CHAPTER 2: SYSTEM CHARACTERIZATION

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CHAPTER 2: SYSTEM CHARACTERIZATION

2.1 OBJECTIVE OF SYSTEM CHARACTERIZATION

The purpose of combined sewer system (CSS) characterization, monitoring, and modeling is to better understand the response of the system to various wet weather events, the characteristics of the overflows, and the water quality impacts that could result from combined sewer overflow (CSO) discharges. The CSS characterization information is imperative to developing a CSO control plan adequate to meet the Clean Water Act (CWA) and Amended Consent Decree (ACD) requirements. For the purposes of the Integrated Overflow Abatement Plan (IOAP), except where specifically noted otherwise, the term “Consent Decree” will be understood to mean the ACD as it was entered into Federal Court on April 15, 2009.

The major elements of a sewer system characterization are listed below with the description from the United States Environmental Protection Agency (EPA) Guidance: Combined Sewer Overflows Guidance for Long-Term Control Plan (EPA 832-B-95-002). Subsequent sections of this Volume describe major elements in more detail:

- Rainfall Records - “permittee should evaluate flow variations in the receiving water body to correlate between CSOs and receiving water condition”
- CSS Characterization - “permittee should evaluate the nature and extent of its sewer system through evaluation of available sewer system records, field inspections and other activities...”
- Monitoring - “monitoring program that measures the frequency, duration, flow rate, volume and pollutant concentration of CSO discharges and assesses the impact of the CSOs on the receiving waters.” This includes the following: number of CSOs, locations of CSOs, frequency of CSOs, volume of CSOs, concentration and mass of pollutants discharged at CSOs, impacts of the CSOs on the receiving waters and their designated uses, and mathematical modeling.

The characterization of the Louisville and Jefferson County Metropolitan Sewer District’s (MSD) CSS was performed as outlined above, through review of existing information, field investigation, monitoring, and mathematical modeling of the sewer system.

2.2 IMPLEMENTATION OF NINE MINIMUM CONTROLS

The EPA CSO Control Policy, published April 19, 1994, provides guidance to stakeholders for coordinating the planning, selection, and implementation of CSO controls that meet the requirements of the CWA. Among other things, the Policy establishes two main objectives for permittees: implementation of nine minimum controls (NMC), and development and implementation of a Long-Term Control Plan (LTCP).

As the name implies, a LTCP is intended to be a far-reaching plan that presents a comprehensive approach to the identification, evaluation, and implementation of long-term, capital-intensive controls to reduce the impact of CSOs. The development and implementation of a LTCP can take several decades to complete.

Conversely, it was intended that the NMCs "reduce CSOs and their effects on receiving water quality, do not require significant engineering studies or major construction, and can be implemented in a relatively short period of time." [1] The EPA envisioned that "implementing the nine minimum controls is among the first steps a municipality should take to reduce combined sewer overflow impacts." [2] Similar to the intent of the LTCP, efforts undertaken for the NMCs are not considered as temporary measures. They should be integrated into a community's long-term efforts to control CSOs. The intent of the nine minimum controls is as follows:

- Proper operation and regular maintenance programs for the CSS and the CSOs
- Maximize use of the collection system for storage
- Review and modification of pretreatment requirements to assure CSO impacts are minimized
- Maximization of flow to the publicly owned treatment works (POTW) for treatment
- Elimination of CSOs during dry weather
- Control of solid and floatable materials in CSOs
- Pollution prevention programs to reduce contaminants in CSOs
- Public notification to ensure that the public receives adequate notification of CSO occurrences and combined sewer impacts
- Monitoring to characterize effectively CSO impacts and the efficacy of CSO controls

Communities with collection systems that contain CSOs were to implement the NMCs by January 1, 1997.

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[1] US EPA, Combined Sewer Overflows, Guidance For Nine Minimum Controls, EPA 832-B-95-003, 1995 § 1.6

[2] ibid., § 1.8

2.2.1 History of Nine Minimum Controls

MSD began the initial phase of a CSO abatement program in 1991, prior to the release of the EPA guidance. These initial efforts included work on both the NMC and the CSO LTCP. This initial effort culminated in the development of a Combined Sewer Operational Plan, which is contained in two documents: Combined Sewer Operational Plan 1996 Update, and 1997 Update. Also in 1997, MSD prepared the NMC Compliance Report, which summarized NMC activities completed to date, showing compliance with EPA's Combined Sewer Overflow Control Policy January 1997 deadline for NMCs. Since 1997, MSD has continued to implement the NMC program and has prepared regular updates to the original Combined Sewer Operational Plan. In June of 2003, MSD prepared the NMC Compliance Report Update, which summarized the continuation of implementation of NMC activities from January 1997 through June 2003.

Additionally, as part of the Consent Decree, another updated compliance report was required. This comprehensive report titled, “Nine Minimum Controls Compliance Report,” dated September 15, 2006, contains an updated summary of NMC activities completed throughout the life of the program up to September 2006. This report is available on the MSD website http://www.msdlouky.org/projectwin/ in the public document repository.

In addition to the compliance report requirement in the Consent Decree, there were specific NMC activity requirements. A summary of the NMC Early Action Plan (EAP) requirements completed, as required by Paragraph 24a of the Consent Decree, are summarized in Volume 1, Chapter 4, Section 4.1.4 of this IOAP.

2.2.2 Continuation of Nine Minimum Controls

MSD continues its efforts for NMCs with a focus on high value and sustainable activities. An example is proper operation and sustained maintenance of the collection system through inspection and cleaning of catch basins and sewer mains. Another example is reducing the potential for dry weather overflows through increased inspection and maintenance of “hot spots,” such as areas impacted by fats, oils or grease (FOG). These activities are managed through MSD’s Hansen Information Management System (Hansen). Other examples include pollution prevention efforts that are being expanded through greater enforcement of current pretreatment and hazardous materials ordinances, and increased interaction with non-domestic dischargers and significant industrial users.

Public notification is continually being enhanced through the “Project Waterways Improvement Now” (Project WIN) website, which is regularly updated to include current and pertinent information related to the implementation of the NMCs and LTCP. Moreover, the frequency of public meetings is increasing and the content of these meetings is expanding with the implementation of the NMCs and development of the Final CSO LTCP.

MSD continues to submit quarterly and annual status reports documenting the accomplishments of the NMC program as required by the Consent Decree. These reports are available on MSD’s website for the public to review.

Detailed examples of MSD's efforts for continuation of NMC activity as a long-term program include:

1. Proper operation and maintenance (O&M) programs
    - In-field inspection of CSOs
    - Regular cleaning and tele-inspection of CSS pipes and siphons
    - Regular updating of the CSO inventory which contains drawings and key physical data of each CSO asset
    - Work order management system (Hansen) for inspection, maintenance, and documentation of CSOs
    - Annual training for personnel who inspect and maintain CSOs; this training also includes topics such as coding of field data and overflow response
2. Maximize use of the collection system for storage
    - Regular hydraulic analysis of the CSO overflow structures, seeking new opportunities to remove regulators or raise dams for additional in-system storage
    - Evaluating and revising the operational set points of the Real Time Control (RTC) system to increase in-system storage
    - Maintaining a robust hydraulic computer model of the CSS as an evaluation tool for improvement to maximize storage options
3. Review and modification of pretreatment requirements to minimize CSO impacts
    - Field inspection of streams and creeks for illicit discharges
    - On-going quality and quantity monitoring of non-domestic discharges that discharge to the CSS
    - Notification to non-domestic discharges of upcoming rain events requesting “wet weather control strategies” be implemented for upcoming event
    - Required wet weather control strategies (that is, hold and release and/or delayed cleaning operations during and for a certain time after wet weather events of a defined level by receiving CSO) for new wastewater discharge permits issued to facilities discharging to the CSS
    - Evaluated green infrastructure opportunities for existing permittees undergoing expansions
4. Maximization of flow to the POTW for treatment
    - On-going tracking of flow at Morris Forman Water Quality Treatment Center (WQTC), striving for increased treatment at the plant
    - Regular analysis of the Morris Forman WQTC for operational changes to increase combined sewage flow treated

5. Elimination of CSOs during dry weather

- Weekly inspections of CSOs to address potential dry weather overflows
- On-going monitoring of possible dry weather overflow data to address recurring dry weather overflows situations programmatically

6. Control of solid and floatable materials in CSOs

- Regular maintenance of installed solids and floatables (S&F) devices at the CSOs
- Regular cleaning of trapped street curb inlets, to collect and remove trash and grit from street runoff
- Commitment to install more robust S&F control technologies at CSO LTCP projects

7. Pollution prevention programs to reduce contaminants in CSOs

- Regular cleaning of trapped street curb inlets, to collect and remove trash and grit from street runoff
- On-going coordination with Louisville Metro Public Works to maintain commitment to regularly clean streets and pick up litter

8. Public notification to ensure that the public receives adequate notification of CSO occurrences and combined sewer impacts

- Annual inspection and maintenance of overflow advisory signage along the Ohio River and forks of Beargrass Creek
- Annual mailing of information about CSOs to customers within 500 feet of the Ohio River and forks of Beargrass Creek
- Maintaining the Project WIN website which includes public document repository of program outreach and documents and quarterly and annual reports
- Automatic email service that sends emails notifying customers of possible CSO events
- Publishing MSD “Update” and MSD “Crosscurrents” which is sent to customers to inform them of various program activities. Examples include not pouring grease down the sink, and staying out of streams after a rain event, etc.

9. Monitoring to characterize effectively CSO impacts and the efficacy of CSO controls

- Monitoring the largest CSOs for overflow volume and frequency
- Monitoring streams to obtain data such as stream flow, pH, dissolved oxygen and other environmental data
- Expanding CSS flow monitoring as part of each of the Final CSO LTCP projects
- Maintaining the existing rain gauge network which covers the entire MSD service area

2.3 USACE FLOOD PUMP STATION OPERATIONS

MSD has the responsibility for the operation and maintenance of an extensive flood protection system that was developed by the US Army Corps of Engineers (USACE) in the 1950s. A significant portion of this flood protection system, 11 of 16 flood pump stations and 162 flood control gates, are associated with MSD's CSS. Therefore, the flood protection system and the CSS operate in an integrated manner when the flood protection system is activated as a result of elevated Ohio River levels. When the USACE developed the flood protection system, their focus was to protect the community from flood damage. The minimization of overflows from the CSS was not the priority.

As a provision under the Consent Decree, entered into Federal Court April 15, 2009, MSD is required to provide for the following outcomes:

- Paragraph 25b, (2) A. (i) - "The final Long-Term Control Plan shall meet the following goals: Ensure that if CSOs occur, they are only as a result of wet weather (this goal shall include addressing those discharges resulting from MSD's compliance with the requirements of the USACE' Ohio River Flood Protection System Pumping Operations Manual, dated 1954 and revised 1988);"
- Paragraph 26b, (2) B. (i) - "The final Long-Term Control Plan shall include, at a minimum, the following elements: The results of characterization, monitoring, modeling activities and design parameters as the basis for selection and design of effective CSO controls (including controls to address those discharges resulting from MSD's compliance with the requirements of the USACE' Ohio River Flood Protection System Pumping Operations Manual, dated 1954 and revised 1988);"

Pursuant to this requirement of the Consent Decree, the flood pump station projects identified by this evaluation process to eliminate dry weather overflows will become a component of the selected plan and not be subject to a cost benefit analysis.

The USACE designed and constructed two types of flood pump stations within the CSS. There are dual-purpose flood pump stations that serve as both a sanitary pump station that conveys dry weather flow (DWF) to the interceptor and a flood pump station that conveys wet weather flow to the river during elevated river stages. Also, there is single-purpose flood pump station that serves only to convey wet weather flow to the river during elevated river stages. The following describes the various modes of operation that can exist at a flood pump stations and the potential for them to result in a dry weather overflow.

- **Sanitary Mode** – this mode only applies to dual-purpose flood pump stations. Sanitary pumps at the flood pump stations are set to discharge DWF to the interceptor, flood pumps are deactivated, and flood control gates are positioned to discharge wet weather overflows directly to the Ohio River as a permitted CSO. The dual-purpose flood pump stations are in this mode until the river level reaches the elevation of the top of the CSO dam and before the river mixes with the DWF. This USACE prescribed mode of operation does not result in dry weather overflows.

- **Plant Idle Mode** – this mode is different for the two types of flood pump stations and can be defined for each as follows:
    - Single-Purpose flood pump stations – the plant idle mode for single-purpose flood pump stations means that the facility is inactive and that flood control gates are positioned to convey wet weather flows directly to the Ohio River as a permitted CSO. This USACE prescribed mode of operation does not result in a dry weather overflow.
    - Dual-Purpose flood pump stations - the plant idle mode for dual-purpose flood pump stations means that all pumping at the facility has stopped, the flood pump stations have been isolated from the CSS and all flow is conveyed to the river during both dry and wet weather. During dry weather periods this USACE prescribed mode of operation results in a continuous dry weather overflow. During wet weather it results in a permitted CSO.
- **Minor Flood Mode** – this applies to single-purpose flood pump stations and indicates a mode of operation between plant idle and flood mode which requires the repositioning of selected flood control gates. The flood pumps are deactivated during this mode. There is the potential that the USACE prescribed mode of operation can result in a dry weather overflow.
- **Flood Mode** – this mode is different for the two types of flood pump stations and can be defined for each as follows:
    - Single-Purpose flood pump stations – the flood mode for single-purpose flood pump stations means that the flood pumps have been activated (energized) and are available to pump wet weather flows to the Ohio River as permitted CSOs and that all flood control gates are positioned to prevent the river from backing up into the CSS due to elevated river levels. This USACE prescribed mode of operation does not result in dry weather overflows.
    - Dual-Purpose flood pump stations - the flood mode for dual-purpose flood pump stations means that the flood pumps have been activated (energized) and are available to pump both wet and dry weather flows to the Ohio River and all flood control gates are positioned to prevent the river from backing up into the CSS due to elevated river levels. During dry weather periods this USACE prescribed mode of operation results in a continuous dry weather overflow. During wet weather it results in a permitted CSO.

Throughout the development of MSD's CSO Abatement Program, specific opportunities were identified where modifications in the original procedures outlined in the USACE's Ohio River Flood Protection System Pumping Operations Manual, dated 1954 and revised 1988 (USACE Manual) could be modified to reduce overflows from the CSS and still maintain the integrity of the level of flood protection provided by the system. During 2002, MSD modified operating parameters at three flood pump stations (4th Street Flood Pump Station, 34th Street Flood Pump Station and Paddy's Run Flood Pump Station) and respectively modified the USACE Manual upon approval from USACE. These modifications reduced the frequency and volume of CSOs at these locations.

The following flood pump stations within the CSS were evaluated to define specific physical and/or operational modifications necessary to ensure that the USACE prescribed modes of operation, as described above, do not result in dry weather overflows:

- 4th Street Flood Pump Station and 17 flood control gates
- 5th Street Flood Pump Station and 7 flood control gates
- 10th Street Flood Pump Station and 11 flood control gates
- 17th Street Flood Pump Station and 10 flood control gates
- 27th Street Flood Pump Station and 12 flood control gates
- 34th Street Flood Pump Station and 20 flood control gates
- Beargrass Creek Flood Pump Station and 13 flood control gates
- Paddy's Run Flood Pump Station, Sluice Gate Chamber, and 15 flood control gates
- Shawnee Flood Pump Station and 24 flood control gates
- Starkey Flood Pumping Station and 8 flood control gates
- Western Flood Pump Station and 25 flood control gates

Figure 2.3.1 at the end of the chapter provides a location map for the eleven flood pump stations evaluated.

Appendix 2.3.1 is a USACE Flood Pump Station Operation Modification Technical Memorandum which provides a detailed summary of the current operational modes of each of the considered flood pump stations and recommendations for operational and/or physical modifications. The results of the evaluation revealed that six of the flood pump stations require operational modifications and five require physical modifications to ensure that dry weather overflows do not result from mandated operational procedures as outlined in the USACE Manual. To implement the projects identified in the Technical Memorandum the following actions will need to taken:

- Develop plans and specifications for each of the identified projects.
- Prepare revisions to the USACE Manual that reflects the operational and physical modifications proposed by this Technical Memorandum.
- Secure review and approval by the USACE. Coordination with, and approval by the USACE will be required prior to any modifications being made to the congressionally authorized flood protection works for Louisville, Kentucky. A reasonable amount of time for USACE involvement has been included in the scheduled completion dates for the proposed projects. However, although it is not anticipated, delays in USACE approval and responses beyond these time estimates could impact scheduled completion dates.

2.4 DESCRIPTION OF SYSTEM/COMPILATION OF EXISTING DATA

The objective of the system characterization is to understand the complete CSS and receiving water to establish the existing baseline conditions. This section presents a detailed description of the physical characteristics of the CSS and receiving stream watersheds, as well as a description of the pipe network flow monitoring and CSS water quality sampling.

2.4.1 Overview of CSO System and Watershed/Sewershed Mapping

The sewer system owned, operated and maintained by MSD has evolved for almost a century and a half into an extensive network of both sanitary and combined sewers, diversion structures, mechanical regulators and other flow control devices, WQTCs, and pump stations. The expanse of the overall separate sanitary sewer service area and the limit of the older combined sewer area are exhibited in Figure 2.4.1 at the end of this chapter. The combined sewer area encompasses 24,000 acres (37 sq. miles) which is about one-third of the Morris Forman WQTC service area. MSD has subdivided the combined sewer area into three regions for study and evaluation purposes. A detailed description of the CSS within each region is provided in the following sections. See Figure 2.4.2 at the end of this chapter. As part of the green infrastructure analysis, MSD performed additional characterization of the entire combined system along with more detailed evaluations of each sewershed with active overflows.

An important element of this analysis was a detailed evaluation of the impervious area characteristics across the entire CSS. The goal of the exercise was to determine the distribution of impervious area, including roadways, rooftops, parking lots and sidewalks, in an effort to understand the major sources of stormwater runoff to the CSS.

This data was further analyzed to calculate the distribution of impervious areas within each of the following landuse classifications.

- Residential
- Commercial
- Industrial
- Parks/Open Space
- Vacant Land
- Public Space

Based on this evaluation, green infrastructure programs were developed targeting specific landuse types. For example, downspout disconnection, and rain barrel and rain garden programs focus on residential landuses. In addition, MSD evaluated each CSO sewershed with an active overflow for the following information:

- Total area of roadways
- Total area of rooftops
- Total area of miscellaneous transportation (parking lots and sidewalks)
- Area of public rooftops
- Area of public parking lots
- Number of catch basins
- Area of single family rooftops
- Number of single family homes
- Suitability for downspout disconnect

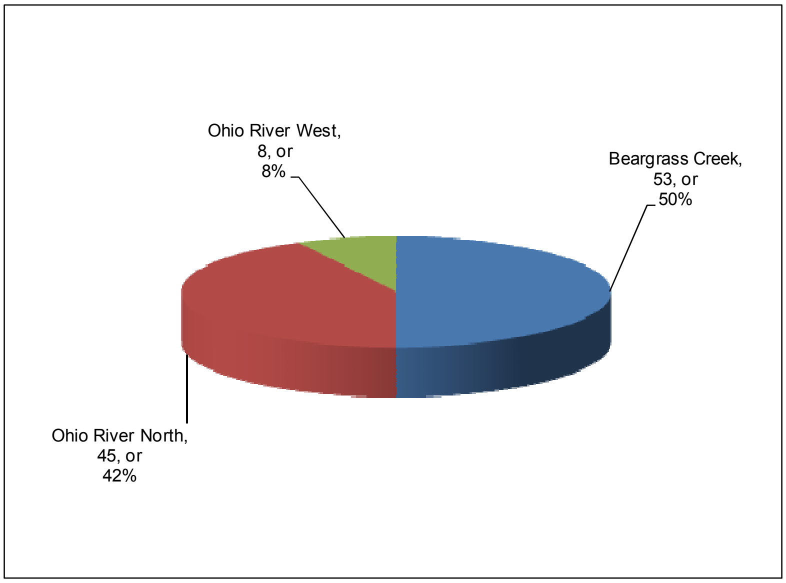
This higher level of characterization allows MSD to properly evaluate and select green infrastructure techniques for individual sewersheds as well as the entire CSS. For specific results and a more elaborate explanation of this characterization effort, please refer to Chapter 3, Section 2.1.4.

2.4.2 Collection System Understanding

In the CSS, DWFs are conveyed to the Morris Forman WQTC to remove pollutants before discharging to the Ohio River. During wet weather conditions, when capacity of the CSS is exceeded, the excess flow, a mixture of sewage and stormwater runoff, is discharged to the South Fork Beargrass Creek, Middle Fork Beargrass Creek, Muddy Fork Beargrass Creek, and the Ohio River. The typical system constrictions are presented schematically and graphically in Figures 2.4.3 through 2.4.6 at the end of this chapter. The CSS receives flows from upstream separate sewer areas at six major boundary locations. Approximately 45 percent of the total sanitary flow conveyed to the Morris Forman WQTC is contribution from the upstream separate sewer system.

There are 106 active CSOs within the MSD service area. Figure 2.4.7 presents the distribution of CSO locations within each major geographical area: Ohio River North, West and Beargrass Creek.

FIGURE 2.4.7 NUMBER OF CSOS PER REGION



A computer model was utilized to project the average annual hydraulic volume within the CSS. Figure 2.4.8 presents a summary of the Average Annual Overflow Volume (AAOV) by major geographical region, along with the percentage of the total CSO system volume by region. A comparison of the AAOV expressed as a percentage of the receiving stream flow to which the CSOs discharge is provided in Table 2.4.1.

FIGURE 2.4.8 VOLUME OF CSOS PER REGION

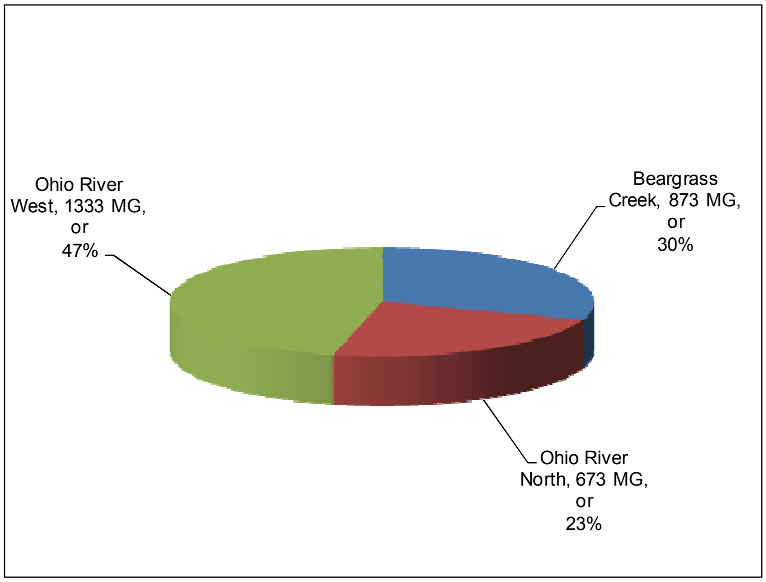


TABLE 2.4.1

CSO AAOV AS PERCENTAGE OF RECEIVING STREAM FLOW

CSO Region	Volume of Stream Flow MG/Yr	Volume of CSOs MG/Yr	CSO Volume as Percentage of Stream Flow
Beargrass Creek	27,989	873	3.119%
Ohio River North	65,838,307	637	0.001%
Ohio River West	65,838,307	1,333	0.002%
MG – million gallons			

To project annual hydraulic loads, the following information was used:

- Typical rainfall year information described in Chapter 2, Section 4.3
- Calibrated computer simulation model described in Chapter 2, Section 4.6.
- Three United States Geological Survey (USGS) Stream Flow gauges were used to estimate the volume of stream flow on Beargrass Creek and Ohio River: USGS 03292500 South Fork of Beargrass Creek at Louisville, USGS 03293000 Middle Fork of Beargrass Creek at Old Cannons Lane, and USGS 03294500 Ohio River at Louisville.

2.4.3 Rainfall Monitoring

Having accurate rainfall data is critical for proper CSS characterization, as well for performance monitoring of CSO controls that are in place. The EPA CSO Policy requires that the permittee evaluate flow variations in the receiving water body to correlate between CSOs and receiving water condition. This cannot be done without accurate rainfall monitoring.

2.4.3.1 Rainfall Monitoring History

MSD has been monitoring rainfall since 1991. The initial rain gauges were installed in 1991 as a joint effort between MSD and the USGS and the information was to be used for MSD studies and USGS research.

In 1997, MSD took over sole responsibility for the rain gauge network. Because the data logger type rain gauges were non-telemetered, MSD personnel was required to download the information stored within each of the rain gauges. Though labor intensive, these rain gauges worked extremely well.

The rain gauges recorded total rainfall in five-minute increments. Eight of these gauges were located within or adjacent to the combined sewer drainage area and the data from these gauges were used in the model calibration process. The locations of these eight gauges are listed in Table 2.4.2 and are shown in Figure 2.4.9 at the end of this chapter.

TABLE 2.4.2

ORIGINAL RAIN GAUGE LOCATIONS

RAIN GAUGE NO.	LOCATION
6	Seneca Golf Course along Bon Air Avenue
7	Louisville Water Tower at Zorn Avenue
9	Iroquois Golf Course along Taylor Boulevard
10	Morris Forman Treatment Plant along Algonquin Parkway
14	Standiford Field along Standiford Avenue
19	South Fork Beargrass Creek at Trevilian Way
20	USGS Office on Bradley Avenue
29	Downtown Louisville at MSD Headquarters, 6th & Cedar

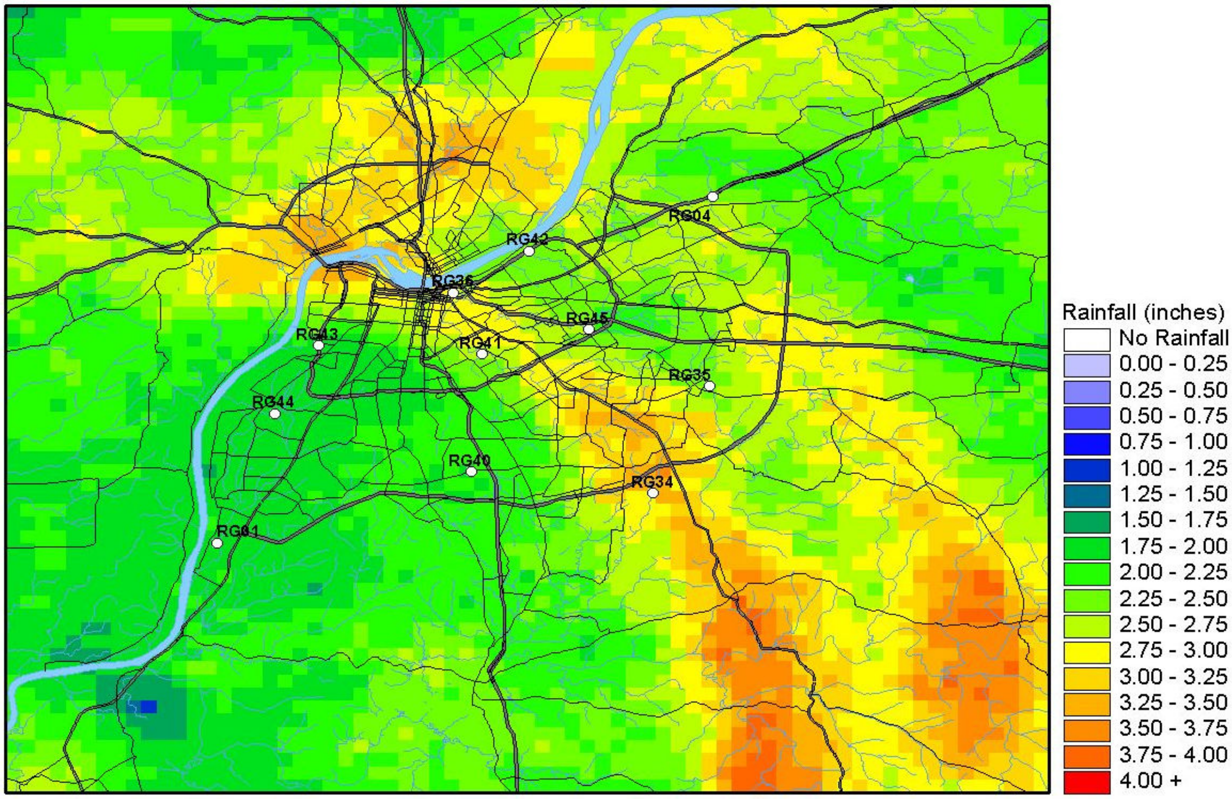
Source: 1993 Combined Sewer Operational Plan

In 1997, 11 telemetry-equipped rain gauges were installed. The primary purpose of these rain gauges was to provide real-time data for emergency response and engineering support. The majority of these rain gauges were installed at MSD facilities located throughout Jefferson County. For the purposes of emergency response support, the rain gauges performed adequately. However, with the implementation of the RTC project, these telemetry-equipped rain gauges did not meet the requirements of RTC because the geographic distribution and the telemetry system used at the time were deemed insufficient to provide the needed information in a timely manner. In order to meet the goals of the RTC project and to provide better emergency response support, the telemetry-equipped rain gauge system required modification.

In the Spring of 2003, 15 new telemetry-equipped rain gauges, replacing original 11 gauges were installed throughout Jefferson County. This updated rain gauge system serves two primary functions - to calibrate weather service Next-Generation Radar (NEXRAD) with rain gauge data, and to assist in providing accurate two-hour predictive rainfall data. Currently, this information is utilized by MSD's RTC project and for emergency response preparation. The new rain gauge network also provides a better geographical coverage of Louisville Metro as shown in Figure 2.4.10 at the end of this chapter.

The majority of the storms approaching Louisville Metro approach from the northwest. Therefore, MSD established three additional satellite-enabled rain gauges in the Southern Indiana counties of Harrison, Floyd, and Clark. These rain gauges provide MSD with the ability to better calibrate rainfall predictions based on storms approaching from the northwest. Since the RTC project requires a two-hour predictive capability, rain gauges located outside Jefferson County provide MSD with the data needed to make these predictions. Figure 2.4.11 is a graphical presentation of radar rainfall.

FIGURE 2.4.11 EXAMPLE OF RADAR RAINFALL



2.4.3.2 Basis of Typical Year Analysis

EPA's CSO Control Policy (1994) requires the effectiveness of CSO controls to be evaluated on a "system-wide, annual average basis." Identification of annual average rainfall conditions is a fundamental step in the LTCP process.

At the time of the initial model development (early 1990s), 31-years of rainfall records (1960 to 1991) were obtained from National Oceanographic and Atmospheric Administration (NOAA) as recorded at the National Weather Service (NWS) at Standiford Field. The rainfall records data was categorized by peak intensity, total rainfall, and duration.

Several approaches were available to analyze the performance of the CSS. Continuous simulation of long-term rainfall records was thought to provide more reliable predictions of overflow quantity on a regional basis than other methods considered at that time. However, due to limitations in computer processing time and data storage considerations that existed in the early 1990s, continuous simulation of an annual rainfall record was a significant limiting factor.

An alternate approach was developed which used detailed simulations for a number of discrete events. This approach allowed for generation of detailed model output (volumes, durations, peak rates) that would be useful for preliminary engineering planning, as well as data that would be useful for developing long-term overflow statistics. This approach was used in the initial stages of the project to estimate AAOVs.

A series of reference storms of varying return frequency were extracted from the NWS 31-year rainfall record based on a statistical analysis of key parameters in the rainfall record (total precipitation, intensity, duration). Ten actual historical storms were simulated using the sewer system model, and overflow volumes for each CSO and runoff volume for each drainage catchment were obtained. A mathematical regression of the data points provided predictive equations for overflow volume and runoff based on total rainfall for each storm in the historical record. The predicted volumes for all storms over the years provided an estimate of the AAOV for each CSO.

The combination of improvements in computer hardware technology and improvements in the model software since the early 1990s made continuous model simulation over long periods significantly more feasible. One of the many benefits from continuous simulation was that this technique automatically accounted for intermittent dry periods between rain events and for consecutive, closely spaced events. In 2004, MSD changed its method of calculating AAOV from a reference storm approach to a typical rainfall year approach using continuous model simulation. The analysis methodology currently being used is described in further detail in the following paragraphs.

A statistical analysis of a 54-year historical rainfall record (1948-2002) at KY4954 - Louisville Standiford Field gauge, was performed for the Jefferson County region in 2003 and updated in early 2008. The characteristics of a typical yearly rainfall that could be used for continuous simulation to obtain estimates of AAOV were determined. Individual rain events were sorted and ranked according to six characteristics: number of events, total precipitation, average intensity, maximum intensity, duration, and antecedent dry period.

Two different methods were used to determine the typical year. One method was to determine the typical year by selection of an entire historical year that most closely matched the average rainfall characteristic values from 54 years of record. Each individual year was compared to the average values for the six statistics noted above, and the year having values closest to the means was selected as the typical year. From this method, historical year 2001 was selected as the historical typical year.

Another method of establishing a typical year was also examined. This method consisted of "building" a year comprised of 12 individual months, wherein each month was extracted from the historical database based on matching the average characteristics on a monthly basis rather than an annual basis. The details of this analysis were provided in a Technical Memorandum in March 2008 Appendix 2.4.1 includes the Rainfall Selection Analysis Technical Memorandum with a full description of the methodology applied.

The overall 55-year mean for each of the six storm statistics, along with the mean statistics for 2001 and the monthly synthetic year as described above are presented below in Table 2.4.3.

TABLE 2.4.3

OVERALL MEAN FOR 2001 AND A SYNTHETIC YEAR

Parameter	Overall Mean 1948 - 2002	Year 2001	Synthetic Year
Number of Events	92	91	91
Total Duration, Hours	530	516	568
Total Depth, Inches	41.25	42.83	40.84
Maximum Storm Average 60-Minute Intensity, Inch/Hour	1.19	0.83	0.84
Average Storm Intensity, Inch/Hour	0.08	0.08	0.07
Time From Last Event, Hours	92	91	89

Sewer system model simulations were conducted for both the typical years selected using each methodology described above. Ultimately, application of the 2001 historical precipitation event sequence was selected as the more appropriate method to use in evaluating CSO control alternatives for the following reasons:

- Represented a typical year of precipitation characteristics reasonably well, although not quite as well as a synthetic year might
- The receiving water models used for the Water Quality Tool (WQT) and Ohio River water quality impact analyses used the rainfall history and stream flow data from the same time, year 2001.
- Sewer system modeling required to establish baseline CSO loadings, size CSO control alternatives and evaluate their performance also utilized the 2001 rainfall year to:
    - Maintain consistency between the CSO load projections and water quality impact analyses
    - Maximize use of available overall system configuration and operating data for assessment of results
    - Avoid potential confusion with regulatory agencies, stakeholders and the public that could arise by applying different precipitation records over different timeframes in the analyses.

2.4.4 Flow Monitoring

Monitoring programs for CSO control planning serve many objectives, including those listed in the CSO Guidance for LTCPs (EPA, September 1995):

- Define the CSSs hydraulic response to rainfall
- Determine CSO flows and pollutant concentrations/loadings
- Evaluate the impacts of CSOs on receiving water quality
- Support the review and revision of water quality standards
- Support implementation and documentation of the NMC
- Support the evaluation and selection of long-term CSO controls
- Gain a thorough understanding of the CSS
- Adequately characterize the CSS response to wet weather events, such as the number, location, and frequency of the CSOs and the volume, concentration and mass of pollutants discharged
- Support a mathematical model to characterize the CSS
- Support the development of appropriate measures to implement the NMC
- Support LTCP development
- Evaluate the expected effectiveness of the NMCs and, if necessary, the long-term CSO controls

Achievement of these objectives requires both monitoring for flows and sampling for water quality characteristics. Flow monitoring in the combined sewer service area, including CSOs, is commonly used to refine understanding of the system and to calibrate and verify models used to evaluate impacts of potential CSO control alternatives. Water quality sampling in the CSS, including CSOs, is commonly used to characterize the contents of the combined sewer over flows, identify “hot spots” of higher strength sewage, and characterize the quality of CSO discharges.

The combination of flow monitoring and sampling is used to characterize pollutant loadings from CSOs into the receiving waters. Sampling in the receiving waters is used to evaluate impacts from CSOs relative to other pollutant loadings in the receiving waters and to calibrate and verify models for evaluation of alternative loading scenarios.

MSD flow monitoring includes data from receiving water flow monitoring stations operated by USGS, data from long-term sewer flow monitoring stations, and data from several study-specific short term flow monitoring locations. The locations of the long-term sewer system and receiving water monitoring stations are located in the September 15, 2006, submittal of the NMC Compliance Report.

The sewer system flow monitoring data was coupled with episodic CSO flow monitoring to calibrate and verify models that both expand the characterization of CSOs and allow evaluation of the effectiveness of CSO control alternatives. Table 2.4.4 describes the locations of long-term CSO flow monitors.

TABLE 2.4.4

SUMMARY OF 22 LONG-TERM SEWER FLOW MONITORS

CSO No	Sites	Description	Receiving Water	Installation Date
127	Etley Avenue	Etley Avenue	MF BGC	Jun-05
140	Locust Street	Locust Street	MF BGC	Jun-05
166	Lexington Rd @ I-64 Over Pass	Beals Branch Sanitary Diversion	MF BGC	Dec-06
206	Cherokee Park	Cherokee Park @ Spring Dr	MF BGC	Jun-05
125	Grinstead Dr & I-64 near entrance ramp	REG NO 24 - Grinstead Dr	MF BGC	Nov-07
132	Brownsboro Rd @ Storage Co.	REG NO 35 - Brownsboro Rd.	Muddy Fork BGC	Dec-06
019	34th Street & Rudd	34th Street Pump Station	Ohio River	May-05
105	Broadway & Western Pkwy	Western Outfall @ Broadway	Ohio River	Dec-06
189	Shawnee Park Pump Station	Northwestern Sanitary Diversion	Ohio River	Apr-06
190	Northwestern Pkwy	Seventeenth St Sanitary Diversion	Ohio River	Jul-06
191	Bells Lane	Southwestern Pump Station	Ohio River	Jul-06
210	Whayne Supply @ Diversion Structure	45th Street-Greenwood	Ohio River	Jul-06
211	Whayne Supply @ Diversion Structure	Main Diversion Structure	Ohio River	Jul-05
108	Newburg Road	REG No 1 - Newburg	SF BGC	Jun-05
117	Dry Run Sewer @ Beargrass Creek	REG No 11 - Dry Run	SF BGC	Jun-05
118	Broadway & Beargrass Creek	REG No 15 - East Broadway	SF BGC	Jul-06
151	Castlewood Avenue	REG No 5 - Castlewood	SF BGC	Jun-05
152	Ruffer Avenue	REG No 7 - Southeastern	SF BGC	Jun-05
182	Shelby & Burnett Street	SBR Shelby & Burnett	SF BGC	Jul-06
146	Swan Street South Fork of BGC	Sneads Branch Diversion	SF BGC	Mar-08
88	Brownsboro Rd @ Beargrass FPS	Mellwood Avenue Interceptor	SF BGC	Jun-06
110	Eastern Parkway	REG No. 3-Gross Avenue	SF BGC	Jul-05

It is not feasible to monitor flows at some CSO locations directly; hence, hydraulic models are commonly calibrated and applied to estimate the frequency and volume of overflows from inaccessible or hydraulically complex CSO locations. The models use proven engineering principles, primarily hydrologic calculations, conservation of mass and conservation of energy, to estimate flows at unmonitored locations. In addition, the accuracy of flow monitors is highly dependent upon the ability to calibrate and verify the installed monitor for the range of flow conditions. It is impossible to calibrate or verify monitors for peak flow conditions in the field; hence, monitored flow data during CSOs is far less accurate than monitored data for non-overflow conditions. Hydraulic models are proven by testing them against measured conditions at the monitored locations during non-surcharged (non-peak) flow conditions when data are most reliable, then by comparing them to the less accurate data collected during peak flow conditions.

MSD performed flow monitoring specifically to calibrate the model during the years 1993, 2002, and 2007. The work done in 1993 was to provide data for the initial calibration of the model. In 2002 and 2007, flow monitoring was performed to re-calibrate the model. A discussion of the results of the flow monitoring and sampling programs is described later in this Chapter under the respective discussions of the Beargrass Creek regional facilities and the Ohio River regional facilities.

MSD maintains the long-term flow monitors to observe flow rates and to monitor changing system conditions in its systems. MSD operates six permanent, hard-wired monitors, four in the combined sewer area, and two in the west county area. The permanent monitors are integrated into the RTC systems. The monitors in the combined sewer area provide a strong base for quantifying the flows in the CSS and for calibrating hydraulic models of the combined sewer area. MSD deploys temporary monitors when necessary to further refine or confirm the understanding of the flows in the CSS. MSD will also deploy several simpler devices (floats, chalk lines) and post-storm inspections to confirm the frequency of CSOs.

MSD resolved to monitor all CSOs which have an estimated overflow exceeding 10 MG AAOV as predicted by the XP-SWMM model. MSD remains committed to monitoring flows from these sites where feasible. MSD will re-evaluate the CSOs which have overflows exceeding 10 MG AAOV, using InfoWorks CS model and develop a plan to monitor these locations.

2.4.4.1 Flow Monitoring – 1992 Program

During the original development of the CSS model, flow monitoring was conducted in two phases due to the large combined sewer area and complexity of the system. For Phase I, the installation of the flow meters began in late November and early December 1991. By the first week of January 1992, 23 flow meters were installed at various locations in the central and western part of Louisville Metro and in the area around the Robert J. Starkey Pumping Plant, formerly known as the Buchanan Street Pump Station. The 24th flow meter was installed on the Northwestern Sanitary Trunk Sewer during the third week of January. The flow meter locations for Phase I are shown on Figure 2.4.12 at the end of this chapter.

Phase II of the flow monitoring program commenced in April 1992. For this phase, 17 of the 24 flow meters from Phase I were relocated from the western and central portions of the combined sewer area to the basins of the Middle and South Forks of Beargrass Creek. The flow meter locations for the Phase II flow monitoring are shown on Figure 2.4.13 at the end of this chapter.

This particular flow monitoring effort officially ended on June 20, 1992. Nine different storm events were chosen from the information obtained by the rain gauges and flow monitors during Phase I, and four different storm events were chosen from data recorded during Phase II for calibration purposes. A separate report, titled "Report on Combined Sewer System Flow Monitoring" (Tenney Pavoni Associates Inc., 1993) details the flow monitoring conducted on the CSS.

2.4.4.2 Flow Monitoring – 2002 Program

During the year 2002, additional flow monitoring of the CSS was performed as a part of the model maintenance activity. A total of 19 flow meters were installed for the monitoring period of January 29, 2002, to April 11, 2002. Upon completion of this monitoring period, data from the flow monitors were analyzed to establish baseline flow(s) for DWFs characteristics in each basin. Additionally, wet weather and DWFs analyses were performed and the information was utilized to update the original model calibration. During the year 2002 monitoring period, five significant storm events (that is, rain events exceeding 0.5 inches) occurred. For calibration, the fourth and fifth events were selected for simulation. The fourth storm event, March 19, and the fifth storm event, March 25, recorded totals of 2.9 inches and 2.8 inches of rainfall, respectively. Figure 2.4.14 at the end of this chapter shows the flow meter sites. A separate report, titled "Flow Monitoring Report" (GRW Engineers Inc., 2002) details the flow monitoring conducted on the CSS.

2.4.4.3 Flow Monitoring – 2007 Program

During the year 2007, additional flow monitoring of MSD's system was performed to support hydraulic modeling. Approximately 145 flow monitors were temporarily installed by a contractor beginning in January 2007 through mid June 2007 throughout the MSD service area. Of the 145 monitors, 25 monitors were located within the CSS area. Upon completion of this monitoring period, data from the flow monitors were analyzed to establish baseline flow(s) and diurnal patterns for each basin. The flow monitor sites within the CSS area are exhibited in Figure 2.4.15 at the end of this chapter.

2.4.4.4 Upcoming Flow Monitoring Efforts

MSD is in the process of finalizing a permanent flow monitoring program. According to the "Combined Sewer Overflows - Guidance for Monitoring and Modeling" (EPA, 1999) document, a CSS monitoring program will support in-depth system characterization and post-construction compliance monitoring that are central elements in the LTCP.

MSD currently has various permanent sewer flow monitors in place throughout the Louisville Metro area and is proposing additional permanent sewer flow monitors. Temporary flow monitors will supplement permanent flow monitors in key areas of the sewer system at a minimum of every two years to assist in monitoring the IOAP capital projects. The temporary monitors will be placed in areas affected by capital construction, green infrastructure, and sewer rehabilitation. MSD will supplement permanent flow monitor data to express a more accurate portrayal of the effectiveness of the projects and the data collected will support the recalibration of the hydraulic and water quality models. Figure 2.4.16, at the end of this chapter, exhibits the locations of the permanent flow monitors currently installed. Refer to IOAP Volume 1 Chapter 6 titled “Post Construction Compliance Monitoring” for more details.

2.4.5 CSO Water Quality Characteristics

Monitoring data available for CSO characterization and planning includes both monitoring for flows and sampling for water quality characteristics. Section 10.4 of the NMC Compliance Report (MSD, September 15, 2006) provides a summary of past flow monitoring and sampling activities, while the Post Construction Compliance Monitoring Plan addresses ongoing monitoring, sampling and modeling activities in Volume 1 Chapter 6.5 of the IOAP.

The environmental data collected through stream and sewer monitoring as well as grab samples during dry and wet weather are analyzed every two years in a synthesis report. MSD published its most recent report in December 2007 in cooperation with the University of Louisville. The report assesses to some degree, the full set of environmental data collected within MSD’s long term monitoring network, identify correlations between data sets and associate probable water quality, stream health, and habitat impacts. The report also provides recommendations for improvements in data collection and quality control. The first report, published in 1999, provided recommendations to establish MSD’s current monitoring network and MSD continues to implement additional recommendations from this and the 2007 report to improve data quality. The next synopsis report, which will further this analysis, will be completed in December 2009.

While the majority of the collected data sets shows high variability, this aspect is characteristic of most other long term monitoring efforts for complex, highly urbanized watersheds. The variability does not indicate that the data is unreliable, only that system model calibration efforts and outputs must be reviewed cautiously and that solutions to improve water quality should be applied conservatively.

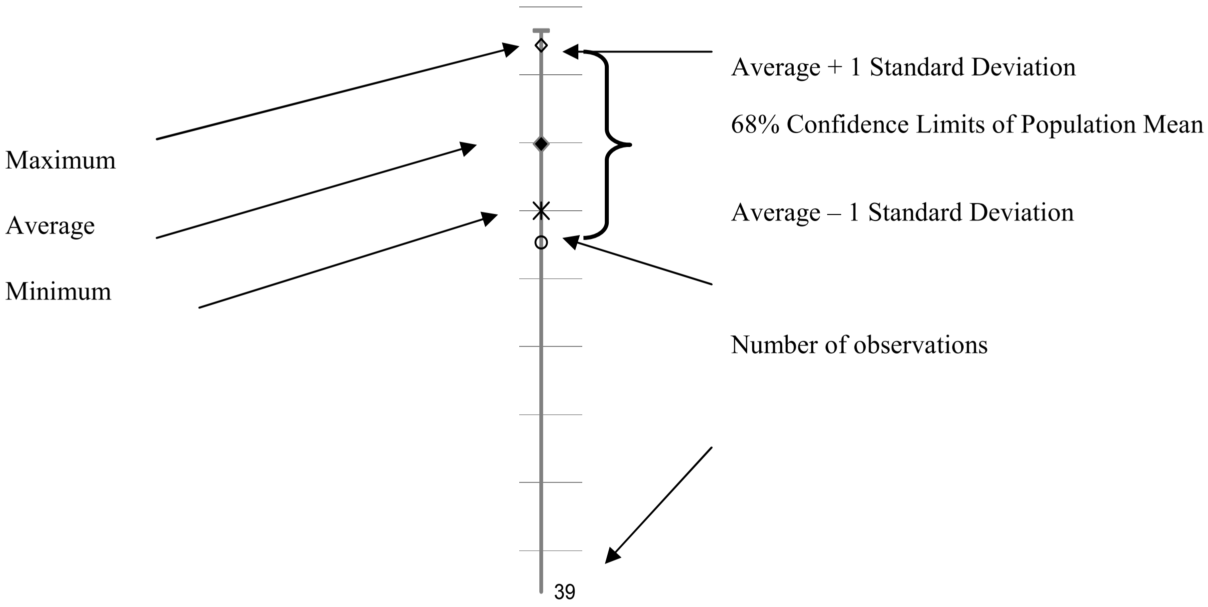
2.4.5.1 CSS Sampling of CSOs

Past sampling of CSOs in MSD sewers yielded a multitude of observations of numerous distinct analyzes. The full range of analyzes and their observations are listed in a Technical Memorandum titled Interim CSO LTCP Addendum in November 2006. Figure 2.4.17, at the end of this chapter, shows the location of the CSO and CSS sites monitored to-date within the MSD system.

Most samples were collected by automated samplers using consistent sampling protocols that included more frequent sampling early in a storm, tapering off to less frequent through the remainder of the first three hours of the storm. This sampling protocol is biased toward the early “first flush” portion of the overflow hydrograph. Site storm samples were composited on a flow proportional basis prior to analysis; thus, each data point approximates an event mean concentration for that particular storm and event.

Table 2.4.5 at the end of chapter, summarizes the data collected to-date in the CSOs for TSS, biochemical oxygen demand, and fecal coliform. As previously noted, the samples show a variability that is characteristic of environmental sampling, and even more prevalent in wet weather sampling. The standard deviation of the observations is the selected measure of the variability. If the data are normally distributed, one can be 68 percent confident that the average of the population is within one standard deviation of the average calculated from the observations. The significance of multiple observations at one site is commonly graphed as explained in Figure 2.4.18.

FIGURE 2.4.18 VARIABILITY CHART



Statistically, the population mean is somewhere within the confidence limits. Any value within those limits is not statistically different from the sample average. TSS, biochemical oxygen demand, and fecal coliform data are summarized here because of the perceived significance to CSO LTCP planning. TSS are summarized because it is commonly of interest in wastewater impact evaluations and is used as a surrogate for pollutants known to ‘attach’ to sediments. Biochemical oxygen demand is summarized because it is commonly of interest in wastewater impact evaluations and because it is related to dissolved oxygen, one of the two parameters cited by Kentucky Department of Environmental Protection (KDEP) as out of compliance in the receiving waters. Fecal coliform is summarized because it is commonly of interest in wastewater impact evaluations and because it is cited by KDEP as “out of compliance” in the receiving waters.

Figure 2.4.19 illustrates that the TSS data in the CSOs show a high degree of variability. With the degree of variability evidenced, it is not possible to conclude that any site has a total suspended solids (TSS) concentration that is significantly different from any other site. CSO019 shows some evidence of a higher concentration, but with only six observations, it shows only weak evidence of a higher TSS concentration. Given the inherent variability evidenced in the data, it is unlikely that more samples would result in concentrations that show significant variation between the sites. All of the sites with more than six observations have data consistent with a mean event concentration of 200 million gallons per liter (mg/l) TSS. That is to say, 200 mg/l TSS is within one standard deviation of the mean for all sites with multiple observations.

FIGURE 2.4.19 SUMMARY OF CSO WATER QUALITY DATA FOR TOTAL SUSPENDED SOLIDS

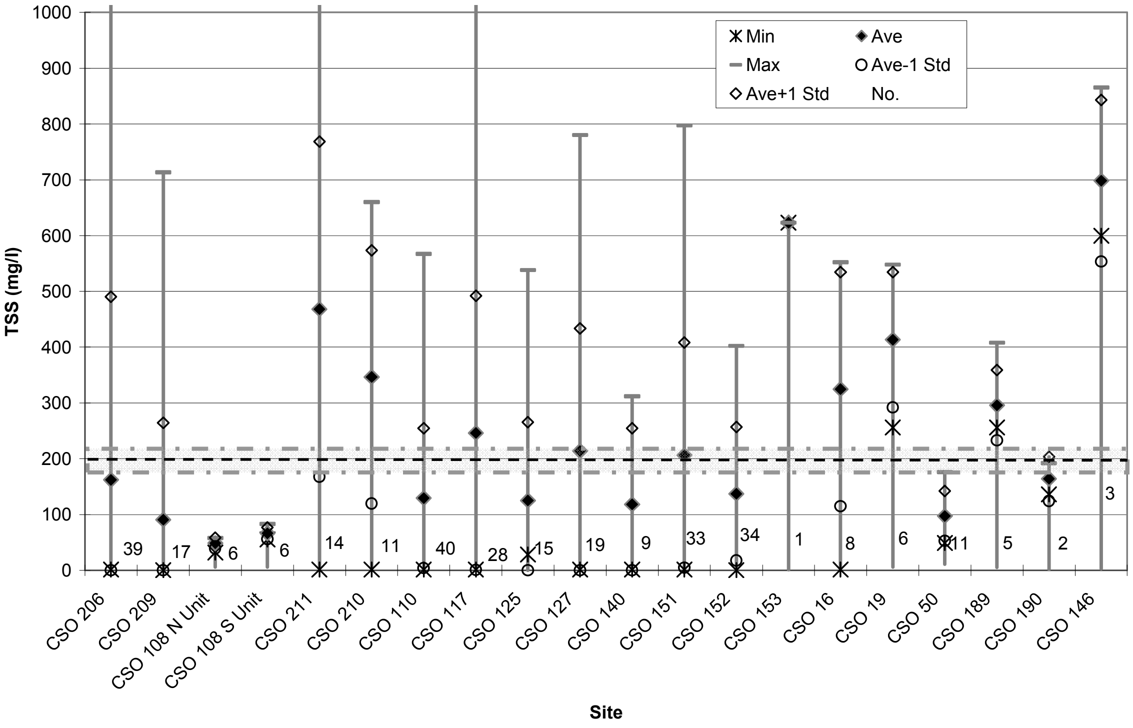


Figure 2.4.20 illustrates that the biochemical oxygen demand data in the CSO samples show a high degree of variability as well. With the degree of variability evidenced, it is not possible to conclude that any site has a biochemical oxygen demand concentration that is significantly different from any other site. There is no statistically significant difference between sites draining highly commercialized or industrialized zones. Given the inherent variability evidenced in the data, it is unlikely that more samples would result in concentrations that show significant variation between the sites. Most of the sites, particularly those with more than six observations, are consistent with a mean event concentration of 75 mg/l biochemical oxygen demand. That is to say, 75 mg/l biochemical oxygen demand is within one standard deviation of the average for the sites. The exceptions would indicate that some sites (for example, CSO 140) might have lower average concentrations.

FIGURE 2.4.20 SUMMARY OF CSO WATER QUALITY DATA

FOR BIOCHEMICAL OXYGEN DEMAND

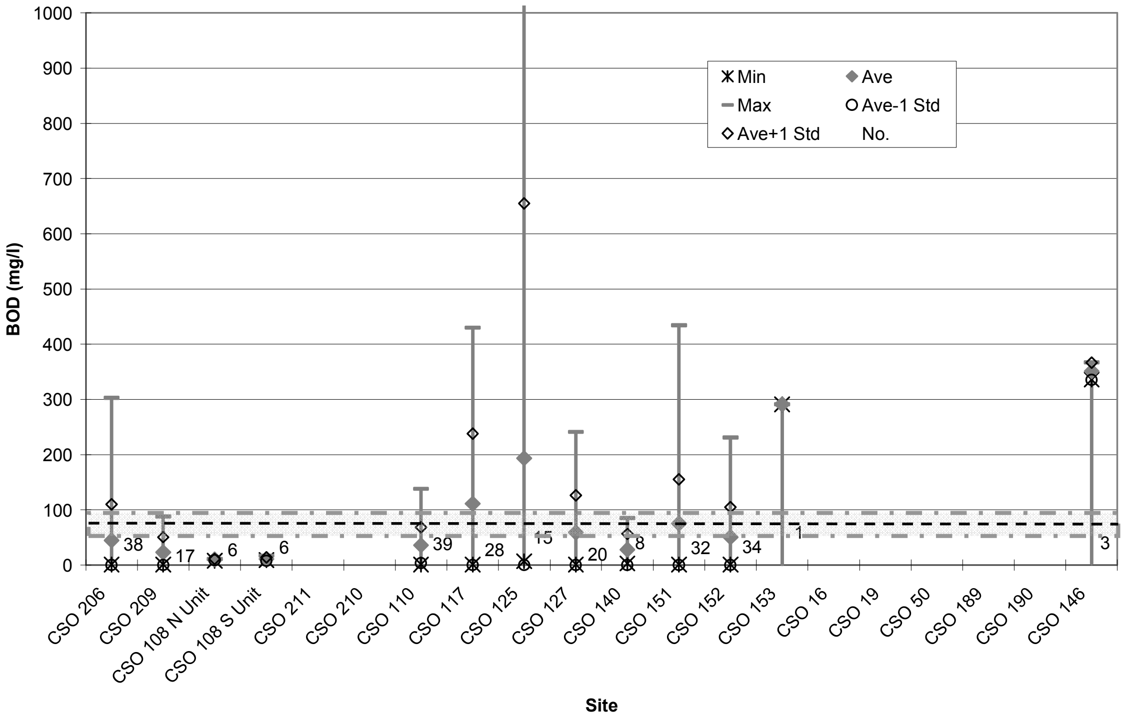
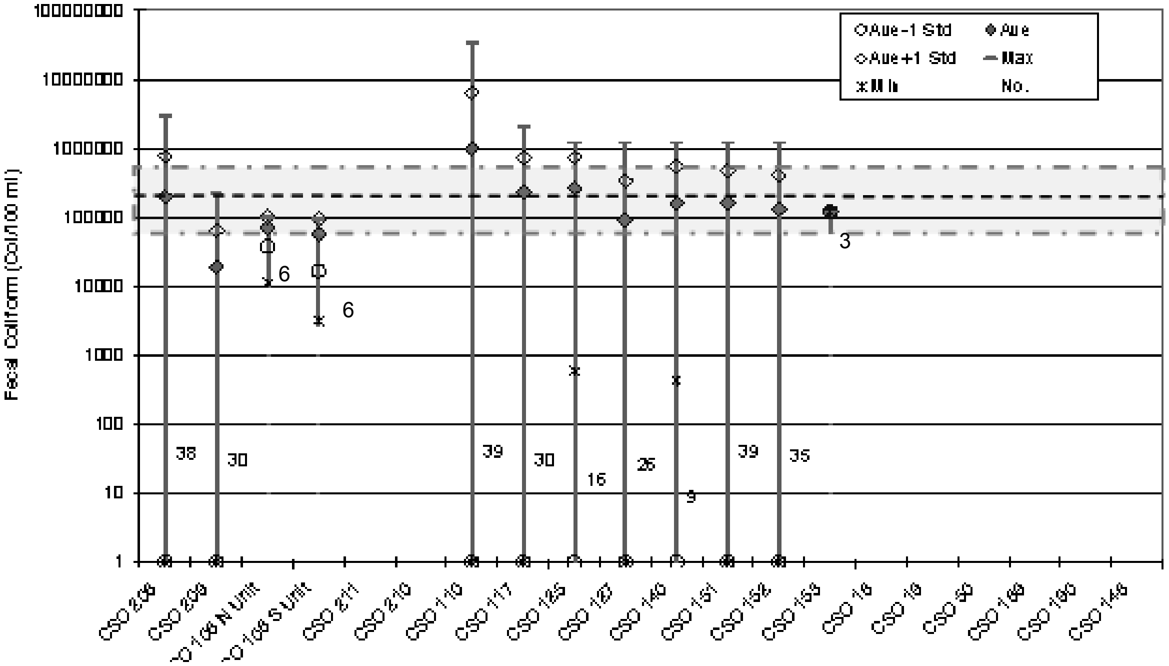


Figure 2.4.21 illustrates that the fecal coliform data in the CSO samples show a higher degree of variability. Measurement of fecal coliform is itself imprecise, with expectations that duplicate measurements from one sample will often vary by an order of magnitude. Consequently, variations less than an order of magnitude are arguably insignificant. With the degree of variability evidenced in the CSOs, it is not possible to conclude that any site has a fecal coliform concentration that is significantly different from any other site. There is no distinguishable difference between sites draining highly commercialized or industrialized zones. Given the inherent variability evidenced in the data, it is unlikely that more samples would result in concentrations that show significant variation between the sites. All of the sites have observations consistent with an event mean concentration of 250,000 col/100 ml fecal coliform. That is to say, 250,000 col/100 ml fecal coliform is within one standard deviation of the mean for all sites.

FIGURE 2.4.21 SUMMARY OF CSO WATER QUALITY DATA FOR FECAL COLIFORM

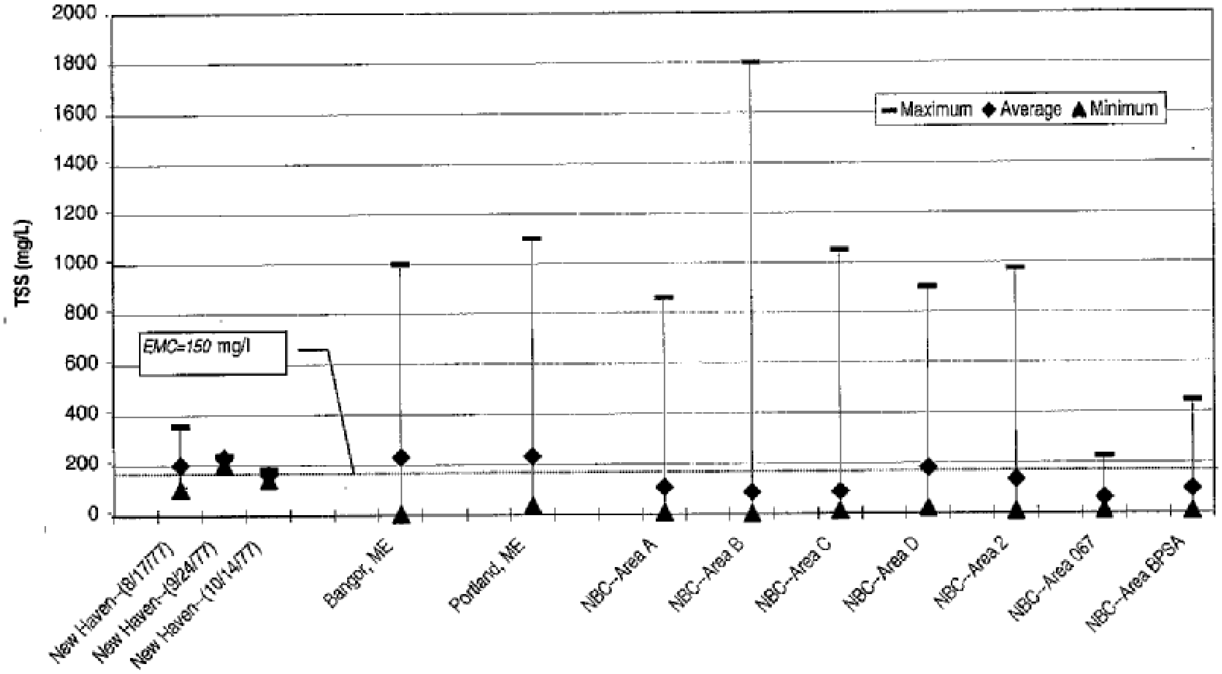


The extreme variability shown in the data is expected. Indeed, CSO long-term control planning in several municipalities (Bangor ME, Portland ME, New Haven CT, Narragansett Bay Commission RI, Milwaukee WI, and Atlanta GA) have observed similar variations and an inability to distinguish CSO concentrations from different landuse areas. For example, Figure 2.4.22 shows TSS data from 12 New England sampling sites where all were deemed consistent with as single event mean concentration of 150 mg/l.

For purposes of analyzing loadings from CSOs, the mean concentrations cited above have been used for all CSO sites and all storm conditions. The data, and the precedents set in numerous other CSO planning studies, do not support varying the concentration estimates by site characteristics or by storm characteristics. That is not to say that variations do not exist. Even though the data do not show statistically valid higher concentrations for more urbanized sites, it is commonly assumed that more urbanized sites have a higher risk of spills of highly contaminated materials. Consequently, CSOs from highly urbanized sites may be prioritized for control independent of sampling data that demonstrate a higher strength discharge.

FIGURE 2.4.22 SUMMARY OF CSO WATER QUALITY DATA

FOR MULTIPLE NEW ENGLAND SITES



2.4.5.2 CSS Sampling of Non-CSOs

Data for the non-CSO sites within the MSD combined sewer service were summarized in Technical Memorandum titled Interim CSO LTCP Addendums. These data, too, show a high variability. The ranges of TSS, biochemical oxygen demand and fecal coliform data observed in the non-CSO CSS samples are charted in Figures 2.4.23, 2.4.24 and 2.4.25, respectively. The non-CSO CSS data are often higher than the means (dashed lines) used for the CSO data. The non-CSO CSS data include primarily observations during dry weather conditions that are far different from the conditions prevailing when the CSOs can be sampled. The non-CSO CSS samples, however, provide observations of the constituents that potentially could flush into the CSOs.

MSD continues to scrutinize the non-CSO sampling data to identify impacts, if any, from significant industrial dischargers or other non-domestic dischargers of concern that have been issued general discharge permits. The grab sample concentrations at these sites are highly variable and water quality modeling using continuous simulations was used to estimate the systematic impact of the proposed CSO control plan. Due to the sample variability, any particular grab sample or set of samples for one parameter is not reliable for direct application of a CSO control. The best available water quantity and quality models calibrated using the full environmental data set is relied upon for overflow control assessment. The additional data tables and possible uses of the data are described in Appendix 2.4.9 Non-CSO Sewer Sampling Data Characterization.

FIGURE 2.4.23 SUMMARY OF NON-CSO CSS WATER QUALITY DATA FOR TOTAL SUSPENDED SOLIDS (TSS)

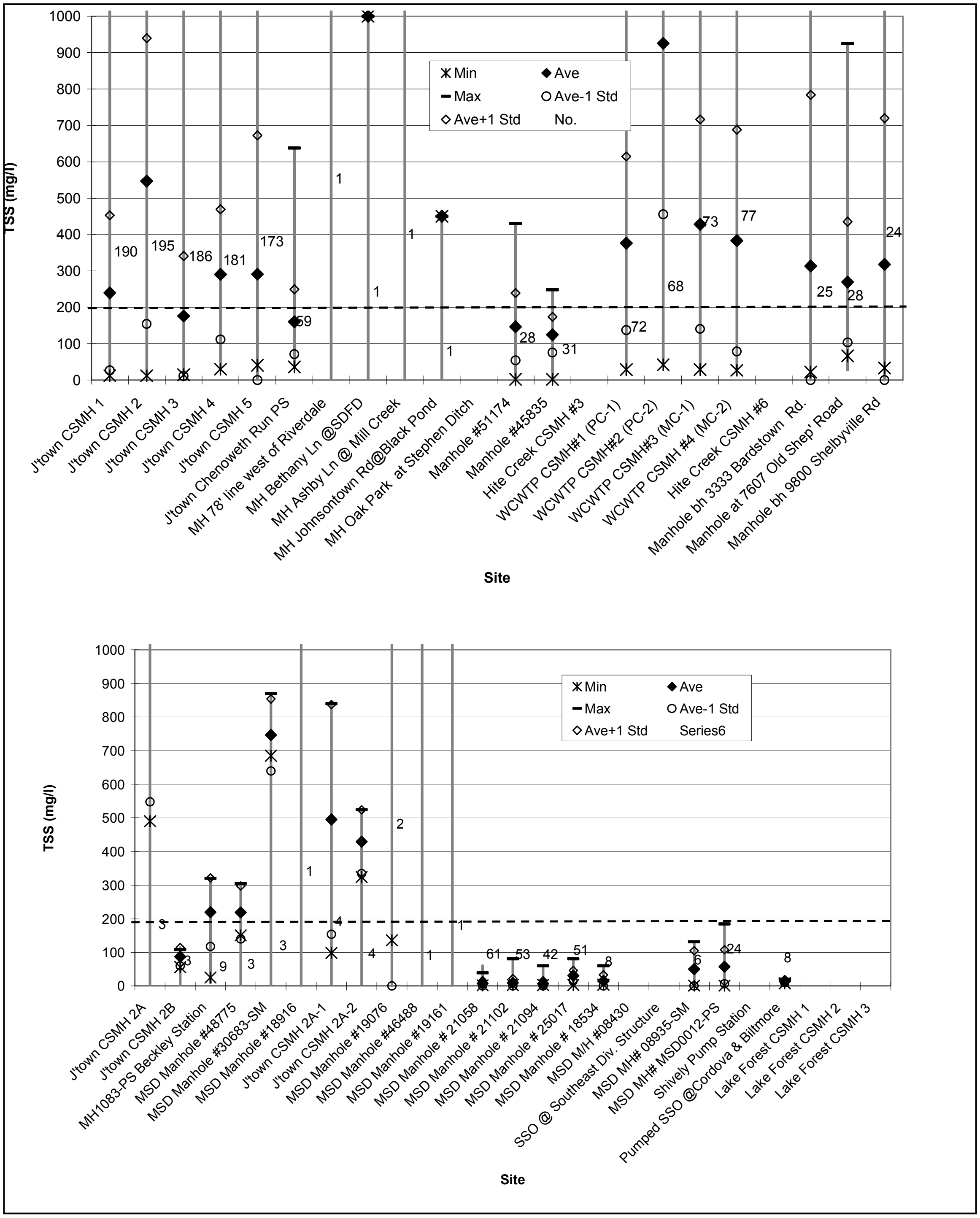


FIGURE 2.4.24 SUMMARY OF NON-CSO CSS WATER QUALITY DATA FOR BIOCHEMICAL OXYGEN DEMAND (BOD)

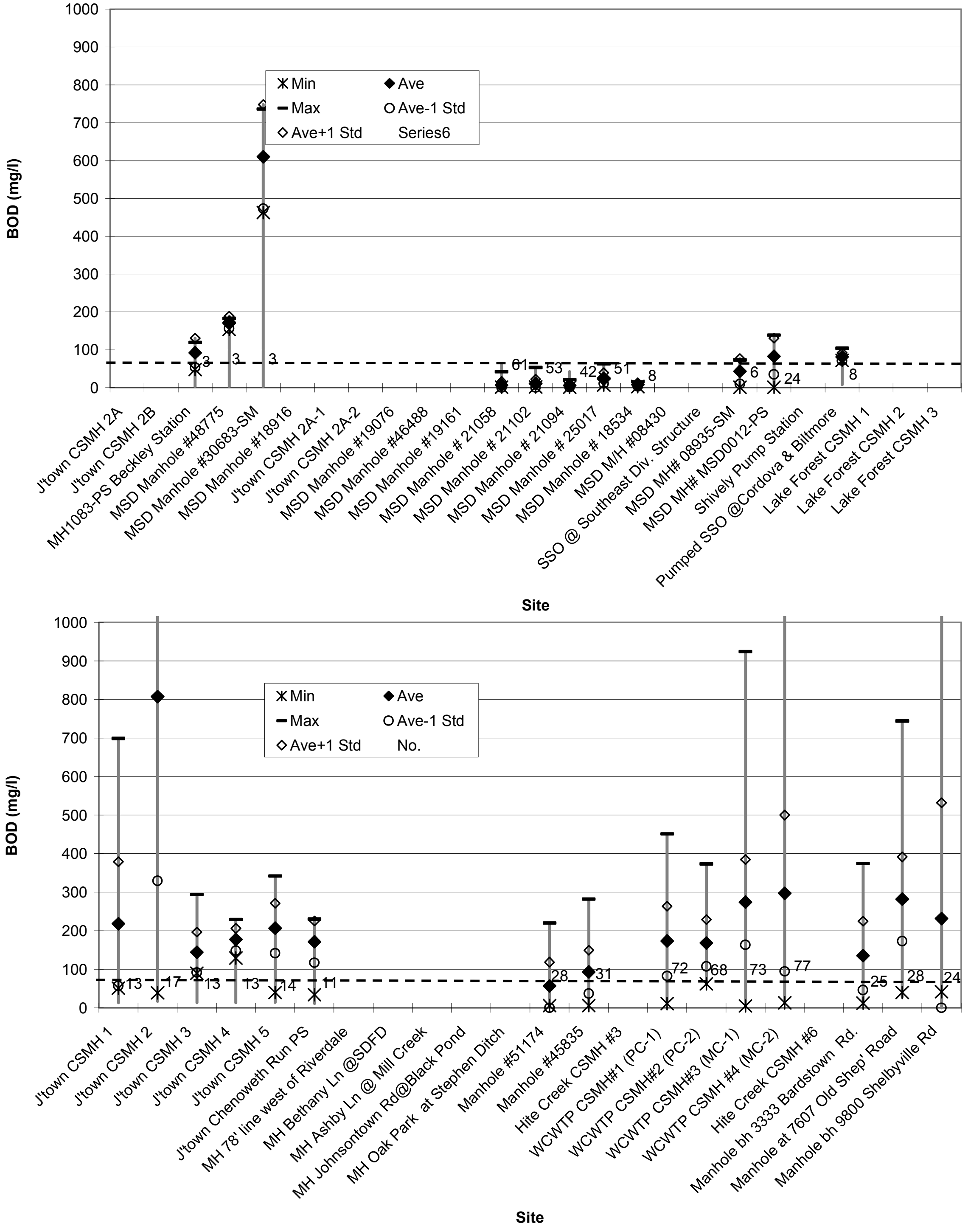
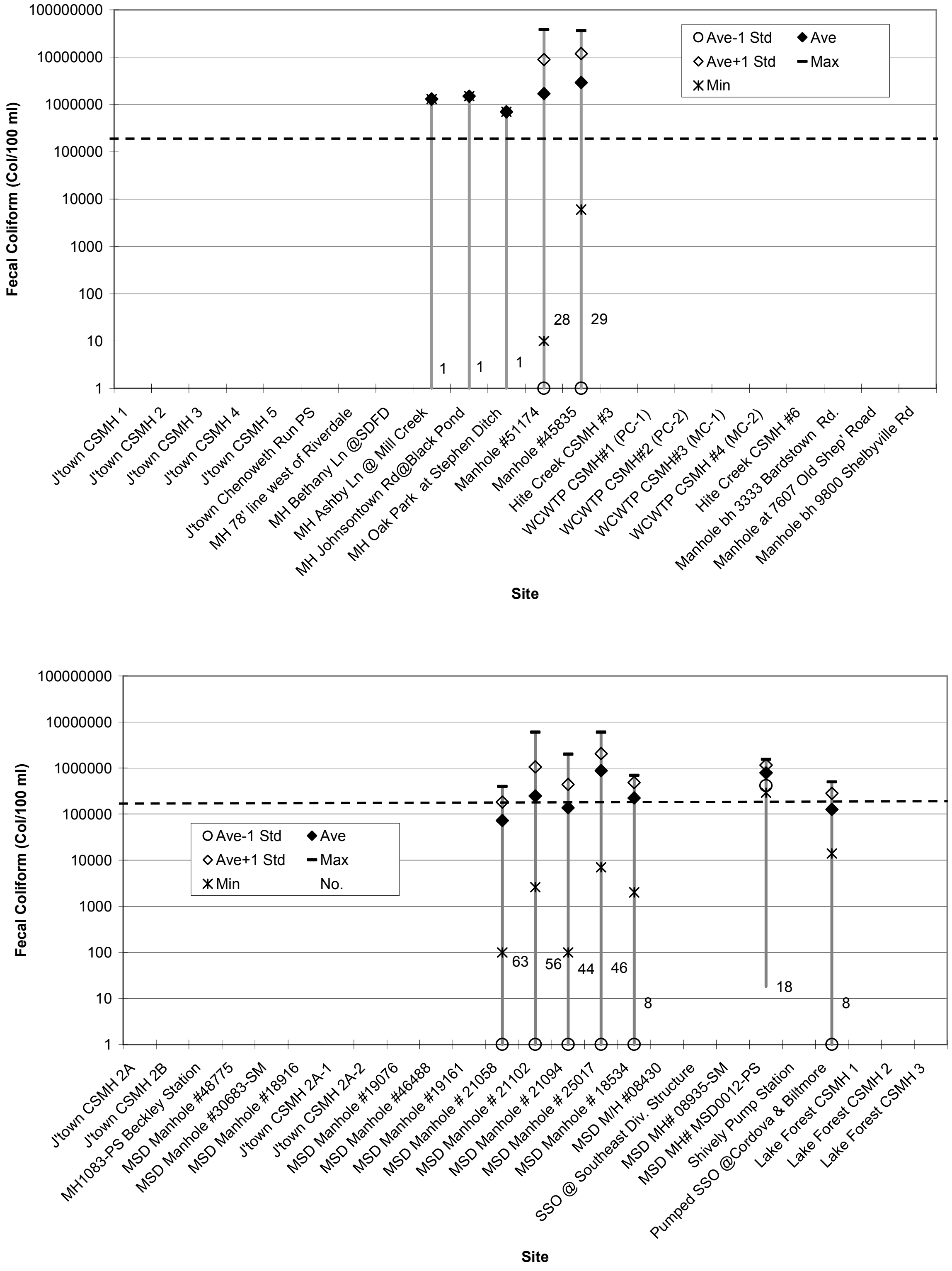


FIGURE 2.4.25 SUMMARY OF NON-CSO CSS WATER QUALITY DATA FOR FECAL COLIFORM



2.4.6 Combined Sewer System Modeling

The CSO Control Policy describes modeling as a valuable tool for characterizing a CSS. EPA supports the proper and effective use of models. The sophistication of the model should relate to the complexity of the system to be modeled.

2.4.6.1 CSS Modeling Objectives

The development and calibration of the MSD CSS model was a part of early efforts associated with the CSO Abatement Program. The major objectives of the initial model development were to:

- Comply with CSO Policy Requirements
- Estimate CSO hydraulic and pollutant loads
- Assist in identifying the location of significant CSOs
- Assist in evaluating and prioritizing corrective actions

2.4.6.2 CSS Model Selection

The CSS model was originally developed in EPA Storm Water Management Model (SWMM) versions 4.05 and 4.3 as part of early efforts associated with the CSO Abatement Program in early 1990s. The selection of the hydraulic model for initial CSS model was based on the complexity and size of the MSD collection and conveyance system and the SWMM's ability to simulate full hydrodynamic equations. SWMM was a comprehensive water quantity and quality computer program available at the time of initial CSS model development.

In the late 1990s, the CSS model was converted from EPA's SWMM to proprietary XP-SWMM software for five primary benefits listed below:

- Useful graphical user interface
- Utilization of geographic information systems (GIS)
- Enhanced SWMM capabilities
- One simulation for entire CSO service area
- Fewer input/output boundary conditions to reconcile between simulations

The conversion of EPA-SWMM model to XP-SWMM model created one system-wide model to represent the CSS with approximately 2,000 nodes and 600 subcatchments. MSD continued to update the CSS model to reflect changing system conditions in the CSS by incorporating physical changes to various system features, and to take advantage of significant advances in computer hardware and software since the development of the model. The end product of this significant undertaking during the early 1990s and during 2004 was a working computer model of the CSS for use in predicting and analyzing the response of the system to various rain events.

MSD performed an extensive evaluation of commercially available computer models as well as the assessment of hydraulic sewer system modeling program and made a decision to convert all existing sewer models to InfoWorks Collection System (CS) format. The primary benefit of the model conversion was the decrease in run-time and ability to code in RTC rules to analyze the system benefit more accurately. The selection of InfoWorks CS model meets the criteria for selection of a CSS hydraulic model based on EPA Guidance: “Combined Sewer Overflows: Guidance for Monitoring and Modeling” (EPA 832-B-99-002). Criteria include:

- Ability to accurately represent CSSs hydraulic behavior
- Ability to accurately represent runoff in the CSS drainage basin
- Extent of monitoring
- Need for long-term simulations
- Need to assess water quality in CSS
- Need to assess water quality in receiving waters
- Ability to assess the effects of control alternatives
- Use of the presumption or demonstration approach
- Ease of use and cost

2.4.6.3 Model Description

The original CSS model was developed to include sewers larger than approximately 48 inches in diameter in general. However, in the Beargrass Creek, sewer sizes greater than 48 inches were very limited; therefore, sewer sizes as small as 12 and 24 inches were presented in the model to provide sufficient details for assessing CSO discharges. More detail information on original model development is documented in the 1993 “Combined Sewer Operational Plan,” Chapter 5.

In late 1997, the existing six EPA SWMM models were converted to XP-SWMM. Upon completion of the conversion to XP-SWMM, the six individual models were combined into one XP-SWMM to create one system-wide model. After integration of the six models into one model, CSS model consisted of approximately 2,000 manholes and 600 subcatchment areas.

As part of the NMC, MSD frequently updates the CSS model to reflect changing system conditions in the CSS. During MSD’s fiscal year 2004, the CSS model was updated and calibrated to reflect the following changes:

- Reflect changing system conditions within the CSS by incorporating physical changes to various system features;
- Take advantage of significant advances in computer hardware and software since the original model construction; and
- Modify the model to be able to simulate typical year rainfall (long-term) simulations

The general overview of MSD sewer modeling history is documented in Sewer Modeling History Report (2007) and available for review in Appendix 2.4.2, Louisville/Jefferson County MSD Sewer Modeling History Report.

In 2007, MSD developed a "Hydraulic Sewer System Modeling Guideline Manual" (see Appendix 2.4.3) to standardize model development and improve the detail, quality, and functionality of sewer models. MSD contracted two modeling experts to provide independent peer review of the modeling approach and the Modeling Guideline Report, Dry Weather Flow Memorandum, and the rainfall-derived infiltration and inflow (RDI/I) Flow Memorandum. The comments provided from the peer reviewers were incorporated into the draft final version of the Modeling Guideline Manual. The Beargrass Creek Integrated Hydraulic Model Peer Review Report is available for review in Appendix 2.4.4.

Model Conversion

The existing CSS model was converted to InfoWorks CS and upgraded in detail to meet the standards of modeling guideline document developed for MSD sewer system modeling. The model conversion and expansion was completed in 2007. Figure 2.4.26 at the end of this chapter is a diagram exhibiting the history of development of the CSS model. Key model inputs and sources of the data are listed in Table 2.4.6.

TABLE 2.4.6

CSS MODEL KEY INPUTS AND SOURCES

Type	Data	Sources
Hydrologic	CSO-Subcatchment area	Delineation using GIS and Field visits
	Surface Slopes	Estimated using GIS
	Roughness and percent imperviousness	Estimated using GIS
	Width	Estimated using GIS
	Rainfall Data	Hourly data from NWS gauge at Standiford Field Airport
		Ten-min radar rainfall data from 1-km pixel
		Five-min data from USGS/MSD rain gauge network
Hydraulic	Nodes and Conduits	GIS/ As built drawings/Surveying
	Diversion Structures	GIS/ As built drawings/CSO Inventory Records/Field visit
	Pump Stations	GIS/ As built drawings/Interview with operations/ Draw-down test
	Inflatable Dam /RTC operating scheme	As built drawings/ Rules developed by engineer
	Dry Weather Flow	Diurnal Pattern developed based on 2007 Flow monitoring data
	Inflow from Separate Sewer System	Flow monitoring data/ SSS model hydrographs

The expansion of the CSS model to include sewer sizes as small as 18 inches (except for the Beargrass Creek area where some pipe sizes were as small as 8 inches) was necessary to represent the CSS system more accurately. This was completed as part of conversion process.

The current CSS model configuration includes approximately 12,000 nodes and 2,900 subcatchments compared to previous 2,000 nodes and 600 subcatchments in XP-SWMM model.

The newly updated CSS model includes the RTC rules of nine Phase I & II sites to model the system response accurately. Detailed descriptions of the model incorporation of RTC rules are provided for reference in Appendix 2.4.5, RTC Incorporation Technical Memorandum. See Figure 2.4.27 at the end of this chapter for the extent of CSS modeling area.

2.4.6.4 Model Calibration/Validation

Model calibration of the converted CSS model was completed from January through May 2007 to ensure the CSS model accurately represents the sewer system. Approximately 25 in-system locations were monitored to support hydraulic model calibration. In addition to the in-system monitors, overflow data from approximately 15 CSO sites were available for model calibration and validation. Figure 2.4.15 at the end of this chapter exhibits the location of flow monitors used for model calibration/validation purpose.

Based on review of the flow monitoring data, April 14, 2007, with a total rainfall depth of 1.3 inches was selected as the calibration event. April 12, through May 7, 2007, was selected as the validation period. It was recommended by independent peer reviewers to perform continuous calibration/validation rather than traditional independent event calibration and validation to better capture conditions during multiple rainfall events and inter-event dry weather period. The long-term calibration/validation approach was recommended because since the CSS model is used to perform annual simulations.

One of the most important input parameters in the sewer system modeling for calibration purposes is precipitation data. The precipitation data used for model calibration was 1-kilometer pixel size radar rainfall data provided by MSD. Using the radar rainfall data provided better spatial and temporal coverage of the modeling area during calibration period.

Dry Weather Flow

DWFs in the previous CSS models in XP-SWMM format were estimated from in-system flow monitoring data collected at a number of locations within the system, as well as available treatment plant and pump station flow rates. Based on an assumption that infiltration into the CSS is non-excessive, dry weather constant flow inputs (without diurnal pattern) were allocated to each subcatchment in the model based on the ratio of subdrainage area size to the total drainage area size upstream of the flow monitoring location.

Based on the modeling guideline document, the latest CSS model updated the representation of DWFs in the CSS model by distributing flows using census data and applying diurnal pattern developed based on flow monitoring data. The advantage of using this method is that the models would represent the DWF and wet weather flow capacity more accurately than previous methods used. Figures 2.4.28 and 2.4.29 present two examples of diurnal patterns used in the model to predict sanitary flows in the system.

FIGURE 2.4.28 DIURNAL FLOW PATTERN

OHIO RIVER INTERCEPTOR NEAR MAIN AND 15TH STREET

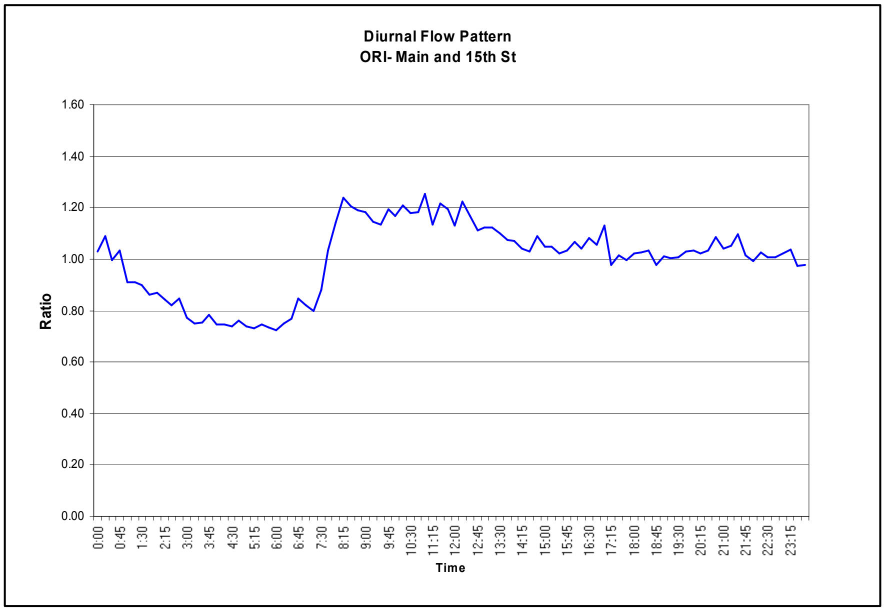
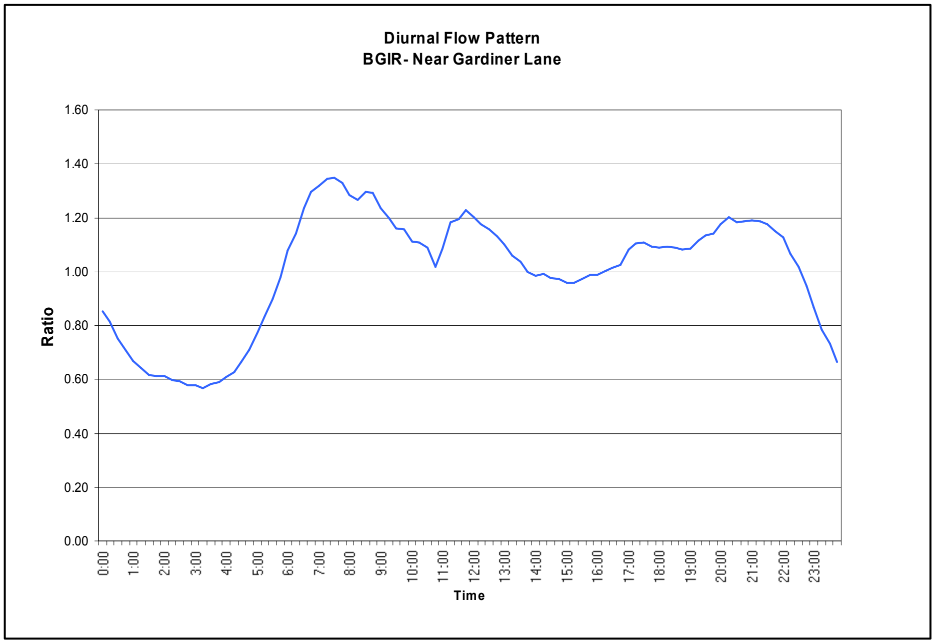


FIGURE 2.4.29 DIURNAL FLOW PATTERN

BEARGRASS INTERCEPTOR RELIEF NEAR GARDINER LANE



DWF calibration was performed to ascertain that the model appropriately calculated the DWFs at various flow monitoring locations based on new methodology. Another aspect of DWF calibration is to understand the overflow structure configuration and/or other system configuration. Once the DWF simulation is successful, the model is then ready for wet weather calibration to determine the system response to a wet weather event.

Wet Weather Flow

The objective of the wet weather flow calibration is to simulate a series of wet weather events, by use of the best available data, and compare data predicted to actual data recorded at particular locations. Realistically, it would be impossible to simulate exactly any particular storm event due to the large number of input variables, but by adjusting portions of the input data; results were obtained which reasonably approximated actual storm events.

Originally, in 1992, nine different storm events were chosen from the information obtained at the rain gauges and flow monitors during 1992 flow monitoring Phase I, and four different storm events were chosen from data recorded during 1992 flow monitoring Phase II for the wet weather calibration. The storm events were chosen because they represented a wide range of storm types. In most cases, a good correlation was achieved between two or three individual storm events at most sites, although some deviation between observed and predicted data was observed for another event. The Combined Sewer Operational Plan 1993, Chapter 5, details information from the original calibration.

The XP-SWMM version of CSS model was re-calibrated in 2004 using two different storm events: March 19 with a total of 2.9 inches of rain, and March 25 with a total of 2.8 inches of rain. The model was then executed using a two-week (March 15 to April 2, 2002) continuous simulation. The model predicted hydrographs within the system, which were compared to the monitored data, and a good correlation was found in most cases. The shapes and magnitudes of the hydrographs indicated that the original model was well calibrated for most of the service area. The updated XP-SWMM combined sewer model re-calibration, using 2002 flow meter data, was performed using the same method as outlined in the 1993 Combined Sewer Operational Plan.

The latest CSS model calibration in InfoWorks CS format was performed on April 14, 2007, and validation was performed on a continuous simulation. April 12, 2007 through May 7, 2007, was selected as a calibration and validation period to compare the model-predicted results to monitored data. In general, the plots of observed versus modeled depth and flow throughout the collection system demonstrated that the model simulated the actual collection system response reasonably well on an overall basis. Table 2.4.7 presents a summary of the model wet weather flow calibration results for the major sewers. Calibration metrics that fell outside of MSD's modeling guidelines (10 percent) are shown in **Bold Red** text.

TABLE 2.4.7

SUMMARY OF WET WEATHER FLOW CALIBRATION RESULTS

Node ID	Sewer Name	Meter Site	Monitored Flow Volume (MG)	Modeled Flow Volume (MG)	Percent Error (Volume)
Middle Fork Trunk (MFT) Sewer Area					
08769	MFT-Downstream end	Cabel St. & E. Washington St.	63.8	64.2	0.6%
24418	MFT-Lower Middle	Lexington Rd. & Bike Path	55.6	56.2	1.1%
45835	MFT-Upper Middle	Seneca Park Rd. and Alta Vista Rd.	48.0	43.8	-8.7%
24551	MFT-Upstream end	Seneca Park Rd. & Pee Wee Reese Rd.	43.5	43.2	-0.7%
Northeastern Sanitary Trunk Sewer (NSTS) Area					
08792	Mellwood	Mellwood Ave. & Delmont Ave.	3.3	3.4	1.2%
40248-X	NSTS	Louisville Metro Impound Lot	7.2	7.2	-0.6%
Beargrass Interceptor (BGI) and Beargrass Interceptor Relief (BGIR) Sewer Area					
08770	BGI	Buchanan St. & E. Washington St.	42.04	55.77	**32.8%**
08954	BGI	Near Nightingale Pump Station	40.6	31.2	**-23.1%**
27293	BGI [1]	Trevilian Way	NA	14.2	NA
16762	BGI	Downstream of SED	14.1	14.0	-0.4%
23214	BGIR	1718 Gardiner Ln.	17.2	17.4	-1.2%
50499	BGIR	Newburg Rd. & Trevilian Way	27.7	28.8	4.0%
71867	Tributary to BGI	937 S. Shelby St.	11.5	12.4	7.7%
08940	Tributary to CSO151	Castlewood Dell	2.3	2.6	**13.0%**
Southwestern Outfall Area					
10167	Cardinal Sewer	Union Ave. & Fayette Ave.	33.0	31.1	-5.7%
23167	Upper Dry Run Trunk	Lennox Ave. & S. Floyd St.	44.7	49.9	**11.5%**
50950	SW Branch	Bells Lane & S. 41st St.	198.3	175.1	**-11.7%**
Ohio River Interceptor (ORI), Western Interceptor, Southern Outfall, and Northwestern Interceptor Area					
08843	CRD [2]	S. 8th Street & Magazine St.	2.2	0.2	**-88.9%**
08726-SM	Northwestern Interceptor	Shawnee Park Rd. & W. River Park Dr.	16.0	15.2	-5.1%
08112-SM	Western Interceptor	1366 S. 45th St.	22.1	22.5	1.8%
08635	Western Interceptor	4526 W. Broadway	9.7	10.6	9.3%
04250	38th Branch	W. Market St. & S. 38th St.	8.3	7.8	-6.0%
67892	Southern Outfall	Wilson Avenue & S. 12th St.	39.9	43.0	7.7%
08116	ORI	Fordson Way & Cecil Ave.	149.7	154.3	3.1%
08761-SM	ORI	Main St. & 15th St.	103.9	147.7	**42.4%**
Morris Forman WQTC					
Plant	MFWQTC Effluent Data [3]	Plant Inflow Hydrograph from CSS model	328.0	386.5	**17.2%**

Notes:
1. This meter location experienced data loss (4/15/07 through 4/26/07) during calibration/validation period.
2. Central Relief Drain (CRD) meter data not used for dry weather flow calibration. To simulate backwater condition, daily Ohio River level data provide by the USACE was applied.
3. Morris Forman WQTC influent data was not available. Effluent flow data was compared to modeled inflow data for general comparison purposes.

The following summarizes the results of the latest CSS model calibration efforts in 2007.

Middle Fork Trunk Sewer Area

A total of four calibration locations were available in the Middle Fork Trunk Sewer service area, including one upstream boundary location. After conducting the wet weather calibration efforts, all four sites exhibited good correlations between observed data and model-predicted data in flow, depth and velocity. The total volume action level of 10 percent was met at all four of these locations.

Northeastern Sanitary Trunk Sewer Area

Two flow monitors (MH 08792 at Mellwood Avenue and MH 40248-x at the Louisville Metro Auto Impoundment Lot) were installed in the Northeastern Sanitary Trunk Sewer to characterize the inflow to the Robert J. Starkey Pump Station from the northeastern area. The hydrographs at both locations exhibited good correlation between the observed and model- predicted flows. The total volume action level of 10 percent was met at both locations.

Beargrass Interceptor and Beargrass Interceptor Relief Sewer Area

A total of eight calibration locations were available in the vicinity of the Beargrass Interceptor and Beargrass Interceptor Relief service area. For the most part, the model was able to predict the total volume of flow to meet the calibration criteria of 10 percent. Two (**MH 08770 and MH 08954**) of eight flow monitoring location calibration results will be improved by further investigation and continued analyses of operating strategy of the Nightingale Pump Station and Robert J. Starkey Pump Station. **MH 08940** calibration results were barely outside of the action level (13.0 percent or 0.2 MG). As part of continuing model maintenance activity, these sites will be closely monitored for next re-calibration task.

Southwestern Outfall Sewer Area

Three calibration locations existed in the service area of the Southwestern Outfall sewer, which is the largest pipe system in the MSD service area. The model reasonably predicted the flow rates measured and one of these calibration locations met the 10 percent action level while the other two locations (**MH 50950** and **MH23167**) were barely outside of the action level (11.7 percent and 11.5 percent). As the modeling program continues, this will be one area that will receive more focus to evaluate the calibration of the flow meters and monitor RTC responses.

Ohio River Interceptor, Western Interceptor, Southern Outfall, and Northwestern Interceptor Area

A total of seven flow monitoring locations were available for the wet weather flow calibration in the northwestern part of Louisville Metro, which includes service areas contributing to the Ohio River Interceptor, Western Interceptor, Southern Outfall and Northwestern Interceptor. As shown in Table 2.4.7, the model-predicted volumes were within the calibration action level of 10 percent, except for two locations discussed further below.

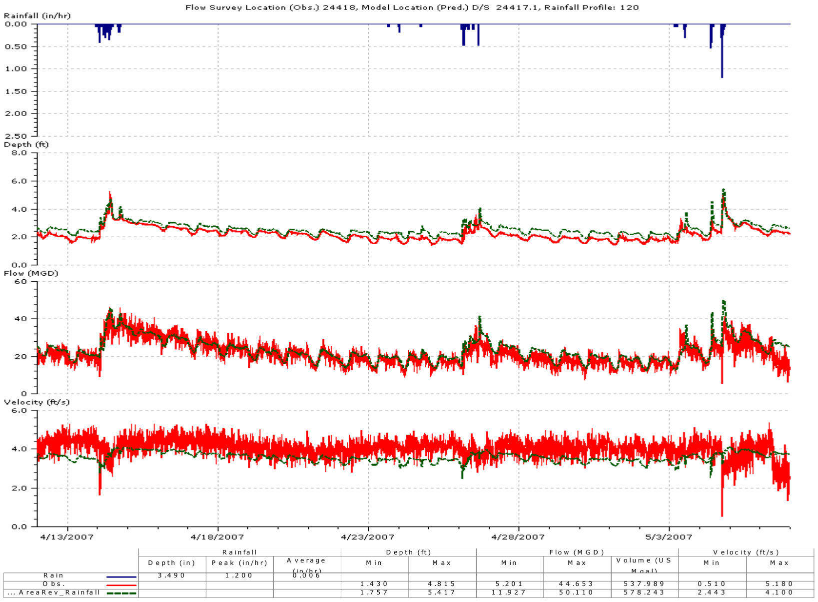
MH 08843: At this calibration/validation location flow was measured in the Central Relief Drain Sewer. This site was not considered for DWF calibration since Central Relief Drain does not carry sanitary flow. For wet weather flow calibration, this site experienced a backwater condition from the Ohio River due to an elevated river stage. Although the model-predicted volume at this location is significantly less than the observed data by percent error, the total volume measured is very small when compared to the flow at the Morris Forman WQTC (2.2 MG vs. 328.0 MG) and to other CSO locations. Further investigation of the Central Relief Drain system will result in a better understanding of the operating behavior in the service area. Furthermore, it would be beneficial to place temporary flow meters to monitor additional upstream characteristics. The investigation results will be used for re-calibration in the near future to improve calibration results of the model at this location.

MH 08761-SM: The Flow Meter at this calibration location measured the flow in the Ohio River Interceptor about midway between the Robert J. Starkey Pump Station and the Main Diversion Structure. The model-predicted volume at this location (148 MG) is about 42 percent higher than the observed volume (104 MG). This same trend was recognized during the DWF calibration. Based on other system calibration results and review of additional metering sites (downstream site shows 3.1 percent error by volume) modelers determined that additional flow monitoring and further investigation of the Robert J. Starkey Pump Station is required to improve calibration results of the model at this location.

Figures 2.4.30 and 2.4.31 are example hydrographs of the good calibration/validation results. A detailed description of the model development and calibration/validation is provided for reference in Appendix 2.4.6, CSS Model Calibration and Validation Technical Memorandum.

FIGURE 2.4.30 EXAMPLE CALIBRATION/VALIDATION HYDROGRAPH

MIDDLE FORK TRUNK - LEXINGTON RD AND BIKE PATH



	Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
	Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	3.490	1.200	0.006							
Obs.				1.430	4.815	5.201	44.653	537.989	0.510	5.180
... AreaRev_Rainfall				1.757	5.417	11.927	50.110	578.243	2.443	4.100

FIGURE 2.4.31 EXAMPLE CALIBRATION/VALIDATION HYDROGRAPH

CARDINAL SEWER - UNION AND FAYETTE AVENUE

	Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
	Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	3.690	1.260	0.006							
Obs.				0.466	2.300	0.676	28.457	230.741	1.280	5.980
... AreaRev_Rainfall				0.579	5.678	2.586	31.053	198.540	2.886	7.114

The calibrated and validated model was subject to a Quality Assurance/Quality Control (QA/QC) process. The QA/QC process involved peer review of the model, reporting discrepancies in a QA/QC checklist and a comments form. Full CSS Model QA/QC documentation is available for review in Appendix 2.4.7, CSS Model QA/QC.

2.4.6.5 Model Application

The CSS model has been used as a tool to perform numerous analyses, such as flooding analyses and development analyses. Specific applications include evaluation to determine the AAOV and percent capture impact of the initial draft 1996 LTCP elements and compliance with NMC requirements.

During 2008, the CSS model was used to generate the hydraulic statistics to determine average annual CSO characteristics and establish the "baseline" condition of the system using 2001 rainfall data. The CSS model was used to generate the baseline AAOV and post LTCP AAOV or residual AAOV after the Final CSO LTCP is completed. The summary report of CSO LTCP characteristics is available for review in Appendix 2.4.8, CSO LTCP Characteristics Summary Report. The CSS modeling program enabled MSD to determine interceptor sewer conveyance and system storage capacities, characterize overflows and pollutant loads to receiving streams and to evaluate various CSO control strategies.

2.5 COMPILATION EXISTING DATA – BEARGRASS CREEK

This section presents a detailed description of the physical characteristics of the Beargrass Creek Region of the CSS. Presented herein is an overview of the collections system mapping, an overview of the pipe network, major interceptors, all pumping stations, and a description of the individual CSOs.

2.5.1 Beargrass Creek Region Overview and Mapping

The combined sewer collection and conveyance system in the Beargrass Creek Region consists of those sewers contributing dry and wet weather flow to the Robert J. Starkey Pumping Plant, including the interceptors along the South and Middle Forks of Beargrass Creek, the Northeastern Sanitary Trunk, and related collector sewers. See Figure 2.5.1 at the end of this chapter. Much of the interceptor network in this region has limited wet weather conveyance capacities. Although nearly all wastewater flows generated in the Beargrass Creek Region are tributary to the Robert J. Starkey Pumping Plant, two exceptions exist:

- Flows spilling into the Beargrass Interceptor Relief Sewer are subsequently pumped over to the Southwestern Outfall service area via the Nightingale Pump Station.
- Flows diverted from the Beargrass Interceptor to the Southeastern Interceptor and Northern Ditch Interceptor systems, via the Southeastern Diversion, upstream of the combined sewer area.

At this time, 53 CSOs are located in the Beargrass Creek Region, with many discharge outlets located along much of the lengths of South and Middle Fork of Beargrass Creek. The slope of the interceptors serving these areas is marginal and requires a relatively high water surface elevation to maintain flow in the sewers even under dry weather conditions.

2.5.2 Collection System Understanding

This section presents an overview of the major assets within the CSS, including major sewers, major pumps stations and the CSOs. The system components are presented in group, aligned by reaches of Beargrass Creek.

2.5.2.1 Beargrass Creek Region Major Interceptors/Relief Sewer Drains

The major interceptors included in the Beargrass Creek Region are designed to route sanitary flow and allotted quantities of diluted stormwater to the Morris Forman WQTC via either the Robert J. Starkey Pumping Plant or Nightingale Pump Station. A description of the major components of the CSS within the Beargrass Creek Region is presented below.

Beargrass Interceptor

The Beargrass Interceptor was originally constructed beginning in the early 1900s and has been reconstructed many times over the years. The line varies in size, shape and grade from a 6'-6" x 6'-1-1/2" basket-handle sewer with a 0.05 percent slope near its outlet end to a 36-inch circular sewer with a 0.073 percent slope just south of the Watterson Expressway (I-264). Estimated full flow capacities range between 74.4 million gallons per day (mgd) and 11.2 mgd, respectively.

Beargrass Interceptor Relief Sewer

The Beargrass Interceptor Relief Sewer was constructed in the 1960s and 1970s to relieve the surcharged Beargrass Interceptor. The Beargrass interceptor is located on the north side of the South Fork of Beargrass Creek, whereas the relief sewer is located on the south side of the creek between the Watterson Expressway and Nightingale Road. Most of the sewer tributaries to the Beargrass Interceptor from the south were connected to the relief sewer during its construction. The Beargrass Interceptor Relief is a 48-inch circular sewer with a varying grade. Based on a minimum slope of 0.037 percent and a maximum slope of 0.12 percent; estimated full flow capacities range from 16.5 mgd in the upstream sections to 31.1 mgd in the downstream sections.

Middle Fork Trunk Sewer

The Middle Fork Trunk Sewer serves the Middle Fork Basin of Beargrass Creek, is circular in shape and varies in size and grade throughout its length. At its outlet end, the 60-inch pipe on a slope of 0.095 percent has an estimated full flow capacity of 49.4 mgd. Typical daily DWF in the Middle Fork Trunk Sewer is about 16 mgd.

Northeastern Interceptor

The Northeastern Interceptor was originally a branch of the Beargrass Interceptor and is actually two sewers constructed in an over-under configuration. The upper Northeastern Sanitary Trunk Sewer was designed to collect sanitary flow from the northeastern portion of the city and convey it westward to the Beargrass Interceptor for discharge into the Ohio River. The lower Northeastern Storm Drain was designed to convey stormwater eastward for discharge into Beargrass Creek. After construction of these sewers, several sanitary sewers were erroneously connected to the Northeastern Storm Drain. Later, the construction of the McAlpine Locks and Dam raised the normal pool of the Ohio River from elevation 412.00 to 420.00. This submerged the Northeastern Storm Drain over most of its length and resulted in very low velocities that allowed septic conditions to develop in the sewer during dry weather periods. The Letterle

Pump Station (formerly the Point Pump Station) was constructed to alleviate this condition by intercepting the Northeastern Storm Drain and discharging flow into the Northeastern Sanitary Trunk Sewer. During high flow periods, the pump station was designed to discharge the combined flow directly into Beargrass Creek. The Northeastern Sanitary Trunk Sewer is a 5-7-1/2" x 4'-0" basket-handle sewer with a 0.05 percent slope. The estimated flow capacity is 31.9 mgd. The Northeastern Storm Drain is a rectangular sewer of varying width and height. At the downstream end, the 6'-0" x 4'-9" Storm Drain is on a grade of 0.105 percent and provides an estimated full flow capacity of 78.3 mgd.

The Letterle Pump Station Elimination project eliminated the Letterle Pump Station and re-routing sewers that contributed flow. The storm drain (lower sewer) carried primarily storm flow but contained some sanitary sewage due to improperly connected property service connections. The project included removing all sanitary connections to the lower sewer and allowing it to carry stormwater only to the Beargrass Creek. The Letterle Pump Station was decommissioned and the CSO145 outfall was eliminated and converted into a stormwater outfall.

Sneads Branch Relief Drain

Beginning around 1950, the Sneads Branch Relief Drain was constructed to relieve flooding from the overloaded sewers in the area along Shelby Street near the South Fork of Beargrass Creek. This drain relieves combined sewers using side overflow weirs at 11 locations, and receives stormwater discharges from catch basins along its route. The drain discharges directly to the South Fork of Beargrass Creek and carries stormwater and the overflows of the combined sewers it relieves. An inflatable dam was constructed in 2001 at the outlet to store overflow for pumping into the Beargrass Interceptor Sewer. At the outlet end, the 11'-0" semi-elliptical drain line has a slope of 0.125 percent with an estimated full flow capacity of 473 mgd.

2.5.2.2 Beargrass Creek Region Major Pump Stations

Robert J. Starkey Pumping Plant – Sanitary and Flood

The Buchanan Street Pump Station, renamed the Robert J. Starkey Pumping Plant in 2005, located on the east corner of Buchanan and Franklin Streets, was constructed by the USACE in the 1950s as part of Louisville’s flood control system. The Robert J. Starkey Pump Plant functions as a wastewater pump facility during non-flood conditions. The Beargrass Interceptor, Middle Fork Trunk, and the Northeastern Interceptor converge just outside of the pump station. A common 6' x 8' rectangular sewer conveys all flow into the pump station. The pump station was originally equipped with four pumps rated at 31 mgd each for a total of 124 mgd. Recently, the pump plant has been upgraded and is now equipped with four pumps rated at 35 mgd each for a total of 140 mgd. Flow in excess of station capacity is discharged via gravity to the Ohio River through two overflow points. When Ohio River stage elevations prevent the discharge of overflow by gravity, the pump station switches to flood pumping and discharges to the river. A schematic of the pump station and influent sewers is shown on Figure 2.5.2 at the end of this chapter.

Nightingale Pump Station - Sanitary

The Nightingale Pump Station, which is located at the end of Nightingale Road on the west side of the South Fork of Beargrass Creek, was designed to convey flow in the Beargrass Interceptor Relief Sewer through the Manning Road-Cardinal Drive Sewer and into the Upper Dry Run Trunk and eventually to the Southwestern Outfall. A schematic of the pump station and influent sewers is shown on Figure 2.5.3 at the end of this chapter. The pump station was built in conjunction with the Beargrass Interceptor Relief sewer to prevent overflows from the Beargrass Interceptor during high flow conditions. The Nightingale Pump Station is designed with three 16" pumps rated at 8,750 gallons per minute (gpm) each for a total capacity of 26,250 gpm or about 37 mgd.

2.5.2.3 Beargrass Creek Region Combined Sewer Overflows

Table 2.5.1 on the next two pages lists CSOs located within the Beargrass Creek Region. A detailed description and discussion of each CSO structure and its discharge outfall is provided in Appendix 2.5.1, CSO Fact Sheets. A sample Summary Sheet for a CSO is shown in Figure 2.5.4 at the end of this chapter.

TABLE 2.5.1

BEARGRASS CREEK SOUTH FORK AREA CSO TABLE

CSO NO.	CSO Name	Drainage Area (AC)	S&F Device	Overflow Type	Baseline AAOV (MG/Yr)	Overflow Incidents (# of/Yr)	Average Duration of Overflows (Hrs)	Average Volume Per Incident (1,000 Gal)
CSO018	**Nightingale Pump Station**	NA	Multi	High Level Pipe W/ Side Weir	18.69	13	5.98	1,437.55
CSO082	**Beargrass Interceptor Beargrass Creek**	NA	Cyclone	High Level Pipe	1.10	24	2.98	45.70
CSO083	**Brent Street & Broadway Connect**	38.09	Baffle	Diversion Dam	0.00	0	0.00	0.00
CSO084	**Brent Street at Beargrass Creek**	125.07	Baffle	Diversion Dam	17.91	34	4.00	526.85
CSO091	**Schiller Avenue Overflow**	14.99	Screens	Orifice	1.62	34	4.38	47.67
CSO092	**St Catherine Street @ Beargrass Creek**	7.65	Screens	Leaping Weir	0.00	0	0.00	0.00
CSO097	**Cantonment Siphon Number 2**	0.00	Baffle	High Level Pipe	12.31	44	5.78	279.76
CSO106	**Royal - Neff**	11.80	Screens	Diversion Dam	0.33	17	2.40	19.49
CSO108	**Regulator Number 1 - Newburg**	485.22	Continuous Deflection Separator	Diversion Dam	10.35	9	5.17	1,149.69
CSO109	**Regulator Number 2 - Deer Park**	95.36	Screens	Orifice	0.22	3	1.98	72.20
CSO110	**Regulator Number 3 - Goss Avenue**	73.04	Basket	Orifice	27.53	44	6.18	625.60
CSO111	**Emerson Street Sewer**	99.35	Baffle	Diversion Dam	0.00	0	0.00	0.00
CSO113	**Ellison Avenue Sewer**	67.62	Screens	Diversion Dam	7.72	37	4.70	208.56
CSO117	**Regulator Number 11 - Dry Run**	74.17	Baffle	Diversion Dam W/ Regulator	92.76	39	6.27	2,378.36
CSO118	**Regulator Number 15 - East Broadway**	354.12	Baffle	Diversion Dam W/ Regulator	99.69	39	5.92	2,556.07
CSO119	**Brent Street Sewer**	7.58	Cyclone	High Level Pipe	12.38	40	5.10	309.57
CSO120	**Phoenix Hill Sewer**	16.51	Baffle	Diversion Dam	9.22	51	6.88	180.85

TABLE 2.5.1

BEARGRASS CREEK SOUTH FORK AREA CSO TABLE

CSO NO.	CSO Name	Drainage Area (AC)	S&F Device	Overflow Type	Baseline AAOV (MG/Yr)	Overflow Incidents (# of/Yr)	Average Duration of Overflows (Hrs)	Average Volume Per Incident (1,000 Gal)
CSO121	**Regulator Number 18 - Green Street**	107.19	Baffle	Diversion Dam W/ Regulator	11.22	28	3.98	400.73
CSO137	**Calvary Cemetery**	26.65	Screens	Diversion Dam	3.97	37	4.48	107.22
CSO141	**Baxter Avenue at Beargrass Creek**	7.72	Screens	Orifice	5.06	27	3.82	187.34
CSO146	**Sneads Branch Diversion**	112.60	Baffle	Rack Bars	63.67	59	7.55	1,079.21
CSO148	**Eastern Parkway Diversion**	24.89	Screens	Diversion Dam	1.26	26	3.65	48.51
CSO149	**Dry Run Diversion**	226.53	Baffle	Diversion Dam	56.35	37	5.07	1,522.87
CSO151	**Regulator Number 5 - Castlewood**	219.74	Basket	Orifice	80.26	57	7.72	1,408.14
CSO152	**Regulator Number 7- Southeastern**	260.56	Basket	Orifice	75.35	51	7.25	1,477.47
CSO153	**Cooper Street**	41.65	Screens	Diversion Dam	15.59	56	7.63	278.32
CSO179	**Kentucky Street Sewer Overflow**	456.17	Baffle	Side Weir	0.00	0	0.00	0.00

Sneads Branch (11 CSOs)

As noted earlier, the Sneads Branch Relief Drain was constructed to relieve flooding from an overloaded sewer in the area along Shelby Street near the South Fork Beargrass Creek. The drain relieves combined sewers using overflow weirs at 11 locations, and receives stormwater discharges from catch basins along its route. Because the Sneads Branch Relief Drain was constructed specifically to convey the excess flows from each of the noted CSOs, the Drain itself does not function as a consolidation sewer to bring the excess flows to a common point. As a part of RTC Phase I, an inflatable gate was installed at Sneads Branch to capture flows from the 11 CSOs. Pumps send re-captured overflows back into the Beargrass Interceptor for treatment at the Morris Forman WQTC.

The storage capacity of Sneads Branch Inflatable Dam is approximately 2.5 MG and it captures approximately 86 percent of overflow volume from individual CSOs upstream during a typical simulation. During larger wet weather events, in excess of in-line storage capacity, the inflatable dam will modulate to maintain a water level to protect homes from flooding, while maximizing capture of as much CSO as possible. Table 2.5.2 summarizes the hydraulic characteristics of CSOs located within the Sneads Branch Relief area.

TABLE 2.5.2

BEARGRASS CREEK SNEADS BRANCH CSO SUMMARY TABLE

CSO NO.	CSO Name	Drainage Area (AC)	S&F Device	Overflow Type	Baseline AAOV (MG/YR)	Overflow Incidents (# of/Yr)	Average Duration of Overflows (Hrs)	Average Volume Per Incident (1000 Gal)
CSO142	**Sneads Branch Relief - Logan Street and St Catherine Street**	NA	Sneads Branch Inflatable Dam	Side Weir	0.00	0	0.00	0.00
CSO174	**Sneads Branch Relief - Goss Avenue and Boyle**	157.47	Sneads Branch Inflatable Dam	Side Weir	37.31	57	7.58	654.48
CSO180	**Sneads Branch Relief - Ormsby Avenue Relief**	6.81	Sneads Branch Inflatable Dam	Side Weir	0.27	11	1.87	24.96
CSO182	**Sneads Branch Relief - Shelby Street and Burnett Avenue**	221.65	Sneads Branch Inflatable Dam	Side Weir	44.75	44	5.48	1016.93
CSO183	**Sneads Branch Relief - Alexander and Keswick**	3.62	Sneads Branch Inflatable Dam	High Level Pipe	0.00	0	0.00	0.00
CSO184	**Sneads Branch Relief - Fetter and Alexander**	104.84	Sneads Branch Inflatable Dam	Side Weir	0.43	13	1.98	33.26
CSO185	**Sneads Branch Relief - Shelby Street and Keswick**	108.19	Sneads Branch Inflatable Dam	Side Weir	0.55	7	1.98	78.08
CSO186	**Sneads Branch Relief - Logan Street and Oak Street**	4.69	Sneads Branch Inflatable Dam	Side Weir	0.00	0	0.00	0.00
CSO187	**Sneads Branch Relief - Shelby Street and Camp Street**	7.19	Sneads Branch Inflatable Dam	Side Weir	0.00	0	0.00	0.00
CSO188	**Sneads Branch Relief - Shelby Street and Clay Street**	13.11	Sneads Branch Inflatable Dam	Side Weir	0.03	8	1.65	3.31
CSO205	**Sneads Branch Relief - Morgan Street Relief**	11.52	Sneads Branch Inflatable Dam	High Level Pipe	0.00	0	0.00	0.00

Middle Fork (Eight CSOs)

CSO206 Manhole Separation and Property Service Reconnection was completed and certified March 31, 2009. Table 2.5.3 summarizes the hydraulic characteristics of CSOs located within the Beargrass Creek Middle Fork area.

TABLE 2.5.3

BEARGRASS CREEK MIDDLE FORK AREA CSO SUMMARY TABLE

CSO NO.	CSO Name	Drainage Area (AC)	S&F Device	Overflow Type	Baseline AAOV MG/YR)	Overflow Incidents (# of/Yr)	Average Duration of Overflows (Hrs)	Average Volume Per Incident (1000 Gal)
CSO086	**Payne Street and Spring Street**	6.07	Screens	Leaping Weir	0.00	0	0.00	0.00
CSO140	**Locust Street**	75.54	Baffle	Diversion Dam	17.00	54	6.17	314.85
CSO144	**Vance Street Regulator**	16.40	Screens	Diversion Dam	0.00	0	0.00	0.00
CSO127	**Etley Avenue**	192.26	Screens	Diversion Dam	4.62	21	2.97	220.02
CSO126	**Regulator Number 26 - Raymond Avenue**	35.29	Cyclone	Diversion Dam	0.58	13	1.42	44.25
CSO125	**Regulator Number 24 - Grinstead Drive**	391.03	Screens	Diversion Dam	48.38	54	5.40	895.99
CSO166	**Beals Branch Sanitary Diversion**	696.65	Screens	Diversion Dam W/ Rack Bars	10.12	19	3.02	532.54
CSO130	**Webster Street**	28.41	Screens	Diversion Dam	0.84	9	2.62	93.33
CSO206	**Cherokee Park @ Spring Drive**	464.7	Sewer Separation Project In Progress					

Northeastern Area (Six CSOs)

In January 2001, the public portion of CSO088 was separated. An evaluation of the CSO closure was performed during the year 2005 to determine the effectiveness of the separation and potential influence of a proposed downspout disconnection project. Through this evaluation it was determined that CSO088 operates as a relief point for the Mellwood Interceptor, therefore a downspout disconnection program would have a minimal impact on CSO volume and frequency. CSO088 also has been identified as a CSO with potential backwater impact from the Beargrass Creek during high Ohio River elevation. Table 2.5.4 summarizes the hydraulic characteristics of CSOs located within the Northeastern Area of South Fork Beargrass Creek area.

TABLE 2.5.4

BEARGRASS CREEK NORTHEASTERN AREA CSO SUMMARY TABLE

CSO NO.	CSO Name	Drainage Area (AC)	S&F Device	Overflow Type	Baseline AAOV (MG/YR)	Overflow Incidents (# of/Yr)	Average Duration of Overflows (Hrs)	Average Volume Per Incident (1000 Gal)
CSO088	**Mellwood Avenue Interceptor**	18.80	Screens	Leaping Weir	0.58	6	1.98	96.28
CSO093	**Spring Street**	20.79	Screens	Leaping Weir	1.81	37	4.68	48.79
CSO131	**Regulator Number 33 - Mellwood Avenue and Frankfort Avenue**	50.33	Cyclone	Orifice	0.06	2	1.88	28.66
CSO132	**Regulator Number 35 - Brownsboro**	674.01	Baffle	Diversion Dam	149.77	56	7.53	2674.53
CSO154	**Mellwood Avenue @ Schoeffle**	31.02	Screens	Diversion Dam	1.92	15	4.03	127.73
CSO167	**Brownsboro Lat Number 2**	11.00	Baffle	Diversion Dam	0.96	12	2.08	79.88

2.6 COMPILATION AND ANALYSIS OF EXISTING DATA – OHIO RIVER

This section presents a detailed description of the physical characteristics of the Ohio River Region of the CSS. Presented herein is an overview of the collections system mapping, an overview of the pipe network, major interceptors, all pumping stations and a description of the individual CSOs.

2.6.1 Ohio River Region Overview and Mapping

The Ohio River Interceptor and Central Relief Drain service areas are designated as the Ohio River North Region since they are downstream of the Robert J. Starkey Pumping Plant and overflow into the Ohio River. See Figure 2.6.1 at the end of this chapter. The collection and conveyance networks in this Region are relatively small with limitations in wet weather capacity. The Ohio River Interceptor conveys flows to the Main Diversion Structure (CSO211) near the Morris Forman WQTC from the Robert J. Starkey Pump Plant, 4th Street and 34th Street Pump Stations, as well as gravity systems generally serving the areas along the south shore of the Ohio River. Forty-nine individual overflow relief structures are widely scattered throughout the two service areas.

In the Ohio River West Region, the conveyance systems consist of much larger interceptors and trunk sewers that exist in either of the Beargrass Creek or Ohio River North Region. Major sewers and service areas in the Ohio River West Region include the Northwestern Interceptor, Western Interceptor, Western Outfall, Southern Outfall, and the Southwestern Outfall. See Figure 2.6.2 at the end of this chapter. With the exception of the Western Interceptor, the conveyance capacities of these facilities are generally much larger than the capacity required for DWF only, since they must also convey storm flows from small and large events. Taken together, the Northwestern Interceptor, Western Outfall, Southern Outfall, and Southwestern Outfall service areas can nearly contain wet weather flows from storms of 0.10 inch/hour or less in intensity. Considerable overflow can occur for storms having greater intensities. Eight CSO locations exist in this western part of the MSD service area, all of which are located near the downstream ends of the conveyance systems in each area.

2.6.2 Collection System Understanding

2.6.2.1 Ohio River North Region Major Interceptors/Relief Sewer Drains

As part of the CSO study, the major interceptors, relief sewer and drains in the Ohio River North Region were designed to route sanitary flow and allotted quantities of diluting stormwater to the Morris Forman WQTC for treatment and final discharge to the Ohio River. A description of the CSS within the Ohio River Region is presented below.

Ohio River Interceptor

In the mid-1950s, the state ordered MSD to provide primary wastewater treatment and eliminate the discharge of raw sewage into the Ohio River. As a result, the Ohio River Interceptor and three major pump stations were constructed to collect flow from eastern, central, and northwestern portions of the system and convey it to the Morris Forman WQTC. Until that time, numerous individual sewers located in the north central section of the city discharged directly into the river. The design and construction of the Ohio River Interceptor enabled these lines to be intercepted and the sewage to flow by gravity to the treatment plant. In addition, the Robert J. Starkey, 4th Street, and 34th Street Pump Stations, which were constructed by the USACE as part of the city's flood control system, were also designed to be utilized as sanitary pumping facilities during non-flood periods. The Ohio River Interceptor, Western Interceptor, and Southern Outfall join south of 45th Street and Winnrose Way at the Main Diversion Structure located on the Whayne Supply Company property.

The Ohio River Interceptor enters the diversion structure as an 8'-0" circular sewer and exits as an 11'-0" semi-elliptical sewer flowing to the Morris Forman WQTC. The Ohio River Interceptor passes under the Southern Outfall in a siphon type arrangement but is open on the top, on each side of the Southern Outfall, within the diversion structure. The Southern Outfall is also open on the top within the structure. The Ohio River Interceptor is routinely backfilled by the Southern Outfall during wet weather. Because the Ohio River Interceptor is lower, water surface elevations equalize in both sewers resulting in some storage being provided before an overflow occurs.

Between the Morris Forman WQTC and the Main Diversion Structure, the Ohio River Interceptor is an 11'-0" semi-elliptical sewer with a slope of 0.03 percent. The estimated full capacity of the line in this reach is about 250 mgd. Upstream of the Main Diversion Structure, the interceptor varies in size, shape, and grade throughout its length. At its outlet end, the 8'-0" circular pipe on a slope of 0.08 percent has an estimated full flow capacity of 155 mgd. Typical daily flow is about 45 mgd.

38th Street Branch Interceptor

The 34th Street Pump Station serves the northwestern portion of the city from about 12th Street westward to the Ohio River. The flow from the station discharges into the 38th Street Branch Interceptor at 35th Street and Northwestern Parkway. The 38th Street Branch Interceptor in turn conveys the flow southward in 38th Street to the Ohio River Interceptor at 38th and Herman Streets. The 38th Street Sewer parallels the branch interceptor along 38th Street but continues one block further south before discharging into the Northwestern Interceptor.

The 38th Street Branch Interceptor is circular in shape and varies in size and grade from a 36-inch sewer with a 0.15 percent slope at its outlet end to a 30-inch sewer with a 0.39 percent slope at its upstream terminus. Estimated full flow capacity range is between 16.6 mgd and 17.2 mgd, respectively.

Central Relief Drain

In the mid to late 1930s, in response to flooding in the central business district from overtaxed combined sewers, the Central Relief Drain was constructed. This drain was designed to only receive flow during wet weather and relieves the combined sewers in the central part of the city at 14 locations. At each location, a side overflow weir was constructed on the sewer being relieved. When flow in the combined sewer reaches the level of the weir, a portion of the flow is relieved into the Central Relief Drain and transported to the Ohio River. The remaining flow continues through the combined sewer to its destination. Around 1950, the Central Relief Drain was extended south and relief was provided at 13 additional locations. Any flow that enters the Central Relief Drain must be discharged to the Ohio River.

A flood control gate is closed when the upper pool of the Ohio River reaches elevation 439.0 that protects the Central Relief Drain. When this gate is closed, all flow in the Central Relief Drain is diverted to the 5th Street Flood Pump Station and discharged to the Ohio River. Near its outlet end, the 6'-5" x 9'-7-1/2" inverted egg-shaped drain line with a slope of 0.335 percent has an estimated full flow capacity of 305 mgd.

4th Street Relief Sewer

The 4th Street Relief Sewer was designed and constructed to relieve sewers in the central business district that were being surcharged during periods of dry weather. For this reason, at each relief point, all flow in the combined sewers was diverted into the relief sewer. The relief sewer originally discharged flow into the Ohio River at the northern end of 4th Street. The 4th Street Pump Station was built in conjunction with the Ohio River Interceptor when the treatment facilities were built. A dam was constructed across the relief sewer to divert DWF into the pump station. The pump station discharges into the Ohio River Interceptor. Excess flow during wet weather tops the dam and continues through the relief sewer to the river. The majority of the 4th Street Relief Sewer was constructed in a tunnel and is of such depth that the crown of the sewer is below the basement level of most of the adjacent buildings. Just upstream of the pump station, the 7'-6" semi-elliptical relief sewer with a slope of 0.20 percent has an estimated full flow capacity of 215 mgd.

2.6.2.2 Ohio River North Region Major Pump Stations

The northern region of the Ohio River sewershed contains many larger pump stations, many of which are facilities that are part of the CSS and operate during Ohio River flood and non-flood modes. The pump stations within this region include: 4th Street Pump Station, 34th Street Pump Station, 5th Street Pump Station, 10th Street Pump Station, 17th Street Pump Station, and 27th Street Pump Station.

4th Street Pump Station - Sanitary and Flood

The 4th Street Pump Station, located on the southeast corner of 4th and Main Streets, was constructed by the USACE in the 1950s as part of Louisville’s flood control system and functions as a wastewater pumping facility. During non-flood conditions, the flow in the 4th Street Relief Sewer is diverted into the pump station and discharged to the Ohio River Interceptor. Per the USACE operational manual, during flood periods the pump station can discharge into the Ohio River Interceptor or the Ohio River, depending on flow.

The 4th Street Relief Sewer was built in the late 1920s to relieve overloaded sewers along 4th Street, Muhammad Ali Boulevard, Chestnut Street and Broadway. The relief sewer was designed to relieve all flows in the overloaded sewers, not just excess flows. Therefore, sanitary flow is present in the relief sewer continuously. A plan view of the pump station, sewers, diversions and gates is presented in Figure 2.6.3 at the end of this chapter.

The 4th Street Pump Station contains a sanitary wet well, a flood wet well and six pumps (three sanitary pumps and three flood pumps). The sanitary pumps can also be used as flood pumps. There are two 35 horsepower sanitary pumps rated at 4,000 gpm at 25 feet of head and one 60 horsepower sanitary pump rated at 5,900 gpm at 35.7 feet of head. The sanitary pumps discharge into a common header, which leads to either the Ohio River Interceptor or the flood pump discharge chamber. Fourth Street has three 350 horsepower stormwater pumps with a total station capacity of 95,400 gpm.

The 4th Street Pump Station is the ninth flood pump station to be placed into service should flooding occur on the Ohio River. This facility is not placed in flood operation mode until the river elevation exceeds elevation 436.3. This facility is expected to operate as a flood pump facility about once every five years on average.

34th Street Pump Station - Sanitary and Flood

The 34th Street Pump Station, which is located just south of the levee on 34th Street, was constructed by the USACE in the 1950s as part of Louisville's flood control system and functions as a wastewater pump facility. The station conveys flow from the northern portion of Louisville Metro to the Ohio River Interceptor or to the lower pool of the Ohio River, depending on flow and river elevation. A plan of the pump station, sewers, diversions and gates is presented in Figure 2.6.4 at the end of this chapter.

A diversion dam on the sewer flowing north on 34th Street diverts low flows through a 24-inch sewer into the pump station. The pump station discharges to the 38th Street Branch Interceptor that conveys the flow to the Ohio River Interceptor at 38th Street and Herman Street. The diversion dam is designated as CSO 019. Excess flow tops the dam and is discharged through the sewer to the lower pool of the Ohio River. When the river stage exceeds elevation 421.00, the pump station is shut down and backwater and sewage is allowed to pond in the sewer system.

The pump station contains two sanitary pumps rated at 4,250 gpm each at 31.5 feet of head and four storm pumps rated at 15,600 gpm each at 34 feet of head. The sanitary pumps can also be used for flood pumping.

The 34th Street Pump station is the thirteenth station to be placed into service should flooding occurs on the Ohio River. This facility is not placed in flood operation mode until river elevation exceeds 434.6. This facility is expected to operate as a flood pump facility about once every five years on average.

5th Street Pump Station - Flood

The 5th Street Pump station, which is located at 100 Place Montpelier, north of Main Street adjacent to the floodwall, was constructed by the USACE in the 1950s as part of Louisville's flood control system. This facility is equipped with three 50 horsepower pumps and one 25 horsepower pump providing a total capacity of approximately 37,000 gpm at minimum design head. The minimum water level elevation in the wet well is 426.75 based on the smaller pump and 437.00 for the larger pumps. The maximum design pumping elevation is 440.00.

The 5th Street Pump Station is the seventh station to be placed into service should flooding occur on the Ohio River. This facility is not placed in operation until the river elevation exceeds 434.3. Above this level, the facility is used to pump excess combined flows from the sewers in 5th, 6th, and 7th Streets and storm flows accumulated between Main Street and the floodwall to the river. Normal flows in these sewers, up to the capacities of their appropriate diversion structures, are conveyed to the Ohio River Interceptor. This facility is placed in operation about once every five year on average.

10th Street Pump Station - Flood

The 10th Street Pump Station, which is located on the southwest corner of 10th and Rowan Streets, was constructed by the USACE in the 1950s as part of Louisville's flood control system. This facility utilizes three 200 horsepower pumps and one 25 horsepower unit to achieve a total capacity of approximately 90,000 gpm at minimum design head. The minimum water level elevation in the wet well is 420.50 based on the smaller pump and 427.70 for the larger pumps. The maximum design pumping elevation is 432.10.

The 10th Street Pump Station is the eighth station to go on-line should flooding occur on the Ohio River. This facility is not placed in operation until the river elevation exceeds 434.6. At various stages above this level, the facility is used to pump excess combined flows from the sewer in 8th, 9th, 10th, 11th, 12th, and 13th Streets and storm flows accumulated between Main Street and the floodwall to the river. At upper gauge elevation 439.00, flow in the Central Relief Drain is diverted to the pump station. Normal flows in the numerous tributary sewers in 8th through 13th Streets, up to the capacities of their appropriate diversion structures, are conveyed to the Ohio River Interceptor. This facility is placed in operation about once every five years on average.

17th Street Pump Station - Flood

The USACE constructed the 17th Street Pump Station, which is located at the beginning of 17th Street north of Northwestern Parkway and adjacent to the floodwall, constructed by the USACE in the 1950s as part of Louisville's flood control system. The facility is equipped with three 75 horsepower pumps and one 15 horsepower pump providing a total capacity of approximately 496.0 gpm at minimum design head. The minimum water level elevation in the wet well is 427.25 based on the smaller pump and 433.00 for the larger pumps. The maximum design pumping elevation is 438.20.

The 17th Street Pump Station is the eleventh station to be placed into service should flooding occur on the Ohio River. This facility is not placed in operation until the river elevation exceeds 437.5. Below this level, normal flow in the sewer in 17th Street is conveyed to the 34th Street Pump Station and discharged into the Ohio River Interceptor. High flows top the diversion dam in Northwestern Parkway just upstream of the 17th Street station and are discharged by gravity directly into the river. Above river elevation 437.5 on the upper gauge, combined flows in the sewer in 17th Street are routed to the 17th Street facility and pumped into the river. This facility is placed in operation about once every five to ten years on average.

27th Street Pump Station - Flood

The 27th Street Pump Station, which is located at 27th Street and the floodwall, was constructed by the USACE in the 1950s as part of Louisville's flood control system. The facility utilizes four 350 horsepower pumps and one 60 horsepower unit to achieve a total capacity of approximately 198,150 gpm at minimum design head. The minimum water level elevation in the wet well is 419.25 based on the smaller pump and 428.20 for the larger pumps. The maximum design pumping elevation is 433.20.

The 27th Street Pump Station is the tenth station to be placed into service should flooding occur on the Ohio River. The 27th Street Pump Station is not placed in operation until the river elevation exceeds 436.8. Below Ohio River elevation 427.5, normal flows in the sewer in 22nd and 27th Streets are conveyed around the 27th Street facility to the 34th Street Pump Station and discharged into the Ohio River Interceptor. High flows overflow the diversion dam just upstream of the 34th Street station and are discharged by gravity directly into the river. Between upper gauge elevations 427.5 and 436.8, normal flows are handled in the same manner prescribed above, but a portion of the high flows is diverted by gravity directly into the Portland Canal instead of traveling all the way to 34th Street. Above river elevation 436.8 on the upper gauge, combined flows in the sewers in 22nd and 27th Streets are routed to the 27th Street Pump Station and pumped into the river. This facility is placed in operation about once every five to ten years on average.

2.6.2.3 Ohio River North Region Combined Sewer Overflows

The following is a list of CSOs located within the Ohio River North Region. Table 2.6.1 summarizes the hydraulic characteristics of CSOs located within the Ohio River North Region.

Note that CSO023 is one of three CSOs within the entire CSS that does not have solids and floatables control. A concerted effort was made in August of 2006 to design and install devices but because of physical limitations of the diversion structure, it was not feasible to install solids and floatables device without extensive engineering or construction. Therefore, solids and floatables will be addressed as part of the Final CSO LTCP at these locations.

TABLE 2.6.1

OHIO RIVER NORTH CSO SUMMARY TABLE

CSO NO.	CSO Name	Drainage Area (AC)	S&F Device	Overflow Type	Baseline AAOV (MG/YR)	Overflow Incidents (# of/Yr)	Average Duration of Overflows (Hrs)	Average Volume Per Incident (1000 Gal)
CSO019	**34th Street Pump Station**	1,094.02	Baffle	Diversion Dam	297.91	60	8.10	4965.23
CSO022	**4th Street Pump Station**	100.89	Baffle	Diversion Dam	0.95	4	2.23	238.69
CSO023	**Ohio River Interceptor @ 4th Street Pump Station**	0.0	None	Side Weir	74.00	28	5.32	2642.72
CSO050	**12th Street**	36.32	CDS	Diversion Dam	38.87	41	8.15	948.08
CSO051	**11th Street**	6.34	Baffle	Diversion Dam	3.84	28	4.93	137.24
CSO052	**10th Street**	8.70	Baffle	Diversion Dam	8.43	27	8.00	312.27
CSO054	**7th Street**	7.06	Cyclone	Diversion Dam	0.11	23	2.25	4.75
CSO053	**8th Street**	34.12	Baffle	Diversion Dam	4.52	23	3.57	196.41
CSO055	**6th Street**	18.03	Baffle	Diversion Dam	18.44	28	8.40	658.74
CSO056	**5th Street**	22.03	Baffle	Diversion Dam	2.74	18	3.83	152.29
CSO057	**1st Street Overflow Weir**	-	Screens	High Pipe	0.00	0	0.00	0.00
CSO058	**Preston Street Overflow Weir**	105.41	Baffle	Side Weir	116.64	50	8.65	2332.90
CSO150	**8th Street @ Common Place**	1.79	Baffle	Diversion Dam	7.81	31	7.97	251.88
CSO155	**Rowan Street and 12th Street**	11.93	Screens	Diversion Dam	2.05	39	4.80	52.57
CSO156	**6th Street & Washington Sanitary Diversion**	0.0	Screens	Diversion Dam	0.09	10	2.65	9.27
CSO160	**Sewer in Alley Sanitary Diversion**	1.98	Baffle	Diversion Dam	0.28	28	3.53	9.96
CSO161	**Market Street Sanitary Diversion**	2.54	Screens	Diversion Dam	0.01	1	1.92	10.05
CSO190	**17th Street Sanitary Diversion**	145.41	Baffle	Diversion Dam	36.19	49	5.32	738.54
CSO207	**2nd Street and Jefferson Street**	2.5	Screens	Diversion Dam	0.05	2	1.93	25.08
CSO208	**12th Street and Jefferson Street**	11.19	Screens	Diversion Dam	0.33	11	1.95	29.81
CSO172	**Adams Street**	13.67	Screens	Side Weir	1.28	31	4.05	41.14
CSO062	**Logan Company**	-	Screens	Diversion Dam	0.00	0	0.00	0.00
CSO020	**Buchanan Pump Station**	86.59	Screens	Diversion Dam	6.29	11	3.43	571.61

Central Relief Drain (22 CSOs)

The following is a list of active CSOs located within Central Relief Drain area. Table 2.6.2 summarizes the hydraulic characteristics of CSOs located within the Central Relief Drain of the Ohio River North area.

TABLE 2.6.2

OHIO RIVER NORTH CENTRAL RELIEF DRAIN CSO SUMMARY TABLE

CSO NO.	CSO Name	Drainage Area (AC)	S&F Device	Overflow Type	Baseline AAOV (MG/YR)	Overflow Incidents (# of/Yr)	Average Duration of Overflows (Hrs)	Average Volume Per Incident (1000 Gal)
CSO026	**Central Relief Drain - 6th Street and Broadway**	8.38	Baffle	Side Weir	0.00	0	0.00	0.00
CSO027	**Central Relief Drain - 7th Street and Broadway**	10.08	Baffle	Side Weir	0.00	0	0.00	0.00
CSO028	**Central Relief Drain - 6th Street and York Street**	6.11	Cyclone	Side Weir	0.00	0	0.00	0.00
CSO029	**Central Relief Drain - 8th Street and York Street**	34.78	Baffle	Side Weir	4.53	33	4.12	137.38
CSO031	**Central Relief Drain - 6th Street and Breckinridge Street**	3.75	Baffle	Side Weir	0.00	0	0.00	0.00
CSO034	**Central Relief Drain - 4th Street and York Street**	5.09	Cyclone	Side Weir	0.00	0	0.00	0.00
CSO035	**Central Relief Drain - 2nd Street and Broadway Number 1**	14.26	Baffle	Side Weir	0.21	11	1.95	18.86
CSO036	**Central Relief Drain - 3rd Street and Broadway**	23.08	Baffle	Side Weir	0.02	4	1.42	4.55
CSO038	**Central Relief Drain - 5th Street and Broadway**	9.49	Baffle	Side Weir	0.00	0	0.00	0.00
CSO178	**Central Relief Drain - 9th Street and York Street "B"**	58.02	Baffle	Side Weir	0.60	11	1.82	54.84
CSO181	**Central Relief Drain - 2nd Street and Broadway Number 2**	22.63	Baffle	Side Weir	0.01	3	1.43	3.61

TABLE 2.6.2

OHIO RIVER NORTH CENTRAL RELIEF DRAIN CSO SUMMARY TABLE

CSO NO.	CSO Name	Drainage Area (AC)	S&F Device	Overflow Type	Baseline AAOV (MG/YR)	Overflow Incidents (# of/Yr)	Average Duration of Overflows (Hrs)	Average Volume Per Incident (1000 Gal)
CSO192	**Central Relief Drain - South 6th Street and Garland Street**	9.00	Screens	Side Weir	0.00	0	0.00	0.00
CSO193	**Central Relief Drain - South 6th Street and Kentucky Street**	22.69	Baffle	Side Weir	0.04	5	1.85	7.22
CSO195	**Central Relief Drain - South 4th Street and Oak Street**	7.28	Baffle	Side Weir	2.19	55	5.75	39.90
CSO196	**Central Relief Drain - South 3rd Street and Oak Street**	2.18	Baffle	Side Weir	0.13	11	1.83	12.13
CSO197	**Central Relief Drain - South 3rd Street, South of Oak Street**	4.54	Screens	Side Weir	3.02	47	5.10	64.21
CSO198	**Central Relief Drain - South 3rd Street and Ormsby Avenue**	4.40	Baffle	Side Weir	0.00	2	1.08	1.24
CSO199	**Central Relief Drain - South 3rd Street, North of Magnolia Street**	8.64	Screens	Side Weir	0.46	45	4.67	10.26
CSO200	**Central Relief Drain - South 3rd Street and Magnolia Street**	10.28	Screens	Side Weir	4.91	65	7.43	75.56
CSO201	**Central Relief Drain - S 5th Street and Kentucky Street**	8.33	Screens	Side Weir	0.00	0	0.00	0.00
CSO202	**Central Relief Drain – South Ormsby Avenue, West of 3rd Street**	5.3	Screen	Side Weir	0.00	0	0.00	0.00
CSO203	**Central Relief Drain - South 4th Street and Ormsby Avenue**	14.24	Baffle	Side Weir	0.00	0	0.00	0.00

2.6.2.4 Ohio River West Region Major Interceptors/Relief Sewer Drains

Northwestern Interceptor and Western Interceptor

The Northwestern Interceptor and Western Outfall were constructed around 1911 and 1870, respectively, and both at one time discharged directly into the lower pool of the Ohio River around Shawnee Park. In the early part of the 1900s, park visitors and patrons of a nearby amusement park extensively used this area. The direct discharges from the Western Outfall produced some offensive conditions during periods of low water. Thus, the Western Interceptor was constructed in conjunction with the Northwestern Interceptor. The Western Interceptor was designed to intercept the DWF in both the Northwestern Interceptor and the Western Outfall and convey it to the Southern Outfall, which then were discharged downstream of Shawnee Park and the amusement park.

When the treatment facilities at Morris Forman WQTC were constructed, the Western Interceptor was redirected into the Ohio River Interceptor just upstream of the CSO211. Today, a CSO remains on the Western Interceptor at that point of redirection. Excess flow continues through the Western Interceptor to the Southern Outfall downstream of the CSO211.

Between its outlet end and Broadway, the Western Interceptor is a 5'-0" circular sewer with a slope of .055 percent and provides an estimated full flow capacity of 36.8 mgd. At Broadway, the interceptor becomes a 3'-6" circular sewer on the same grade and remains as such until it terminates at its junction with the Northwestern Interceptor. The estimated full flow capacity of the smaller section is reduced to approximately 14.4 mgd. Peak wet weather flow in the Western Interceptor has been measured at up to 20 mgd.

Western Outfall

The Western Outfall drains the area along Broadway from the Ohio River east to about 12th Street, encompassing about 1,800 acres. DWF from the Western Outfall is directed into the Western Interceptor just south of Shawnee Park in Broadway. Excess flows top an overflow diversion dam and continue through the Western Outfall to the river. When the lower gauge reaches elevation 435.0, a flood control gate on the Western Outfall is closed and any excess flow is directed into the Shawnee Park Flood Pump Station, which is then pumped to river.

The eastern portion of the Western Outfall service area, notably that area located along Maple Street, has surcharged several times in recent years, flooding vehicles and yards with combined sewage. This low-lying area is especially susceptible to flooding from sewer surcharges. Although the Western Outfall is relatively large in diameter, its flat slope results in insufficient capacity to convey all flows during high intensity storm events. The result is basement backups, sewer surcharging, and/or surface flooding during heavy rains. Surface flooding has occurred all along this sewer since as far back as 1910.

The segment of the Western Outfall in Broadway between Southwestern Parkway and 28th Street is a 10'-6" diameter circular brick sewer that was constructed circa 1873. Just west of the Southwestern Parkway, the sewer becomes 11'-9" in diameter. Based on plans developed during the underground sewer investigations of 1937, the outfall line has an estimated grade of 0.052 percent providing a full flow capacity of approximately 355 mgd upstream of the diversion dam.

Peak wet weather flow in the Western Outfall has been measured at over 220 mgd at about two-thirds full. Typical daily flow is 3 or 4 mgd.

Southern Outfall

The Southern Outfall serves a combined sewer area of about 3,500 acres and has an unsurcharged full flow capacity of about 765 mgd at its lower end. The Southern Outfall was constructed around 1912 and discharges to the lower pool of the Ohio River, just upstream of the treatment plant. Continued growth and development in the service area of the Southern Outfall has increased runoff to the extent that basement backups and surface flooding occur during intense storms.

When the diversion structure was built, a dam was constructed across the Southern Outfall to divert DWF through a drop connection into the Ohio River Interceptor to the Morris Forman WQTC. High flows top the dam in the diversion structure and continue through the Southern Outfall to the river. The Western Parkway Flood Pump Station provides flood protection for the Southern Outfall. When the lower gauge of the river exceeds elevation 416.4, the flood control gates are closed and the pump station begins operation. Overflow from the diversion structure is then pumped to the river.

Southwestern Outfall

The Southwestern Outfall serves the southwestern section of Louisville Metro and through its branches also serves the south central portion. Flows collected in the south central area north of the Watterson Expressway are routed via the Manning Road - Cardinal Drive Sewer and Upper Dry Run Trunk Sewer to a junction with the Southwestern Outfall at Taylor Boulevard and Oleanda Avenue. In a similar fashion, flows collected in south central Louisville, south of the Watterson Expressway, are conveyed through the Northern Ditch Trunk Interceptor and Mill Creek Trunk Sewer to the same junction point with the Southwestern Outfall at Taylor and Oleanda.

Flow in the Beargrass Interceptor Relief Sewer is discharged by the Nightingale Pump Station into the upstream end of the Manning Road - Cardinal Drive Sewer and thus enters the Southwestern system. In addition, other sewers, normally a tributary to the Beargrass Interceptor, can be diverted behind the Bashford Manor Mall through the Southeastern Interceptor, Northern Ditch Trunk Interceptor, and Mill Creek Trunk Sewer to the Southwestern Outfall. This diversion can be accomplished manually and is limited by the capacity of the Northern Ditch Pump Station. The Southwestern Outfall is diverted near Bells Lane and Watterson Expressway to the Southwestern Pump Station where the flow is pumped through the Southwestern Branch Interceptor to the Morris Forman WQTC.

The Southwestern Outfall, constructed in the 1930s, drains a combined sewer area of about 7,700 acres. The expanse of the service area of the Southwestern Outfall dictated its large size, 18'-4" x 27'-6" at one point. This sewer is considered the outstanding accomplishment of the Commissioners of Sewerage. In both length and size, it was one of the largest sewers built in the United States during that era. The Southwestern Outfall is an inverted egg-shaped sewer with varying width, height, and grade throughout its length. At the Southwestern Pump Station, the

18'-4" x 27'-6" line was constructed on a slope of 0.087 percent and provides an estimated capacity of 2,556 mgd flowing full.

DWF in the Southwestern Outfall is diverted by a 6-foot high dam into the Southwestern Pump Station and discharged through the Southwestern Branch Interceptor to Morris Forman WQTC. For a majority of its length, the 6'-0" circular Southwestern Branch Interceptor was laid on a slope of 0.07 percent and provided an estimated full flow capacity of 74 mgd. The 104 mgd capacity of the pump station exceeds the maximum unsurcharged capacity of the Branch Interceptor.

Normal lower pool elevation on the Ohio River is 383.00. Because of the presence of the McAlpine Locks and Dam at Louisville, the lower pool elevations fluctuate much more than the upper pool elevations. Lower pool elevations exceed 400.00 quite regularly. In consideration, the Southwestern Outfall is protected by three large electrically operated sluice gates just below the Southwestern Pump Station.

Southwestern Branch Interceptor

The Southwestern Branch Interceptor conveys flow discharged from the Southwestern Pump Station to the Morris Forman WQTC. For a majority of its length, the 6'-0" circular sewer was laid on a slope of 0.07 percent and provided an estimated full flow capacity of 72 mgd. It should be noted that the 104 mgd capacity of the pump station exceeds the maximum unsurcharged capacity of the Southwestern Branch Sewer.

2.6.2.5 Ohio River West Region Major Pump Stations

Northern Ditch Pump Station - Sanitary

The Northern Ditch Pump Station is located on the Northern Ditch Trunk Interceptor on New Way southeast of Strawberry Lane. The facility differs from other stations discussed herein in that it functions solely as a sanitary lift station (LS). Flow in the 72-inch interceptor is lifted approximately 24 feet and discharged into a 60-inch downstream continuation of the interceptor that ultimately flows to the Mill Creek Trunk Sewer and Southwestern Outfall. See Figure 2.6.5 at the end of this chapter. The Northern Ditch Pump Station utilizes four submersible propeller pumps each rated at 14,400 gpm for a total constructed capacity of 57,600 gpm. Due to limited capacity in the discharge chamber and downstream sewer, only three pumps are operated simultaneously. The fourth pump is used as a stand-by. Therefore, the maximum discharge from the pump station is 43,200 gpm or 62 mgd. The full flow capacity of the Northern Ditch Interceptor, upstream of the pump station is about 52 mgd.

Southwestern Pump Station

The Southwestern Pump Station is located just south of Bells Lane on the west side of the Watterson Expressway. The facility was designed to intercept flow in the Southwestern Outfall and convey it via the Southwestern Branch Interceptor to the Morris Forman WQTC. Excessive high flows in the Southwestern Outfall overflow a diversion dam and continue through the outfall line to the Ohio River. See Figure 2.6.6 at the end of this chapter.

The pump station has an east and west wet well, each fed by a 60" sewer. Mechanical screening is provided on both of the wet well inlets. Two 30-inch centrifugal pumps draw from the west wet well and two 20-inch centrifugal pumps draw from the east wet well. The bottom elevation of the wet wells is 382.25. An opening in the dividing wall at elevation 393.34 connects the wet wells. The four pumps are rated at 24,000 gpm each. The fourth pump is used as a standby. Therefore, maximum discharge from the pump station is 104 mgd.

Shawnee Park Pump Station - Flood

The Shawnee Park Pumping Station is located at 612 Southwestern Parkway in the middle of Shawnee Park. The facility has five 800 horse power pumps and one 75 horse power pump providing a total capacity of approximately 526,500 gpm at minimum design head. The minimum water level elevation in the wet well is 412.50 based on the smaller pump and 420.00 for the larger pumps. The maximum design pumping elevation is 426.50.

The Shawnee Park Pumping Station is not placed in operation until the river level reaches elevation 435.00 on the lower gauge. Below this level, normal flows in the Northwestern Interceptor and Western Outfall enter the Western Interceptor and are eventually conveyed to the Morris Forman WQTC. Excessive high flows in the Northwestern Interceptor are diverted at its junction with the Western Interceptor to the Ohio River. In a similar fashion, excessive high flows in the Western outfall overflow the diversion dam in Broadway and discharge to the river. Above river elevation 435.00 on the lower gauge, combined flows from both the Northwestern Interceptor and Western outfall are routed to the Shawnee facility and pumped into the river. Shawnee is the fourteenth station to be placed into service should flooding occur on the Ohio River. This pump station operates about once every five to ten years on average.

Western Parkway Pump Station - Flood

The Western Parkway Pumping Station is located on the Southern Outfall west of Southwestern Parkway at 1300 Southwestern Parkway. The facility is equipped with four 1,250 horse power and three 450 horse power pumps capable of discharging a total flow of approximately 810,000 gpm at minimum design head. The minimum water level elevation in the wet well is 412.60 based on the smaller pumps and 417.00 for the larger pumps.

The Western Parkway Pumping Station is not placed in operation until the river elevation exceeds 416.4 on the lower gauge. Below this level, normal flows in the Ohio River Interceptor, Southern Outfall, Western Interceptor, and 45th Street-Greenwood Avenue Sewer converge at the CSO211 and continue to the Morris Forman WQTC. Excessive high flows overflow the dam in the main diversion structure and are conveyed by gravity through the Southern Outfall to the Ohio River. Above river elevation 416.4 on the lower gauge, the Western Parkway facility is used to pump the combined flow in the Southern Outfall downstream of the CSO211 into the river. Western Parkway facility is the first station to be placed in service should flooding occur on the Ohio River. This facility can be expected to operate about once or twice a year on average and one of the pumps may run for a short period of time.

Paddy's Run Pump Station - Flood

The Paddy's Run Pumping Station, which is located at 4200 Campground Road, is equipped with four 1,250 horse power pumps and two 700 horse power units providing a total capacity of approximately 607,500 gpm at minimum design head. The minimum water level elevation in the wet well is 402.25 based on the smaller pumps and 427.60 for the larger pumps. The maximum design ponding elevation is 434.00.

The Paddy's Run Pumping Station is not placed in operation until the river elevation exceeds 435.3 on the lower gauge. Above this level, the facility is used to pump the surface water in Paddy's Run and excess combined flow in the Southwestern Outfall that overflows the diversion dam at the Southwestern Pump Station to the river. Paddy's Run is the twelfth station to go on line should flooding occur on the Ohio River. This facility can be expected to operate about once every five to ten years on average.

2.6.2.6 Ohio River West Region Combined Sewer Overflows

The following is a list of CSOs located within the Ohio River West Region. Table 2.6.3 summarizes the hydraulic characteristics of CSOs located within the Ohio River North Region.

Note that CSO015, the operating procedures for the outfall gate are being modified to operate as a baffle. The procedures will be revised and implemented by March 31, 2010.

CSO015 and CSO211 are two of three CSOs within the entire CSS that do not have solids and floatables control. A concerted effort was made in August of 2006 to design and install devices but because of physical limitations of the diversion structures, it was not feasible to install solids and floatables device without extensive engineering or construction at these locations. Therefore, solids and floatables will be addressed as part of the Final CSO LTCP projects for these CSO locations.

TABLE 2.6.3

OHIO RIVER WEST REGION CSO SUMMARY TABLE

CSO NO.	CSO Name	Drainage Area (AC)	S&F Device	Overflow Type	Baseline AAOV (MG/YR)	Overflow Incidents (# of/Yr)	Average Duration of Overflows (Hrs)	Average Volume Per Incident (1000 Gal)
CSO015	**Southwestern Pump Station**	7,496.70	Baffle	Diversion Dam	494.56	61	7.23	8,108
CSO016	**Miles Park Bypass**	-	Screens	Side Weir	29.65	29	6.22	1,023
CSO104	**Southwest Parkway Sewer @ Broadway**	62.04	Screens	Diversion Dam	0.20	5	2.12	41
CSO105	**Western Outfall @ Broadway**	1,881.20	None	Diversion Dam	21.43	19	3.75	1,128
CSO189	**Northwestern Sanitary Diversion**	1,148.65	Baffle	Side Weir	175.79	37	6.03	4,751
CSO191	**Algonquin Parkway Sanitary Diversion**	339.75	Baffle	Diversion Dam	32.42	19	6.65	1,706
CSO210	**45th Street - Greenwood**	166.67	Baffle	Diversion Dam	195.57	51	8.12	3,835
CSO211	**Main Diversion Structure**	3,554.89	None	Inflatable Dam	373.17	29	4.23	12,868

2.7 RECREATIONAL USE SURVEY

The process to evaluate and select CSO control approaches considers several community values identified by the Wet Weather Team (WWT) Stakeholder Group. These values include the protection of the environment, compliance with regulatory requirements, and protection of public health. The performance measures established to quantify protection of public health consider the potential public contact with sewer overflows.

To assist in identifying the locations with the greatest potential for public contact with sewer overflows, MSD conducted a Recreational Use Survey within the Beargrass Creek and Ohio River Watersheds. The result of this survey is summarized in a technical memorandum and was used in the evaluation of overflow control measures, and the prioritization of project implementation schedules. The results may also be useful in the water quality standards review suggested by the CSO Policy and LTCP guidance documents prepared by EPA.

2.7.1 Study Area

The Recreational Use Survey study area consists of the Beargrass Creek and Ohio River watersheds. The Beargrass Creek watershed is further subdivided into three forks (Muddy, Middle, and South) as show below.

- Ohio River Region
- Beargrass Creek Muddy Fork
- Beargrass Creek Middle Fork
- Beargrass Creek South Fork

2.7.2 Survey Locations

Thirteen sites were identified for the Recreational Use Survey, which included four locations within the Ohio River Region watershed, one location within the Beargrass Creek Muddy Fork watershed, six locations within the Beargrass Creek Middle Fork watershed, and two locations within the Beargrass Creek South Fork watershed. During the kickoff meeting on May 14, 2007, two sites (11 – Brown Park and 13 - Louisville Junior Academy) were removed from the survey, because they were located upstream of the CSO area.

Two sites (14 - Eva Bandman Park and 15 - Eva Bandman Park) were added on May 18, 2007, as a follow-up to the kickoff meeting. The Eva Bandman Park was split into two sites because the park is located in both the Ohio River watershed and the Beargrass Creek confluence. On September 1, 2007, two sites (16 - Beargrass Creek at Irish Hill and 17 - Butchertown Trail) were added to the list of survey sites to provide additional data within Beargrass Creek Middle Fork and Beargrass Creek confluence, respectively.

The final list of Recreational Use Survey Sites and associated watersheds are listed in Table 2.7.1 below. Figure 2.7.1 at the end of this chapter indicates the survey site locations, watershed boundaries, and identified CSO locations. Of the 17 survey sites identified in Table 2.7.1, 10 were located downstream of the CSO area in Table 2.7.2.

Survey site fact sheets containing locations, descriptions and site photos are located in Appendix 2.7.1, Recreational Use Survey Technical Memorandum.

TABLE 2.7.1

LIST OF RECREATIONAL USE SURVEY SITES

Site Number	Site Name	Watershed	Comments
1	Riverside, Farnsley Moremen Landing	Ohio River	-
2	Riverview Park	Ohio River	-
3	Waterfront Park	Ohio River	-
4	Cox Park (Public Boat Ramp)	Ohio River	-
5	Louisville Soccer Park	Muddy Fork BGC	-
6	Cherokee Golf Course	Middle Fork BGC	-
7	Cherokee Park	Middle Fork BGC	-
8	Seneca Park (Scenic Loop & Maple)	Middle Fork BGC	-
9	Seneca Park (Big Rock)	Middle Fork BGC	-
10	Seneca Golf Course (1 Mile Stretch)	Middle Fork BGC	-
11	Brown Park		Removed May 14, 2007
12	Joe Creason Park	South Fork BGC	-
13	Louisville Junior Academy		Removed May 14, 2007
14	Eva Bandman Park	Ohio River	Added May 18, 2007
15	Eva Bandman Park	Beargrass Creek Confluence	Added May 18, 2007
16	Beargrass Creek At Irish Hill	Middle Fork BGC	Added September 1, 2007
17	Butchertown Trail	Beargrass Creek Confluence	Added September 1, 2007

TABLE 2.7.2

RECREATIONAL USE SURVEY SITES LOCATED WITHIN/DOWNSTREAM OF THE CSS

SITE NUMBER	SITE NAME	WATERSHED
1	Riverside, Farnsley Moremen Landing	Ohio River
2	Riverview Park	Ohio River
3	Waterfront Park	Ohio River
6	Cherokee Golf Course	Beargrass Creek Middle Fork
7	Cherokee Park	Beargrass Creek Middle Fork
8	Seneca Park (Scenic Loop & Maple)	Beargrass Creek Middle Fork
14	Eva Bandman Park	Ohio River
15	Eva Bandman Park	Beargrass Creek Confluence
16	Beargrass Creek at Irish Hill	Beargrass Creek Middle Fork
17	Butchertown Trail	Beargrass Creek Confluence

2.7.3 Study Design

The Recreational Use Survey was conducted from May 1 through November 29, 2007, to coincide with the Kentucky recreational season. During the months of May through August, the sites were visited twice on the weekends and twice during the week. During September, October, and November, the sites were visited twice on the weekends and once during the week. Table 2.7.3 summarizes the number of site visits conducted at each survey site during the study. Appendix 2.7.1 provides a detailed list of survey site visits conducted throughout the duration of the study.

TABLE 2.7.3

SURVEY SITE VISITS

Site Number	Site Name	# of Site Visits
1	Riverside, Farnsley Moremen Landing	104
2	Riverview Park	104
3	Waterfront Park	104
4	Cox Park (Public Boat Ramp)	104
5	Louisville Soccer Park	104
6	Cherokee Golf Course	104
7	Cherokee Park	104
8	Seneca Park (Scenic Loop & Maple)	104
9	Seneca Park (Big Rock)	104
10	Seneca Golf Course (1 mile stretch)	104
11	Brown Park	8
12	Joe Creason Park	104
13	Louisville Junior Academy	8
14	Eva Bandman Park	94
15	Eva Bandman Park	94
16	Beargrass Creek at Irish Hill	32
17	Butchertown Trail	32

Survey locations 11 and 13 were visited only eight times, because they were removed from the survey on May 14, 2007. Survey locations 14 and 15 were added on May 18, 2007, and survey locations 16 and 17 were added on September 1, 2007, and therefore have a reduced number of site visits.

During the daily site visits, field data at each site was reported on a form entitled Field Data Sheet for Recreational Use Stream Survey. In addition, a minimum of three photos were taken per site (upstream, downstream, and observed recreational activity). Field data reported on the form included:

- Site Information: Name, Location Description, GPS Coordinates
- Photo Log ID Number
- Date & Time
- Personnel
- Current Weather Conditions
- Weather Conditions for Past 7 Days
- Number of People Observed
- Recreational Activities Observed
- Type of Water Contact

SURVEY CATEGORIES

Contact activities:

Boating
Wading
Jet Ski
Kayak
Fishing
Swimming
Water Ski
Study

Non-contact activities:

Dog Walking
Playground
Walking/Jogging
Working
Sunbathing
Party/Picnic
Lounging
Sport
Bike Riding

Type or magnitude of the contact:

Incidental
Below Waist
Full
Below Ankle
Below Neck
Non Contact

Recreational activities were split into two subcategories: contact activities and non-contact activities. In addition, the number of people was further subdivided into adults and children, because children are at greater risk of ingestion and present a higher degree of health impact. For purposes of this study, children represented ages 12 and younger.

A summary sheet was created to analyze the field data for all the survey sites. Field data included on the summary sheets include the site description, number of people observed, recreational activities observed and magnitude of water contact. See Appendix 2.7.1, Recreational Use Survey Technical Memorandum, for more details on the survey information.

The survey results are divided into the following categories:

- Adults observed at the site
- Children observed at the site
- Adults observed participating in non-contact activities
- Children observed participating in non-contact activities
- Adults observed participating in contact activities
- Children observed participating in contact activities
- Contact observed

In order to provide assistance in evaluating and selecting overflow control approaches that protect public health, the recreational use survey site locations with the greatest potential contact with overflows need to be identified and prioritized.

The following four parameters were selected to rank and prioritize the survey site locations:

1. Average number of people observed per site visit;
2. Percent contact observed;
3. Potential for water contact; and
4. Percent children observed.

An overall summary of the survey results from these seventeen locations throughout the duration of the study are presented in Table 2.7.4 at the end of this chapter. Potential contact is defined as the number of adults and children participating in contact activities but where no contact was observed; therefore, having the potential for water contact.

Each survey site was scored on a twenty-point scale (1 = Low and 20 = High) for each parameter with the exception of the percent contact observed parameter, where a weighting factor was applied. A weighting factor (doubling the parameter score) was applied to this parameter, because it represents direct water contact and was therefore considered of greater relative importance. Once the parameters were scored for each survey site, a priority rating was applied to each survey site. The priority rating is based on the sum of the parameter scores following applications of weighting factors.

The priority rating categories range from High (greatest potential for public contact with) to Low (least potential for public contact). The resultant priority scale has a potential maximum of 100 and minimum of zero as shown below:

High:	51-100
Medium:	21-50
Low:	0-20

2.7.4 Conclusions

Of the seventeen survey sites observed, Seneca Park at Big Rock scored the highest rating equal to 56 and was the only site identified as high priority. Four sites were identified with medium priority and the remaining twelve sites were categorized as low priority. The priority rating scores for all survey sites are listed on Table 2.7.5.

Of the 10 survey sites located within/downstream of the CSS, no sites were identified as high priority. Riverview Park and Cherokee Golf Course ranked the highest of the 10 sites with a rating equal to 26 and 25, respectively. These two sites were the only sites identified as medium priority and the remaining eight sites were categorized as low priority. The priority rating scores for the survey sites within the CSS are listed on Table 2.7.6.

TABLE 2.7.5

SURVEY SITE PRIORITY RATING SCORES

Park ID	Park Name	Watershed	Average People	% Children	% Potential	% Contact	Total	Rating
9	**Seneca Park - Big Rock**	Middle Fork BGC	9	6	6	40	52	High
2	**Riverview Park**	Ohio River	12	5	12	9	26	Medium
6	**Cherokee Golf Course - Lexington Rd**	Middle Fork BGC	4	1	20	4	25	Medium
4	**Cox Park**	Ohio River	20	3	16	5	24	Medium
5	**Louisville Soccer Park**	Muddy Fork BGC	4	20	1	1	22	Medium
3	**Waterfront Park**	Ohio River	18	7	8	4	19	Low
12	**Joe Creason Park**	South Fork BGC	5	10	0	0	10	Low
17	**Butchertown Greenway**	BGC Confluence	2	1	8	0	9	Low
1	**Farnsley Moremen Landing**	Ohio River	5	5	1	1	7	Low
7	**Cherokee Park - Shelter**	Middle Fork BGC	10	6	0	0	6	Low
14	**Eva Bandman Park - Ohio River**	Ohio River	11	2	3	1	6	Low
15	**Eva Bandman Park - Beargrass Creek**	BGC Confluence	3	0	6	0	6	Low
16	**Beargrass Creek at Irish Hill**	Middle Fork BGC	3	4	0	0	4	Low
10	**Seneca Golf Course**	Middle Fork BGC	8	1	1	1	3	Low
8	**Seneca Park - Scenic Loop**	Middle Fork BGC	6	1	1	0	2	Low
11	**Brown Park**	-	8	0	0	0	0	Low
13	**Louisville Junior Academy**	-	4	0	0	0	0	Low

TABLE 2.7.6

SURVEY SITES WITHIN/DOWNSTREAM OF THE CSS PRIORITY RATING SCORES

Park ID	Park Name	Watershed	Average People	% Children	% Potential	% Contact	Total	Rating
2	**Riverview Park**	Ohio River	12	5	12	9	26	Medium
6	**Cherokee Golf Course - Lexington Rd**	Middle Fork BGC	4	1	20	4	25	Medium
3	**Waterfront Park**	Ohio River	18	7	8	4	19	Low
17	**Butchertown Greenway**	BGC Confluence	2	1	8	0	9	Low
1	**Farnsley - Moremen Landing**	Ohio River	5	5	1	1	7	Low
7	**Cherokee Park - Shelter**	Middle Fork BGC	10	6	0	0	6	Low
14	**Eva Bandman Park - Ohio River**	Ohio River	11	2	3	1	6	Low
15	**Eva Bandman Park - BGC**	BGC Confluence	3	0	6	0	6	Low
16	**Beargrass Creek at Irish Hill**	Middle Fork BGC	3	4	0	0	4	Low
8	**Seneca Park - Scenic Loop**	Middle Fork BGC	6	1	1	0	2	Low

2.8 ECOLOGICAL CHARACTERIZATION (SENSITIVE AREA STUDY)

The CSO Control Policy requires consideration and priority ranking of CSO discharges to areas meeting the criteria of sensitive area classification. Using CSO Policy criteria, all forks of Beargrass Creek are classified as sensitive, so no prioritization is possible using these criteria.

To allow prioritization of CSO discharges, MSD developed a process to rate the ecological condition of each stream reach (defined as length between CSO outfalls). Further assessment was necessary to prioritize implementation of the various CSO controls. Beargrass Creek is an urbanized stream, which has resulted in severe stresses to its aquatic environment. These stresses have been caused by the large extent of paved surfaces (Figure 2.8.1 at the end of this chapter) as well as inputs from both non-point and point sources of pollution. Existing stream conditions range from somewhat natural channels with typical biotic components (Figure 2.8.2) to channelized, concrete-lined channels with little to no natural aquatic habitat (Figure 2.8.3).

FIGURE 2.8.2 TYPICAL GOOD QUALITY PORTION OF BEARGRASS CREEK

FIGURE 2.8.3 TYPICAL POOR QUALITY PORTION OF BEARGRASS CREEK

The overall goal of this ecological reach characterization was to construct a framework for prioritizing proposed CSO controls based on the degree of benefit anticipated to be gained by the ecological components of Beargrass Creek from implementation of CSO control measures. Specific study objectives include:

- Provide an ecological component to the decision-making process regarding phasing of CSO controls;
- Provide a measure for distinguishing stream reaches and CSO control projects based on aquatic ecology; and
- Rate and rank stream reaches based on ecologically-related parameters, with high scores indicating those reaches that will benefit most from water quality improvements.

The study is presented here in terms of methodology, results, and conclusion.

2.8.1 Methodology

The ecological characterization study uses an approach that incorporates the biological integrity of existing aquatic communities, as well as the associated physiographic and geomorphologic characteristics of the stream, its riparian corridor, and societal values. The study was undertaken based on identification of discrete stream reaches, selection of appropriate assessment parameters, and the assessment/scoring of each reach under each parameter.

2.8.1.1 Reach Identification

Stream reaches were delineated based on CSO discharge locations, with each reach beginning at a CSO outfall location and continuing downstream to the next CSO outfall location. Some stream reaches may consist of multiple CSOs when the outfalls were located at the same general geographic location and were all considered a component of the same reach. Each stream reach is numbered based on a fork identifier (MU = Muddy Fork; MI = Middle Fork; S = South Fork) and the CSOs that discharges to it. A total of 37 stream reaches were identified: one in Muddy Fork Beargrass Creek; eight in Middle Fork Beargrass Creek; and 28 in South Fork Beargrass Creek.

2.8.1.2 Parameter Selection

Because the effects of CSO discharges are a concern to a diverse group of constituents (residents, communities, businesses, environmental groups, and MSD), prioritization of CSO control measures must consider numerous factors. These include environmental, economic feasibility, asset protection, public health, and regulatory compliance performance. Parameters for each reach were scored using either in situ field observations or from GIS data obtained from federal, state, and local sources. All of the data used for the rating system were organized and used for analysis, display, and query in a GIS using ArcGIS 9.2 software.

Stream reach rating parameters were chosen for this project to reflect the complex dynamics of ecological conditions of streams and the surrounding landuses. A multi-parameter approach was necessary to accurately characterize existing/potential condition of stream reaches, especially in this highly urbanized environment. The 10 parameters selected for this characterization include:

- Accessibility – A measure of the potential for human contact with the creek. Data were obtained through field observations. Reaches where access was encouraged (trails to creek, gradual stream bank angles, lack of fencing, or public ownership) scored high whereas areas where access was discouraged (thick vegetation, fences, steep bank angles, or private ownership) scored low. High scores for this parameter indicate more accessible reaches that would most benefit from water quality improvements.
- Threatened/Endangered Species – A defined component of sensitive areas. Protected species occurrence information in the Beargrass Creek Watershed was obtained through a formal data request to the Kentucky State Nature Preserves Commission. Potential threatened/endangered species within the project area include 14 mussels, two

crustaceans, one insect, and two fish species. The presence of potential habitat for these species was determined based on qualitative observations of stream substrate and overall aquatic habitat in the field by qualified ecologists. High scores for this parameter indicate a greater potential for the presence of one of these species or their habitats, and reaches that would most benefit from water quality improvements.

- Stream Rapid Bioassessment Protocol – A method for assessing stream habitat quality and its ability to harbor a healthy ecological community. Data were obtained at each reach using the EPA's Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers (Barbour et al. 1999). High scores indicate a reach with habitat characteristics that would potentially contain a healthier biological community, and would most benefit from water quality improvements.
- Bank Erosion Hazard Index – A measure of the potential for streambank erosion. Bank Erosion Hazard Index is a quantitative prediction tool to assess erosion potential using a multi-parameter scoring system based on field measurements of bank heights, angles, materials, layers, rooting depth and density, and amount of bank protection (Rosgen 2001). The Bank Erosion Hazard Index data were obtained from the Stream Assessment Report for the Beargrass Creek Watershed. High scores for this parameter reflect a reach with low erosion potential; an indicator of stable habitat for aquatic communities that would most benefit from water quality improvements. Although stream reaches located within the concrete-lined portion of South Fork Beargrass Creek would rate high because of their stability and limited potential to contribute to downstream sedimentation, these reaches are rated low based on their overall inability to harbor the important biological/organic components of natural streambanks or provide basic aquatic habitat.
- Index of Biotic Integrity – An index developed for rating fish community assemblages as an indicator of the degree of impact from pollutants. Data were obtained from MSD's 2005 Long-Term Monitoring Network program. The Index of Biotic Integrity is a multi-metric fish index, which measures stream health using fish community data (Karr et al. 1986). High scores for this parameter indicate a stream reach with favorable ecological integrity that warrants stream protection, and that would most benefit from water quality improvements.
- CSO AAOV – Overflow volume for each CSO was obtained from O'Brien & Gere; a typical rainfall year data was applied to CSS model to predict AAOV. High scores for this parameter represent CSO discharge locations with lower discharge and imply less severe impacts to the reach, healthier aquatic communities, a reduced risk to public health, and a reach that would most benefit from water quality improvements.
- Landuse – A classification system describing the types of human activities (e.g. parks, residences, industrial, etc.) for a given area. Data were created by Louisville Metro Planning and Design Services in 1992 and were obtained through MSD. For this analysis, landuse data were clipped within a 200-foot buffer around each reach and the percentage of each landuse type was determined. High scores represent reaches with a high probability of community activity near the creek (e.g. parks and public areas), that would benefit the most from water quality improvements. See Figure 2.8.4.

- Landcover – Types of vegetative or manmade features covering a landscape. Data were obtained from the USGS National Landcover Database. The National Landcover Database is derived from 2001 satellite (Landsat) imagery and uses the Anderson Level II classification system (Anderson et al. 1976). Landcover raster data were extracted from a 200-foot buffer around each reach using ESRI ArcGIS Spatial Analyst software and the percentage of each type of landcover type was calculated. High scores represent reaches with landcover types that provide shading (tree cover) and reduced stormwater runoff to the creek (pervious surfaces), and would thus benefit most from in-stream water quality improvement.
- Restoration Potential – A qualitative assessment of benefits a stream reach may realize considering the level of effort required to restore aquatic/riparian habitat functions. Reaches were scored based on qualitative field observations by qualified ecologists at each reach in terms of the feasibility and need for stream restoration activities. Feasibility is defined in terms of the scale of construction (for example, costs and effort associated with planting trees, bank shaping, and removal of concrete lining) and accessibility (e.g. equipment access, property ownership, terrain) necessary to perform the work. High scores indicate reaches where lower-cost restoration efforts would provide immediate stream habitat benefits, and benefit the most from water quality improvements.
- Reach Length – The physical measurement of each reach. Length was measured in the GIS as the length from the CSO discharge point along the centerline of the channel to the beginning of the next reach. High scores correspond to longer stream reaches suggesting that water quality improvements and protection measures would provide more benefit to the overall aquatic system by improving a larger portion of the creek per CSO control measure.

2.8.1.3 Scoring

Parameter scores and subsequent reach priority ratings were graded relative to the distribution of results across all reaches within the CSS. The results provide a means for comparing stream reaches located only within the CSS and do not reflect conditions comparative to reaches outside of the CSS or reference conditions. The rating scale reflects the ecological condition of each stream reach and the degree of ecological benefit to be gained by water quality improvements. “Ecological condition” for these purposes was considered to be the existing, or realistic potential of, stream-related communities in terms of biological integrity, ecological function, and aesthetic/public health value. Based on this approach, reaches with high ratings would realize greater benefit from water quality improvements and, therefore, should be given higher priority during the CSO control and implementation decision process.

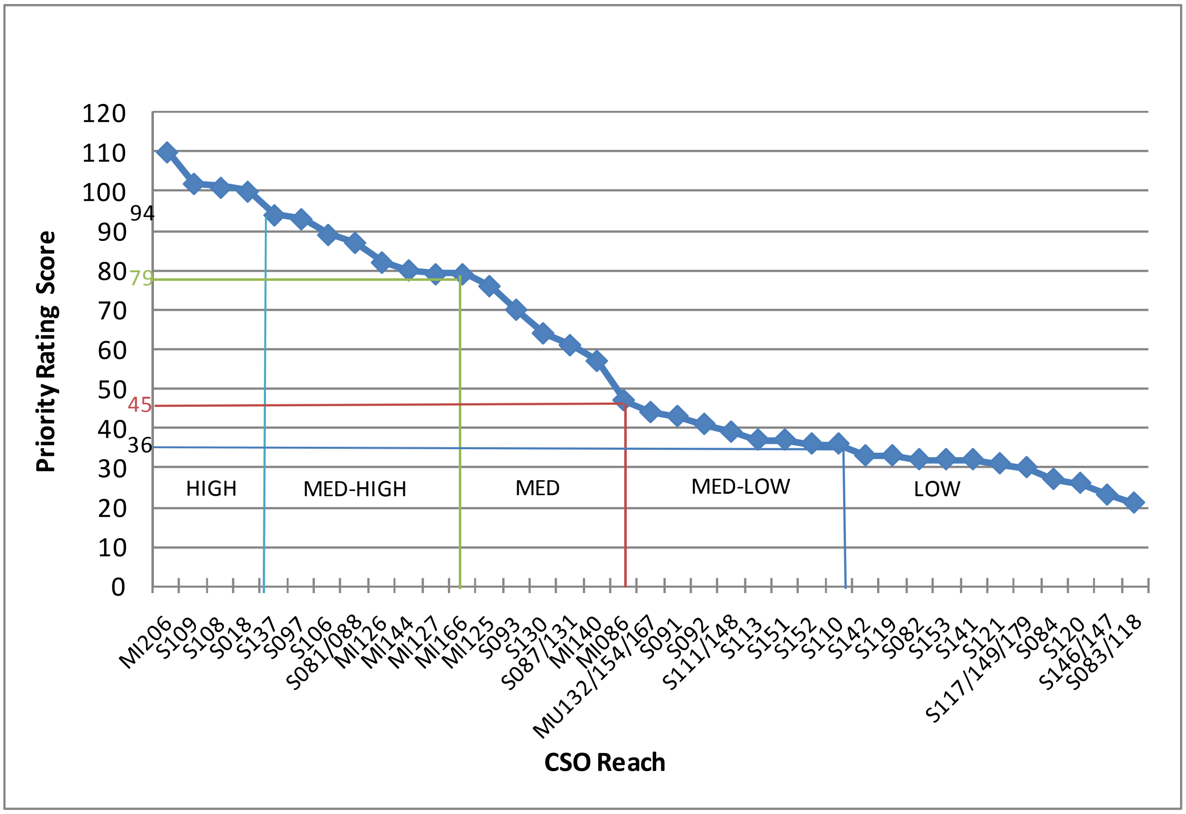
Each reach was assessed under each of the 10 parameters and scored on a 10-point scale, with one being the lowest and 10 the highest. The raw scores for each reach were then adjusted based on a weighting factor for individual parameters to obtain an overall priority rating.

The weighting factor involved doubling the score for three parameters:

1. Threatened/endangered species
2. Stream Rapid Bioassessment Protocol
3. Index of Biotic Integrity

These parameters represent direct measures of existing ecological condition and were therefore, considered of greater relative importance in scoring. The final priority rating is based on the sum of the parameter scores following application of the parameter weighting factor. Potential scores could range from 13 (lowest ecological integrity) to 130 (highest ecological integrity). The scores were then broken into five distinct priority categories for data summary purposes: highest priority; high/medium; medium priority; medium/low; and lowest priority. Breaks between priority rating categories were defined based on the distribution of results using only unique values. An attempt was made to evenly distribute reaches across the priority rating categories; however, final break points were chosen at distinct gaps between reach priority scores. Refer to Figure to 2.8.5 below.

FIGURE 2.8.5 BEARGRASS CREEK ECOLOGICAL REACH CHARACTERIZATION



2.8.2 Results

The final scores of all reaches ranged from 21 to 110 and are provided in Tables 2.8.1 and 2.8.2. The distribution of priority rating scores across the five priority categories is depicted in Figure 2.8.6 at the end of this Chapter.

TABLE 2.8.1

DISTRIBUTION OF PRIORITY RATING SCORES

Score	Priority Category	Number of Reaches
95-130	Highest Priority	4
80-94	High/Medium	6
46-79	Medium Priority	8
37-45	Medium/Low	6
13-36	Lowest Priority	13

Overall, existing ecological condition tends to decrease as the creek moves downstream through the watershed. This suggests that water quality improvements within the upper portions of the watershed may produce greater beneficial effects to the aquatic system as a whole than similar water quality improvements to downstream reaches.

Examples of characterization results are outlined in Table 2.8.2 for high, medium, and low priority reaches.

TABLE 2.8.2

REACH SCORE DISTRIBUTION

Priority Score	Reach Number	Priority Score	Reach Number
110	MI-206	44	MU-132/154/167
102	S-109	43	S-091
101	S-108	41	S-092
100	S-018	39	S-111/148
94	S-137	37	S-113
93	S-097	37	S-151
89	S-106	36	S-110
89	S-081/088	36	S-152
84	MI-126	33	S-119
80	MI-144	33	S-142
79	MI-127	32	S-082
79	MI-166	32	S-141
76	MI-125	32	S-153
70	S-093	31	S-121
64	S-130	30	S-117/149/179
61	S-087/131	27	S-084
57	MI-140	26	S-120
47	MI-086	23	S-146/147
		21	S-083/118
PRIORITY SCORES		**46-79 Medium**	
95-130 Highest Priority		**37-45 Medium/Low**	
80-94 High/Medium		**13-36 Lowest Priority**	

2.8.2.1 High Priority

The upper portions of Middle and South Forks of Beargrass Creek rated higher. These reaches are characterized by wooded riparian corridors and have received fewer human-made disturbances. The highest priority stream reach score is the most upstream reach in Middle Fork at Cherokee Park, Reach MI-206. See Figure 2.8.7. This reach rated as high priority due to its higher quality of aquatic habitat, potential for threatened/endangered species and Index of Biotic Integrity scores. It also exhibits moderately stable banks, is located within a more vegetated watershed, has a relatively low AAOV, good restoration potential, and high accessibility. It scored 110.

FIGURE 2.8.7 HIGH PRIORITY REACH

(MIDDLE FORK BEARGRASS CREEK CSO206)

2.8.2.2 MEDIUM PRIORITY

An example of a medium-rated priority reach is Reach MI-086 (Figure 2.8.8). It has poor accessibility, low quality habitat, and low potential for threatened/endangered species. It also exhibits high discharge volumes (low AAOV score), is located within a developed watershed, and is a relatively short reach. It scored 47.

FIGURE 2.8.8 MEDIUM PRIORITY REACH (MIDDLE FORK BEARGRASS CREEK CSO086)

2.8.2.3 Low Priority

The concrete-lined portion of South Fork Beargrass Creek rated lowest of all reaches and would benefit least from water quality improvements. Reach S-081/118 (Figure 2.8.9) scored low for most parameters. It has poor accessibility and little to no viable aquatic habitat, although it did exhibit a moderate fish population (Index of Biotic Integrity). It also has a large AAOV, urban/developed landuse and landcover, little restoration potential, and short reach length. It scored 21.

FIGURE 2.8.9 LOW PRIORITY REACH (SOUTH FORK BEARGRASS CREEK CSO081 AND CSO118)

2.8.3 Conclusion

In order to provide cost-effective CSO control implementation, it is important that a phased approach be used that will target the most problematic areas while protecting existing sensitive features. Because CSOs impact a diverse set of constituents, numerous factors must be considered when prioritizing and evaluating CSO control alternatives.

The Beargrass Creek Ecological Reach Characterization Report (Appendix 2.8.1) presents one component of a multifaceted decision process framework that is being used in development of a LTCP for the Louisville Metro CSS. This tool was developed to provide a means for comparing individual stream reaches within the CSS in terms of ecological condition. High scores/ratings indicate more favorable ecological conditions that would most benefit from water quality improvements. The results do not imply that stream reaches with high priority ratings should be the sole target for CSO control activities since all portions of Beargrass Creek must meet water quality standards. The parameters used for this rating system were chosen in an attempt to reflect the complex and dynamic interaction between ecological condition of streams, diverse constituencies, and varied landuse practices in urban environments. Results of this prioritization process and ecological reach ranking are one of numerous components integrated into the Final CSO LTCP selection process and implementation schedule, to be established by the community Stakeholder Group in compliance with the value-based risk management process.

2.9 RECEIVING WATER CHARACTERIZATION

System characterization, monitoring, and modeling are one of the nine elements of a long-term CSO control plan. Receiving water characterization, monitoring, and modeling "establishes the existing baseline conditions and provides the basis for determining receiving water goals and priorities and identifying specific CSO controls in the LTCP" (EPA, 1995). MSD has conducted receiving water monitoring and reviewed water quality data for Beargrass Creek and the Ohio River near Louisville (river mile 594 to 620) since the start of the CSO program in 1991 (MSD, 2006a; MSD, 2006b). The most recent assessments are documented in *Water Quality Status Report: Beargrass Creek and Ohio River at Louisville* (LimnoTech, 2007).

This section presents the water quality standards and summarizes the findings of the 2007 assessment, and provides a review of data obtained after the status report was completed.

The review of the available receiving water quality data show that the following:

- All three tributary branches of Beargrass Creek and the Ohio River (river mile 593 to 621) are listed as being impaired by pathogens. E. Coli and fecal coliform bacteria concentrations are significantly higher during wet weather conditions. CSOs are contributing to these impairments.
- The lower portions of Beargrass Creek, Middle Fork, and Muddy Fork are listed as being impaired by organic enrichment (causing low dissolved oxygen levels). pH violations may also be indicative of organic impairment. CSOs may be contributing to these impairments.
- Biological conditions are generally poor to fair at most of the monitored locations, which is not uncommon for urbanized watersheds.

The receiving water data were used to calibrate and confirm the receiving water quality models. The models were then applied to establish current (baseline) conditions, establish how CSOs and other sources are impacting water quality, and to assess the effectiveness of controls in attaining water quality standards.

2.9.1 Water Quality Standards

Water quality standards are established for MSD's receiving waters by the Kentucky Natural Resources and Environmental Protection Cabinet Department for Environmental Protection and the Ohio River Valley Water Sanitation Commission (ORSANCO). Kentucky's Water Quality Regulations establish surface water use classifications for all waters of the Commonwealth. Kentucky has designated stream uses for the surface water bodies within the Ohio River near Louisville and the Beargrass Creek Basin is summarized in Table 2.9.1.

ORSANCO has designated the Ohio River as "public and industrial water supplies after reasonable treatment, suitable for recreational usage, capable of maintaining fish and other aquatic life."

TABLE 2.9.1

STREAM USE DESIGNATION

Stream	Use Designation
Ohio River - Main Stem	Warm Water Aquatic Habitat, Primary Contact Recreation, Secondary Contact Recreation, Domestic Water Supply
South Fork Beargrass Creek and Tributaries	Warm Water Aquatic Habitat, Primary Contact Recreation, Secondary Contact Recreation
Middle Fork Beargrass Creek and Tributaries	Warm Water Aquatic Habitat, Primary Contact Recreation, Secondary Contact Recreation
Muddy Fork Beargrass Creek and Tributaries	Warm Water Aquatic Habitat, Primary Contact Recreation, Secondary Contact Recreation

To protect warm water aquatic life uses, Kentucky's standards require that:

- Dissolved oxygen is to be maintained at a minimum concentration of 5.0 mg/l daily average; the instantaneous minimum shall not be less than 4.0 mg/l.
- Total dissolved solids and TSS are not to be changed to the extent that the indigenous aquatic community is adversely affected.
- pH to be no greater than nine, and no less than six at any time.
- The addition of settleable solids that may alter the stream bottom to affect productive aquatic communities adversely is prohibited.
- The concentration of un-ionized ammonia shall not be greater than 0.05 mg/l at any time in-stream after mixing.

ORSANCO's standards also require that the dissolved oxygen in the main stem of the Ohio River not be less than 5.1 mg/l during the August 15 to June 15 spawning season. Kentucky and ORSANCO have bacteria criteria for protection of primary contact recreational uses (for example, swimming), as shown in Table 2.9.2. These criteria apply during the recreation season of May 1 to October 31. Kentucky's standards apply during any 30-day period whereas ORSANCO's standards are applied on a monthly basis.

For the non-recreational period from November 1 to April 30, Kentucky's fecal coliform criteria are the same as the criteria for secondary contact recreation (that is, "waters that are suitable for partial body contact recreation, with minimal threat to public health due to water quality"). Kentucky's standards state:

"Fecal coliform content shall not exceed 1,000 colonies per 100 ml as a thirty (30) day geometric mean based on not less than five (5) samples; nor exceed 2,000 colonies per 100 ml in twenty (20) percent or more of all samples taken during a thirty (30) day period."

ORSANCO has also established criteria for the Ohio River main stem for protection of public water supply uses at all times as follows:

"Fecal coliform bacteria content shall not exceed 2,000/100 ml as a monthly geometric mean based on not less than five samples per month."

TABLE 2.9.2

INDICATOR BACTERIA CRITERIA FOR PROTECTION OF PRIMARY CONTACT RECREATION

Indicator Bacteria	Standard	Geometric Mean[1] (per 100 ml)	Instantaneous Maximum[2] (per 100ml)	Period For Measuring Compliance
Fecal Coliform bacteria	Kentucky	200	400 (no more than 20%)	Any 30-day period
	ORSANCO	200	400 (no more than 10%)	Monthly
E. Coli bacteria	Kentucky	130	240	Any 30-day period
	ORSANCO	130	240	Monthly

[1] The geometric mean for both Kentucky and ORSANCO are to be calculated using no less than 5 samples.

[2] Kentucky and ORSANCO allow 20% of the samples during a period to exceed the instantaneous maximum criterion. ORSANCO's standards specify that E. Coli shall not exceed 240 per 100 ml in any sample.

A key principle of the 1994 CSO Control Policy is "[r]eview and revision, as appropriate, of water quality standards and their implementation procedures when developing CSO control plans to reflect site-specific wet weather impacts of CSOs" (59 FR 18688). Review and revision of standards is accomplished through a Use Attainability Analysis (UAA). A UAA is a structured scientific assessment of the factors affecting the attainment of uses specified in Section 101(a)(2) of the CWA. In response to directives from Congress, EPA developed guidance in 2001 for coordinating water quality standards reviews for water bodies where long-term CSO control plans will be implemented because "implementation of this principle has not progressed as quickly as expected" (US EPA, 2001). Several states such as Maine (MDEP, 2003), Massachusetts (MassDEP, 2007), and Indiana (IDEM, 2008) have adopted provisions in their water quality standards to recognize the challenges associated with attaining recreational uses even after CSO controls have been fully implemented. ORSANCO has provisions in its water quality standards for the Ohio River allowing for development and application of alternative criteria if CSO communities have submitted a long-term CSO control plan and a UAA.

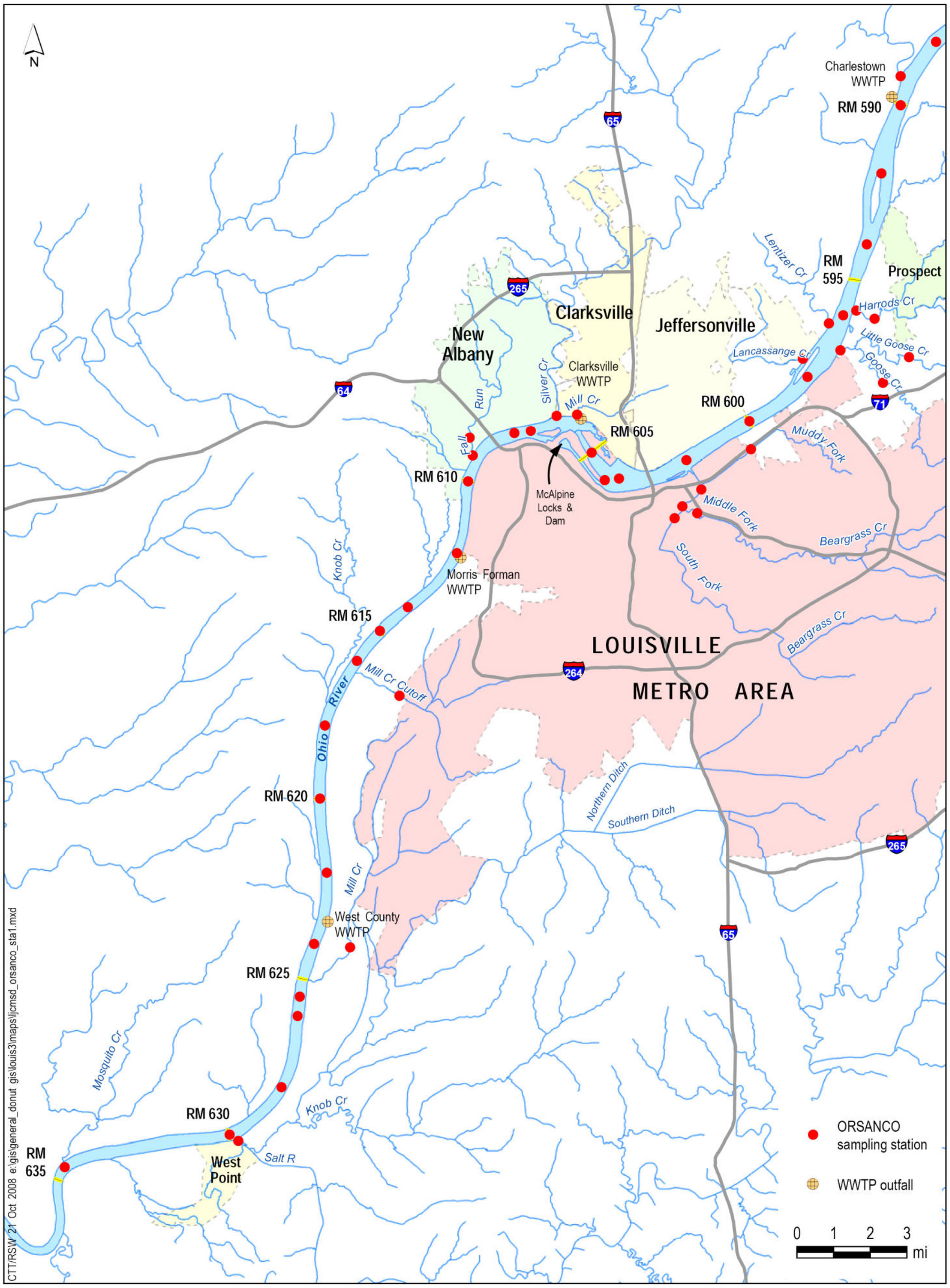
2.9.2 Receiving Water Quality Monitoring Analysis – Ohio River

Receiving water quality data are available for the Ohio River from ORSANCO for 2000 to 2007. ORSANCO's monitoring stations (and Ohio River miles) are shown on Figure 2.9.1. A total of 596 fecal coliform measurements and 596 E. Coli measurements were taken as part of ORSANCO's routine monitoring on the Ohio River in the Louisville Metro area during the period 2000-2007. E. Coli data (1,008 measurements) were obtained from ORSANCO's five-week longitudinal, "snapshot" and tributary only surveys of the Ohio River for the period October 2003 to October 2007. Both data sets were analyzed in terms of average concentrations during wet and dry weather periods as well as percentage of individual samples exceeding specific target levels. Samples were characterized as "wet" using hourly rainfall from the Louisville International Airport (Standiford Field) and the following criteria:

- Precipitation greater than or equal to 0.1 inch within 24 hours of sample collection;
- Precipitation greater than or equal to 0.25 inch within 25-48 hours of sample collection; and
- Precipitation greater than or equal to 0.5 inch within 49-72 hours of sample collection.

A separate analysis was conducted on the bacteria data collected by ORSANCO as part of their Wet Weather Demonstration Project during 2001. Water quality data for other parameters from ORSANCO's routine sampling of the Ohio River main stem are summarized as well.

FIGURE 2.9.1 ORSANCO OHIO RIVER MONITORING STATIONS



2.9.2.1 Average Bacterial Concentrations from Routine Monitoring

Figure 2.9.2 shows a summary display of average fecal coliform concentrations for each of the routine ORSANCO monitoring stations, stratified by climatic condition. Concentrations at River Mile 594.0 (upstream of the CSOs) are similar to concentrations at River Mile 608.7 (downtown, downstream of the CSOs). The highest concentrations are observed at River Mile 619.3, which is downstream of the Mill Creek Cutoff. Concentrations at this location are also noticeably higher during wet weather periods. Results are displayed in similar format in Figure 2.9.3 for E. Coli, with similar results.

FIGURE 2.9.2 AVERAGE FECAL COLIFORM LEVELS DURING WET AND DRY PERIODS AT THREE STATIONS ON THE OHIO RIVER NEAR LOUISVILLE, KY USING DATA FROM 2000 TO 2007

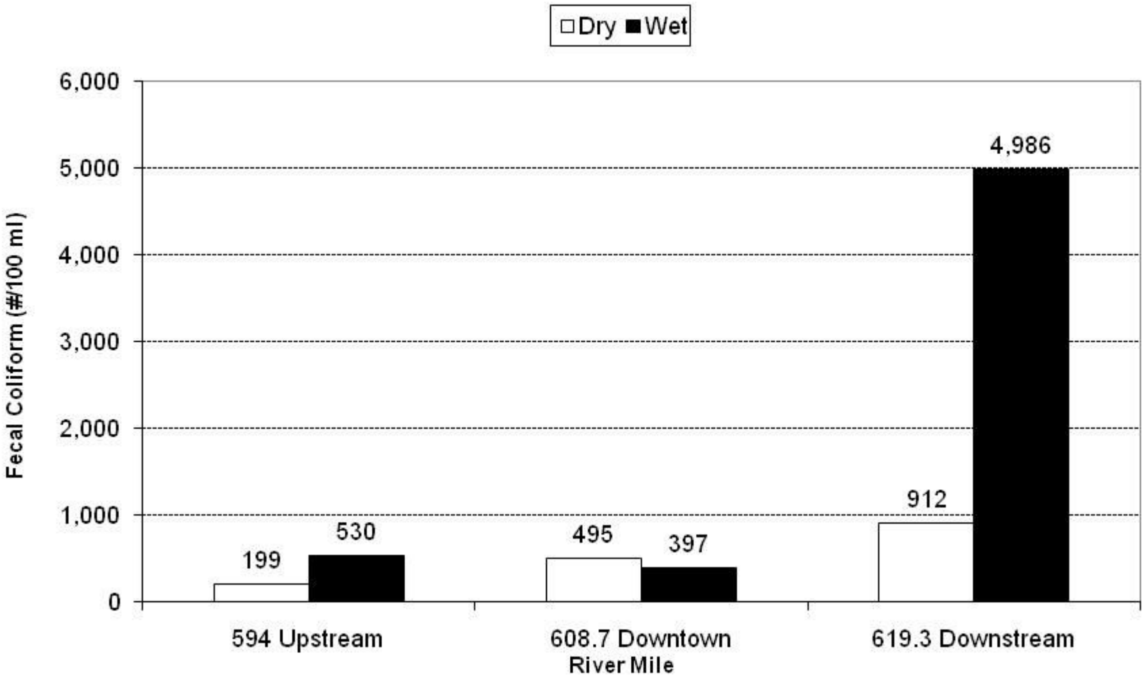
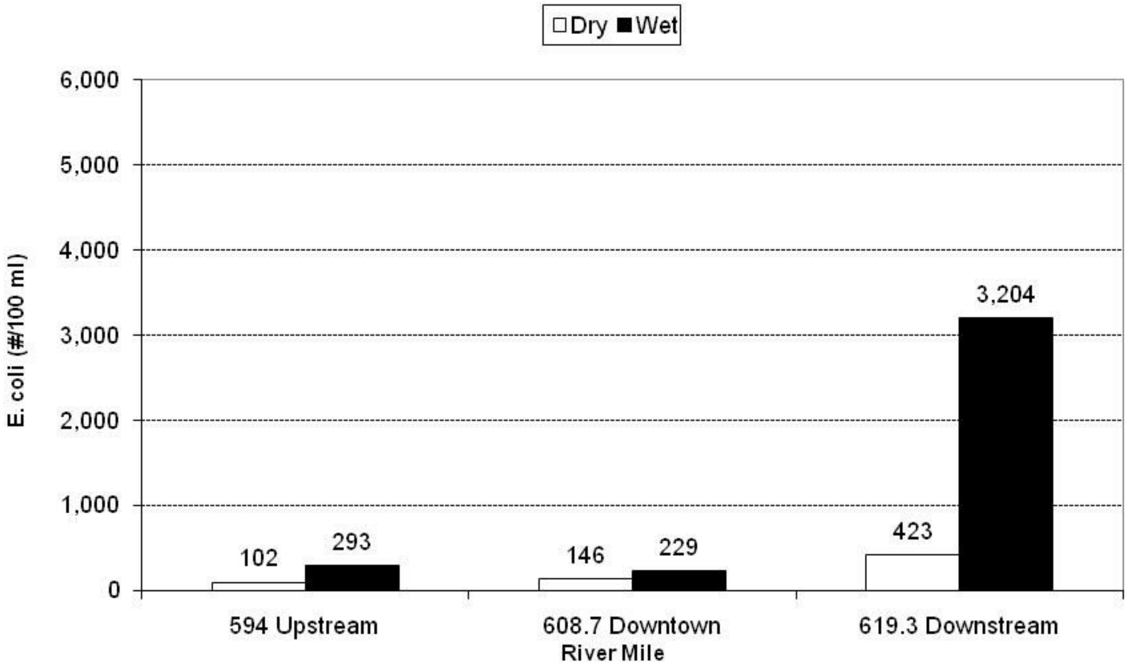


FIGURE 2.9.3 AVERAGE E. COLI LEVELS DURING WET AND DRY PERIODS AT THREE STATIONS ON THE OHIO RIVER NEAR LOUISVILLE, KY USING DATA FROM 2000 TO 2007



Figures 2.9.4 and 2.9.5 show temporal variability in average (geometric mean) dry and wet weather concentrations at the location upstream of the CSOs (River Mile 594) for fecal coliform and E. Coli, respectively. Figures 2.9.6 and 2.9.7 provide similar results for River Mile 608.7 (downtown, downstream of the CSOs), while Figures 2.9.8 and 2.9.9 represent 619.3 (downstream of the Mill Creek Cutoff). No long-term trend is consistently observed across all three stations.

FIGURE 2.9.4 AVERAGE FECAL COLIFORM LEVELS DURING WET AND DRY PERIODS AT RIVER MILE 594 ON THE OHIO RIVER

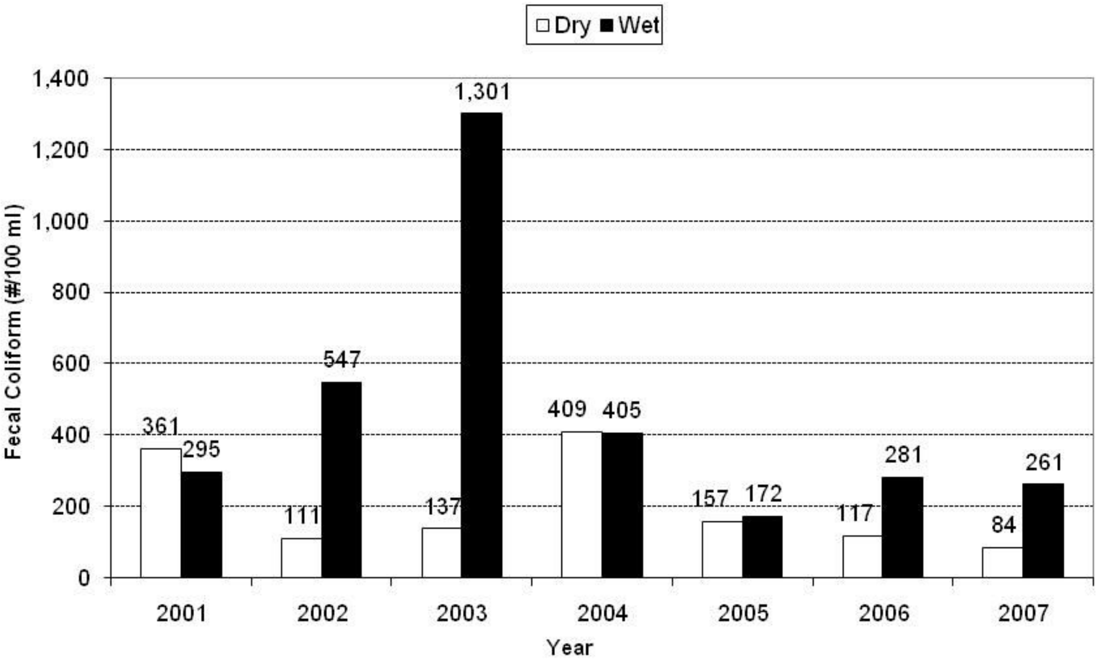


FIGURE 2.9.5 AVERAGE E. COLI LEVELS DURING WET AND DRY PERIODS AT RIVER MILE 594 ON THE OHIO RIVER

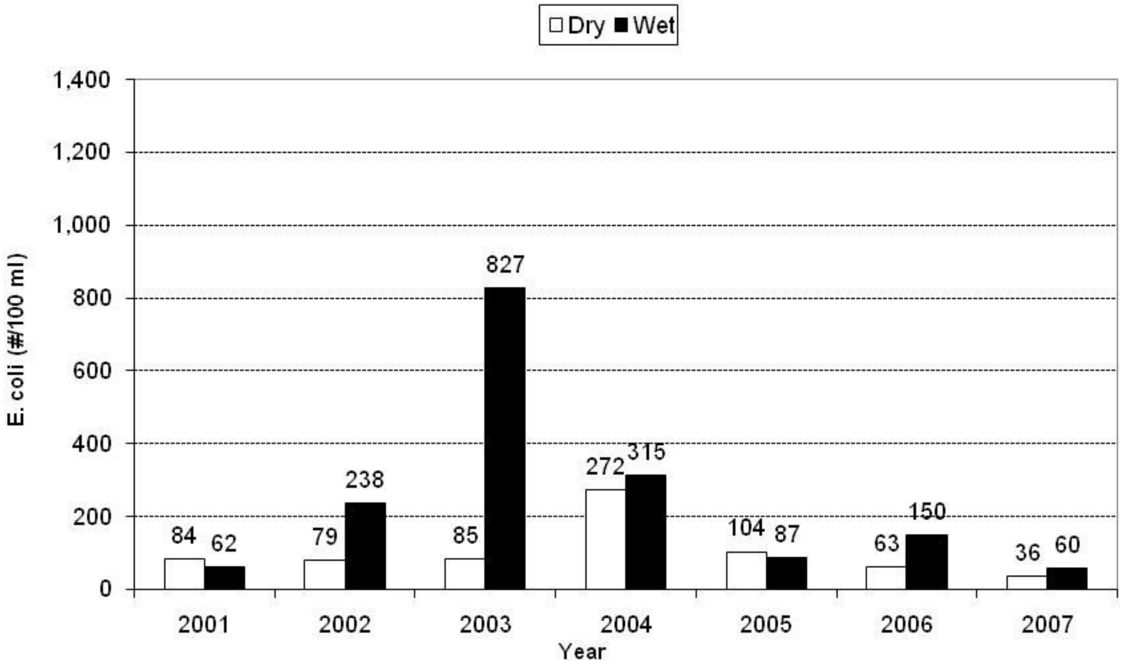


FIGURE 2.9.6 AVERAGE FECAL COLIFORM LEVELS DURING WET AND DRY PERIODS AT RIVER MILE 608.7 ON THE OHIO RIVER

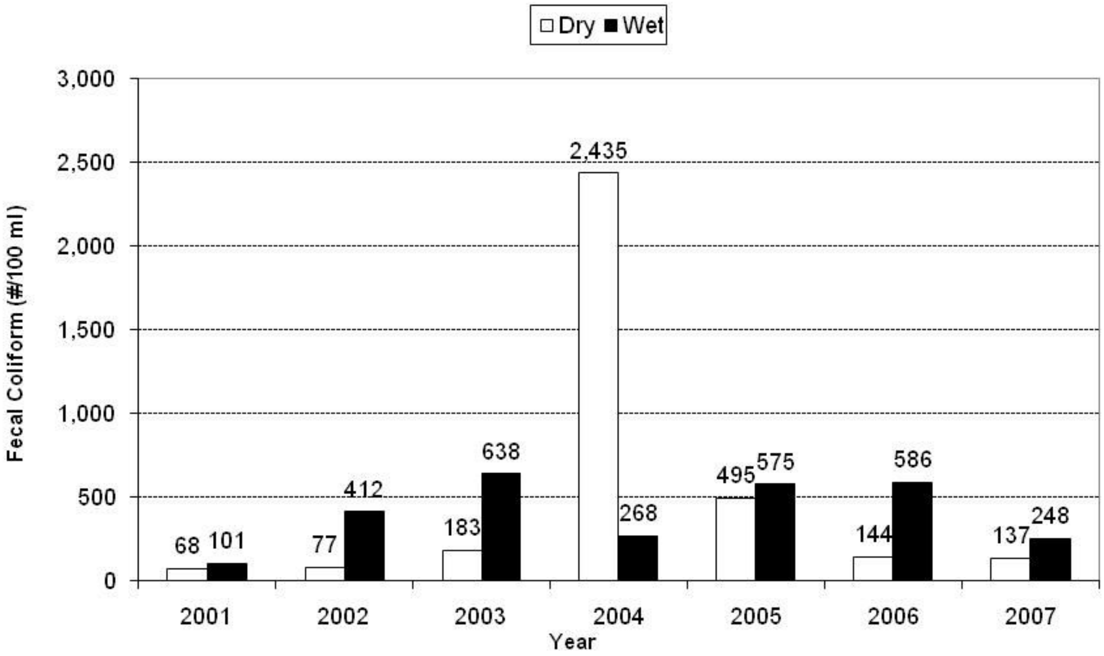


FIGURE 2.9.7 AVERAGE E. COLI LEVELS DURING WET AND DRY PERIODS AT RIVER MILE 608.7 ON THE OHIO RIVER

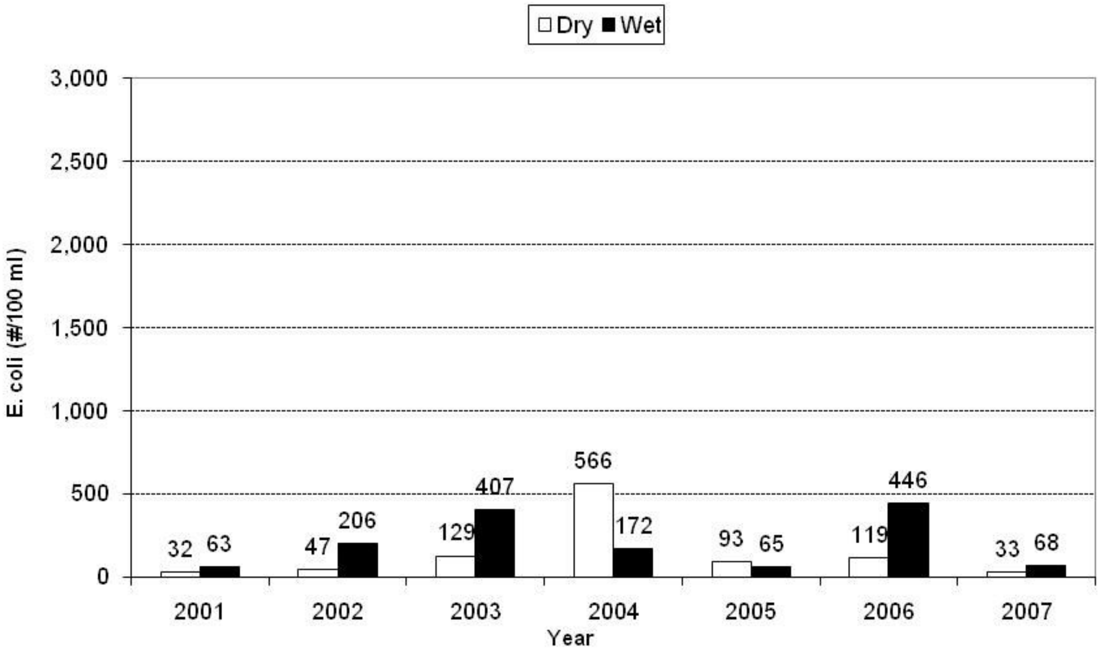


FIGURE 2.9.8 AVERAGE FECAL COLIFORM LEVELS DURING WET AND DRY PERIODS AT RIVER MILE 619.3 ON THE OHIO RIVER

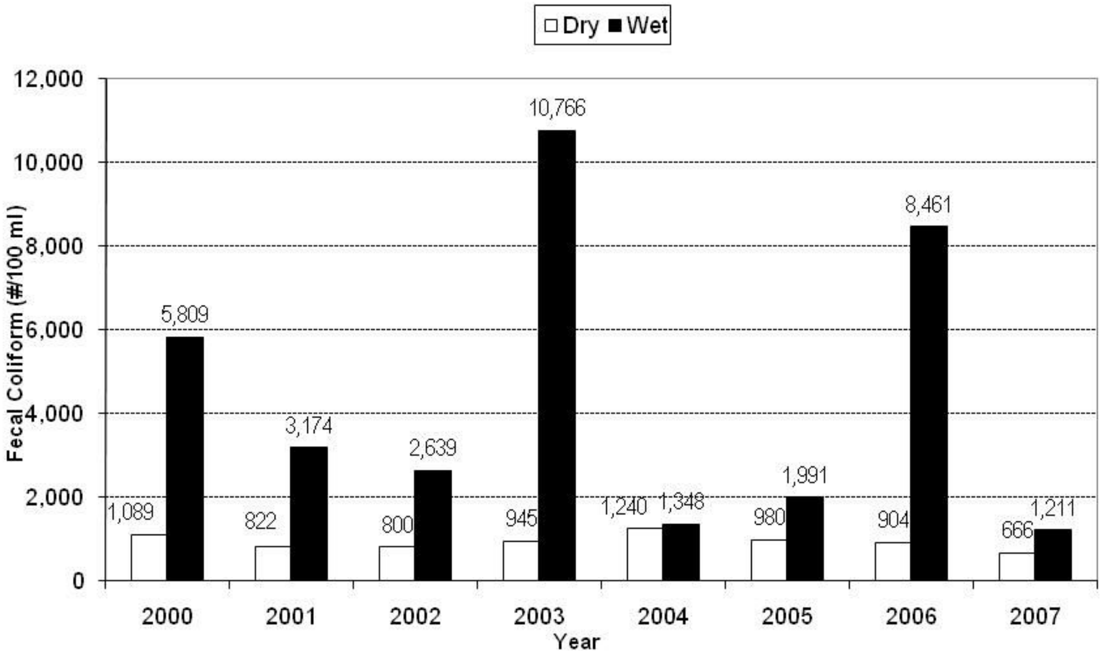
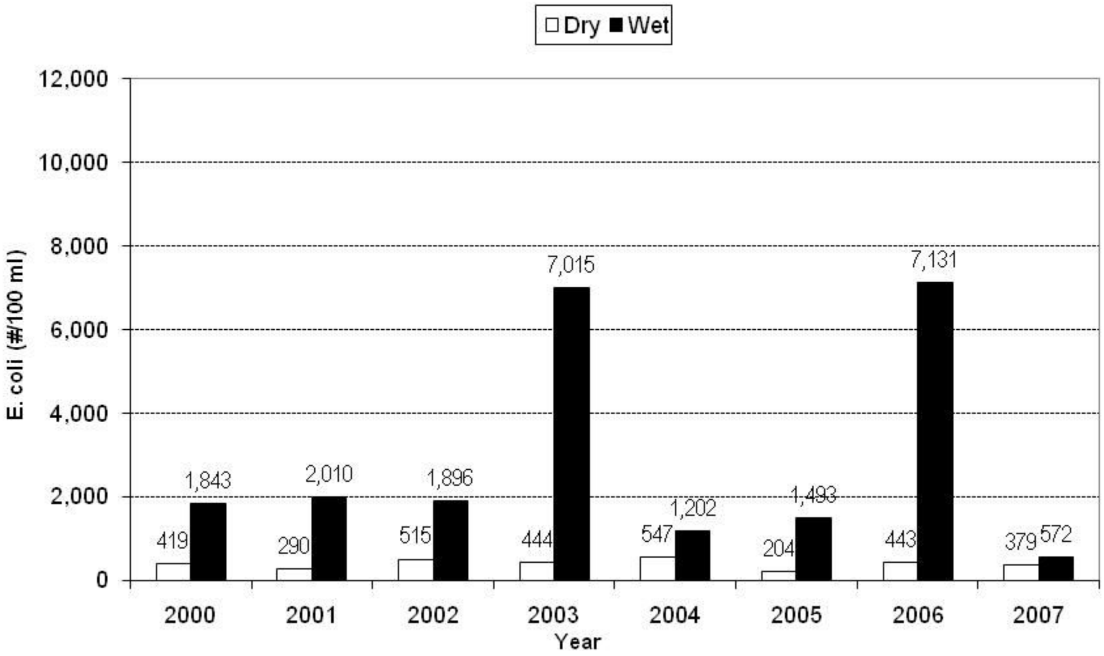


FIGURE 2.9.9 AVERAGE E. COLI LEVELS DURING WET AND DRY PERIODS AT RIVER MILE 619.3 ON THE OHIO RIVER



2.9.2.2 Frequency of Exceedance of Bacterial Targets from Routine Monitoring

This section examines the frequency of exceedances of the monthly geometric mean criteria and the instantaneous maximum in the Ohio River exceeded the fecal coliform and E. Coli criteria. Available routine monitoring data from each station was used to calculate the number of exceedances of the geometric mean criterion for each monthly period. Available data was used to calculate the percent of samples that were greater than the instantaneous maximum criterion for dry and wet weather samples. Note that this is not a direct comparison to water quality standards for fecal coliform, since the criteria allow for 10 percent of the samples to exceed the criterion during a month. A comparison to the instantaneous maximum criterion for fecal coliform was conducted based on the percentage of samples exceeding the criterion each month.

The comparison of the geometric mean criterion for E. Coli is shown in Table 2.9.3. In most instances, there were five samples collected during each month (a few of the months had only four samples). Exceedances are relatively infrequent (17-50 percent) at the upstream and downtown stations, but are prevalent (67-100 percent) at the downstream station.

TABLE 2.9.3

NUMBER OF EXCEEDANCES OF THE E. COLI 30-DAY GEOMETRIC MEAN OF 130 PER 100 ML

Year	RM 594.0 (Upstream)			RM 608.7 (Downtown)			RM 619.3 (Downstream)		
	No. Months GM > 130	Total No. Months	% Months GM > 130	No. Months GM > 130	Total No. Months	% Months GM > 130	No. Months GM > 130	Total No. Months	% Months GM > 130
2000							5	6	83%
2001	0	6	0%	0	6	0%	6	6	100%
2002	2	6	33%	1	6	17%	4	6	67%
2003	3	6	50%	3	6	50%	6	6	100%
2004	3	6	50%	2	6	33%	6	6	100%
2005	0	2	0%	0	2	0%	2	2	100%
2006	0	6	0%	1	6	17%	6	6	100%
2007	0	6	0%	0	6	0%	1	6	17%

Table 2.9.4 shows that exceedances of the fecal coliform geometric mean criterion are similar to those of the E. Coli criterion. Exceedances are relatively infrequent (17-67 percent) at the upstream and downtown stations, but are prevalent (50-100 percent) at the downstream station.

TABLE 2.9.4

NUMBER OF EXCEEDANCES OF THE FECAL COLIFORM

30-DAY GEOMETRIC MEAN OF 200 PER 100 ML.

Year	RM 594.0 (Upstream)			RM 608.7 (Downtown)			RM 619.3 (Downstream)		
	No. Months GM > 200	Total No. Months	% Months GM > 200	No. Months GM > 200	Total No. Months	% Months GM > 200	No. Months GM > 200	Total No. Months	% Months GM > 200
2000							6	6	100%
2001	1	6	17%	0	6	0%	6	6	100%
2002	2	6	33%	1	6	17%	6	6	100%
2003	3	6	50%	4	6	67%	6	6	100%
2004	2	6	33%	2	6	33%	5	6	83%
2005	0	2	0%	1	2	50%	2	2	100%
2006	0	6	0%	1	6	17%	6	6	100%
2007	0	6	0%	1	6	17%	3	6	50%

Table 2.9.5 shows the percent of samples where the E. Coli concentrations were greater than the instantaneous maximum criterion of 240 per 100 ml. Table 2.9.6 shows a similar comparison for fecal coliform. Again, the percentage of samples that were greater than the criteria levels was similar at the location upstream of the CSOs (River Mile 594) and downstream of the CSOs (River Mile 608.7). The percentage of samples with concentrations that were greater than the instantaneous maximum criterion were higher downstream of the Mill Creek Cutoff (River Mile 619.3).

TABLE 2.9.5

NUMBER OF E. COLI SAMPLES THAT WERE GREATER THAN THE INSTANTANEOUS MAXIMUM OF 240 PER 100 ML

River Mile (RM)	No. of Dry Weather Samples		% Dry	No. of Wet Weather Samples		%Wet	%All Samples
	Greater Than	Total		Greater Than	Total		
RM 594.0	11	104	11%	19	85	22%	16%
RM 608.7	11	103	11%	20	86	23%	16%
RM 619.3	38	116	33%	66	102	65%	48%

TABLE 2.9.6

NUMBER OF FECAL COLIFORM SAMPLES THAT WERE GREATER THAN THE INSTANTANEOUS MAXIMUM OF 400 PER 100 ML

River Mile	No. of Dry Weather Samples		% Dry	No. of Wet Weather Samples		%Wet	%All Samples
	Greater Than	Total		Greater Than	Total		
RM 594.0	8	104	8%	21	85	25%	15%
RM 608.7	10	103	10%	23	86	27%	17%
RM 619.3	51	116	44%	75	102	74%	58%

2.9.2.3 Longitudinal and "Snapshot" Data for the Ohio River

E. Coli data (1,008 measurements) were obtained from ORSANCO's five-week longitudinal, "snapshot" and tributary surveys of the Ohio River and tributary mouths for the period October 2003 to October 2007. For the Ohio River main stem, data were collected on the Kentucky side (left-descending bank), the middle of the river, and the Indiana side (right-descending bank). Louisville Metro CSO study area. Results for these surveys are presented in Figures 2.9.10 through 2.9.14.

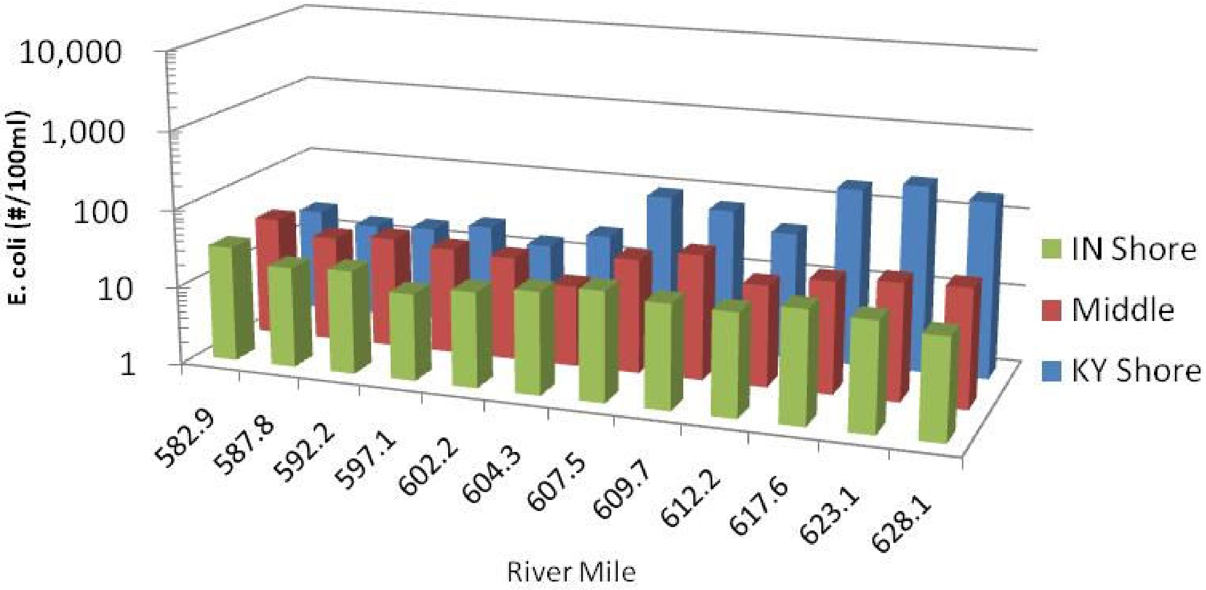
Surveys were generally conducted on a weekly basis during the longitudinal surveys. Some of the data therefore reflect dry weather conditions, and some of the data reflect wet weather conditions. Table 2.9.7 provides a summary of the number of surveys that were reflective of dry and wet weather conditions and the total amount of rain falling during that period or preceding the survey. The May 25 to June 22, 2006, survey (Figure 2.9.10) is reflective of more wet weather conditions whereas the October 4 – 8, 2007, (Figure 2.9.11) is reflective of dry weather conditions. Under wet weather conditions, E. Coli concentrations increase in the CSO-impacted area but are highest well downstream of the CSO-impacted area.

TABLE 2.9.7

NUMBER OF DRY AND WET WEATHER SURVEY DAYS FOR THE ORSANCO LONGITUDINAL AND TRIBUTARY SURVEYS

Survey Period	No. of Survey Days		Total Rain (in)
	Dry	Wet	
October 2 - 30, 2003	3	2	2.15
May 12 - June 7, 2005	4	1	5.53
May 25 to June 22, 2006	4	1	6.24
July 24 to August 21, 2006	3	2	4.63
July 30 - 31, 2007	1	1	0.58
September 4 - 5, 2007	2	0	0
October 4 - 8, 2007	2	0	0

FIGURE 2.9.10 E. COLI CONCENTRATIONS FOR THE OCTOBER 2-30, 2002 LONGITUDINAL SURVEY OF THE OHIO RIVER



LONGITUDINAL SURVEY OF THE OHIO RIVER

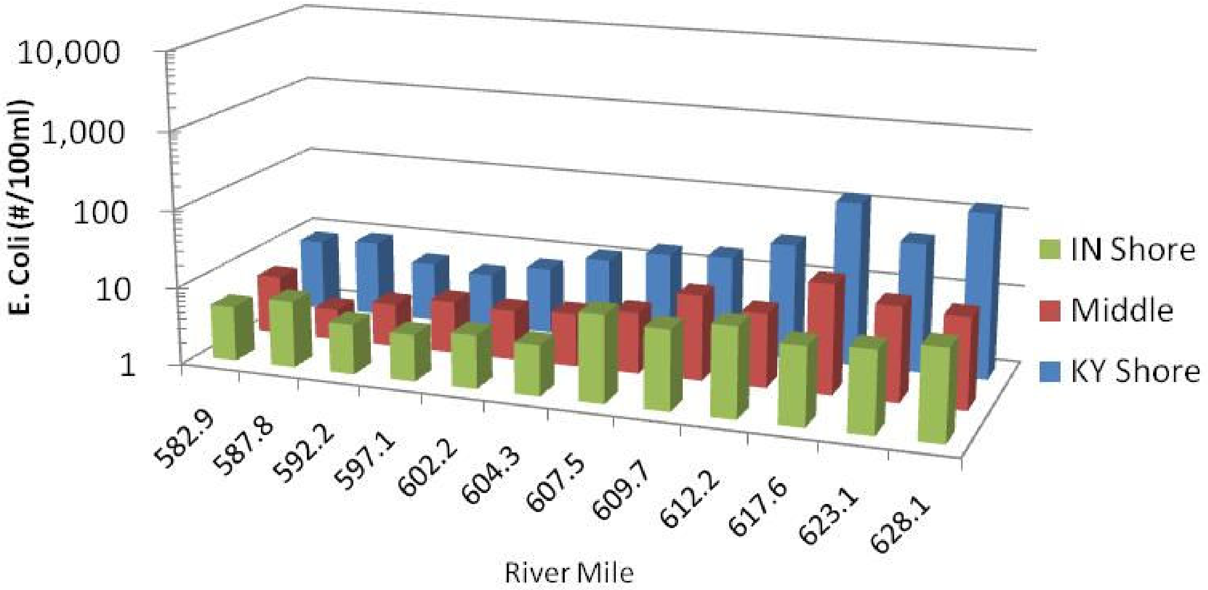


FIGURE 2.9.12 E. COLI CONCENTRATIONS FOR THE MAY 25 TO JUNE 22, 2006
LONGITUDINAL SURVEY OF THE OHIO RIVER

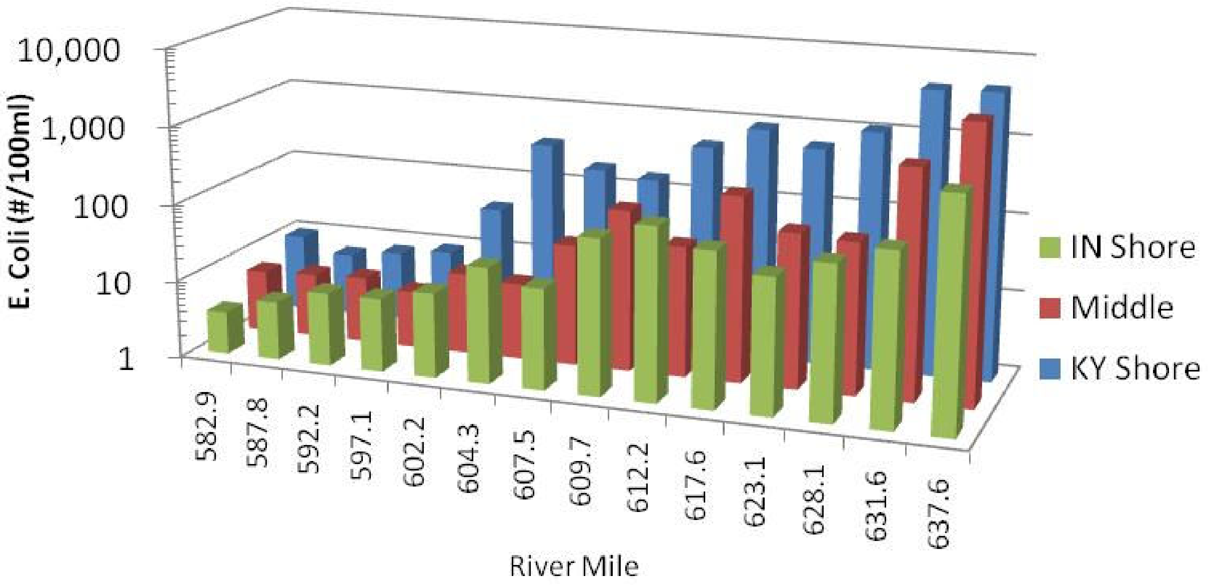


FIGURE 2.9.13 E. COLI CONCENTRATIONS FOR THE JULY 24 TO AUGUST 21, 2006 LONGITUDINAL SURVEY OF THE OHIO RIVER

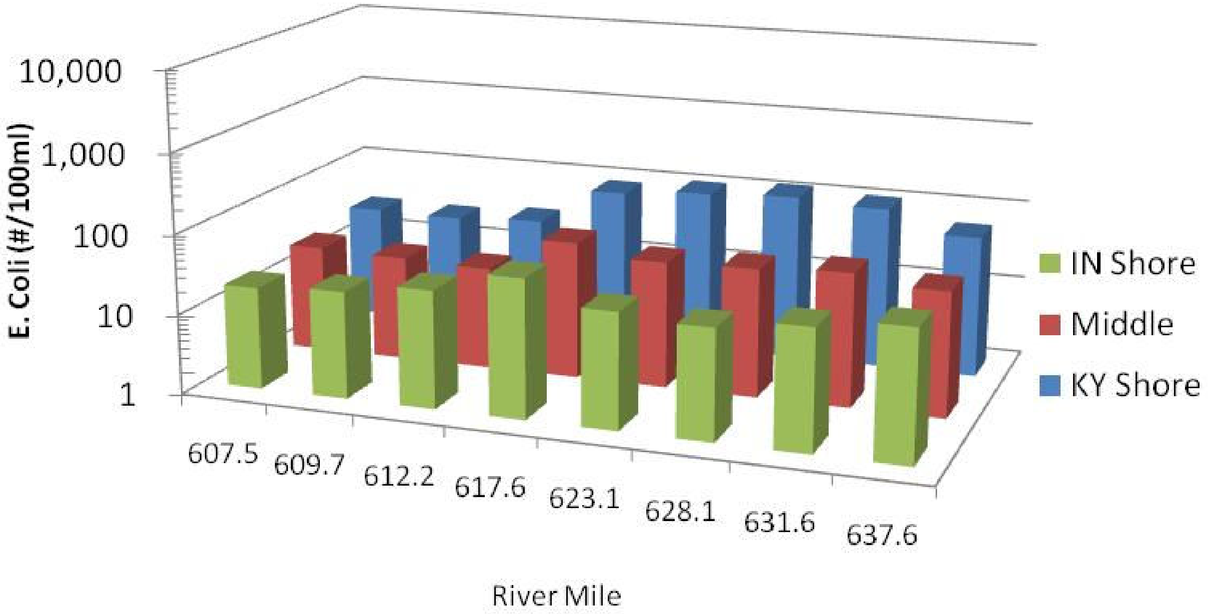


FIGURE 2.9.14 E. COLI CONCENTRATIONS FOR THE OCTOBER 4 -8, 2007 LONGITUDINAL SURVEY OF THE OHIO RIVER

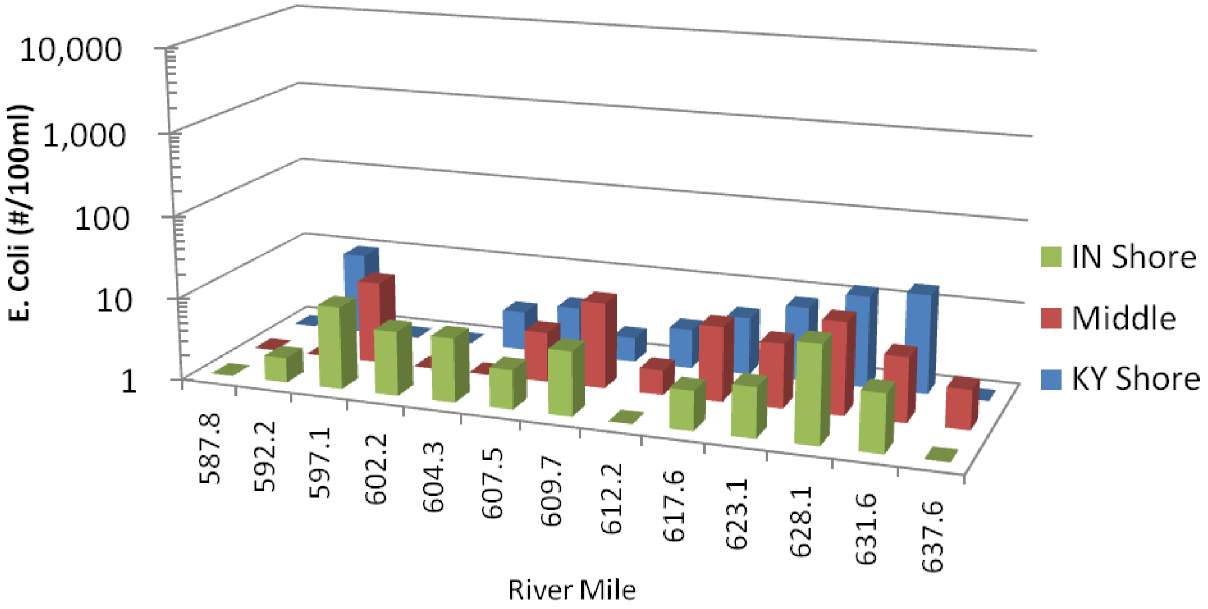


Table 2.9.8 presents a summary of the total number of E. Coli longitudinal survey samples available from 2003 to 2007 for the Ohio River main stem along the Kentucky shore that exceeded the instantaneous maximum criterion of 240 per 100 ml. Although there is an increase (6 to 19 percent) within the CSO-impacted area, the largest increase is downstream of the Mill Creek Cutoff.

The tributary sampling data are presented in Table 2.9.9 for periods when data were collected on Beargrass Creek. In general, concentrations in Beargrass Creek are significantly higher than the other tributaries. E. Coli concentrations at some of the other tributaries exceed the instantaneous maximum criterion of 240 per 100 ml. The percent of samples at the tributary mouths that exceeded the instantaneous maximum (shown in Table 2.9.10) was greater than 10 percent for all tributaries and was highest for Beargrass Creek (100 percent).

TABLE 2.9.8

PERCENT OF LONGITUDINAL E. COLI SAMPLES ON THE OHIO RIVER THAT EXCEEDED THE INSTANTANEOUS MAXIMUM OF 240 PER 100ML (2003-2007)

Station	No. >240	Total No.	Percent > 240
RM_582.9	0	15	0%
RM_587.8	0	16	0%
RM_592.2	0	16	0%
RM_597.1	0	16	0%
RM_602.2	1	16	6%
RM_604.3	3	16	19%
RM_607.5	4	21	19%
RM_609.7	4	21	19%
RM_612.2	3	21	14%
RM_617.6	8	21	38%
RM_623.1	8	21	38%
RM_628.1	8	21	38%
RM_630	5	10	50%
RM_631.6	11	20	55%
RM_637.6	9	20	45%
Total	**64**	**271**	**24%**

RM = River Mile

TABLE 2.9.9

E. COLI CONCENTRATIONS FOR THE MOUTHS OF THE OHIO RIVER TRIBUTARIES

Tributary Station	May 25 to June 9, 2005 (#/100 ml)	July 30 to 31, 2007 (#/100 ml)	September 4 to 5, 2007 (#/100 ml)	October 4 to 8, 2007 (#/100 ml)
RM_595.9-Harrods_Ck	268	990	629	327
RM_597-Goose_Ck	759	113	8	71
RM_602.1-a_Muddy_Fk_BGC	5,438	353	216	399
RM_602.1-b_Middle_Fk_BGC	12,597	10,200	12,700	14,100
RM_602.1-c_South_Fk_BGC	7,278	680	194	634
RM_605.2-Cane_Run	3,400	1,210	5,400	361
RM_606.2-Mill_Ck (IN)	2,370	133	130	228
RM_606.5-Silver_Ck	3,670	290	25	435
RM_609.3-Falling_Run	4,214	469	55	1,150
RM_616.4-Mill_Ck_Cutoff	1,566	104	10	5
RM_625-Mill_Ck(KY)	976	47	11	57
RM_629.9-b_Salt_Ck	132			7
RM = River Mile				

TABLE 2.9.10

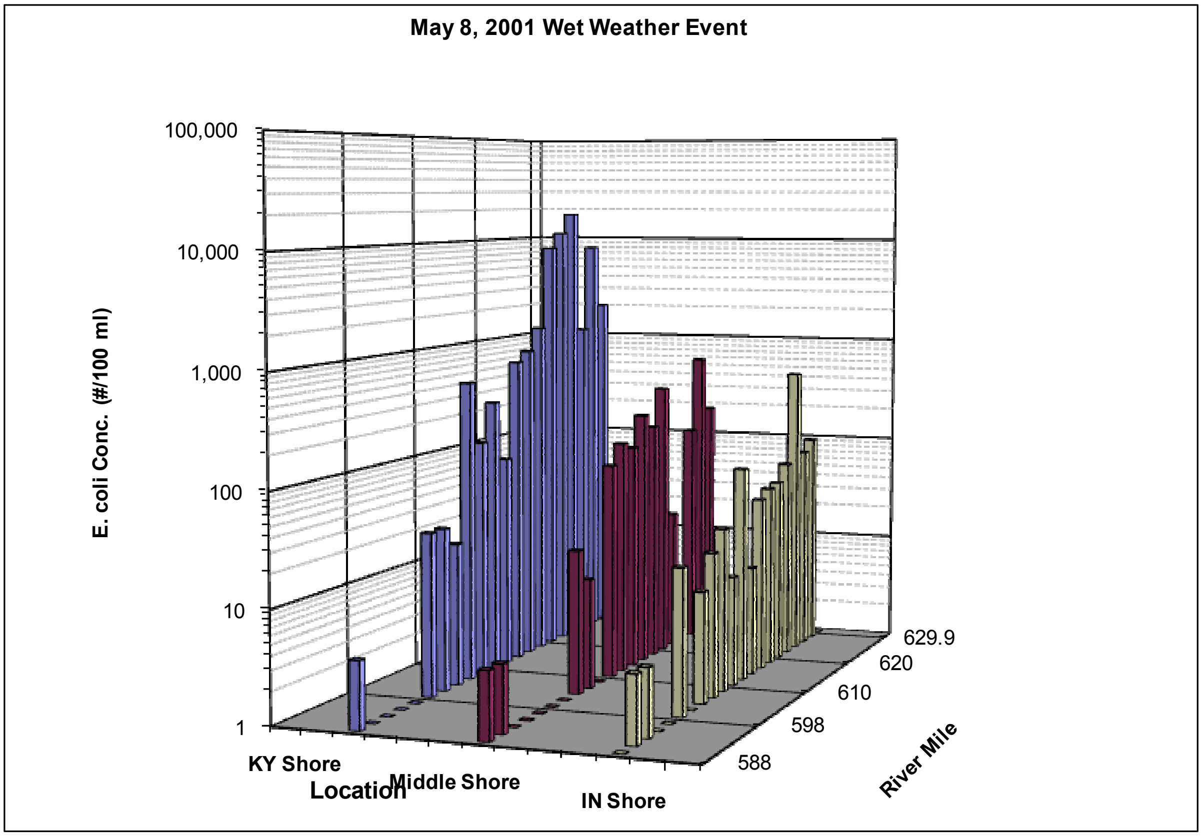
PERCENT OF E. COLI SAMPLES ON THE OHIO RIVER TRIBUTARY MOUTHS THAT EXCEEDED THE INSTANTANEOUS MAXIMUM OF 240 PER 100 ML (2003-2007)

Station	No. > 240	Total No.	Percent > 240
RM_595.9-Harrods_Ck	6	8	75%
RM_597-Goose_Ck	4	8	50%
RM_602.1-a_Muddy_Fk_BGC	7	8	88%
RM_602.1-b_Middle_Fk_BGC	8	8	100%
RM_602.1-c_South_Fk_BGC	7	8	88%
RM_605.2-Cane_Run	13	13	100%
RM_606.2-Mill_Ck (IN)	6	13	46%
RM_606.5-Silver_Ck	9	13	69%
RM_609.3-Falling_Run	9	13	69%
RM_616.4-Mill_Ck_Cutoff	4	13	31%
RM_625-Mill_Ck (KY)	2	13	15%
RM_629.9-b_Salt_Ck	3	21	14%
Total	**78**	**139**	**56%**
RM = River Mile			

2.9.2.4 ORSANCO Wet Weather Demonstration Project

The data collected during the ORSANCO Wet Weather Demonstration Project in 2000-2002 provide much more spatial resolution on bacterial concentrations. Results for the only wet weather event that was monitored after the year 2000 near Louisville are shown in Figure 2.9.15, which shows longitudinal and lateral variation in concentrations. Concentrations are observed to increase as the river moves downstream through the Louisville metropolitan area. Concentrations are also observed to be consistently higher along the Kentucky shoreline than they are in the middle of the river channel.

FIGURE 2.9.15 E. COLI CONCENTRATIONS OBSERVED DURING MAY, 2001 ORSANCO WET WEATHER EVENT



2.9.2.5 Other Parameters

ORSANCO collects other parameters beyond bacteria as part of its routine monitoring. Results for these parameters are shown in Table 2.9.11. As discussed previously, the known impairments associated with the CSOs are limited to bacteria.

TABLE 2.9.11

SUMMARY OF ORSANCO ROUTINE MONITORING DATA FROM 2000-2007 FOR OTHER PARAMETERS

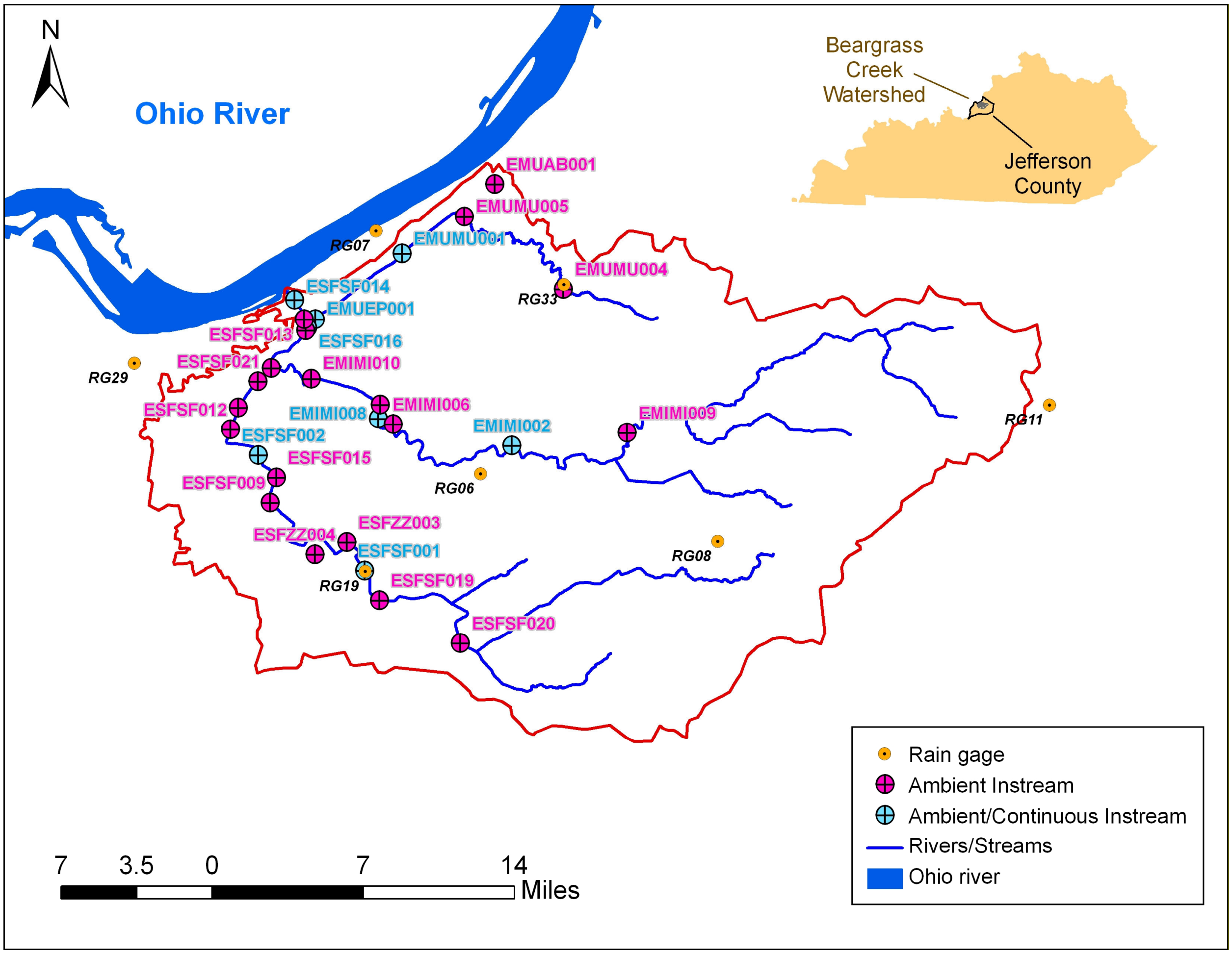
Parameter	Number of Samples	Average	Minimum	Maximum
Ammonia as Nitrogen (MG/l)	147	0.06	0.03	0.27
Nitrate-Nitrite as N (MG/l)	155	1.17	0.06	2.41
Total Kjeldahl Nitrogen (MG/l)	152	0.62	0.10	2.95
Total Phosphorus (MG/l)	152	0.16	0.01	1.94
Chlorophyll (ug/l)	196	6.6	0	36.67
Turbidity (ntu)	196	46.46	0	347
pH	196	7.9	7.4	8.5
Copper (ug/l)	34	3.2	0.9	9.3
Hardness (MG/l)	34	143.6	111.5	205.7
Nickel (ug/l)	34	3.9	1.1	13.1
Lead (ug/l)	34	1.8	0.3	9.3
Zinc (ug/l)	34	10	1.8	46.2

2.9.3 Receiving Water Quality Monitoring Analysis – Beargrass Creek

Data available for Beargrass Creek included fecal coliform and continuous monitoring data from MSD's long-term monitoring network (LTMN); other parameters from the LTMN; biological data from the LTMN; and other studies that were conducted to support development of the Beargrass Creek Water Quality Tool (Tetra Tech, 2008). Figure 2.9.16 shows the three forks of Beargrass Creek and the location of the LTMN network and rainfall gages.

For the fecal coliform and other parameters from the LTMN ambient stations, rainfall data were used to assign each sample as a "wet" or "dry" sample with the criteria discussed in Section 2.9.3. For data preceding May 2003, hourly rainfall from the Louisville International Airport was used. In May 2003, MSD installed a high frequency (5 minute) rain gage network. MSD selected the nearest rainfall gages to each Beargrass Creek ambient station to make the assignment of "wet" or "dry" samples for the data collected after April 2003.

FIGURE 2.9.16 LOCATION OF MSD'S BEARGRASS CREEK MONITORING STATIONS

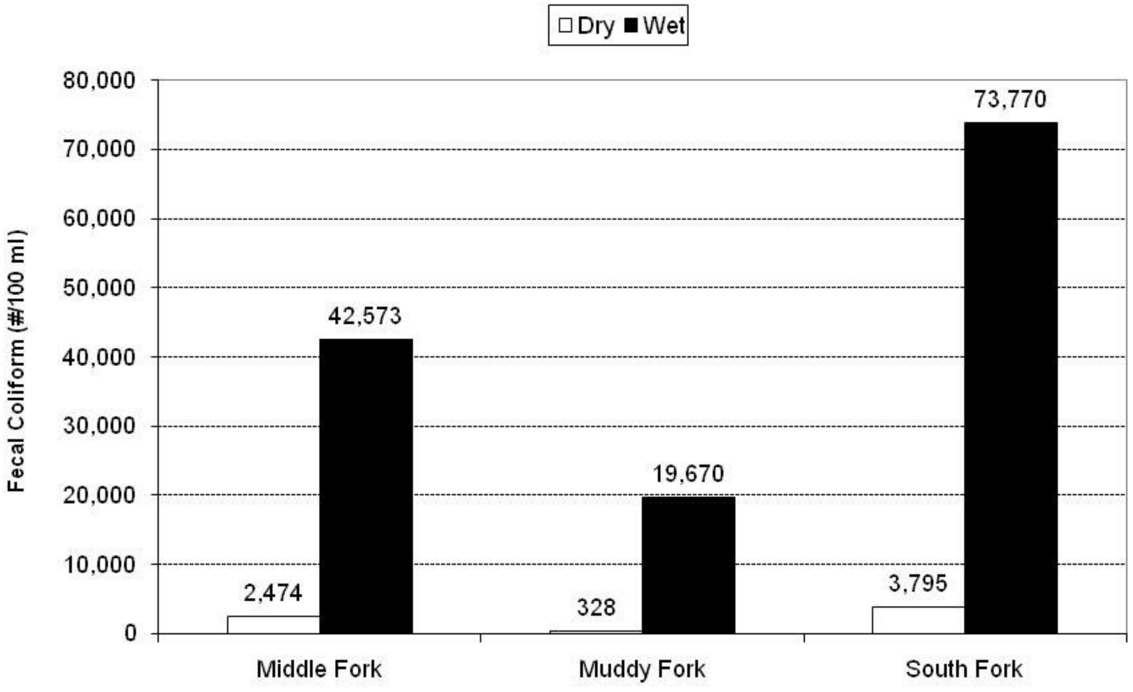


2.9.3.1 Average Fecal Coliform Concentrations

A total of 1,840 fecal coliform measurements were collected by MSD throughout the Beargrass Creek watershed during the period 2000-2007. These data were analyzed in both terms of average concentrations during wet and dry weather periods as well as percentage of individual samples exceeding specific target levels associated with the water quality standards.

A summary display of average concentrations is provided in Figure 2.9.17, which stratifies results by tributary branch and climatic condition. Average concentrations are higher in the Middle and South Forks than in Muddy Fork during both dry and wet weather. Concentrations in all three tributaries are also noticeably higher during wet weather periods.

FIGURE 2.9.17 AVERAGE FECAL COLIFORM IN BEARGRASS CREEK 2000-2007



Figures 2.9.18 through 2.9.21 show annual variation in fecal coliform concentrations in the Middle, Muddy, and South Forks, respectively. Concentrations are higher in the years 2000, 2001, and 2007 for all three forks. Concentrations are higher in years when additional sampling was performed for special wet weather monitoring studies.

FIGURE 2.9.18 AVERAGE FECAL COLIFORM ON THE MIDDLE FORK OF BEARGRASS CREEK

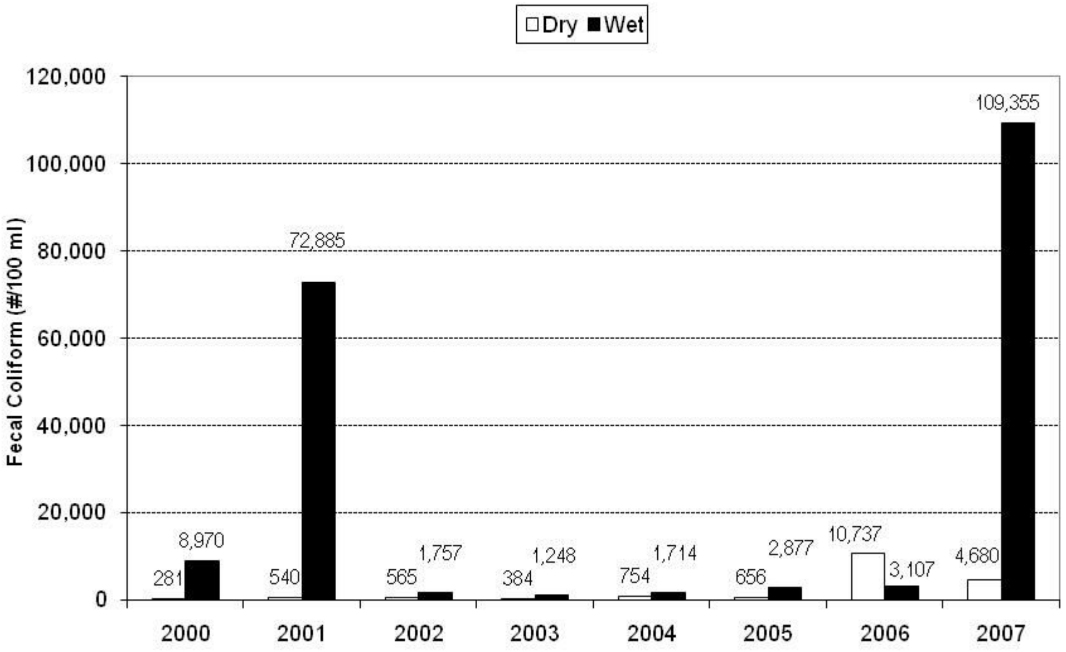


FIGURE 2.9.19 AVERAGE FECAL COLIFORM ON THE MUDDY FORK OF BEARGRASS CREEK

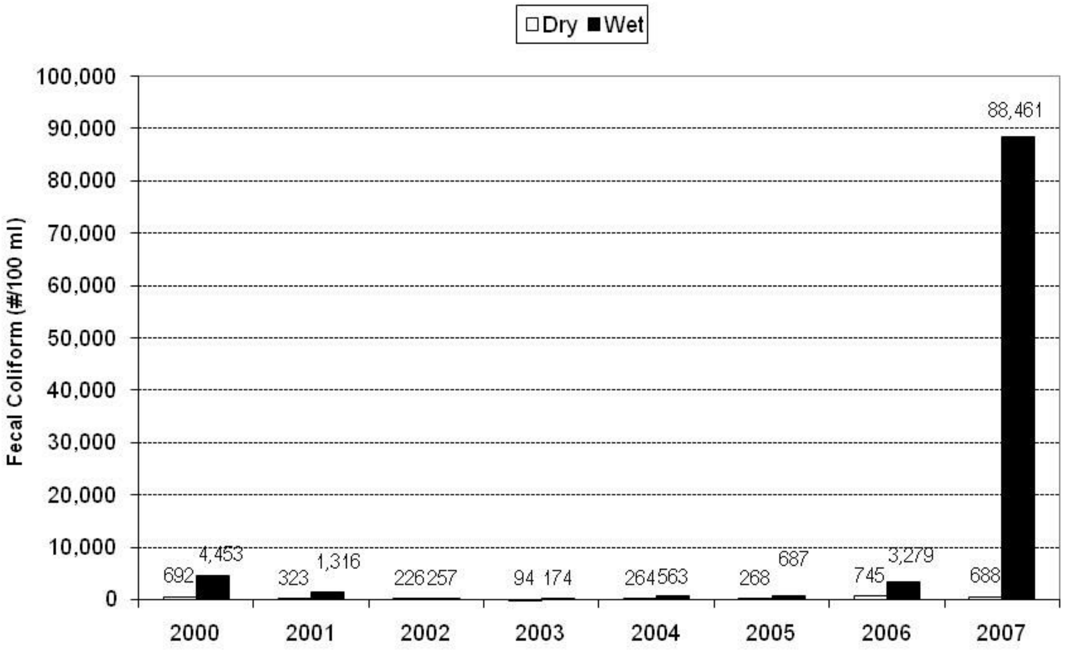


FIGURE 2.9.20 AVERAGE FECAL COLIFORM ON THE SOUTH FORK OF BEARGRASS CREEK

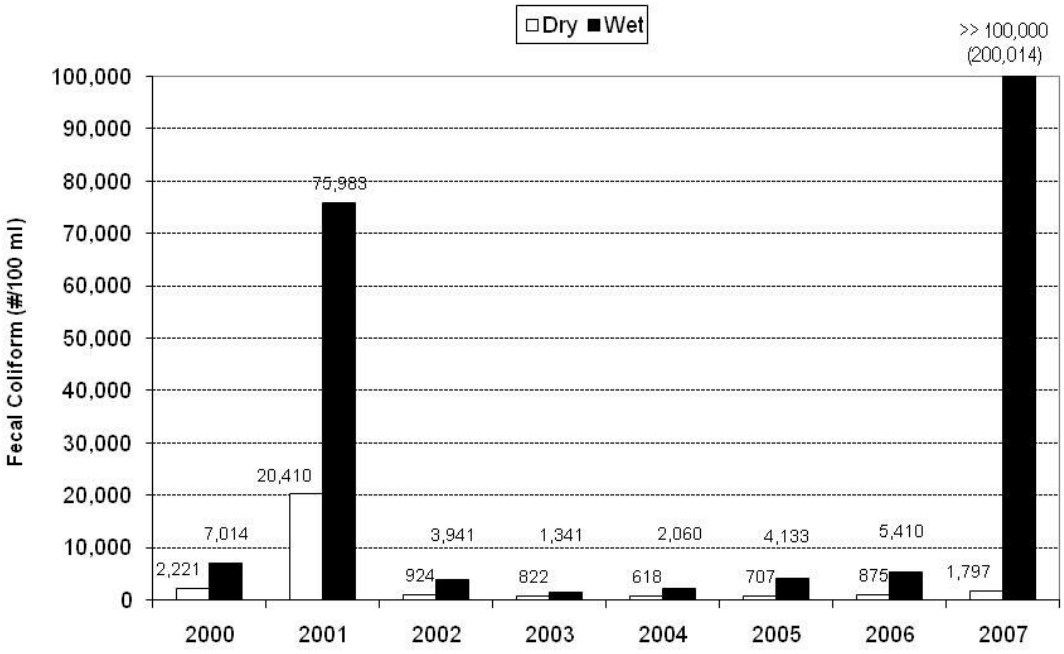
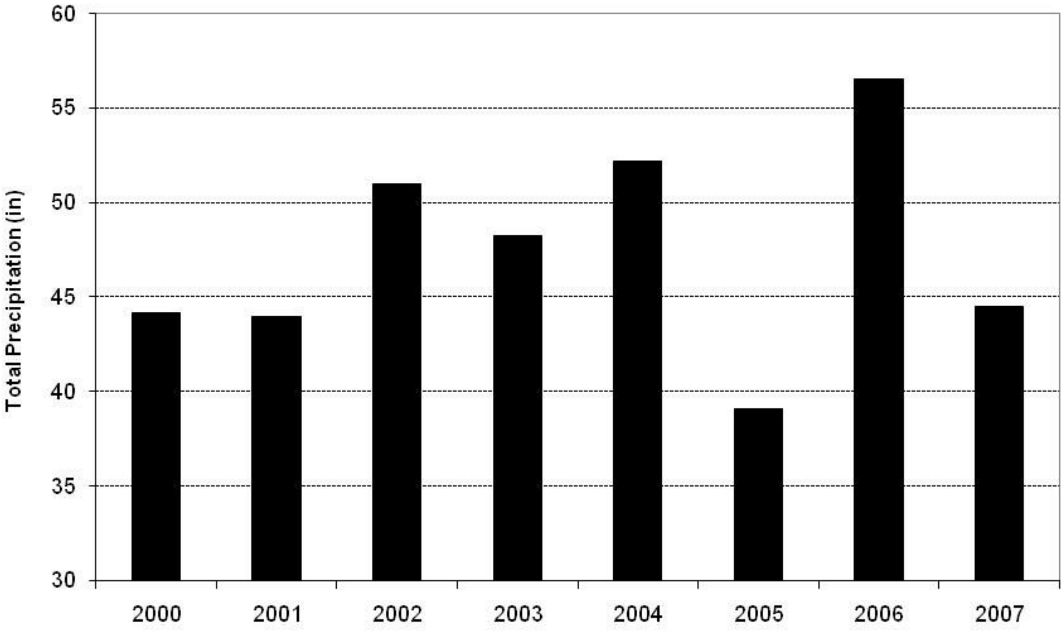


FIGURE 2.9.21 ANNUAL RAINFALL TOTAL AS MEASURED AT THE LOUISVILLE STANDIFORD FIELD



2.9.3.2 Frequency of Exceeding Target Levels

As discussed in Section 2.9.2, water quality standards for indicator bacteria in waters designated for primary contact recreation consist of two parts. During the recreation season (May-October), the fecal coliform concentrations shall not exceed 200 per 100 ml as a geometric mean based on not less than five samples taken during a 30-day period. Further, the fecal coliform concentration shall not exceed 400 colonies 100 ml in 20 percent or more of all samples taken during a 30-day period.

This section examines the frequency of time that these target values are exceeded. It should be noted that this analysis does not represent a direct comparison to water quality standards, as individual measurements are being compared to targets representing a geometric mean or 80 percentile. Data were not necessarily collected of sufficient frequency to allow for a direct comparison.

Available data from each branch were used to calculate the number of exceedances of the geometric mean criterion (Table 2.9.12). Exceedances are prevalent for all six years on all three branches, with the average exceedance percentage across the three branches ranging from 69-79 percent.

TABLE 2.9.12

EXCEEDANCES OF THE 30-DAY GEOMETRIC MEAN (200 PER 100 ML) FECAL COLIFORM TARGET IN EACH BRANCH OF BEARGRASS CREEK FROM MAY – OCTOBER

Year	Middle Fork			Muddy Fork			South Fork		
	Exceed	Total	Percent	Exceed	Total	Percent	Exceed	Total	Percent
2000	5	6	83%	5	6	83%	4	6	67%
2001	4	6	67%	5	6	83%	3	6	50%
2002	3	6	50%	2	6	33%	4	6	67%
2003	3	6	50%	1	6	17%	3	6	50%
2004	5	6	83%	3	6	50%	5	6	83%
2005	6	6	100%	5	6	83%	6	6	100%
2006	6	6	100%	6	6	100%	6	6	100%
2007	6	6	100%	6	6	100%	6	6	100%
Total	**38**	**48**	**79%**	**33**	**48**	**69%**	**37**	**48**	**77%**

Table 2.9.13 presents a similar exceedance analysis; using the 80th percentile fecal coliform standard (400 per 100 ml). The percent of time that the target is exceeded is less than for the geometric mean criteria, which is expected because the target value is higher. Nonetheless, these percentages indicate that water quality standards are likely not being met over large periods of time. The nature of the target is that no more than 20 percent of the samples should exceed it, and the observed percentage exceedance ranges from 42-61 percent.

TABLE 2.9.13

NUMBER OF EXCEEDANCES OF THE 80TH PERCENTILE FECAL COLIFORM STANDARD (400 PER 100 ML) IN EACH BRANCH OF BEARGRASS CREEK FROM MAY-OCTOBER, 2000-2007

	Middle	**Muddy**	**South**
Exceed	385	151	455
Total	634	358	805
%	61%	42%	57%

2.9.3.3 Continuous Monitoring Data

As shown in Figure 2.9.22, MSD has operated seven continuous water quality monitors in the Beargrass Creek watershed. Data from these monitors are summarized in the report entitled *Water Quality in Jefferson County, Kentucky: A watershed synthesis report, 2000-2005* (Jin, 2007). Figures 2.9.22 to 2.9.27 present a summary of the percent of days where the daily average dissolved oxygen criterion of 5.0 mg/l was violated. Stations are presented in upstream to downstream order for each of the three forks. Both the raw and the USGS corrected data is presented because the sondes (continuous monitors) were subject to fouling and many of the raw data were considered unreliable. MSD has since replaced these sondes with sensors that are less prone to fouling. Corrected data were not provided for 2005. In general, there are less violations at the locations upstream of the sanitary sewer overflows (SSOs) and the CSOs.

FIGURE 2.9.22 PERCENT DAILY AVERAGE DISSOLVED OXYGEN VIOLATIONS

IN BEARGRASS CREEK, 2000

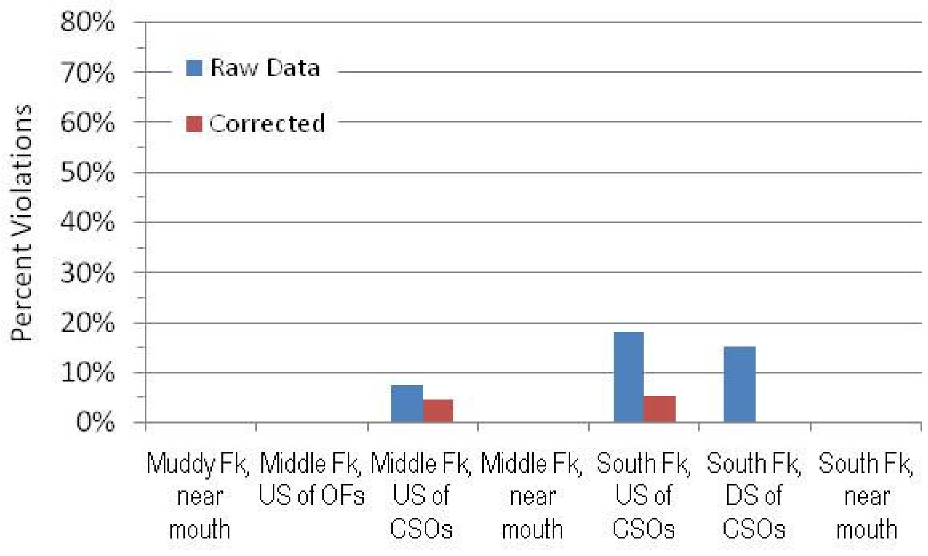


FIGURE 2.9.23 PERCENT DAILY AVERAGE DISSOLVED OXYGEN VIOLATIONS IN BEARGRASS CREEK, 2001

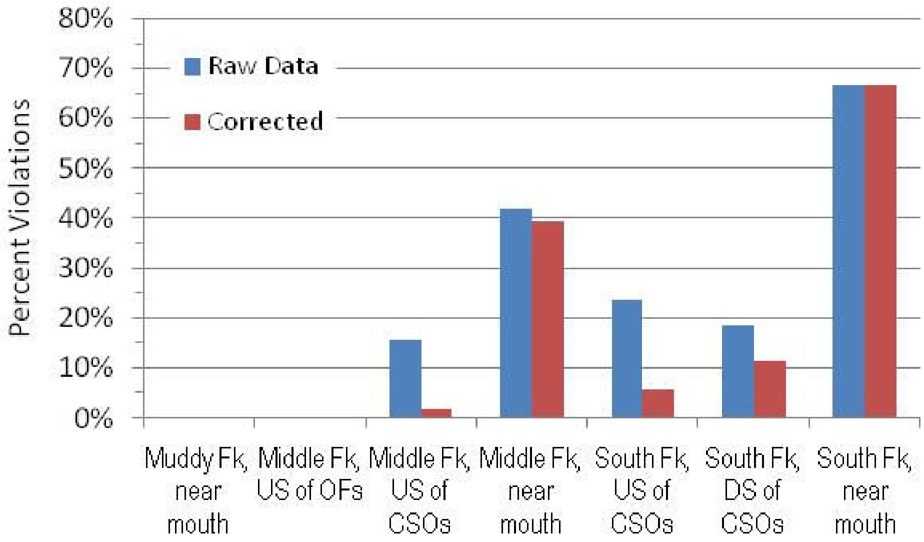


FIGURE 2.9.24 PERCENT DAILY AVERAGE DISSOLVED OXYGEN VIOLATIONS IN BEARGRASS CREEK, 2002

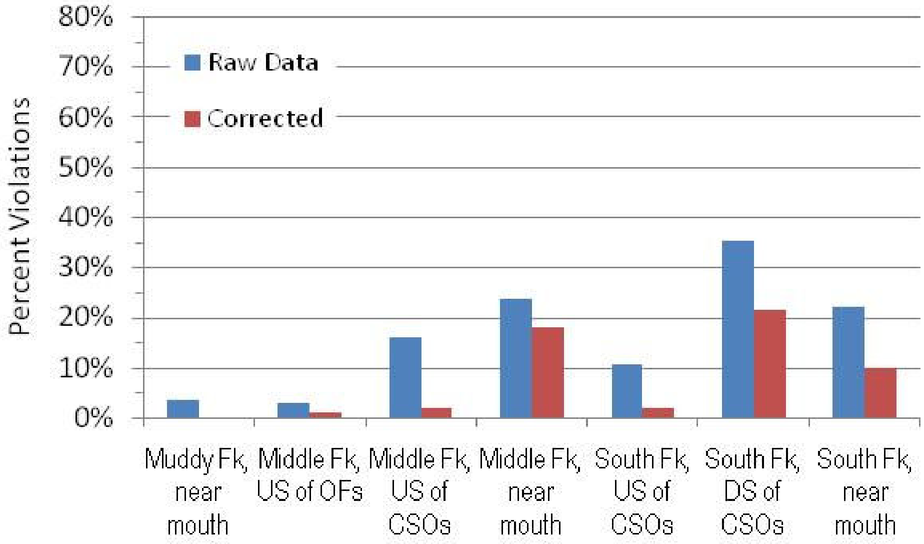


FIGURE 2.9.25 PERCENT DAILY AVERAGE DISSOLVED OXYGEN VIOLATIONS IN BEARGRASS CREEK, 2003

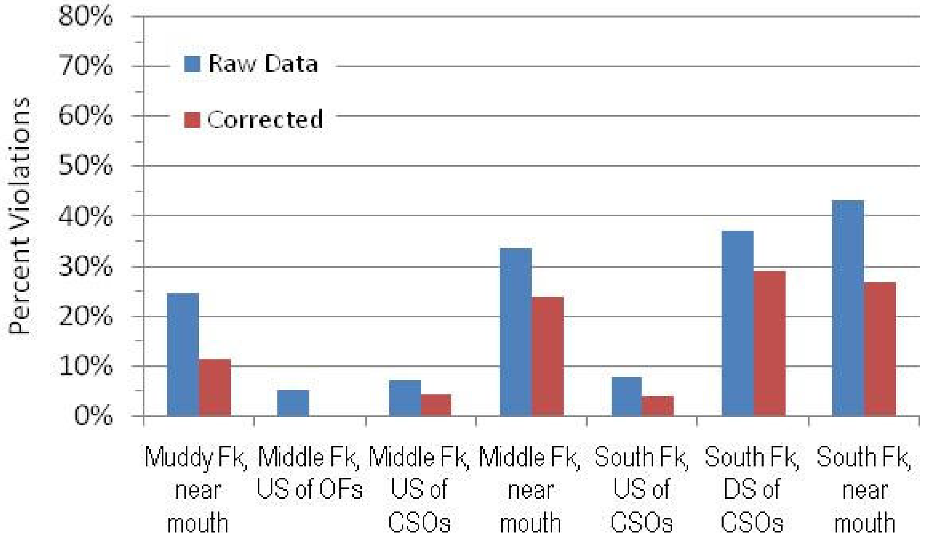


FIGURE 2.9.26 PERCENT DAILY AVERAGE DISSOLVED OXYGEN VIOLATIONS IN BEARGRASS CREEK, 2004

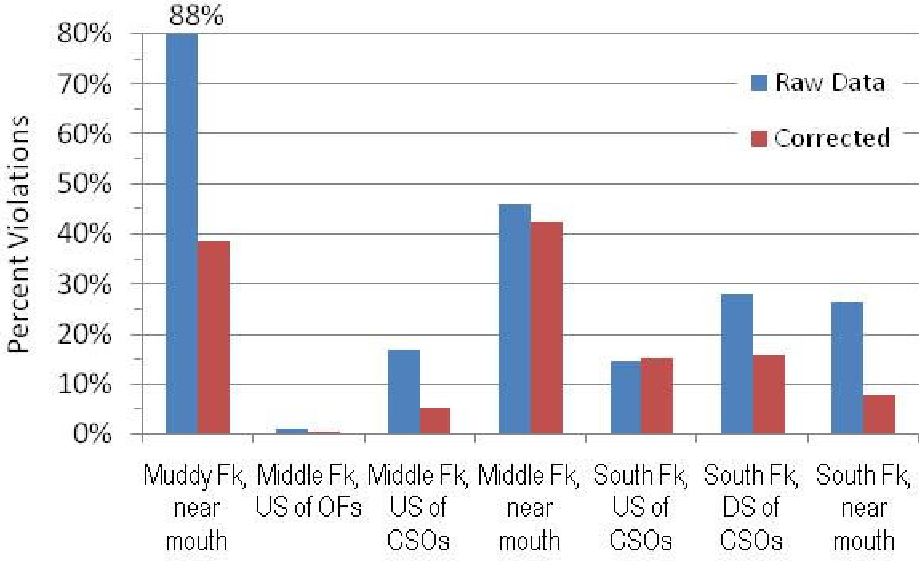
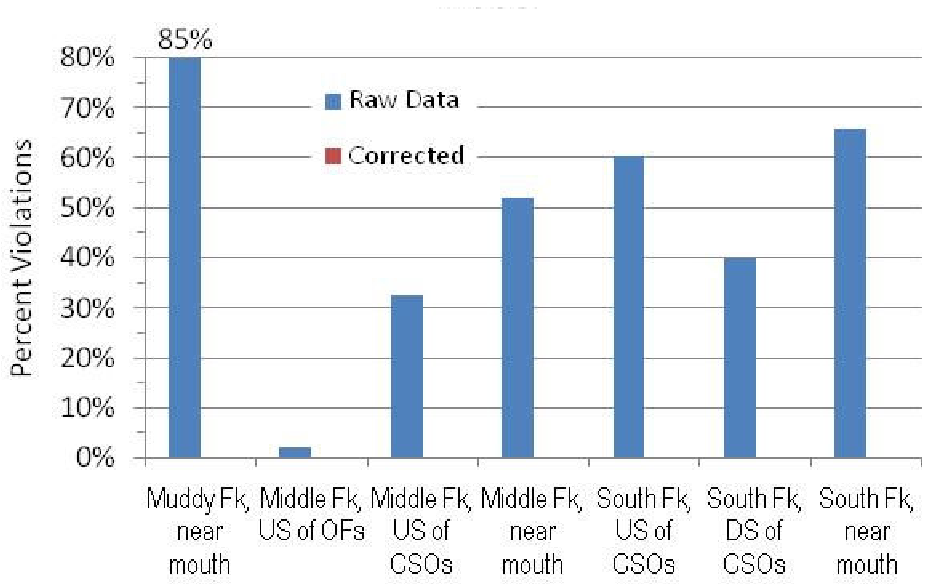


FIGURE 2.9.27 PERCENT DAILY AVERAGE DISSOLVED OXYGEN VIOLATIONS IN BEARGRASS CREEK, 2005



The evaluation of the daily average pH reported in the Synthesis Report indicated that there were occasional violations of the minimum and maximum pH criteria. This occurred at all locations with the exception of EMIMI002 on the Middle Fork, upstream of the CSOs.

2.9.3.4 Biological Data

MSD conducts biological (fish and macroinvertebrate), habitat and bioassessment data at the long-term monitoring network stations. Data are summarized in the Synthesis Report for 2000 to 2005 (Jin, 2007). Macroinvertebrate biotic integrity scores ranged from vary poor to fair at all locations, depending on the year. The fish index of biotic integrity, which is often highly variable particularly for urbanized streams, ranged from poor to excellent. The diatom bioassessment index ranged from fair to excellent.

2.9.3.5 Other Parameters

MSD collects other parameters beyond bacteria as part of its routine monitoring. Results for these parameters for 2000-2006 are shown in Tables 2.9.14 through 2.9.16.

TABLE 2.9.14

SUMMARY OF WATER QUALITY DATA FOR MIDDLE FORK (2000-2007)

Parameter	Number of Samples	Average	Minimum	Maximum
Ammonia as Nitrogen (MG/l)*	141	0.32	0.05	10.00
Nitrate (MG/l)	9	0.74	0.05	1.10
Nitrite (MG/l)	9	0.02	0.01	0.04
Total Kjeldahl Nitrogen (MG/l)	155	16.2	0.2	832.0
Total Phosphorus (MG/l)	153	0.23	0.02	2.28
TSS (MG/l)**	508	71	0	5,916
pH	30	6.68	4.21	8.76
Copper (ug/l)	120	0.092	0.002	2.62
Hardness (MG/l)	82	203	7	337
Nickel (ug/l)	106	0.071	0.001	1.960
Lead (ug/l)	148	0.011	0.0005	0.239
Zinc (ug/l)	116	0.341	0.008	9.150

*Does not include suspect ammonia data from 9/13/01 and 10/30/01, which were > 50 MG/l. These data are undergoing further investigation.

**TSS data are from 2000-2006.

TABLE 2.9.15

SUMMARY OF WATER QUALITY DATA FOR MUDDY FORK (2000-2007)

Parameter	Number of Samples	Average	Minimum	Maximum
Ammonia as Nitrogen (MG/l)	394	0.15	0.05	1.46
Nitrate (MG/l)	3	1.04	0.67	1.23
Nitrite (MG/l)	3	0.02	0.01	0.03
Total Kjeldahl Nitrogen (MG/l)	205	0.7	0.04	2.6
Total Phosphorus (MG/l)	361	0.112	0.006	7.17
TSS(MG/l)*	396	14	1	246
pH	375	7.27	5.05	10.43
Copper (ug/l)	214	0.010	0.002	0.028
Hardness (MG/l)	253	285	3	469
Nickel (ug/l)	200	0.003	0.001	0.124
Lead (ug/l)	284	0.002	0.001	0.040
Zinc (ug/l)	204	0.021	0.003	0.430

*TSS data are from 2000-2006.

TABLE 2.9.16

SUMMARY OF WATER QUALITY DATA FOR SOUTH FORK (2000-2007)

Parameter	Number of Samples	Average	Minimum	Maximum
Ammonia as Nitrogen (MG/l)	192	0.68	0.05	34.0
Nitrate (MG/l)	9	0.74	0.48	0.90
Nitrite (MG/l)	9	0.04	0.01	0.08
Total Kjeldahl Nitrogen (MG/l)	241	9.45	0.40	801
Total Phosphorus (MG/l)	210	0.454	0.013	14.700
TSS (MG/l)*	565	96	0	1,470
pH	52	6.95	5.13	8.00
Copper (ug/l)	162	0.148	0.003	6.290
Hardness (MG/l)	107	198.1	7.0	379.0
Nickel (ug/l)	170	0.067	0.001	2.050
Lead (ug/l)	204	0.040	0.001	2.100
Zinc (ug/l)	177	0.482	0.008	23.000

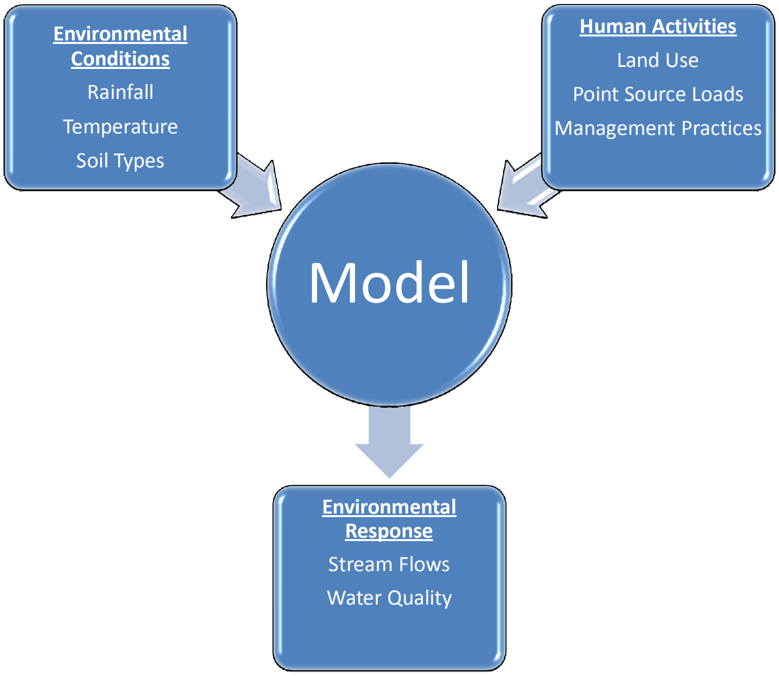
*Does not include suspect ammonia data from 9/13/01, 10/30/01, 11/8/01, and 11/14/01, which were > 50 MG/l. These data are undergoing further investigation.

**TSS data are from 2000-2006.

2.9.4 Receiving Water Quality Modeling Overview

A water quality model is a series of mathematical equations describing real world processes. The mathematical equations contained in the model are based upon scientific principles describing known relationships that affect water quality. As a depicted in Figure 2.9.28, water quality models are designed to convert inputs on environmental conditions and human activities into outputs of water quality.

FIGURE 2.9.28 SIMPLE DEPICTION OF A WATER QUALITY MODEL



Mathematical models, such as water quality models, are commonly used to predict the consequences of future actions for complicated analyses when it is unfeasible to gain the necessary information via trial and error. In the context of the CSO LTCP, water quality model answers will be used to define the water quality benefit to be obtained by various levels of CSO control, allowing MSD to define optimal controls prior to spending millions of dollars on implementation.

The water quality models developed for the Final CSO LTCP describe water quality throughout MSD's service area. The Beargrass Creek WQT predicts water quality throughout all branches of Beargrass Creek, while the Ohio River Water Quality Model predicts water quality in the Ohio River. Both models predict how concentrations change over distance in a downstream direction, and the Ohio River Water Quality Model also considers lateral variation in water quality, i.e. the difference in concentration between the Kentucky shoreline, mid-channel areas, and the Indiana shoreline. Both models also consider how concentrations change over time, on an hour-by-hour basis over the course of a year.

2.9.5 Beargrass Creek Water Quality Model

The CWA has the goal of making our nation's waters suitable for the uses of drinking water, aquatic habitat, and recreation through the establishment of water quality standards. When a stream is polluted to the level that the water quality standards are no longer met, it is designated by the state or federal government as impaired. This triggers the next step in the CWA requirements - a study of the reasons for the impairment and a measurement of the amount of pollution that needs to be reduced, known as the Total Maximum Daily Load (TMDL) study. Watershed managers need to know the sources and amounts of pollutants so that they can develop and implement plans to make the needed improvements.

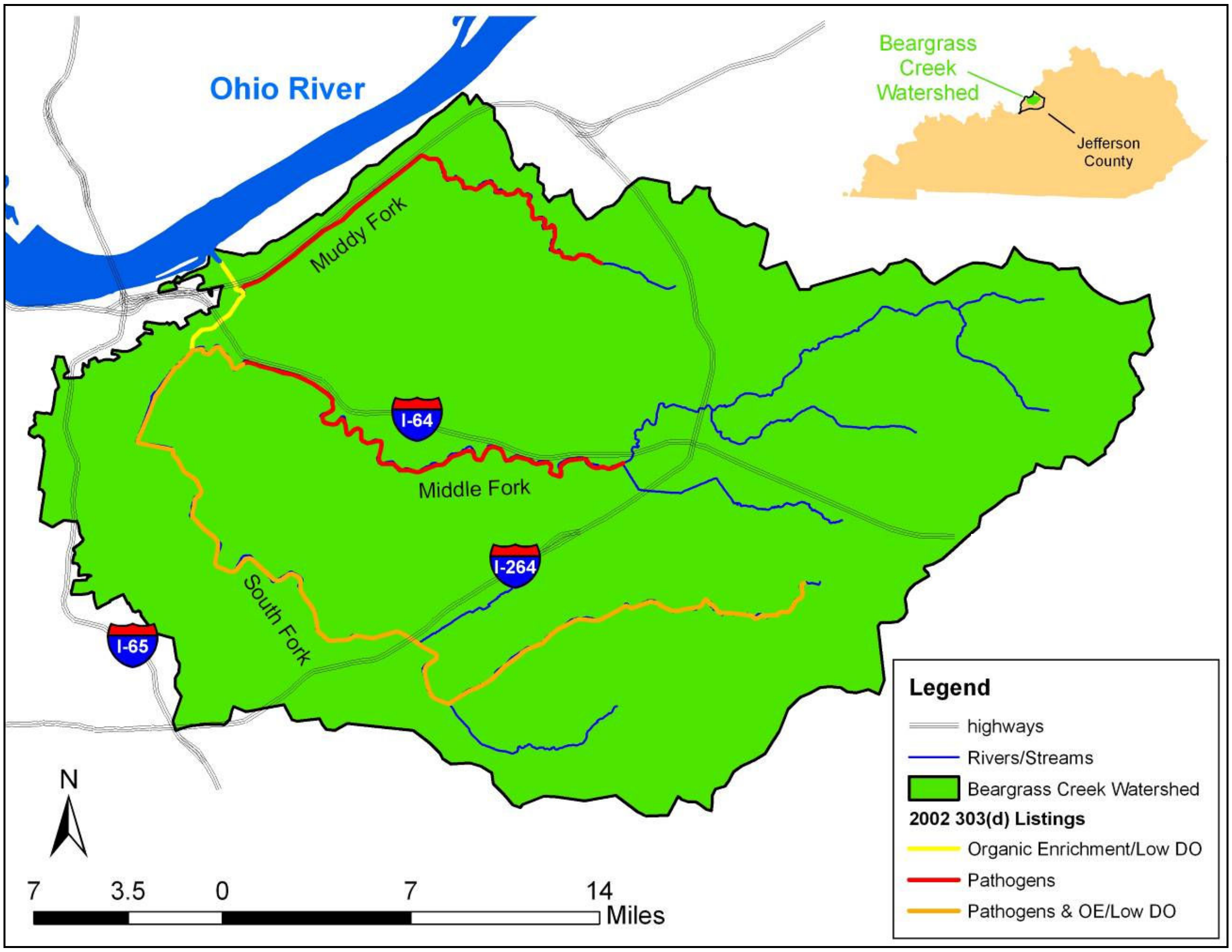
Water quality in streams and rivers is a result of the interactions between the water flow, pollutants, living systems, weather, and chemical changes. Water resource engineers have developed computer programs that simplify these systems so that they can be better understood. These computer programs, or models, can also be modified to predict the effects of changes in pollution levels and other systems in "what if" scenarios.

2.9.5.1 Beargrass Creek Receiving Water Modeling Objectives

Beargrass Creek has a 61 square-mile watershed with a variety of landuses, ranging from farmland, suburban residential areas, historic parks, and urban areas. Discharges to the stream include stormwater runoff from the Municipal Separate Storm Sewer System (MS4), nonpoint source discharges, CSOs, and SSOs.

KDEP has determined that portions of Beargrass Creek do not support the Designated-Use Criteria for Primary Contact Recreation and Aquatic Life due to pathogens, organic enrichment/low dissolved oxygen, and habitat alteration. These segments are in the Middle Fork (25-mi^2 drainage area), Muddy Fork (9-mi^2 drainage area), and South Fork (27-mi^2 drainage area) sub-basins of Beargrass Creek. See Figure 2.9.29 below.

FIGURE 2.9.29 SEGMENTS OF BEARGRASS CREEK LISTED AS IMPAIRED BY PATHOGENS AND/OHIO RIVER ORGANIC ENRICHMENT/LOW DISSOLVED OXYGEN



The Beargrass Creek watershed is drained by an extensive system of natural stream segments, open concrete channels, storm sewers, sanitary sewers, and combined sewers. This watershed also has karst geology in some areas. The complex hydrology and combination of point and nonpoint sources pose significant technical obstacles for the prediction of water quality.

In the 1990s, MSD and the KDEP discussed the need for water quality improvements in Beargrass Creek, beginning with the preparation of TMDL studies to determine the pollutant loading reductions that would be needed to attain the stream's designated uses. MSD offered to partner with the KDEP to develop watershed and stream water quality models that would be used to develop the TMDLs. MSD wanted to use the models for use in planning sewer overflow controls and to ensure that the TMDLs include all sources of pollutant loading to the stream, not just CSOs.

The initial plan for a modeling system was to link two existing models: the watershed model Hydrologic Simulation Program – FORTRAN that had been developed by the USGS for part of the watershed, and the existing SWMM model used by MSD to simulate CSOs. These linked models would generate a continuous simulation of the runoff, sewer overflows, stream flows, and water quality to provide a more complete assessment of the water quality effects of overflows and runoff. The linked models were named the Beargrass Creek WQT.

Overflow Abatement Modeling Objectives

MSD's objectives for the modeling system were to quantify the effects of sewer overflows on water quality and to provide a tool that could be used to predict the future effects of various overflow abatement projects. The ability to predict water quality impacts of projects would allow MSD to prioritize efforts to get the best results.

When the WQT was being planned, MSD used the AAOV of each CSO as a measure of its relative importance and need for abatement, but recognized that this method may oversimplify the relationship and could cause inefficient use of capital funds by focusing on the larger, more expensive abatement projects. CSOs affect receiving stream water quality by the amount of overflow, but factors such as frequency, location, receiving stream flow rate and water quality should also be taken into account.

Overflow abatement costs are also not always directly associated with the AAOV. There are many types of abatement, each with its application and costs that vary widely depending on the specific location and amount of control desired.

Water Quality Modeling Objectives

Because the water quality impairments in Beargrass Creek include both pathogens and organic enrichment, the models had to have the ability to simulate the movement of pollutants in the stream and the dissolved oxygen concentrations that result directly from the pollutants and indirectly from algae in the stream.

Accurate prediction of fecal coliform concentrations must take into account the transport and mixing of the bacteria, including association with solids and storage in stream sediments. In addition, there is a loss of bacteria over time due to die-off, which varies with temperature and exposure to sunlight.

Dissolved oxygen in a stream is affected by many variables, including direct consumption of oxygen from bacteria that break down organic compounds, respiration of aquatic life (both plants and animals), increased oxygen from aeration, temperature effects, sunlight/shade, etc.

MSD recognized that the connection of a complex stream water quality system with a complex CSS would make for complex relationships between the two and that a computer modeling system would be needed to guide overflow abatement.

Environmental Data Variance

Environmental data variance is discussed extensively in Appendix 2.9.1, Beargrass Creek Water Quality Tool Model Calibration and Validation Report. The fecal coliform and dissolved oxygen data sets, in particular, show a great deal of variability, which caused some areas within the water quality model calibration to fall short of the targets within the Quality Assurance Project Plan (QAPP). The best available data sets were used for calibrating the Beargrass Creek water quality model, although additional data is being continuously collected by MSD.

In order to address variability and QAPP calibration targets, a review of the QAPP targets may be needed as well as additional stream monitoring and sampling using more stringent data collection, equipment calibration, and data quality control procedures. These activities are being discussed for Beargrass Creek among the parties involved in the development of the draft Beargrass Creek TMDLs and associated water quality model.

However, for the purpose of assessing CSO impacts under existing system conditions and simulating anticipated conditions after implementing MSD's proposed Final Long Term Control Plan, the water quality model for the Beargrass Creek is sufficiently accurate and the best available assessment tool to support the analysis of water quality impacts from the demonstrative CSO control approach developed by MSD. The modeling approach undertaken for the system was supported by a relatively large amount of reliable environmental data and subjected to much third party scrutiny and quality control, in comparison with typical efforts.

2.9.5.2 Beargrass Creek Water Quality Model Selection

As discussed above, the initial plan for the WQT was to use the Hydrologic Simulation Program – FORTRAN and SWMM models that were already available and in use separately, combining them to operate as a single system. Initially, the plan was to modify these models to run as an integrated system and then to calibrate and validate the resulting system's simulation results using monitoring data. This type of combination of Hydrologic Simulation Program – FORTRAN and SWMM was unprecedented. The models required substantial modification to merge them into an integrated system. For example, the Hydrologic Simulation Program – FORTRAN model had been developed for the Middle and South Forks of Beargrass Creek, but not the Muddy Fork. The SWMM model was set up to simulate specific rain events, rather than continuous simulation. Both models had specific data file requirements for input and output that were not directly compatible, requiring development of data transfer programs that could manage large and complex files.

As the WQT was developed and calibration was planned, the models were re-evaluated several times. The following models were considered as replacement models for all or part of the receiving stream simulation originally performed with Hydrologic Simulation Program – FORTRAN:

- CE-QUAL-W2 (version 3.1)
- CE-QUAL-RIV1 (version EPD-RIV1)
- CE-QUAL-ICM

- EFDC-WASP (WASP6)
- BRANCH-BLTM

MSD and its consultants also considered replacing some Hydrologic Simulation Program – FORTRAN functions with the SWMM model and other hydraulic models.

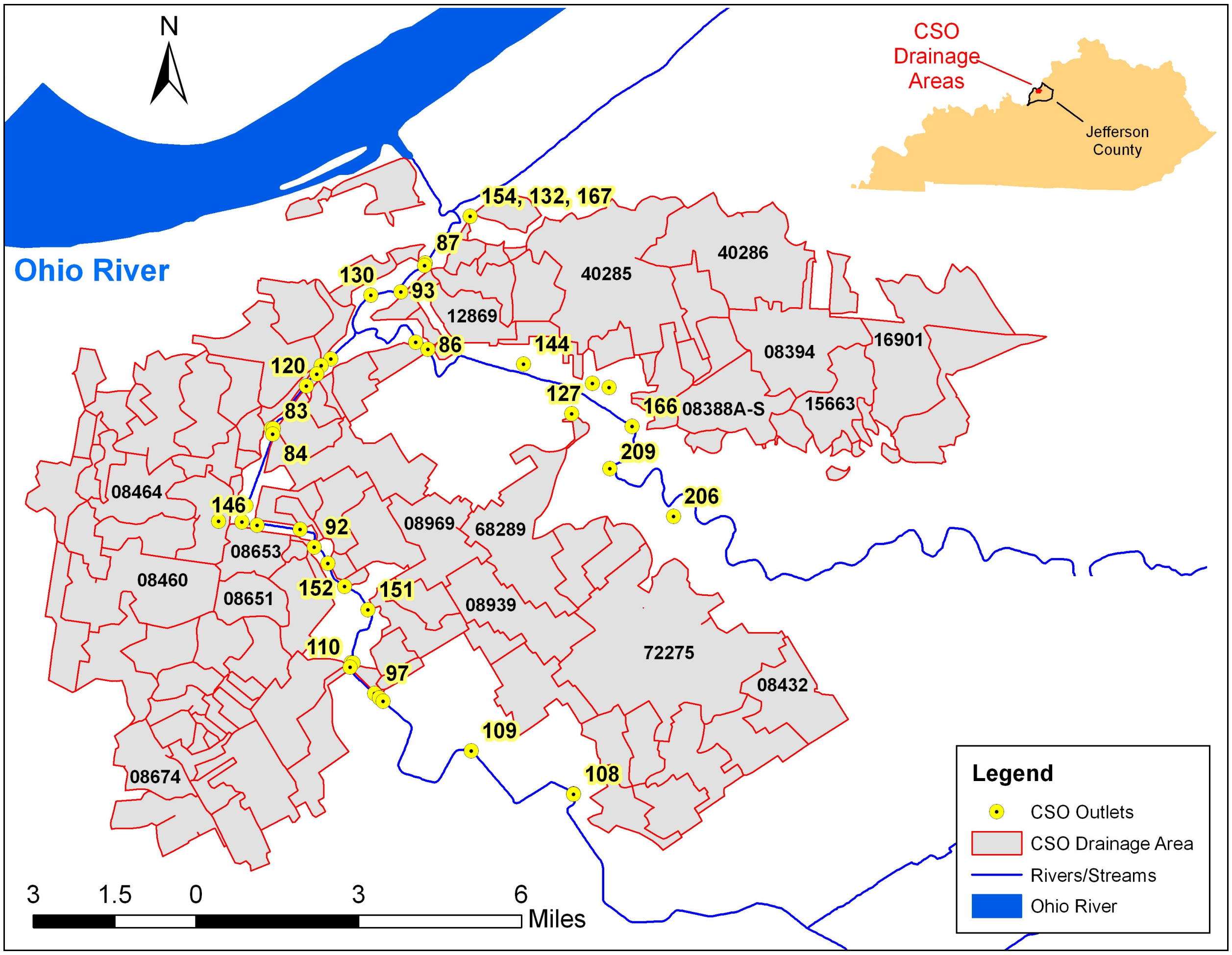
2.9.5.3 Beargrass Creek Water Quality Model Description

Although other models were considered, the Hydrologic Simulation Program – FORTRAN and SWMM models have remained a part of the WQT. Some additional models were added, however, to address specific needs. The following overview describes the functions of the WQT.

- Hydrologic Simulation Program – FORTRAN - the watershed model that uses actual precipitation data from a specific time period, landuse, and topography data to generate runoff and subsurface water flow that is routed to Beargrass Creek directly or indirectly through the storm sewer system, the CSS, or tributaries and ditches.
- XP-SWMM - the combined sewer model that receives runoff flow from the watershed model (see Figure 2.9.30), combines the stormwater flow with sanitary sewer flow that varies in amount throughout the day, and produces a CSO output.
- Simulated SSO flow from a separate simulation program that relates SSO volume to precipitation based on hydraulic model results.
- Hydrologic Simulation Program – FORTRAN, RIV1H, and WASP – the receiving stream models that simulate the flow rate and water quality of Beargrass Creek as a series of stream segments or reaches, getting inputs of flows and pollutants on a continuous basis from the above models; RIV1H and WASP are used in the lower Beargrass Creek area where more complex stream hydraulic conditions required the use of these models for both hydrology and water quality.

Data transfer programs known as bridge routines are needed to convert the large amounts of flow and water quality data at each location and time interval from one model's data format to another.

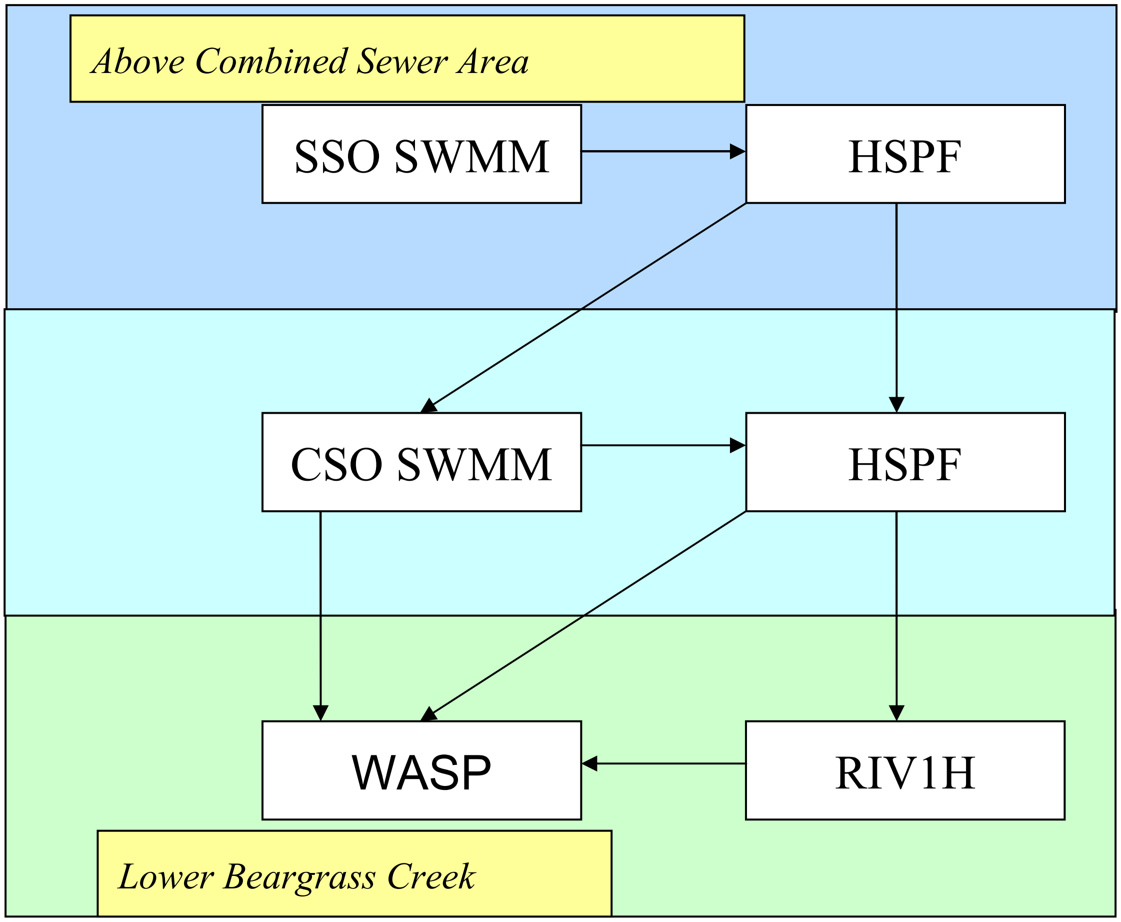
FIGURE 2.9.30 CSO DRAINAGE AREAS



The original models needed additional modifications to meet the project objectives. The Hydrologic Simulation Program – FORTRAN model's receiving water simulation was refined to smaller stream reaches, the CSO drainage areas were refined in the Hydrologic Simulation Program – FORTRAN watershed (Figure 2.9.30), precipitation information was processed to specific watershed areas, the SWMM model was converted from the EPA version to the XP Software version, and many other adjustments were made.

Figure 2.9.31 illustrates the inter-relationships between these models within the WQT.

FIGURE 2.9.31 RELATIONSHIPS BETWEEN THE MODELS OF THE BEARGRASS CREEK WATER QUALITY TOOL



2.9.5.4 Beargrass Creek Water Quality Model Development

Model development and calibration were performed in accordance with a QAPP and regular consultation with Dr. Lindell Ormsbee of the Kentucky Water Resources Research Institute. Peer reviewers Tony Donigian and Wayne Huber evaluated the model development process and final system, providing valuable input that improved the end result. The WQT calibration and validation have been completed and documented in the Tetra Tech report to MSD "Beargrass Creek Water Quality Tool Model Calibration and Validation Report," May 2008 (see Appendix 2.9.1).

The WQT performs a continuous simulation of rainfall, runoff, sewer overflows, stream flow, and water quality in surface water and groundwater over the five-year period from January 1, 2000, through December 31, 2004. The actual conditions for this period are the baseline condition against which TMDL allocations and overflow abatement scenarios are assessed. In some analyses, the year 2001 was used as a representative year for the comparisons.

2.9.5.5 Overview of Beargrass Creek Water Quality Model Results

In June 2008, the WQT was used to generate the pollutant load allocations used by Kentucky Water Resources Research Institute to develop both fecal coliform and organic enrichment/low dissolved oxygen TMDLs for the KDEP. Currently, the WQT is being used to quantify pollutant loads and their effects on Beargrass Creek water quality for various scenarios considered for overflow abatement planning. The following summarizes the results of these efforts.

TMDLs

The TMDL reports have been completed by Kentucky Water Resources Research Institute and submitted to the KDEP for review. The fecal coliform TMDL was presented for public comment on September 11, 2008. The TMDLs were developed on a sub-basin basis, with each of the major basins (Muddy, Middle, and South) subdivided into three or four subwatersheds. Loads were allocated on an annual basis and then expressed in terms of a daily load. The TMDL is the maximum load that, with a margin of safety, could be applied to Beargrass Creek without causing water quality standards violations above a minimal level. Two scenarios were used to develop load allocations for the TMDL. Both scenarios included elimination of SSOs and modification of minor sources.

- Scenario I - CSO reduction (95 percent reduction in volume, 50 percent concentration reduction).
- Scenario II - Sewer separation (100 percent).

In the Organic Enrichment TMDL, the pollutant loading is expressed as biochemical oxygen demand. Sources are SSOs, CSOs, stormwater, and groundwater. Of these sources, the stormwater source is the largest (65 percent) and CSOs are the next-largest source (28 percent). The total biochemical oxygen demand wasteload reductions in the TMDL range from 49 to 71 percent for Scenario I (CSO reduction through storage) and 49 to 65 percent for Scenario II (sewer separation).

The fecal coliform TMDL was prepared using similar methods in terms of the load allocation scenarios and sub-basins. Stormwater is the largest source of fecal coliform (61 percent) and CSOs are the next-largest source (38 percent). The total fecal coliform wasteload reductions in the TMDL range from 95 to 96 percent for both scenarios.

Overflow Abatement Scenarios

Various scenarios have been evaluated with the WQT to predict the water quality effects of planned abatement approaches. Results are evaluated in terms of attainment of the fecal coliform water quality standard, which has 30-day geometric mean and instantaneous maximum criteria. (See Figures 2.9.32 and 2.9.33) There are also different levels for these criteria in the summer or recreational season and the winter season. Scenarios are compared to the baseline or actual condition for the five-year period 2000 - 2004 or for the representative year 2001.

Scenarios are developed by MSD and its overflow abatement consultants as the planning work proceeds. Several scenarios have been completed and more are expected to be performed in the future. The following summarizes the findings to date.

No CSOs/SSOs

The WQT simulated the effects of eliminating SSOs and CSOs completely. The results were used in development of the TMDLs. This scenario reduced, but did not eliminate, violations of the primary recreation and aquatic life water quality standards (fecal coliform and dissolved oxygen criteria, respectively).

CSO-Only

The WQT was set up to make CSOs the only source of fecal coliform bacteria, eliminating the pathogens from all other sources. This scenario is designed to distinguish the effect that CSOs have on water quality alone. The predicted water quality standard compliance for this case was much higher than baseline confirms with background loads, virtually eliminating excursions in the upper reaches of all three forks. However, there remained violations of the geomean standard at the mouths of South (41 percent of the year), Middle (<one percent), and Muddy Forks (four percent). At the confluence with the Ohio River, the predicted nonattainment rates were 48 and 17 percent for the geomean and maximum standards, respectively. The simulation also predicted that the maximum standard would be exceeded four to seven percent of the time from the mouth of South Fork to the Beargrass Creek Flood Pumping Station.

CSO-Only with Reductions

An additional set of simulations was added to the above scenario that reduced the fecal coliform concentrations in the CSOs by 50 and 90 percent. All other parameters remained the same. The reductions further reduced but did not eliminated violations. For example, at the Beargrass Creek Flood Pump Station the scenarios predicted geomean water quality standard violations would drop from 72 percent for the baseline to 41 percent for CSOs-only to about 11 percent for the 90 percent reduction case. The effects of the CSO-only simulations were greater on the 30-day geometric mean standard attainment, especially the winter standard.

Simulated zero, two, four, and eight overflows per year scenarios were evaluated in August 2008. This analysis varied from previous WQT simulations in that the CSS hydraulic model had changed from XP-SWMM to the new InfoWorks model. These simulations showed that reductions in CSOs did have an effect, but the differences between the levels of control were small. The results are shown on Figures 2.9.32 and 2.9.33. Figure 2.9.32 incorporates the 20 percent allowance for exceedance of the maximum standard.

After the IOAP projects were defined, the WQT was used to predict the water quality effects of the planned controls on SSO and CSO discharges to Beargrass Creek. These simulations, discussed in detail in Chapter 4, Section 4.4.2, predict that, when these levels of control were combined with the CSO-Only assumption, both geometric mean and instantaneous maximum water quality standards would be met in the stream for the entire typical year.

FIGURE 2.9.32 RECREATIONAL WATER QUALITY STANDARD ANALYSIS (MAXIMUM CRITERIA) FOR VARIOUS OVERFLOW SCENARIOS AS COMPARED TO CURRENT CONDITIONS (BASELINE) AT THE MOUTH OF BEARGRASS CREEK AT THE OHIO RIVER

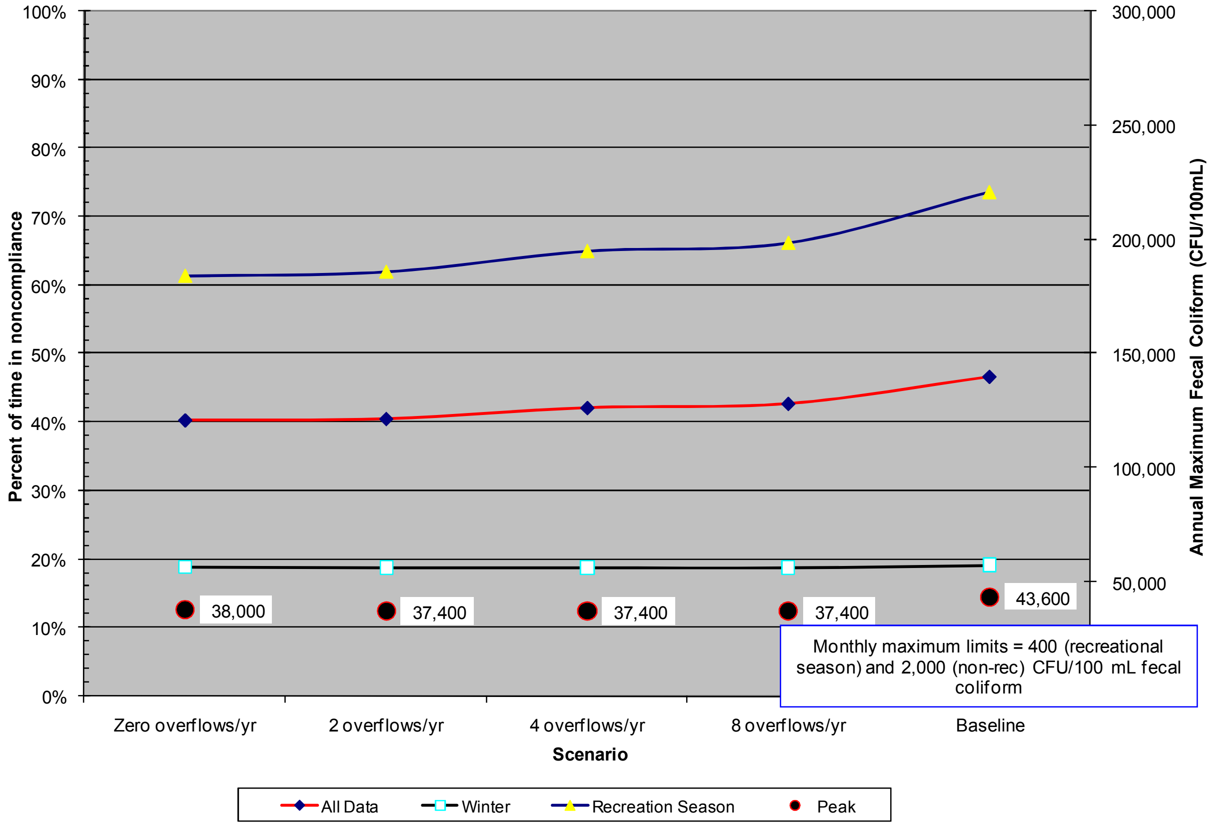
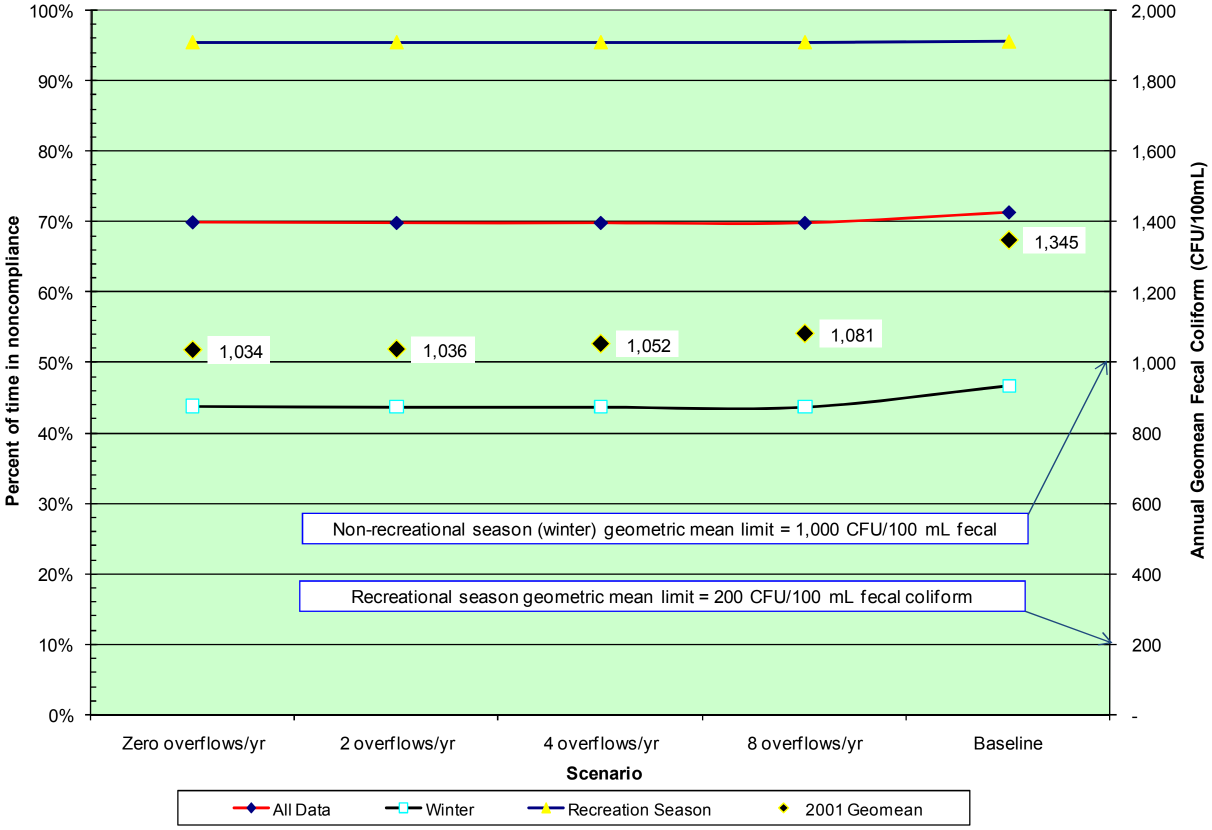


FIGURE 2.9.33 RECREATIONAL WATER QUALITY STANDARD ANALYSIS (GEOMEAN CRITERIA) FOR VARIOUS OVERFLOW SCENARIOS AS COMPARED TO CURRENT CONDITIONS (BASELINE) AT THE MOUTH OF BEARGRASS CREEK AT THE OHIO RIVER



2.9.6 Ohio River Water Quality Model

The Ohio River water quality model was initially developed in 2005 as part of a demonstration project along the Ohio River conducted by the Ohio River by ORSANCO. This section provides an overview of the development and application of the Ohio River water quality model applied for development of the Final CSO LTCP.

2.9.6.1 Ohio River Water Quality Modeling Objectives

The specific objective of the water quality models developed for the CSO LTCP is to predict the water quality expected to result from the various CSO control alternatives that are being considered. Water quality predictions will be characterized in several ways, including:

- Percent of time in compliance with the geometric mean water quality standard for fecal coliform bacteria;
- Percent of time in compliance with the single sample maximum water quality standard for fecal coliform bacteria; and
- Maximum fecal coliform concentration.

Results will be provided for multiple locations throughout Beargrass Creek and the Ohio River, as well as for both the recreational season and the non-recreational season. These results will be used to support a cost-benefit analysis that defines the relationship between the cost of the pollution control alternatives and the resulting water quality benefit. This information will allow MSD (and its stakeholders) to select a LTCP that best balances improvements in water quality with the cost of implementation.

2.9.6.2 Ohio River Water Quality Model Selection

The water quality model selected for the Ohio River portion of this study was originally developed as part of a wet weather demonstration project conducted on the Ohio River by ORSANCO (2005). This section presents the model selection process originally applied for the ORSANCO project, and demonstrates the relevance of the water quality model selection to the current CSO LTCP process. The factors considered in selecting a water quality model include the following categories:

- Management objectives
- Project constraints
- Site-specific characteristics

Specifics on how these factors are incorporated into the model selection process are detailed elsewhere (ORSANCO, 1999). However, primary emphasis in model selection was given to the study's modeling objectives, which included:

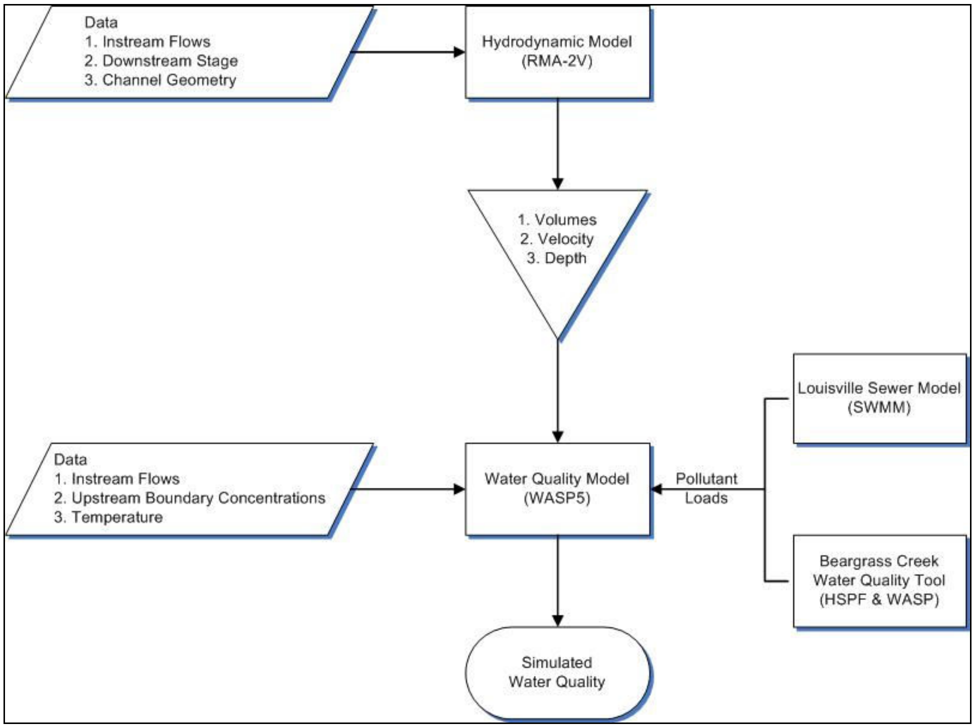
- Define the parameters that violate water quality standards during wet weather in the Ohio River under present conditions. Parameters considered include fecal coliform, E. Coli and, potentially, dissolved oxygen.
- Estimate the duration of criteria exceedance for all parameters.
- Provide a description of the spatial extent (that is, area) of exceedance.

These original ORSANCO objectives are consistent with the objectives of the water quality model for the CSO LTCP process.

Based upon these objectives, project constraints, and site-specific characteristics of the Ohio River, the "Water Quality Analysis Simulation Program, Version 5 (WASP5) was selected to be used as the water quality model for the Ohio River. This model is supported by the EPA and has been widely used. It has the capability to simulate all of the parameters of concern in the study, to provide time-variable simulations capable of defining the duration of criteria exceedances, and to simulate lateral and longitudinal concentration gradients important in large rivers. The WASP5 model was successfully applied to the section of the Ohio River near Cincinnati in a similar wet weather demonstration study (ORSANCO, 2002, A Study of Impacts and Control of Wet Weather Sources of Pollution on Large Rivers).

Application of the WASP5 model to the Ohio River required interaction with other models. Because lateral variation in flow and quality are important in the Ohio River, the USACE hydrodynamic model, Resource Management Associates-2V, was applied by the USGS for the original ORSANCO study to describe the routing of the water flowing through the river. Resource Management Associates-2V simulates lateral and longitudinal variability in river hydraulics. CSO discharging directly to the Ohio River were defined using the CSS model developed by O'Brien and Gere. CSO and stormwater loads from Beargrass Creek were simulated with the Beargrass Creek Water Quality Tool. A flowchart depicting how the Ohio River Water Quality Model interacts with these other models is shown in Figure 2.9.34.

FIGURE 2.9.34 OHIO RIVER WATER QUALITY MODELING FLOW CHART



2.9.6.3 Ohio River Water Quality Model Description

This section describes the basic formulations used in the WASP5 water quality model. WASP5 is a three-dimensional finite difference model that computes constituent concentration in a compartmentalized representation of the physical study area using the principle of conservation of mass. WASP5 can simulate the dynamic response of aquatic systems to pollutant loadings, including CSO discharges and tributary inflows.

The model balances water volume and constituent mass in each model segment over space and time using a governing equation that includes the following water quality processes: 1) transport processes, such as advection, diffusion, dispersion and boundary exchanges; 2) external loadings such CSO; and 3) transformation such as decay. A more rigorous description of the governing equation and water quality processes used in the model is available in the user's manual (Ambrose et al., 1993).

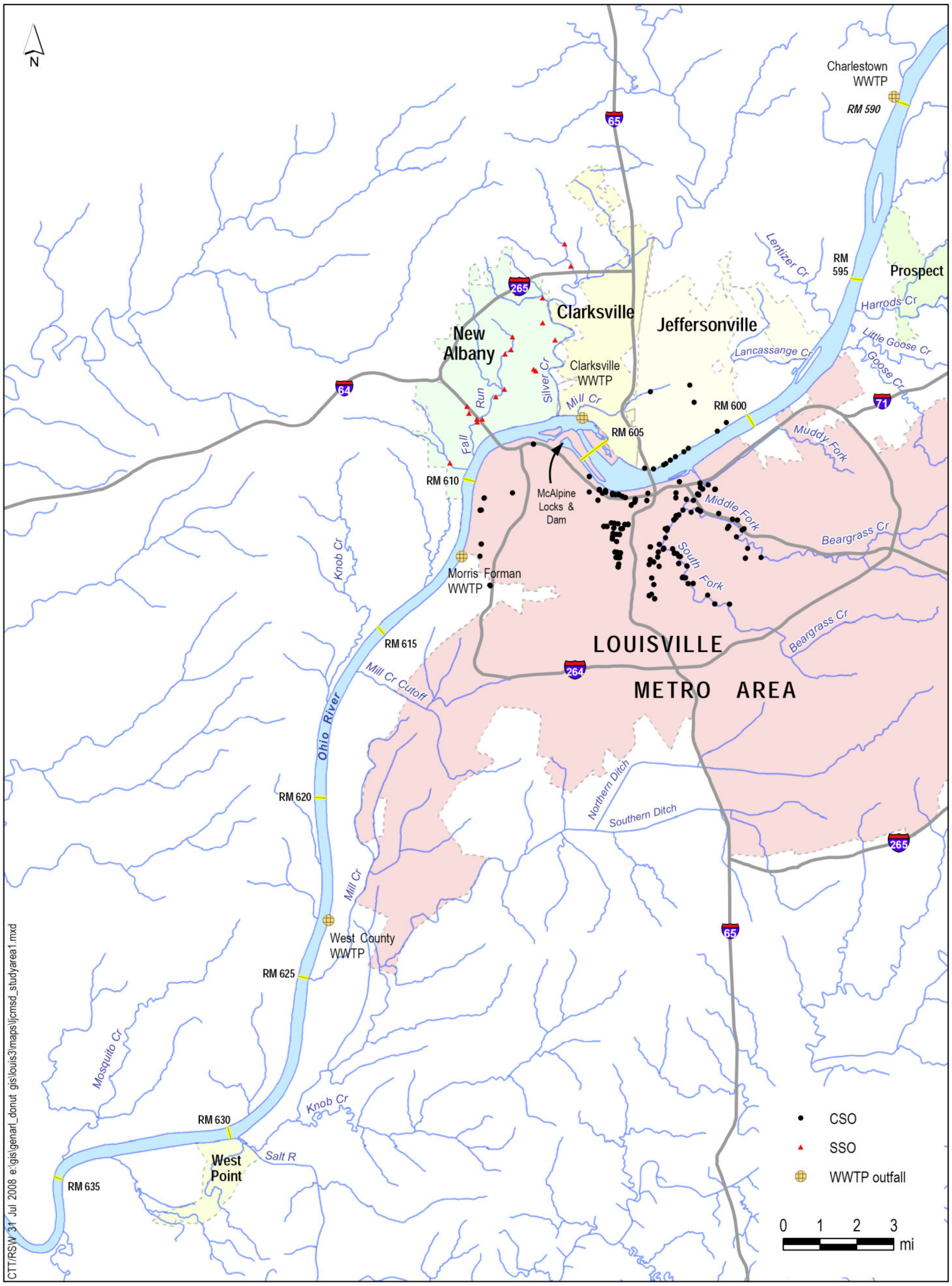
For this study, WASP5 was applied in a two-dimensional mode to address lateral and longitudinal variations in concentration. Model simulated concentrations represent a vertically averaged (or depth-averaged) concentration. EUTRO5 is a sub-component of the WASP5 model used to simulate conventional pollution such as dissolved oxygen, biochemical oxygen demand, nutrients and eutrophication, while TOXI5 is the sub-model used to simulate toxic pollution resulting from constituents such as metals, organic chemicals and bacteria.

In the ORSANCO (2002) study of the Ohio River near Cincinnati, the EUTRO5 model code was modified so that bacteria and dissolved oxygen constituents could be simulated simultaneously in a single model run. This version of the model was used for calibration and validation, although bacteria were the only constituent simulated in this study.

The WASP5 model was constructed in two sections to correspond to the Resource Management Associates-2V model formulations of the study area. The first section covered the portion of the study area upstream of McAlpine Locks and Dam, or approximately from river mile 590 to river mile 607. The second section of the model covered the portion of the study area downstream of McAlpine Locks and Dam, approximately from river mile 607 to river mile 635. These sections were later combined into a single model.

The water quality model covers (see Ohio River Study Figure 2.9.35) the portion of the Ohio River from upstream of the Louisville Metro area (river mile 590) extending downstream to just below the confluence with the Salt River at river mile 635. McAlpine Locks and Dam are located in the center of the model domain at river mile 607. The hydrodynamic model domain was split into two sections with McAlpine Locks and Dam as the boundary between the sections. McAlpine Locks and Dam system includes upper and lower sets of tainter gates and a hydropower plant whose operations vary depending on flow through the system. The increased flow complexity around the McAlpine Locks and Dam necessitated the split in the hydrodynamic modeling. The water quality model was originally set up in the two sections that corresponded to the hydrodynamic model sections and was then combined into a single model prior to calibration and validation.

FIGURE 2.9.35 OHIO RIVER STUDY AREA



Model Segmentation

The water quality model is two-dimensional, describing concentration variations both laterally and longitudinally. Water quality model results are vertically averaged. The modeled area includes all of the CSOs from both Louisville MSD and Jeffersonville, Indiana discharging directly into the Ohio River as well as tributaries that receive CSO loads from these sewerage districts and SSO loads from New Albany, Indiana.

- Kentucky tributaries considered in the model consist of Harrod's Creek, Little Huckleberry Creek, Goose Creek, Beargrass Creek, Mill Creek Cutoff, and Mill Creek.
- Indiana tributaries considered in the model are 14-Mile Creek, Lancassange Creek, Lentizer Creek, Silver Creek, Fall Run, Vincennes Run, French Creek, and 4-Mile Creek. Discharges from WQTCs with outfalls to the Ohio River are also included in the model domain.

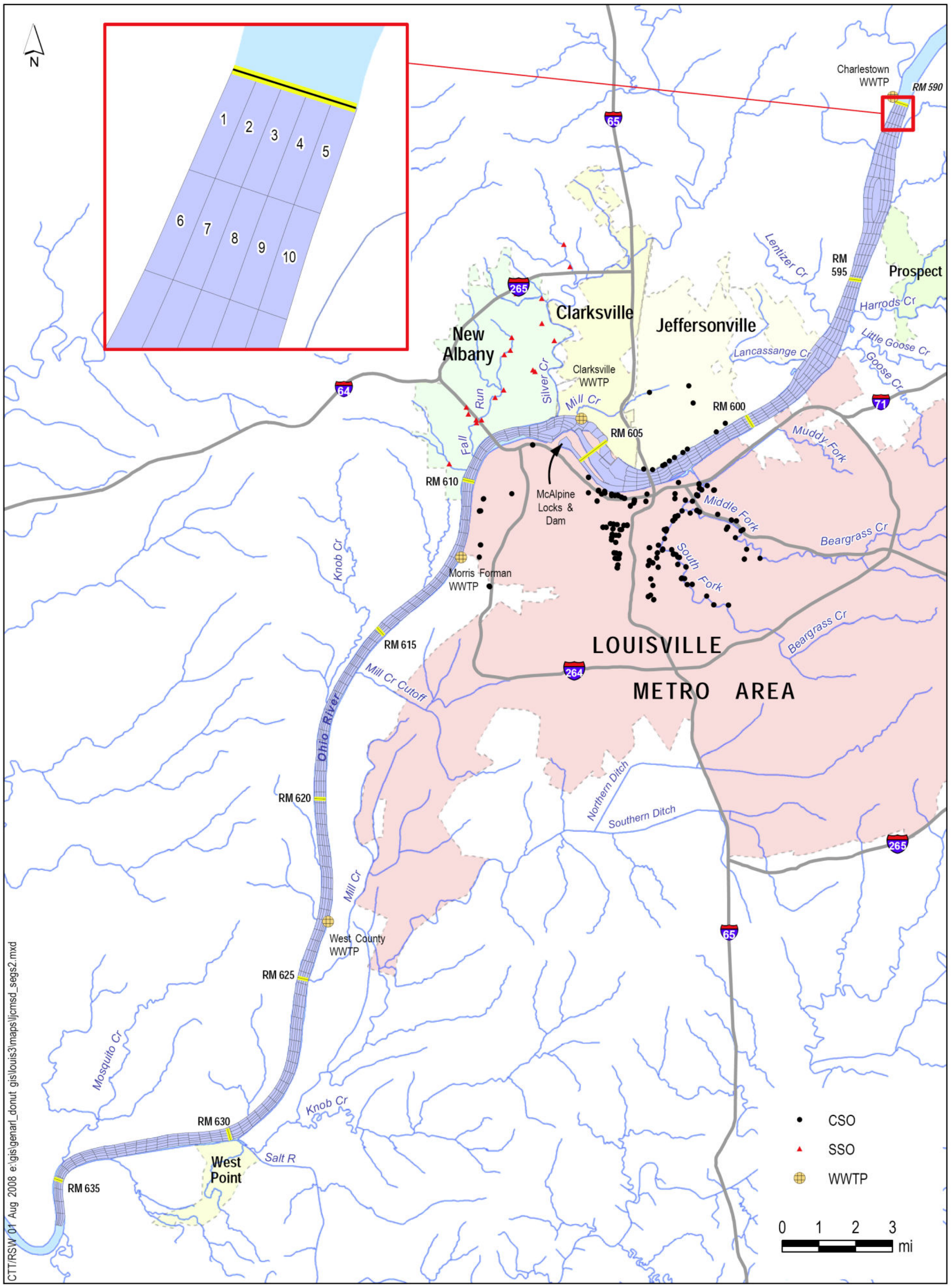
Consequently, the portion of the Ohio River simulated with the water quality model is the area where the biggest impacts from CSOs are expected and where near shore effects would be most pronounced.

The scale required by the Resource Management Associates-2V model for hydrodynamic stability was too refined to adapt directly for use in the water quality model. As a result, the WASP5 water quality model segmentation was defined as a “subset” of the hydrodynamic grid, where a WASP5 segment contained, on average, twenty-four hydrodynamic model elements. The model’s spatial resolution was based upon the approach used in the Cincinnati project (ORSANCO 2002), where it was determined that the model would consist of five lateral segments, approximately divided as follows:

- Bankside channels (one on each shore) = ~10 percent of each cross-sectional area
- Intermediate channels (one on each side of the centerline) = ~20 percent of each cross-sectional area
- Center segment = ~40 percent of each cross-sectional area

The average segment lengths were defined by the length of the hydrodynamic elements and were approximately 0.30 miles in length. The model segmentation immediately upstream of McAlpine Locks and Dam was much larger than the rest of the model domain so that the flow through the Locks and Dam under varying conditions could be reasonably simulated using some simplifying assumptions. The area immediately downstream of the Locks and Dam does not maintain the five segment lateral geometry because of the complexity in river bathymetry and flow patterns through the Locks and Dam area. The WASP5 segmentation is shown in Figure 2.9.36.

FIGURE 2.9.36 WASP5 MODEL SEGMENTATION



The water quality model contains 738 segments in the Ohio River. Of these, 228 segments span the reach upstream of McAlpine Locks and Dam and 510 segments span the reach downstream of McAlpine Locks and Dam.

Linkage to Hydrodynamic Model

The hydrodynamic model results are used to drive the transport in the water quality model. However, direct use of the Resource Management Associates-2V model results in the WASP5 model is not possible for several reasons. First, the Resource Management Associates-2V model is spatially defined by a set of nodes whereas the WASP5 model is spatially defined by a series of segments. The Resource Management Associates-2V model produces a velocity field defined at the nodes, while WASP5 requires a set of balanced and routed steady state flows defined for segment interfaces. Thus, the Resource Management Associates-2V results have to be translated into WASP5 segment space. The second reason is that Resource Management Associates-2V conserves momentum but does not inherently conserve water mass, which is required by the WASP5 model under the steady state flow conditions for which the Resource Management Associates-2V simulations were conducted.

A computer program was created and used to convert finite element nodal information from the hydrodynamic model into water quality model segment volumes, dispersion areas and mixing lengths. A series of three programs were created to transform the Resource Management Associates-2V model results into inputs for the WASP5 model. These programs performed the following operations:

- Converted strings of Resource Management Associates-2V nodes into WASP5 segment interfaces;
- Smoothed (balanced) the inter-segment flows calculated by Resource Management Associates-2V for the WASP5 segment interfaces;
- Converted the individual smoothed segment flows into flow routings through the WASP5 model so that water volume was balanced in each water quality model segment.
- As expected for a large river system, the linkage between the Resource Management Associates-2V model and the WASP5 model routes the majority of the flow downstream from one segment to a segment immediately downstream of it rather than laterally to an adjacent segment.

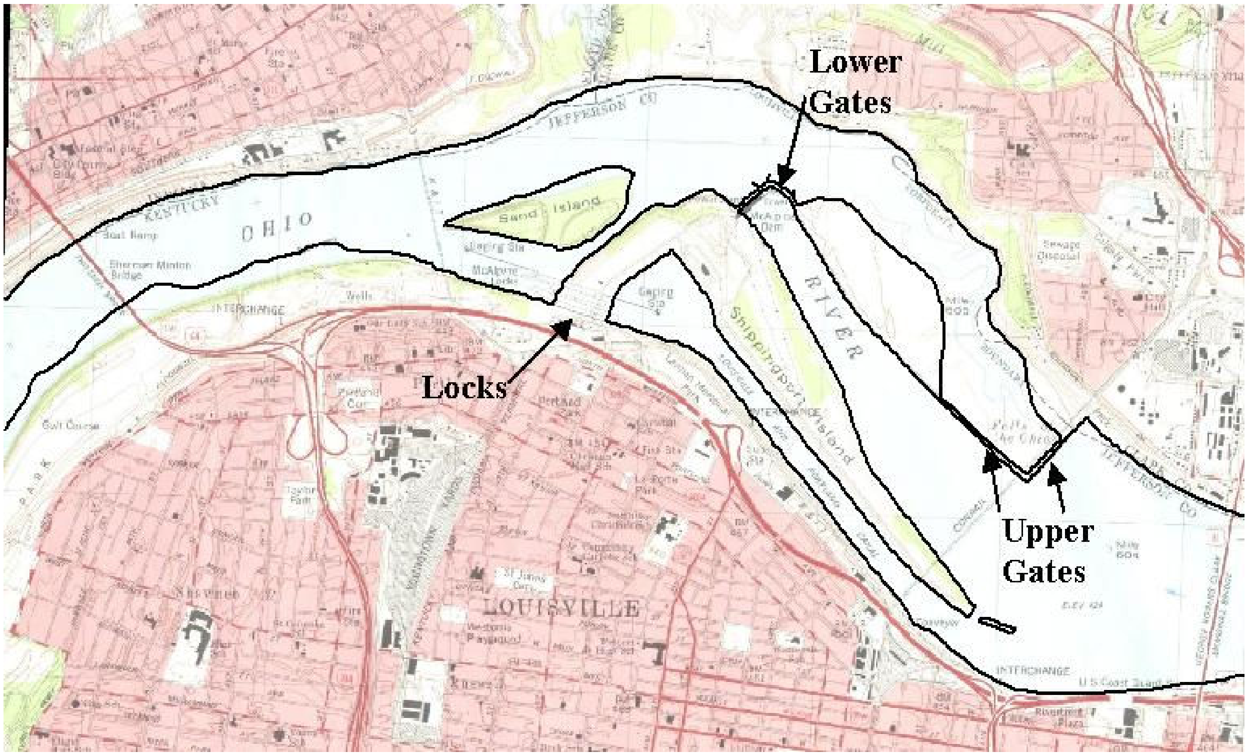
Flow around McAlpine Locks and Dam

The hydrodynamic-water quality model linkage was complicated by the need to incorporate a representation of the McAlpine Locks and Dam and its operating rules into the routings. The area of the river immediately upstream and downstream of McAlpine Locks and Dam (approximately 1.5 miles in either direction) is complex and varies depending on the upstream flow and hydropower needs. Routings through the McAlpine Locks and Dam area were balanced by hand as described below.

McAlpine Locks and Dam consist of structures on the Ohio River extending from river mile 604.4 to river mile 607.4. There are three discharge points, which are illustrated in Figure 2.9.37:

- The lower gates consist of four gates and a number of hydropower units for producing electricity
- The upper gates consist of five gates
- The locks discharge a relatively small portion of the flow

FIGURE 2.9.37 MCALPINE LOCK AND DAM



Each hydropower unit discharges at a rate of several thousand cubic feet per second (cfs) when operating. The remaining flow, other than the Locks, is split between the lower gates and the upper gates depending on the ratio of feet of gate opening for each (that is, one gate open one foot gives one foot of gate opening). Configurations vary based on the time of year, number of hydropower units in operation, etc. Thus, it may not be possible to predict the specific operation of the dam at a given time. However, Table 2.9.17 presents information prepared by the USGS showing typical modes of operating procedure.

TABLE 2.9.17

OPERATING PROCEDURES OBSERVED AT MCALPINE DAM

Discharge, cfs	Lower Gate Opening, ft	Upper Gate Opening, ft	Hydro Units in Operation
200,000	32	65	5
100,000	4	39	6
43,000	7	1	7
36,000	9	0	5
23,000	11	0	1
23,000	2	0	4
16,000	1	0	3
6,500	1	0	1
cfs - cubic feet per second			

A set of empirical equations was developed by regression analysis, based on the data in Table 2.9.17 to predict a reasonably likely operating procedure for a given flow. Equation 1 (r^2 = 0.999) relates flow to hydropower units in operation and feet of gate opening. This equation predicts a discharge of 3,882 cfs from each operating hydropower unit (slightly less than the USGS estimate of 4,000 to 4,400 cfs per unit), a discharge of 1,835 cfs for each foot of total gate opening, plus a constant 951 cfs, which is assigned to the locks discharge.

$$Flow,(cfs) = [3{,}882 * (\#HydroUnits)] + [1{,}835 * (GateOpening, ft)] + 951 \qquad \text{(Eq'n 1)}$$

Equation 2 (r^2 = 0.502) relates the number of hydro units in operation (when the result is rounded to the nearest integer) to the flow.

$$\text{Units} = -10.61 + 1.407 \times (\ln(\text{Flow, cfs} - 951)) \qquad \text{(Eq'n 2)}$$

From equations 1 and 2, the flow through the locks, the hydro units, and the total gate flow is predicted. The remaining variable is the split in gate flow between the lower and upper gates. Equation 3 (r^2 = 0.887) relates the ratio of flow through the lower gates to total gate flow, to the total flow. As in Table 1, no flow is predicted through the upper gates if total flow is less than 36,000 cfs.

$$\frac{\text{Lower Gate}}{\text{Gate Total}} = 1.0 \quad \textit{if} \ (\text{discharge} \leq 36{,}000 \text{ cfs}) \qquad \text{(Eq'n 3b)}$$

$$\frac{\text{Lower Gate}}{\text{Gate Total}} = \min\left(1.0,\ 0.1667 + \frac{1.083e9}{(\text{Flow, cfs - 951})^2}\right) \qquad \text{(Eq'n 3b)}$$

A spreadsheet was developed which uses the Resource Management Associates-2V to WASP5 flow routing just above the dam, the above equations, and simple hand-developed flow routing relationships to route flow through the dam and downstream to the start of the downstream Resource Management Associates section. The routings generally transport flow to the segment immediately downstream of the segment being routed.

An analysis of routings around the McAlpine Locks and Dam indicates that the fraction of flow through each model segment can be described using routings corresponding to three flow regimes. The low flow routings simulate conditions when the upper gates are closed and are based on the spreadsheet results for a flow of 22,900 cfs, which corresponds to the 25th percentile flow at the USGS Gauge (gauge number 03294500) below McAlpine Locks and Dam. The average flow routings simulate conditions between 36,000 cfs and 70,000 cfs when the upper gates are open but less so than the lower gate openings (see Table 2.9.17). The average flow routings for this flow regime were developed from the spreadsheet results for a flow of 42,150 cfs, the median summer flow based on records at the USGS gauge. High flow routings simulate conditions above 70,000 cfs when the flow is split largely between the hydropower units and the upper gates with only a small fraction of flow going through the lower gates. The high flow routings for this flow regime were developed from the spreadsheet results for a flow of 96,625 cfs, which corresponds to the 75th percentile flow at the USGS gauge below McAlpine Locks and Dam. The choice of representative routing used in the model is dependent on the upstream flow at the boundary of the model domain and can be changed daily.

2.9.6.4 Ohio River Water Quality Model Calibration and Validation

Water quality model calibration consists of performing model simulations for some period of historical conditions for which observed water quality data are available. Model predictions are compared to the observed data to ensure that the model matches observed conditions and, as necessary, certain model parameters are adjusted to allow model predictions to best match observed data. The Ohio River water quality model calibration consisted of two parts, 1) calibration of lateral mixing coefficients to dye survey data, and 2) calibration to observed wet weather Ohio River bacteria concentrations.

ORSANCO conducted two dye surveys in the Ohio River during the Fall of 1999 and Spring of 2000 to determine the magnitude of this mixing under a range of flow conditions. The results from these surveys were used to calibrate dispersion coefficients in the WASP5 water quality model as described below.

The Ohio River Water Quality Model was calibrated to data collected by ORSANCO for four wet weather water quality surveys between 1998 and 2001. The model was originally calibrated for the ORSANCO study, and then improved upon for the LTCP. The landside loadings used in the original version of the Ohio River Water Quality Model were taken from an HSPF-based model named the Louisville/Southern Indiana Water Quality Model (ORSANCO, 24). The Louisville/Southern Indiana Water Quality Model did not explicitly model CSOs, and used regression equations to predict CSO volume as a function of precipitation. Complete documentation of the ORSANCO study is contained in Appendix 2.9.2, Wet Weather Impact Study on the Ohio River (Louisville/Southern Indiana Area). Significant efforts have been made in improving the landside loading inputs to the Ohio River Water Quality Model as part of this

LTCP effort. The Beargrass Creek Water Quality Tool (described earlier in this report) was used to calculate all landside loading to Beargrass Creek, as well as their transfer to the Ohio River. The InfoWorks CS (also described earlier in this report) model was used to calculate all direct CSO discharges to the Ohio River.

In the current recalibration phase, the improved landside loads have been applied to the existing model and the model has been rerun. In addition to comparing model output to observed data at specific points in time, specific calibration metrics were defined. Application of these metrics demonstrated that the quality of the current calibration is as better than the original calibration. Complete documentation of the Ohio River Water Quality model is contained in Appendix 2.9.3, Ohio River Water Quality Model Calibration Report.

2.9.6.5 Overview of Ohio River Water Quality Model Results

The Ohio River water quality model was run to predict fecal coliform concentrations in the Ohio River for a series of alternative loading scenarios. Five scenarios were analyzed, corresponding to baseline, zero overflows per year, two overflows per year, four overflows per year, and eight overflows per year. The baseline simulation corresponds to no additional controls, while the remaining simulations reflect the control of CSOs to a given number per year. Simulations were conducted to represent year 2001 environmental conditions.

These simulations reflect loading reductions from Louisville Metro/Jefferson County CSOs that discharge directly to the Ohio River, as well as CSOs that indirectly reach the Ohio River via Beargrass Creek. O'Brien & Gere provided hydrographs for those CSOs discharging directly to the Ohio River for the baseline condition, as well as the two, four, and eight overflows per year conditions. fecal coliform load loading from these CSOs was simulated by applying an assumed Event Mean Concentration of 650,000 colony forming unit (cfu)/100 ml), based upon previous analysis done during the ORSANCO study. TetraTech provided results from their Beargrass Creek Water Quality Tool to represent the total Beargrass Creek load. These loads reflect both CSO and stormwater loading to Beargrass Creek. Upstream boundary concentrations were based on recently observed data, and were set at a concentration of 73 cfu/100 ml when river flows were 200,000 cfs or less, and 655 cfu/100 ml when river flows were greater than 200,000 cfs. All other external loads to the Ohio River (i.e. other tributaries, Indiana CSO and stormwater loads) were left unchanged from the scenario analysis conducted previously for the ORSANCO Ohio River water quality modeling work.

Figure 2.4.21, which summarized of CSO water quality data, demonstrated the high degree variability in observed fecal coliform concentrations throughout the collection system. Average CSO fecal coliform concentrations at individual CSOs are seen to range from less than 100,000 up to 1,000,000 cfu/100 ml. Given the wide range of the observed data between locations, and the fact that most of the data used to derive the 250,000 cfu/100 ml estimate were collected from the Beargrass Creek watershed, the decision was made to maintain the difference in assumed Event Mean Concentrations between CSOs discharging into Beargrass Creek and those discharging directly to the Ohio River. Insufficient data specific to Ohio River CSOs was available to justify changing the previously estimated values for these CSOs and potentially invalidate the calibration of the Ohio River water quality model.

Results were examined at five locations along the length of the Ohio River, in terms of peak concentration and compliance with existing water quality standards. The locations examined are:

- Upstream of the Louisville Metro area
- Immediately upstream of Beargrass Creek
- At the I-65 bridge
- Downtown Louisville Metro
- Below the Morris Forman WQTC
- At the confluence of the Salt River

Results are summarized in Table 2.9.18 in terms of percentage noncompliance with the single sample maximum water quality standard and the maximum concentration during the recreational season (cfu/100 ml). Percent noncompliance with the geometric mean water quality standard was also evaluated and was 0 percent at all locations for all scenarios.

TABLE 2.9.18

SUMMARY OF OHIO RIVER MODEL RESULTS

Location	**% Noncompliance with Maximum Standard during Recreational Season**					**Maximum Concentration during Recreational Season (cfu/100 ml)**				
	# of Overflows/Year					**# of Overflows/Year**				
	Baseline	**8**	**4**	**2**	**0**	**Baseline**	**8**	**4**	**2**	**0**
Upstream	33	33	33	33	33	650	650	650	650	650
Above Beargrass Creek	33	33	33	33	33	9,900	9,900	9,900	9,900	9,900
I-65 Bridge	33	33	33	33	33	6,600	6,700	6,700	6,700	6,700
Downtown	100	33	33	33	33	6,900	5,300	5,300	5,300	5,300
Below Morris Forman WQTC	100	83	83	83	83	100,000	46,000	46,000	46,000	46,000
Confluence Salt River	67	67	67	67	67	56,000	56,000	56,000	56,000	56,000

These results demonstrate that an improvement in water quality is seen both in downtown Louisville Metro and below the Morris Forman WQTC when moving from baseline conditions to a CSO control scenario of eight overflows per year, both in terms of compliance with water quality standards and maximum concentration. Water quality benefits of CSO control are not observed in the Ohio River when reducing CSO overflows to less than eight per year, nor are the benefits observed in the areas upstream and far downstream of Louisville Metro. These results also indicate that elimination of CSOs will not result in compliance with water quality standards at any of the locations investigated, as stormwater sources alone are sufficient to cause water quality standards violations.

TABLE 2.4.5

SUMMARY OF CSO DATA FOR Biochemical oxygen demand (BOD), FECAL COLIFORM-AND TSS

Site		BOD							Fecal							TSS						
Location	Description	No.	Min	Ave	Max	Stdev	Ave-1 Stdev	Ave+1 Stdev	No.	Min	Ave	Max	Stdev	Ave-1 Stdev	Ave+1 Stdev	No.	Min	Ave	Max	Stdev	Ave-1 Stdev	Ave+1 Stdev
C0000008	CSO 206	38	1	45	303	65	0	110	38	1	195060	3000000	568375	1	763435	39	1	162	1540	328	0	490
C0000009	CSO 209	17	1	23	88	28	0	51	30	1	19220	216000	45283	1	64503	17	0	91	713	173	0	264
C0000011	CSO 108 N Unit	6	8	10	11	1	9	11	6	11000	70000	98000	32150	37850	102150	6	32	49	58	10	39	58
C0000012	CSO 108 S Unit	6	9	11	17	3	8	14	6	3200	56333	93000	39784	16549	96117	6	55	66	83	10	56	77
C0000024	CSO 110	39	1	36	138	33	3	69	39	1	999820	34000000	5432671	1	6432491	40	1	129	567	125	4	254
C0000025	CSO 117	28	1	111	430	127	0	238	30	1	232297	2093000	505435	1	737732	28	1	246	1023	246	1	492
C0000026	CSO 125	15	7	193	1330	462	0	655	16	580	267524	1200000	465486	1	733010	15	28	125	538	140	0	265
C0000027	CSO 127	20	1	59	241	67	0	126	26	1	91631	1200000	246505	1	338136	19	1	214	780	219	0	433
C0000028	CSO 140	8	3	28	85	28	0	57	9	430	158067	1200000	391367	1	549433	9	1	118	312	136	0	254
C0000029	CSO 151	32	1	75	434	80	0	155	39	1	159507	1200000	305968	1	465475	33	1	207	797	202	5	408
C0000030	CSO 152	34	1	51	231	55	0	105	35	1	132094	1200000	273698	1	405792	34	0	137	402	120	18	257
C0000031	CSO 153	1	291	291	291				3	120000	120000	120000	0	120000	120000	1	623	623	623			
C0000042	CSO 016															8	1	325	552	210	115	535
C0000043	CSO 019															6	256	413	548	121	292	535
C0000044	CSO 050															11	49	97	176	45	53	142
C0000045	CSO 189															5	256	296	408	63	233	359
C0000046	CSO 190															2	136	164	192	40	124	204
C0000104	CSO 146	3	336	351	367	16	335	367								3	600	698	865	145	553	843
C0000017	CSO 210															11	1	347	660	227	120	573
C0000016	CSO 211															14	1	468	1260	200	168	768

TABLE 2.7.4

OVERALL SUMMARY OF THE RECREATIONAL USE SURVEY RESULTS

Park ID	Park Name	Watershed	# of Site Visits	Total Observed			Avg Observed			Non-Contact Activities			Contact Activities			Contact	% Children	% Potential	% Contact
				Total	Adults	Children	Total	Adults	Children	Total	Adults	Children	Total	Adults	Children	Observed		Contact	
1	**Farnsley - Moremen Landing**	Ohio River	104	962	880	82	10	9	1	939	857	82	23	23	0	1	8.52%	2.29%	0.10%
2	**Riverview Park**	Ohio River	104	2,631	2,411	220	27	24	3	1,630	1,435	195	1,001	976	25	74	8.36%	35.23%	2.81%
3	**Waterfront Park**	Ohio River	104	4,294	3,703	591	42	36	6	3,302	2,751	551	992	952	40	47	13.76%	22.01%	1.09%
4	**Cox Park**	Ohio River	104	4,890	4,677	213	48	45	3	2,434	2,240	194	2,456	2,437	19	71	4.36%	48.77%	1.45%
5	**Louisville Soccer Park**	Muddy Fork BGC	104	829	502	327	9	5	4	827	500	327	2	2	0	1	39.45%	0.12%	0.12%
6	**Cherokee Golf Course - Lexington Rd**	Middle Fork BGC	104	793	783	10	9	8	1	292	291	1	501	492	9	9	1.26%	62.04%	1.13%
	Cherokee Park - Shelter	Middle Fork BGC	104	2,427	2,175	252	24	21	3	2,427	2,175	252	0	0	0	0	10.38%	0.00%	0.00%
8	**Seneca Park - Scenic Loope**	Middle Fork BGC	104	1,220	1,210	10	13	12	1	1,190	1,180	10	30	30	0	0	0.82%	2.46%	0.00%
9	**Seneca Park - Big Rock**	Middle Fork BGC	104	2,096	1,865	231	21	18	3	1,485	1,301	184	611	564	47	267	11.02%	16.41%	12.74%
10	**Seneca Golf Course**	Middle Fork BGC	104	1,799	1,792	7	19	18	1	1,785	1,778	7	14	14	0	1	0.39%	0.72%	0.06%
11	**Brown Park**	-	8	129	129	0	17	17	0	129	129	0	0	0	0	0	0.00%	0.00%	0.00%
12	**Joe Creason Park**	South Fork BGC	104	976	798	178	10	8	2	976	798	178	0	0	0	0	18.24%	0.00%	0.00%
13	**Louisville Junior Academy**	-	8	59	59	0	8	8	0	59	59	0	0	0	0	0	0.00%	0.00%	0.00%
14	**Eva Bandman Park - Ohio River**	Ohio River	94	2,348	2,281	67	26	25	1	2,135	2,068	67	213	213	0	3	2.85%	8.94%	0.13%
15	**Eva Bandman Park - BGC**	BGC Confluence	94	519	519	0	6	6	0	426	426	0	93	93	0	0	0.00%	17.92%	0.00%
16	**Beargrass Creek at Irish Hill**	Middle Fork BGC	32	202	190	12	7	6	1	202	190	12	0	0	0	0	5.94%	0.00%	0.00%
17	**Butchertown Greenway**	BGC Confluence	32	53	52	1	3	2	1	41	40	1	12	12	0	0	1.89%	22.64%	0.00%
		TOTAL =	**1,412**	**26,227**	**24,026**	**2,201**	**299**	**268**	**31**	**20,279**	**18,218**	**2,061**	**5,948**	**5,808**	**140**	**474**	**8.39%**	**20.87%**	**1.81%**