SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM

FINAL PROJECT REPORT

Assessment of Water Quality Trends in the Upper Cumberland River Basin: Focus on Pathogen Impairment

January, 2006

This project was conducted in cooperation with the State of Kentucky and the United States Environmental Protection Agency, Region 4.

Grant # C9994861-99

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EXECUTIVE SUMMARY

This project consisted of analyzing existing water quality data for streams in the Upper Cumberland River Basin, with a particular focus on pathogen trends. According to the most recent 303(d) list of Kentucky waters, the majority of streams assessed in the Upper Cumberland Basin are impaired for primary recreational contact as a result of pathogens. The state pathogen standard for primary contact recreation is expressed in a dual form which specifies that the 30-day geometric mean of fecal coliform counts not exceed 200 colonies per 100 mL (on a minimum of five samples) and not more than 20 percent of samples should exceed 400 colonies per 100 mL (KAR, 2002).

Historical monitoring data were utilized to assess fecal coliform concentrations and to evaluate the level of success of previous and ongoing projects in the basin. These projects are being funded and implemented through Section 319(h) of the EPA Clean Water Act, Eastern Kentucky PRIDE, the USCOE 531 wastewater program, and the Kentucky Wastewater Program to reduce the level of pathogens in the basin. The assessment utilized historic monitoring data obtained from four different sources: 1) the KYDOW ambient water quality network, 2) the KYDOW focused sampling network, 3) the Kentucky Watershed Watch network, and 4) the University of Kentucky monitoring network. The evaluation involved the analysis of the combined data sets using standard statistical measures to assess pathogen trends and project impacts. Land use patterns were documented to help identify likely pathogen sources, and areas of BMP implementation were examined for correlation with any water quality improvements. Decreases in fecal coliform concentrations were noted for several individual sampling sites throughout the basin and for the aggregated data from the entire basin considered together.

Statistical analysis shows that water quality at the majority of sites has improved. However, the percentage is somewhat less over the last 5 years, than the previous 10 years. Two sites showed statistically significant deterioration of water quality conditions related to fecal coliform bacteria: Straight Creek in Bell County and the Cumberland River in Harlan County.

All of the monitoring sites located downstream of completed projects associated with Eastern Kentucky PRIDE showed some improvement, with those in Laurel, Bell, and Whitley more statistically significant than those in Harlan County.

Products generated under this project are to be disseminated via print and electronic means to the widest possible audience, utilizing targeted email, the internet, news media and presentations to the Upper Cumberland River Basin Team, local officials and others. An Upper Cumberland Pathogen Summit was held on November 15, 2005 at Pine Mountain State Park to share project results with interested stakeholders. Additional data and details on the specific types of analyses associated with the study can be obtained from the following web site: (http://pride.uky.edu/ucproject/uchome.html).

The project was coordinated by the Kentucky Water Resources Research Institute (KWRRI) at the University of Kentucky and involved staff from the KWRRI as well as faculty and students from the Department of Civil Engineering. The project was coordinated with personnel associated with the Kentucky Division of Water.

ACKNOWLEDGEMENTS

The authors would like to express their thanks to the Kentucky Division of Water staff, in particular Ms. Julie Smoak, Ms. Maleva Chamberlain, and Mr. Robert Miller who participated in the project and helped coordinate the Upper Cumberland Pathogen Summit. The authors would also like to express their thanks to Mr. Gary Beck with the Kentucky Division of Water who helped supply much of the pathogen data analyzed in the study. The authors would also like to thank all of the speakers who volunteered to participate in the Upper Cumberland Pathogen Summit, including Richard Thomas with Eastern Kentucky PRIDE, Peter Goodman with the Kentucky Division of Water, Clement Solomon with the National Onsite Demonstration Program, Blaine Early with the Upper Cumberland River Watershed Watch, Rodney Hendrickson with the NRCS Cumberland Valley RC&D Council, and Andy Meadows, with the Cumberland Valley Area Development District. Finally, the authors would like to thank Ms. Stephanie Jenkins, Ms. Anna Hoover, Ms. Charlie Mynhier, and Mr. Jim Kipp, all with the Kentucky Water Resources Research Institute who provided logistical support for the Upper Cumberland Pathogen Summit as well as the production of this report.

INTRODUCTION

The upper Cumberland River Basin (8-digit USGS HUC 05030101) has continued to be significantly impacted by pathogen problems for several years. These impacts are due to various causes including the improper operation of wastewater treatment plants, straight pipes and failing onsite treatment systems, and other non-point sources. The Kentucky Division of Water began an extensive sampling effort in 1993 that has continued up to the present. In 1998, a formal TMDL (Total Maximum Daily Load) for the entire region was developed that focused on eliminating point sources primarily associated with improperly operated wastewater treatment plants within the basin. The total maximum daily load for fecal coliforms (FC) was expressed in terms of an equivalent concentration of 400 colonies per 100 mL. Twenty-one main stream stations and seven municipal effluents in the basin were monitored throughout the primary contact recreation (PCR) season while facility upgrading occurred. In 1995, permitted discharges in the drainage basin were warned by letter that noncompliance with their KPDES permit limit for fecal coliform bacteria would result in a $1000 fine.

During the 1995-1996 PCR seasons, each facility was sampled twice. This strategy of controlling known point sources was partially successful. Noncompliance among package treatment plants fell from a high in 1995 of 55 percent to a low in 1996 of 11 percent. Compliance and stream sampling has continued up to the present, but FC levels have continued to be unacceptable the upper part of the drainage basin, primarily due to numerous illegal straight pipe discharging untreated waste, failing septic systems, and non-complying municipal and package treatment plants (Beck, 1998).

In 1999, a Clean Water Action Plan was funded for the Upper Cumberland River. The plan states in part “There are efforts being made to reduce the numbers of straight pipes and failing septic systems. Section 319 funding will be used to augment these efforts.” This project was undertaken to (1) assess changes in water quality and (2) target watershed-based plan development and BMP implementation in areas that are not meeting water quality standards.

Partially in response to the continuing presence of high pathogen levels in streams in eastern Kentucky, the Eastern Kentucky PRIDE program was initiated in 1997 to help provide resources to address the problem. This program has provided grants to eliminate straight pipes and failing septic systems, as well coordinated larger wastewater projects that have received additional funding support through the US Environmental Protection Agency and the US Army Corps of Engineers.

PROJECT STUDY AREA: UPPER CUMBERLAND REGION

The project study area is shown in Figure 1. The study area is referred to as the upper Cumberland River basin and is identified by an 8-digit USGS HUC (United States Geological Survey Hydrologic Unit Code) number 05030101.

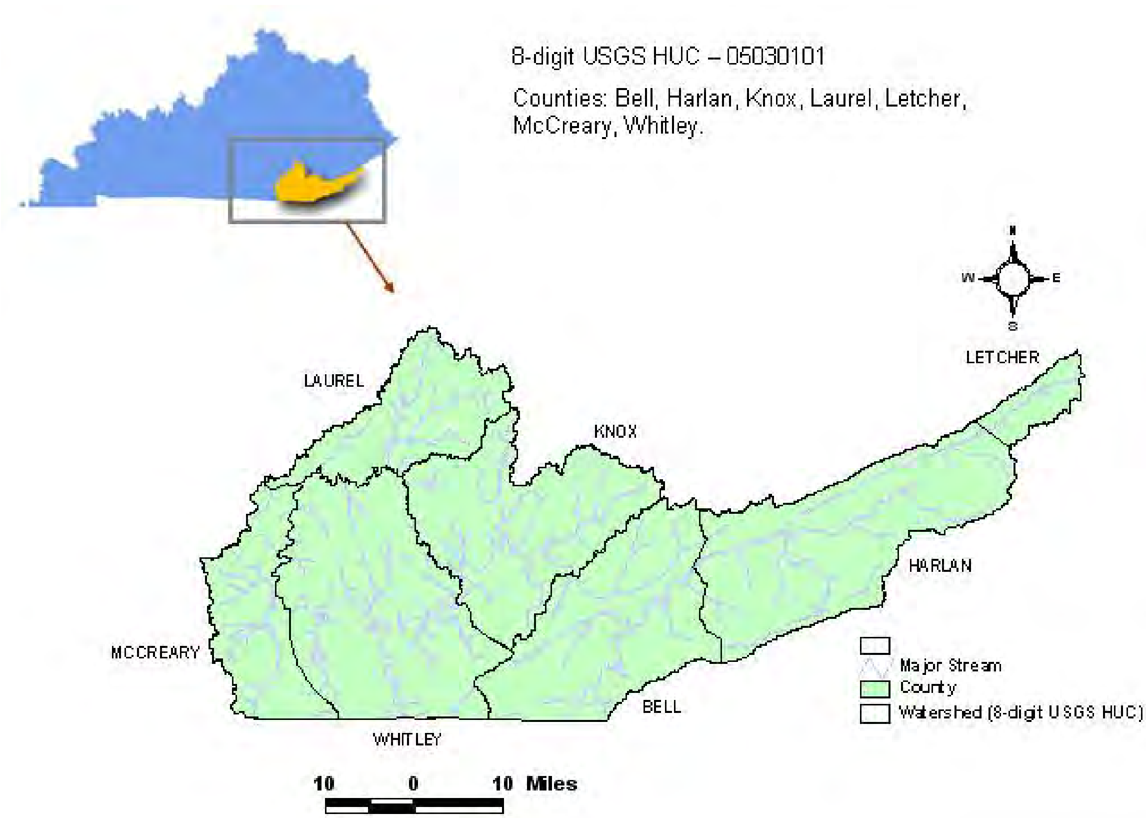

Figure 1 Location of project study area

The following sections provide details of physiography, topography, and hydrology of the upper Cumberland River basin compiled by KWRRI (PRIDE, 2005).

PHYSIOGRAPHY

The upper Cumberland sub-basin is located in the Eastern Kentucky Coal Field physiographic region. This is the most significant coal-producing region in the state and is important in terms of natural gas production. The region is characterized by high, sharp-crested ridges with little level upland area and narrow stream valleys and also is characterized by forest vegetation typical of the Eastern Mesophytic Forest, one of the most biologically diverse resources in North America. The underlying rock formations include sandstone, siltstone, and shale, with some interbedded coal deposits. The fresh-saline water interface is less than 200 feet below the land surface. Topography represented by a digital elevation model (DEM) for the region is shown in Figure 2.

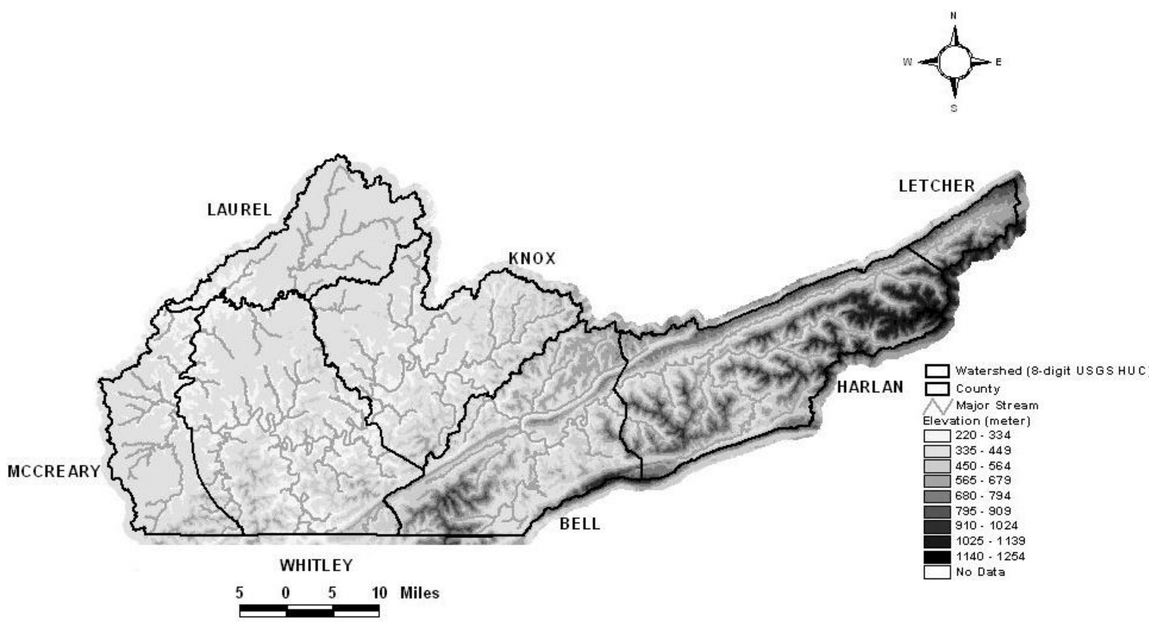

Figure 2 Topography of the upper Cumberland region as depicted by a digital elevation model (DEM)

Elevations range from 220 m (722 ft) to 1254 m (4114 ft) with most of the higher elevations in the southeastern part of the region.

HYDROLOGY

The upper Cumberland sub-basin is classified as an USGS 8-digit hydrologic unit referenced as HUC # 05130101. The Cumberland River flows southwest from Letcher County through Bell County, then westward until the borders between Whitley and McCreary Counties, and finally northward toward Laurel County. The sub-basin includes all of Whitley and parts of Letcher, Harlan, Bell, Knox, Laurel, and McCreary Counties. A map with the basin outline and county boundaries in the region is shown in Figure 3. Major tributaries in the upper Cumberland sub-basin include Clover Fork, Poor Fork, Straight Creek, Stinking Creek, Marsh Creek, and Clear Fork. Groundwater is presently the most common source of domestic water for rural residents of the basin. The aquifer yields more than 50 gallons per minute for public and industrial water supplies.

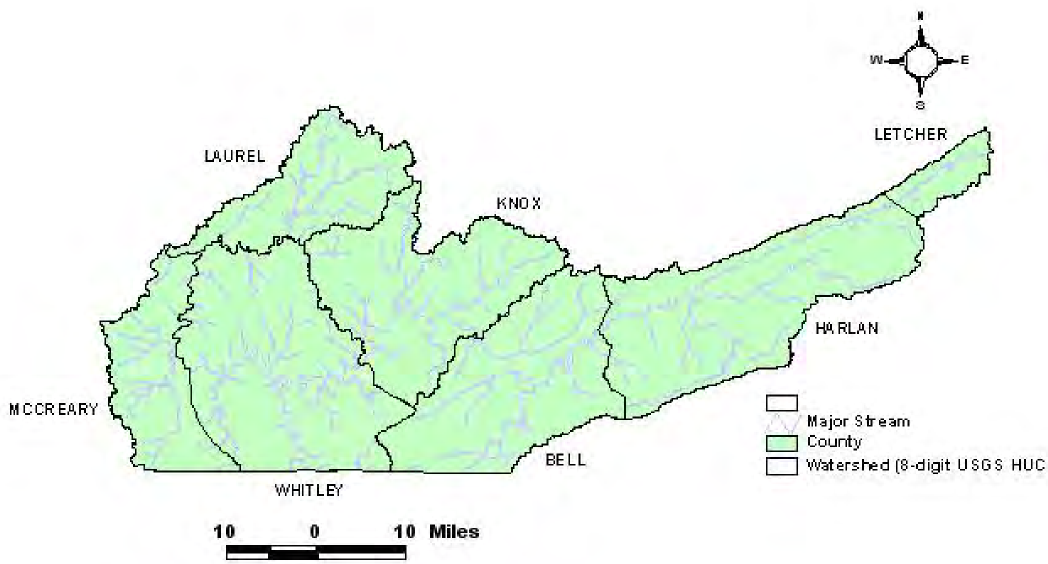

Figure 3 Counties in the upper Cumberland region

Land use in the region is largely dominated by forest. Major land use types include forest (80%), urban (8%), cropland and pasture (11%) and lakes and reservoirs (1%). A specific breakdown of the land use categories using an Anderson Level 2 land use classification system (Anderson et al., 1976) is provided in Table 1. Data from USEPA (USEPA, 2005) is used to develop the land use map shown in Figure 4.

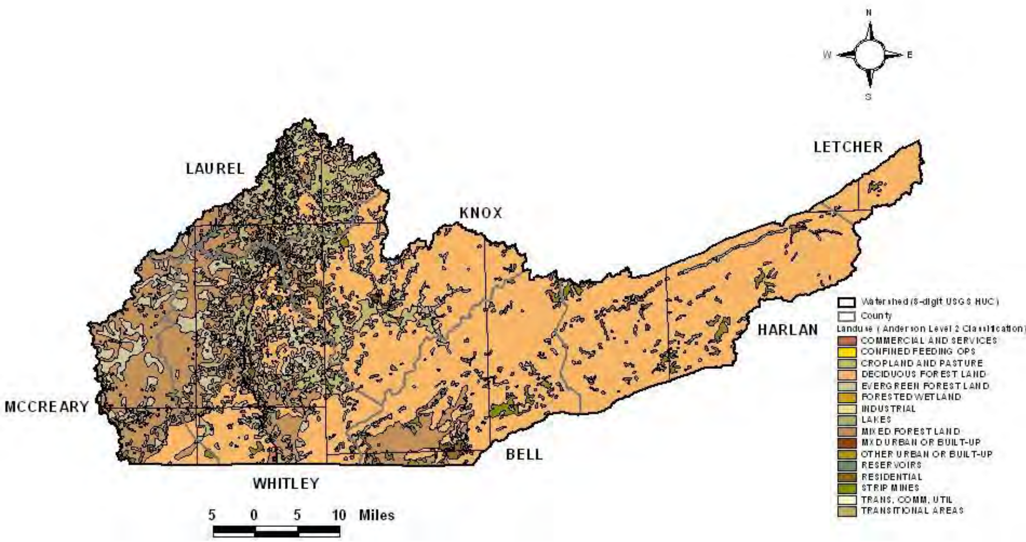

Figure 4 Land use patterns in the upper Cumberland region

Table 1 Land use classification in the upper Cumberland region

Land Use (Level 2 Classification)	**Area (Acres)**	**Percent (%)**
Commercial and services	4,299	0.336
Confined feeding operations	51	0.004
Cropland and pasture	142,762	11.157
Deciduous forest land	748,083	58.465
Evergreen forest land	55,966	4.374
Forested wetland	255	0.020
Industrial	1,046	0.082
Lakes	33	0.003
Mixed forest land	220,979	17.270
Mixed urban or built-up land	16	0.001
Other urban or built-up land	586	0.046
Reservoirs	6,589	0.515
Residential	35,960	2.810
Strip mines	57,284	4.477
Transmission and communication, utilities	3,589	0.280
Transitional areas	2,031	0.159
Total	**1,279,529**	**100**

WATER QUALITY PROBLEMS

The 2002 Kentucky 305(b) stream assessment identified over 400 miles of impaired streams within the upper Cumberland region (KYDOW, 2002). A major cause of pollution in the region is pathogens. Pathogen problems are commonly caused by straight pipes and failing septic and wastewater treatment systems. It has been estimated that there are over 6000 straight pipes and failing septic systems in this region (PRIDE, 2005). A second major environmental impact in the region is related to mining activities. However, because of the nature of the coal seams in eastern Kentucky, most of the impacts are related to siltation and habitat alteration with minor pH impairment. Most of the observed pH impairment is limited to McCreary and Whitley counties as a result of the more acidic coal-bearing seams that occur there. Stream segments are classified based on current conditions that support or nonsupport designated uses (aquatic life, fish consumption, primary and secondary contact recreation and drinking water supply). The miles of impaired streams in the upper Cumberland region that do not partially or fully support the designated uses are provided in Table 2.

Table 2 Impaired miles of streams in counties of the upper Cumberland region

County	Miles
Bell	79.84
Harlan	141.4
Knox	63.73
Laurel	26.64
Letcher	51.86
McCreary	41.6
Whitley	31.16

PATHOGEN IMPAIRMENT

Bacteriological problems in the upper Cumberland region can be linked to at least four specific causes associated with improper disposal of sewage (Beck, 1998). These include: 1) the improper operation of existing wastewater treatment plants, 2) the improper operation of existing package plants (small privately owned treatment units), 3) failing septic systems, and 4) straight pipes. An estimate of the number of potential sources associated with each category is provided in Table 3.

POLLUTION SOURCES

There are 13 wastewater treatment plants in the upper Cumberland region (Figure 5). Improper operation of many of these treatment plants has historically been a significant source of pathogen impairment in the streams of Eastern Kentucky. During the 1990s, the Division of Water initiated a program of wastewater plant monitoring and fines that resulted in significant reductions of fecal coliform bacteria in the Upper Cumberland River Basin. There are 40 package plants in the upper Cumberland region (Figure 6). The vast majority are residential plants located in Harlan, McCreary, and Laurel counties. Soils in these counties are generally inadequate to support more traditional septic systems. Based on data collected by the area development districts, it is estimated that there are approximately 2400 straight pipes and at least 4400 failing septic systems in the upper Cumberland region. A recent report by USEPA (2002) summarized the extent of un-permitted sewage discharges from straight pipes and wastewater problems in Harlan County. The documented locations of straight pipes and failing septic systems (PRIDE, 2005) in the region are shown in Figures 7 and 8; these likely represent only a portion of the actual numbers.

Table 3 Pollution sources in the upper Cumberland region by county

County	Number of			
	Straight Pipes	**Failing Septic Systems**	**Wastewater Treatment Plants**	**Package Plants**
Bell	364	367	2	5
Harlan	1712	2433	6	12
Knox	173	428	1	2
Laurel	16	317	2	6
Letcher	126	0	0	1
McCreary	35	21	1	9
Whitley	34	840	1	5
Total	**2460**	**4406**	**13**	**40**

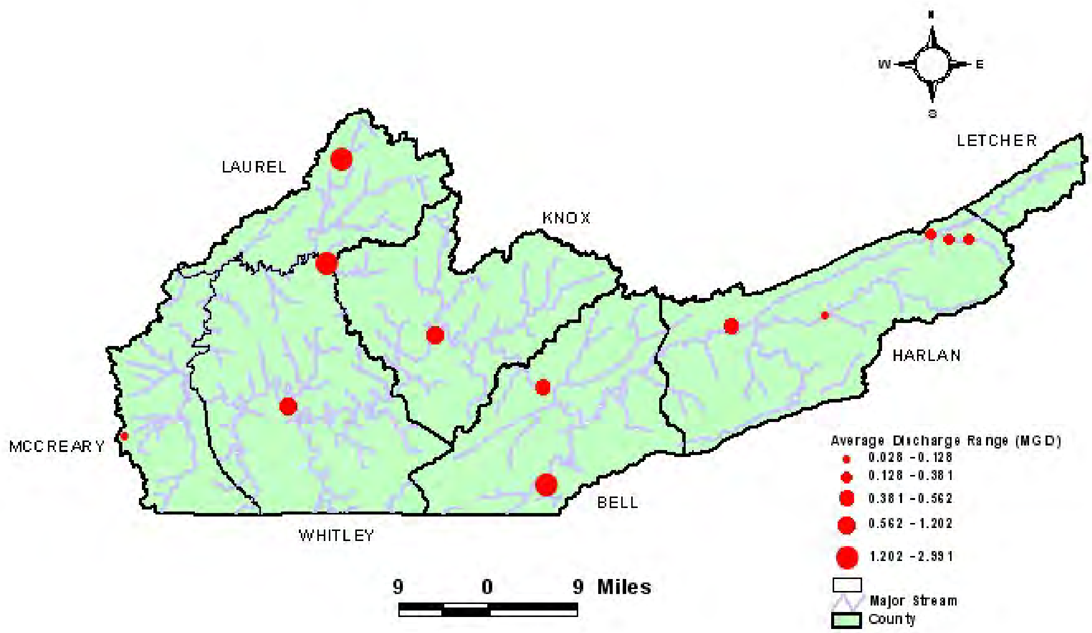

Figure 5 Location of wastewater treatment plants in the upper Cumberland region

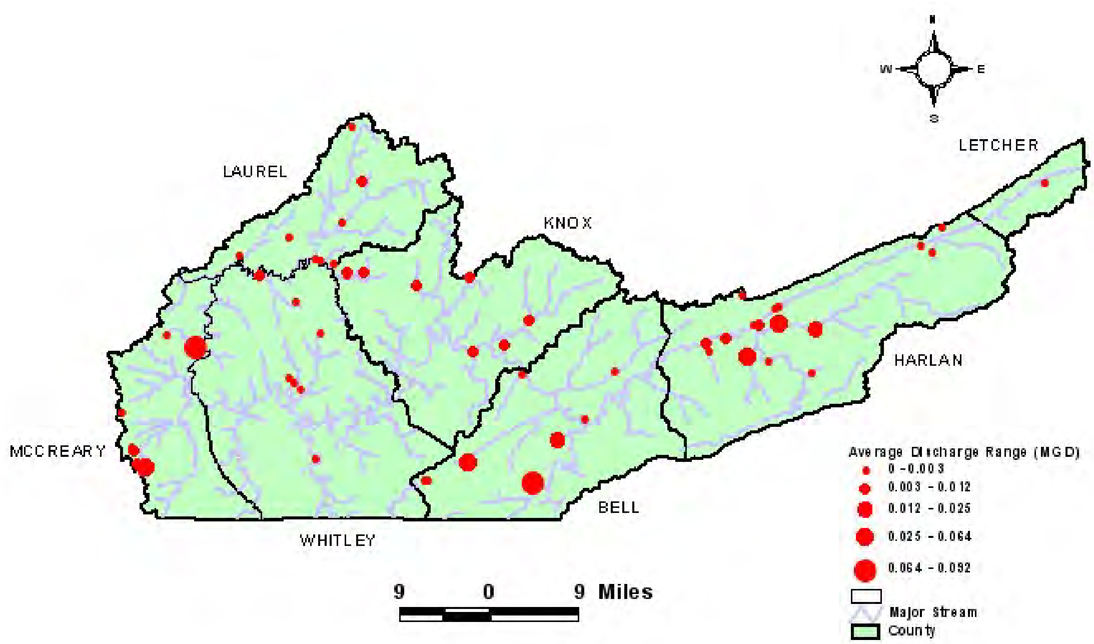

Figure 6 Location of package plants in the upper Cumberland region

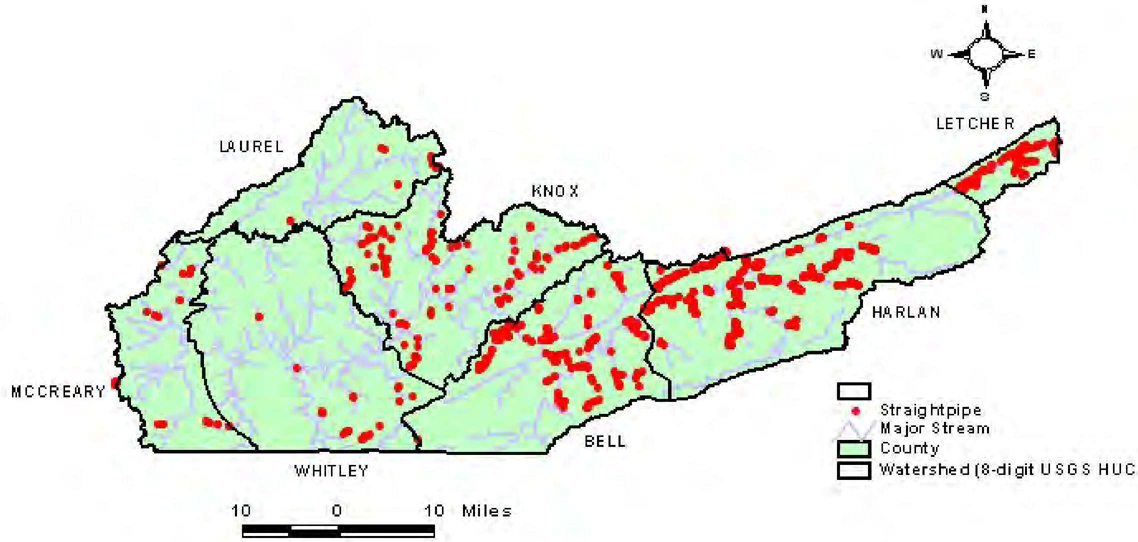

Figure 7 Location of straight pipes in the upper Cumberland region

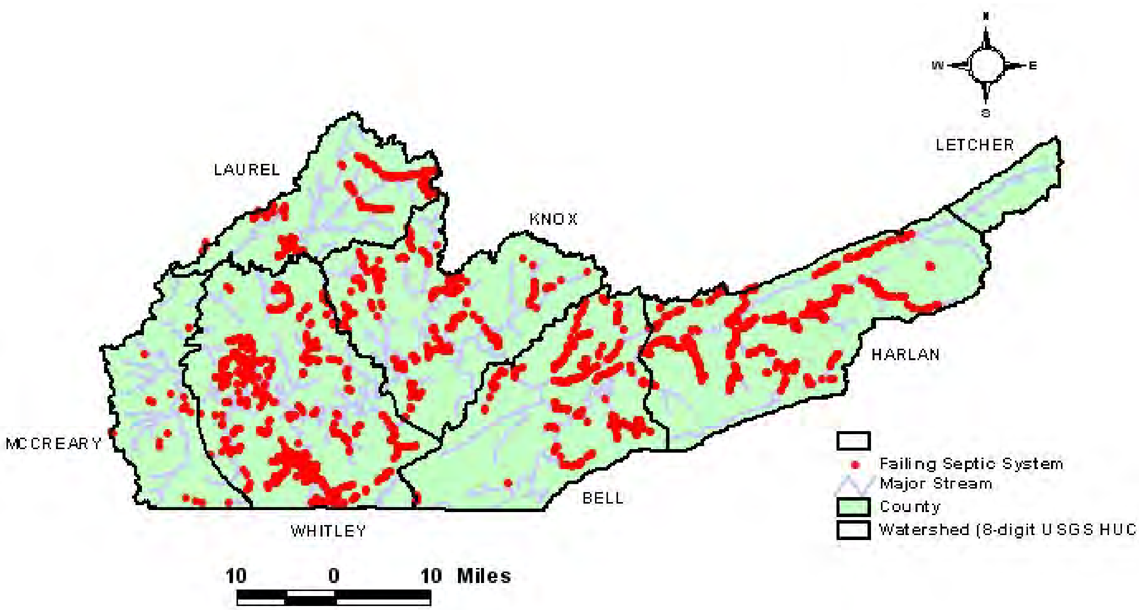

Figure 8 Location of failing septic systems in the upper Cumberland region

ASSESSMENT OF PATHOGEN IMPAIRMENT

Coliform bacteria are a category of relatively harmless microorganisms that live in large numbers in the intestines of human beings and of warm- and cold-blooded animals. They aid in the digestion of food. They are sometimes quantified from water samples as Total Coliform bacteria. A specific subgroup of Total Coliform bacteria is fecal coliform bacteria, the most common member being *Escherichia coli*. These organisms may be separated from the Total Coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals.

The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of humans or other animals. At the time this occurred, the source water may have been contaminated by pathogens or disease-producing bacteria or viruses which can also exist in fecal material. Waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. The presence of fecal contamination in water is an indicator that a potential health risk exists for anyone exposed to this water. Fecal coliform bacteria may occur in ambient water as a result of the overflow of domestic sewage or through other non-point sources of human and animal waste.

The commonwealth of Kentucky uses fecal coliform bacteria as an indicator of the possible presence of pathogens (i.e. viruses, etc) in surface waters. According to Kentucky Administrative Regulation (KAR, 2002) surface water standards document the water quality standard for fecal coliform is tied to primary and secondary contact recreational uses. The water quality standard requirements for these designated uses are:

- Primary contact recreation (May 1 – October 31)
  Fecal coliform count shall not exceed 200 colonies per 100 mL as a monthly geometric mean based on not less than 5 samples per month; nor exceed 400 colonies per 100 mL in twenty percent (20%) or more of all samples taken during the month.

- Secondary contact recreation (year round)
  Fecal coliform count shall not exceed 1000 colonies per 100 mL as a monthly geometric mean based on not less than 5 samples per month; nor exceed 2000 colonies per 100 mL in twenty percent (20%) or more of all samples taken during the month.

This study uses fecal coliform bacteria concentration as a measure of water quality associated with pathogen impairment in streams.

PROGRAMS

Several environmental programs have been implemented to improve water quality of streams in the upper Cumberland region over the last several years. These include various targeted state and federal programs as well as PRIDE (Personal Responsibility in Desirable Environment). A brief overview of these programs is provided in the following sections.

STATE PROGRAMS

Several Kentucky statewide environmental programs have an impact in the upper Cumberland region. These include: the Kentucky Watershed Management Framework, the Kentucky TMDL program, the Kentucky Nonpoint Source program, the Kentucky Agriculture Water Quality Act, the Kentucky EQIP program, the Kentucky Division of Conservation Direct Aid Program and Water Quality Cost Share Program, the Department for Environmental Protection 201 Wastewater Facilities Planning Program and State Revolving Loan Fund, and the State Water Resource Development Commission.

FEDERAL PROGRAMS

Several federal programs have provided funding for projects in the Upper Cumberland River Basin. These include projects initiated by the US Environmental Protection Agency (USEPA) and the US Army Corps of Engineers (USACE). PRIDE helps coordinate many projects such as the US CORPS 531 Program, and various EPA Water Quality Earmarks that have been authorized in the upper Cumberland region that are coordinated through the Kentucky Division of Water. Each of these programs is discussed in the following sections.

ENVIRONMENTAL PROTECTION AGENCY (EPA) PROJECTS

Funding for numerous water quality projects in the counties in the Upper Cumberland River Basin have been included in EPA appropriations bills. These projects include extensions of wastewater collection lines and upgrades or expansions of existing wastewater treatment plants to better serve the local communities. The location and status of the EPA projects in the region are shown in Figure 9. Project details and costs are included in Table 4.

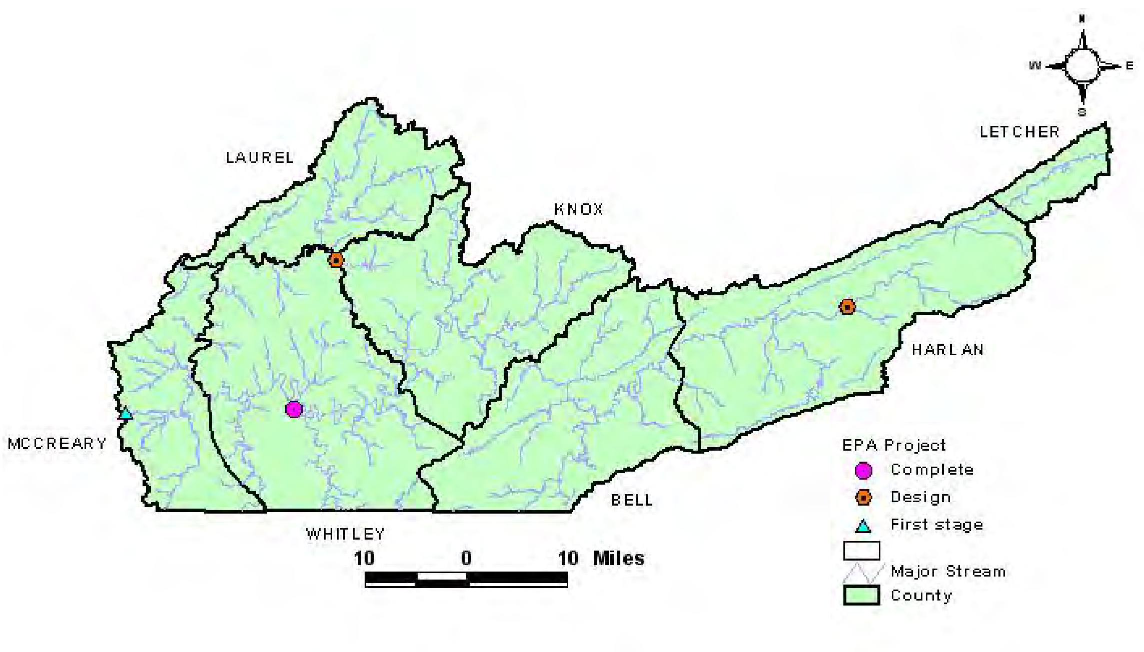

Figure 9 Location and status of EPA projects in the upper Cumberland region

Table 4 EPA construction grants in the upper Cumberland region

Project Location	Cost	County	Project Type	Number of Households Served	Phase
City of Harlan	$950,250	Harlan	Extension of sewer lines	450	Design
City of Sterns	$950,250	McCreary	Upgrade wastewater treatment facility	100	Design
City of Corbin	$1,750,000	Whitley	New sewer line	300	Design
City of Williamsburg	$3,000,000	Whitley	Rebuild sewage treatment plant	1630	Completed

USCOE 531 PROJECTS

Section 531 of the 1996 Water Resources Development Act authorizes a program whereby the U.S. Army Corps of Engineers (USCOE) can provide design and construction assistance for water related environmental infrastructure projects in Eastern and Southern Kentucky. These projects address wastewater, water supply, surface water resource, and related problems. The USCOE can provide grants to counties, cities and utilities to pursue innovative wastewater treatment projects (cluster, peat systems and wetlands) in rural areas where traditional treatment methods would be too costly. The grants cover 75% of project costs, and the local entity must raise the remaining 25%. These grants are awarded once annually. The location of USCOE 531 projects in the region are shown in Figure 10. A detailed list of projects along with the cost and the number of houses served is provided in Table 5.

Table 5 COE531 grants in the upper Cumberland region

Project Location	Cost	County	Project Type	Number of Households Served	Phase
Corbin City Utilities	$72,750	Laurel	New sewer line	15	Completed
City of Middlesboro	$273,000	Bell	Extension of sewer lines	40	Completed
City of Evarts	$450,000	Harlan	Extension of sewer lines	400	Completed
Laurel Co Fiscal Court	$501,000	Laurel	Sewer service	99	Completed
City of Cumberland	$465,000	Harlan	Sewer service	893	Under Construction
City of Middlesboro	$536,423	Bell	Extension of sewer lines	35	Working On Design
Black Mountain Utility District	$695,754	Harlan	Installation of package plant	120	Working On Design

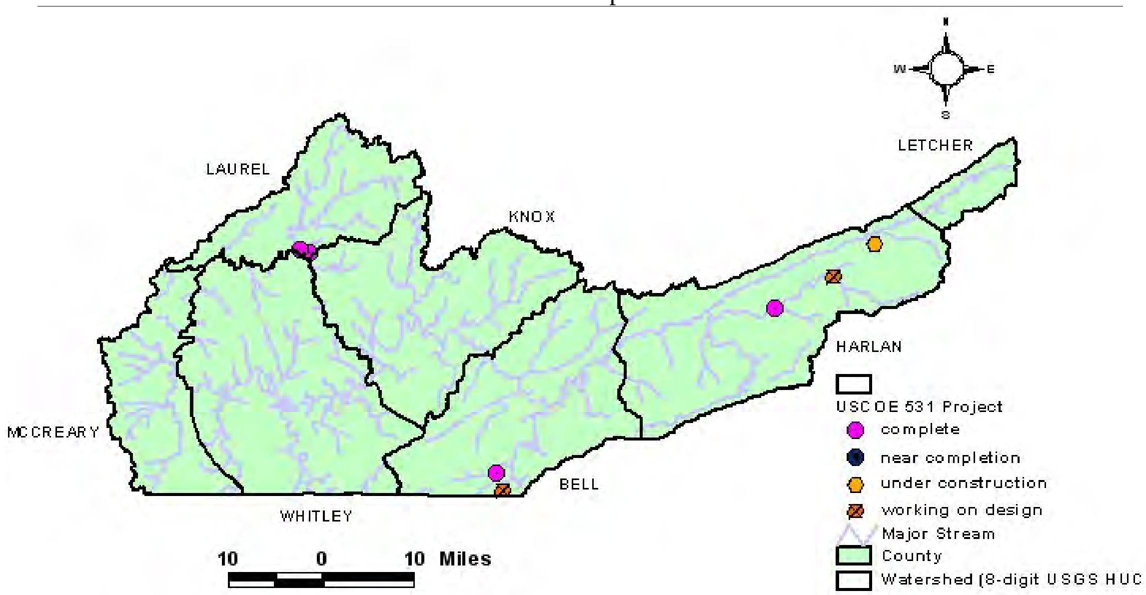

Figure 10 Location and status of COE531 projects in the upper Cumberland region

PRIDE PROGRAMS

The PRIDE initiative was announced by U.S. Congressman Hal Rogers and Kentucky Natural Resources and Environmental Protection Cabinet Secretary James Bickford in 1997. PRIDE is the first comprehensive, region-wide, local/state/federal cooperative effort designed to address the serious challenge of cleaning up Kentucky's rivers and streams of sewage and garbage, ending illegal trash dumps and promoting environmental awareness and educational programs. Each county and community in the 40-county PRIDE region, which includes upper Cumberland region, has a PRIDE Coordinator who works directly with the PRIDE Office to help organize cleanup activities and other PRIDE initiatives and assist local officials with the PRIDE programs and application process.

PRIDE and PRIDE-related projects have received federal funding through the U.S. Department of Commerce and the National Oceanic Atmospheric Administration (NOAA). PRIDE projects types include: 1) the Community Grant Program, 2) the Education Program, 3) the Revolving Loan Program, 4) the Homeowner Septic System Grant Program, 5) the PRIDE Super Grant Program, and 6) the Wastewater Construction Program. The wastewater construction and the homeowner septic system grant programs are directly relevant to reduction of pathogen impairment in streams.

PRIDE WASTEWATER CONSTRUCTION PROJECTS

This program enables counties and cities to apply for grant dollars (with no match requirement) to extend treatment lines into unsewered areas. All Rural Development Administration policies and guidelines apply to this program and it is available to all counties throughout the upper Cumberland region. The application period is usually opened in August every year. The location and status of wastewater construction projects are shown in Figure 11. Other project details are given in Table 6.

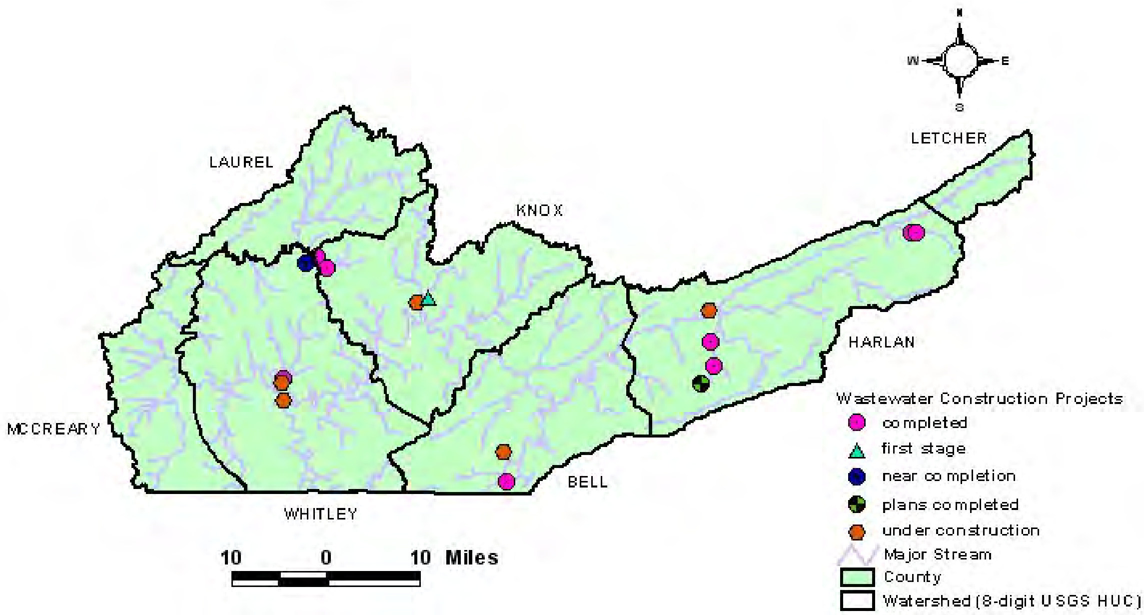

Figure 11 Location and status of wastewater construction projects in the upper Cumberland region

Table 6 PRIDE Wastewater construction grants in the upper Cumberland region

Project Location	Cost	County	Project Type	Number of households served	Phase
City of Middlesboro	$971,194	Bell	Extension of sewer lines	60	Completed
City of Harlan	$1,000,000	Harlan	Extension of sewer lines	307	Under Construction
City of Williamsburg	$463,930	Whitley	Sewer line connection	30	Completed
Corbin City Utilities	$479,505	Knox	Extension of sewer lines	50	Completed
Bell Co Fiscal Court	$403,000	Bell	Extension of sewer lines	187	Under Construction
City of Benham	$87,000	Harlan	Replace sewer lines	11	Completed
City of Loyall	$324,460	Harlan	Extension of sewer lines	44	Under Construction
City of Harlan	$750,000	Harlan	Extension of sewer lines	410	Completed
City Utilities Commission of Corbin	$944,890	Knox	Extension of sewer lines	82	Completed
City Utilities Commission of Corbin	$162,325	Knox	Extension of sewer lines	11	Near Completion
City of Williamsburg	$999,960	Whitley	Extension of sewer lines	85	Under Construction
Knox Co Fiscal Court	$872,075	Knox	Extension of sewer lines	70	Under Construction
City of Williamsburg	$300,000	Whitley	Extension of sewer lines	11	Under Construction
City of Lynch	$30,000	Harlan	Improve sewer line	389	Completed
City of Harlan	$1,401,551	Harlan	Extension of sewer lines	300	Plans Completed
Barbourville Utility Commission	$820,500	Knox	Gravity flow sewer construction	80	First Stage
Black Mountain Utility District	$88,000	Harlan	Package plant construction	16	Completed

PRIDE HOMEOWNER SEPTIC SYSTEM LOAN/GRANT PROGRAM

PRIDE, in association with local Area Development Districts (ADDs) and Resource Conservation and Development Districts (RC&Ds), has established a grant program for low-income homeowners to hook onto existing sewage treatment lines or to install a septic system following an initial loan program. To qualify for a grant, the homeowner must meet the Housing and Urban Development (HUD) poverty guidelines, must be the property deed holder, and must have existing electricity at the home. A map with the location of septic system loan and grants in the region developed by KWRRI with information provided by PRIDE is shown in Figure 12.

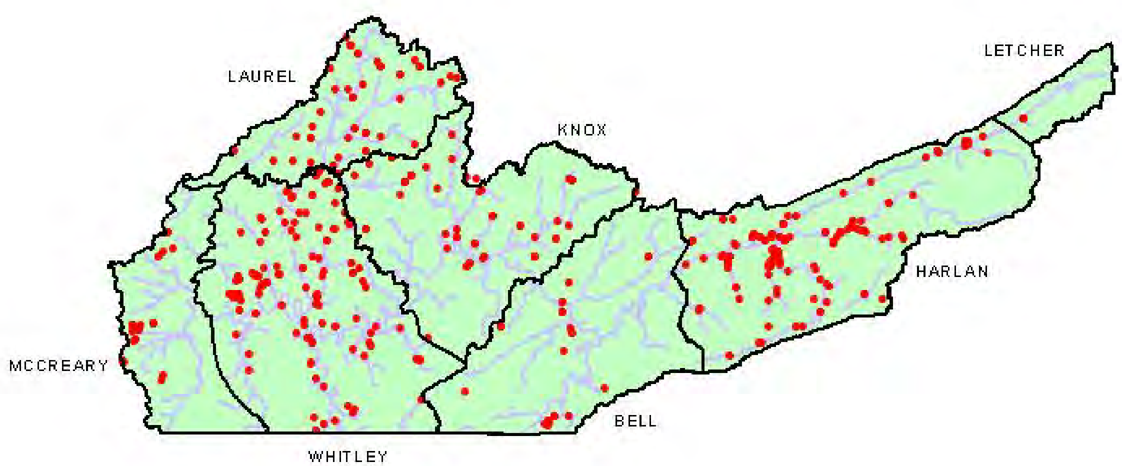

Figure 12 Location of septic system loan and grants in the upper Cumberland region.

PROJECT GOALS

The main goal of this project was to quantify the level of success of previous and ongoing programs/projects to reduce the level of fecal coliform concentrations in the streams in the upper Cumberland River Basin.

OBJECTIVES

The main objectives of the study were as follows:

1. Identify, select and assemble available monitoring and project data sets.
2. Conduct a comprehensive deterministic and stochastic analysis of the data to draw conclusions about pathogen (fecal coliform) concentrations at several levels.
3. Assess the impact of existing water quality projects at the regional, county, and point level of interest.

MONITORING

The efficient utilization of federal funds for improving the water quality and aquatic habitat of the region requires a mechanism for assessing and evaluating the impacts of proposed and ongoing projects as well as some mechanism for prioritizing the allocation of additional funds. In order to evaluate the effectiveness of these projects, it is important to provide a formal monitoring and assessment program based on sound scientific principles. The following sections provide details of monitoring sites that were used to support an assessment of water quality conditions in the upper Cumberland region.

MONITORING NETWORK AND DATA

Water quality data from the upper Cumberland basin were assembled from four existing sources: 1) KYDOW ambient sampling, 2) KYDOW focused sampling, 3) PRIDE focused sampling (University of Kentucky) and 4) PRIDE synoptic sampling (Kentucky Watershed Watch Program). While the first three data sets were collected with standard and documented QA/QC protocols, the synoptic sampling was collected by volunteers without the benefit of an officially approved QA/QC protocol, although industry standards were still generally followed. Nonetheless, the resulting analyses generally focused on the first three data sets, although the synoptic data were also used to evaluating general regional or county trends.

KENTUCKY DIVISION OF WATER SAMPLING NETWORK

Monitoring stations associated with the KYDOW (Kentucky Division of Water) ambient network are normally sampled every other month. However, during the particular year that the basin is in the monitoring phase of the five year management cycle of the Kentucky Watershed Management Framework (Ormsbee and McAlister, 2005), ambient stations are sampled once a month. The locations of DOW ambient stations are shown in Figure 13. Information on each of the stations is provided in Table 7. As part of the normal ambient sampling, each of the stations was sampled for dissolved oxygen, temperature, pH, ammonia, metals, and fecal coliform.

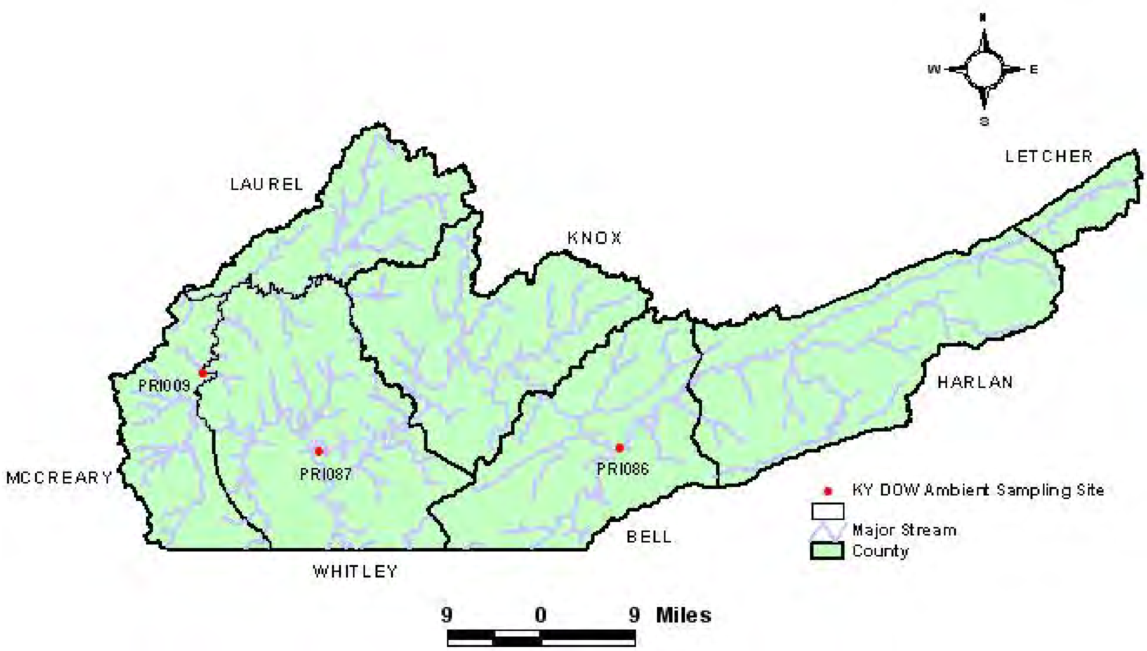

Figure 13 Location of KYDOW Ambient sampling sites in the upper Cumberland region

Table 7 KYDOW ambient sampling sites in the upper Cumberland region

Station	County	Stream	Nearest Community
PRI009	McCreary	Cumberland River at Cumberland Falls	-
PRI086	Bell	Cumberland River at Calvin	Pineville(U)
PRI087	Whitley	Clear Fork near Williamsburg	Williamsburg (D)

KENTUCKY DIVISION OF WATER FOCUSED SAMPLING NETWORK

In addition to bi-monthly ambient data, the KYDOW has conducted intensive TMDL sampling in the upper Cumberland River. Each of the intensive stations was sampled for temperature, pH and fecal coliform. Locations of focused sampling sites in the upper Cumberland region are shown in Figure 14. Information on each of the stations is provided in Table 8.

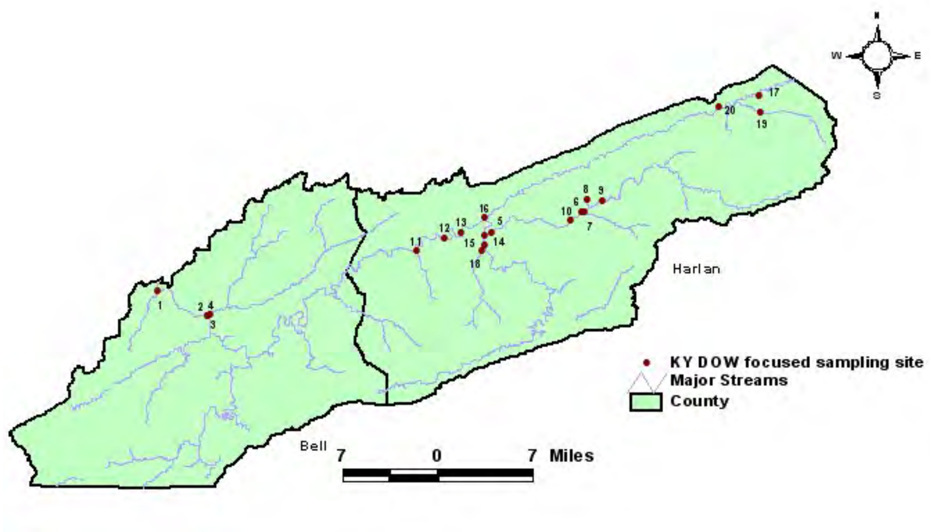

Figure 14 Location of KYDOW focused sampling sites in the Bell and Harlan counties of upper Cumberland region

Table 8 KYDOW focused sampling sites in the upper Cumberland region

Number on Map	Station	County	Stream	Nearest Community
1	BCR18	Bell	Cumberland River	Pineville (U)
2	BCR19	Bell	Cumberland River	Pineville(U)
3	BCR19A	Bell	Cumberland River	Pineville(U)
4	BTR20	Bell	Straight Creek	Pineville(U)
11	HCR32	Harlan	Cumberland River	Wallins(U)
12	HCR33	Harlan	Cumberland River	Loyall(U)
13	HCR35	Harlan	Cumberland River	Loyall (U)
14	HCR37	Harlan	Cumberland River	Cawood(u), Loyall(D)
16	HPF38	Harlan	Poor Fork	Evarts(U), Loyall(D)
17	HTR45	Harlan	Poor Fork	Cumberland (D)
19	HWP48	Harlan	Looney Creek	Cumberland (D)
5	HCF53	Harlan	Clover Fork	Evarts(U), Harlan(D)
6	HCF56	Harlan	Clover Fork	Dizney(U), Evarts(D)
7	HCF56A	Harlan	Yocum Creek	Dizney U) , Evarts(D)
8	HCF56B	Harlan	Bailey Creek	Closplint (U), Evarts (D)
9	HCF56D	Harlan	Clover Fork	Closplint(U), Evarts (D)
18	HTR62	Harlan	Catron Creek	Cawood(U), Loyall(D)
15	HMF621	Harlan	Martins Fork	Cawood(U), Loyall(D)
10	HCF65	Harlan	Clover Fork	Evarts(U), Harlan(D)
20	HPF41	Harlan	Poor Fork	Cumberland(U), Totz(D)

(U: upstream, D: downstream)

UNIVERSITY OF KENTUCKY SAMPLING NETWORK

In September 2000, the University of Kentucky Water Resources Research Institute was contracted by PRIDE to provide an ongoing assessment of the impacts of various PRIDE programs on the water quality of the PRIDE region, including the Upper Cumberland River Basin. This annual assessment involves the collection of water quality data (including fecal coliforms) at 12 different sites across the basin (see Figure 15).

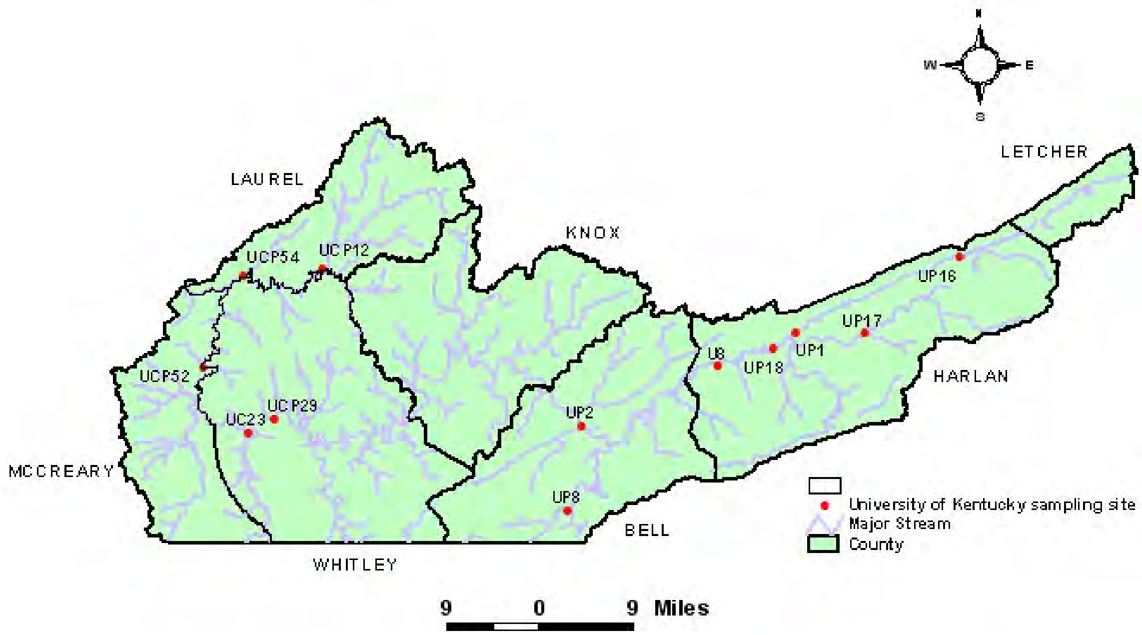

Figure 15 Location of University of Kentucky sampling sites in the upper Cumberland region

A description of each of the sites is provided in Table 9. Additional information about the UK sampling and assessment program can be found at: http://pride.uky.edu.

Table 9 University of Kentucky sampling sites in the upper Cumberland region

Station	County	Stream and Location	Nearest Community
U8	Harlan	Cumberland River downstream of new Route 2007b	Wallins (U)
UC23	Whitley	Jellico Creek on route 478	-
UCP12	Laurel	Laurel River on route 312	Corbin(U)
UCP29	Whitley	Cumberland River on route 204	Williamsburg(U)
UP1	Harlan	Poor Fork of Cumberland between 421 and 119	Cumberland(U)
UP2	Bell	Cumberland River just upstream of 119 Bridge	Pineville(D)
UP8	Bell	Yellow Creek on HWY 441 Bridge	Meldrum (D)
UP16	Harlan	Poor Fork of Cumberland on 119 Bridge	Cumberland (U)
UP17	Harlan	Clover Fork of Cumberland River on Route 38 Bridge	Evarts
UP18	Harlan	Cumberland River at Loyall	Loyall (U)
UCP52	McCreary	Cumberland River	Leavy(U), Corbin(U)
UCP54	Laurel	Laurel River	-

KENTUCKY WATERSHED WATCH SAMPLING NETWORK

Educational grants from PRIDE and other organizations have been used to support volunteer sampling efforts across the upper Cumberland area. These grants have been awarded to volunteer groups associated with the Kentucky Watershed Watch Program. Watershed Watch monitoring stations in the upper Cumberland region are shown in Figure 16.

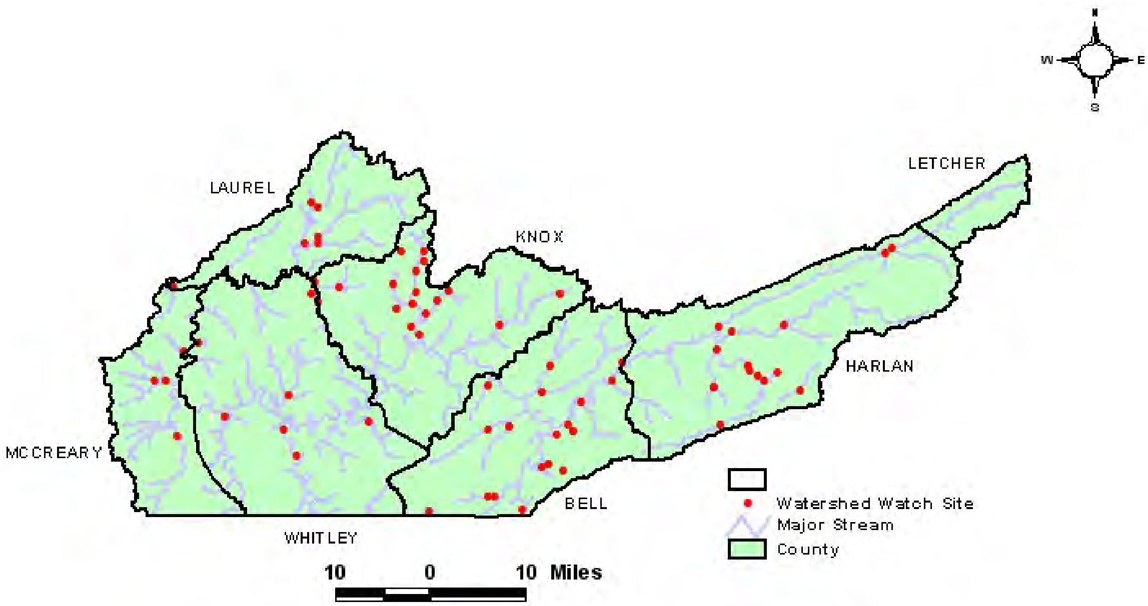

Figure 16 Location Watershed Watch sampling sites in the upper Cumberland region

QUALITY ASSURANCE AND QUALITY CONTROL

The water quality assessment of the upper Cumberland region is based on data obtained from the Kentucky Division of Water (KYDOW) ambient network, Division of Water focused sampling network, the University of Kentucky targeted sampling. Sampling protocols for the first three sets of data have been reported elsewhere (KYDOW, 2005; KYWWQAP, 2005). Operational procedures and quality assurance and quality control (QA/QC) for the University of Kentucky sampling program can be accessed through the pride.uky.edu web site (PRIDE, 2001). Sampling procedures were written to conform to the Kentucky Ambient/Watershed Water Quality Monitoring Guidelines as well as applicable EPA sampling protocols.

MONITORING RESULTS AND ASSESSMENTS

Observed concentrations of fecal coliform were evaluated for a number of streams in the upper Cumberland region. To develop a comprehensive understanding of stream impairment due to pathogens, assessments were carried out at four different levels. These included: 1) regional, 2) county, 3) point, and 4) project locations. These different levels provide an overall assessment of the potential stream impairment caused by pathogens and provide a method to evaluate the impact of completed projects in various segments of the upper Cumberland River region.

ASSESSMENT FRAMEWORK

A data assessment framework was developed in the initial stages of the project. A schematic of the framework is shown in Figure 17. The assessment framework defined the analysis based on two characteristics, the type of analysis and the level at which the analysis was carried out. Two types of analyses, deterministic and stochastic (statistical), formed the major elements of the framework. Four spatial levels were considered during the water quality assessment.

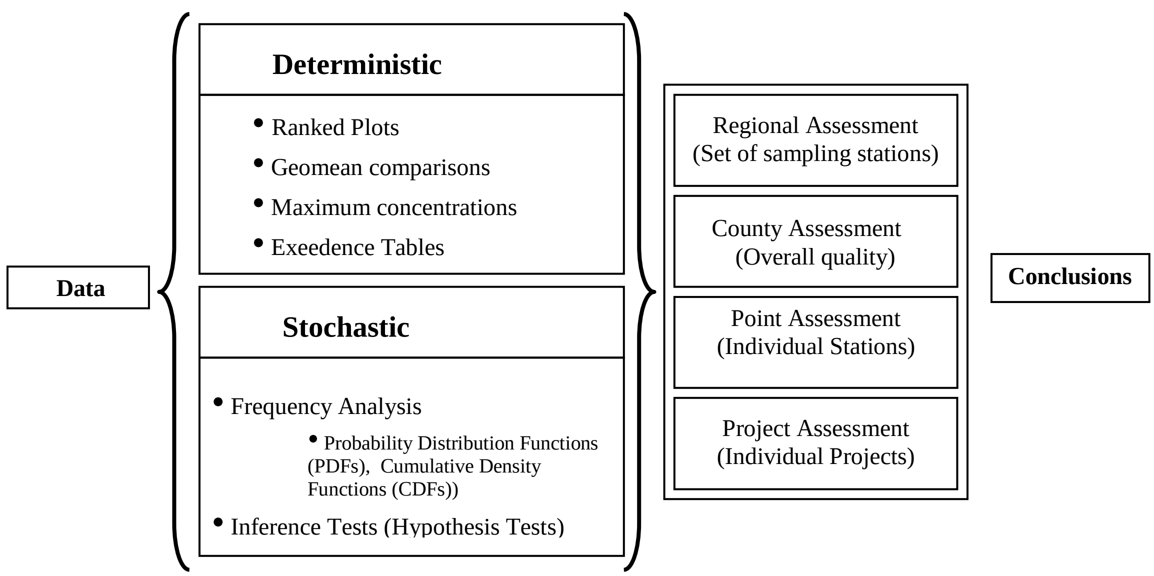

Figure 17 Data assessment framework

DETERMINISTIC ANALYSIS

In deterministic analysis, the randomness associated with the measured data is not considered and the raw data is used to assess any trends or overall changes in fecal coliform values. Four different approaches were used to assess the trends: 1) ranked plots, 2) geomeans, 3) extreme (maximum) values and 4) exceedence percentages. The following sections provide a discussion of these four approaches.

RANKED DATA PLOT

A ranked data plot is a graphical representation of the entire raw data set which illustrates a complete summary of the data. The available data were sorted in ascending order from the minimum to the maximum value. The ranked plot was then generated by plotting the concentration values at equally spaced intervals along the x-axis. Ranked data plots from two monitoring periods can reveal differences in the data distributions.

GEOMETRIC MEAN

An arithmetic mean calculated from concentration data can be used as a measure of water quality at specific point of interest. This measure provides a single value representing the average quality of the stream in reference to the water quality standards set for designated uses. Another measure, similar to the arithmetic mean, is a geometric mean (GM). The geometric mean is the nth root of the product of positive numbers (a_1, a_2, a_3… a_n) given by

$$GM = \sqrt[n]{a_1}, a_2, a_3 \ldots\ldots a_n \qquad (1)$$

Geometric means (GM) are acknowledged as a better measure for variables that are positively skewed distributions (e.g. microbial concentrations that vary over several orders of magnitude). The geometric mean was therefore a logical choice for evaluation of the central tendency of fecal coliform concentrations. In the current assessment study, geometric means were used to represent the average value of measured fecal concentrations for various groups of data.

EXTREME VALUE ANALYSIS

Extreme maximum concentration values observed in each monitoring year were plotted for comparison. Since extreme values are often important from a water quality standard perspective, they provide valuable information about the observed data. Extreme values may indicate high concentrations due to non-point sources in the case of wet events or potential point source discharges in the case of dry events.

EXCEEDENCE PERCENTAGE

Comparing observed concentrations to quantitative standards is another method of evaluating monitored water quality data. Exceedence percentage refers to the percentage of time that the measured concentration of fecal coliform bacteria exceeded the water quality standards at a particular location in a stream. Calculation of exceedence percentages for several different years provided information about changes in violations of water quality standards defined by the numerical standard set by the state. Exceedence percentages are not influenced by extreme concentration values.

STOCHASTIC ANALYSIS

In stochastic analysis, the randomness associated with measured data is considered and the raw data is used to assess any trends or overall changes in the average values. Fecal coliform concentrations were considered as random variables and conclusions regarding the trends were made in a probabilistic sense. Two methods were used to assess the trends: 1) frequency analysis and 2) statistical analysis. The following sections provide brief discussions about these indices.

FREQUENCY ANALYSIS

Observed fecal coliform data were used to develop histograms (plots of frequency at which the data occur within discrete intervals). Probability Density Function (PDF) plots and accumulated relative frequency plots illustrating Cumulative Density Function (CDF) were prepared and used to compare the data. Plots from different monitoring periods were compared to assess changes in water quality.

STATISTICAL ANALYSIS

Statistical analyses were conducted to assess the monitored data and make inferences about the mean fecal concentration values. In order to assess the changes (improvements or deteriorating conditions), historical monitoring data were split into two data sets (sample populations) and compared.

The following steps were carried out for the statistical analysis.

1. Sample populations were checked to see if they fit a specific probability distribution (e.g., normal or log-normal distribution)
2. The sample variances ($\boldsymbol{S}_1^2, \boldsymbol{S}_2^2$) were calculated for the two data sets and checked to see if the were equal or unequal. For data sets with equal variances, a comparison was made using a t-test. For data sets with unequal variances, a comparison was made using Satterthwaite's modified t-test (Iman and Conover, 1983)
3. Sample means ($\overline{\mathbf{x}_1}, \overline{\mathbf{x}_2}$) were then calculated for the data sets and checked to see if they were statistically different at a specified significance level using hypothesis tests.

Probability plots on normal or log-normal paper were used to visually check the hypothesized distributions. A goodness-of-fit test (i.e., Kolmogorov-Smirnov) was also conducted to ensure the validity of hypothesized data distributions. F-tests were carried out to ascertain if the variances were equal or not equal. A t-test was used to make inference about differences in sample mean values. A significance level of 0.05 was used. The procedures for these tests are discussed in detail elsewhere (Gilbert, 1987; Ott, 1995).

The available data was checked for any inconsistencies and gaps before it was adopted for the analysis. Table 10 provides information about the data sources and monitoring periods utilized for analysis in this study. The stochastic analysis was conducted using data sets to identify and assess long- and short-term water quality trends separately. Comparisons were based on: 1) data from monitoring years 1994-1998 versus 1999-2005 for the long-term analysis and 2) data from 2001-2003 versus 2004-2005 for the short-term analysis.

Table 10 List of data sources and length of data used for analysis

Data Source	Monitoring Period	Samples/year
KY DOW Ambient Data	1994-2005	3 – 6
KY DOW Focused Data	1994-2005*	6
PRIDE/UK Data	2001-2005	5 – 10
PRIDE/WW data	1999-2005	1 – 2

*Data from year 2001 was not available.

RESULTS AND ANALYSIS

REGIONAL ASSESSMENT

Regional assessment was carried out using several approaches: 1) ranked plots, 2) geomean comparisons, 3) extreme value analysis, and 4) cumulative density functions. Results of these analyses are included in Appendices B & C. The ranked plot (Figure B1) shows the range of coliform concentrations over each respective period. Geometric means of fecal concentrations calculated as aggregate annual values for all of the regional data show a general decrease over the past 10 years (Figure B2). Annual extreme concentrations for the region show a similar, but more variable pattern (Figure B3).

Cumulative density function (CDF) comparisons for long-term (Figure C1) and short-term periods (Figure C2) illustrate that fecal coliform concentrations have decreased on a regional basis. The probabilities of concentrations less than 400 counts/100 mL and less than 1000 counts/100 mL have increased over the last five years indicating improvement in water quality.

Additional CDF comparisons used to assess the potential influence of dry and wet events on fecal coliform concentrations in streams are documented in Appendix D. If the recorded precipitation was more than 0.3 inches summed over the day of sampling and the preceding two days, then the event was considered as a wet event. Sampling events with 0.3 inches of precipitation or less over the 3-day period were considered dry events. The probabilities of concentrations less than 400 counts/100 mL and also 1000 counts/100 mL have increased over the last five years for both wet and dry sampling events (suggesting overall improvement in water quality).

COUNTY ASSESSMENT

Assessment of fecal coliform concentrations using annual geometric means for the past 5 years was conducted. The aggregate geometric mean value for each county was calculated from all concentration values from all sampling stations during a calendar year. Results are presented graphically in Appendix E (Figures E1 – E6). Geomean-based county assessments suggest that fecal coliform concentrations are either stable are decreasing over the last three years. However, some counties still have annual geometric mean values above 200 counts/100 mL during some years, which would indicate a violation of the water quality standard for primary recreational contact.

Maximum yearly concentrations for each of the counties are also illustrated in Appendix E (Figures E7 – E12). In general, the maximum values have declined over the past few years, but values above 1000 counts/100 mL still occur in some years.

POINT ASSESSMENT

Deterministic and stochastic analyses were conducted using the sampling data at individual monitoring locations for several years. Exceedence and statistical analyses were conducted as a part of the point assessment.

Exceedence percentages were calculated for all the KYDOW focused sampling sites from years 1998 to 2005. Table 11 lists the exceedence percentages based on the Kentucky state water quality standard 400 counts/100 mL. Exceedence percentages have generally decreased over the past 7 years. The average percentages calculated for data splits (years 1998-2002 compared with 2003-2005) show improvement and suggest decreasing violations. However, 11 focused sampling sites still show average exceedence percentages above 50% for the period 1998-2005. The sampling station, HMF621 with 100 % percentage of exceedence for all years is located directly downstream of the community of Sunshine. The community has approximately 300 households with inadequate wastewater service. A projected funded by PRIDE is underway to extend sewer lines to this community and to remove the direct discharge of sewage to Martins Fork.

Table 11 Percentage of samples with fecal coliform above 400 counts/100 mL for all KYDOW focused sampling stations

Number on Map	Station ID	Year: 1998	1999	2000	2002	2003	2004	2005	
		Percentage (%) of collected samples that are above 400 counts/100ml							Average
1	**BCR18**	71	67	67	0	50	33	40	47
2	**BCR19**	43	0	0	0	33	50	20	21
3	**BCR19A**	29	0	0	0	33	50	20	19
4	**BTR20**	71	17	17	20	0	50	40	31
11	**HCR32**	43	0	0	20	33	17	0	16
12	**HCR33**	86	50	17	40	100	67	40	57
13	**HCR35**	83	83	33	20	67	33	60	54
14	**HCR37**	86	33	33	20	0	17	60	36
16	**HPF38**	14	17	17	0	0	17	20	12
20	**HPF41**	71	83	83	40	67	67	60	67
17	**HTR45**	14	67	83	60	67	0	60	50
19	**HWP48**	71	67	33	60	33	100	20	55
5	**HCF53**	57	33	33	0	100	67	20	44
6	**HCF56**	100	83	100	100	33	33	40	70
7	**HCF56A**	86	67	67	80	67	67	80	73
8	**HCF56B**	100	100	100	80	67	50	80	82
9	**HCF56D**	71	83	83	60	33	17	20	52
18	**HTR62**	100	83	83	80	67	50	60	75
15	**HMF621**	100	100	100	100	100	100	100	100
10	**HCF65**	57	83	67	0	67	33	20	47
	Average	**68**	**56**	**51**	**39**	**51**	**46**	**43**	**50**
	Average(1998-202)		**54**	**Average(2003-2005)**		**47**			

Table 12 lists the exceedence percentages based on the water quality standard, 1000 counts/100 mL. The average percentages calculated from data splits (years 1998-2002 versus 2003-2005) suggest decreasing violations. However, two focused sampling sites show average exceedence percentages above 50% for the period 1998-2005.

Table 12 Percentage of samples with fecal coliform above 1000 counts/100 mL for all KYDOW focused sampling stations

Number on Map	Station ID	Year 1998	1999	2000	2002	2003	2004	2005	
		Percentage (%) of collected samples that are above 1000 counts/100ml							Average
1	**BCR18**	43	33	0	0	0	0	40	17
2	**BCR19**	29	0	0	0	0	0	0	4
3	**BCR19A**	29	0	0	0	0	0	0	4
4	**BTR20**	29	0	17	0	0	0	20	9
11	**HCR32**	14	0	0	0	33	17	0	9
12	**HCR33**	57	17	0	20	33	17	0	21
13	**HCR35**	33	50	17	0	33	17	20	24
14	**HCR37**	14	0	33	0	0	0	0	7
16	**HPF38**	14	0	17	0	0	0	0	4
20	**HPF41**	29	33	50	20	0	33	40	29
17	**HTR45**	0	17	67	60	0	0	40	26
19	**HWP48**	57	50	33	20	0	50	0	30
5	**HCF53**	29	17	17	0	0	33	0	14
6	**HCF56**	43	50	100	100	0	17	20	47
7	**HCF56A**	86	50	67	60	0	50	20	48
8	**HCF56B**	71	100	83	20	0	33	80	55
9	**HCF56D**	0	33	50	40	0	0	20	20
18	**HTR62**	71	50	17	40	0	17	40	34
15	**HMF621**	57	67	83	0	67	33	80	55
10	**HCF65**	14	83	50	0	67	17	20	36
	Average	**36**	**33**	**35**	**19**	**12**	**17**	**22**	**25**
	Average (1998-2002)			**31**	**Average (2003-2005)**			**17**	

STATISTICAL ANALYSIS

Statistical analysis was conducted using data sets to infer changes in the mean concentrations of fecal coliform over two monitoring periods. To conduct statistical analysis, null and alternative hypotheses were initially defined. The narrative form of these hypotheses is included in Appendix F.

Tests were conducted using the procedures outlined in Table F1 of Appendix F to derive conclusions about the observed data. The data at all the sampling stations used in the current study followed a log-normal distribution. This was observed through probability plots and confirmed using a standard goodness-of-fit test. Results from F-tests are not included in this report. However, final results relating to null and alternative hypotheses derived from T-tests are reported using two data sets from different monitoring periods. Inference tests conducted using mean concentrations of fecal coliform for a long-term comparison, at different sampling sites are shown in Table 13.

Table 13 Summary of statistical inference tests based on two data sets (1994-1998, 1999-2005) for KYDOW focused sampling stations

Number on Map (Figure 14)	**Station**	$\mathbf{Log_{10}(\overline{x}_1)}$ **(1994-1998)**	$\mathbf{Log_{10}(\overline{x}_2)}$ **(1999-2005)**	**Hypothesis**	**Conclusion**
1	BCR18	3.176	2.478	H_a is true	Mean Values are not equal
2	BCR19	2.468	1.970	H_a is true	Mean Values are not equal
3	BCR19A	2.882	2.038	H_a is true	Mean Values are not equal
4	BTR20	2.747	2.288	H_a is true	Mean Values are not equal
5	HCF53	2.859	2.489	H_a is true	Mean Values are not equal
6	HCF56	3.188	2.671	H_a is true	Mean Values are not equal
7	HCF56A	3.379	2.931	H_a is true	Mean Values are not equal
8	HCF56B	3.358	3.004	H_a is true	Mean Values are not equal
9	HCF56D	2.804	2.691	H_o is true	Mean values are equal
10	HCF65	3.266	2.823	H_a is true	Mean Values are not equal
11	HCR32	2.766	2.214	H_a is true	Mean Values are not equal
12	HCR33	3.126	2.639	H_a is true	Mean Values are not equal
13	HCR35	3.245	2.672	H_a is true	Mean Values are not equal
14	HCR37	2.943	2.495	H_a is true	Mean Values are not equal
15	HMF621	3.422	3.184	H_a is true	Mean Values are not equal
16	HPF38	2.453	2.229	H_a is true	Mean Values are not equal
20	HPF41	3.110	2.809	H_a is true	Mean Values are not equal
17	HTR45	2.926	2.838	H_o is true	Mean values are equal
18	HTR62	3.384	2.786	H_a is true	Mean Values are not equal
19	HWP48	2.637	2.779	H_o is true	Mean values are equal

($\mathbf{\overline{x}_1}$, $\mathbf{\overline{x}_2}$: sample means, H_a: Alternative hypothesis, H_o: Null hypothesis)

The conclusions tabulated in Table 13 provide information about the mean values from which a final assessment of improvement was deduced. This was done by checking the mean values of fecal coliform concentrations from the two different monitoring periods along with the hypothesis conclusion. The final assessment criteria for water quality are provided in Table 14.

Table 14 Assessment criteria used to comment on condition of water quality

Scenario	Comparison of Mean Values	Hypothesis	Assessment
1	$\mathbf{Log_{10}(\overline{x_1}) > Log_{10}(\overline{x_2})}$	H_a is true	Improvement
2	$\mathbf{Log_{10}(\overline{x_1}) > Log_{10}(\overline{x_2})}$	H_o is true	Improvement (Statistically no change)
3	$\mathbf{Log_{10}(\overline{x_1}) < Log_{10}(\overline{x_2})}$	H_a is true	Worse
4	$\mathbf{Log_{10}(\overline{x_1}) < Log_{10}(\overline{x_2})}$	H_o is true	Worse (Statistically no change)

($\overline{\mathbf{x_1}}$, $\overline{\mathbf{x_2}}$: sample means, H_a: Alternative hypothesis, H_o: Null hypothesis)

The final assessment criteria (Table 14) and the results of statistical inference tests reported in Table 13 were used to evaluate improvement or deterioration of water quality at specific sampling stations. The long-term assessment for different sampling stations is given in Table 15 and also visually depicted in Figure 18.

Table 15 Water quality trends at stations in Bell and Harlan counties based on statistical analysis of data (1994-2005)

Station	Assessment	Station	Assessment
BCR18	Improvement	HCR32	Improvement
BCR19	Improvement	HCR33	Improvement
BCR19A	Improvement	HCR35	Improvement
BTR20	Improvement	HCR37	Improvement
HCF53	Improvement	HMF621	Improvement
HCF56	Improvement	HPF38	Improvement
HCF56A	Improvement	HPF41	Improvement
HCF56B	Improvement	HTR45	Improvement (statistically no change)
HCF56D	Improvement (statistically no change)	HTR62	Improvement
HCF65	Improvement	HWP48	Worse (statistically no change)

Summaries of statistical inference tests based on data sets used for short-term comparison at different KYDOW focused sampling stations are reported in Table 16.

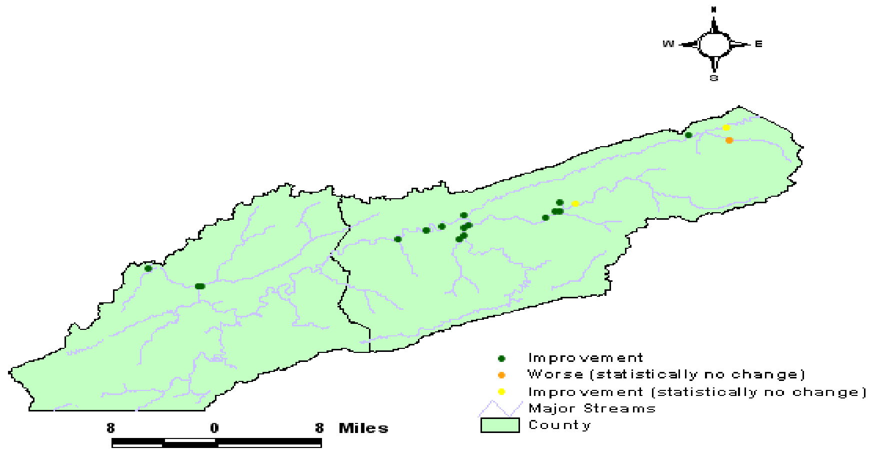

Figure 18 Map showing water quality trends at different stations in Bell and Harlan Counties based on statistical analysis of data (1994-2005)

Table 16 Summary of statistical inference tests based on data sets from 2001-2003 and 2004-2005 for KYDOW focused sampling stations

Number on Map (Figure 14)	**Station**	$\mathbf{Log_{10}(\overline{x_1})}$ **(2001-2003)**	$\mathbf{Log_{10}(\overline{x_2})}$ **(2004-2005)**	**Hypothesis**	**Conclusion**
1	BCR18	2.469	2.487	H_o is true	Mean values are equal
2	BCR19	1.640	2.300	H_a is true	Mean Values are not equal
3	BCR19A	1.775	2.301	H_a is true	Mean Values are not equal
4	BTR20	2.101	2.475	H_a is true	Mean Values are not equal
5	HCF53	2.331	2.647	H_o is true	Mean values are equal
6	HCF56	3.086	2.525	H_a is true	Mean Values are not equal
7	HCF56A	3.120	2.742	H_a is true	Mean Values are not equal
8	HCF56B	3.174	2.835	H_a is true	Mean Values are not equal
9	HCF56D	2.885	2.498	H_a is true	Mean Values are not equal
10	HCF65	2.764	2.880	H_o is true	Mean values are equal
11	HCR32	2.089	2.338	H_o is true	Mean values are equal
12	HCR33	2.513	2.766	H_a is true	Mean Values are not equal
13	HCR35	2.712	2.633	H_o is true	Mean values are equal
14	HCR37	2.551	2.440	H_o is true	Mean values are equal
15	HMF621	3.162	3.207	H_o is true	Mean values are equal
16	HPF38	2.204	2.256	H_o is true	Mean values are equal
20	HPF41	2.910	2.707	H_o is true	Mean values are equal
17	HTR45	3.014	2.650	H_a is true	Mean Values are not equal
18	HTR62	2.842	2.733	H_o is true	Mean values are equal
19	HWP48	2.829	2.722	H_o is true	Mean values are equal

($\overline{x_1}$, $\overline{x_2}$: sample means, H_a: Alternative hypothesis, H_o: Null hypothesis)

The final assessment criteria (Table 14) and the results of statistical inference tests reported in Table 16 were used to evaluate improvement or deterioration of water quality at specific sampling stations. The short-term assessment for different sampling stations is given in Table 17 and also visually depicted in Figure 19.

Table 17 Water quality trends at stations in Bell and Harlan counties based on statistical analysis of data (2001-2005)

Station	Assessment	Station	Assessment
BCR18	Worse (statistically no change)	HCR32	Worse (statistically no change)
BCR19	Worse	HCR33	Worse
BCR19A	Worse	HCR35	Improvement (statistically no change)
BTR20	Worse	HCR37	Improvement
HCF53	Worse (statistically no change)	HMF621	Worse (statistically no change)
HCF56	Improvement	HPF38	Worse (statistically no change)
HCF56A	Improvement	HPF41	Improvement (statistically no change)
HCF56B	Improvement	HTR45	Improvement
HCF56D	Improvement	HTR62	Improvement (statistically no change)
HCF65	Worse (statistically no change)	HWP48	Improvement (statistically no change)

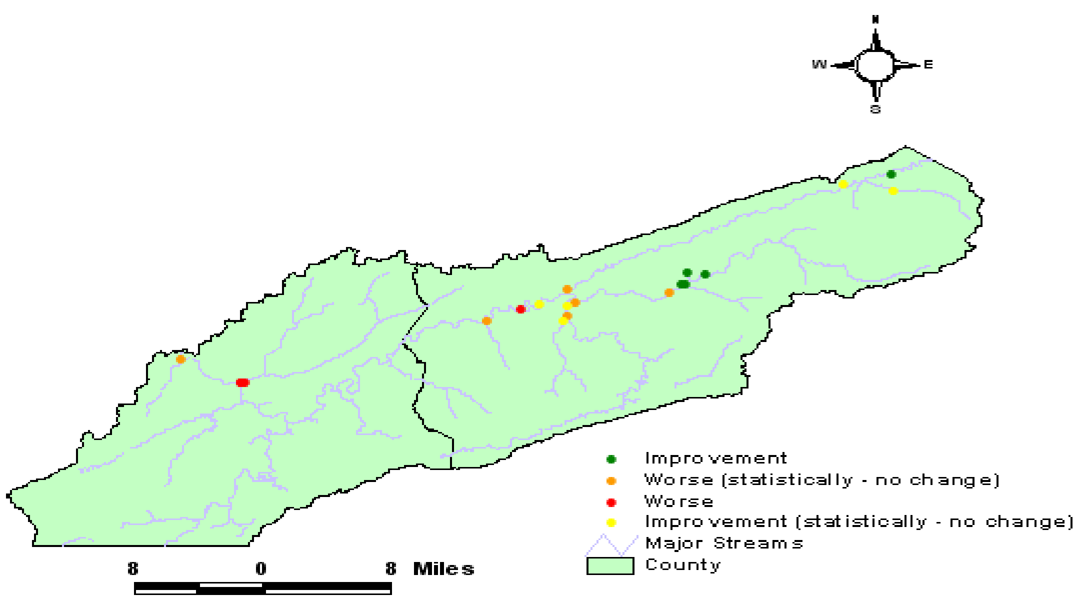

Figure 19 Map showing water quality trends at different stations in Bell and Harlan Counties based on statistical analysis of data (2001-2005)

Results from statistical analysis of short-term data sets from the University of Kentucky sampling sites are reported in Table 18.

Table 18 Summary of statistical inference tests based on data sets from 2001-2003 and 2004-2005 for UK sampling stations

Station	$\mathbf{Log_{10}(\overline{x_1})}$ **(2001-2003)**	$\mathbf{Log_{10}(\overline{x_2})}$ **(2004-2005)**	**Hypothesis**	**Conclusion**
U8	2.472	1.431	H_a is true	Mean Values are not equal
UC29	2.386	2.197	H_o is true	Mean values are equal
UCP12	1.662	1.210	H_a is true	Mean Values are not equal
UCP23	2.219	1.870	H_a is true	Mean Values are not equal
UP2	2.381	2.118	H_o is true	Mean values are equal
UP8	2.337	1.856	H_a is true	Mean Values are not equal
UP16	2.563	2.641	H_o is true	Mean values are equal
UP17	2.540	2.419	H_o is true	Mean values are equal
UP18	2.895	2.524	H_o is true	Mean values are equal
UP1	2.447	2.136	H_o is true	Mean values are equal

($\overline{x_1}$, $\overline{x_2}$: sample means, H_a: Alternative hypothesis, H_o: Null hypothesis)

The results of statistical inference tests reported in Tables 18 were used to evaluate improvement or deterioration of water quality at specific sampling stations. The assessment for different University of Kentucky sampling stations is given in Table 19 and also visually depicted in Figure 20.

Table 19 Water quality trends at stations in upper Cumberland region based on statistical analysis of University of Kentucky sampling data (2001-2005)

Station	**Assessment**
U8	Improvement
UC29	Improvement (statistically no change)
UCP12	Improvement
UCP23	Improvement
UP2	Improvement (statistically no change)
UP8	Improvement
UP16	Worse (statistically no change)
UP17	Improvement (statistically no change)
UP18	Improvement (statistically no change)
UP1	Improvement (statistically no change)

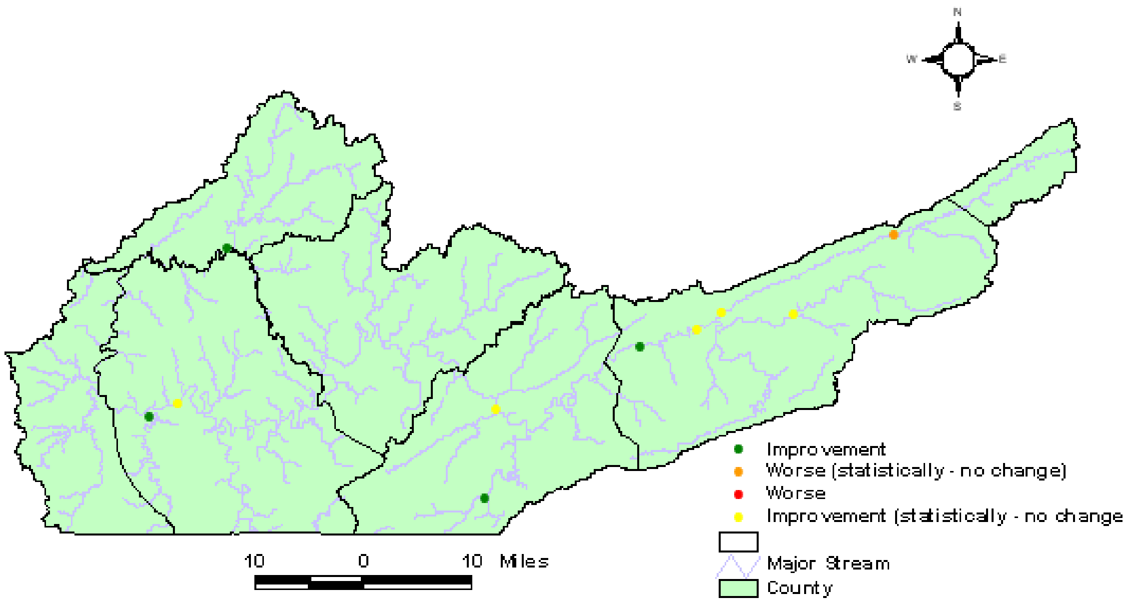

Figure 20 Map showing water quality trends at different stations in the upper Cumberland region based on statistical analysis of data (2001-2005)

PROJECT ASSESSMENT

Monitoring stations located downstream of completed water quality projects in the upper Cumberland region were identified and used to assess water quality improvements using statistical analysis. Completed projects in the upper Cumberland region and the associated downstream monitoring stations are provided in Appendix F. Assessment results reported in Tables 17 and 19 were used to evaluate whether improvement occurred at monitoring locations downstream of specific project sites. The short-term assessment for different sampling stations is given in Table 20.

Table 20 Water quality improvements at stations downstream of completed projects based on data from 2001-2005.

Project Location	Monitoring Station	Assessment
City of Middlesboro	UP8	Improvement
City of Harlan	HTR62	Improvement (statistically no change)
City of Williamsburg	UCP29	Improvement (statistically no change)
Corbin City Utilities	UCP12	Improvement
City of Benham	HWP48 UP16	Improvement (statistically no change)
City of Harlan	HTR62	Improvement (statistically no change)
City Utilities Commission of Corbin	UCP12	Improvement
City of Lynch	HWP48	Improvement (statistically no change)
Corbin City Utilities	UCP12	Improvement
City of Middlesboro	UP8	Improvement
City of Evarts	HCF65	Improvement
Laurel Co Fiscal Court	UPC12	Improvement
City of Williamsburg	UCP29	Improvement (statistically no change)

In general, stream quality seems to be improving at sampling sites downstream of completed projects. However, at some locations the improvement is not statistically significant at the chosen significance level (i.e., 0.05).

CONCLUSIONS

A regional analysis based upon long term (1994-2005) and short term (2001-2005) data comparisons indicate that pollution problems in the upper Cumberland River basin are improving. Deterministic and stochastic analyses confirm overall improvement in fecal coliform concentrations.

Cumulative density functions developed for sample data sets for both wet and dry events indicate that the probability of finding higher fecal coliform concentrations has declined over time.

Annual maximum values indicate decreasing fecal coliform concentrations at all sampling locations. Similar conclusions can be drawn for most sampling locations using geometric means for comparison. County analyses based on recent (2001-2005) data indicate that fecal coliform concentrations in all of the counties seem be improving. Counties whose aggregate geometric means are less than 200 counts/100 mL include Bell, Knox, Laurel, McCreary, and Whitley. The aggregate geometric mean for Harlan County remains greater than 200 counts/100 mL. Data from package plant discharges indicate that non-compliance with state regulations is still a problem throughout the region.

Exceedence analysis of data from KYDOW focused sampling sites (Harlan and Bell Counties) reveals some improvement. Several sampling sites in Harlan County continue to exhibit problems associated with high fecal coliform concentrations. The sampling sites and their respective stream locations are:

- HCR35 (Cumberland River)
- HPF41, UP16 (Poor Fork)
- HTR45 (Poor Fork)
- HCF56 (Clover Creek)
- HCF56A (Yocum Creek)
- HCF56B (Bailey Creek)
- HTR62 (Catron Creek)
- HMF621 (Martins Fork)

The station HMF621 is located downstream of the community of Sunshine which has inadequate wastewater service. A PRIDE –funded project is underway to extend sewer lines to this community.

Statistical analysis shows that water quality at the majority of sites has improved. However, the percentage is somewhat less over the last 5 years, than the previous 10 years. Two sites showed statistically significant deterioration of water quality conditions related to fecal coliform bacteria:

- BTR20 (Straight Creek)
- HCR33 (Cumberland River)

All of the monitoring sites located downstream of completed projects showed some improvement, with those in Laurel, Bell, and Whitley more statistically significant than those in Harlan County. While it is reasonable to associate a decrease in the fecal coliform concentrations with the recently completed water quality improvement projects, the contribution of these projects in reducing fecal pollution may only be confirmed using statistical inference tests with continued long-term monitoring effort. It is important to note that many projects in the region were under construction and not fully operational at the time that data used in the analysis was collected.

SUMMARY OF PUBLIC PARTICIPATION

Products generated by this project will be disseminated via print and electronic means to the widest possible audience, utilizing targeted email, the internet, news media and presentations to the Upper Cumberland River Basin Team, local officials and others. The investigators will partner with the Kentucky Division of Water and the Basin Team to seek out appropriate venues. It is anticipated the materials will be useful far beyond the end of the project period.

DISSEMINATION OF ASSESSMENT RESULTS

The Kentucky Water Resources Research Institute and the Division of Water are committed to disseminating this information and promoting the results from the analysis conducted in this study as a basis for prioritization of funds. A project web site (http://pride.uky.edu/uchome/ucproject.html) with all details of the analysis conducted as a part of the project is under construction and will be available by February 2006.

UPPER CUMBERLAND PATHOGEN SUMMIT

An "Upper Cumberland Pathogen Summit" was held on November 15, 2005, at Pine Mountain State Park, Kentucky. The summit was open to the public and the audience included specific invitees; personnel from the Kentucky Division of Water; members of Kentucky Watershed Watch, the Cumberland River Basin Team, and the Cumberland River Watershed Watch; local elected officials; and representatives of citizens groups. Results of this project were reviewed and discussed at this meeting. Speakers from the EPA-funded National Onsite Demonstration Program, Kentucky Division of Water, PRIDE, and other agencies described several monitoring efforts, innovative technologies for water quality improvement, sources of funding, and successful project implementations specific to the region. The summit ended with a panel discussion conducted by invited experts who provided insightful views and comments on the programs and the overall state of water quality in the region. Complete details of the summit will be available on the web site: http://pride.uky.edu/uchome/ucproject.html by February 2006.

RECOMMENDATIONS

The assessment study conducted during this project provided results based upon available data that suggest fecal coliform concentrations are decreasing at point, regional and county levels. Recommendations from the current study include:

- Increase monitoring stations to cover locations that have shown consistently high fecal coliform concentrations through Kentucky Watershed Watch sampling efforts.
- Increase sampling frequency to capture variability in pollutant loads associated with wet and dry events.
- Develop an organized monitoring plan for specific project sites that received state and federal funds to assess improvements in stream quality.

- Measure discharge at all the sampling locations.
- Target watershed-based plan development to areas which have worsened or shown no improvement in pathogen impairment and prioritize wastewater construction projects and BMP implementation in these areas.

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APPENDICES

APPENDIX A: Financial and administrative closeout

APPENDIX B: Regional data assessment (ranked plot, geomeans and maximum annual values)

APPENDIX C: Cumulative probability density plot comparisons

APPENDIX D: Cumulative probability density plots for wet and dry events

APPENDIX E: Annual geometric mean and maximum fecal coliform concentrations by county

APPENDIX F: Statistical hypothesis tests used in the study

APPENDIX G: Completed projects in the upper Cumberland region and monitoring stations identified for data analysis

APPENDIX A: Financial and Administrative Closeout

OUTPUTS (MILESTONES)

Milestone	Expected Begin Date	Expected End Date	Actual Begin Date	Actual End Date
1. Receive Cabinet approval on final drafts of all materials developed under this lead legal agreement and on existing materials used for outreach, education, or technical training under this legal agreement	Duration			
2. Submit Annual Reports and/or participate in Division of Water sponsored NPS Conference(s)	Duration			
3. Begin data collection	4/2005	5/2005	5/2005	6/2005
4. Collect GIS coverages	4/2005	5/2005	5/2005	6/2005
5. Compile data into database	5/2005	6/2005	6/2005	7/2005
6. Perform statistical analysis of data	6/2005	8/2005	7/2005	10/2005
7. Summarize results	8/2005	9/2005	9/2005	10/2005
8. Prepare and submit draft to DOW	9/2005	10/2005	10/2005	3/2006
9. Publicize project via meetings, media, and internet: pride.uky.edu/uchome/ucproject.html	9/2005	10/2005	9/2005	3/2006
10. Plan and organize pathogen summit	9/2005	10/2005	9/2005	11/2005
11. Hold Upper Cumberland pathogen summit:	10/2005	11/2005	11/15/2005	11/15/2005
12. Prepare and disseminate final report	12/2005	12/2005	1/2006	3/2006

ORIGINAL PROJECT BUDGET

Budget Summary:

Budget Categories	Project Activity Categories						
	BMP Imple-mentation	Project Manage-ment	Education, Training, or Outreach	Monitoring	Technical Assistance	Other	Total
Personnel		**$16,160**	**$4,267**			**$ 53,559**	**$73,986**
Supplies						**$2,000**	**$2,000**
Equipment							
Travel			**$400**			**$500**	**$900**
Workshop			**$1,070**				**$1,070**
Operating Costs		**$7,644**	**$2,714**			**$ 26,515**	**$36,873**
Other							
TOTAL		**$23,804**	**$8,451**			**$ 82,574**	**$114,829**

Detailed Budget:

Budget Categories	Section 319(h)	Non-Federal Match	Total
Personnel	**$57,826**	**$ 16,160**	**$73,986**
Supplies	**$2,000**		**$2,000**
Equipment			
Travel	**$900**		**$900**
Contractual			
Operating Costs	**$ 6,180**	**$ 30,693**	**$36,873**
Workshop	**$1,070**		**$1,070**
TOTAL	**$67,976**	**$46,853**	**$114,829**
	59.2%	**40.8%**	**100.00%**

ACTUAL EXPENSES

Budget Summary:

Budget Categories	Project Activity Categories						
	BMP Imple-mentation	Project Manage-ment	Public Education	Monitoring	Technical Assistance	Other	Total
Personnel		$16,497.56	$4,356.13			$54,677.77	$75,531.46
Supplies						$ 218.19	$ 218.19
Equipment							
Travel			$ 415.26				$ 415.26
Workshop			$ 745.87				$ 745.87
Operating Costs		$7,777.86	$2,053.72			$25,778.11	$35,609.69
Other							
TOTAL		$24,275.42	$7,570.98			$80,674.07	$112,520.47

Detailed Budget:

Budget Categories	Section 319(h)	Non-Federal Match	Total
Personnel	$59,177.14	$ 16,354.32	$75,531.46
Supplies	$ 218.19		$ 218.19
Equipment			
Travel	$ 415.26		$ 415.26
Workshop	$745.87		$745.87
Operating Costs	$ 6,055.66	$ 29,554.03	$ 35,609.69
Other			
TOTAL	$66,612.12	$45,908.35	$112,520.47
	59.2%	40.8%	100%

The University of Kentucky was reimbursed $66,612.12 out of the award budget of $67,976.00. A total of $1,363.88 federal funds remain unspent. No equipment was purchased by UK as part of this contract. There were no special grant conditions for this contract.

APPENDIX B: Regional data assessment (ranked plot, geomeans and maximum annual values)

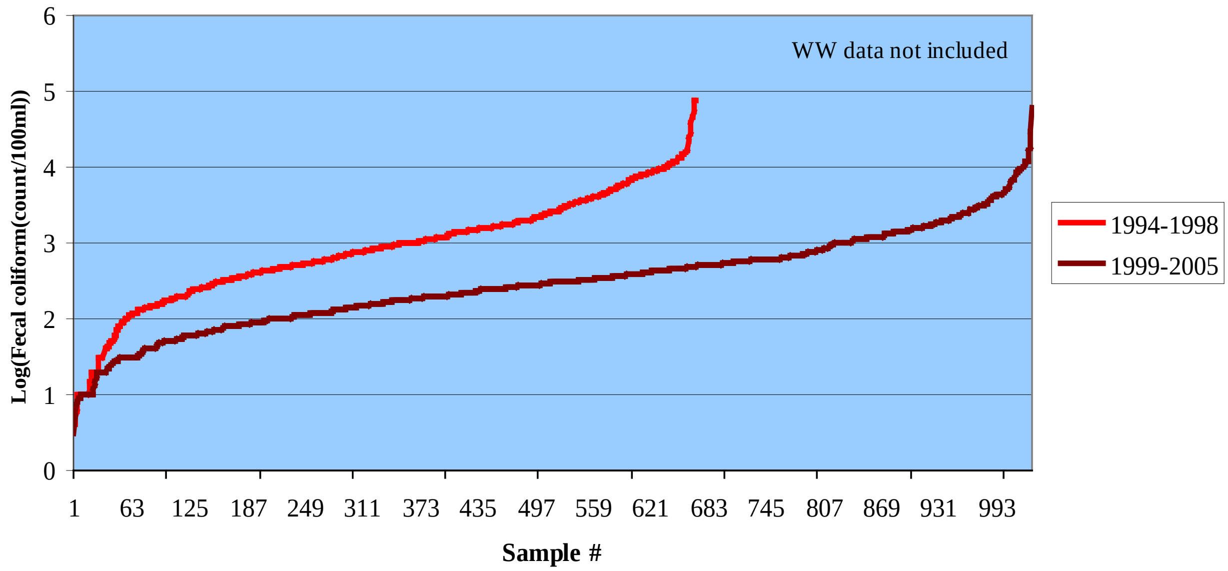

Figure B1 Regional ranked plot of fecal coliform data

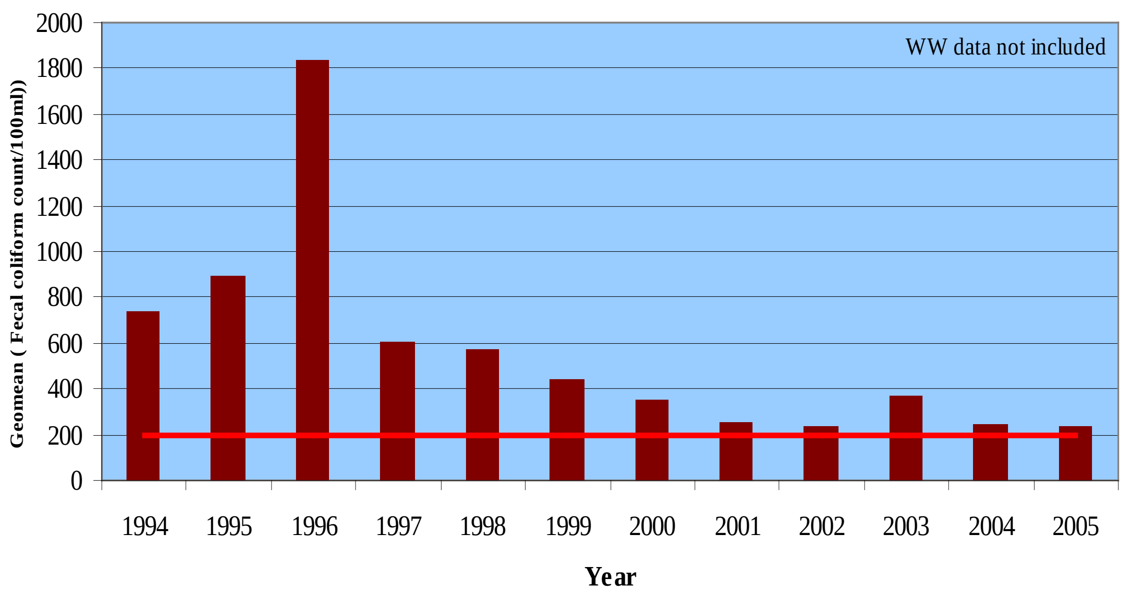

Figure B2 Annual geomean values for fecal coliform data at the regional level

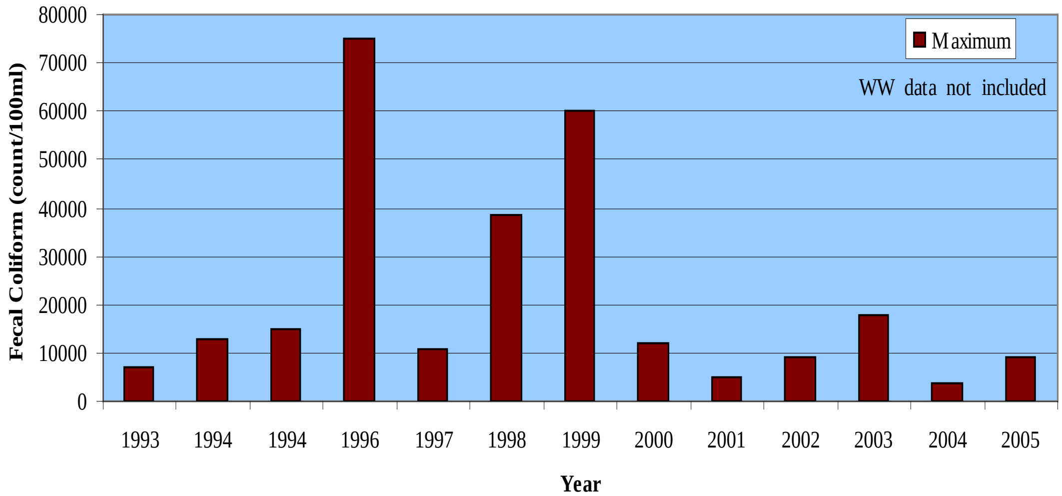

Figure B3 Maximum annual values of fecal coliform at the regional level

APPENDIX C: Cumulative probability density plot comparisons

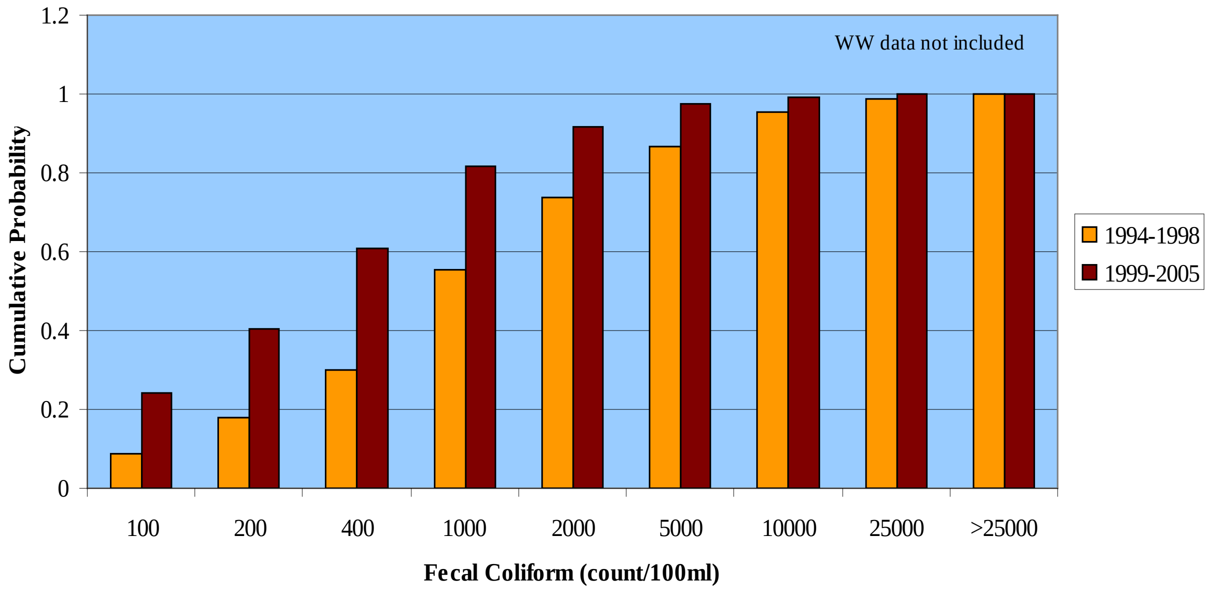

Figure C1: Cumulative probability density plots for long-term data sets at regional level

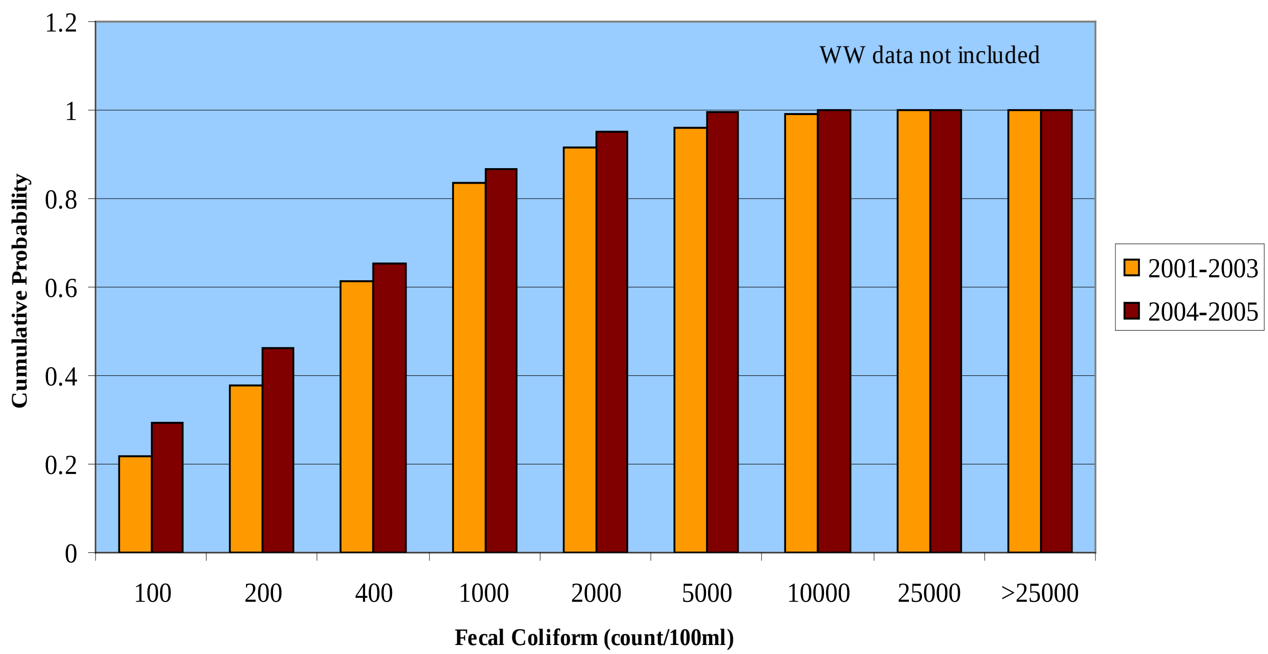

Figure C2: Cumulative probability density plots for short-term data sets at regional level

APPENDIX D: Cumulative probability density plots for wet and dry events

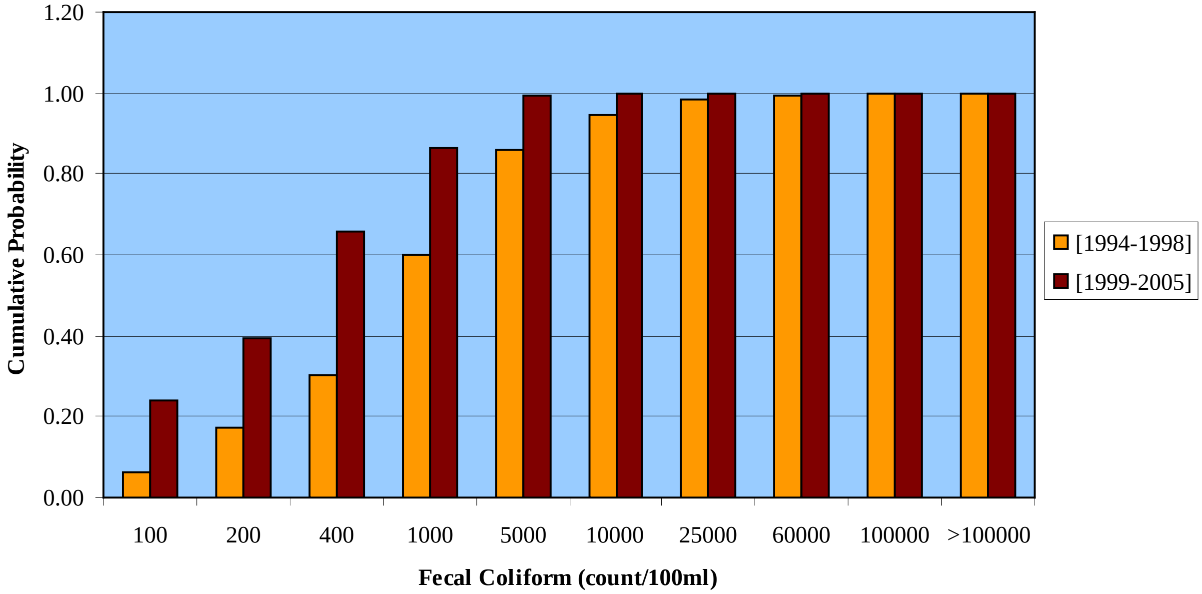

Figure D1: Cumulative probability density plots for long-term data sets using KYDOW focused data for dry-events

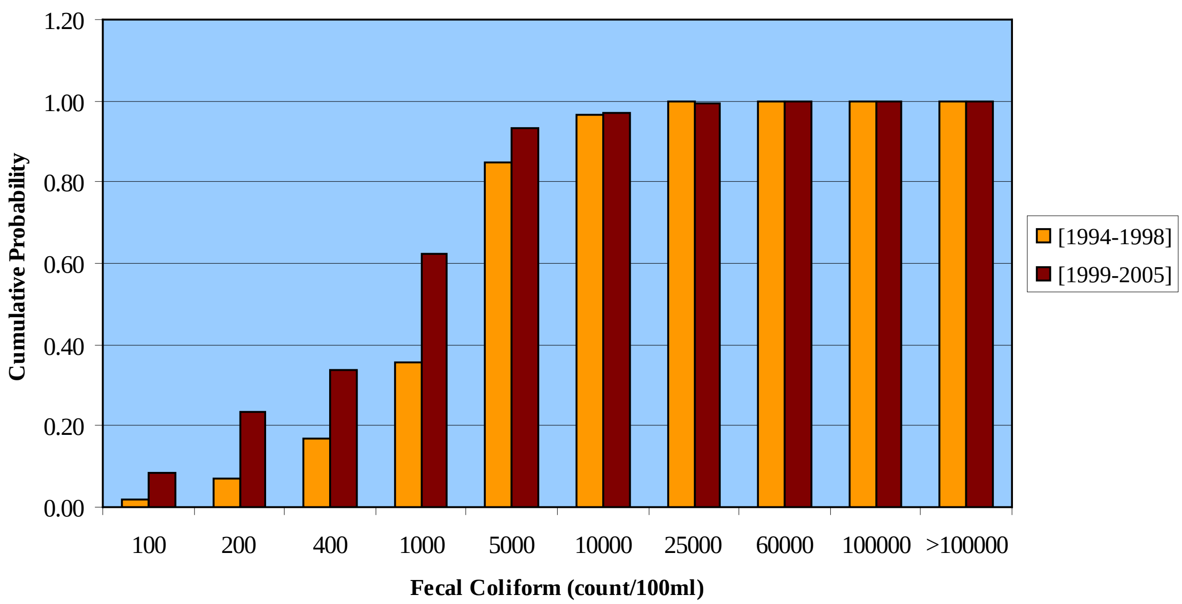

Figure D2: Cumulative probability density plots for long term data sets based on KYDOW focused data for wet-events

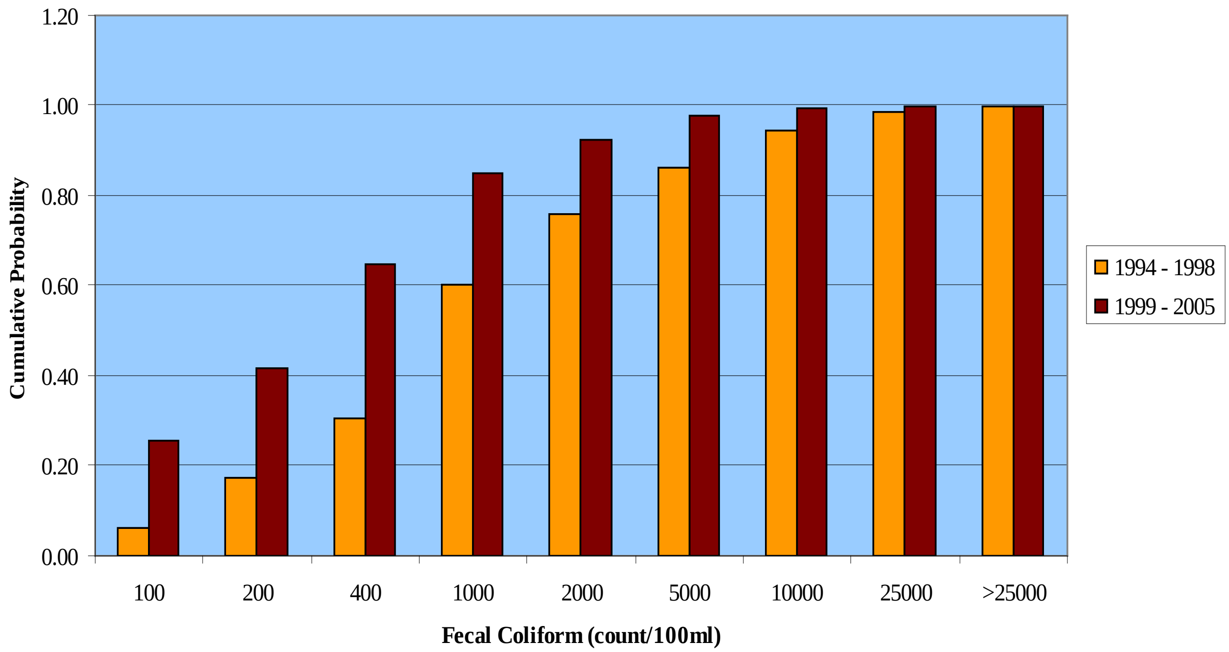

Figure D3: Cumulative probability density plots for long-term data sets at regional level for dry events

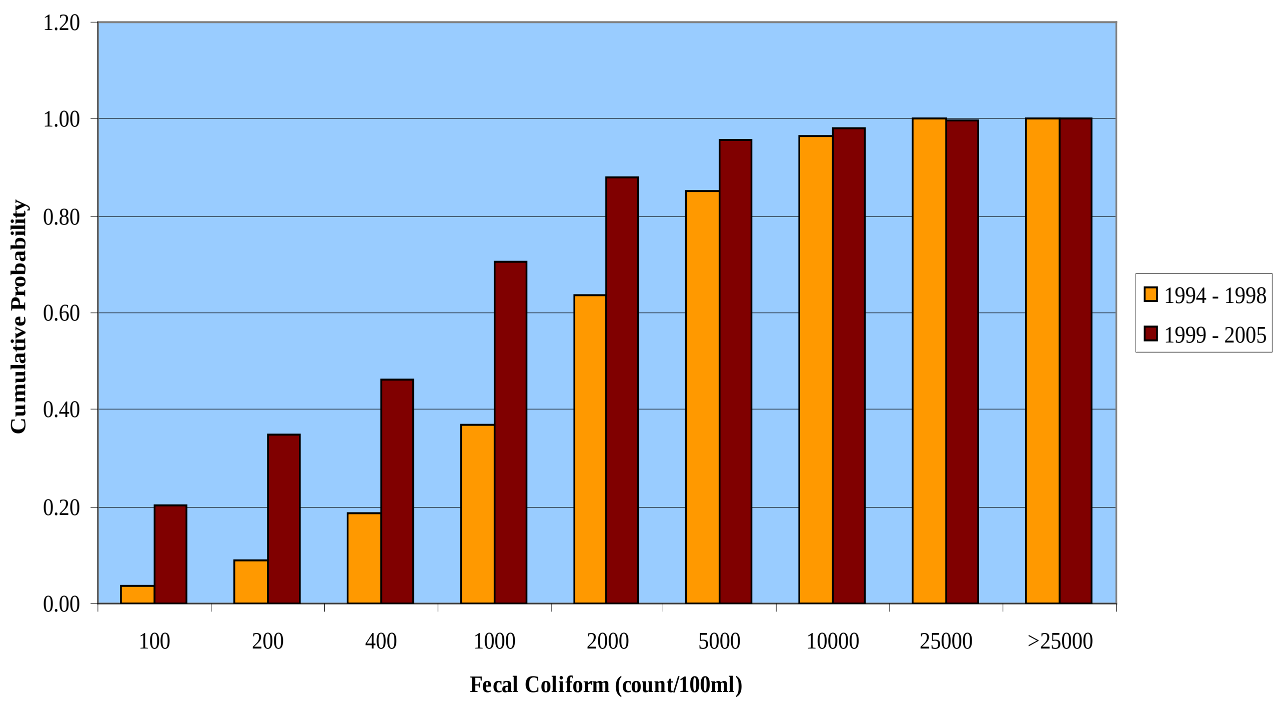

Figure D4: Cumulative probability density plots for long-term data sets based on data at regional level for wet events.

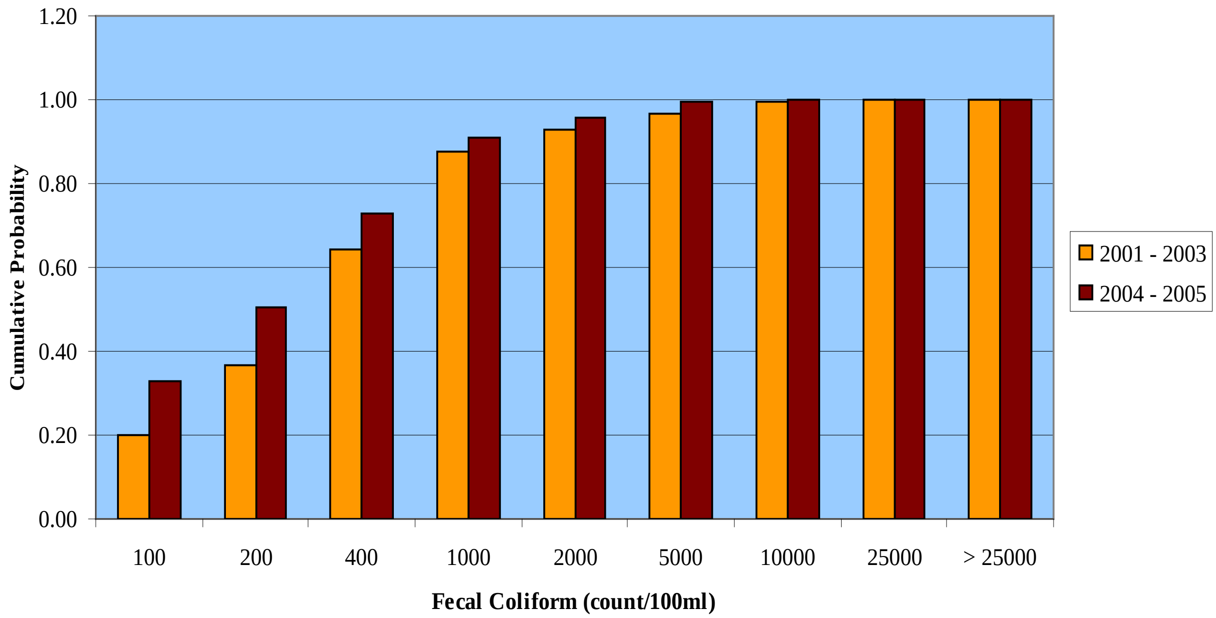

Figure D5: Cumulative probability density plots for short-term data sets based on data at regional level for dry events.

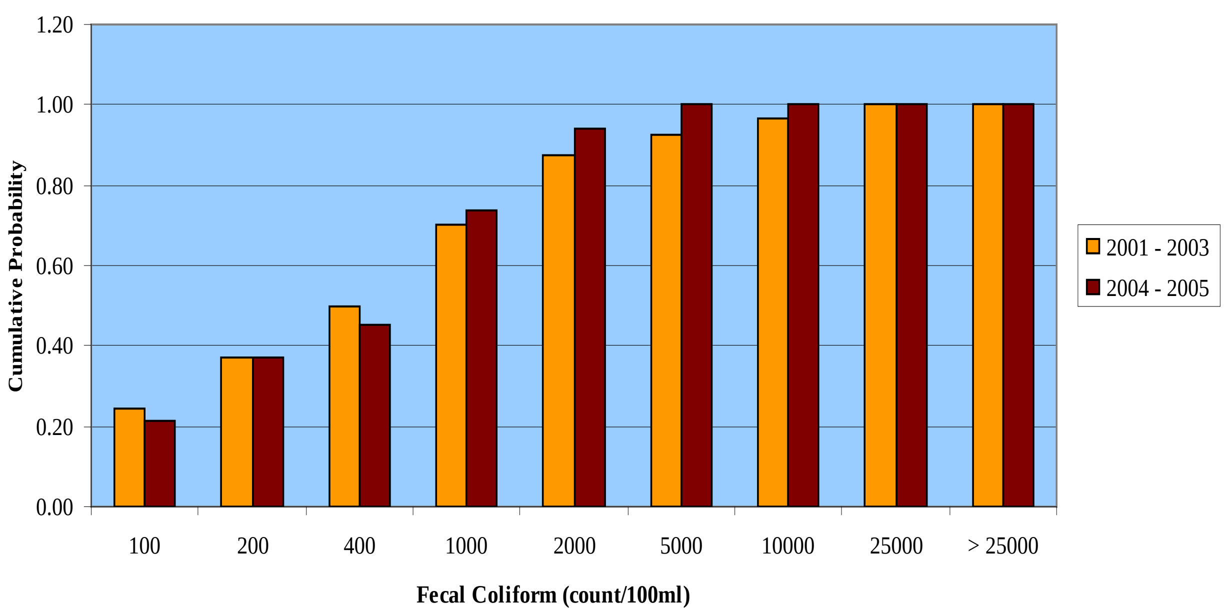

Figure D6: Cumulative probability density plots for short-term data sets based on data at regional level for wet events

APPENDIX E: Annual geometric mean and maximum fecal coliform concentrations by county

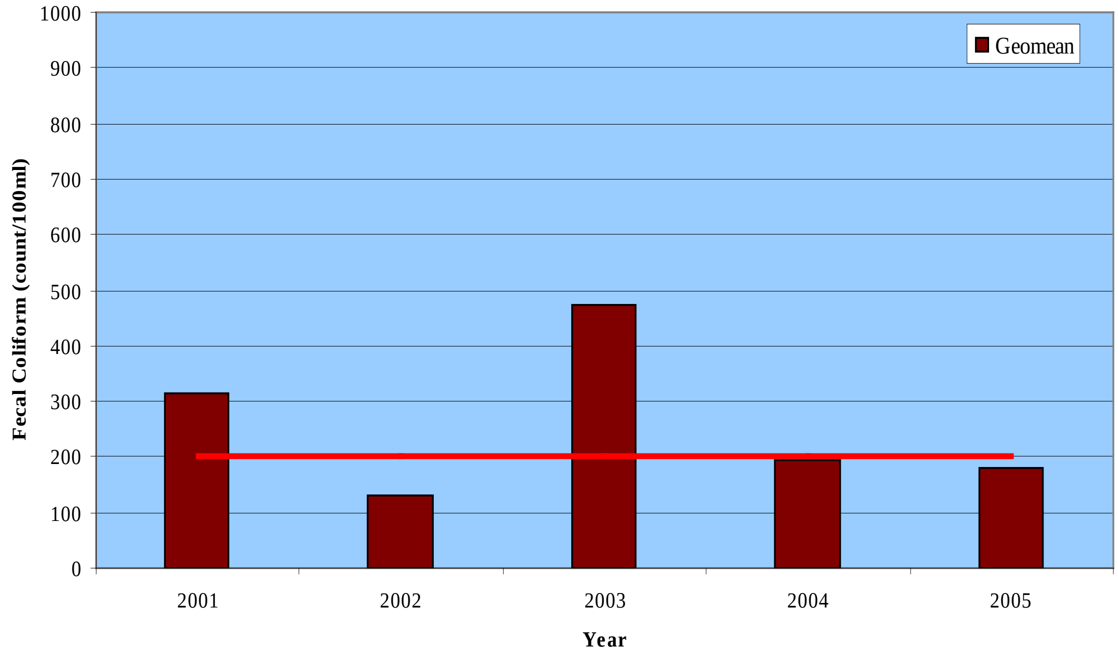

Figure E1: Annual geometric mean values of fecal coliform for Bell County

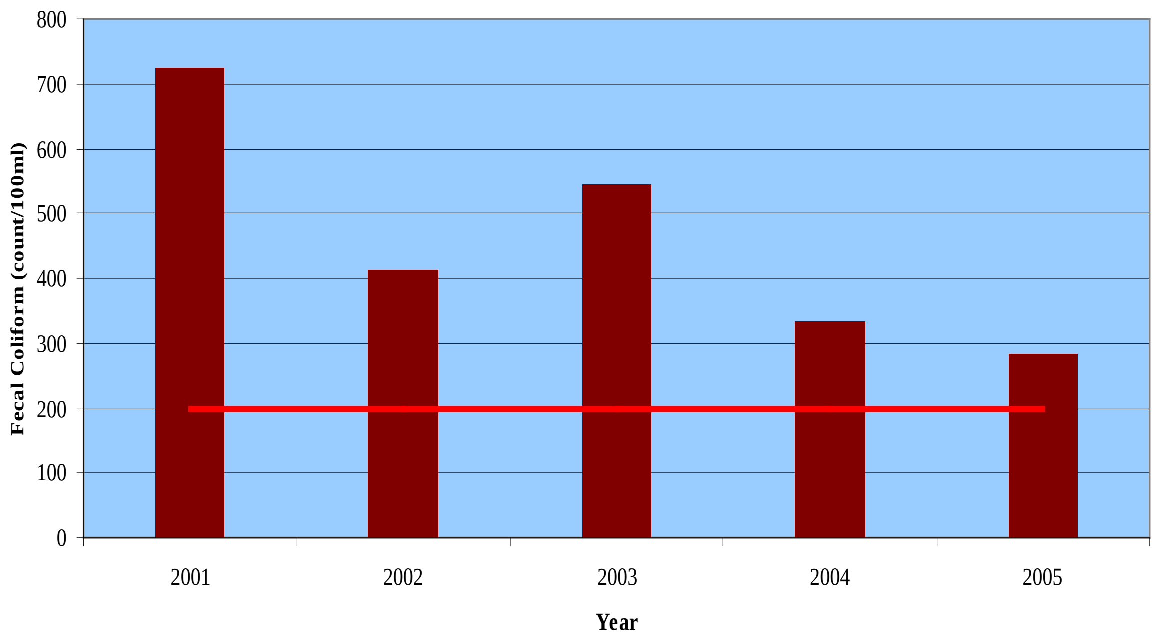

Figure E2: Annual geometric mean values of fecal coliform for Harlan County

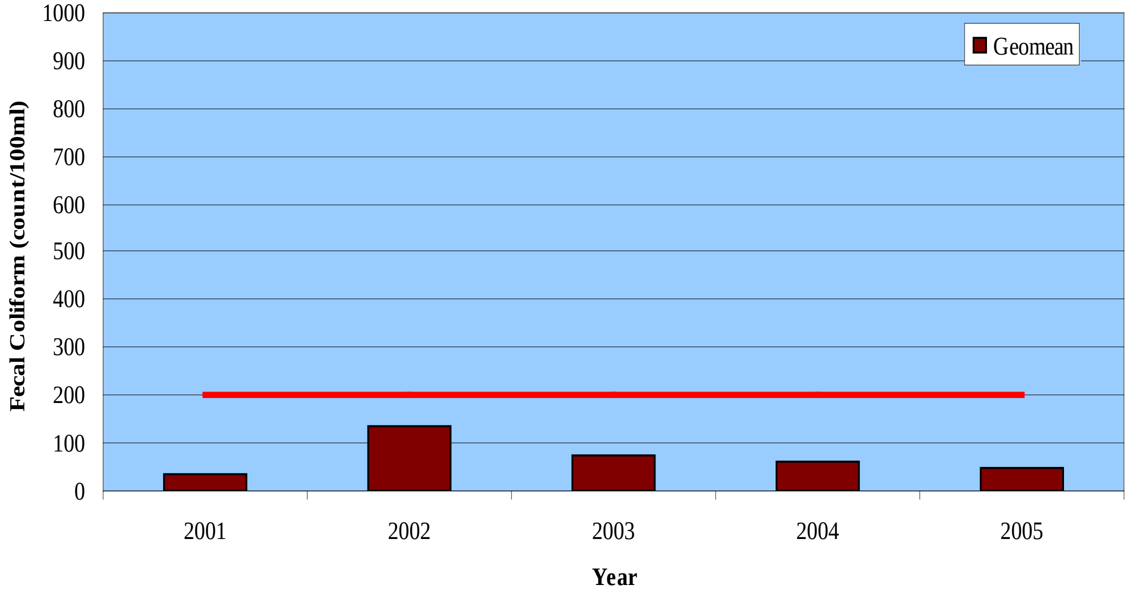

Figure E3: Annual geometric mean values of fecal coliform for McCreary County

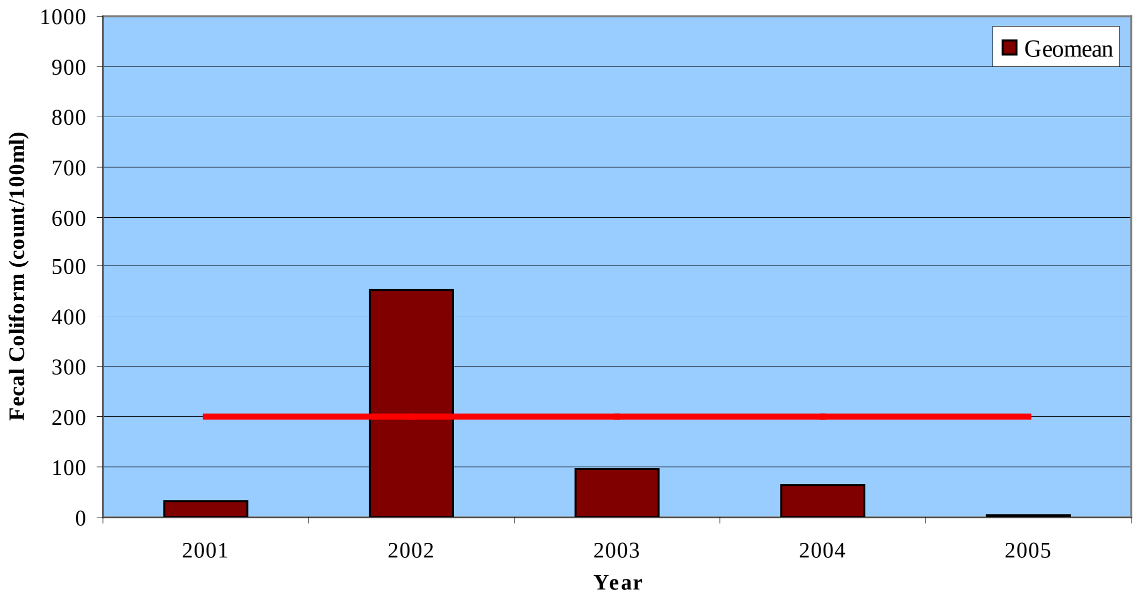

Figure E4: Annual geometric mean values of fecal coliform for Laurel County

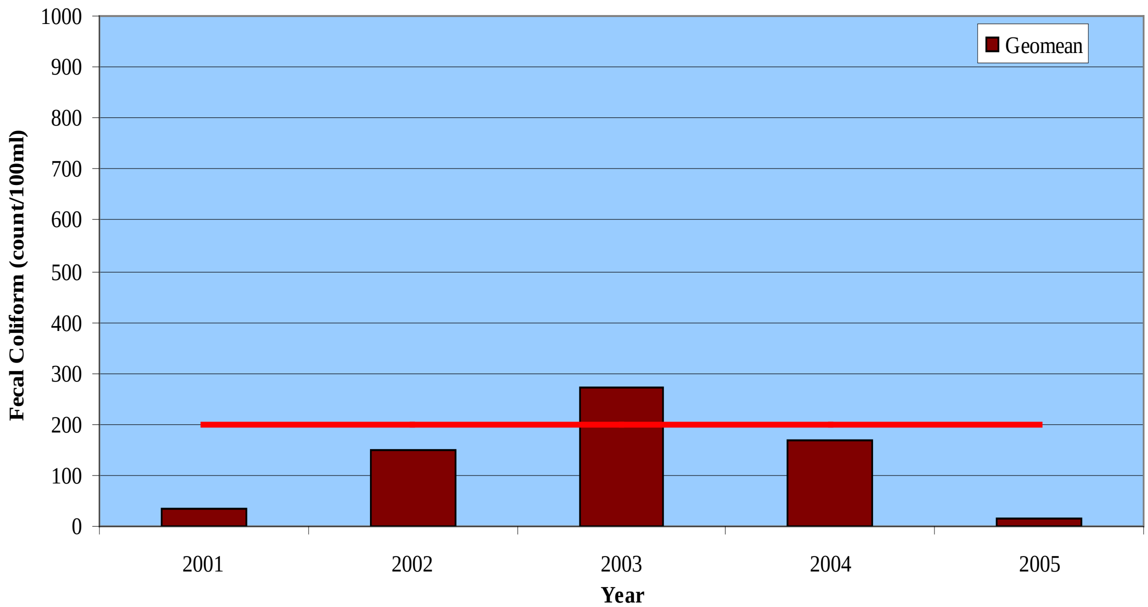

Figure E5: Annual geometric mean values of fecal coliform for Whitley County

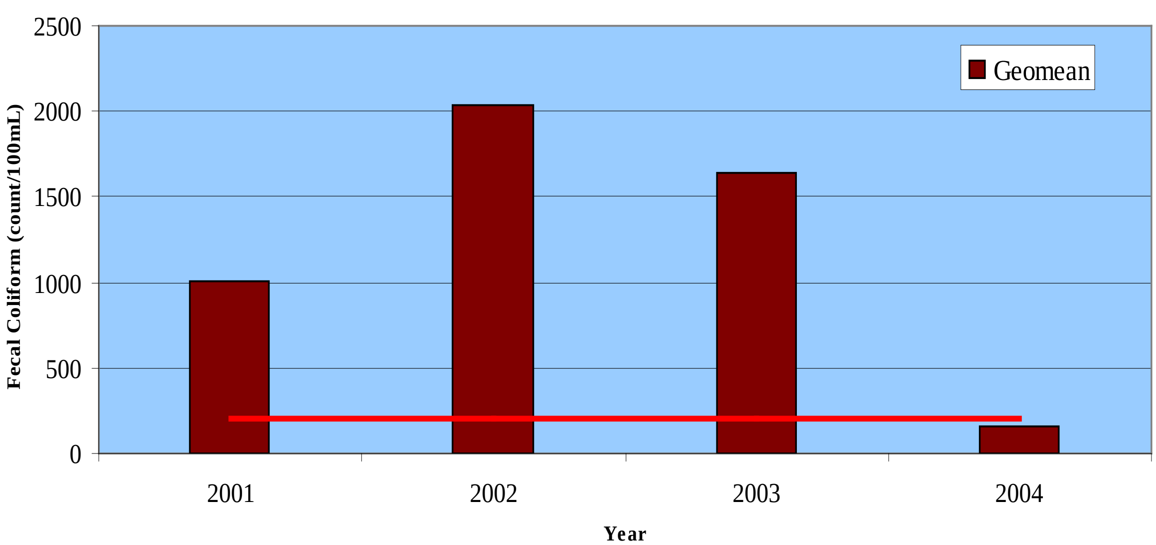

Figure E6: Annual geometric mean values of fecal coliform for Knox County

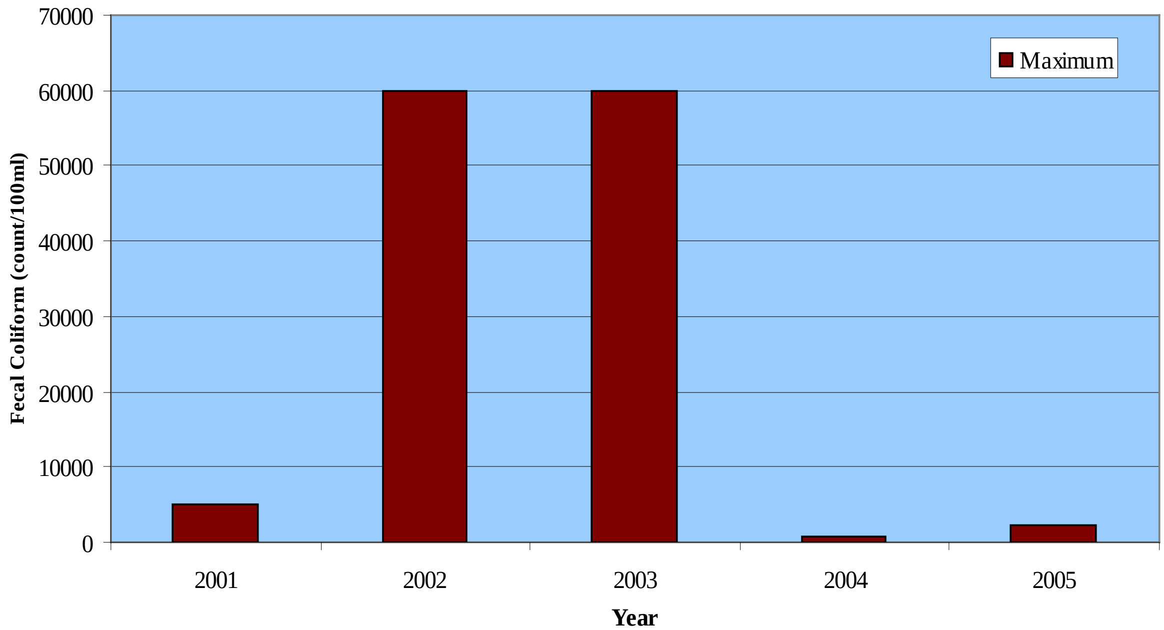

Figure E7: Annual maximum fecal coliform values in Bell County

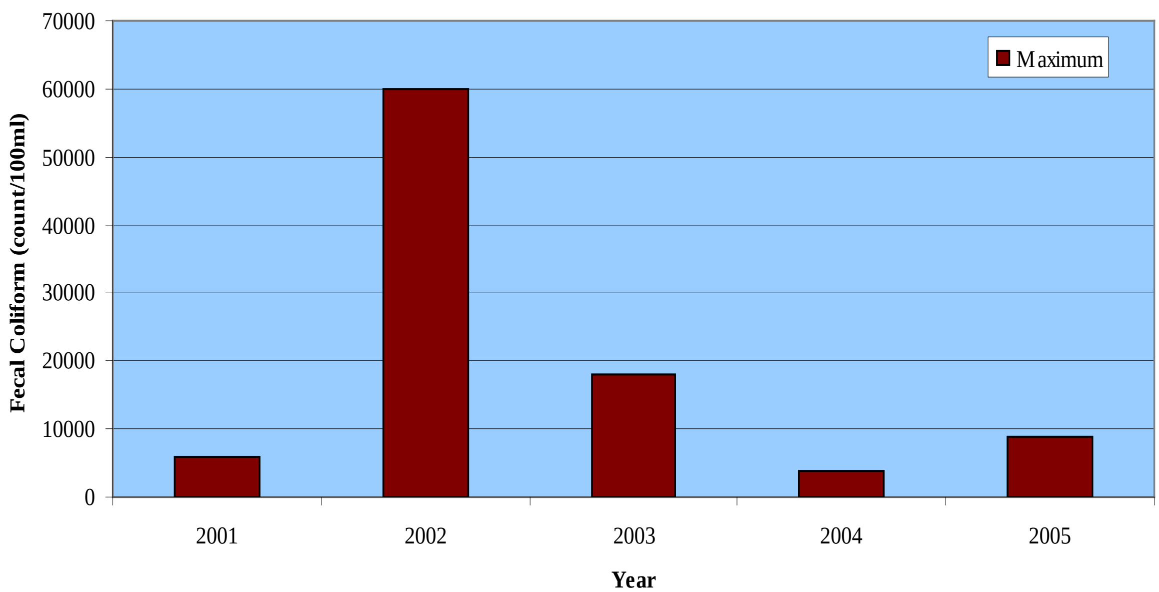

Figure E8: Annual maximum fecal coliform values in Harlan County

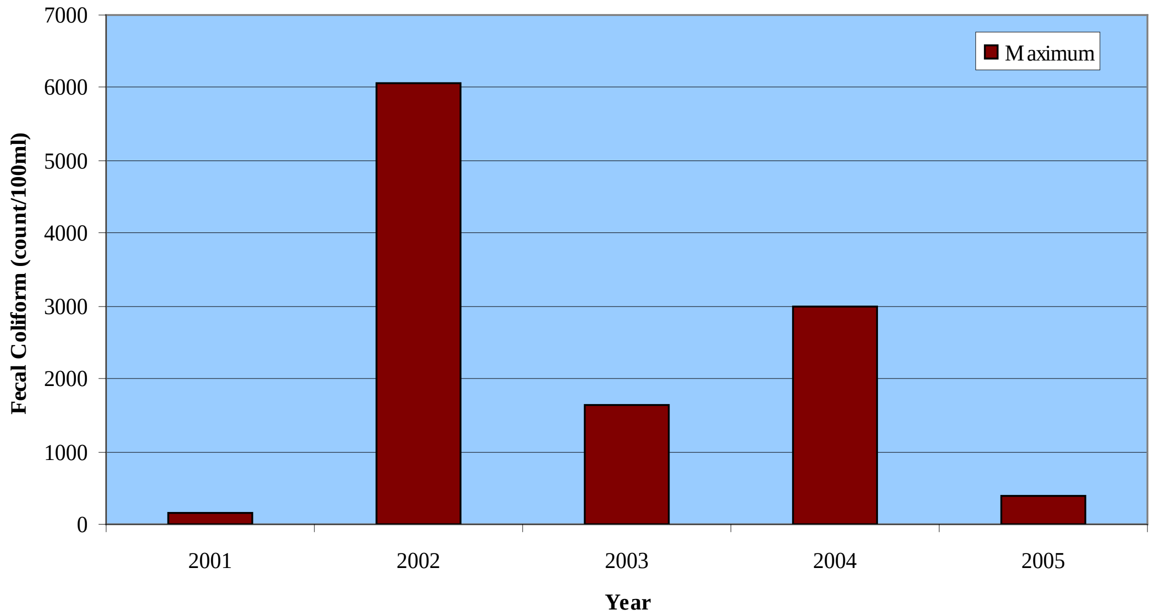

Figure E9: Annual maximum fecal coliform values in McCreary County

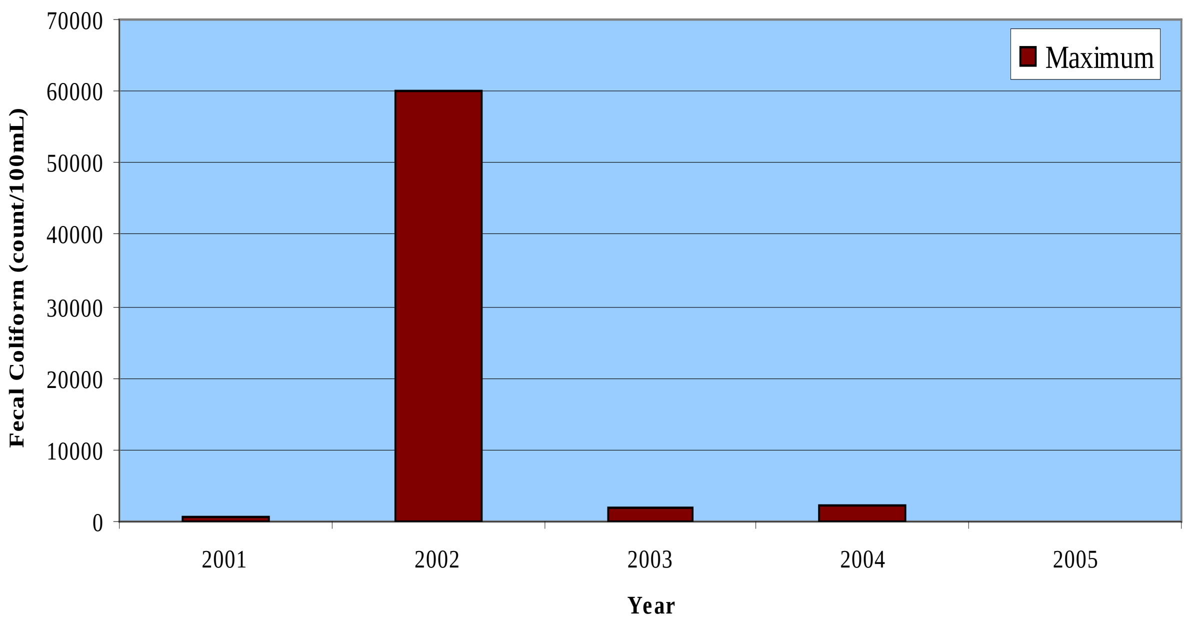

Figure E10: Annual maximum fecal coliform values in Laurel County

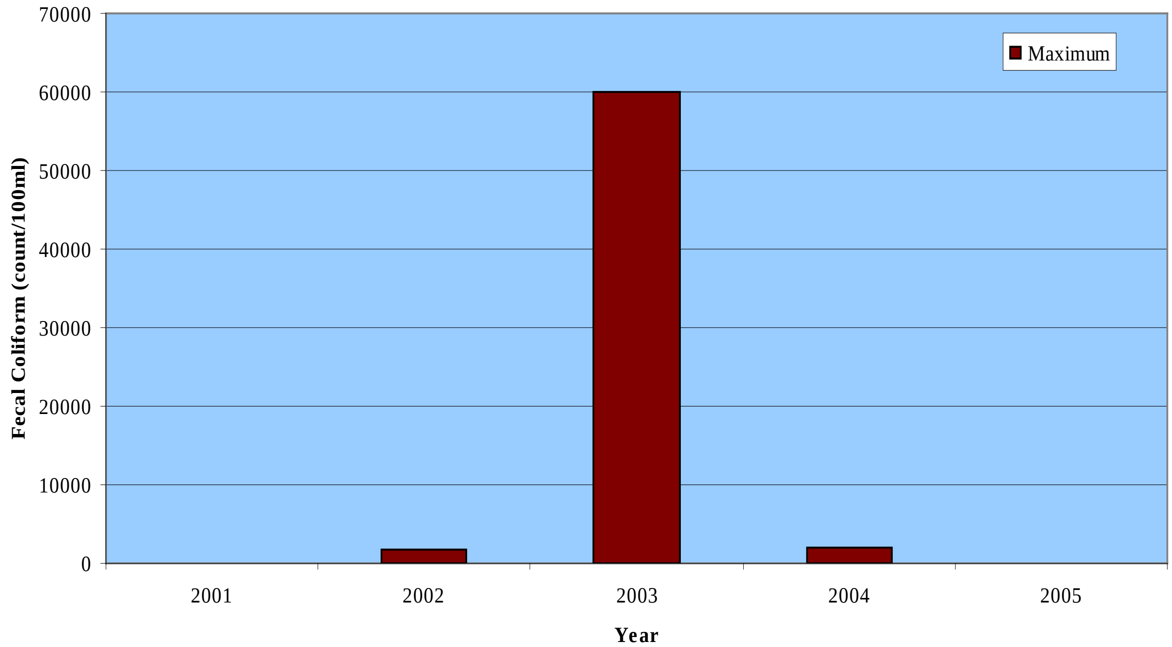

Figure E11: Annual maximum fecal coliform values in Whitley County

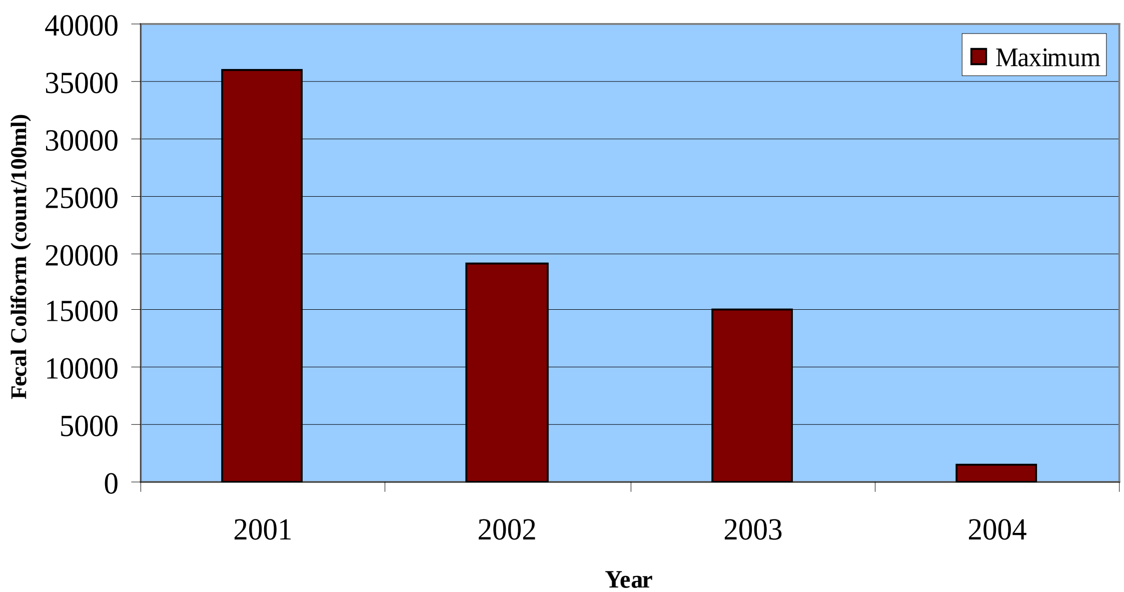

Figure E12: Annual maximum fecal coliform values in Knox County

APPENDIX F: Statistical hypothesis tests used in the study

Table F1. Statistical hypothesis tests used in the study

Statistical Test	Purpose	Null hypothesis (H_o)	Alternative Hypothesis (H_a)
Kolmogorov Smirnov Test	Goodness-of-fit test	Data follows the hypothesized distribution (i.e., Lognormal)	Data does not follow the hypothesized distribution
F-Test	Test for equality of variances	$S_1^2 = S_2^2$	$S_1^2 \neq S_2^2$
T-Tests [Equal variance – Student's Two Sample t-test] [Unequal variance – Satterthwaite's Two Sample t-Test)	Test for equality of means	$\overline{x}_1 = \overline{x}_2$	$\overline{x}_1 \neq \overline{x}_2$

T-test for equal sample variances:

$$t = \frac{\left|\overline{x_1} - \overline{x_2}\right|}{\sqrt{\frac{n_1 + n_2}{n_1 n_2}\left(\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}\right)}} \qquad \text{(F1)}$$

Degrees of freedom (*df*):

$$df = n_1 + n_2 - 2 \qquad \text{(F2)}$$

n_1: number of samples in data set #1, n_2: number of samples in data set #2. S_1^2 and S_2^2 are sample variances, $\overline{x}_1$ and $\overline{x}_2$ are mean values of data sets #1 and #2 respectively.

T-test for unequal sample variances (Satterthwaite's Modified T-Test)

$$t = \frac{\left| \overline{x}_1 - \overline{x}_2 \right|}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \qquad \text{(F3)}$$

Degrees of freedom (*df*):

$$df = \frac{\left[\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2} \right]^2}{\frac{S_1^4}{n_1^2 (n_1 - 1)} + \frac{S_2^4}{n_2^2 (n_2 - 1)}} \qquad \text{(F4)}$$

APPENDIX G: Completed projects in the upper Cumberland region and monitoring stations identified for data analysis

Table G1: Completed projects in the upper Cumberland region and monitoring stations identified for data analysis

Project Location	Agency	County	Monitoring Station
City of Middlesboro	PRIDE*	Bell	UP8
City of Harlan	PRIDE*	Harlan	HTR62
City of Williamsburg	PRIDE*	Whitley	UCP29
Corbin City Utilities	PRIDE*	Knox	UCP12
City of Benham	PRIDE*	Harlan	HWP48, UP16
City of Harlan	PRIDE*	Harlan	HTR62
City Utilities Commission of Corbin	PRIDE*	Knox	UCP12
City of Lynch	PRIDE*	Harlan	HWP48, UP16
Corbin City Utilities	COE531	Laurel	UCP12
City of Middlesboro	COE531	Bell	UP8
City of Evarts	COE531	Harlan	HCF65
Laurel Co Fiscal Court	COE531	Laurel	UPC12
City of Williamsburg	EPA	Whitley	UCP29

* Waste Water Construction Grants