Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

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Chapter 5
Visualizing DSM2 Simulation Results with ArcMap

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5.1 Introduction

The Delta Simulation Model 2 (DSM2) has been widely used for three types of Delta simulations: historical conditions, near- and long-term forecasting, and planning studies. DSM2 simulations have been applied for various purposes. Some examples include forecasting water quality in the Delta and the California Aqueduct system, generating hydrologic information for a permit application, and providing support for litigation. Since DSM2 simulation results can be presented to members of the public coming from various backgrounds, it is vital to present simulation results tailored to meet the needs of different audiences. In the past, the visualization of DSM2 EC (Electrical Conductivity) results was readily accepted. Even so, it takes many steps to prepare an animation, and the process relies on a program called Tecplot, which was fairly uneconomical to purchase, especially considering that Tecplot has been rarely used by other staff in the Bay-Delta Office.

In this chapter, we will present several ways to visualize DSM2 simulation results with ArcMap, a product of Environmental Systems Research Institute (ESRI). A programming language, Python, is used to convert DSM2 output to ArcGIS geodatabase or NetCDF files.

5.1.1 Python

Python is a widely used, general purpose, high-level programming language. As an open source and freely distributed language, Python has an extensive standard library that provides tools suited for many tasks. It is great for use as a scripting language to connect existing components together. Python was introduced to the ArcGIS community at version 9.0. Since then, it has been accepted as the scripting language of choice for ArcGIS users and its use has continued to grow. At ArcGIS Desktop 10, Python scripting is tightly integrated into ArcMap and ArcCatalog, allowing users to create and automate geographic information system (GIS) workflows quickly and easily. Python scripts can be executed outside of ArcMap's Python console to perform geographic data analysis, data conversion, data management, and map automation. In the Bay-Delta Office, a large number of site packages or modules were developed to post-process DSM2 simulation results.

5.1.2 ArcGIS

ArcGIS is a GIS developed by ESRI for working with maps and geographic information. ArcMap is the main component of ESRI's ArcGIS suite of geospatial processing programs. It is used primarily to view, edit, create, and analyze geospatial data. Animation tools are available in ArcMap since ArcGIS 9.2 was released. A Python site package, ArcPy that comes with ArcGIS 10, enables the integration of ArcGIS tools and functionality in Python.

5.1.3 DSM2 Output

DSM2 supports two types of output format, which are the U.S. Army Corps of Engineers' Hydrologic Engineering Center Data Storage System (HEC-DSS) and Hierarchical Data Format (HDF). Both were originally developed at the National Center for Supercomputing Applications. DSM2 uses HEC-DSS files to store simulation results at specified locations and time intervals, and HDF5 files to store simulation results for all DSM2 upstream and downstream channels. Before DSM2 8.1, only hydro simulation results could be stored in HDF5 files. Now both Hydro and QUAL simulation results, such as EC, EC fingerprinting and volumetric fingerprinting can also be stored in HDF5 files. Accordingly, animations can be created for all DSM2 simulation results.
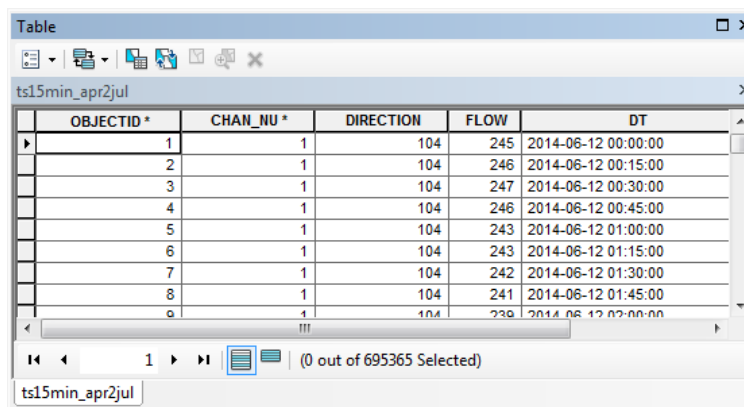
5.1.4   NetCDF

NetCDF is an array-based data structure for storing multidimensional data. It is interoperable with HDF5, and so a common program can be used to view both HDF5 and NetCDF data. ArcGIS version 9.2 introduces support for working with NetCDF files. With the Multidimension Tools toolbox, a user can create raster layers, feature layers, and table views from NetCDF data in ArcMap, or convert feature, raster, and table data to NetCDF. At any given time, only one slice of multidimensional data is visible.

5.2   Steps to Create Animation in ArcMAP

It takes several steps to create animations to visualize DSM2 simulation results.

Step 1: Data Conversion

DSM2 simulation results cannot be directly imported to ArcMap for visualization. As a result, Python scripts were written to store DSM2 simulation results in ArcGIS geodatabase in the form of a data table with at least three fields: channel number, date/time, and value (Figure 5-1). Python scripts were also written to convert DSM2 simulation results to raster and store in a NetCDF file (Figure 5-2).

Figure 5-1 A Table Stored in Geodatabase with Flow Results Retrieved from a DSM2 HDF5 File
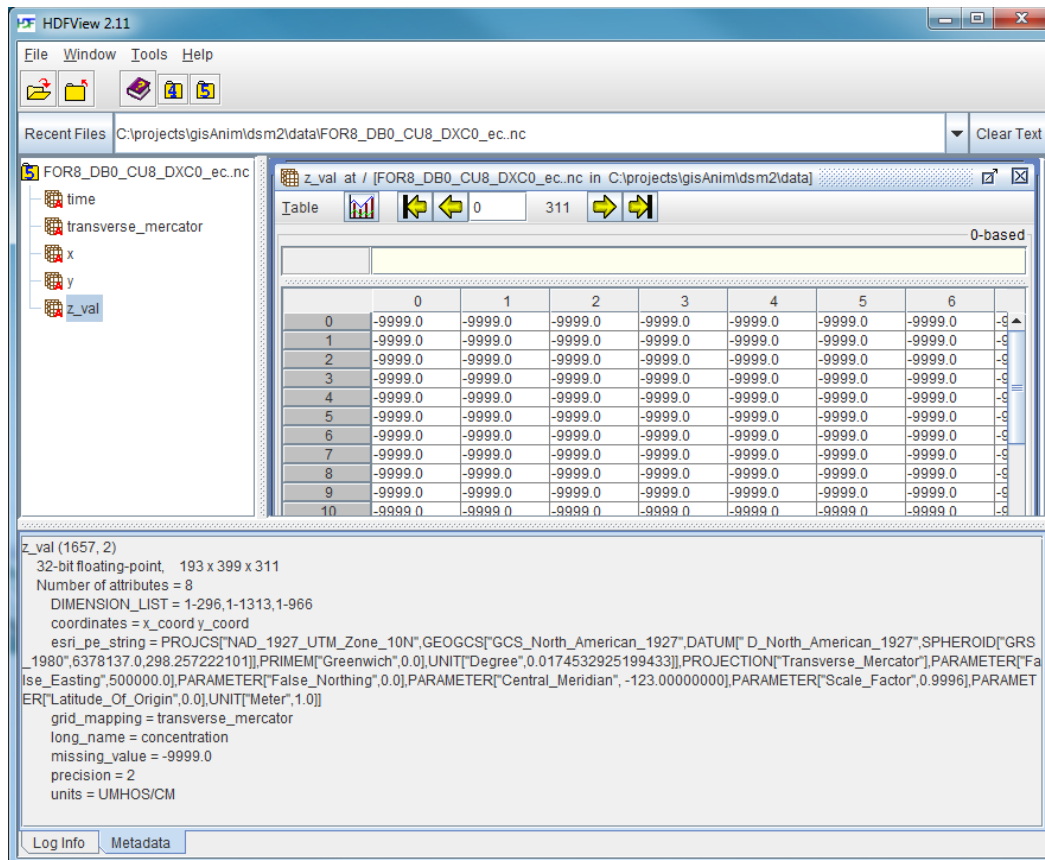
Figure 5-2 A NetCDF File Opened with HDFView

To store DSM2 simulation results in ArcGIS geodatabase, the Python scripts first call functions in Vtools developed by the Bay-Delta Office to read DSM2 simulation results from HEC-DSS files, or call the site package h5py to read DSM2 simulation results from HDF5 files. Then, the Python scripts save time series data in an Excel csv file. Finally, the Python scripts call the function TableToGeodatabase_conversion in site package ArcPy to store the table from the Excel csv file in a geodatabase that can be used in the next step.

To store DSM2 simulation results in NetCDF files, a Python script uses h5py to read DSM2 simulation results from a HDF5 file. Each time the script reads data for all channels, but only for a one-time step. Then, the Python script saves data in an Excel csv file, creates an ArcGIS shape file from the Excel csv file, converts the shape file to a raster file, exports the raster file to an ASCII file, and stores ASCII data in a NetCDF file. The steps are repeated until all the simulation results during the period specified by a user are processed. Figure 5-3 shows the flowchart for post-processing DSM2 simulation results stored in a HDF5 file and stored in a NetCDF file, which can be used in the next step.
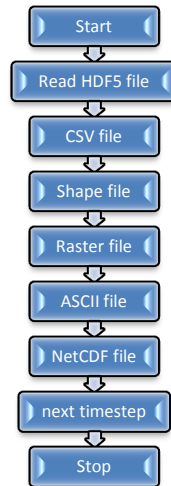
Figure 5-3 Processes for Storing DSM2 Simulation Results to a NetCDF File

Step 2: Add Data to ArcMap

A table with stored DSM2 results in a geodatabase does not have spatial information. Once it is added to ArcMap, it can be joined with a geographic layer by using a join key. From ArcMap, right click the table, from the content menu, choose "joins and relates" -> "join…", a window with join information will pop up. Figure 5-4 is such a window which shows the table (ts15min_apr2jul) in a geodatabase that is joined to a DSM2 channel layer using the common field for Channel Number. After the Join operation is finished, the geographic layer contains time series from another table.
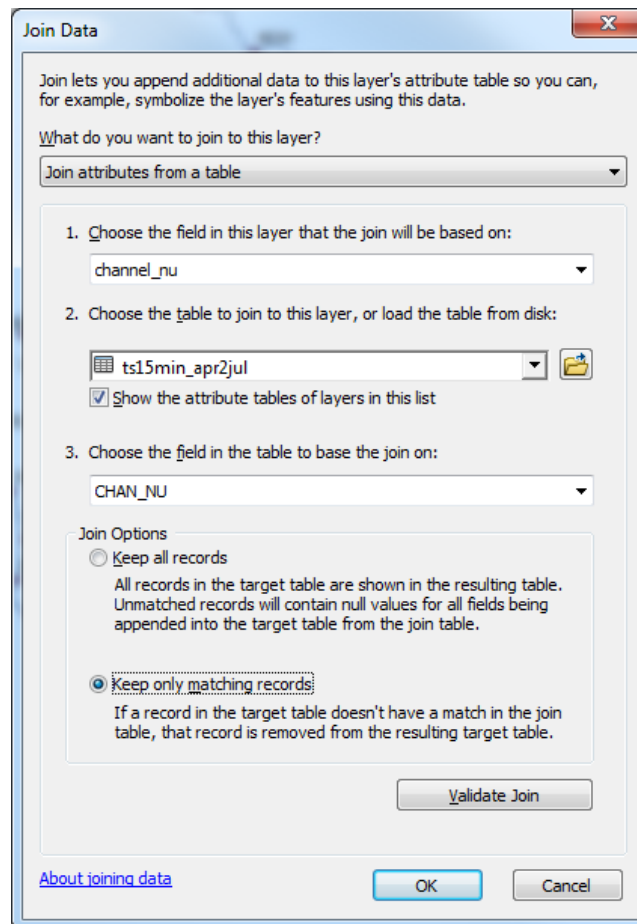
Figure 5-4 Time Series Data is Appended to the Attribute Table of a Layer with Geographic Information by Using the Join Operation

Multidimensional data stored in a NetCDF file can be loaded as a raster layer through the Multidimension Tools in ArcMap Toolbox as shown on the left side of Figure 5-5. The NetCDF file contains geographic information, such as coordinates and spatial reference, so it does not need to get this information from another geographic layer.
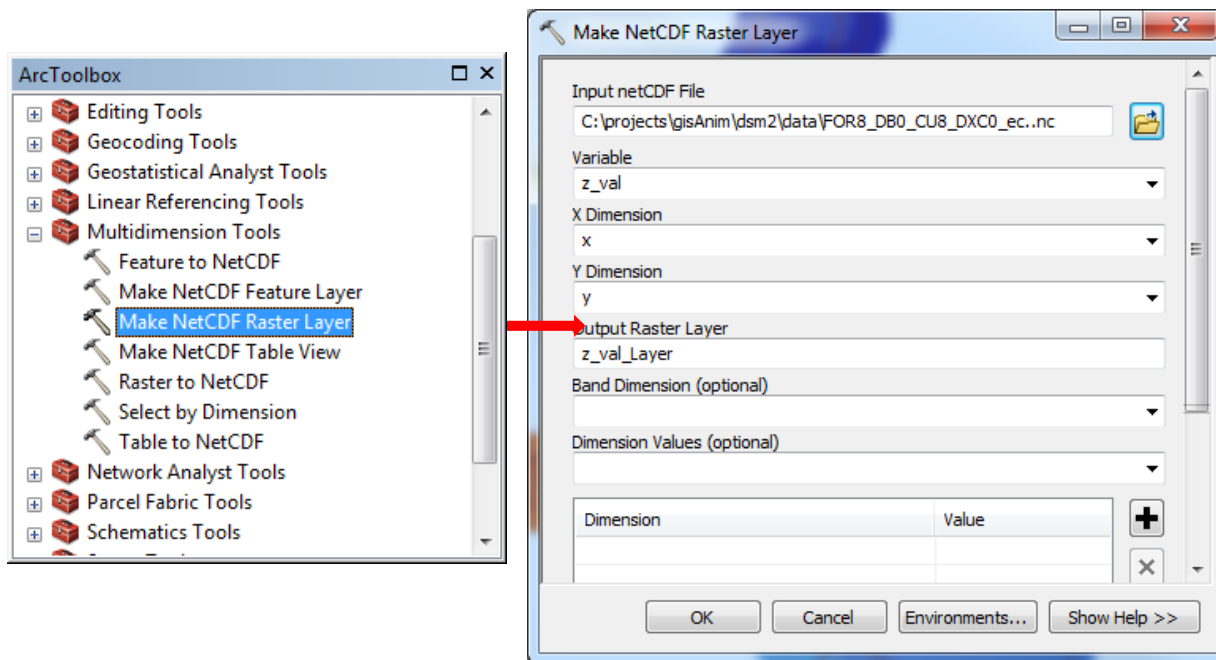
Figure 5-5 Data Stored in a NetCDF File is Loaded to ArcMap as a Raster Layer through Multidimension Tools

Step 3: Enable Time on a Layer

Once the table is joined to a layer or is loaded as a raster layer, access the layer properties by right-clicking the layer name in the Table of Contents pane. Navigate to the Time tab and check the box labeled as "Enable time on this layer". ArcMap needs to know which table field contains time information, as well as the format. If the Join operation was successful, the fields that represent the data joined to the geographic layer are visible from the table of the geographic layer. If the Join operation was not successful, then check files created by Python scripts to ensure they are correctly created. In this example, the Time Field is labeled DT. Also, specify the date/time format (Figure 5-6). Available time formats are listed on the drop-down list shown in Figure 5-6.

If a geographic layer gets its data from a data table through the Join operation, which is a way we recommend, then it is also necessary to enable time on the data table as well. To do this, right-click the data table in the Table of Contents pane. Follow the same steps listed to enable time on the geographic layer.
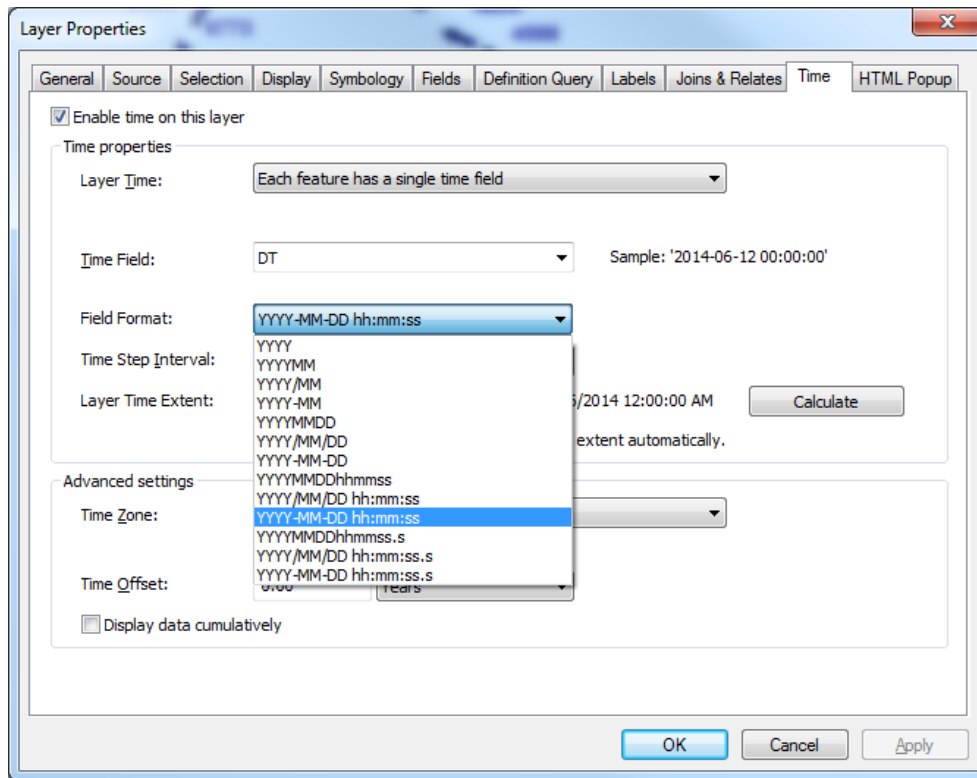
Figure 5-6 Enable Time on a Layer

Step 4: Configure Visual Display

In this step, it is necessary to specify what will be shown on the map. For a feature class layer, enter the Layer Properties window by right-clicking the layer name in the Table of Contents pane. Navigate to the Symbology tab and click on it. The options for Symbology are displayed in Figure 5-7. In this example, table field Flow is chosen to show on this map as either red or blue arrows that represent negative or positive flow. On the right side near the bottom of the window is the "Advance" pushbutton with a pull-down menu. From there, choose the "rotation" option and set the direction of flow to the direction of a channel, which is a field in the geographic layer. The size of an arrow can be specified to represent the magnitude of flow by choosing the "size" option and assigning the size of an arrow to be a function of flow (in this example, the function is 3*log(abs(flow rate))). Also, the Layer Properties window has an option to show flow numbers from the Labels tab.

A raster layer can show data for the whole domain at each time step so the spatial change of EC, flow, velocity and other DSM2 outputs can be animated. For a raster layer, follow similar steps to specify how to visualize data. From the Layer Properties window, navigate to the Symbology to choose Color Ramp and Range, navigate to the NetCDF to select variable to be animated, and the x and y dimensions, and navigate to the Time tab to check 'Enable time on this layer" , specify time dimension, and field format for Date/Time.
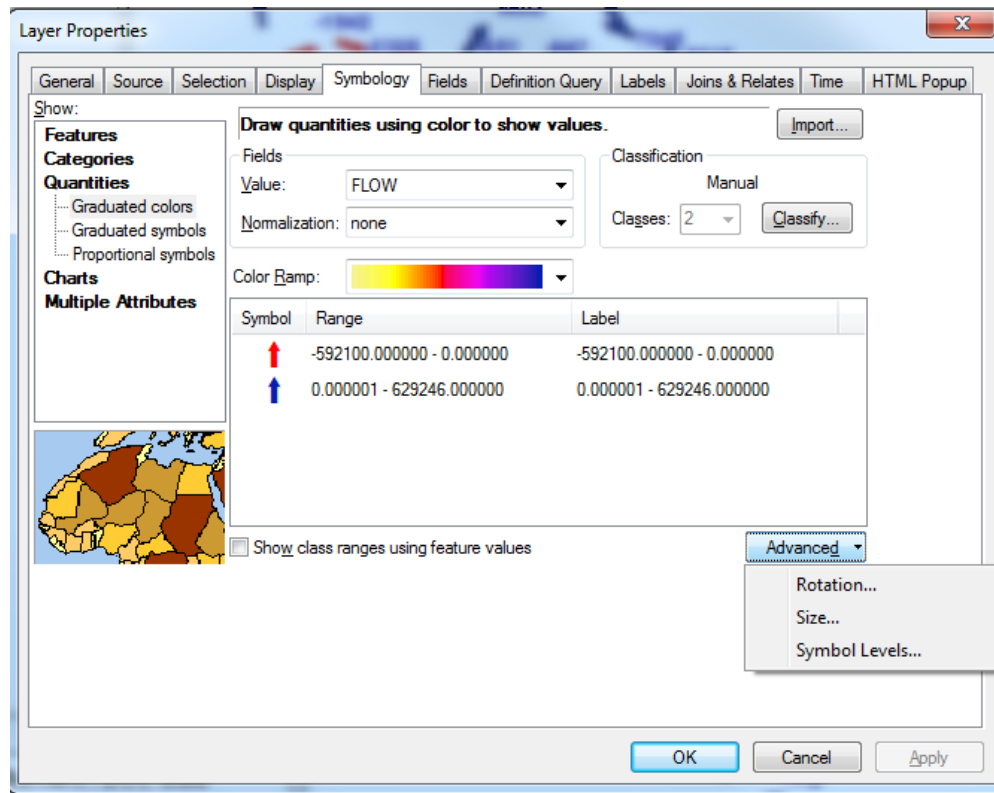
Figure 5-7 Configure Visual Display

Step 5: Start Visualization

Now that ArcGIS understands the data structure, start time visualization. From the Tools toolbar, which contains the most commonly used tools, open the Time Slider window (Figure 5-8). The slider spans the time range of the data, identifies what point in this range is currently displayed on the map, and allows for access to a variety of playback and recording options. To access these options, click the Options button (the middle button of the three buttons on the top left of the window shown in Figure 5-8).
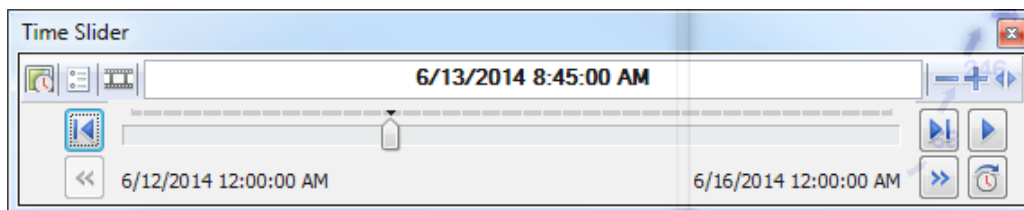

Figure 5-8 Time Slider

This is a Play button. By clicking on it, the data from the first time point to the last will be played.

This is the Forward button with data point moving forward in one-step increments. The buttons with an arrow pointing from right to left and a vertical line is the Reverse button.

This button exports the display to video. This is the final step.

Step 6: Export to Video

Once the map is satisfactory, export the map to video or to sequential images. Click the Export to Video button on the Time Slider window. Videos can be exported as AVI files or other formats, while sequential images are exported to a folder either as bitmaps or JPEGs. The first attempt may not produce the desired results, but trying different options (video resolution, fame rate, enable off-screen recording, and etc.) should produce a satisfactory product.

5.3 Examples

Any DSM2 simulation results can be visualized with ArcMap. Templates have been developed to visualize flow, stage, velocity, EC, EC fingerprint, and volumetric fingerprint. Animations can be created from either a feature class layer or a raster layer. Figure 5-9 is an example of visualizing stage data through a feature layer. Two sets of bars stand side by side. The bar on the left side is a stage profile for the scenario without drought barriers. The bar on the right side is a stage profile for the scenario with drought barriers. The two stars indicate the two proposed drought barrier locations. Figure 5-10 is an example of visualizing data contained in both a feature layer and a raster layer. EC values are shown as rasters for the entire Delta. X2 location (the location where the salinity of the water near the bottom is 2 parts per thousand) is marked as black. Inflow and outflow/exports are shown in text.
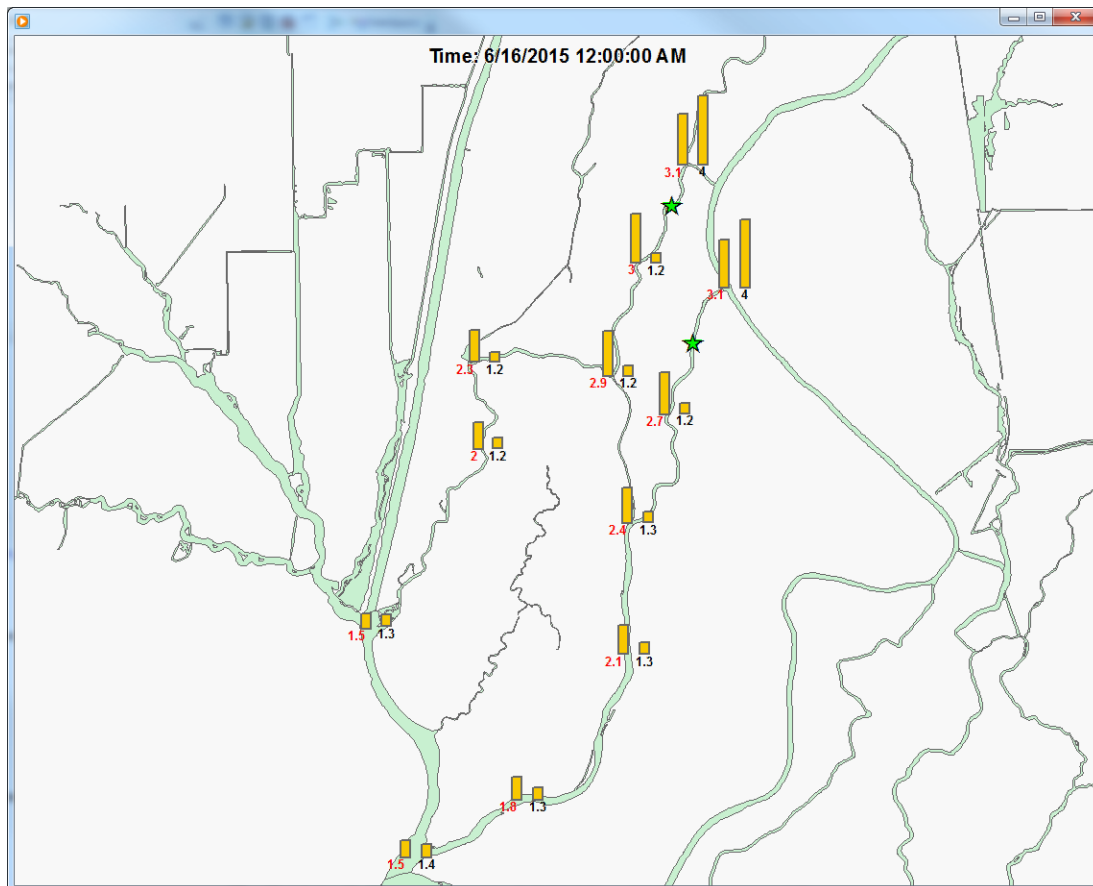

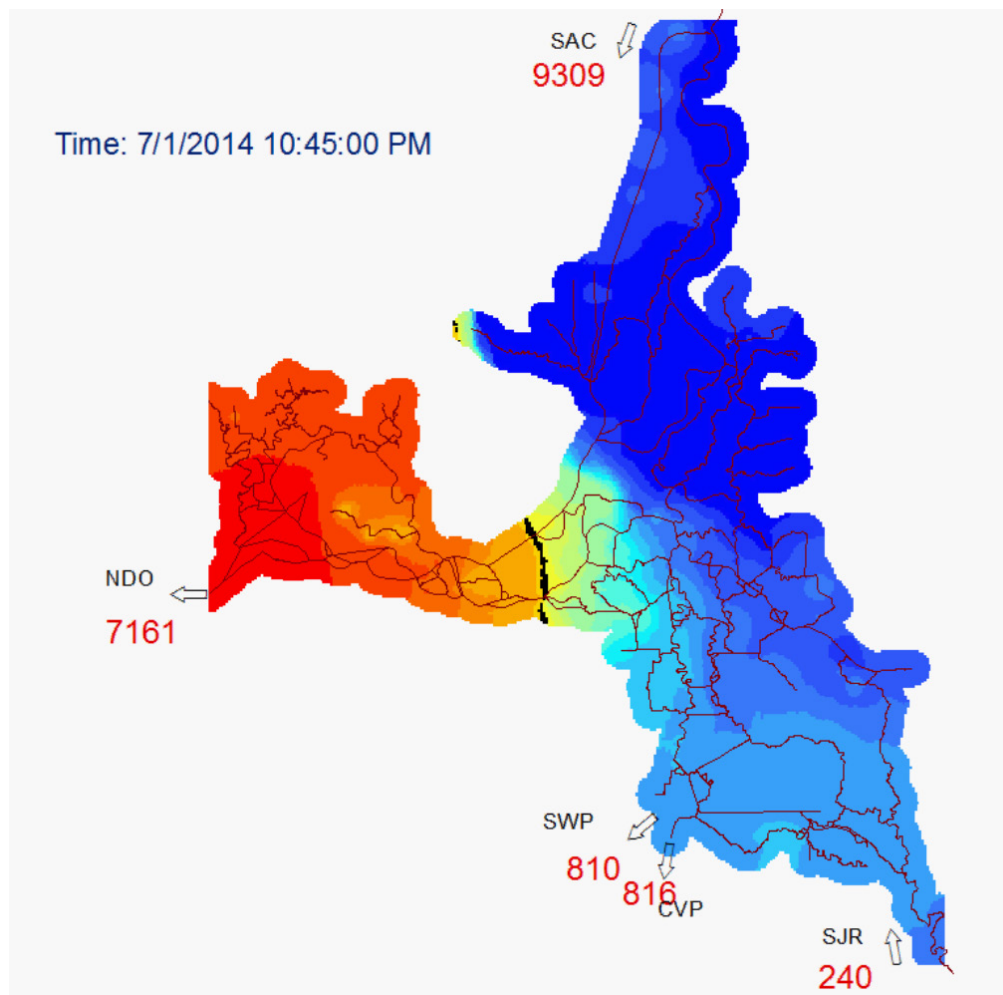**Figure 5-9 Stage Profile for Two Scenarios (with/without barriers)**

Figure 5-10 EC in the Delta with X2 Shown in Black

5.4   Conclusions

Visualization tools can help in understanding Delta hydrodynamics, and the tools also make it easier to verify model results and compare different scenarios. In this chapter, we pointed out the programs/tools that were used to create animations for visualizing DSM2 simulation results with ArcMap. We listed the key steps to create an animation from scratch, and provided two animation examples; one for a feature layer and another one mainly for a raster layer. With ArcMap, we may place several animations together without much extra work. A user can also show static information along with dynamic information to enhance visualization effects. With the help of Python scripts, it is much easier to create animations for visualizing DSM2 simulation results with ArcMap.

5.5   References

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Denniston R. 2011. *Time Series Visualizations in ArcGIS – An Introduction*. Data and Visualization Services. Duke University Libraries. Durham (NC): Viewed online at: http://blogs.library.duke.edu/data/2011/07/18/time-series-visualizations-in-arcgis-an-introduction/.

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