NHD-Based RiverSpill

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Abstract

The RiverSpill time-of-travel spill model is being updated to use the National Hydrography Dataset in geodatabase format. Mean flow volume and velocity attributes are linked to the NHD flowlines. USGS real-time stream flow gages are also being indexed to NHD so that travel time and concentration is based on flow conditions at the time of the spill event. This model forms the basis of the transport module of the Incident Command Tool for Protecting Drinking Water (ICWater). Public water supply intakes, HazMat sites, dams, pipelines, bridges, and railroads are also included as part of ICWater. Both stand-alone and web-based versions are being developed.

Background

The objective of this project is to implement the Incident Command Tool for Drinking Water Protection (ICWater) that will:

- Integrate critical data needed to evaluate and respond to an incident into a GIS-referenced system.
- Predict dispersion of waterborne contaminants by integrating the EPA and TSWG funded RiverSpill system with the National Hydrography Dataset (NHD)
- Incorporate interfaces between field sensors and RiverSpill
- Develop an interface for input of field reports by first responders and mobile units.
- Incorporate an interface for inclusion of hospital admissions data
- Contain GIS layers and databases to display water threats in relation to: surface water contamination sensor locations; sensor outputs; the location of dams, reservoirs, and locks; the location of surface water bodies; all public drinking water intakes; roads and other terrestrial transportation networks; topography; and population
- Provide secure web-based access to local incident commanders, and to a centralized, regional or national command center.
- Provide the capability of tracking human pathogens, toxic chemicals, and radioactive substances that pose significant threat to public safety in case they were used to attack water sources.

This program will result in significant changes to the current RiverSpill application. These changes include: (1) the replacement of the Enhanced Reach File version 1 (ERF-1) with the National Hydrography Dataset, (2) replacement of Arcview 3.x with ARCGIS version 9 and (3) the inclusion of a web-based version of RiverSpill (Samuels et al, 2003a, Samuels and Ryan 2004, Samuels et al, 2004). The functionality will be developed on a phased basis. ICWater's core component, RiverSpill, is a GIS-based system used to track and model the flow and concentration of contaminants in source water supplies. With RiverSpill, personnel can calculate, locate, and map the population that could be at risk from the contamination of a public water supply, by providing data through a variety of modules. In addition, the model calculates the travel time of a contaminant based upon stream flow, decay, and dispersion of the constituent introduced in surface waters.

Sponsors and Partners

The development and implementation of ICWater is a collaboration of government agencies, a regional river basin commission and private industry (see figure 1). The main sponsoring organization is the US Department of Agriculture (USDA) Forest Service and its desire to provide spill response tools to their Incident Commanders. The Technical Support Working Group (TSWG) is managing the ICWater contract. TSWG is the "U.S. national forum that identifies, prioritizes, and coordinates interagency and international research and development (R&D) requirements for combating terrorism. The TSWG rapidly develops technologies and equipment to meet the high priority needs of the combating terrorism community, and addresses joint international operational requirements through cooperative R&D with major allies."

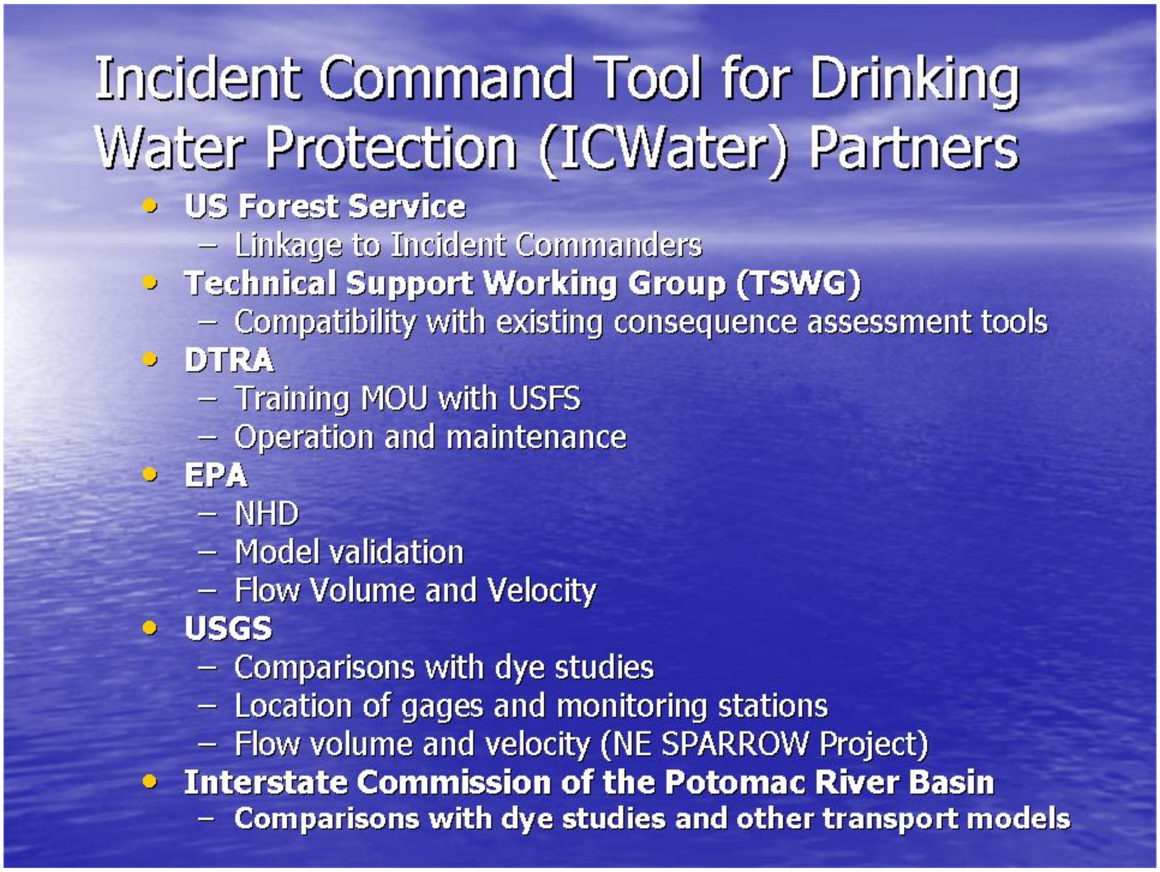


Figure 1. ICWater Partners and their roles.

The Defense Threat Reduction Agency has signed a Memorandum of Understanding with the Forest Service to provide training on ICWater to first responders. The US Environmental protection Agency (EPA) has supported the development of the RiverSpill model (Samuels et al, 2003b) which is the core component of ICWater. EPA and the US Geological Survey (USGS) are providing value added attributes (VAAs) to the NHD such as mean flow volume and velocity. This product is called NHDPlus (Simley, 2005). Finally, through funding from EPA Region 3, a version of RiverSpill is being calibrated for the Potomac River Basin with the participation of the Interstate Commission of the Potomac River Basin (ICPRB).

National Hydrography Dataset (NHD)

ICWater is being developed using the 1:100,000 scale (medium resolution) NHD which is available for all hydrologic units in the continental US. The data was downloaded from the USGS NHD Server in pre-staged personal geodatabases by subregion. The VAAs are being made available by EPA and the US Geological Survey (USGS) for individual hydrologic regions (see figure 2) with hydro region 5 being used for development purposes. The USGS also provided mean flow volume and velocity on NHD reaches for hydro region 1 (New England) through the Sparrow Program (Moore and Johnston, 2004).

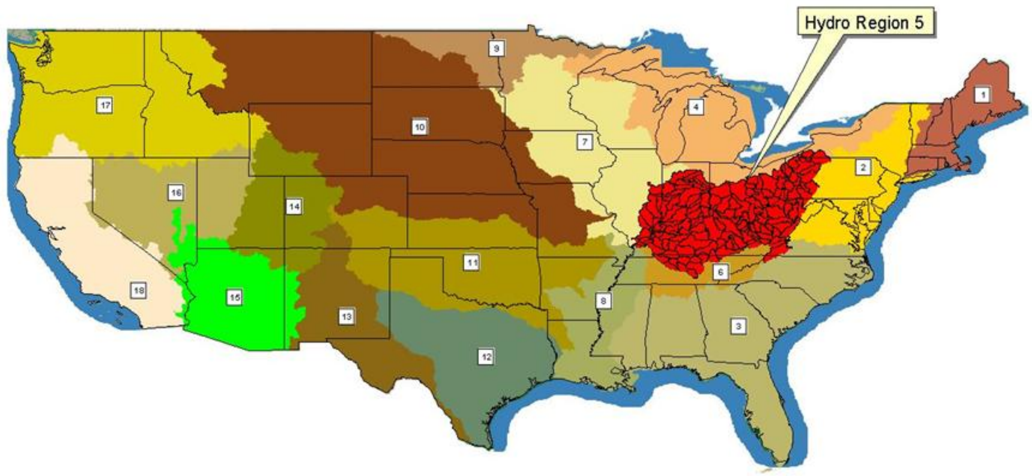


Figure 2. USGS hydrologic regions for the continental US.

ICWater, RiverSpill and NHD

To begin an ICWater session using the NHD-based RiverSpill, a data loader is implemented through a graphical user interface (see figure 3). This data loader allows for NHD, map background layers, USGS gages and highway bridges to be displayed based on a map extent (state or county) and spill origin (latitude/longitude coordinate, street address or intersection, highway bridge). The data loader displays NHD for all subregions that intersect the map extent (state or county). Both flowlines and NHD area features are displayed. ICWater has options to use the ESRI Streetmap as map background or transportation and boundary layers that are bundled with ARCGIS (version 9). Additional categories of assets such as public water supply intakes, sewage treatment plants, pipelines, Federal lands, HAZMAT sites, etc. can be added to the map background through ICWater's asset manager and display tools. User supplied assets can also be added. The NHD flowlines and their associated mean flow and velocity data are used in conjunction with USGS real-time stream flow gauging stations to navigate downstream (figure 4). For downstream tracing, a graphical user interface allow for input of the spill size, type instantaneous or continuous), agent type (chemical, biological or radiological) and choice of flow data (automated location of nearest real-time gage, user selected gage, use of mean flow or user specified flow). Once the trace is completed, a breakthrough curve (concentration vs. time) can be generated for any location on the trace (figure 5).

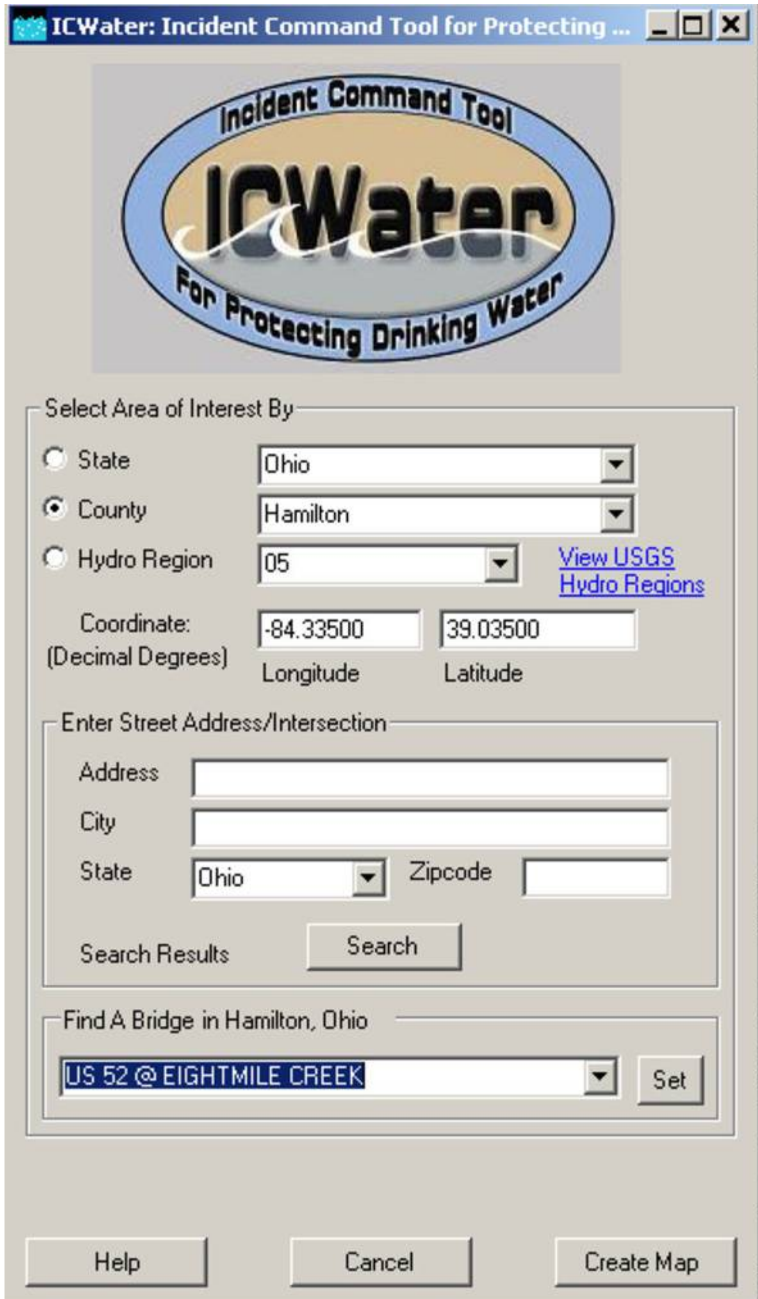


Figure 3. ICWater graphical user interface for the data loader.

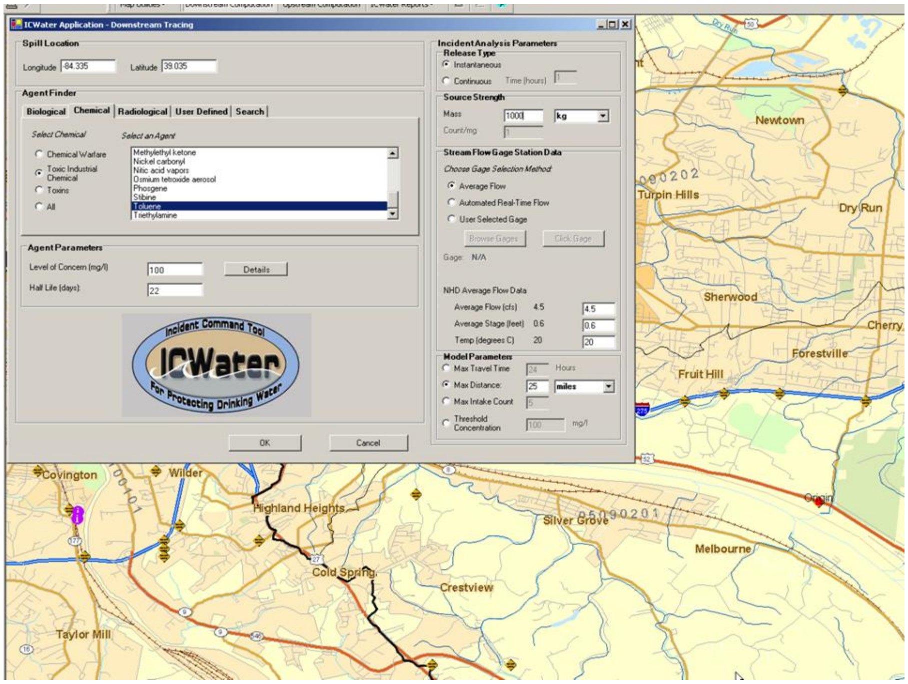


Figure 4. ICWater downstream trace graphical user interface.

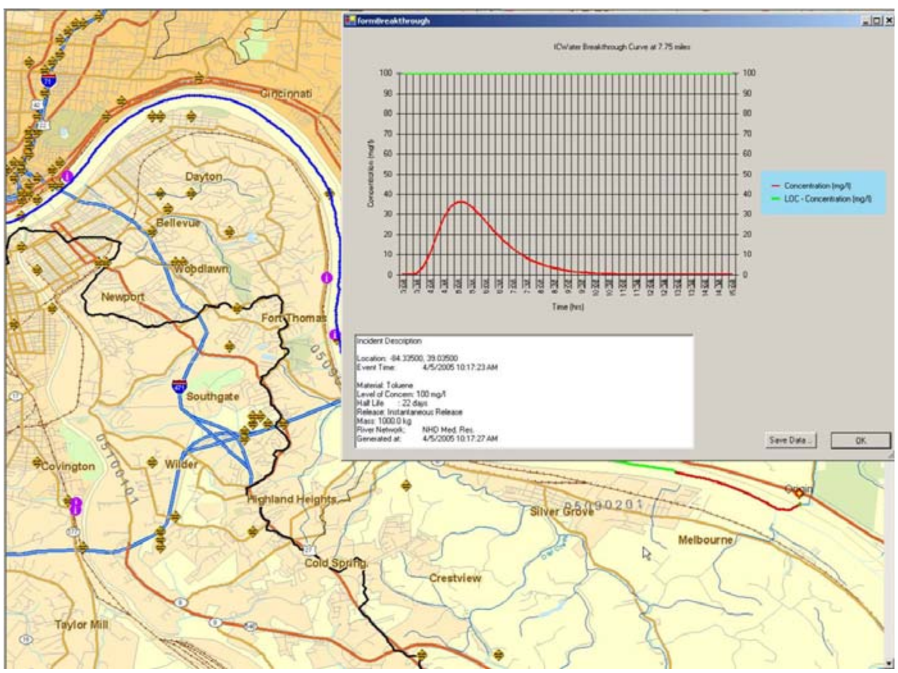


Figure 5. Breakthrough curve along the downstream trace.

The NHD can also be navigated in the upstream direction (figure 6) based either on distance or time. If time is chosen, the travel time upstream can be based on flow from real-time gages, mean flow or user specified flow. The total distance or time upstream of a location can be sub-divided into zones and assets such as HazMat sites, municipal and industrial dischargers, dams, etc can be overlaid. A report in html format can also be generated which shows the location of the upstream assets and a table of asset attributes.

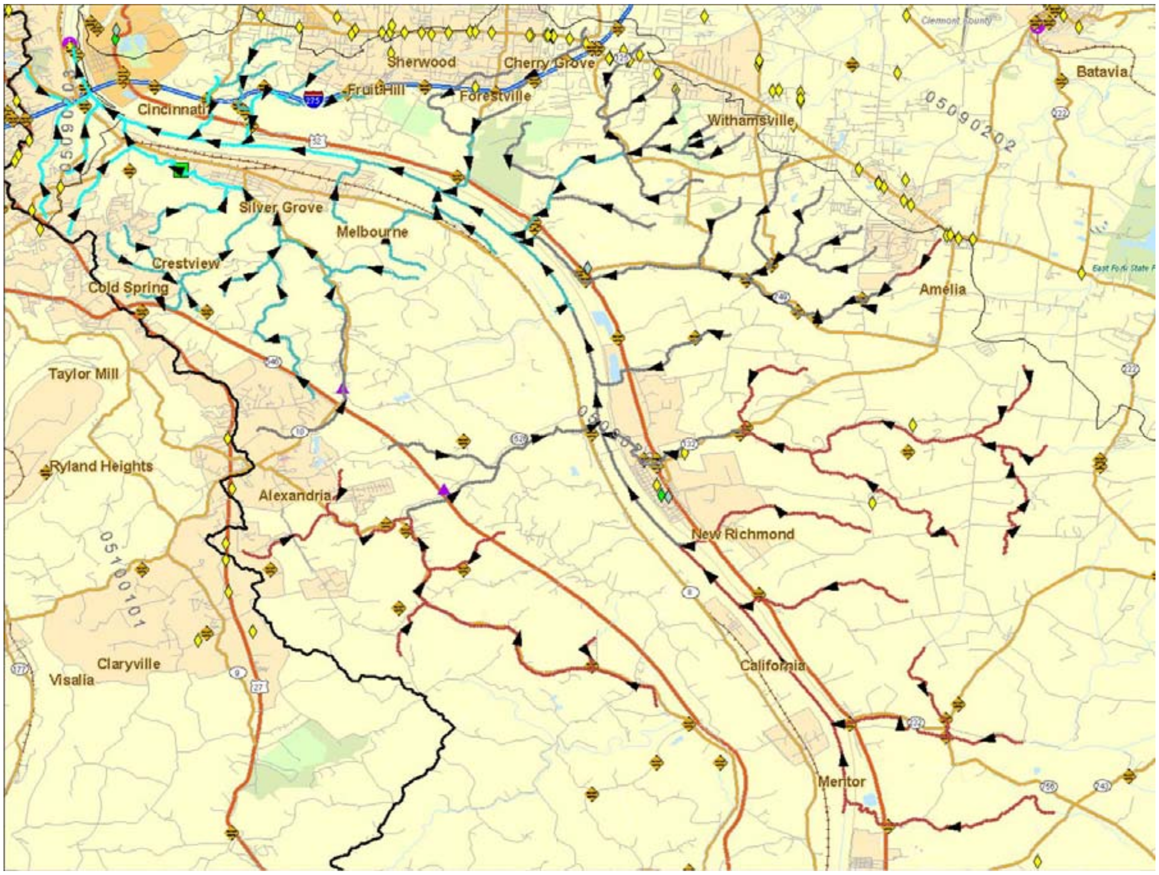


Figure 6. ICWater upstream map display.

RiverSpill Calibration and Validation

In cooperation with the ICPRB, a calibration and validation study of RiverSpill was undertaken for the Potomac River Basin. Data from USGS dye studies (Taylor, 1970) along with information from the ICPRB Toxic Spill model (Hogan et al, 1986) was used to calibrate coefficients to convert stream flow into velocity. Model runs were performed on streams where dye studies were undertaken and the results were compared. Figure 7 shows a map of the USGS dye measurement sites on the Monocacy River. The measured flows at three sites are shown along with the flows estimated by RiverSpill. There was excellent agreement between measured flows and RiverSpill calculated flows. Comparisons were made between observed and modeled distance and travel-time. These results are shown in figure 8. On average, distances differed by 4% and travel time differed by 11%. Comparisons were also made for concentration (see figure 9). Concentrations differed between 29 and 37%.

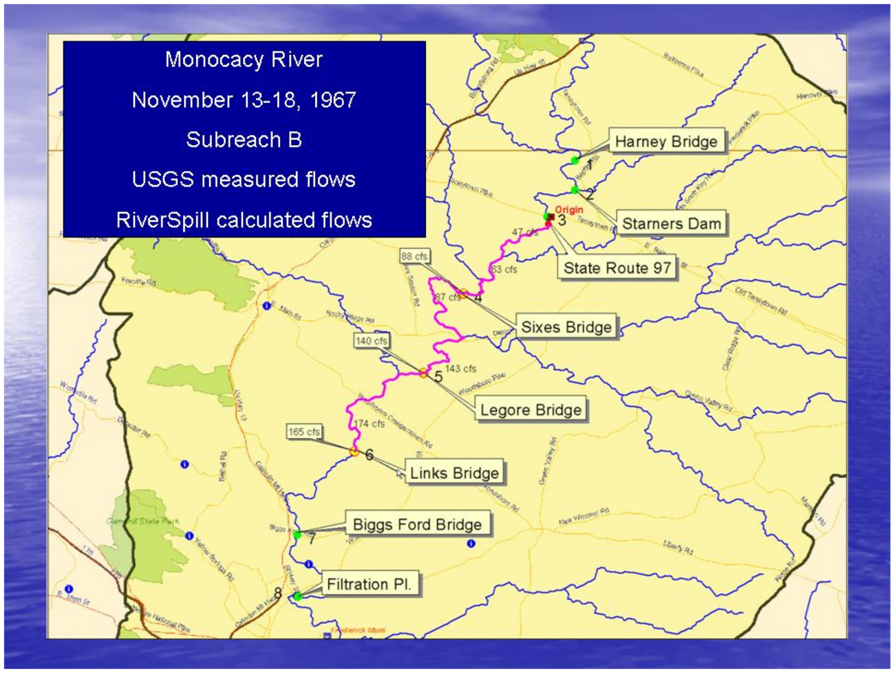
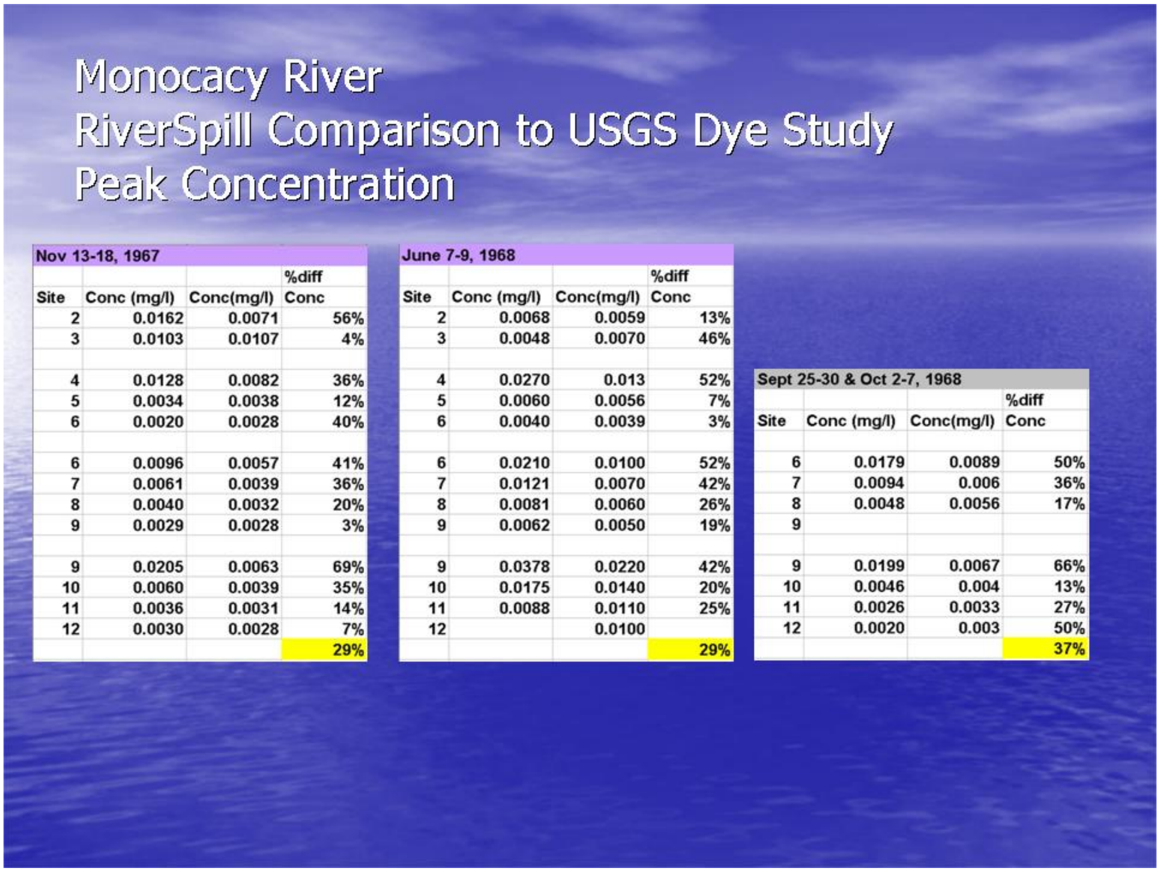


Figure 7. USGS dye study sites on the Monocacy River.

Monocacy River
RiverSpill Comparison to USGS Dye Study
Distance and Peak Time

Nov 13-18, 1967							
	Observed (dye)		Modeled (RiverSpill)			%diff	%diff
Site	Distance(mi)	Time (hrs)	Distance (mi)	Time (hrs)		dist	time
2	1.75	35.50	1.89	37.67		8%	6%
3	4.70	51.00	4.56	49.06		3%	4%
4	5.80	27.20	6.20	30.48		7%	12%
5	14.15	57.00	14.94	62.06		6%	9%
6	20.55	72.50	20.95	77.52		2%	7%
6	6.40	12.60	5.91	14.30		8%	13%
7	11.40	23.00	11.67	27.80		2%	21%
8	16.65	33.50	16.72	39.50		0%	18%
9	21.30	43.80	21.60	51.10		1%	17%
9	4.55	8.60	4.51	9.35		1%	9%
10	11.70	29.00	12.39	25.86		6%	11%
11	17.15	40.50	18.59	38.63		8%	5%
12	21.00	48.80	22.20	45.92		6%	6%
					avg	4%	11%

Figure 8. RiverSpill comparison to USGS dye study – Monocacy River



Nov 13-18, 1967			
			%diff
Site	Conc (mg/l)	Conc(mg/l)	Conc
2	0.0162	0.0071	56%
3	0.0103	0.0107	4%
4	0.0128	0.0082	36%
5	0.0034	0.0038	12%
6	0.0020	0.0028	40%
6	0.0096	0.0057	41%
7	0.0061	0.0039	36%
8	0.0040	0.0032	20%
9	0.0029	0.0028	3%
9	0.0205	0.0063	69%
10	0.0060	0.0039	35%
11	0.0036	0.0031	14%
12	0.0030	0.0028	7%
			29%

June 7-9, 1968			
			%diff
Site	Conc (mg/l)	Conc(mg/l)	Conc
2	0.0068	0.0059	13%
3	0.0048	0.0070	46%
4	0.0270	0.013	52%
5	0.0060	0.0056	7%
6	0.0040	0.0039	3%
6	0.0210	0.0100	52%
7	0.0121	0.0070	42%
8	0.0081	0.0060	26%
9	0.0062	0.0050	19%
9	0.0378	0.0220	42%
10	0.0175	0.0140	20%
11	0.0088	0.0110	25%
12		0.0100	
			29%

Sept 25-30 & Oct 2-7, 1968			
			%diff
Site	Conc (mg/l)	Conc(mg/l)	Conc
6	0.0179	0.0089	50%
7	0.0094	0.006	36%
8	0.0048	0.0056	17%
9			
9	0.0199	0.0067	66%
10	0.0046	0.004	13%
11	0.0026	0.0033	27%
12	0.0020	0.003	50%
			37%

Figure 9. RiverSpill concentration comparison to USGS dye study – Monocacy River.

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References

Hogan, K.B., Nelson, G.A., Steiner, R.C., Spielman, B. and Sheer, S.P. 1986. A toxic spill model for the Potomac River basin, Interstate Commission on the Potomac River basin, Report No. 86-2a, 84p.

Moore, R.B. and Johnston, C.M. 2004. New England Sparrow: Application of the National Hydrography Dataset for Water-Quality Nutrient Modeling. Proceedings, Geographic Information Systems and Water Resources III, American Water Resources Conference, May 17-19, 2004, Nashville, TN

Samuels, W.B., Amstutz, D., Pickus, J. and Bahadur, R., 2003a. Integrating the National Hydrography Dataset Into RiverSpill, Proceedings, ESRI International Users Conference, July 8-13, 2003, San Diego, CA

Samuels, W.B., Bahadur, R., Pickus, J. Amstutz, D., and McCormack, K., 2003b. RiverSpill: A Real-Time Emergency Response and Planning Tool, Proceedings Water Security in the 21st Century, July 30 – August 1, 2003, Washington, DC

Samuels, W.B. and Ryan, D, 2004. Using NHD in the Incident Command Information Tool, Proceedings ESRI International User Conference, August 9-23, 2004, San Diego, CA.

Samuels, W.B., Bahadur, R., Pickus, J. Amstutz, D. and Ryan, D. 2004, Development of the Incident Command Information Tool (ICIT) for Drinking Water Protection, Proceedings, Geographic Information Systems and Water Resources III, American Water Resources Conference, May 17-19, 2004, Nashville, TN

Simley, J. 2005. USGS National Hydrography Dataset Newsletter Vol. 4, No. 6, April 2005, http://nhd.usgs.gov/newsletters/News_April_05.pdf

Taylor, K.R., 1970. Traveltime and concentration attenuation of a soluble dye in the Monocacy River, Maryland, State of Maryland, Maryland Geological Survey Interim Circular No. 9. 23p.

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