Transboundary Module -- Marissa Reno

1. Description of the data with citations.

1.1. Hydrologic Inflows:

The transboundary module of the Iraq Water Systems Planning Model calculates inflows from the Tigris and Euphrates at the Iraq border. Because there is no information on existing or planned Iranian projects on the Greater Zab, Lesser Zab, or Diyala tributaries, inflows from these tributaries are treated in the Surface Water Module; inflows from the Karkeh are treated in the Marsh Module. The critical hydrologic inputs to the Transboundary Module are the inflows from the major tributaries to the Tigris (Batman, Garzan, and Botan) and the Euphrates (Furat Su, Murat Su, and Khabour). This module also considers all other tributary flows included in the 2005 Schematic Diagram for Main Control Structures for Tigris & Euphrates Basin (Schematic Diagram for Main Control Structures for Tigris & Euphrates Basin. Sep 30, 2005. Ministry of Water Resources, General Directorate of Water Resources Management (Hydrological Studies Center). [\..\..Iraq water data\Maps\Schematic_Page_2.jpg]), provided by Maged Hussein, hereafter referred to as the "2005 MoWHSC Schematic Diagram", but these are considered minor compared to those previously listed. When a tributary name is not available from the 2005 MoWHSC Schematic Diagram, the tributary is referenced to the dams that it occurs between or above. Listed starting with the most upstream tributary, the nine minor tributaries contributing to the Tigris are the inflow to Kralkizi Dam, Dipni, inflow to Devegecidi Dam, Gok Su, Savur, Ambar, Pumuk, unnamed tributary downstream of Silvan upstream of Kayser (abbreviated "ds Silvan us Kayser", and unnamed tributaries downstream of Ilisu and upstream of Cizre (abbreviated "ds Ilisu us Cizre"); the seven minor tributaries contributing to the Euphrates are the Perl Su, unnamed tributary downstream of Keban upstream of Karakaya (abbreviated "ds Keban us Karakaya"), Omsli, Gak Su, Begirman, Kara Su, and Nizip.

Monthly tributary inflows, in cubic meters per second, to the Tigris and Euphrates are derived from gage data obtained from two sources. The first source is daily gage data collected on the Garzan (gage 2603, 37°57'54"N 41°20'45"E) and the Furat Su (gage 2119, 39°41'02"N 39°23'37"E. The second source is select monthly gage data provided in spreadsheet form by Ali K. Jasim, a Water Resources Management Engineer at the Iraq Ministry of Water's Hydrological Studies Center (MoWHSC), in an email on January 9, 2008. The following table summarizes the data from each of these sources used for module input.

Gage Location	Time Scale	Range	Source
Euphrates Hit	Monthly	1932-1972	HSC
Euphrates Husaybah	Monthly	1973-2007	HSC
Tigris Mosul City	Monthly	1931-1985	HSC
Tigris above Mosul Reservoir	Monthly	1986-2007	HSC
Furat above Keban Dam	Daily	1954-1987	Gage 2119
Garzan	Daily	1945-1986	Gage 2603

Table 1: Summary of data used in Transboundary Module.

The gage data for the Garzan and Furat Su are combined with the data provided by the MoWHSC to generate a complete record that spans the entire period over which the model is currently run (October 1930 through September 2007); these data sets are referred to as the Garzan and Furat Su reference hydrographs and appear in the model as variables named 'tb tigris tributary inflow_reference hydrograph' (Garzan) and 'tb euphrates tributary inflow_reference hydrograph' (Furat Su). These reference hydrographs are then used to generate synthetic flow records for the twenty remaining tributaries. The table below lists each tributary considered in the Transboundary Module and describes how the flow record used as model input is generated.

Tributary	River	Flow Record Description
Inflow to Kralkizi	Tigris	Scaled and weighted Garzan reference hydrograph.
Dipni	Tigris	Scaled and weighted Garzan reference hydrograph.
Inflow to Devegecid	Tigris	Scaled and weighted Garzan reference hydrograph.
Gok Su	Tigris	Scaled and weighted Garzan reference hydrograph.
Savur	Tigris	Scaled and weighted Garzan reference hydrograph.
Ambar	Tigris	Scaled and weighted Garzan reference hydrograph.
Pumuk	Tigris	Scaled and weighted Garzan reference hydrograph.
Batman	Tigris	Scaled and weighted Garzan reference hydrograph.
Garzan	Tigris	Oct-1945 to Sep-1986: gage data (M. Ozger). Oct-1931 to Sep-1945 and Oct-1986 to Sep-2007: synthetic data predicted from correlation with Tigris gage data (HSC). Transboundary Module variable 'tb tigris tributary inflow_reference hydrograph'.
Botan	Tigris	Scaled and weighted Garzan reference hydrograph.
ds Silvan us Kayser	Tigris	Scaled and weighted Garzan reference hydrograph.
ds Ilisu us Cizre	Tigris	Scaled and weighted Garzan reference hydrograph.
Furat Su	Euphrates	Oct-1954 to Sep-1987: gage data (M. Ozger). Oct-1931 to Sep-1954 and Oct-1987 to Sep-2007: synthetic data predicted from correlation with Tigris gage data (HSC). Transboundary Module variable 'tb euphrates tributary inflow_reference hydrograph'.
Murat Su	Euphrates	Scaled and weighted Furat Su reference hydrograph.
Perl Su	Euphrates	Scaled and weighted Furat Su reference hydrograph.
ds Keban us Karakaya	Euphrates	Scaled and weighted Furat Su reference hydrograph.
Omsli	Euphrates	Scaled and weighted Furat Su reference hydrograph.
Gak Su	Euphrates	Scaled and weighted Furat Su reference hydrograph.
Begirman	Euphrates	Scaled and weighted Furat Su reference hydrograph.
Kara Su	Euphrates	Scaled and weighted Furat Su reference hydrograph.
Nizip	Euphrates	Scaled and weighted Furat Su reference hydrograph.
Khabour	Euphrates	Scaled and weighted Furat Su reference hydrograph.

Table 2: Tributaries included in the Transboundary Module with descriptions of how flow records are generated.

A complete description of the method by which the Garzan and Furat Su reference hydrographs were scaled and weighted will be included in the final report.

1.2. Salinity of Hydrologic Inflows

We have not found data showing observed salinity of the twenty-two tributary inflows to the Tigris and Euphrates upstream of the Iraq border. We are using pre-development averages of 250 ppm for the Tigris as it enters Iraq and 450 ppm for the Euphrates as it enters Iraq. These values were provided by May Yousif, an Irrigation and Drainage Engineer at the Iraq MoWHSC, during the first Iraq Water Resource Modeling Workshop (November 2007, Amman, Jordan). As upstream development occurs during the model simulation, evaporative losses from each system are calculated and the pre-development salinity values concentrated by a factor corresponding to these losses.

1.3. Hydrologic Losses

The Transboundary Module models losses due to reservoir evaporation and crop evapotranspiration. Reservoir evaporation is modeled using available surface area to volume relationships and one year of monthly evaporation rates that are repeated each year that the model is run. Surface area and volume data for each reservoir are further discussed in section 1.4. The evaporation data are the average of rates calculated with the Penman formula using measurements taken at the Diyarbakir, Siirt, and Cizre meteorological stations. The description of these data and a table of values can be found on pages 20 through 21 of the Ilisu Dam and HEPP: Environmental Impact Assessment Report, published in July 2005 by the Ilisu Consortium [http://www.dsi.gov.tr/ilisu/ilisu_ced_eng_ek1.PDF]. Losses due to crop evapotranspiration are estimated by multiplying irrigated acreage (hectares) by a consumptive withdrawal term (meters per year). Because much of the irrigable area in Turkey and Syria has yet to come under cultivation, total potential acreages are included in the model along with controls for when acreages begin to be irrigated and how long it takes for the full area to come under development. Total irrigated acreages by project closely follow the information supplied on the 2005 MoWHSC Schematic Diagram and have been checked against and refined according to additional information on the GAP project (http://www.gap.gov.tr/gap_en.php). The value for the consumptive withdrawal term is fixed at 1.6 meters per year and comes from Ali, A.M., T. Hantush, and D.Y. Bashoo, Water resources in Iraq, provided by UNESCO's Ryuichi Fukuhara.

1.4. Reservoir Operations

Reservoir operations are modeled in the Transboundary Module using the following reservoir properties: year online, inactive pool volume, capacity, conservation storage, min/max/desired release (for purposes other than irrigation), irrigation release, and primary purpose. The table below summarizes the sources used to determine these properties, with the exception of irrigation release (see section 1.3 for this information). Each source is represented by a number in the table; numbers with corresponding detailed information on the source are shown below the table. If no source is listed, then the value is approximated in the model; a complete description of the method by which these properties are estimated will be included in the full report.

Reservoir	Reservoir Property							
	Year Online	Inactive Volume	Capacity	Cons. Storage	Min release	Max release	Desired release	Primary purpose
Kralkizi	1		1,2,3					1,3
Dicle	1		1,2,3					1,3
Devegecidi	1		1,2,3					1,3
Silvan								3,4
Kayser			2					4
Batman	1		1,2					1,3
Garzan			2,3[c]					3,4
Sirvan								
Eruh								
Ilisu		4	4		4	4	4	3,5
Cizre		4	3,4					3,4
Hakarri								
Alpaslan								
Gulbahar								

Uzuncayir								
Keban	1		1,2,3		6	6	1,4,6	1,3,6
Karakaya	1		1,2				1,4,6	1,3,6
Ataturk	3	6	2,6				1,4,6	1,3
Biercik	1		1,2					1,3
Kayacik	1		1					1,3
Karkamis	3		2					3
Tisherin	3		2					3
Al-Tabaka	3,5,6[c]		2,3,6[c]					3
Al-Ba'th	3.5		2.5					3
Al-Khabour								

[1] Turkey General Directorate of State Hydraulic Works dam search, http://www.dsi.gov.tr/baraj/aramaeng.cfm.
[2] 2005 MoWHSC Schematic Diagram.
[3] The Mesopotamian Marshlands: Demise of an Ecosystem. 2001. UNEP/DEWA/GRID http://www.grid.unep.ch/product/publication/download/mesopotamia.pdf
[4] Ilisu Dam and HEPP: Environmental Impact Assessment Report. July 2005. Ilisu Consortium. http://www.dsi.gov.tr/ilisu/ilisu_ced_eng_ek1.PDF
[5] Rivers of Fire: The Conflict Over Water in the Middle East. 1999. Arnon Soffer.
[6] The Euphrates River and the Southeast Anatolia Development Project. 1991. John F. Kolars and William A. Mitchell.
[c] Indicates conflicting values from sources listed.

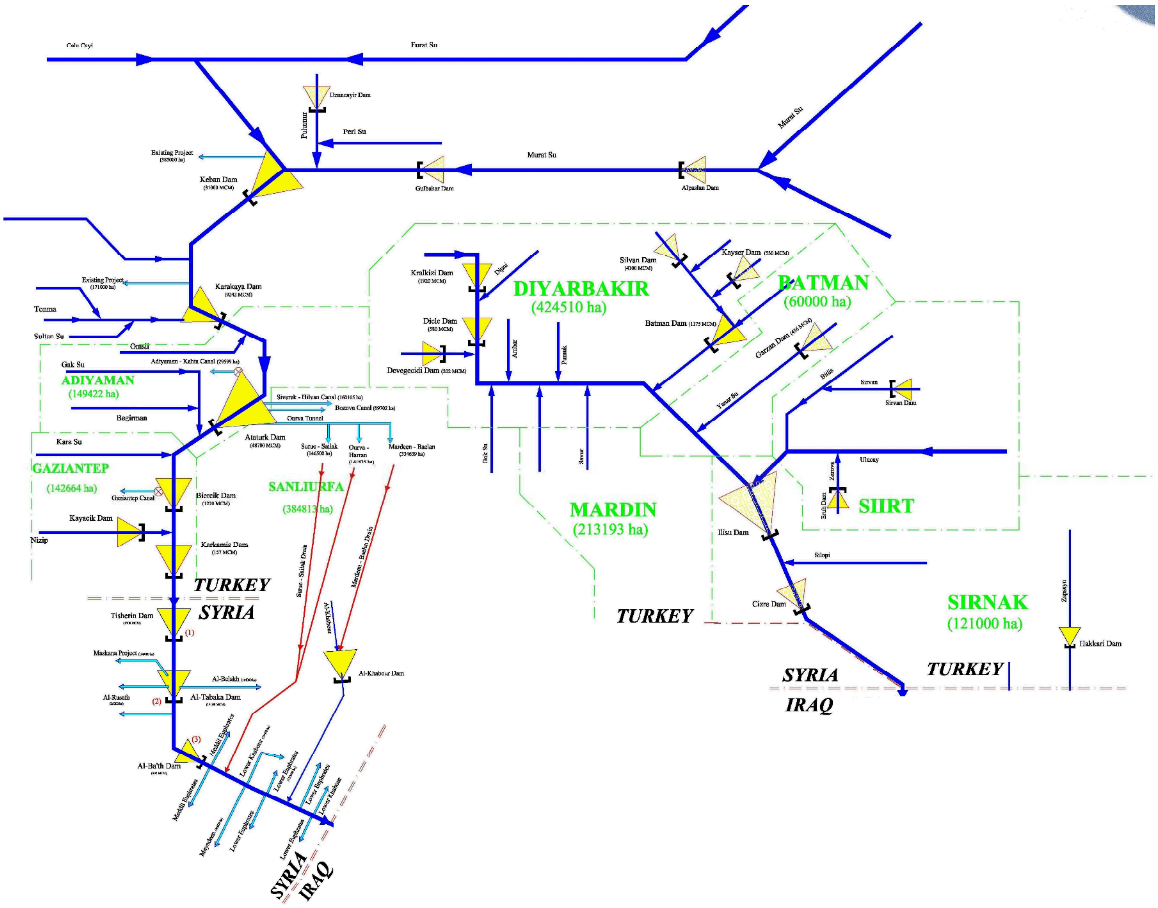
Table 3: Reservoir properties used to guide reservoir operations in Transboundary Module.

In general, and very simply, each reservoir operates as follows: Inflow is equal to outflow until the year that the reservoir comes online. Release from the reservoir is equal to zero until the reservoir volume plus the inflow volume are greater than the inactive pool volume, and then releases occur according to rates specified by min/max/desired and irrigation release. Flood control releases occur when the reservoir volume plus the inflow volume are greater than conservation storage.

2. Simplified model structure

2.1. Model Structure:

The 2005 MoWHSC Schematic Diagram provided the conceptual structure around which the Transboundary Module was created. The relevant portion of this diagram is reproduced below. This module provides the quantities of water and salt that enter Iraq via the Tigris and the Euphrates. Water is introduced to the model via tributary inflows (described in section 1.1). These tributary inflows move through the system at each timestep unless they are stored or diverted (see sections 1.3 and 1.4). Salts are introduced to the model at the border only due to lack of data (see section 1.2).



3. Major assumptions

3.1. Hydrologic assumptions

- Flows are constant at each calculation point for the entire (monthly) timestep.
- Tributary inflows are well approximated by scaling to long-term annual averages at only a few major points in the system.
- Evaporation is the same every year in a given month.
- Evaporation is the same at all reservoirs.
- Precipitation gains to reservoirs are negligible.
- Conveyance losses are negligible.
- Groundwater interactions are negligible.

3.2. Salinity modeling assumptions

- Instantaneous mixing of concentrated water as it flows into Iraq.
- Salinization of agricultural lands is not yet a major problem in either Turkey or Syria (i.e., there are no major efforts in Turkey or Syria to flush salts from the soils, and therefore only a small fraction of the salts that are deposited on irrigated land are washed back into the Tigris or Euphrates).

4. Data and information gaps

4.1. Hydrologic data and information

- Tributary flow records.
- Evaporation rates with improved spatial (by region or reservoir) and temporal resolution.
- Reservoir properties used to guide reservoir operations (see Table 3)
- Surface area to volume relationships for each reservoir.
- Current irrigated acreages in Turkey and Syria and future projections for rates at which irrigation projects will come online.

4.2. Salinity data and information

- Salinity data for all tributary inflows to the Tigris and Euphrates upstream of the Iraq border.

5. Interface issues

The interface has not been developed, however I don't anticipate major issues outside the normal challenges in visualizing historic runs versus observed and scenario results in a straight forward way.

6. Other issues

- Scaling and weighting of tributary inflows: without flow records for twenty of the twenty-two modeled tributaries, we need to make sure that the settings we use to match observed historic flows at the border are reasonable.

7. Next steps

- Assign reasonable scaling and weighting factors to tributary inflows.
- If discovered, incorporate observed flow and salinity data.
- Run scenarios.
- Develop interface.
- Complete description of method for scaling and weighting the Garzan and Furat Su reference hydrographs.
- Complete description of method for estimating reservoir properties.
- Complete full, highly-detailed report on module.