Wheeling Use Attainability Analysis Demonstration Project Final Report

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ORSANCO

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EXECUTIVE SUMMARY

This report presents the results of a Demonstration Project to develop a framework for conducting a Use Attainability Analysis (UAA) for recreational use in a section of the Ohio River near Wheeling, West Virginia (Hannibal Pool). A UAA is a scientific assessment of the factors affecting the attainment of uses (e.g. fishable/swimmable) specified in the Clean Water Act (USEPA 1983). ORSANCO has defined the Ohio River as "suitable for recreational usage" (ORANCO, 2006). Bacteria standards have been developed to protect human health for "contact recreation" (ORSANCO, 2006). Contact recreation can include full immersion activities such as swimming or water-skiing or partial immersion activities such as wading or boating. Elements of the project included developing and applying watershed and river models to simulate bacteria (*E. coli*) and a framework to efficiently evaluate results.

The initial purpose of this project was to investigate the level of recreational use that can be attained during periods of wet weather flow in a 40-mile section of the Ohio River in an urban industrial setting. A lack of site-specific data for wet weather loadings in the communities and watershed prevented completion of the UAA. Thus, the objective for this project was to develop a framework that communities in the Wheeling area can use to complete a UAA once more extensive data and information are collected.

The study area extends from the Pike Island Locks and Dam (river mile 84.3) to Hannibal Locks and Dam (river mile 126.4) near New Martinsville, Ohio. West Virginia communities with wastewater discharges along this portion of the river include Wheeling, Benwood, McMechen and Moundsville. Ohio communities with wastewater discharges along this portion of the river include Martins Ferry, Bridgeport, and Bellaire. There are approximately 180 combined sewer overflows (CSOs) to the Ohio River and its tributaries in this area.

A watershed model that simulates runoff in the area tributaries and CSO volume from urban areas was developed with USEPA's Storm Water Management Model (SWMM) and constrained with the available spatial and flow data. The Ohio River model was developed with USEPA's Environmental Fluid Dynamics Code (EFDC) model. It is a linked hydrodynamic-water quality model and was configured in two dimensions (vertically averaged) for this river reach. The watershed model results and data-based estimates of source concentration were used as inputs to the river model. River model results for a simulation of the September 2001 wet weather event compared favorably to data. It should be noted that while the data to support the Ohio River EFDC model are fairly robust, the data available to constrain the watershed SWMM model are nominal and consequently, render results from both models as coarse estimates of actual conditions. However, both models can be readily updated as more information becomes available.

A "Simulation Management" approach was used to develop the modeling framework. "WinEFDC" is a Visual Basic 6.0 application that interfaces with supporting Microsoft Excel workbooks and Microsoft Access databases as well as the river model FORTRAN executable files. Key features of the WinEFDC simulation management framework include:

- A user-friendly "scenario builder" interface that can be used to interactively specify source load levels;
- Efficient pre-processing of model input data using a companion Microsoft Access database template; and,
- Visualization tools that allow the user to plot, animate, and further examine river model (EFDC) hydraulic and water quality results.

The modeling framework was constructed to allow users to evaluate results compared to current water quality standard criteria and also to each of these alternative water quality standard options.

Several options have been used in other areas of the country to revise water quality standards (ORSANCO 2004), including:

1. High flow exclusion;
2. Establishment of a wet weather sub-use category; and,
3. Alternative numeric water quality criteria.

Table ES-1 presents a summary describing how these alternative water quality standard options were incorporated into the modeling framework (along with the current water quality standard numeric criteria). Velocity output from the model is used to evaluate the potential effects of a high flow exclusion approach. The wet weather sub use approach can be evaluated by specifying a temporary water quality standard suspension period (e.g. 48 hours) and a minimum storm size that would trigger a suspension period (e.g. 0.5 inch storm or larger). The current *E. coli* numeric water quality standard criterion can be replaced by an alternative criterion by the user within the model framework. Table ES-2 presents a summary of alternative *E. coli* numeric criteria (EPA, 1986).

Table ES-1. Description of Numeric Criteria Evaluation Options.

No	Parameter[1]	Description	Evaluation Period	Default Value[2]	Units	Basis for Inclusion
1	*E. coli*	Single sample maximum concentration not to be exceeded	Hourly	240	cfu/100 ml	Current WQS
2	Velocity	Instantaneous maximum velocity corresponding to unsafe contact recreation conditions	Hourly	2	mph	Evaluate effectiveness of high flow exclusion as an alternative WQS Note that numeric values may differ depending on the type of recreational activity (e.g. swimming vs. boating)

No	Parameter[1]	Description	Evaluation Period	Default Value[2]	Units	Basis for Inclusion
3	Event Duration	Pre-defined period after a storm event meeting a rainfall threshold when contact recreation is not safe	Hourly	a. 48 b. 0.5	a. hours b. inches	Evaluate effectiveness of wet weather sub-use as an alternative WQS Note: The actual values will be a function of the level of CSO control that can be achieved without resulting in widespread social and economic impacts.
4	EC 10% exc. (30 d)	Compliance based on meeting current WQS at least 90% of the time within a 30-day period	Rolling 30-day	240	cfu/100 ml	Evaluate effectiveness of alternative numeric criteria (Similar to current Ohio WQS)
5	EC geomean (30 d.)	30-day geometric mean	Rolling 30-day	130	cfu/100 ml	Current WQS
6	EC (Velocity filter)	Hours of exceedance of *E. coli* single sample maximum when hours exceeding velocity criterion are excluded	Hourly	*E. coli* = 240 Velocity = 2 Event duration = 48 Event storm size = 0.50	*E. coli* = cfu/100 ml Velocity = mph Duration = hours Storm Size = inches	Evaluate remaining impact on use if a high-flow exclusion were included in the water quality standards
7	EC (Vel+Event filter)	Hours of exceedance of *E. coli* single sample maximum when hours exceeding velocity and event duration criteria are excluded	Hourly	*E. coli* = 240 Velocity = 2 Event duration = 48 Event storm size = 0.50	*E. coli* = cfu/100 ml Velocity = mph Duration = hours Storm Size = inches	Evaluate remaining impact on use if a high-flow exclusion and a temporary use suspension were included in the water quality standards

Notes:

[1] The parameter field corresponds to the entries in the 'Select Criteria' list box on the visualization interface (see Figure 4-11)

[2] Default values are based on current water quality standards or criteria applied in other sites/States. Note that each of these values can be changed to a user-defined value.

Table ES-2. Alternate Water Quality Numeric Criteria for *E. coli* (cfu/100 ml).[1]

Illness Rate (per 1000)	Geometric Mean Density	Designated Beach Area (75% C.L.)	Moderate Full Body Contact Recreation (82% C.L.)	Lightly Used Full Body Contact (90% C.L.)	Infrequently Used Full Body Contact (95% C.L.)
8	126	235	298	409	575
9	161	300	381	523	736
10	206	385	489	668	940
11[1]	263	490	622	855	1,202
12[1]	335	624	793	1,089	1,531

Illness Rate (per 1000)	Geometric Mean Density	Designated Beach Area (75% C.L.)	Moderate Full Body Contact Recreation (82% C.L.)	Lightly Used Full Body Contact (90% C.L.)	Infrequently Used Full Body Contact (95% C.L.)
13[1]	428	797	1,013	1,391	1,956
14[1]	547	1,019	1,294	1,778	2,500

Notes:
[1] EPA does not support the extension of the freshwater pathogen criteria to an illness rate beyond 10 per 1000 (1%).

The visualization tools allow the user to select an existing scenario and generate spatial (downriver) profile animations, time series graphics, and map-based animations of the EFDC river model results. Inputs to the river model from CSOs and major tributary watersheds are also displayed on the map-based animations. The user can also select an existing scenario and generate spatial (downriver) profiles of exceedances of current and user-specified numeric criteria for both *E. coli* and velocity (see Table ES-1 for default criteria).

Seven screening-level source reduction scenarios were simulated with the Ohio River model. Source reductions for CSO ranged from 0 (base) to 100% while nonpoint and upstream source reductions ranged from 0 to 60%. Results were compared to current and alternative water quality standard criteria. Major findings from this application include:

- Peak concentrations in the river exceed 100,000 cfu/100 ml in rare instances;
- Even if CSOs are completely eliminated, exceedances of existing single sample maximum and 30-day geometric mean water quality standard numeric criteria will still occur in the Hannibal pool due to loads from nonpoint and upstream sources;
- The most effective scenario (fewest water quality exceedances) was the scenario that addressed all three sources (CSO, nonpoint, and upstream); and,
- Concentrations leaving the pool exceed each criterion less than ten percent of the time but these results reflect the effect of a poorly constrained bacterial loss rate in the model.

To complete the UAA at this study area, the following additional data needs were identified:

- Accurate combined sewer overflow (CSO) volumes;
- Nonpoint source (tributary) *E. coli* concentrations under varying environmental conditions;
- Refinement of upstream boundary concentrations;
- Economic data for each community; and
- Feasible control alternatives.

Public domain models for the watershed and Ohio River were selected so that they could be adapted to other portions of the Ohio River or to other large rivers, such as the Mississippi River. This would require updating the models' configuration and inputs to reflect new site conditions. It is recommended that experienced modelers adapt the models to a new site to ensure that models are configured correctly and that results from the new application are reasonable.

1. INTRODUCTION

This report presents the results of a Demonstration Project to develop a framework that can be applied to establish a wet weather, recreational Use Attainability Analysis (UAA) in an urban industrial river. A UAA is a scientific assessment of the factors affecting the attainment of designated uses (e.g. fishable/swimmable) specified in the Clean Water Act (USEPA 1983). This Demonstration Project focused on a 40-mile reach of the Ohio River near Wheeling, West Virginia called Hannibal Pool.

Elements of the project included developing watershed and river models to simulate bacteria (*E. coli*) and a framework to evaluate results. Refined estimates of bacteria loads from combined sewers and stormwater and additional data are needed before the framework can be applied to support the development of UAA to confirm the highest attainable recreational use for the Ohio River at Hannibal Pool. Additional application or analyses beyond the scope of this project can be undertaken by the project stakeholders, which include the Ohio River Valley Water Sanitation Commission (ORSANCO), EPA Region 3, West Virginia Department of Environmental Protection, Ohio EPA, and seven communities in West Virginia and Ohio.

Project funding was provided by the EPA Region 3 through a grant. The following sections in this chapter provide descriptions of project objectives and background information.

1.1 PROJECT OBJECTIVES

The initial purpose of this project was to investigate the level of recreational use that can be attained during periods of wet weather flow in a 40-mile section of the Ohio River in an urban industrial setting. A lack of site-specific data for wet weather loadings in the communities and watershed prevented completion of the UAA. Thus, the objective for this project was to develop a framework that communities in the Wheeling area can use to complete a UAA once more extensive data and information are collected.

1.2 SITE BACKGROUND

The study area, shown in Figure 1-1, extends from the Pike Island Locks and Dam (river mile 84.3) to Hannibal Locks and Dam (river mile 126.4) near New Martinsville, Ohio. West Virginia communities with wastewater discharges along this portion of the river include Wheeling, Benwood, McMechen and Moundsville. Ohio communities with wastewater discharges along this portion of the river include Martins Ferry, Bridgeport, and Bellaire. In the nineteenth century, this area was the center of the steel industry along the Ohio River; therefore, the communities on both sides of the river are heavily developed along the riverfront. There are approximately 180 combined sewer overflows (CSOs) to the Ohio River and its tributaries in this area (based on the USEPA's Permit Compliance System (PCS) database (http://www.epa.gov/enviro/html/pcs/index.html)).

Under the Ohio River Valley Water Sanitation Compact, the states of West Virginia and Ohio have committed to work together to control pollution in the Ohio River to protect designated uses. Both states have designated the river for contact recreation use in their water quality standards. The provision of secondary treatment with disinfection to sewage discharged to the river, together with adequate treatment of industrial wastes, has greatly improved conditions since the 1970s. Elevated bacteria levels during and after precipitation events, however, make the river unsuitable for contact recreation.

1.3 EXISTING USES AND WATER QUALITY STANDARD CRITERIA

The Ohio River is designated for contact recreation use. ORSANCO has published the following bacteria Pollution Control Standards for the Ohio River to protect that use (ORSANCO, 2003):

> *To provide protection to human health, the following criteria shall be met outside the mixing zone:*
>
> > *1b. Maximum allowable level of fecal coliform bacteria for contact recreation—for the months of May through October, content shall not exceed 200/100 ml as a monthly geometric mean, based on not less than five samples per month, nor exceed 400/100 ml in more than 10 percent of all samples taken during the month.*
> >
> > *1c. Maximum allowable level of Escherichia coli bacteria for contact recreation—for the months of May through October, measurements of Escherichia coli bacteria may be substituted for fecal coliform. Content shall not exceed 130/100 ml as a monthly geometric mean, based on not less than five samples per month, nor exceed 240/100 ml in any sample.*

USEPA has determined that *E. coli* is a better indicator than fecal coliform for pathogenic micro-organisms that affect human health (USEPA, 1986, 2004). Therefore, some states have been transitioning their bacterial water quality standard numeric criteria from fecal coliform to *E. coli* (although other states are waiting for further conclusions by EPA to see if alternate indicators beyond E-coli are more appropriate). For these reasons and because the Ohio River dataset for *E. coli* is more robust than the fecal coliform dataset in this study area, *E. coli* was used as the parameter to evaluate recreational use attainment in the Ohio River with the modeling tools.

1.4 RELATING PROJECT RESULTS TO UAA OPTIONS

According to the UAA portion of the Clean Water Act (40CFR 131.10(g)), up to six factors may potentially affect the attainment of water quality standards (both designated uses and the criteria protecting those uses). These factors are:

1. Naturally occurring pollutant concentrations;
2. Natural, ephemeral, intermittent, or low flow conditions or water levels;

3. Human caused conditions or sources of pollution;
4. Dams, diversions, or other types of hydrologic modification;
5. Physical conditions related to the natural features of the waterbody; and,
6. Substantial and widespread economic and social impact.

Data and modeling tools such as the ones used for this project (described in Section 2) can be used to evaluate each of these factors and to develop an appropriate strategy for revising water quality standards. For example, as more site-specific information becomes available, a model scenario that only includes natural bacteria sources, such as wildlife, and pre-development hydrology may quantify the ability of the Ohio River to attain water quality standards based on factor 1.

The third technical factor, human caused conditions that cannot be remedied or would cause more environmental damage to correct than to leave in place, has been suggested as a factor that may be appropriate for urban areas where complete CSO removal is not feasible because of altered hydrology or economic limitations (NACWA, 2005). Seven model runs, with varying levels of source control, were conducted to evaluate the benefit of reducing human sources, primarily CSO. The results of these scenarios are described in Section 3 (though the model results should not be used as a basis for management decisions, given the uncertainty in the source loads).

Several options have been used in other areas of the country to revise water quality standards (ORSANCO 2004), including:

1. High flow exclusion;
2. Establishment of a wet weather sub-use category; and,
3. Alternative numeric water quality criteria.

The modeling framework (described in Section 4) was constructed to allow users to evaluate results compared to current water quality standard criteria (Section 1.3) and also to each of these alternative water quality standard options.

Table 1-1 presents a summary describing how these alternative water quality standard options were incorporated into the modeling framework (along with the current water quality standards). Velocity output from the model is used to evaluate the potential effects of a high flow exclusion approach. The wet weather sub use approach can be evaluated by specifying a temporary water quality standard suspension period (e.g. 48 hours) and a minimum storm size that would trigger a suspension period (e.g. 0.5 inch storm or larger). The current *E. coli* numeric water quality standard can be replaced by an alternative criterion by the user within the model framework. Table 1-2 presents a summary of alternative *E. coli* numeric criteria (EPA, 1986, 2004).

See Section 4.3 for a more detailed description of the exceedance evaluation portion of the modeling framework.

Table 1-1. Description of Numeric Criteria Evaluation Options.

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1	*E. coli*	Single sample maximum concentration not to be exceeded	Hourly	240	cfu/100 ml	Current WQS
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4	EC 10% exc. (30 d)	Compliance based on meeting current WQS at least 90% of the time within a 30-day period	Rolling 30-day	240	cfu/100 ml	Evaluate effectiveness of alternative numeric criteria (Similar to current Ohio WQS)
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Notes:

[1] The parameter field corresponds to the entries in the 'Select Criteria' list box on the visualization interface (see Figure 4-11)

[2] Default values are based on current water quality standards or criteria applied in other sites/States. Note that each of these values can be changed to a user-defined value.

Table 1-2. Alternate Water Quality Numeric Criteria for *E. coli*.

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8	126	235	298	409	575
9	161	300	381	523	736
10	206	385	489	668	940
11[1]	263	490	622	855	1,202
12[1]	335	624	793	1,089	1,531
13[1]	428	797	1,013	1,391	1,956
14[1]	547	1,019	1,294	1,778	2,500

Notes:
[1] EPA does not support the extension of the freshwater pathogen criteria to an illness rate beyond 10 per 1000 (1%).

2. MODEL DEVELOPMENT

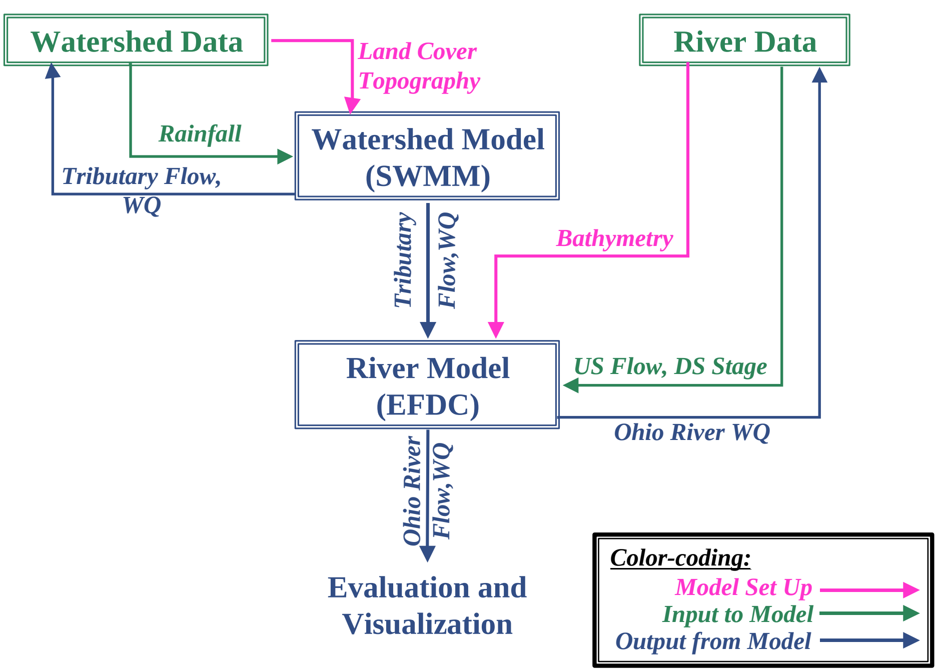
This section presents the development of the watershed and river models and a summary of the information and data used to support the models. Models are used to fill data gaps in space and time and can be used to forecast the relative benefit of future source controls. Models that are well-constrained by data can offer insight into how each of the technical attainment factors described in 40CFR131.10(g) are impacting a given surface water than from the data alone.

Watersheds of major tributaries and collection system areas in urban centers were simulated using EPA's Storm Water Management Model (SWMM). The Ohio River hydrodynamics and water quality were simulated using EPA's Environmental Fluid Dynamics Code (EFDC) model. Supporting data include water quality, hydrodynamic and spatial (GIS) data. It should be noted that while the data to support the Ohio River EFDC model are fairly robust, the data available to constrain the watershed SWMM model are nominal and consequently, render results from both models as coarse estimates of actual conditions.

2.1 DATA

Data were compiled to support model development and to verify that simulated flows and concentrations were within observed ranges of values. This section briefly describes the available data and how they were used to support the modeling effort. Figure 2-1 shows how the datasets described in this section were used to inform the modeling framework.

Figure 2-1. How Data Fits Into Modeling Framework.



All of the water quality and hydrodynamic data were compiled into a Microsoft Access database. This task ensured that all of the data were centralized in a single data repository and were expressed in a consistent manner.

2.1.1 Datasets

Table 2-1 presents a summary of the available water quality and hydrodynamic datasets for the Ohio River and area tributaries.

Table 2-1. Data Sources for the Wheeling Study Area.

Location	Data Type	Source	Description	Date
Ohio River	Bathymetry	USACE	Sounding data (bottom elevation) collected in Ohio River every 10-20 feet along a 500x500 ft grid.	2000-2001
Ohio River	Flow	USACE	Stage-discharge relationship at Pike Island and Hannibal Dam	2000-2004
Ohio River	Stage	USACE	Hourly stage data above and below Pike Island and Hannibal Dams	2000-2004
Ohio River, Watershed	Water Quality	ORSANCO	Wet weather sampling for Wheeling Wet Weather Demonstration Project	1998-2001
Ohio River	Water Quality	ORSANCO	Routine weekly monitoring during recreation season near Wheeling	1998-2004
Ohio River	Water Quality	ORSANCO	Weekly longitudinal survey for 5-week period during each year	2003-2004
Ohio River, Watershed	Water Quality	City of Wheeling	Monitoring in Ohio River near confluence of Wheeling Creek (WV) and in Wheeling Creek	1993-1998
Watershed	Rain	NCDC	Hourly precipitation for five gages in and near study area	1970-2004
Watershed	Flow	USGS	Captina Creek daily flow at two gages (03114000, 03113990)	1926-present
Watershed	Water Quality	WVDEP	Periodic monitoring data downloaded from USEPA STORET database	2000

Each of the water quality, hydrodynamic and GIS datasets are briefly described in the following section. Table 2-2 presents a summary of hydrodynamic and water quality conditions observed in the Hannibal Pool of the Ohio River.

Table 2-2. Statistical Summary of Hydrodynamic and Bacteria Data for the Ohio River.

Parameter	Number of Values	Minimum	Maximum	Average	5th Percentile	25th Percentile	50th Percentile	75th Percentile	95th Percentile
Upstream Flow (cfs)	58,369	1,166	348,000	47,886	13,875	23,208	36,443	65,672	109,637
Downstream Stage (ft)	58,369	11.50	22.10	12.86	12.40	12.70	12.90	13.00	13.20
Upstream *E. coli* Conc. (cfu/100 ml)	182	<10	2,300	172	8	20	53	168	630
Wheeling Area *E. coli* Conc. (cfu/100 ml)	353	<10	16,000	619	12	66	209	492	3,040
Downstream (Hannibal Dam) *E. coli* Conc. (cfu/100 ml)	72	<10	830	86	3	9	37	97	385

Water Quality Datasets

ORSANCO has conducted bacteria monitoring in the Wheeling area during the contact recreation season for over ten years. Since 2001, that monitoring has consisted of five samples per month from each of three locations- one upstream of the city, one within the urbanized area, and one downstream of the city. Sample analysis includes *E. coli* bacteria. The results indicate that criteria to protect contact recreation are met in about three-fourths of the months at the upstream site, but are exceeded in 22 of 29 months (76%) at the midway location and in two-thirds (67%) of all months at the downstream location.

ORSANCO has also conducted intensive sampling in the study area including both "wet" and "dry" weather sampling collections over two day periods from multiple sites on the Ohio River and from the mouths of tributaries. The wet weather survey conducted in September 2001 was simulated with the river model and compared to the in-stream *E. coli* data.

ORSANCO initiated intensive longitudinal *E. coli* surveys for a five week period in the summers of 2003 and 2004. Samples were collected approximately every five miles and each river mile was sampled along each near shore and in the center channel. These data were used primarily to develop the upstream boundary concentration input to the water quality model.

Tributary water quality data are available from the West Virginia Department of Environmental Protection (WVDEP), the City of Wheeling and the City of Moundsville. Because the numeric water quality standards in West Virginia are based on fecal coliform as the indicator species, the only bacteria data from these sources are for fecal coliform. As described in Section 2.2.1, these data were translated to an estimated *E. coli* equivalent and used to develop representative concentrations for each tributary to input into the river model. No state or municipal data were available for the tributaries on the Ohio side of the river.

Hydrodynamic Datasets

The U.S. Army Corps of Engineers manages the lock and dam operations at both Pike Island and Hannibal. The Corps maintains gages above and below each dam that record the river stage on an hourly frequency. Further, the Corps has developed a stage-discharge curve that describes the relationship between river stage and flow. A mathematical function was fit to the stage-discharge profile and used to estimate hourly flow from the stage data. Data were available from 1993-present. However, gaps in the dataset restricted the usable portion to the period of 2000-2005. Hourly flow data derived from the gage below Pike Island were used for the river model's upstream boundary flow input. Hourly stage data at the upstream gage at Hannibal Dam were used for the river model's downstream boundary.

The U.S. Geological Survey (USGS) has monitored flow on Captina Creek since the 1920s. The gage (USGS ID 03114000, drainage area = 134 mi^2) located just downstream of the confluence of the creek with Anderson Run was used from 1926 until May 2003. The gage was moved further upstream (USGS ID 03113990, drainage area = 127 mi^2) in June 2003 and is being used presently. The data from these gages were compared to the flows simulated in the Captina Creek subwatershed using the watershed model, as described in Section 2.2.2.

Rainfall data are used as input to the watershed model to simulate runoff to the tributaries and municipal collection systems. There are several gages in the vicinity of the study area but the gages with the longest and most complete periods of record lie outside the Hannibal Pool watershed. Data from 1970 to the present were considered for this project (see Section 3.2). Data from the gages (shown in Figure 2-2) were compiled to generate an hourly rainfall record for use in the watershed model.

Spatial Data

Spatial data includes information about the Ohio River itself and the surrounding watershed. The USACE completed a detailed bathymetric survey of this section of the Ohio River in 2000-2001. Sounding data were collected approximately every 10 feet along a 500 x 500 ft grid of the Ohio River. These data were used to inform the bottom surface elevations used in the river model.

Land use, soil, elevation, municipal city boundaries and CSO location information from GIS were used to develop the site-specific characteristics of the watershed model, such as slope and percent impervious area.

2.1.2 Major Findings

Conditions in the Hannibal Pool of the Ohio River based on the available water quality data indicate the following findings:

- Contact recreation criteria are generally met in the Ohio River under dry weather conditions, but are exceeded in much of the study area under wet weather conditions (ORSANCO, 2002);

- Wet weather sources clearly influence frequency of bacteria violations (ORSANCO, 2004);

- The upper river, which includes Hannibal Pool, tends to have more frequent violations and higher concentrations than pools in the Ohio River further downstream (in the middle river); and,

- The entire river has met water quality standards during dry weather (ORSANCO, 2004).

2.2 WATERSHED MODEL

This section describes the development and application of the USEPA Storm Water Management Model (SWMM) to estimate flows and loads to the Ohio River. The model was configured to simulate runoff in the major tributary watersheds and urban areas in the Hannibal Pool watershed. Figure 2-2 shows the SWMM watershed model domain and extent. Very little data were available to inform or constrain the land side runoff and loads. For example, none of the communities in the study area have models to estimate CSO volume on an event basis. Therefore, source loads and volumes are very uncertain and should be considered, at best, as screening level accuracy. However, the model configuration allows the user to distinguish between sources that have human origins, such as CSO, and natural sources (such as wildlife) that are incorporated into the tributary nonpoint source loads. Natural sources are one factor that may be considered in Use Attainment Analyses (see Section 1.4).

SWMM is a well known, public domain model that is readily configured to site-specific characteristics. It works well in urban areas, where most of the *E. coli* load in this study area is believed to originate. However, it can also simulate runoff from land to tributaries and transport in the tributaries to the Ohio River. Therefore, it is well-suited for the needs of this project, since it can be updated relatively easily as more site-specific information on sources become available.

2.2.1 SWMM Model Development

Spatial elevation data were used to delineate major tributary watersheds draining to the Ohio River in the Hannibal Pool reach. A total of 18 tributary watersheds were simulated with SWMM, eight in Ohio and ten in West Virginia, as shown in Figure 2-2.

Smaller tributaries were treated as areas that drain directly to the Ohio River. Table 2-3 summarizes the tributary watershed information used in the SWMM model.

Table 2-3. Tributary Characteristics and Inputs to River Model.

River Mile	Name	State	Drainage Area (mi^2)	Dry *E. coli* EMC	Wet *E. coli* EMC	Notes
86.1	Glenn's Run (WV)	WV		182	1,431	Wet/dry data available
86.4	Glenn's Run (OH)	OH		182	1,431	No data available
90.2	Wheeling Cr. (OH)	OH		140	4,925	Wet/dry data available
90.8	Wheeling Cr. (WV)	WV		112	1,566	Wet/dry data available
91.7	Caldwell Run	WV		1,560	4,200	Wet/dry data available
93.4	Bogg's Run	WV		822	7,430	Wet/dry data available
94.7	McMahon Cr.	OH		22	3,872	Wet/dry data available (fecal)
95.8	McMechen's Run	WV		2,280	9,288	Wet/dry data available
96.8	Jim Run	WV		2,440	2,440	Wet/dry data available
98.7	Wegee Cr.	OH		65	8,400	No data available-used Proctor Creek data
102.5	Grave Cr.	WV		399	5,705	Wet/dry data available
105.0	Pipe Cr.	OH		182	1,431	No data available-used Glenn's Run (WV)
109.6	Captina Cr.	OH		58	512	Wet/dry data available
113.8	Fish Cr.	WV		112	1,566	Wet/dry data available
118.0	Sunfish Cr.	OH		31	476	Wet/dry data available
119.8	Opposum Cr.	OH		65	8,400	No data available-used Proctor Creek data
122.1	Proctor Cr.	WV		65	8,400	Wet/dry data available

Elevation data were also used to estimate the slope, which affects the timing of runoff to the tributaries and transport to the river. Land use and soil data were used to estimate the level of imperviousness in each tributary subwatershed. As noted in Section 2.1.1, tributary *E. coli* data are limited. Therefore, representative or event mean concentrations (EMCs) for dry and wet weather were developed from the available data for each tributary (see Table 2-3). Fecal coliform data from WVDEP and the Cities of Wheeling and Moundsville were translated to an *E. coli* equivalent by assuming 70% of the fecal coliform were *E. coli* (based on data and analysis by ORSANCO). The median dry weather concentration in each tributary was used as the dry weather EMC while the 75th percentile wet weather concentration was used as the wet weather EMC. For tributaries that receive CSO, such as Wheeling Creek (WV), data from locations upstream of the CSO-impacted area were used to develop the EMCs. The loads from the CSOs discharging to creeks were estimated separately within the SWMM model and input directly to the Ohio River model.

Municipal areas were excluded from the tributary subwatersheds so that their runoff could be calculated separately and apportioned between the community's waste water treatment plant and CSO. Five CSO communities were specified in the model domain. These include Wheeling, Benwood, McMechen and Moundsville in West Virginia and East Ohio Regional Water Authority, which includes the communities of Bellaire, Bridgeport and Brookside. Approximately 180 CSOs were included in the model domain.

Due to a lack of information, CSO loads were estimated based on certain general parameters. The CSO volume for each community was estimated using the following general equation:

CSO Volume = Rainfall Volume Collected in the CSO Service Area – Volume to WWTP

The total volume in the CSO service area was simulated using the site-specific inputs for each municipal area. Approximately 50% of the rainfall volume was assumed to reach the collection system. Further, it was assumed that approximately 50-70% of the volume in the collection system was conveyed to the wastewater treatment plant (WWTP) for treatment, with the remainder being discharged as CSO. In general, the CSO volume was typically 20-25% of the total rainfall volume in the sewered area. CSO volumes for each community were compared to volumes from similarly sized communities to ensure that values were somewhat realistic.

Because no data were available for individual CSOs, the CSOs in each community were grouped geographically into a single input location to the river model. Table 2-4 presents a summary of the CSO inputs to the river model. No site-specific measurements of *E. coli* have been made in any of the area CSOs. Therefore, a literature-based concentration of 500,000 cfu/100 ml (EPA, 2002) was used to estimate the CSO load into the river.

Table 2-4. CSO Inputs to the River Model.

CSO Group	RM Start	RM End	Name	Location	No. Outfalls	Model Input RM	Flow fraction	*E. coli* EMC	Notes
1	86.3	87.8	Upper Wheeling (WV) CSO	Upper	7	86.7	0.64	500,000	Includes 1 CSO discharging to Glenn's Run (WV)
1	86.3	87.8	Upper Wheeling (WV) CSO	Midway	4	87.3	0.36	500,000	
2	89.0	92.7	Wheeling (WV) CSO near (above) Wheeling Cr.	West	7	89.7	0.07	500,000	
2	89.8	90.8	Wheeling Island CSO	East	5	90.4	0.05	500,000	
2	89.8	90.8	Wheeling Island CSO	West	9	90.0	0.09	500,000	
2	90.8	90.8	Wheeling Cr. (WV) CSO	Confluence	62	90.8	0.61	500,000	
2	89.0	92.7	Wheeling (WV) CSO near (below) Wheeling Cr.	Upper	11	91.6	0.11	500,000	Includes 6 CSOs discharging to Caldwell Run

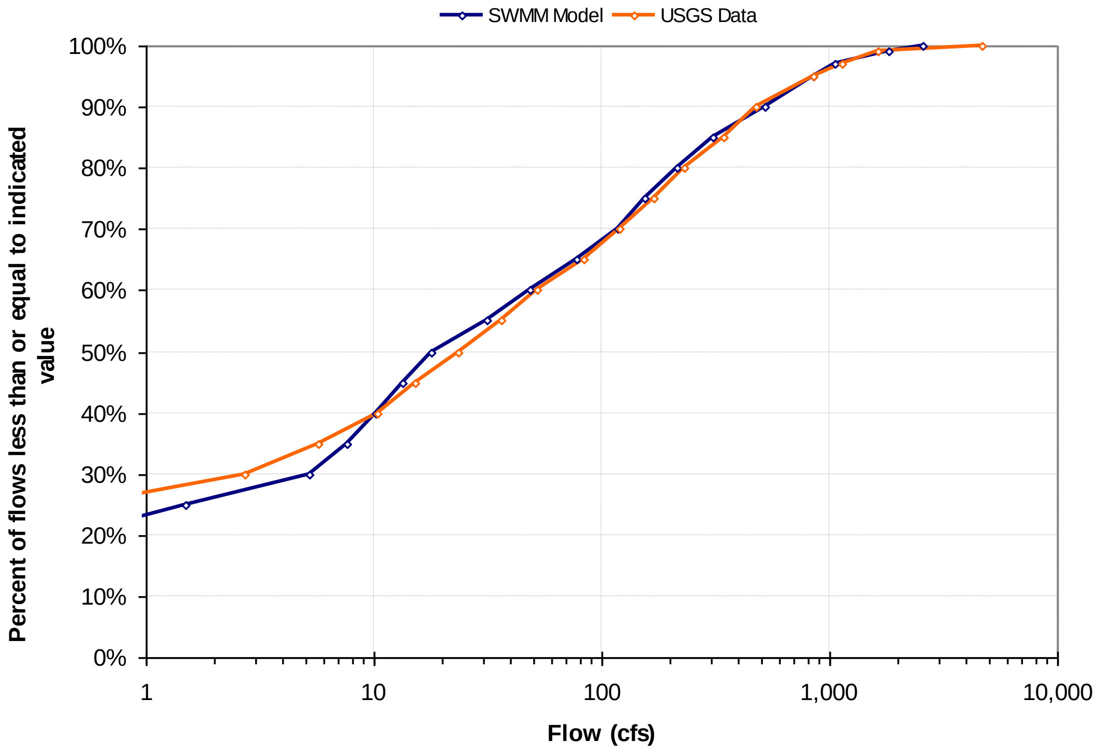
CSO Group	RM Start	RM End	Name	Location	No. Outfalls	Model Input RM	Flow fraction	*E. coli* EMC	Notes
2	89.0	92.7	Wheeling (WV) CSO near (below) Wheeling Cr.	Lower	8	92.5	0.07	500,000	
3	90.1	90.6	EORWA CSO near Bridgeport	Middle	10	90.2	0.43	500,000	Includes 8 CSOs discharging to Wheeling Cr. (OH)
3	90.1	90.6	EORWA CSO near Bridgeport	Lower	7	90.5	0.30	500,000	
3	88.8	90.6	EORWA CSO near Bridgeport	Upper	6	88.6	0.26	500,000	
4	92.9	95.2	Bellaire CSO	Upper	10	93.4	0.42	500,000	Includes 4 CSOs discharging to Indian Run (OH)
4	92.9	95.2	Bellaire CSO	Middle	7	94.2	0.29	500,000	Includes 2 CSOs discharging some distance from the Ohio River
4	92.9	95.2	Bellaire CSO	Lower	7	94.9	0.29	500,000	Includes 1 CSO discharging to McMahon Cr.
5	93.3	95.3	Benwood CSO	Upper	4	93.5	0.36	500,000	Includes 3 CSOs discharging to Bogg's Run (WV) from Benwood and 1 CSO from Wheeling
5	93.3	95.3	Benwood CSO	Middle	4	94.2	0.36	500,000	Includes 3 CSOs discharging to Bogg's Run (WV)
5	93.3	95.3	Benwood CSO	Lower	3	95.2	0.27	500,000	
6	95.7	96.8	McMechen CSO	Upper	2	95.9	0.4	500,000	Includes 2 CSOs discharging to McMechen's Run (WV)
6	95.7	96.8	McMechen CSO	Lower	3	96.6	0.6	500,000	Includes 1 CSOs discharging near Jim Run (WV)
7	101.5	102.4	Moundsville CSO	All	4	102.1	1	500,000	Includes 4 CSOs discharging to Grave Cr (WV)

Hourly rainfall data (described in Section 2.1.1) were input to the model for all of the simulations. Hourly flow results from each tributary and CSO group were output from the SWMM model and used as input to the river model.

2.2.2 Comparison to Flow Data

The only tributary subwatershed where flow data are available is Captina Creek (OH). These data were used to evaluate the parameterization of the SWMM model. A cumulative frequency distribution was developed using the flow data for a five year period, 1986-1990, and compared to the distribution of flows predicted by the SWMM model for the same period. Results are shown in Figure 2-3. As the figure shows, the SWMM model flow distribution is similar to the distribution of the data.

Figure 2-3. Comparison of Modeled and Observed Flows in Captina Creek.



2.3 RIVER MODEL

This section describes the development and application of the USEPA Environmental Fluid Dynamics Code (EFDC) model to simulate flow and water quality in the Hannibal Pool reach of the Ohio River. EFDC is a well known, public domain model that is readily configured to site-specific characteristics. The EFDC model links the river hydrodynamics and water quality into a single model, providing better representation of lateral transport across the river. EFDC also provides a more realistic simulation of in-stream velocity, which is a potential factor affecting recreational use in the river. However, as noted in the previous section, the volumes and loads to the river are highly uncertain and therefore, the in-stream concentrations predicted by EFDC are also highly uncertain.

2.3.1 EFDC Model Development

Figure 2-4 shows the EFDC watershed model domain and extent. The model has approximately 2,000 cells spanning the 40-mile reach of Hannibal Pool. Between six and nine cells are used to span the width of the river. Each cell is approximately 0.1 to 0.3 miles long. Model geometry is more detailed in areas near islands and in the very "curvy" sections of the river. The river is one-dimensional with respect to depth (e.g.

each cell spans the depth of the river). Cells where at least 50% of the surface area is dry (on land), such as islands, were treated as dry cells in the model and masked. Approximately 1,840 grid cells in the model are wet. Hourly velocity and *E. coli* concentration outputs from these cells are stored in the model output files.

Bottom surface elevation and shoreline delineation data for the Ohio River were available from the U.S. Army Corps of Engineers (USACE), as described in Section 2.1.1. The bottom surface elevation data were interpolated to estimate a representative average bottom surface elevation in each cell. Hourly flow data from the USACE at Pike Island Dam were used as the upstream flow boundary. Concentration data collected by ORSANCO were used to develop an upstream boundary time series for each simulation period. Hourly stage data from the USACE at Hannibal Dam were used to specify the downstream boundary.

2.3.2 Comparison to Wet Weather *E. coli* Data

The river model was run for the September 24-26, 2001 wet weather event that ORSANCO monitored for the Wet Weather Demonstration Project. Rainfall during this storm event averaged 0.80 inches across the study area (ORSANCO, 2002). Hourly tributary and CSO volumes and loads were generated using the SWMM watershed model and input into the river model.

ORSANCO monitored concentrations in the river on September 25 and 26, 2001 at three locations across each sampling transect: 1) the left descending bank (LDB) or West Virginia near shore, 2) the mid-channel (MID) or center of the river, and, 3) the right descending bank (RDB) or the Ohio near shore. Results were evaluated for each section of the river. The objective of this modeling exercise was to reproduce the magnitude of the *E. coli* concentration observed in the data on the day of sampling at each location. Results can be viewed in these animation files: PlotEFDC_Cali_LDB.xls (West Virginia near shore), PlotEFDC_Cali_MID.xls (mid-channel), PlotEFDC_Cali_RDB.xls (Ohio near shore). These animations show the daily minimum and maximum concentration for each day of the simulation and animate the hourly results output by the model. In general, the river model reproduces the in-stream concentrations at nearly every monitoring location on both days of the event.

3. MODEL APPLICATION

This section describes the application of the modeling tools for a set of screening level source reduction scenarios. The approach was to identify recreation season (May through October) period with "average" conditions, identify source reduction scenarios and to incorporate updates to the model to facilitate its use for this application. Each of these components is described in this section. It should be emphasized that all current model inputs for source loads are highly uncertain and the results presented in this section should not be used as a basis for management decisions.

3.1 SUMMARY

Seven scenarios were simulated with the Ohio River model. Source loads were reduced by applying a scaling factor to the concentration inputs to the river model. Source reductions for CSO ranged from 0 (base) to 100%. Nonpoint and upstream source reductions were also simulated in a couple of the scenarios. Results were compared to current and alternative water quality standard criteria. Major findings from this application include:

- Simulated concentrations are consistent with observed data;
- Peak concentrations in the river exceed 100,000 cfu/100 ml in rare instances;
- Even if CSOs are completely eliminated, exceedances of existing single sample maximum and 30-day geometric mean water quality standards will still occur in the Hannibal pool due to loads from nonpoint and upstream sources;
- The most effective scenario (fewest water quality exceedances) was the scenario that addressed all three sources (CSO, nonpoint, and upstream);
- Concentrations leaving the pool exceed each criterion less than ten percent of the time but these results reflect the effect of a poorly constrained bacterial loss rate in the model;
- Exceedances of the current numeric *E. coli* criteria would still occur even if high flow exclusion and/or temporary use suspension criteria were incorporated into the water quality standards; and,
- "Near shore" (as represented in the model, ~200 feet from shore) velocities can exceed 2 miles per hour (mph), a level that has been used as a threshold for unsafe swimming (ORSANCO, 2004). (Note: The actual numeric values for a velocity threshold when the UAA is completed will be updated to reflect additional data and information. It may differ from the value used in this project (2 mph) depending on the type of recreational activity (e.g. swimming vs. boating)).

3.2 DEVELOPMENT OF A "TYPICAL" RECREATION SEASON

The urban drainage, sewers, and the nearby tributaries in the Hannibal Pool reach of the Ohio River comprise a complex interrelated system. Several highly variable natural forces, primarily rainfall and river flows profoundly influence this system. Rainfall over the study area, when it occurs in sufficient amount, generates urban storm water, CSO, and increased treated wastewater flow. It also generates contaminated runoff from nonpoint sources, such as agriculture and wildlife. These events can all contribute bacteria and pollutants to the Ohio River and nearby tributaries.

The effect of these contributors on the Ohio River mainly depends on the magnitude and duration of rainfall events and on the prevailing ambient river conditions controlling dilution and transport of the pollutants. This variability and complexity poses a significant challenge to accurately assessing the performance of wet weather and CSO control alternatives for each community in the study area. Continuous simulation is generally acknowledged as a superior approach for modeling wet weather controls and water quality effects (EPA, 1999).

The impacts of wet weather sources on receiving water largely depend on three factors:

- **Time of year**. This is important because the recreation season occurs from May through October (when people are most likely exposed to bacteria from body contact).

- **Total amount of rain.** Rainfall characteristics determine the magnitude and duration of the CSO discharges and wet weather source runoff.

- **Upstream flow rate of the Ohio River**. The upstream flow rate affects the magnitude of the upstream pollutant loads, serves to flush pollutants out of the river and also provides dilution of the landside pollutant loadings.

Five years (2000-2004) having complete upstream Ohio River flow data, were considered for this application of the model. Flow in Hannibal Pool is regulated based on hydropower needs and so the upstream flow is not a function of environmental conditions. The rainfall during each year was compared to historical rainfall data from 1970 to the present to identify the recreation season (May through October) that most closely resembles the average conditions observed in the long-term rainfall record.

The recreation season during 2003 was identified as a "typical" recreation season based on the rainfall criteria shown in Table 3-1. Storm sizes during 2003 ranged from 0.10 inches to 2.00 inches. Appendix A presents a summary of the storm characteristics in the 2003 recreation season.

Table 3-1. Comparison of 2003 Rainfall (May-Oct.) to Average Historical Characteristics.

Criterion	Units	Historical (1970-2004) Average (Range)	2003 Value
Total Rainfall	Inches	19.26 (7.20-31.80)	19.70
Max. Storm	Inches	2.19 (0.60-5.20)	2.00
Avg. Storm Duration	Hours	3.93 (2.48-6.91)	3.89
Total Hours Rain	Hours	218 (104-452)	253

3.3 DEVELOPMENT OF SOURCE REDUCTION SCENARIOS

The river model includes *E. coli* loads from three different types of sources: upstream, CSO and nonpoint (tributary and direct drainage) sources. Table 3-2 presents the level of source reductions in each scenario that were simulated with the river model. Reductions were focused primarily on CSO sources, since CSOs will be reduced through implementation of long term control plans. However, two of the recommended scenarios also addressed reductions in non-point sources from within and upstream of the study area. Appendix B includes a memorandum describing the development of the source reduction scenarios.

Table 3-2. Recommended Source Reduction Scenarios.

Scenario No.	CSO	Non-point Source	Upstream[1]	Basis	Model Run No.
1	0	0	0	Assess current conditions	31
2	75%	0	0	Corresponds to 15 overflows /rec season in Wheeling and EORWA	32
3	85%	0	0	Corresponds to 9 overflows/rec season in Wheeling and EORWA	33
4	95%	0	0	Corresponds to 3 overflows/rec season in Wheeling and EORWA	34
5	95%	30%	45%	Scenario simulating likely level of achievable reductions[2]	35
6	100%	0	0	Best case CSO reduction only	36
7	0	60%	40%	Best case NPS reduction only	37

Notes:

[1] Upstream loads were estimated to be comprised of 25% CSO and 75% NPS based on the number of CSOs located in the upstream pool.
[2] Information used to develop the likely level of achievable reductions were documented in a memorandum provided to the stakeholders on June 21, 2006, and attached to this report.

3.4 BASELINE SOURCE INPUTS

Table 3-3 presents a summary of the inflow volumes and *E. coli* loads by source type for the 2003 recreation season. Four source types are summarized:

- Tributary or non-point sources: These loads corresponds to the tributary subwatersheds simulated with the watershed model;
- Direct drainage sources: These loads correspond to area in the watershed model that drain directly to the Ohio River and are not within a combined sewer service area;
- CSO sources: These loads correspond to combined sewer overflows, which were simulated for each community.
- Upstream sources: These loads correspond to sources upstream of Pike Island Dam (the model upstream boundary) and include a mixture of loads from non-point sources and CSO communities. Concentration data collected by ORSANCO at their upstream location during the 2003 routine monitoring (available at http://www.orsanco.org/) were used to develop an upstream boundary time series. The data showed that wet and dry period data were similar and could be combined, and that mid channel data were consistently higher than left and right bank data, so that the left and right bank series could be obtained by scaling down the mid channel by a constant factor.

Table 3-3 also includes values tabulated during wet weather conditions only (when CSOs and NPS sources are active) and for the entire period. Flow in Hannibal pool is dominated by the upstream Ohio River flow, which accounts for 98% of the inflow volume in the study reach (95% of the wet weather volume). CSOs account for 55% of the wet weather load and nonpoint (NPS) sources (tributary and direct drainage) account for approximately 14% of the wet weather load (percentages of tabulated values relative to the total load are shown in parentheses for each source type). The percentage of each source type's total load that occurs during wet weather is also provided in the last column of the table. Nearly all (93%) of the tributary and direct drainage loads are delivered to the river during wet weather. However, most of the upstream load is delivered during dry weather (since only 15% of the upstream load is delivered during wet weather).

Table 3-3. 2003 Recreation Season Volume and *E. coli* Load by Source Type.

	Volume (MG)		Total *E. coli* Load (cfu)		
SourceType	Wet Weather	All (Total)	Wet Weather	All (Total)	% of Total from Wet
Tributary (NPS)	52,795 (4.6%)	83,391 (1.2%)	4.61E+09 (12.6%)	4.97E+09 (5.0%)	93%
Direct Drainage (NPS)	6,493 (0.6%)	9,733 (0.15%)	3.74E+08 (1.0%)	4.00E+08 (0.4%)	93%
CSO	1,074 (0.1%)	1,074 (0.02%)	2.02E+10 (55.1%)	2.02E+10 (20.3%)	100%

SourceType	Volume (MG)		Total *E. coli* Load (cfu)		
	Wet Weather	**All (Total)**	**Wet Weather**	**All (Total)**	**% of Total from Wet**
Upstream	1,076,721 (94.7%)	6,333,976 (98.5%)	1.14E+10 (31.2%)	7.39E+10 (74.3%)	15%
Total	*1,137,083*	*6,428,175*	*3.66E+10*	*9.94E+10*	*37%*

Table 3-4 presents a summary of estimated CSO volume and number of overflow events by community for selected storm events and for the entire recreation season. Note that these values are highly uncertain and there are no data available to constrain or verify their magnitude or frequency. Rather, the reasonableness of these estimates was based on professional judgment, experience and comparison to overflow characteristics of other CSO communities in the region.

Table 3-4. CSO Volume by Community.

Community	Number of outfalls	Total Volume (MG)					No. of CSO Events
		0.6" (5/5/03)	1.1" (7/10/03)	1.6" (5/9/03)	2.0" (9/18/03)	**Entire Rec. Season**	
Wheeling CSOs	113	18.2	43.7	85.2	120.6	**743**	60
EORWA near Bridgeport	23	4.98	12.2	22.6	32.0	**195**	60
Bellaire CSOs	24	1.8	6.3	11.0	17.8	**73**	47
Benwood CSOs	11	0	1.2	4.8	10.2	**31**	29
McMechen CSOs	5	0	1.2	3.5	7.3	**22**	19
Moundsville CSOs	4	0	0.6	1.3	3.6	**10**	18

3.5 MODEL RESULTS

Tables 3-6 through 3-11 in the subsections below present model results with respect to criteria exceedances, for selected key locations in the modeled portion of the Ohio River, and for various criteria. It should be emphasized that all current model inputs for source loads are highly uncertain and the results presented in this section should not be used as a basis for management decisions. Therefore, results are presented for a subset of model grid cells that were selected based on their geographical significance to key loading inputs or landmarks within the pool. Table 3-5 defines these key locations by river mile and lateral portion of the river. Lateral locations are abbreviated as LDB for Left Descending Bank (i.e., West Virginia Near Shore), MID for Mid-Stream, or RDB for Right Descending Bank (i.e., Ohio Near Shore).

Table 3-5. Key Locations for Evaluating Water Quality Standard Exceedances.

Key Location No.	Description	River Mile	Lateral Location	Significance
1	Upstream boundary	86.44	MID	Define impact from upstream sources. ORSANCO's upstream rec-season monitoring point.
2	Below Wheeling Cr.	91.03	LDB	Reflects most of Wheeling CSO loads.
3	Below Wheeling	93.05	LDB	Characterize impact of all of Wheeling CSO sources.
4	Below Moundsville	102.76	LDB, RDB, and/or MID	Below last CSO input. Wheeling area loads are laterally well-mixed.
5	Below Wheeling Creek, OH	90.70	RDB	Reflects most of EORWA CSO loads.
6	Below EORWA CSOs	95.00	RDB	Last Ohio CSO load.
7	Below Powhaten Point and Captina Creek	112.02	MID	All CSO loads are laterally well-mixed.
8	Downstream boundary	126.04	MID	Define impact leaving pool.

3.5.1 In-stream Concentrations

Simulated concentrations are consistent with observed data in the Ohio River. Table 3-6 shows *E. coli* concentrations at key locations for three selected events. "No Storm" is represented by dry conditions on 7-23-2003 at 00:00. "Medium Storm" is represented by a storm of modest size, 0.4 inches of rainfall, on 5-31-2003 at 16:01 (6 hours into the storm). "Large Storm" is represented by the largest rainfall event of the 2003 season, 2.0 inches, on 9-18-2003 at 01:58 (5 hours into the storm). Concentrations can be seen to be quite variable and are sensitive to storm event size and to the time and place of measurement. Modeled concentrations – using the given assumptions about upstream boundary concentrations and tributary loads– can exceed 100,000 cfu/100ml near the upstream boundary but can fall to the single digits at the downstream end of the pool.

Table 3-6. Typical *E.coli* concentrations (cfu/100 ml)-Base Scenario.

Location (RM/lat. loc.)[1]	Simulated Range	No Storm	Medium Storm	Large Storm
1 (86.44/MID)	7 – 1,474	105.0	558	120
2 (91.03/LDB)	6 – 7,657	66.6	1,410	7,657
3 (93.05/LDB)	5 – 8,764	59.6	1,818	4,718
4 (102.76/LDB)	9 – 4,945	39.5	484	1,545

Location (RM/lat. loc.)[1]	Simulated Range	No Storm	Medium Storm	Large Storm
4 (102.76/RDB)	3 – 5,134	33.8	216	31.6
4 (102.76/MID)	3 – 5,122	34.5	212	29.3
5 (90.70/RDB)	24 – 21,865	71.3	3,983	21,865
6 (95.00/RDB)	16 – 15,896	59.0	859	9,599
7 (112.02/MID)	1 – 3,865	18.9	116	14.1
8 (126.04/MID)	1 – 2,447	4.7	54.9	4.87

Notes:

[1] "Lat. Loc" = lateral location, which describes the portion of the river transect where the evaluation is being conducted. The lateral location is based on a downstream orientation. Individual conventions used in the table include:

LDB = left descending bank (near West Virginia shoreline)
MID = center channel (center of the river)
RDB = right descending bank (near Ohio shoreline)

3.5.2 Exceedances of Current Water Quality Standard Numeric Criteria

This section presents a comparison of model scenario results to the current Ohio River *E. coli* water quality standard numeric criteria (presented in Section 1.3). As more information on source loads is incorporated into the framework, the effectiveness of each scenario in meeting water quality standard criteria might be significantly different than the results shown in this section.

Comparison to Single Sample Maximum E. coli Water Quality Standard Criterion

Table 3-7 shows the hours of exceedance (out of a total of 4,417 possible hours in the recreation season) for which the *E. coli* concentration at the indicated key location was over the single sample maximum water quality standard criterion of 240 cfu/100ml. Scenarios include a range of CSO-only percent reductions from zero (the base scenario) to 100%. It appears from these results that CSO-only controls are of limited usefulness, and that they reach a point of diminishing returns as the reduction percentage increases. Note that the first location is upstream of all CSO inputs; therefore, it does not show any benefit from reducing CSO loads.

Table 3-7. Hours of exceedance of *E. coli* Single Sample Maximum Water Quality Standard Criterion (240 cfu/100 ml) for CSO Reduction Scenarios.

Location (RM/lat. loc.)	Base (0%)	CSO-75%	CSO-85%	CSO-95%	CSO-100%
1 (86.44/MID)	1,343	1,343	1,343	1,343	1,343
2 (91.03/LDB)	1,551	1,408	1,366	1,288	1,250
3 (93.05/LDB)	1,477	1,327	1,275	1,194	1,153
4 (102.76/LDB)	1,250	1,142	1,113	1,085	1,070

Location (RM/lat. loc.)	Base (0%)	CSO-75%	CSO-85%	CSO-95%	CSO-100%
5 (90.70/RDB)	1,635	1,584	1,574	1,547	1,526
6 (95.00/RDB)	1,475	1,402	1,379	1,357	1,333
7 (112.02/MID)	701	542	512	480	467
8 (126.04/MID)	353	257	248	242	238

Table 3-8 a,b,c shows the hours of exceedance (out of a total of 4,417 possible unfiltered hours in the recreation season) for which the *E. coli* concentration at the indicated key location was above the water quality standard criterion of 240 cfu/100ml. The percent of the total hours is also shown in parentheses. Scenarios include no reduction (the Base scenario), reduction of all sources (95% for CSOs, 30% for non-point sources, and 45% for the upstream boundary load), 100% reduction of CSOs only, and reduction of non-point sources (0% for CSOs, 60% for non-point sources, and 40% for the upstream boundary load).

The a-table shows exceedances for all hours of the entire season. The b-table excludes high water velocity (above 2 mph) conditions from exceedance totals. This analysis is intended to show the remaining impact on use if a high-flow exclusion were included in the water quality standards. The c-table excludes both high water velocities and rainfall events (at least 0.5 inches in the event, and a period of 48 hours from the start of the rainfall event). This analysis is intended to show the remaining impact on use if both a high flow exclusion and a temporary use suspension were incorporated into the water quality standards.

It appears from these results that reducing all sources has substantially more impact than reductions limited to only CSOs or only non-point sources. Some locations show much lower rates of exceedance when high-flow or temporary use suspension criteria are included. In some cases the number of hours of exceedance is very sensitive to velocity and/or rainfall event filtering criteria.

Table 3-8a. Hours of exceedance of *E. coli* 240 standard; No Filtering.

Location (RM/lat. loc.)	**Base** (No reductions)	**AllSrc** (CSO-95%) (NPS-30%) (US-45%)	**CSO100** (CSO-100%) (NPS-0) (US-0)	**NPS60** (CSO-0) (NPS-60%) (US-0)
1 (86.44/MID)	1,343 (30.4%)	563 (12.7%)	1,343 (30.4%)	747 (16.9%)
2 (91.03/LDB)	1,551 (35.1%)	490 (11.1%)	1,250 (28.3%)	889 (20.1%)
3 (93.05/LDB)	1,477 (33.4%)	431 (9.8%)	1,153 (26.1%)	864 (19.6%)
4 (102.76/LDB)	1,250 (28.3%)	450 (10.2%)	1,070 (24.2%)	630 (14.3%)
5 (90.70/RDB)	1,635 (37.0%)	744 (16.8%)	1,526 (34.5%)	933 (21.1%)
6 (95.00/RDB)	1,475 (33.4%)	537 (12.2%)	1,333 (30.2%)	799 (18.1%)
7 (112.02/MID)	701 (15.9%)	224 (5.1%)	467 (10.6%)	434 (9.8%)
8 (126.04/MID)	353 (8.0%)	126 (2.8%)	238 (5.4%)	255 (5.8%)

Table 3-8b. Hours of exceedance of *E. coli* 240 standard; Velocity Filtering.

Location (RM/lat. loc.)	**Base** (No reductions)	**AllSrc** (CSO-95%) (NPS-30%) (US-45%)	**CSO100** (CSO-100%) (NPS-0) (US-0)	**NPS60** (CSO-0) (NPS-60%) (US-0)
1 (86.44/MID)	825 (18.7%)	214 (4.8%)	825 (18.7%)	278 (6.3%)
2 (91.03/LDB)	231 (5.2%)	31 (0.7%)	110 (2.5%)	154 (3.5%)
3 (93.05/LDB)	1,072 (24.3%)	233 (5.3%)	793 (17.9%)	572 (12.9%)
4 (102.76/LDB)	1,189 (26.9%)	395 (8.9%)	1,014 (23.0%)	571 (12.9%)
5 (90.70/RDB)	1,621 (36.7%)	730 (16.5%)	1,512 (34.2%)	919 (20.8%)
6 (95.00/RDB)	1,450 (32.8%)	512 (11.6%)	1,308 (29.6%)	774 (17.5%)
7 (112.02/MID)	408 (9.2%)	56 (1.3%)	208 (4.7%)	243 (5.5%)
8 (126.04/MID)	306 (6.9%)	91 (2.1%)	191 (4.3%)	210 (4.7%)

Table 3-8c. Hours of exceedance of *E. coli* 240 standard; Velocity and Rainfall Event Filtering.

Location (RM/lat. loc.)	**Base** (No reductions)	**AllSrc** (CSO-95%) (NPS-30%) (US-45%)	**CSO100** (CSO-100%) (NPS-0) (US-0)	**NPS60** (CSO-0) (NPS-60%) (US-0)
1 (86.44/MID)	727 (16.5%)	184 (4.2%)	727 (16.5%)	236 (5.3%)
2 (91.03/LDB)	145 (3.3%)	8 (0.2%)	89 (2.0%)	71 (1.6%)
3 (93.05/LDB)	754 (17.1%)	167 (3.8%)	657 (14.9%)	319 (7.2%)
4 (102.76/LDB)	799 (18.1%)	209 (4.7%)	736 (16.7%)	285 (6.4%)
5 (90.70/RDB)	1,192 (27.0%)	473 (10.7%)	1,146 (25.9%)	567 (12.8%)
6 (95.00/RDB)	1,029 (23.3%)	294 (6.7%)	954 (21.6%)	451 (10.2%)
7 (112.02/MID)	219 (5.0%)	34 (0.8%)	172 (3.9%)	81 (1.8%)
8 (126.04/MID)	165 (3.7%)	82 (1.9%)	161 (3.6%)	94 (2.1%)

Comparison to 30-day Geometric Mean E. coli Water Quality Standard Criterion

Table 3-9 shows the number of periods of exceedance for which the 30-day geometric mean *E. coli* concentration at the indicated key location was above the water quality standard criterion of 130 cfu/100ml. Rolling 30-day periods of model results were considered so there are 155 periods in the recreation season. Scenarios include reduction of all sources (95% for CSOs, 30% for non-point sources, and 45% for the upstream boundary load), 100% reduction of CSOs only, and reduction of non-point sources (0% for CSOs, 60% for non-point sources, and 40% for the upstream boundary load). These results show reductions from all sources and reductions from non-point sources (including some reduction of the upstream boundary) to be similar to each other, and both well below the CSO-100% scenario.

Table 3-9. Periods of exceedance of *E. coli* 130, 30-day rolling average standard.

Location (RM/lat. loc.)	**Base** (No reductions)	**AllSrc** (CSO-95%) (NPS-30%) (US-45%)	**CSO100** (CSO-100%) (NPS-0) (US-0)	**NPS60** (CSO-0) (NPS-60%) (US-0)
1 (86.44/MID)	76 (49.0%)	42 (27.1%)	76 (49.0%)	50 (32.3%)
2 (91.03/LDB)	74 (47.7%)	31 (20.0%)	66 (42.6%)	42 (27.1%)

Location (RM/lat. loc.)	**Base** (No reductions)	**AllSrc** (CSO-95%) (NPS-30%) (US-45%)	**CSO100** (CSO-100%) (NPS-0) (US-0)	**NPS60** (CSO-0) (NPS-60%) (US-0)
3 (93.05/LDB)	63 (40.6%)	29 (18.7%)	60 (38.7%)	31 (20.0%)
4 (102.76/LDB)	48 (31.0%)	28 (18.1%)	40 (25.8%)	28 (18.1%)
5 (90.70/RDB)	110 (71.0%)	36 (23.2%)	93 (60.0%)	45 (29.0%)
6 (95.00/RDB)	81 (52.2%)	32 (20.6%)	71 (45.8%)	32 (20.6%)
7 (112.02/MID)	30 (19.3%)	4 (2.6%)	29 (18.7%)	9 (5.8%)
8 (126.04/MID)	12 (7.7%)	0 (0.0%)	10 (6.5%)	0 (0.0%)

3.5.3 Comparison of Model Results to Additional Criteria

This section presents a comparison of model results to alternative criteria that have been cited in the literature or used at other sites. Two comparisons are presented: velocity criteria and alternative numeric *E. coli* criterion.

Velocity Comparisons

As a large river, the Ohio can have very high flows with corresponding velocities that are unsafe for recreational use. The Kansas Department of Health and Environment has determined that swimming is unsafe when in-stream velocities are greater than 2 miles per hour (mph) (ORSANCO, 2004). Further, power fishing boats are physically limited from use in Kansas streams when the in-stream velocity reaches 3.4 mph. These criteria were applied to the model results to better understand how in-stream velocities could affect recreational use in this reach of the Ohio River.

Table 3-10 shows the hours of exceedance (out of a total of 4,417 possible hours in the recreation season) for which the water velocity at the indicated key location was over the indicated limit of 2.0, 3.0, or 3.4 mph. All scenarios are represented in Table 3-10 as they are hydraulically identical. It appears from these results that water velocities above 2.0 mph are quite common, but velocities above 3.4 mph are rare.

Table 3-10. Hours of exceedance of velocity standard.

	LDB			MID			RDB		
Loc.	**2.0 mph**	**3.0 mph**	**3.4 mph**	**2.0 mph**	**3.0 mph**	**3.4 mph**	**2.0 mph**	**3.0 mph**	**3.4 mph**
1 (86.44/MID)	--	--	--	796	0	0	--	--	--
2 (91.03/LDB)	2,624	283	57	--	--	--	--	--	--
3 (93.05/LDB)	568	0	0	--	--	--	--	--	--
4 (102.76/LDB)	82	0	0	988	29	0	57	0	0
5 (90.70/RDB)	--	--	--	--	--	--	14	0	0
6 (95.00/RDB)	--	--	--	--	--	--	31	0	0
7 (112.02/MID)	--	--	--	554	0	0	--	--	--
8 (126.04/MID)	--	--	--	85	0	0	--	--	--
Worst	2,720	283	57	2,835	378	71	670	0	0
Best	0	0	0	0	0	0	0	0	0

Comparisons to Alternative E. coli Numeric Criteria

Comparisons to alternative E. coli numeric criteria were conducted as an exercise to gain insight into the model results. Actual analysis and development of alternative numeric criteria would also factor in aspects of a UAA that were not addressed in this scope, such as surveys of actual recreational use and public participation. Table 3-11 shows the hours of exceedance (out of a total of 4,417 possible hours in the recreation season) for which the *E. coli* concentration at the indicated key location was above an alternative numeric criterion of 2,500 cfu/100ml, which is often used as a secondary contact recreation water quality standard numeric criterion. Scenarios include no reduction (the base scenario), reduction of all sources (95% for CSOs, 30% for non-point sources, and 45% for the upstream boundary load), 100% reduction of CSOs only, and reduction of non-point sources (0% for CSOs, 60% for non-point sources, and 40% for the upstream boundary load). It appears from these results that controlling CSOs alone is sufficient to greatly reduce exceedances, at this high criteria level.

Table 3-11. Hours of Exceedance of *E. coli* 2,500 criterion.

Location (RM/lat. loc.)	**Base** (No reductions)	**AllSrc** (CSO-95%) (NPS-30%) (US-45%)	**CSO100** (CSO-100%) (NPS-0) (US-0)	**NPS60** (CSO-0) (NPS-60%) (US-0)
1	0	0	0	0
2	38	0	0	35
3	42	0	0	38
4	23	0	0	16
5	138	11	13	117
6	70	0	0	63
7	9	0	0	8
8	0	0	0	0

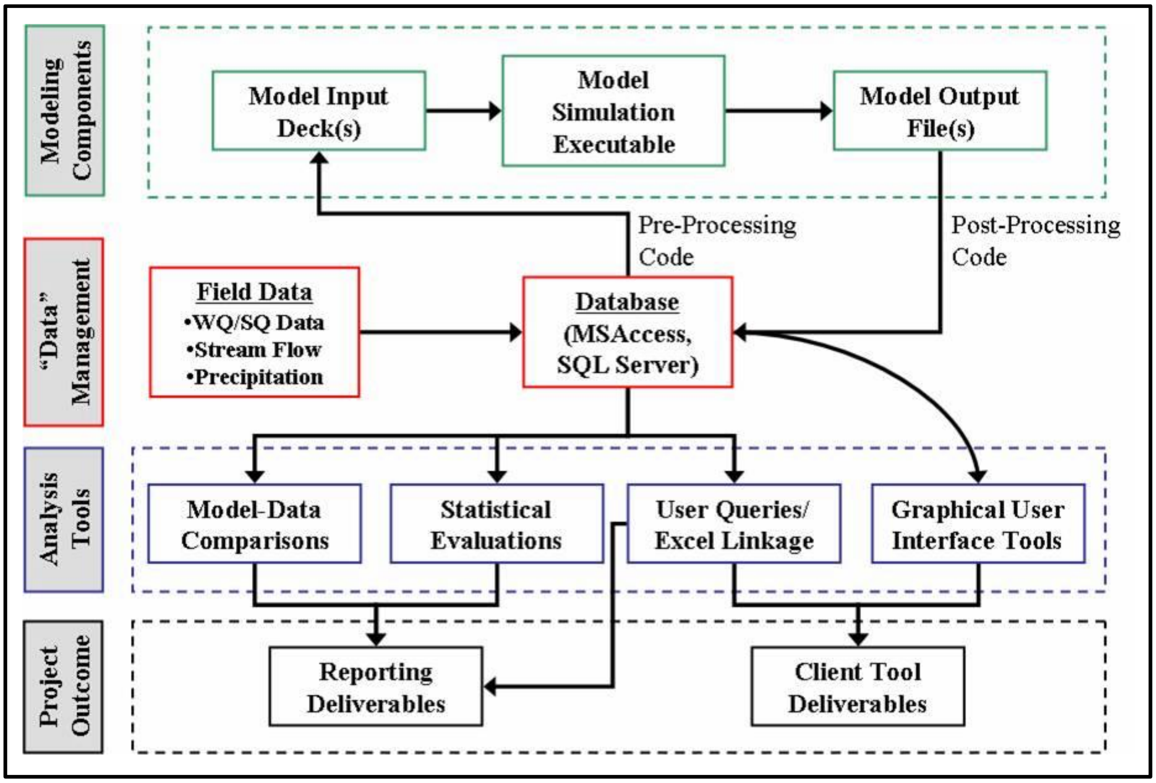
4. MODEL FRAMEWORK

One of the objectives of the grant was to develop a framework around the watershed and river models that would facilitate the models' use by stakeholders to complete the UAA at a future date. This section describes the development of a modeling framework to run the river model, evaluate results and calculate exceedances of user-defined criteria.

A "Simulation Management" approach (Figure 4-1) was used to develop the modeling framework. "WinEFDC" is a Visual Basic 6.0 application that interfaces with supporting Microsoft Excel workbooks and Microsoft Access databases as well as the river model FORTRAN executable files. Key features of the WinEFDC simulation management framework include:

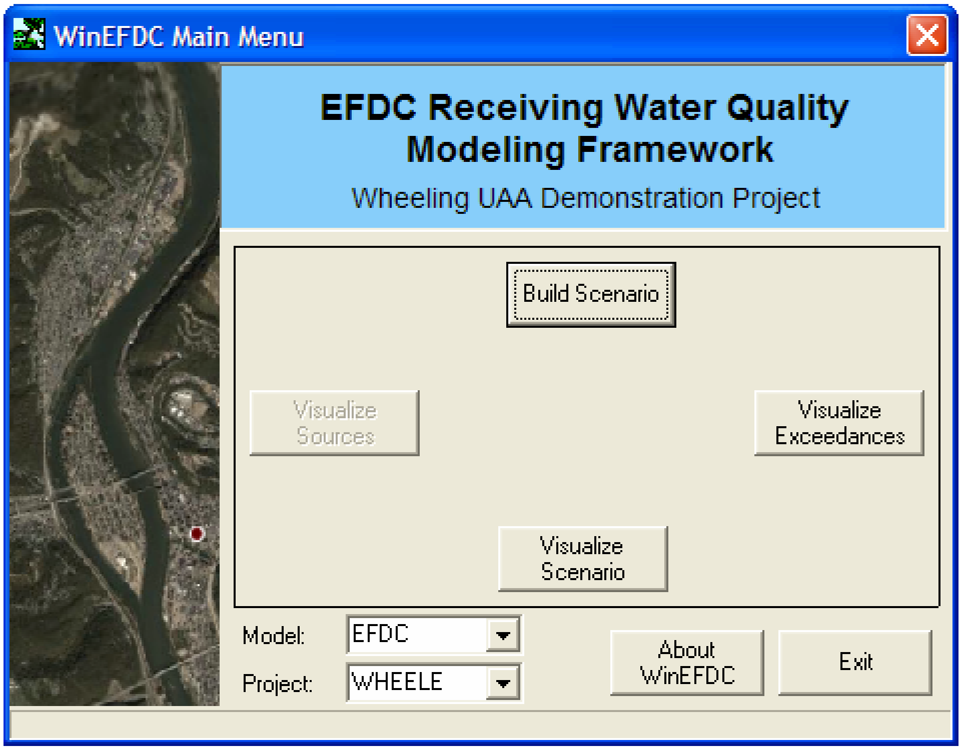
- A user-friendly "scenario builder" interface that can be used to interactively specify source load levels;
- Efficient pre-processing of model input data using a companion Microsoft Access database template; and,
- Visualization tools that allow the user to plot, animate, and further examine river model (EFDC) hydraulic and water quality results.

Figure 4-1. "Simulation Management" Flow Chart.



When the WinEFDC executable program is launched, the Main Menu form (Figure 4-2) is initiated.

Figure 4-2. WinEFDC Main Menu.



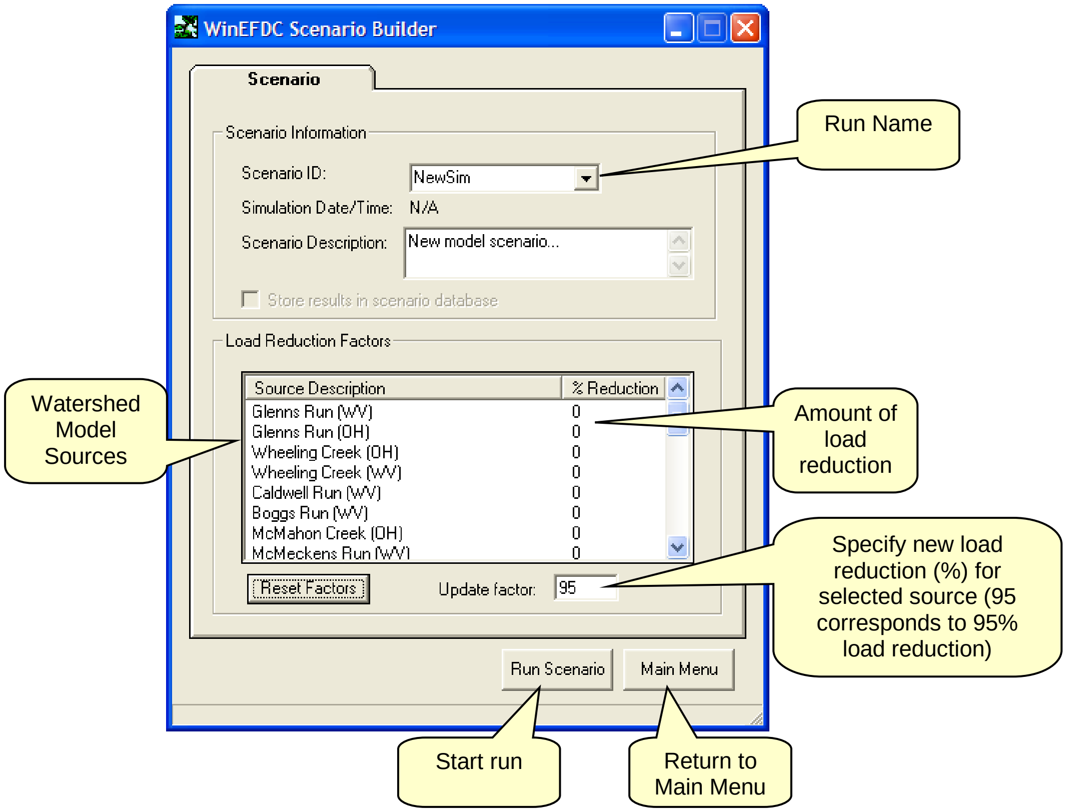
From this menu, the user can start a new model run by clicking on the “Build Scenario” button, review previously generated model results by clicking on the “Visualize Scenario” button or evaluate exceedances of current and user-specified criteria by clicking on the “Visualize Exceedances” button. Details on each utility are discussed in the following sections.

4.1 SCENARIO CONTROL MENU

The WinEFDC framework stores all of the files associated with a water quality simulation in a single folder, which is given the name of the model run. This scenario-specific folder includes the pre-processing Access database and a collection of raw input/output files for the EFDC model. The Scenario Builder interface (Figure 4-3) handles all of the pre-processing tasks necessary to run the EFDC model for the 2003 recreation season and constructs a subset of the raw model input files from scratch based on user selections within the interface. The user can scroll through each watershed model source and specify a percent load reduction. The load input to the river model will be specified as

$$\text{Load into River} = \text{Base Load}_{\text{Watershed Model}} \times [100\% - (\text{Specified \%Load Reduction})]$$

Figure 4-3. Scenario Builder Interface.



Once the 'Run Scenario' button is clicked, the framework will execute the following tasks:

1. Set up a run folder with the name specified in the 'Scenario ID' field;
2. Construct the concentration input file using the watershed model results stored in the pre-processing Access database and the reductions specified on the Scenario Builder control;
3. Copy the additional input files needed to run the EFDC model to the run folder;
4. Run the EFDC model; and,
5. Return user to the Main Menu form (Figure 4-2).

The framework has limited flexibility with respect to the watershed model. The choice of modeling platform or the configuration of the current SWMM watershed model may be changed when the UAA is completed or when more information is available to constrain that model. Therefore, for the purpose of this project, the SWMM watershed model was run for the 2003 recreation season and the results were "fixed" in the Access database pre-processor. The watershed model concentration results are scaled within EFDC based on the user-specified load reduction percentages. A value of 0% reduction corresponds to the current or base condition in the watershed model tributaries and CSOs. Other key model inputs, such as the *E. coli* loss rate, that were established based on calibration, literature, or professional judgment, have also been "fixed" in the EFDC input files and cannot be modified directly from the WinEFDC framework.

4.2 VISUALIZE SCENARIO MENU

The WinEFDC framework provides a comprehensive menu of post-processing options. These visualization tools can be used to quickly evaluate model simulation results and construct presentation-quality graphics and animations. The 'Visualize Scenario' option allows the user to select an existing scenario and generate spatial (downriver) profile animations, time series graphics, and map-based animations of the EFDC river model results. Inputs to the river model from CSOs and major tributary watersheds are also displayed on the map-based animations.

4.2.1 Graphical Display of Results

Figure 4-4 shows the Visualize Scenario interface configured to evaluate spatial profiles.

Figure 4-4. Visualize Scenario Interface (spatial animation)

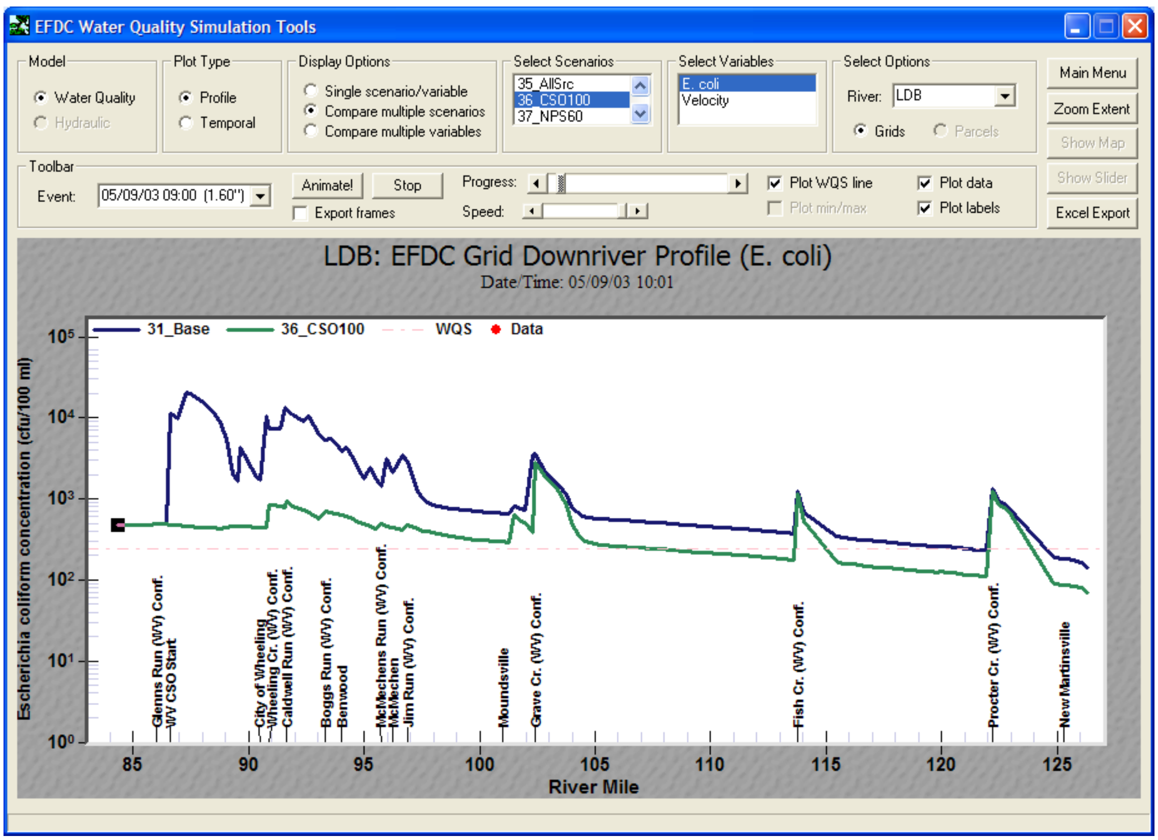
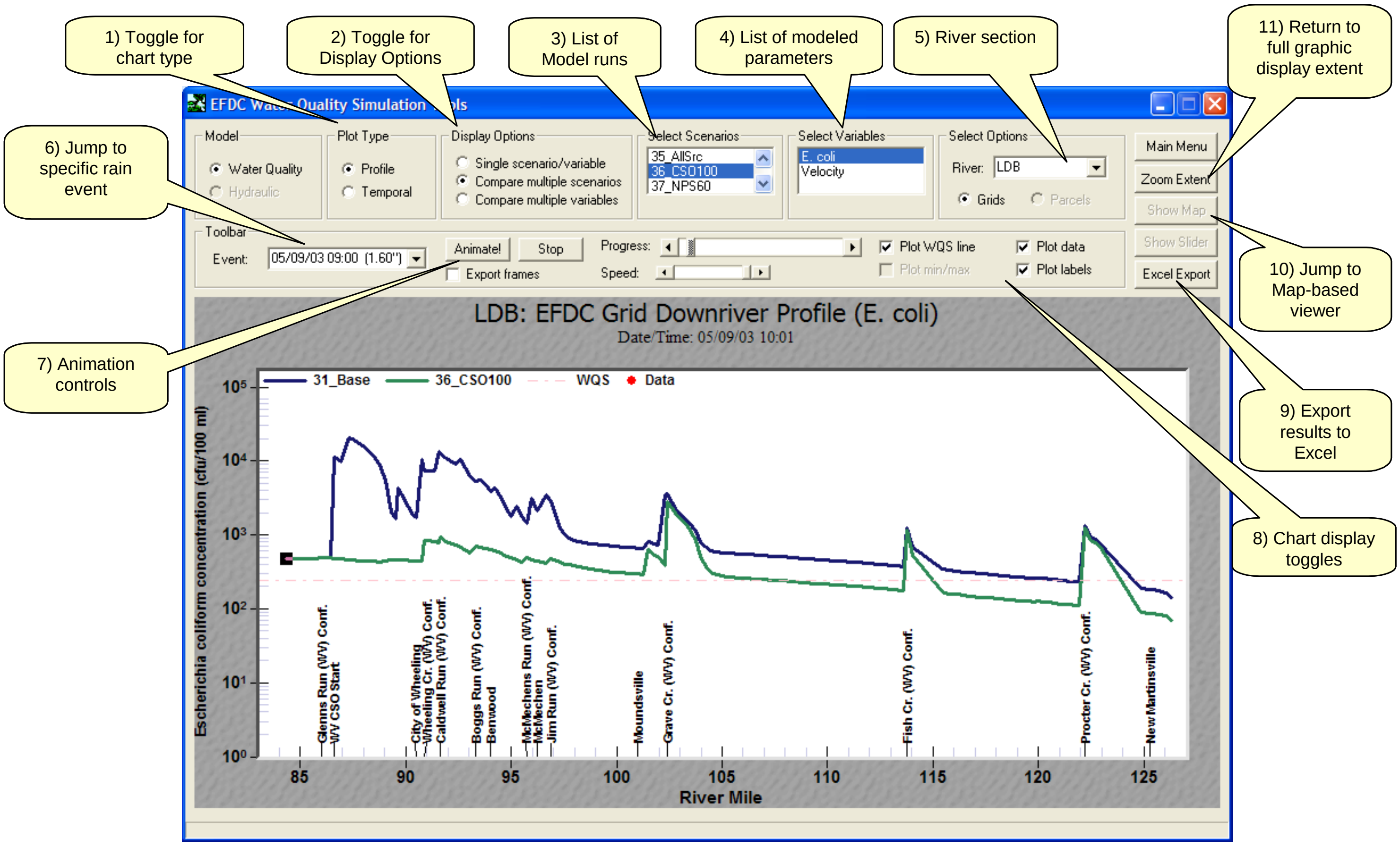


Figure 4-5 shows the same form with numbered callout boxes. The functionality of each callout box is described below.

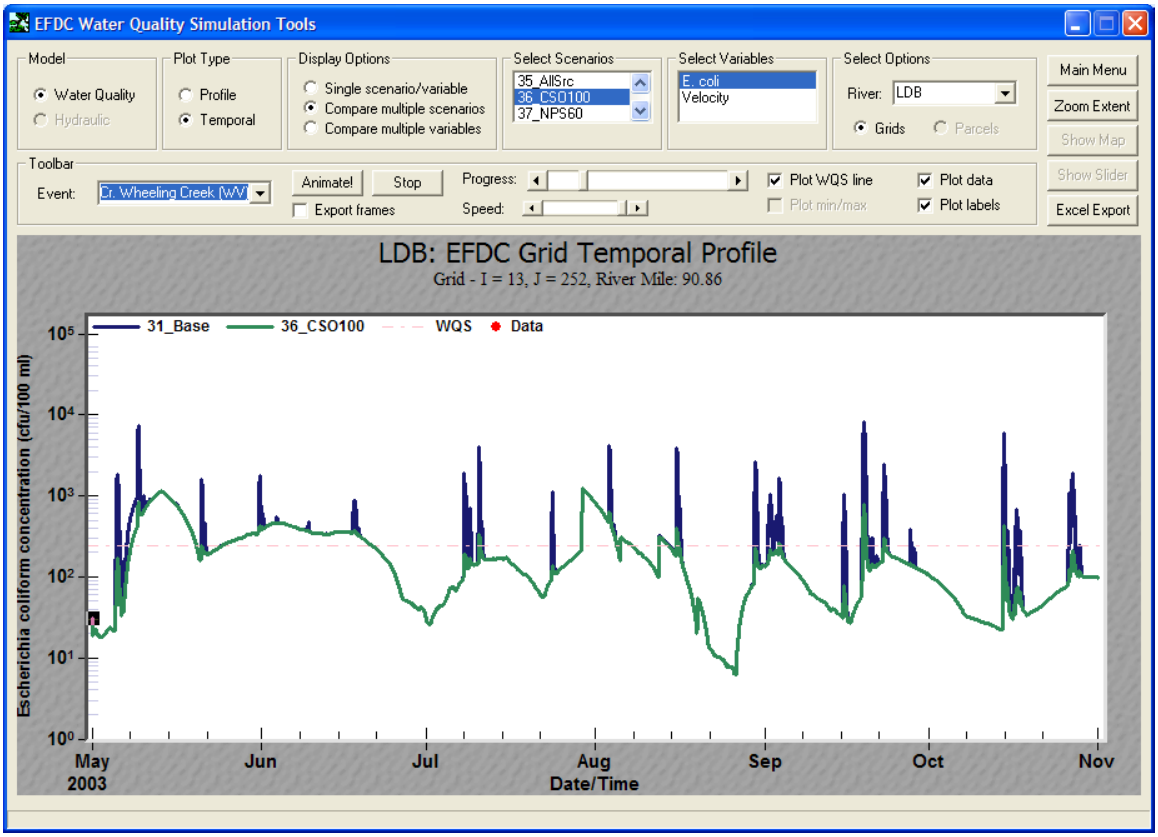
Figure 4-5. Visualize Scenario Interface with Labels (Spatial Animation).



When the Visualize Scenario interface is launched, the user can opt for a number of visualization graphics and display controls. These include:

1. Callout box 1: Selecting either a profile (e.g. spatial) or temporal plot. Figure 4-6 shows an example of a temporal plot near Wheeling Creek, WV. In the spatial plot, the x-axis corresponds to river mile (from upstream to downstream). In the temporal plot, the x-axis corresponds to date-time. The y-axis in both plots is the parameter (*E. coli* or velocity) value.

Figure 4-6. Temporal Graphic from the Visualization Scenario Form.



2. Callout box 2: Selecting display of a single scenario, multiple scenarios, or multiple variables (*E. coli* and velocity) for a single scenario. In the example shown in Figure 4-5, the Multiple Scenarios display option was selected and the graphic shows the results for two model runs, 31_Base (Base condition- shown as blue line) and 36_CSO100 (100% CSO control-shown as green line).

3. Callout box 3: Selecting which model run scenarios to visualize. The example shows that the scenario called 36_CSO100 has been selected (which is shown in the graph as the green line).

4. Callout box 4: Selecting which model result to display. In this example, the model's *E. coli* output is displayed.

5. Callout box 5: Selecting which section of the river to display. Results are generated for the left descending bank (West Virginia near shore) or LDB, the right descending bank (Ohio near shore) or RDB, and center channel or MID. In this example, results are shown for the left descending bank. The sections of the river adjacent to Wheeling Island (WI_WS = Wheeling Island west shore, WI_ES = Wheeling Island east shore) and Fish Island (FI_WS =

Fish Island west shore, FI_ES = Fish Island east shore) can also be selected in this control.

6. Callout box 6: This control lists all of the storm events in the 2003 recreation season and allows the user to jump to a specific storm event. The start date-time of the storm is provided and the size of the storm is shown in parentheses. In this example, the user has jumped to the 1.60-inch storm that started on 05/09/03 09:00.

7. Callout box 7: This area of the form contains controls and options for animating spatial (downriver) profiles. The 'Animate' and 'Stop' buttons allow the user to initiate or stop an animation through time of the graphic display. The Progress scroll bar will advance as the animation is running. However, the user can also manually control the scroll bar with their mouse. The speed of the animation can be controlled with the Speed scroll bar.

   The final animation control is the check box labeled "Export Frames". When this control is checked, the graphical display at each output time interval is saved as a bitmap (*.bmp) image. These bitmap images can be combined into an animated movie using a software package such as AVI Constructor (http://order.kagi.com/cgi-bin/store.cgi?storeID=R8J&&).

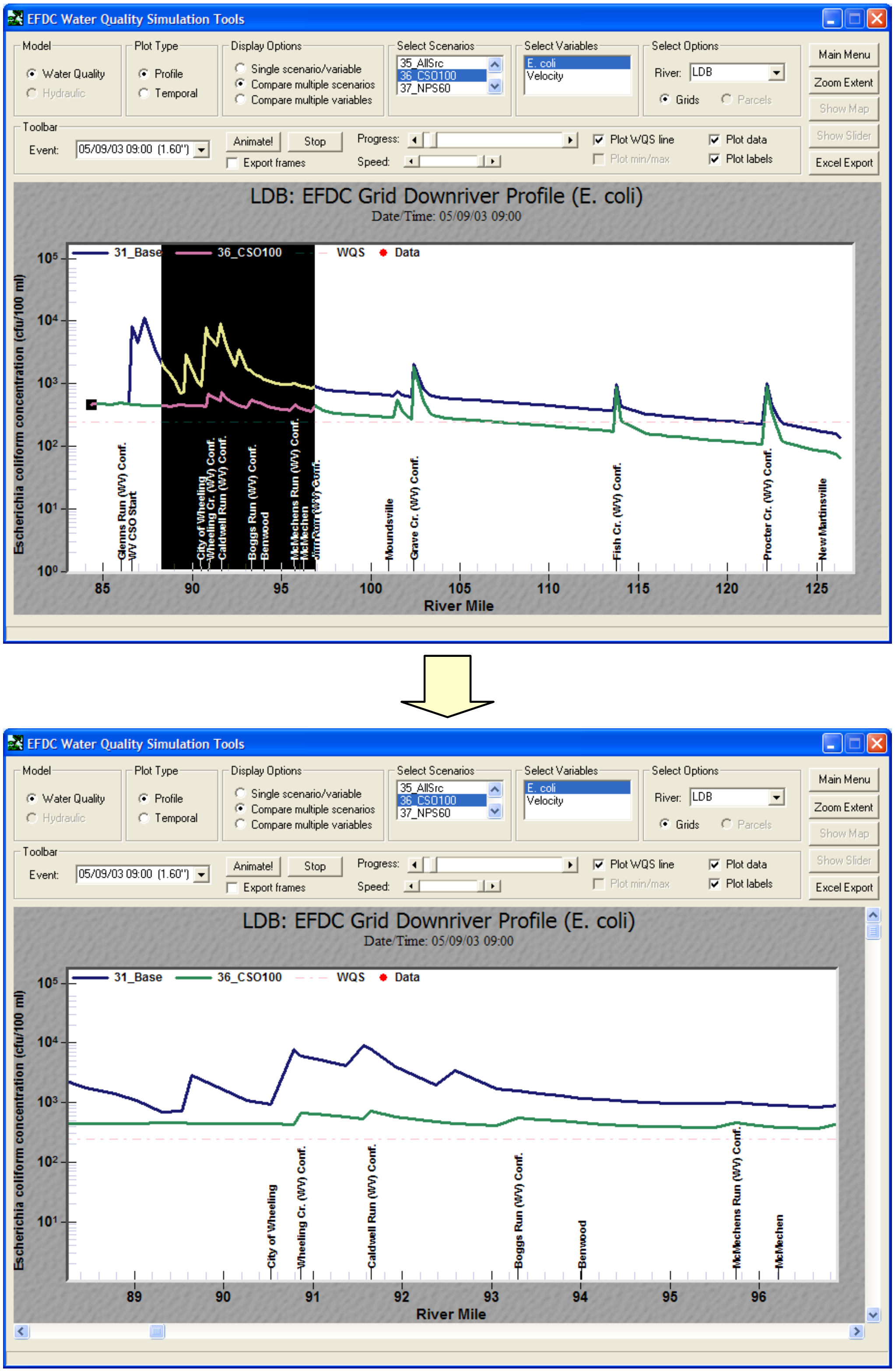
8. Callout box 8: This callout box orients the user to three active controls affecting the display in the graphical portion of the form. The user can check or toggle on features that will include the water quality standard numeric criteria (Plot WQS), data (Plot data), and/or labels (Plot labels). In this example, all three features are turned on and displayed in the spatial profile (although there are no data available to display).

9. Callout box 9: This control will export the model results displayed to an Excel workbook in a matrix format where each hour is stored by row and each river mile is stored by column in a worksheet. The parameter result (*E. coli* or velocity) for each hour/river mile are the values in the workbook. The framework will prompt the user to enter a file name for the Excel file and will allow the user to specify a file path to save the file.

10. Callout box 10: This control will change the interface from showing a graphical display to showing a GIS-type map display. This option is only active when the first display option (callout box 2) is set to the first choice (Single scenario/single variable) and a single model run (callout box 3) is selected. The map-based view is described in more detail below.

11. Callout box 11: The visualization interface allows the user to select and zoom in on a portion of the graph by clicking and dragging with his/her mouse, as shown in Figure 4-7. The "Zoom Extent" button resets the graphical display to the full river extent.

Figure 4-7. Example of Zooming In on Specified Section of River.



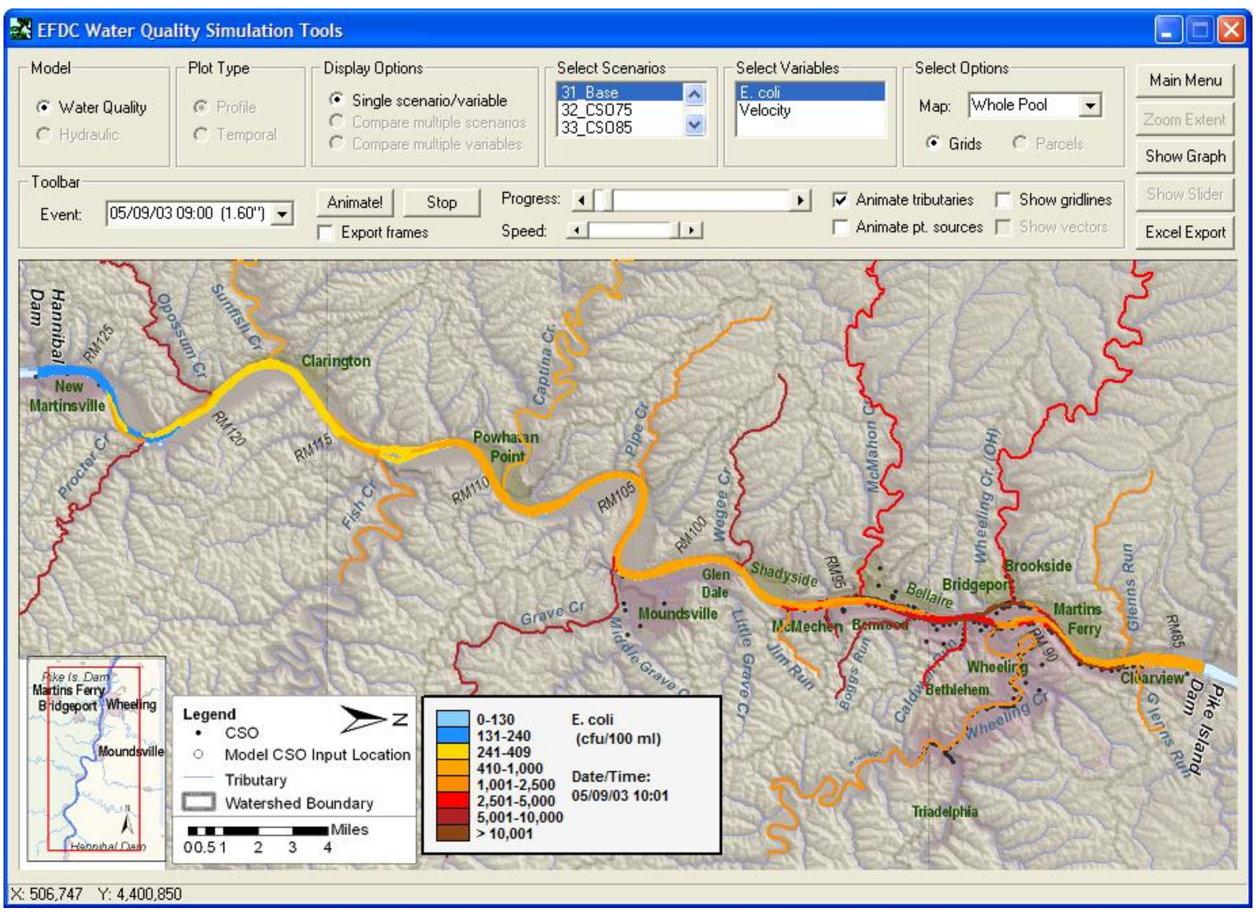
4.2.2 GIS Map-Based Display of Results

Figure 4-8 shows an example of the map-based view. The map has been rotated 90o clockwise to accommodate the constraints of the form sizing. The river flows from right to left across the screen, starting at Pike Island Dam and flowing downstream to Hannibal Dam. A smaller map in the lower left corner shows the true orientation and the portion of the study area displayed in the big map.

The map also contains two legends, one showing map features and one describing the concentrations or velocities associated with the colors displayed in the animation. The legend in the map was set up to correspond to the following criteria:

- Light blue: *E. coli* concentration < current 30-day geometric mean criterion (130 cfu/100 ml);
- Dark blue: *E. coli* concentration < current single sample maximum criterion (240 cfu/100 ml);
- Yellow: *E. coli* concentration < USEPA lightly used full body contact criterion (409 cfu/100 ml);
- Orange: *E. coli* concentration < USEPA infrequently used full body contact criterion (2,500 cfu/100 ml); and,
- Red: *E. coli* concentration > all USEPA criterion (see Table 1-2).

Figure 4-8. Map-Based Viewer for Animating Results.

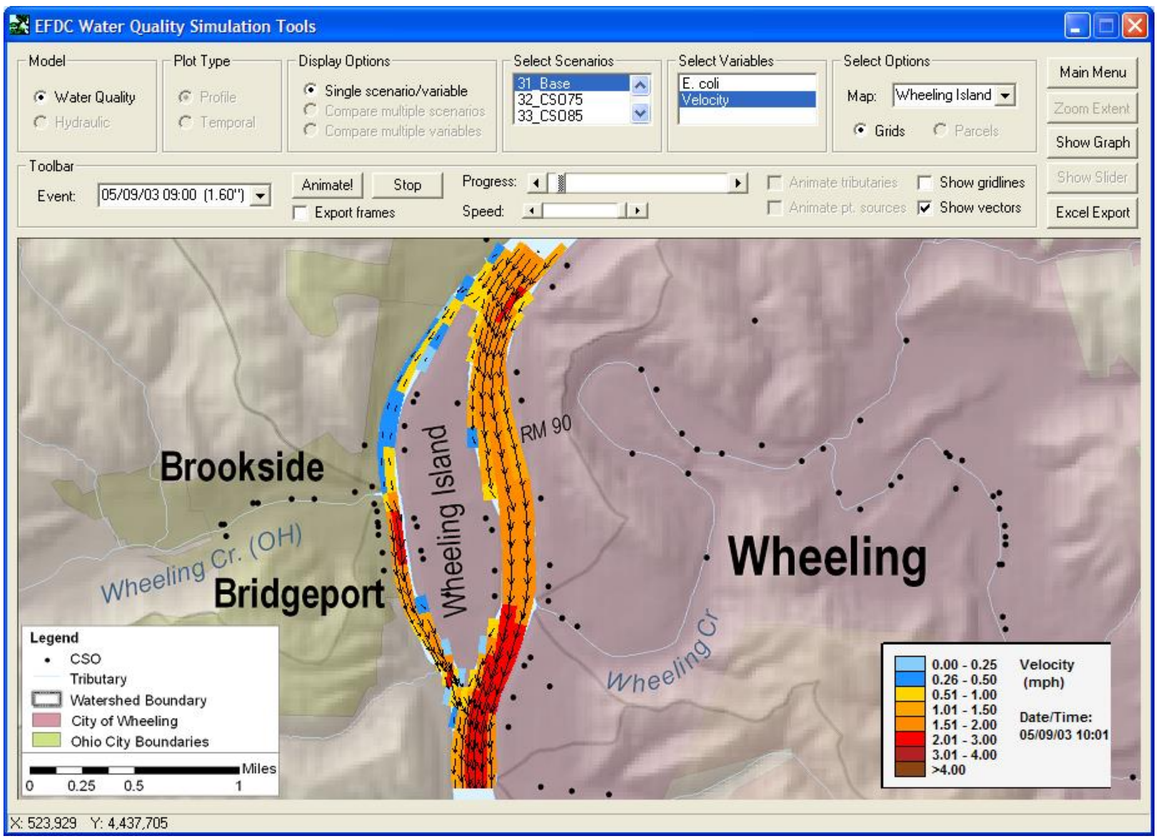


The controls on the form are similar to the standard X-Y graphical display with the following exceptions:

1. The 'Select Options' control allows the user to select the displayed map from a list of maps rather than a portion of the river (e.g. LDB, RDB, etc.);

2. The checkbox controls for the map display allow the user to animate tributaries (as shown), point sources (e.g. CSO load input locations, which are not shown), and to show the model cell boundaries (gridlines). When the velocity variable is selected, the user also has the option to add vectors to the display, as shown in Figure 4-9.

Figure 4-9. Map Animation Around Wheeling Island Showing Velocity Vectors.



As with the graphical display, map images can also be saved and combined into a movie file. A movie of a one-inch storm (7/10/2003) event has been saved in the following file: Base_1-inch_Storm_WholePool.AVI as an example. The upper pool is animated for the same storm in this file: Base_1-inch_Storm_UpperPool.AVI.

4.3 EXCEEDANCES MENU

The WinEFDC framework provides a comprehensive menu of current and alternative water quality standard visualization options. The 'Visualize Exceedance' interface allows the user to select an existing scenario and generate spatial (downriver) profiles of exceedances of current and user-specified numeric criteria for both *E. coli* and velocity. In addition, a subset of criteria can be combined into a single evaluation to understand the effect of each criterion relative to the others. Table 4-1 presents a summary describing the criteria that can be evaluated in this interface.

Table 4-1. Description of Numeric Criteria Evaluation Options.

No	Parameter[1]	Description	Evaluation Period	Default Value[2]	Units	Basis for Inclusion	Active Display Options in Framework[3]
1	*E. coli*	Single sample maximum concentration not to be exceeded	Hourly	240	cfu/100 ml	Current WQS	All[4]
2	Velocity	Instantaneous maximum velocity corresponding to unsafe contact recreation conditions	Hourly	2	mph	Evaluate effectiveness of high flow exclusion as an alternative WQS	Compare multiple variables
3	Event Duration	Pre-defined period after a storm event meeting a rainfall threshold when contact recreation is not safe	Hours	a. 48 b. 0.5	a. hours b. inches	Evaluate effectiveness of wet weather sub-use as an alternative WQS	Compare multiple variables
4	EC 10% exc. (30 d)	Compliance based on meeting current single sample max WQS at least 90% of the time within a 30-day period	Rolling 30-day	240	cfu/100 ml	Evaluate effectiveness of alternative numeric criteria (Similar to current Ohio WQS)	Compare multiple criteria; Compare multiple scenarios
5	EC geomean (30 d.)	30-day geometric mean	Rolling 30-day	130	cfu/100 ml	Current WQS	Compare multiple criteria; Compare multiple scenarios
6	EC (Velocity filter)	Hours of exceedance of *E. coli* single sample maximum when hours exceeding velocity criterion are excluded	Hourly	*E. coli* = 240 Velocity = 2 Event duration = 48 Event storm size = 0.50	*E. coli* = cfu/100 ml Velocity = mph Duration = hours Storm Size = inches	Evaluate remaining impact on use if a high-flow exclusion were included in the water quality standards	Compare multiple criteria; Compare multiple scenarios
7	EC (Vel+Event filter)	Hours of exceedance of *E. coli* single sample maximum when hours exceeding velocity and event duration criteria are excluded	Hourly	*E. coli* = 240 Velocity = 2 Event duration = 48 Event storm size = 0.50	*E. coli* = cfu/100 ml Velocity = mph Duration = hours Storm Size = inches	Evaluate remaining impact on use if a high-flow exclusion and temporary use suspension were included in the water quality standards	Compare multiple criteria; Compare multiple scenarios

Notes:

[1] The parameter field corresponds to the entries in the 'Select Criteria' list box on the visualization interface (see Figure 4-11, described in the next section)

[2] Default values are based on current water quality standards or criteria applied in other sites/States. Note that each of these values can be changed to a user-defined value.

[3] This field corresponds to the Display Options toggle in the upper left hand corner of the visualization interface (see Figure 4-11, described in the next section)

[4] This criterion is labeled "*E. coli* (no filter)" when either the 'Compare multiple criteria' or 'Compare multiple scenarios' display options are selected.

Figure 4-10 shows the ' Visualize Exceedance' interface form.

Figure 4-10. Visualize Exceedance Interface Form.

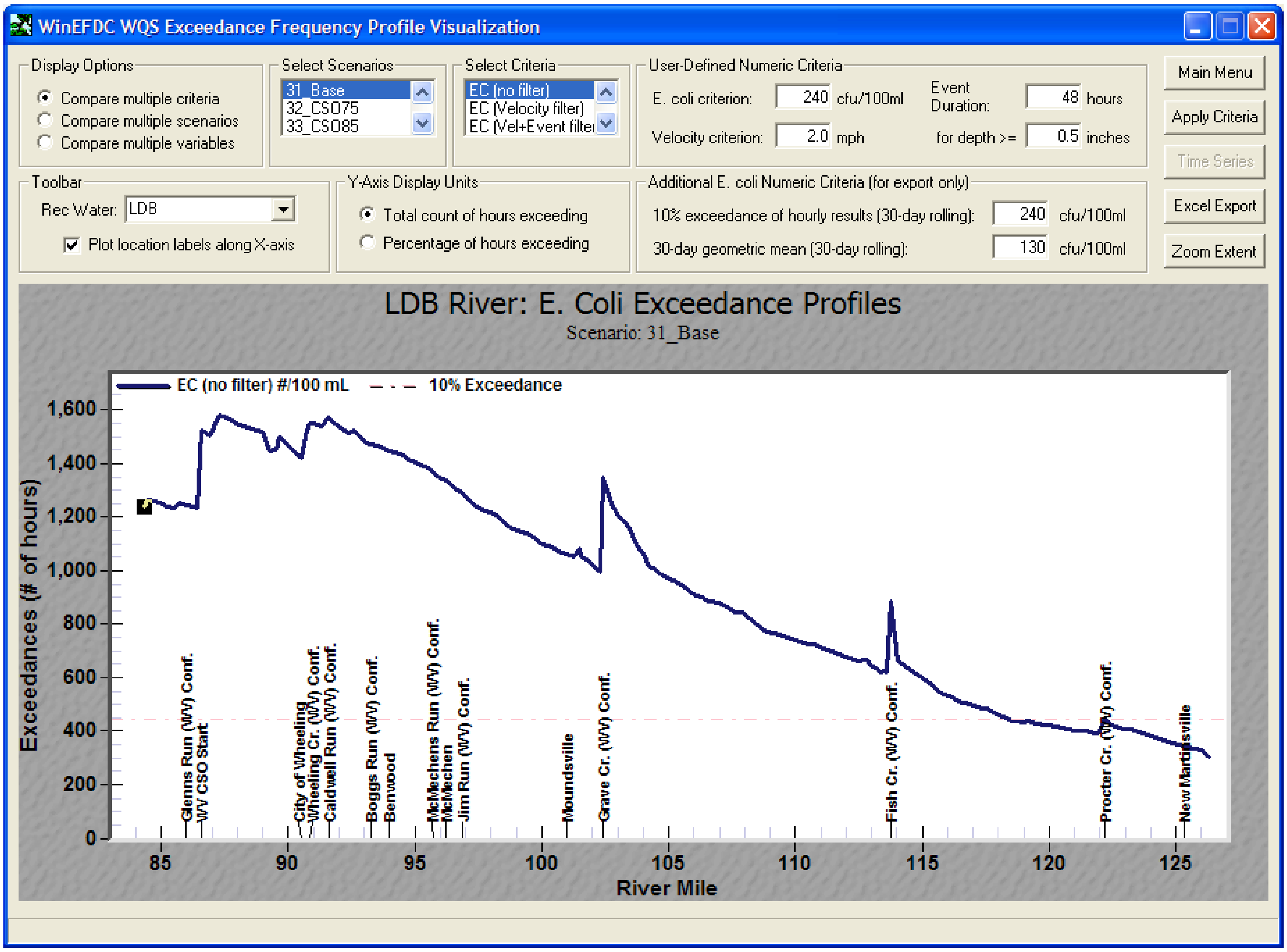
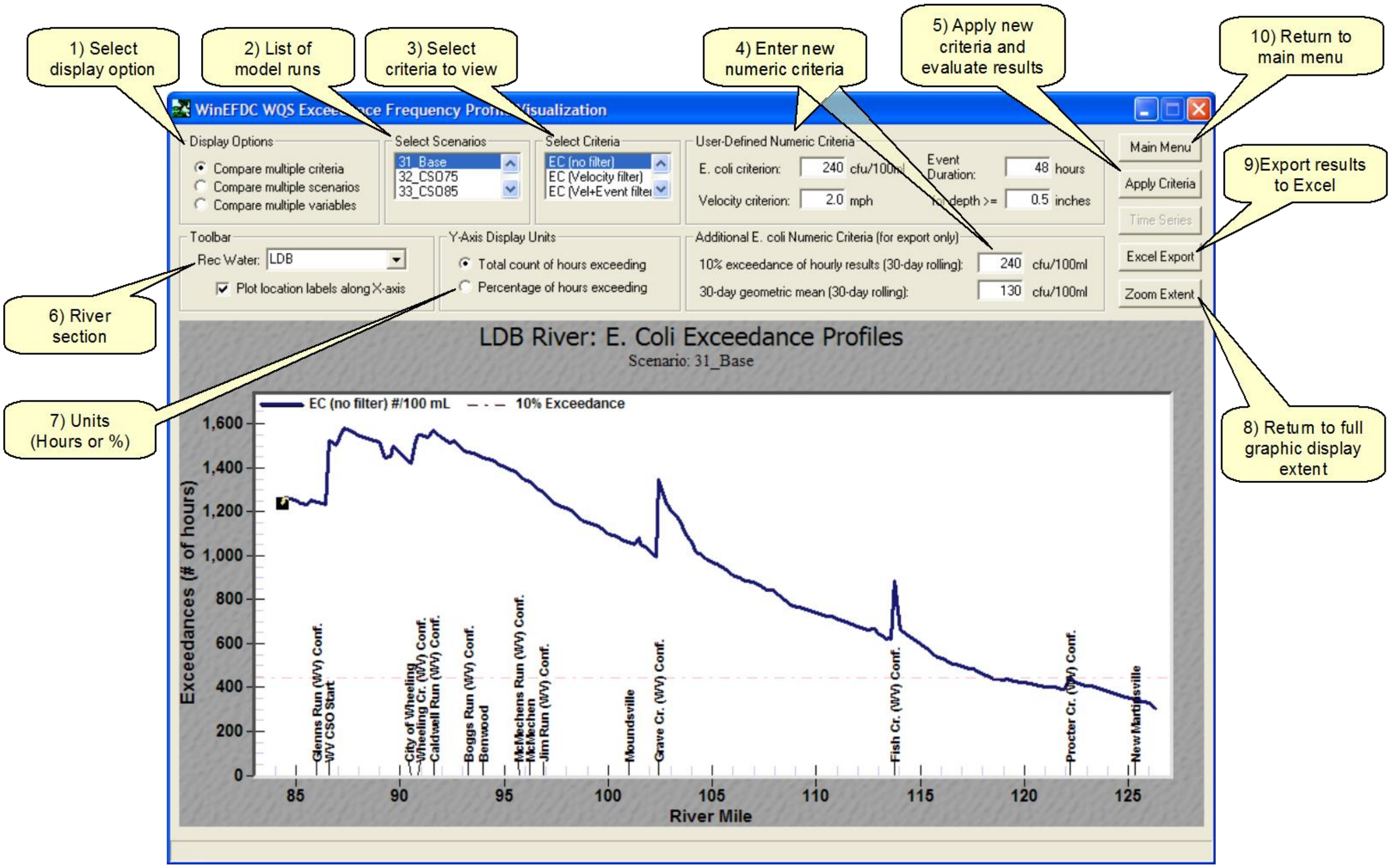


Figure 4-11 shows the same form with numbered callout boxes. The functionality of each callout box is described below.

Figure 4-11. Visualize Exceedance Interface Form with Labels.



When the Visualize Exceedance interface is launched, the user can opt for a number of visualization graphics and display controls. These include:

1. Callout box 1: This set of options corresponds to the last column in Table 4-1. Examples of the graphical display associated with each Display Option are presented in more detail in the following sections.

2. Callout box 2: This control allows the user to select which model run scenarios to visualize. The example shows that the scenario called 31_Base has been selected (and is shown in the graph as the blue line). Multiple model runs can be selected when the “Compare Multiple Scenarios” display option (callout box 1) is selected.

3. Callout box 3: This control shows the criteria evaluation options presented in Table 4-1. When the “Compare Multiple Criteria” display option (callout box 1) is selected, more than one selection in this control can be made. When the “Compare Multiple Scenarios” display option is selected, only one

value from this control can be selected. When the "Compare Multiple Variables" display option is selected, this control box is inactive (see discussion below).

4. Callout box 4: Selecting the numeric value associated with each variable/criterion is controlled in the two sections indicated on the form. The upper section, labeled 'User-Defined Numeric Criteria' is used to specify values associated with instantaneous criteria (numbers 1-3 in Table 4-1). Hourly model results are compared directly to these criteria to determine exceedances.

   The second section, which is located just below the first section and labeled 'Additional *E. coli* Numeric Criteria', is used to specify values associated with temporally averaged (e.g. rolling 30-day) criteria, which correspond to entries 4-5 in Table 4-1. Hourly model results are temporally averaged (if necessary), then evaluated against the numeric criteria on a rolling 30-day basis.

5. Callout box 5: If the user specifies a new numeric criterion, the 'Apply Criteria' button must be clicked to initiate the comparison of model results to the new criteria.

6. Callout box 6: This control allows the user to select which section of the river to display. Results are generated for the left descending bank (West Virginia near shore) or LDB, the right descending bank (Ohio near shore) or RDB, and center channel or MID. In this example, results are shown for the left descending bank. The sections of the river adjacent to Wheeling Island (WI_WS = Wheeling Island west shore, WI_ES = Wheeling Island east shore) and Fish Island (FI_WS = Fish Island west shore, FI_ES = Fish Island east shore) can also be selected in this control. The same convention is used in the 'Visualize Scenario' interface form (see callout box 5 in Figure 4-5).

7. Callout box 7: This control allows the user to toggle between hours of exceedance and the percent of the time period exceeded on the graph's y-axis.

8. Callout box 8: The visualization interface allows the user to select and zoom in on a portion of the graph by clicking and dragging with his/her mouse, as shown in Figure 4-7. This control resets the graphical display to the full river extent.

9. Callout box 9: This control will export the model results displayed to an Excel workbook in a matrix format where each river mile and location (e.g. LDB, MID, RDB) is stored in the rows and each exceedance criteria is stored in the columns of the workbook. The matrix is populated with the exceedance results. The framework will prompt the user to enter a file name for the Excel file and will allow the user to select a file path to save the file.

10. Callout box 10: This control will return the user to the Main Menu form (Figure 4-2).

Examples that illustrate the variety of the graphical display are shown for each of the 'Display Options' selections.

4.3.1 Comparing Multiple Criteria

The 'Compare multiple criteria' selection in the 'Display Options' control allows users to evaluate model results with respect to one or more *E. coli* criteria. Figure 4-12 presents an example of plotting exceedances for current *E. coli* water quality standard numeric criteria. In this example, the blue line corresponds to exceedances of the single sample maximum criterion of 240 cfu/100 ml (specified in the 'User-Defined Numeric Criteria' section) and the green line corresponds to exceedances of the 30-day geometric mean criterion of 130 cfu/100 ml (specified in the 'Additional *E. coli* Numeric Criteria' section). Because the single sample maximum criterion is evaluated for 4,416 hours in the recreation season, while the geometric mean criterion is evaluated for 154 rolling 30-day periods, the results are expressed as percents of their respective period. In this example (mid-channel results), the geometric mean criterion is exceeded more frequently than the single sample maximum except between river mile 102 and river mile 104 (note that these model results may not be representative of actual in-stream conditions because of the uncertainty in the source loads input to the model).

Figure 4-12. *E. coli* Exceedances of Current Water Quality Standard Numeric Criteria.

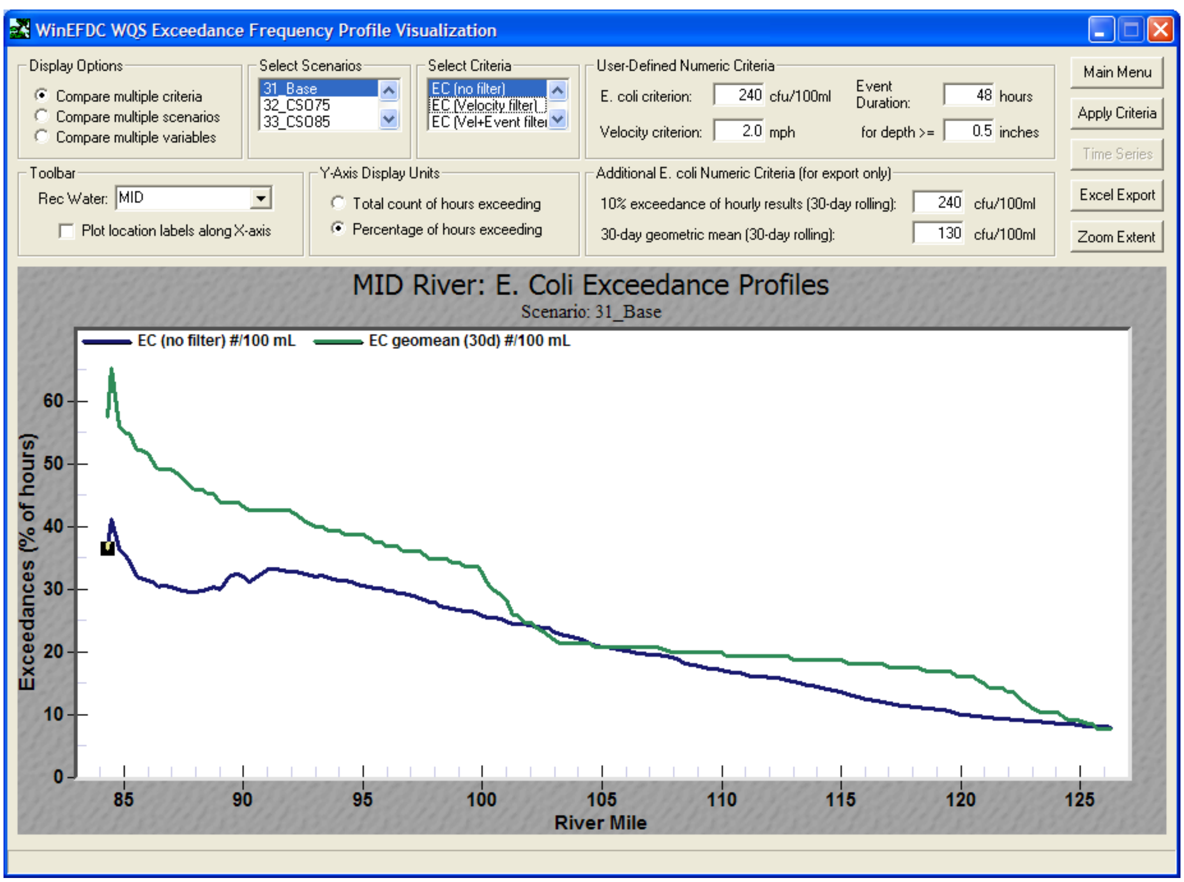
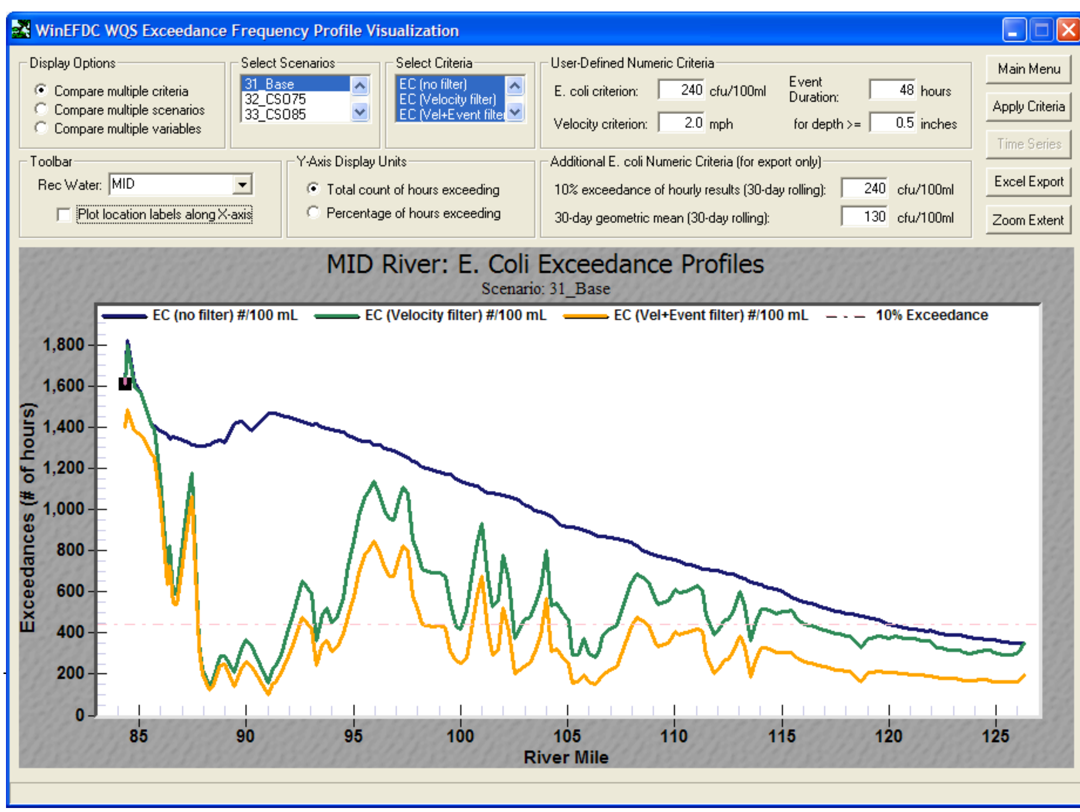


Figure 4-13 shows an example of an evaluation of *E. coli* numeric criteria with respect to the current water quality standard numeric criterion (blue line) and in the context of possible alternative criteria (see numbers 1, 6 and 7 in Table 4-1). For example, a combination of high flow exclusion (expressed as a maximum velocity) and *E. coli* single sample maximum can be considered by selecting the criteria 'EC (velocity filter)' in the 'Select Criteria' control. In this case, the graph (green line) shows the number of hours that the *E. coli* model results still exceed the numeric criterion of 240 cfu/100 ml when all of the hours where the high flow exclusion criterion applied were filtered out of the tabulation. This option is intended to allow the user to evaluate the remaining impact on use if a high-flow exclusion was included in the water quality standards.

A similar analysis can be performed considering both high flow exclusion (velocity filter) and wet weather sub-use (event duration filter). In this case, the graph (yellow line) shows the number of hours that the *E. coli* criteria is exceeded even when all of the hours where the high flow exclusion AND wet weather sub-use criteria are excluded. This option is intended to allow the user to evaluate the remaining impact on use if a high-flow exclusion and a temporary use suspension were included in the water quality standards.

The decrease in the hours of exceedance between the current water quality standard (blue line) and the velocity-filtered results (green line) in Figure 4-13 indicate that many of the hours when the *E. coli* concentration is greater than the numeric criterion (240 cfu/100 ml) occur when the velocity is greater than the velocity criterion (2 mph), particularly between river mile 88 and river mile 96. The addition of a wet weather sub-use criterion (yellow line) reduces but does not eliminate the number of hours *E. coli* exceeds 240 cfu/100 ml.

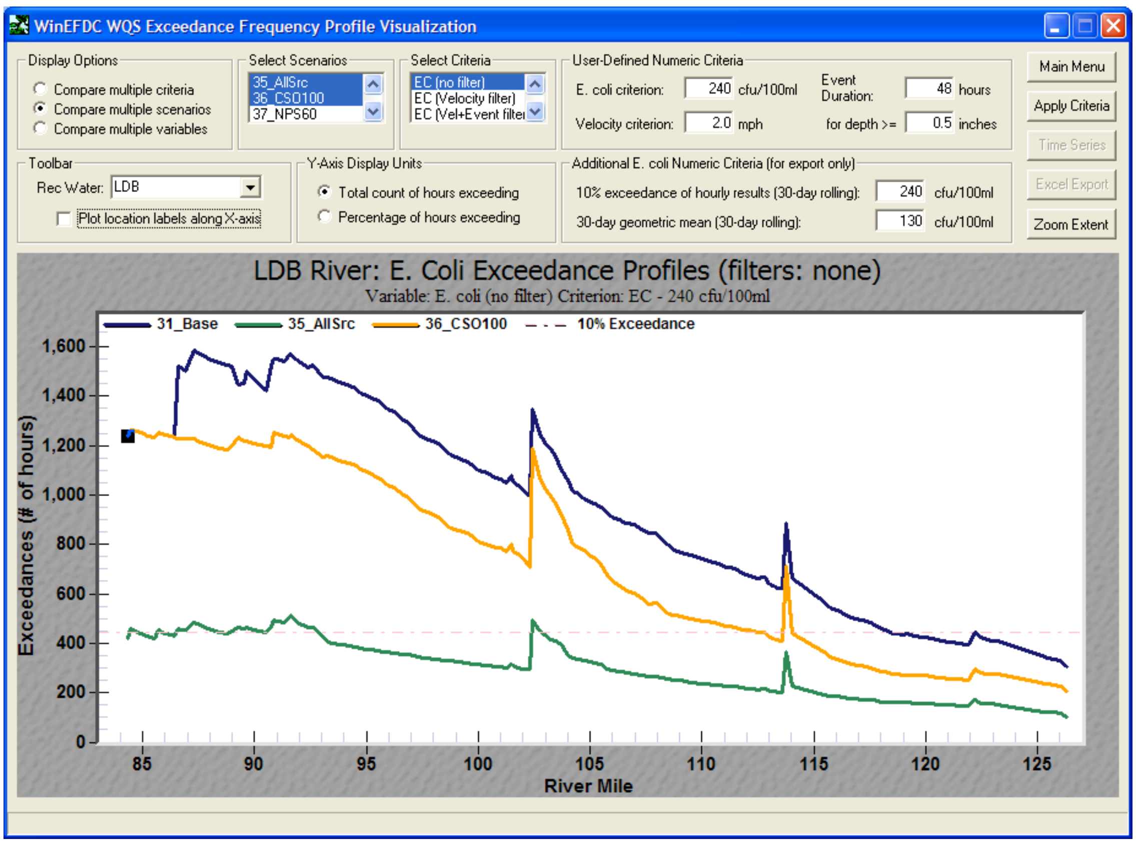
Figure 4-13. Example Comparison of *E. coli* Results to Multiple Criteria



4.3.2 Comparing Multiple Scenarios (to a Single Criteria)

The 'Compare multiple scenarios' selection in the Display Option control allows users to evaluate model results from one or more model runs by applying one of the *E. coli* criteria shown in the 'Select Criteria' list box. Figure 4-14 presents an example showing exceedances of the current *E. coli* single sample maximum water quality standard for three scenarios (see Table 3-2): 31_Base (Base condition-shown as blue line), 35_AllSrc (95% CSO control, 30% NPS control and 45% upstream control-shown as green line) and 36_CSO100 (100% CSO control-shown as yellow line). In this example, the model run 35_AllSrc has the fewest exceedances associated with it.

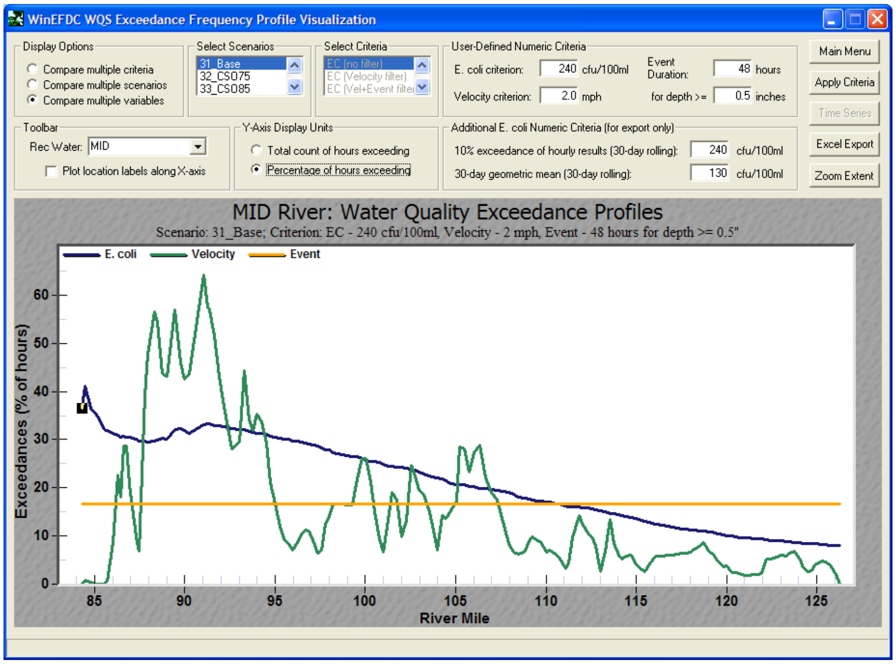
Figure 4-14. Exceedance Comparison for Multiple Scenarios.



4.3.3 Comparing Multiple Variables

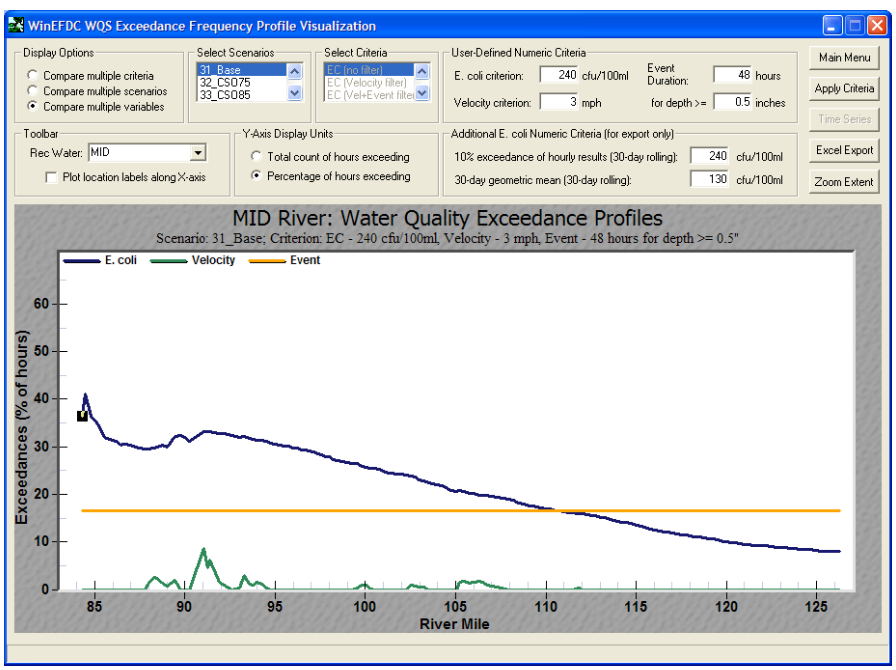
The 'Compare multiple variables' selection in the Display Options control allows users to view exceedances from each type of user-defined instantaneous criteria: *E. coli* single sample maximum, maximum velocity and event duration. Each criterion is graphed as a separate series, as shown in Figure 4-15. In this example, provided for the Base scenario, the velocity criterion (green line) is the most restrictive near Wheeling (river miles 87 through 92) because it has the most exceedances. Further downstream, application of a wet weather sub-use criterion (yellow line) would be the most restrictive criterion.

Figure 4-15. Exceedance Comparison for Multiple Variables.



As discussed previously, the user can specify a numeric criterion of their choosing for any of the variables shown in the upper right hand portion of the form. Figure 4-16 shows the same analysis as Figure 4-15, but the velocity criterion has been changed from 2 mph to 3 mph. As this figure illustrates, there are very few hours when the velocity in this section of the river exceeds 3 mph.

Figure 4-16. Exceedance Comparison for Multiple Variables Using New Velocity Criterion.



4.4 SYSTEM REQUIREMENTS

The modeling tools are complex and resource intensive. The river model contains 1,841 active (e.g. wet) grid cells in which the concentration and velocity are recomputed every 2.5 seconds or a total of 6,359,040 time steps during the typical recreation season simulation. A total of 8,129,856 model output values, corresponding to hourly output from all of the model's active grid cells, were stored for processing and evaluation. Table 4-2 presents a summary of the recommended minimum computer requirements needed to ensure relatively quick model simulation time and responses in the visualization interfaces to user selections.

Table 4-2. Recommended Minimum Computer Requirements for Models and Framework.

Component	Recommended Minimum
Hard Drive Storage	20 GB
Processing Speed	978 MHz
RAM	1.00 GB

A computer meeting these requirements will complete a simulation of the typical recreation season in approximately 7 hours. A computer with three times as much processing speed and RAM can complete a simulation in approximately 4 hours. The responsiveness of the model framework to user selections is also improved with a more powerful computer. However, a computer meeting the recommendations provided in Table 4-2 will provide a timely response to user selections with minimal wait time for updating results.

5. NEXT STEPS

This section presents suggestions for the use of this modeling framework to complete a Use Attainability Analysis (UAA) in the study area and the potential application to other Ohio River or large river communities.

5.1 DATA NEEDS FOR THIS USE ATTAINABILITY ANALYSIS

The product of this project is a set of modeling tools and framework that are in place to allow communities in the study area to complete a UAA. However, there are several gaps in the available information for this study area that will need to be addressed before a UAA can be completed. These include:

- Accurate combined sewer overflow (CSO) volumes: Since most of the *E. coli* wet weather load is believed to originate from local CSOs, collection system models that can simulate the amount of CSO volume for varying storm events would provide more realistic simulations of the impact of these sources on Ohio River water quality during a typical recreation season and would allow future users to evaluate uses with respect to third factor in the UAA guidance (see Section 1.4 for evaluation factors).

- Nonpoint source (tributary) *E. coli* concentrations under varying environmental conditions: Nearly all of the available tributary bacteria data in West Virginia was for fecal coliform. Collecting *E. coli* data in the study area tributaries during dry and wet weather would allow future users to develop a more mechanistic relationship between environmental conditions and corresponding tributary concentration. Since there is very little *E. coli* data available in the Ohio tributaries, additional *E. coli* data collected during wet and dry weather would provide similar constraints for the Ohio tributary loads.

- Economic data for each community: The economic cost associated with meeting water quality standards is a factor (#6 in Section 1.4) that may be considered in evaluating the use attainment level of a stream.

- Feasible control alternatives: The control alternatives simulated during this project were screening level estimates, applied equally to all CSOs for all events. Control alternatives that can simulate capture of a specific storm size or account for geographic application of controls will provide more realistic improvements in in-stream water quality and a more accurate assessment of the appropriate use or water quality standards for the river.

5.2 TRANSFERRING FRAMEWORK TO OTHER OHIO RIVER OR LARGE RIVER COMMUNITIES

Public domain models for the watershed and Ohio River were selected so that they could be adapted to other portions of the Ohio River or to other large rivers, such as the

Mississippi River. This section describes the updates that would be needed to each model in order to customize them for use at other sites.

Table 5-1 describes a list of changes to the watershed SWMM model would be needed for its application to a different site. Note that although inputs for the RUNOFF and TRANSPORT blocks can be combined into a single file, they are discussed separately here for clarity. Note also that, unlike EFDC, the names for the SWMM input files can be chosen by the user.

Table 5-1. Adapting SWMM Model Input Files to a New Site.

Model File	Change/Update	Description
runoff.inp	Physical characteristics of water - and sewersheds Rainfall data[1]	This file contains the physical data for the tributary watersheds and combined sewersheds, including area, slope, surface roughness, infiltration and storage characteristics. This information is specified for each water- and sewershed model. This file can also contain rainfall data (see note below)
transport.inp	Average annual base flow Monthly flow factors	The SWMM TRANSPORT block is used to generate the dry weather base flow from the tributaries. Seasonal variations in base flow are handled by specifying an annual average flow and twelve monthly flow factors. A different set of flow factors can be applied to each tributary, if supporting information is available.

Notes:
[1] The rainfall can also be specified in the RAIN block of the SWMM model.

Table 5-2 contains a list of changes to the river EFDC model input files to customize its use at another location.

Table 5-2. Adapting EFDC Model Input Files to a New Site.

Model File	Change/Update	Description
cell.inp, cellt.inp	Model grid	These files contain a plan view of the model grid layout. The grid needs to overlay the river. A new site may require a more refined grid if it has lots of external sources or river with lots of bends or it could be coarser than current grid.
dxdy.inp, lxly.inp	Grid cell bathymetry Grid cell dimensions	The files contain the dimensions (x,y,z) of each grid cell. These would need to updated to reflect new river bathymetry and morphometry.

Model File	Change/Update	Description
efdc.inp	External source input locations Bacteria loss rate Simulation time period Model time step	Site specific information in this file includes the location of external (e.g. CSO, upstream, tributary) sources and the bacteria loss rate. This file also contains inputs controlling the start time, duration and computational time step of the simulation.
qser.inp	Flow time series	Site specific flows for each source during the simulation period would be updated in this file.
dser.inp	*E. coli* concentration time series	Site specific *E. coli* concentrations during the simulation period for each source would be updated in this file.
pser.inp	Downstream boundary stage time series	If the stage was used as the downstream hydraulic boundary at a new site, the time series of downstream depth would be updated in this file.

Although the models can be readily transferred for use on another site, it is recommended that experienced modelers update these models to ensure that they run properly and do not produce erroneous results.

Adapting the framework to another site would require updating the information in the tables of the pre-processor Access database to reflect the new site information. GIS views of the new study area would be needed for use in the map-based visualization. Some code changes reflecting the default values on the visualization forms (such as default values for numeric criteria) could be done for convenience but is not necessary for the framework to be successfully transferred to another site.

6. REFERENCES

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United States Environmental Protection Agency (USEPA).1983. *Technical Support Manual: Waterbody Surveys and Assessments for Conducting Use Attainability Analyses*; EPA-440486037. Washington, DC.

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USEPA. 2004. *Water Quality Standards for Coastal and Great Lakes Recreation Waters; Final Rule.* 40 CFR Part 131. Federal Register / Vol. 69, No. 220 / Tuesday, November 16, 2004, pp. 67217-67243.

APPENDIX A

Appendix A. Memorandum Describing Reduction Scenarios

Memorandum

DATE: June 6, 2006
PROJECT: **WHEELE**

TO: **Jason Heath**
ORSANCO

FROM: **Carrie Turner**
CC: Dave Dilks

SUBJECT: **Recommended Reduction Scenarios for Wheeling UAA Demonstration Project**

This memorandum is a follow-up to the project conference call on May 15, 2006. During the call, questions regarding the level of reduction by source type and the relative magnitude of *E. coli* loads by each source type in the study area (combined sewer overflows (CSOs), nonpoint sources (NPS), upstream sources) were raised and not resolved. This memorandum presents inflow volumes and *E. coli* loads into Hannibal Pool of the Ohio River for the 2003 recreation season by source type, literature review information on bacteria removal efficiency for nonpoint source best management practices (BMPs), and recommended reduction scenarios to be considered for this project. The purpose of this memorandum is to provide the necessary information to reach consensus on the reduction scenarios that will be simulated under this project.

In summary, Table 1 presents recommended source reductions to be considered for the model scenarios. These recommendations focus primarily on CSO sources, since CSOs will be reduced through implementation of long term control plans. However, two of the recommended scenarios also address reductions in non-point sources from within and upstream of the study area.

Table 1. Recommended Source Reduction Scenarios.

Scenario No.	CSO	Non-point Source	Upstream[1]	Basis
1	0	0	0	Assess current conditions
2	75%	0	0	Corresponds to 15 overflows /rec season in Wheeling and EORWA
3	85%	0	0	Corresponds to 9 overflows/rec season in Wheeling and EORWA
4	95%	0	0	Corresponds to 3 overflows/rec season in Wheeling and EORWA
5	95%	30%	45%	Scenario simulating likely level of achievable reductions
6	100%	0	0	Best case CSO reduction only
7	0	60%	40%	Best case NPS reduction only

Notes:
[1] Upstream loads were estimated to be comprised of 25% CSO and 75% NPS

The following sections present additional supporting information from the study area and project that serve as the basis for these recommendations.

2003 Recreation Season E. coli Loads

Table 2 presents a summary of the inflow volumes and *E. coli* loads by source type for the 2003 recreation season. Four source types are summarized:

- Tributary or non-point sources: These loads corresponds to the tributary subwatersheds simulated with the watershed model;
- Direct drainage sources: These loads correspond to area in the watershed model that drain directly to the Ohio River and are not within a combined sewer service area;
- CSO sources: These loads correspond to combined sewer overflows, which were simulated for each community.
- Upstream sources: These loads correspond to sources upstream of Pike Island Dam (the model upstream boundary) and include a mixture of loads from non-point sources and CSO communities.

Table 2 includes values tabulated during wet weather conditions only (when CSOs and NPS sources are active) and for the entire period. Flow in Hannibal pool is dominated by the upstream Ohio River flow, which accounts for 98% of the inflow volume in the study reach (95% of the wet weather volume). CSOs account for 55% of the wet weather load and NPS sources (tributary and direct drainage) account for approximately 14% of the wet weather load (percentages of tabulated values relative to the total load are shown in parentheses for each source type). The percentage of the total load that occurs during wet weather is also provided.

Table 2. 2003 Recreation Season Volume and *E. coli* Load by Source Type.

SourceType	Volume (MG)		Total *E. coli* Load (cfu)		
	Wet Weather	**All (Total)**	**Wet Weather**	**All (Total)**	**% of Total from Wet**
Tributary (NPS)	52,795	83,391	4.61E+09 (12.6%)	4.97E+09 (5.0%)	93%
Direct Drainage (NPS)	6,493 (0.6%)	9,733	3.74E+08 (1.0%)	4.00E+08 (0.4%)	93%
CSO	1,074 (0.1%)	1,074	2.02E+10 (55.1%)	2.02E+10 (20.3%)	100%
Upstream	1,076,721 (94.7%)	6,333,976	1.14E+10 (31.2%)	7.39E+10 (74.3%)	15%
Total	*1,137,083*	*6,428,175*	*3.66E+10*	*9.94E+10*	*37%*

Table 3 presents a summary of estimated CSO volume and number of overflow events by community for selected storm events and for the entire recreation season. Note that these values are highly uncertain and there are no data available to constrain or verify their magnitude or frequency. Rather, the reasonableness of these estimates was based on professional judgment, experience and comparison to overflow characteristics of other CSO communities in the region.

Table 3. CSO Volume and *E.coli* Loads by Community.

Community	Number of outfalls	Total Volume (MG) 0.6" (5/5/03)	1.1" (7/10/03)	1.6" (5/9/03)	2.0" (9/18/03)	Total	No. of CSO Events
Wheeling CSOs	113	18.2	43.7	85.2	120.6	**743**	60
EORWA near Bridgeport	23	4.98	12.2	22.6	32.0	**195**	60
Bellaire CSOs	24	1.8	6.3	11.0	17.8	**73**	47
Benwood CSOs	11	0	1.2	4.8	10.2	**31**	29
McMechen CSOs	5	0	1.2	3.5	7.3	**22**	19
Moundsville CSOs	4	0	0.6	1.3	3.6	**10**	18

Non-point Source Reductions

As shown in Table 2, non-point sources, both within Hannibal pool and from upstream, comprise about one-third of the load in Hannibal pool. Bacteria reductions from different non-point source best management practices (BMPs) documented in the literature were compiled and evaluated to develop recommendations for reducing non-point sources in one or more of the model reduction scenarios. Table 4 presents a range in bacteria reductions obtained from the literature. The literature information suggests that most BMPs achieve reductions in bacteria between 30-60%.

Table 4. Observed Bacteria Reductions Associated with Best Management Practices.

No	BMP Category	BMP Description	Applicable BMPs	Range in % Reduction
1	Tillage Practices	Leaving plant cover on fields	1. Conservation tillage 2. Contour plowing 3. Cover crops	*No info available for bacteria*
2	Riparian Buffers	Trees, shrubs, grassland vegetation planted near streams	1. Filter strips 2. Constructed wetlands	29% - 78%
3	Livestock Exclusion	Fencing to prevent access to streams	1. Fencing	29% - 60%
4	Septic Corrective Measures	Upgrade septic to function properly-reduce failure rate	1. Septic pumping 2. Septic replacement 3. Straight pipe discharge elimination	90%
5	Ponds	Temporary detention of stormwater in ponds	1. Wet ponds 2. Dry ponds	40% - 78%
6	On-Site Basins	Parcel-level stormwater collection areas that promote infiltration	1. Rain gardens 2. Infiltration trenches	90%
7	Pet Waste Education	Education to promote picking up after your pet	1. Pet waste education	10-90%

Source Reduction Scenarios

The primary objective of this project is to develop a modeling framework that the local communities can use to conduct a Use Attainability Analysis (UAA). Although the project resources are not sufficient to conduct a UAA, applying the model for several screening level reduction scenarios will provide insight regarding the conditions that are needed for the Ohio River to meet bacteria water quality standards.

Seven reduction scenarios are proposed for consideration in Table 1. These were developed to reflect project objectives and stakeholder interests. These recommendations focus primarily on CSO sources, since CSOs will be reduced through implementation of long term control plans. Several scenarios do not have include any CSO reduction. These scenarios are intended to reflect water quality if no effort was made to control CSO sources in the future. Scenario 7 simulates the effect of focusing control efforts on non-point sources only.

However, five of the seven scenarios include reductions in CSO loads at various levels that were estimated to represent a range of possible levels of CSO control. The lower bound level of control is estimated as 75% (scenario 2). As communities undergo evaluation of CSO control options in the future, it seems likely that the “knee of the curve” analysis, corresponding to the most cost-effective level of control, will occur between 75 and 95%. Three of the scenarios simulate this range with CSO control simulated at 75% (scenario 2), 85% (scenario 3), and 95% (scenario 4). For bracketing purposes, the effect of complete CSO control (no CSO overflow) is simulated in scenario 6, in which CSO loads are reduced 100%.

The information presented in the previous section indicates that bacteria loadings can be reduced approximately 30-60% through the implementation of best management practices. Two scenarios are recommended for consideration to address non-point source control. Scenario 5 includes control of the non-point sources upstream of and within the Hannibal Pool watershed. The control level is moderate (as is the CSO control level), and was developed to simulate the effect on water quality from a realistic set of source reductions. Scenario 7 provides a upper bracketing of the benefit of non-point source control by simulating reductions solely in those sources at the maximum level indicated in the literature.

Due to project resource limitations, the number of reduction scenarios needs to be restricted to 6-7 scenarios (assuming one scenario is current conditions or no reduction). This set of scenarios is presented as a starting point for additional discussion among the stakeholders, in hopes of reaching consensus on the scenarios within two weeks (June 20, 2006).

Appendix B. Responses to West Virginia Comments on Draft Report

LimnoTech
Water | Environment | Scientists | Engineers

MEMORANDUM

DATE: October 5, 2007

FROM: Carrie Turner

PROJECT: WHEELE

TO: Jason Heath (ORSANCO)

CC:

SUBJECT: Response to West Virginia Comments on Draft Wheeling Report

Summary

This memorandum presents a summary of comments on the Draft Wheeling Use Attainability Analysis Demonstration Project received from West Virginia. LimnoTech has developed responses that address the each comment, as shown in the following section.

Comments and Responses

1) Pg ES-2--reference in Table ES-1 to "primary contact recreation" is misleading as this is not ORSANCO's definition for this Designated Use. The correct definition is "contact recreation" and as many times as I have attempted to point this out, this critical aspect keeps getting lost in the mire of this issue. Primary Contact is generally referred to as "full body immersion" and the definition used by ORSANCO is "where the human body may come in contact with the water of the Ohio River". If ORSANCO intends to further clarify that this definition was intended to mean "full body immersion", maybe reference to "primary contact" would suffice. However, unless or until this is done, I see this as ripe for a 3rd party challenge as my read of "the human body may come in contact" is as any part of the body.

LTI Response: Duly noted. Additional clarification was added to the Executive Summary describing ORSANCO's designated use and bacteria criteria (in their Pollution Control Standards). References to Primary Contact Recreation were changed to Contact Recreation where appropriate to reflect ORSANCO's language. In some instances, the use of the term "primary contact recreation" was used where the intent of the text is full body immersion.

2) Pg ES-3--Table ES-2 (and Table 1-2) refers to 7 separate Illness Rates. Although EPA's May 2002 Draft Implementation Guidance document acknowledged the potential application of 8-14 cases/1000 risk levels, EPA's later Nov 2003 Draft eliminated references to allowing risk levels above 1% as greater than 1% for E-coli based upon the calculated regression line of observed data results in bacteria densities greater than the observed range. Therefore, EPA recommended that states adopt freshwater criteria based on risk levels at or below 1%. Not sure if the consultant was aware of this albeit neither Draft" document was ever finalized.

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LTI Response: A footnote was added to Tables ES-2 and 1-2 indicating that EPA does not support the extension of the freshwater pathogen criteria to illness rates greater than 10 per 1,000.

3) Pg, ES-4--not sure what is meant by "Refinement of upstream boundary concentrations" as a further data need?

LTI Response: As noted in the report, ORSANCO has been collecting data in the Ohio River at three locations near Wheeling. One of these locations is upstream of the City and served as the dataset for specifying the upstream model boundary concentrations. This sampling program consists of collecting samples approximately once per week for the purpose of evaluating compliance with the geometric mean water quality standard criterion. There are limited time-intensive data that characterize the response of the upstream watershed to storm events (e.g. multiple samples collected over the 48-72 hours corresponding to storm event conditions in the river). ORSANCO conducted one wet weather survey with E. coli monitoring over a two-day storm period. More wet weather monitoring is recommended so that the upstream load can be realistically represented in the model (and distinguished from the loads originating within the Hannibal Pool watershed).

4) Pg 2--suggest delete reference to "Standard" in the 1.3 title as what is being evaluated is the "criteria". Note that this correction must also be applied elsewhere throughout the document where applicable. Also, note again that the Ohio River is not designated for "primary contact rec use" so this reference again needs to be corrected. Further, in the 2nd main para., should correct and add that "some" states have been transitioning". A number of states are still awaiting further conclusions by EPA to see if alternate indicators beyond E-coli are more appropriate.

LTI Response: The text in this section has been modified as suggested.

5) Pg 7, Table 2-1--curious as to why only WVDEP 2000 data was used as one of the data sources? My understanding is that DEP has much more data, possibly not accessible in Storet for a longer period. If more is sought, contact is John Wirts or Pat Campbell.

LTI Response: Additional data to support the models and use attainment analysis are always welcome. The final report for this project will include this summary response. If one of more of the West Virginia communities chooses to move forward with completing the Use Attainability Analysis, they can allocate necessary resources to include new and larger datasets into the analysis.

6) Pg. 8,Table 2-2 & 1st para. under Water Quality Datasets--appears somewhat odd that reference is made with an average of 172 in the upstream that the use is met 3/4 of the time yet the downstream at an average of only 86 is exceeded 67% of all months?

LTI Response: LimnoTech apologizes for the confusion. Table 2-2 presents a statistical summary of the data at Hannibal Dam, which is the downstream end of the study area. The first paragraph under Water Quality Datasets is describing the data collected by ORSANCO at their three monitoring locations near Wheeling. The most downstream of these locations is approximately one mile downstream of the City of Wheeling and approximately 36 miles upstream of Hannibal Dam. Data from this location are not summarized in Table 2-2.

7) Pg. 10, 2.2.1--reference is to 18 tributary watersheds yet only 17 are noted on Table 2-3. Apparently Little Wheeling in WV has been omitted based on Figure 2.2.

LTI Response: Section 2.2.1 describes the SWMM model developed to simulate runoff in the tributary watersheds. In this model, the study area was subdivided into 18 watersheds. Note that as shown in Figure 2-2, the Wheeling Creek (WV) watershed was modeled in SWMM with two watersheds-one to represent runoff in Little Wheeling Creek (a tributary to Wheeling Creek) and one to represent runoff in Wheeling Creek itself. The runoff from these two watersheds were summed into a single input to the Ohio River model and so Little Wheeling Creek was not included in Table 2-3, which summarizes the tributary inputs to the river model.

8) Pg. 11--reference made to "Five CSO Communities" but description reflects six?

LTI Response: As noted in the text, the East Ohio Regional Sewer Authority (EORWA) includes the cities of Bellaire, Bridgeport and Brookside. However, Bellaire is located far enough downstream from Bridgeport and Brookside that their CSO load was input to the river model as a separate set of inputs from the EORWA inputs.

9) Pg. 18, Table 3.1--appears to be omission of rainfall description, units and 2003 value on one of the lines. Also, in Table 3.2. can there be an explanation of why the 60%/40% reductions were chosen as the "best case" example for Scenario 7.

LTI Response: The information in Table 3-1 is complete. One of the rows in Table 3-1 was split over two pages, which is likely the cause of confusion. The table has been reformatted to eliminate this problem. The 60%/40% reductions in Table 3-2 were selected as best case NPS reductions based on discussion with ORSANCO, literature information regarding BMP removal effectiveness, knowledge of pollution control efforts in the area, and best professional judgment. The reduction scenarios were presented to stakeholders in a memorandum (LimnoTech, June 6, 2006) for comment. This memorandum has been included in the final report.

10) Pg. 19, Table 3-3-not sure I can follow the meaning of the last column "% of total from Wet"? May need further explanation.

LTI Response: The values in this column of the table (column 6) were calculated as the Wet Weather E. coli Load (column 4) divided by the Total E. coli Load (column 5). The intent of this column was to characterize how much of the total E. coli from each source type was delivered to the Ohio River during wet weather versus dry weather. As the values show, most of the upstream load was delivered during dry weather (because the percent of total from wet is only 15%) whereas nearly all of the load from the rest of the sources were delivered during wet weather (all percentages > 90%).

11) Pg. 20, Table 3-4--title of this table appears in error as presume all values offered are in terms of MG and not E-coli counts? If this is the case, following question is how the volume goes down between a 0.6" and the 1.1" rains in the last four noted communities?

LTI Response: The title of this table is in error. The reference to "E. coli Loads" has been removed. The table has also been updated to correct the volumes for the 0.6" and 1.1" storms. A summing error occurred during the construction of this table.

12) Pg. 21, Table 3-6--is "lat. loc." the correct description? Do understand the following descriptions of MID, LDB and RDB but not sure what "lat. loc" means.

LTI Response: Yes, "Lat-loc" is the correct description and refers to the lateral location in the river, looking downstream where the results were evaluated. A footnote has been added to this table to provide additional clarification.

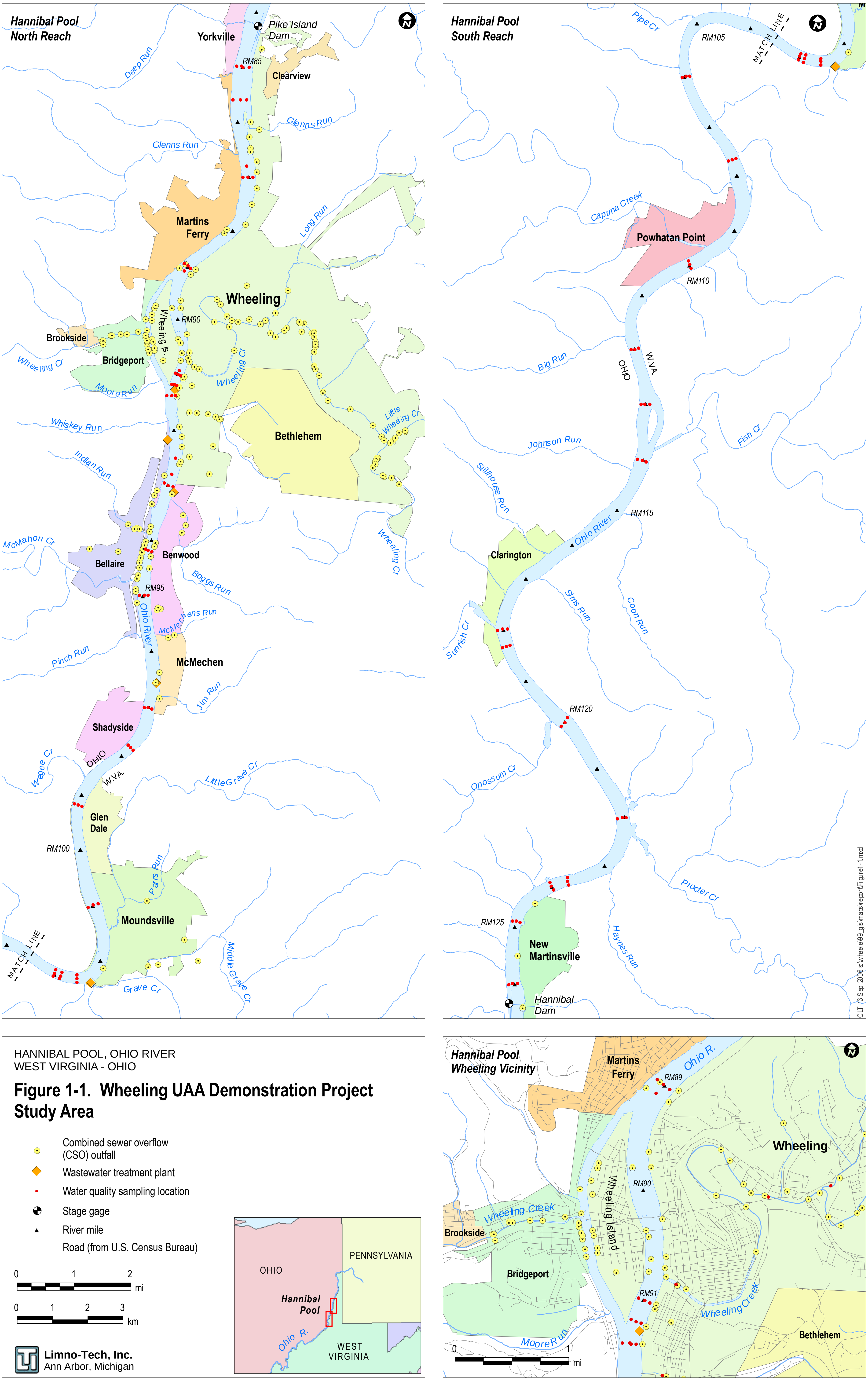

Figure 1-1. Wheeling UAA Demonstration Project Study Area

HANNIBAL POOL, OHIO RIVER
WEST VIRGINIA - OHIO

Figure 2-2. Watershed Model Tributary Areas

- USGS flow gage
- Tributary water quality sampling location
- Rainfall gage

0 5 mi

0 5 10 km

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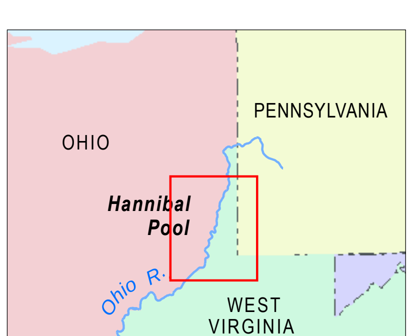

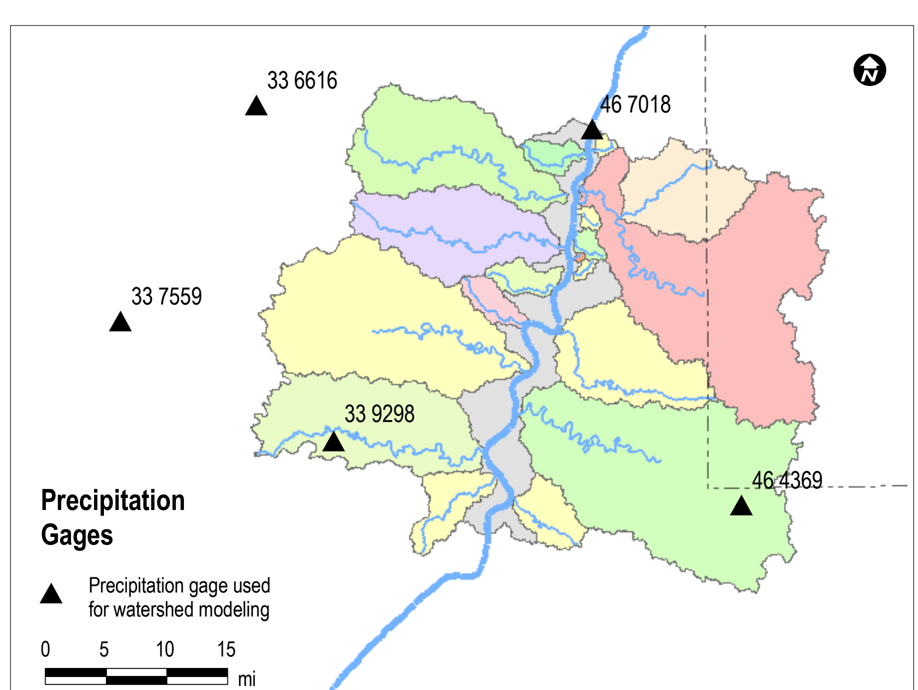

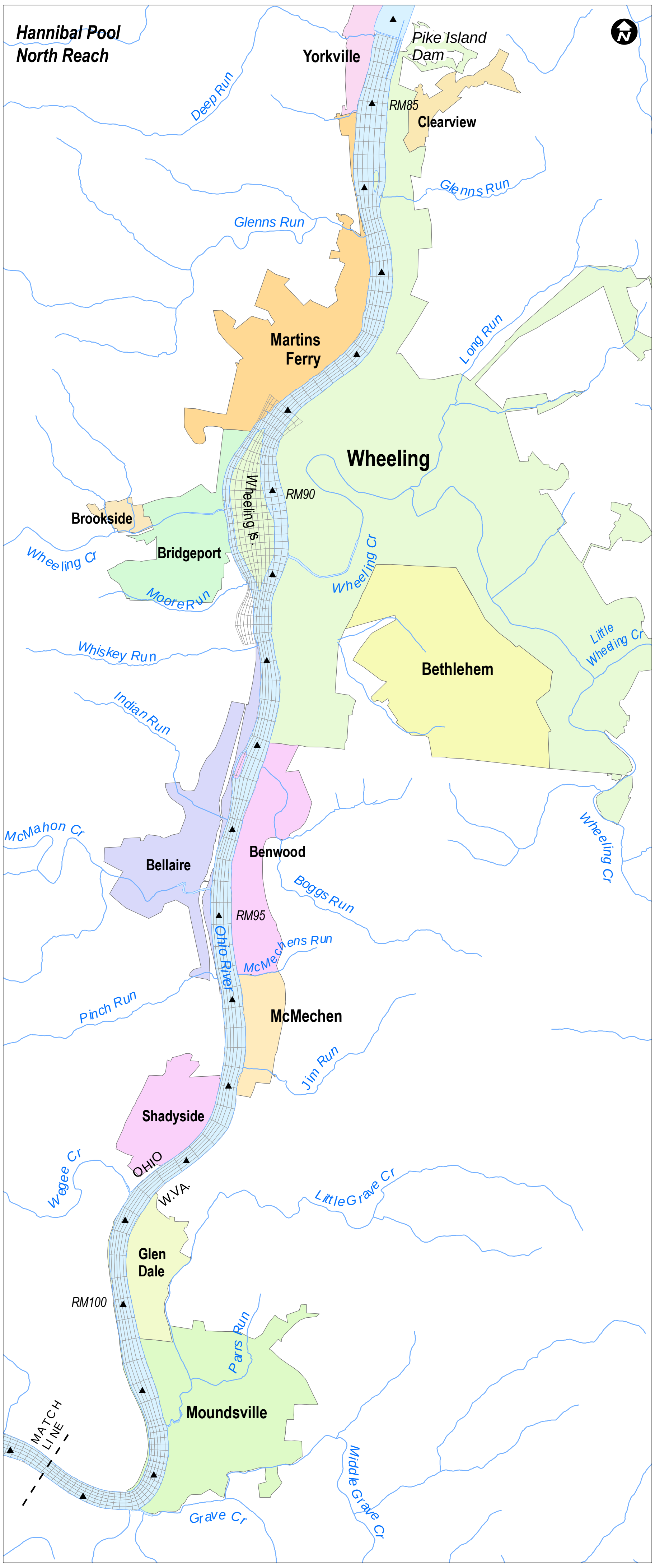

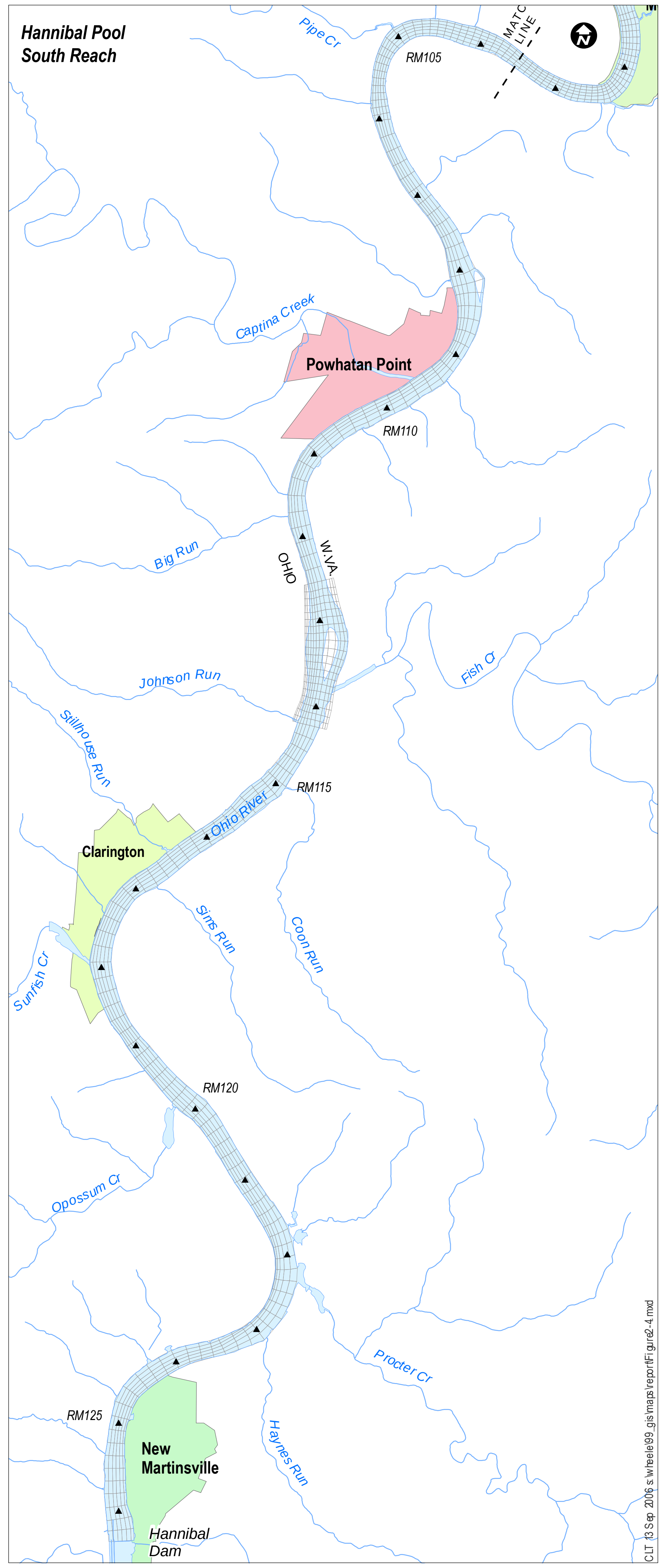

HANNIBAL POOL, OHIO RIVER
WEST VIRGINIA - OHIO

Figure 2-4. EFDC Model Grid

EFDC model grid cells

River mile

Combined sewer overflow
(CSO) outfall

0 1 2 mi

0 1 2 3 km

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