SPARROW-WEB: A GRAPHICAL INTERACTIVE SYSTEM FOR DISPLAYING REACH-LEVEL WATER-RESOURCE INFORMATION FOR RIVERS OF THE CONTERMINOUS UNITED STATES

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ABSTRACT: The U.S. Geological Survey (USGS) has developed an interactive Web-based tool called SPARROW-Web, for displaying water-quality model results and associated reach-level information for more than 63,000 rivers in the conterminous United States. Access is provided through a user-navigated hierarchical system of mapped watersheds, based on the Water Resources Council hydrologic drainage basin classification for the United States. These nested drainage basin classifications include 18 water-resources regions, 204 subregions, 334 accounting units, and 2,106 hydrologic cataloging units (HUC). Interactive maps of the HUC watersheds include state and county boundaries, major cities, HUC names and HUC code numbers, and river reaches from the enhanced U.S. Environmental Protection Agency's River Reach File (1:500,000 RF1). Additional information can be accessed below the cataloging unit interactive maps that reference the "Science in Your Watershed" Web site. This site provides access to USGS National Water Information System (NWIS) real-time streamflow stations and other water-resource information related to the selected watershed. Selection of an individual river reach on the HUC-level maps displays stream characteristics such as mean discharge and velocity, and watershed characteristics for the drainage basin above the reach, including drainage area, land-use, population, nutrient sources, and predictions of mean-annual nutrient concentrations and yields (total nitrogen and phosphorus) from the SPARROW (SPAtially Referenced Regressions On Watershed attributes) model. The model predictions also include natural background concentrations and yields of nutrients for the river reach. The collection of stream water-quality statistics in SPARROW-Web and the HUC-level Web links to other water information provides efficient user access to a comprehensive and consistent set of water-resources information for the conterminous United States.
KEY TERMS**:** SPARROW-Web; river reach; watershed model; hydrologic unit code; modeling; nutrient concentrations; nutrient yields; nutrient flux; nitrogen; phosphorus.

INTRODUCTION

SPARROW-Web is an hypertext markup language (html) 4.0-compliant set of Web pages designed to display SPARROW (SPAtially Referenced Regressions On Watershed attributes) model predictions at the river reach-level within a selected watershed cataloging unit and additionally link to basin level water resource information. The USGS has developed and implemented the SPARROW model (Smith et al., 1997) to provide spatially detailed predictions of water quality for major streams and rivers of the conterminous United States. This paper briefly describes the methods and content used in the SPARROW graphical interactive system (SPARROW-Web) for displaying reach-level water-resource information for rivers of the conterminous United States. A more detailed description of the data sources can be accessed at the methodology link on the SPARROW-Web home page.

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SPARROW-Web Structure

The water-resource region map on the SPARROW-Web home page is an interactive image map that allows the user to navigate through four nested hydrologic unit boundary map layers, subdividing the United States by watersheds (Figure 1). The watersheds are displayed from the largest drainage basins (regions) to the smallest drainage basins (cataloging units). The hydrologic unit codes consist of a two-digit number, which sequentially accumulates from a two-digit region number, to a four-digit subregion number, to a six-digit accounting unit number and finally an eight-digit cataloging unit number (i.e., hydrologic unit code, HUC). The first level of classification divides the Nation into 18 major geographic regions (Alaska, Hawaii and the Caribbean are not included). The second level of classification divides the 18 regions into 204 subregions. A subregion includes the area drained by a river system, a reach of a river and its tributaries in that reach, a closed basin, or a group of streams forming a coastal drainage area. The third level of classification subdivides the subregions into 334 accounting units. The fourth level of classification is the 2,106 cataloging units, which are the smallest units in the hierarchy of hydrologic units (land drainage areas range from 100 – 22,313 km^2 or 39 – 8615 $miles^2$, respectfully). A cataloging unit is a geographic area representing part or all of a topographically defined drainage basin. Each hydrologic unit basin has been assigned a hydrologic numeric code and a name corresponding to the principal hydrologic feature within that geographic area (Seaber et al., 1987).

Figure 1 – As the hierarchy of the hydrologic unit maps subdivide into smaller basins, the numbering scheme of the basins increases cumulatively by two-digit values. Users can click anywhere on the "Water Resource Regions" map area to display a chosen region. From the region map, the user can click on the map area to display the nested subregions, accounting units, and cataloging unit maps of any watershed across the United States.

As a user navigates through SPARROW-Web to the smallest drainage basin, rivers along with other geographic features of the watershed are displayed on the cataloging unit map (Figure 2). Hydrologic features (streams, lakes, and bays) are shown in blue. Cultural features (political boundaries, geographic coordinates, State and county names) are represented as shades of black. Hydrologic unit boundaries and the 2-, 4-, 6-, and 8-digit hydrologic codes are in green. An optional pull-down menu interface, which is accessible from the internal home page (http://water.usgs.gov/nawqa-only/sparrowweb), enables a user to navigate the site. The menu allows users to select any combination of region, subregion, accounting unit, and cataloging unit numbers, and to display the associated watershed map. The menu allows users an additional method of locating specific watersheds and basins of interest, (through a single click) bypassing the hierarchical hydrologic map unit

sequence. Documentation of menu use can be accessed by clicking on the "Help" button. To revert from the menu selection interface, a "Non-GUI" option has been provided (Figure 2).

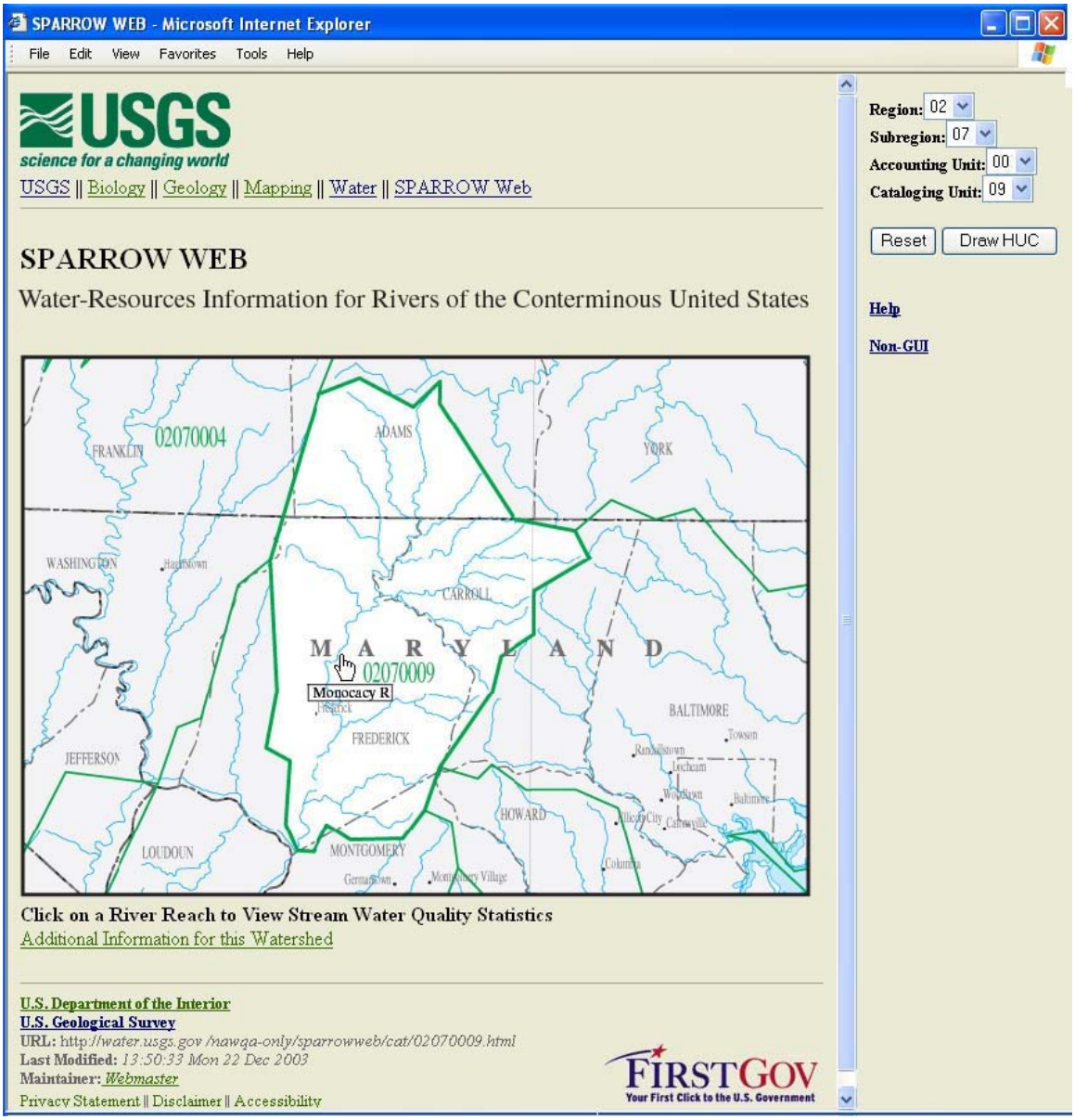

Figure 2 – SPARROW model predictions for a river reach can be displayed by clicking on a river reach within the cataloging unit map boundary. Compliant html Web browsers that recognize "alt" tags from cursor movements can display individual river names when the cursor is placed over the rivers within the cataloging unit boundaries. Directly below the cataloging unit map, a link labeled "Additional Information for this Watershed" also is accessible.

Basin-level Information

A Geographic Information System (GIS), Arc/Info™, was used for compilation of the region, subregion, accounting unit and cataloging unit boundary maps (Steeves and Nebert, 1994). Arc Macro Language (AML) scripts specifying HUC selections from the digital 1:250,000-scale Hydrologic Unit Code map were written within cursor routines. The cursor routines identify every basin by its HUC number value. The AML sets the page size of the map to 8.778 by 6.028 inches, selects the basin, specifies the map angle to use for the selected region, overlays other digital coverage layers for an ideal cartographic representation of the geographic basin, outputs the map file to a postscript format, and deletes any extraneous files. Another AML nested in the cursor routine recalculates the page size of the map from inches to pixels (632 by 434

pixels), outputs the pixel dimensions of the HUC boundaries to a html file for image map location boundaries, accesses item attributes in the polygon attribute table (PAT) for alternative descriptive text "alt tags" (Lemay, 1999) in the html files, then continues on to the next selected basin number value within the cursor routine. For each HUC, the cursor routine generates a postscript file used as the watershed map, and an html file used for the image map coordinates. The geographic locations of the smaller watershed polygon boundaries nested within each larger watershed polygon boundaries, along with the HUC numbering convention of the Hydrologic Unit Map were selected to generate the hierarchical image maps and associated hyperlinks. Basin names and HUC values were added to the PAT, along with plot angle information, and other descriptive text for the watersheds throughout the SPARROW-Web application. By performing various relates, reselects and calculations the PAT of the "Hydrologic Unit Map" was populated with alternative or descriptive text "alt tags" used to enhance the html coding required for a 508-compliant Web site (See Accessibility link at the bottom of Figure 2), (Section 508 and Accessibility at the USGS). The html files were generated for each HUC by converting the watershed boundaries to page size dimensions, then to pixel coordinates (representing the X and Y dimensions of the HUC boundaries) and writing the coordinates to html files. The basin maps were generated for each HUC by converting the geographic features to page size dimensions, then to postscript files. The postscript files were cartographically edited and enhanced using Adobe Illustrator™ software, and then converted to raster files (jpg) using Adobe Photoshop™ software, to be viewed on the intranet. The watershed map files and the associated html files were named by the HUC numbering convention stored in the PAT.

Reach-level Information

The SPARROW model predictions were linked to SPARROW-Web, thus providing access to individual reach-level predictions of nutrient concentrations and loadings for rivers and streams and nutrient sources in drainage basins of the conterminous United States. By selecting a river reach within the cataloging unit watershed map, a tabular page listing is displayed showing the statistics from the SPARROW model predictions for the drainage area upstream of the river reach and associated basin water-quality information and other geographic information (Figure 3).

GIS processing techniques were used to geographically link the SPARROW model predictions page to the individual river reach segments displayed in the SPARROW-Web cataloging unit maps. The river reach file RF1 (U.S. EPA, 1998) was enhanced and renamed ERF1_2 (Nolan et al., 2002). The enhanced version of the vector river reach file ERF1_2 was converted to a raster GRID format. In GRID, the raster river reach cells were expanded to a cell size of 20 creating a wider river thickness that was used within the cataloging unit watershed boundaries for selecting river reaches. The expanded river thickness of the raster cells were then converted to polygons. The polygon coverage of the river cells were built from groups of contiguous raster cell borders having the same cell values from the original vector data. These cell values were based on the unique identifier-number (E2RF1). The contiguous GRID cells with the same values were grouped together to form polygons. Items from the vector river reach file were added to the polygon river reach file so relations between the two files could be established. By converting the vector attributes to raster cells, and then to polygons, the geographic attributes could be accurately related from one file to the other. The raster coverage was expanded approximately 150 meters around each river reach segment relative to the extent of the region image map it resides in. The ERF1_2 coverage was divided into the 18 designated HUC regions to expedite the computer processing routine, which generated a total of 2,106 cataloging unit html files. The associated extended polygon boundaries of the river reaches within each cataloging unit boundary were individually selected, converted from geographic coordinates to page-size inches, and then converted to pixel dimensions. More than 63,000 river boundary hyperlinks and their associated river names for the 2,106 cataloging unit maps were generated. The E2RF1 number, a unique 5-digit reach-identifier in the PAT is used as the link to the SPARROW model prediction html page.

The cursor routine sequentially selects a cataloging unit boundary by the 8-digit HUC number, selects the expanded ERF1_2 river reach polygons that are geographically located within that HUC boundary, records the river reach polygon's unique 5-digit reach-identifier (E2RF1) to be used as hyperlinks for each river reach to the SPARROW model predictions page, then continues on to the next selected HUC boundary within the cursor routine - to execute again. The text files were named by the HUC numbering convention stored in the PAT with the html extension added.

Supporting the SPARROW models and the SPARROW-Web application is an enhanced version of the U.S. Environmental Protection Agency (U.S EPA) River Reach File 1 (RF1) hydrographic data consisting of approximately 63,000 reach segments for the conterminous United States (Alexander et al., 1999; Nolan et al., 2002). Additional upgrades to the RF1 file (ERF1-version 2.0) include revised estimates of drainage area based on the HYDRO1k Digital Elevation Model (DEM) for North America (Nolan et al., 2002). Mean annual streamflow for RF1 reaches were estimated by W.E. Gates and Associates, Inc. in the late 1970's using USGS gage records from approximately 4,100 sites for the period of record and procedures for interpolating flows along reach segments (U.S. EPA, 1982). Water velocity also was estimated by W.E. Gates and Associates, Inc. in the late 1970's based on the use of 2,229 water time-of-travel field measurements made by Federal (primarily USGS) and state agencies. Population within RF1 reach catchments were estimated from 1990 U.S. Bureau of Census data (GeoLytics, 1996). A GIS overlay of U.S. Census block-group polygons and RF1 reach catchments

(as determined from HYDRO1k) was used to obtain area-weighted estimates of population for the reach catchments. Land cover for the RF1 reach watersheds was based on data from the 1992 nationally consistent land cover data set of the conterminous United States (National Land Cover Data 1992 or NLCD 92). Land cover is defined at 30 meter resolution according to a modified Anderson level II classification (21 classes) based on Multi-Resolution Land Characteristics (MRLC's) Landsat 5 Thematic Mapper (TM) satellite data archive (USGS, 1990).

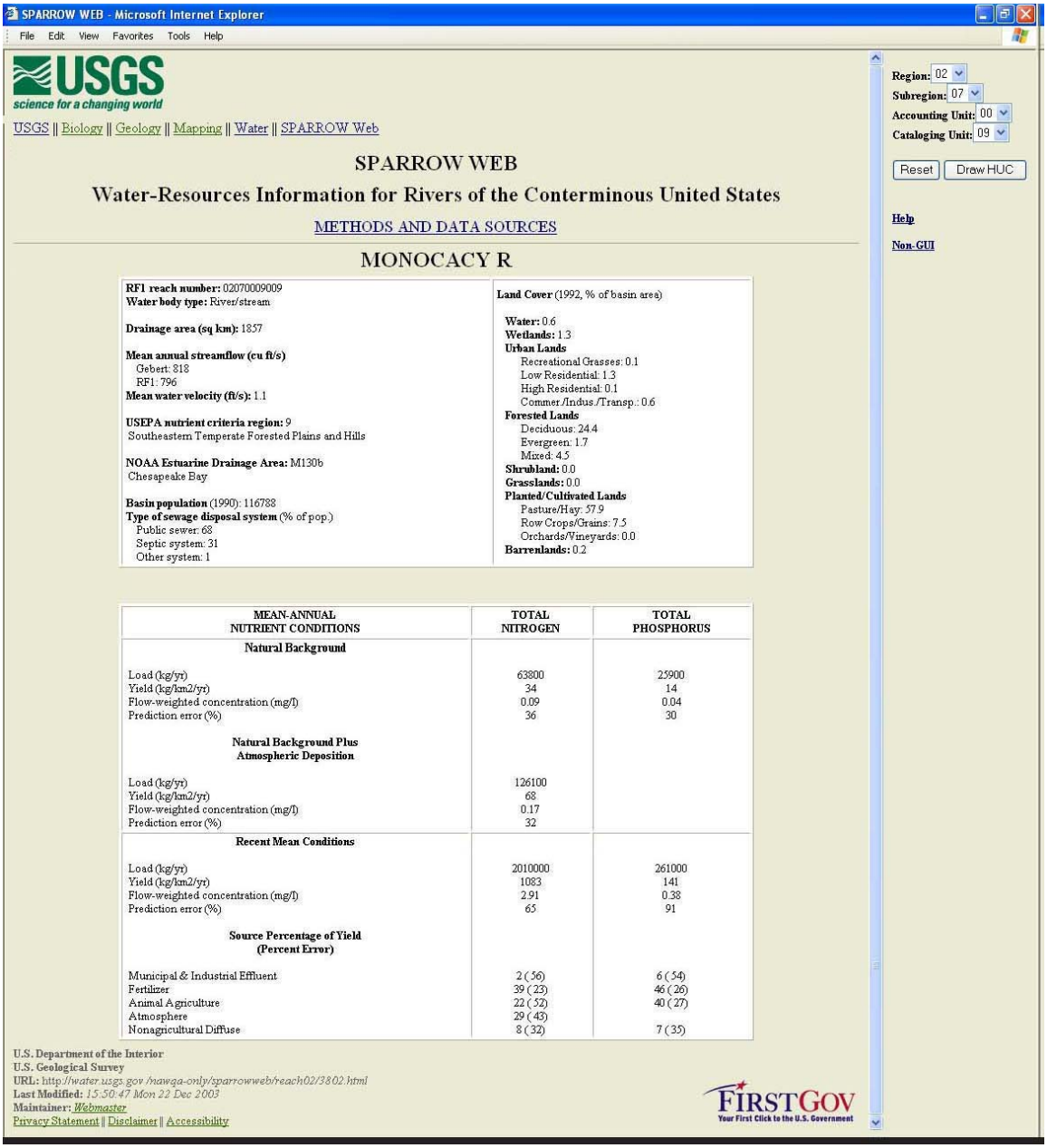

Figure 3 – An example of a SPARROW model prediction page for the selected Monocacy River reach of the Potomac watershed. This page is accessed from the region 02, subregion 07, accounting unit 00, cataloging unit 09, and by clicking on the Monocacy River within the eight-digit (02070009) HUC boundary.

Estimates of total nitrogen (TN) and total phosphorus (TP) loads (kilograms per year), yields (kilograms per square kilometer per year), and concentrations (flow weighted in milligrams per liter) for each reach are based on two statistical watershed models, which were applied to surface waters of the conterminous United States. Mean-annual natural background TN and TP stream water loads, yields, and concentrations were previously published in (Smith et al. (2003). The mean-annual nutrient loads, yields, and flow-adjusted concentrations are estimated from applications of the SPARROW watershed model (Smith, et al. 1997; Alexander et al. 2000, 2001). For example, the mean annual TN and TP loads, yields

and concentrations for the long-term and natural background conditions of the Monocacy River reach, Potomac watershed for the total drainage area above the reach are listed in the lower part of the table of the Web page shown in Figure 3. The contributions of nutrient sources to the total nutrient load at the reach outlet are reported as a percentage of the total load.

Stream reach predictions of long-term mean-annual nutrient conditions reflect 1987 nutrient inputs and mean streamflow conditions during the period 1970 to 1992. The SPARROW model separately quantifies the contributions of the major nutrient sources at the river reach outlet. The nutrient estimates account for the terrestrial and aquatic losses of nutrients as a function of various watershed properties, e.g., soil drainage and in-stream nutrient attenuation. The SPARROW model statistical data files can be downloaded as tab-delimited text files for the reaches within each of the 18 water-resources regions of the conterminous United States (data are not yet available for Alaska, Hawaii, and the Caribbean). The files can be transferred into spreadsheet software for further analysis.

Additional Water Resource Information

A link located directly below the cataloging unit map pages labeled "Additional Information for this Watershed" connects the user to a USGS water-resources links page imbedded within the "Science in Your Watershed" Web site at http://water.usgs.gov (See Figure 2). On the "Science in Your Watershed" Web site, USGS links of scientific information are displayed for each specific watershed. In the upper right hand corner of this links page located on the "Science in Your Watershed" Web page, additional corresponding Web links specific for that watershed are accessible through the green "Watershed Information Network" triangle icon (Figure 4).

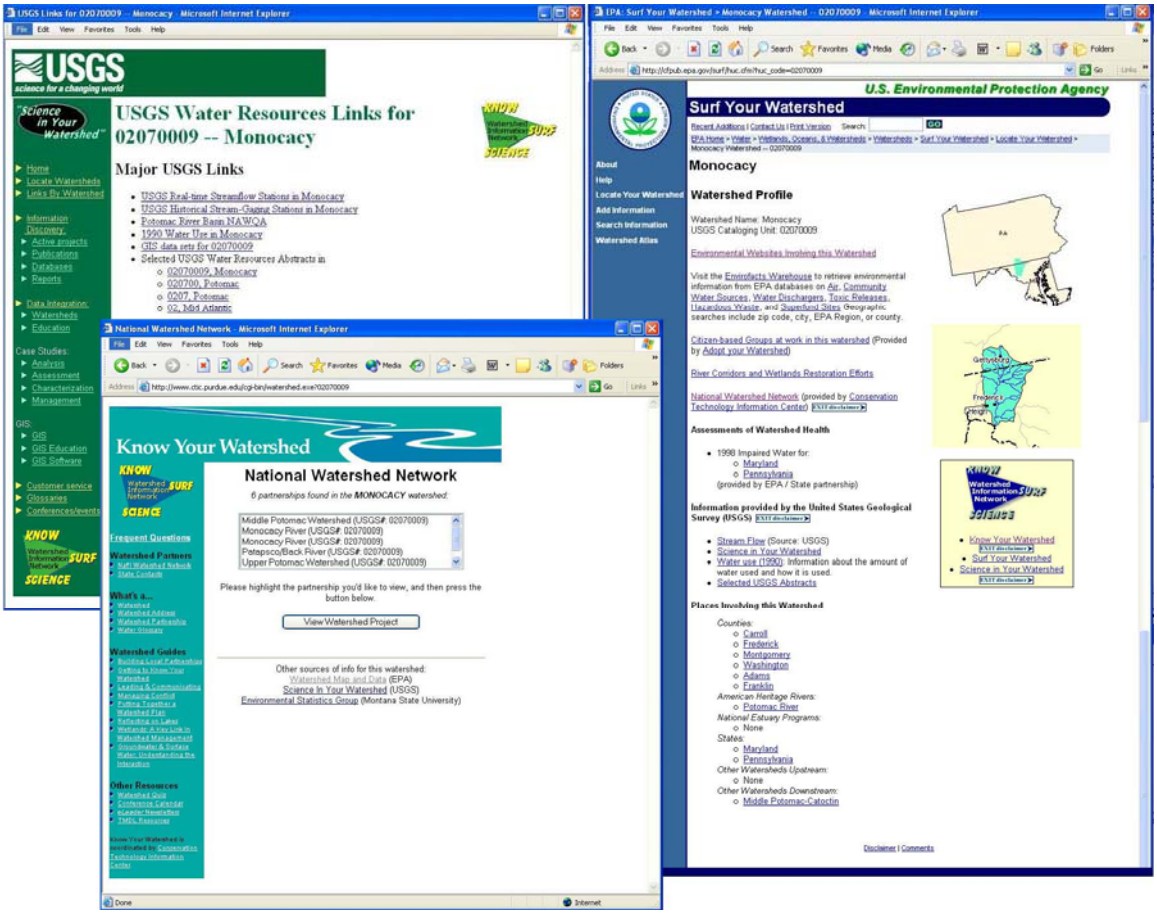

Figure 4. – The link below every cataloging unit watershed map page on the SPARROW-Web site generates a watershed link to the USGS "Science in Your Watershed," allowing users to link to additional water-resource and watershed-specific information from "Know Your Watershed" Conservation Technology Information Center and "Surf Your Watershed" U.S. Environmental Protection Agency.

The corners of the triangle icon are direct links to additional water-resource information Web sites for the selected watershed. The two links, "Know Your Watershed" at http://www.ctic.purdue.edu/KYW/KYW.html maintained by the

Conservation Technology Information Center and "Surf Your Watershed" at http://www.epa.gov/surf/ maintained by the U.S. Environmental Protection Agency, contain additional watershed and water-resource information. These combined Web sites contain scientific information organized by watershed. This water-resource information, coupled with observations and measurements made by watershed groups, provide a very powerful foundation for evaluating the status and health of a watershed.

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