

Getting Started Modeling the Lower Bear River Basin with the Water Evaluation and Planning (WEAP) Tool

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Summary

This document provides directions and prompts to get started using the Water Evaluation and Planning (WEAP) system to simulate reservoir operations in the Lower Bear River, Utah. Students will (i) add demand site(s), reservoir(s), transmission links, and return flows to complete the Lower Bear River schematic, (ii) enter data for these model elements, (iii) define scenarios to represent both current conditions and adding two new reservoirs, and (iv) simulate and identify the effects each new reservoir will have on water deliveries to new urban users in Cache County.

Introduction

The Bear River covers an area of about 7,600 square miles in Utah, Idaho and Wyoming (Figure 1). There are numerous reservoirs in the Bear River basin including upstream storage reservoirs like Woodruff, Bear Lake, and Oneida Narrows. On the Little Bear River which is a tributary to the Bear River, there is also Hyrum Reservoir. Cutler Reservoir is located on the Bear River but has very little storage capacity. Additionally, there are several proposed on- and off-stream storage reservoirs including Barrens, Above Cutler, Honeyville, and a site above Honeyville that could supply water to either Cache or Box Elder Counties or the Wasatch Front. The most senior (highest priority) water rights holder in the basin is the Bear River Canal Company which is located in Box Elder county downstream of Cutler Reservoir. The lower Bear River study area starts at the Idaho-Utah border and has its outlet at the Great Salt Lake. The major tributaries to the Lower Bear River include the Cub, Little Bear, and Malad Rivers. There are major demand urban and agricultural demand sites both in Cache Valley and Box Elder County. The Utah Division of Water Resources (UDWR) developed the GenRes (FORTRAN) model to simulate the monthly historical (1966-2006) water allocation within the basin. Here, we will construct a simplified version of the UDWR model in WEAP.

Original UDWR Model

The UDWR GenRes model (Figure 2) includes 6 existing reservoirs (Idaho, Oneida, Millcreek, Hyrum, Willard Bay, and Davis), 3 potential reservoirs (Barrens, Washaskie, Mainstem), and 11 service areas (including the Bird Refuge). A service area is a group of canals

or diversions that serve agricultural, urban, or environmental users and is alternatively referred to as a “demand site” in WEAP. The UDWR model allocates water among service areas based on priorities (Table 1). Demand sites that have the high priorities (numbers closest to 1) are allocated their full delivery targets first before sites with lower priorities are allocated any water.

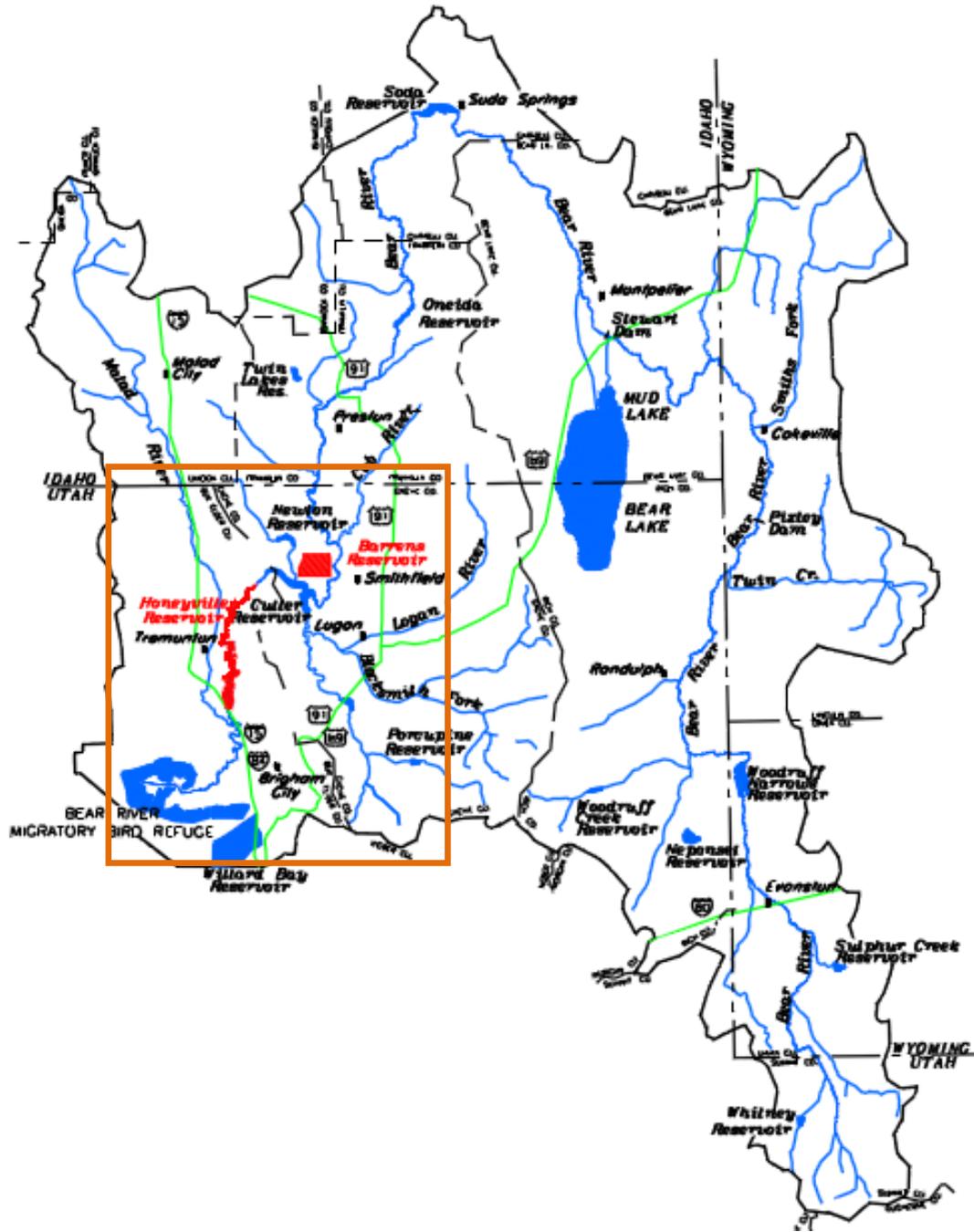


Figure 1. Bear River Basin with Lower Bear River study area highlighted in orange (adapted from UDWR, 2000).

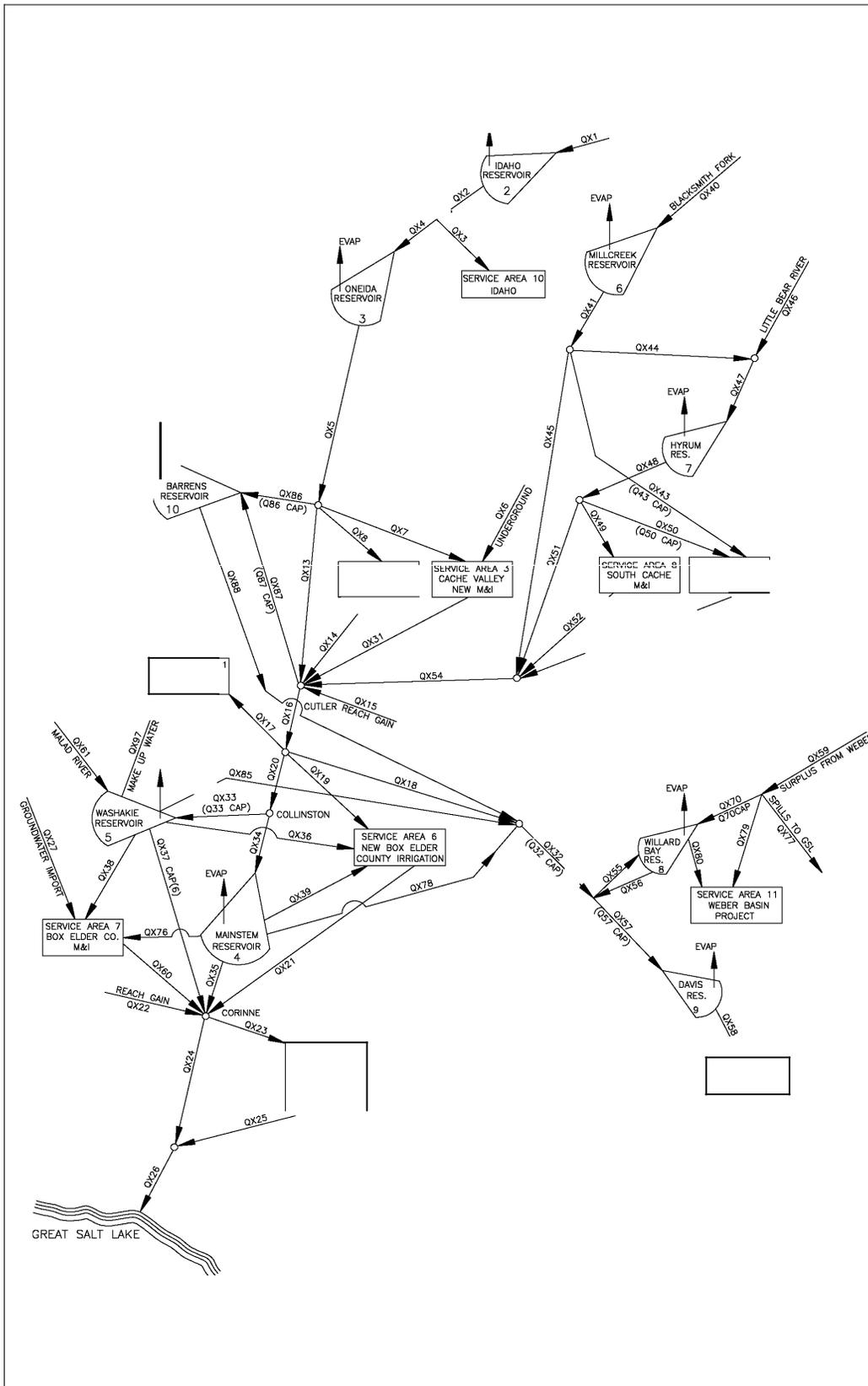


Figure 2. UDWR Bear River simulation model schematic

The WEAP Model

WEAP was developed by the Stockholm Environmental Institute in 1988 and is a software package to help plan and manage water supply. WEAP operates on the principle of mass-balance, and allocates water based on the priorities specified for the system components such as the demand sites, reservoirs, environmental flows (SEI, 2007). WEAP has been used in numerous water resources studies throughout the world, including the Aral Sea (Raskin et al., 1992); Upper Chattahoochee River Basin, Georgia (Johnson, 1994); South Africa (Levite et al., 2003); Sacramento River, California (Purkey et al., 2008); Austin, Texas; Portland, Oregon; and Philadelphia, Pennsylvania (Huber-Lee et al., 2005). Here, you will use WEAP to represent demand sites, reservoirs, transmission links (diversions), and return flows and enter their data.

WEAP partitions reservoir storage into zones (Figure 3). The Flood Zone is reserved to capture flood flows, while the Conservation Zone defines water storage to meet the full delivery requirements of urban, agricultural, hydropower, or other demand sites that draw from the reservoir. Should reservoir storage drop into the Buffer Zone, water deliveries are cut back below the full delivery amount. This cutback amount is specified by the buffer coefficient which determines the fraction of water in the buffer zone to be released. Users can enter the reservoir zone levels and buffer coefficient in WEAP to create model scenarios representing different reservoir storage and release operations and simulate the associated results such as deliveries to and shortages at demand sites (SEI, 2007).

This document will guide you through completing a WEAP model for the Lower Bear River. You will specify three scenarios. One scenario will represent a base case of current conditions (only existing reservoirs). A second scenario will add the proposed reservoir Above Cutler to the base case. And a third scenario will add the proposed Barrens reservoir to the base case. Finally, you will simulate each scenario to determine the effects on the demand sites.

Table 1. Bear River Basin Demand Site Priorities

Priority	Service Area No.	Name	Use Type
Included in WEAP Model			
1	1	Bear River Canal (Company)	Irrigation
2	2	Bird Refuge	Environmental
6	3	Cache Valley New	Municipal
3	4	Cache Valley Irrigation	Irrigation
4	6	New Box Elder County	Irrigation
5	7	Box Elder County	Municipal
Excluded from WEAP Model			
NA	5	Wasatch Front	Municipal
NA	8	South Cache	Municipal
NA	9	South Cache	Irrigation
NA	10	Idaho	Irrigation
NA	11	Weber Basin	Municipal

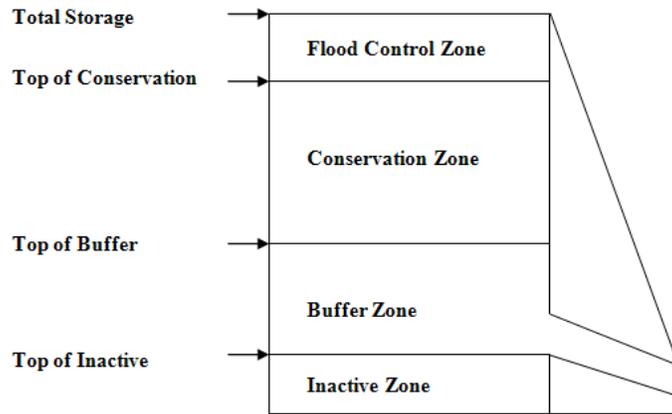


Figure 2. Definition of the operation zone parameters required by WEAP (Adapted from SEI, 2007).

Simplifying Assumptions

In building the WEAP model from the UDWR Fortran model, you should:

1. Use UDWR model flows on QX5 (release from Oneida) to represent headflow on the lower Bear River. This assumption avoids the need to model upstream Idaho reservoirs, demand sites, diversions, and head flows.
2. Similarly, use UDWR model flows on QX54 to represent flow on the Little Bear and Blacksmith Fork rivers into Cutler. Again, this assumption avoids the need to model upstream components on those rivers.
3. Ignore head flows, reservoir operations, and demand sites in the Weber Basin and along the Watach Front.
4. Ignore the Barrens, Washakie, and Mainstem (Honeville) reservoirs since they are no longer under serious consideration.

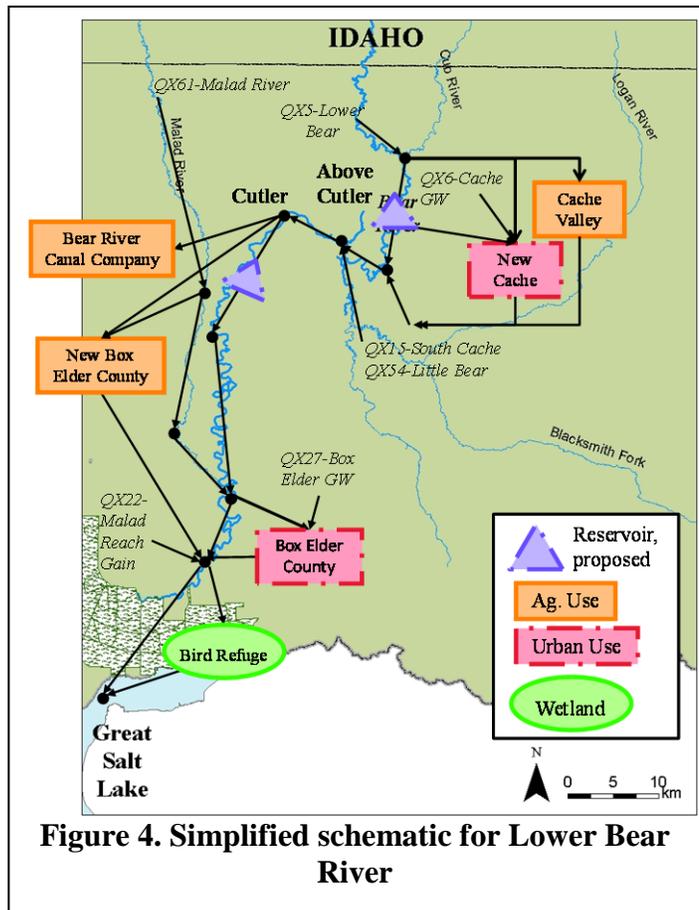


Figure 4. Simplified schematic for Lower Bear River

These assumptions will allow you to simplify the model schematic (Figure 4).

Directed Activity

Below are the steps to follow to get started with building a model of the Lower Bear River in WEAP. Instructions in **Bold** or *Italic* refer to WEAP program items (windows, menus, tabs, input items, etc.). There are also numerous resources—User Guide, forums, etc.—available to help you use WEAP which we will introduce you to in the next section.

WEAP Resources, Installation, and Sample River Basins

1. Go to the WEAP home page (<http://www.weap21.org/>) and overview the resources available for you. These resources include a demonstration, user guide, tutorials, and user forums.
2. Download and install WEAP (skip Step 2 if you are working on a computer where the program is already installed).
 - a. On the left side of the WEAP home page under **Using WEAP**, click **Download**, join the WEAP forum, login with your newly assigned password, and follow the directions from there. Also, read the box “Download WEAP” (below) and start downloading.

Download WEAP

The free, **evaluation** version of WEAP (53 MB) is a fully working version of the software--only the Save Data feature is disabled. To enable, you will need a license number (see step 2b below). This download can also be used to upgrade any existing versions of WEAP.

WEAP requires Windows 2000, XP, Vista or 7, and at least 256 MB of RAM. To install WEAP, right click on the setup program (WEAP_Install.exe) and choose Run as Administrator. The WEAP program (weap.exe) will install under Program Files; WEAP data files will be stored under My Documents.

In some cases, when WEAP is first run the following error message appears: 'Unable to merge new configuration, use BDE Administrator to merge your new configuration'. This is not a problem--click OK to continue. It may also suggest that you should restart your computer, but this is not necessary.

- b. The free version of WEAP you downloaded is an evaluation version and therefore has limited use. Opening the program will prompt you to register the program. To register, enter the **User Name** and **Registration Code** (provided by your professor). After registering, enter your initials and click “End user information” in the window provided.
3. Open the program and explore the *Weaping River Basin* sample model.

- a. In the **Schematic** mode (click top icon at left), explore the system spatial configuration. How many reservoirs, aquifers, and demand sites are in the sample model?
- b. In the **Data** mode (click second icon at left), explore the types of data entered. The data is organized into a tree of *Key Assumptions, Demand Sites, Hydrology, Supply and Resources, Water Quality and Other Assumptions*. How are demands disaggregated and entered for the South City and Agricultural North demand sites? Is this disaggregation the same for other sites? Note this disaggregation is different from demand data in the Weber River Basin case study.
- c. In the **Results** mode, explore the numerous available results for one or multiple model runs (scenarios); four scenarios are defined in the model (*Demand Measures, Integrated Measures, Reference, and Supply Measures*). In the **Chart** view, use the drop-down menu to select results to view. What menu option would you select to view shortages at a demand site (i.e., the difference between the actual delivery and the delivery target)?
- d. Click the **Scenario** icon to view, define, and compare results from the various scenarios created.

The Lower Bear River Basin

Area Setup

4. Unzip the zip file named [LowerBearRiver-WEAP-Start.zip](#) available on the class website which contains a partially-complete WEAP watershed for the Lower Bear River basin. Unzip the folder into *C:\Documents and Settings\...\My Documents\WEAP Areas*. Keep the area name *LowerBearRiver-CEE5460*. If WEAP is already open, close and then reopen it.
5. From the **Area** menu, select **Open** and select the area *LowerBearRiver-CEE5460* from the list. The model should load, and you should see the Lower Bear River Basin schematic. Note that this project includes many of the schematic elements for the Lower Bear River Basin but a few are missing! Compare the WEAP schematic to Figure 4.
 - a. What reservoirs, demand sites, and other elements need to be added in WEAP?

Model Schematic

6. The **Schematic** mode has three tool boxes arranged in a column just to the right of the *Schematic, Data, Results*, etc. icons at the far left. The top box provides tools to add

elements to the model. The middle box shows GIS files which can be layered onto the schematic. And the lower box shows a wide-angle zoom of the schematic.

7. Now, add the elements you identified as missing in Step 5a.
 - a. To add a Demand Site (Service Area in Figure 2 or Box in Figure 4), go to the top box and check *Demand Site*.
 - i. Click the *Demand Site* label in the box, drag it, and drop it at the desired location. Note that you need place Demand Sites only approximately on the WEAP schematic since no shape file layers exist to help in placing.
 - ii. After dropping, a **General Info** window will open. Enter a *Name* and *Optional Label*.
 - iii. Use Table 1 to decide the *Demand Priority*. Recall this priority (similar to water rights) determines the order in which scarce water is allocated and delivered to demand sites. Higher priority (lower numbered) sites receive their full demands before lower priority (higher numbered) sites receive any water.
 - iv. Keep all other options to default values and click **OK**.
 - b. Repeat Step 7a for other Demand Sites that need to be added to the schematic.
 - c. Add *Transmission Links* by dragging the transmission link tool, clicking on the starting point, and dragging to an ending point at a desired *Demand Site*. Keep all other options to default values. You can also add a *Return Flow* from a *Demand Site* back to the river using a similar procedure.
 - d. Place the proposed *reservoirs* in their target locations. Again, click and drag the reservoir icon to the appropriate location on the schematic. In the **General Info** window that opens, enter a *Name*. Leave the *Demand Priority* at the default setting of 99. Since the reservoir is new, it will have the lowest priority to fill should there be surplus water in a year.
 - e. All the other river and groundwater components should be present on the schematic. But check!
8. After adding all the missing elements, save your work!

Data Entry

9. Now enter data for the model elements present on the schematic by selecting the **Data** icon. When entering data, make sure to press Enter after each data entry. Also, information on inflows, demand sites, and reservoirs that you can use for inputs is organized in the file LowerBearRiverModelData.xlsx also available on the class website. You will need to enter data for headflows, reach gains, demand sites, transmission links, return flows, and reservoirs.
10. First, on the **Data For** dropdown list, make sure to select *Current Accounts*.
11. **Headflows**. **Headflows** are the most upstream flow inputs to river elements in the WEAP model and are indicated by the corresponding most-upstream arrows in Figure 4 on each river. Each arrow is also labeled with a name. To assign headflow data:
 - a. In the data tree, select **Supply and Resources=>River**. A data window will open with the **Headflow** tab highlighted. You will be prompted to enter average monthly inflow at the head of the river. Below, you will see a table for the three rivers (Bear River, Little Bear River, and Malad). Headflow data has already been entered for the Bear River. The original headflow data is located on the “QX5-LowerBRInflow” worksheet of the Excel file. The worksheet was saved in CSV (comma separated values) format in the WEAP area, then WEAP reads in the CSV file. Now repeat this process for the Little Bear and Malad rivers.
 - b. In the Excel file, select the worksheet that has headflow data for the Little Bear River. On the **File** menu, select **Save As...** and in the window that opens set **Save as type:** to *CSV (comma delimited) *.csv* and give the file an appropriate name and save it in your WEAP area folder. Note, saving an Excel file as a CSV will only save the active worksheet.
 - c. Back in WEAP, click inside the cell in the **1966** column for the river. A dropdown list icon will appear. Click it and select *ReadFromFile Wizard*. A file window will open. Navigate to and select the CSV file you created in step 10(a)i. A new window will show you a graph of the time-series you just selected. Click **Finish** to return to the Data window.
 - d. Repeat steps b and c to define the headflow for the Malad River. Note, you will not enter water quality or cost data for rivers.
12. **Reach inflows**. **Reach inflows** are local or tributary inflows (sometimes called reach gains) that flow into a river at downstream locations. These reach inflows are also indicated by arrows in Figure 4 and labeled by source (QX15-South Cache Reach Gain; QX22-Malad Reach Gain). Note that the reach inflow data time-series you have been

provided includes values that are both positive (gains) and negative (losses). WEAP can only accept positive values. To accommodate this: In Excel, split each reach inflow time series into two time series – and two CSV files. One time series to represent the non-negative values (substitute zeros for original values that are negative; Series A). And a second series that only shows the negative values but turns them positive; Series B. i.e., Original = Series A – Series B).

- a. *Reach gains (positive values)*. Return to the data tree and open the **River=>Bear River** branches and select **Reaches**. The **Surface Water Inflow** tab will appear at the right with a table for all the Bear River reaches. Enter reach inflows (positive values) for the reaches that require it as you did in steps 11b and 11c above. Note, only select reaches have reach inflows. And you need only enter **Surface Water Inflow** data for reaches. To which reaches did you assign reach gains?
 - b. *Reach losses (negative values)*. We will represent reach losses as required diversions out of the river. We will add a flow requirement to the diversion to require flow through the diversion to represent the reach loss.
 - i. On the schematic, add a **Diversion** just below the node you assigned the reach gain to in step (a). Make sure the *Priority* is set to 1 (so the reach loss is satisfied first) and leave all settings at their default values.
 - ii. Add a **Flow Requirement** to the diversion you created in step b(i). Right-click on the flow requirement, and select **Edit Data=>Minimum Flow Requirement**. In the data window that opens, click the cell for 1967-2006, open the drop-down list, and select *ReadFromFile Wizard*. Then read in the file you created to represent the negative values.
13. *Demand Sites*. Demand sites are locations where water is desired to be used and are represented by boxes or ovals in Figure 4. In the schematic, right click one of the Demand Sites. Select **Edit Data=>Method**. A data window will open.
- a. Select the **Advanced** button at the far right. In the **Method** table, click the Demand Site name, select *Specify monthly demand*, and press enter.
 - b. Select the **Water Use** button. On the *Annual Activity Level* tab, change **Unit** to *AF* (acre foot). Click in the cell 1967-2006, select *Monthly timeseries wizard*, and enter montly demands in the new window using the demand site data provided in the Excel file.
 - c. On the **Consumption** tab, enter the appropriate *Consumption* rate for the site based on the return flow fraction data provided in the Excel file.

- d. Ignore the **Loss and Reuse, Demand Management, Water Quality, and Cost** buttons. But verify that the **Priority** setting is correct. Remember that priorities for demand sites should all be less than the priorities previously entered for reach losses Step 12b.
 - e. Repeat steps a to d for each Demand Site.
14. *Transmission Links*. In the schematic, right click on a *Transmission Link* and select **Edit Data=>Maximum Flow Volume**. Leave nearly all settings at their default values (i.e., unlimited capacity, no losses, and no costs). On the Supply Preference tab, verify that transmissions from the Bear River have highest priority (1) and that transmissions from other sources (the Malad River, groundwater, etc.) have lower priority (2).
 15. Return Flows. Right click on a Return Flow, and select **Edit Data=>Return Flow Routing**. Again, leave all settings at their default values (i.e., 100% return flow routing, zero loss from system, zero groundwater loss, zero gain from groundwater, and no costs). *What does a setting of 100% return flow routing mean?*
 16. *Reservoir Data*. On the schematic, right click on a reservoir you created in Step 7, and select **Edit Data=>Storage Capacity**. A data window will open. Enter the **Physical, Operation, and Priority** data for the reservoir by clicking the various buttons.
 - a. **Physical Data**: On the *Storage Capacity* and *Initial Storage* tabs, enter data using the appropriate units. On the *Volume Elevation Curve* tab, use the two column table provided to enter data for the Volume-Elevation Curve. On the *Net Evaporation* tab, chose *Monthly Time-Series Wizard* under the year 1950. Then enter the monthly values provided. Leave *Loss to Groundwater* at the default setting of zero.
 - b. **Operation Data** defines the reservoir zones (pools) and releases from them. Enter storage volumes that correspond to the *Top of Conservation, Top of Buffer, and Top of Inactive* pools. Enter the *Buffer Coefficient* as a number between 0 and 1 to indicate the fraction of water in the buffer pool available for release each month (should the storage level drop into the buffer pool). Remember, the new proposed reservoirs will be used primarily to supply water and the buffer pool represents the storage level at which deliveries to demand sites are cut back (by the buffer coefficient).
 - c. Note, you will not enter hydropower, water quality, or cost data for reservoirs.
 - d. Make the reservoir inactive (for the base case). Click the **Physical Button** again. In the **Storage Capacity** tab, set the reservoir capacity to zero.

17. Congratulations! You have now (hopefully) entered all the model data.

Model Results

18. With the system schematic represented and all pertinent data entered, you can now run the model and generate results for the base case that represents current conditions.
19. Click the **Results** icon. When asked to recalculate results, select **Yes**.
20. There are numerous results to view and explore in WEAP. To view results for an element, right-click the element and select **View Results** and the result type. For example:
 - a. Which demand site(s) have unmet demand (i.e., experience shortage(s))?
 - b. What is the reliability of deliveries to the Bear River Canal Company and New Urban Users in Cache County?
 - c. What is the annual firm yield / annual firm delivery to New Urban Users in Cache County (a water year starts in October and ends in September of the following year)?
 - d. A variety of tools are available at the right-hand-side of plots to reformat and export results, including exporting to Excel. What is the delivery-reliability curve for New Urban Users in Cache County?

Scenario Explorer

21. Scenarios allow you to test the effects of new infrastructure, operations, demand forecasts, climate projections, or other changes to model inputs. In this exercise, you will create and test two scenarios representing the addition of two new reservoirs.
22. The first scenario will add the Above Cutler reservoir.
 - a. First, create the scenario. Click the **Data** icon. On the top row of the data page, click the **Manage Scenarios** button. In the **Manage Scenarios** window select *Current Accounts(1966)* and click the **Add** button at the top left corner of the window. Finally, **Name** the new scenario something meaningful like *With Above Cutler*. Click **OK** and close the windows to return to the **Data** page.

Now change one or more inputs to reflect the new scenario. What input data did you change and where? [Hint: Return to Step 16].

- b. Run the new scenario (see Step 19). What are the answers to questions 20a–d above?
23. Create a second scenario that represents the inclusion of the 2nd reservoir instead of Above Cutler. (Hint, either repeat Step 22 or use the dashboard in the Scenario Explorer). Again, what are the answers to questions 20a–d above? To compare results among scenarios:
 - a. Go to the **Results** mode. Select a result type from the dropdown menu located on the top middle of the screen. Choose a convenient unit for the volume.
 - b. Choose a location, make sure that the *All months* option is selected, and unselect the **Monthly Average** box.
 - c. In the dropdown menu to the right of the label **Monthly Average**, choose *No Comparison*. From the far right drop down menu, choose *All Scenarios*. Make sure *All Years* is selected at the bottom of the window.

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