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Development of a Data Analysis Framework for CSOs

Lindell E. Ormsbee
University of Kentucky College of Engineering, lindell.ormsbee@uky.edu

A. Reddy
University of Kentucky

D. McPherson
University of Kentucky

S. Gruzesky
University of Kentucky

A. Jain
University of Kentucky

DEVELOPMENT OF A DATA ANALYSIS FRAMEWORK FOR ASSESSMENT AND MANAGEMENT OF COMBINED SEWER OVERFLOWS IN KENTUCKY

1994 ANNUAL REPORT

REPORT UKCE9501

by

L. Ormsbee, Associate Professor
Department of Civil Engineering
University of Kentucky , Lexington, Kentucky 40506-0281

and

A. Reddy, D. McPherson, S. Gruzesky, A. Jain, Graduate Students
Department of Civil Engineering, University of Kentucky

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EXECUTIVE SUMMARY

This report records the progress made in satisfying the two primary objectives associated with the project. The specific objectives include:

1) To develop a database framework for use in assessment and management of combined sewer overflows in Kentucky.

2) To assess the impact of CSOs on the water quality of the Northern Kentucky region through data collection and analysis and prelimary model construction.

During the first year of the project, extensive data collection and analysis was performed on Banklick Creek which flows into the Licking River approximately 3 miles south of the confluence of the Licking River with the Ohio River. The results of this study have been reported previously (Ormsbee et. al., 1994a). During the second year of the project the primary focus shifted to the Licking River. The results of this study have been reported in a separate study (Ormsbee et. al., 1995).

The CSO database component of the project was begun in September 1993. Initial work included an investigation of acceptable hardware and software platforms for use in constructing the planned CSO database. The final selected framework includes an integrated environment which links a graphic creation module (ArcCad), a graphic display module (ArcView), a database module (dBase IV) and numerical model environment (Quatro Pro). The propose environment also includes translation software to provide a linkage between the decision support system and the natioanl EPS PCS database environment. A discussion of the final selected framework has been reported under separate cover (Ormsbee, et. al., 1994b).

Both components of the study were conducted through the Kentucky Water Resources Research Institute of the University of Kentucky and were funded by the Kentucky Natural Resources and Environmental Protection Cabinet through a grant from the United States Environmental Protection Agency. It is expected that the results of the database study will provide the Kentucky Division of water with a comprehensive tool for assessment and management of CSOs in the state of Kentucky. It is expected that the results of water quality assessment study will provide valuable information for use by the Kentucky Division of Water in the preparation of CSO permits for the Northern Kentucky region.

I. CSO ASSESSMENT STUDY

1. The CSO assessment of the Licking River was initiated in June of 1994 although actual preparation began in January. Between June and September 1994, extensive sampling was conducted on the Licking River. The results of this investigation have been reported under separate cover (Ormsbee, et. al., 1995). A summary of the monthly activities as related to this study is provided in the following paragraphs.

January 1994: During January, the sampling protocol for the Licking River was established. Sampling equipment was tested and repaired. Analysis of the results from Banklick Creek revealed some variability with regard to the impact of the Church Street CSO. As a result, a decision was made to take some additional samples from this site.

February 1994: During the month of Februrary preparations continued for the planned sampling on the Licking River. The necessary equipment was obtained and supplies were obtained. A continuous raingage was installed at the Taylormill Fire station for monintoring regional rainfall during the sampling effort.

March 1994: Anticipated sampling during the month of March was prevented as a result of the high water levels on the Licking River which had flooded the numerous pump stations along the River bank.

April 1994: During the month of April, the proposed sampling protocol was tested and finalized. A decision was made to sample the river using the Division of Water boat.

May 1994: Sampling on the Licking River was again hampered as a result of high water levels. As a result, monitoring equipment was re-installed in the Church Street CSO on Banklick Creek. Two Flow-Tote flow meters were also installed at key locations within the sewer system to monitor flow conditions downstream of the Church Street CSO. Stream base line samples were taken directly upstream and down stream of the Church Street CSO in order to obtained a refined assessment of the impact of the Church Street CSO. A new continuous raingage was installed across from the Church Street CSO at the water treatment plant.

June 1994: Nine different sets of samples were collected during the month of June. The majority of these samples were collected on the Licking river before and after the storm events. Two separate samples were collected during storm events from the Eighth Street outfall.

July 1994: Four sets of baseline samples for long-term analysis and two sets of samples for the short-term analysis were collected on Licking river. Long-term samples were collected on Eighth Street CSO and upstream and down stream sites. In addition two sets of short-term samples were collected from the Church Street CSO.

August 1994: Four sets of baseline samples from all eight sites were collected from the Licking River for long-term analysis. Two of these sets were collected on the same day after the storm event. Four additional sets of samples were collected from the Church Street CSO for short-term analysis. Two extra sets of samples were collected from Banklick Creek after the storm events.

September 1994: Several attempts were made to obtain a final set of samples on the Licking River. Unfortunately, September turned out to be a very dry month and no additional samples were obtained.

October 1994: During the month of September, two of the four personnel involved in the sampling effort left the project. In addition, both graduate students involved in the BOD and solids analysis graduated and were no longer available to the project. As a result a decision was made to terminate the sampling effort. Consequently, the boat was returned to Divsion of Water personnel and the sampling equipment associated with the Church Street CSO was removed and returned to the Florence office of the Kentucky EPA.

November 1994: During the month of November, work on the Licking River report was begun. In addition, several data analyses were initiated on the collected data.

December 1994: During the month of December, work continued on the preparation of the Licking River report.

II. CSO DATABASE STUDY

1. The CSO database component of the project was begun in February 1993 and has continued up to the present. During the Spring of 1994 a final database framework was developed that utilizes existing off the shelf components. A detailed description of the proposed framework has been presented previously (Ormsbee, et. al., 1994b). The implementation of the proposed framework has been delayed as a result of the delayed release of ArcView II and the lack of sufficient personnel within the Division of Water. In an attempt to help aleviate the later problem a research engineer was assigned to the KPDES branch during 1995. It is anticipated that the recent release of ArcView II and the availability of additional staff will facilitate the final development and implementation of the proposed environment. A summary of the monthly activities as related to the database effort is provided in the following paragraphs.

January 1994: Work was continued on gathering data files to construct the GIS database. Discussions were continued with the Division of Water Frankfort Personnel about the proposed database component and some modifications were made.

February 1994: After considering several packages, a decision was made to utilize ArcCAD and ArcView for the proposed spatial databased environment. In addition, a decision was made to utilize U.S. Census Burea TIGER files for creation of the background maps for the CSO database. Efforts were begun to become more familiar with the TIGER file format in order to be able to integrate them into ArcINFO Coverage files.

March 1994: Work Continued on developing the required attribute data for the CSO database. As a pilot project, work on an initial spatial database for Banklick Creek was begun.

April 1994: After meeting with state officials, work was begun on an interface program that would provide a conversion of ASCII files into files compatible with dBASE IV. The dBASE IV database program was chosen for use in the proposed environment due to its compatability with both ArcCAD and ArcView.

May 1994: A preliminary dBASE IV program was developed for use in accessing CSO data associated with Banklick Creek.

June 1994: The framework for the proposed database framework was finalized. Work was begun on a summary report of the proposed framework along with a paper to be presented at the 1994 Water Environment Federation Conference on CSOs.

July 1994: A paper entitled "A spatial decision support system for the assessment and management of CSOs in the State of Kentucky" was presented at the 1994 WEF Conference on CSOs which was held in Louisville, Kentucky.

Aug 1994: A presentation of the proposed spatial decision support system was made to state officials. Work continued on developing the required interfaces between the various components of the system.

September 1994: A meeting was held with the Division of Water Personnel to finalize the database protocol for the Permit Compliance System format. A detailed workplan was prepared for the development and implementation of the proposed plan.

October 1994: Work continued on finalizing the integration requirements associated with the proposed plan. Updated versions of AcrCAD and AutoCAD 12 were obtained and installed. A plan to send an individual to work in Frankfort with state officials to implement the plan was proposed.

November 1994: After nearly a six month delay, ArcView II was finally received and installed. Mr. Reddy began working in Frankfort in the KPDES Branch

December 1994: Mr. Reddy continued to make progress in laying the ground work for implementing the proposed environment.

III. TRAVEL LOG

1. As part of the project, a state vehicle was assigned to the project. A list of the trips taken as part of the project either in the state vehicle or private vehicles is provided in Table 1.

Table 1. 1994 Project Travel Log

DATE	FROM	TO	REASON
2/23/94	LEXINGTON	COVINGTON	PRACTICE FOR SAMPLING
3/30/94	LEXINGTON	COVINGTON	EQUIPMENT INSTALLATION
4/5/94	LEXINGTON	FRANKFORT	MEETING WITH DIVISION OF WATER PERSONNEL
4/22/94	LEXINGTON	COVINGTON	MEETING WITH SANITATION DIST PERSONNEL
4/28/94	LEXINGTON	COVINGTON	PRACTICED SAMPLING PROTOCOL
3/5/94	LEXINGTON	COVINGTON	COLLECT STREAM SAMPLES
5/13/94	LEXINGTON	COVINGTON	INSTALLATION OF EQUIP. AT CHURCH STREET
5/14/94	LEXINGTON	COVINGTON	COLLECT STREAM SAMPLES AND INSTALLATION OF RAINGAGE
5/15/94	LEXINGTON	COVINGTON	COLLECT STREAM AND CSO SAMPLES
5/16/94	LEXINGTON	COVINGTON	COLLECT STREAM AND CSO SAMPLES
5/25/94	LEXINGTON	COVINGTON	COLLECT STREAM AND CSO SAMPLES
5/26/94	LEXINGTON	COVINGTON	COLLECT STREAM SAMPLES

6/7/94	LEXINGTON	COVINGTON	COLLECT STREAM BASELINE SAMPLES
6/9/94	LEXINGTON	COVINGTON	COLLECT STREAM BASELINE SAMPLES
6/10/94	LEXINGTON	COVINGTON	COLLECT STREAM SAMPLES
6/14/94	LEXINGTON	COVINGTON	COLLECT STREAM BASELINE SAMPLES
6/16/94	LEXINGTON	COVINGTON	COLLECT STREAM BASELINE SAMPLES
6/21/94	LEXINGTON	COVINGTON	COLLECT STREAM BASELINE SAMPLES
6/23/94	LEXINGTON	COVINGTON	COLLECT STREAM AND CSO SAMPLES
6/24/94	LEXINGTON	COVINGTON	COLLECT STREAM AND CSO SAMPLES
6/27/94	LEXINGTON	COVINGTON	COLLECT STREAM BASELINE SAMPLES
6/28/94	LEXINGTON	COVINGTON	COLLECT STREAM SAMPLES
7/1/94	LEXINGTON	COVINGTON	COLLECT STREAM SAMPLES
7/2/94	LEXINGTON	COVINGTON	COLLECT STREAM BASELINE SAMPLES
7/6/94	LEXINGTON	COVINGTON	COLLECT STREAM BASELINE SAMPLES
7/7/94	LEXINGTON	COVINGTON	COLLECT STREAM AND CSO SAMPLES
7/8/94	LEXINGTON	COVINGTON	COLLECT STREAM AND CSO SAMPLES
7/9/94	LEXINGTON	COVINGTON	COLLECT STREAM AND CSO SAMPLES
7/11/94	LEXINGTON	LOUISVILLE	CSO CONFERANCE
7/11/94	LEXINGTON	LOUISVILLE	CSO CONFERANCE

14-Jul	LEXINGTON	COVINGTON	COLLECT BASELINE STREAM SAMPLES
7/15/94	LEXINGTON	COVINGTON	COLLECT STREAM AND CSO SAMPLES
7/21/94	LEXINGTON	COVINGTON	COLLECT BASELINE STREAM SAMPLES
7/22/94	LEXINGTON	COVINGTON	COLLECT STREAM AND CSO SAMPLES
7/26/94	LEXINGTON	COVINGTON	COLLECT STREAM BASELINE SAMPLES
7/27/94	LEXINGTON	COVINGTON	COLLECT STREAM AND CSO SAMPLES
8/3/94	LEXINGTON	COVINGTON	COLLECT STREAM SAMPLES
8/4/94	LEXINGTON	COVINGTON	COLLECT STREAM SAMPLES
8/5/94	LEXINGTON	COVINGTON	COLLECT STREAM AND CSO SAMPLES
8/20/94	LEXINGTON	COVINGTON	COLLECT LONGTERM STREAM SAMPLES
8/21/94	LEXINGTON	COVINGTON	COLLECT LONGTERM STREAM SAMPLES
9/12/94	LEXINGTON	FRANKFORT	MEETING WITH DIVISION OF WATER PERSONNEL
9/21/94	LEXINGTON	CINCINNATI	TRIP TO CINCINNATI FOR EPA CONFERANCE
9/22/94	LEXINGTON	CINCINNATI	TRIP TO CINCINNATI FOR EPA CONFERANCE
9/23/94	LEXINGTON	COVINGTON	COLLECT STREAM SAMPLES AND REMOVE EQUIPMENT
10/28/94	LEXINGTON	COVINGTON	RETURN THE EQUIPMENT
12/5/94	LEXINGTON	COVINGTON	RETURN THE STATE VEHICLE

IV. MEETING LOG

1. As part of the project, several meetings were held, either with state officials or representatives of the Sanitation District #1 of Kenton and Campbell Counties. A list of the meetings held as part of this project are provided in Table 2.

Table 2. 1994 Project Meeting Log

DATE	MET WITH	REASON
4/5/94	DIVISION OF WATER	PROJECT OVERVIEW AND DISCUSS ABOUT CSO DATABASE
4/22/94	SANITATION DIST	PROJECT OVERVIEW AND EQUIPMENT INSTALLATION
8/04/94	DIVISION OF WATER	PRESENT RESULTS OF BANKLICK CREEK STUDY
9/12/94	DIVISION OF WATER	DISCUSS ABOUT THE PCS FORMAT PROTOCOL

V. PUBLICATIONS AND PRESENTATIONS

As part of the project several publications were produced and several presentations were made. A list of the associate publications and presentations is provided below:

Chinnatimmareddy, R., "Combined Sewer Overflow Management on a GIS Environment," presented at the 1993 Kentucky Water Resources Symposium, Lexington, Kentucky.

Gruzesky, S., "Combined Sewer Overflows and their Effects on Receiving Waters in Northern Kentucky," presented at the 1993 Kentucky Water Resources Symposium, Lexington, Kentucky.

Ormsbee, L., Gruzesky, S., Jain, A., and Reddy, A., 1994, *CSO Impact Assessment of Banklick Creek*," Report UKCE9402.

Ormsbee, L., Reddy, A., Jain, A., and Gruzesky, S., 1994, *A Spatial Decision Support System for Assessment and Management of CSOs in the State of Kentucky*, Report UKCE9403.

Ormsbee, L., Reddy, A., Gruzesky, S., and Jain, A., 1994, "A Decision Support System for Management and Assessment of CSOs in Kentucky," *Proceedings of the 1994 WEF Specialty Conference on a Global Perspective for Reducing CSOs*, Louisville, Kentucky.

Jain, Ashu, "Northern Kentuck CSO Study," presented at the 1994 ORSANCO Conference on CSO Impacts, Louisville, Kentucky,

Gruzesky, S., 1994, *An Evaluation of the Combined Sewer System and Impacts of the Combined Sewer Discharges on Banklick Creek*, MSCE Report, University of Kentucky, Lexington, Kentucky.

VI. SUMMARY

During the second year of the project, sampling was completed on the Licking River. In addition, more detailed sampling was conducted on the Church Street CSO on Banklick Creek. A final report on the Licking River sampling effort is expected at the end of January. The framework for the propsed CSO Decision Support System was developed and finalized and initial steps were taken to begin the implementaion of the proposed system. The proposed decision support system will be able to be implemented using PC based computer technology along with existing commercially available databases and GIS software. It is expected that the developed environment will be useful for providing a graphical interface with the EPA PCS database as well as providing additional tools for use in the assessment and management of combined sewer overflows in Kentucky.

The initial CSO and stream sampling associated with Banklick Creek revealed that pollutant loadings on the creek always increased following a storm event. However, the impact of a specific overflow event appears to be highly dependent upon antecedent flow conditions, the creek volume and flow velocity, and the magnitude of the associated storm event. The CSO sampling associated with the Licking River has revealed that the primary pollutant loadings are associated with fecal contamination. In most cases, the dissolved oxygen levels remained above acceptable levels following storm events, although noticeable decreases were observable.

During the next six month period, it is anticipated that the essential components of the proposed decision support system will be put in place. In addition, the required linkages between the proposed environment and the existing PCS system should be established. As a result of the data obtained from the study, several student projects have also been initiated. It is anticpated that the results of these studies will be available in August 1995.

VI. REFERENCES

Ormsbee, L., Gruzesky, S., Jain, A., and Reddy, A., 1994a, *CSO Impact Assessment of Banklick Creek*, Report UKCE9402.

Ormsbee, L., Reddy, A., Jain, A., and Gruzesky, S., 1994b, *A Spatial Decision Support System for Assessment and Management of CSOs in the State of Kentucky*, Report UKCE9403.

Ormsbee, L., Jain, A., Reddy, A., McPherson, D., 1995, *CSO Impact Assessment of the Licking River*, Report UKCE9502.

CSO Project

Monthly Report for the Month of November 1994

Work Accomplished in November

During the month of November, Dr. Ormsbee continued to work on the 1994 Annual Project Report and the Licking River Data Collection and Analysis Report. A new graduate student was recruited to develop an oxygen depletion model for the Licking River, while Mr. Reddy continued work on an oxygen depletion model for Banklick Creek.

As a result of the loss of several project personnel, and decreasing temperatures, a decision was made to terminate the sampling effort on the Licking River. As a result, Mr. Reddy was re-assigned from the University of Kentucky to the KPDES Branch of the Division of Water. On Monday's Mr. Reddy meets with Dr. Ormsbee at the University of Kentucky to review his progress and to continue work on the Licking River report while during the rest of the week Mr. Reddy works in Frankfort under the supervision of Mr. John Drake with the KPDES Branch with KPDES. The initial focus of his responsibilities in Frankfort are as follows:

1) Prepare and send questionnaires to all CSO permit holders to obtain basic system information.

2) Work with the data processing branch to develop a protocol for processing information associated with CSO questionnaires.

3) Evaluate the available GIS resources within the Division of Water.

During the initial week of his assignment, Mr. Reddy became familiar with the Federal Regulations associated with the new 1994 CSO strategy as well the standard operation procedures associated with the KPDES Branch. The majority of Mr. Reddy's activities during November centered on investigating the steps required to implement a GIS database system and in preparing and distributing a CSO questionnaire. The developed questionnaire has the following format.

1) CSO identification file layout
2) CSO sample information file layout.
3) Description of parameter codes and shape codes.

The information included in the questionnaire will help the KPDES Branch to document and track information associated with each CSO through the EPA PCS system.

Project Goals for December

During the month of December work will continue on the two project reports. Mr. Reddy will continue to work on the construction of a GIS environment for the CSO data.

CSO IMPACT ASSESSMENT FOR BANKLICK CREEK

REPORT UKCE9402

by

L. Ormsbee, Associate Professor
Department of Civil Engineering
University of Kentucky , Lexington, Kentucky 40506-0281

and

S. Gruzesky, A. Jain, A. Reddy, McPherson, D.
Graduate Students
Department of Civil Engineering, University of Kentucky

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EXECUTIVE SUMMARY

This report contains the results of a combined sewer overflow (CSO) impact assessment study for Banklick Creek which flows into the Licking River just south of Covington, Kentucky in Kenton County Kentucky. This study is a component of a larger study that was conducted to determine the general impact of CSOs in the Northern Kentucky region. The study was conducted through the Kentucky Water Resources Research Institute of the University of Kentucky and was funded by the Kentucky Natural Resources and Environmental Protection Cabinet through a grant from the United States Environmental Protection Agency.

The original objective of this study was to quantify the impact of combined sewer overflows on Banklick Creek. This was accomplished by instrumenting and sampling two combined-sewer discharge pipes along with seven separate stream locations. The two combined-sewer discharge pipes were located between KY16 and KY177 while the stream samples were collected at various points between I275 and the mouth of Banklick Creek. Initial baseline sampling of the creek indicated the probable occurrence of additional overflows at the Lakeview Pump Station creek crossing. Because of sampling difficulties, this site was not instrumented although stream samples were taken upstream and downstream of the site in an attempt to assess its possible impact.

This report contains the results of the sampling effort for the period 7/1/93-11/1/93. During this time period, water quality samples were collected for 5 baseline events, 4 short term (6 hours) events, 2 intermediate (2 day) events and 3 long term (3-5 days) events. A total of 220 separate stream samples and 44 separate CSO samples were collected. Each sample was analyzed for the following parameters: 1) Dissolved Oxygen, 2) Conductivity, 3) Temperature, 4) PH, 5) Fecal Coliform, 6) Fecal Strep, 7) BOD, 8) TSS, 9) VSS. In addition to these samples and analyses, 3 separate samples were analyzed for the full spectrum of priority pollutants.

The results of this study indicate that pollutant loadings on the creek always increased following a storm event - the BOD loadings lower than expected while the fecal loadings much higher than expected. No strong relationship was established between the observed dissolved oxygen levels and the associated BOD concentrations. It is possible that this relationship may be affected by the presence of other chemicals within the stream. In addition, significant eutrophication was observed within certain reaches of the creek during the months of July and August.

The upper reach of Banklick creek consists of a series of pools. The Lakeview Pump Station creek crossing overflow was observed to discharge into a frequently stagnant stream pool which resulted in especially high fecal and low DO readings. Occasionally, baseline samples at the site were very high indicating the possible occurrence of dry weather overflows. Following significant storm events, it appears that the pollutants from this pool may be displaced and move down the creek as pollutant plugs or cells.

Flow and water quality dynamics of the lower reach of Banklick creek appear to be very complex. Travel times between KY16 and KY177 were highly variable and seem to be dependent upon both storm magnitude (flow) and the initial river stage. Both the flow and water quality dynamics appear to be significantly influenced by the backwater effect from the Licking river and the storage effect from off channel storage along the north side of the creek. In some cases, flows in the lower reach were observed to be stopped or even moving upstream. In such instances the lower reach effectively became a stagnant pool.

In general the Lakeview Pump Station SSO appeared to have a greater impact on the water quality of Banklick Creek than the two monitored CSOs. However, both CSOs were observed to have a measured impact. In addition, both CSOs were observed to overflow in response to rainfall events as small as 0.05 inches. Based on the constituent concentrations observed in the CSO discharges it would appear that part of the loadings may in fact be attributable to inputs from the stormwater runoff. If this hypothesis is in fact correct then it may be possible to decrease part of the final stream loadings through various on-site management practices.

I. INTRODUCTION

1.1. Background

The Federal Clean Water Act of 1972 established the National Pollutant Discharge Elimination System (NPDES) for use in limiting pollutant discharges to the nation's waterways. In the past, the primary application of this legislation has been on controlling pollutant discharges from wastewater treatment facilities (WWTF). In recent years, EPA has extended the enforcement of this legislation to include discharges from combined sewer overflows (CSOs). Combined sewers are sewers that collect and convey both stormwater and domestic sewage. During dry periods the sewers are used to convey domestic sewage to wastewater treatment facilities. However, during storm events, the capacity of the collection systems are frequently exceeded so that the excess flows are diverted untreated to receiving waters through various overflow points along the collection system.

Kentucky currently contains approximately 341 CSOs associated with 27 separate wastewater systems. The majority of the CSOs are located in those cities which are located along the Ohio River. In 1990, the Kentucky Division of Water (DOW) prepared and submitted to EPA the Kentucky Combined Sewer Overflow Control Strategy, which established a uniform, statewide approach to developing and issuing KPDES permits for Combined Sewer Overflows (CSOs). Since that time, the program has been implemented as each municipality and sanitation district renews their old KPDES permits. The purpose of the permit program is to 1) insure that any CSO is a result of wet weather flow only, 2) bring all wet weather CSO into compliance with technology-based requirements and applicable water quality standards, and 3) minimize water quality, aquatic biota and human health impacts due to wet weather overflows.

The CSO permit program involves two separate phases. The first phase of the program requires each municipality or sanitation district to 1) identify the receiving water for each overflow, 2) update the existing sewer use ordinance so as to prohibit the construction of any new combined sewers and minimize any new flows into existing combined sewers, and 3) develop a comprehensive Combined Sewer Operational Plan (CSOP) for the system. The first phase of the program is to be completed within 15 months of the issuance of the permit. The second phase of the program involves the implementation of a Combined Sewer Operational Plan (CSOP) so as to reduce the total loading of pollutants entering receiving streams from the combined sewer system.

In order to develop a relevant set of CSO permit requirements associated with each KPDES permit, some understanding of the basic characteristics and impacts of CSOs is needed. In order to obtain a basic understanding of these impacts, at least in Kentucky, the Kentucky Natural Resoucres and Environmental Protection Cabinet secured a grant from the United States Environmental Protection

Agency to investigate and characterize these impacts. The resulting grant was used to study two separate areas within the state that had been identified as having significant CSO impacts. These two areas included the Jefferson County region, and the Northern Kentucky region which includes Boone County, Campbell County, and Kenton County.

The CSO study for Jefferson county was conducted for the Louisville and Jefferson County Metropolitan Sewer District by Tenney Pavoni Associates, Inc. The results of this investigation have been report elsewhere (Tenney Pavoni, 1994). The CSO study for the Northern Kentucky region was conducted by the Kentucky Water Resources Research Institute of the University of Kentucky. Partial results of this study are contained in this report.

1.2. Purpose

The objective of this report is to provide a summary of the methodology and results associated with a water quality sampling effort for Banklick Creek. As early as the 1950s, residents along the banks of Banklick Creek, described the creek as "smelly" and complained about debris left behind receding waters (Cincinnati Enquirer 1988). A 1952 attempt to lessen the creek's odors by building up the banks and containing the creek failed to alleviate the problem. Such problems have continued up to the present as evidenced by the high levels of bacteria that have been measured in the Creek in recent years. One of the most likely sources of such contamination is from combined sewer overflows that exist along the banks of the creek. As a result, this study was initiated in an attempt to identify potential pollutant sources and to measure their associated impact. As discussed previously, this effort was one component of a larger effort to determine the impact of CSO discharges on the Northern Kentucky region.

1.3. Overview

This report has been divided into six sections. The first section provides an introduction and background with regard to the associated study. The second section provides a description of the study area along with an identification of the sampling sites. The third section provides a discussion of the sampling protocol, along with a discussion of the specific water quality constituents that were analyzed. The fourth section presents the results of the sampling effort while the fifth section provides a discussion of the observed results. The final section contains a summary of the results along with conclusions and recommendations for future studies. Logs and figures of the collected data are provided in the report Appendices.

II. STUDY AREA

2.1. Northern Kentucky Region

The purpose of this project is to shed light on the impact of CSOs on various water quality problems that have been observed in the Northern Kentucky region. The Northern Kentucky region is located within the Greater Cincinnati, Ohio area and includes Kenton, Campbell and Boone counties (see Figure 2.1). Information from the 1990 census shows that the population of this area is approximately 300,000.

The climate of the region is temperate and humid. Average monthly temperatures range from a low of 23 F (January) to a high of 87 F (July). Precipitation is fairly well distributed throughout the year. The average annual rainfall is approximately 40 in. The average monthly rainfall for the data collection period of June 1993-November 1993 is shown in Figure 2.2. As can be seen from the figure, rainfall in July was significantly below normal while the rainfall in August was significantly above normal.

At the present time, 90 separate CSOs have been identified in the Northern Kentucky region. These 90 CSOs are distributed among the nine cites shown in Table 2.1. Currently, the sewage from each of these cities is collected within the boundaries of the individual cities and then conveyed by a secondary truck sewer to a wastewater treatment plant that is owned and operated by the

Sanitation District #1 of Campbell and Kenton counties. Although the Sanitation District collects the sewage from the individual cities through its own truck main, it does not currently own the sewers within the individual cities nor is it responsible for the associated CSOs.

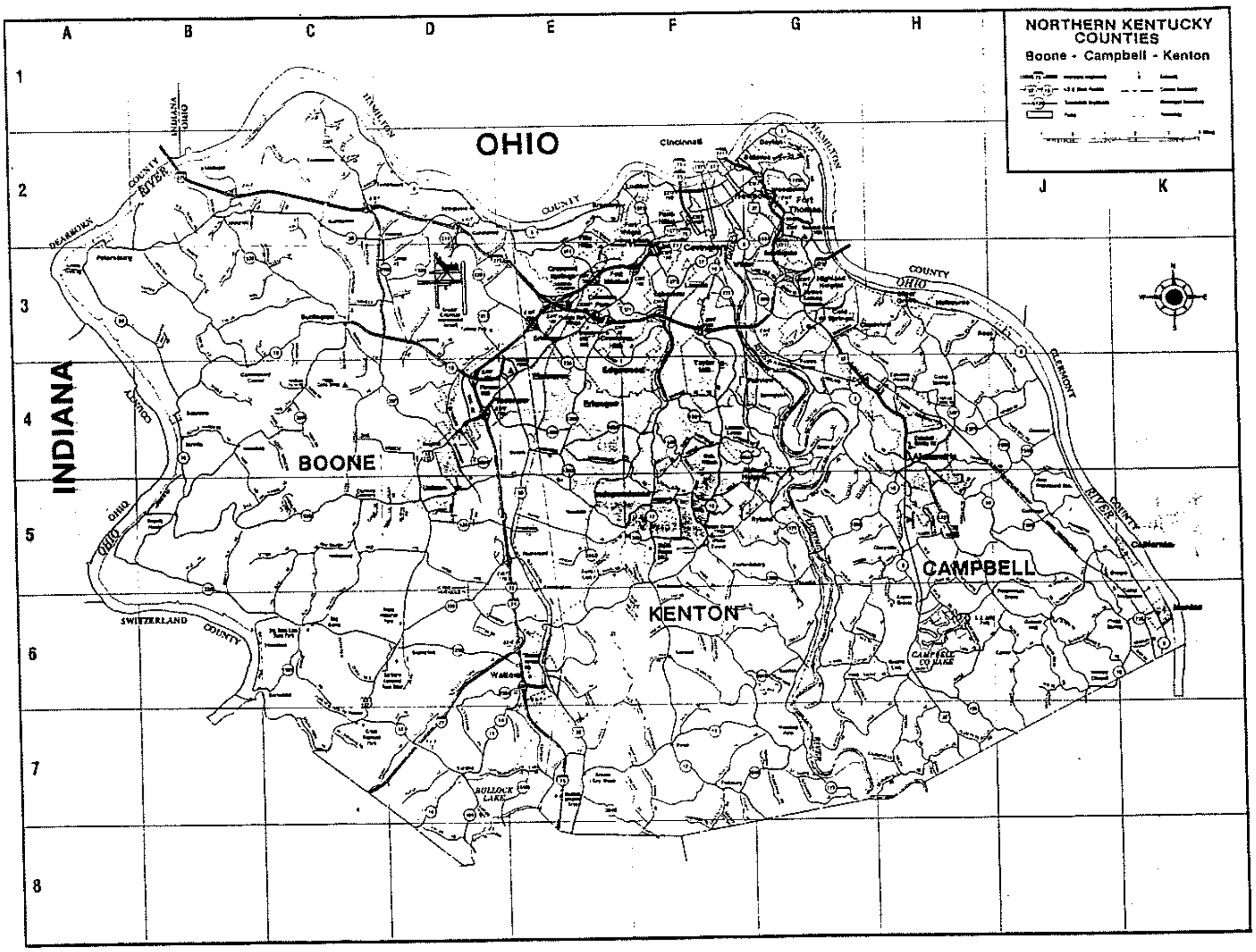

Figure 2.1. Map of Northern Kentucky Area

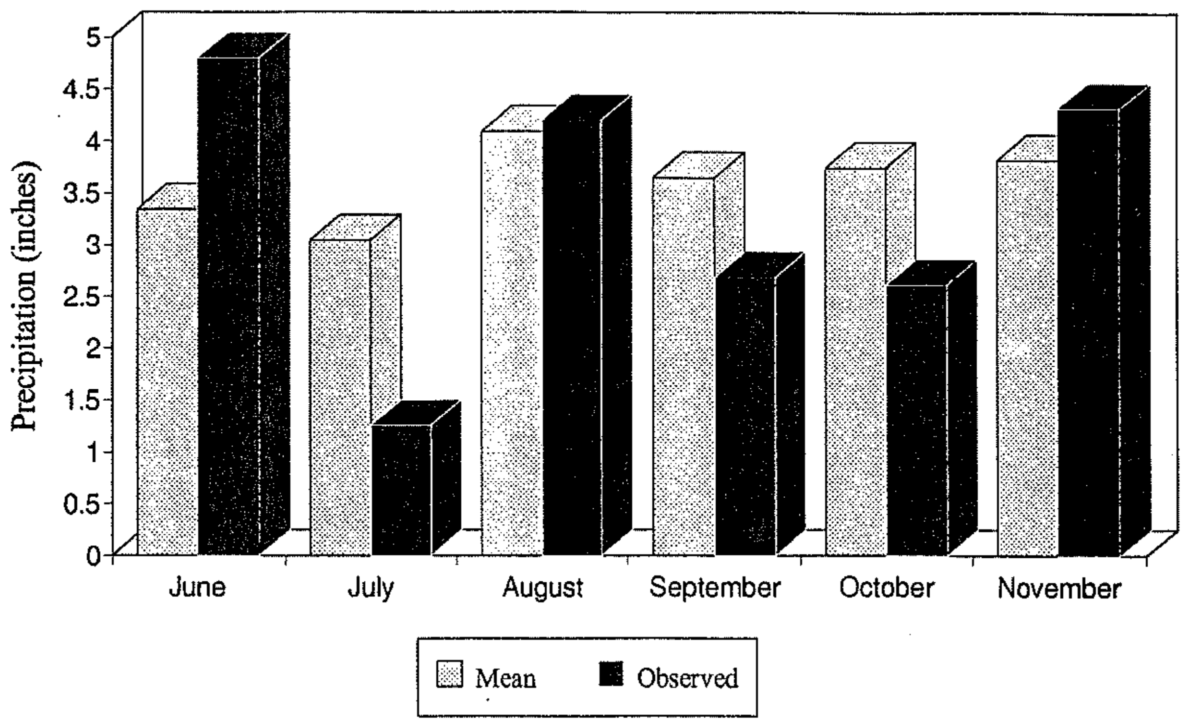

Figure 2.2. Average Monthly Rainfall During Study Period

Table 2.1. Table of Northern Kentucky Cities

City	KPDES Number	Number of CSOs
Bellevue	KY0098337	15
Bromley	KY0098428	2
Covington	KY0098272	63
Dayton	KY0098299	2
Ft. Wright	KY0098311	2
Ludlow	KY0098281	6
Newport	KY0098264	16
Park Hills	KY0098256	8
Taylor Mill	KY0098302	1

Recently, legislation was passed that permits the individual cities to turn control of their collection systems over to the Sanitation District. Such an arrangement will provide a more comprehensive framework for managing the various CSOs and for funding of the necessary improvements to the various sub-systems.

2.2. Banklick Creek

Banklick Creek originates in Boone County and flows north and then east to the Licking River. The Banklick Creek watershed has a total area of 59 sqmi and is characterized by gently sloping to sloping soils that are moderately well drained. The major subsoils in the watershed include both clays and loams. Land use in the study area is primarily urban with some light industry. Agricultural lands are more common upstream of the study area.

In order to obtain an initial understanding of the impacts of CSOs in the Northern Kentucky region, a short (5 mile) section of Banklick Creek was chosen for evaluation (see Figure 2.3). This section was chosen for both logistical reasons (the presence of two separate bridges permitting relatively easy upstream and downstream stream sampling) and for water quality reasons (this section has had a history of water quality problems).

The CSO impact assessment analysis of Banklick creek was accomplished by instrumenting and sampling two combined-sewer discharge pipes along with seven separate stream locations. The two combined-sewer discharge pipes were located between KY16 and KY177 while the stream samples were collected at various points between I275 and the mouth of Banklick Creek. The exact location of each site is shown in Figure 2.3.

2.3. Lakeview Pump Station

Initial baseline sampling of the creek indicated the probable occurrence of additional overflows at the Lakeview pump station creek crossing (see Figure 2.3). Because of technical restrictions, this site was not instrumented although stream samples were taken upstream and downstream of the site (i.e. S1, S2 and S3) in an attempt to assess its possible impact.

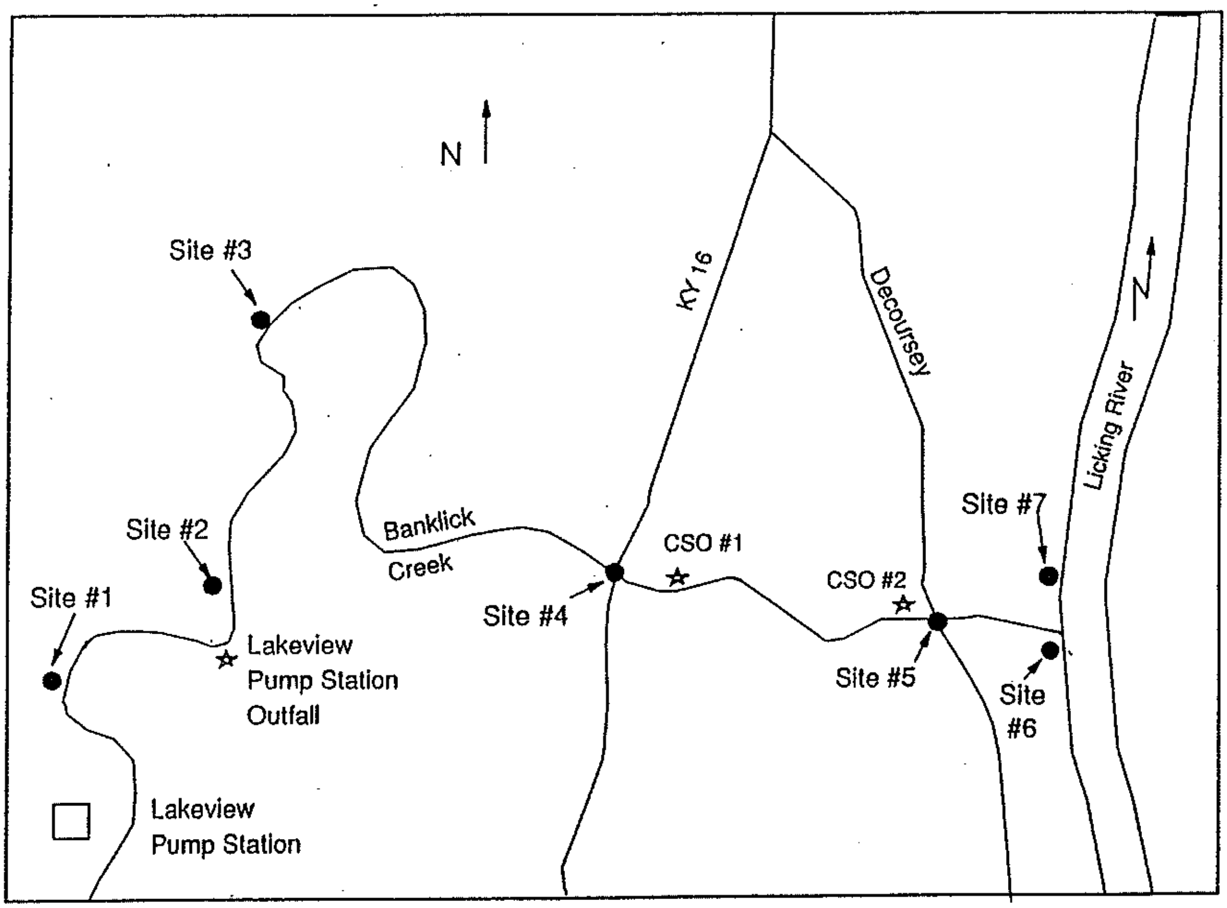

Figure 2.3. Map of Study Area

III. SAMPLING PROTOCOL

3.1. Location of CSO Sample Sites

In order to determine a set of CSO sampling sites, all CSOs were first identified on available sewer maps and then verified in the field. Final selection of the sites was based on a number of factors including: size of the outfall, physical access, safety and security, and requirements for associated streamflow sampling. The two CSOs that were finally selected were observed to discharge into Banklick Creek between KY 16 (CSO 1) and KY 177 (CSO 2) (see Figure 2.3.). The KY16 CSO (C1), consists of a 5 foot diameter pipe and drains an area of approximately 220 acres. The KY177 CSO (C2) consists of a 21 inch diameter pipe and drains an area of approximately 48 acres.

3.2. Location of Stream Sampling Sites

Once the CSO sites were established, the associated stream sampling sites were then determined. Initially, two stream sampling sites were identified, one upstream of the CSOs and one downstream of the CSOs. The upstream site was at the KY 16 bridge while the downstream site was at the KY 177 bridge (i.e S4 and S5). In addition to these two sites, two additional sites where chosen one upstream of the confluence of Banklick Creek and the Linking River and one downstream of the confluence (i.e S6 and S7). These sites were selected for use in assessing the impact of Banklick Creek on the Licking River. Initial preliminary sampling at these sites identified a significant pollution source upstream of the KY 16 sampling site. The most likely source of the pollutants was identified to be a SSO at the Lakeview pumping station river crossing. As a result, three additional stream sampling sites were added to the sampling protocol (i.e. S1, S2, S3) in order to try to assess the impact of the SSO on the associated stream quality. As a result, a total of seven separate stream sites were included in the sampling protocol.

3.3. CSO Sampling Equipment

At each CSO sampling site, an ISCO Model 3230 Flow Meter and an ISCO Model 3700 Portable Sampler were inserted in upstream manholes for use in determining the sewer stage (for use in determining discharge) and for collecting samples of detected overflow events. Each unit was powered by a 6 volt battery that had a continued use life of approximately 3 days. Prior to each storm event both instruments were turned on and the sampler was packed with ice to preserve samples. The flow meter triggered the program of the automatic sampler at the start of an overflow event. The sampler was configured to collected 850 ml of sample every 15 minutes for the first 4 hours of an overflow. The samples collected during each hour were combined into a single composite sample for subsequent laboratory analyses.

3.4. Stream Sampling Equipment

Each stream sample was collected directly from the stream or river banks (i.e. S1, S2, S3, S6, S7) or from a bridge using a horizontal grab sampler (i.e. S4, S5). Samples were collected as close to mid-stream as possible and all within 1 ft of the water's surface because Banklick Creek is both shallow and narrow -- characteristics which allow mixing and limit stratification.

3.5. Sampling Duration

Prior to the occurrence of any overflow event, a series of baseline stream samples were taken at each stream sampling site. Subsequent stream and CSO sampling was performed using two separate protocols depending upon the magnitude of the following rainfall event. In the event of a significant rainfall event, stream samples were taken concurrently with the CSO samples. In the event of a slight or moderate overflow event, stream samples were taken on a daily basis over a three day period. This latter protocol provided an opportunity to assess the migration effects of pollutants from the Lakeview Pumping Station SSO as the pollutants moved down the creek over the first few days following an storm event.

3.6. Analysis of Samples

Generally, temperature (C), conductivity (mS/cm), pH, and DO were recorded for each sample at the time of collection using a Hydrolab H20 transmitter. Laboratory analyses usually included fecal coliform, fecal streptococcus, biochemical oxygen demand, total suspended solids, and volatile suspended solids. These parameters were selected in order to best depict the influence of CSOs on the water quality of receiving streams. Scans for priority pollutants were conducted on a single sample collected from each CSO and from the stream site downstream of the SSO at the Lakeview pumping station. All fecal coliform and fecal streptococcus samples were analyzed by Dr. David Lye of Northern Kentucky University, while both BOD and solids samples were analyzed in the water quality laboratory at the University of Kentucky. Each priority pollutant analysis was performed by Commonwealth Technology Inc., of Lexington, Kentucky.

VI. SAMPLING RESULTS

4.1. Summary

A total of 9 storm events (4 short term, 2 intermediate, and 3 long term) and 5 additional baseline events were sampled from the period between June 21, 1993 and November 16, 1993. A summary of the various events is provided in Table 4.1. Results of the associated water quality analyses are provided in Appendices A-D. A detailed discussion of each of the storm events is provided in the following sections.

Table 4.1 Summary of CSO and Stream Sampling

Beginning Date	Sampling Duration	Rainfall (inches)	CSO Samples	Stream Samples
06/21/93	1 day	None	0	4
07/14/93	2 days	0.05 in	3	8
07/19/93	1 day	None	0	4
07/28/93	1 day	None	0	6
08/03/93	4 days	0.08 in	2	28
08/12/93	1 day	2.23 in	8	21
08/19/93	1 day	None	0	7
08/23/93	5 days	0.47 in	4	28
08/31/93	1 day	None	0	7
09/02/93	2 days	0.80 in	3	9
09/13/93	5 days	0.50 in	3	28
09/24/93	2 days	0.50 in	6	14
10/19/93	2 days	0.50 in	2	12
11/16/93	2 days	1.15 in	20	24

4.2. Short Term Events

Short term events consisted of those events when the CSO samples and the stream samples were taken concurrently. Stream sampling was restricted to those sites directly above and below the two CSO sites (i.e S4 and S5). A discussion of the four short term events is provided in the following sections.

4.2.1 August 12, 1993

The first short term event that was monitored occurred between 0800 and 2100 on August 12, 1993. During that time period, approximately 2.32 inches of rainfall occurred. Because of the timing of the storm, no baseline water quality samples were collected. Four overflow samples were collected from both CSO #1 and CSO #2. Each CSO sample was analyzed for the full range of water quality constituents. The rainfall and CSO discharge hydrographs for this event are shown in Figure A.3, while graphical histograms of the water quality analyses are shown in Figures B.17-B.30. The complete set of results is presented in tabular form in Tables C12-C14. A summary of the average results is provided in Table 4.2.

As can be seen from Table 4.2, the average constituent values all increased following the storm event (with the exception of DO which decreased) indicating the impact of the storm event in decreasing the water quality associated with Banklick Creek. Following the storm event, all of the biological parameter values increased downstream of the two CSOs while the solids loads decreased. The first observation would appear to demonstrate the impact of the CSO loadings while the decrease in solid loadings may be attributable to the decrease in stream velocity associated with the lower reach of Banklick Creek.

Table 4.2. Average Constituent Values for August 12 Event

Site	BOD	DO	FC	FS	TSS	VSS
Site 4	8	6.40	4,800	--	18	3
Site 5	7	6.16	5,400	80	35	4
CSO1	97	6.46	$3.7x10^6$	$5.6x10^4$	79	36
CSO2	77	5.51	$4.3x10^6$	$2.7x10^5$	68	23
Site 4	20	5.51	$1.0x10^6$	$3.7x10^4$	4357	280
Site 5	49	5.23	$1.1x10^6$	$5.1x10^4$	1271	124

Note: BOD = Biochemical Oxygen Demand (mg/l), DO = dissolved oxygen (mg/l), FC = Fecal Coliform (count per 100 ml), FS = Fecal Streptococcus (count per 100 ml), TSS = Total Suspended Solids (mg/l), VSS = Volatile Suspended Solids (mg/l), first set of site values are before storm event while second set of values are after the storm event.

4.2.2. September 25, 1993

The second short term event occurred on September 25, 1994. Approximately 0.5 in of rainfall occurred on this date between 9:30 am and 3:30 pm. During the storm the automatic sampler collected overflow samples for four and two consecutive hours at CSOs 1 and 2, respectively. Stream samples were collected from sites S4 and S5 each hour for 3 hours during the storm. The rainfall and CSO discharge hydrographs for this event are shown in Figure A.7. The laboratory analyses for these samples are presented in Figures B.58-B.66 and Tables C.31-C.32. A summary of the average results are provided in Table 4.3.

As can be seen from Table 4.3, the initial conditions at site S5 were extremely poor, indicating a significant pollution problem. It is hypothesized that the elevated loading are attributable to previous CSO or SSO loadings that have migrated down the stream where they have then collected as a result of the backwater effect from the Licking River. Despite the extremely poor initial conditions, the majority of the average constituent values increased following the storm event (including the DO) indicating the impact of the storm event in decreasing the water quality associated with Banklick Creek. Following the storm event, all of the biological parameter values increased downstream of the two CSOs while the solids loads decreased. As in the previous case, the first observation would appear to demonstrate the impact of the CSO loadings while the decrease in solid loadings may be attributable to the decrease in stream velocity associated with the lower reach of Banklick Creek.

Table 4.3. Average Constituent Values for September 25 Event

Site	BOD	DO	FC	FS	TSS	VSS
Site 4	5	4.06	8000	380	7	1
Site 5	2	2.21	$2.4x10^7$	$1.1x10^5$	10	--
CSO1	200	4.01	$9.9x10^6$	---	130	87
CSO2	103	7.08	$1.7x10^6$	---	143	84
Site 4	6	4.33	$7.8x10^4$	---	54	7
Site 5	37	3.27	$1.1x10^6$	---	10	5

Note: BOD = Biochemical Oxygen Demand (mg/l), DO = dissolved oxygen (mg/l), FC = Fecal Coliform (count per 100 ml), FS = Fecal Streptococcus (count per 100 ml), TSS = Total Suspended Solids (mg/l), VSS = Volatile Suspended Solids (mg/l), first set of site values are before storm event while second set of values are after the storm event.

4.2.3. October 20, 1993

The third short term event occurred on October 20, 1993. Approximately 0.5 inches of rain was received between 1600 on 19 October and 0600 on that date. Overflow samples were collected every 15 minutes following the beginning of the storm event. Heavier rain fell after 0400 which caused on overflow that continued until 1000. Three separate stream samples were collected from stream sites S4 and S5. The rainfall and CSO discharge hydrographs for this event are shown in Figure A.9. The results of the laboratory analyses for these samples is provided in Figures B.67-B.79 and Tables C.33-C.35. A summary of the results is provided in Table 4.4.

As can be seen from Table 4.4, the average constituent values all increased following the storm event (with the exception of DO which decreased) indicating the impact of the storm event in decreasing the water quality associated with Banklick Creek. Following the storm event, the fecal coliform counts increased, the fecal strep counts decreased and the BOD, TSS, and VSS all basically stayed the same downstream of the two CSOs. As a result, it would appear that the impact of the CSO on BOD, TSS, and VSS loadings was minimal although the fecal coliform loadings did increase by a factor of ten.

Table 4.4. Average Constituent Values for October 20 Event

Site	BOD	DO	FC	FS	TSS	VSS
Site 4	4	6.0	2400	1120	301	10
Site 5	3	6.8	8000	100	15	1
CSO1	452	0.9	$1.8x10^8$	$4.0x10^6$	738	602
CSO2	305	---	$1.6x10^7$	$6.6x10^5$	455	291
Site 4	12	3.9	$6.2x10^5$	$1.2x10^4$	61	8
Site 5	11	5.8	$1.1x10^6$	$9.5x10^3$	59	7

Note: BOD = Biochemical Oxygen Demand (mg/l), DO = dissolved oxygen (mg/l), FC = Fecal Coliform (count per 100 ml), FS = Fecal Streptococcus (count per 100 ml), TSS = Total Suspended Solids (mg/l), VSS = Volatile Suspended Solids (mg/l), first set of site values are before storm event while second set of values are after the storm event.

4.2.4. November 17, 1993

The fourth short term event occurred on November 17, 1993. A total of approximately 0.5 inches of rainfall was received on this date between the hours of 1:00 am and 2:00 pm. Baseline stream-samples were previously collected on November 16, 1993. This storm caused an overflow event to begin at approximately midnight on November 26 and continue through the afternoon. Overflow-samples were collected from both CSO #1 and #2 from between midnight to 0400 and then again from between 1015 and 1400 from CSO 1 only. During this event, 4 stream samples were collected from both stream sites S4 and S5. The rainfall and CSO discharge hydrographs for this event are shown in Figure A.10. The laboratory results from the analyses of these samples are provided in Figures B80-B91 and Tables C.36-C.39. A summary of the results are provided in Table 4.5.

Table 4.5. Average Constituent Values for November 17 Event

Site	BOD	DO	FC	FS	TSS	VSS
Site 4	15	17	31,000	8,000	60	11
Site 5	12	10	41,000	6,200	46	4
CSO1	223	8	$2.6x10^7$	$2.4x10^5$	62	36
CSO2	126	10	$9.9x10^6$	$1.5x10^5$	97	38
Site 4	14	10	$3.3x10^5$	$3.1x10^4$	294	34
Site 5	16	9	$1.4x10^5$	$2.5x10^4$	279	49

Note: BOD = Biochemical Oxygen Demand (mg/l), DO = dissolved oxygen (mg/l), FC = Fecal Coliform (count per 100 ml), FS = Fecal Streptococcus (count per 100 ml), TSS = Total Suspended Solids (mg/l), VSS = Volatile Suspended Solids (mg/l), first set of site values are before storm event while second set of values are after the storm event.

As can be seen from Table 4.5, the average constituent values all increased following the storm event (with the exception of DO which decreased) indicating the impact of the storm event in decreasing the water quality associated with Banklick Creek. However, in this case, the both the fecal coliform and fecal strep counts were lower at Site 5 following the storm than at Site 4 but higher than the baseline events. As a result, the impact of the CSOs is masked as a result of increased loadings at Site 4. That is to say, it is unclear whether the increase in pollutant loadings at Site 5 are directly attributable to the CSO loadings or from other sources upstream of Site 4 that may have migrated down to Site 5 during the storm event.

4.4. Intermediate Events

Intermediate events consists of those events when the CSO overflow event occurred late at night or early in the morning and in which stream samples were taken the day before and the morning or afternoon following the overflow event. In general, the intermediate events were restricted to sampling at stream sites S4 and S5. A discussion of the two intermediate events is provided in the following sections.

4.4.1. July 14, 1993

The first intermediate event that was monitored occurred between 1730 and 2030 on July 14, 1993. During that time period, approximately 0.50 inches of rainfall occurred. Prior to the storm event, baseline water quality samples were collected at sites S4-S7. Two overflow samples were collected from CSO #1 (downstream from KY16) while one overflow sample was collected from CSO #2 (upstream from KY 177). The rainfall hyetograph and CSO discharge hydrographs for this event are shown in Figure A.1, while graphical histograms of the water quality analyses are shown in Figures B.1-B.8. The complete set of results is presented in tabular form in Tables C.2-C.4. A summary of the results is provided in Table 4.6.

Table 4.6. Average Constituent Values for July 14 Event

Site	BOD	DO	FC	FS	TSS	VSS
Site 4	9	4.1	40	---	18	11
Site 5	7	7.1	4.9×10^4	---	3	2
CSO1	13	---	---	---	80	45
CSO2	19	---	---	---	381	143
Site 4	20	2.9	3.2×10^6	7.0×10^3	333	205
Site 5	7	2.8	7.5×10^6	1.0×10^4	15	5

Note: BOD = Biochemical Oxygen Demand (mg/l), DO = dissolved oxygen (mg/l), FC = Fecal Coliform (count per 100 ml), FS = Fecal Streptococcus (count per 100 ml), TSS = Total Suspended Solids (mg/l), VSS = Volatile Suspended Solids (mg/l), first set of site values are before storm event while second set of values are after the storm event.

As can be seen from Table 4.6, the average constituent values all increased following the storm event (with the exception of DO which decreased) indicating the impact of the storm event in decreasing the water quality associated with Banklick Creek. Following the storm event, both the fecal coliform counts and fecal strep counts increased downstream of the CSOs indicated their probable impact. Of particular note were the extremely low dissolved oxygen readings that were obtained after the storm event. Also of interest is the high level of fecal counts at Site 5 prior to the storm event. It is again hypothesized that these high levels may be due to prior loadings that have collected in the lower reach as a result of the backwater effects of the Licking River. However, these readings due not seem to correlate well with either the observed oxygen levels or the BOD levels.

4.4.2. September 3, 1993

The second intermediate event that was monitored occurred between 0100 and 0300 on September 3, 1993. During that time period, approximately 0.8 inches of rainfall occurred. Three overflow samples were collected from CSO #1 while no samples were collected from CSO #2 due to equipment problems. Each CSO sample was analyzed for the full range of water quality constituents. The rainfall and CSO discharge hydrographs for this event are shown in Table A.5, while graphical histograms of the water quality analyses are shown in Figures B.41-B.49. The complete set of results is presented in tabular form in Tables C.22-C.24. A summary of the results of this event are provided in Table 4.7

Table 4.7. Average Constituent Values for September 3 Event

Site	BOD	DO	FC	FS	TSS	VSS
Site 4	25	4.6	900	200	42	10
Site 5	22	5.6	$1.8x10^4$	---	43	5
CSO1	86	5.9	$2.4x10^7$	$1.3x10^5$	89	32
CSO2	---	---	---	---	---	---
Site 4	23	5.5	$4.6x10^5$	$2.4x10^4$	165	12
Site 5	32	6.2	$5.0x10^3$	$1.1x10^4$	221	17

Note: BOD = Biochemical Oxygen Demand (mg/l), DO = dissolved oxygen (mg/l), FC = Fecal Coliform (count per 100 ml), FS = Fecal Streptococcus (count per 100 ml), TSS = Total Suspended Solids (mg/l), VSS = Volatile Suspended Solids (mg/l), first set of site values are before storm event while second set of values are after the storm event.

The results from this storm event are very similar to the results of July 14, 1993 in that the baseline data reveal low fecal counts at stream Site 4 with very high counts at Site 5. Other than showing a general increase in the total pollutant loadings following the storm, the results from this storm fail to reveal any specific trends.

4.5. Long Term Events

Long term events consisted of those storm events when the stream samples were taken one day before and several days after a particular storm event. For each long term event, stream samples were taken at all seven stream sampling sites (i.e. S1-S7). The long term sampling protocol provided an opportunity to assess the impacts of both CSO #1 and CSO #2 as well as the migration effects of pollutants from the Lakeview Pumping Station SSO as the pollutants moved down the creek over the first few days following an storm event. During the sampling period, three different long term events were monitored. Each of these events is discussed in the following sections.

4.5.1. August 4, 1993

Baseline samples were collected at all streamflow sites on August 3, 1993. On August 4, 1993 a 0.08 inch rainfall event occurred that caused an 0.5 hour overflow event to occur early in the morning. Within a couple of hours of the overflow event, stream samples were collected from all 7 sites. Additional post-storm samples were collected on August 5th and 6th. The rainfall hyetograph and CSO discharge hydrographs for this event are shown in Figures A.2. The results of the laboratory analysis of these samples is illustrated in Figures B.9-B.16 and Tables C.7-C11.

An examination of the various water quality parameters revealed three interesting observations. First, the baseline fecal coliform and fecal strep values were already well above acceptable levels. Second, the two small CSO overflows did not appear to significantly impact the pollutant loadings on Banklick Creek. For most cases, the pollutants loadings at stream site S5 were actually lower than at site S4. Third, the primary source of pollutants associated with the baseline data and the subsequent post overflow data would appear to be the SSO associated with the Lakeview Pump

Station. This hypothesis is supported by the high BOC, FC, and FS levels and the extremely low DO levels at stream site S2. It should be noted that these conditions were already present in the baseline values for these constituents indicating the probable occurrence of a dry weather overflow event sometime prior to the actual storm event. It would also appear that there was an additional SSO overflow event associated with the storm event as evidenced by the increase in all pollutant loadings at site S2 on August 4. Based on an examination of the Figures B9-B16 it would appear that the storm of August 4 primarily created an overflow at the SSO which along with the associated storm runoff displaced pollutants from the SSO pool which then migrated down Banklick Creek over the next several days. This hypothesis is supported by the shift in pollutant loadings from site S2 to the downstream sites and by the general degradation of dissolved oxygen over the next several days.

Compared to baseline samples which were collected on August 3, 1993, fecal coliform counts increased at stream sites S4 and S5 for the first day after the rain. Fecal coliform remained relatively unchanged at the Lakeview stream sites (i.e. S1-S3) throughout the sampling period. Although 100,000,000 and 11,200,000 colonies per 100 ml were detected in samples collected from CSO 1 and 2, respectively, the associated stream data did not clearly identify the source of the pollutants.

The light rainfall and associated overflows on the 4th of August did not appear to greatly influence DO levels in Banklick Creek. DO levels remained around 5 mgl at the Lakeview upstream site (i.e S1) and around 1 mgl at the Lakeview downstream site (i.e S2). DO levels also remained above 5 mgl at both stream sites S4 and S5 following the overflow event. The most noticeable decline was at site S4 which dropped from 12.3 mg/l (baseline) to 6.86 mg/l the day after the rain.

The BOD concentrations for individual sites were similar over the sampling period, although the BOD of the stream site downstream of Lakeview (i.e. S2) was markedly greater than the BOD of the other stream sites during the first 2 days of the sampling period. The results suggested little impact from the BOD of the overflows detected from CSOs 1 (94 mg/l) and 2 (73 mg/l).

Total and volatile suspended solids increased from 19 to 202 mg/l and from 7 to 42 mg/l, respectively, from the day before to the day after the storm for the stream site downstream of the Lakeview CSO. TSS and VSS remained essentially unchanged for other stream sites over the sampling period.

4.5.2. August 24, 1993

Approximately 0.5 inches of rainfall was received on the night of August 24th which triggered an overflow of a 2 hour duration. Overflow samples were collected between 2030 and 2130. The first set of samples were collected after the rainfall from 1030 to 1330 on 25 August. Addition samples were collected from all 7 sites on 26 and 27 August. The laboratory results of these samples are presented in Figures B.31-B.40 and Tables C.16-C.20.

Similar to the event of August 4, 1994, the baseline values would appear to indicate the prior occurrence of a dry weather overflow event at the Lakeview Pump Station SSO. This hypothesis is supported by the high pollutants loadings and associated low dissolved oxygen readings at site S2. As with the previous event, it would appear that the storm event caused an additional SSO overflow event to occur downstream of the Lakeview Pump Station which then migrated downstream to the other sites. As with the previous storm, this had the impact of significantly decreasing the dissolved oxygen values at the downstream sites although some recovery was observed by August 6th.

The impacts of the two CSOs on the lower reach of Banklick Creek are somewhat inconclusive although the pollutant loadings at Site S5 generally show an increase with regard to Site S4. It should be noted, however, that both sites show significant increases together, indicating a significant pollutant source upstream of site S4. At the present time this is thought to be attributable to the Lakeview Pump Station SSO although there may be some additional secondary sources that may be influencing the loadings at site S4.

Fecal coliform concentrations of samples collected on August 25 from sites S4 and S5 were markedly greater than those of baseline samples collected from these locations on 23 August. The increase in fecal coliform counts reflected the impact of overflows which contained fecal coliform concentrations as high as 25,000,000 colonies per 100 ml. As seen from the figures, fecal coliform levels remained elevated over the 3-day sampling period.

Fecal streptococci results implied a trend similar to that of fecal coliform. Following the storm event, the number of streptococci colonies increased at both sites S4 and S5 as well as unexpectedly upstream of the Lakeview SSO (Site S1). In contrast, the baseline streptococci count at the stream site downstream of the Lakeview SSO exceeded that of post-storm samples collected there. Over the 3-day period, generally streptococci levels fell at stream sites. A comparison of the streptococci levels detected at site S4 and S5 did not indicate that discharge from the sampled SSO had a significant additive impact on stream levels of streptococci.

DO levels decreased following the storm at the 3 most downstream sites and DO remained below 1 mgl downstream of the Lakeview SSO at site S2. It appears that DO began to increase by 27 August, 3 days after the storm.

BOD increased the day after the storm at stream sites S2-S5.

BOD in overflow samples reached 140 mg/l but did not appear to greatly impact BOD levels at site S5.

TSS and VSS followed similar trends. Results for both parameters indicated that solids increased following the storm and in general decreased over the 3-day sampling period. The concentration of solids was greater in the overflow samples collected during the first hour than during the those collected in the second hour. The consistently higher solid values at site S4 as compared to site S5 indicated that solids discharged between the two sites did not noticeably increase their concentration in the stream.

4.5.3. September 15, 1993

On the morning of September 15, 1993, approximately 0.5 inches of rain was received. A combined sewer overflow event subsequently occurred in CSO #1 at approximately 4:00 am. This event triggered the automatic sampler (CSO #1 only) which collected samples for 3 nonconsecutive hours. The rainfall hyetograph and CSO discharge hydrographs for this event are shown in Figure A.6. The laboratory results of the samples collected from this event are illustrated in Figures B.50-B.57 and Tables C.25-C.29.

As with the previous two events, the baseline values would appear to indicate the prior occurrence of a dry weather overflow event at the Lakeview Pump Station SSO. This hypothesis is again supported by the high pollutants loadings and associated low dissolved oxygen readings at site S2. Unlike the previous two events, it does not appear that the storm event caused an additional SSO overflow event to occur downstream of the Lakeview Pump Station although it may have flushed out some of the pollutants in the pool downstream of the site which may then have migrated downstream to the other sites. This hypothesis is supported by two observations. First, unlike the previous two storms, the associated dissolved oxygen values were only marginally affected by the pollutant loadings. Second, the majority of pollutants loadings downstream of site S2 actually decreased following the storm event (the dissolved oxygen values actually increased). However, while the pollutant loadings at site S2 appeared to decrease following the storm event, the pollutant loadings at site S1 actually increased. The most likely source of this increase in pollutant loadings would be from an overflow event at the Lakeview Pump Station itself, which is located further upstream from site S1. Thus while it would appear that a overflow event did not occur at the Lakeview Pump Station SSO it does appear probable that a pollutant discharge did occur from the pump station itself.

As with the previous storm, the impacts of the two CSOs on the lower reach of Banklick Creek are somewhat inconclusive although the pollutant loadings at Site S5 generally show an increase with regard to Site S4, especially the fecal coliform loadings. It should be noted, however, that both sites show significant increases together, indicating a significant pollutant source upstream of site S4. As with the previous cases this is thought to be attributable to the Lakeview Pump Station SSO although there may be some additional secondary sources that may be influencing the loadings at site S4.

The concentration of fecal coliform in the samples collected on September 15th was greater than that in baseline samples collected on September 13th for sites S3-S5 while the fecal coliform counts decreased just downstream of the Lakeview SSO at site S2. Fecal coliform in overflow samples collected from CSO 1 exceeded 200,000,000 colonies in 100 ml of sample which appeared to lead to an increase in the concentration of fecal coliforms in the stream as evidenced by the higher concentration of coliform at both sites S4 and S5 for all sampling days. Fecal coliform concentrations appeared to decrease by 17 September.

Compared to baseline samples fecal streptococci was greater at all stream sites on September 15. The most notable difference was at site S5 which increased from 20 to 16,800 colonies per 100 ml, again suggestive of the impact of the upstream CSOs. The streptococci in samples collected on subsequent days decreased for most sites.

Compared to the baseline readings, the dissolved oxygen (DO) decreased, albeit slightly, at sites S3-S5 and increased just downstream of the Lakeview CSO at site S2. Otherwise DO did not vary significantly during the sampling period.

The high level of BOD from all of the 3 overflow samples (all from CSO1), ranging from 273 to 484 mg/l, did not correlate with the relatively low BOD readings (11 mg/l) from the sample readings associated with site S5. Interestingly, results from samples collected at the stream site downstream of the Lakeview SSO indicated a decrease in BOD at this location following the storm event.

TSS and VSS did not noticeably increase following the storm event at sites S3-S5, despite the high solid concentrations detected in overflow samples. In contrast, solid concentrations of the samples collected from the 2 stream sites that bracketed the Lakeview SSO (i.e S1 and S2) did increase for the day after the storm only.

4.6. Baseline Events

In addition to the data associated with the observed storm events, several data were taken in anticipation of a storm event that never occurred. The results of the water quality analyses associated with these events are provided in Appendix C.

4.7. Priority Pollutant Events

Three separate priority pollutant samples were collected during the study. Analyzed parameters included 1) total cynide, 2) ammonia nitrogen, 3) phenols, 4) total phosphorus, 5) metals, 6) organic pesticide/ herbicides, 7) organic pesticides/pcb's, 8) organic semivolatiles, 9) and organic volatiles. The results of each of the three samples are discussed in the following sections.

4.7.1 July 16, 1993

The first sample was taken from CSO #2 on July 16, 1993. All parameters values that were measured above detectable limits are shown in Table 4.8. The complete set of results of the analysis are provided in Appendix D.

4.7.2 August 26, 1993

The second sample was taken at stream site S2 just downstream from the Lakeview Pump Station SSO. All parameter values that were measured above detectable limits are shown in Table 4.9. The complete results are provided in Appendix D.

Table 4.8 Priority Loadings for Site S2 on August 26, 1993

Parameter	Results (mg/l)
Cyanide	0.005
Nitrogen Ammonia	7.900
Oil & Grease	7.000
Phenols	0.019
Total Phosphorus	1.600
Total Cadmium	0.010
Total Chromium	0.012
Total Copper	0.018
Total Lead	0.008
Total Zinc	0.030
Toluene	0.098

Table 4.9 Priority Pollutant Loadings for CSO#1 on July 16, 1993

Parameter	Results (mg/l)
Cyanide	0.006
Nitrogen Ammonia	1.600
Oil & Grease	19.00
Phenols	0.021
Total Phosphorus	1.300
Total Chromium	0.010
Total Copper	0.0420
Total Lead	0.010
Total Silver	0.0025
Total Tallium	0.009
Total Zinc	0.007

4.7.3 December 10, 1993

The third sample was take at CSO#1. All parameter values that were measured above detectable limits are shown in Table 4.10. The complete set of results of the analysis is provided in Appendix D.

Table 4.10 Priority Loadings for CSO#1 on December 10, 1993

Parameter	Results (mg/l)
Cyanide	0.005
Nitrogen Ammonia	4.900
Oil & Grease	9.000
Phenols	0.034
Total Phosphorus	2.100
Total Copper	0.018
Total Silver	0.0013
Total Zinc	0.040
Chloroform	0.007

V. WATER QUALITY MODEL PARAMETERS

5.1. General Parameters

There are numerous physical, chemical, and biological parameters that can be monitored in a stream system. These parameters can provide clues as to the source of pollution entering the system. They are also useful tools for characterizing the overall health of a surface water and predicting its response to pollutant loads. The parameters monitored in the Northern Kentucky Combined Sewer Overflow (CSO) Study for Banklick Creek consisted of:

1)	Physical Parameters:	Temperature
		Flow
2)	Chemical Parameters:	Dissolved Oxygen (DO)
		pH
		Conductivity
		Five Day BOD
		Total Suspended Solids (TSS)
		Volatile Suspended Solids (VSS)
		Priority Pollutants (at select locations)
3)	Biological Parameters:	Fecal Coliform (FC)
		Fecal Streptococcus (FS)

Although suspended solids are often considered a physical parameter, they will be classified in this report as a chemical parameter. This is done because the relationship between TSS and VSS is indicative of the chemical composition of the suspended solid.

Following is a brief summary of the significance of each parameter as well at the type of information that may be obtained by studying them. In addition a brief discussion of the expected parameter correlations is provided.

5.2. Flow Parameters

The CSO study estimated the flow in Banklick Creek and directly measured the flow of selected CSO discharges. Flow is a crucial variable because pollutant loading and transport is entirely dependent upon it. Flow also effects how sensitive the water system is to pollutant stress. Also, when receiving water flow rate is estimated, the location of critical (or minimum) dissolved oxygen content can be predicted.

5.3. Temperature Parameters

Temperature is a very important parameter because of its effects on the ability of various chemical reactions to occur, as well as corresponding reaction rates. The dissolved oxygen content of water varies with temperature, as does biological activity.

5.4. Dissolved Oxygen

Dissolved Oxygen (DO) is one of the most useful indicators of the health of a water system. DO is required for the respiration of aerobic microorganisms that consume organic pollutants in water, as well as all other aerobic life forms. It also represents the receiving water's ability to recover from organic pollutant loadings, such as CSO discharges. Kentucky's water quality criteria for DO is > 5 mg/l.

5.5. pH

Like temperature, pH has important effects on the survival and growth rate of microorganisms. The optimum pH for growth is 6.5-7.5.1. Measured pH values less than 4 and greater than 9 are harmful to aquatic life. The pH also effects the formation of various chemical complexes. The forming of complexes can place toxic constituents into a form that is not bioavailable, and therefore no longer toxic.

5.6 Conductivity

The conductivity of water indicates the amount of free ions in solution. Water that is free of dissolved mineral salts has little capacity for carrying electric current, making its conductivity low.

5.7 BOD5

Five day BOD is the most widely used measure of organic pollution. It determines the quantity of oxygen that will be required to biologically stabilize the organic matter present. This parameter is valuable for predicting the oxygen depletion that the water system will experience.

5.8 Total Suspended Solids:

Total Suspended Solids (TSS) is the solid matter in water which will not settle out and cannot be removed by filtration. The material is removed by biological oxidation. Because of this, when there is an increase in TSS, there will generally be a decrease in DO. High TSS will also effect water color, and reduce plant photosynthesis. In contrast though, high TSS can reduce the toxicity of metals. Dissolved metals tend to adsorb onto particles of suspended matter, making them nontoxic to aquatic life.

5.9 Volatile Suspended Solids

Volatile Suspended Solids (VSS) is a portion of TSS. It represents the organic content (versus the mineral content) of TSS. High VSS indicates that the pollution source is organic in nature, such as domestic sewage. The biological oxidation associated with high VSS loading will reduce the DO concentration.

5.10 Fecal Coliform

Fecal Coliform (FC) is an indicator organism that lives in the intestinal tract of humans and other animals. Its presence in water indicates that other pathogens (such as salmonella) may also be. Due to its origin, increased FC counts indicate increased organic pollutant loading. The water quality standard for water contact is 200 counts/100 ml.

5.11 Fecal Streptococcus

Fecal Streptococcus (FS), like FC is an indicator organism which lives in the intestinal tract of humans and animals. The difference between FC and FS is that FS is more indicative of animal waste. This is because the quantity of fecal coliforms and fecal streptococci that are discharged by humans are significantly different from the quantities discharged by animals. The ratio of FC/FS can indicate if the source of pollution tends to be from animal or human waste.

5.12 Priority Pollutants

Priority Pollutants include those pollutants that are suspected to be a carcinogen, mutagen, geratogen, or have a high acute toxicity. The presence of a high concentration of a priority pollutant can provide clues regarding the source of pollution. It could also indicate appropriate locations to focus pollutant elimination/minimization efforts. A complete Priority Pollutant scan was conducted at three locations on Banklick Creek. One was conducted at a stream sampling site, while the other two were collected from CSO discharges. The results of three scans indicate that significant concentrations of Priority Pollutants are not present in Banklick Creek.

5.13 Discussion:

Correlation analysis can provide an indication of the interdependence between two parameters. A strong correlation between parameters may imply similar sources or other related factors which deserve further examination. However, if a weak correlation, or no correlation is found where a strong one is expected, this requires investigation as well. It could mean that some previously ignored variable has significant impact on the water system, and must be taken into consideration.

5.13.1 Flow/Pollutant Correlations - Often, flow can be expected to exert the main influence on pollutant concentrations, although many other factors have an influence also. Flow is highly variable, which can make it difficult to determine the relationship between flow and concentration. Generally, flow exhibits an inverse relationship with concentration.

The flow/concentration relationship is more difficult to determine in faster flowing waters. It is easier to evaluate standing water because the longer residence time gives the pollutants a chance to react, allowing their effects to be evaluated.

The study of Banklick Creek revealed that its response to pollutant loading was highly dependent on flow. During low flow conditions, even a relatively small rain storm could result in an extreme adverse response and slow recovery. Pollutants accumulated in the system, causing high BOD and bacterial counts, and low DO. Large rain storms produced greater CSO discharges, but also significantly increased the stream flow. The result was that the pollutants were flushed out and the stream recovered quickly.

5.11.2 Flow/DO Relationships - In contrast to the flow/pollutant concentration relationship is the flow/DO concentration relationship. The flow/DO relationship is a direct proportion (up to a maximum limit for DO concentration). This is because high flow has turbulent mixing which entrains air. Also, the increased residence time that organic pollutants have in a low flow scenario allows for more bioactivity. The bioactivity depletes the quantity of oxygen available. This relationship was quite noticeable on Banklick Creek. During high flow conditions, DO concentrations did not drop below Kentucky's water quality standard of 5 mg/l. O < 5 mg/l was common during periods of low flow.

5.11.3. Temperature/DO Relationship - Oxygen gas is more soluble at lower temperatures, which allows DO concentrations to increase as temperature decreases. Another factor that contributes to this relationship is that bioactivity increases with increasing temperatures, therefore microorganisms consume more DO at higher temperatures. This relationship was noticeable on Banklick Creek. The DO range in the late summer tended to vary between 3 mg/l-7 mg/l and in the late fall between 6 mg/l-10 mg/l.

5.11.4. pH/Conductivity Relationship - pH reflects the carbon dioxide content of water. Water with high pH generally has higher levels of carbonates and associated salts, which would produce a higher conductivity. In contrast, higher pH also allows the formation of organic and inorganic complexes, which would reduce the conductivity. This is a difficult relationship to characterize because these two factors act in opposite directions. The Banklick Creek results do not indicate a relationship between these two parameters.

5.11.5. pH/Bioactivity Relationship: pH has an important effect on the survival and growth rate of bacteria. Acidic waters tend to have lower nutrient contents and less abundant aquatic life. The optimum pH for growth is between 6.5-7.5. The pH of Banklick Creek facilitates optimum growth, with pH values normally between 7.0-8.0. Algal growths that were observed in the creek throughout the summer are evidence of this relationship.

5.11.6 BOD/DO Relationship - Since BOD is an indication of the oxygen depletion potential of a water sample, an inverse relationship would be expected to exist between the two parameters. This relationship was not readily observed on Banklick Creek. This could be due to several factors. Oxygen can be introduced to the water through turbulent mixing, increasing the DO content. The amount of time that has passed since the pollutant was introduced and the sample was taken will also have a strong influence. If only a short time has passed, both BOD and DO could be elevated because little bioactivity has occurred yet. If the pollutant has existed in the system for some time, both the organic matter and oxygen content would be reduced. Therefore, this relationship will only occur when the BOD load exceeds the water's oxygen content, and if a significant period of time has passed that allows bioactivity to occur.

5.11.7. BOD/Fecal Coliform Relationship - Since BOD is an indication of organic pollution and FC is an indication of human or animal waste, a direct relationship would be expected between these two parameters. This was not a consistent relationship on Banklick Creek. Fecal Coliform counts tended to remain elevated more so than did BOD concentrations. This inconsistency could be due to the pollutants' residence time in the receiving water, if BOD has a faster decay rate than FC.

5.11.8. TSS/VSS Relationship - VSS represents the organic portion of TSS. Throughout the Banklick Creek study the proportion of VSS to TSS remained consistent, with the majority of TSS being organic in nature. This indicates that the pollution has a consistent composition that is primarily organic. Domestic sewage discharges would fit this description.

5.11.9. TSS/Toxic Metals Relationship - As TSS increases, the toxicity of metals in water decreases. This is because the adsorption of metals onto particulates increases as the solids concentration increases. In this form, metals are not bioavailable, and therefore not toxic. This relationship was not investigated on Banklick Creek because the priority pollutants scans indicate that significant concentrations of metals are not present.

5.11.10. FC/FS Relationship - The FC/FS relationship is a useful one to study because the ratio of FC to FS is a good indicator of whether the pollutant source is from human or animal waste.6 A FC:FS ratio greater than four indicates that the source of bacteria is from human waste, while a FC:FS ratio less than one indicates that the origin is from animal waste. This was not a consistent relationship on Banklick Creek, although normally FC was much greater than FS. This inconsistency may be due to different decay rates between FC and FS. Because of this and other limitations, the FC:FS ratio may be useful as a broad indicator of pollutant source, but should not be relied on solely. This ratio, as applied to Banklick Creek, indicates that the pollutant source is from human waste.

5.12. Data Interpretation

The correlations listed above can assist in data interpretation and predictions of water system response. Care must be taken however when evaluating data because failure to consider all variables involved can lead to incorrect conclusions. Such variables include masking effects of one parameter on another and differential flow within the system.

Masking can be described as one parameter acting on another in such a manner that false conclusion can be drawn from the data. Examples of masking are:

- Various chemical constituents may inhibit microorganism growth. This will yield a low five day BOD test result, compared to the result if the chemical constituents were not present.

- Photosynthesis of aquatic plants can produce elevated DO levels which would indicate a healthy water system. At night those DO levels could drop significantly and cause fish kills.

- High suspended solids concentrations can inhibit plant growth by preventing the penetration of sunlight. This could mask the presence of high nutrient concentrations.

Differential flow within the stream has a strong influence on pollutant transport and residence time. Predictions of system response can be completely wrong if a bad assumption regarding flow in the system is employed. Banklick Creek, for example, has variable flow characteristics. They range from ponding water, to meandering flow, to steady flow, to backflow, at different locations in the creek. These vary significantly with runoff.

5.13. Conclusion

In order to correctly characterize the health of a water system, all variables acting on the system should be studied. Placing disproportionate weight on one parameter or another can lead to incorrect conclusions. There are numerous interrelationships that can occur at any point in time. Because of this, it is important to become very familiar with the water system over time. This is the only means of identifying trends and characterizing the system's health.

VI. SUMMARY AND CONCLUSIONS

The objective of this study was to quantify the impact of combined sewer overflows on Banklick Creek. This was accomplished by instrumenting and sampling two combined-sewer discharge pipes along with seven separate stream locations. The two combined-sewer discharge pipes were located between KY16 and KY177 while the stream samples were collected at various points between I275 and the mouth of Banklick Creek. Initial baseline sampling of the creek indicated the probable occurrence of additional overflows at the Lakeview pump station creek crossing. Because of technical restrictions, this site was not instrumented although stream samples were taken upstream and downstream of the site in an attempt to assess its possible impact.

The results of this study indicate that pollutant loadings on the creek always increased following a storm event - the BOD loadings lower than expected while the fecal loadings much higher than expected. Of particular interest was the fact that the two monitored CSOs located between KY16 and KY177 were observed to overflow in response to rainfall events as small as 0.05 inches. In general, many of the CSO pollutants loadings exhibited a first flush phenomenon, indicating either the influence of stormwater pollutants on the resulting loadings or the scouring of biological loadings that may have already been present in the sewer. Many of the pollutant loadings associated with the higher intensity storms were higher than originally anticipated, indicating the possible significant impact of stormwater pollutants on the CSO discharges.

In general, the ratio of VSS to TSS in the CSO discharges was consistent with the expectation that the primary source would be due to organic loadings. As expected, the observed ratio in the stream samples was much lower, which would be expected in the presence of more inorganic loadings. The ratio of FS to FC in the CSO discharges was again generally consistent with ratios indicative of human fecal loadings, while the ratios in the stream were again less, which would be expected as a result of the influence of non-human wastes that find their way into the stream.

No strong relationship was established between the observed dissolved oxygen levels and the associated BOD concentrations. It is possible that this relationship may be affected by the presence of other chemicals within the stream. In addition, significant eutrophication was observed within certain reaches of the creek during the months of July and August.

The various baseline samples would appear to indicate the possible occurrence of dry weather overflows associated with the SSO downstream of the Lakeview pump station. Stream samples on the upper reaches of Banklick creek also would appear to indicate the occurrence of wet weather overflows associated with both the Lakeview Pump Station SSO and the Lakeview Pump Station itself.

The upper reach of Banklick creek consists of a series of pools. The Lakeview pump station SSO was observed to discharge into a frequently stagnant stream pool which resulted in especially high fecal and low DO readings. Following significant storm events, it appears that the pollutants from this pool are displaced and move down the creek as pollutant plugs or cells. In general, it would appear that the loadings from these sites had a much greater impact on the subsequent stream water quality than the observed CSO discharges.

In summary, it would appear that the primary source of water quality problems on Banklick Creek are from both dry and wet weather overflows associated with the Lakeview Pump Station. The impact of the two CSOs on the stream quality was observable in many storm events although it was somewhat unclear in others. This variability may be somewhat attributable to the magnitude of the storm event and the resulting CSO discharge, the water quality dynamics of the creek, and the masking effect of pollutants that appear to migrate down from the Lakeview Pump Station site. Both the flow and water quality dynamics appear to be significantly influenced by the backwater effect from the Licking river and the storage effect from off channel storage along the north side of the creek. Travel times between KY16 and KY177 are highly variable and seem to be dependent upon both storm magnitude (flow) and the initial river stage. In some cases, flows in the lower reach were observed to be stopped or even moving upstream. In such instances the lower reach effectively became a stagnant pool.