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THE NHD: QAQC, EDITING AND ARCHYDRO APPLICATION IN NORTHEAST FLORIDA

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ABSTRACT: The Surface Water Quality Monitoring (SWQM) Program at the St. Johns River Water Management District used portions of the 100k NHDinArc (nhd.route.rch and nhd.region.wb) to develop a district-wide Arc Hydro application. Modifications were necessary, particularly to the flowlines (nhd.route.rch which became HydroEdge in Arc Hydro), in order to produce an adequate representation of surface water for the District. Datasets representing significant "points of interest" (HydroPoint) were acquired from various project groups, including water quality monitoring points, engineering structures, hydrologic data services, etc., that were incorporated into the HydroNetwork through the establishment of relationship classes. Meanwhile, the Department of Water Resources at the District provided funding for the QAQC and editing of the 24k NHDinGEO, which will be used to repopulate the flowlines (HydroEdge) and waterbody feature classes in the Arc Hydro geodatabase. This paper will focus on how the NHD was used to develop the Arc Hydro geodatabase.
KEY TERMS: Arc Hydro; NHD; water quality; watershed; drainage areas; geodatabase development.*

INTRODUCTION

The St. Johns River Water Management District (SJRWMD), along with its four Florida sister agencies, was created to ensure the sustainable use and protection of the state's water resources for the benefit of the people and the state. Comprising approximately 12,600 square miles in northeastern and east-central Florida, the SJRWMD includes all or part of eighteen counties (Figure 1), including Flagler and St. Johns counties, which are among the fastest growing counties in the nation (1st and 9th, respectively) based on U. S Census Bureau data (U.S Census Bureau, 2005). Thus, water management in the SJRWMD is essential. The SJRWMD accomplishes its mission through regulation, applied research, assistance to federal, state, and local governments, operation and maintenance of water control works, and land acquisition and management.

The Surface Water Quality Monitoring (SWQM) program of the Environmental Assessment section at SJRWMD, established in 1983, maintains a monitoring network of 73 sites located through the SJRWMD area. Fourteen of these sites are part of the Florida Department of Environmental Protection (FDEP) Temporal Variability Network and are sampled 12 times a year. The remaining sites are sampled 6 times a year. Water quality sampling includes a broad spectrum of analysis and includes monitoring of sediments for priority pollutants and benthic community sampling to enhance understanding of the biological consequences of sediment pollution. The program provides support for modeling efforts involving surface water quality and produces a biennial Districtwide assessment of surface water quality status and trends. In 2003, the SWQM program added Arc Hydro, a new ArcGIS data model framework developed by the Center for Research in Water Resources (CRWR) at the University of Texas and ESRI, to support its Districtwide water quality and quantity assessments.

The National Hydrography Dataset (NHD) is a framework for surface water hydrography that can be used in other data models designed for specific applications. In the case of the St. Johns River Water Management District, the Arc Hydro data model was chosen because of its hydrologic and water quality monitoring applications. Early versions of the NHD were used as a data source for the Arc Hydro model, bringing together a good geometric representation of surface water with a well developed suite of tools for applications.

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The primary goal of the SWQM Arc Hydro project was to define the drainage areas for the program's 73 water quality monitoring sites. This is accomplished by the "Trace feature by NextDownID attribute" function in Arc Hydro. An additional advantage of Arc Hydro for the SWQM program is that it allows the incorporation of the SWQM time-series data (water quality, sediment pollutants and benthic community data) into GIS, which has previously not been easily accomplished, because geospatial and temporal data are commonly held in different formats and archiving environments (Maidment, 2002).

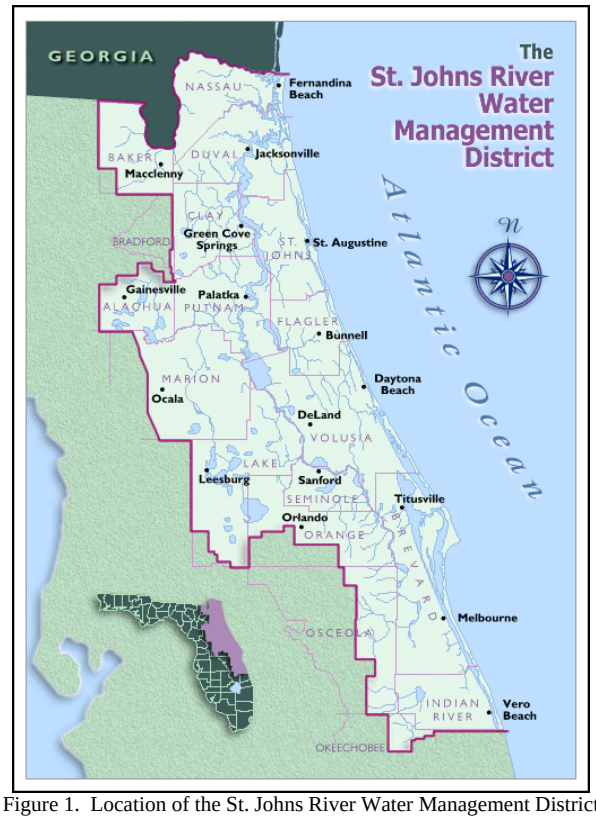

Figure 1. Location of the St. Johns River Water Management District

THE ARC HYDRO NETWORK

The Arc Hydro network is a critical component of the Arc Hydro model (Figure 2); in fact, Arc Hydro could not do what it does without the network. The Arc Hydro network is composed of the feature classes 1) HydroEdge, 2) HydroJunction and 3) HydroNetworkJunction (Figure 3). HydroJunctions are created on the network at or near points of interest in order to link, through the creation of relationship classes (in ArcCatalog), important features such as water quality monitoring sites and drainage areas (catchments) to the network. The HydroNetworkJunctions are generic junctions created by the ArcGIS geometric network builder. HydroEdges are the vector path through which water flows. These are traditionally generated from a digital elevation model (DEM) using raster tools in the Arc Hydro toolbar or they can be acquired from an existing dataset such as the National Hydrography Dataset (NHD) (Maidment, 2002, Obenour, 2002, Zoun et al., 2003). Due to the limitations of the current SJRWMD DEM, it was determined that the best source of the features for the HydroEdge feature class would be the NHD. This paper will focus on use of the NHD in developing the HydroEdge feature class for the SJRWMD Arc Hydro geodatabase, necessary for generation of the Arc Hydro network.

The Arc Hydro geometric network enables tracing of water movement upstream and downstream through streams, rivers and water bodies, which allows for the generation of the drainage areas for the SWQM program's 73 water quality monitoring sites (by virtue of the creation of relationship classes and the "Trace feature by NextDownID attribute" tool). For a full explanation of Arc Hydro, see Maidment, 2002.

CONVERTING THE NHD REACHES INTO ARC HYDRO HYDROEDGES

The HydroEdge feature class is critical to the development of the Arc Hydro network, which allows water flow direction to be modeled. The network must sufficiently represent the surface water features of the project area, which in the

case of SJRWMD is quite large. The project's design criteria required that the HydroEdge feature class represent all significant rivers, streams and canals of the SJRWMD area, and provide network location for the 73 SWQM water quality sampling sites, as well as for a representative set of other hydrologic points of interest chosen to be included in the project (i.e. USGS stream gage sites, engineering structures, springs, a separate set of lake monitoring sites, etc.) (Ceric et al, 2005). This criterion required the creation of new HydroEdges in areas that the NHD lacked reaches, particularly in areas dominated by wetlands (NHD waterbody feature type Swamp/Marsh) for which connecting reaches had not been created (Fox, 2003; Fox et al, 2004, 2005). An additional design criterion included creating a method to deal with multiple flow outlets along the coast, which for the SJRWMD is complicated by the existence of the Atlantic Intracoastal Waterway (i.e. Arc Hydro was designed for a dendritic flow structure, Maidment 2002).

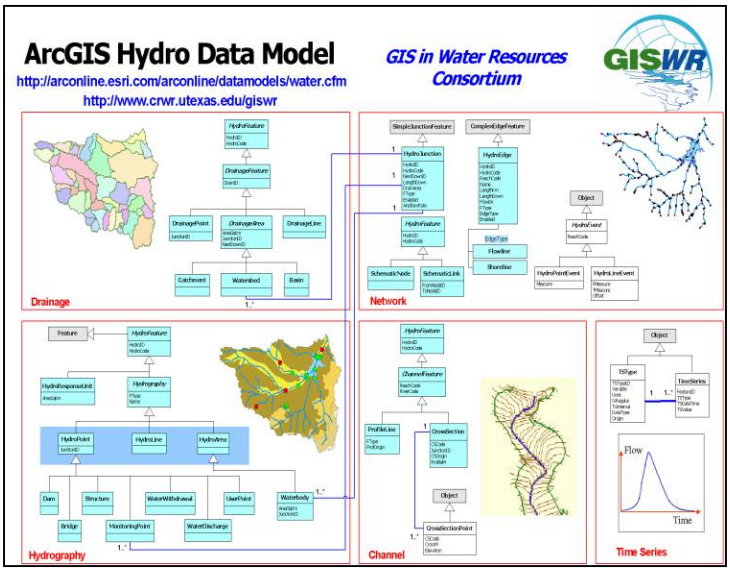

Figure 2. The Arc Hydro Data Model (Maidment, 2002).

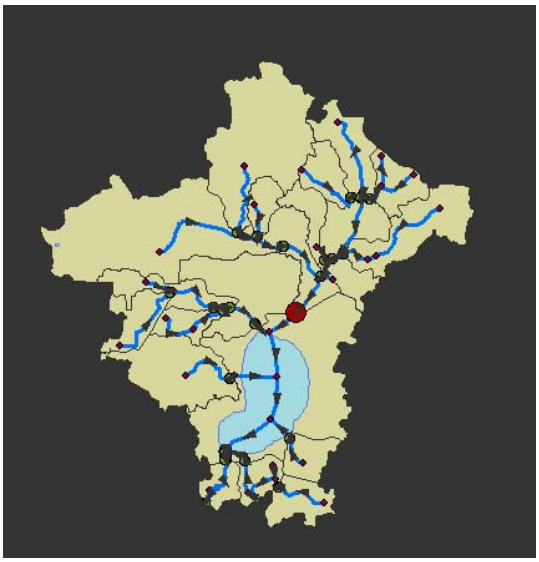

Figure 3. The Arc Hydro network carrying flow through Newnan's Lake located in the western-central region of the SJRWMD. The blue lines are HydroEdges, the small red dots are HydroNetworkJunctions and the green dots are HydroJunctions. The large red dot is one of the SWQM program's monitoring points. The arrowheads on the HydroEdges show flow direction.

Challenges and Solutions

Creation of HydroEdges for All Necessary Flowlines

The Arc Hydro geometric network, as with anything in GIS, is only as good as the data from which it is composed. The medium resolution (1:100,000-scale) NHDinArc (the only version of NHD that was available at project onset) provided a good starting point for the development of the HydroEdge feature class for the Districtwide Arc Hydro project. The conversion of the NHD data to the geodatabase format to populate the HydroEdge feature class (which will not be necessary with the now available NHDinGEO) was not a problem. Features taken from the NHD were modified as needed, while maintaining the NHD system for permanent water feature identifiers. This will allow access to additional information maintained in the NHD. Additional HydroEdge features were created as needed to meet the design criteria (Figure 4); these "temporary reaches" would later provide a guide for QAQC and editing of the 24K NHDinGEO, which SJRWMD undertook shortly after its release by USGS (Lake, 2005). The SWQM Arc Hydro project was fortunate to have the involvement of engineering staff (D. Clapp) in the development of the HydroEdge feature class. In ArcMap, the HydroEdge features derived from the NHD were compared to the most current aerial photography (2004 digital orthophoto) and USGS quad maps for modifications. Additional data layers were used as needed. This review and editing process with a hydrologist, with 25 years of experience at SJRWMD, is actually the process of converting knowledge of SJRWMD hydrology into a geographic information system, which can be readily accessed by others and maintained and further modified as needed. Thus, local scientific knowledge has been converted into a format that will extend beyond the working group that created it. Arc Hydro allows for easy dissemination of this knowledge within a larger group of scientists and engineers at SJRWMD, who are dependent upon the best available data to do their jobs. Passing this information on to the National Hydrography Dataset through data stewardship allows for the dissemination of this knowledge beyond SJRWMD (Simley, 2003).

Multiple Outlets Along the Atlantic Coast

To handle the problem with multiple outlets to the Atlantic Ocean, the dendritic form of Arc Hydro was enforced by creating an artificial break in the HydroEdges at the approximate point of flow divergence on the outgoing tide in the Atlantic Intracoastal Waterway and at other necessary locations. These points were termed "TidalNullPoints" (Figure 5). Once the HydroEdges had been split, the sinks (outlets) could be properly identified and the flow direction could be set using the Arc Hydro Network tools. A peer review of the SJRWMD Arc Hydro database (ESRI, 2005) indicates that breaking the HydroEdges is not necessary in order to have flow diverge in opposing directions from the TidalNullPoints.

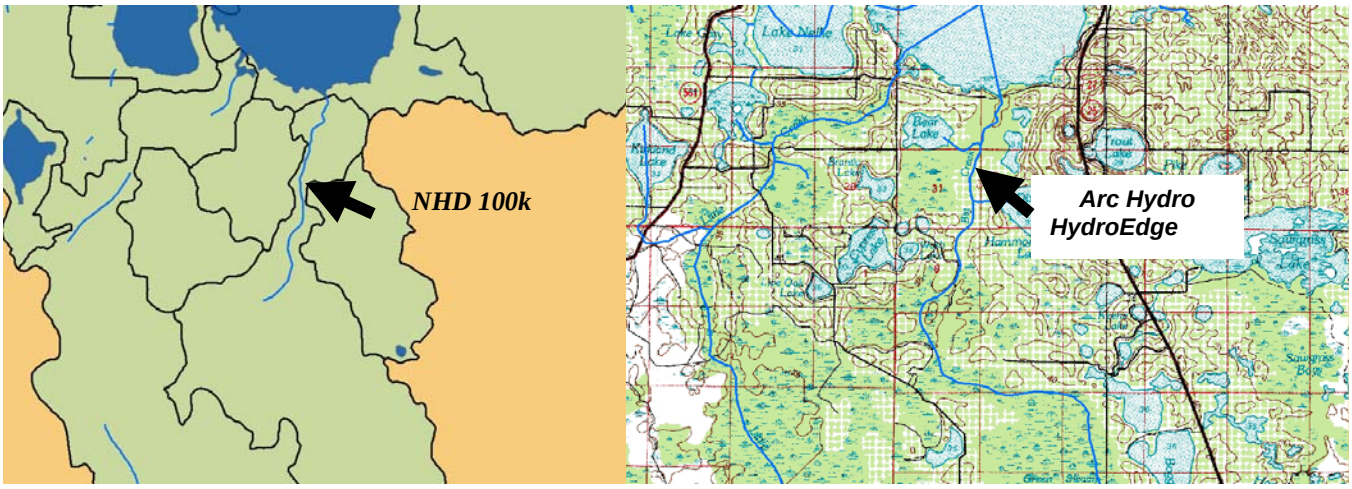

Figure 4: New HydroEdges created. HydroEdge features from the NHD are shown in the left panel while the modified and new HydroEdges are shown in the right panel

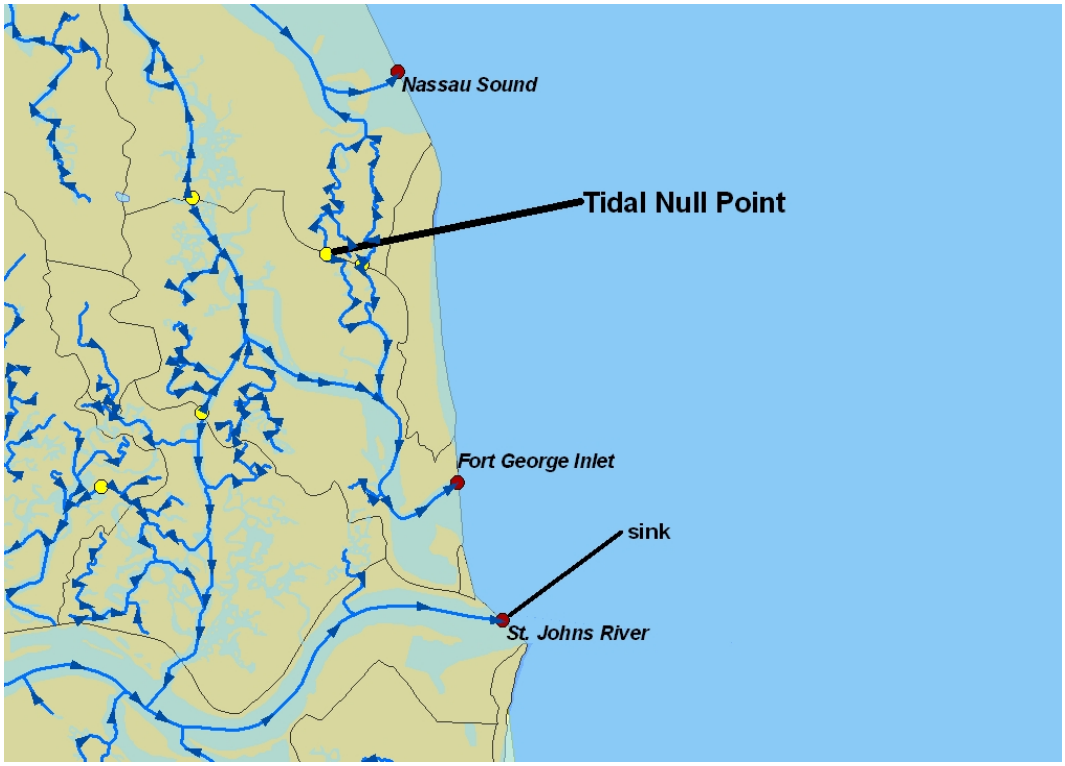

Figure 5. TidalNullPoints created for 3 of the 9 outlets along the Atlantic coast of the SJRWMD. The sinks used to determine flow direction during Arc Hydro network generation are also displayed.

Internal Sinks

Not all surface water within the SJRWMD becomes part of the network paths that flow out to the ocean network sinks (Figure 5). Many areas, such as shown in Figure 6, have surface water flow that enters into a sink and may or may not become part of surface water flow. Note the arrows on the HydroEdges indicating direction of flow. The areas displayed with hatching in Figure 5 have been designated as noncontributing to surface water flow.

Springs

There are many springs within the SJRWMD area. The area that contributes recharge to a spring has been defined as the land-surface area wherein water entering the ground water system at the water table eventually discharges to that spring. A particle tracking method (Shoemaker, et al. 2004) was used to delineate that area for Blue Springs in central Florida. This was modeled in Arc Hydro by assigning the same JunctionID to all catchments that were delineated by the particle tracking method (Figure 7). (Please note: The term "catchment" is used here to simplify the text. The term "catchment" is used at SJRWMD to refer to the smallest vector-based watershed unit available for analysis, not necessarily the smallest possible watershed unit.)

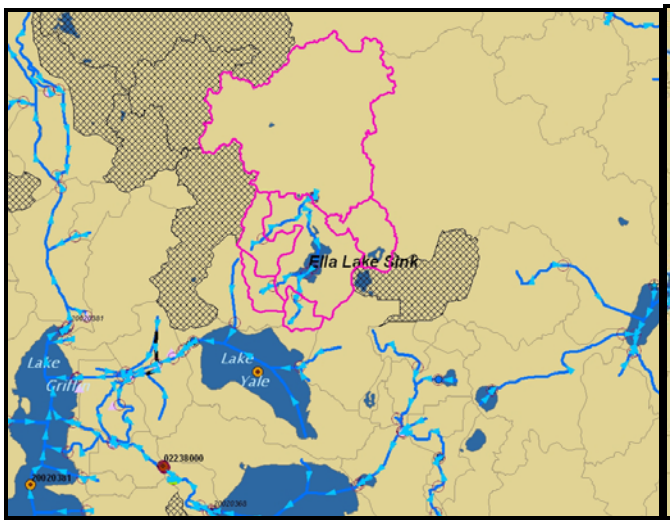

Figure 6. An internal sink at Lake Ella

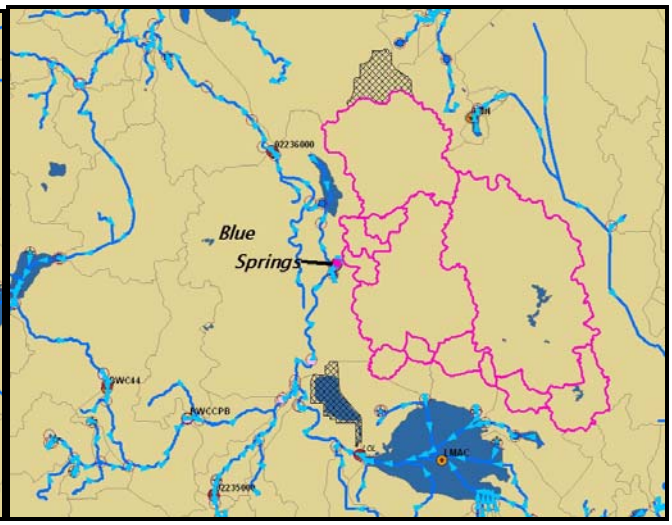

Figure 7. Catchments that supply recharge to Blue Springs.

Alternate flow paths

The establishment of restoration areas is among the methods used by the SJRWMD in accomplishing its mission to ensure the sustainable use and protection of water resources within its boundaries. Over the course of relatively short periods of time, the flow paths of surface water within these areas may be changed. The flow path within Arc Hydro for the Emeralda Marsh Conservation Area (EMCA) shown in Figure 8 was designed to incorporate a planned change that alters the flow between catchments. The HydroEdge shown in black within the highlighted area has been disabled until the planned change to flow within this area is made.

Shared JunctionIDs

Working at the scale of the entire SJRWMD area necessitated the establishment of shared JunctionIDs by neighboring catchments in which surface water flow has not been adequately mapped to date, in order to meet a reasonable deadline for the production of the data necessary for building the Arc Hydro geodatabase. Arc Hydro allows for the disabling of flow between catchments to by simply changing the JunctionID to <null> within the attribute table. This feature within Arc Hydro is useful in the case of catchments in farmed areas within SJRWMD, particularly in the Upper St. Johns River Basin, in which the pumping of surface water may significantly change the areas contributing to surface water flow. Figure 9 demonstrates the shared JunctionID of two catchments.

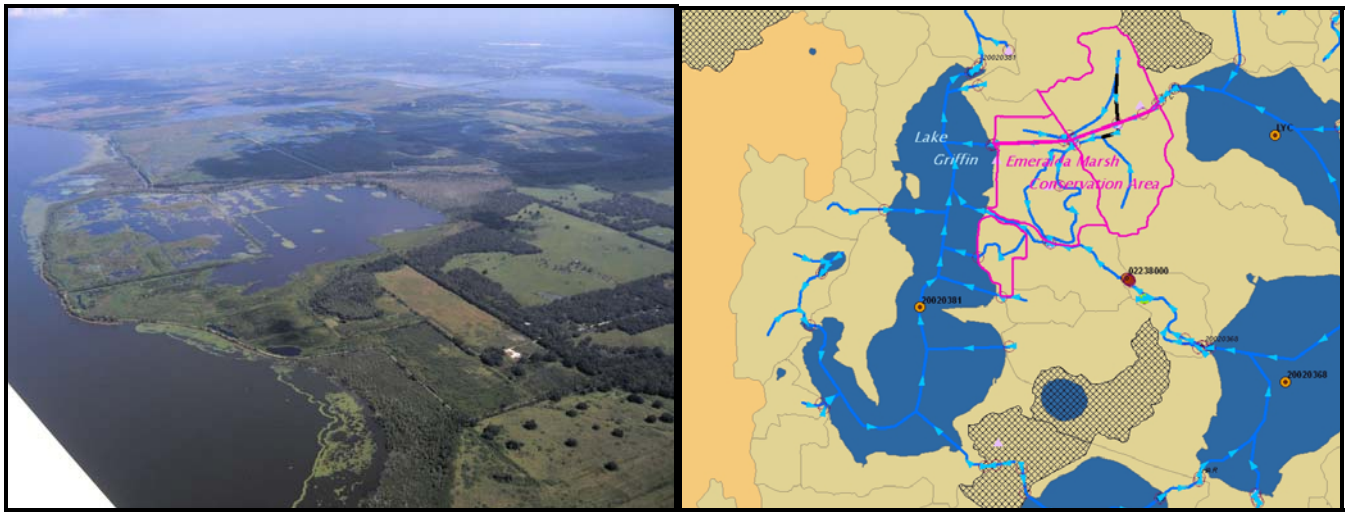

Figure 8. The photo in the left panel shows the eastern shore of Lake Griffin with EMCA in the center of the photo. The Arc Hydro model is shown in the right panel with the EMCA catchments highlighted. The HydroEdge for future surface water flow within EMA is shown in black. Note the flow directions indicated by the arrows on the HydroEdges. (Photo by John Stenberg, SJRWMD.) Flowlines on lakes do not represent the actual path of water flow, but exist to establish network connectivity.

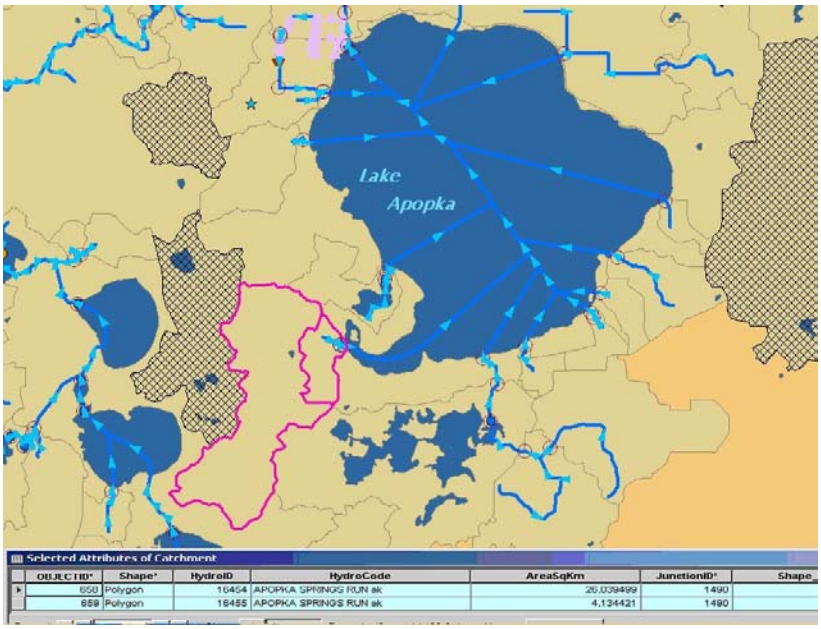

Figure 9. Shared JunctionIDs between neighboring catchments. The HydroEdges on Lake Apopka are not meant to represent the actual flow of water through the lake. Rather, they exist to create the network connectivity for Arc Hydro.

Surrogate HydroJunctions

Of the 73 water quality monitoring sites in the SWQM program, 43 are located in streams or rivers, 24 are located in lakes, 5 are located in tidal areas and 1 is located in a spring (figure 7). The Arc Hydro "Trace feature By NextDownID attribute" function operates to select all of the catchments (or other features linked to HydroJunction based on an established relationship class) downstream (and/or upstream) from the selected HydroJunction. For stream sites, the catchment boundary is located immediately upstream to the monitoring point (see the point labeled 02238000 in the center of figure 8). A problem is created for the lake and tidal water quality monitoring sites in which the water quality monitoring point is located in the lake or estuary, which in turn is located within a catchment (figure 10, panel a). The placement of the HydroJunction for the surrogate point just downstream of the lake catchment boundary allows the "Trace feature by NextDownID attribute" tool to correctly include the lake catchment in the results (figure 10, panel c).

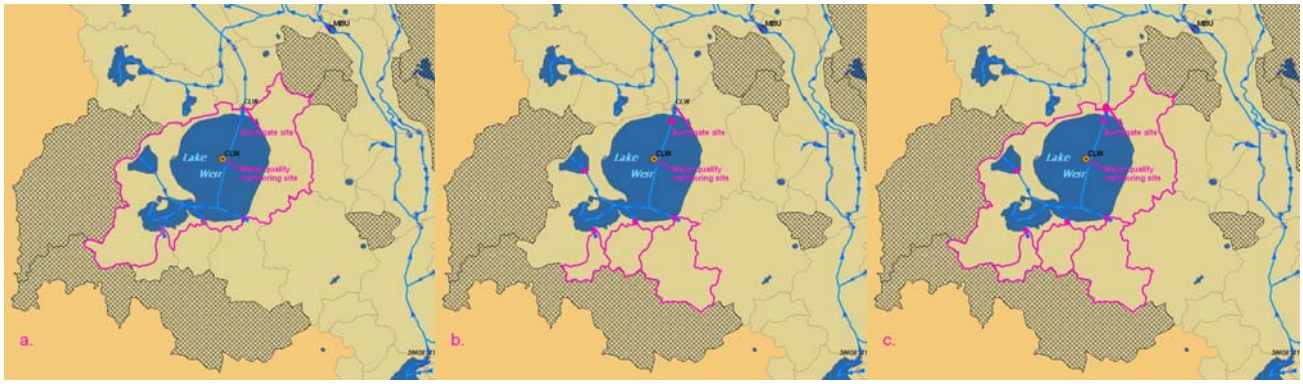

Figure 10. The surrogate HydroJunction for a water quality monitoring site in a lake. Panel a shows the outline of the catchment for Lake Weir. Panel b shows the results for the "Trace feature by NextDownID attribute" tool when using a HydroJunction within the lake and panel c shows the results for the surrogate HydroJunction located just downstream of the catchment boundary. The areas indicated in hatching are considered to be noncontributing to surface water flow. Arrows on the HydroEdges indicate direction of surface water flow.

USEFUL ARC HYDRO PRODUCT

Once the Arc Hydro network has been created, features can be linked to it by creation of the appropriate relationship classes (in ArcCatalog or by application of the Arc Hydro schema, Maidment, 2002). As the primary goal of this project was to define the drainage areas for the SWQM 73 water quality monitoring sites, the proper linkage of the local drainage areas (SJRWMD_catchment) to the Arc Hydro Network was critical. SJRWMD's hydrologist also reviewed this process. The SJRWMD_catchment boundaries can be seen in Figures 3 through 10. Using the "Trace feature by NextDownID attribute" tool from the water quality monitoring sites generates the drainage area for each water quality monitoring site.

From the newly defined drainage areas for the water quality monitoring sites spatial summaries for a variety of GIS layers were derived by the use of a new tool created by a SWQM Arc Hydro customization project. The spatial summaries, along with site descriptions and water quality data, are being used to develop web-based water quality watershed fact pages, in cooperation with SJRWMD's Office of Communications and Governmental Affairs. These fact pages are being designed to enhance communication of water quality information to the public by SJRWMD staff. Sample pages from the web site are shown in Figure 11.

CONCLUSIONS

Using the NHD to develop the Arc Hydro HydroEdge feature class has provided SJRWMD with a working Districtwide Arc Hydro network that performs the function for which it was designed and lays the groundwork for expanding into additional applications. QAQC and editing of the 24k NHDinGEO is ongoing at SJRWMD. Once completed, features from the NHDinGEO will replace the current HydroEdge features.

In conclusion, Arc Hydro is a powerful framework for building a water resources information system. Among the benefits realized by the SWQM program's Arc Hydro project are a reduction/elimination of data redundancy and efficient and cost-effective data integration and presentation. The SWQM Arc Hydro project and its product, the water quality watershed fact pages, would not have been possible at SJRWMD without the NHD.

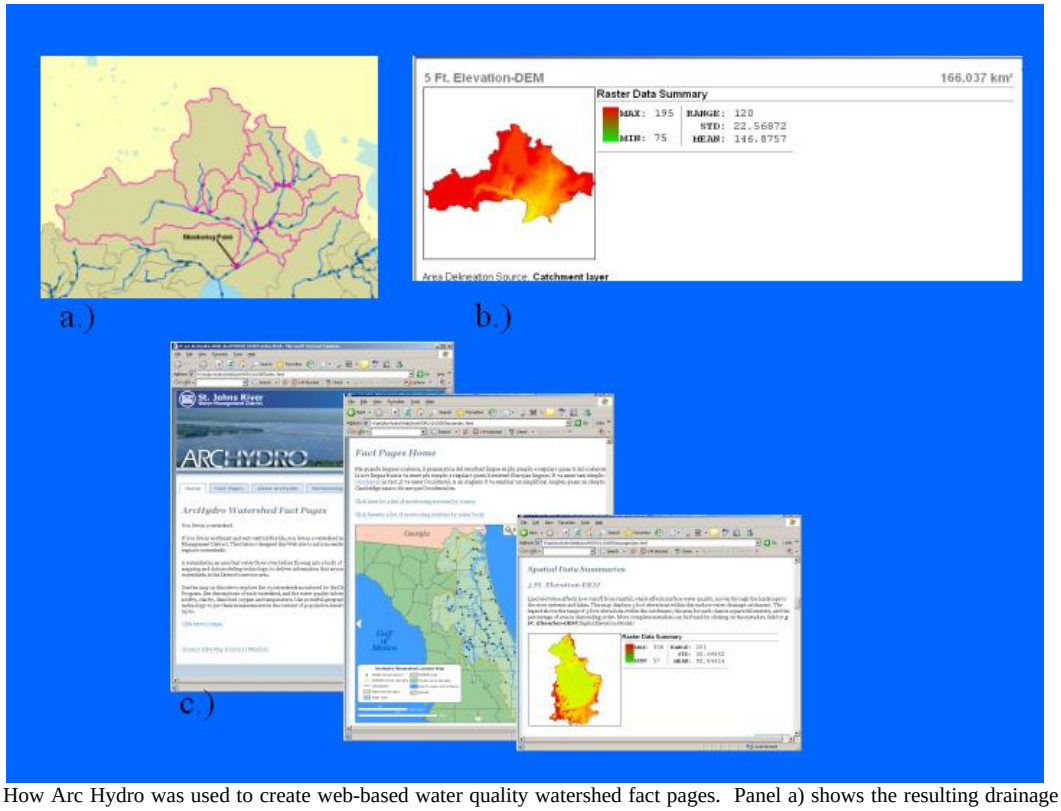

Figure 11. How Arc Hydro was used to create web-based water quality watershed fact pages. Panel a) shows the resulting drainage area from the "Trace feature by NextDownID attribute", b) shows the spatial summary tool results for elevation for the area defined in a) and c) shows some sample pages from the web site.

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