Dry Creek Watershed Plan

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This project is funded in part by a grant from the U.S. Environmental Protection Agency under 319(h) of the Clean Water Act through the Kentucky Division of Water to the Kentucky Waterways Alliance (Grant # C9994861-04).

Draft Dry Creek Watershed-based Plan
Chapter 1: An Introduction

Introduction
The Dry Creek Watershed-based Plan (WBP) outlined all point and nonpoint pollution sources in the watershed, quantified the pollution coming from each source, and made recommendations for Best Management Practices (BMPs) to improve water quality in Dry Creek.

Watershed
The Dry Creek watershed is approximately 7,500 acres or 11.7 square miles in size and is located in Rowan County, Kentucky (Figure 1.1). It is a major tributary to the Triplett Creek. This HUC 14 (05100101130120) watershed is mainly forested, with hay/pasture fields located along most of the creeks and residential and business development concentrated at the mouth of the watershed (see map and table on Land Use and Land Cover in the section on Nonpoint Sources in Chapter 2). Because of the steep terrain, road and housing construction are concentrated along the creek and its tributaries. Apartment construction accelerated in the area along Dry Creek from the year 2004 to 2008. Approximately half of that residential development occurred outside of the area served by Morehead Utility Plant Board's sewer lines. In addition, many of the disturbed hill slopes were not reseeded, contributing to visible erosion.

The Kentucky Division of Water 2008 Integrated Report to Congress (KDOW, 2008) identified a portion of Dry Creek as impaired to the extent that it only partially supports aquatic life. The impaired reach extends from the mouth of Dry Creek (0.0 miles) to a point 2.5 miles upstream (Figure 2.8, Chapter 2). The impaired reach therefore includes sites DC-0.28 and DC-1.89 and ends 0.34 miles downstream of DC-2.84. Pollutants recognized in the KDOW (2008) report include nutrient/eutrophication biological indicators, sedimentation/siltation, and organic enrichment (sewage) biological indicators.

The Division of Water has also collected samples from Dry Creek and determined that it is polluted by sediment (dirt) and sewage. This pollution prevents the creek from supporting all of the aquatic creatures, such as fish and insects, which are supposed to live in the water. Dry Creek is also polluted by nutrients (i.e., phosphorous and nitrogen from sources such as fertilizer).

Ongoing and recently initiated water quality monitoring efforts by faculty, staff and students in Morehead State University's Institute for Regional Analysis and Public Policy, Biology, Environmental Sciences, and Earth System Science programs provide or will provide data on bacteria (i.e., *E. coli*), nutrients, wildlife habitat and biological assessments, discharge (stream flow), streambank instability, and sediment for the Dry Creek watershed. Measurements of discharge, suspended sediment concentrations (SSC) and geomorphic assessment of bank instability are in progress. Nutrient data from 1998-1999 and limited summer data from 2007 suggest that excess nutrient input into the creek exists. Most of the bacteria data were collected prior to the installation of sewer lines and indicates bacteria contamination in Dry Creek. Collaborative sampling events, where water samples are simultaneously collected for sediment, nutrients, and bacteria have been completed as part of this project. Simultaneous sampling provides a better 'snapshot' of the watershed's influence on water quality and assists in identifying potential sources of pollution. To further assist in this effort, and to facilitate the development of best management practices, the field data were used to provide inputs for a load estimation analysis via the PREdiCT model.

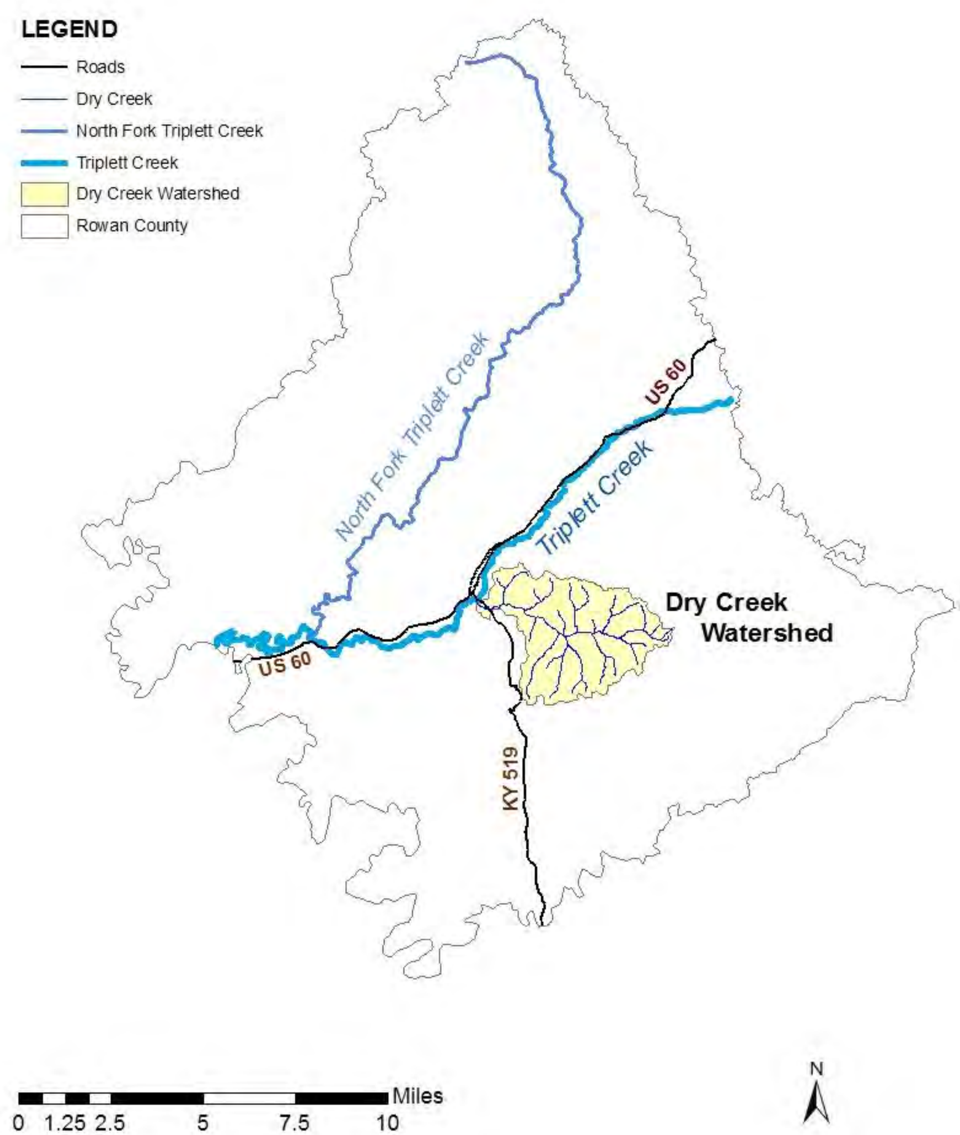

Figure 1.1 Location of Dry Creek watershed in Rowan County, Kentucky (sources: Kentucky Geological Survey, Kentucky Division of Geographic Information).

Goals

The goals presented below are separated into two sections. "Short-term" or project goals are those that were completed by March 2010, when the 319 (h) funding from the Kentucky

Division of Water expired for this project. "Long-term" goals are those goals related to implementing the actual WBP for Dry Creek following the completion of this project.

The major goals of this project were to develop a WBP for the Dry Creek Watershed, educate the community about the need for and usefulness of a WBP, and identify best management practices that will improve water quality to the point that Dry Creek meets all water quality standards and can be removed from the 305(b) report (i.e., the Integrated Report Volume I).

The short-term goals of the project, then, were those that can be completed within the time frame of the Memorandum of Agreement between the Kentucky Waterways Alliance (KWA) and Morehead State University. The goals are not presented here in order of importance. The project's short-term goals were:

Goal 1: Conduct community outreach to inform members of the Dry Creek watershed and Public Officials of the water quality issues in Dry Creek.
Measurement:

1. Conduct two roundtable meetings.
2. Present a status report to the Morehead City Council and Rowan County Fiscal Court on a quarterly basis.
3. Conduct regularly scheduled meetings.
4. Speak to at least two organizations that are interested in improving water quality.
5. Utilize the local paper and radio station to inform area citizens on the status of the project.

Goal 2: Identify a number of Best Management Practices (BMPs) that address water quality issues and are economically and socially feasible to implement.
Measurement:

1. Develop a functional list of BMPs, including cost estimates for their implementation.
2. Prioritize the BMPs based on their potential ability to improve water quality.
3. List possible agencies that could assist with the funding and technical aspects of BMP implementation.
4. Present the BMP list (with costs) to the watershed team, City Council, Rowan County Fiscal Court, and concerned citizens.

Goal 3: Complete a comprehensive monitoring and assessment plan that identifies the causes and sources of impairments.
Measurement:

1. Completion and approval of a QAPP that outlines a monitoring plan.
2. Completion of water quality assessment.

3. Completion of a comprehensive report on the results of the monitoring and assessment.

The Dry Creek Watershed Team also established some initial long-term goals based on participant input from the first two Community Roundtable events, which were held on February 5 and 9, 2008 at the Clearfield Elementary School (in the Dry Creek watershed). A report of these roundtable discussions can be found in an Appendix A. These goals are not presented here in order of importance. The initial long-term goals are:

Goal 1: Decrease the severity and frequency of flooding.

Goal 2: Decrease the sediment loads in Dry Creek.

Goal 3: Decrease nutrient loads in Dry Creek.

Goal 4: Decrease bacteria levels to meet Primary Contact standards.

Goal 5: Improve water quality so that Dry Creek can be safely used as a recreational resource (i.e. fishing, swimming hole, and canoeing/kayaking).

These long-term goals will be refined as the data collection and analysis are completed.

Partners and Stakeholders

The watershed planning effort is funded in part by a grant from the U.S. Environmental Protection Agency under 319(h) of the Clean Water Act through the Kentucky Division of Water to the Kentucky Waterways Alliance.

In 2004, a group of citizens complained about an increase in the frequency and severity of flooding on the west end of Morehead and in the Clearfield area. As citizens and local officials began to discuss the issue and possible solutions, it became apparent that no simple, one-time fix existed. In response, the City of Morehead formed the Triplett Creek Committee, which consists of citizens from both Morehead and Clearfield; a biologist and geologist from MSU; the Rowan County Solid Waste and Flood Plain Manager; representatives from the United States Forest Service, KDFWR, US Division of Agriculture Natural Resources Conservation Service; and the Licking River Basin Coordinator. This committee will serve and assist with the development of the Dry Creek WBP along with KWA and the Kentucky Division of Water.

Since a group had already been established, these members were asked to participate in creating the Dry Creek WBP. The official representation on the team is Morehead State University (faculty, staff and students), Morehead Utility Plant Board, Licking River Basin Coordinator, Rowan County Fiscal Court, City of Morehead, USFS, Rowan County Extension Service, citizens living in and near the Dry Creek watershed, and a community representative. This list may grow as the planning process continues and the watershed team identifies more partners and stakeholders. KWA served as a non-voting member. The primary role of KWA was to provide guidance during the process of developing the WBP. The attendance of at least six members of the watershed team is required in order to have a quorum. Major decisions required an 80% majority vote. The team used the "spirit" of Roberts Rules of Order to conduct its meetings. The stakeholder contact list started with 33 people. This stakeholder list was developed from phone conversations, as well as one-on-one conversations with those interested in the process. In addition to the stakeholder list, the Rowan County Fiscal Court and City Council were regularly updated on the planning process via briefings during regularly scheduled meetings. Kentuckians for the Commonwealth and the Morehead New Cities committee have also been provided regular updates on the WBP process.

Dry Creek Watershed-based Plan Draft
Chapter 2: Watershed Inventory

INTRODUCTION

The Dry Creek watershed is located in Rowan County, Kentucky, just outside the city limits of Morehead. The community of Clearfield is located at the mouth of Dry Creek (see map in Chapter 1). The watershed, a major tributary to the Triplett Creek, is approximately 7500 acres or 11.7 square miles in size. The watershed's steep terrain has had the effect of concentrating road, housing construction, and hay production along Dry Creek and its tributaries, which has resulted in the significant removal of stream bank vegetation and buffer zones. Moreover, the proximity of housing to streams often leaves insufficient area for septic tank leach beds to function properly. Various stream alterations have also been made throughout the watershed, including channel straightening, utility crossings, bank stability structures (gabion baskets, piles of concrete and large rocks), stream bank vegetation removal, and bridge construction. Ten bridges cross Dry Creek alone.

THE NATURAL ENVIRONMENT: LAND AND WATER

Geology and Topography

Streams in the Dry Creek watershed have eroded through nearly horizontal layers of sedimentary rock (for details see Hoge and Chaplin, 1972). Most of the highest elevations around the boundary of the watershed (for example, near Triangle Tower and along East Clack Mountain Road) are capped by pebbly, cliff-forming sandstone. Higher ridges and spurs between major tributaries within the watershed are capped by limestone, dolostone, and shale (for example, upper 0.75 mile of Triangle Tower Road). The steep valley walls of hollows (Figure 2.1) are primarily underlain by siltstone and thin shales. The valley floors of major tributaries and Dry Creek itself are dominated by sediment deposited by streams during floods (alluvium). Near the valley edges, alluvium is mixed with deposits derived from steep, adjacent slopes by slow down-slope soil movement (creep) and debris flows ("landslides"). Structures such as faults and folds are absent in the watershed. Bedrock, however, is extensively fractured throughout the entire watershed.

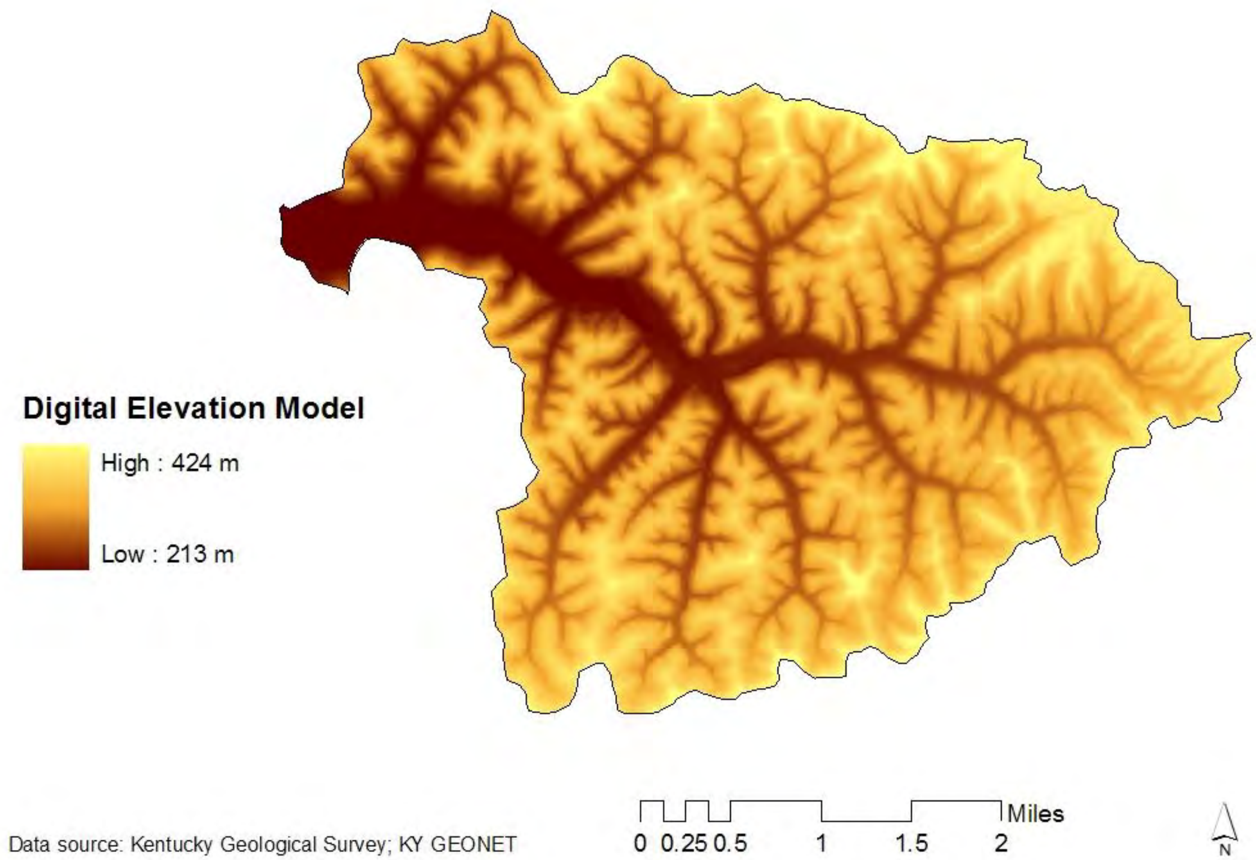

Figure 2.1. Map showing the distribution of elevation in the Dry Creek watershed.

Soils

Soils on slopes and along steep stream banks erode rapidly when vegetation is removed. This has led to gullying on unprotected slopes and has enhanced slumping (small landslides) along stream banks. Figure 2.2 shows the distribution of major soil units in the watershed. Silt loams (50-80% silt, 0-50% sand, 0-27% clay) dominate the entire watershed. These soils generally drain well but not too rapidly and are good for agriculture and properly installed septic systems. Coarser soils (e.g., sandy and gravely loams) tend to occupy lower slopes and floodplain areas adjacent to major tributaries. These coarser grained soils drain more quickly, are still quite fertile, and probably still allow septic system installation except in areas too close to streams. Rocky soils (rocky sandy loams) tend to occupy steep slopes below eroding sandstone cliffs, are quite thin and drain very rapidly – usually too rapidly for successful installation of septic systems.

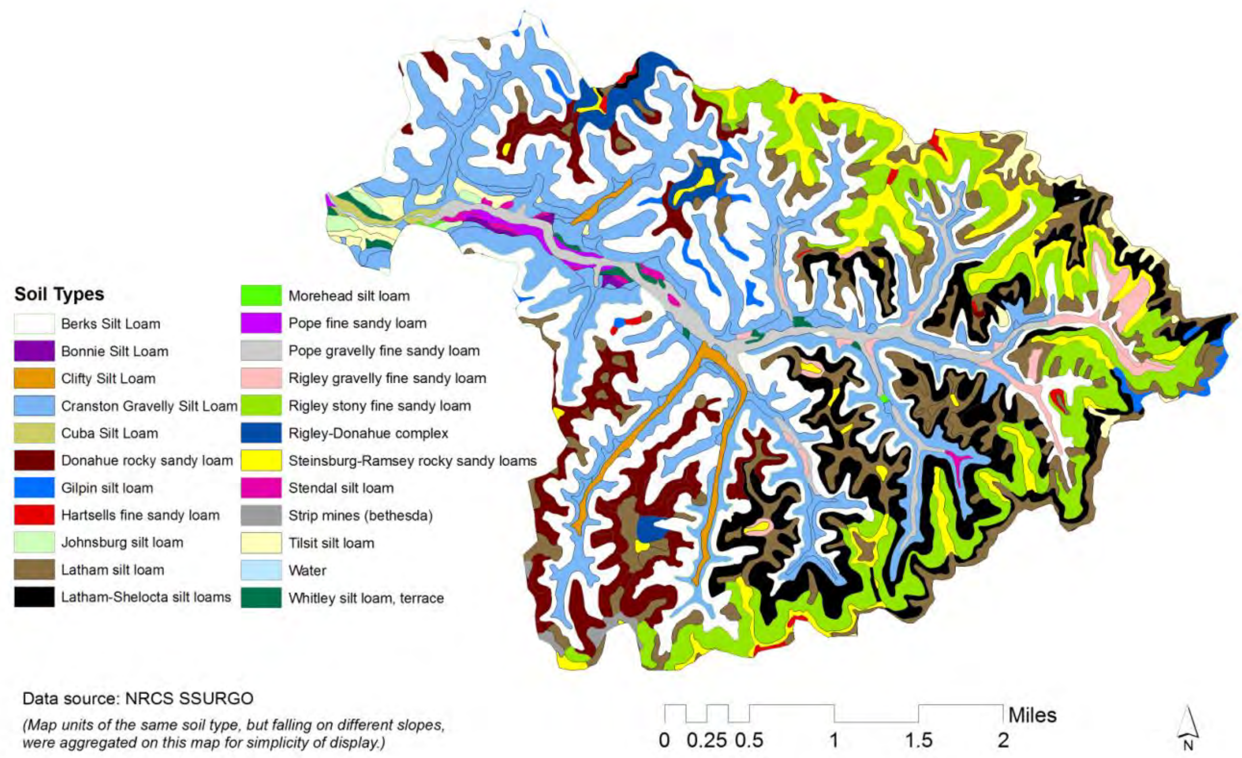

Figure 2.2. Map showing the distribution of major soil units in the Dry Creek watershed.

Hydrology

Dry Creek is surrounded and fed by small streams in "hollows" (steep, narrow valleys), which lack bottomland (floodplains). When flowing, streams in these hollows have small waterfalls, some pools, and long stretches of rapids. These small streams join like tree branches to form larger, slower, winding (meandering) streams, which flow through wider valleys with well-developed floodplains (good bottomland). The streams in these larger valleys flow in ditch-like (entrenched) channels with eroding banks.

In order to accomplish the goals of this watershed-based plan, flow in Dry Creek must be measured. Stream gages are stations that measure the amount of water that flows past a point in a stream during a given period of time. No state or federal government stream gages exist in the Dry Creek watershed. Instead, MSU geologists have installed "rulers" (standard, enameled steel staff gages) on bridges at three sites along Dry Creek and have been measuring flow at these sites for approximately one year. Flow measurements will be used to determine the amount of contaminants (loads) flowing through Dry Creek and its tributaries.

Ultimately, flow in the Dry Creek watershed is controlled by climate and precipitation. Monthly average temperatures in the watershed range from a low of approximately 31º F in January to a high of nearly 74º F in July. Annual average precipitation is approximately 43 inches. Flow is highly variable in summer due to the intermittent nature of precipitation. Late August through October tends to be the driest period. During this time, most tributaries, and sometimes even

Dry Creek itself, stop flowing. Steadier, lighter rains occur frequently from about late November to April, a period when soil moisture is replenished, the ground remains moist to saturated, and groundwater almost continuously feeds all but the smallest tributaries. An average of nearly six inches of intermittent snow falls between rain events from December through March. The snow usually melts quickly, which further contributes to soil moisture, groundwater, and overland flow.

Most flooding in the Dry Creek watershed is minor and infrequent. Much of the watershed experiences flash flooding only during high intensity storms, especially where small bridges and culverts are not sized properly to handle high flows. Flash flooding is largely due to rapid runoff over the steep slopes in and around hollows. Heavy forest cover tends to slow or completely intercept water flowing over the land during all but the most intense storms. Some homes are constructed in flood prone areas that are vulnerable to flash flooding.

Flooding along Dry Creek and its larger tributaries is less frequent and less severe than one might expect. The primary reason is that larger streams are deeply entrenched and seldom flow out onto their floodplains anymore. Several reaches of Dry Creek have also been channelized and artificially confined by rock basket (gabion) walls (for example, near Ravenswood Bridge) and crude walls of stacked concrete debris, appliances, tires, etc. The net effect is that severe flooding is confined to the lowest reaches of Dry Creek, especially near the confluence with Triplett Creek (for example, near Save-a-Lot and the Clearfield Post Office). Flooding near this confluence usually results from back-up of Triplett Creek floodwaters into Dry Creek.

During dry periods, groundwater seepage (baseflow) is the only reason Dry Creek and its tributaries continue to flow. Groundwater is pushed downhill by gravity through fractured rocks, soil, and sediment and feeds all but the highest headwater streams in the watershed. The fact that bedrock in the Dry Creek watershed is highly fractured greatly enhances groundwater flow. The combination of steep terrain and highly fractured bedrock causes the groundwater contribution to streams to change fairly rapidly, within hours to at most a few days.

Sinkholes and cave systems (karst) probably do not directly feed long stream reaches anywhere in the watershed. The distribution of potential karst in the Dry Creek watershed is shown in Figure 2.3. The more detailed map of Hoge and Chaplin (1972) shows that limestone occurs on or near the tops of ridges in the blue-shaded areas of Figure 2.3 and that no karst features recognizable at the 1:24000 scale exist. Small sinkholes and minor caves are common in similar settings south of Morehead, however, so springs and seeps on steep slopes at the base of sandstone cliffs and at the base of limestone outcrops may be fed by small, discontinuous cave systems. These springs, in turn, may feed the heads of small, intermittent streams.

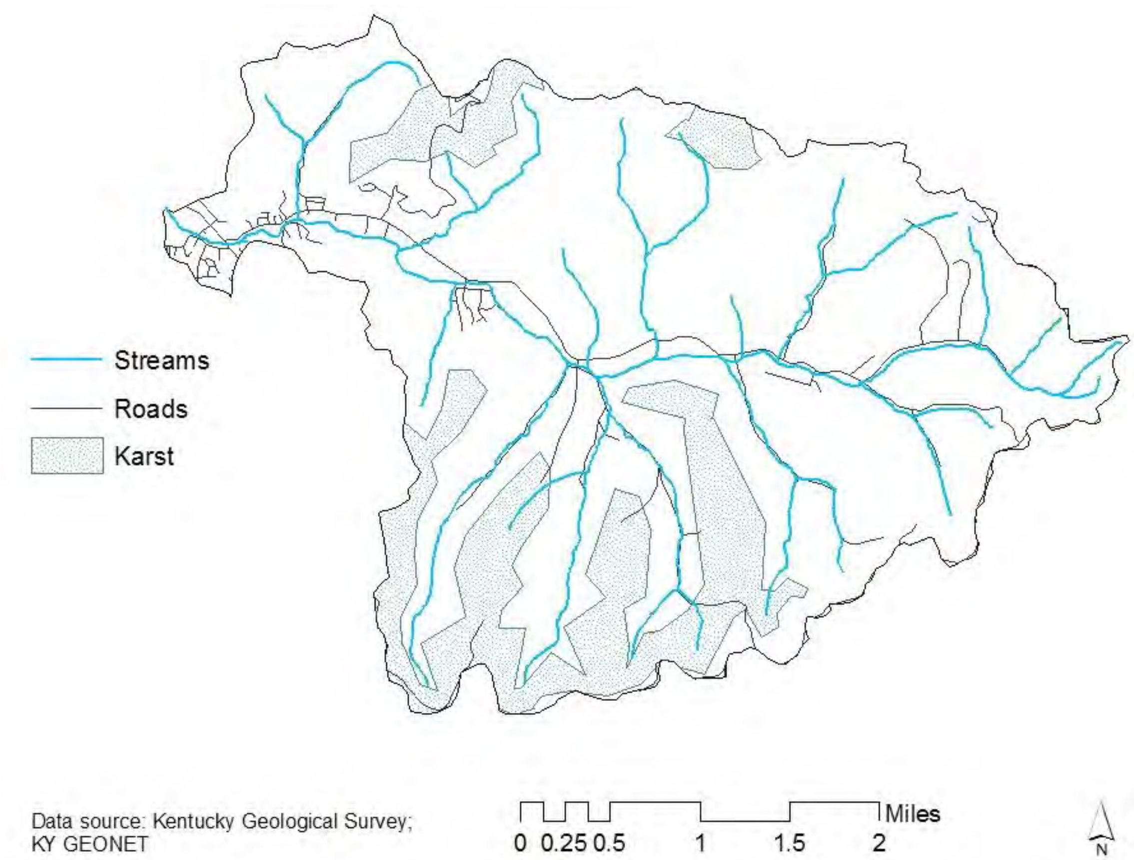

Figure 2.3 Map showing potential karst areas in the Dry Creek watershed.

THE NATURAL ENVIRONMENT: LIFE

Flora and Fauna

The flora and fauna (plants and animals) of the Dry Creek watershed are diverse. According to the Kentucky State Nature Preserves Commission (2007), there are a number of endangered, threatened, or sensitive plant and animal species in Rowan County (Table 2.1). Some of these species can be found or were probably at one time located in the Dry Creek Watershed. These species can be used as indicators of the health of a stream (Humphries et. El, 2006). A list of species specific to the Dry Creek Watershed is not available. The ecosystems in the watershed range from Oak Pine ridge top forest to riparian ecosystems.

Table 2.1. Summary of the number of each floral and faunal group listed as endangered, threatened, or sensitive in Rowan County (KSNPC, 2007).

Group	Endangered	Threatened	Sensitive
Mosses	1	3	
Vascular Plants	2	2	10
Reptiles			1
Insects		1	2
Mammals	2		5
Breeding Birds			2
Amphibians			1

Most of the riparian ecosystems in the Dry Creek watershed have been extremely altered, but the watershed is still mostly forested (79.88%; Figure 2.4). Floodplain ridges/terrace forest and Bottomland Hardwood Forest are listed as imperiled in the state because of their rarity due to a very restricted natural range, very few populations (often 20 or fewer), steep declines, or other factors making them very vulnerable to extirpation from the state (KSNPC, 2007). The threat to these communities in the Dry Creek watershed is that the deeply entrenched streams in this basin have become disconnected from their floodplains. When the stream becomes disconnected it increases channelization and bank erosion. In addition, vital habitats such as wetlands and bottomland forest are stressed or disappear without the influx of floodwaters. A report by the Kentucky State Natural Preserves Commission (KSNPC, 2007) lists a number of wildlife species that are extremely dependent on healthy riparian ecosystems (areas along creeks and rivers) for survival. Examples of species dependent on riparian ecosystems include Eastern Hellbender Salamander (*Cryptobrandrus alleganiensis*), Least Weasel (*Mustela nivalis*), Jointed Rush (*Juncus articulatus*), Kentucky Ladyslipper Orchid (*Cypripedium kentuckiense*), and Waterplantain Spearwort (*Ranunculus ambigens*). Much of the native vegetation along the creek banks has been disturbed. As a result, nonnative plant species such as Japanese knot weed and honey suckle have successfully invaded the area.

THE REGULATORY ENVIRONMENT

Floodplain Regulation

Flooding is a simple natural phenomenon that occurs regularly with any waterway. Flooding can be worse if an area has a lot of land surfaces that don't allow water to sink in or infiltrate back into the soil ("impervious surface") like a parking lot. This is because there is more water from a rain or snow event running off to the lowest point of town instead of infiltrating. A healthy riparian zone and an undeveloped floodplain can help decrease the severity of flooding. As an area becomes more developed with more impervious surfaces, the more frequent severe flooding may be.

The Dry Creek watershed includes both 100-year floodplain (Figure 2.4) and floodway designations. In Figure 4, the floodplain is outlined in dark blue. These flood hazard areas are regulated by county ordinance and state regulations. The 100-year floodplain represents the area that would be flooded if a flood having a one percent chance of being equaled or exceeded in any given year occurred. The designated floodway refers to the stream and that portion of the adjacent 100-year floodplain specified by a local ordinance or indicated on National Flood Insurance Program maps that must be kept free of obstructions to the passage of flood flows.

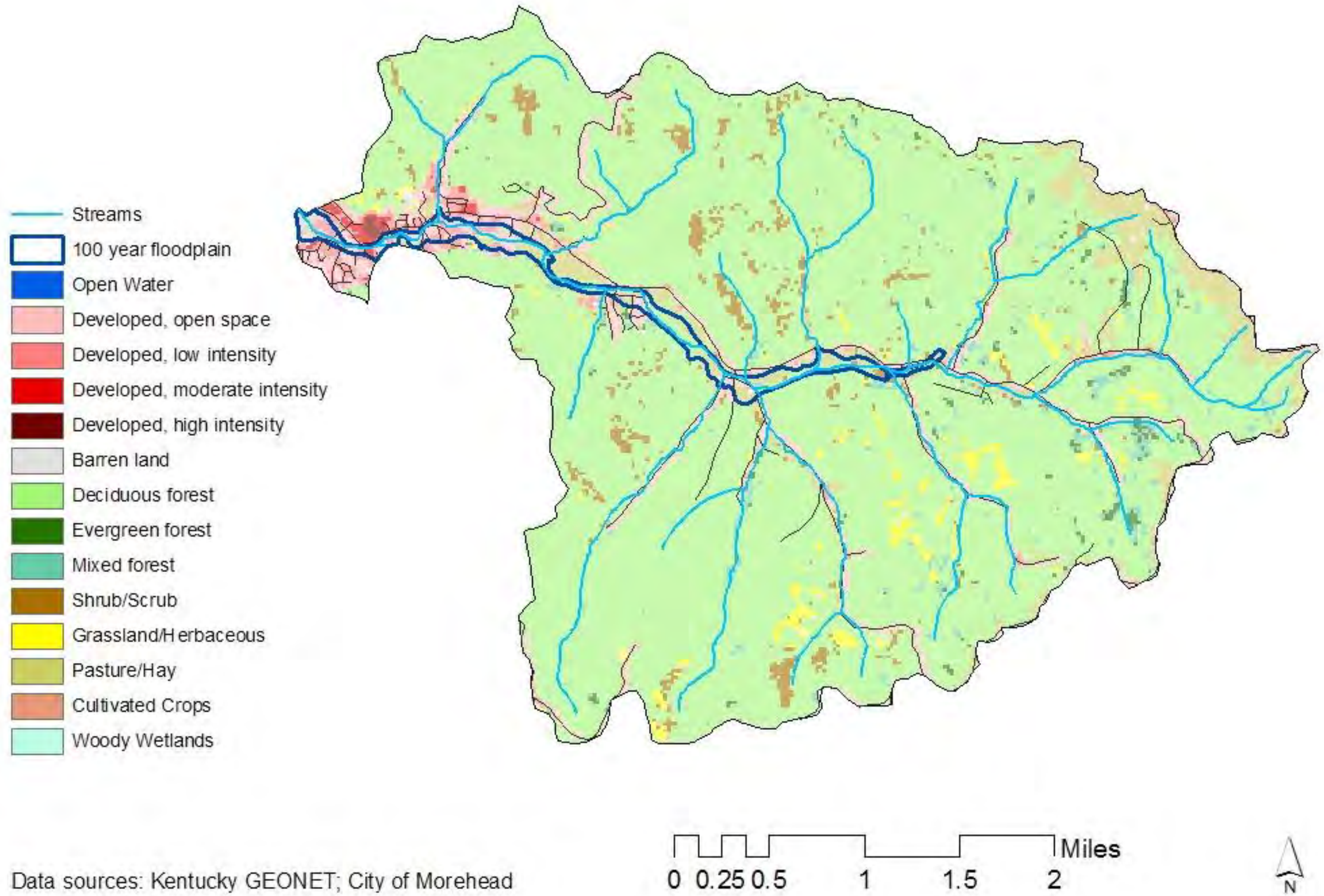

Figure 2.4 Map showing the 100-year floodplain and the 2005 land use/land cover in the Dry Creek watershed.

Permits must be obtained from both the Kentucky Division of Water (KDOW) and the Rowan County Floodplain Department to fill and/or construct buildings in the floodplain. Filling or constructing in the regulatory floodway is prohibited. In addition to construction in the floodplain, permits must also be obtained from both the KDOW and Rowan County Floodplain Department to construct in or along a waterway. Before a permit can be issued the intent of the permit and the location must be advertised in the local paper.

Since April 2003, KDOW has issued 22 floodplain permits in the Dry Creek watershed (Figure 2.5). These permits have been issued for several purposes, including bridges, culverts, stream bank stabilization, apartment construction, restoration of flooded county-owned property, and pipeline maintenance.

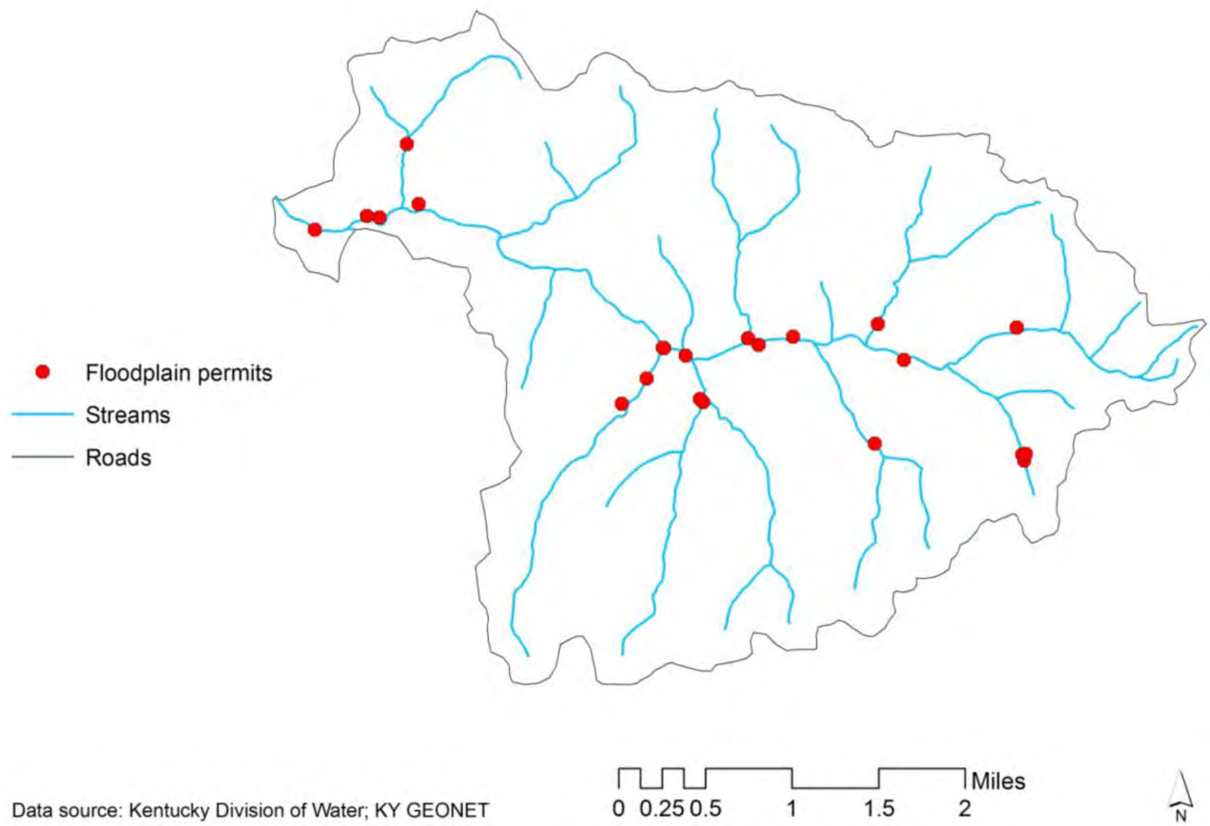

Figure 2.5. Map showing floodplain permits issued for the Dry Creek watershed since April 2003.

Water Supply
All residences in the watershed are connected to Rowan Water Incorporated waterlines (Figure 2.6). Any remaining wells are abandoned or used only for minor irrigation. Some minor withdrawals from streams for irrigation may also occur, but this is unconfirmed.

In Kentucky, the water withdrawal program administered by KDOW regulates all withdrawals of water greater than 10,000 gallons per day from any surface, spring, or groundwater source with the exception of: water required for domestic purposes; agricultural withdrawals, including irrigation; steam-powered electrical generated plants regulated by the Kentucky Public Service Commission; or injection underground as part of operation for the production of oil and gas. As of June 9, 2008, according to the Water Quantity Section of KDOW, there were no permitted water withdrawals in the Dry Creek watershed. This means that large quantities of water are not being extracted from Dry Creek. It is important to understand the amount of water flowing in a stream (“in stream flow” or “flow”) because the flow impacts many aspects of the stream itself including water quality, habitat, flooding, and many others.

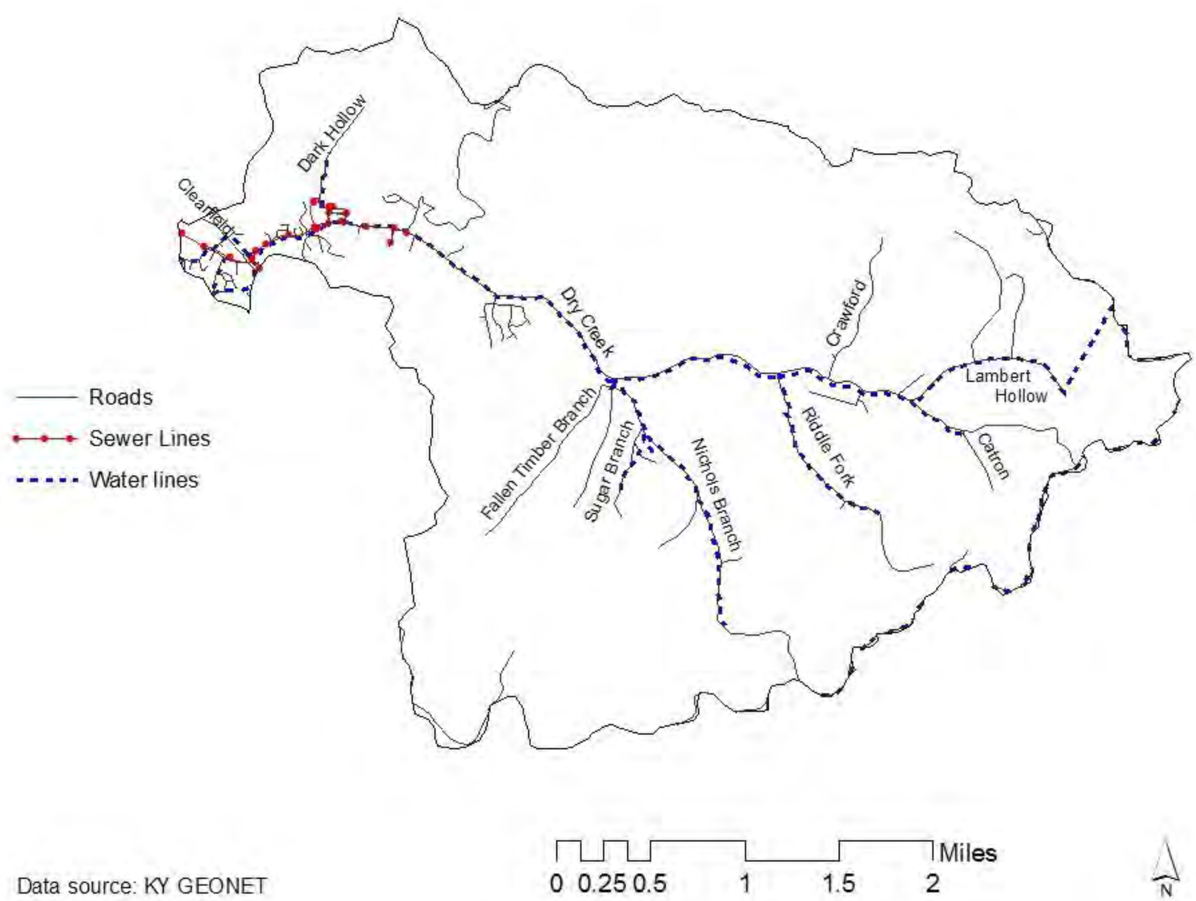

Figure 2.6. Map showing sewer and water lines in the Dry Creek watershed.

Watershed Management Activities

Source Water Protection Plans

Source Water Protection Plans are required under the Safe Drinking Water Act to assess the quantity of water used in a public water system and to formulate protection plans for the source waters used by these systems. According to KDOW, Watershed Management Branch, there are no public drinking water sources in the Dry Creek watershed, and therefore, no existing Source Water Protection Plans have been developed for the watershed.

Wellhead Protection Plans
Wellhead Protection Plans are used to assist communities that rely on groundwater as their public water source. According to the Wellhead Protection Program of KDOW, there are no Wellhead Protection plans in Rowan County because all public water sources in the county use surface water.

Groundwater Protection Plans
Groundwater Protection Plans (GPPs) are required for anyone engaged in activities that have the potential to pollute groundwater. Activities that would require a GPP include pesticide application or storage for commercial purposes, installation or operation of on-site sewage disposal systems, storing or handling of road oils, or any mining activity. According to the Groundwater Section of KDOW, there are no GPPs in the Dry Creek watershed. However, there may be facilities in the watershed area that need a GPP.

For more information on what types of facilities require GPPs or guidance on how to write a plan, visit the Groundwater Section of the KDOW website. It is part of this watershed-based plan to implement education and awareness campaigns on the need for groundwater protection and active GPPs.

Past or Current Watershed-based Plans
No watershed-based plans have been developed for the Dry Creek in the past.

Wastewater Authorities

Wastewater 201 Plan
In 1998 Morehead Utility Plant Board completed a Facility Update Plan for sanitary sewer system improvements. There is a copy on file at the Morehead Utility Plant Board office. The total capital cost of the 201 plan is estimated to be over $25,000,000. The purpose of a 201 plan is to develop an effective planning tool that will provide an accurate forecast of future wastewater needs for Rowan County. The 201 plan reflects areas that have been designated as needing sewer infrastructure. This is based on population density and economic feasibility of installing sewer infrastructure. Areas not included in the 201 plan may still have wastewater problems that may need to be addressed through other alternatives. These alternatives include septic system maintenance and clean out. Public education and outreach efforts can be of assistance in these areas.

A portion of the Dry Creek Watershed is included in this area (Figure 2.7). The facility plan includes the following information and will be for a planning period of 20 years.

- Existing/Proposed System Mapping
- Flow Projections
- Capacity Analysis
- Alternative Analysis for unsewered areas and expansion of Wastewater Plant
- Financing strategies

Only a portion of the Dry Creek watershed is included in part of the 201 plan. The sections that are covered are part of the 0-2 year plan and presently have city sewer available. The areas that are not showing planned sewer projects are the less populated areas. These areas include the area of Dry Creek about Tower Road. The red lines on the map below represent existing sewer lines. The green grid shows the area that is part of the MUPB 201 plan.

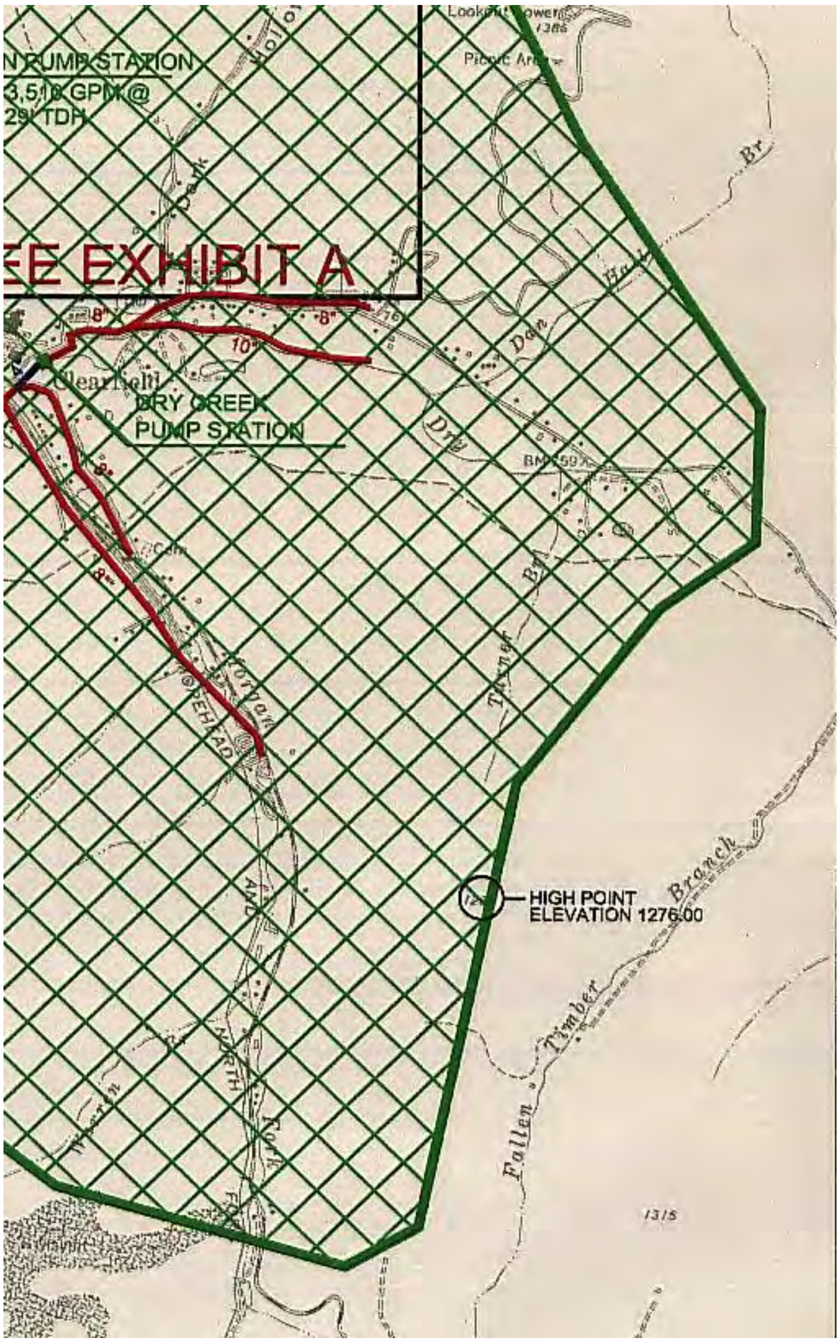

Figure 2.7. City of Morehead Sanitary Sewer System Layout and Planning Area from Morehead Utilities Plant Board 201 Plan showing the Dry Creek Watershed area.

Agricultural Water Quality Plans

The Kentucky Agriculture Water Quality Act was passed in 1994, with the main goal of protecting surface and groundwater resources from pollution as a result of agriculture and silviculture activities. As a result of this law, any farm operation on a tract of land situated on ten or more contiguous acres that engage in agriculture or silviculture activities is to develop and implement a water quality plan based on guidance from the Kentucky Agriculture Water Quality Plan. The Kentucky Agriculture Water Quality Plan consists of best management practices from six areas: 1) Silviculture, 2) Pesticide & Fertilizer, 3) Farmsteads, 4) Crops, 5) Livestock and 6) Streams and Other Water. Landowners must prepare and implement these plans based on their individual farm operations and keep a record of planning and implementation decisions. The Agriculture Water Quality Plan generally gives an overview of each landowner's decisions regarding how they plan to address potential water quality impacts generated by their operation. These plans are maintained on file with the individual farm operator or owner. A landowner certification can be filed with the Rowan County Extension Office if the owner/operator desires to do so. Because of the self certification requirement established in the Act, there is no way of knowing the actual number of farms with completed water quality plans on their agricultural enterprise.

Agricultural activities in the Dry Creek watershed include livestock and some row crop production. Beef cattle, tobacco, hay, and pasture land are found in or adjacent to the watershed. Forest activities including timber harvesting and firewood removal also occur in the watershed. The majority of producers in the watershed likely have completed an Agriculture Water Quality Plan. According to the Rowan County Extension Agent for Agriculture and Natural Resources, there are an estimated six working farms in the Dry Creek watershed. Several best management practices have been adopted. The practices are designed to decrease the amount of sediment, nutrients (such as fertilizer), and pathogens from entering waterways. Agricultural best management practices that have been adopted by producer in the watershed that protect water quality:

1. Construction and use of animal waste facilities that reduce manure movement into streams.
2. Adoption of rotational grazing practices that promotes adequate vegetative cover and reduces soil erosion/movement of sediment into streams.
3. Proper disposal of fallen livestock that eliminates movement of disease causing organisms into waterways.
4. Row cropping on the contour and use of buffer strips to reduce soil erosion.
5. Soil testing/fertilize application practices that reduce movement of excess nutrients into streams.
6. Planting winter cover crops that reduce bare soil and minimize soil erosion/stream sedimentation

Despite the implementation of best management practices several agricultural practices still exist that have a negative impact on the water quality in the Dry Creek watershed. Observed practices include 1) stocking rates and poor soil fertility for some farms in the Dry Creek watershed have resulted in some over-grazing and exposed soil; 2) limited row cropping on excessively steep slopes has resulted in some soil erosion; 3) removal of trees from stream bank to maximize crop and livestock production. These practices allow excess sediments and nutrients to enter the waterways. See chapter one for more information and the impact of sediments and nutrients. Chapter 3 contains specific information to the Dry Creek watershed.

Special Land Use Planning: Subdivision Regulations

Morehead City Council and Rowan County Fiscal Court are currently working on a set of subdivision regulations. These regulations have not yet been approved. There are several sections that pertain to watershed-based plan:

- Section 603.6 titled Flood Hazards mentions that the project must comply with applicable floodplain ordinances.

- Section 606, “Natural Features” states: "the street plan and lot arrangement of a proposed subdivision shall be so designed as to preserve natural features such as trees, streams natural lay of the land, and disposition of the topsoil.”

- Section 807.3, “Storm Drainage” requires adequate provisions for stormwater drainage and prohibits cross connections between sanitary sewers and stormwater drainage systems.

- Section 810, “Bridges” states: all bridges shall be designed by an engineer and constructed to an engineer's specification or to Kentucky Department of Transportation specifications, whichever is more restrictive.

- Section 811.3, “Maintenance Bond” states: In cases where the Joint Planning Commission deems that drainage, soil conditions, steep topography, amounts of cut and fill and /or type of construction warrant, the Commission shall require the posting of a maintenance bond, or similar guarantee, to cover workmanship, street or utility installation and repair for a period of one year after completion of the streets or utility or after final plat approval, whichever occurs last. The bond amount shall be for at least a minimum of ten (10) percent of the cost of reconstruction.

These regulations will assistant in the protection of waterways. The protection of natural features should reduce the amount of channelization of small streams. This will allow for the natural flow of the streams, reducing the rate at which the water flows into larger streams, potentially reducing the intensity of flooding. In addition, tree cover is necessary for bank stability, maintaining cooler water temperatures, and reducing sediment inputs.

The elimination of cross connections between sanitary sewers and stormwater drainage systems will reduce the amount of over flow occurring at the pumping stations and manholes. Once the system overflows the stormwater system discharges water, which is a combination of storm water and sewer into the waterways. This has been a regular problem for Morehead Utility Plant Board, which has been documented by the Kentucky Division of Water (Morehead Office).

The maintenance bond will allow for corrective action to be taken if the construction is not completed properly. This may be very helpful to ensure that land is properly re-vegetated after construction projects. Land left barren after construction is a commonly observed problem in the watershed. The negative impact of barren land can easily be observed during rains when the sediment is being directly washed into the streams. The aftermath results are the loss of quality top soil and gullied land.

Regulations not included that would be helpful would be 1) the reduction of curbs to allow water to flow over pervious surfaces (non-paved), and 2) the creation of buffer zones between creeks and construction projects. Both of these actions would allow for the quantity of water entering our waterways to be reduced. In addition, the speed at which the run off enters the waterway is reduced. As a result, the amount of water entering streams during a rain event is reduced, reducing the intensity of flooding in the area. These recommendations also reduce the amount of sediment entering the waterway, especially clay particles. A reduction in the amount of sediment entering the waterways also reduces the nutrients that “cling” to the sediment particles.

Regulatory Status of Waterways

The Kentucky Division of Water is required by the EPA to assign designated uses to each of the state’s waterways, such as recreation, aquatic habitat, fishing and drinking water. For each use, certain chemical, biological, or descriptive (“narrative”) criteria apply to protect the stream so that its uses can safely continue. These criteria are used to determine whether a stream is listed as “impaired” and therefore needs a watershed-based plan or Total Maximum Daily Load.

Designated Uses

Dry Creek’s designated uses are warm water aquatic habitat, primary and secondary contact recreation, and drinking water supply.

Impairment Status

The Kentucky Division of Water 2008 Integrated Report to Congress (KDOW, 2008) identifies a portion of Dry Creek as impaired to the extent that it only partially supports aquatic life. The impaired reach extends from the mouth of Dry Creek (0.0 miles) to a point 2.5 miles upstream (Figure 2.8, Chapter 2). The impaired reach therefore includes sites DC-0.28 and DC-1.89 and ends 0.34 miles downstream of DC-2.84. Pollutants recognized in the KDOW (2008) report include nutrient/eutrophication biological indicators, sedimentation/siltation, and organic enrichment (sewage) biological indicators.

This pollution prevents the creek from supporting all of the aquatic creatures, such as fish and insects, which would live in the water. This designation is based on field work completed by the US Forest Service (USFS) and Kentucky Department of Fish and Wildlife Resources (KDFWR) in 2005. While only this half mile section of the creek is listed as impaired by the Division of Water for certain parameters, this does not mean that other impaired areas do not exist in Dry Creek, or that there are not other types of pollutants (e.g., nutrients). This simply means that only this one half mile area was tested and only then for its capacity to support aquatic life.

Special Use Waters

Kentucky identifies certain Special Use Waters, and they receive greater protection. These waters include Outstanding State Resource Watershed, Reference Reach Waters, Kentucky Wild Rivers, and Outstanding National Resource Waters. Special Use designations are made because of some exceptional quality of the water that needs further protection. As of June 25, 2008, there are no identified Special Use Waters in the Dry Creek watershed.

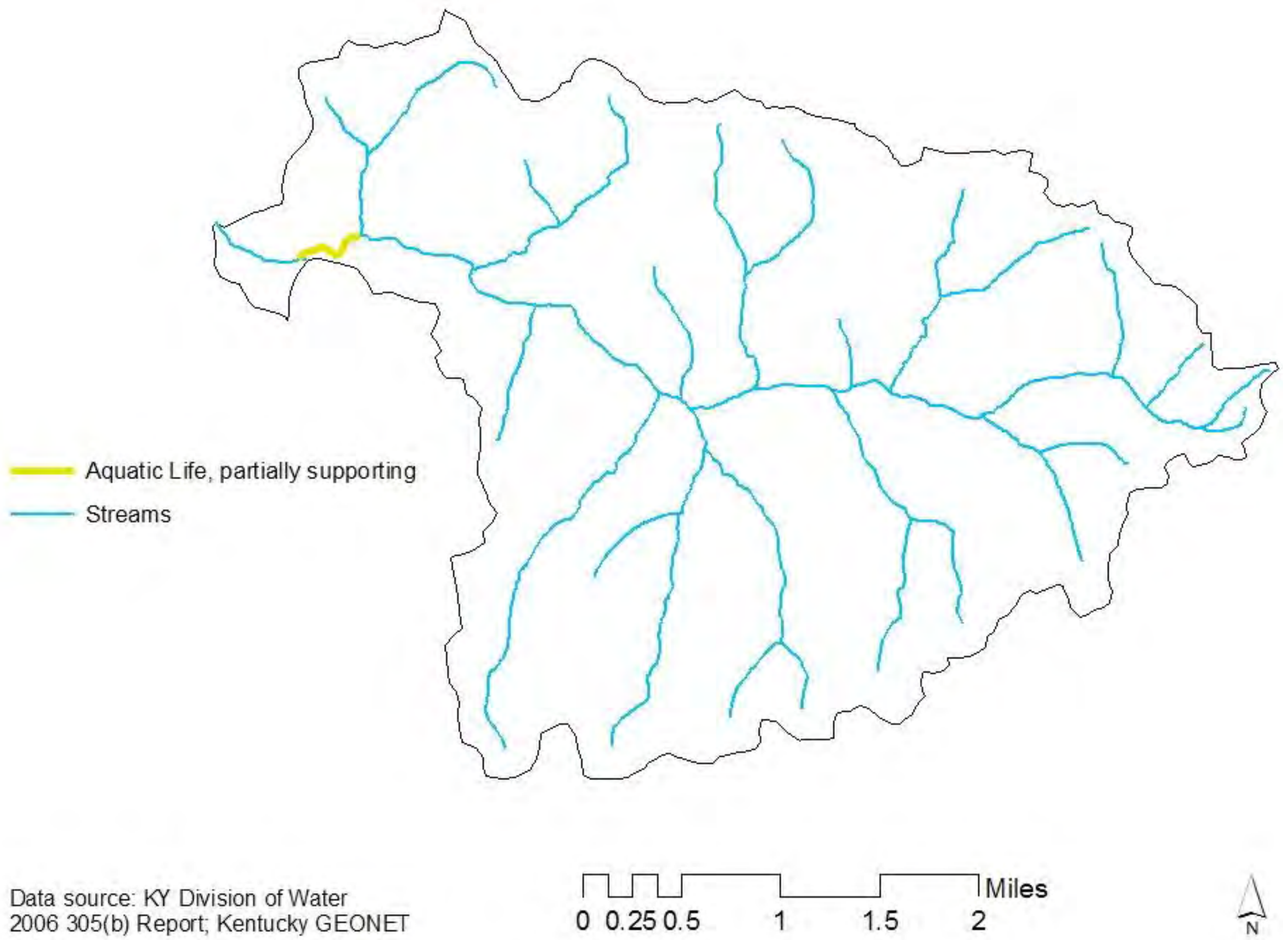

Figure 2.8. Impaired section of Dry Creek from the 2008 Kentucky 305(b) Report.

Total Maximum Daily Load Report

The Clean Water Act requires Kentucky to list streams that it finds as impaired for studies that will determine the amount of pollution they can assimilate while still meeting water quality standards. The outcome of such studies is a TMDL (Total Maximum Daily Load) Report. These reports set limits on the pollutants that can be discharged into these waters and provide general guidance for implementation. Watershed plans act as useful tools to implement TMDLs. Currently, there is no TMDL Report for Dry Creek.

HUMAN ACTIVITIES AFFECTING WATER QUALITY

Land Use

This watershed is mainly forested with residential development concentrated near the mouth of Dry Creek and along the roads which run along the streams (Figure 2.4). Table 2.2 shows the distribution of land use and land cover types in the watershed in 2005. Overall, the watershed contains approximately 1.4% impervious surfaces. Impervious surfaces are those surfaces like roads and parking lots and building roofs that do not allow water to pass through them. This means that when rain hit these surfaces, it does not infiltrate into the soil, but instead runs off. This runoff may eventually make it to a waterway like Dry Creek. This runoff affects streams in many ways. First, runoff water will bring with it any pollution that it has crossed on its way to the stream such as oil and dirt from roads, pet waste, agricultural and lawn chemicals, and many other possible substances. These substances have the potential to degrade the water quality of the stream. The runoff will also increase the flow of the waterway, and perhaps cause erosion and flooding issues downstream. Additionally, if the water runs over hot pavement on its way to the waterway, it could increase the temperature of the water. This can harm aquatic organisms. High or increasing percentages of impervious surfaces in a community (usually from development) are increasingly seen as problematic for waterways for these reasons.

The steep terrain has concentrated road and housing construction along the creek, and apartment construction has been accelerating along Dry Creek in recent years. Approximately half of the recent residential development has occurred outside of the area served by the Morehead Utility Plant Board's (MUPB) sewer lines. In addition, many of the disturbed sites have not been reseeded, allowing for visible erosion. Dry Creek is on the state's list for partially supporting aquatic life and pollution due to sediment. Dry Creek is also polluted by nutrients.

Table 2.2 Percent land use and land cover in the Dry Creek watershed in 2005.

Land use/Land cover Class *	Description *	Percent (%) **
Open water	All areas of open water, generally with less than 25% cover of vegetation or soil	0.01
Developed, open space	Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.	5.07
Developed, low intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.	1.92
Developed, moderate intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units	0.32
Developed, high intensity	Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover.	0.06
Barren land	Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material, with little or no "green" vegetation present regardless of its inherent ability to support life. Vegetation, if present, is more widely spaced and scrubby than that in the "green" vegetated categories; lichen cover may be extensive	0.19
Deciduous forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.	79.19
Evergreen forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.	0.69
Mixed forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.	1.71
Shrub/Scrub	Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.	2.79
Grassland/Herbaceous	Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.	2.10
Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.	5.88
Cultivated crops	Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.	0.04
Woody wetlands	Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.	0.01
TOTAL		100.00

*Source: Multi-Resolution Land Characteristics Consortium, EPA; **Source: Kentucky GEONET

Thirty-five percent (2616 acres) of the Dry Creek watershed comprises land owned by the US Forest Service, which is largely found on hill slopes in the central portion of the watershed (Figure 2.9). Nearly four percent of the watershed is scheduled to be logged sometime in the next four to five years primarily to remove trees damaged during the February 2003 ice storm. Within this area, 98 acres will be commercially logged (cut and removed), while 178 acres will be non-commercially logged (cut and left in place).

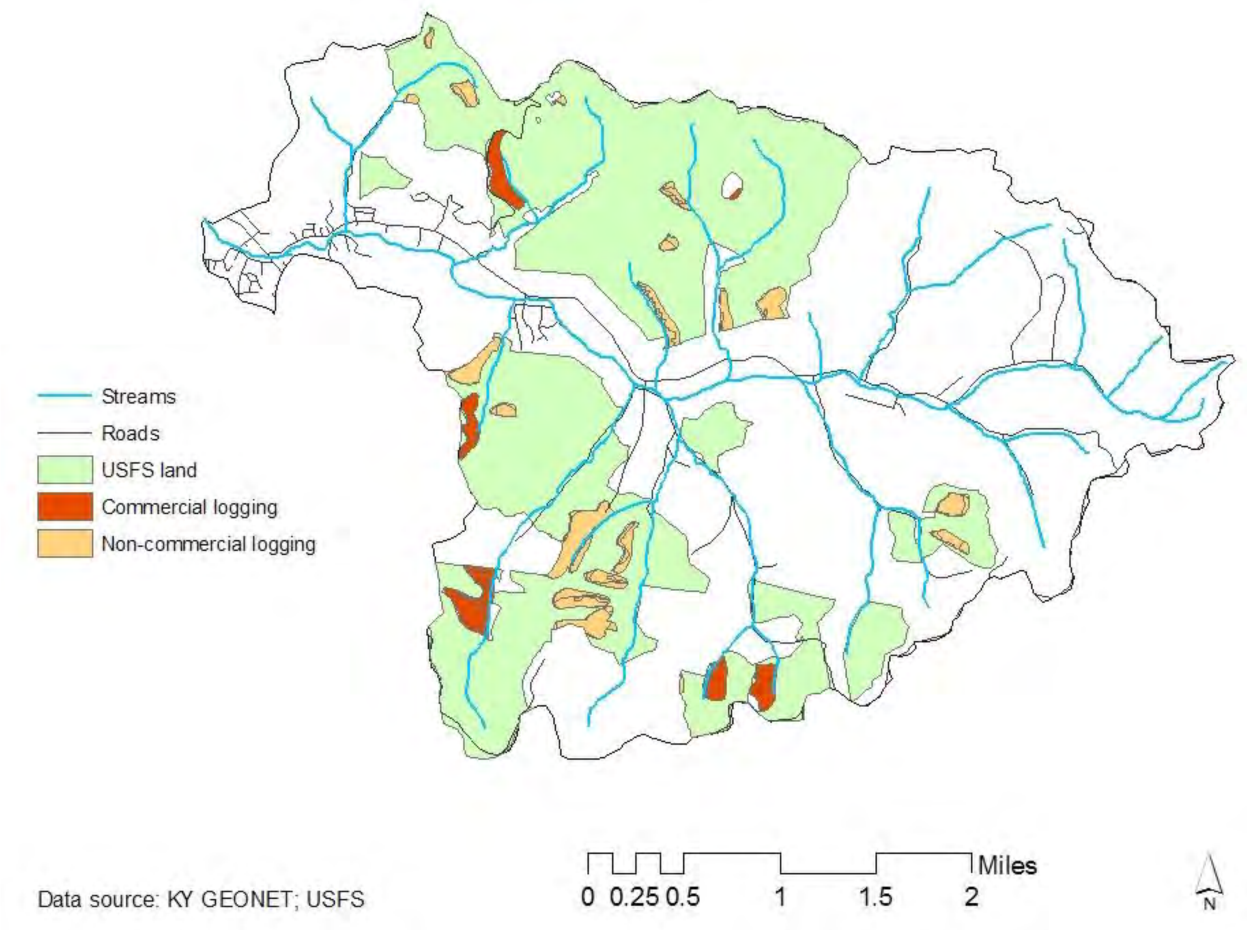

Figure 2.9. Map showing US Forest Service stands in the Dry Creek watershed, including those marked for future logging (commercial and non-commercial) due to the 2003 ice storm.

Permitted Point Sources

Point sources of pollution are those that have a known discharge point, such as a pipe. In most cases, point sources are required to operate under a Kentucky Pollutant Discharge Elimination System (KPDES) permit issued by the Kentucky Division of Water. Examples of point source discharges include industrial and wastewater treatment plants that discharge directly to a stream, and certain livestock facilities. KDOW maintains records on permits and related water quality monitoring. Information can also be obtained from the EPA's online Envirofacts Data Warehouse, a website used by KDOW to provide permit information. It is updated often and available for public use.

The Dry Creek watershed does not have any known major point sources of pollution. As a result, there are no permits for Municipal, Industrial, Wastewater, or Stormwater Discharges, Combined Sewer Systems and Overflows and Municipal Storm Separate Sewer Systems. There are no known discharges within the Dry Creek Watershed. This statement is based on visual observation and an internet search at the US EPA EnviroMapper for water.

Wetlands and In-stream Construction or Disturbance

Section 404 of the Clean Water Act regulates the discharges of dredged or fill materials into the waters of the United States, including small stream and wetlands adjacent or connected to regulated waters. Activities that result in physical disturbances to wetlands or streams are regulated by the US Army Corps of Engineers under Clean Water Act section 404 and require a Clean Water Act section 401 Water Quality Certification issued by the Kentucky Division of Water. Permits are required for the discharge of dredged or fill materials into navigable waters. Examples of projects are bridge and pipeline construction across a waterways and the filling of a wetland. As part of the permit application a public notice and opportunity for public input are required. The size and impact of the project will determine the type of mitigation that will be required.

Rowan County must also issue a permit for construction in or over a waterway. Before any permit of this type can be issued, the intent of the permit with the location must be advertised in the local paper. A request from the Army Corps of Engineers for records of 404 permits for Rowan County for the years 2000 to 2009 yielded two permits, neither for the Dry Creek watershed.

These regulations were developed to prevent pollutants such as sediment from entering waterways during construction and mining practices. In addition, the disturbances to wetlands (which act as sponges absorbing pollutants) have negatively impacted water quality and increased the severity of flooding.

Demographics and Social Issues

According to the 2000 US Census, the total population of the Dry Creek watershed is 754 persons, with a population density of 68.9 persons per square mile. The unemployment rate in the watershed is 8.6%. Most of the population has received little formal education. 44% have not received a high school diploma, while 27% have received a high school diploma or equivalent, and 29% have some college experience or have received a college degree. The average age for those living in the watershed is 40.9.

Most housing in the watershed consists of single family units (240 or 58%). Mobile homes were the second most common housing type with 157 units (38%). Housing units are mostly rural (69%), with farms comprising only 13 of the 415 units. Rental units make up about 25% of the housing inventory. A complete summary of the Dry Creek watershed's demographics can be found in Appendix C.

Only a small portion of the residents in the Dry Creek watershed have access to municipal sewer infrastructure (Figure 2.6). Presently, the MUPB has sewer lines installed as far as Fire Tower Road, which is approximately 1.5 miles up Dry Creek Road from the mouth of the watershed. The MUPB has submitted a request to extend the sewer lines, however, actual construction has not occurred due to low population density and a lack of funding. Residents in the Ravenswood subdivision have informally complained about a number of failing septic systems in the area, including three people who attended the first Dry Creek watershed Community Roundtable meeting.

EXISTING WATER QUALITY DATA

Data presented in Chapter 2 are existing data gathered from a variety of places. The data reported on in Chapter 3 and used for pollutant load reduction calculations and BMP recommendations are data that were collected specifically through this watershed planning project.

Bacteria

Certain bacteria, such as *Escherichia coli*, are normal inhabitants of the gastrointestinal tract of mammals and birds. Therefore, *E. coli* can be used as an indicator of fecal contamination of the watershed. Currently, there are bacterial data for ten locations along the Dry Creek watershed collected prior to the start of this watershed project (Figure 2.10). These data were used to establish a baseline database, to refine the identification of sampling sites, and to help determine the sources of fecal contamination. Nine of the samples sites were collected by faculty and students from MSU. The tenth location is sampled by a volunteer from the Licking River Watershed Watch. The Licking River Watershed Watch samples have been under unacceptable bacteria levels. More than likely this is the result of limited sampling and samples not immediately collected after a rainfall.

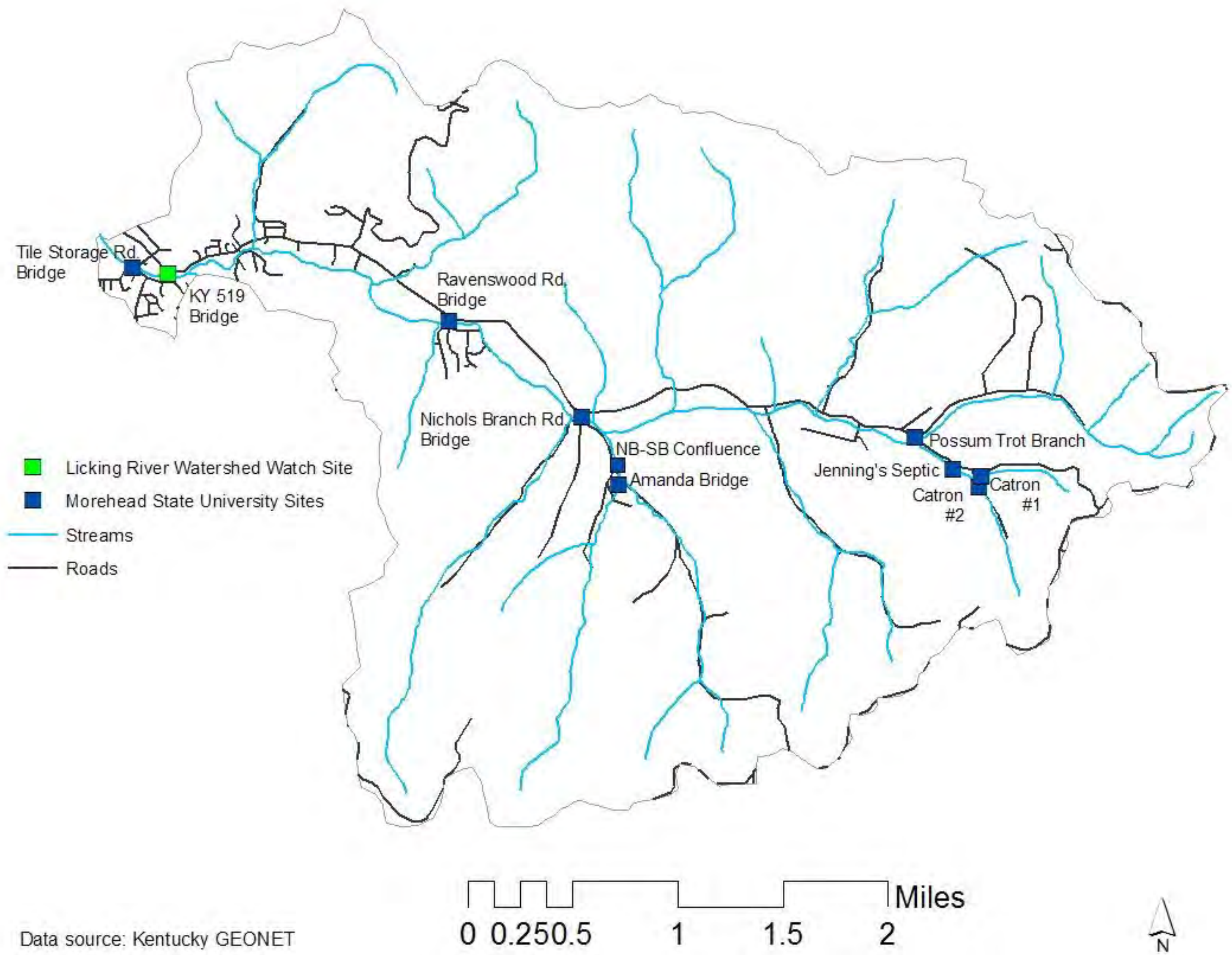

Figure 2.10 Map showing the bacterial sampling sites in the Dry Creek watershed.

All bacterial counts, collected by MSU, varied over the range of the sampling sites and over time during the fall evaluation period (24 October to 14 November 2007). The *E. coli* count for the sampling sites tested ranged from 0 to 2,260 colonies per 100 mL. The highest counts were observed following a significant rain event on 23-24 October 2007, where seven of eight sites sampled exceeded EPA standards of 130 colonies per 100 mL for *E. coli* bacteria. Only one site, Nichol's Bridge, exhibited a geometric mean (312 colonies per 100 mL for all five sampling dates) that exceeded the EPA standard for primary recreational contact of 130 *E. coli* colonies per 100 mL. Fecal coliform to fecal streptococci (enterococci) ratios indicate that the possible sources of fecal contamination are animal (FC:FS < 0.7) or a mix of animal and human (FC:FS = 0.7 – 4.0).

Spring data were collected between 31 March and 21 April 2008. The bacteria counts were lower than in the fall sampling. The *E. coli* count for the sampling sites tested ranged from 0 to 320 colonies per 100 mL. The sample site at Lambert Hollow was consistently higher than any other sampling location, ranging from 40 to 320 colonies per 100 mL. The *E. coli* counts on two sampling dates at Lambert Hollow exceeded the EPA standard for primary recreational contact of 130 colonies per 100 mL. However, the geometric mean of the five sampling dates for Lambert Hollow was 124 colonies per 100 mL, below the EPA standard. The other sites evaluated during the spring collection were well below the EPA standard.

Physicochemical

Preliminary physicochemical data in Table 2.3 show temperature and pH readings within expected levels set by the KDOW. However, water temperature appears to be increasing as water moves downstream. This may be the result of a lack of tree cover over the stream. An increase in temperature causes a decrease in the amount of dissolved oxygen in the water, which decreases the amount and type of organisms that can survive. Temperature also affects conductivity - the warmer the water, the higher the conductivity. Instruments used to measure these parameters, the YSI and Hydorlab, auto correct for DO and Conductivity. However, it is still correct to say that DO impacts conductivity.

Table 2.3 Physicochemical data collected at Nichols Branch Bridge and Highway 519 bridge over Dry Creek in 2006.

	Temp, F		**Conductivity**		**pH**		**DO mg/L**	
Date	Nichols Branch	519 Bridge	Nichols Branch	519 Bridge	Nichols Branch	519 Bridge	Nichols Branch	519 Bridge
7/18/2006	80.67	87.42	211	305	7.82	8.43	9.43	10.27
8/1/2006	77.99	81.01	241	392	7.94	7.72	8.52	8.00
9/1/2006	67.06	69.15	239	335	no reading	no reading	8.50	9.70

KDOW regulates conductivity with narrative criteria, but has no numeric criteria. Numeric conductivity criteria have been established only for the main stem of the Ohio River. The limit is 800 umhos/cm. Conductivity guidance has been developed by EPA for coal permitting and is currently being reviewed by the Kentucky Division of Water. In the Dry Creek watershed, an elevated conductivity is considered to be approximately 300 umhos/cm and above. This is based on the Reference Reach levels for the Western Allegheny Ecoregion (reference reaches are discussed further in Chapter 3, p. 42).

Conductivity is measured to assist with determining pollution sources. Higher conductivity measurements indicate higher levels of dissolved minerals, charged particles, and sediment. Certain physiological effects on plants and animals are often affected by the amount of ions in the water. A rise in the conductivity could indicate that a septic system is failing because of the presence of chloride, phosphate, and nitrate.

Like conductivity, pH affects many chemical and biological processes in the water. For example, different organisms flourish within different ranges of pH with 6.5-8.0 providing conditions for a greater diversity of species. Low pH can reduce reproduction, as well as allow toxic elements and compounds to become mobile and available for uptake by aquatic plants and animals. This can produce conditions that are toxic to aquatic life, particularly to sensitive species like rainbow trout.

Nutrients

Initial nutrient data were collected in 1998 and 1999. These data were collected for the Gateway Health Department to assist with applications to get sewer infrastructure installed. Since then, only a few water samples have been collected for nutrient analysis. The most recent samples were collected in 2006, as part of a larger watershed sampling of the Triplett Creek Watershed. The limited numbers of samples provide some insight, although not conclusive, into some possible sources of pollutants. Increasing ammonium levels, which are often associated with animal (including human) waste, indicate increasing animal waste in a downstream direction. In contrast, the concentration of phosphate decreases downstream, suggesting less pollution from septic systems toward the mouth of Dry Creek. This is consistent with the presence of sewer lines in the downstream sampling areas. This is in line with the installation of sewer infrastructure by Morehead Utility Plant Board. The nitrate concentration, which also decreases in the downstream direction, supports this hypothesis as well. An increased soluble and insoluble sulfate concentrate has been observed. The source of this nutrient is unknown at this time.

Habitat Assessment

In order to provide a consistent assessment of habitat quality in the Dry Creek watershed, the same assessment protocols used by the Licking River Watershed Watch have been adopted. This method utilizes a visual assessment of in-stream and riparian habitat quality including substrate, channel morphology, bank structure, and riparian vegetation. Table 2.4 shows both the parameters used to conduct the assessments and a summary of the data collected in the fall of 2007. Kentucky was in a drought at that time, which resulted in quite low habitat scores due to the lack of water in the streams. Values for vegetative protection and bank stability were consistently low. The overall habitat scores ranged from 26 to 104. The maximum overall score is 200 and the minimum score is 0. A score of 130 is the minimum score that qualifies as a "supporting" habitat score. The overall score is determined by evaluation of 13 statements. These statements cover vegetation, habitat, and bank stability. The score can be affected by recent rainfall, which may affect the number of riffles and velocity of water. For this reason, May and June are typically the best times to conduct a habitat assessment. The approximate locations of the habitat assessments are shown in Figure 2.11.

Table 2.4. Summary of initial Habitat Assessment data collected in the Dry Creek watershed.

Site ID	***Headwaters***	***Jennings Septic***	***Ravenswood Bridge***	***Sugar Branch***	***Lambert Hollow***	***519 Bridge***	***Tile Storage Rd***
Epifaunal Substrate	5	7	17	7	0	0	0
Embeddedness	10	3	12	9	13	18	2
Velocity	5	6	4	1	0	0	0
Sediment Deposition	9	9	7	7	0	17	1
Channel Flow Status	4	3	1	2	0	0	0
Channel Alteration	8	6	7	1	11	7	8
Frequency of Riffles	17	17	18	17	0	0	0
Left Bank Stability	8	4	9	8	7	9	2
Right Bank Stability	8	3	9	4	6	8	1
LB Vegetative Protection	9	3	9	1	7	8	9
RB Vegetative Protection	9	4	9	0	7	8	2
LB Riparian Vegetative Zone Width	1	1	1	10	2	0	1
RB Riparian Vegetative Zone Width	4	2	1	4	1	0	0
Total Score	**97**	**68**	**104**	**71**	**54**	**75**	**26**

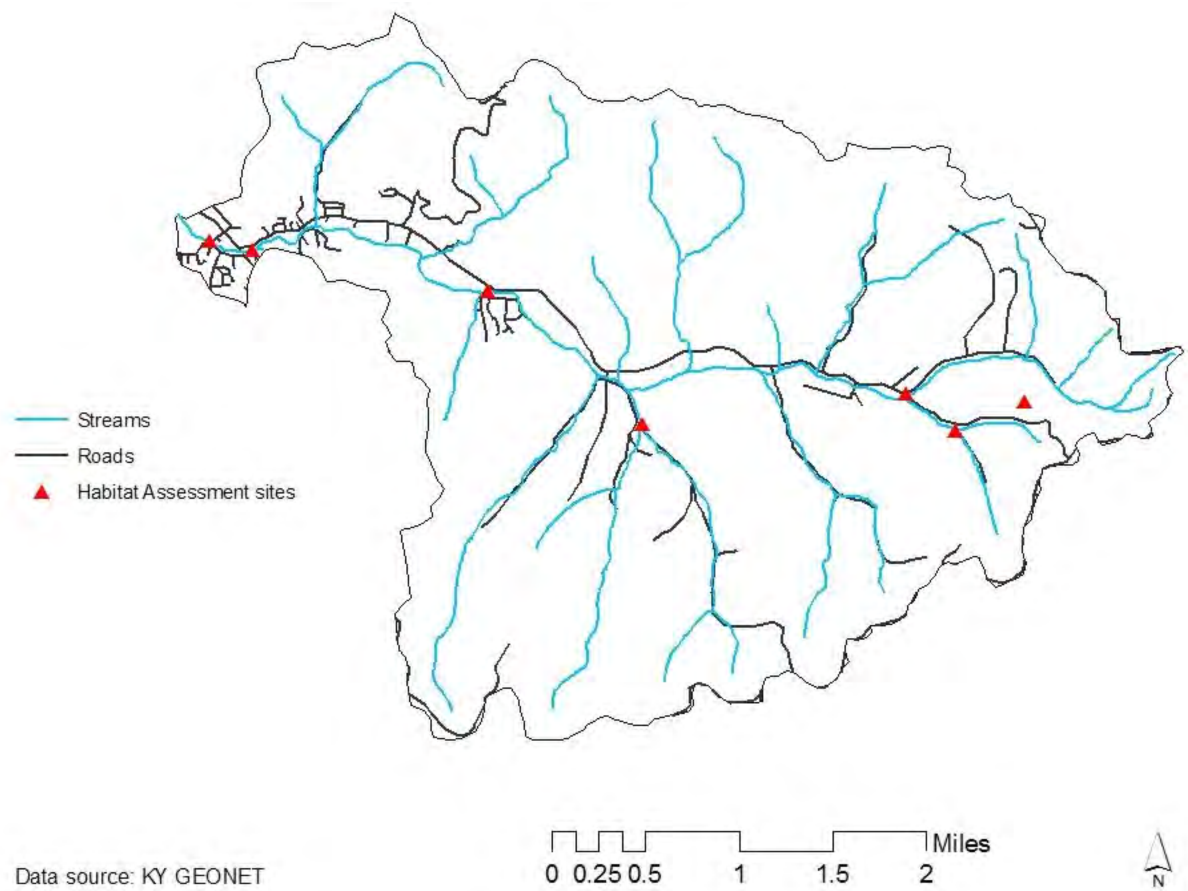

Figure 2.11. Map showing data collection sites for the initial Dry Creek Habitat Assessment completed in 2007.

Macroinvertebrates

There are limited macroinvertebrate data available for the Dry Creek watershed. One data set was collected in the summer of 2006 just downstream from the HWY 519 Bridge over Dry Creek by a Morehead State University graduate student (R. Johnson) for his M.S. thesis research. Figure 2.12 shows a summary of the number of macroinvertebrate species falling into each indicator group as determined by the Kentucky Water Watch Biological Monitoring Assessment Project. The good indicator group is made up of organisms that are generally pollution-intolerant. The moderate indicator group consists of organisms that can exist in a wide range of water quality conditions. The poor water quality indicator group includes organisms that are generally tolerant of the effects of pollution, such as low dissolved oxygen and excessive sedimentation. The absence of certain macroinvertebrates does not provide information on the source of the pollution, but they are able to provide us with some in sight to the extent pollutants are impacting streams.

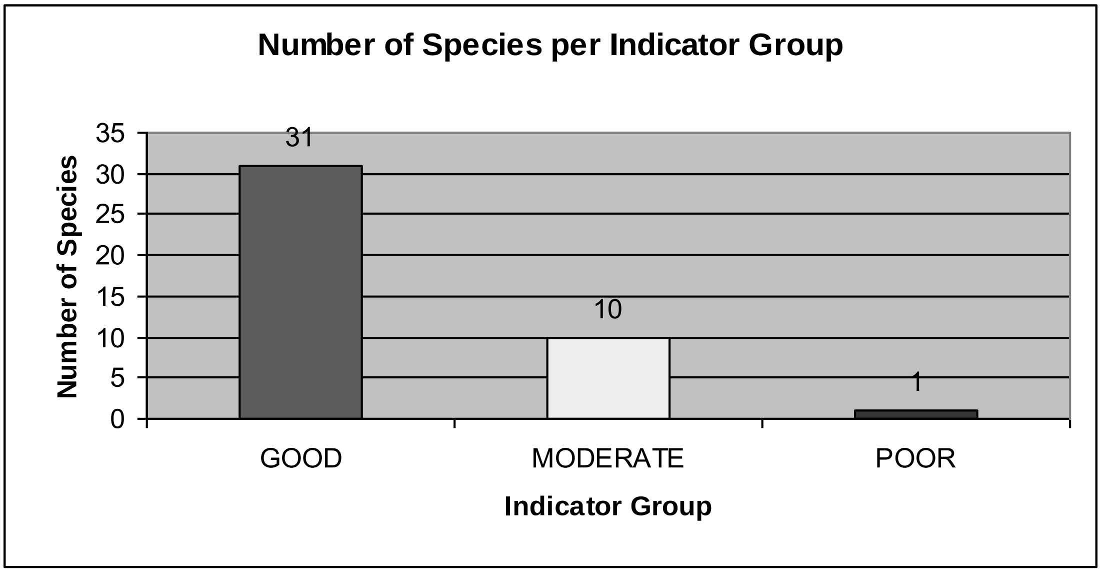

Figure 2.12. Summary of macroinvertebrate data collected in the summer of 2006, by indicator group (data from R. Johnson).

The United States Forest Service conducted another macroinvertebrate analysis near the mouth of Dry Creek on June 11, 1999. According to the results provided by Jon Walker, Hydrologist for the Daniel Boone National Forest, the macroinvertebrate rating was fair. The Macroinvertebrate Biotic Index rating was 57.96. More details of this study can be obtained from the USFS Daniel National Forest, Winchester Office.

The biotic index is a rating of water quality based on organisms (such as insects) living in the streams. Macroinvertebrates are primarily immature aquatic insects, crustaceans (crayfish), and other invertebrates that are visible without the use of magnification. Biotic index scores are related to the dissolved oxygen levels in streams. The dissolved oxygen levels are affected by stream temperatures (cold water has more oxygen) and riffles. The biotic index is different than other indicators because it represents the quality of the water over time. It also provides a picture of watershed health as organisms in the stream are ultimately affected by land use. Scores for biotic index can range from 0 to 100.

Ichthyofaunal

Fish are valuable assessments tools for evaluating the health of streams and watersheds because of their long life spans (2-10 years) and reliance on water for habitat. As a result they can reflect both long-term and short-term water quality. In addition, fish are a visible and valuable component of waterways that the public can easily relate too.

The most recent ichthyofaunal (fish) study of Dry Creek occurred from May 1999 – January 2000. There were two sampling sites evaluated, the first (#21) was located 0.6 km from the mouth, downstream of KY 519 bridge, and the second (#27) was located 3.1 km from the mouth, at bridge on Cardinal Road. Table 2.5 lists the 19 different fish species that were collected during the sampling period.

Table 2.5 List of Ichthyofaunal found in the Dry Creek, May 1999 – January 2000.

Common Name	**Scientific Name**
central stone roller	*Campostoma anomalum*
spot fin minnow	*Cyprinella spiloptera*
silver jaw minnow	*Ericymba buccata*
stripped shiner	*Luxilus chrysocephalus*
rosy face shiner	*Notropis rubellus*
blunt nose minnow	*Pimephales notatus*
creek chub	*Semotilus atromaculatus*
northern hog sucker	*Hypentelium nigricans*
northern stud fish	*Fundulus catenatus*
rock bass	*Ambloplites rupestris*
green sunfish	*Lepomis cyanellus*
long ear sunfish	*Lepomis megalotis*
blue gill	*Lepomis macrochirus*
spotted [Kentucky] bass	*Micropterus punctulatus*
green side darter	*Etheostoma blennioides*
rainbow darter	*Etheostoma caeruleum*
fantail darter	*Etheostoma flabellare*
Johnny darter	*Etheostoma nigrum*
banded darter	*Etheostoma zonale*

The Index for Biotic Integrity (IBI) scores for site # 21 was 36.3, and for site # 27 was 37.0 (on a scale of 60 [best] to 12 [worst]). Both scores are rated as fair to poor (McCafferty, 2000). The Index of IBI was first developed for use in small warm water stream by Dr. James Karr (Simon and Lyons, 1995). The index uses 12 categories, five points each, that that reflected fish species richness and composition, number and abundance of indicator species, trophic organization and function, reproductive behavior, fish abundance, and condition of individual fish.

Geomorphic

MSU geologists are focused on efforts that primarily involve measuring stream flow in Dry Creek, measuring "muddiness" of water (suspended sediment concentrations), and measuring bank erosion rates. These methods are detailed in the QAPP (Appendix B).

Results of the geomorphic portion of the watershed inventory are preliminary, and data gaps, especially at moderate to high flow, still exist. Efforts to monitor bank instability include visual assessment and GPS location of actively eroding banks (Figures 2.13 and 2.14), bank pinning, and measurement of channel cross-sections. So far, nearly 60 sites experiencing erosion or some form of mass wasting (for example, small slumps or "landslides') have been identified along Dry Creek and Sugar Branch alone. Results and summaries of our attempts to fill data gaps are discussed in Chapter 3 of this watershed-based plan.

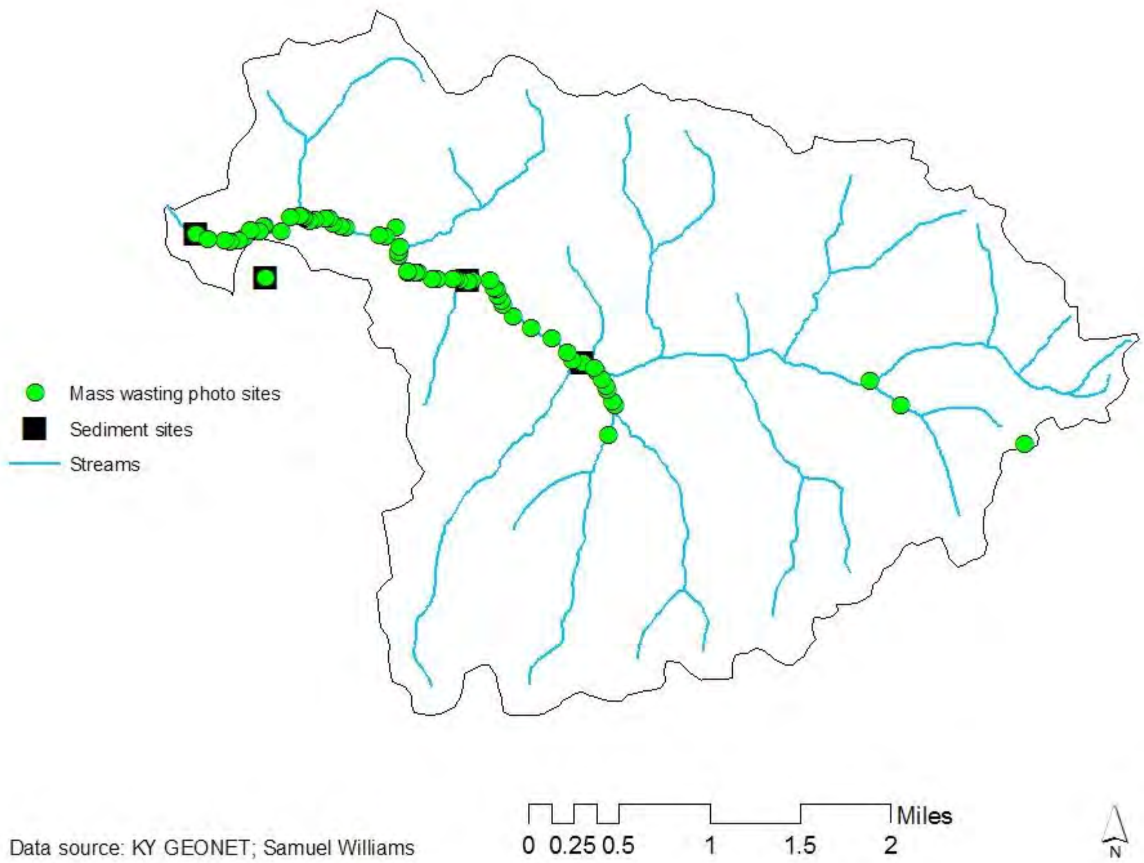

Figure 2.13 Map showing the locations of sediment testing sites and areas experiencing erosion or mass wasting in those parts of the Dry Creek watershed assessed to date.

Figure 2.14 Photo showing erosion and mass wasting at a site on Dry Creek.

Bank pinning and cross-section measurements are in their earliest stages. These methods measure the amount of bank material lost to erosion and mass wasting. Monitoring has begun on two sites, one in colluvium ("landslide" deposits) near the confluence of Sugar Branch and Dry Creek (3.03 stream miles from the mouth of Dry Creek) and another in alluvium (sediment deposited by streams during floods) at the Tile Storage Road Bridge (0.28 stream miles from the mouth of Dry Creek). Scouting for other easily accessible locations is ongoing. Results of these efforts and summaries of our attempts to fill data gaps will be discussed in Chapter 3 of this watershed-based plan.

PLAN FOR COLLECTING MORE DATA

The Dry Creek Watershed Planning Team followed the data collection guidelines outlined in "Creating a Formula for Success in the Salt and Licking River Basins grant #04-12: Monitoring plan for the Dry Creek Watershed-Based Plan, Version 3." This Quality Assurance Project Plan (QAPP), outlines all procedures for collecting and analyzing data for the Dry Creek monitoring plan, and was approved by the Kentucky Division of Water in May 2008 and is included as Appendix B.

Samples were collected on the first Tuesday of every month from June 2008 through February 2009. Information gathered on these dates helped fill existing data gaps and ensure that there was sufficient field sampling to constitute a comprehensive investigation of the watershed. In addition to the monthly sampling, autosamplers and hydrolabs were used to sample over a 24-hour time period during each season. Also, there was one sampling event (5 samples collected over 28 days) in November – December to calculate a geometric mean. The dates of the geometric sampling were November 4, 11, 18, 24, and December 2, 2008. Geometric mean samples for bacterial analysis have been collected in the watershed for all other seasons. The autosamplers, which are programmed to collect water samples over a 24 hour period, were set up at sites B and F on the first Tuesday of May, August, October, and December. The autosamplers were programmed to collect a water sample (500 mL) every hour for 24 hours. The hydrolabs were set up at each of the sites on the first Tuesday of the month. The hydrolabs were programmed to record pH, temperature, conductivity, and dissolved oxygen every 30 minutes for one week.

SUMMARY AND CONCLUSIONS

A number of problems negatively impact water quality within the Dry Creek watershed. The lack of good sewer infrastructure is probably of greatest concern because of the detrimental impact on humans who come into contact with the water during periods of high bacteria counts. According to residents that attended the community meeting, there have been numerous complaints of septic tank overflows which have allowed raw sewage to percolate above ground and create a health hazard and bad odors.

Other problems include nutrient and sediment pollution, but these seem to be less of a concern for most residents. Perhaps this is because nutrients and sediment do not smell and do not constitute obvious health hazards. Most residents notice times when excessive algae clogs streams, but most do not realize that nutrient pollution is the primary cause of this condition. Few people consider “dirt” or “mud” as a pollutant since few understand the role of sediment in transporting adsorbed (attached) pollutants or its role in destroying habitat. And while few people notice that their land by the creek is gradually disappearing due to erosion or creep, they do notice sudden losses due to slumping (“landslides”). The fact that the county has constructed gabion walls and that residents have armored stream banks with concrete debris, tires, etc. is vivid testament that bank instability is a serious issue. It is also a likely source for much of the “muddiness” seen in Dry Creek and its tributaries after storms.

A very positive aspect of the watershed is that headwater areas have experienced minimal development. Fallen Timber Branch, a major tributary of Dry Creek, also has experienced minimal development and channel alteration. Most of the other major tributaries of Dry Creek show signs of impairment. Extensive erosion and mass wasting along stream banks have been recorded on Dry Creek and Sugar Branch and are likely to exist throughout the watershed. The most difficult challenge associated with developing a watershed-based plan for the Dry Creek watershed will be to restore the natural flow of Dry Creek and its major tributaries.

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Dry Creek Watershed-based Plan
Chapter 3: Analysis of Impairments

INTRODUCTION

The previous chapter described natural conditions, existing impairments, land use and infrastructure in the Dry Creek Watershed. In Chapter 3, we use new data collected specifically for this study to identify pollutants, portions of the watershed most affected by these pollutants, and possible sources and causes of impairments. In Chapter 4, data analysis and model results presented here will guide our choices of Best Management Practices (BMPs) and help us set target values consistent with our watershed goals. Results presented below also define baseline (pre-BMP implementation) conditions in the watershed. After BMPs are implemented, additional field data will be collected and compared to these baseline data in order to assess BMP effectiveness and to determine whether we meet our target values.

Understanding Water Quality Data

In order to identify impaired waters in the Dry Creek Watershed, results from recently collected samples must be compared to established water quality criteria. For pollutants or physical parameters with statutory, numerical water quality criteria (WQC), this is a simple task. Identifying impairments caused by parameters with only narrative (descriptive, non-numerical) WQC is far more difficult.

For some pollutants (for example *E. coli*) an enforceable, statutory ("legal") WQC already exists. If the amount of pollutant in a sample exceeds the WQC, something in the watershed upstream of the sampling site is causing the impairment and some action must be taken to correct the problem. Comparing data to the WQC can be as simple as constructing a bar graph with a line drawn at the WQC. Sites exceeding the WQC will have bars higher than the line.

For other pollutants, the Kentucky Division of Water (KDOW) has not yet established WCQs. In these cases, we are forced to compare our data to other criteria. One approach is to compare data for each potential pollutant to a WQC set by another community or state with similar climate, topography, geology and land use. Another approach is to compare our data to reference reach waters, which are examples of the least-impacted streams in the region. Even though they may not be pristine, reference reach streams serve as physical, chemical and biological benchmarks of the least-disturbed conditions attainable in the region.

New data collected for this project and discussed later in this chapter are compared to WQC and reference reach data. Target values from reference reach data are based on averages of measurements from streams in the Western Allegheny Ecoregion (bioregion).

Concentrations, Loads and Yields

Samples represent far more than the amount of pollutant in the small volume of water collected. The sample is assumed or designed to represent all water flowing past the monitoring site at the time of sampling. And since the water originally flowed over and under the ground to reach the stream, the sample also reflects conditions in the watershed above the site. Expressions of the amount of contamination in stream water must reflect this reality. The terms explained below convey this information and will be used to compare our data to WQC and other criteria.

Concentration is the amount of a pollutant in a given amount of water, for example pounds per gallon (lbs/gal) or milligrams per liter (mg/L). If a large amount of pollutant is contained in a small amount of water, concentration is high. If the amount of pollutant is decreased in the same volume of water or if more clean water is added, the concentration decreases (i.e., the concentration is diluted).

The pollutant load of a stream is the weight (or mass) of a pollutant that moves through the stream over some period of time. Example units are pounds per year (lbs/yr) or kilograms per day (kg/d). To calculate load, the concentration determined from water samples is multiplied by discharge, which is a measurement of the amount of water passing one place in the channel in a period of time (e.g., cubic feet/second). An example of the use of loads is the establishment of Total Maximum Daily Loads (TMDLs) by the Kentucky Division of Water. A TMDL is an enforceable limit and represents the amount of a pollutant that a water body can receive and still meet established water quality criteria for designated uses. TMDLs also allocate the load among the various sources (e.g., industries, public utilities, etc.) that release the pollutant into the water body.

The yield of a particular pollutant is the load produced, on average, by each acre of land above the sampling point over a period of time. In other words, yield is the pollutant load divided by the area of the sub-basin upstream of a sampling site. Typical units are pounds per year per acre (lbs/yr/ac) or tons per year per square mile (tons/yr/sq mi). For example, a suspended sediment yield of 100 lbs/yr/ac means that, on average, every acre above the sampling point contributes 100 lbs/yr to the load. If in the course of comparisons, we find that two apparently similar sub-basins have very different yields, we might look more closely at their land use in order to identify a possible cause for the discrepancy.

NEW DATA COLLECTED

Chapter 2 summarized our understanding of conditions in the Dry Creek Watershed at the start of our efforts to develop this watershed-based plan and also identified information gaps that could only be filled by collecting new data. Here we summarize the types of new data we collected, where we sampled and made our measurements, and how we went about this work.

The various types of new data collected, the procedures/equipment used to acquire these data and the targets based on WQC or reference reach averages are summarized in Table 3.1. Collection sites are listed in Table 3.2 and shown in Figure 3.1. For those who are interested, detailed descriptions of the methods used to collect and analyze these data are outlined in the Quality Assurance Project Plan (QAPP) approved by the Kentucky Division of Water on June 6, 2008. The QAPP, entitled *Creating a Formula for Success in the Salt and Licking River Basins:*

Quality Assurance Project Plan for Watershed-based Planning and Monitoring in the Dry Creek Watershed (Version 4, Grant No: #04-12) is included as Appendix B.

Table 3.1 Summary of the types of new data collected, procedures/equipment used, and target values for each parameter

Parameter	Procedure / Equipment	Target Value	
		WQC	Ref. Reach
Dissolved oxygen	MS5 Datasonde and YSI 556	Min. 5.0 mg/L 24-hour ave, never below 4.0 mg/L	
pH	MS5 Datasonde and YSI 556	6 to 9 with less than a 1.0 change over 24-hours	
Temperature	MS5 Datasonde and YSI 556	Not to exceed temperature guidelines, see chapter 3 section on temp.	
Conductivity	MS5 Datasonde and YSI 556		145 µs/cm max.
Ammonia	SEAL™ AQ2	0.05 mg/L	
Phosphorus, Total	FOSS Tecator™ Digestor		0.0255 mg/L
Organic Nitrogen	Perkin Elmer 2400	NA	NA
Alkalinity	ASTM class A buret		41.6 mg/L
Habitat assessment	Habitat assessment form		Total score of 165
Biological assessment		No WQC or Ref. reach ave. Target is a “good” score on form	
Discharge (flow)	USGS Pygmy or AA flowmeter	NA	NA
Suspended sediment conc. (SSC)	Denver analytical balance, Gooch crucibles, 934-AH filters, vacuum, drying oven	NA, see chapter 4	
Total suspended solids (TSS)	Denver analytical balance, filters, vacuum		3.39 mg/L
Escherichia coli	Membrane filtration	Monthly geometric range of less than 130 cfu/100 mL or less than 240 cfu/100 mL or greater in 20% of samples	
E. coli DNA fingerprinting	Ethidium bromide-stained agarose gel, strain dendrograms	NA	NA

Table 3.2. Dry Creek Watershed-based Plan monitoring sites#.

Site #	Description	Parameters*
DC-0.28	Tile Storage Road Bridge	PGQNTS
DC-1.89	Ravenswood Bridge	PGQNTS
DC-2.84	Nichols Branch Rd. Bridge	PGQNTS
DC-4.52	Lambert Hollow Road	PQNT
SB-0.28	Sugar Creek Road Bridge	PQNT
SB-0.35	Amanda's Bridge	PQNT
UNK A	Below Catron Bridge	PQNT
UNK B	Above Catron Bridge	PN
UNK C	Catron Road	P

* P = Pathogens, G = Staff Gage, Q = Flow, N = Nutrients, T = TSS, S = SSC
# Amanda's Bridge was added since the development of the QAPP and a site originally proposed at the 519 Bridge was removed because of road construction.

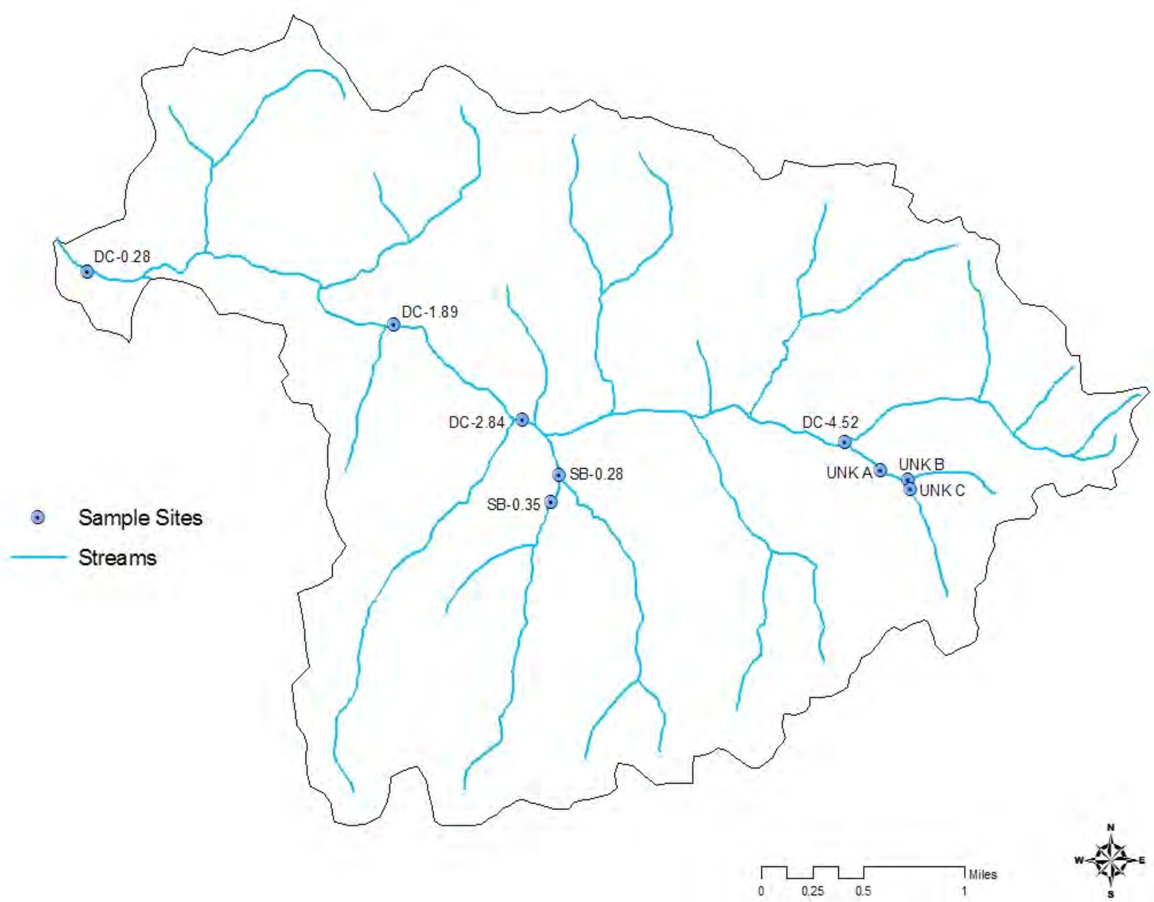

Figure 3.1 Monitoring sites where new samples and measurements were collected for this project.

Calculation of Loads

Methods used to calculate loads are not included in the QAPP (Appendix B). A brief explanation is included here so that results can be more fully understood and critically evaluated.

While the formula for calculating load is simple, choosing a method that generates representative loads from any given data set is complicated (Quilbe' *et al.*, 2006). Complications primarily arise from bias caused by infrequent sampling. To be truly representative, samples must be collected frequently (daily preferably) and at all flow conditions from a trickle to a raging flood. However, the time and expense of such sampling efforts is usually prohibitive, and we are often left with data sets that consist of monthly measurements for many but certainly not all flow conditions typical of any given year.

Given the time and funding constraints of the KWA grant for the Dry Creek Watershed-based Plan, annual loads for each potential pollutant were estimated using two simple approaches, both of which are subject to bias. First, loads were estimated by averaging all instantaneous loads (loads at the time of sampling) for all sampling dates. Second, loads were estimated by averaging concentrations of all samples and then multiplying the result by the mean annual flow (MAF). MAF is the average flow that can be expected for a stream in a year. MAF data used for these calculations were obtained from http://kygeonet.ky.gov/kyhydro/viewer.htm, which are derived from regression equations in Martin (2002).

For *E. coli*, a more sophisticated approach was used to compare measured instantaneous loads to allowable loads based on the WQC and our flow data. The resulting graphs, called load duration curves, are included and discussed in Appendix C for those who are interested.

RESULTS AND SIGNIFICANCE OF NEW DATA

Water Quality Data for Parameters with Set Standards (WQC)

All of the following parameters have statutory surface water WQC, which are listed in 401 KAR 10:031. Impairments are indicated when values (e.g., concentrations) from our field data fall outside of the numerical criterion. Parameters without straightforward, numerical criteria are presented and discussed in a separate subsection.

Dissolved Oxygen

Background and General Importance for Water Quality

Dissolved oxygen (DO) is a measure of the amount of oxygen in water. DO is affected by temperature and various biological processes. Cold water holds more oxygen that warm water. Flowing water also contains higher DO levels than standing water. DO is low in water containing high amounts of rotting organic matter (e.g., dead plants, sewage) since the microorganisms responsible for decomposition use oxygen. Aquatic animals are most vulnerable to lower DO levels in the early morning on hot summer days because water temperatures are higher then, stream flows are low, and aquatic plants do not produce oxygen at night.

The WQC for DO in warm water aquatic habitats (WAH) are: a) "dissolved oxygen shall be maintained at a minimum of five and zero-tenths (5.0) mg/L as a twenty-four (24) hour average in water with WAH use; b) the instantaneous minimum shall not be less than four and zero-tenths (4.0) mg/L in water with WAH use."

Results for DO Measurements

Table 3.3 Summary of 24-hour average DO (mg/L) values collected with Hach Hydrolabs.

Month	Date Deployed	Ending Date	Site ID	DO (mg/L)
June	6/17/2008	6/21/2008	DC-0.28	6.60
June	6/17/2008	6/23/2008	DC-1.89	5.12
June	6/17/2008	6/21/2008	DC-2.84	5.90
Nov	11/24/2008	11/30/2008	DC-0.28	11.57
Nov	11/24/2008	11/30/2008	DC-2.84	11.49

Table 3.4 Summary of instantaneous minimum DO (mg/L) values collected with Hach Hydrolabs.

Month	Date Deployed	Ending Date	Site ID	DO (mg/L) min.
June	6/17/2008	6/21/2008	DC-0.28	4.62
June	6/17/2008	6/23/2008	DC-1.89	3.85
June	6/17/2008	6/21/2008	DC-2.84	3.07
June	6/17/2008	6/18/2008	DC-4.52	7.24
Nov	11/24/2008	11/30/2008	DC-0.28	13.13
Nov	11/24/2008	11/30/2008	DC-2.84	9.33
Jan	1/10/2009	1/18/2009	DC-0.28	10.6
Jan	1/10/2009	1/15/2009	DC-2.84	10.59
Mar	3/25/2009	4/1/2009	DC-0.28	6.89
Mar	3/25/2009	4/1/2009	DC-2.84	3.96

Table 3.5 Summary of instantaneous minimum DO (mg/L) values collected with YSI probes.

Site ID	Date	DO (mg/L) min.
DC-0.28	8/5/08	4.02
DC-1.89	8/5/09	5.7
DC-2.84	9/2/08	6.79
DC-4.52	7/1/08	7.80
SB-0.28	3/31/08	7.75
SB-0.35	3/31/08	8.71
UNKA	4/21/08	8.41
UNKB	7/1/08	7.64

Analysis of DO Results

Water at all monitored sites met the WQC of 5.0 mg/L average DO over a 24-hour period, although DC-1.89 and DC-2.84 almost fell below this minimum acceptable level (see Table 3.3). Unfortunately, data collected every 30 minutes with the Hach Hydrolabs (Table 3.4) indicates that water at two sites periodically fell below the WQC of 4.0 mg/L DO for instantaneous readings. DC-1.89 and DC-2.84 were below 4.0 mg/L in June and DC-2.84 was below 4.0 mg/L in March. All DO readings measured with YSI Probes during water sampling events (Table 3.5) were compliant, although DC-0.28 nearly fell below the 4.0 mg/L minimum allowed by the WQC. DO is discussed more in the "Impairments Associated with Selected Physical and Chemical Parameters" section of this chapter.

pH

Background and General Importance for Water Quality

The acidity and alkalinity of surface waters are measured using pH. The pH of stream water is determined by rainwater pH, by interactions with rocks, sediment and soil, and by biological processes. The greatest diversity of aquatic species is found in waterways with a pH range of 6.5 – 8.0.

The WQC for WAH and recreational use states that "pH shall not be less than six and zero-tenths (6.0) nor more than nine and zero-tenths (9.0) and shall not fluctuate more than one and zero-tenths (1.0) pH unit over a period of twenty-four (24) hours." Recreational use WQC apply to waterways between May 1 and October 31.

Results for pH Measurements

Table 3.6. Summary of pH readings recorded with the Hydrolabs.

Month	Date Deployed	Ending Date	Site ID	pH max.	pH min.	Max 24 hr. pH change
June	6/17/2008	6/21/2008	DC-0.28	8.86	7.53	0.91
June	6/17/2008	6/23/2008	DC-1.89	8.07	7.38	0.63
June	6/17/2008	6/21/2008	DC-2.84	7.56	7.08	0.56
June	6/17/2008	6/18/2008	DC-4.52	7.7	7.48	0.22
Nov	11/24/2008	11/30/2008	DC-2.84	6.94	6.39	0.55
Nov	11/24/2008	11/30/2008	DC-0.28	7.59	6.49	0.69
Jan	1/10/2009	1/18/2009	DC-0.28	7.78	6.18	1.6
Jan	1/10/2009	1/15/2009	DC-2.84	6.93	6.69	0.22
Mar	3/25/2009	4/1/2009	DC-0.28	7.52	6.78	0.63
Mar	3/25/2009	4/1/2009	DC-2.84	7.21	5.95	1.26

Analysis of pH Results

Water measurements at most sites meet the WQC for pH (Table 3.6). One site (DC-2.84) had an instantaneous reading that did not fall between 6.0 and 9.0 (Table 3.6). Two sites (DC-0.28 and DC-2.84) showed pH changes greater than 1.0 over a 24-hour period and therefore did not meet the WQC, one site in January, the other in March. All readings taken during sampling events with YSI probes met the WQC. pH is discussed more in the "Impairments Associated with Selected Physical and Chemical Parameters" section of this chapter.

Alkalinity

Background and General Importance for Water Quality

Alkalinity is one of the best measurements for determining the streams capacity to neutralize acidic pollution from rainfall or wastewater. The alkaline compounds in the water (carbonates, bicarbonates, and hydroxides) combine with hydrogen to neutralize acidic inputs. Without this ability, streams would become acidic very quickly.

The WQC for alkalinity states that "Natural alkalinity as $CaCO_3$ shall not be reduced by more than twenty-five (25) percent. If the natural alkalinity is below twenty (20) mg/L $CaCO_3$, there shall not be a reduction below the natural level."

Results for Alkalinity Measurements

A natural alkalinity ($CaCO_3$) for the Licking River Basin is 41.6 mg/L based on an average value from Western Allegheny Reference Reach (KDOW, 2009b). Of the 85 samples collected in the watershed, 24 had alkalinities of less than 41.6 mg/L.

Analysis of Alkalinity Results

One sample, collected at DC-2.84 on 2/16/09, had low alkalinity (28 mg/L) and was reduced by 25% or more. DC-2.84 also had low alkalinity (32 mg/L) on 3/31/09. This value was 23% below 41.6 mg/L. DC-4.52 had low alkalinity (31.8 mg/L) on 4/14/09. Although sites DC-4.52 and DC-2.84 were not reduced by 25%, they are close enough to raise concern and to warrant more monitoring.

Temperature

Background and General Importance for Water Quality

Temperature in stream water can be affected by many factors. A loss of tree cover and shade tends to increase temperature. Excess sediment in the water also tends to increase temperature since the sunlight will heat the cloudy water faster than clear water. Increases in water temperature can adversely affect aquatic life since higher temperatures decrease DO.

The WQC for temperature states, "Temperature shall not exceed thirty-one and seven-tenths (31.7) degrees Celsius (eighty-nine (89) degrees Fahrenheit).

1. The normal daily and seasonal temperature fluctuations that existed before the addition of heat due to other than natural causes shall be maintained.
2. The cabinet may determine allowable surface water temperatures on a site-specific basis utilizing available data that shall be based on the effects of temperature on the aquatic biota that utilize specific surface waters of the commonwealth and that may be affected by person-induced temperature changes. a. Effects on downstream uses shall also be considered in determining site-specific temperatures. b. Values in Table 3.7 are guidelines for surface water temperature."

Table 3.7 WQC guidelines for surface water temperatures

Month/Date	Period Average		Instantaneous Maximum	
	(°F)	(°C)	(°F)	(°C)
January 1-31	45	7	50	10
February 1-29	45	7	50	10
March 1-15	51	11	56	13
March 16-31	54	12	59	15
April 1-15	58	14	64	18
April 16-30	64	18	69	21
May 1-15	68	20	73	23
May 16-31	75	24	80	27
June 1-15	80	27	85	29
June 16-30	83	28	87	31
July 1-31	84	29	89	32
August 1-31	84	29	89	32
September 1-15	84	29	87	31
September 16-30	82	28	86	30
October 1-15	77	25	82	28
October 16-31	72	22	77	25
November 1-30	67	19	72	22
December 1-31	52	11	57	14

Results of Temperature Measurements

Table 3.8. Summary of Hydrolab temperature readings that exceed temperature guidelines

Month	Date Deployed	Ending Date	Site ID	Ave. Temp (°C)	Max. Temp (°C)
Mar	3/25/2009	4/1/2009	DC-0.28	10.09	23.04
Mar	3/25/2009	4/1/2009	DC-2.84	9.47	21.63

Table 3.9. Summary of YSI Probe date and site that exceed temperature guidelines.

Date	Site ID	Temp (°C)	Degrees above
1/6/08	DC-1.89	10.04	0.04

Analysis of Temperature Results

None of the hydrolab temperature readings exceeded period average data. However, sites DC-0.28 and DC-2.84 did exceed instantaneous maximum temperatures in March (Table 3.8). All other temperatures recorded using the Hydrolabs were compliant. DC-1.89 was the only site to exceed instantaneous temperature readings (Table 3.9), using the YSI probes. Temperature is discussed more in the "Impairments Associated with Selected Physical and Chemical Parameters" section of this chapter.

Ammonia

Background and General Importance for Water Quality

Ammonia can be toxic to aquatic organisms. Some freshwater species are more sensitive than others. In 2004, the EPA began reviewing WQC for ammonia. According to several studies summarized in proceedings from the 2005 *Mussel Toxicity Testing Workshop*, some freshwater mussel species are more sensitive to ammonia exposure than other aquatic life (http://earth1.epa.gov/waterscience/criteria/ammonia/). These studies suggest that the criterion should be lower than 0.05 mg/L.

The existing WQC states, "Ammonia is the concentration of the un-ionized form shall not be greater than 0.05 mg/L at any time in-stream after mixing. Un-ionized ammonia shall be determined from values for total ammonia-N, in mg/L, pH and temperature, by means of the following equation:

$$Y = 1.2(\text{Total ammonia-N})/(1+10^{pKa-pH})$$
$$pKa = 0.0902 + (2730/(273.2 + T_c))$$

where:

T_c = temperature, degrees Celsius
Y = un-ionized ammonia (mg/L)"

Results of Ammonia Measurements

Of the 14 data points, five exceed the 0.05 mg/L.

Analysis of Ammonia Results

DC-1.89 had the most elevated and varied levels of ammonia with values ranging from 0.002 to 2.062 mg/L. All Dry Creek sites with ammonia data had at least one sample that exceeded 0.05 mg/L. No data exist for UNKA, UNKB, SB-0.35, and DC-4.52. Ammonia appears to be a common problem since all of the Western Allegheny Reference Reach data reported 0.05 mg/L at all sites.

Escherichia coli

Background and General Importance for Water Quality

Escherichia coli (Fig. 3.2), like many other bacteria, normally lives in the gastrointestinal tract of warm-blooded vertebrates (mammals and birds). Like all organisms, *E. coli* exhibits strain variation, in this case reflecting adaption to life inside different vertebrate hosts (and, more recently, life in the laboratory environment). Most strains are harmless. A few strains of *E. coli* are pathogenic, however.

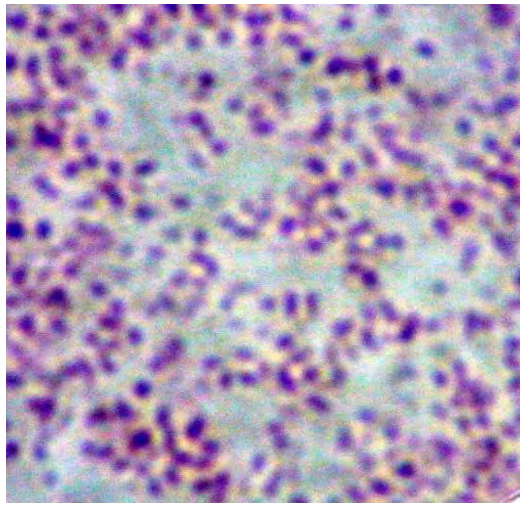

Figure 3.2. Gram-stained *Escherichia coli* cells collected from the Dry Creek watershed; magnified 1,000x.

E. coli cells are voided with feces by birds and mammals, including humans, at densities of millions of cells per gram of feces. Pathogenic microbes that infect the gastrointestinal tract are also voided with feces. These pathogens are often transmitted from one host to the next by feces-contaminated water. Testing water samples for specific pathogens is expensive and technically demanding. On the other hand, testing water samples for the presence of *E. coli* is relatively inexpensive, accurate, and simple. Given these facts, *E. coli* is commonly used as an indicator of fecal (and thus, potential pathogen) contamination in watersheds.

The state and federal governments have set various WQC for *E. coli* depending on the designated use(s) of a given stream, river or lake. For primary contact recreational use (swimming, wading, etc.), the WQC established by the KDOW for *E. coli* is 130 CFU/100 mL (this value represents a geometric mean of five samples collected over a 30-day period; CFU = colony forming unit, i.e., a viable bacterial cell); or 240 CFU/100 mL in no more than 20% of samples collected (KDOW, 2008). *E. coli* levels that exceed these established limits are associated with the presence of more aggressive pathogenic microbes that cause gastrointestinal illness (Dufour, 1984), and often indicate that a stream is impaired for its intended use.

Results of E. coli Sampling

Figures 3.3 and 3.4 show the geometric means of *E. coli* counts for sites in the Dry Creek Watershed for spring and summer 2008.

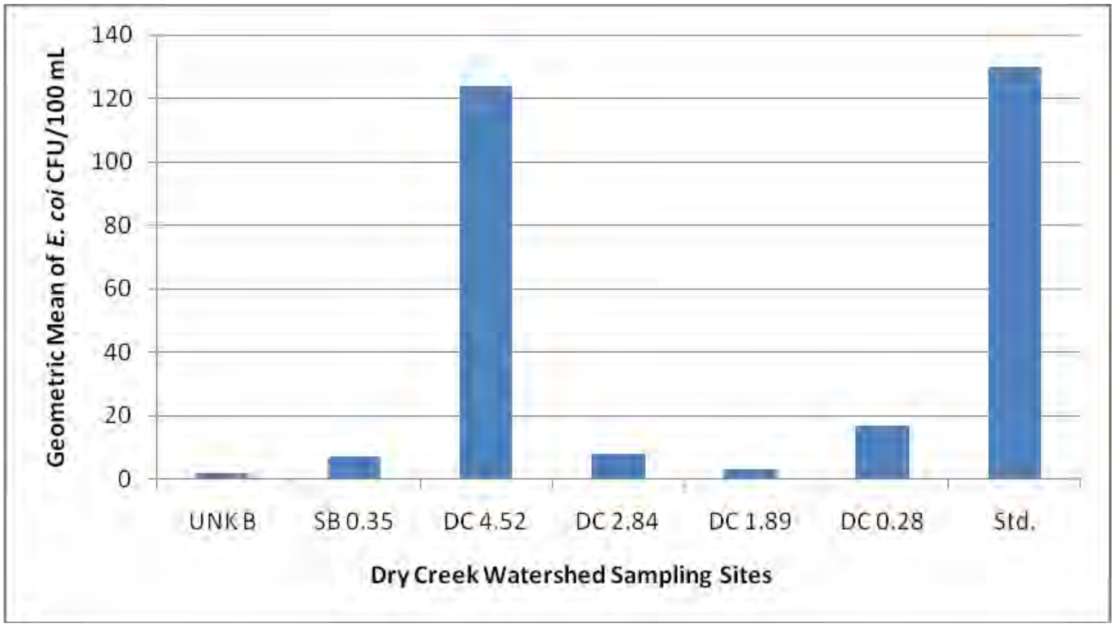

Figure 3.3 Geometric means of *E. coli* counts in the Dry Creek watershed, March-April 2008.

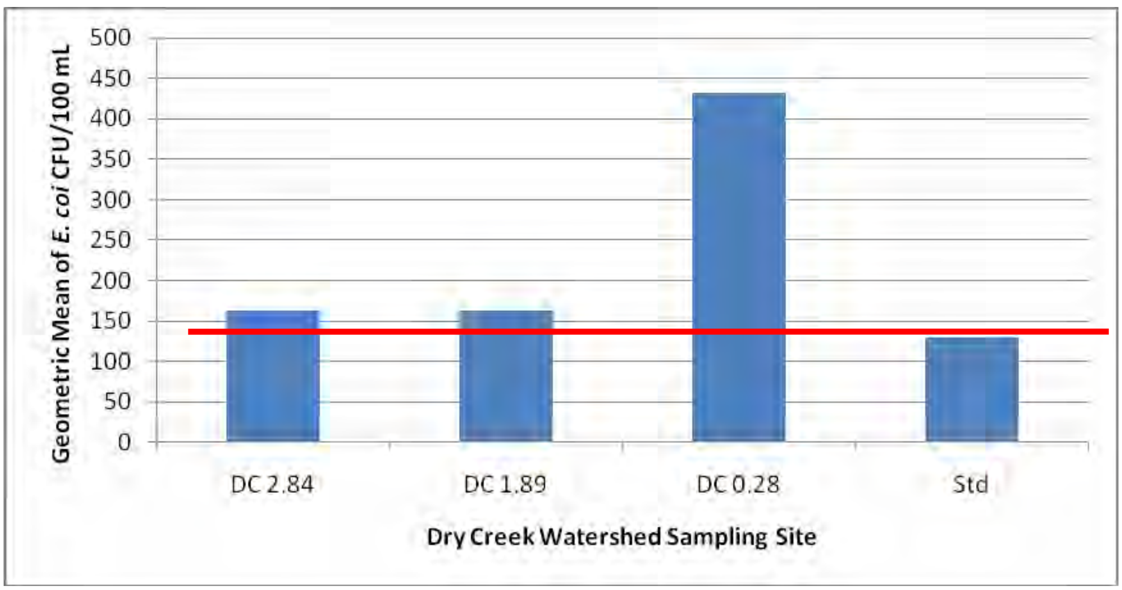

Figure 3.4. Geometric means of *E. coli* counts in the Dry Creek Watershed, August-September 2008. The red bar indicates the KDOW limit of 130 *E. coli*/100 mL.

Analysis of E. coli Sampling Results

No sites exhibit geometric means that exceeded KDOW limits during the spring 2008 sampling period. However, one site, DC-4.52, had 40% of samples that exceeded the KDOW limit of 240 *E. coli*/100 mL during that sampling period. Three sites (DC-2.84, DC-1.89, and DC-0.28) exceeded the limit of 130 *E. coli*/100 mL during the summer 2008 recreation season, and thus are impaired. Load duration curves and additional discussion of *E. coli* data are contained in Appendix C.

Water Quality Data for Parameters without Set Standards (WQC)
The parameters presented in this section lack specific (numeric) statutory criteria and must be compared to other criteria or interpreted within the general language of a narrative WQC. When possible, Western Allegany Reference Reach data (KDOW, 2009b) were used for comparison. In these cases, the average of each water chemistry parameter listed in KDOW (2009b) was calculated and used as an informal numeric WQC. For brevity, these informal WQC are referred to as 'reference reach data' in the remainder of this document.

Specific Conductance (Conductivity)
Background and General Importance for Water Quality
Conductivity is an indirect measurement of the number of ions and other charged particles in water and is often associated with elevated bacteria, phosphate, and nitrate. An example of human impacts on conductivity is the salting of roads, which increase conductivity. The WQC states, "total dissolved solids or specific conductance shall not be changed to the extent that the indigenous aquatic community is adversely affected." Based on reference reach data, 145 µs/cm appears to be the maximum value for conductivity before aquatic life is adversely affected.

Results of Conductivity Measurements
Table 3.10. Summary of Conductivity data collected using the Hydrolabs.

Month	Date Deployed	Ending Date	Site ID	Max Cond. (µs/cm)
June	6/17/2008	6/21/2008	DC-0.28	313
June	6/17/2008	6/23/2008	DC-1.89	195
June	6/17/2008	6/21/2008	DC-2.84	177
June	6/17/2008	6/18/2008	DC-4.52	781
Nov	11/24/2008	11/30/2008	DC-2.84	146
Nov	11/24/2008	11/30/2008	DC-0.28	454
Jan	1/10/2009	1/18/2009	DC-0.28	166
Jan	1/10/2009	1/15/2009	DC-2.84	113
Mar	3/25/2009	4/1/2009	DC-0.28	517
Mar	3/25/2009	4/1/2009	DC-2.84	128

Table 3.11. Summary of conductivity measurements (µs/cm) recorded during sampling events.

Site ID	Min	Max	Median
DC-0.28	66	492	220
DC-1.89	47	436	131
DC-2.84	47	242	129
DC-4.52	77	158	93
SB-0.28	114	250	131
SB-0.35	108	148	131
UNKA	92	182	123
UNKB	86	209	124

Analysis of Conductivity Results

All of the sites had maximum conductivity measurements above 145 µs/cm (Table 3.10 and 3.11). Generally higher conductivities were measured at sites in lower portions of the watershed. Morgan Fork (MF), a tributary not included in the Dry Creek HUC 14, appears to contribute to elevated conductivity levels at DC-0.28. A maximum measurement of 594 micromhos/cm was recorded at MF-0.25. Conductivity is discussed more in the "Impairments Associated with Selected Physical and Chemical Parameters" section of this chapter.

Total Suspended Solids

Background and General Importance for Water Quality

Total suspended solids (TSS) represent fine particles suspended in the water column. TSS consists of organic and inorganic solids, usually fine sediment and algae. It negatively impacts water quality by reducing sunlight penetration for aquatic plants, which provide oxygen and food for organisms. Settling of suspended solids can also cover creek bottoms, destroying habitat and smothering spawning areas. TSS shows considerable variation since it is controlled by many factors (e.g., discharge, rain events, land use, geology, productivity, nutrient levels, etc.).

The WQC states, "Total suspended solids shall not be changed to the extent that the indigenous aquatic community is adversely affected." Based on the reference reach data, 3.39 mg/L is used here as an informal maximum concentration that will not adversely impact aquatic life.

Results of TSS Measurements

Table 3.12. Summary of TSS (mg/L) for all sites.

Site	Average TSS	Median TSS	Maximum TSS	Minimum TSS
DC-0.28	14.11	5.0	156.6	0.4
DC-1.89	3.52	2.0	12.4	0.0
DC-2.84	3.75	1.6	21.2	0.4
DC-4.24	1.90	2.0	3.2	0.4
SB-0.28	5.0	1.4	17.2	0.0
SB-0.35	16.0	3.6	44.4	0.0
UNKA	3.47	2.0	8	0.4
UNKB	1.5	1.6	2.4	0.4
MF-0.25	10.7	1.6	102.8	0

Analysis of TSS Results

Every sampling site had TSS levels above 3.39 mg/L (Table 3.12). DC-0.28 had the most elevated values with a maximum concentration of 156.6 mg/L. Again, DC-0.28 is strongly influenced by Morgan Fork, which will be discussed further under the "Causes and Sources" section later in this chapter.

Sediment

Background and General Importance for Water Quality

As summarized in USEPA (2006, p. 99), sediment presents a "unique water quality problem when compared to most toxic chemicals, in that suspended solids and bedded sediments (including the organic fraction) occur naturally in water bodies in natural or background amounts and are essential to the ecological function of a water body." Examples of the beneficial effects of sediment in healthy streams include nutrient delivery and creation of micro-habitat such as sand bars. But excessive sediment, whether suspended ("floating") or bedded ("settled"), is the leading cause of stream impairment in the United States. Excessive sediment can adversely affect aquatic life (e.g., by smothering fish spawning beds); increase costs for some types of drinking water treatment systems; and hide the bottom and hazardous obstacles from swimmers, waders, and boaters.

The unique nature of sediment as a pollutant and the bewildering number of factors that control sediment supply and transport in streams (e.g., geology, topography, climate, discharge, land use, etc.) have presented huge obstacles in establishing a WQC for sediment (USEPA, 2006). Even comparing sediment data from place to place is difficult. Consequently, development of a widely applicable, numerical WQC is impossible. Most states, including Kentucky, rely on narrative criteria instead (USEPA, 2006, Appendix C). Unfortunately, narrative criteria are subject to multiple interpretations and provide only limited guidance. To make matters worse, Western Allegany Reference Reach data (KDOW, 2009b) provide no information for direct comparison with Dry Creek suspended sediment concentration (SSC) data.

Results of SSC Measurements

Suspended sediment concentration, sediment load, and sediment yield data collected in the Dry Creek Watershed are summarized in Tables 3.13 and 3.14. Implications of these data are discussed under "Sources and Locations of Impairments" and in Appendix C.

Table 3.13. Summary data for suspended sediment concentration (SSC)

Site	Suspended Sediment Concentration (mg/L)		
	Min+	Max	Ave
DC-0.28	0.75	235.29	12.27
DC-1.89	0.31	159.60	7.01
DC-2.84	0.65	108.13	10.21
MF-0.25	0.35	341.30	25.48

+ Minimum values reflect the lowest flow conditions that could still be sampled and measured. Minimum values are effectively 0 mg/L (un-measurable) at very low flows.

Table 3.14. Suspended Sediment Loads (lb/yr) and Yields (lb/yr/ac)

Site	Area above site	Ave. SSC x MAF		Ave. instantaneous loads	
	(acres)	Load	Yield	Load	Yield
DC-0.28*	7595	279498	36.80	5214329	686.55
DC-1.89	5875	154175	26.24	5430405	924.32
DC-2.84	4935	190574	38.62	3898636	790.00
MF-0.25	1339	130145	97.20	7012016	5237.00

* Morgan Fork is not included in the HUC-14 for Dry Creek but is a major tributary of Dry Creek. The confluence of Dry Creek and Morgan Fork is 0.28 miles (1500 ft) upstream of site DC-0.28. The drainage area and suspended sediment load of Morgan Fork has been subtracted from DC-0.28 values.

Nitrogen

Background and General Importance for Water Quality

Nitrogen occurs in the environment in several forms, most of which are major nutrients for plants and algae. Nutrient enrichment of surface waters may cause excessive algae and aquatic plant growth. The resulting, often explosive, plant and algae growth can cause large DO fluctuations. During daylight hours, this growth causes excessive DO production but at night, when photosynthesis ceases, plants and decomposers use up much of the oxygen. After seasonal die-off, rotting of excessive vegetation produced by nutrient enrichment may create large oxygen demands thus reducing DO and suffocating fish and other aquatic organisms.

Results of Nitrogen Measurements

Table 3.15. Summary of nitrogen data per site.

DC-0.28 (w/o MF)	Max. mg/L	Load (lb/yr)	Yield (lb/yr/ac)
NH4	1.724	763.343	0.085
Nitrate	0.435	177.393	0.020
NH4 + Nitrate		34087.370	3.855
DC-1.89			
NH4	1.771	976.496	0.166
Nitrate	0.963	223.234	0.038
NH4 + Nitrate		12897.800	2.195
DC-2.84			
NH4	1.382	486.254	0.099
Nitrate	1.172	218.524	0.044
NH4 + Nitrate		11915.67	2.410
DC-4.52			
NH4	0.452	18.609	0.029
Nitrate	0.641	29.224	0.046
NH4 + Nitrate		19049.670	29.905
SB-0.28			

NH4	0.210	16.406	0.012
Nitrate	1.840	82.367	0.061
NH4 + Nitrate		34023.120	25.165

Analysis of Nitrogen Results

All of the instantaneous combined nitrogen concentrations (Table 3.15) were lower than Total Nitrogen levels (10 mg/L) reported by the EPA to cause human health problems. It is important to note that only nitrate and ammonium data was collected for this project. Total nitrogen levels for this project were not compared to reference reach values because different laboratory methods were used to analyze samples. Combined nitrogen levels and all types of nitrogen were elevated at all sites lacking central sewer infrastructure (i.e., county sewer lines). The portion of the watershed around site DC-0.28 is entirely served by centralized sewers. In general, nitrogen input decreases in sites closer to the mouth of Dry Creek. Nitrogen is discussed more in the "Impairments Associated with Selected Physical and Chemical Parameters" section in this chapter.

Phosphorus

Background and General Importance for Water Quality

Total phosphorus (TP) is made up of soluble and non-soluble phosphorus. Soluble phosphorus (dissolved phosphate or ortho-phosphorus) is more readily available for use by organisms and is more likely to lead to rapid algal growth. Therefore, this nutrient can lead to low DO and higher pH. Non-soluble phosphorus is sediment-bound and is less likely to promote rapid algal growth but remains available for organism use for longer time periods.

Results of Phosphorous Measurements

The average TP of the reference reach streams is 0.0255 mg/L. All of the sites in this study had at least one data point that exceeded 0.0255 mg/L of TP (Table 3.16).

Table 3.16. Summary of Total Phosphorus data for each site.

DC-0.28 (w/o MF)	Load (lb/yr)	Yield (lb/yr/ac)	Max. conc. (mg/L)	(Median conc. mg/L)
Dis. P	50.284	0.006	0.265	0.019
TP *	309.280	0.035	0.561	0.366
DC-1.89				
Dis. P	76.167	0.013	0.581	0.020
TP	293.6145	0.050	0.928	0.451
DC-2.84				
Dis. P	44.336	0.009	0.185	0.023
TP	181.391	0.037	0.898	0.041
DC-4.52				
Dis. P	1.666	0.003	0.029	0.033
TP	1.615	0.003	0.118	0.020
SB-0.28				
Dis. P	11.415	0.008	0.211	0.066
TP	8.0766	0.006	0.227	0.045
SB-0.35				
Dis. P	1.0984	0.002	0.026	0.015

TP	4.654	0.007	0.396	0.057
UNKA				
Dis. P	0.479	0.002	0.025	0.011
TP	0.664	0.002	0.113	0.016

*The TP values at this site *include* MF, since no TP data for MF exist.

Analysis of Phosphorous Measurements

TP concentrations greatly exceed the 0.0255 mg/L found in reference streams. The highest concentrations were found on the main stem of Dry Creek at sites DC-1.89 and DC-2.84. Phosphorus is discussed more in the "Impairments Associated with Selected Physical and Chemical Parameters" section in this chapter.

Sulfate

Background and General Importance for Water Quality

Sulfate (SO_4) occurs naturally in water. Ingestion of water containing very high levels of sulfate can cause diarrhea. To prevent aesthetic effects (i.e., bad taste and odor), sulfate in drinking water currently has a secondary maximum contaminant level (SMCL) of 250 (mg/L).

The EPA website states (http://safewater.custhelp.com/cgi-bin/safewater.cfg/php/enduser/std_adp.php?p_faqid=1509):

"After reviewing the best available public health and occurrence information, EPA has made the determination not to regulate sulfate with a NPDWR at this time, because it would not present a meaningful opportunity for health risk reduction for persons served by public water systems (PWSs). Although sulfate occurs in many PWSs nationally, the weight of evidence suggests that the adverse health effect is generally mild, of short duration, and generally occurs at concentrations considerably greater than 500 mg/L, except in very limited circumstances when sulfate co-occurs with magnesium and high total dissolved solids, which exacerbate its laxative effects. EPA is issuing a final Drinking Water Advisory to provide guidance to communities that may be exposed to drinking water with high sulfate concentrations (68 FR 42897, 42905; July 18, 2003)."

Results of Sulfate Measurements

Table 3.17 Sites where sulfate concentration (mg/L) exceeded those from reference reach data.

Site ID	Max. concentration	Median concentration
DC-1.89	98.28	15.33
DC-2.84	102	16.73
UNKA	38.6	6.69

Analysis of Sulfate Results

The average sulfate value of the reference reach data is 16.75 (mg/L). Sites UNKA, DC-2.84, and DC-1.89 exceeded 16.75 mg/L (Table 3.17). None of the values exceeded the EPA drinking water maximum contaminant levels of 500 mg/L.

STREAM ASSESSMENT

As discussed in Chapter 2, various land use practices negatively impact the water quality of Dry Creek and its tributaries. An EPA Watershed Inventory Form, which was downloaded from the EPA Watershed web site, was used to conduct a visual watershed inventory for the Dry Creek Watershed. Results of this inventory identify the presence of 10 bridges, 15 drain pipes, 7 drainage ditches, 1 storm drain, 3 vehicle crossings, and 4 natural gas pipeline crossings on Dry Creek. Approximately 1 mile of 5.8 miles of Dry Creek has been straightened. In addition, there are signs of ATV use along and in Dry Creek for short sections as well as obvious use of equipment (e.g., Bobcats or front-end loaders) to move large quantities of gravel. The alterations described above do not include Dry Creek tributaries, only Dry Creek itself. Figures 3.5 through 9 show examples of commonly observed, poor land use practices.

Figure 3.5. Example of vegetative cover being removed and not replanted.

Figure 3.6. Examples of pipeline crossings on Dry Creek.

Figure 3.7. Examples of stream straightening and private bank armoring.

Figure 3.8. An example of poor land use. The photo on the left is a road cut into a hillside. Note the overhanging, eroded bank and gullied road. The photo on the right is the same site during moderate rainfall.

Figure 3.9. Removal of trees from riparian zones (left) and channelization/bank armoring (right).

Habitat Assessments

Habitat assessments focus primarily on riparian zone habitats (stream banks). The worst possible score is 0, while the best possible score is 200. For this study, assessments were completed during each season in order to observe different flow conditions since flow strongly affects scoring. Results were then averaged for each site (Table 3.18).

Habitat quality varies widely throughout the watershed (Table 3.18). Riparian zones have been extensively altered. Trees have been removed from one side and, in many cases, both sides of streams. The best score for the sites investigated was 126 (DC-0.28, Figure 3.10) and the worst score was 51 (SB-0.35, Figure 3.9).

Figure 3.10. Photos of sites with best (DC-0.28, left) and worst habitat scores (SB-0.35, right).

The lowest average scores were assigned to riparian vegetation zones. Highest scores would be given to a site that has vegetation cover of 18 meters or more. The vegetation cover is scored higher if it consists of native plants. The average vegetation zone scores for the entire assessment was 2 (left bank) and 3 (right bank). The maximum score per bank is 20. The lack of vegetation cover is a large contributor of bank erosion. Vegetative protection and velocity/depth regimes each had an average score of 4 out of 20.

Although the SOP followed for Dry Creek watershed project is not identical to the SOP used to obtain reference reach data, some comparisons can be made. The average habitat score of the reference reach data (with the same scoring criteria) is 165. None of the average scores along Dry Creek were over 100.

Table 3.18. Averaged habitat assessment data.

Site ID	DC-0.28	DC-1.89	DC-2.84	DC-4.52	SB-0.28	SB-0.35	UNKA
Epifaunal Substrate	7.2	7.8	11.2	4.8	5.4	5.2	8.25
Embeddedness	9.4	12.6	13.2	13.4	9.8	12.2	12.25
Velocity	5.4	3	6.2	4	3	3.2	2
Sediment Deposition	9	7.8	9.8	6.8	9.2	10	15
Channel Flow Status	11.8	7.8	8.2	3.2	6	5.8	5.75

Channel Alteration	5.2	5.8	6.8	12.4	5.6	7	15.25
Frequency of Riffles	5.8	8.8	11.2	7.2	6.2	6.0	1.25
Left Bank Stability	6.6	4.0	6.0	6.0	5.8	4.6	8.25
Right Bank Stability	7	5.2	5.2	6.2	2.8	4.4	7.5
LB Vegetative Protection	7.4	4.6	3.8	3.8	2	2.6	7.75
RB Vegetative Protection	7.8	7.2	4.4	4.2	1.4	2.2	6.75
LB Riparian Vegetative Zone Width	1	1.2	3.6	2.6	2.6	0.8	6
RB Riparian Vegetative Zone Width	3.4	2.4	2.4	2.4	3.8	0.8	2.5
Total Average Score	87	78.2	92	77	63.6	64.8	98.25

Ichthyofauna

The most recent ichthyofaunal (fish) study of Dry Creek was conducted from May 1999 to January 2000 (McCafferty and Eisenhour, 2001). Two sites were evaluated, the first (#21, in McCafferty and Eisenhour, 2001) was located 0.6 km from the mouth of Dry Creek (downstream of the KY 519 bridge) and the second (#27, in McCafferty and Eisenhour, 2001) was located 3.1 km from the mouth of Dry Creek (at Cardinal Road bridge). Nineteen different fish species were collected during the sampling period. The Index for Biotic Integrity (IBI) scores for site #21 was 36.3 and for site #27 was 37.0 (where 60 is the best possible score and 12 the worst). McCafferty and Eisenhour (2001) rated both scores as fair to poor. Table 3.19 shows which of the 19 species found in Dry Creek are also found in reference reach streams.

Although many of the species found in the Triplett Creek Watershed are also found in reference reach streams, this does not necessarily indicate that the water and habitat quality is good. High diversity and high abundance of all species and of individuals in a single species are better indicators of water and habitat quality. The number of fish species in the Triplett Creek watershed has not changed significantly over the past 100 years even though some sensitive species have disappeared and non-native species have moved in (McCafferty and Eisenhour, 2001).

Table 3.19. Summary of ichthyofaunal study of Dry Creek.

Ichthyofauna (fish) in Dry Creek	Found in Reference Streams (Y= yes, N=no)
Campostoma anomalum (central stone roller)	Y
Cyprinella spiloptera (spot fin minnow)	Y
Ericymba buccata (silver jaw minnow)	N
Luxilus chrysocephalus (stripped shiner)	Y
Notropis rubellus (rosy face shiner)	Y
Pimephales notatus (blunt nose minnow)	Y
Semolitus atromaculatus (creek chub)	Y
Hypentelium nigricans (northern hog sucker)	Y
Fundulus catenatus (northern stud fish)	N

Ambloplites rupestris (rock bass)	Y
Lepomis cyanellus (green sunfish)	Y
Lepomis megalotis (long ear sunfish)	Y
Lepomis microchirus (blue gill)	Y
Micropterus punctulatus [spotted (Kentucky) bass]	Y
Etheostoma blennioides (green side darter)	Y
Etheostoma caeruleum (rainbow darter)	Y
Etheostoma flabellare (fantail darter)	Y
Etheosomta nigrin (Johnny darter)	Y
Etheostoma zonale (banded darter)	Y

Biological Assessment

For this Watershed Based Plan a simple biological assessment was completed because of the short timeframe of the project and budget restrictions. The biological assessment consisted of the identification of common aquatic macroinvertebrates (e.g., dragon fly larvae). Macroinvertebrates are pollutant input indicators because they respond quickly to changes in water quality.

The assessment was completed once during each season. Figure 3.11 is a summary of the average results by site. The good indicators (group 1) are made up of organisms that are generally pollution-intolerant. The moderate indicators (group 2) consist of organisms that are able to tolerate a wide range of water quality conditions. The poor water quality indicators (group 3) include organisms that are generally tolerant of the effects of pollution such as low dissolved oxygen and excessive sedimentation. The absence of certain macroinvertebrates does not provide information on the source of the pollution, but it does provide us with some insight regarding the extent to which pollutants are impacting streams.

The good water quality indicator species increased in locations where water was present all year. A predominance of positive water quality indicators was present at UNKA. This site does not have houses upstream and is mostly wooded. At site SB-0.28, aquatic worms were often observed in large quantities, which accounts for the high amount of Group 3 (bad) indicators.

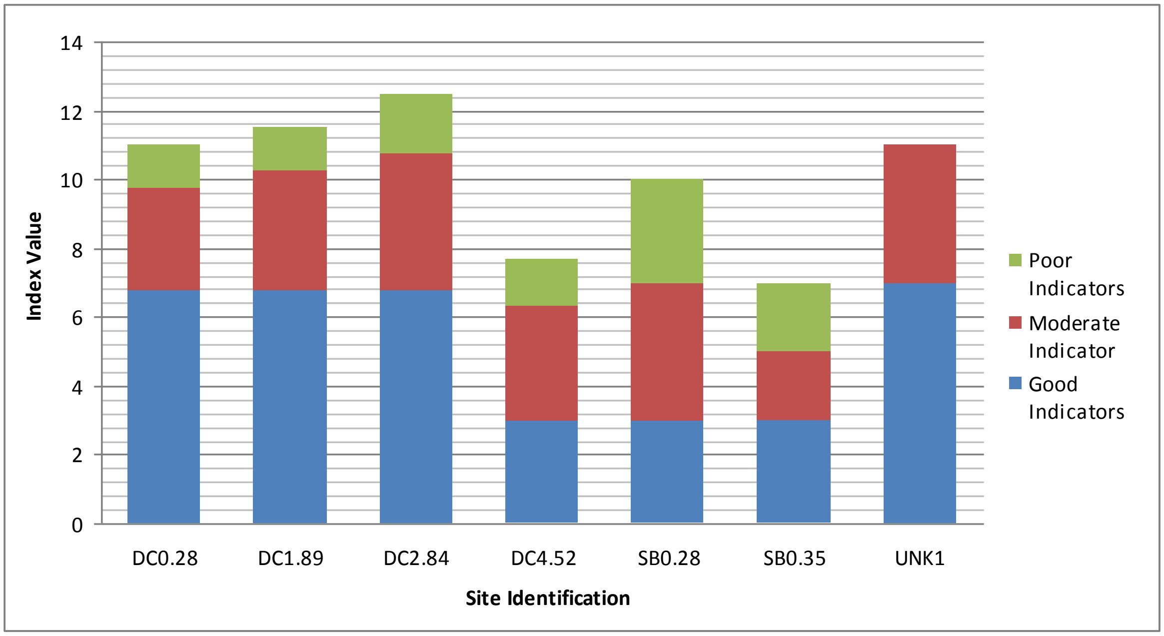

Figure 3.11. A summary by site of the average index value for each taxa group.

POLLUTANT LOAD PREDICTION

Model setup

A Geographic Information Systems (GIS)-based water quality model approved by the Environmental Protection Agency (EPA), the ArcView-based Generalized Watershed Loading Function (AVGWLF; http://www.avgwlf.psu.edu), was used to estimate annual average sediment, nitrogen (total and dissolved) and phosphorous (total and dissolved) loads for the Dry Creek Watershed and selected sub-basins (Figure 3.12). ESRI's ArcGIS software was used to delineate sub-basins upslope of each field sampling site using a 10 m digital elevation model of the watershed. AVGWLF predictions were made using inputs of daily rainfall and temperate, along with GIS-based map layers depicting watershed conditions (e.g., soils, land use, and elevation), and information on existing livestock operations and Best Management Practices (BMPs). Output sediment and nutrient loadings were calculated for each watershed/sub-basin as a whole, as well as for variable-size source areas (e.g., developed, forested and hay/pasture) within each watershed/sub-basin.

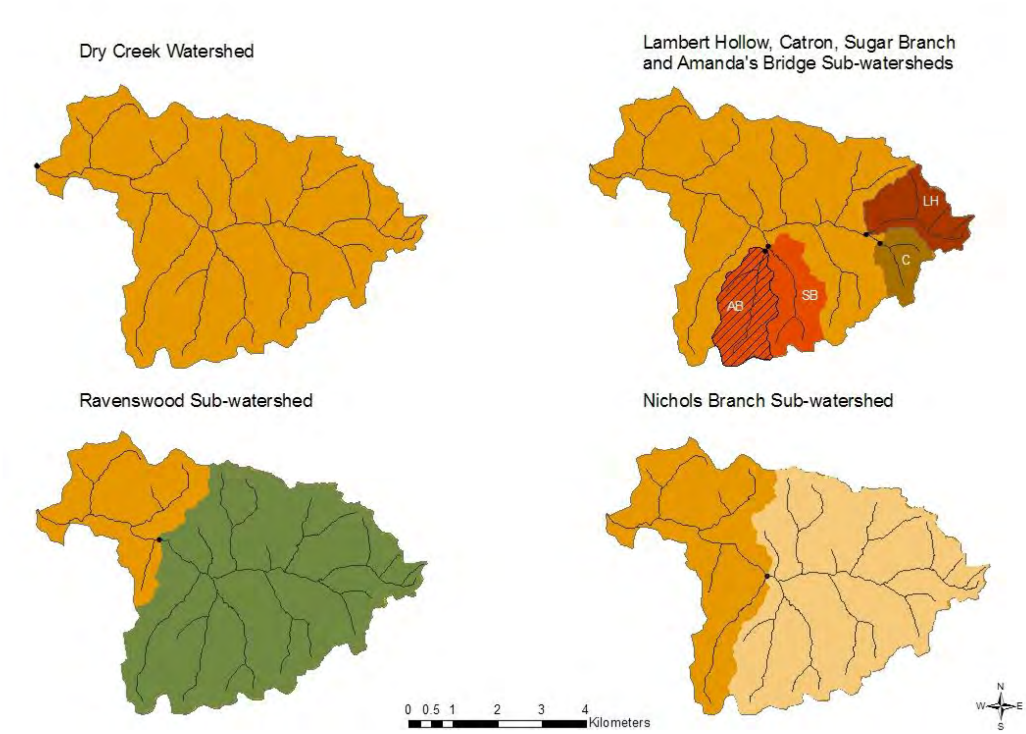

Figure 3.12: Dry Creek watershed and sub-basins. Black dots show locations of sampling sites shown in Figure 3.1.

Two sets of model simulations were run for each watershed/sub-basin (hereafter, watershed), one for a three-year ‘wet’ period and one for a three-year ‘dry’ period. Total rainfall was 150 inches for the wet period (2004-2006) and 119 inches for the dry period (1999-2001). The use of two climate periods was an attempt to provide upper (wet period) and lower (dry period) prediction limits which should encompass the range of possible model predictions for each watershed. With the exception of rainfall and temperature data, the same set of input files was used to run the model for each climate period in each watershed.

Table 3.20 highlights key characteristics of each watershed including its size, the amount of land under forest, agriculture and development, stream miles running through agricultural land, and total stream miles. Amanda’s Bridge, a sub-basin of the Sugar Branch watershed, is the most heavily forested of all the watersheds and, not surprisingly, contains the least amount of agricultural and developed land. Lambert Hollow contains over twice as much agricultural land as the next leading watersheds, Nichols Branch and Catron. Outside of the Dry Creek Watershed, Catron contains the highest amount of developed land. With the exception of Amanda’s Bridge, between 15% and 19% of the total stream miles in each of the remaining watersheds run through agricultural land.

Table 3.20. Selected characteristics of the Dry Creek Watershed and sub-watersheds*

	Dry Creek *(DC-0.28)*	Ravenswood *(DC-1.89)*	Nichols Branch *(DC-2.84)*	Lambert Hollow *(PT-0.01)*	Catron *(UNK1)*	Sugar Branch *(SB-0.28)*	Amanda's Bridge *(SB-0.35)*
Area (acres)	7464	5737	4833	630	352	1304	659
% Forested	84	87	86	74	82	91	96
% Agriculture	8	9	10	21	10	6	2
% Developed	7	4	4	4	7	3	2
Stream Miles in Agriculture	4.4	3.9	3.6	0.5	0.2	0.8	0.1
Total Stream Miles	28.2	21.9	18.9	3.3	1.2	4.3	2.2

*The Forested category includes coniferous, deciduous and mixed forest types; the Agriculture category includes both row crops and hay/pasture; the Developed category includes both low and high intensity development.

Model Results

Results by Sub-basin

Modeled loads were compared with field-based average annual load values estimated by: (1) averaging all available instantaneous load values and (2) averaging concentrations of all available instantaneous load values and then multiplying the results by mean annual flow (MAF) values obtained from the Kentucky GEONET's Hydrologic Viewer (http://kygeonet.ky.gov/kyhydro/viewer.htm); MAF values were derived from regression equations in Martin (2002). Table 3.21 shows AVGWLF model predictions of average annual sediment, nitrogen and phosphorous loads. Due to sampling limitations, field-based estimates of sediment load were only available for the Dry Creek Watershed and the Ravenswood and Nichols Branch watersheds, while field-based phosphorous loads (only) were available for all watersheds.

Model predicted sediment and total and dissolved nitrogen loads all increased with watershed size in both the wet and dry periods. Total and dissolved phosphorous loads followed the same trend, with the exception of the Lambert Hollow watershed, which generated more total phosphorous than the larger Sugar Branch watershed. This may be explained by the fact that the Lambert Hollow watershed contains approximately 85% of the cattle in the Dry Creek Watershed, while Sugar Branch holds the remaining 15% plus a few horses.

Table 3.21. AVGWLF model predictions of average annual sediment, nitrogen (total and dissolved), and phosphorous (total and dissolved) loads for the wet and dry climate periods. All values are in lbs/yr.

Loads	Dry Creek *(DC-0.28)*	Ravenswood *(DC-1.89)*	Nichols Branch *(DC-2.84)*	Lambert Hollow *(PT-0.01)*	Catron *(UNK1)*	Sugar Branch *(SB-0.28)*	Amanda's Bridge *(SB-0.35)*
Wet period							
Sediment	2,504,451	1,620,398	1,358,048	134,482	94,799	383,604	130,073
Total P	3,946	3,258	2,950	1,162	126	816	240
Diss. P	666	551	487	146	38	110	42
Total N	40,349	31,993	27,503	5,732	1,687	7,317	3,300
Diss. N	32,869	25,779	21,720	2,811	1,526	5,844	2,959
Dry period							
Sediment	1,479,302	943,578	787,050	77,162	52,911	216,053	72,752
Total P	2,438	2,053	1,881	851	68	494	132
Diss. P	346	287	251	73	18	57	22
Total N	23,071	18,453	15,933	3,708	882	4,173	1,825
Diss. N	18,021	14,169	11,892	1,429	791	3,212	1,637

AVGWLF load predictions in Table 3.21 were divided by the corresponding watershed area in order to calculate average annual yields in lbs/yr/acre for each climate period (Table 3.22). The most forested watershed, Amanda's Bridge, had the lowest value of sediment yield followed by the Lambert Hollow and Catron watersheds at the head of the Dry Creek Watershed. Lambert Hollow, which contains the greatest amount of land in agriculture (as well as most of the cattle), produced the highest total and dissolved phosphorous and total nitrogen yields; dissolved nitrogen yields were very similar across all watersheds.

Table 3.22. AVGWLF model-based calculations of average annual sediment, nitrogen (total and dissolved), and phosphorous (total and dissolved) yields for the wet and dry climate periods. All values are in lbs/yr/acre.

Yields	Dry Creek *(DC-0.28)*	Ravenswood *(DC-1.89)*	Nichols Branch *(DC-2.84)*	Lambert Hollow *(PT-0.01)*	Catron *(UNKA)*	Sugar Branch *(SB-0.28)*	Amanda's Bridge *(SB-0.35)*
Wet period							
Sediment	335.54	282.50	280.99	213.80	269.32	294.17	197.38
Total P	0.53	0.57	0.61	1.85	0.36	0.63	0.36
Diss. P	0.09	0.10	0.10	0.23	0.11	0.08	0.06
Total N	5.41	5.58	5.69	9.11	4.79	5.61	5.01
Diss. N	4.40	4.49	4.49	4.47	4.34	4.48	4.49
Dry period							
Sediment	198.19	164.50	162.85	122.67	150.32	165.68	110.40
Total P	0.33	0.36	0.39	1.35	0.19	0.38	0.20
Diss. P	0.05	0.05	0.05	0.12	0.05	0.04	0.03
Total N	3.09	3.22	3.30	5.90	2.51	3.20	2.77
Diss. N	2.41	2.47	2.46	2.27	2.25	2.46	2.48

Results by Sub-basin and Land Use Type

AVGWLF model calculations of average annual sediment, nitrogen and phosphorous yields (lbs/yr/acre) by watershed and major land use type (forest, agriculture and developed) for each climate period are displayed in Table 3.23 (wet) and Table 3.24 (dry). In all watersheds, in both climate periods, the greatest amount of sediment was produced by developed land, usually followed by agricultural land. Not surprisingly, pollutant loads were larger for all land use types in the wet climate period than in the dry period.

Table 3.23. AVGWLF model-based calculations of average annual sediment, nitrogen (total and dissolved), and phosphorous (total and dissolved) yields for the *wet* climate period – by land use type (source). All values are in lbs/yr/acre.

	Sediment	Total P	Dissolved P	Total N	Dissolved N
Dry Creek (DC-0.28)					
Forest	147.03	0.27	0.01	0.64	0.20
Agriculture	121.48	0.54	0.53	1.49	1.49
Developed	400.37	0.11	0.00	0.87	0.00
Ravenswood (DC-1.89)					
Forest	142.62	0.26	0.01	0.63	0.20
Agriculture	144.88	0.58	0.56	1.54	1.53
Developed	570.86	0.07	0.00	0.52	0.00
Nichols Branch (DC-2.84)					
Forest	135.28	0.24	0.01	0.60	0.20
Agriculture	153.10	0.58	0.56	1.56	1.52
Developed	760.74	0.07	0.00	0.51	0.00
Lambert Hollow (DC-4.52)					
Forest	90.21	0.17	0.00	0.47	0.20
Agriculture	260.87	0.88	0.88	2.26	2.26
Developed	317.20	0.07	0.00	0.54	0.00
Catron (UNK A)					
Forest	121.91	0.21	0.01	0.56	0.20
Agriculture	123.65	0.56	0.56	1.49	1.49
Developed	1339.59	0.08	0.00	0.53	0.00
Sugar Branch (SB-0.28)					
Forest	193.86	0.35	0.01	0.78	0.20
Agriculture	262.41	0.73	0.61	1.71	1.71
Developed	843.67	0.05	0.00	0.53	0.00
Amanda's Bridge (SB-0.35)					
Forest	177.08	0.32	0.01	0.73	0.20
Agriculture	147.98	0.54	0.60	1.61	1.61
Developed	646.52	0.00	0.00	0.68	0.00

Table 3.24. AVGWLF model-based calculations of average annual sediment, nitrogen (total and dissolved), and phosphorous (total and dissolved) yields for the *dry* climate period – by land use type (source). All values are in lbs/yr/acre.

	Sediment	Total P	Dissolved P	Total N	Dissolved N
Dry Creek (DC-0.28)					
Forest	81.91	0.15	0.00	0.35	0.10
Agriculture	66.26	0.26	0.26	0.75	0.75
Developed	224.21	0.07	0.00	0.61	0.00
Ravenswood (DC-1.89)					
Forest	79.28	0.14	0.00	0.34	0.10
Agriculture	79.02	0.28	0.27	0.78	0.77
Developed	317.14	0.05	0.00	0.32	0.00
Nichols Branch (DC-2.84)					
Forest	75.57	0.14	0.00	0.33	0.10
Agriculture	86.12	0.29	0.27	0.79	0.77
Developed	421.33	0.05	0.00	0.33	0.00
Lambert Hollow (DC-4.52)					
Forest	52.22	0.09	0.00	0.26	0.11
Agriculture	146.74	0.46	0.44	1.22	1.22
Developed	158.60	0.07	0.00	0.40	0.00
Catron (UNK A)					
Forest	68.58	0.12	0.00	0.30	0.10
Agriculture	80.54	0.25	0.25	0.73	0.73
Developed	714.46	0.08	0.00	0.36	0.00
Sugar Branch (SB-0.28)					
Forest	108.12	0.19	0.00	0.43	0.10
Agriculture	145.78	0.34	0.29	0.87	0.87
Developed	474.55	0.05	0.00	0.31	0.00
Amanda's Bridge (SB-0.35)					
Forest	97.22	0.18	0.00	0.18	0.10
Agriculture	103.55	0.27	0.27	0.81	0.81
Developed	430.98	0.00	0.00	0.39	0.00

Predictive Uncertainty

As is the case with any water quality model, there are a number of assumptions and generalizations associated with the AVGWLF model structure, and its application in this watershed, that may contribute to uncertainty in model predictions. This uncertainty, in turn, may help explain differences between modeled values and field-based load estimates of sediment, nitrogen and phosphorous. Predictive uncertainty may arise due to the empirical nature of the model's algorithms, which were developed using information from other regions and geographic scales. Moreover, model default values (e.g., for initial water storages and the groundwater recession coefficient) were used in a number of instances due to the lack of specific knowledge for the watershed area. Other contributions to predictive uncertainty could derive from inaccuracies in the GIS data layers used to represent watershed conditions, the degree to which the wet and dry periods are representative of climate extremes in the watershed, and the lack of model calibration due to data limitations. Finally, comparisons between model predictions and field-based estimates were constrained by the lack of certainty associated with different approaches used to calculate loads from field datasets.

Predicting Load Reductions

An EPA-approved model, the Pollutant Reduction Impact Comparison Tool (PRedICT; http://www.predict.psu.edu), will be used to estimate annual average pollutant (sediment, nitrogen and phosphorous) load reductions related to selected user-defined BMPs scenarios for the Dry Creek Watershed (and sub-basins). Average annual loads predicted using the AVGWLF model will be used to initialize the PRedICT model. In PRedICT, each scenario may include one or more agricultural, farm animal, urban and/or wastewater BMP selected from the model library. These scenarios will be selected from the library based upon input from qualified project personnel and other experts and relevant stakeholders. Library BMPs (and associated cost estimates) will be refined as needed in order to more accurately represent local knowledge/conditions.

Load Reductions Needed

Calculating the estimated load reduction needed to meet WQC or reference reach averages is an important part of selecting appropriate BMPs and achieving the goals and objectives of the Watershed Based Plan. Table 3.25 summarizes the reduction (in percent) needed to meet WQC and averages derived from reference stream data. The data below only include parameters whose load reductions can be predicted by the model based on specific BMPs.

The annual load required to meet WQC and reference stream data targets was calculated by multiplying the maximum acceptable limits by mean annual flow (MAF). It is obvious from these comparisons that a significant amount of load reduction is needed to reduce pollution to the point where Dry Creek is no longer impaired.

Table 3.25. Percent load reductions needed to reach WQC or reference reach averages

Site Identification And Nutrient	Current Estimated Annual Load	Annual Load at WQC or Ref. Stream Ave.	Total Load Reduction Needed to meet Standards and References	% Reduction Needed
DC-0.25 (w/Morgan Fork)				
TSS	11632	3251	8381	72%
Ammonia	763	48	715	94%
TP	309	24	285	92%
DC-1.89				
TSS	2707	2601	106	3%
Ammonia	486	33	453	93%
TP	294	20	274	93%
DC-2.84				
TSS	2979	2206	773	26%
Ammonia	486	33	453	93%
TP	181	17	164	91%
DC-4.52				
Ammonia	19	4	15	78%
SB-0.28				
TSS	891	604	287	32%
Ammonia	16	9	7	46%
TP	8	5	3	43%
SB-0.35				
TSS	1315	279	1036	79%
TP	5	2	3	56%

SOURCES AND LOCATIONS OF IMPAIRMENTS

The Kentucky Division of Water 2008 Integrated Report to Congress (KDOW, 2008) identifies a portion of Dry Creek as impaired to the extent that it only partially supports aquatic life. The impaired reach extends from the mouth of Dry Creek (0.0 miles) to a point 2.5 miles upstream (Figure 2.8, Chapter 2). The impaired reach therefore includes sites DC-0.28 and DC-1.89 and ends 0.34 miles downstream of DC-2.84. Pollutants recognized in the KDOW (2008) report include nutrient/eutrophication biological indicators, sedimentation/siltation, and organic enrichment (sewage) biological indicators.

Data presented in the previous section of this chapter allow us to draw some important conclusions regarding the impairment and pollutants reported to Congress. Our data also suggest that additional stream reaches are impaired.

Impairment Associated with *E. coli*

E. coli has been used in this study to assess pollution due to organic enrichment (sewage) biological indicators as identified in KDOW (2008). Geometric means (Figures 3.3 and 3.4) demonstrate that impairment is seasonal but provide little information regarding sources and causes of the impairment. Load duration curves and DNA fingerprinting (Appendix C) yield significantly more information as to probable sources and causes.

Sources and Causes

Load duration curves (LDCs) in Appendix C (Figures D4, D5 and D6) indicate that *E. coli* impairment occurs during the primary contact recreation season (May to October). Since this also coincides with the dry season, when streams are primarily fed by groundwater, instantaneous loads that dramatically exceed the LDC represent storm events. This implies that fecal contamination traveled to nearby streams in runoff and that the *E. coli* originated from wildlife, livestock or pets. Instantaneous loads that slightly exceed or lie close to the LDC suggest that *E. coli* was carried to Dry Creek by groundwater, which implies that *E. coli* originated from septic systems or perhaps leaking sewer lines. For a more detailed discussion, including comparisons with climatic records to identify wet versus dry periods, see Appendix D.

DNA fingerprinting analysis was conducted on selected *E. coli* isolates collected from the watershed in June 2009 to determine the host source of the bacteria (see Table 3.26 for the *E. coli* counts of June 2009).

Table 3.26. *E. coli* counts for selected sites in the Dry Creek Watershed for 23 June 2009.

Site #	Dry Creek Sampling Location	CFU/100 mL*
UNK A	Jennings	0
UNK B	Catron #2 (East)	760
UNK C	Catron #1 (West)	20
DC 4.52	Lambert Hollow	40
SB 0.28	Sugar Creek Road Bridge	60
DC 2.84	Nichol's Bridge	40
DC 1.89	Ravenswood Bridge	130
MF 0.23	Morgan Fork	140
DC 0.28	Tile Storage Road, Sample 1	420
DC 0.28	Tile Storage Road, Sample 2	440

*CFU/100mL represents Escherichia coli colony forming units per 100 mL of water sample.

Bacterial isolates from sites containing counts that exceeded the state WQC of 130 *E. coli* per 100 mL of water were evaluated. After each watershed bacterial isolate's identity was confirmed as *E. coli*, DNA was extracted and a DNA fingerprint was produced. Each watershed *E. coli* DNA fingerprint was compared to a panel of 92 *E. coli* DNA fingerprints from a variety of known host sources (humans, horses, cattle, sheep, goats, pigs, chickens, dogs, cats, and deer). Table 3.27 depicts the results of the analysis. Dendogram analysis of the watershed *E. coli* isolates suggest that most of the bacteria evaluated (up to 75%) originated from humans, while a smaller number originated from domesticated animals. These data suggest that human fecal sewage is the major source of *E. coli* in the four Dry Creek watershed sites assessed.

Table 3.27. Results of host source DNA fingerprinting analysis of *E. coli* watershed isolates.

Site #	Location	Total # of Isolates Tested	# testing positive for specific host source				
			Human	Bovine	Feline	Swine	Unknown
UNK B	Catron #2 (East)	8	6 (75%)	1 (12.5%)			1 (12.5%)
DC 1.89	Ravenswood	6	4 (67%)		1 (16.7%)		1 (16.7%)
MF 0.23	Morgan Fork	4	3 (75%)				1 (25%)
DC 0.28	Tile Storage Road	12	9 (75%)	1 (8.3%)		1 (8.3%)	2 (16.6%)

Impairment Associated with Sediment

While we may not be able to assess sediment concentrations and loads relative to a firm WQC, KDOW (2008) identifies sedimentation/siltation as a pollutant in the impaired reach. Use of the term sedimentation/siltation implies bedded sediment has been observed and problems such as smothering of spawning beds exist.

Sources and Causes

The sediment measured using SSC methods primarily consists of inorganic clay, silt and sand but also includes well-decomposed organic matter typically found in soils (USEPA, 2006). Sources for this pollution are geological materials (e.g., soil, rock, colluvium, alluvium) and, unlike TSS, are not dependent on nutrient and productivity levels. Impairment by sedimentation/siltation is caused by deposition of clay, silt and sand when water slows down and can no longer keep the sediment in suspension (e.g., at low flows or when water enters pools or eddies).

Stream bank erosion probably represents the largest source for suspended sediment in the Dry Creek watershed (see Appendix C for supporting evidence). The results of habitat assessments and photographic documentation presented in this chapter indicate that the primary cause of excessive bank erosion is removal of riparian vegetation. Channel alteration and gravel mining have also accelerated bank erosion in many places. The unfortunate result is that bank erosion is extremely widespread and is occurring to varying degrees along every stream in the watershed. All streams are entrenched for at least part of their length. A notable exception is Fallen Timber Branch, which appears to be in much better condition than most tributaries largely due to the fact that it is less developed. The most severely eroding bank appears to be near SB-0.23 (Figure D1, Appendix C). At this location, Sugar Branch is confined by a nearby bridge and bank armoring and is forced to flow directly into unstable colluvium at the base of a steep hillside.

Runoff over unimproved roads and bare ground (Figures 3.5 and 3.8) also appears to be a significant source of sediment in the watershed. The combination of the eroding bank at SB-0.23 and the eroding road and adjacent road cut shown in Figure 8 probably contributed to elevated SSC and loads detected at site DC-2.84 (Tables 3.13 and 3.14). The significantly lower SSC and loads detected at DC-1.89 (Tables 3.13 and 3.14) most likely results from dilution by the relatively unspoiled waters of Fallen Timber Branch, which flows into Dry Creek between DC-2.84 and DC-1.89.

Sediment influx into the lowest reaches of Dry Creek (near DC-0.28) during the monitoring period was extreme due to construction on KY 519. Extreme SCC and suspended sediment loads from Morgan Fork (Figure 3.13) dramatically affected data at DC-0.28 (Tables 3.13 and 3.14). The ultimate cause of the very high SSC, loads, and yields from Morgan Fork and the lowest reaches of Dry Creek were complete denudation of vegetative cover and the use of heavy machinery in and near the streams. But the problem was much worse than it should have been because contractors did not install erosion prevention and sediment controls during most of the construction project (Figure 3.14). A few erosion prevention and sediment controls appeared after a resident of the Dry Creek watershed complained to the local Kentucky Division of Water office.

Figure 3.13: View of Morgan Fork and Dry Creek confluence looking upstream from near KY 519 bridge. Note high suspended sediment load (cloudy water) coming from Morgan Fork on the right side of Dry Creek.

Figure 3.14: Sample of images taken during KY 519 construction, which show a complete absence of the erosion prevention and sediment controls required by state contracts.

Impairment Associated with Selected Physical and Chemical Parameters
Several of the physical and chemical parameters examined in this study address impairments caused by nutrient/eutrophication biological indicators and organic enrichment (sewage) biological indicators as indentified in KDOW (2008). Relationships between various parameters are examined in the context of these pollutants.

Factors Affecting Eutrophication (Low Dissolved Oxygen)
Poor habitat quality is the number one impact on temperature and DO. Although there are many parameters that can impact DO, only temperature showed a negative relationship to DO levels (Figure 3.15). Temperate increases are likely the result of tree removal. Another possible source of high water temperature is runoff from pavement since roads exist along most of Dry Creek and along major tributaries. In addition to temperature, low water velocity also contributed to excessive DO loss, again due to habitat destruction.

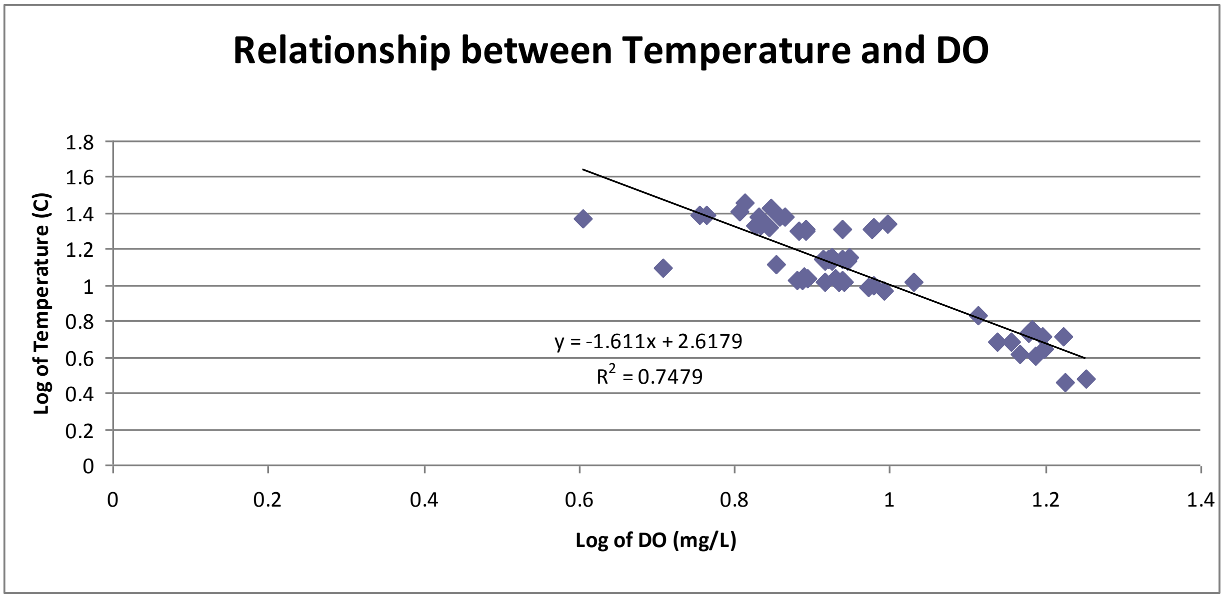

Figure 3.15. Relationship between temperature and DO (mg/L).

Low DO is also associated with nutrient enrichment. Despite this fact, no direct graphical relationship was observed between DO and nutrient levels. Sampling sites with the lowest DO were in sections of the stream with higher nutrient concentrations. Diurnal (daily) DO levels were evaluated for excessive utilization of oxygen at night and increased production of oxygen during the day. Although there were fluctuations in the DO levels, it does not appear to be excessive or that DO values were always lowest in pre-dawn hours. Still, production in the stream has been affected by nutrients and diurnal DO levels reflect this fact, most obviously at DC-0.28. The highest water temperatures in the watershed were recorded at DC-0.28.

The pH levels in the Dry Creek watershed also exceed KDOW WQC regulations. At this time, the possible source of the problem cannot be identified with our data. More data will be collected as part of the Triplett Creek 319h grant.

Factors Affecting Nutrient Enrichment

Ammonia is the only nutrient investigated in this study with a statutory WQC. The other nutrient parameters are based on reference reach data, which is an informal comparison. Of the 14 ammonia data points, five exceed the WQC of 0.05 mg/L. DC-1.89 had the most elevated and varied levels of ammonia, ranging from 0.002 to 2.062 mg/L. The reference reach data reported 0.05 mg/L at all sites. DC-1.89 is also located in an area that has had numerous unofficial complaints about sewer smells. All the sites with ammonia data had at least one sample that exceeded 0.05 mg/L. No data exist for sites UNKA, UNKB, SB-0.35, and DC-4.52.

Conductivity is often associated with elevated bacteria, phosphate, and nitrate; however, no meaningful correlations were found between any of the nutrients and conductivity. Dissolved phosphorus had the highest correlation with an R^2 value of 0.3725 (Figure 3.16). A similar approach was used to explore possible relationships between pH, nutrients, conductivity, temperature, and DO but none were significant.

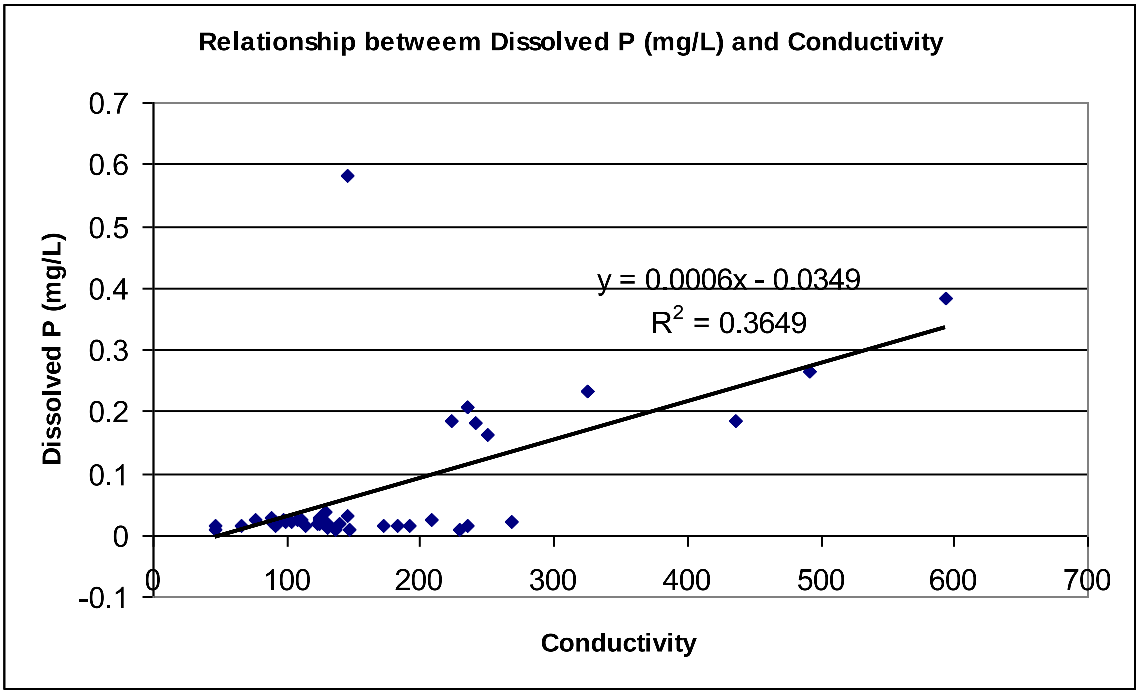

Figure 3.16 Relationships between nutrients and conductivity.

There does appear to be a strong correlation between the presence of sewer infrastructure and nutrients. The concentrations of dissolved P, TP, and various forms of nitrogen decrease between DC-1.89 (Ravenswood Bridge) and DC-0.28 (Tile Storage Road Bridge). There appears to be some influence from Morgan Fork based on results from DC-0.28 but we cannot determine the impact of this tributary with our current data set. New data are being collected at Morgan Fork, DC-0.28, and DC-2.84 as part of the Triplett Creek 319h grant.

Biological Indicators of Impairment

Time limitations and budget constraints did not allow us to examine biological indicators in detail. However, existing icthyofuanal and macroinvertebrate data and our limited field observations clearly indicate that sediment, low DO, temperature, pH, and habitat loss have had a negative impact on aquatic communities. Species observed show low diversity and a majority of the populations that do exist indicate poor water quality.

OVERALL SUMMARY FOR EACH SAMPLING SITE

Tables 3.28-36 summarize parameter results, targets, implied impairments, and the possible sources and causes of impairments for each sampling site in the watershed. Only parameters with targets based on WQC or reference reach averages are included.

Table 3.28. Overall summary table for DC-0.28 (Tile Storage Road Bridge)

Parameter	Target Met (Yes/No)	Impairment Source	Impairment Cause
Dissolved oxygen	Yes, 2 of 2 24-hour ave. events; Yes, 5 of 5 inst. events	NA	NA
pH	Yes, btw. 6-9 for 4 of 4 events; No, pH change > 1.0 in 24 hr. for 1 of 4 events	Nutrients, temperature, dissolved oxygen	Eutrophication, shade loss, warming of cloudy water
Alkalinity	Yes, none had $CaCO_3$ reduced more than 25%	NA	NA
Temperature	No, March only	Sediment, riparian buffer, humans	shade loss, warming of cloudy water, failed or failing septic systems
Ammonia	No, 1 of 4	Livestock, pets, humans	Animals in/near stream, failed or failing septic systems
E. coli	Yes for spring event; No for summer event	Livestock, pets, humans	Animals in/near stream, failed or failing septic systems
Conductivity	No, 7 of 12 instantaneous	Sediment, dissolved ions	Erosion, lawn care products
TSS	No, 22 of 35	Sediment, algae, organic matter	Erosion, excess algal growth, excess nutrients
Total Phosphorous	No, all higher	Excess nutrients, dishwasher detergents, fertilizer	Excessive fertilizer use, failed or failing septic systems, gray water lines
Stream assessment score	No	Multiple sources	Vegetation removal, channel alteration, gravel mining, others

Table 3.29. Overall summary table for DC-1.89 (Ravenswood Bridge)

Parameter	Target Met (Yes/No)	Impairment Source	Impairment Cause
Dissolved oxygen	Yes, 1 of 1 24-hour ave. events; No, 1 of 2 inst. events	NA	NA
pH	Yes, btw. 6-9 for 1 of 1 events; Yes, pH change < 1.0 in 24 hr. for 1 of 1 events	NA	NA
Alkalinity	Yes, none had $CaCO_3$ reduced more than 25%	NA	NA
Temperature	No, January	Sediment, riparian buffer, humans	shade loss, warming of cloudy water, failed or failing septic systems
Ammonia	No, all but 2	Livestock, pets, humans	Animals in/near stream, failed or failing septic systems
E. coli	Yes for spring event; No for summer event	Livestock, pets, humans	Animals in/near stream, failed or failing septic systems
Conductivity	No, 4 of 12 instantaneous	Sediment, dissolved ions	Erosion, lawn care products
TSS	No, 4 of 11	Sediment, algae, organic matter	Erosion, excess algal growth, excess nutrients
Total Phosphorous	No, 5 of 6	Excess nutrients, dishwasher detergents, fertilizer	Excessive fertilizer use, failed or failing septic systems, gray water lines
Stream assessment score	No	Multiple sources	Vegetation removal, channel alteration, gravel mining, others

Table 3.30. Overall summary table for DC-2.84 (Nichols Branch Rd. Bridge)

Parameter	Target Met (Yes/No)	Impairment Source	Impairment Cause
Dissolved oxygen	Yes, 2 of 2 24-hour ave. events; No, 2 of 5 inst. events	Nutrients, temperature, sediment	Eutrophication, shade loss, warming of cloudy water
pH	Yes, btw. 6-9 for 4 of 4 events; No, pH change > 1.0 in 24 hr. for 1 of 4 events	Nutrients, temperature, dissolved oxygen	Eutrophication, shade loss, warming of cloudy water
Alkalinity	No, $CaCO_3$ reduced more than 25% for 1 event	Landscape, humans, nutrients, dissolved oxygen	Altered landuse, failed or failing septic systems, shade loss
Temperature	No, March exceed.	Sediment, riparian buffer, humans	shade loss, warming of cloudy water, failed or failing septic systems
Ammonia	No, 2 of 4	Livestock, pets, humans	Animals in/near stream, failed or failing septic systems
E. coli	Yes for spring event; No for summer event	Livestock, pets, humans	Animals in/near stream, failed or failing septic systems
Conductivity	No, 3 of 9	Sediment, dissolved ions	Erosion, lawn care products
TSS	No, all higher	Sediment, algae, organic matter	Erosion, excess algal growth, excess nutrients
Total Phosphorous	No, 4 of 5	Excess nutrients, dishwasher detergents, fertilizer	Excessive fertilizer use, failed or failing septic systems, gray water lines
Stream assessment score	No	Multiple sources	Vegetation removal, channel alteration, gravel mining, others

Table 3.31. Overall summary table for DC-4.52 (Lambert Hollow Road)

Parameter	Target Met (Yes/No)	Impairment Source	Impairment Cause
Dissolved oxygen	Yes, 2 of 2 inst. events	Nutrients, temperature, sediment	Eutrophication, shade loss, warming of cloudy water
pH	Yes, btw. 6-9 for 1 of 1 events; Yes, pH change < 1.0 in 24 hr. for 1 of 1 events	NA	NA
Alkalinity	Yes, none had $CaCO_3$ reduced more than 25 %	NA	NA
Temperature	Yes	NA	NA
Ammonia	No data	NA	NA
E. coli	Yes for < 130 *E. coli*/100mL during spring event; No for 40% samples > 240 *E. coli*/100mL; No data collected for summer event	Livestock, pets, humans	Animals in/near stream, failed or failing septic systems
Conductivity	No, 1 of 4	Sediment, dissolved ions	Erosion, lawn care products
TSS	No, 1 of 4	Sediment, algae, organic matter	Erosion, excess algal growth, excess nutrients
Phosphorous	No, 1 of 1	Excess nutrients, dishwasher detergents, fertilizer	Excessive fertilizer use, failed or failing septic systems, gray water lines
Stream assessment score	No	Multiple sources	Vegetation removal, channel alteration, gravel mining, others

Table 3.32. Overall summary table for SB-0.28 (Sugar Creek Road Bridge)

Parameter	Target Met (Yes/No)	Impairment Source	Impairment Cause
Dissolved oxygen	Yes, 1 of 1 inst. events	NA	NA
pH	No data	NA	NA
Alkalinity	Yes, none had $CaCO_3$ reduced more than 25 %	NA	NA
Temperature	Yes	NA	NA
Ammonia	No, 1 of 1	Livestock, pets, humans	Animals in/near stream, failed or failing septic systems
E. coli	No data	Livestock, pets, humans	Animals in/near stream, failed or failing septic systems
Conductivity	No, 2 of 5	Sediment, dissolved ions	Erosion, lawn care products
TSS	No, 1 of 4	Sediment, algae, organic matter	Erosion, excess algal growth, excess nutrients
Phosphorous	No, 1 of 1	Excess nutrients, dishwasher detergents, fertilizer	Excessive fertilizer use, failed or failing septic systems, gray water lines
Stream assessment score	No	Multiple sources	Vegetation removal, channel alteration, gravel mining, others

Table 3.33. Overall summary table for SB-0.35 (Amanda's Bridge)

Parameter	Target Met (Yes/No)	Impairment Source	Impairment Cause
Dissolved oxygen	Yes, 1 of 1 inst. events	Nutrients, temperature, sediment	Eutrophication, shade loss, warming of cloudy water
pH	Yes		
Alkalinity	Y, none had $CaCO_3$ reduced more than 25 %		
Temperature	Yes		
Ammonia	No data		
E. coli	Yes for spring event; No data collected for summer event	Livestock, pets, humans	Animals in/near stream, failed or failing septic systems
Conductivity	No, 1 of 3	Sediment, dissolved ions	Erosion, lawn care products
TSS	No, 2 of 3	Sediment, algae, organic matter	Erosion, excess algal growth, excess nutrients
Phosphorous	No, 1 of 1	Excess nutrients, dishwasher detergents, fertilizer	Excessive fertilizer use, failed or failing septic systems, gray water lines
Stream assessment score	No	Multiple sources	Vegetation removal, channel alteration, gravel mining, others

Table 3.34. Overall summary table for UNK A (Below Catron Bridge)

Parameter	Target Met (Yes/No)	Impairment Source	Impairment Cause
Dissolved oxygen	Yes, 1 of 1 inst. events	Nutrients, temperature, sediment	Eutrophication, shade loss, warming of cloudy water
pH	Yes, 1 of 1		
Alkalinity	Yes		
Temperature	Yes		
Ammonia	No data	Livestock, pets, humans	Animals in/near stream, failed or failing septic systems
E. coli	No data	Livestock, pets, humans	Animals in/near stream, failed or failing septic systems
Conductivity	No, 1 of 3	Sediment, dissolved ions	Erosion, lawn care products
TSS	No, 1 of 3	Sediment, algae, organic matter	Erosion, excess algal growth, excess nutrients
Phosphorous	No, 1 of 1	Excess nutrients, dishwasher detergents, fertilizer	Excessive fertilizer use, failed or failing septic systems, gray water lines
Stream assessment score	No	Multiple sources	Vegetation removal, channel alteration, gravel mining, others

Table 3.35. Overall summary table for UNK B (Above Catron Bridge)

Parameter	Target Met (Yes/No)	Impairment Source	Impairment Cause
Dissolved oxygen	Yes, 1 of 1 inst. events	Nutrients, temperature, sediment	Eutrophication, shade loss, warming of cloudy water
pH	Yes	NA	NA
Alkalinity	Yes	NA	NA
Temperature	Yes	NA	NA
Ammonia	No data	NA	NA
E. coli	Yes for spring event; No data collected for summer event	Livestock, pets, humans	Animals in/near stream, failed or failing septic systems
Conductivity	No, 1 of 3	Sediment, dissolved ions	Erosion, lawn care products
TSS	No, 1 of 3	Sediment, algae, organic matter	Erosion, excess algal growth, excess nutrients
Phosphorous	No, 1 of 1	Excess nutrients, dishwasher detergents, fertilizer	Excessive fertilizer use, failed or failing septic systems, gray water lines
Stream assessment score	No data	Multiple sources	Vegetation removal, channel alteration, gravel mining, others

PRESENT AND FUTURE STRESSORS ON THE WATERSHED

Increased Development and Impervious Surfaces

Development is likely to increase in the watershed, primarily in the form of single unit housing and apartments. Future development upstream of the current reach of county sewer lines (see Figure 2.6, Chapter 2 for sewer infrastructure) could lead to more septic systems and potentially higher pathogen loads in the watershed, particularly if the systems are improperly sized or too close to streams. Runoff from lawns could wash fertilizers into nearby streams, which would further increase already high nutrient loads. Runoff laden with other widely used lawn care products (e.g., herbicides and pesticides) could further reduce the diversity of aquatic organisms.

Of course development also increases the percentage of land covered by impervious surfaces. The fact that paved surfaces and rooftops do not allow water to pass through them, i.e., they are impervious, gives rise to a wide range of negative environmental and economic impacts. For example, because impervious surfaces serve as collectors of solid and liquid pollutants (road salt, antifreeze, fertilizers, pet waste) and debris (brake dust, tire rubber, litter, sediment) they are one of the primary contributors to non-point source (NPS) pollution in streams. NPS pollution significantly reduces the quality of water available for human needs (e.g., drinking water) and degrades the integrity of aquatic ecosystem structure and functioning.

In addition to water quality effects, impervious surfaces also impact the quantity and timing of water reaching streams and rivers. Precipitation falling on impervious surfaces reaches the stream channel faster and in greater amounts compared to vegetated surfaces, thereby increasing the risk of flooding and channel erosion and decreasing the amount of groundwater recharge. Other important consequences of paving watersheds include higher steam water temperatures from runoff over warmed asphalt and higher air temperatures due to warmed asphalt and reduced vegetation. Removal of vegetation to build houses, roads, and parking areas reduces shade and evapotranspiration, both of which cool the land surface.

It is generally accepted by watershed and ecosystem management professionals that significant hydro-ecological impairment (e.g. polluted water and increased flooding) occurs once a watershed contains 10% impervious surfaces, and that greater than 25% impervious surface area generally leads to severe levels of impairment. While less than 10% of the land in the Dry Creek Watershed is currently classified as developed (paved roads, parking lots, rooftops, etc.), this percentage is likely to increase in the future.

Removal of Riparian Zone Vegetation

Removal of riparian zone vegetation is widespread and likely to continue. Some of the problems associated with this activity were alluded to earlier. For example, removal of vegetation from stream banks greatly accelerates erosion, which leads directly to higher SSC and sediment loads. The removal of trees increases evaporation from streams, which can decrease flow. Wholesale removal of willows, sycamores, and river birches decreases transpiration (water "sucked-up" by trees) and allows more groundwater to seep into channels, which ironically tends to help streams flow longer during the dry season. This apparent advantage is outweighed by even more problems, however. Once the vegetation is removed, runoff reaches streams faster, which tends to produce more flooding. Removal of riparian trees also increases water temperature as more sunlight hits the stream, which in turn leads to decreased DO.

Channel Alteration and Gravel Mining

Channel alteration is widespread throughout the watershed but is especially prevalent along Dry Creek. Figures 3.5, 3.6, 3.7, and 3.9 represent a small sample of the dozens of images we have showing various forms of channel alteration (e.g., pipeline crossings, bank armoring, and channelization).

Gravel mining (Figures 3.17, 3.18), is occurring in Dry Creek and may have been more widespread in the past. (In fact, gravel mining with improper heavy equipment in the streambed appears to be a common practice throughout the entire Triplett Creek watershed.) Several unimproved access roads lead to the Dry Creek streambed (Figure 3.18). Some of these roads appear to still be in use, while others are eroded and overgrown.

Channel alteration and gravel mining have and probably will continue to cause a variety of problems in the watershed. Habitat destruction is obvious based on assessments conducted for this study. Complete removal of gravel bars near pools and riffles has eliminated spawning areas from many parts of Dry Creek. The rapid appearance of "new" gravel due to colluvium and bedrock erosion (Figures D2 and D3, Appendix C) virtually assures that disruptive gravel mining will continue. All of these practices tend to increase flow velocity and accelerate down-cutting and bank erosion. Channel entrenchment is likely to worsen in the future.

Figure 3.17: Gravel mining in Dry Creek. In left image, gravel has been scraped down to bedrock and piled against the bank as a form of armoring. Note leaning and curved trees caused by bank erosion and undercutting. Right image shows access road to streambed and obvious signs of gravel mining, including tire tracks leading from the streambed to this loading area.

Figure 3.18: More unimproved access roads to Dry Creek streambed. Note fine-grained sediment deposited on the channel bottom, an example of impairment due to sedimentation/siltation. Most of the gravel has been removed in both images.

Floodplain In-filling

A few relatively small floodplain in-filling projects are in progress within the watershed. All are primarily intended to raise housing construction sites above the 100-year floodplain, the extent of which is shown by Figure 2.4 in Chapter 2. In the middle and upper parts of the watershed these projects are less likely to cause problems as they appear to be dispersed and Dry Creek seldom overflows its banks there. In the lower, more developed part of the watershed, however, Dry Creek still occasionally overflows its banks onto the floodplain, usually due to back-up from Triplett Creek flooding. Excessive floodplain in-filling in this part of the watershed could have serious consequences in adjacent upstream and downstream areas that remain un-filled. Homes and businesses occupying raised land may escape floodwaters but neighbors in the original (lower) floodplain areas will experience worse flooding than before the in-filling projects were completed.

Logging

Thirty-three percent of the land in the Dry Creek Watershed is owned by the U.S. Forest Service (USFS). The majority of USFS land is located in the mid-watershed area, only a small stand is found in the lower, largely developed, watershed area, and none in the headwaters area (Figure 2.9, Chapter 2). As a result of the February 2003 ice storm, damaged trees on USFS land are being or will be logged in one of two ways. Approximately 1.3% of the USFS land will be logged commercially, which involves cutting down and removing the damaged tress. Another roughly 2.4% of USFS land will be logged non-commercially, where damaged trees are cut down and left in place to provide wildlife habitat, to add nutrients to soils through decay, etc.

Timber harvesting can have lasting impacts on both the quality of the water and the amount of water flowing in watershed streams. Removing trees from hill slopes results in more rain and snowfall reaching the surface and, consequently, the stream channel. In addition, bare hill slopes are prone to soil erosion by wind and water which, in turn, increases the amount of sediment and other materials (e.g., leaves, dead wood) entering the stream. Hence, logging may contribute to both degraded water quality as well as increased flooding risk.

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Dry Creek Watershed-based Plan Draft
Chapter 4: Best Management Practices Implementation Plan

INTRODUCTION

The results of fieldwork conducted for this watershed-based plan and summarized in Chapter 3 validates KDOW's recent decision (KDOW, 2008) to extend impaired status for Dry Creek to 2.5 stream miles (i.e., from the mouth to a point 2.5 miles upstream). Previous impaired waters lists (303d) designated only 0.5 stream miles as polluted (i.e., from the mouth to a point 0.5 miles upstream). Importantly, Chapter 3 results also indicate that other reaches of Dry Creek and its tributaries are impaired by the same pollutants identified in KDOW (2008) and that several physical parameters related to this pollution exceed established Water Quality Criteria (WQC).

In Chapter 4, we set targets, suggest Best Management Practices (BMPs) and outline an implementation plan that will help the community meet our ultimate goal of improving the quality of impaired waterways and protecting high quality waterways within the Dry Creek Watershed. BMPs are land use practices or construction projects that maintain high quality waterways and improve water quality of impacted streams. Typical BMPs include treatment options (e.g., septic systems), practices to control runoff (e.g., restoration or maintenance of vegetation), operating procedures (e.g., ordinances, agricultural water plans), and public education.

Our top priority in selecting BMPs to improve Dry Creek and its tributaries was to address impairments identified by citizens, KDOW (2008) and the results of our one-year scientific monitoring program (Chapters 2 and 3). From this initial list, we chose the most effective, economic and politically feasible options to present to the public. The deliberation process involved conversations between MSU scientists; local, state and federal officials; an experienced and well-regarded environmental consultant; and included widely publicized efforts to solicit feedback from citizens who live in the watershed (e.g., community roundtables). The views of all stakeholders who chose to participate were taken into consideration. Therefore, the BMPs and implementation plan presented below represent our best effort to appeal to as many interest groups as possible yet still adhere to the underlying scientific basis of the watershed-based plan.

GOALS AND OBJECTIVES

Table 4.1 summarizes identified problems in the watershed, relates these problems to scientific results presented in Chapters 2 and 3, and lists long-term goals that must be met in order to correct or at least decrease the severity of these problems.

Table 4.1. Concerns with water quality in the Dry Creek Watershed, their potential causes, and long-term goals that must be met to correct the problems.

Concerns	**Probable Cause/s**	**Supporting Data**	**Assessment**	**Long-Term Goal**
Unsafe swimming and wading conditions	Failed and failing septic systems, domesticated animal waste	KDOW (2008), field data	Measure bacteria counts, DNA fingerprinting of *E. coli*	• Decrease nutrient loads in Dry Creek. • Decrease bacteria levels to meet Primary Contact Recreation standards. • Improve water quality so that Dry Creek can be safely used as a recreational resource (i.e. fishing, swimming, and canoeing/kayaking).
Sewer Odors	Failed and failing septic systems	KDOW (2008), field observations	Measure bacteria counts, DNA fingerprinting of *E. coli*	• Decrease bacteria levels to meet Primary Contact standards. • Improve water quality so that Dry Creek can be safely used as a recreational resource (i.e. fishing, swimming, and canoeing/kayaking).
Land loss from eroding creek banks	Vegetation removal along stream banks, stream straightening, gravel mining	Visual observations, measured channel cross-sections, bank pins	Stream assessment, measured channel cross-sections, bank pins	• Decrease severity and frequency of flooding. • Decrease sediment loads in Dry Creek. • Decrease nutrient loads in Dry Creek. • Improve water quality so that Dry Creek can be safely used as a recreational resource (i.e. fishing, swimming, and canoeing/kayaking).
Decrease in fish populations	Low dissolved oxygen, loss of habitat and shade cover, gravel mining	McCafferty and Eisenhour (2001)	Field measurements, observations made by fishermen	• Decrease severity and frequency of flooding. • Decrease sediment loads in Dry Creek. • Decrease nutrient loads in Dry Creek. • Decrease bacteria levels to meet Primary Contact standards. • Improve water quality so that Dry Creek can be safely used as a recreational resource (i.e. fishing, swimming, and canoeing/kayaking).
Excessive nutrients	Failed and failing septic systems, domesticated animal waste	KDOW (2008), field data	Field measurements	• Decrease sediment loads in Dry Creek. • Decrease nutrient loads in Dry Creek. • Decrease bacteria levels to meet Primary Contact standards. • Improve water quality so that Dry Creek can be safely used as a recreational resource (i.e. fishing, swimming, and canoeing/kayaking).
Loss of native vegetation and	Removal of vegetation cover for	Visual observations, 2007 KSNPC	Maps, visual observations	• Decrease severity and frequency of flooding. • Decrease sediment loads in Dry Creek.

ecosystems	road and housing development	Report		• Decrease nutrient loads in Dry Creek. • Decrease bacteria levels to meet Primary Contact standards. • Improve water quality so that Dry Creek can be safely used as a recreational resource (i.e. fishing, swimming, and canoeing/kayaking).
Excessive sediment inputs	Removal of vegetation cover for road and housing development, poor land use management, vegetation removal along stream bank, stream straightening	2008 Integrated Report, field data collection	Field measurements and observations	• Decrease severity and frequency of flooding. • Decrease sediment loads in Dry Creek. • Decrease nutrient loads in Dry Creek. • Improve water quality so that Dry Creek can be safely used as a recreational resource (i.e. fishing, swimming, and canoeing/kayaking).

Each long-term goal outlined in Table 4.1 requires considerable effort. To properly focus these efforts and achieve the desired results, specific objectives must be met. These objectives and their relationship to each goal are summarized in Table 4.2.

Table 4.2. Objectives for achieving long-term goals.

Goal	Source/Cause/Pollutant	Indicators	Objective
Decrease the severity and frequency of flooding	**Removal of native vegetation and riparian zones (banks and wetlands):** the removal of native vegetation reduces the watershed's ability to absorb and store water, which increases runoff; more water enters the streams at a faster rate. **Runoff from disturbed land:** sediment input fills-in creeks causing water to more easily overflow its banks.	Less flooding and flash flooding	Reduce erosion from run-off associated with vegetation disturbances and construction Reduce sediment from bank erosion Increase native plants in riparian zones and throughout watershed Restore native wetland areas to absorb water
Decrease the	**Runoff from disturbed land:**	SSC,	Reduce sediment loss

sediment loads	sediment input fills-in creeks causing water to more easily overflow its banks. Sediment loads also negatively impact water temperature, nutrient concentrations, and aquatic habitat. **Removal of stream bank vegetation:** the removal of vegetation from the bank allows sediment to easily erode.	TSS, bank measurements, visual observations, water temperature, land cover, nutrient concentrations, Conductivity, pH, alkalinity	from run-off associated with vegetation disturbances and construction Increase stream bank and riparian zone vegetation Stabilize stream banks Restore and/or construct wetlands Educate the public
Decrease nutrient loads	**Removal of native vegetation and riparian zones (wetlands):** the removal of native vegetation reduces the watershed's ability to filter water. **Runoff from disturbed land:** nutrient inputs are often attached to sediment particles. **Residential inputs:** urban run-off from paved surfaces, washing cars, lawn fertilizers, and failed septic systems can add nutrients to the streams.	Nutrients concentrations, SSC, TSS, water temperature, land cover, dissolved oxygen, conductivity, pH alkalinity	Reduce sediment loss from run-off associated with vegetation disturbances and construction Restore and/or construct wetlands Reduce loads from failed/failing septic systems Educate the public
Decrease bacteria levels to meet Primary Contact standards	**Residential inputs:** failed septic systems increase bacteria entering the waterways. **Runoff from livestock operations:** bacteria levels increase without proper vegetative buffer zones and creek fencing.	Bacteria counts, nutrients, visual survey, odors	Reduce bacteria loads from failed/failing septic systems and livestock operations Restore and/or construction wetland Educate home and land owners
Improve water quality so that Dry Creek can be safely used as a recreational resource	**Residential inputs:** failed septic systems increase bacteria entering our waterways; urban run-off from paved surfaces, washing cars, lawn fertilizers, and failed septic systems can	Bacteria counts, nutrients, temperature, dissolved oxygen, conductivity, land cover,	Reduce bacteria loads from failed/failing septic systems and livestock operations Restore and/or

	add nutrients to the streams. **Runoff from livestock operations:** bacteria levels increase without proper vegetative buffer zones and creek fencing. **Removal of native vegetation and riparian zones (wetlands):** the removal of native vegetation reduces the watershed's ability to filter water. **Runoff from disturbed land:** nutrients are often attached to sediment particles; sediment input fills-in creeks causing water to more easily overflow its banks. Sediment loads also negatively impact water temperature, nutrient concentrations, and aquatic habitat.	pH, alkalinity, visual survey	construct native wetland areas to absorb water and filter pollutants Reduce sediment loss from run-off associated with vegetation disturbances and construction Reduce sediment from bank erosion through stabilization and vegetation cover Increase native plants in riparian zones and watershed Educate the public

Best Management Practices Needed to Meet our Goals and Objectives
Following the approach outlined in the introduction and taking into consideration the concerns, goals and objectives outlined in Tables 4.1 and 4.2, MSU scientists developed a list of BMPs. This list was then discussed with Barry Tonning, Director of Applied Research for Tetra Tech, Inc., a global environmental engineering and services firm. After this meeting, the technical team agreed to present the following list of BMPs to the public:

1) Enforcement of existing local ordinances and state and federal regulations;
2) Public education;
3) Repair and replacement of failing or failed septic systems;
4) Expansion of Morehead Utility Plant Board sewer lines to at least Ravenswood;
5) Stream bank stabilization;
6) Improved riparian buffer zones;
7) Grazing land management/seeding of barren land;
8) Fencing livestock out of streams;
9) Wetland creation (e.g., near the mouth of Dry Creek, other areas if possible).

Attempts to Receive Feedback on Suggested BMPs
Shortly after development of this list, an attempt was made to present the information to local officials and the general public in order to gain feedback and comments. The Kentucky Waterways Alliance project manager and MSU scientific team scheduled another community roundtable for November 20, 2009 and publicized the event through local radio stations, the *Morehead News*, the MSU website, posted flyers, and the NewCity Morehead Facebook page. Unfortunately, only members of the Dry Creek Watershed Committee attended. After some

discussion, Mr. Tonning suggested that we post our PowerPoint presentations on YouTube in hopes that this convenience might solicit greater public participation and comment on the suggested BMPs.

YouTube videos will be posted in February 2010. Once posted, we will monitor the site and gather information regarding the number of viewers who accessed the videos as well as any comments posted by viewers. This information will be helpful as the Triplett Creek Watershed Committee develops strategies to inform the public on water quality issues in the Triplett Creek Watershed.

Other forums that were used to solicit public input regarding BMPs included attending meetings with the Morehead City Council, Rowan County Fiscal Court, and NewCity Morehead held in January 2010. A short presentation was given to each group, along with handouts on monitoring results and suggested BMPs. The participants were asked to complete a simple BMP rating form. The results of the public ratings are summarized below.

So far, attempts to garner input have resulted in the return of only seven BMP rating forms. Five of the forms were complete and two incomplete. Although BMP scores varied greatly, the expansion of Morehead Utility Plant Board sewer lines to the Ravenswood area consistently ranked highest. Enforcement of existing ordinances and laws was the second highest average score, followed by repair and replacement of failing or failed septic systems. A summary of all results is included in Table 4.3 (highest ranking on top, lowest ranking on bottom).

Table 4.3 Average scores for BMP rating forms with highest scoring BMP at the top and lowest ranking at the bottom. Ten is the highest score per category.

BMP	Effective-ness	Implemen-tation Cost	Added Benefits	Public Acceptance	Maintenance /Ongoing Cost	Sum of average scores
Expansion of Morehead Utility Plant Board sewer lines to Ravenswood area	9.4	8.1	9.0	7.6	7.6	41.7
Enforcement of existing ordinances and laws	8.4	6.6	6.3	7.3	5.4	34
Repair and replacement of failing or failed septic systems	7.9	6.9	7.8	5.4	5.8	33.8
Public Education	6.9	7.1	7.2	6.7	5.6	33.5
Stream bank stabilization	7.0	7.1	6.8	6.4	5.6	32.9
Improved riparian buffer zones	6.9	7.4	5.8	5.4	5.0	30.5
Grazing land management/seeding of barren land	6.3	6.9	5.5	5.7	5.2	29.6
Fencing off of stream areas from livestock	5.7	5.9	4.5	4.1	5.2	25.4
Wetland creation near mouth of Dry Creek	4.5	6.7	4.3	3.5	4.8	23.8

WATER QUALITY TARGETS

In order to assess whether goals have been met, it is necessary to relate objectives to target values for water quality parameters that will be monitored after BMP implementation. Target values are set at established WQC if they exist or at average parameter values from reference reach streams in the Western Allegheny Ecoregion. In the case of suspended sediment derived solely from erosion of geologic materials (i.e., SSC), the Commonwealth of Kentucky has not established a WQC and no reference reach data exist. Therefore, we suggest setting target scores of 10-15 (or better) on "embeddedness" and "sediment deposition" on habitat assessment forms to be completed after BMP implementation. Our reasoning is that settling of suspended sediment leads to impairment due to sedimentation/siltation, a pollutant identified in KDOW (2008). Scores in the 10-15 range, while not optimal, would indicate improvement.

The same approach was used to set target values for habitat and biological assessments. A habitat assessment score of 130 or greater at the sites would indicate improvement. A score of 130 or more can be achieved by implementing the recommended BMPs. The habitat assessment category called "Channel Alteration" will be practically impossible to improve, however, since much of the disturbance is the result of road building. Achieving a score of "good" or "better" on the biological assessment sheets, which are simple volunteer forms, would indicate improvement at each site.

The tables presented below summarize target values for each sub-watershed (sub-basin) and relate these targets to the goals and objectives outlined in Tables 4.1 and 4.2. Sub-basins are defined as the catchment area upstream of each sampling site (see Chapter 3, Figure 3.11). More detailed information regarding the natural and land use conditions in these portions of the Dry Creek watershed can be found in Chapter 2.

Amanda's Bridge Sub-basin

The Amanda's Bridge sub-basin encompasses the catchment area above sample site SB-0.35. This 667 acre (1.042 sq. mi.) is mostly forested but contains several apartment units and a few single-family residences. Many of the water quality issues in this sub-basin are obvious, even to the untrained eye. Field data that support these observations are limited due to persistent low flow or dry conditions.

Table 4.4 Relationship between objectives and target values for the Amanda's Bridge sub-basin.

Goal	Objective	Indicator	Target value	Basis
Decrease the sediment loads in Dry Creek	Increase stream bank and riparian zone vegetation Stabilize stream banks Educate the public	TSS	3.39 mg/L for low and intermediate flows	Reference data
		SSC	Embeddedness and sediment deposits of sub-optimal or optimal	Technical team suggestion
		Habitat Assessment	130	Technical team suggestion

Decrease nutrient loads in Dry Creek	Reduce sediment loss from run-off associated with vegetation disturbances Reduce loads from failed/failing septic systems Educate the public	Ammonia	0.05 mg/L	WQC
		Conductivity	145 µs/cm max.	Reference data
		Total Phosphorus	0.0255 mg/L	Reference data
Decrease bacteria levels to meet Primary Contact standards	Reduce bacteria loads from failed/failing septic systems Educate home and land owners	Bacteria count	Monthly geometric range of 130 cfu/100 mL or 240 CFU/100 mL in no more than 20% of samples	WQC
		Biological assessment (volunteer form)	Score of "Good"	Literature values

Sugar Branch Sub-basin

The Sugar Branch sub-basin includes the land area above sampling site SB-0.23. This 1353 acre (2.112 sq. mi.) sub-basin is mostly forested but includes several residential areas. The stream has been altered by road construction and some livestock reside in the watershed.

Table 4.5 Relationship of objectives to target values in the Sugar Branch sub-basin.

Goal	**Objective**	**Indicator**	**Target value**	**Basis**
Decrease the sediment loads in Dry Creek	Increase stream bank and riparian zone vegetation	SSC	Embeddedness and sediment deposits of sub-optimal or optimal	Technical team suggestion
	Stabilize stream banks	TSS	3.39 mg/L for low and intermediate flows	Reference data
	Educate the public	Habitat Assessment	130	Technical team suggestion
Decrease nutrient loads in Dry Creek	Reduce sediment loss from run-off associated with vegetation disturbances	Ammonia	0.05 mg/L	WQC
		Conductivity	145 µs/cm max.	Reference data

	Reduce loads from failed/failing septic systems Educate the public	Total Phosphorus	0.0255 mg/L	Reference data
Decrease bacteria levels to meet Primary Contact standards	Reduce bacteria loads from livestock run-off Educate home and land owners	Bacteria count	Monthly geometric range of 130 cfu/100 mL or 240 CFU/100 mL in no more than 20% of samples	WQC
		Biological Assessment (volunteer form)	Score of “Good”	Technical team suggestion

Lambert Hollow Sub-basin

The Lambert Hollow sub-basin includes the land area above sampling site DC-4.52. This 637 acre (0.996 sq. mi.) sub-basin is mostly forested but includes several residential sites and some livestock production. A few obviously disturbed areas exist in this sub-basin. As in the Amanda’s Bridge sub-basin, extended periods of low flow make it difficult to acquire field samples and flow measurements.

Table 4.6. Relationship of objectives to target values in the Lambert Hollow sub-basin.

Goal	Objective	Indicator	Target value	Basis
Decrease the sediment loads in Dry Creek	Increase stream bank and riparian zone vegetation Stabilize stream banks Educate the public	SSC	Embeddedness and sediment deposits of sub-optimal or optimal	Technical team suggestion
		TSS	3.39 mg/L for low and intermediate flows	Reference data
		Habitat Assessment	130	Technical team suggestion
Decrease nutrient loads in Dry Creek	Reduce sediment and nutrients from run-off associated with vegetation disturbances Reduce loads from failed/failing septic systems	Ammonia	0.05 mg/L	WQC
		Conductivity	145 µs/cm max.	Reference data
		Total Phosphorus	0.0255 mg/L	Reference data

	Educate the public			
Decrease bacteria levels to meet Primary Contact standards	Reduce bacteria loads from failed/failing septic systems Educate home and land owners	Bacteria count	Monthly geometric range of 130 cfu/100 mL or 240 CFU/100 mL in no more than 20% of samples	WQC
		Biological Assessment (volunteer form)	Score of "Good"	Technical team suggestion

Nichols Branch Sub-basin

The Nichols Branch sub-basin includes the land area above sampling site DC-2.84. The total land area in this sub-basin is 4935 acres (7.711 sq. mi.). This sub-basin is mostly forested and includes several residential areas (including apartment complexes), as well as some livestock and hay production. The stream in this sub-basin has been altered by road construction and some livestock reside in the watershed. Since flow below DC-2.84 (Nichol's Branch Road Bridge) persists almost year-round, the goal to improve water quality so that Dry Creek can be safely used as a recreational resource has been added. Below this point, we have observed wading and fishing in the stream. A few whitewater kayakers also use this stream.

Table 4.7. Relationship of objectives to target values in the Nichols Branch sub-basin.

Goal	Objective	Indicator	Target value	Basis
Decrease the sediment loads in Dry Creek	Increase stream bank and riparian zone vegetation Stabilize stream banks Educate the public	SSC	Embeddedness and sediment deposits of sub-optimal or optimal	Technical team suggestion
		Channel cross-section, bank pins	Reduce or halt changes in channel cross-section	Technical team suggestion, literature values
		TSS	3.39 mg/L for low and intermediate flows	Reference data
		Habitat Assessment	130	Literature values
Decrease nutrient loads in Dry Creek	Reduce sediment loss from run-off associated with vegetation disturbances	Ammonia	0.05 mg/L	WQC
		Conductivity	145 µs/cm max.	Reference data

	Reduce loads from failed/failing septic systems Educate the public	Total Phosphorus	0.0255 mg/L	Reference data
Decrease bacteria levels to meet Primary Contact standards	Reduce bacteria loads from failed/failing septic systems Educate home and land owners	Bacteria count	Monthly geometric range of 130 cfu/100 mL or 240 CFU/100 mL in no more than 20% of samples	WQC
		Biological Assessment (volunteer form)	Score of "Good"	Technical team suggestion
Improve water quality so that Dry Creek can be safely used as a recreational resource	Reduce bacteria loads from failed/failing septic systems and livestock operations Restore and/or construct native wetland areas to absorb water and filter pollutants Reduce sediment loss from run-off associated with vegetation disturbances and construction Reduce sediment from bank erosion through stabilization and vegetation cover Increase native plants in riparian zones and watershed Educate the public	pH	6 to 9 with less than a 1.0 change over 24-hours	WQC
		Alkalinity	41.6 mg/L	Reference data
		SSC	Embeddedness and sediment deposits of sub-optimal or optimal	Technical team suggestion
		TSS	3.39 mg/L for low and intermediate flows	Reference data
		Habitat Assessment	130	Literature values
		Ammonia	0.05 mg/L	WQC
		Conductivity	145 µs/cm max.	Reference data
		Total Phosphorus	0.0255 mg/L	Reference data
		Bacteria count	Monthly geometric range of 130 cfu/100 mL or 240 CFU/100 mL in no more than 20% of samples	WQC
		Biological Assessment (volunteer form)	Score of "Good"	Technical team suggestion
		Temperature	Not to exceed temperature	WQC

			guidelines	

Ravenswood Sub-basin

The Ravenswood sub-basin includes the land area above sampling site DC-1.89. The total land area in this watershed is 5875 acres (9.180 sq. mi.). This sub-basin is mostly forested and includes several residential sites (including apartment complexes), as well as some livestock and hay production. The stream has been altered by road construction and some livestock reside in the watershed.

Table 4.8. Relationship of objectives to target values in the Ravenswood sub-basin.

Goal	Objective	Indicator	Target value	Basis
Decrease the sediment loads in Dry Creek	Increase stream bank and riparian zone vegetation Stabilize stream banks Educate public	SSC	Embeddedness and sediment deposits of sub-optimal or optimal	Technical team suggestion
		TSS	3.39 mg/L for low and intermediate flows	Reference data
		Habitat Assessment	130	Technical team suggestion
Decrease nutrient loads in Dry Creek	Reduce sediment loss from run-off associated with vegetation disturbances Reduce loads from failed/failing septic systems Educate public	Ammonia	0.05 mg/L	WQC
		Conductivity	145 µs/cm max.	Reference data
		Total Phosphorus	0.0255 mg/L	Reference data
Decrease bacteria levels to meet Primary Contact standards	Reduce bacteria loads from failed/failing septic systems Educate home and land owners	Bacteria count	Monthly geometric range of 130 cfu/100 mL or 240 CFU/100 mL in no more than 20% of samples	WQC
Improve water quality so that Dry Creek can be safely used as a recreational resource	Reduce bacteria loads from failed/failing septic systems and livestock operations	pH	6 to 9 with less than a 1.0 change over 24-hours	WQC
		Alkalinity	41.6 mg/L	Reference data

	Restore and/or construction native wetland areas to absorb water and filter pollutants Reduce sediment loss from run-off associated with vegetation disturbances and construction Reduce sediment from bank erosion through stabilization and vegetation cover Increase native plants in riparian zones and watershed Educate the public	SSC	Embeddedness and sediment deposits of sub-optimal or optimal	Technical team suggestion
		TSS	3.39 mg/L for low and intermediate flows	Reference data
		Habitat Assessment	130	Technical team suggestion
		Ammonia	0.05 mg/L	WQC
		Conductivity	145 µs/cm max.	Reference data
		Total Phosphorus	0.0255 mg/L	Reference data
		Bacteria count	Monthly geometric range of 130 cfu/100 mL or 240 CFU/100 mL in no more than 20% of samples	WQC
		Biological Assessment (volunteer form)	Score of "Good"	Technical team suggestion

Dry Creek Basin

The Dry Creek basin includes the land area above sampling site DC-0.28 and includes almost the entire Dry Creek watershed. The total land area in this watershed is 7595 acres (11.867 sq. mi.). This sub-basin is mostly forested with several residential sites (including apartment complexes), as well as livestock and hay production. The stream has been altered by road construction and some livestock reside in the watershed.

Table 4.9. Relationship of objectives to target values in the Dry Creek basin.

Goal	Objective	Indicator	Target value	Basis
Decrease the severity and frequency of flooding	Reduce sediment loss from run-off associated with vegetation disturbances and	SSC	Embeddedness and sediment deposits of sub-optimal or optimal	Technical team suggestion

	construction Reduce sediment from bank erosion Increase native plants in riparian zones and watershed Restore native wetland areas to absorb water	Channel cross-section, bank pins	Reduce or halt changes in channel cross-section	Technical team suggestion, literature values
		TSS	3.39 mg/L for low and intermediate flows	Reference data
		Habitat Assessment	130	Technical team suggestion
Decrease the sediment loads in Dry Creek	Reduce sediment loss from run-off associated with vegetation disturbances and construction Increase stream bank and riparian zone vegetation Stabilize stream banks Restore and/or construction wetlands Educate the public	SSC	Embeddedness and sediment deposits of sub-optimal or optimal	Technical team suggestion
		TSS	3.39 mg/L for low and intermediate flows	Reference data
		Habitat Assessment	130	Technical team suggestion
Decrease nutrient loads in Dry Creek	Reduce sediment loss from run-off associated with vegetation disturbances Reduce loads from failed/failing septic systems Educate the public	Ammonia	0.05 mg/L	WQC
		Conductivity	145 µs/cm max.	Reference data
		Total Phosphorus	0.0255 mg/L	Reference data

Decrease bacteria levels to meet Primary Contact standards	Reduce bacteria loads from failed/failing septic systems Educate home and land owners	Bacteria count	Monthly geometric range of 200 cfu/100 mL and one-time sampling of 320 cfu/100 mL	WQC
		Biological Assessment (volunteer form)	Score of "Good"	Technical team suggestion
Improve water quality so that Dry Creek can be safely used as a recreational resource	Reduce bacteria loads from failed/failing septic systems and livestock operations Restore and/or construction native wetland areas to absorb water and filter pollutants Reduce sediment loss from run-off associated with vegetation disturbances and construction Reduce sediment from bank erosion through stabilization and vegetation cover Increase native plants in riparian zones and watershed Educate the public	pH	6 to 9 with less than a 1.0 change over 24-hours	WQC
		Alkalinity	41.6 mg/L	Reference data
		SSC	Embeddedness and sediment deposits of sub-optimal or optimal	Technical team suggestion
		TSS	3.39 mg/L for low and intermediate flows	Reference data
		Habitat Assessment	130	Technical team suggestion
		Ammonia	0.05 mg/L	WQC
		Conductivity	145 µs/cm max.	Reference data
		Total Phosphorus	0.0255 mg/L	Reference data
		Bacteria count	Monthly geometric range of 130 cfu/100 mL or 240 CFU/100 mL in no more than 20% of samples	WQC
		Biological Assessment (volunteer form)	Score of "Good"	Technical team suggestion
		Temperature	Not to exceed temperature guidelines	WQC
		pH	6 to 9 with less than a 1.0 change over 24-hours	WQC

ACTION ITEMS

Given the overall goals and objectives of this plan, the selected BMPs and the target values we will use to measure the effectiveness of BMPs (Tables 4.4 – 4.9), specific steps or actions are required to implement the BMPs. Actions deemed necessary for each sub-basin are related to goals, objectives and specific BMPs in the tables below.

Table 4.10. Summary of action items for BMPs in the Amanda's Bridge sub-basin.

Goal	Objective	BMP	Action Items
Decrease the sediment loads in Dry Creek	Increase stream bank and riparian zone vegetation Stabilize stream banks Educate the public	Place vegetated buffer strips along the main stream channel Enforce current laws and regulations Education	1. Secure local cost share money to do on-ground BMP demonstration. 2. Obtain funding for local landowners to implement BMPs. 3. Develop a workshop to educate landowners regarding BMP options. 4. Provide monitoring information to local and state agencies. 5. Work with local agencies to provide other educational opportunities for landowners.
Decrease nutrient loads in Dry Creek	Reduce sediment loss from run-off associated with vegetation disturbances Reduce loads from failed/failing septic systems Educate the public	Place vegetated buffer strips along the main stream channel Enforce current laws and regulations Education	1. Secure local cost share money to do on-ground BMP demonstration. 2. Obtain funding for local landowners to implement BMPs. 3. Develop a workshop to be held to educate landowners regarding BMP options. 4. Provide monitoring information to local and state agencies. 5. Work with local agencies to provide other education opportunities for landowners.
Decrease bacteria levels to meet Primary Contact standards	Reduce bacteria loads from failed/failing septic systems Educate home and land owners	Upgrade septic systems Enforce current laws and regulations Education	1. Work with Rowan County Health Department to provide assistance. 2. Help qualifying homeowners with grant programs to buy/upgrade septic systems. 3. Provide monitoring information to local and state agencies. 4. Work with local agencies to provide other education opportunities for landowners.

Table 4.11. Summary of action items for BMPs in Sugar Branch sub-basin.

Goal	Objective	BMP	Action Items
Decrease the sediment loads in Dry Creek	Increase stream bank and riparian zone vegetation Stabilize stream banks Educate public	Stabilize 170' of bank below bridge near SB-0.23 Implement grazing land management Enforce current laws and regulations Education	1. Secure local cost share money to do on-ground BMP demonstration. 2. Develop a workshop to educate landowners regarding BMP options. 3. Work with landowner to develop agreements to implement BMPs. 4. Provide monitoring information to local and state agencies. 5. Work with local agencies to provide other education opportunities for landowners.
Decrease nutrient loads in Dry Creek	Reduce sediment loss from run-off associated with vegetation disturbances Reduce loads from failed/failing septic systems Educate the public	Implement grazing land management Enforce current laws and regulations Education	1. Secure local cost share money to do on-ground BMP demonstration. 2. Develop a workshop to educate landowners regarding BMP options. 3. Provide monitoring information to local and state agencies. 4. Work with local agencies to provide other education opportunities for landowners.
Decrease bacteria levels to meet Primary Contact standards	Reduce bacteria loads from livestock run-off Educate home and land owners	Implement grazing land management Enforce current laws and regulations Education	1. Secure local cost share money to do on-ground BMP demonstration. 2. Develop a workshop to educate landowners regarding BMP options. 3. Provide monitoring information to local and state agencies. 4. Work with local agencies to provide education opportunities for landowners.

Table 4.12. Summary of action items for BMPs in Lambert Hollow sub-basin.

Goal	Objective	BMP	Action Items
Decrease the sediment loads in Dry Creek	Increase stream bank and riparian zone vegetation Educate the public	Place vegetated buffer strip and fencing along ¼ mile of the stream channel	1. Secure local cost share money to do on-ground BMP demonstration. 2. Develop a workshop to educate landowners regarding BMP options. 3. Work with landowner to develop

		Enforce current laws and regulations Education	agreements to implement BMPs. 4. Provide monitoring information to local and state agencies. 5. Work with local agencies to provide other education opportunities for landowners.
Decrease nutrient loads in Dry Creek	Reduce sediment and nutrients from run-off associated with vegetation disturbances Reduce loads from failed/failing septic systems Educate the public	Upgrade Septic Systems Place vegetated buffer strip and fencing along ¼ mile of the stream channel Enforce current laws and regulations Education	1. Secure local cost share money to do on-ground BMP demonstration. 2. Develop a workshop to educate landowners regarding BMP options. 3. Help qualifying homeowners with grant programs to buy new/upgrade septic systems. 4. Provide monitoring information to local and state agencies. 5. Work with local agencies to provide other education opportunities for landowners.
Decrease bacteria levels to meet Primary Contact standards	Reduce bacteria loads from failed/failing septic systems Educate home and land owners Reduce bacteria loads from livestock run-off	Upgrade Septic Systems Place vegetated buffer strip and fencing along ¼ mile of the stream channel Enforce current laws and regulations Education	1. Secure local cost share money to do on-ground BMP demonstration. 2. Develop a workshop to educate landowners regarding BMP options. 3. Help qualifying homeowners with grant programs. 4. Work with Rowan County Health Department. 5. Provide monitoring information to local and state agencies. 6. Work with local agencies to provide other education opportunities for landowners.

Table 4.13. Summary of action items for BMPs in Nichols Branch sub-basin*

Goal	Objective	BMP	Action Items
Decrease the sediment loads in Dry Creek	Increase stream bank and riparian zone vegetation Educate the public	Place vegetated buffer strip along main stream channel Enforce current laws and regulations	1. Secure local cost share money to do on-ground BMP demonstration. 2. Work with Fish and Wildlife and other agency to obtain cost share for landowners. 3. Provide monitoring information to local and state agencies. 4. Work with local agencies to
Decrease nutrient loads in Dry Creek	Reduce sediment and nutrients from run-off associated		

	with vegetation disturbances Reduce loads from failed/failing septic systems Educate the public	Education	provide other education opportunities for landowners.

*Note that the goal of decreasing bacteria levels to meet Primary Contact standards is not in this table. Implementation of BMPs in the sub-basins of Sugar Branch, Amanda's Bridge, and Lambert should address most of the bacteria issues in the Nichols Branch sub-basin.

Table 4.14. Summary of action items for BMPs in Ravenswood sub-basin

Goal	Objective	BMP	Action Items
Decrease nutrient loads in Dry Creek	Reduce loads from failed/failing septic systems Educate the public	Expand MUPB sewer to the Ravenswood area Enforce current laws and regulations Education	1. Secure local cost share funds and grants. 2. Develop a workshop to educate landowners regarding BMP options. 3. Help qualifying homeowners with grant programs. 4. Provide monitoring information to local and state agencies. 5. Work with local agencies to provide other education opportunities for landowners.
Decrease bacteria levels to meet Primary Contact standards	Reduce bacteria loads from failed/failing septic systems Educate home and land owners Reduce bacteria loads from livestock run-off		

Table 4.15. Summary of action items for BMPs in Dry Creek basin.

Goal	Objective	BMP	Action Items
Decrease the severity and frequency of flooding	Reduce sediment loss from run-off associated with vegetation disturbances and construction Reduce sediment from bank erosion Increase native plants in riparian	Place vegetated buffer strips along the main stream channel Enforce current laws and regulations Education	1. Investigate with cost share programs for local landowners. 2. Develop a workshop to educate landowners regarding BMP options 3. Work with Fish and Wildlife and other agency to obtain cost share for landowners. 4. Provide monitoring information to local and state agencies. 5. Work with local agencies to provide other education

	zones and watershed Restore native wetland areas to absorb water		opportunities for landowners.
		Construct a wetland of about ¾ acre	6. Apply for grants to construct wetlands. 7. Utilize 319 funds if possible. 8. Work with landowners and DOT.
Decrease the sediment loads in Dry Creek	Reduce sediment loss from run-off associated with vegetation disturbances and construction Increase stream bank and riparian zone vegetation Stabilize stream banks Restore and/or construction wetlands Educate the public	Place vegetated buffer strips along the main stream channel Enforce current laws and regulations Education	1. Investigate with cost share programs for local landowners. 2. Develop a workshop to educate landowners regarding BMP options. 3. Work with Fish and Wildlife and other agency to obtain cost share for landowners. 4. Provide monitoring information to local and state agencies. 5. Work with local agencies to provide other education opportunities for landowners.
		Construct a wetland of about ¾ acre	6. Apply for grants to construct wetlands. 7. Utilize 319 funds if possible. 8. Work with landowners and DOT.
Decrease nutrient loads in Dry Creek	Reduce sediment loss from run-off associated with vegetation disturbances Reduce loads from failed/failing septic systems Educate the public	Place vegetated buffer strips along the main stream channel Enforce current laws and regulations Education	1. Investigate with cost share programs for local landowners. 2. Develop a workshop to educate landowners regarding BMP options. 3. Work with Fish and Wildlife and other agency to obtain cost share for landowners. 4. Provide monitoring information to local and state agencies. 5. Work with local agencies to

			provide other education opportunities for landowners.
		Construct a wetland of about ¾ acre	6. Apply for grants to construct wetlands. 7. Utilize 319 funds if possible. 8. Work with landowners and DOT.
Decrease bacteria levels to meet Primary Contact standards	Reduce bacteria loads from failed/failing septic systems Educate home and land owners	Place vegetated buffer strips along the main stream channel Enforce current laws and regulations Education	1. Investigate with cost share programs for local landowners. 2. Develop a workshop to educate landowners regarding BMP options. 3. Work with Fish and Wildlife and other agency to obtain cost share for landowners. 4. Provide monitoring information to local and state agencies. 5. Work with local agencies to provide other education opportunities for landowners.
		Construct a wetland of about ¾ acre	6. Apply for grants to construct wetlands. 7. Utilize 319 funds if possible. 8. Work with landowners and DOT.
Improve water quality so that Dry Creek can be safely used as a recreational resource	Reduce bacteria loads from failed/failing septic systems and livestock operations Restore and/or construction native wetland areas to absorb water and filter pollutants Reduce sediment loss from run-off associated with vegetation disturbances and	Place vegetated buffer strips along the main stream channel	1. Investigate with cost share programs for local landowners. 2. Develop a workshop to educate landowners regarding BMP options. 3. Work with Fish and Wildlife and other agency to obtain cost share for landowners.
		Construct a wetland of about ¾ acre Enforce current laws and regulations Education	4. Apply for grants to construct wetlands. 5. Utilize 319 funds if possible. 6. Work with landowners and DOT. 7. Provide monitoring information to local and state agencies. 8. Work with local agencies to provide other education opportunities for landowners.

	construction Reduce sediment from bank erosion through stabilization and vegetation cover Increase native plants in riparian zones and watershed Educate the public		

HUMAN RESOURCES AND FUNDING MECHANISMS

So how will we pay for implementing BMPs, how much will it cost, and who will be responsible for getting the job done? The following table summarizes the answers to these questions. Note that all BMPs for each sub-basin are now combined since the same approaches are used throughout the Dry Creek Watershed.

Table 4.16 Human resources and funding mechanisms for implementing the plan

BMP	Responsible Party	Technical Assistance	Cost	Funding Mechanisms
Enforcement of current laws and ordinances	Rowan County Fiscal Court Rowan County Health Department KY Division of Water KY Transportation Cabinet	Rowan County Fiscal Court Rowan County Health Department KY Division of Water KY Transportation Cabinet KY Waterways Alliance	$0 - $60,000	Existing internal funding of agencies (general funds) 319 (h) grant
Education	Landowner and all other citizens Public Officials KY Transportation	NRCS Morehead State University UK Agriculture Extension Services	$0 - $100,000	Existing internal funding of agencies (general funds) EPA Environmental Education Grants

	Cabinet	Licking River Watershed Watch KY Division of Water KY Division of Forestry Kentucky Waterways Alliance		Serve and Learn Grants National Fish and Wildlife Resources East KY PRIDE 319 (h) grant River Network/MillerCoors Watershed Protection Grants KY EXCEL program
Place vegetated buffer strips along the main stream channel	Landowner	NRCS Fish and Wildlife KY Department of Fish and Wildlife Resources (KDFWR)	\$1,500 per mile ~\$9,000 for the entire main stem of Dry Creek	319 (h) grant NRCS cost share programs KDFWR cost share programs In-Lieu Fee Program
Construct a wetland of about ¾ acre	Landowner (DOT and MUPB)	Triplett Creek Committee USFS East KY PRIDE KDFWR	\$15,000 to \$30,000	5 Star Grant KDFWR cost share programs 319(h) grant NRCS Wetland Reserves Program In-Lieu Fee Program
Expand MUPB sewer to the Ravenswood area	Landowner MUPB	Gateway ADD Rowan County Health Department MUPB Triplett Creek	\$15,000 to \$25,000 per home	EPA grants and other Federal Cost share Homeowner

		Committee		
Upgrade septic systems	Landowner Health Department	Health Department	$3,000 - $10,000 per house	East KY PRIDE Homeowners
Fencing along stream channel	Landowner	NRCS Morehead State University UK Agriculture Extension Services KY Division of Water	$15,000 per mile $3,758 for recommended section	Landowner KDFWR cost share programs NRCS cost share programs 319 (h) grant
Implement grazing land management	Landowner	NRCS Triplett Committee UK Agriculture Extension Services	$360 per acre	Landowner 319 (h) grant NRCS cost share programs
Stabilize 170’ of eroding bank below Sugar Branch Bridge	Landowner, possibly aided by the county if legal issues are settled	NRCS Triplett Creek Committee UK Agriculture Extension Services KY Division of Water	$25 to $300 per foot depending on method used $4,250 to $51,000 for recommended section	Landowner 319 (h) grant In-Lieu Fee Program

INDICATORS AND MILESTONES

To assist with the implementation plan it is important to develop indicators and milestones for each BMP. Table 4.17 describes these indicators and milestones.

Table 4.17 Measuring progress toward goals and success of action items

BMP	Indicators to Measure Progress	Milestones			
		Short term	Medium term	Long term	Extended
Enforcement of current laws and ordinances	Communication and follow up meetings with state and local officials	Initial meetings on the current laws and ordinances that apply	Development of plan to implement enforcement needs	Obtain funding and program needs to enforce plan	Obtain funding and program needs to enforce and revise plan as needed
Education	Hold 2 Workshops 1. Farmers 2. Homeowners	Develop specific needs for each workshop and agenda	Host two workshops		
Place vegetated buffer strips along the main stream channel	18 meter native vegetation buffer along streams	Contact key landowners	Host workshops		
Construct a wetland of about ¾ acre	Construction of wetland	Apply for grant funding	Construction preparations	Complete installation	Monitoring
Expand MUPB sewer to the Ravenswood area	Installation of sewer lines	Internal discussion of feasibility	Public forum		
Upgrade septic systems	Homeowners making necessary upgrades to failing septic systems	Work with funding agency and county Health Department to develop a plan	Contact landowners and assist with financial support		
Fencing along stream channel	Fencing installed	Work with funding agencies, NRCS, and Ag. Extension officer	Contact landowners and assist with financial support where appropriate		

Implement grazing land management	Grazing land management plans implemented	Work with funding agencies, NRCS, and Ag. Extension officer	Contact landowners and assist with financial support where appropriate	Ongoing support from NRCS and the Ag. Extension officer	
Stabilize 170' of bank near Sugar Branch Bridge	Installation of a major stream bank stabilization project	Work with Rowan County Fiscal Court to develop a design and implementation strategy	Completion of stream bank stabilization		

EXPECTED OUTCOMES AND LOAD REDUCTIONS

Predicting Model Load Reductions

Initial Plan

An EPA-approved model, the Pollutant Reduction Impact Comparison Tool (PRedICT; http://www.predict.psu.edu), was to be used to estimate annual average pollutant (sediment, nitrogen and phosphorous) load reductions related to selected user-defined BMPs scenarios for the Dry Creek Watershed (and sub-watersheds). Average annual loads predicted using the AVGWLF model were to be used to initialize the PRedICT model. In PRedICT, each scenario may include one or more agricultural, farm animal, urban and/or wastewater BMP selected from the model library. These scenarios were to be selected from the library based upon input from qualified project personnel and other experts and relevant stakeholders. Library BMPs (and associated cost estimates) were to be refined as needed in order to more accurately represent local knowledge/conditions.

Unforeseen Problem with PRedICT

An unforeseen problem arose with the PRedICT model as this phase of the modeling work was to get underway. Earlier in this project PRedICT's tutorial dataset was run through the model in order to check for any potential problems/errors with the model software – none were found. However, as soon as the first PRedICT model simulation was begun in the 'pollution load reduction' modeling phase of this project a software 'run time' error was encountered. The program developer was immediately contacted and agreed to troubleshoot the problem. The appropriate files were sent to the developer for inspection at this time.

In the meantime, C. McMichael attempted to run the model on a separate computer, but ran into the same software error. A few weeks later the developer contacted C. McMichael to say that his technical support team was no longer available and that he did not have very much time to devote to this problem himself, but that he would do his best to get it resolved as soon as possible. The developer suggested a possible work-around using the functioning AVGWLF model. This option was investigated by C. McMichael, but she concluded that it would not be possible to obtain the desired information using this approach. Consequently, the PRedICT-based load reduction modeling work will not be completed in time to be included in the Dry Creek Watershed-based Plan.

Revised Plan
Since the Dry Creek Watershed is in the Triplett Creek Watershed, a basin for which a 319(h) grant has been obtained, the load reduction modeling for the Dry Creek Watershed will occur as a part of this larger watershed project. If the problem with the PRedICT model is not resolved in a reasonable period of time, C. McMichael will investigate an alternative model (STEP-L) for use in modeling load reductions in the Dry Creek Watershed.

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Chapter 5: Implementation and Post-monitoring

ORGANIZATION

Successful implementation and monitoring of the BMPs recommended in Chapter 4 will depend on the continued work of the Triplett Creek Watershed Committee, public and local government officials, and key partners such as the Kentucky Department of Fish and Wildlife Resources, the Kentucky Division of Water, Morehead State University, the Rowan County Health Department, and the US Forest Service. We also hope to maintain our successful working relationship with the Kentucky Waterways Alliance, which has been instrumental in helping us develop this watershed-based plan.

The Triplett Creek Committee will be responsible for implementing the Dry Creek Watershed-based Plan. Although the Triplett Creek Watershed Committee includes members from most of the local, state and federal organizations listed above and, of course, concerned citizens, MSU will continue to serve as the lead organization. The implementation and post-monitoring phases of the Dry Creek Watershed-based Plan will be rolled into a USEPA/KDOW 319(h) nonpoint source pollution grant awarded to MSU to develop a watershed-based plan for the entire Triplett Creek Watershed. The 319(h) grant will continue through 2013 and is currently funding the salary for a part-time watershed coordinator. The watershed coordinator will keep the Triplett Creek Watershed Committee updated on progress through e-mail, web site postings and periodic meetings, including public roundtables and presentations to the Rowan County Fiscal Court, Morehead City Council, and other community organizations.

Implementation Team
Core members of the implementation team will include the MSU Watershed Coordinator, the Licking River Basin Coordinator, and the Rowan County Solid Waste and Flood Plan Manager. This core group will be responsible for keeping the larger Triplett Creek Watershed Committee informed regarding ongoing activities and will draw upon community assets as needed to implement the WBP.

Technical Team
The same technical team that conducted pre-implementation monitoring and GIS-based mapping/modeling will monitor post-implementation effectiveness of BMPs. As during the pre-monitoring phase, this team will consist of an ecologist, a geographer, a geologist, and a microbiologist from MSU. The technical team will draw upon the expertise of planners, environmental engineering consultants and construction contractors as needed to develop or refine BMP implementation plans.

MONITORING PLAN
The recently awarded 319(h) grant to develop a Triplett Creek Watershed-based plan will fund the post-monitoring phase of the Dry Creek WBP. Post-implementation monitoring of Dry Creek

BMPs will be conducted using the approach and methods outlined in the *Triplett Creek Watershed Based Plan* (CFDA Number: 66.460; Control Program #C9994861-08) and its accompanying Quality Assurance Project Plan (QAPP). These documents are included as Appendix D and were prepared by Geoffrey W. Gearner, PhD; April D. Haight, MS; Christine E. McMichael, PhD and Steven K. Reid, PhD.

Post-BMP implementation monitoring of Dry Creek will be conducted at only two of the sites monitored during the pre-BMP implementation phase: DC-0.28 (Tile Storage Road) and DC-2.84 (Nicolas Branch Bridge). Limiting the number of sampling sites is necessary due to the large number of sites included in the Triplett Creek Watershed QAPP.

It is important to note that a site on Morgan Fork, a major tributary of Dry Creek 1500 feet upstream of DC-0.28, will be monitored as part of the Triplett Creek WBP. During the Dry Creek pre-BMP implementation phase, only flow and suspended sediment concentration were monitored at this site. After installation of Dry Creek BMPs (probably 2012), monitoring at the two Dry Creek sites and on Morgan Fork will include measuring flow; sampling for bacteria, sediment, nutrients, and habitat; recording temperature, pH, dissolved oxygen, and conductivity; and habitat assessment. The influence of Morgan Fork on bacteria and nutrient loads at DC-0.28, now a significant gap in our knowledge, will be better understood after this sampling period. See Appendix D for further details.

EVALUATION PLAN

Approach

The Triplett Creek Watershed Committee will utilize public input, the degree of success in meeting BMP implementation milestones and post-BMP monitoring to evaluate the effectiveness of the Dry Creek WBP. Specific action items toward BMP implementation and the target values that we hope to achieve using each BMP were outlined in Chapter 4. Progress on action items will be evaluated at our regular scheduled meetings of the Triplett Creek Watershed Committee. Once BMPs are in place, indicators of their effectiveness will be evaluated at these meetings as well.

Implementation

Success in implementing action items towards BMP implementation in each Dry Creek sub-basin will be assessed by the Triplett Creek Watershed Committee using score-cards. The score cards will be updated every 4 months for the committee to review and discuss. Table 5.1 is an example of a score-card for action items associated with a single BMP.

Table 5.1. Example score-card for action items associated with a single BMP

BMP	Action Items	No Progress	In Progress	Progress Stalled	Adaptive Strategy	Completed
Enforce current laws and regulations	4. Investigate cost share programs for local landowners. 5. Develop a workshop for landowners. 6. Work with Fish and Wildlife and other agencies to obtain cost share for landowners. 4. Provide monitoring information to local and state agencies. 5. Work with local agencies to provide other education opportunities for landowners.					

Outcome Indicators

Post-BMP implementation water quality and geomorphic monitoring data will be compared to target values chosen in Chapter 4 (Tables 3 through 8) in order to assess whether our objectives are being met. Concentrations and physical parameter values before and after BMP implementation will be compared. In addition, loads calculated using post-implementation concentrations and mean annual flow (MAF) will be used to calculate post-implementation loads. Comparison of these loads with pre-BMP implementation loads and with loads calculated using established water quality criteria (WQC x MAF) will determine whether water quality is actually improving.

Outreach

Outreach efforts generally take the form of meetings, community roundtables, presentations, workshops, and field trips. At the end of each activity, evaluation forms will be distributed to participants in order to rate the effectiveness of the event. As discussed under “Adaptive Management” below, we have already found that many of these traditional approaches to outreach are ineffective not because of the quality of the event but because very few people attend.

Adaptive Management

The ultimate, long-term goal of the Dry Creek Watershed-based Plan is to improve water quality, preferably to the point where Dry Creek can be removed from the KDOW impaired waterways list (i.e., the Integrated Report Volume I). The Triplett Creek Watershed Committee will utilize passive and evolutionary adaptive management strategies as needed. In this strategy we will use the information available to choose best management options and regular committee meetings to solicit feedback and review new information. To ensure that the committee is showing progress to the community, and to encourage public involvement, we will implement well-publicized independent projects to address practical problems. If, however, we find that action items are not being completed, that the public is not participating or responding to outreach efforts, or that post-BMP implementation monitoring results indicate that our objectives are not being met, we must adapt.

In fact, we have already been forced to adapt. For example, committee members originally agreed to hold a series of periodic community roundtables in order to inform citizens and local officials of the nature and purpose of this study, scientific findings regarding the state of the watershed and BMPs that should help solve identified problems. Neither event was well attended despite being widely publicized. As a result, a decision was made to begin attending City Council and Fiscal Court meetings and to use YouTube and social networking sites as additional venues to disseminate information, a process that is still ongoing.

For example, if, in the future we discover that few landowners chose to re-vegetate eroding banks or re-seed barren land, even if we provide the seed, then alternative approaches can be pursued. We may host a field trip to sites that have implemented good practices versus sites with bad practices. Or, we convince the city or county to try an inexpensive BMP on public property and compare the results to another public property were the problem is ongoing but unaddressed, then host a field trip to highlight the effectiveness of the implemented BMP. Even if the field trips themselves were poorly attended, we would still video document the event, post it to YouTube, then publicize the posting to local media, KWA, MSU, the city, the county and other stakeholder groups.

PRESENTATION OF THE PLAN AND ITS RESULTS

Many of the methods use to share the plan and its results to different constituencies are discussed in the previous two sections. To date, we have geared various presentations to different audiences based on such factors as technical background, position in the community (e.g., citizen, politician, civil servant), and education level. The basic content of each presentation will be the same but the method of delivery and amount of technical language used may be altered. We will utilize local community networks and organizations (e.g., KWA, Watershed Watch) to share findings about the watershed, as well as public forums, news articles, e-mails, the web, and radio. But, as previously discussed, our early experiences indicate that we will have to be much more creative.

Some of the strategies that will be presented to gain public and political support include:
- Advertize the fact that the costs of implementing BMPs can be subsidized or shared.
- Investigate the most cost effective way for the audience to engage in positive behavior changes.
- Investigate incentives to encourage positive behavior.
- Piggyback onto an existing projects.

- Educate the target audiences on real and perceived risks of poor water quality.
- Provide statistics to show levels of risk.
- Research current community positive behaviors as well as negative behaviors.
- Develop messages that make it socially desirable to protect waterways.
- Provide frequent and strategically placed prompts to remind people of desired behavior.
- Identify early adopters in the community, and partner with them to spread the word and convince others to adopt the new behavior. They can help develop new social norms that include positive environmental behaviors.
- Provide training through workshops on the new behavior.
- Show the immediate consequences of both adopting and not adopting the behavior.
- Identify and communicate actual or estimated environmental, social, and economic impacts (e.g., statistics, before- and-after photos) of the opposing behavior and the recommended behavior.
- Provide statistics on the collective impacts of individual actions.

ADDITIONAL INFORMATION

This watershed-based plan was developed with support and funding from the Kentucky Waterways Alliance. For more information about the process you can contact Tessa Edelen, KWA Watershed Program Director, or April Haight, Morehead State University's Center for Environmental Education Director.

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Appendix A

Roundtable Discussion

Outline for Dry Creek Roundtable Report

I. Executive Summary

II. Introduction

A. Background Information
B. Roundtable Agenda
C. How Roundtable Information Will be Utilized

III. Responses from Roundtable
IV. Conclusion

A. Impacts of the Roundtable on the Planning Process and the Community

B. Roundtable Participant Questionnaire Results

V. Appendices

A. Map of Watershed

B. Roundtable Attendance List

C. Roundtable Agenda

D. Roundtable Questionnaires and Results

I. Executive Summary

The Dry Creek Watershed-based Plan Roundtables were held on February 5 and 9, 2008 at the Clearfield Elementary School in Clearfield, Kentucky (Rowan County). The two roundtables attracted 25 people, nine of those being first-time participants in the project.

A tributary of Triplett Creek, the Dry Creek watershed is a 7500 acre area located just southeast of Morehead. Dry Creek is listed as impaired for aquatic life in the Kentucky Division of Water's 2006 Integrated Report. To address point and non-point source pollution in Dry Creek, Morehead State University and the Kentucky Waterways Alliance are working in partnership, with community input, to create a watershed-based plan.

The roundtables were held with the intent of drawing more stakeholders into the watershed planning process, increasing the public visibility, educating the public on water quality issues in the Dry Creek watershed, and to gain stakeholders' input for the planning process.

Several roundtable participants volunteered to serve on the Watershed Planning Team, and several others indicated interest in becoming trained volunteers to conduct water quality testing in Dry Creek. At the roundtables, participants were informed about issues facing the watershed and, thanks to publicity and good attendance, public visibility was enhanced by the event.

The overall project to develop a watershed-based plan is funded in part by a grant from the U.S. Environmental Protection Agency under §319(h) of the Clean Water Act through the Kentucky Division of Water to the Kentucky Waterways Alliance *(Grant # C9994861-04).*

The Dry Creek Watershed Planning Team will continue to work to develop the plan through early 2010. Another roundtable is planned for 2009 after a draft watershed-based plan has been completed and is ready to present to the public.

II. Introduction

A. Background Information

A tributary of Triplett Creek, the Dry Creek watershed is a 7500 acre area located just southeast of Morehead. Dry Creek is listed as impaired for aquatic life in the 2006 Integrated Report. The Dry Creek watershed is mainly forested with housing developments concentrated at the mouth of the creek. To address pollution in Dry Creek, Morehead State University and the Kentucky Waterways Alliance are working together, with community input, to create a watershed-based plan. The roundtables were held to draw more stakeholders into the watershed planning process, increase the public visibility, educate the public on issues facing the Dry Creek watershed, and to gain stakeholders' input for the planning process.

B. Roundtable Agenda

The Dry Creek Watershed Planning Team chose to hold two roundtables in order to involve a greater number of stakeholders. The first roundtable was held on the evening of Tuesday, February 5, 2008. The second roundtable was held the following Saturday morning, February 9. Both roundtables followed the same agenda, outlined below.

As participants arrived at the event, they were asked to register and to fill out a "Pre-Roundtable Assessment" to garner prior knowledge about the discussion topics planned for the roundtable. (Following the event, each participant was asked to complete a "Post-Roundtable Assessment" to determine how much they learned at the event.)

After registration, April Haight, the Facilitator for the Dry Creek Watershed Planning Team, welcomed the group and led group introductions. Several members of the Watershed Planning Team presented on the project. Katie Holmes from the Kentucky Waterways Alliance presented background on watersheds and the watershed-based planning process. Christi McMichael introduced information on land cover and land use in the Dry Creek watershed, and the affect this has on water quality. April Haight covered the results of habitat assessments performed in the Dry Creek watershed and presented research on nutrient levels in the watershed. Steve Reid explained sediment and erosions issues in the watershed. Finally, Geoff Garner told the group about bacteria in Dry Creek.

Following the presentations, Tom Carew led the group in a moderated discussion of the following questions:

- How do you use the creek?
- How would you like to use the creek?
- How do you use the watershed?
- Why is the watershed important to you?
- What are the problems in the watershed?
- What are your goals for the watershed?

C. How Roundtable Information Will be Utilized

The Dry Creek Watershed Planning Team is in the beginning stages of working on a watershed-based plan for the Dry Creek watershed. At its next meeting, the team will consider the input from roundtable participants, and will decide which problems and goals should be incorporated into the scope of the plan.

All comments from participants in the roundtable have been included in this report to provide an accurate representation of the discussion that occurred. Some comments may not be appropriate to incorporate into the plan at this time, but all feedback will be reviewed by the team.

III. Responses from Roundtable

Participants at both of the roundtables were asked the following questions:

- How do you use the creek?
- How would you like to use the creek?
- How do you use the watershed?
- Why is the watershed important to you?
- What are the problems in the watershed?
- What are your goals for the watershed?

The following were the participants' responses:

How do you use the creek?
1. Children play in the creek (or aren't allowed to because it is too dirty)
2. Kayaking at high flows
3. Cleaning out trash
4. Fishing
5. Get bait from creek
6. Gravel Mining

How would you like to use the creek?
1. Fishing (safely)
2. Swimming hole
3. Kayaking (too "dirty" now)
4. Safely play in the creek
5. Drink out of the creek
6. Better fish habitat
7. More wildlife
8. Educational purposes – students could catch critters, etc.
9. Play area for kids

How do you use the watershed/what do you seeing happening to the watershed in the future?

1. 1-2 dozen cattle in the watershed
2. More residential/rental construction has come in/will be coming
3. Expanded sewer has been requested
4. More trailer parks have been developed
5. Increased logging – 300 acres of National Forest land is about to be logged
6. No official hiking trails in Dry Creek
7. Agriculture
8. Residential
9. Vegetable gardens

Why is the watershed important to you?
1. Feeds into Triplett Creek – lots of people fish there and some paddle there
2. Flooding concerns
3. Health and well-being of environment and the people who use it
4. Importance of water as a resource in general
5. Property being lost to bank erosion

What are the problems in the watershed (both on land and in the creek)?
1. Flooding
2. Infill of floodplain and floodway/illegal building in floodplain
3. Flat land is hard to find in Dry Creek (that is not in the floodplain)
4. Erosion around roadways (and no guardrails) (Could get transportation department involved in the project)
5. Property Loss into the creek due to erosion
6. How to attract interest in BMPs? (Resentment from the Daniel Boone Forest taking land from Rowan Co. residents) Incentives- put $ in their pockets!
7. Channelization
8. Bridges lead to more erosion (seen some improvement with new bridges)
9. No ordinances
10. Gravel mining
11. Trash in creek
12. Low diversity of minnows (indicator of other problems)
13. Creek is better than it was in the 80s and 90s, but there is a long way to go
14. Large algal blooms
15. Sewers not available throughout watershed
16. Increased paving increases erosion, which increases flooding – needs better management
17. Farmers are concerned about having to implement BMPs
18. Floodplain management is a concern
19. Home septic systems over flowing resulting in bad odor

What are your goals for the watershed?
1. Opportunity to have local official be trained on good planning and zoning ordinances.
2. Get the tourism department involved in project – have creek clean ups and increase tourism.
3. Hopes plan is successful and that it will expand to Christy Creek next.
4. Create more stable creek banks.
5. Expand sewer infrastructure.

IV. Conclusion

A. Impacts of the Roundtable on the Community and the Planning Process

Publicity for the roundtables reached many watershed residents. Public service announcements ran on a local radio station, WMKY, for the weeks leading up to the roundtables, and flyers advertising the roundtables were posted at public places throughout the Dry Creek watershed. The local newspaper, *The Morehead News* ran notices about the roundtables. Preceding the second roundtable, Watershed Planning Team members went door-to-door in the watershed to talk to residents about the roundtable and encourage public participation. Many area residents said that they had seen the notices in the newspaper, and that they were aware of the roundtable.

The roundtables drew additional residents from the Dry Creek watershed and the surrounding area to be a part of the process. Additionally, some members of potential partner agencies, such as The Nature Conservancy and Morehead Public Utilities, attended the roundtables, and have expressed interest in the project. The Watershed Planning Team will benefit from the added knowledge of the watershed that these residents and possible partner agencies bring to the table.

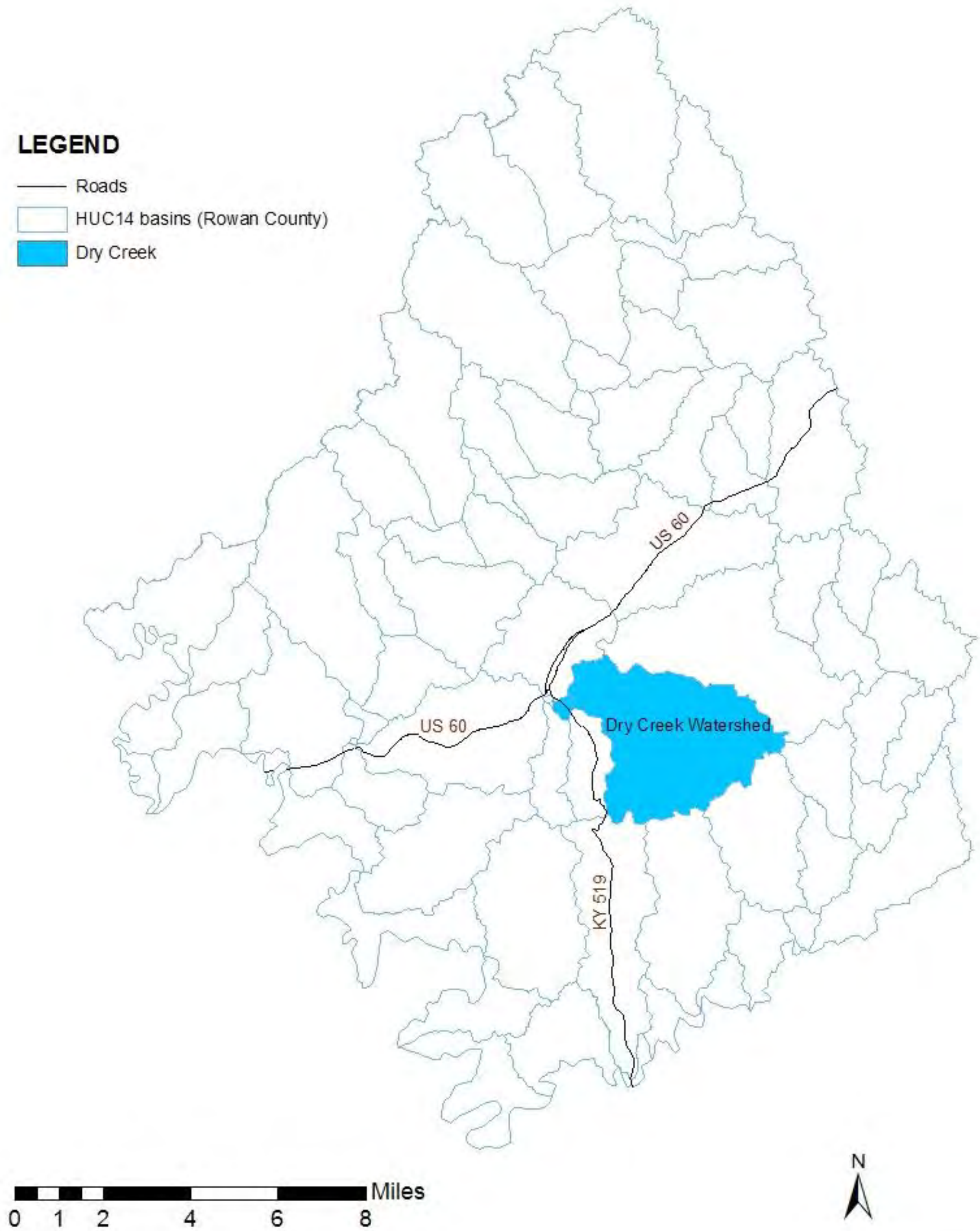
Through discussions held at the roundtable, the Watershed Planning Team learned about additional issues to add to the plan, and about potential programs that could be helpful to the watershed-based plan.

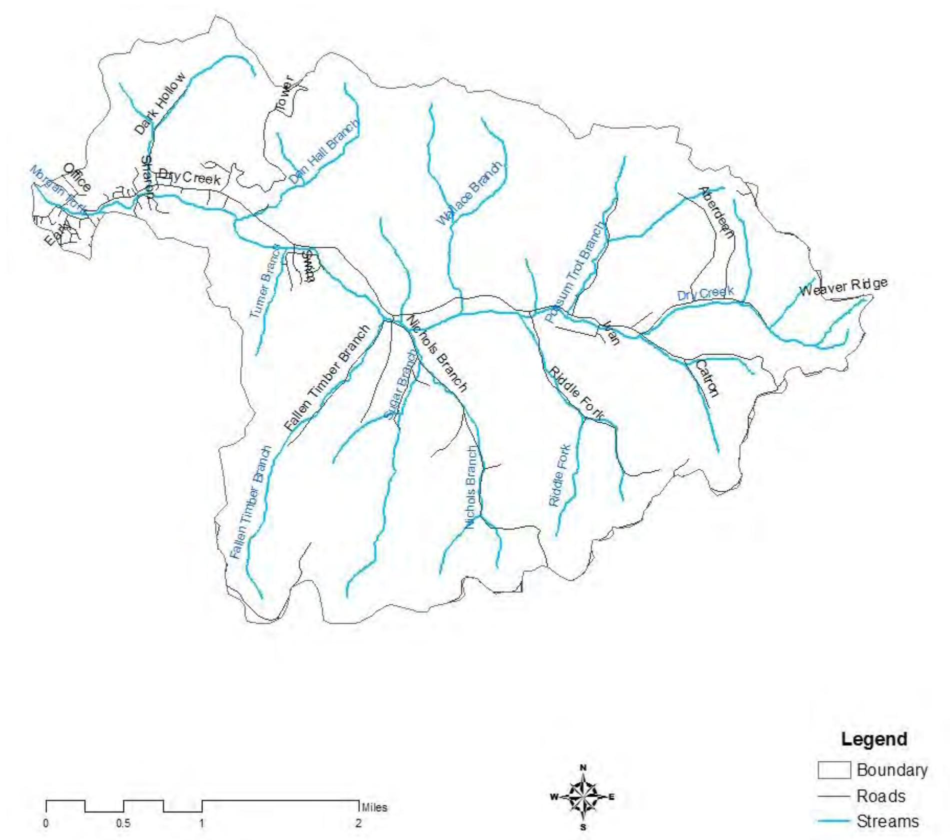
B. Roundtable Participant Survey Results

As participants arrived at the event, they were asked to register and to fill out a "Pre-Roundtable Questionnaire" to garner prior knowledge about the discussion topics planned for the roundtable. Following the event, each participant was asked to complete a "Post-Roundtable Questionnaire" to determine how much they learned at the event. These questionnaires were identified with numbers, not names, so that people would feel comfortable answering truthfully. The roundtable questionnaires and results are attached to this report.

Unfortunately, only two roundtable participants turned in both the pre-roundtable and post-roundtable questionnaires. Both of their post-roundtable questionnaires showed that these participants had expanded their understanding of watershed issues during the roundtable. Both participants indicated that prior to the roundtable they had not heard of a watershed-based plan and did not have a good understanding about what defines a watershed. In their post-roundtable assessments, these two participants both indicated that they had a better understanding of "the process involved in the development of a watershed-based plan" than before the roundtable. They also indicated they felt they could now successfully define the term "watershed." Though these results aren't statistically significant for the entire group, they do indicate that the roundtable accomplished its educational goals among a few participants. The Watershed Planning Team has discussed more systematic ways to ensure that more surveys are completed at future roundtables.

Maps of Watershed





Roundtable Questionnaires and Results

Number __1__

Pre-roundtable Questionnaire

Dry Creek Watershed-based Plan

1. Had you ever heard of a Watershed-based plan before this meeting? Yes No

2. Do you have a good understanding of what a watershed is? Yes No

3. Name two pollutants in the Dry Creek.

   a. _____________________

   b. _____________________

4. Do you know the difference between non-point and point source pollutant?
   Yes No

Number __1__

Post-roundtable Questionnaire

Dry Creek Watershed-based Plan

1. Do you feel that you have more of an understanding of the process involved in the development of a watershed-based plan than before this meeting? Yes No

2. Could you explain to someone what a watershed is? Yes No

3. Name two problems caused by pollution in Dry Creek.

   a. ____________________

   b. ____________________

4. List two possible sources of non-point source pollution in the Dry Creek Watershed.

   a. ____________________

   b. ____________________

Results from Questionnaires:

Pre-roundtable Questionnaire	**Respondent 1**	**Respondent 2**	**Respondent 3**	**Respondent 4**	**Respondent 5**	**Respondent 6**	**Respondent 7**
Had you heard of a Watershed-based plan before this meeting?	No	No	Yes	Yes	No	Yes	
Do you have a good understanding of what a watershed is?	No	No	Between yes and no	Yes	Yes	Yes	
Name two pollutants in Dry Creek.	Septic	Septic	E. Coli	Human waste E. Coli	Sediment	Sewer	
	Trash	Trash	Fecal Coliform	Non-biodegradable pollutants (mercury)	Fecal Coliform	Trash - junk	
Do you know the difference between non-point and point source pollution?	No	No	Yes	Yes	Yes	Yes	

Post-roundtable Questionnaire	**Respondent 1**	**Respondent 2**	**Respondent 3**	**Respondent 4**	**Respondent 5**	**Respondent 6**	**Respondent 7**
Do you feel that you have more of an understanding of the process involved in the development of a watershed-based plan than before this meeting?	Yes	Yes					No
Could you explain to someone what a watershed is?	Yes	Yes					Yes
Name two problems caused by pollution in Dry Creek.	Septic	Septic					E. Coli
	Trash (cars) in Bank!!!	Trash					Chemicals
List two possible sources of non-point source pollution in Dry Creek Watershed.							Sewer
							Chemicals

Appendix B

The Dry Creek Watershed Planning QAPP is on file with the Kentucky Division of Water.

Appendix C

Bank Erosion Contribution to Suspended Sediment Load

Two sites in the Dry Creek watershed have been monitored in order to estimate the portion of the suspended sediment load derived from bank erosion, one at SB-0.23 and one 200 ft downstream of DC-0.28. While not included in the KWA grant or the QAPP in Appendix C, the work was begun during the KWA pre-monitoring period by a recent MSU geology graduate and continues as part of a larger 319h grant for the entire Triplett Creek. Detailed methods are outlined in a separate QAPP for the 319h grant but are summarized here.

Just downstream of SB-0.23, a 170 ft segment of Sugar Branch is eroding colluvium at the base of a steep slope (Figure D1). Two monumented cross-sections within this stream reach were measured in March 2009 and again in September 2009 (Figures D2, D3). Accurately scaled drawings of channel cross-sections from both dates (not shown) were superimposed and the area of lost bank material determined. Volume of material lost was estimated by multiplying the reach length (170 ft) by the average area lost over the reach (22.72 ft^2). The bulk density of the bank material was assumed to be the same as that determined for similar bank material at another location in the Triplett Creek watershed. Bulk density there was calculated by collecting a known volume of bank material, drying and weighing the sample, then dividing the dry weight by sample volume. Finally, the estimated volume lost to erosion was multiplied by bulk density and divided by the time between cross-section measurements to calculate load.

$22.72 \text{ ft} \times 170 \text{ ft} \times (1 \text{ m} / 3.28 \text{ ft})^3 \times 1719 \text{ kg/m}^3 \times 2.2 \text{ lb/kg} = 413937 \text{ lb}$

$(413937 \text{ lb} / 165\text{days}) \times 365 \text{ days/yr} = 915678 \text{ lb/yr}$

Figure D1: Monitored channel cross-section (SB-0.23a) within 170 ft reach just downstream of SB-0.23 where Sugar Branch erodes colluvium at the base of a steep slope.

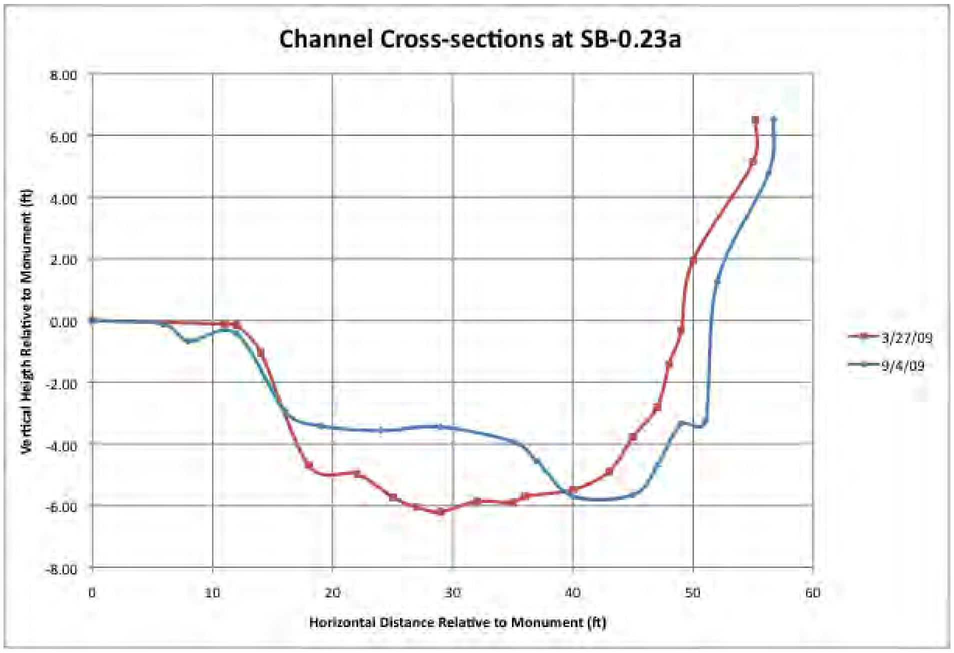


Figure D2: Comparison of same channel cross-section near SB-0.23 measured on different dates. Area on right side of graph shows lost material (blue line right of red line). Area in center shows new gravel bar (blue line above red line).

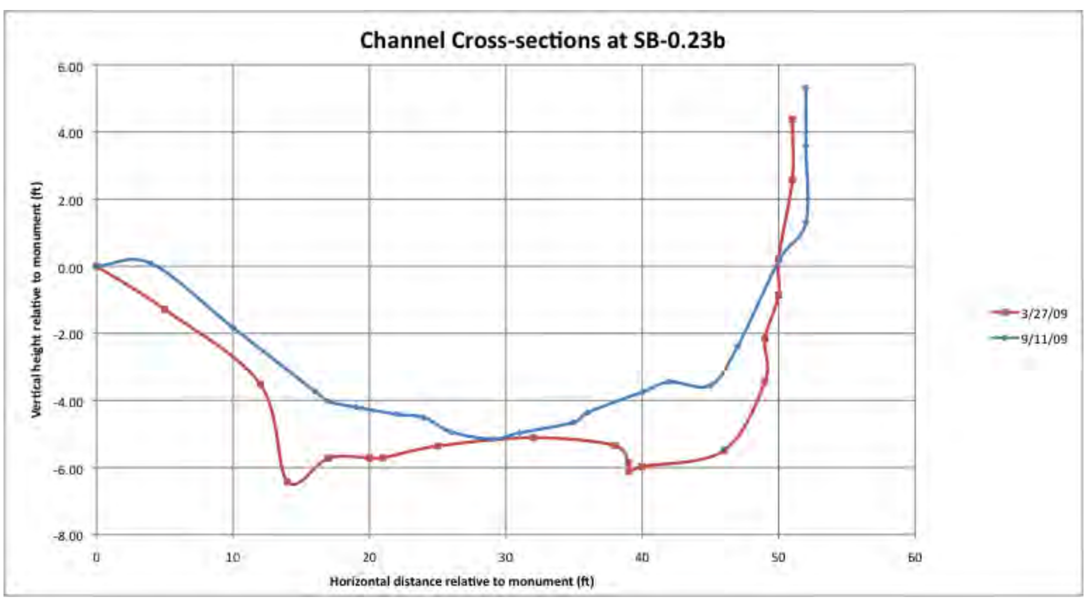


Figure D3: Comparison of same channel cross-section (43 feet downstream of SB-0.23a) measured on different dates. Upper half of right side shows lost material (blue line right of red line). The rest of the channel is covered in new gravel bars (blue line above red line).

Not all of the 915678 lb/yr load lost to bank erosion at SB-0.23 contributes to suspended sediment load. Although detailed grain size analysis of colluvium has not been performed, visual estimates suggest that about 50% of the colluvium is angular gravel and the rest mostly silt and clay. Gravel from the eroded colluvium forms bars (Figures D2, D3), which move slowly downstream while the eroded fine material is swept rapidly downstream as suspended load. Therefore, a reasonable estimate of the contribution to suspended sediment load from this single (170 ft) eroding reach is approximately 457839 lb/yr.

The same approach has also been used at a site 200 ft downstream of DC-0.28 where the bank material consists of alluvium largely made of clay, silt and sand. Results of calculations similar to those outlined above indicate a 260800 lb/yr contribution to suspended sediment load by a single (65 ft) reach (assumes 80% of eroded material moves downstream as suspended load).

Implications for the Dry Creek Watershed

The condition of every stream bank in the watershed has not been documented but erosion and mass wasting are widespread along Dry Creek (Chapter 2, Figure 12). Still, using conservative assumptions, an estimate of the importance of bank erosion as a source of sediment impairment is possible. Based on 1:24000 scale topographic maps, about 32200 ft (6.1 mi) of Dry Creek and its major tributaries (excluding the relatively untouched Fallen Timber Branch) flow immediately adjacent to very steep slopes. Therefore, banks at the bases of these slopes probably consist of colluvium. If we assume that 5% of these banks are eroding as badly as the 170 ft reach at SB-0.23, we arrive at the following estimate.

(0.05 x 32200 ft x 457839 lb/yr) / 170 ft = 4336004 lb/yr

Similarly, 18000 ft (3.4 mi) of Dry Creek and its major tributaries (again excluding Fallen Timber Branch) flow through valleys wide enough to contain significant alluvium. If we assume that 5% of these banks are eroding as badly as the 65 ft reach below DC-0.28, we arrive at the following estimate.

(0.05 x 18000 ft x 260800 lb/yr) / 65 ft = 3611076 lb/yr

Even based on these conservative estimates, it appears as though most suspended sediment moving through Dry Creek and its tributaries is derived from bank erosion. (The effects of KY 519 construction on suspended sediment in Morgan Fork and at DC-0.28 are discussed in Chapter 3).

Load Duration Curves for *E. coli*

Load duration curves are an excellent way to compare instantaneous loads from field data to loads based on a WQC and discharge data from the same year. Concentration data alone can be somewhat misleading since any concentration above the WQC suggests impairment (for example, Figures 2 and 3 in Chapter 3) but yields little information regarding sources and causes of impairment. Seasonal variations in flow (e.g., moist vs. dry conditions) and related variations in acceptable loads are readily apparent on these graphs.

Methods outlined in USEPA (2007) and KDOW (2009c) were used to construct load duration curves for *E. coli* at the three sites with staff gages and discharge ratings (i.e., our best flow data). Unfortunately, no state or federal government gaging stations exist and searches of the USGS discharge database yielded no adequate proxy data that mimics the size, geology, topography, and hydrologic conditions of the Dry Creek watershed. Therefore, the curves presented here use only discharge (and *E. coli* concentration) data collected by MSU scientists for the KWA grant. The overall form of the curves is typical of small, steep watersheds which respond rapidly to precipitation events and which go dry for part of the year. Longer period flow data would "smooth" the curves but their form would remain approximately the same. Despite this limitation, the load duration curves for sites DC-0.28, DC-1.89, and DC-2.84 (Figures D4, D5, and D6) are true snapshots of watershed conditions during the sampling period.

In addition to the geometric mean data for *E. coli* discussed in Chapter 3, MSU biologists collected intermittent *E. coli* samples throughout the year. Here, all samples are considered individually, even those collected to calculate geometric means. Therefore, a WQC for primary contact recreation of 240 colonies/100 mL was converted to billions of colonies/day and used to

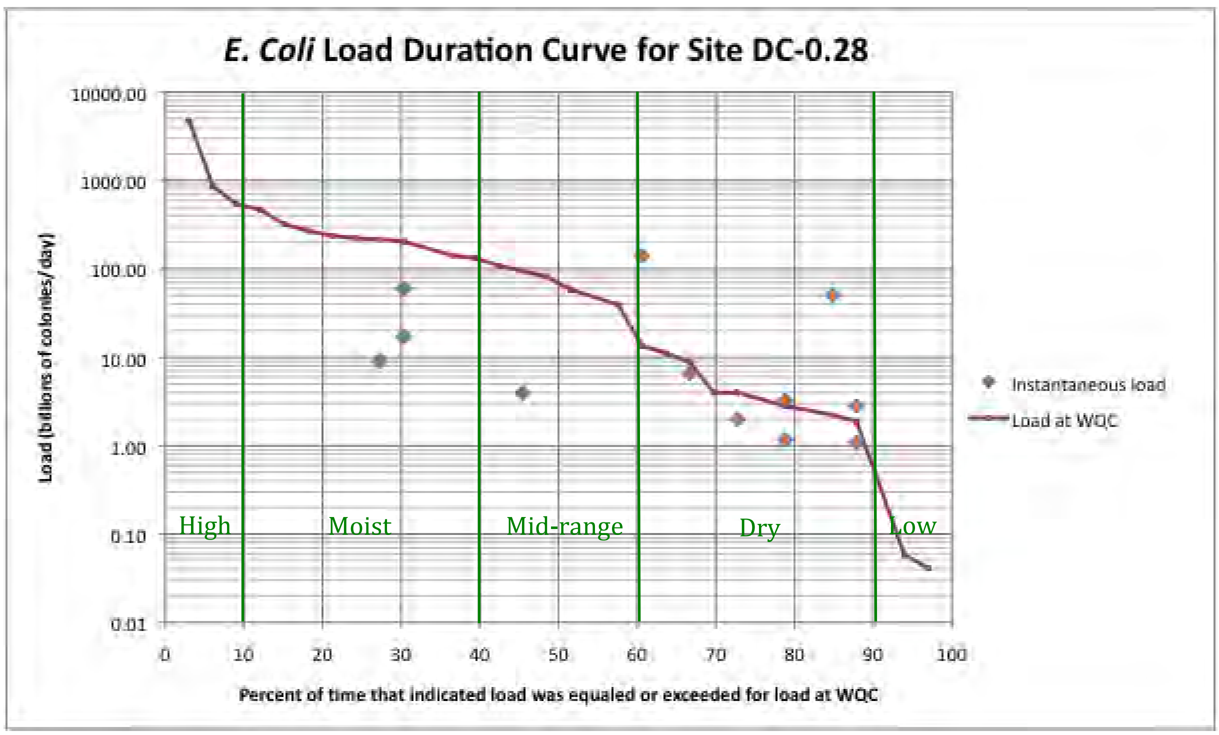


Figure D4: Load duration curve for DC-0.28 (Tile Storage Road Bridge). Orange diamonds are instantaneous loads for samples collected during the recreation season.

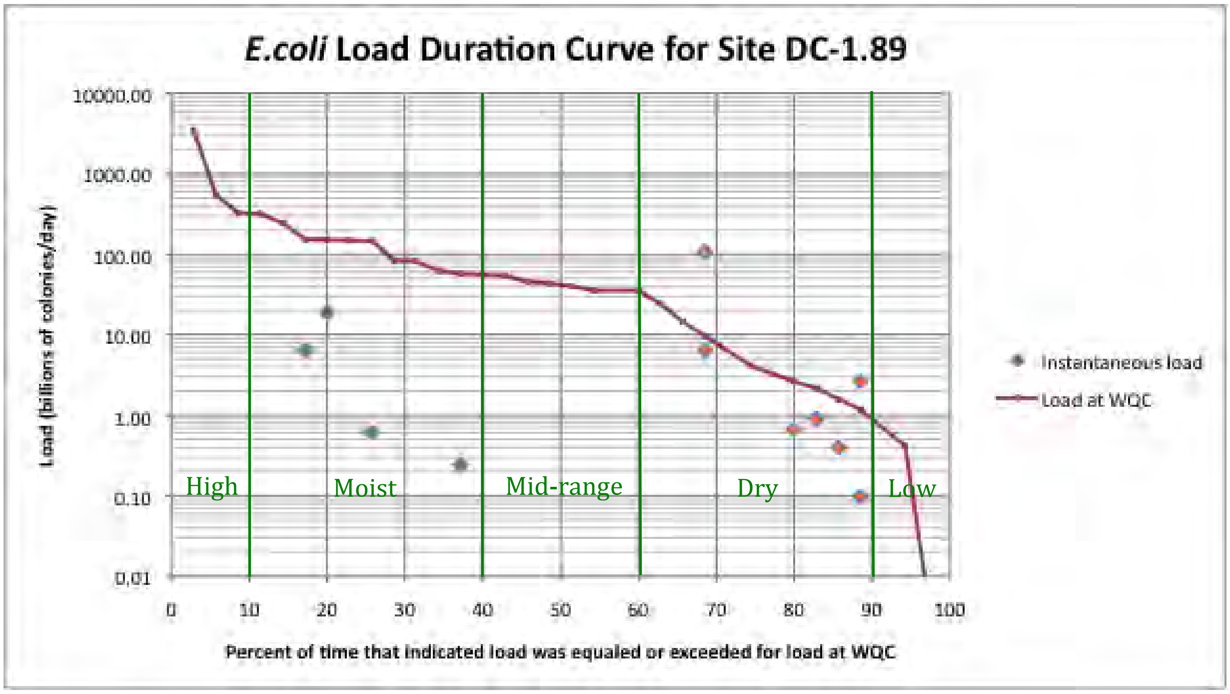


Figure D5: Load duration curve for DC-1.89 (Ravenswood Road Bridge). Orange diamonds are instantaneous loads for samples collected during the recreation season.

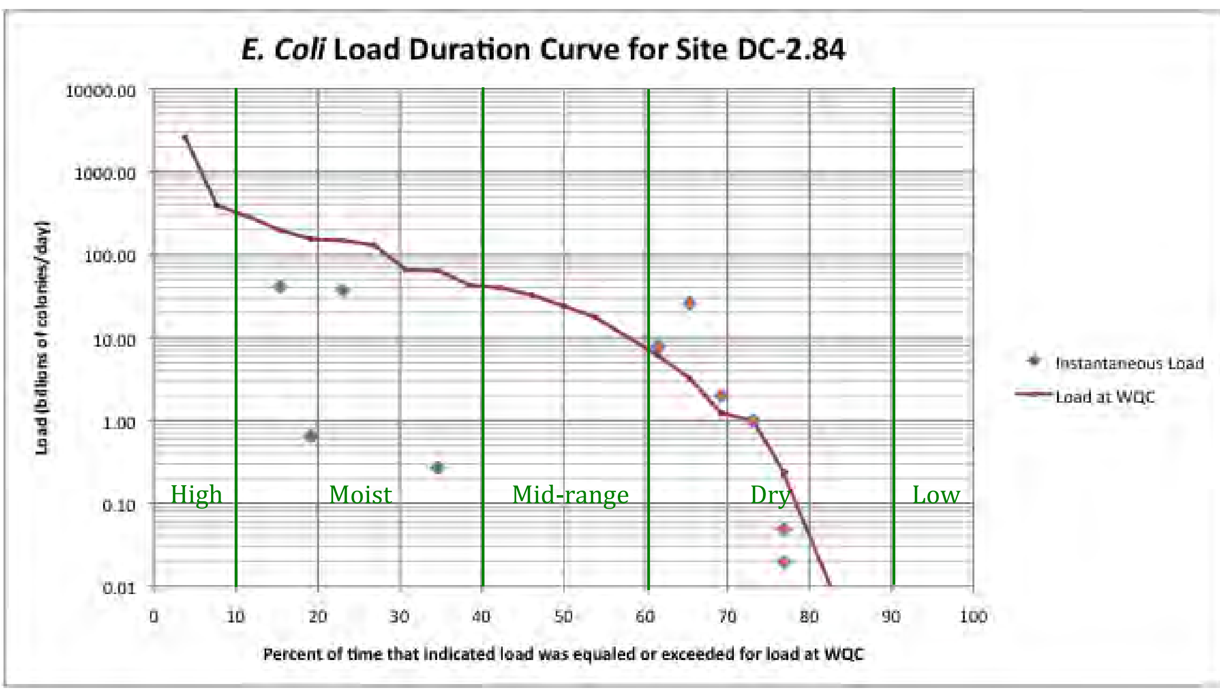


Figure D6: Load duration curve for DC-2.84 (bridge over Sugar Branch). Orange diamonds are instantaneous loads for samples collected during the recreation season.

draw the load duration curve (red line) on Figures D4, D5, and D6. Diamonds are instantaneous loads based on our field data. Orange diamonds represent samples collected during the primary contact recreation season (May through October). Blue diamonds represent samples collected at other times of the year. Green lines and text indicate flow conditions.

The most important point to remember when interpreting load duration curves is that instantaneous loads (diamonds) that fall below the curve (red line) are safe while those that plot above the curve represent impairment and potential exposure to unsafe levels of pathogens. Figures D4, D5, and D6 all show periodic impairment by *E. coli* during the critical primary contact recreation season (orange diamonds), precisely the time when people are in the water. In all cases, these impairments occur during dry conditions when streams are flowing but generally low (except during storms). Periods of no flow are indicated to the right of the point where the red line disappears at the bottom of the graph (for example, at DC-2.84 Dry Creek dries up more often than sites downstream).

The fact that instantaneous *E. coli* loads exceed (or nearly exceed) loads for the WQC during dry flow conditions is informative. During dry and low flow periods, streams are primarily fed by groundwater seeping into the channel (baseflow). During storms, overland flow (runoff) rapidly enters streams, which quickly rise in response but then almost as quickly fall back to baseflow conditions. On Figures D4, D5 and D6 a few instantaneous loads (orange diamonds) greatly exceed the load duration curve (red line). All but one of these very high loads can be attributed to a storm event based on comparisons with 2008 precipitation data. For these events, the *E. coli* most likely originated from wildlife, livestock or pets and was washed into the streams by runoff. Most of the *E. coli* samples collected during the recreation season (most of the orange diamonds) only slightly exceed or lie close to the load duration curve (red line) and cannot be associated with storm events recorded in 2008 precipitation data. These samples therefore represent baseflow which suggests that poorly functioning or improperly installed septic systems or possibly leaking sewer lines must have contaminated groundwater before it entered the streams. The *E. coli* from these samples most likely originated from humans (see section on DNA fingerprinting of *E. coli* below).

One sample collected on 8/21/08 at DC-0.28 is a notable exception to the LDC interpretations above. The sample, which had an *E. coli* concentration of 5440 colonies/100 mL, is represented by the orange diamond far above the red line on the right side of Figure D4. Comparisons with 2008 precipitation records indicate that no rain fell the week before or after this sample was collected. Furthermore, samples collected on the same day at DC-1.89 and DC-2.84 indicate nothing out of the ordinary (both had *E. coli* concentrations of 20 colonies/100 mL). These facts suggest a sewer line break, livestock in the water, a septic system overflow or other such event along Dry Creek below Ravenswood Bridge (DC- 1.89) or along Morgan Fork. We have yet to identify the exact cause of this *E. coli* spike.

DNA Fingerprinting of *E. coli*

Recent work has shown that strains of *E. coli* that are adapted to and associated with specific animal hosts have unique DNA fingerprints. These fingerprints are generated by a method called repetitive sequence polymerase chain reaction (repPCR), a DNA amplification technique that uses a thermostable replication enzyme and serial cycling of varying temperatures. The DNA of *E. coli* (and numerous other bacterial species) has a short, highly conserved nucleotide sequence that is repeated many times throughout the genome. These sequences are referred to as BOX. BOX sequences occur in both frontwards and backwards orientations on both strands of DNA. The BOX A1R primer is a short sequence of single-stranded DNA that can base pair (i.e., specifically bind to) BOX sequences. Amplification of DNA between the BOX sequences results in a collection of PCR products that are then resolved by agarose gel electrophoresis, producing a pattern of bands referred to as a DNA fingerprint (see Figures D7 and D8).

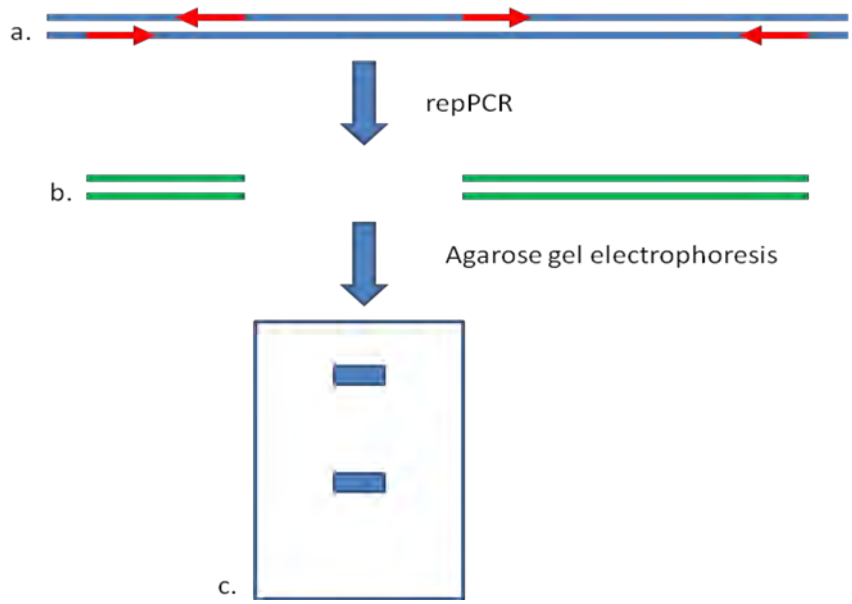


Figure D7. Schematic representation of DNA fingerprinting. (a.) *E. coli* DNA contains repeated, highly conserved nucleotide sequences called BOX (the red arrows). (b.) repPCR can amplify the region between properly oriented BOX sequences, producing multiple copies of each segment. (c.) The different sized DNA segments produced by repPCR can be separated from one another and visualized by agarose gel electrophoresis. The smaller fragments move faster through the gel than the larger fragments, producing a pattern of DNA bands in the gel with the largest fragment at the top and smallest fragment at the bottom of the gel.

Repetitive sequence PCR of *E. coli* DNA can produce 20 or more bands of DNA in agarose gels, collectively referred to as a DNA fingerprint. DNA fingerprints are like genetic barcodes in that strains of *E. coli* isolated from different known bird and mammal hosts exhibit unique DNA fingerprints that are host specific. In this project we have collected and DNA fingerprinted *E. coli* from a variety of vertebrate hosts, including human, horse, cattle, pig, goat, sheep, dog, cat, chicken, and white tail deer. All DNA fingerprints were compiled into a database and assessed by computer software for pattern and cluster analyses to produce a dendrogram that shows the relatedness of *E. coli* strains to one another, resulting in a database referred to as DNA fingerprint library (Figure D9). The software utilized in this study was Nonlinear's TotalLab, a software package that will analyze images of all types of gels as well as construct dendrograms. For image analysis of digitized photos of ethidium bromide-stained agarose gels of repPCR products (see Fig. D8), TotalLab analyzes each lane of bands by counting bands, then comparing the migration of each band to a standard DNA ladder, calculating the basepair size of each band in a lane, then stores this information in a database. For dendrogram construction, we chose the unweighted pair-group method using arithmetic averages (UPGMA) analysis method, a numerical taxonomic method commonly employed in this type of analysis. Once the database was constructed, TotalLab conducts the analysis by pairing one *E. coli* DNA fingerprint with each of all of the other *E. coli* DNA fingerprints in the database, and calculates a similarity coefficient for each pair (i.e., how many [or percentage of] bands in the fingerprint of the total number of bands present are shared by each pair of fingerprints). It does this for every possible pair of fingerprints in the database. TotalLab then uses this analysis to construct the dendrogram (see Fig. D9).

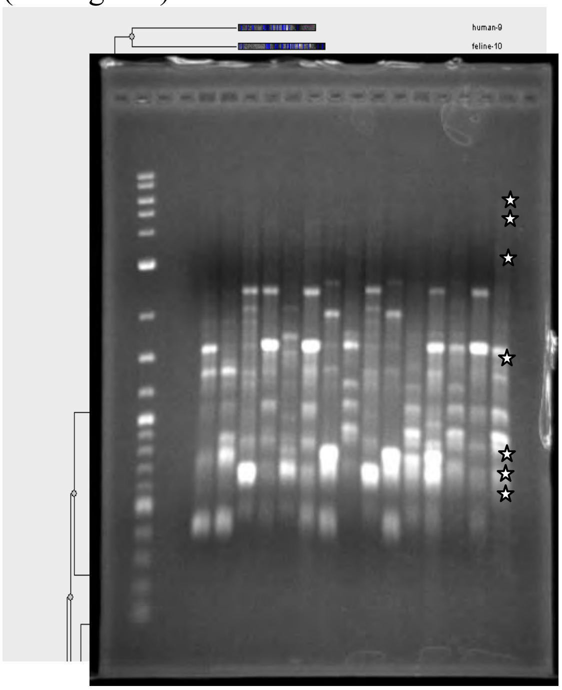


Figure D8. Ethidium bromide-stained agarose gel of repPCR products of *E. coli* isolates obtained from the Dry Creek Watershed. The lane in the far left lane contains DNA size standards (ladder).

Figure D9. Partial dendrogram of vertebrate *E. coli* DNA fingerprints, and Dry Creek Watershed *E. coli* DNA fingerprints. The latter are denoted by the stars.

To determine the original host organisms of fecal contamination in the watershed, *E. coli* that is isolated from samples is DNA fingerprinted, and then compared to the DNA fingerprint library. DNA fingerprinting analysis was conducted on selected *E. coli* isolates collected in June 2009 (see Table 24 of Chapter 3 for the *E. coli* counts of June 2009). Bacterial isolates from sites containing counts that exceeded the state standard of 130 *E. coli* per 100 mL of water were evaluated. After each bacterial isolate from each sampling site was confirmed as *E. coli*, DNA was extracted and a DNA fingerprint was produced. DNA fingerprint results were then compared to a panel of 92 *E. coli* DNA fingerprints from the library of known host sources. Dendrogram analysis of the watershed *E. soli* isolates suggest that most of the bacteria evaluated (up to 75%) originated from humans, while a smaller number originated from domesticated animals (Table 25, Chapter 3). These data suggest that human fecal sewage is the major source of *E. coli* in the four Dry Creek watershed sites assessed in June 2009. Results of DNA fingerprinting also support our interpretation of the load duration curves (Figures D4, D5 and D6) and further suggest that poorly functioning or improperly installed septic systems or leaking sewer lines are causing unsafe levels of pathogens during primary contact recreation season.

Appendix D

Comments from KDOW for the Triplett Creek Watershed Based Plan

The items in this appendix will be addressed as part of the larger Triplett Creek Watershed Plan.

1. Page 25, first paragraph – The development of the identified regulations in this paragraph would be good BMPs to include in Chapter 4. Keep this in mind as the plan is modified as part of the Triplett Creek plan.

2. Page 33, Bacteria – "The highest counts were observed following a significant rain event on 23-24 October 2007, where seven of eight sites sampled exceeded EPA standards of 130 colonies per 100 mL for *E. coli* bacteria. (and) The *E. coli* counts on two sampling dates at Lambert Hollow exceeded the EPA standard for primary recreational contact of 130 colonies per 100 mL. The Water Quality section reviewer indicated that it may not be appropriate to compare a single sample to a geomean value and suggest comparing to the instantaneous 240 colonies/100ml E. coli standard. Please consider for future iterations of this plan as part of the larger Triplett Creek project.

3. Also, according to the Director's office, the agency did conduct work on a numeric standard which was subsequently published in a journal by Greg Pond. The value was 500 umhos/cm and is currently proposed by US EPA for use with coal permits. It may be appropriate to include this value as a benchmark for the Triplett Creek watershed plan.

4. Page 47, D.O. – The following information was provided by the reviewer from the Director's office and should be considered with the future iterations as part of the Triplett Creek plan: The last sentence in this section on factors affecting dissolved oxygen levels isn't exactly true. Aquatic animal life is most vulnerable in the morning because dissolved oxygen levels are generally lowest at that time. Water temperatures are not usually higher then but are often lowest at that time of day. After dark, the air temperature continues to cool with the lowest temperatures occurring in the early morning, the cooler air temperatures draw more heat from the water thereby cooling it. The primary factor controlling the relatively lower stream water dissolved oxygen level in the morning is respiration by aquatic plants. During the dark, plant photosynthesis results in more oxygen being used than is released. In general, the highest D.O. levels are at twilight after a day of plant growth and the lowest in the morning.

5. Page 52, Analysis of Ammonia Results - Were the results converted to un-ionized ammonia prior to comparing to the .05 mg/L criteria? If so, suggest indicating that sites had at least one sample that exceeded the un-ionized ammonia criteria of 0.05 mg/L.

6. Page 56, Total Suspended Solids, "Based on the reference reach data, 3.39 mg/L is used here as an informal maximum concentration that will not adversely impact aquatic life." – The following is the comment from the Water Quality section reviewer. This

should be considered for future iterations of the plan as part of the Triplett Creek plan: Reference reaches are sampled when the biologists know that TSS is low because they need to be able to see things to collect biology. Thus, this value is skewed toward the low end because samples are collected only when TSS is low. Suggest using 3.39 as a goal for non-storm samples, but realize that a higher value that would still support aquatic life is expected during rain events. You may want to re-state their goal to allow for some level of higher value during rain events.

7. Page 75, Sources and Causes, third paragraph – Refer to comment #13. 130 is the geomean, 240 is the instantaneous maximum allowed.

8. Page 79, Factors Affecting Nutrient Enrichment, third sentence - Were samples converted to unionized ammonia before the comparison was made?

9. Page 89, Increased Development and Impervious Surfaces – It may be beneficial to indicate that BMPs exist to lessen the impacts of development and that these BMPs will be suggested as part of the plan.

10. The areas of this chapter that include the following goals: decrease the severity and frequency of flooding; decrease the sediment loads; decrease the nutrient loads and improving overall water quality need some work beyond the current time frame. Specifically as they relate to the physical stream processes. Margi Jones will discuss this with you further for the Triplett Creek plan.

11. Page 97, Best Management Practices Needed to Meet our Goals and Objectives – Suggest expanding on #1. Based on the threats identified and current suspected sources, there are a number of ordinances and regulations that need to be met. These include the Construction General permit, Floodplain regs, 401/404, Ag.Water Quality Act, Forest Conservation Act, and Timber Harvest Compliance requirements. It may also be necessary to develop additional local ordinances in the future including items such as the promotion of better development practices (Green Infrastructure).

12. Pages 99 -107, Tables 4.4 – 4.9 - See comments above regarding using 3.39 for TSS, 0.05 mg/L is for **un-ionized** ammonia and need to re-state the bacteria limits (shall not exceed 240 in greater than 20% of samples collected..).