Arc Hydro Data Model:
A Hydrologic Data Integration Tool

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The volume of geographic information for water resources studies is steadily increasing. The National Elevation Dataset now covers the nation with elevation points every 30 meters, and is locally supplemented by LIDAR (Light Detection And Ranging) measurements down to one-meter spacings. The National Hydrography Dataset allows upstream and downstream tracing through the nation's river and stream network, in many states at the 1:24,000 scale of detailed topographic maps. USDA soils databases and NASA land cover databases define land-surface properties. Coupled to that, the USGS National Water Information System provides real-time data on streamflow updated every 4 hours from about 5,000 stream gauges, and the National Weather Service streams out Nexrad radar rainfall information so that the time between measurement of rainfall and receipt of the measured information by the user is about two minutes, even less than the time the rain takes to fall to the ground. How can hydrologists take advantage of these vast arrays of free information?

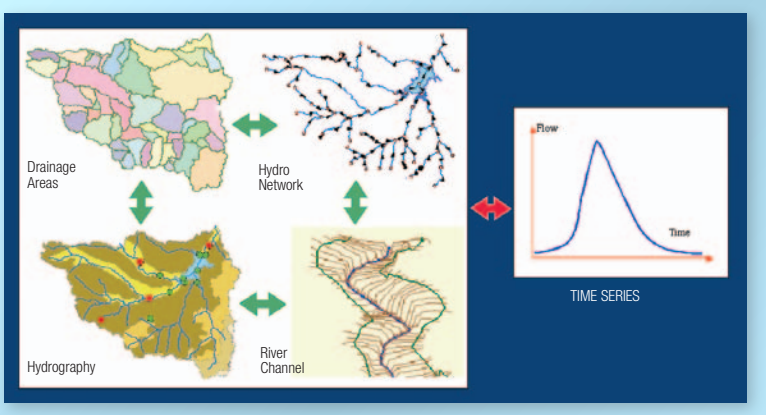
What Arc Hydro Does

Arc Hydro is a data model and toolset for integrating geospatial and temporal water resource information run within ESRI's ArcGIS geographic information system. Although implemented in a commercial GIS environment, the data model and toolset are in the public domain and available free of charge under the "Hydro" heading at www.esri.com/software/arcgisdatamodels.

Arc Hydro was developed by a GIS and Water Resources Consortium of data providers and users, coordinated by the Center for Research in Water Resources of the University of Texas at Austin. Arc Hydro was designed to answer the following questions:

- How can geospatial data describing the land surface and time series of water resources measurements be effectively combined?
- How can the resulting data structure be linked to hydrologic simulation models?
- How can raster GIS information, such as digital elevation models of land surface terrain, be combined with vector GIS information on stream networks and gauging station locations?
- How can datasets be regionalized so that detailed examination of a project area can be embedded within a less detailed description of the river basin or study region surrounding the project area?
- How can the 3-D shape and properties of a river channel be described?

These tasks sound fairly complicated, and they are. But, like building a house, it helps to have a set of plans and a toolkit to go through the construction process. The "plans" are formed using the Arc Hydro data model structures, which are divided into four geospatial components and a time series component (see figure below). The construction of the database consists of filling in these data structures with information for the region under consideration, a task carried out with ArcGIS functions and a special Arc Hydro toolkit created by ESRI. For example, any geospatial feature can be linked to a time series of its water properties using its HydroID, a unique integer identifier created by the Arc Hydro tools.



Arc Hydro components.

Data Modeling

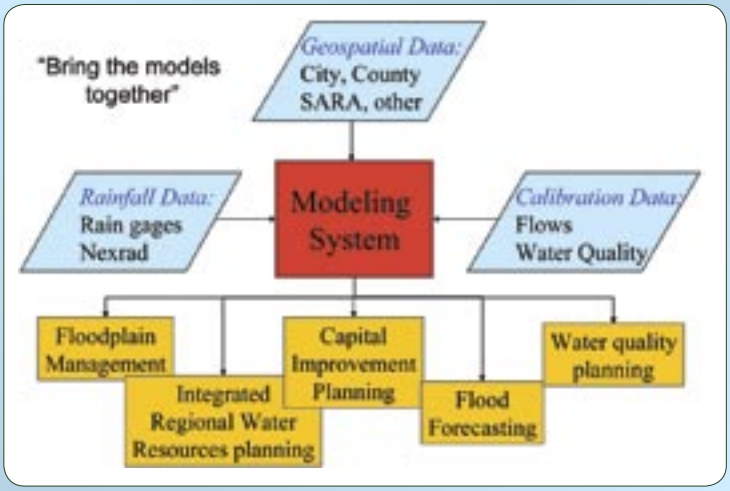
Arc Hydro is a data model, which may seem like a contradiction in terms, because we think of a "hydrologic model" as a set of equations that represent hydrologic processes. Put the "data" into the model and it produces results. What, then, is meant by a "data model"?

Imagine that our goal is to describe the hydrologic environment within which the hydrologic processes function, instead of describing *how* they function. First, the watersheds, stream networks, channels, structures, measurement stations, and land surface properties that cover the study region must be carefully defined. Combining this geographic description with time series information on water resources measurements for this region results in a "data model" that describes the complex water landscape in a simplified way. By linking hydrologic simulation models to our data model, we can create a "hydrologic information system." The way Arc Hydro works in practice is best illustrated with some examples.

Arc Hydro for Urban Hydrology

The San Antonio River Authority, in collaboration with Bexar County and the city of San Antonio, Texas, is implementing Arc Hydro to support the development of a regional watershed modeling system. The eventual goal of this system is to integrate various kinds of hydrologic simulation models to understand the impacts of actions such as land use changes on flooding, groundwater, water supply, and water quality (see diagram above right). A pilot study of the Salado and Rosillo Creek watersheds in San Antonio has been completed in which existing HEC-HMS and HEC-RAS models are integrated using the Arc Hydro data model such that Nexrad

rainfall maps can quickly be converted to a flood inundation map through an application called "Map2Map." Map2Map makes use of the ArcGIS version 9 Model Builder, a visual environment for linking tasks in an automated workflow sequence.



San Antonio regional watershed modeling system.

Arc Hydro for River Basin Hydrology

The Texas Commission for Environmental Quality (TCEQ) implemented a customized version of Arc Hydro called "WRAP Hydro" for supporting the Water Rights Analysis Package (WRAP), a long-term hydrologic simulation model used for analyzing water availability at water permit locations. The WRAP process calls for simulation of monthly naturalized flows for about 50 years at each control point on the river network where one or more water permits have been issued. The larger river basins in Texas have hundreds or even thousands of these control points. At each of them, the drainage area is delineated using a digital elevation model, then linked to the river and stream network so that their hydrologic connectivity can be determined automatically. In addition, the flow length along the stream network between the control points is determined to allow for seepage loss computations.

During the five-year period from 1998 to 2003, TCEQ compiled geospatial data for more than 10,000 control points on the 23 river and coastal basins of Texas, ending with the Rio Grande basin. Building Arc Hydro for the Rio Grande was particularly challenging because the standardized GIS data from USGS on the U.S. side (watersheds and subwatersheds) had to be combined with comparable data on the Mexican side (cuencas and subcuencas) to form a seamless, binational database. The portion of the Rio Grande basin draining to the Texas border from Mexico was divided into 16 subregions, nine on the U.S. side and seven on the Mexican side. Using a 30-meter digital elevation model, watersheds were delineated for each subregion separately, then combined with the vector river network to form a coherent model for the entire basin. Without the formality of the Arc Hydro and WRAP Hydro data models and tools, this task would have been impossible. The Mexican National Water Commission is providing additional detail to incorporate representation of the Mexican side of the database. This binational geodatabase uniquely allows analysis of water availability for the U.S. side alone, the Mexican side alone, or both together, thus serving the needs of water management institutions on both sides of the border.

Conclusions

The San Antonio and Rio Grande examples show that Arc Hydro effectively provides a basis for developing an integrated water resources information infrastructure for a region. This infrastructure takes time and effort to build, but once constructed, creates a robust framework for integrating hydrologic simulation models and conducting analyses with a degree of speed and sophistication otherwise difficult or impossible to attain. For a simple water resources project, much of this sophistication may be superfluous, but the basic tasks that the Arc Hydro tools perform, such as watershed delineation and stream network definition, are still useful. Arc Hydro is currently suitable only for surface water resources, but a companion data model to describe groundwater resources is being developed.

The creation of the Arc Hydro data model, tools, and applications involves a large team of people including CRWR graduate students, ESRI professional staff, and many project collaborators and sponsors, to all of whom the author is indebted.
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Further Reading.....

Maidment, D.R., Arc Hydro: GIS for Water Resources, ESRI Press, Redlands CA, 2002. (see "Arc Hydro" under GIScience at gis.esri.com/esripress.)