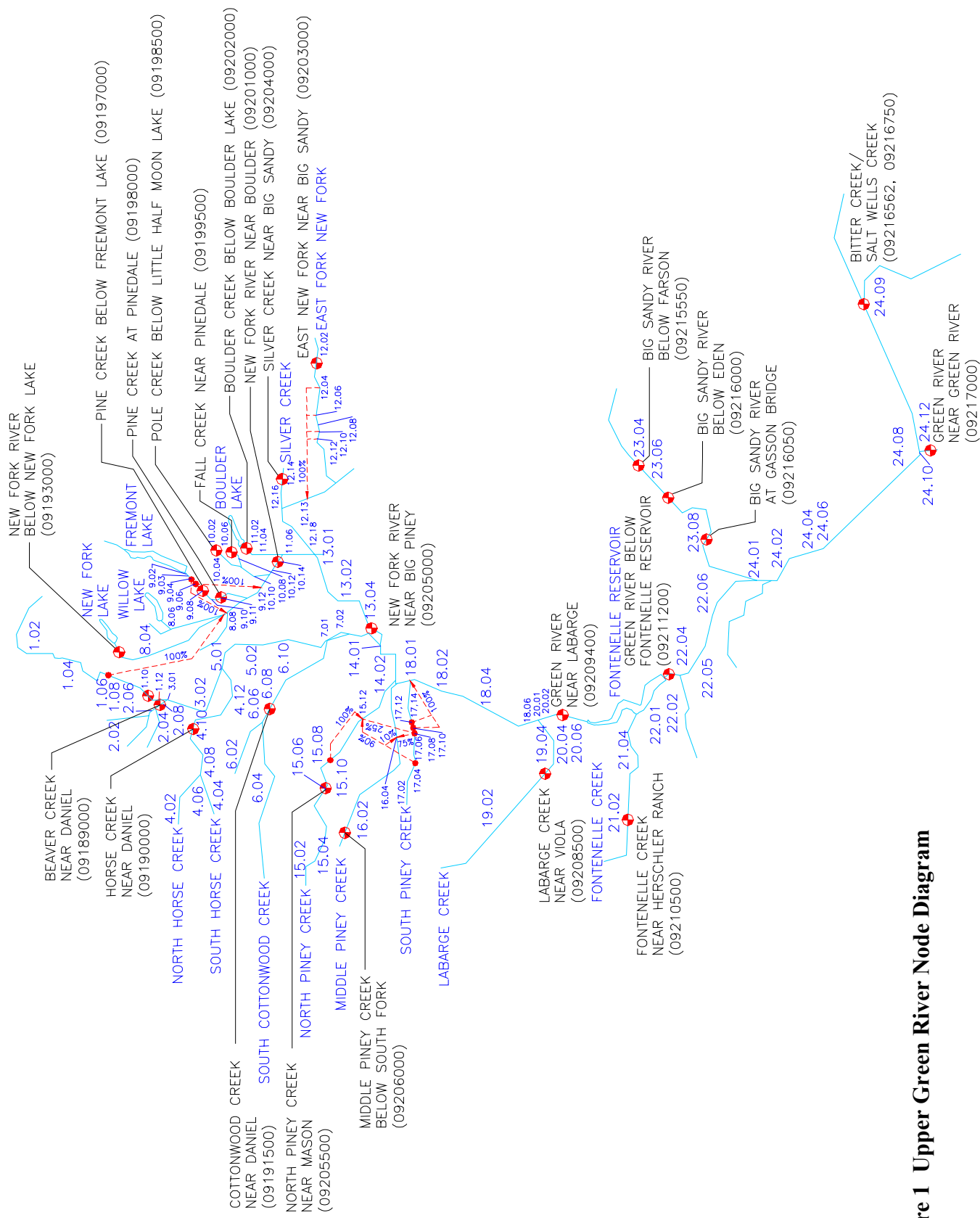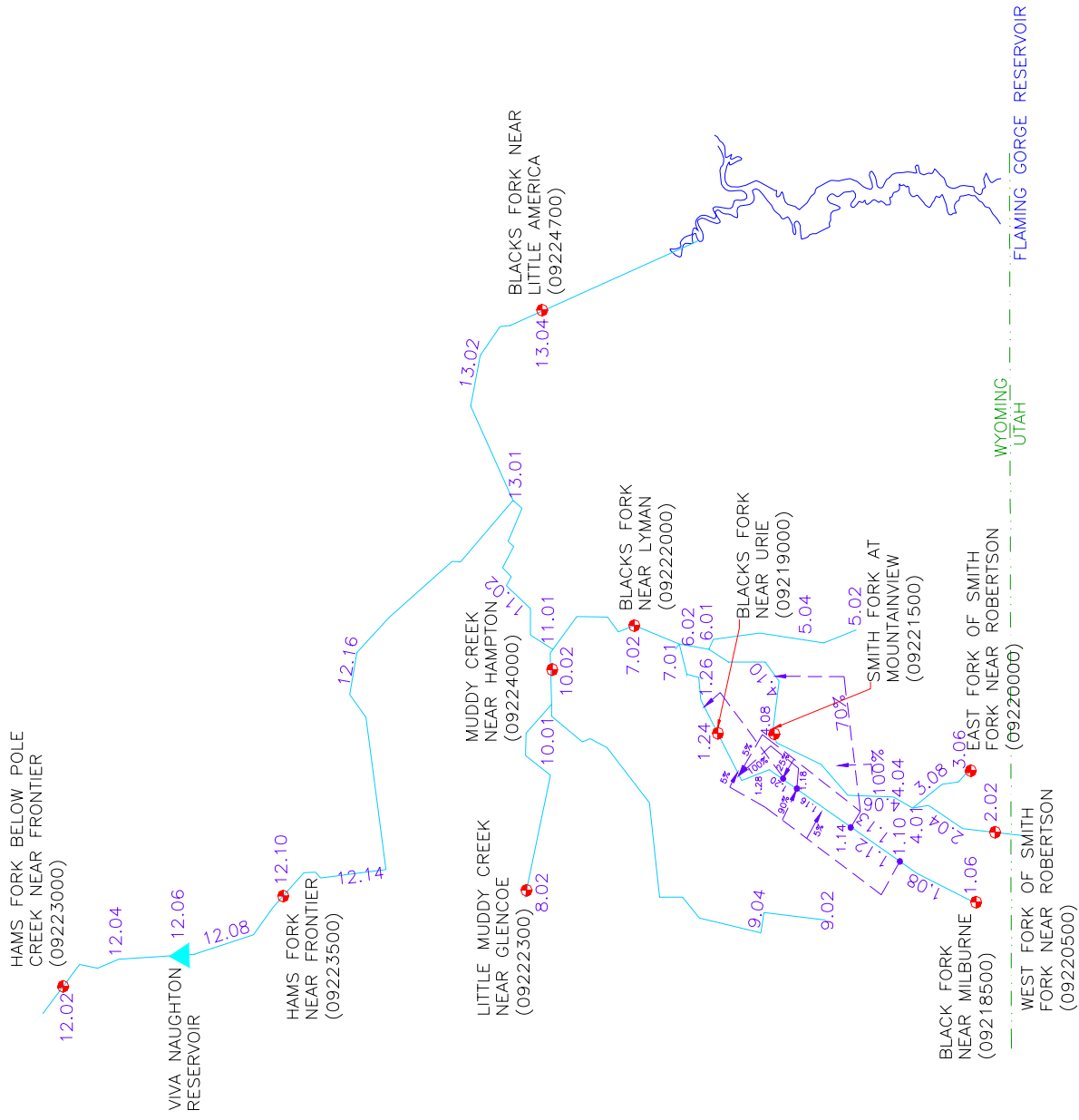
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**Figure 1  Upper Green River Node Diagram**

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NEW FORK RIVER BELOW NEW FORK LAKE (09193000)

PINE CREEK BELOW FREEMONT LAKE (09197000)

PINE CREEK AT PINEDALE (09198000)

POLE CREEK BELOW LITTLE HALF MOON LAKE (09198500)

FALL CREEK NEAR PINEDALE (09199500)

BOULDER CREEK BELOW BOULDER LAKE (09202000)

NEW FORK RIVER NEAR BOULDER (09201000)

SILVER CREEK NEAR BIG SANDY (09204000)

EAST NEW FORK NEAR BIG SANDY (09203000)

EAST FORK NEW FORK

BIG SANDY RIVER BELOW FARSON (09215550)

BIG SANDY RIVER BELOW EDEN (09216000)

BIG SANDY RIVER AT GASSON BRIDGE (09216050)

BITTER CREEK/ SALT WELLS CREEK (09216562, 09216750)

GREEN RIVER NEAR GREEN RIVER (09217000)

NEW FORK LAKE

FREMONT LAKE

WILLOW LAKE

BOULDER LAKE

SILVER CREEK

NEW FORK RIVER NEAR BIG PINEY (09205000)

FONTENELLE RESERVOIR

GREEN RIVER BELOW FONTENELLE RESERVOIR (09211200)

GREEN RIVER NEAR LABARGE (09209400)

BEAVER CREEK NEAR DANIEL (09189000)

HORSE CREEK NEAR DANIEL (09190000)

COTTONWOOD CREEK NEAR DANIEL (09191500)

NORTH PINEY CREEK NEAR MASON (09205500)

NORTH HORSE CREEK

SOUTH HORSE CREEK

SOUTH COTTONWOOD CREEK

NORTH PINEY CREEK

MIDDLE PINEY CREEK

MIDDLE PINEY CREEK BELOW SOUTH FORK (09206000)

SOUTH PINEY CREEK

LABARGE CREEK

LABARGE CREEK NEAR VIOLA (09208500)

FONTENELLE CREEK

FONTENELLE CREEK NEAR HERSCHLER RANCH (09210500)

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**Figure 2  Blacks Fork Node Diagram**

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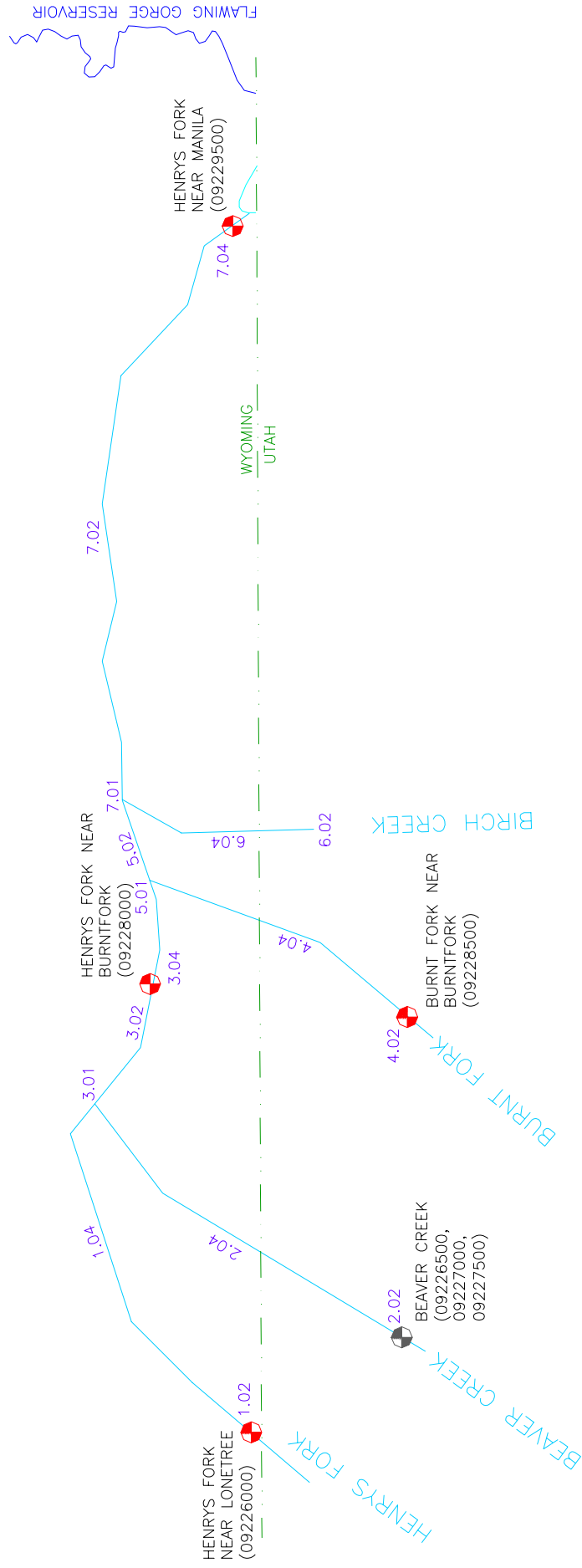


**Figure 3  Henrys Fork Node Diagram**

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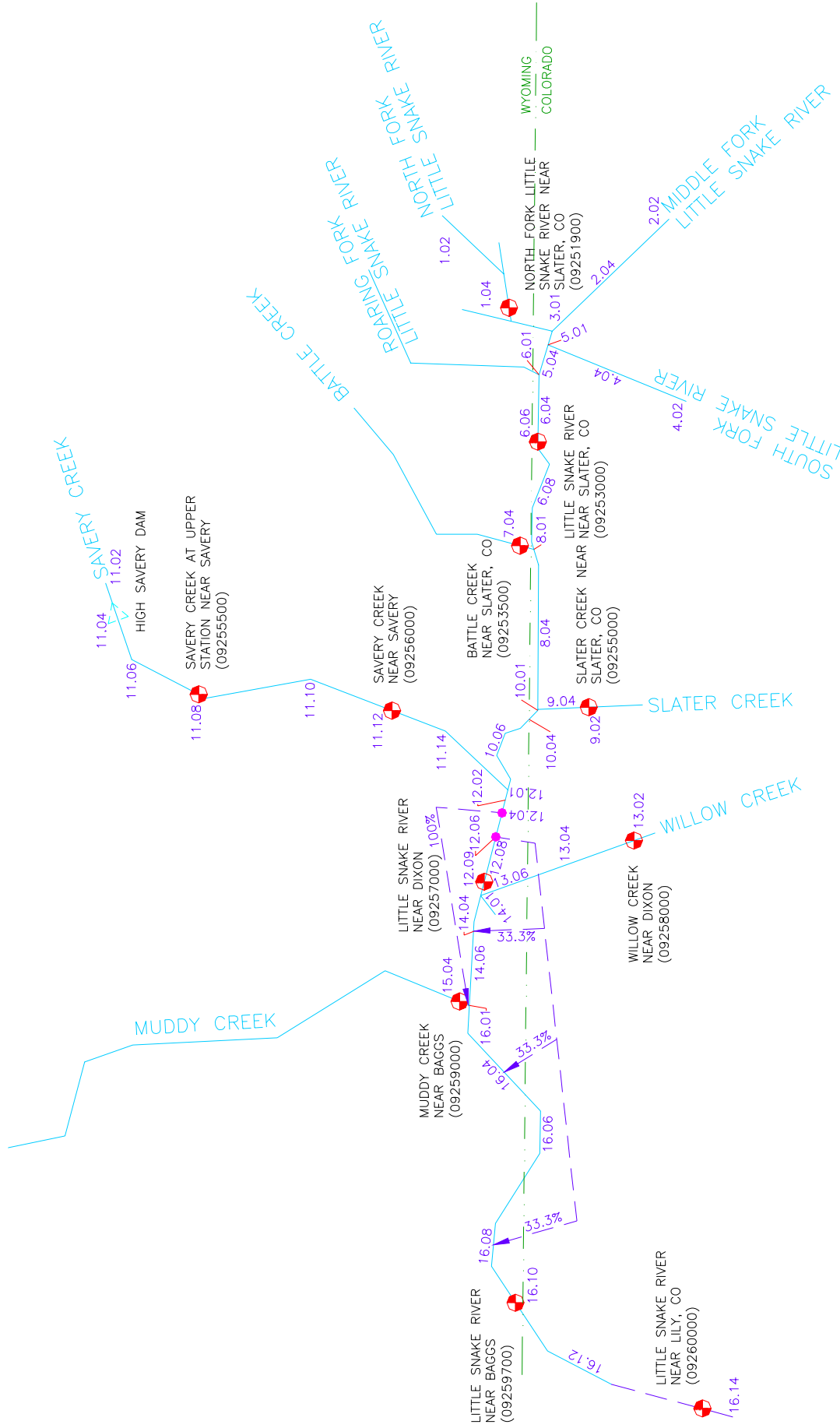


**Figure 4  Little Snake River Node Diagram**

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*Model Development*

The model was developed using Microsoft® Excel 97. The workbooks contain macros written in Microsoft® Excel Visual Basic programming language. The primary function of the macros is to facilitate navigation within the workbook.  There are no macros that need to be executed to complete computation of any formulas or results.  In other words, whenever a number is input into any cell anywhere in the workbook, the entire workbook is recalculated and updated automatically.

The model was developed with the novice Excel user in mind and it is assumed that the user has an basic level of proficiency in spreadsheet usage and programming. Every effort has been taken to lead the User through the model with interactive buttons and mouse-driven options. This memorandum will not provide instructions in the use of Excel for this spreadsheet.

*Model Structure and Components*

Each of the Green River sub-basin models is a workbook consisting of numerous individual pages (worksheets).  Each worksheet is a component of the model and completes a specific task required for execution of the model.  There are five basic types of worksheets:

- *Navigation Worksheets*: Graphical User Interfaces (GUIs) containing buttons used to move within the workbook;

- *Input Worksheets*: raw data entry worksheets (USGS Gage data or headwater inflow data, Diversion Data, etc.);

- *Computation Worksheets*: compute various components of the model (reservoir evaporation, irrigation return flows, etc.);

- *Reach/Node Worksheets*: calculate node by node computations of the water budget; and

- *Results Worksheets*: tabulate and present the model output.

In the following sections, each component of the Green River Basin Models is discussed in greater detail.  A general discussion of each component includes a brief overview of the function. The discussion of each component also generally includes two sections:

**Engineering Notes:**   Detailed discussion of methodologies, assumptions, and sources used in the development of that component; and

**User Notes**:    "How to" instructions for model Users.

Programmer Notes, which are instructions and suggestions for programmers modifying the model, are included in **Appendix C**.  These will assist state staff with any modifications of this model to analyze changed conditions or other applications in the Green River Basin.  Additionally, since this model may be a basis for developing spreadsheet models for other basins, this will serve as a guide for other consultants.

**The Navigation Worksheets**

A GUI was developed to assist the User in navigating the sub-basin workbooks. The top-level navigation sheet is initialized by opening the appropriate Green River Basin Model Excel file:

- Upper Green River Model.xls,

- Blacks Fork River Model.xls,

- Henrys Fork River Model.xls, or

- Little Snake River Model.xls.

The GUI provides a brief tutorial and information regarding the current model version (see **Figure 5**). From the GUI, the User may select the dry, normal, or wet year model.
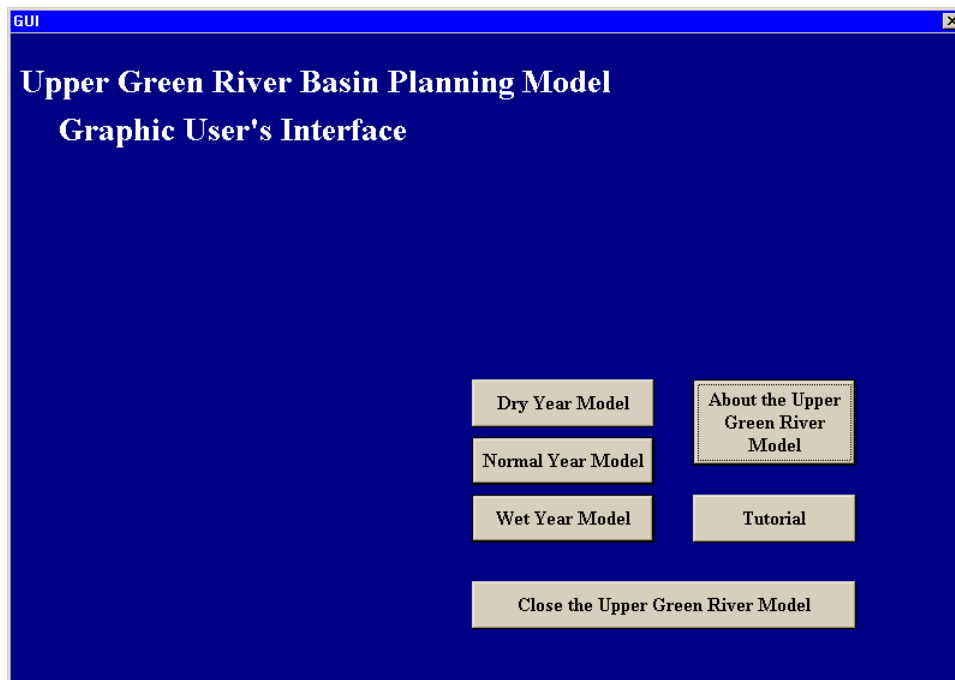


**Figure 5 Graphical User's Interface for the Upper Green River Model**

<u>**User Notes:**</u>

Upon opening the selected sub-basin Green River Model file, the User is presented with several options:

**Dry Year Model:**      Open the Dry Year Model workbook,

**Normal Year Model:**      Open the Normal Year Model workbook,

**Wet Year Model:**      Open the Wet Year Model workbook,

**About the (Sub-basin) Model:**  Obtain information pertaining to the current version of the model,

**Tutorial:**  Open a brief tutorial that describes the general structure of a spreadsheet workbook

**Close the (Sub-basin) Model:**  Close any open workbooks.

The Dry, Normal, and Wet Year models each have two main navigation worksheets to view other portions of the workbook. A third sheet contains a diagram of the basin to orient the user, and could be programmed for navigation in the future. For Users experienced with Excel spreadsheets, all conventional spreadsheet navigation commands are still operative (e.g., page down, GOTO, etc.).

*The Central Navigation Worksheet*

The Central Navigation Worksheet is the "heart" of the model.  From here, the User can "jump" to and from any worksheet in the model. **Figure 6** displays the Central Navigation Worksheet from the Upper Green River Basin Dry Year Model.
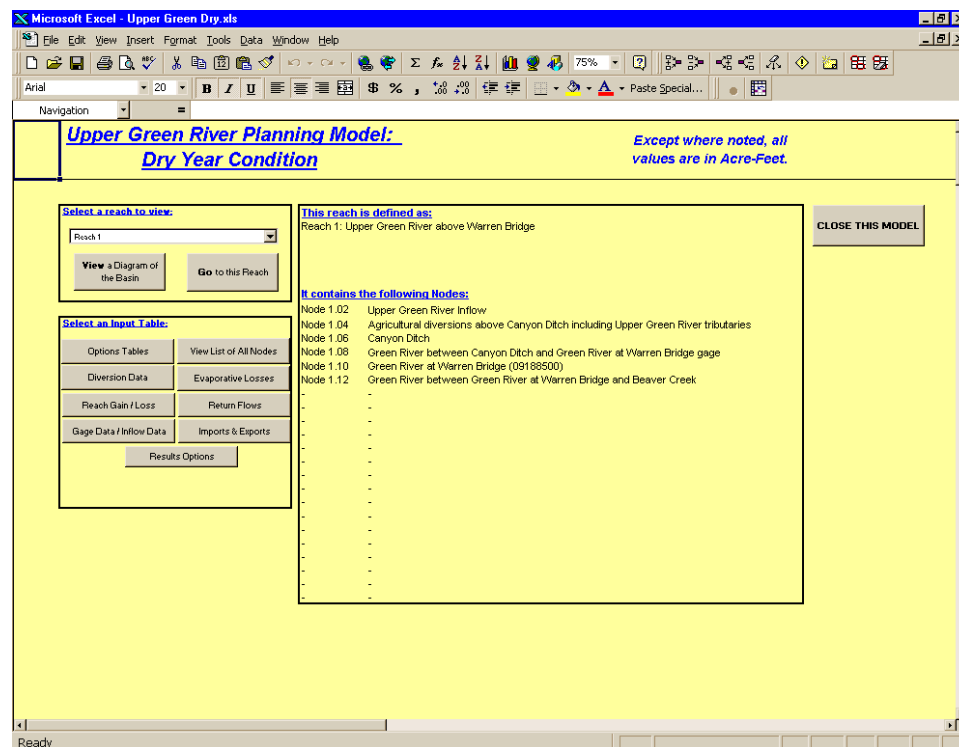


**Figure 6 Central Navigation Worksheet for the Upper Green River Planning Model: Dry Year Condition**

**User Notes:**

This is the first worksheet the User sees upon selecting a hydrologic condition from the GUI. Using the gray buttons, the User can "jump" to

- the basin diagram (View a Diagram of the Basin),

- any of the Reach/Node worksheets (Go to this Node),

- the Input Worksheets and Computation Worksheets (Options Tables, Diversion Data, Reach Gain/Loss, Gage Data/Inflow Data, View List of all Nodes, Evaporative Losses, Return Flows, Imports & Exports), and

- the Results Navigator (Results Options) which leads in turn to several summaries of output.

The User specifies the reach he wants to go to by selecting it from the pull-down menu. When a reach is selected, the table to the right lists all the nodes in that reach by number and name.

*The Basin Map*

### User Notes

The Basin Map Worksheet provides a simple "stick diagram" of the basin.

*The Results Navigator*

### User Notes



**Figure 7 Results Navigator**

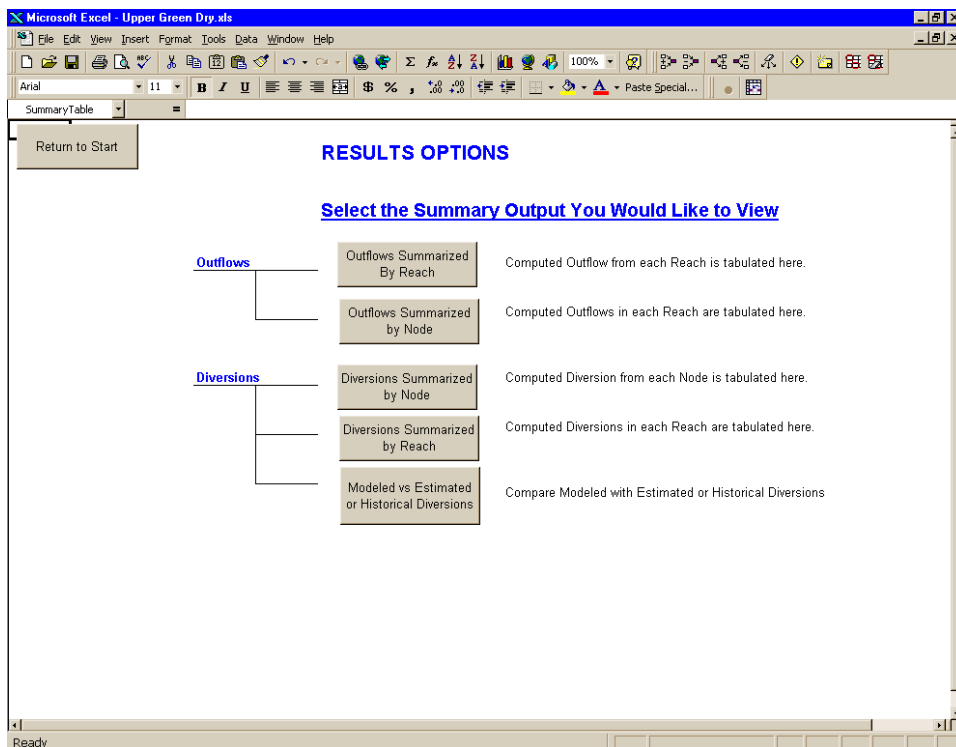January 2, 2001                                                                                          Page 12

The Results Navigator (**Figure 7)** allows selection of any of the following output tabulations:

- Outflows summarized by reach

- Outflows summarized by node

- Diversions summarized by node

- Diversions summarized by reach

- Modeled versus estimated or historical diversions

**The Input Worksheets**

*Master List of Nodes*

The model is structured around nodes at which mass balance calculations are made and reaches that connect the nodes. Nodes are points on the river that represent such water resources features as gage locations, diversion headgates, major tributary confluences within the Green River Basin, or reservoirs. **Tables 1** through **4** list the nodes for the four sub-basin models.

**Table 1 Upper Green River Basin Model Nodes**

| Node No. | Node Name |
|---|---|
| Node 1.02 | Upper Green River Inflow |
| Node 1.04 | Agricultural diversions above Canyon Ditch including Upper Green River tributaries |
| Node 1.06 | Canyon Ditch |
| Node 1.08 | Green River between Canyon Ditch and Green River at Warren Bridge gage |
| Node 1.10 | Green River at Warren Bridge (09188500) |
| Node 1.12 | Green River between Green River at Warren Bridge and Beaver Creek |
| Node 2.02 | Middle & North Beaver Creek inflow & diversions |
| Node 2.04 | South Beaver Creek inflow & diversions |
| Node 2.06 | Beaver Creek mainstem |
| Node 2.08 | Beaver Creek near Daniel (09189000) |
| Node 3.01 | Confluence of Beaver Creek and Green River |
| Node 3.02 | Green River between Beaver and Horse Creeks |
| Node 4.02 | North Fork Horse Creek inflow & diversions |
| Node 4.04 | South Fork Horse Creek inflow & diversions |
| Node 4.06 | Confluence of North and South Fork Horse Creek |
| Node 4.08 | Between confluence of North and South Fork Horse Creek and Horse Creek near Daniel gage |
| Node 4.10 | Horse Creek near Daniel (09190000) |
| Node 4.12 | Below Horse Creek near Daniel Gage and above Green River |
| Node 5.01 | Confluence of Horse Creek and Green River |
| Node 5.02 | Green River between Horse and Cottonwood Creeks |
| Node 6.02 | N Cottonwood Creek and tributaries inflow & diversions |
| Node 6.04 | S Cottonwood Creek and tributaries inflow & diversions |

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**Table 1 Upper Green River Basin Model Nodes (cont'd)**

| Node No. | Node Name |
|---|---|
| Node 6.06 | Confluence of North and South Cottonwood Creeks |
| Node 6.08 | Cottonwood Creek near Daniel (09191500) |
| Node 6.10 | Cottonwood Creek below Cottonwood Creek nr Daniel gage |
| Node 7.01 | Confluence of Cottonwood Creek and Green River |
| Node 7.02 | Green River between Cottonwood Creek and New Fork River |
| Node 8.02 | New Fork River below New Fork Lake, near Cora (09193000) |
| Node 8.04 | West Fork New Fork diversions above Willow Creek |
| Node 8.06 | Willow Creek |
| Node 8.08 | West Fork New Fork between Willow and Duck Creeks (including Duck Creek) |
| Node 8.10 | West Fork New Fork River between Duck Creek and Pine Creek |
| Node 9.02 | Pine Creek |
| Node 9.03 | Town of Pinedale |
| Node 9.04 | Fremont Ditch |
| Node 9.06 | Highland Canal |
| Node 9.08 | Pine Creek below Fremont Lake (09197000) |
| Node 9.10 | Below Pine Creek below Fremont Lake gage and Pine Creek at Pinedale gage |
| Node 9.11 | Pine Creek at Pinedale (09198000) |
| Node 9.12 | West Fork New Fork River between Pine and Pole Creeks |
| Node 10.02 | Pole Creek below Little Half Moon Lake (09198500) |
| Node 10.04 | Pole Creek diversions above Fall Creek confluence |
| Node 10.06 | Fall Creek near Pinedale (09199500) |
| Node 10.08 | Fall Creek diversions |
| Node 10.10 | Pole Creek diversions between Fall Creek and West Fork New Fork |
| Node 10.12 | West Fork New Fork River between Pole and Boulder |
| Node 10.14 | New Fork River near Boulder (09201000) |
| Node 11.02 | Boulder Creek below Boulder Lake, near Boulder (09202000) |
| Node 11.04 | Boulder Creek diversions |
| Node 11.06 | West Fork New Fork River between Boulder Creek and East Fork New Fork River |
| Node 12.02 | East Fork New Fork near Big Sandy (09203000) |
| Node 12.04 | Overland Ditch |
| Node 12.06 | East Fork Ditch |
| Node 12.08 | East Fork aggregation |
| Node 12.10 | Gilligan-Iven Ditch |
| Node 12.12 | Tibbals Ditch |
| Node 12.13 | East Fork between Muddy and Silver Creeks |
| Node 12.14 | Silver Creek near Big Sandy (09204000) |
| Node 12.16 | Silver Creek diversions |
| Node 12.18 | East Fork New Fork diversions below Silver Creek |
| Node 13.01 | Confluence of East Fork and West Fork New Fork River |

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**Table 1 Upper Green River Basin Model Nodes (cont'd)**

| Node No. | Node Name |
|---|---|
| Node 13.02 | New Fork diversions below East and West Forks |
| Node 13.04 | New Fork River near Big Piney (09205000) |
| Node 14.01 | Confluence of New Fork River and Green River |
| Node 14.02 | Green River between New Fork River and Piney Creeks |
| Node 15.02 | Upper North Piney Creek inflow & diversions |
| Node 15.04 | North Piney Creek near Mason (09205500) |
| Node 15.06 | North Piney Canal |
| Node 15.08 | Between North Piney Canal and Musselman |
| Node 15.10 | Musselman |
| Node 15.12 | Below Musselman |
| Node 16.02 | Middle Piney Creek below South Fork, near Big Piney (09206000) |
| Node 16.04 | Aggregation below Middle Piney gage |
| Node 17.02 | Upper South Piney Creek including Fish & Beaver Creeks |
| Node 17.04 | South Piney Ditch |
| Node 17.06 | Aggregation between South Piney and Yankee Ditch |
| Node 17.08 | Homestake Ditch |
| Node 17.10 | Yankee Ditch |
| Node 17.12 | Reardon Ditch |
| Node 17.14 | Aggregation below Reardon |
| Node 18.01 | Confluence of Pineys and Green River |
| Node 18.02 | Confluence of Dry Piney and Green River |
| Node 18.04 | Green River between Dry Piney and LaBarge Creek |
| Node 18.06 | Town of LaBarge |
| Node 19.02 | LaBarge Creek inflow & diversions |
| Node 19.03 | Anderson-Howard Ditch |
| Node 19.04 | LaBarge Creek near Viola (09208500) |
| Node 19.06 | Below LaBarge Creek near Viola gage and above LaBarge No. 2 Ditch |
| Node 19.08 | LaBarge No. 2 Ditch |
| Node 20.01 | Confluence of LaBarge Creek and Green River |
| Node 20.02 | Green River between LaBarge and Green River near LaBarge Gage |
| Node 20.04 | Green River near LaBarge (09209400) |
| Node 20.06 | Between Green River nr LaBarge gage and Fontenelle Res |
| Node 21.02 | Fontenelle Creek nr Herschler Ranch (09210500) |
| Node 21.04 | Below Fontenelle Creek nr Herschler Ranch gage |
| Node 22.01 | Fontenelle Reservoir |
| Node 22.02 | Green River below Fontenelle Reservoir (09211200) |
| Node 22.04 | Confluence of Slate Creek and Green River |
| Node 22.05 | Exxon Shute Creek |
| Node 22.06 | Seedskadee National Wildlife Refuge |
| Node 23.04 | Big Sandy River below Farson (09215550) |

**Table 1 Upper Green River Basin Model Nodes (cont'd)**

| Node No. | Node Name |
|---|---|
| Node 23.06 | Confluence of Bone Draw and Big Sandy |
| Node 23.08 | Big Sandy River at Gasson Bridge, near Eden (09216050) |
| Node 24.01 | Confluence of Big Sandy River and Green River |
| Node 24.02 | FMC-Westvaco / FMC-Granger / Town of Granger |
| Node 24.04 | OCI |
| Node 24.06 | General Chemical / Church & Dwight / Solvay |
| Node 24.08 | Rock Springs/Green River/Sweetwater County JPB / FS Industries / Jim Bridger Pipeline |
| Node 24.09 | Bitter Creek (09216562) and Salt Wells (09216750) |
| Node 24.10 | Confluence of Bitter Creek and Green River |
| Node 24.12 | Green River near Green River (09217000) |

**Table 2 Blacks Fork River Model Nodes**

| Node No. | Node Name |
|---|---|
| Node 1.26 | Below Blacks Fork near Urie gage |
| Node 2.02 | West Fork of Smith Fork near Robertson (09220500) |
| Node 2.04 | Below West Fork Smiths Fork nr Robertson and above confluence with East Fork Smith Fork |
| Node 3.06 | East Fork of Smith Fork near Robertson (09220000) |
| Node 3.08 | East Fork of Smith Fork gage and above confluence with West Fork Smith Fork |
| Node 4.01 | Confluence of East and West Fork of Smiths Fork |
| Node 4.04 | Below confluence of East and West Fork Smith Fork and above BVJPB pipeline |
| Node 4.06 | BVJPB Pipeline (Smiths Fork) |
| Node 4.08 | Smiths Fork near Mountain View (09221500) |
| Node 4.10 | Between Smiths Fork near Mountain View gage and confluence with Cottonwood Creek |
| Node 5.02 | Cottonwood Creek |
| Node 5.04 | Agricultural diversions on Cottonwood Creek |
| Node 6.01 | Confluence Cottonwood Creek and Smiths Fork |
| Node 6.02 | Smiths Fork agricultural diversions between Cottonwood Creek and Blacks Fork |
| Node 7.01 | Confluence Smiths Fork and Blacks Fork |
| Node 7.02 | Blacks Fork near Lyman (09222000) |
| Node 8.02 | Little Muddy Creek near Glencoe (09222300) |
| Node 9.02 | Upper Muddy Creek |
| Node 9.04 | Upper Muddy Creek agricultural diversions |
| Node 10.01 | Confluence of Little Muddy Creek and Muddy Creek |
| Node 10.02 | Muddy Creek nr Hampton (09224000) |
| Node 11.01 | Confluence Muddy Creek and Blacks Fork |

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**Table 2 Blacks Fork River Model Nodes (cont'd)**

| Node No. | Node Name |
|---|---|
| Node 11.02 | Blacks Fork agricultural diversions between Muddy Creek and Hams Fork |
| Node 12.02 | Hams Fork below Pole Creek near Frontier (09223000) |
| Node 12.04 | Hams Fork between Hams Fork below Pole Creek gage and Viva Naughton |
| Node 12.06 | Viva Naughton Reservoir |
| Node 12.08 | Below Viva Naughton Reservoir |
| Node 12.10 | Viva Naughton Power Plant |
| Node 12.14 | City of Kemmerer |
| Node 12.16 | Below Kemmerer and above Hams Fork/Blacks Fork confluence |
| Node 13.01 | Confluence Hams Fork and Blacks Fork |
| Node 13.02 | Agricultural diversions below confluence of Hams Fork and Blacks Fork |
| Node 13.04 | Blacks Fork near Little America (09224700) |

**Table 3 Henrys Fork River Model Nodes**

| Node No. | Node Name |
|---|---|
| Node 1.02 | Henrys Fork near Lonetree (09226000) |
| Node 1.04 | Below Henrys Fork nr Lonetree and above confluence with Beaver Creek |
| Node 2.02 | Beaver Creek Inflows (09226500, 09227000, 09227500) |
| Node 2.04 | Beaver Creek diversions |
| Node 3.01 | Confluence Beaver Creek and Henrys Fork |
| Node 3.02 | Diversions below Beaver Creek and above Henrys Fork near Burntfork gage |
| Node 3.04 | Henrys Fork near Burntfork (09228000) |
| Node 4.02 | Burnt Fork near Burntfork (09228500) |
| Node 4.04 | Burnt Fork diversions |
| Node 5.01 | Confluence Burnt Fork and Henrys Fork |
| Node 5.02 | Henrys Fork diversions between Burnt Fork and Birch Creek |
| Node 6.02 | Birch Creek inflows |
| Node 6.04 | Birch Creek diversions |
| Node 7.01 | Confluence Birch Creek and Henrys Fork |
| Node 7.02 | Henrys Fork diversions between Birch Creek and Henrys Fork near Manila gage |
| Node 7.04 | Henrys Fork near Manila, UT (09229500) |

**Table 4 Little Snake River Model Nodes**

| Node No. | Node Name |
|---|---|
| Node 1.02 | Cheyenne State I & II diversions |
| Node 1.04 | North Fork Little Snake River nr Slater (09251900) |
| Node 2.02 | Middle Fork Little Snake River |
| Node 2.04 | CO diversions on Middle Fork Little Snake |
| Node 3.01 | Confluence of Middle Fork and North Fork Little Snake |
| Node 4.02 | South Fork Little Snake River |
| Node 4.04 | CO diversions on South Fork Little Snake |

**Table 4 Little Snake River Model Nodes (cont'd)**

| Node No. | Node Name |
|---|---|
| Node 5.01 | Confluence of South Fork Little Snake and Little Snake |
| Node 5.04 | CO diversions on Little Snake d/s of South Fork |
| Node 6.01 | Confluence of Roaring Fork Little Snake and Little Snake |
| Node 6.04 | CO diversions on Little Snake d/s of Roaring Fork |
| Node 6.06 | Little Snake River near Slater (09253500) |
| Node 6.08 | CO diversions below Little Snake nr Slater gage |
| Node 7.04 | Battle Creek near Slater (09253500) |
| Node 8.01 | Confluence of Battle Creek and Little Snake |
| Node 8.04 | CO diversions on Little Snake d/s of Battle Creek |
| Node 9.02 | Slater Creek near Slater, CO (09255000) |
| Node 9.04 | CO diversions on Slater Creek |
| Node 10.01 | Confluence of Slater Creek and Little Snake |
| Node 10.04 | CO diversions on Little Snake d/s of Slater Creek |
| Node 10.06 | WY diversions on Little Snake d/s of Slater Creek |
| Node 11.02 | Above High Savery Dam |
| Node 11.04 | High Savery Dam |
| Node 11.06 | WY diversions below High Savery and above Savery Creek at Upper Station |
| Node 11.08 | Savery Creek at Upper Station nr Savery (09255500) |
| Node 11.10 | WY diversions between Savery Crk at Upper Station and Savery Crk nr Savery |
| Node 11.12 | Savery Creek near Savery (09256000) |
| Node 11.14 | WY diversions between Savery Creek near Savery and confluence |
| Node 12.01 | Confluence of Savery Creek and Little Snake |
| Node 12.02 | WY diversions between Savery Creek and First Mesa Canal |
| Node 12.04 | First Mesa Canal |
| Node 12.06 | Westside Canal |
| Node 12.08 | Town of Dixon |
| Node 12.09 | Little Snake River near Dixon (09257000) |
| Node 13.02 | Willow Creek near Dixon (09258000) |
| Node 13.04 | CO diversions on Willow Creek |
| Node 13.06 | WY diversions on Willow Creek |
| Node 14.01 | Little Snake River downstream of Dixon gage |
| Node 14.04 | WY diversions between Willow Creek and Muddy Creek |
| Node 14.06 | Town of Baggs |
| Node 15.04 | Muddy Creek near Baggs (09259000) |
| Node 16.01 | Confluence of Muddy Creek and Little Snake |
| Node 16.04 | WY diversions between Muddy Creek and state line |
| Node 16.06 | CO diversions on Little Snake d/s of Muddy Creek |
| Node 16.08 | WY diversions between state line and Little Snake near Baggs |
| Node 16.10 | Little Snake River near Baggs (09259700) |
| Node 16.12 | CO diversions below Little Snake nr Baggs gage |
| Node 16.14 | Little Snake River near Lily, CO (09260000) |

### Engineering Notes

The delineation of a river basin by reaches and nodes is more an art than a science. The choice of nodes must consider the objectives of the study and the available data. It also must contain all the water resources features that govern the operation of the basin. The analysis of results and their adequacy in addressing the objectives of the study are based on the input data and the configuration of the river basin by the computer model.

The following reaches and nodes are contained in each basin model:

- Upper Green River Basin: 24 reaches, 111 nodes

- Blacks Fork River Basin: 13 reaches, 44 nodes

- Henrys Fork River Basin: 7 reaches, 16 nodes

- Little Snake River Basin: 16 reaches, 48 nodes

### User Notes

This worksheet presents a master list of all nodes included in the Green River Basin Models. The list allows the User to view a simple, comprehensive listing of all nodes within the model, organized by reach and node number. This master list governs naming and numbering conventions on many worksheets, so changing the list must be carefully done and checked. Many of the calculations within the spreadsheet are dependent on the proper correlation of node names and numbers.

Note that the numbering convention used for node identification includes the reach number and the relative location of the node within it. Node numbers are in stream order.

*Gage Data*

Monthly stream gage data were obtained from the Wyoming Water Resources Data System (WRDS) for each of the stream gages used in the model. Linear regression techniques were used to estimate missing values for the many gages that had incomplete records. Once the gages were filled in for the study period, monthly values for Dry, Normal, and Wet conditions were averaged from the Dry, Normal, or Wet years of the study period.

Headwater inflow at several ungaged locations is also on the Gage Data worksheet. Different approaches to estimating the flow were used, depending on the complexity of the stream system and availability of data. The model uses estimated flow at ungaged headwater nodes as if they were gages.

### Engineering Notes

Missing gage data were handled using procedures prioritized as follows:

1) Independent gage has data for the entire study period. Fill the record for the dependent gage by regressing available monthly data against the independent gage. Compare the historical average monthly flow hydrograph to the synthesized monthly hydrograph. If the hydrographs are not similar, proceed to the next step.

2) Independent gage has data for the entire study period. Fill the record for the dependent gage by regressing available annual data against the independent gage, then distribute the estimated annual flow to monthly using average monthly distribution of the dependent station for the available period of record.

3) Independent gage has historical data for part of the study period and synthesized data for the remainder. Fill the record for the dependent gage by regressing available monthly data against the historical data for the independent gage. Next, extend the dependent gage using this same relationship with filled data for the independent gage.

4) Do not fill; average the available Dry, Normal, or Wet year streamflows

If the first approach did not deliver acceptable results, the second was tried, and so on. **Appendix A** contains a spreadsheet summarizing the filling techniques used in the Green River Basin Models.

Inflows at ungaged headwater nodes were generally estimated by taking a drainage area-based proportion of flows at a nearby or downstream gage. In some cases, this yielded implausible results, i.e., the estimated flows appeared too low because they did not support the estimated diversion from the reach, or the flows appeared too high and implied large channel losses between the headwaters and the next downstream gage. To better calibrate the model in these cases, estimated net depletions above the next downstream gage were added to the flows of the downstream gage. The resulting virgin flow was taken to be the headwater node inflow.  On several Wyoming Range streams (Beaver Creek, Horse Creek, and Cottonwood Creek), there were two ungaged tributary headwaters upstream of the first gage. Virgin flow above the downstream gage was assigned to the two ungaged points based on drainage area.

The Gage Data worksheet contains equations for calculating headwater inflow for nodes where downstream gage and net depletions were used to estimate ungaged inflows.

**User Notes**

The Gaging Data Table presents the average historical monthly gaging data for each hydrologic condition used in the model. Only the data pertaining to the hydrologic condition being modeled are included in each respective model.

*Diversion Data*

Diversions in the Green River Basin Models are attributable either to Municipal and Industrial (M&I) use, or Agricultural use.  The spreadsheets model only the consumptive portion of all M&I diversions. Agricultural diversion nodes fall into two categories: explicitly modeled structures, and aggregated structures. Explicitly modeled structures were structures for which adequate historical diversion records and a high confidence estimate of irrigated area were available. These structures generally served as indicators of irrigation practice throughout the basin. Their entire diversions and resulting return flows were included in the model. For the aggregate structures, consumptive use only was modeled.

Data on the diversion data sheet are used to calculate ungaged reach gains and losses, and in some cases, inflow at ungaged headwater nodes. They are also used as the diversion demand in the Reach/Node worksheets.

### Engineering Notes
Collection of agricultural diversion data is discussed in the technical memorandum *Irrigation Diversion Operation and Description*. These data were reviewed and ditches that had sufficient diversion data for analysis of average dry, normal and wet year conditions were selected for explicit modeling. No attempts were made to fill missing records. Diversion data for explicitly modeled structures are the average dry, normal and wet year monthly diversions, calculated from the available records.

The diversion estimates for aggregated structures are the result of a great deal of analysis outside of the spreadsheet. Estimation of consumptive irrigation requirement (CIR), supply-limited consumptive use, and number of irrigation days are described in **Appendix B**. To summarize here, diversions for the aggregated structures are modeled as being 100 percent consumptive, and reflect both consumptive irrigation requirement and cessation of diversion due to lack of supply, for dry-up, or for other operations. Diversions for aggregated structures were calculated as the product of estimated irrigated acreage, monthly CIR, and the fraction of the month in which diversion was practiced. Monthly CIR is estimated as a function of latitude, precipitation, and temperature, and therefore varies for dry, normal, and wet conditions (see **Appendix B**). Number of irrigation days was estimated for explicitly modeled structures, as described in **Appendix B**. The number of irrigation days for normal hydrologic conditions was used in the dry and wet year models as well as the normal year model. The basis for this approach is that number of irrigation days in historically dry years does not represent demand. In other words, irrigators were probably shorted and would have taken more water if it had become available.

Municipal and industrial diversions were taken from the technical memoranda *Green River Basin Plan, Basin Water Use Profile – Municipal* and *Green River Basin Plan, Basin Water Use Profile – Industrial.* Values reported in these memoranda represent the consumptive use portion of the municipal and industrial (M&I) diversions. No attempts were made to estimate return flows. With the exception of the Cheyenne Stage I and II diversions discussed below, no attempts were made to develop dry, normal and wet year M&I diversions. Given the lack of available data for all other M&I users and the relatively small magnitude of these uses, averages of all available data were used under all three hydrologic conditions.

### User Notes

The diversion data worksheet contains only input data for each node for an average dry, normal, or wet year. Note that all nodes are listed in the table, even if no diversions occur at them. At the top of the worksheet are buttons that will take the User to the table summarizing the total monthly diversions in each reach. With the exception of this summary table, no computations occur within this worksheet.

*Import and Export Data*

### Engineering Notes

The only imports or exports modeled in the Green River Basin Models are the Cheyenne Stage I and Stage II exports from the upper reaches of the North Fork of the Little Snake River. Historical records were obtained for the study period (1971-1998). Monthly exports were averaged for the Dry, Normal and Wet years of the study period, as indicated by the Little Snake River Basin index gage, Little Snake River near Slater, CO (USGS Station No. 09253000).

### User Notes

The Imports / Exports Table summarizes the monthly imports to or exports from other basins. As noted above, only the Cheyenne Stage 1 and II exports were explicitly modeled. However, the node water balance tables in the Reach/Node Worksheets are set up to incorporate imports to or exports from any node.

*Options Tables*

Two tables are included in the Options Tables worksheet:

- Irrigation Return Pattern – a percentage representing the amount of the diversion that returns to the river, and

- Irrigation Return Lags – a percentage representing the amount of the return flow that reaches the river in the month of the diversion and in subsequent months.

These tables store the patterns referenced in the Return Flow calculation worksheet (to be discussed in a following section).

### Engineering Notes

The unused, or inefficient, portion of diversions are returned to the river either by direct surface runoff, or through the alluvial aquifer. For modeling purposes, an estimate must be made of amount, location, and timing of returns. The Options Table addresses amount and timing of return flows.

The Irrigation Return Pattern table provides the monthly return fractions for every diversion in the model. There is one pattern made up of zeros in every month, which is applicable to all M&I nodes and aggregated irrigation diversions. Monthly efficiencies for explicitly modeled irrigation diversions are unique for each structure, and were developed by dividing consumptive use (for dry, normal or wet conditions) by historical diversions (for dry, normal, or wet conditions). Efficiencies were limited to 55 percent, as described in **Appendix B.** The return flow fraction is defined as (1.0 – Efficiency).

Irrigation Return Lags for M&I nodes and aggregated irrigation diversions were set to zero, because return flows are not modeled. Lags for explicitly modeled structures within the

Upper Green River Basin were based on Williams, "A Model of the Green River Using the Wyoming Integrated River System Operation Study (WIRSOS)," M.S. Thesis, University of Wyoming, Department of Civil Engineering, December 1995. . Lags for explicitly modeled structures within the Little Snake River Basin were based on Stone & Webster Engineering Corporation, "Streamflow Depletion Study, Sandstone Reservoir", prepared for the Wyoming Water Development Commission, February 13, 1987. The lags used in the Little Snake models were adopted for use in the Blacks Fork models because there was no basin specific source available. No lags were used in the Henrys Fork model because no structures were modeled explicitly.

### User Notes

The Options Tables incorporate the information used in the computation of irrigation return flow quantities and their timing. The data in the first table, "Irrigation Return Patterns," consist of the percentages of water diverted which eventually will return to the river and be made available to downstream users.

The second worksheet table, "Irrigation Return Lags", controls the timing of these returns. Flows diverted in any month can be lagged up to three months beyond the month in which they are diverted. An example pattern is:

| Month | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Percent | 50 | 25 | 15 | 10 |

For a diversion occurring in June, 50 percent of the Total Irrigation Returns (i.e., that portion not lost to consumptive use, evaporation, etc.) will return in June, 25 percent will return in July, 15 percent will return in August, and the remaining 10 percent will return in September.

## The Computation Worksheets

The Computation Worksheets are calculators for parameters required by the Reach/Node water balance computations. They use data supplied in the Input Worksheets. Irrigation returns, ungaged reach gains and losses and evaporative losses are calculated in the Computation Worksheets.

### Irrigation Returns

The unused portion of a headgate diversion either returns to the river as surface runoff during the month it is diverted, or "deep percolates" into the alluvial aquifer. The deep percolation portion returns to the river through the aquifer but generally lags the time of diversion by several months. Location of the return flow's re-entry to the stream is an important factor in modeling the basin, and depends on the specific topography and layout of the irrigation system.

The Irrigation Return Worksheet has three tables. The first one calculates the amount of return flow resulting from each month's diversion at each node, and distributes it in time and place according to the information in the Options Table. The second table in the worksheet then effectively "collects" all the incoming return flows for each month at each node, regardless of source. This table produces the return

flow component of inflow at each node.  The third table summarizes return flows back to the stream by reach.

### Engineering Notes

Table 5 shows a typical irrigation return flow calculation for the Canyon Ditch on the Upper Green River.

**Efficiency Pattern:** The value entered here is used to look up the Irrigation Return Pattern found in the Options Table.

**Total Diversions:** These values are referenced from the Diversion Data input worksheet.

**Total Irrigation Returns:** These data are computed by multiplying the Total Diversions by the selected Irrigation Return Pattern for the month.  For example, if a month shows a Total Diversion of 1000 acre-feet and an irrigation return fraction of 80%, the Total Irrigation Returns from that diversion for that month will be 800 acre-feet.

## Table 5 Sample Irrigation Return Flow Calculation

**Node 1.06** | **Canyon Ditch**

**Efficiency Pattern = 2**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Diversions = | 0.0 | 0.0 | 0.0 | 1,835.4 | 3,028.2 | 3,982.0 | 2,017.4 | 2,060.0 | 0.0 | 0.0 | 0.0 |
| Total Irrigation Returns = | 0.0 | 0.0 | 0.0 | 1,100.3 | 2,017.2 | 2,828.4 | 1,138.2 | 1,987.6 | 0.0 | 0.0 | 0.0 |

**Return Pattern = 2**

| **TO:** | **Percent** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Node 8.08 | 100.0% | 0.0 | 0.0 | 0.0 | 689.5 | 1,425.5 | 2,215.0 | 1,499.8 | 1,977.9 | 707.3 | 371.3 | 185.5 |
| West Fork New Fork between Willow and Duck Creeks (including Duck Creek) | 0.0% | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 0.0% | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 0.0% | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 100.0% | 0.0 | 0.0 | 0.0 | 689.5 | 1,425.5 | 2,215.0 | 1,499.8 | 1,977.9 | 707.3 | 371.3 | 185.5 |

**Return Pattern:** The value entered here is used to look up the Irrigation Return Lag found in the Options Table.

**To and Percent:** This feature allows the User to define the node(s) in the model where irrigation returns will return and in what percentages. Total Irrigation Returns are distributed according to the node numbers entered in the To box, their corresponding percentages of the Total Irrigation Returns, and the Irrigation Return Lag pattern in the Options Table. The percentages entered at each node must total either 0 or 100% or a warning message will appear.

Previous modeling reports, information obtained from the district hydrographers, and the irrigated acreage GIS theme were used to estimate return flow locations.

**Irrigation Returns: Node Totals Table:** This table collects all of the irrigation returns that have been sent to each Node and provides their sum.

**Irrigation Returns: Reach Totals Table:** This table collects all of the irrigation returns that have been sent to each Reach and provides their sum

## User Notes

This worksheet computes the return flows from irrigation diversions. All cells that can be modified by the User are highlighted in yellow.

Buttons at the top of the worksheet can take the User directly to each of the three tables in the Irrigation Return Worksheet. "View Individual Nodes" jumps the User to first table, which calculates return flows from each node and distributes them in time and place. "View 'Node Totals' Summary Table" jumps the User to the second table, the Node Totals Table. "View 'Reach Totals' Summary Table" jumps the User to the Reach Totals Table.

*Evaporative Losses*

Two reservoirs are explicitly modelled in the Green River Basin Models: Fontenelle Reservoir in the Upper Green River Basin and Viva Naughton Reservoir in the Blacks Fork River Basin. High Savery Dam in the Little Snake River Basin has been included in the Little Snake Model but shows no storage because it is currently under construction. Other reservoirs, such as Big Sandy, Eden, Meeks Cabin and Stateline, were not included because there were insufficient historical data or operational information to include them in the models. This spreadsheet calculates evaporation losses which are included in the mass balance calculations at each reservoir node.

### Engineering Notes

Evaporation, precipitation and area-capacity data for each of the modeled reservoirs was obtained from the technical memorandum *Green River Basin Plan, Reservoir Data*. Historical end-of-month reservoir contents were obtained from the USGS for Fontenelle Reservoir and from Scottish Power for Viva Naughton Reservoir. Dry, normal and wet year

end-of-month contents were determined for each reservoir for modeling the respective hydrologic conditions.

**User Notes**

Monthly gross evaporation (inches) and total precipitation (inches) data are included in the table. The net evaporation in inches is then calculated within the worksheet. The end-of month surface area is calculated from the area-capacity table and used to determine the mean monthly evaporative loss in acre-feet. As with other tables in the model spreadsheet, cells that require an entry are highlighted in yellow.

*Reach Gain/Loss*

The Green River Basin Models simulate major diversions and features of the basins, but many water features, such as small tributaries and diversions lacking historical records, are not explicitly included in the computer representation of the physical system.  Therefore, some features are aggregated and modeled, while many others are lumped together between measured flow points in the river by a modeling construct called ungaged reach gains and losses.  These ungaged gains and losses account for all water in the budget that is not explicitly named and can reflect ungaged tributaries, groundwater/surface water interactions, lagged return flows associated with structures that divert consumptive use only in the model, or any other process not explicitly or perfectly modeled.

**Engineering Notes**

Ungaged gains and losses are computed between gages using a water budget approach, as:

$$\{Q_{downstream} - Q_{upstream}\} + \Sigma \text{ Diversions within Reach} - \Sigma \text{ Return flows to Reach} \ +/- \ \Delta \text{ Storage}$$

All terms are supplied from either the Input Worksheets or the Computation Worksheets. As part of calibration, ungaged gains/losses were reviewed to determine if they were reasonable. Where monthly ungaged inflow did not look like the expected hydrograph for the reach, modeling assumptions, simplifications, and aggregations were reviewed to determine whether they might account for the unusual flow patterns.

**User Notes**

The worksheet collects all positive values (Reach Gains) and all negative values (Reach Losses) and creates the two Reach Summary Tables which are viewable by selecting the "Summary" button.

**Reach/Node Tables**

Each non-storage node is represented in the spreadsheet by an inflow section, which includes inflow from the upstream node, irrigation returns, ungaged gains, and imports, if applicable; and an outflow section, which includes ungaged losses and diversions, if applicable.  The algebraic sum of these flows are then the net outflow from the node.  In the case of storage nodes, evaporation is included as a loss

and flow can either go to or come from storage. Again, the water balance is done for the node and outflow is calculated.

### Engineering Notes

This is the heart of the spreadsheet model where water budget calculations are performed for each node represented in the basin. Water balance is maintained in a river reach, or at least between reach gain/loss points, by performing the water budget calculations at each node until the outflow from the bottom node in each reach equals the gage flow at that point.

### User Notes

The Node Tables compute the flow available to downstream users (NET flow) using a water budget approach.

The nodes must be organized in a upstream-to-downstream order within each reach. Historical diversions at each node are automatically referenced from the Diversion Data worksheet. In the event that the historical demand cannot be met based upon available streamflow, the model will determine the amount that is available and enter that amount. In that event, a warning will be presented to inform the User that a diversion has been shorted.

The following subsections contain miscellaneous notes about specific nuances within the Reach/Node tables in the four sub-basin models. See the Basin Map and Node list within each model for the locations of the reaches and nodes discussed below.

*Upper Green River Model*

Reach 1

Node 1.06 - Canyon Ditch: Return flows are directed to the West Fork New Fork between Willow and Duck Creeks (Node 8.08)

Reach 8

Node 8.06 – Willow Creek: This node includes Willow and Lake Creeks and Willow Lake. It was not modeled as a separate reach due to limited data available on the operation of Willow Lake.

Node 8.08 – West Fork New Fork between Willow and Duck Creeks: The effects of Duck Creek have been incorporated into this node. Duck Creek was not modeled explicitly.

Reach 9

Node 9.04 – Fremont Ditch: Return flows are directed to the West Fork New Fork between Willow and Duck Creeks (Node 8.08)

Node 9.06 – Highland Canal: Return flows are directed to the West Fork New Fork between Pine and Pole Creeks

Reach 10

Node 10.02 – Pole Creek below Little Half Moon Lake and Node 10.06 – Fall Creek near Pinedale: Pole Creek and Fall Creek were modeled within one reach to reduce the number of separate reach worksheets required for the model.

Reach 12

Node 12.04 – Overland Ditch: Return flows are directed to the East Fork River between Muddy and Silver Creeks (Node 12.13).

Node 12.06 – East Fork Ditch: Return flows are directed to the East Fork River between Muddy and Silver Creeks (Node 12.13).

Node 12.10 – Gilligan-Iven Ditch: Return flows are directed to the East Fork River between Muddy and Silver Creeks (Node 12.13).

Node 12.12 – Tibbals Ditch: Return flows are directed to the East Fork River between Muddy and Silver Creeks. (Node 12.13)

Reach 15

Node 15.06 – North Piney Canal: Return flows from North Piney Creek provide much of the flow for Meadow Canyon and West Meadow Canyon Creek where they are re-diverted by other uses.  It was assumed that this diversion and re-diversion continued until the water was used to extinction.  To capture this in the model, it was assumed that North Piney Canal consumes 100 percent of its historical diversion and no diversions for Meadow Canyon or West Meadow Canyon Creek were modeled.

Reach 17

Node 17.04 – South Piney Ditch and Node 17.08 – Homestake Ditch: Return flows are directed to North Piney Creek below the Musselman Ditch (Node 15.12) and Middle Piney Creek (Node 16.04). No flow returns to South Piney Creek.

Node 17.10 – Yankee Ditch and Node 17.12 – Reardon Ditch: Return flows are directed to the confluence of South Piney Creek and the Green River. The return flows are not available for use by aggregated diversions below the Reardon Ditch.

Reach 19

Node 19.03 – Anderson-Howard Ditch: Return flows are directed to LaBarge Creek below the Viola gage (Node 19.06) and the Green River above Fontenelle Reservoir (Node 20.06).

Reach 23

Big Sandy and Eden Reservoirs were not included in this model.  Extensive attempts were made to develop a simple operations model for the reservoirs, with limited success.  Since there are no

plans to expand the Eden Project in the near future, it was decided to start the model below the project.  This assumes that the project will continue to operate as it has in the past.

Reach 24

Bitter and Salt Wells Creeks were included within this reach and not modeled as a separate reach because there was limited flow data available and no irrigated lands indicated by the irrigated lands mapping.

*Blacks Fork Model*

Reach 1

Meeks Cabin Reservoir was not included in the model because of the limited data available on its operations.  However, the model was constructed in such a manner so that a node or nodes representing Meeks Cabin Reservoir could be added in the future.

Node 1.13: BVJPB Pipeline (Blacks Fork): Bridger Valley Joint Powers Board (BVJPB) has storage rights in State Line Reservoir (limited to 800 AF/YR) and direct flow rights from Blacks Fork and Smiths Fork River.  The historical usage reported in the technical memorandum "Basin Water Use Profile – Municipal" was distributed between this node and Node 4.06 based upon the proportion of the permitted use.

Node 1.20 – Fort Bridger Canal / Center / Twin Buttes: These ditches are in close proximity. They were combined at one node because it was difficult to assign the irrigated lands to a single ditch.

Reach 3

Stateline Reservoir was not included in the model because of the limited data available on its operations.  However, the model was constructed in such a manner so that a node or nodes representing Stateline Reservoir could be added in the future.

Reach 4

Node 4.06 – BVJPB Pipeline (Smiths Fork): See notes above for Node 1.13.

Reach 12

Node 12.06 – Viva Naughton Reservoir: Since there is not a USGS gage located immediately downstream of the reservoir, historical release records provided by Scottish Power were used to determine a reservoir gain/loss term.

*Henrys Fork Model*

> Reach 2

> Node 2.02 - Inflows from the East Fork, Middle Fork and West Fork Beaver Creeks were combined into one node. This simplification was necessary because it was difficult to differentiate the irrigated lands served by each tributary.

*Little Snake River Model*

> Acreage for irrigated lands in Colorado (Nodes 2.04, 4.04, 5.04, 6.04, 6.08, 8.04, 9.04, 10.04, 13.04, 16.06, and 16.12) were determined from the GIS mapping developed by the Colorado Water Conservation Board as part of the Colorado River Decision Support System.

> Reach 11

> Node 11.04 – High Savery Dam: This node has been included so that the operation of the reservoir can be included in the model once it is completed.

> Reach 12

> Node 12.06 – Westside Canal: Westside Canal intercepts the flows of Willow Creek, then bypasses unneeded flows to the Little Snake River. For this reason, the flows of Willow Creek are added to the flows of the Little Snake at Westside Canal and not at the confluence of the Little Snake River and Willow Creek.

> Reach 13

> Node 13.06 – WY Diversions on Willow Creek: See notes above for Node 12.06.

**The Results Worksheets**

Several forms of model output can be accessed from the Summary Options worksheet. These include river flow data (by node or by reach), and diversion data (by node, by reach, or simulated compared to historical).

*Outflows*

This worksheet summarizes the flows at all nodes in the model. The "Outflow Calculations: By Node" table summarizes the net flow for all nodes. The nodes are grouped by reach. The "Outflow Calculations: By Reach" table presents the net flow for each reach.

A primary purpose for developing the spreadsheet models was to determine surface water availability under baseline as well as future conditions. The Outflow by Reach table provided the basis for determination of baseline surface water availability, as described in the task memorandum ***Green River Basin Plan – Available Surface Water Determination.***

*Diversions*

This worksheet summarizes the diversions at all nodes in the model.  The "Summary of Diversion Calculations: By Node" tables summarizes the computed diversions which are made at each node. The nodes are grouped by reach. The "Summary of Diversion Calculations: By Reach" table presents the total diversions taken within each reach. The "Comparison of Estimated vs Historical Diversions" table presents comparison results and would indicate if any shortages occurred to target diversion volumes.

**APPENDIX A**

**Summary of Gage Filling**

**Summary of Gage Filling in Upper Green Model**

| USGS Station No. (Dependent Gage) | USGS Station Name (Dependent Gage) | Period of Record From | Period of Record To | Period of Fill From | Period of Fill To | USGS Station No. (Independent Gage) | USGS Station Name (Independent Gage) | Relationship | $R^2$ | No. of Observations |
|---|---|---|---|---|---|---|---|---|---|---|
| 09188500 | Green River at Warren Bridge, near Daniel | Oct-31<br>Oct-93 | Sep-92<br>Present | Oct-92 | Sep-93 | 09209400 | Green River near LaBarge | y = 0.3058x + 208.68 | 93.2% | 408 |
| 09189000 | Beaver Creek near Daniel | Oct-38 | Sep-54 | Oct-70 | Sep-98 | 09205500 | North Piney Creek near Mason (Marbelton) | y = 0.9245x - 15549 [1] | 76.3% | 16 |
| 09190000 | Horse Creek near Daniel | Oct-31<br>Sep-82 | Oct-54<br>Sep-85 | Oct-70<br>Oct-85 | Sep-83<br>Sep-98 | 09205500 | North Piney Creek near Mason (Marbelton) | y = 1.3664x - 9279.9 [1] | 76.6% | 23 |
| 09191500 | Cottonwood Creek near Daniel | Oct-38 | Sep-54 | Oct-70 | Sep-98 | 09205500 | North Piney Creek near Mason (Marbelton) | y = 1.998x - 35378 [1] | 93.9% | 16 |
| 09193000[2] | New Fork River below New Fork Lake, near Cora | Oct-38<br>Apr-72 | Oct-71<br>Oct-72 | Oct-70 | Sep-98 | 09201000 | New Fork River near Boulder | y = 0.1583x - 624.4 [1] | 78.6% | 372 |
| 09196500[2] | Pine Creek above Fremont Lake | Oct-54 | Nov-97 | Dec-97 | Sep-98 | 09205000 | New Fork River near Big Piney | y = 0.1696x - 37212 [1] | 90.8% | 43 |
| 09197000[2] | Pine Creek below Fremont Lake | Apr-85<br>Apr-88 | Sep-86<br>Present | | | | | | | |
| 09198000 | Pine Creek at Pinedale | Oct-15 | Sep-54 | Oct-70 | Sep-98 | 09201000 | New Fork River near Boulder | y = 0.3919x - 1487.5 [1] | 92.7% | 468 |
| 09198500 | Pole Creek below Little Half Moon Lake, near Pinedale | Oct-38 | Sep-71 | Oct-71 | Sep-98 | 09196500 | Pine Creek above Fremont Lake | y = 0.732x - 14384 [1] | 96.0% | 17 |
| 09199500 | Fall Creek near Pinedale | Oct-38 | Sep-71 | Oct-71 | Sep-98 | 09196500 | Pine Creek above Fremont Lake | y = 0.3075x - 10319 [1] | 94.1% | 17 |
| 09201000 | New Fork River near Boulder | Oct-14 | Sep-69 | Oct-70 | Sep-98 | 09196500 | Pine Creek above Fremont Lake | y = 3.035x - 116268 [1] | 94.8% | 15 |
| 09202000 | Boulder Creek below Boulder Lake, near Boulder | Oct-38<br>May-72 | Oct-71<br>Sep-73 | Nov-71<br>Oct-73 | Apr-72<br>Sep-98 | 09205000 | New Fork River near Big Piney | y = 0.2312x + 19741 [1] | 94.0% | 17 |
| 09203000 | East Fork River near Big Sandy | Oct-38 | Sep-92 | Oct-92 | Sep-98 | 09205000 | New Fork River near Big Piney | y = 0.1331x + 3934.3 [1] | 95.7% | 38 |
| 09204000 | Silver Creek near Big Sandy | Oct-38 | Sep-71 | Oct-71 | Sep-98 | 09205000 | New Fork River near Big Piney | y = 0.0666x + 1916.5 [1] | 95.5% | 17 |
| 09205000 | New Fork River near Big Piney | Sep-54 | Present | | | | | | | |
| 09205500 | North Piney Creek near Mason (Marbelton) | Oct-31<br>May-72 | Oct-71<br>Sep-72 | Nov-71<br>Oct-72 | Apr-72<br>Sep-98 | 09188500 | Green River at Warren Bridge, near Daniel | y = 0.1576x-17099 [1] | 77.7% | 40 |
| 09206000 | Middle Piney Creek below South Fork, near Big Piney, WY | Aug-39<br>Oct-41 | Sep-40<br>Sep-54 | Oct-70 | Sep-98 | 09205500 | North Piney Creek near Mason (Marbelton) | y = 0.4502x - 88.57 | 88.9% | 170 |

Task 3B Surface Water Data Synthesis and Spreadsheet Model Development

| | Dependent Gage | Period of Record | | Period of Fill | | Independent Gage | | Relationship | $R^2$ | No. of Observations |
|---|---|---|---|---|---|---|---|---|---|---|
| USGS Station No. | USGS Station Name | From | To | From | To | USGS Station No. | USGS Station Name | | | |
| 09208500 | LaBarge Creek near Viola | Oct-40 | Sep-49 | Oct-70 | Sep-98 | 09205500 | North Piney Creek near Mason (Marbelton) | y = 1.6913x - 3854.3 [1] | 92.0% | 9 |
| 09209400 | Green River near LaBarge | Oct-63 | Present | | | | | | | |
| 09210500 | Fontenelle Creek near Herschler Ranch, near Fontenelle | Oct-51 | Present | | | | | | | |
| 09211200 | Green River below Fontenelle Reservoir | Oct-63 | Present | | | | | | | |
| 09212500[2] | Big Sandy River (Creek) at Leckie Ranch near Big Sandy | Oct-39 / Mar-72 | Oct-71 / Sep-87 | Nov-87 / Oct-72 | Feb-72 / Sep-98 | | | | | |
| 09213500[2] | Big Sandy River near Farson | Apr-53 | Present | | | | | | | |
| 09214000[2] | Little Sandy Creek near Elkhorn | Oct-39 | Sep-71 | | | | | | | |
| 09214500[2] | Little Sandy Creek near Eden | Oct-54 | Sep-81 | | | | | | | |
| 09215000[2] | Pacific Creek near Farson | Oct-54 | Sep-73 | | | Used Normal, Wet and Dry values from available historical data | | | | |
| 09215550 | Big Sandy River below Farson | Jun-81 | Present | Oct-70 | May-81 | 09216050 | Big Sandy River at Gasson Bridge, near Eden | y = 0.9108x - 1418.7 | 97.7% | 220 |
| 09216000[2] | Big Sandy River (Creek) below Eden | Oct-54 | Jun-81 | | | | | | | |
| 09216050 | Big Sandy River at Gasson Bridge, near Eden | May-72 | Present | Oct-70 | Apr-72 | 09216000 | Big Sandy River (Creek) below Eden | y = 1.0376x + 722.37 | 99.0% | 111 |
| 09216562 | Bitter Creek above Salt Wells Creek | Jun-76 | Sep-81 | | | Used average of available historical data | | | | |
| 09216750 | Salt Wells Creek near Salt Wells | Jun-76 | Sep-81 | | | Used average of available historical data | | | | |
| 09217000 | Green River near Green River | Apr-51 | Present | | | | | | | |

[1] Regression based on historical annual flows. Monthly flows were estimated based on a normal, wet and dry distribution pattern determined from the available historical data.
[2] Not in final model

## Summary of Gage Filling in Blacks Fork Model

| Dependent Gage | | Period of Record | | Period of Fill | | Independent Gage | | Relationship | $R^2$ | No. of Observations |
|---|---|---|---|---|---|---|---|---|---|---|
| USGS Station No. | USGS Station Name | From | To | From | To | USGS Station No. | USGS Station Name | | | |
| 09217900[1] | Blacks Fork near Robertson | Jul-66 Oct-92 | Sep-86 Present | Oct-86 | Sep-92 | Located above Meeks Cabin. May not be used. Marginal regression (78%) which overpredicts winter flows. | | | | |
| 09218500 | Blacks Fork near Millburne | Oct-39 thru Sep-98, no winter records since Sep-92 | | Winter records Oct-92 thru Sep-98 | | Missing records filled with USBR records for releases from Meeks Cabin Reservoir. | | | | |
| 09219000 | Blacks Fork near Urie | Oct-37 | Sep-55 | Oct-70 | Sep-98 | 09222000 | Blacks Fork near Lyman | y = 0.4293x - 61.257 | 93.4% | 216 |
| 09220000 | East Fork of Smith Fork near Robertson | Jul-39 thru Sep-98, no winter records since Oct-71 | | Winter records Oct-71 thru Sep-79 | | Missing records filled using percentage of winter months flow to total irrigation season flow for period prior to construction of Stateline Reservoir. | | | | |
| | | | | Winter records Oct-79 thru Sep-92 | | 09218500 | Blacks Fork near Millburne | y = 0.3225x + 222.58 | 79.6% | 36 |
| | | | | Winter records Oct-92 thru Sep-98 | | Missing records filled with USBR records for releases from Stateline Reservoir. | | | | |
| 09220500 | West Fork of Smith Fork near Robertson | Jul-39 thru Oct-71, May-72 thru Sep-81 (no winter records during this period) | | Nov-71 thru Apr-72, winter records Oct-72 thru Oct-80, Oct-81 thru Sep-98 | | 09221500 | Smith Fork at Mountainview | y = 0.4134x - 58.84 | 83.5% | 192 |
| 09221500 | Smith Fork at Mountainview | Oct-41 | Sep-57 | Oct-70 | Sep-98 | 09222000 | Blacks Fork near Lyman | y = 0.3524x + 168.94 | 92.3% | 192 |
| 09222000 | Blacks Fork near Lyman | Oct-37 Jun-62 | Sep-57 Sep-83 | Oct-83 | Sep-98 | 09224700 | Blacks Fork near Little America | y = 0.4495x + 319.43 | 87.4% | 256 |
| 09222300 | Little Muddy Creek near Glencoe | Jul-76 | Sep-80 | | | Used average of available historical data | | | | |
| 09222400 | Muddy Creek near Hampton | Jul-75 | Sep-81 | | | Used average of available historical data | | | | |
| 09223000 | Hams Fork below Pole Creek near Frontier | Oct-52 | Present | | | | | | | |
| 09223500[1] | Hams Fork near Frontier | Oct-45 Apr-72 | Oct-71 Sep-72 | Nov-71 Oct-72 | Mar-72 Sep-98 | 09223000 | Hams Fork below Pole Creek near Frontier | y = 1.3158x + 49.851 | 93.2% | 229 |
| 09224700 | Blacks Fork near Little America | Jun-62 | Present | | | | | | | |

[1] Not in final model

Task 3B Surface Water Data Synthesis and Spreadsheet Model Development

**Summary of Gage Filling in Henrys Fork Model**

| Dependent Gage | | Period of Record | | Period of Fill | | Independent Gage | | Relationship | $R^2$ | No. of Observations |
|---|---|---|---|---|---|---|---|---|---|---|
| USGS Station No. | USGS Station Name | From | To | From | To | USGS Station No. | USGS Station Name | | | |
| 09226000 | Henrys Fork near Lonetree | Oct-42 | Sep-54 | Oct-70 | Sep-98 | 09229500 | Henrys Fork near Manila | y = 0.2968x + 11286 (annual flow) | 94.5% | 26 |
| 09226500 | Middle Beaver Creek near Lonetree | Oct-48 | Sep-70 | Oct-70 | Sep-98 | 09226000 | Henrys Fork near Lonetree | y = 0.5424x + 74.347 | 95.7% | 256 |
| 09227000 | East Fork Beaver Creek near Lonetree | Oct-48 | Sep-62 | Oct-70 | Sep-98 | Used Normal, Wet and Dry values from available historical data | | | | |
| 09227500 | West Fork Beaver Creek near Lonetree | Oct-48 | Sep-62 | Oct-70 | Sep-98 | 09226000 | Henrys Fork near Lonetree | y = 0.3714x + 143.51 | 94.2% | 168 |
| 09228000 | Henrys Fork near Burntfork | Oct-42 | Sep-54 | Oct-70 | Sep-98 | 09229500 | Henrys Fork near Manila | y = 0.8512x - 294.6 | 94.0% | 144 |
| 09228500 | Burnt Fork near Burntfork | Apr-43 | Sep-83 | Oct-84 | Sep-98 | 09226000 | Henrys Fork near Lonetree | y = 0.63x + 294.04 | 92.1% | 318 |
| 09229500 | Henrys Fork near Manila | Oct-28 | Sep-93 | Oct-93 | Sep-98 | 09222000 | Blacks Fork near Lyman | y = 0.5412x + 561.86 | 86.7% | 256 |

## Summary of Gage Filling in Little Snake River Model

| Dependent Gage | | Period of Record | | Period of Fill | | Independent Gage | | Relationship | $R^2$ | No. of Observations |
| USGS Station No. | USGS Station Name | From | To | From | To | USGS Station No. | USGS Station Name | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 09251800 | North Fork Little Snake River near Encampment | Oct-56 | Oct-65 | Oct-70 | Sep-98 | 09251900 | North Fork Little Snake River near Slater, CO | y = 0.6015x - 34.862 | 96.4% | 84 |
| 09251900 | North Fork Little Snake River near Slater, CO | Apr-56 | Sep-63 | Oct-70 | Sep-98 | 09253000 | Little Snake River near Slater, CO | y = 0.1984x + 106.14 | 99.3% | 90 |
| 09253000 | Little Snake River near Slater, CO | Oct-43 Oct-50 | Sep-47 Present | | | | | | | |
| 09253500 | Battle Creek near Slater, CO | Oct-42 | Sep-51 | Oct-70 | Sep-98 | 09255000 | Slater Fork (Creek) near Slater, CO | y = 1.065x - 82.943 | 92.0% | 107 |
| 09255000 | Slater Fork (Creek) near Slater, CO | Jul-31 | Present | | | | | | | |
| 09255500 | Savery Creek at Upper Station, near Savery | Oct-40 Oct-52 | Sep-41 Sep-71 | Oct-71 | Sep-98 | 09256000 | Savery Creek near Savery | y = 0.3987x + 399.7 | 95.1% | 228 |
| 09256000 | Savery Creek near Savery | Oct-41 Oct-47 Apr-72 Apr-85 | Sep-46 Sep-71 Sep-72 Sep-92 | Oct-71 Oct-72 Oct-92 | Mar-72 Mar-85 Sep-98 | 09255000 | Slater Fork (Creek) near Slater, CO | y = 1.2986X + 436.42 | 86.8% | 438 |
| 09257000 | Little Snake River near Dixon | Mar-38 | Sep-97 | Winter records since Oct-72, Oct-97 thru Sep-98 | | 09260000 | Little Snake River near Lily, CO | y = 0.9442x - 1844.2 | 96.7% | 396 |
| 09258000 | Willow Creek near Dixon | Oct-53 | Sep-93 | Oct-93 | Sep-98 | 09255000 | Slater Fork (Creek) near Slater, CO | y = 0.0993x + 152.72 | 82.8% | 480 |
| 09259000 | Muddy Creek near Baggs | Oct-87 | Sep-91 | Oct-71 Oct-91 | Sep-87 Sep-98 | No relationships found. Used average of historical data | | | | |
| 09259700 | Little Snake River near Baggs | Oct-62 | Sep-68 | Oct-70 | Sep-98 | 09260000 | Little Snake River near Lily, CO | y = 1.0066x - 833.93 | 99.6% | 84 |
| 09260000 | Little Snake River near Lily, CO | Oct-21 | Present | | | | | | | |

**APPENDIX B**

**Determination of CIR, Consumptive Use, and Irrigation Days**

# MEMORANDUM

January 12, 2001

TO:          File

FROM:        Meg Frantz and Linda Williams

SUBJECT:     **Green River Basin Plan**
             **Crop Consumptive Use**

Estimating crop consumptive use for the Green River basin required three steps:

1. Determine consumptive use (CU) and crop irrigation requirement (CIR) for appropriate crops at climate stations, based on the data collected for use in **WWRC Publication #92-06 – Consumptive Use and Consumptive Irrigation Requirements in Wyoming** (Dr. Larry Pochop, Travis Teegarden, Greg Kerr, Dr.Ronald Delaney and Dr. Victor Hasfurther)[1] , for historical Normal, Wet, and Dry years.[2] CU represents total water consumed by the crop, while CIR (as defined for WWRC Publication #92-06) is the consumptive use requirement of a crop minus precipitation. In the referenced document, all precipitation is considered to be effective.  CIR will be used for the model, but CU was calculated at this step for other use within the Green River Basin Plan.

2. Spatially distribute representative CIR values across the basin, based on crop distribution and location relative to climate stations. Twelve zones were identified to cover the basin. The zones represented areas with internally similar crop distributions, and climate regime that could fairly be represented by one or two climate stations.

3. Estimate number of days of irrigation each month, under normal hydrologic condition and irrigation practices.

## CIR at Climate Stations

The maximum and minimum values of CU and CIR reported in WWRC Publication #92-06 represent the extremes of the data available.  Given that the our task is to develop spreadsheet models that represent "average" dry and wet years, in addition to "average" normal years, the use of the maximum and minimum values would over- and under-estimate crop consumptive use for the representative dry and wet years.

To develop less extreme estimates of CU and CIR at the eight climate stations in or near the Green River basin, we obtained from Dr. Pochop the estimated monthly crop CU and Consumptive Irrigation Requirement (CIR) estimates developed for the work reported in WWRC Publication #92-06. These eight stations and the period for which data were available are:

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[1] This document is currently available from the UW Cooperative Extension Service as UW MP-87.
[2] The reader is referred to the Technical Memorandum Task 3A – Surface Water Data Collection and Study Period Selection for the definition of Normal, Wet and Dry years.

- Big Piney (1956-1990)
- Encampment (1956-1990)
- Farson (1956-1983)
- Green River (1956-1990)
- Kemmerer (1956-1990)
- Pinedale (1956-1990)
- Rock Springs (1956-1990)
- Wamsutter (1977-1990)

Using the monthly CU and CIR estimates available for the basin study period for each station, we averaged normal, dry and wet year values for CU and CIR for mountain meadow hay, pasture grass hay, and alfalfa. Data was not available for all three crops at some of the eight stations. Normal, wet, and dry years were those identified in Task 3A, based on gage records at the appropriate index gage. Summaries of the CU estimates for mountain meadow hay, pasture grass, and alfalfa can be found in **Tables 1** through **3**, respectively. **Tables 4** through **6** present CIR for these same crops, during normal, dry, and wet years. These tables also include the index gage used to select normal, dry and wet years.

CU and CIR estimates were missing at some stations, for some months of Dr. Pochop's study, presumably because the underlying climate data were unavailable. Among the missing were August and September values at Big Piney for all dry years common to Dr. Pochop's study and this study. For purposes of the spreadsheet model, dry year values determined for the Pinedale station will be substituted for these months.

**Zoned CIR**

CIR zones were based on crop distribution zones developed by States West.  These zones are color-coded in **Figure 1** and described in the Figure 1 legend. The crop distribution zones were each assigned the most representative climate station, based on review of numerous monthly evapotranspiration isohyetal maps produced by States West, and evaporation isohyetal maps in the Wyoming Water Atlas. Several crop distribution zones (e.g., Little Snake basin) were further subdivided into two zones for the purpose of CIR estimation because climate conditions varied widely over the crop distribution zone. Different climate stations were used in the subdivisions. As a result, twelve CIR zones as shown in Figure 1 were identified in total.

Monthly CIR for Normal, Wet, and Dry years for the twelve CIR zones are presented in **Table 7**. These values are weighted by both crop within the zone, and climate station. The Big Sandy zone is the only zone that uses two climate stations, with equal weighting.

**Irrigation days**

Number of irrigation days per month was inferred from structures that were explicitly modeled. These are structures for which we have relatively high confidence in both diversion records and amount of irrigated acreage. In addition, discussions with the hydrographers and irrigation districts were taken into account. For each month at the explicitly modeled structures, Normal year CIR was calculated, assuming irrigation practices as described to us by the hydrographer or users. For instance, if onset of irrigation was typified as mid-May, CIR was estimated as one-half of the Normal year CIR for the month of May.  Efficiency was then calculated as the monthly CIR divided by diversions for the month.

Efficiency was not allowed to exceed 55 percent in any month. If efficiency was above this value, the number of irrigation days was reduced until the efficiency was reached.

Fifty-five percent is high for on-farm irrigation efficiency but was selected for several reasons. First, the two explicitly modeled structures in the Little Snake basin, Westside Canal and First Mesa Ditch, exhibited late season efficiencies at about this level, assuming irrigation throughout the month. Secondly, the Colorado River Decision Support System similarly assumes a maximum efficiency of 60 percent. These values may not actually be achieved, but CIR presumes the crop growing to full potential, with no lack of water supply. It is believed that in the Green River basin, as throughout the arid west, crop growth at less than the biological potential in the latter part of the season is acceptable.

Aggregated structures in the model were represented as irrigating for the average number of irrigation days indicated by the explicitly modeled structures within the same sub-basin. The Little Snake River basin was an exception to this approach, however. Diversion and irrigated acreage information were sufficient for only two Little Snake River structures to be modeled explicitly: the Westside and First Mesa Canals. These ditches have senior rights and are located favorably to receive a large physical supply. The irrigation day analysis indicated that these two ditches could irrigate throughout the season without being supply-limited. From general knowledge of the basin and particular work on the High Savery project, it is clear that these two ditches do not represent diversion conditions for most irrigation structures in the basin. In a separate analysis, StatesWest determined a representative number of irrigation days for the aggregated structures of the Little Snake River basin. That work is documented in the task memorandum "Basin Water Use Profile – Agricultural". **Table 8** shows the irrigation days in each sub-basin

**Table 6 – Consumptive Use Estimates for Mountain Meadow Hay**

| Climate Station Name | Index Gage | Type of Year | Apr | May | Jun | Jul | Aug | Sep | Oct | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Big Piney | Green River at Warren Bridge | Normal | 0.00 | 4.17 | 6.22 | 7.19 | 5.28 | 1.72 | 0.00 | 24.58 |
| | | Dry | 0.00 | 3.48 | 7.65 | 7.20 | --- | --- | 0.00 | --- |
| | | Wet | 0.00 | 4.44 | 6.86 | 7.02 | 5.41 | 1.29 | 0.00 | 25.02 |
| Encampment | Little Snake near Slater, CO | Normal | 1.13 | 4.74 | 7.13 | 7.91 | 6.56 | 3.78 | 0.00 | 31.24 |
| | | Dry | 1.32 | 5.04 | 7.80 | 8.40 | 6.19 | 4.09 | 0.00 | 32.82 |
| | | Wet | 0.86 | 4.47 | 6.47 | 7.85 | 6.45 | 3.65 | 0.00 | 29.76 |
| Farson | Big Sandy River at Gasson Bridge | Normal | 0.61 | 4.23 | 6.78 | 8.15 | 6.25 | 2.13 | 0.00 | 28.15 |
| | | Dry | 0.80 | 4.49 | 8.15 | 7.99 | 5.66 | 2.20 | 0.00 | 29.29 |
| | | Wet | 0.47 | 3.76 | 6.12 | 7.21 | 5.98 | 2.09 | 0.00 | 25.62 |
| Kemmerer | Hams Fork below Pole Creek near Frontier | Normal | 0.48 | 4.64 | 6.76 | 8.14 | 6.15 | 2.98 | 0.00 | 29.15 |
| | | Dry | 0.60 | 4.21 | 7.57 | 8.24 | 6.15 | 3.13 | 0.00 | 29.89 |
| | | Wet | 0.34 | 4.13 | 6.03 | 7.48 | 6.21 | 2.48 | 0.00 | 26.66 |
| Pinedale | Pine Creek above Fremont Lake | Normal | 0.00 | 3.90 | 6.25 | 7.08 | 5.22 | 1.02 | 0.00 | 23.47 |
| | | Dry | 0.00 | 3.83 | 6.71 | 7.36 | 5.14 | 1.07 | 0.00 | 24.11 |
| | | Wet | 0.00 | 3.72 | 5.95 | 6.50 | 5.39 | 0.89 | 0.00 | 22.45 |
| Wamsutter | Little Snake near Slater, CO | Normal | 1.46 | 4.82 | 8.05 | 8.76 | 6.72 | 3.99 | 0.00 | 33.80 |
| | | Dry | 1.72 | 5.41 | 8.62 | 9.09 | 6.80 | 4.41 | 0.00 | 36.04 |
| | | Wet | 0.89 | 4.41 | 5.92 | 8.34 | 6.64 | 3.53 | 0.00 | 29.72 |

**Table 7 - Consumptive Use Estimates for Pasture Grass and Grass Hay**

| Climate Station Name | Index Gage | Type of Year | Apr | May | Jun | Jul | Aug | Sep | Oct | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Big Piney | Green River at Warren Bridge | Normal | 0.00 | 3.29 | 5.22 | 5.91 | 4.27 | 1.37 | 0.00 | 20.05 |
| | | Dry | 0.00 | 2.75 | 6.42 | 5.91 | --- | --- | 0.00 | --- |
| | | Wet | 0.00 | 3.51 | 5.76 | 5.76 | 4.36 | 1.04 | 0.00 | 20.43 |
| Farson | Big Sandy River at Gasson Bridge | Normal | 0.53 | 3.75 | 5.69 | 6.56 | 4.93 | 1.68 | 0.00 | 23.13 |
| | | Dry | 0.70 | 3.98 | 6.83 | 6.43 | 4.46 | 1.73 | 0.00 | 24.13 |
| | | Wet | 0.40 | 3.33 | 5.13 | 5.80 | 4.72 | 1.65 | 0.00 | 21.02 |
| Green River | Big Sandy River at Gasson Bridge | Normal | 1.67 | 4.68 | 6.82 | 7.65 | 6.66 | 4.05 | 0.34 | 31.88 |
| | | Dry | 2.11 | 5.28 | 7.60 | 8.51 | 6.47 | 4.22 | 0.38 | 34.57 |
| | | Wet | 1.41 | 4.56 | 6.43 | 7.70 | 6.49 | 3.77 | 0.33 | 30.68 |
| Kemmerer | Hams Fork below Pole Creek near Frontier | Normal | 0.41 | 4.11 | 5.67 | 6.55 | 4.85 | 2.35 | 0.00 | 23.95 |
| | | Dry | 0.52 | 3.73 | 6.35 | 6.63 | 4.85 | 2.47 | 0.00 | 24.54 |
| | | Wet | 0.30 | 3.66 | 5.05 | 6.02 | 4.90 | 1.95 | 0.00 | 21.87 |
| Pinedale | Pine Creek above Fremont Lake | Normal | 0.00 | 3.08 | 5.24 | 5.81 | 4.22 | 0.81 | 0.00 | 19.16 |
| | | Dry | 0.00 | 3.03 | 5.63 | 6.05 | 4.15 | 0.86 | 0.00 | 19.71 |
| | | Wet | 0.00 | 2.93 | 4.99 | 5.33 | 4.36 | 0.71 | 0.00 | 18.33 |
| Rock Springs | Big Sandy River at Gasson Bridge | Normal | 1.27 | 4.54 | 6.82 | 7.66 | 6.70 | 4.10 | 0.67 | 31.76 |
| | | Dry | 1.57 | 4.85 | 7.69 | 8.53 | 6.67 | 4.35 | 0.79 | 34.44 |
| | | Wet | 1.07 | 4.62 | 6.84 | 7.66 | 6.39 | 3.96 | 0.59 | 31.12 |

**Table 8 – Consumptive Use Estimates for Alfalfa**

| Climate Station Name | Index Gage | Type of Year | Apr | May | Jun | Jul | Aug | Sep | Oct | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Big Piney | Green River at Warren Bridge | Normal | 0.00 | 3.47 | 5.47 | 6.20 | 4.47 | 1.43 | 0.00 | 21.04 |
| | | Dry | 0.00 | 2.90 | 6.73 | 6.20 | -- | -- | 0.00 | -- |
| | | Wet | 0.00 | 3.70 | 6.03 | 6.05 | 4.58 | 1.09 | 0.00 | 21.44 |
| Encampment | Little Snake near Slater, CO | Normal | 1.02 | 4.32 | 6.26 | 6.88 | 5.93 | 3.40 | 0.00 | 27.82 |
| | | Dry | 1.19 | 4.60 | 6.86 | 7.31 | 5.60 | 3.68 | 0.00 | 29.22 |
| | | Wet | 0.78 | 4.08 | 5.69 | 6.83 | 5.83 | 3.29 | 0.00 | 26.49 |
| Farson | Big Sandy River at Gasson Bridge | Normal | 0.56 | 3.94 | 5.96 | 6.89 | 5.17 | 1.76 | 0.00 | 24.26 |
| | | Dry | 0.73 | 4.18 | 7.16 | 6.76 | 4.68 | 1.82 | 0.00 | 25.33 |
| | | Wet | 0.43 | 3.49 | 5.38 | 6.09 | 4.95 | 1.73 | 0.00 | 22.06 |
| Green River | Big Sandy River at Gasson Bridge | Normal | 1.76 | 4.92 | 7.15 | 8.02 | 7.01 | 4.26 | 0.36 | 33.48 |
| | | Dry | 2.21 | 5.55 | 7.97 | 8.92 | 6.82 | 4.44 | 0.40 | 36.30 |
| | | Wet | 1.49 | 4.79 | 6.74 | 8.07 | 6.83 | 3.96 | 0.34 | 32.22 |
| Kemmerer | Hams Fork below Pole Creek near Frontier | Normal | 0.43 | 4.32 | 5.95 | 6.88 | 5.09 | 2.46 | 0.00 | 25.12 |
| | | Dry | 0.55 | 3.91 | 6.65 | 6.97 | 5.09 | 2.58 | 0.00 | 25.75 |
| | | Wet | 0.31 | 3.84 | 5.30 | 6.32 | 5.14 | 2.04 | 0.00 | 22.95 |
| Pinedale | Pine Creek above Fremont Lake | Normal | 0.00 | 3.25 | 5.50 | 6.10 | 4.42 | 0.85 | 0.00 | 20.11 |
| | | Dry | 0.00 | 3.19 | 5.90 | 6.35 | 4.35 | 0.90 | 0.00 | 20.68 |
| | | Wet | 0.00 | 3.10 | 5.23 | 5.60 | 4.57 | 0.74 | 0.00 | 19.24 |
| Rock Springs | Big Sandy River at Gasson Bridge | Normal | 1.34 | 4.77 | 7.14 | 8.03 | 7.05 | 4.32 | 0.70 | 33.36 |
| | | Dry | 1.65 | 5.10 | 8.05 | 8.94 | 7.03 | 4.58 | 0.82 | 36.15 |
| | | Wet | 1.13 | 4.85 | 7.17 | 8.03 | 6.72 | 4.16 | 0.61 | 32.67 |
| Wamsutter | Little Snake near Slater, CO | Normal | 1.32 | 4.40 | 7.08 | 7.62 | 6.07 | 3.59 | 0.00 | 30.07 |
| | | Dry | 1.55 | 4.93 | 7.57 | 7.91 | 6.15 | 3.97 | 0.00 | 32.07 |
| | | Wet | 0.80 | 4.02 | 5.20 | 7.25 | 6.01 | 3.18 | 0.00 | 26.46 |

**Table 4 – Consumptive Irrigation Requirement Estimates for Mountain Meadow Hay**

| Climate Station Name | Index Gage | Type of Year | Apr | May | Jun | Jul | Aug | Sep | Oct | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Big Piney | Green River at Warren Bridge | Normal | 0.00 | 2.67 | 5.65 | 6.13 | 4.46 | 1.06 | 0.00 | 19.97 |
| | | Dry | 0.00 | 2.34 | 7.41 | 6.34 | --- | --- | 0.00 | --- |
| | | Wet | 0.00 | 3.78 | 5.38 | 5.94 | 4.53 | 0.39 | 0.00 | 20.01 |
| Encampment | Little Snake near Slater, CO | Normal | 0.26 | 3.16 | 6.08 | 6.68 | 5.66 | 2.74 | 0.00 | 24.58 |
| | | Dry | 0.40 | 3.43 | 7.14 | 6.71 | 4.88 | 3.19 | 0.00 | 25.75 |
| | | Wet | 0.08 | 3.29 | 4.97 | 6.35 | 5.62 | 2.51 | 0.00 | 22.82 |
| Farson | Big Sandy River at Gasson Bridge | Normal | 0.09 | 3.22 | 6.11 | 7.11 | 5.81 | 1.62 | 0.00 | 23.95 |
| | | Dry | 0.27 | 3.38 | 8.11 | 4.71 | 4.17 | 1.76 | 0.00 | 22.40 |
| | | Wet | 0.00 | 0.55 | 5.21 | 6.42 | 4.45 | 1.11 | 0.00 | 17.74 |
| Kemmerer | Hams Fork below Pole Creek near Frontier | Normal | 0.11 | 3.41 | 5.91 | 7.13 | 5.31 | 2.15 | 0.00 | 24.01 |
| | | Dry | 0.00 | 2.94 | 6.91 | 7.58 | 5.40 | 2.62 | 0.00 | 25.46 |
| | | Wet | 0.00 | 3.10 | 5.12 | 6.32 | 4.59 | 0.82 | 0.00 | 19.94 |
| Pinedale | Pine Creek above Fremont Lake | Normal | 0.00 | 2.37 | 5.46 | 5.78 | 4.32 | 0.32 | 0.00 | 18.25 |
| | | Dry | 0.00 | 1.98 | 6.42 | 6.40 | 4.31 | 0.56 | 0.00 | 19.66 |
| | | Wet | 0.00 | 2.14 | 4.64 | 5.21 | 3.82 | 0.02 | 0.00 | 15.83 |
| Wamsutter | Little Snake near Slater, CO | Normal | 0.87 | 3.57 | 7.54 | 7.73 | 5.76 | 3.17 | 0.00 | 28.63 |
| | | Dry | 1.50 | 4.59 | 8.06 | 7.78 | 5.66 | 3.85 | 0.00 | 31.44 |
| | | Wet | 0.42 | 3.77 | 4.61 | 6.38 | 4.94 | 1.73 | 0.00 | 21.85 |

**Table 5 - Consumptive Irrigation Requirement Estimates for Pasture Grass and Grass Hay**

| Climate Station Name | Index Gage | Type of Year | Apr | May | Jun | Jul | Aug | Sep | Oct | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Big Piney | Green River at Warren Bridge | Normal | 0.00 | 1.82 | 4.65 | 4.85 | 3.44 | 0.81 | 0.00 | 15.57 |
| | | Dry | 0.00 | 1.61 | 6.18 | 5.05 | --- | --- | 0.00 | --- |
| | | Wet | 0.00 | 2.85 | 4.27 | 4.68 | 3.48 | 0.24 | 0.00 | 15.53 |
| Farson | Big Sandy River at Gasson Bridge | Normal | 0.07 | 2.74 | 5.01 | 5.53 | 4.47 | 1.20 | 0.00 | 19.02 |
| | | Dry | 0.17 | 2.87 | 6.79 | 3.15 | 2.97 | 1.29 | 0.00 | 17.24 |
| | | Wet | 0.00 | 0.37 | 4.23 | 5.01 | 3.19 | 0.88 | 0.00 | 13.66 |
| Green River | Big Sandy River at Gasson Bridge | Normal | 0.94 | 3.60 | 6.29 | 6.95 | 6.05 | 3.11 | 0.06 | 27.01 |
| | | Dry | 1.49 | 4.55 | 6.91 | 6.93 | 5.87 | 3.62 | 0.15 | 29.52 |
| | | Wet | 0.68 | 3.36 | 5.59 | 7.16 | 5.82 | 2.86 | 0.03 | 25.49 |
| Kemmerer | Hams Fork below Pole Creek near Frontier | Normal | 0.09 | 2.88 | 4.82 | 5.54 | 4.01 | 1.56 | 0.00 | 18.90 |
| | | Dry | 0.00 | 2.46 | 5.69 | 5.98 | 4.10 | 1.96 | 0.00 | 20.18 |
| | | Wet | 0.00 | 2.63 | 4.14 | 4.86 | 3.28 | 0.47 | 0.00 | 15.37 |
| Pinedale | Pine Creek above Fremont Lake | Normal | 0.00 | 1.61 | 4.45 | 4.51 | 3.32 | 0.22 | 0.00 | 14.11 |
| | | Dry | 0.00 | 1.33 | 5.34 | 5.08 | 3.32 | 0.40 | 0.00 | 15.46 |
| | | Wet | 0.00 | 1.49 | 3.68 | 4.04 | 2.79 | 0.00 | 0.00 | 12.00 |
| Rock Springs | Big Sandy River at Gasson Bridge | Normal | 0.57 | 3.04 | 6.26 | 6.52 | 6.14 | 3.27 | 0.24 | 26.05 |
| | | Dry | 1.06 | 4.21 | 7.01 | 7.64 | 6.13 | 3.90 | 0.49 | 30.42 |
| | | Wet | 0.28 | 3.52 | 6.37 | 6.81 | 5.83 | 2.98 | 0.05 | 25.83 |

**Table 6 – Consumptive Irrigation Requirement Estimates for Alfalfa**

| Climate Station Name | Index Gage | Type of Year | Apr | May | Jun | Jul | Aug | Sep | Oct | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Big Piney | Green River at Warren Bridge | Normal | 0.00 | 1.98 | 4.90 | 5.14 | 3.65 | 0.85 | 0.00 | 16.51 |
| | | Dry | 0.00 | 1.76 | 6.49 | 5.34 | -- | -- | 0.00 | -- |
| | | Wet | 0.00 | 3.04 | 4.55 | 4.97 | 3.70 | 0.27 | 0.00 | 16.53 |
| Encampment | Little Snake near Slater, CO | Normal | 0.21 | 2.77 | 5.22 | 5.65 | 5.03 | 2.36 | 0.00 | 21.25 |
| | | Dry | 0.31 | 2.99 | 6.20 | 5.62 | 4.28 | 2.79 | 0.00 | 22.18 |
| | | Wet | 0.06 | 2.90 | 4.19 | 5.33 | 5.00 | 2.14 | 0.00 | 19.61 |
| Farson | Big Sandy River at Gasson Bridge | Normal | 0.08 | 2.92 | 5.28 | 5.86 | 4.72 | 1.28 | 0.00 | 20.13 |
| | | Dry | 0.20 | 3.07 | 7.12 | 3.48 | 3.19 | 1.38 | 0.00 | 18.44 |
| | | Wet | 0.00 | 0.44 | 4.48 | 5.30 | 3.42 | 0.92 | 0.00 | 14.54 |
| Green River | Big Sandy River at Gasson Bridge | Normal | 1.03 | 3.84 | 6.62 | 7.32 | 6.41 | 3.32 | 0.06 | 28.60 |
| | | Dry | 1.59 | 4.82 | 7.28 | 7.34 | 6.22 | 3.84 | 0.16 | 31.23 |
| | | Wet | 0.73 | 3.59 | 5.90 | 7.53 | 6.17 | 3.06 | 0.03 | 27.00 |
| Kemmerer | Hams Fork below Pole Creek near Frontier | Normal | 0.10 | 3.08 | 5.09 | 5.87 | 4.24 | 1.67 | 0.00 | 20.06 |
| | | Dry | 0.00 | 2.64 | 6.00 | 6.31 | 4.34 | 2.07 | 0.00 | 21.36 |
| | | Wet | 0.00 | 2.81 | 4.39 | 5.16 | 3.52 | 0.52 | 0.00 | 16.39 |
| Pinedale | Pine Creek above Fremont Lake | Normal | 0.00 | 1.75 | 4.70 | 4.80 | 3.52 | 0.24 | 0.00 | 15.01 |
| | | Dry | 0.00 | 1.46 | 5.61 | 5.38 | 3.52 | 0.43 | 0.00 | 16.39 |
| | | Wet | 0.00 | 1.63 | 3.92 | 4.31 | 3.00 | 0.00 | 0.00 | 12.85 |
| Rock Springs | Big Sandy River at Gasson Bridge | Normal | 0.62 | 3.25 | 6.59 | 6.89 | 6.50 | 3.47 | 0.26 | 27.59 |
| | | Dry | 1.13 | 4.46 | 7.37 | 8.05 | 6.48 | 4.13 | 0.52 | 32.14 |
| | | Wet | 0.32 | 3.75 | 6.69 | 7.18 | 6.17 | 3.18 | 0.06 | 27.35 |
| Wamsutter | Little Snake near Slater, CO | Normal | 0.74 | 3.15 | 6.56 | 6.59 | 5.11 | 2.77 | 0.00 | 24.93 |
| | | Dry | 1.33 | 4.12 | 7.02 | 6.60 | 5.00 | 3.41 | 0.00 | 27.48 |
| | | Wet | 0.35 | 3.39 | 3.89 | 5.30 | 4.30 | 1.38 | 0.00 | 18.62 |

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## Percentages Reported by Sub-basin

| | Pasture Grass or Grass Hay | Alfalfa | Small Grains |
|---|---|---|---|
| Henrys Fork, Muddy, New Fork, Slate, Other Upper Green | 100 | 0 | 0 |
| Smiths Fork | 96 | 3 | 1 |
| Fontenelle Creek, Hams Fork, LaBarge Creek | 95 | 5 | 0 |
| Blacks Fork | 90 | 8 | 2 |
| Little Snake | 89 | 11 | 0 |
| Big Sandy | 71 | 26 | 3 |

Irrigation in gray areas is unreported and is assumed 100% Pasture Grass or Grass Hay

N

20    0    20    Miles

Sublette

Lincoln

Green River – Fontenelle Rsvr to LaBarge Cr

New Fork

Green River Above LaBarge Creek

Big Sandy

Big Sandy

Green River to Fontenelle Rsvr

Ham's Fork

Hams Fork

Green River

Blacks Fork

Black's Fork

Muddy Creek

Smith's Fork

Smiths Fork

Henry's Fork

Uinta

Sweetwater

Great Divide Basin

Carbon

Bitter Creek

Little Snake Above Baggs

Little Snake Below Baggs

Little Snake

WYOMING
COLORADO

UTAH

Little Snake

Figure 1  Crop Distribution Zones

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**Table 7 Consumptive Irrigation Requirement By Crop Distribution Zones**

| Zone | Station 1 | Wt | Station 2 | Wt | MMH Wt | PGH Wt | Alf Wt | | Apr | May | Jun | Jul | Aug | Sep | Oct | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Little Snake above Baggs | Big Piney[1] | 1.0 | | 0.0 | 0.89 | 0 | 0.11 | N | 0.00 | 2.59 | 5.57 | 6.02 | 4.37 | 1.04 | 0.00 | 19.59 |
| | | | | | | | | D | 0.00 | 2.27 | 7.31 | 6.23 | 4.22 | 0.54 | 0.00 | 20.57 |
| | | | | | | | | W | 0.00 | 3.70 | 5.29 | 5.83 | 4.43 | 0.37 | 0.00 | 19.62 |
| Little Snake below Baggs | Wamsutter | 1.0 | | 0.0 | 0 | 0.89 | 0.11 | N | 0.70 | 2.96 | 6.28 | 6.28 | 4.82 | 2.60 | 0.00 | 23.62 |
| | | | | | | | | D | 1.27 | 3.91 | 6.71 | 6.27 | 4.71 | 3.22 | 0.00 | 26.08 |
| | | | | | | | | W | 0.33 | 3.21 | 3.68 | 4.99 | 4.02 | 1.23 | 0.00 | 17.46 |
| Big Sandy | Farson | 1.0 | | 0.0 | 0.35 | 0.36 | 0.29 | N | 0.08 | 2.96 | 5.47 | 6.18 | 5.01 | 1.37 | 0.00 | 21.07 |
| | | | | | | | | D | 0.21 | 3.11 | 7.35 | 3.79 | 3.45 | 1.48 | 0.00 | 19.39 |
| | | | | | | | | W | 0.00 | 0.45 | 4.64 | 5.59 | 3.69 | 0.97 | 0.00 | 15.34 |
| New Fork | Pinedale | 1.0 | | 0.0 | 1 | 0 | 0 | N | 0.00 | 2.37 | 5.46 | 5.78 | 4.32 | 0.32 | 0.00 | 18.25 |
| | | | | | | | | D | 0.00 | 1.98 | 6.42 | 6.40 | 4.31 | 0.56 | 0.00 | 19.66 |
| | | | | | | | | W | 0.00 | 2.14 | 4.64 | 5.21 | 3.82 | 0.02 | 0.00 | 15.83 |
| Green River abv LaBarge Creek | Big Piney[1] | 1.0 | | 0.0 | 1 | 0 | 0 | N | 0.00 | 2.67 | 5.65 | 6.13 | 4.46 | 1.06 | 0.00 | 19.97 |
| | | | | | | | | D | 0.00 | 2.34 | 7.41 | 6.34 | 4.31 | 0.56 | 0.00 | 20.95 |
| | | | | | | | | W | 0.00 | 3.78 | 5.38 | 5.94 | 4.53 | 0.39 | 0.00 | 20.01 |
| Green River - Fontenelle Rsvr to LaBarge Creek | Big Piney[1] | 1.0 | | 0.0 | 0.95 | 0 | 0.05 | N | 0.00 | 2.64 | 5.61 | 6.08 | 4.42 | 1.05 | 0.00 | 19.80 |
| | | | | | | | | D | 0.00 | 2.31 | 7.36 | 6.29 | 4.27 | 0.55 | 0.00 | 20.78 |
| | | | | | | | | W | 0.00 | 3.75 | 5.34 | 5.89 | 4.48 | 0.38 | 0.00 | 19.83 |
| Green River - Green River to Fontenelle Rsvr | Farson | 1.0 | | 0.0 | 1 | 0 | 0 | N | 0.09 | 3.22 | 6.11 | 7.11 | 5.81 | 1.62 | 0.00 | 23.95 |
| | | | | | | | | D | 0.27 | 3.38 | 8.11 | 4.71 | 4.17 | 1.76 | 0.00 | 22.40 |
| | | | | | | | | W | 0.00 | 0.55 | 5.21 | 6.42 | 4.45 | 1.11 | 0.00 | 17.74 |
| Hams Fork | Kemmerer | 1.0 | | 0.0 | 0 | 0.95 | 0.05 | N | 0.09 | 2.89 | 4.83 | 5.56 | 4.02 | 1.57 | 0.00 | 18.96 |
| | | | | | | | | D | 0.00 | 2.47 | 5.71 | 5.99 | 4.11 | 1.96 | 0.00 | 20.24 |
| | | | | | | | | W | 0.00 | 2.64 | 4.15 | 4.87 | 3.29 | 0.47 | 0.00 | 15.42 |
| Muddy Creek | Kemmerer | 1.0 | | 0.0 | 0 | 1 | 0 | N | 0.09 | 2.88 | 4.82 | 5.54 | 4.01 | 1.56 | 0.00 | 18.90 |
| | | | | | | | | D | 0.00 | 2.46 | 5.69 | 5.98 | 4.10 | 1.96 | 0.00 | 20.18 |
| | | | | | | | | W | 0.00 | 2.63 | 4.14 | 4.86 | 3.28 | 0.47 | 0.00 | 15.37 |
| Black's Fork | Kemmerer | 1.0 | | 0.0 | 0 | 0.9 | 0.1 | N | 0.10 | 2.90 | 4.84 | 5.57 | 4.03 | 1.57 | 0.00 | 19.02 |
| | | | | | | | | D | 0.00 | 2.48 | 5.72 | 6.01 | 4.12 | 1.97 | 0.00 | 20.30 |
| | | | | | | | | W | 0.00 | 2.64 | 4.17 | 4.89 | 3.30 | 0.47 | 0.00 | 15.47 |
| Smith's Fork | Kemmerer | 1.0 | | 0.0 | 0 | 0.96 | 0.04 | N | 0.09 | 2.89 | 4.83 | 5.55 | 4.02 | 1.57 | 0.00 | 18.95 |
| | | | | | | | | D | 0.00 | 2.47 | 5.70 | 5.99 | 4.11 | 1.96 | 0.00 | 20.23 |
| | | | | | | | | W | 0.00 | 2.63 | 4.15 | 4.87 | 3.28 | 0.47 | 0.00 | 15.41 |
| Henry's Fork | Kemmerer | 1.0 | | 0.0 | 0 | 1 | 0 | N | 0.09 | 2.88 | 4.82 | 5.54 | 4.01 | 1.56 | 0.00 | 18.90 |
| | | | | | | | | D | 0.00 | 2.46 | 5.69 | 5.98 | 4.10 | 1.96 | 0.00 | 20.18 |
| | | | | | | | | W | 0.00 | 2.63 | 4.14 | 4.86 | 3.28 | 0.47 | 0.00 | 15.37 |

[1]Pinedale substituted for Big Piney for DRY August, September, and October

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**Table 8  Modeled number of irrigation days per month**

|  | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|
| **Little Snake** | | | | | | |
| First Mesa Ditch | 0 | 31 | 30 | 31 | 31 | 30 |
| Westside Canal | 0 | 31 | 30 | 31 | 31 | 30 |
| Little Snake Aggregates | 0 | 31 | 30 | 25 | 6 | 5 |
| | | | | | | |
| **Blacks Fork/Henrys Fork** | | | | | | |
| Ft. Bridger/Center/Twin Butte | 0 | 15 | 30 | 23 | 10 | 30 |
| Bridger Butte | 0 | 15 | 30 | 15 | 5 | 15 |
| Blacks Fork Canal | 0 | 15 | 30 | 23 | 10 | 30 |
| Pine Grove Ditch | 0 | 15 | 30 | 23 | 5 | 15 |
| Blacks Fork Aggregates | 0 | 15 | 30 | 21 | 7.5 | 22.5 |
| Henrys Fork Aggregates | 0 | 15 | 30 | 21 | 7.5 | 22.5 |
| | | | | | | |
| **Upper & Mainstem Green** | | | | | | |
| Canyon Ditch | 0 | 31 | 30 | 31 | 31 | 30 |
| Green River Mainstem and Upper Tributary Aggregates | 0 | 31 | 30 | 31 | 31 | 30 |
| Colorado Ditch | 0 | 31 | 30 | 31 | 14 | 30 |
| East Fork Ditch | 0 | 31 | 30 | 31 | 24 | 30 |
| Fremont Ditch | 0 | 31 | 30 | 31 | 28 | 30 |
| Gilligan-Iven | 0 | 31 | 30 | 31 | 28 | 30 |
| Highland Ditch | 0 | 31 | 30 | 31 | 20 | 30 |
| Lee | 0 | 31 | 30 | 31 | 21 | 30 |
| Overland Ditch | 0 | 31 | 30 | 31 | 15 | 30 |
| Paradise | 0 | 31 | 30 | 31 | 31 | 30 |
| Pole Creek No. 2 | 0 | 31 | 30 | 31 | 15 | 30 |
| Tibbals | 0 | 31 | 30 | 31 | 24 | 30 |
| New Fork Aggregates | 0 | 31 | 30 | 31 | 22 | 30 |
| | | | | | | |
| **Piney Creeks** | | | | | | |
| Homestake Ditch | 0 | 31 | 30 | 31 | 24 | 30 |
| Musselman | 0 | 31 | 30 | 18 | 10 | 30 |
| North Piney | 0 | 15 | 30 | 14 | 14 | 30 |
| Reardon | 0 | 31 | 30 | 31 | 15 | 30 |
| South Piney Ditch | 0 | 31 | 30 | 31 | 10 | 7 |
| Yankee | 0 | 31 | 30 | 31 | 31 | 30 |
| N./ S. Piney Creek Aggregates | 0 | 28.3 | 30.0 | 26.0 | 17.3 | 26.2 |
| | | | | | | |
| **La Barge Creek** | | | | | | |
| Anderson-Howard | 0 | 31 | 30 | 31 | 31 | 30 |
| LaBarge No. 2 | 0 | 31 | 30 | 31 | 31 | 24 |
| La Barge Creek Aggregates | 0 | 31 | 30 | 31 | 31 | 27 |

*1) Irrigation days estimated as number of days needed to achieve irrigation efficiency of approximately 55% (July, August, September).*
*2) Generally, used increments of 7, 10 or 15 days for June, July, August (24 = 31 minus 7)*
*3) May values generally either 15 or 31*
*4) June always 30 days unless no irrigation in July*

Task 3B Surface Water Data Synthesis and Spreadsheet Model Development

**APPENDIX C**

**Programmers Notes**

**Programmers Notes**

**Modification of the Green River Model**

The Green River Spreadsheet Model was written assuming that it may be modified for use in future investigations of other Wyoming river basins.  Instructions are incorporated throughout this document providing hints and suggestions to the Programmer.  Some overall suggestions are included here for consideration of the Programmer.

- As a general rule, whenever rows need to be added to any table (e.g. adding a node within an existing Reach), the Programmer should create a template for the new information using existing cells/tables.  Existing worksheet rows which contain the type of information to be inserted should be copied and "inserted" where needed instead of adding them to the bottom of the table.  The Green River Model uses "lookup" functions extensively.  By "inserting" rows, Excel will automatically modify the formulas in cells referencing a table.  If rows are added to a table without insertion, the lookup functions may not "find" the new information.

- The workbooks have been provided with the "protection mode" enabled for each worksheet.  No password has been used, therefore, the Programmer may turn the protection feature off if changes are required (Tools - Protection - Unprotect Worksheet).

- When entering data such as historic diversions, historic USGS gage data, etc., the Programmer should use a "paste special" command to protect the existing format and formulas by inserting only data values (Edit - Paste Special - Values).

- When copying existing formulas or tables, the Programmer should copy and paste entire rows of existing tables (or entire tables where appropriate), in lieu of copying a single cell formula and using it to fill a table.   The reason for this is that many of the "lookup" formulas may not copy to adjacent columns correctly.

- Whenever copying and pasting anything in the workbook, the Programmer should ensure that Excel has been set to copy in the "relative address" mode.

Additional detailed information has been provided to the Programmer in this document with the discussion of each worksheet.

For various sections of the Excel spreadsheet model, programmers notes have been prepared to assist or guide modifications in future modeling efforts.

*GUI*

The GUI was developed using Visual Basic within Microsoft® Excel.  Modification of the GUI requires an understanding of the Visual Basic programming language.  When the User opens the Green River Model file - the GUI - the model is informed where on the User's computer the file is located.  All files must be located in the same folder for the model to operate properly.  Once the GUI is initialized, the model will look in the same location for any additional files.

Future revisions of the Green River Model will require the following minor modifications to the GUI:

1. The names of the Green River files must be replaced with future file names in the programming code associated with each of the three model selection buttons.

2. Text in the forms presented in the GUI must be modified to reflect the future version.

*Navigation Worksheets*

Excel programmers modifying the spreadsheet model will need to modify the Reach/Node Description table located to the right of the visible screen, for the Navigation Worksheet to work properly. If new reaches must be entered, INSERT columns and renumber the header accordingly. This will cause formulas which reference this table to change accordingly. Also, if the table must be expanded vertically (i.e., more nodes must be added than the table currently accommodates), the same practice should be followed. That is, always INSERT rows or columns within the existing table. This allows the Programmer to avoid modification of formulas which influence the table.

The Programmer must also modify the macro associated with the pull-down menu to include all reaches in a new model. Begin by naming a cell in the upper left of any additional Reach worksheets. Then modify the Visual Basic (VB) code to include a "GoTo"reference for that worksheet. Following is the VB code associated with the subroutine named "Reach". New reaches can be incorporated in this macro by copying one "else if" statement and renaming the appropriate range number.

```
Sub Reach()

    If Range("t4") = 1 Then
        Application.Goto Reference:="reach_1"
      ElseIf Range("t4") = 2 Then
        Application.Goto Reference:="reach_2"
      ElseIf Range("t4") = 3 Then
      .
      .
      .
    End If

    End Sub
```

*Results Navigator*

This portion of the worksheet must be customized to correlate with any future versions of this model. Different river basins will have different compact allocation computations and formats.

When incorporated into this model, the Summary Navigator worksheet should be modified to allow the User to "jump" directly to the new tables.

*Diagram of the Basin*

The model diagram is not dynamically linked to the rest of the spreadsheet. It is included as a reference for orientation to the basin, helping the user understand locations of nodes and connectivity of reaches. The four Green River basin diagrams were created in Autocad and imported into their respective spreadsheets. If the diagram is to be changed, the user currently needs to modify the drawing in a drafting package and import it again.

*Master Node List*

This list is referenced throughout the workbook by "lookup" functions. The "lookup" functions primarily associate the name of a node with the node number when it is entered at certain locations. This eases input of information in tables such as the Node Tables, Return Flow Tables, etc. In those tables, the Programmer can simply enter the Node number and the Name is filled in automatically. Therefore, whenever a Node is added to a Reach, it must be inserted in this table.

Because the model frequently uses "lookup" functions, it is highly recommended that the Programmer use Excel's "INSERT ROWS" command whenever adding information to this or other data tables. When information is added this way, formulas which reference the table automatically update to refer to the newly expanded range. If rows are added to the bottom of a listing, the referenced formula may not "find" the new data.

This list is not required to be sorted in any particular order; all formulas referencing the table will retrieve the correct information regardless of order. However, for ease of reading, it is recommended that it be sorted either by node number or by node name.

If the User must add nodes between existing nodes, they do not necessarily need to be numbered in sequential order. The node numbers are not used by the model for anything other than identifiers. The correct sequence of nodes within a reach is determined by the Programmer when building the Reach worksheets.

*Diversion Data*

This table is referenced by several other worksheets in the Green River Model via "lookup" functions

It is important to note that ALL nodes are included in this table, even if no diversions occur at that node (e.g. gaging station nodes). This simplifies the spreadsheet logic used in the Node Tables. By including all nodes in this table, the Node Tables are all identical and can generally be copied as many times as are needed without modification (see User and Programmer Notes pertaining to the node/reach worksheets for exceptions to this rule). Therefore, if no diversions occur at a node, simply leave the data columns blank or insert zeros.

Because the model uses "lookup" functions to retrieve data from this table, it is highly recommended that the Programmer use Excel's "INSERT ROWS" command whenever adding information to this or other data tables. When information is added this way, formulas reference the table automatically

update to refer to the newly expanded range.  If rows are added to the bottom of a listing, the referring formula may not "find" the new data.  After rows are inserted, the Programmer can copy the formulas in the "Name" column to retrieve gage names automatically.

*Import and Export Data*

This table is referenced by several other worksheets in the Green River Model via "lookup" functions.  Any imports or exports which occur at any node of the model must be entered here.  No computations are conducted within this worksheet.

It is important to note that ALL nodes are included in this table, even if no imports or exports occur there (e.g. gaging station nodes).  This simplifies the spreadsheet logic used in the Node Tables.  By including all nodes in this table, the Node Tables are all identical and can be copied as many times as are needed without modification.  Therefore, if no diversions occur at a node, simply leave the data columns blank or insert zeros.

Because the model uses "lookup" functions to retrieve data from this table, it is highly recommended that the Programmer use Excel's "INSERT ROWS" command whenever adding information to this or other data tables.

*Return Flow*

All nodes where diversions occur must be included in the Return Flows worksheet.  If nodes are added, the Programmer should follow the same precautions outlined in the discussion of previous worksheets and use Excel's "INSERT ROWS" commands.  This simplifies modifications because formulas which reference this worksheet via "lookup" functions will be modified automatically.

Once rows are inserted for new nodes, the Programmer can copy an existing  "Node Evaluation" table as many times as needed.  When the Programmer changes the Node Number, the Node Name and Total Diversions will update automatically with a "lookup" to the Master Node List and the Diversions Data worksheets, respectively.

The Programmer must then modify the "Efficiency Pattern", "Return Pattern", "TO" and "Percent" features to represent conditions associated with the diversions from the new node.

To update the "Irrigation Returns: Node Totals Table", the Programmer must first be certain that all nodes are included in the list of nodes.  For simplicity, the Programmer can copy the Node Number column from the Master Node List and paste it here.  Then the Programmer can copy the remaining portion of a row including Name, Monthly Summation, and Reach number as many times as needed.  The Programmer should be cautioned to verify that the ranges referenced in the monthly summation columns span the entire range of Node Evaluation tables following addition of nodes.

To update the "Irrigation Returns: Reach Totals Table" the Programmer must enter all reach numbers in the appropriate columns and then copy the formulas in the January through December columns.  Verify that the range referenced in the monthly summation cells span the entire range of the "Irrigation Returns: Node Totals Table" after it was modified.

*Options Table*

Incorporation of a "Irrigation Return Pattern" or "Irrigation Return Lag" relationship which differs from those included in this model can be done by either over-writing one of the existing lines or by inserting a new line within the existing table. If irrigation returns are determined to require longer than three months before returning to the river system, a column may be inserted in the Irrigation Return Lags table. However, it is important to note that the formulas of the Irrigation Returns worksheet will need modification to reflect any additional months.

*Reach Gain/Loss*

Ungaged Reach Gain/Losses must be computed on a Reach-by-Reach basis in a manner as shown in the "Gain/Loss" worksheet. To do this, the Programmer must reference the appropriate gage data, diversion data, return flow data and reservoir data, building a budget as shown in the worksheet. Each Reach will require construction of an individual table with that Reach's specific conditions incorporated. At the bottom of each computation table, the Programmer must enter a Reach Name which corresponds to the Reach(s) for which the Gains/Losses will be applied. The Reach Names must then be entered into the Summary Table and the tables will automatically update.

Ungaged Reach gains are added to the upstream end of a Reach to make them available to diversions within the Reach. Ungaged Reach losses are subtracted at the downstream end. To facilitate this feature, the Programmer must enter the Reach Name in the Reach Gains line at the upstream node of a reach and the Node Table will automatically update. The Reach Name must also be entered in Ungaged Losses line of the Reach's downstream node and the Node Table will automatically update.

By incorporating Ungaged Gains and Losses, the spreadsheet model is calibrated to match historic gaging data at each gage node.

*Node Tables*

Adaptation of the Green River Model for other river basins will require reconstruction of the Reach/Node worksheets on a node-by-node basis. Because all values in the Node tables are obtained via "lookup" functions, this is a relatively easy task.

The Node Inflow to any Node Table is referenced in one of three ways:

1. If the node is the upstream end of the model, or upstream node of a modeled tributary, the inflow is retrieved from the Gaging Data worksheet using a "vlookup" function. Refer to the Upper Green River Node 1.02 for an example of this method.

2. If the node is located at the upstream end of any other reach, the Node Inflow is referenced as the NET Flow from the Reach that feeds it. In this case, cell references must be manually modified. Refer to the Upper Green River Node 3.01 for an example of this method.

3. If the node is located at any midpoint within a Reach, the Node Inflow is simply the NET Flow from the Node upstream of it. Refer to the Upper Green River Node 1.04 for an example of this method.

Most nodes will be built using the third method described above.  In this case, once the Node Inflow cells have been modified as in the example (i.e., Node 1.04), the Node Table may be copied as many times as needed and the Reach can be constructed in a sequential manner.

The Programmer must enter the Node Number in the cell at the top of each Node Table cell and the worksheet will return the Node Name and all corresponding data from the worksheets referenced.

*Results Worksheets*

The "Outflow Calculations: By Node" tables were generated using lookup functions which reference the corresponding Reach worksheets.  The values in the "Node" column were entered manually and the lookup tables constructed accordingly.

The "Outflow Calculations: By Reach" table simply references the downstream limit of each "Outflow Calculations: By Node" table.

*Diversions Summary*

The "Summary of Diversion Calculations: By Node" tables were generated using lookup functions which reference the corresponding Reach worksheets.  The values in the "Node" column were entered manually and the lookup tables constructed accordingly.

The "Summary of Diversion Calculations: By Reach" table references the "Summary of Diversion Calculations: By Node" tables using SUMIF functions.

The "Comparison of Estimated vs Historical Diversions" table looks up historic diversions for each node in the Diversions Data worksheet.  It also looks up the estimated diversions in the "Summary of Diversion Calculations: By Node" tables and computes the comparisons.

**Specific Instructions for Adding a Single Node to a Green River Basin Model**

The Green River Basin models have been constructed such that new nodes, representing a new point of diversion, a reservoir, a streamflow gage, an instream flow segment or any other point at which the user needs to evaluate, can be added.  The process for adding a new node is described below. Worksheets need to be modified in the order given here.

1. *General*

The workbooks have been provided with the "protection mode" enabled for each worksheet.  No password has been used, therefore the user must turn the protection feature off to make changes (Tools / Protection / Unprotect Worksheet).

The user may also find it helpful to turn on the row and column headers and the sheet tabs on each worksheet to be modified (Tools / Options / View).

It is recommended that the user make any modifications to the model in the order that is presented below.

2.  *Master List of Nodes Worksheet*

    There are two ways of modifying the Master List of Nodes:

    - Enter the node number and name immediately below the last node in the table and above the line labled "Insert new nodes above".

    - INSERT a row at the location where you want to add a new node, then type in the node number and name.

    It is recommended that the user use the second approach so that the list remains in numerical sequence.

3.  *The Central Navigation Worksheet*

    The Reach/Node Description table located to the right of the visible screen must be modified. Go to the column containing the reach that you wish to modify. Type in the node number that you wish to add. If this is not the last node in the reach, it is simplest to retype the subsequent nodes in the rows below rather than inserting a cell.

4.  *Gage Data / Inflow Data Worksheet*

    If the new node to be added represents a gage or an inflow point to the model, the Gage Data / Inflow Data worksheet must be modified. As with the Master List of Nodes, the user can add the new node and relevant data in the next available unused row in the table (as defined by the borders and shading). Alternatively, the user can INSERT a row in the appropriate location to maintain the reach/node sequence, then add the new node and data.

5.  *Diversion Data Worksheet*

    All nodes MUST be included in this table even if no diversion occurs at the node. The user may simply enter the new node and relevant data in the next available unused row in the table (as defined by the borders and shading) or the user can INSERT a row in n the appropriate location to maintain the reach/node sequence, then add the new node and data.

6.  *Import and Export Data Worksheet*

    All nodes MUST be included in this table even if no import or export occurs at the node. The user may simply enter the new node and relevant data in the next available unused row in the table (as defined by the borders and shading) or the user can INSERT a row in n the appropriate location to maintain the reach/node sequence, then add the new node and data.

7.  *Return Flows Worksheet*

    All nodes where diversions occur MUST be included in the Return Flows worksheet. Select an entire Irrigation Return table. COPY the selected cells, INSERT COPIED CELLS and select SHIFT CELLS DOWN. Update the node number in the yellow shaded cell. The node name will automatically update.

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The user must then update the "Efficiency Pattern", "Return Pattern", "TO" and "Percent" cells (shaded yellow) to represent conditions associated with the diversions from the new node.

To update the "Irrigation Returns: Node Totals Table", the user must first be certain that all nodes are included in the list of nodes. For simplicity, the user can copy the Node Number column from the Master Node List and paste it here. Be sure that the Master Node List does not extend past the yellow shaded area. Then the user can copy the Monthly Summation and Reach number equations as many times as needed. The user should be cautioned to verify that the ranges referenced in the monthly summation columns span the entire range of Node Evaluation tables following addition of nodes.

As currently constructed, the "Irrigation Returns: Reach Totals Table" requires no modification for the simple addition of a node. This table will automatically update for up to 35 reaches.

*8.  Options Table Worksheet*

Incorporation of a "Irrigation Return Pattern" or "Irrigation Return Lag" relationship which differs from those included in this model can be done by either over-writing one of the existing lines or by inserting a new line within the existing table. If irrigation returns are determined to require longer than three months before returning to the river system, a column may be inserted in the Irrigation Return Lags table. However, it is important to note that the formulas of the Irrigation Returns worksheet will need modification to reflect any additional months.

*9.  Evaporative Losses Worksheet*

If the new node is a storage node, COPY the rows containing the "Mean Monthly Evaporation (inches)", "Historical End-of-Month Contents (acre-feet)" and "Surface Area (acres)" tables and insert the rows above the "Mean Monthly Evaporation (acre-feet)" table. Update the node number and the node name will automatically update. Enter in gross evaporation and precipitation for the new node. Enter the historical end-of-month contents for the reservoir.

Select and COPY the rows containing the existing area-capacity table, then paste the rows below the existing table. Update the node number and area-capacity information.

The reservoir surface area is calculated by looking up historical end-of-month content and interpolating the surface area from the area-capacity table. The "vlookup' portion of the equation must be updated to correspond to the new area-capacity table.

Enter a new node number and the equation to calculate the mean monthly evaporation within the "Mean Monthly Evaporation (acre-feet)" table. If there is no room available in the table, INSERT a row within the table and add the necessary information.

*10. Reach Gain/Loss Worksheet*

Determine the ungaged reach gain/loss table that the new node is within. Locate the corresponding table in the Reach Gain/Loss Worksheet. Select the row in the diversion portion of the table either above or below where the new node needs to be inserted. COPY the selected cells, then INSERT COPIED CELLS in the appropriate location. Update the node number in the yellow shaded cell. The

node name and diversions associated with the new node will automatically update. Repeat these steps in the returns portion of the table.

## 11. *Reach/Node Worksheet*

Select the rows containing an entire Node table.  COPY the selected rows, then move to the new location in the workbook and select INSERT COPIED CELLS. Update the node number in the yellow shaded cell. The node name, diversions, irrigation returns, ungaged gains/losses and import/exports will automatically update if all the above steps have been completed.

The Node Inflow to any Node Table references one of three sources:

- If the node is the upstream end of the model, or upstream node of a modeled tributary, the inflow is retrieved from the Gaging Data worksheet using a "vlookup" function.

- If the node is located at the upstream end of any other reach, the Node Inflow references the NET Flow from the Reach(s) that feed it.  In this case, cell references must be manually modified.

- If the node is located at any midpoint within a Reach, the Node Inflow is simply the NET Flow from the Node upstream of it.

Most nodes will be built using the third method described above.

If the Reach/Node table represents a reservoir, the user will need to manually update the cells shaded yellow.

As a precautionary measure, it is best to check the Node Inflow in the Reach/Node table below where the new node has been inserted to ensure that the appropriate cells are referenced.