Gunpowder Creek Watershed Plan

Prepared for
Gunpowder Creek Watershed Initiative
December 2014

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EXECUTIVE SUMMARY

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

December 2014

Executive Summary

1.0 Introduction

The Gunpowder Creek Watershed is located in Boone County, Kentucky and flows into the Ohio River. It is the largest watershed in the county (58.2 square miles) and is rapidly developing with continued growth expected in future years. Gunpowder Creek has been listed on the Kentucky Division of Water's (KDOW) 303(d) List for Impaired Waters for sediment, bacteria, and nutrients as a result of the streambank erosion/instability, excess sedimentation, degraded biological communities, and loss of ecological function that exist today. In order to combat these impairments, the Gunpowder Creek Watershed Initiative (GCWI) was developed by the Boone County Conservation District (BCCD). This initiative is funded through federal 319(h) grant funding. The purpose of this document, the *Gunpowder Creek Watershed Plan*, is to better understand the conditions in Gunpowder Creek and develop a plan of action to address the impacts to and protect the resources of the watershed. In addition to BCCD, numerous other stakeholders have been active participants in the GWCI and the development of this plan. The following entities have greatly contributed to the successful development of this document and are valued for their contributions.

- Kentucky Division of Water
- Sanitation District No. 1 of Northern Kentucky (SD1)
- Boone County Planning Commission
- Northern Kentucky University (NKU) Center for Environmental Restoration
- Boone County Fiscal Court
- City of Florence, Kentucky
- City of Union, Kentucky
- Kentucky Transportation Cabinet
- Kenton County Airport Board
- Northern Kentucky Area Development District
- Northern Kentucky Health Department

2.0 Exploring the Gunpowder Creek Watershed

The watershed was explored in great detail to understand its history, development, and resources. Topics covered include a watershed inventory of the location, hydrology, history of flooding, and existing knowledge of stream health; natural features of the watershed (i.e., geology, topography, soils, ecoregions, and climate); the abundance of vegetation and wildlife; human influences (e.g., land use and management); demographics and social issues; and observations by the GCWI.

The watershed is comprised of four smaller watersheds, along with the main Gunpowder Creek Watershed (**Figure ES-1**): South Fork Gunpowder, Fowler Fork, Long Branch, and Riddles Run. The headwaters originate near the Greater Cincinnati/Northern Kentucky International Airport (CVG) on the northern region of the watershed and flow approximately 36 miles southwest to the Ohio River. There is a total of 143.1 miles of blue line streams in the watershed. Many sections throughout the headwaters of Gunpowder Creek, along with sections of South Fork Gunpowder Creek, are listed on KDOW's 303(d) List of Impaired Waters for sedimentation/siltation, nutrient/eutrophication, biological indicators, organic enrichment (sewage), warm water aquatic habitat (nonsupport), and primary contact recreation water (nonsupport). Suspected sources include urban stormwater, agriculture, site clearance, and streambank modifications.

Prior to the development of this *Watershed Plan*, SD1 completed some routine monitoring to characterize the watershed and generally understand stream health. Review of this historic monitoring data indicated high levels of bacteria, degraded biological conditions, as well as severe bank erosion and hydromodification issues. Geomorphically, Gunpowder Creek had noticeable impacts from urbanization to its form, stability, and habitat when compared to local reference streams.

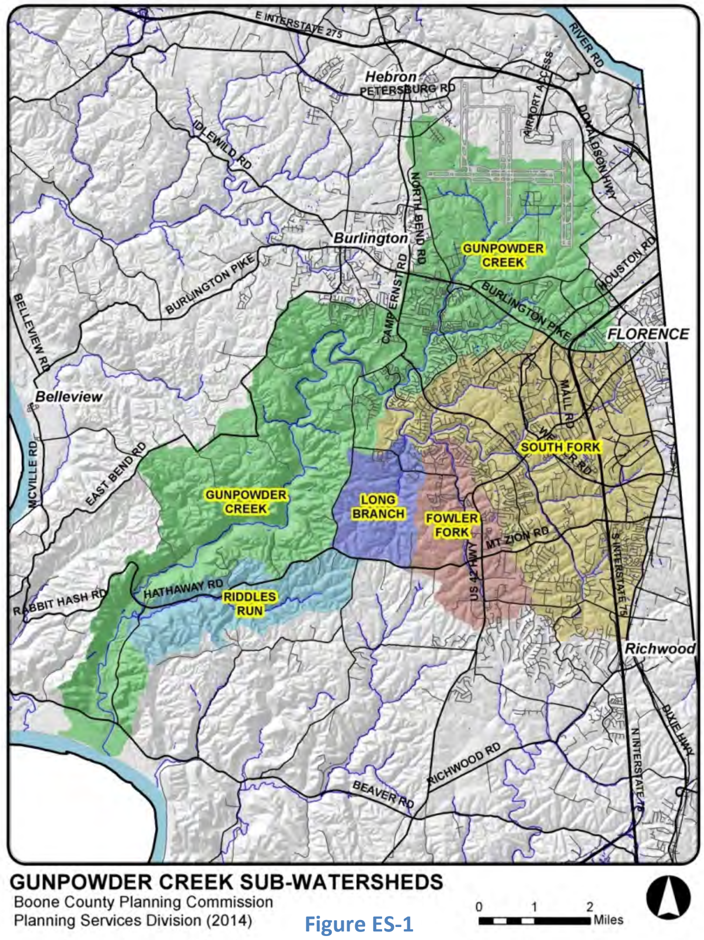

Figure ES-1

In order to understand the changes to the watershed, human influences must be understood. Boone County, which was established in 1799, experienced mild growth until recently when it became one of the fastest growing counties in Kentucky. Dense development includes highly impervious areas such as transportation, industrial, and commercial uses. Nearly all of the development has occurred since 1950, with a 38.2% growth rate from 2000 to 2010 (**Figure ES-2**; BCPC, 2010). Such anthropogenic influences have been particularly extensive in the developed headwaters of the Gunpowder Creek and the South Fork Gunpowder Creek. Future expansion of development into the western portions of the watershed is anticipated to coincide with a continued increase for at least the next 25 years.

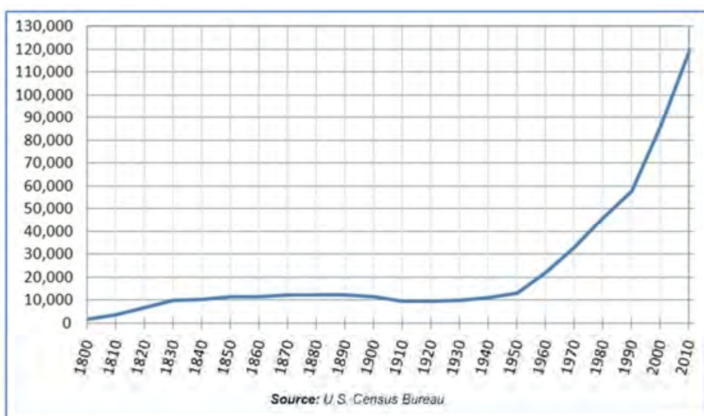

Figure ES-2: Boone County population: 1800 to 2010

Despite these development pressures, much of the land in the watershed is undeveloped (57 percent), which includes woodlands, recreation, and agricultural uses. Residential land comprises nearly 30 percent of the area, with dense development covering nearly 20 percent. Today, the creek is used for many recreational activities, including fishing and kayaking.

3.0 Learning More and Monitoring

After gathering existing data and watershed characteristics, the next step in understanding the health of the watershed was to conduct in-stream monitoring. The GCWI monitoring program involved two phases, with Phase 1 completed in 2011, an extremely wet year with record rainfall, and Phase 2 completed in 2012, a much drier year. This provided insight regarding the types of pollutants washed off the land during rain events versus those released directly to the stream in dry weather. The GCWI monitoring program was multi-faceted and provided a comprehensive understanding of several dimensions of stream health, including: flow monitoring, hydrogeomorphic surveys, habitat assessments, water quality samples, and macroinvertebrate assessments. The variety of these categories provides the breadth and depth to holistically understand the condition of the stream impairments and watershed sources of pollution and degradation.

The monitoring completed as part of the GCWI monitoring program was conducted at the mouth of the subwatersheds, within the main branch, and on some un-named tributaries. As part of this effort, flow, hydrogeomorphic, water chemistry, habitat, and biological data were collected at six sites in the watershed. Additionally, as part of SD1's ongoing Hydromodifiction Monitoring Program, hydrogeomorphic data was collected at three more sites, for a total of 9 sites with hydrogeomorphic data (**Figure ES-3**).

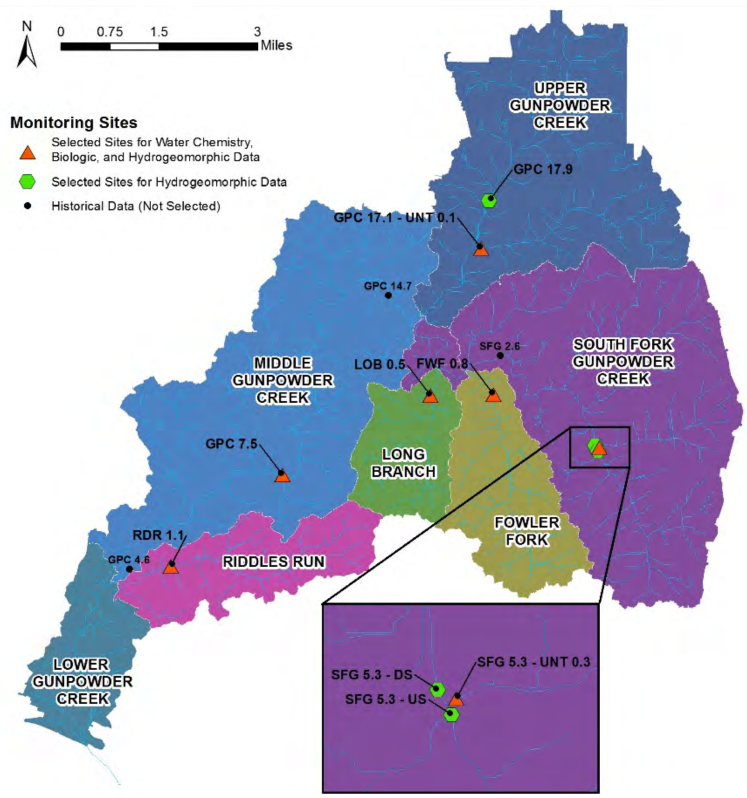

Figure ES-3: GCWI monitoring sites

All monitoring data was collected and analyzed according to industry standard procedures as specified in the *2011 Quality Assurance Project Plan for Gunpowder Creek Watershed Plan* (QAPP). Flow monitoring utilized USGS gauge 03277075 in addition to measurements taken in the field. Hydrogeomorphic surveys were conducted to measure channel instability. Data collected in the field included cross section and profile measurements as well as pebble counts of the bed material. Habitat assessments focused on the quality of in-stream and riparian habitat and were conducted according to KDOW methods (e.g., Barbour *et al.*, 1999; KDOW, 2001). All water quality sampling methods were in accordance with the KDOW Standard Operating Procedures (SOPs). Water quality sampling included both field measurements (e.g., temperature, pH, dissolved oxygen, specific conductance, etc.) as well as parameters measured in the laboratory (e.g., bacteria, sediment, nutrients, etc.). For the biological assessments, benthic macroinvertebrate samples were based on the EPA's Rapid Bioassessment Protocols for high gradient streams (Barbour *et al*., 1999), as adapted for Kentucky.

4.0 Analyzing Results

The analysis of the monitoring data was completed using an integrated approach, which focuses on the concept that there are many interdependencies for overall stream health, highlighted by the stream function pyramid in **Figure ES-4**. Land use and land management alter the flow regime in a stream, which in turn influences the physical characteristics and habitat that are found there. Those changes then impact the quality of the water, which will alter the biotic integrity of the stream. No one component can be evaluated or mitigated on its own; the system must be analyzed holistically.

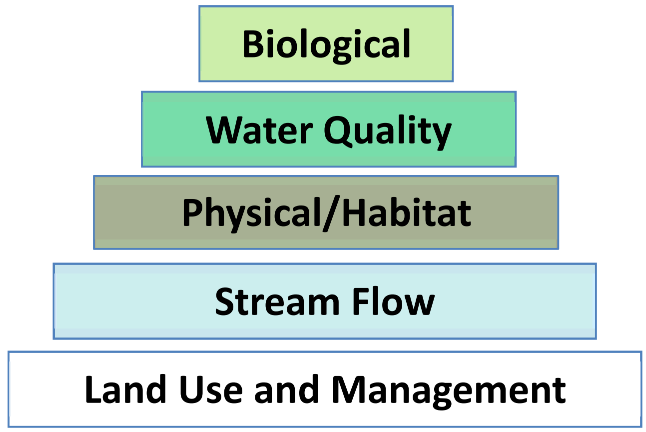

Figure ES-4 - Stream Function Pyramid adapted from Center of Watershed Protection (2011)

The goal of analyzing the monitoring data was to develop an integrated implementation plan for the watershed that will be feasible, efficient, and effective. The overall results from monitoring coincide with preliminary assessments, showing that bacteria and total suspended solids (TSS) are the most concerning pollutants, particularly throughout the developed headwaters and South Fork Gunpowder Creek. In turn, the biology was found to be worst in these most developed subwatersheds, where erosive flows have altered the habitat, impaired the water quality, and lowered the biologic integrity.

Statistical analysis was conducted using the R program in order to identify the strength of the relationship between water quality monitoring data and watershed characteristics. The results of the hydrogeomorphic monitoring were also used to strengthen and tie hydromodification into the analysis. This leads to a better understanding of the sources of all impairments and provides insight into the best management practices (BMPs) that should be employed in the watershed. The following sections present a brief summary of the results of each aspect of GCWI's multi-faceted monitoring program.

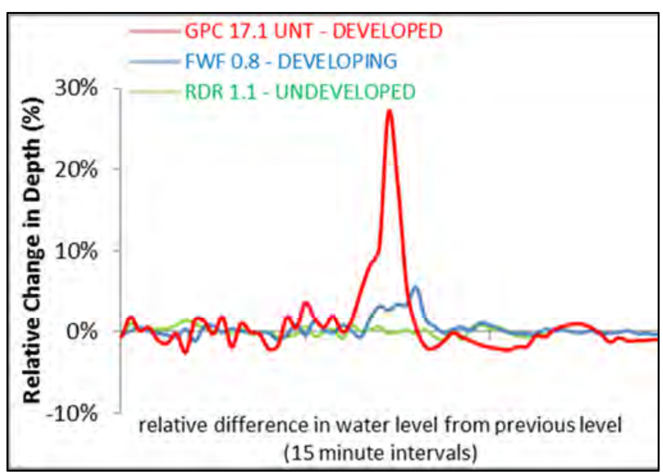

Figure ES-5 - Percent relative change in water depth of time

Stream Flow Results

Flow from three sites with similar watershed size but varying levels of development demonstrated that the most developed site experienced much higher flows (**Figure ES-5**). This urban flow regime is flashier and larger, causing increased erosion, more water quality impairments, degraded habitat conditions, and increased potential for flooding issues.

Hydrogeomorphic (Physical) Results

Analysis of the hydrogeomorphic survey data supports that streams in urban/suburban watersheds are unstable, as the hydrogeomorphic monitoring sites that exhibited the most instability were located in the most developed areas of the watershed (South Fork Gunpowder and the headwaters of Gunpowder Creek). The analysis completed for Gunpowder Creek was generally consistent with an in depth study of Northern Kentucky streams, which demonstrates that development is linked to stream channel enlargement, bed coarsening, shorter riffles, and longer and deeper pools (Hawley *et al.,* 2013). Overall, GCWI evaluated several different parameters to better understand potential sources of impairments. Both barren land and riparian roads were found to have a positive relationship with cross-sectional enlargement, whereas the subwatersheds with greater amounts of barren land or riparian roads exhibited greater channel instability, as measured by a change in the bankfull area. Using that notion, channel instability was also linked to higher average TSS. Furthermore, this watershed plan presents a few hydrogeomorphic monitoring case studies that provide examples of the types of geomorphic concerns that exist throughout the watershed. This includes an extremely dynamic site experiencing bank failure and bed incision, a site experiencing geotechnical mass wasting and bank widening (**Figure ES-6**), and a site with extremely erosive flows that have transported large amounts of woody debris.

Figure ES-6: SFG 5.3-UNT 0.1 tension crack bank failure

Habitat Results

Furthermore, a stable stream system with adequate riparian buffer areas is critical for supporting habitat structure and biologic integrity. Review of the Habitat Assessment Scores indicates that the most unstable site in the South Fork Gunpowder subwatershed (SFG 5.3-UNT 0.1) scored the lowest of all the sites, having the most degraded habitat. In evaluating all of the sites with geomorphic and habitat data, unstable channel conditions, as measured by channel widening (i.e., a change in bankfull top width), illustrated a negative relationship with the Habitat Assessment Scores, meaning that the most unstable sites exhibited the most degraded habitat conditions (**Figure ES-7**). It

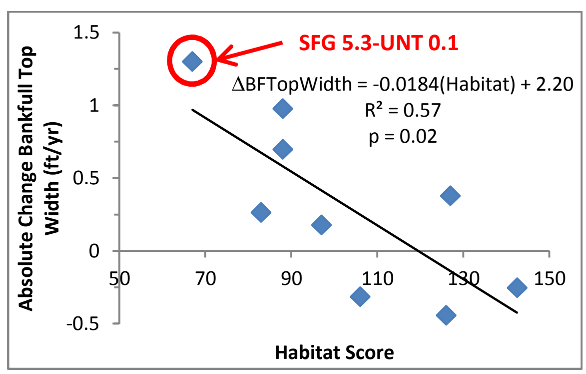

Figure ES-7: Channel widening is negatively correlated to habitat score

Notice the most unstable site, SFG 5.3-UNT 0.1, widened at a rate of more than 1 foot per year and had the lowest habitat score of 67. This site also has the most developed watershed with 41% imperviousness.

can therefore be informed that the erosive, urban flow regime has been a primary cause of the degradation of the Gunpowder Creek in the most developed subwatersheds, leaving homogenous, featureless stream beds composed of exposed bedrocks, short riffles, and long pools.

Water Quality Results

Water quality data were analyzed to evaluate variations in pollutant concentrations and understand the potential causes; parameters were compared to rainfall and stream discharge data. Box and whisker plots were generated using the statistical software R and provided visual observation of the range of sample concentrations in relation to the water quality benchmark for each parameter. While these benchmarks are not definite criteria, they do provide an understanding of the scale of the problems in the watershed as well as interim targets for achieving a healthy stream system. In addition, pollutant load duration curves were developed and then used to analyze the relationship between exceedances in water quality benchmarks and flow conditions (e.g. high flow vs. low flow conditions, wet weather vs. dry weather conditions). The pollutant load determines the specific pollutant amount that is being transported by the stream in terms of weight per period of time (e.g. lbs/day). The load duration curves were also used to estimate overall pollutant loads and calculate pollutant yields.

Figure ES-8 highlights the ratio of annual projected pollutant loads to annual benchmark pollutant loads; it is clear that sediment and bacteria have the highest ratios. Therefore, results of the water quality analysis indicate that bacteria (as measured by *E.coli*) and sediment (as measured by TSS) are the most concerning pollutants in the Gunpowder Creek Watershed, particularly in the most developed regions of the watershed. Other parameters, such as nutrients or dissolved oxygen, were not as concerning.

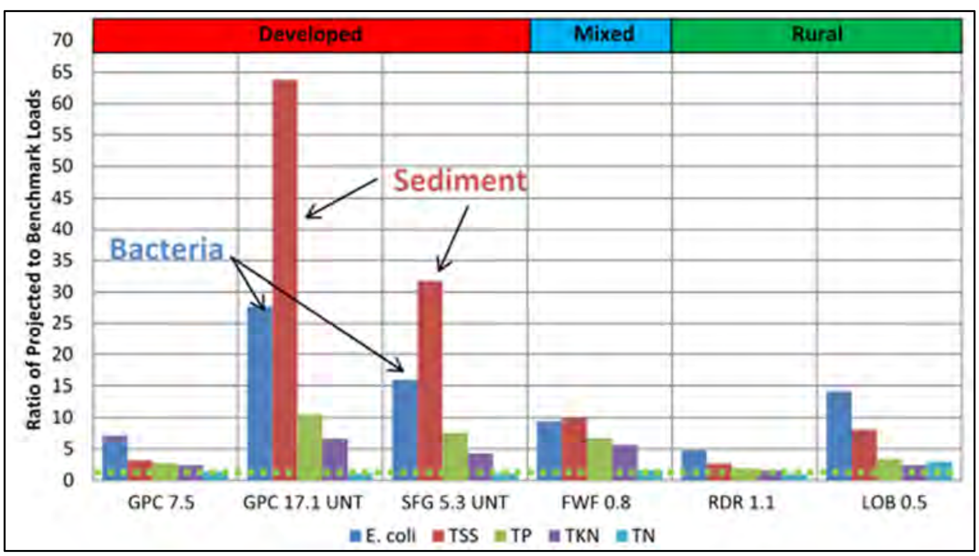

Figure ES-8 – Ratio of annual projected loads to annual benchmark loads

Through further analysis, it was found that under dry conditions, the sites with the most catchment imperviousness had the lowest concentration of *E.coli* in the stream, but that the opposite is true for wet weather conditions. This indicates that the most developed watersheds appear to have a larger concern with bacteria during wet weather whereas the less developed, rural watersheds have higher bacteria concerns during dry weather. Stormwater runoff and animal waste are suspected sources of bacteria in the developed subwatersheds, while septic systems and animals grazing in the streams are suspected sources of bacteria in the rural subwatersheds. As has been noted, TSS is also a pollutant of concern in the watershed and high concentrations of TSS were linked to the most unstable sites in the hydrogeomorphic data analysis. Furthermore, it was found that wet weather causes higher concentrations of TSS in the stream than dry weather does, especially as the percent impervious of the watershed increases. This indicates that bank erosion and channel enlargement are a likely source of the fine sediment found in the stream.

Biological Results

The biological health of the Gunpowder Creek is dependent on all other factors presented above. Statistical analysis between the percent impervious in the watershed and two biologic factors, the MBI Score and the Percent Primary Clinger score, illustrated that the scores decreased with an increase in percent impervious. Therefore, biological integrity suffered the most in the more impervious, developed portions of the watershed. This is consistent with the rest of the data analysis and supports the prioritization of the most developed areas of the watershed.

Potential Sources of Pollutants

These results can be categorized into three types of land use based on watershed imperviousness: developed watersheds (20-40% impervious) on the eastern side of the Gunpowder Creek Watershed, rural watersheds (2-4% impervious) on the southern portion of the Gunpowder Creek Watershed, and mixed use watersheds (developed/rural, 12% impervious). By completing this categorization, the following takeaways can be gleaned.

In developed watersheds, bacteria and suspended sediment are the most concerning parameters during wet weather, most likely caused by animal waste and erosive flows and unvegetated banks, respectively. The likely sources of these include stormwater runoff and bank erosion, respectively. Specific conductance is most concerning during dry weather flow, with a possible cause and likely source being point source treatment. Least concerning in the developed watersheds in Gunpowder is bacteria under dry weather conditions, indicating that one of the primary benefits of watershed development is the expanded sanitary sewer system, which is designed to keep untreated human waste from reaching our streams.

In rural watersheds, dry weather makes bacteria, nutrients, and specific conductance the most concerning pollutants. Bacteria and nutrients likely come from septic systems and/or directly from animals, caused by a lack of septic maintenance and/or inadequate livestock fencing. Specific conductance is possibly from septic systems, point source discharges, and/or natural sources. Nutrients during wet weather events are the least concerning pollutant in rural watersheds.

In mixed use watersheds, bacteria during wet weather events is the most concerning pollutant, which likely comes from stormwater runoff with a possible cause of animal waste. During dry weather, both specific conductance and nutrients are concerning. The likely sources and possible causes are the same as in rural watersheds. Bacteria during dry weather flow is the least concerning pollutant in Gunpowder's mixed use watersheds.

Prioritization

Following the data analysis, the subwatersheds required prioritization to understand which would require stream health improvement actions and which, if any, are in good condition and should be protected from future degradation. The subwatersheds were ranked in numerous ways, including the number of water quality samples exceeding the benchmark concentration, average sample concentrations, projected annual pollutant loads, and pollutant yields. The results of these rankings match the findings in KDOW's 2010 303(d) List of Impaired Waters, showing sediment as a common pollutant and the South Fork Gunpowder and the developed headwaters in the main branch to be the greatest reaches of concern.

5.0 Finding Solutions

Water quality impairments can be mitigated in a variety of ways, using both structural and non-structural BMPs. KDOW provides an extensive list of BMPs in their *Watershed Planning Guidebook for Kentucky Communities* document. These BMPs have been evaluated based on the impairments in the Gunpowder stream network, results of monitoring and data analysis, and existing land uses. Specifically, BMPs focused on stormwater, agriculture, construction, forestry, and onsite wastewater treatment are applicable to the watershed. Education is another valuable BMP that is cost-effective and applicable.

It has been established that TSS is the most concerning pollutant in the Gunpowder Creek Watershed, and more specifically, it was found to be worst in the most developed subwatersheds. The major source of the TSS is suspected to be bank erosion, which is caused by the erosive flows in the creek from stormwater runoff. Therefore, it is clear that stormwater controls must be a key BMP implemented in the watershed. These controls should also help to alleviate bacteria and nutrient impairments in the creek. In order to prioritize BMPs, four implementation categories were developed within Gunpowder Creek Watershed: headwaters/developed areas; undeveloped areas; agricultural areas; and active forestry areas.

Volume-based stormwater controls are the most cost-effective BMP for the developed areas of the watershed. BMPs that are volume-based can control the erosive flows. Filtration-based BMPs would treat the water for TSS, bacteria, and nutrients, but cannot handle the large quantity of water needed to make an impact across the watershed. Examples of volume-based controls include extended detention basins, bioretention basins, constructed wetlands, and retrofits of existing detention/retention basins for improved water quality and channel protection performance.

6.0 Strategy for Success

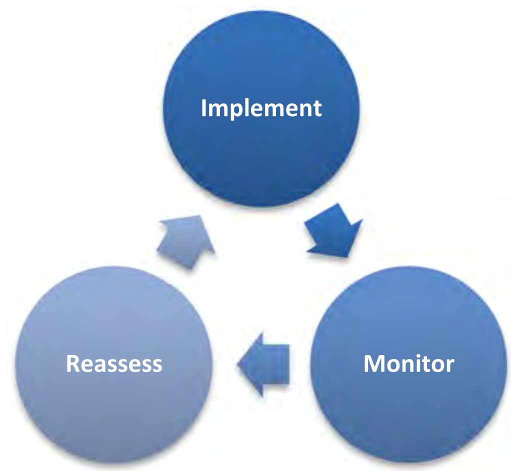

Figure ES-9 – GCWI Watershed Plan approach

Using the data analysis and the BMP evaluation, a combination of BMPs have been selected to achieve the goals of the watershed plan, to address the impacts to and protect the resources of the Gunpowder Creek Watershed. Considerations have been taken into account, including regulatory matters, stakeholder cooperation, political will, available funding, cost-effectiveness, priority areas, existing efforts, and watershed management activities. However, a key element of GCWI's approach for this Watershed Plan is to implement a reasonable level of BMPs and continue to monitor. GCWI plans to make smart investments as opportunities arise, monitor the progress, then reassess through continued monitoring – with the goal to continually improve the effectiveness of the implementation efforts (**Figure ES-9**).

A key consideration in the development of the selected BMPs was the stakeholder cooperation and input from several roundtable discussions. Tailoring the BMPs to the gathered responses provides the supportive foundation for successful implementation of the plan. In addition to the GCWI Steering Committee and regional partners, the public has been actively involved. Three roundtable meetings (**Figure ES-10**) were held to gain feedback on issues and considerations in the watershed.

Figure ES-10 - One of several well-attended public meetings on the Gunpowder Creek Watershed Initiative

Development was a concern from every roundtable group, and stormwater runoff and flooding, considered to be linked to development, were priority issues for the majority of the groups. **Table ES-1** highlights the questions and responses from the roundtable groups. As outlined below, the selected BMPs have been identified, where applicable, to address the dominant issues outlined by the public.

Table ES-1. Questions and dominant responses from 11 roundtable groups with approximately 70 participants

Question	Dominant Responses[1]
1. **Why is a clean healthy stream important to you?**	Recreation (73%), Aesthetics (66%), Quality of Life/Health (54%)
2. **What land uses in the watershed are you most concerned about?**	Development (100%)
3. **What do you think are the most common problems?**	Runoff (73%), Flooding/Safety (66%)
4. **What BPMs do you consider feasible in Gunpowder Creek?**	Detention/Retention (82%), Education (66%), Responsible Development/Ordinances (55%)
5. **What issues in Gunpowder Creek do you consider a priority?**	Stormwater Runoff (66%), Flooding (55%)

*[1]Responses that were listed by more than half of the groups. For a summary of all responses, see supporting handout in **Appendix 6-A**.*

Overall Watershed BMPs

The following BMPs have been considered appropriate measures to implement across the watershed, based on the considerations above.

- Training and technical support program
- Coordination with NKU's Stream and Wetland Restoration Program
- Watershed coordinator position
- Review/Revision of Rules and Regulations
- Success monitoring and analysis
- Stewardship programs
- Riparian plantings

Training and technical support for local designers and contractors can provide education to key individuals on the various BMPs and implementation strategies within the watershed. The education component pairs nicely with the NKU Stream and Wetland Restoration Program, which stabilizes degraded stream reaches and restores habitat after developments or other projects physically alter streams. Training and technical support could also lead to a better understanding of how to cost-effectively design for channel protection on future development projects. By hiring a watershed coordinator, the GCWI would have someone to manage and coordinate implementation efforts in a way that also considers stream channel protection and water quality. This particularly relates to coordination between regional agencies on local projects, such as flood control in Florence or the Whispering Trails subdivision.

Partnered with this is a review and revision of regional rules and regulations related to development practices and stormwater management. Recently, SD1 and the City of Florence developed a BMP Manual which requires water quality treatment of the first 0.8 inches of rain. Adapting this document to include channel protection controls designed for $Q_{critical}$ could drastically improve the effectiveness of strowmater management controls at protecting stream channels from excess erosion. Designing for $Q_{critical}$ would require the capture and release of all storms up to and including the 2-year storm below the critical flow for stream erosion.

Success monitoring and analysis calls on both the GCWI and SD1 as well, to continue water quality and hydromodification monitoring within the watershed. Stewardship programs could be led by the watershed coordinator, and would educate and provide outreach programs for homeowners and large corporate and institutional properties. Riparian plantings could do a lot to buffer overland stormwater runoff prior to entering the creek and protect streambanks from excess erosion.

Developed Headwaters BMPs

As discovered throughout monitoring and data analysis, the developed subwatersheds have the greatest pollutant load ratios for TSS and bacteria in addition to the worst biological indicators. For these reasons, these subwatersheds have been identified as the highest priority for focused efforts to mitigate erosive flows that have altered the habitat, impaired the water quality, and lowered the biologic integrity. The following BMPs have been considered appropriate measures to implement in the developed headwater subwatersheds, based on the considerations above.

- Bioretention
- Detention basin retrofits
- Detention basins
- Wetland creation/restoration
- Pet waste program

Many of the BMPs identified for the developed subwatersheds are stormwater controls, which will be implemented to mitigate erosive flows. While the implementation methods may differ, all four will serve as volume-based BMPs to detain stormwater runoff and filter TSS, bacteria, and nutrients from the runoff. Infiltration-type BMPs are less feasible in this watershed due to the prevalence of clay soils.

Implementation costs and siting restraints will impact which BMPs are selected. Detention basin retrofits are 10 to 100 times more cost-effective and there are many existing basins within the watershed that are potential candidates. New detention basins will be focused in areas with large amounts of impervious area that are currently not detained; coordination with private property owners is anticipated. Bioretention basins could also be installed in these situations and will be evaluated on an individual basis. Wetland creation and restoration may be utilized in low-lying areas adjacent to the channel.

Implementation of a pet waste program, specifically in areas with high dog-walking traffic, could have a significant impact on bacteria in the stream.

Agricultural BMPs

Livestock exclusion fencing has been considered an appropriate measure to implement in agricultural areas, based on the considerations above. In addition to removing cattle and horses from the stream, this effort will also create riparian buffer zones, which will help in filtering waste in overland runoff. As an initial step, an improved inventory of horse properties in the watershed may help to target BMP outreach and implementation.

Undeveloped Areas/Forestry BMPs

Conservation of open areas has been considered an appropriate measure to implement in undeveloped and forested areas, based on the considerations above. As Boone County continues to develop, preserving and improving existing green space will be vital to protecting the county's water resources. The GCWI has already identified publicly owned undeveloped lands that can be targeted for conservation practices.

Subwatershed Prioritization

Subwatersheds were prioritized for implementation, based on the extent of the impairment and number of identified opportunities within each subwatershed, cost, and feasibility. The prioritization is included in the list below, but is subject to change based on changes to the criteria for prioritization as different partnering opportunities arise to implement large, impactful projects throughout the watershed.

1. South Fork (developed headwaters)
2. Riddles Run (agricultural headwaters)
3. Lower Gunpowder (undeveloped bottomlands)
4. Fowler Fork (mixed rural/developed headwaters)
5. Upper Gunpowder (developed headwaters)
6. Long Branch (agricultural headwaters)

Resources

The amount of effort that has been put forth to date have been astounding. Specifically, SD1 and NKU have been extremely valuable in contributing both financial and human resources to the development of the *Gunpowder Creek Watershed Plan*. Moving forward, capitalizing on the existing resources, including the number of existing, non-retrofitted detention basins, will be a key to success. It will be important to piggyback on existing efforts, including the flood control improvements currently underway by SD1 and the City of Florence, and to capitalize on the available resources, including the 535 existing non-retrofitted detention basins and existing large publicly-owned tracts of land, in order implement the integrated solutions for the Gunpowder Creek Watershed.

7.0 Making It Happen

Finally, we come to most important final step: make implementation happen. The efforts completed to date would mean nothing if the plan was not well executed, and this section will highlight the "who" and "how" for implementing the *Gunpowder Creek Watershed Plan*.

Mark Jacobs from BCCD has done a phenomenal job to date, serving as the Watershed Coordinator, and the GCWI Steering Committee has elected to have him continue in this role. Mr. Jacobs, along with members of the technical sub-committee will be the implementation undertakers. The Steering Committee, outlined in Section 1.0, will continue to meet at least every other month to guide implementation efforts.

Public outreach has been integral to the plan's success so far and will continue. The media campaign, presentations, and public meetings have been invaluable. Continued efforts will include articles in the Conservation District's and County's newsletters, among other efforts. Fundraising will be important to continuing efforts. The funding to date has been primarily through a FFY 2009 Kentucky Nonpoint Source Pollution Control Program grant and many non-Federal sources, this will not cover implementation. A grant request has been submitted for FFY 2014 for $1,000,000. The local match portion of $400,000 would likely come from BCCD, SD1, the City of Florence, Boone County Parks, and volunteer time. Additional funding for the GWCI will be sought through local and regional private foundations as well as local, State, and Federal grant sources that may be identified.

Highlighted in **Figure ES-9**, monitoring and evaluating the in-stream success of the implementation efforts are priorities for the GCWI. GCWI will develop a KDOW-approved monitoring plan and Quality Assurance Project Plan (QAPP) to continue to monitor at the established stations. Success will be measured via implementation rate and water quality results from a KDOW-approved in-stream success monitoring program. The plan will be evaluated and updated as implementation efforts continue to work toward the restoration of a healthy Gunpowder Creek.

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CHAPTER 1

Introduction

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

December 2014

Chapter 1: Introduction

This chapter provides a brief overview of the Gunpowder Creek Watershed, the issues it faces, and the community led initiative which has formed to address its future.

1.1 The Watershed

The Gunpowder Creek Watershed is the largest watershed in Boone County, Kentucky, and one of the largest in Northern Kentucky. Flowing southwesterly to its confluence with the Ohio River, the Gunpowder Creek main stem is approximately 36 miles long and encompasses a watershed area of 58.2 square miles. Located entirely in Boone County, Kentucky, the stream originates west of the Cincinnati/Northern Kentucky International Airport (CVG), is home to nearly half of the county's residents and comprises 25% of the land area. The headwaters of the watershed are fairly developed and include portions of the cities of Florence and Union. Downstream, the watershed flows westward into more rural areas of unincorporated Boone County.

Boone County has been growing steadily since the 1960s and consistently ranks as one of the most rapidly developing counties in Kentucky and country. In the coming decades, forecasts show that Boone County will experience continued population growth and development, primarily in the form of suburban residential housing and related land uses. Most of the county's watersheds are already experiencing the impacts associated with this development, including streambank erosion/instability, excess sedimentation, degraded biological communities, loss of ecological function, etc.

The Gunpowder Creek Watershed has been under increasing pressure as development continues to expand to the west. As such, it has been classified on the 303(d) List of Impaired Waters for high levels of sediment, bacteria, and nutrients. In an attempt to address these impacts, the Boone County Conservation District (BCCD), funded in part by a federal 319(h) grant, is working to improve the water quality in the Gunpowder Creek Watershed through the goals of the Gunpowder Creek Watershed Initiative (GCWI) and development of this watershed plan.

1.2 Partners and Stakeholders

The Gunpowder Creek Watershed Initiative (GCWI) is a collaborative effort guided by a Steering Committee of local agencies which have a responsibility to the community to protect natural resources. The key project partners are involved with the implementation of the 319(h) grant and their contact information is as follows:

Agency Name: Boone County Conservation District
Agency Address: 6028 Camp Ernst Road, Burlington, Kentucky 41005
Role/Contribution to Project: Project Steering Committee, Project Administration
Contact Person: Mary Katherine Dickerson
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E-mail address: mdickerson@nkcd.org

Agency Name: Boone County Conservation District
Agency Address: 6028 Camp Ernst Road, Burlington, Kentucky 41005
Role/Contribution to Project: Project Steering Committee, Project Management
Contact Person: Mark Jacobs
Phone No. 859-586-7903
E-mail address: markjacobs@nkcd.org

Agency Name: Northern Kentucky Health Department
Agency Address: 610 Medical Village Drive
Role/Contribution to Project: Project Steering Committee
Contact Person: Steve Divine
Phone No. 859-363-2049
E-mail address: steve.divine@nkyhealth.org

Agency Name: Sanitation District No. 1
Agency Address: 1045 Eaton Drive
Role/Contribution to Project: Monitoring, Data, Education, Project Steering Committee
Contact Person: Matt Wooten
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E-mail address: mwooten@sd1.org

Agency Name: Northern Kentucky University Center for Environmental Restoration
Agency Address: Northern Kentucky University,
510 Johns Hill Road, Highland Heights, Kentucky 41076
Role/Contribution to Project: Project Steering Committee, Project Match
Contact Person: Scott Fennell
Phone No. 859-448-8953
E-mail address: fennells@nku.edu

Agency Name: City of Florence, Kentucky
Agency Address: City of Covington, Florence Government Center,
8100 Ewing Boulevard, Florence, Kentucky 41042
Role/Contribution to Project: Project Steering Committee
Contact Person: Josh Hunt
Phone No. 859-371-5491
E-mail address: joshua.hunt@florence-ky.gov

Agency Name: City of Union, Kentucky
Agency Address: City of Union, Union City Building,
1843 Mt. Zion Road, Union, Kentucky 41091
Role/Contribution to Project: Project Steering Committee
Contact Person: Deanna Kline
Phone No. 859-384-1511
E-mail address: commissionerKline@insightbb.com

Agency Name: Boone County Fiscal Court
Agency Address: 2950 Washington Street, Burlington, Kentucky 41005

Role/Contribution to Project: Project Steering Committee
Contact Person: Scott Pennington
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E-mail address: spennington@boonecountyky.org

Agency Name: Kentucky Transportation Cabinet
Agency Address: 421 Buttermilk Pike, PO Box 17130, Covington, Kentucky 41017
Role/Contribution to Project: Project Steering Committee and Public Outreach
Contact Person: Stacee Hans
Phone No. 859-341-2700
E-mail address: stacee.hans@ky.gov

Agency Name: Kenton County Airport Board
Agency Address: PO Box 752000, Cincinnati OH 45275
Role/Contribution to Project: Project Steering Committee
Contact Person: Donald Chapman
Phone No. 859-767-7884
E-mail address: DChapman@cvgairport.com

Agency Name: Boone County Planning Commission
Agency Address: 2950 Washington St., Room 317, PO Box 958, Burlington, KY 41005
Role/Contribution to Project: Project Steering Committee & Mapping and Plan Development
Contact Person: Kevin Costello, Executive Director
Phone No. 859-334-2196
E-mail address: kcostello@boonecountyky.org

Agency Name: Northern Kentucky Area Development District
Agency Address: 22 Spiral Dr., Florence, KY 41042
Role/Contribution to Project: Project Steering Committee & Reporting
Contact Person: Sara Jo Shipley
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Agency Name: Kentucky Division of Water
Agency Address: 200 Fair Oaks Ln., Frankfort KY 40601
Role/Contribution to Project: Project Steering Committee
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CHAPTER 2

Exploring the Gunpowder Creek Watershed

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

December 2014

Chapter 2: Exploring the Gunpowder Creek Watershed

This chapter describes key features of the Gunpowder Creek Watershed, including its extent, formation, natural and cultural resources, as well as some of its history relative to human use of the landscape. Much of this descriptive material is taken from the Gunpowder Creek Watershed Characterization Report (LimnoTech 2009).

2.1 Watershed Inventory

2.1.1 Watershed Location and Extent

Located entirely within Boone County, the Gunpowder Creek Watershed has a total drainage area of 58.2 square miles and is one of the largest watersheds in Northern Kentucky (**Figure 2-1**). The watershed is roughly triangular in shape with one leg running approximately 9 miles north/south across eastern Boone County. Its headwaters originate in the southern end of the Cincinnati/Northern Kentucky International Airport (CVG) and flow approximately 36 miles south and west to the Ohio River. South of CVG, the watershed drains nearly three quarters of the City of Florence and nearly all of the City of Union, which lies near the southeast end of the triangle. The balance of the watershed falls within unincorporated Boone County, narrowing as it meanders westward across the county. The lower reaches of the stream and its mouth form a valley that is more than one mile wide.

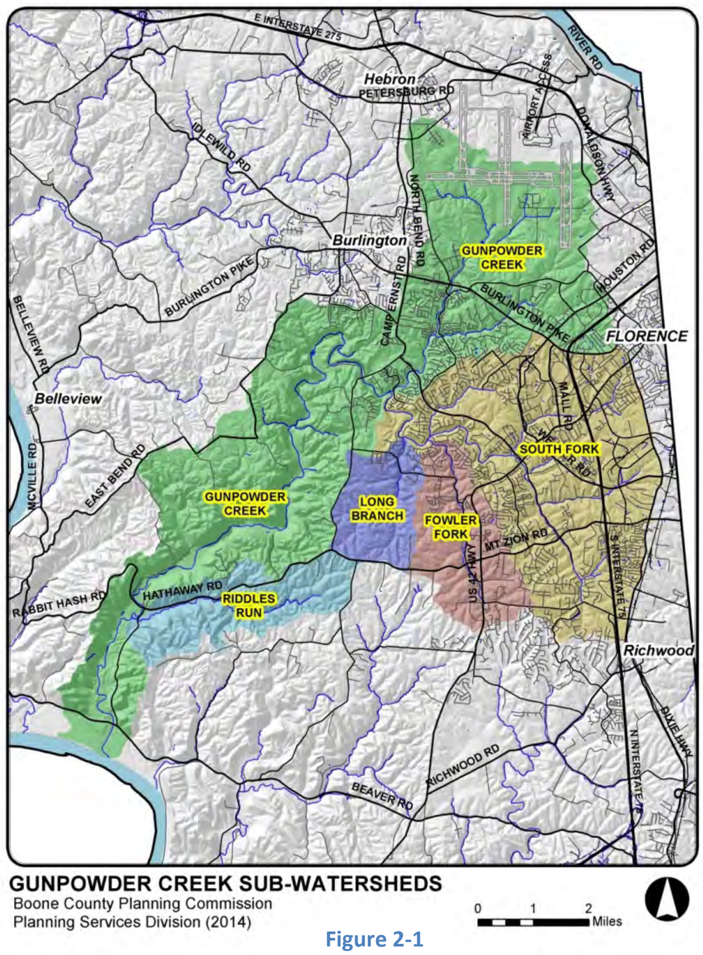

Figure 2-1

2.1.2 Hydrology

The Gunpowder Creek Watershed drains directly into the Ohio River and includes four smaller subwatersheds: South Fork Gunpowder, Fowler Fork, Long Branch, and Riddles Run. South Fork is in the southeast end of the Gunpowder watershed, is the largest of the subwatersheds, and drains much of the City of Florence. Fowlers Fork and Long Branch lie immediately west of South Fork and together, provide much of the drainage for the City of Union. The Riddles Run subwatershed drains much of the southern part of the larger Gunpowder watershed. All of the subwatersheds are located south of the 23.4-mile long main stem. There is a total of 143.1 miles of blue line streams in the Gunpowder Creek Watershed.

One USGS continuous monitoring station is located in the Gunpowder Creek Watershed where the main stem crosses Camp Ernst Road. Approximately 63% of the Gunpowder Creek watershed (36.6 square miles) drains to this station and daily discharge data from April 1999 to present are available. The USGS (2012) reports that between water years 1999 and 2012, the average flow at the station was 59.3 cubic feet per second (cfs), which is more than 26,000 gallons per minute. Ten percent of the recorded flows at this site have been less than 0.94 cfs (about 400 gallons per minute), but flows can increase by up to three orders of magnitude during a storm event. The maximum flow recorded at the USGS station is 6,590 cfs on May 8, 2002, which is nearly 3 million gallons per minute. The periods of high flow tend to be very brief and only last one to two days. In contrast, during extended periods of dry weather, flows at the station can become intermittent. There have been several days with zero flow, including a period during September of 1999 in which there were more than seven days in a row with no flow.

2.1.3 Groundwater – Surface Water Interaction

Groundwater yield in the Gunpowder Creek Watershed varies depending on geological formation. The upper Gunpowder is within the Grant Lake Limestone/Fairview and Bull Fork Formations and the lower Gunpowder is located in Kope Formation. Except near the headwaters, groundwater is generally unavailable on ridgetops. Wells in the valley bottoms can yield 100-500 gallons per day. This water is hard and may contain salt and hydrogen sulfide (Carey and Stickney, 2004). In Boone County, the interface between fresh and saline water ranges from elevations of less than 400 feet ASL along the Ohio River to 700 feet in the highlands of the county. Generally, salt water is found at depths greater than 100 feet below the level of the principal valley bottoms. The high percentages of shale and minimal development of karst features in the Outer Bluegrass rocks indicate a low to moderate sensitivity to groundwater contamination in the Gunpowder Creek Watershed (Ray et al., 1994).

There are many wells in the Gunpowder Creek Watershed. According to the Kentucky Geological Survey at the University of Kentucky, the groundwater that comes out of Boone County tends to be hard and have a high dissolved mineral content. This is at least partially due to the low amount of interaction between Boone County’s ground water and surface water. This low interaction is due to the high clay content in Boone County’s soils, which tends to discourage groundwater infiltration. Drilled wells in areas with glacial drift and outwash (near the Gunpowder Creek/Ohio River confluence) are capable of yielding significantly more groundwater than elsewhere in the watershed (Ray et al., 1994).

2.1.4 Flooding

Like most of Boone County’s streams, portions of Gunpowder Creek have been known to flood periodically since the county was first settled in the late 1790s. The 100-year floodplain extends almost the entire length of both Gunpowder Creek and South Fork Gunpowder Creek. The larger stream’s floodplain is widest, roughly 0.5 miles, between the confluence of Riddles Run and Gunpowder’s mouth at the Ohio River. Frequent episodes of flooding have occurred since the early 1990s, which is an ongoing concern of citizens living along the streams in the watershed. More recently, the smaller tributaries in the watershed have been increasingly affected by flooding, as reported by attendees at public roundtable meetings. Portions of the upper Gunpowder Creek watershed frequently experience flooding, though the most extensive flood zone area identified in the Boone County Comprehensive Plan is the lower East Bend Bottom, at the mouth of Gunpowder Creek (BCPC, 2010). Flooding risks will likely increase with amplified runoff events associated with increased population, expanding development, and associated increases of impervious surface and loss of soil stabilizing vegetation to erosion.

2.1.5 Regulatory Status of Waterways

Gunpowder Creek and its tributaries are designated for warm water aquatic habitat, primary contact recreation, secondary contact recreation, and domestic water supply, applicable at existing points of public waters supply withdrawal (401 KAR 10:026). These uses are defined below.

- **Warm water aquatic habitat** means any surface water and associated substrate capable of supporting indigenous warm water aquatic life.
- **Primary contact recreation** waters means those waters suitable for full body contact recreation during the recreation season of May 1 through October 31.
- **Secondary contact recreation** waters means those waters that are suitable for partial body contact recreation, with minimal threat to public health due to water quality.
- **Domestic water supply** means surface waters that with conventional domestic water supply treatment are suitable for human consumption through a public water system as defined in 401 KAR 8:010, culinary purposes, or for use in any food or beverage processing industry; and meet state and federal regulations under the Safe Drinking Water Act, as amended, 42 U.S.C. 300f – 300j. Two Wellhead protection zones are identified in the watershed. Both are located in floodplain areas of the lower Gunpowder below Riddles Run (see LimnoTech 2009: Fig 9).

Several sections of Gunpowder Creek have been classified on the Kentucky 303(d) List of Impaired Waters for high levels of sediment, bacteria, and nutrients. **Table 2-1** lists each impaired section and the pollutants of concern, as specified in the Kentucky 303(d) List of Impaired Waters (KDOW, 2011). In addition to the list below, there is a Total Maximum Daily Load (TMDL) for ethylene glycol in Upper Gunpowder Creek near river miles 15.4 to 17.1. This is an approved TMDL, is a point source pollutant, and it is already being addressed. It will not be a focus of this watershed plan.

Table 2-1: Stream sections in the watershed on the Kentucky 303(d) List of Impaired Waters

STREAM NAME	RIVER MILES	POLLUTANT	SUSPECTED SOURCE(S)
Gunpowder Creek into Ohio River	0.0 to 15.0	Sedimentation/Siltation	Site Clearance (Land Development or Redevelopment)
Gunpowder Creek	15.4 to 17.1	Nutrient/Eutrophication Biological Indicators	Agriculture; Site Clearance; Unspecified Urban Stormwater
Gunpowder Creek	15.4 to 17.1	Organic Enrichment (Sewage) Biological Indicators	Agriculture; Unspecified Urban Stormwater
Gunpowder Creek	15.4 to 17.1	Sedimentation/Siltation	Agriculture; Highway/Road/Bridge Runoff; Loss of Riparian Habitat; Site Clearance; Streambank Modifications/ Destabilization; Unspecified Urban Stormwater
Gunpowder Creek	18.9 to 21.6	Cause Unknown	Unspecified Urban Stormwater
South Fork Gunpowder Creek	0.0 to 2.0	Nutrient/Eutrophication Biological Indicators, Organic Enrichment (Sewage) Biological Indicators, Sedimentation/Siltation, and Turbidity	Agriculture; Package Plant or Other Permitted Small Flow Discharges; Site Clearance; Post-development Erosion and Sedimentation
South Fork Gunpowder Creek	4.1 to 6.8	Fecal Coliform	Source Unknown

2.1.6 Water Quality and Biology

The Gunpowder Creek Watershed Characterization Report contains a discussion and analysis of water quality data collected from various points in the watershed from 1985 to 2007 (LimnoTech 2009:35). During that time frame, exceednces of both fecal coliform and *E. coli* were common at many locations within the Gunpowder Creek watershed. Additionally, analysis of data collected at the USGS continuous monitoring revealed violations of dissolved oxygen, temperature and pH criteria. As stated earlier, these and other data have led to portions of Gunpowder Creek to be listed as impaired on Kentucky's 303(d) list of impaired waters (Table 2-1).

Stream biology surveys have been conducted at various locations throughout the Gunpowder watershed. KDOW collected both macroinvertebrate and fish data between 1999 and 2004, producing results that indicate wide variability within the quality of biological communities. This variability is exemplified by both the Macroinvertebrate Biotic Index (MBI) ratings ("very poor" to "fair"), and the Kentucky Index of Biotic Integrity (KIBI-fish) ratings ("very poor to excellent").

As part of their efforts to characterize watershed and stream quality in Northern Kentucky, SD1 also collected both fish and macroinvertebrate samples in 2010. Fish samples were collected at five (5) sites throughout the watershed, producing a total of 35 unique taxa and KIBI ratings of generally "fair" to "good." Macroinvertebrate samples were collected at four (4) locations in the watershed, producing 48 unique taxa and MBI ratings of generally "poor" to "fair."

2.1.7 Geomorphology

Rivers come in many shapes and sizes, and fluvial geomorphology is the study of how flowing water shapes the earth's surface, in particular, the form, composition, and stability of a stream channels. The most dominant drivers of stream form include the climate and corresponding flow regime and vegetation resistance, as well as the geologic setting and the relative resistance of rocks/soils, steepness of the topographic setting, valley confinement, and so forth.

The hydrogeomorphic setting of northern Kentucky is relatively homogenous. The average precipitation of 42.5 inches is the same for the entire region, and supports fast growing vegetation with relatively dense root networks of high strength. Clay soils create low infiltration rates and cohesive streambanks. The somewhat soft and shallow limestone bedrock supplies streams with a relatively limited supply of coarse bed material when compared to steeper and less vegetated settings such as the western U.S. Even so, the hill slopes and valley corridors are relatively steep as the precipitation makes its way from the high ridgetops to the much lower Ohio River over relatively short distances.

Although factors such as climate and geology are the dominant drivers of stream morphology at the regional scale, other factors such as urbanization and/or channelization can become the primary driver within an otherwise homogenous setting. As discussed in subsequent sections of this plan, the amount of impervious area such as rooftops and pavement can explain differences in shape and stability between two streams in an otherwise similar setting. For example, the forested reference stream in the adjacent watershed of Double Lick has a relatively similar climatic, geologic, and topographic setting as the unnamed tributary to the South Fork of Gunpowder along Sunnybrook Dr. which drains the industrial area near the intersection of Weaver Road and Dixie Highway. Despite the relatively similar natural settings, the impacts of urbanization have resulted in a stark contrast in stream form, stability, and habitat condition.

2.2 Natural Features

2.2.1 Geology and Topography

The Gunpowder Creek Watershed is located within the Outer Bluegrass Physiographic Region (Ray et al., 1994). It is underlain primarily by Ordovician-age interbedded limestone and shale of between 425 and 500 million years old. Although most of the watershed is underlain by bedrock with a moderate potential for karst development (Paylor and Currens, 2002), rocks in this region generally contain higher percentages of shale layers and do not develop extensive karst features (Ray et al., 1994).

The rolling upland areas of the Gunpowder Creek Watershed are underlain by the Bull Fork Formation and the Grant Lake Limestone/Fairview. These formations produce broad stream valleys and form valley sides. In areas where the shale content increases, erosion increases and creates steep topography. The lower Gunpowder cuts through the erodible shale found in the Kope Formation.This formation contains a large percentage of shale overlapping with limestone and forms steeper topography than the upper Gunpowder. According to the Kentucky Geological Survey, this formation has poor drainage and soft shale which typically results in hillside slippage when exposed to the weather. The floodplains and terraces of Gunpowder Creek and its tributaries include alluvium and glacial sediment deposits of highly erodible material.

The topography of the Gunpowder Creek watershed ranges from broad, gently sloping, uplands in the eastern end of the watershed to deeply dissected valleys in the west. This topographic variation is the result of glacial processes related to the Wisconsin Glaciation of North America, which ended in the Late Pleistocene Era (10,000 - 20,000 years ago). Elevations are higher in the eastern end of the watershed, with upland areas dissected by headwater streams. The highest elevations (965 ft) are found along a ridge that marks the eastern edge of the watershed; U.S. Highway 25 (Dixie Highway) was built along this ridge. The lowest elevation in the watershed (453.6 feet at normal Ohio River pool) is located at the confluence of Gunpowder Creek with the Ohio River.

2.2.2 Soils

Soils in this area formed in semiarid to humid areas, typically under a hardwood forest cover. They have a clay-enriched subsoil and relatively high native fertility. Because of their productivity and abundance, soils in this region represent one of the more important soil orders for food and fiber production. They are widely used both in agriculture and forestry, and are generally easier to keep fertile than other humid-climate soils. These soils are common on limestone plains and support a potential natural vegetation of oak–hickory forest and bluestem prairie.

Three major soil associations occur in the Gunpowder Creek Watershed (see Weisenberger et al., 1973). The Rossmoyne-Jessup association occupies broad, nearly level to sloping ridges and moderately steep side slopes in the glaciated area in the eastern headwaters portion of the watershed. The Eden-Cynthiana association occupies the steep (12-30% slope), highly dissected, portions of the valley, primarily below the South Fork Gunpowder confluence. The Wheeling-Huntington-Alluvial land consists of soils on stream terraces and bottoms and is found along the final 2 miles of the lower Gunpowder to its confluence with the Ohio River.

Soil type affects drainage, flooding, permeability, slope stability, and siltation, all of which interact dynamically in the Gunpowder Creek Watershed. With the exception of streamside alluvial soils, most (83%) of the soils in the watershed are considered either “highly erodible” or “fairly erodible” (14%) as indicated by an index for erodibility (NRCS, 2006). The NRCS uses a formula to determine soil erodibility, and for example, “highly erodible” soils have eight times the tolerable erosion rate. Virtually all of the soils in the county have “very limited” Septic Suitability and those within the Gunpowder Creek Watershed are almost all classed either “well drained” or “moderately well drained.”

2.2.3 Ecoregions

The Gunpowder Creek watershed lies within the Outer Bluegrass Ecoregion 71d, which is characterized by sinkholes, springs, entrenched rivers and intermittent and perennial streams (Woods et al. 2002). Wetlands are not common in this ecoregion or the watershed. Streams typically have relatively high levels of suspended sediment and nutrients. Glacial outwash, which tends to be highly erodible, exists in a few areas within the ecoregion. Pre-settlement conditions in the ecoregion consisted of open woodlands with barren openings, and vegetation was mostly oak-hickory, with some white oak, maple-oak-ash and American beech-sugar maple forests (Woods et al. 2002).

The Kentucky State Nature Preserves Commission (KSNPC) monitors the occurrence of exemplary ecological communities, which are relatively undisturbed or have recovered sufficiently from previous disturbances and have the flora and fauna that are believed to represent the ecological communities that existed in Kentucky at the time of European colonization. KSNPC identified calcareous sub-xeric forest and riparian forest as being present in this watershed, with broad areas of each forest type documented along the south-facing hillsides at the entrance of Gunpowder Creek Nature Park. A smaller area of calcareous sub-xeric forest exists further downstream in the vicinity of Camp Michaels. These communities are rare examples of intact communities of this type in Kentucky (KSNPC, 2007).

The Kentucky Division of Water defines Reference Reach Streams as “a representative subpopulation of the least-impacted streams within a bioregion….serving as chemical, physical and biological models from which to determine the degree of impairment…to similar stream systems in each representative bioregion.

Aquatic habitats in the Gunpowder Creek watershed have been altered from their historical state by agricultural, urban and suburban developments. Habitat assessments have been conducted at ten sites in the watershed, beginning as early as 1977 (**Table 2-2**). These assessments were conducted by KDOW using EPA-established protocols and looked at several components of physical habitat within the stream such as faunal substrate, embeddedness, sediment deposition, channel flow status, bank stability, and riparian vegetation zone width. Rankings ranged from “partially supporting” indicating that available habitat can only partially support a diverse and productive ecosystem, to “fully supporting.” More recently (2007), portions of Gunpowder Creek were observed to have cobble substrate, variable aquatic habitat types (pools, riffles and runs) and clear water during low flows (LimnoTech 2009:8).

Table 2-2: Aquatic habitat and biological sampling data

STREAM	RIVER MILE	MONITORING					
		HABITAT		MACROINVERTEBRATES		FISH	
		Year(s)	Ranking	Year(s)	Ranking	Year(s)	Ranking
Gunpowder	14.1					1977	Poor
Gunpowder	15.1			1999	Fair		
Gunpowder	16.1	1999, 2004	Partially supporting; Supporting but threatened			1999, 2004	Fair
Gunpowder	18.9	2004	Partially supporting				
Gunpowder	19.5			1995	Poor		
South Fork Gunpowder	1					1977	Very poor
South Fork Gunpowder	1.9	1999, 2004	Partially supporting; Fully supporting			1999, 2004	Poor, Excellent
South Fork Gunpowder	4.3	1999	Partially supporting			1977	Poor
Unnamed Gunpowder trib @ RM 19.4	0.1			1995	Very poor		
Unnamed Gunpowder trib @ RM 18.9	0.1	2004	Partially supporting	1995, 2004	Very poor		

2.2.4 Climate

The United States Department of Energy divides the United States into five climate zones. All of Kentucky, including Boone County, is located in the Mixed-Humid climate zone. The Mixed-Humid zone has moderate weather conditions most of the time but is subject to occasional severe weather events. The temperatures in this area are generally lowest in January and highest in July. Precipitation averages 41.2 inches annually, with the wettest months observed between March and July. The temperature ranges from an average of a high of 86°F in July to a low of 22°F in January. According to the Kentucky Climate Center, both rainfall and temperatures have been trending upward in the Bluegrass Regionsince the 1960s.

2.3 Riparian/Streamside Vegetation

At the time of settlement in the Outer Bluegrass, open savannah woodlands were found on most uplands. Most upland forests have been disturbed repeatedly and current community structure is likely very different from the original forests. Forested areas were mostly oak–hickory. Major species in the oak-hickory cover type includes white, black, and northern red oaks. Other important species include sugar maple, beech, black walnut, and yellow-poplar. Bitternut, pignut, or shagbark hickories may also be present. In the eastern portions of Boone County, cane grew along streams and on bottoms. Distinct vegetation grew in areas underlain by glacial drift. Maple–oak–ash forests grew in the northern portion of the watershed where glacial drift deposits have been removed by erosion. American beech–sugar maple grew on upland glacial till sites on Rossmoyne soils. On well-drained soils over coarse glacial outwash deposits in the north included a few, scattered dry prairie sites. Mixed forests contained white oak, northern red oak, hickory, yellow buckeye, white ash, blue ash, eastern red cedar, black walnut, beech, yellow-poplar, basswood, black cherry, sugar maple, chinquapin oak, bur oak, and black locust. Along river drainages and in gorges: white oak, northern red oak, chinquapin oak, white ash, blue ash, sugar maple, red maple, yellow-poplar, and eastern red cedar (*Plant Life of Kentucky, Ronald Jones, 2005*).

Following European settlement, forests in Boone County were cleared for agriculture, which was the dominant landuse in much of the Gunpowder Creek Watershed until development began to expand in the 1980s and 1990s. In agricultural land that has been abandoned, but has yet to be developed, successional fields of broomsedge and sumac and older successional forests of red cedar and black locust grow. Sycamore, silver maple, boxelder, willow, and American elm are common species along Ohio River bottom lands.

The ever increasing invasion of alien species is recognized as one of the leading threats to biodiversity and imposes enormous costs to agriculture, forestry, fisheries, and other human enterprises, as well as to human health. Bush honeysuckles, Dutch elm disease, multi-flora rose, Callery pear, poison hemlock, and garlic mustard are just a few well known invasive species in Boone County. These exotic species, along with more recent invasions from the emerald ash borer,Asian long-horned beetle, Zebra mussel, Asian carp, and many others pose serious threats to stream ecosystems, local ecology and economy. Invasives can result in loss of native species, habitat destruction, soil degradation, and decreased groundwater levels (Higgins, 2013). In Northern Kentucky, streamside Bush honeysuckle threatens frog tadpoles by reducing drainage into wetland spawning areas and by providing a food source that is significantly less nutritious than the native vegetation it replaces (Wallace and Durtsche, 2010).

2.4 Plant and Animal Abundance, Including Rare Species

The Kentucky Department of Fish & Wildlife indicates that over 400 species of wildlife have been observed in Boone County, including 107 species of fish, 25 species of amphibians, 26 species of mammals, and 19 species of reptiles (NatureServe, 2014). According to the Kentucky State Nature Preserve Commission (KSNPC, 2013), of these, several species in the Gunpowder Creek Watershed are of significant concern; **Table 2-3** summarizes these species. Running buffalo clover is a small plant that inhabits streambanks and upland areas; erosion is noted as the biggest threat to this species (KSNPC, 2006). Other factors contributing to population declines are loss of bison populations, nonnative plants, and overall habitat loss (United States Fish and Wildlife Service (USFWS), 2003). The northern leopard frog is an aquatic species that inhabits various habitats including slow flowing areas in creeks and rivers, springs, the nearshore area of lakes, bogs, fens, herbaceous wetlands, riparian areas and grasslands (NatureServe, 2007). Threats to the northern leopard frog include habitat loss, commercial overexploitation, and competition with introduced species. Three of the species identified by KSNPC (Henslow's sparrow, the barn owl, and the redback salamander) are neither aquatic nor dependent on aquatic habitats; however, preservation of the undeveloped lands that serve as their habitats (e.g. grasslands, barns, and woodlands) have clear benefits for the downstream water resources.

Table 2-3: Species of concern in the Gunpowder Creek Watershed

Taxonomic Group	Scientific Name	Common Name	Status	Last	Observed Habitat(s)	Identified Threats
Vascular Plants	Trifolium stoloniferum	Running buffalo clover	Federal - Endangered State - Threatened	2003	Riparian areas, upland areas	Habitat loss, non-native species, bison decline
Breeding Birds	Ammodramus henslowii	Henslow's sparrow	Federal - SOMC State-Special Concern	1950	Grasslands, savannahs	Habitat loss
Breeding Birds	Tyto alba	Barn owl	State - Special Concern	1987	Farms and farm structures	Habitat loss
Amphibians	Plethodon cinereus	Redback salamander	State - Special Concern	1998	Woodlands	Habitat loss, habitat degradation
Amphibians	Rana pipiens	Northern leopard frog	State - Special Concern	1934	Ponds, wetlands, grasslands	Habitat loss, non-native species, commercial overexploitation

2.5 Human Influences and Impacts

Human influences on the Gunpowder Creek Watershed have been significant, especially in the developed headwaters. In order to assess existing land use information and assist in determining potential sources of pollution, the Boone County Planning Commission utilized its detailed Geographic Information System (GIS) database to analyze, collate, and summarize data on a watershed and subwatershed basis. Such data allowed the geospatial characteristics of individual watersheds to be quantitatively described to better understand their geologic, hydrologic, and human impact. Over 40 parameters were summarized for this analysis. A few examples of pertinent GIS parameters include percent impervious surfaces, forest cover, barren land, riparian area, riparian roads, riparian impervious, Kentucky Pollutant Discharge Elimination System (KPDES) outfalls, and National Resource Conservation Service (NRCS) soil types.

2.5.1 History of Human Interaction in the Watershed

Prior to contact with Europeans, Native Americans had occupied Northern Kentucky since at least 9,500 B.C. (see Pollack, 2008). Archaeological evidence suggests that Native Americans began living in and harvesting the natural resources of the Gunpowder Creek Watershed well before the time of Christ. These early inhabitants were semi-nomadic, moving from camp to camp on a seasonal basis, hunting, fishing, and collecting plants from the emerging deciduous forest. They were doubtless attracted to the Gunpowder as a transportation route, but also as a perennial source of water relatively easy to procure dietary protein in the form of fish, fresh water mussels, and other shellfish. Ceremonialism emerged by

1,000 B.C., as did wider trading and more dependence on farming. Camp sites were joined by semi-permanent villages in the lower Gunpowder and burial mounds built by the Adena culture are erected around the county. By A.D. 1,000, permanent villages depended on farming and intensive extraction of natural resources such as freshwater mussels from the larger streams and Ohio River.

The most significant prehistoric sites in the watershed are a series of Fort Ancient villages in the broad bottoms of the lower Gunpowder. This cluster of villages is associated with an even larger grouping of similar sites in the nearby Big Bone and Mud Lick drainages. All are believed to be part of a late prehistoric network of villages scattered along the Ohio River from East Bend to Petersburg. The Fort Ancient people left an impressive archaeological legacy in these villages including house foundations, cemeteries, huge storage and trash pits, tools of bone and stone and perhaps most notably, a range of decorated pottery styles that are hallmarks of the culture (**Figure 2-2**). The Fort Ancient were farmers and favored areas with broad floodplains, such as those in the lower Gunpowder, where they raised corn and other crops. They also heavily exploited freshwater aquatic life. Fort Ancient village sites are rife with bones from virtually every type of freshwater fish (and land animal) in the area, along with vast amounts of mussel shell. Archaeologists believe that the Fort Ancient occupation lasted until about the time of European contact. However, the first Europeans who ventured down the Ohio River in the mid-1700s (most of them in search of Big Bone Lick or other useful natural resources) found no villages and falsely assumed that Kentucky had no aboriginal population.

Figure 2-2: Typical decorated pottery of the Fort Ancient culture

The French lost control of the Ohio Valley following the French & Indian Wars and the first settlers began trickling down the river into the area by the late 1780s (Warminski 2002). Tanners Station (the precursor to Petersburg) was arguably the first, but European footholds were soon established elsewhere, including in North Bend and East Bend Bottoms and at the mouth of Taylors Creek. All of these early settlements had one thing in common: the Ohio River. The river (and its tributaries) was the superhighway of its day and remained the dominant transportation corridor for people and goods until the latter 19th Century. Flatboats, skiffs, and (later) riverboats plied the river and ferries connected it to neighboring towns on the opposite shores.

When Boone County became a county in 1799, less than 200 men owned all of the land and the county's population was just 1,500. Over the next few decades, the population swelled to 10,000. Streams such as Woolper Creek, Big Bone Creek, and Gunpowder Creek were charted to their headwaters and settlement, resource extraction, and land clearing/planting was in full swing. Nineteenth century agricultural activity in Boone County was largely subsistence in nature and most farms were 50-150 acres. Many of the narrow floodplains and terraces along the middle and lower Gunpowder were cleared and cultivated, as were the rolling uplands in the eastern watershed. Farms had diversified production that included row crops, livestock, and tobacco, as well as the occasional mill, distillery, rope walk, or other cottage industry.

Figure 2-3: Stonework and water wheel of "The Grand Water Power"

In 1817, a Virginian named Lewis Crisler settled along Gunpowder Creek about 2 miles south of Burlington (Kreinbrink 2006). Crisler quickly took advantage of the stream's awesome hydraulic power by damming the creek on the upstream side of an oxbow and hewing a channel through the bedrock to create a mill race over to the downstream side of the peninsula – some 1,500 feet away. He used the harvested limestone bedrock to build a huge gristmill and sawmill complex. The mills' massive stonework and ingenious waterworks earned it the local nickname "The Grand Water Power" (**Figure 2-3**). While Crisler's mill was an extreme example of the hydromodifications used in mill construction, other milling operations on the stream also relied on dam construction, stream channel alteration, and excavation of mill ponds and mill races.

The budding agrarian commerce of the 19th Century spawned an extensive network of roads through the Gunpowder Creek Watershed and beyond. The mill became the center of a small farming community and a destination for locals hungry for a way to reduce their grain into meal and harvested timber to lumber. A portion of the 1883 Atlas near the Grand Water Power provides a snapshot of the network (**Figure 2-4**), which provided much greater connectivity through the watershed than today's public road system. The map also shows that homesteads were prevalent, which was the case throughout the watershed. In fact, there are probably fewer people living in the central and lower Gunpowder valley now than in the 1880s. These home sites commonly include stone house foundation and/or chimney remains, wells/cisterns, a root cellar, and perhaps an ice house. While most of the old road beds and mill races are lost to the Gunpowder's maze of meander loops, remnant stone walls that once lined the roads and property lines may yet be found buried in the streamside underbrush. These archaeological ghosts are the most visible evidence of the several thousand years of near-continuous occupation and use of the Gunpowder Creek Watershed.

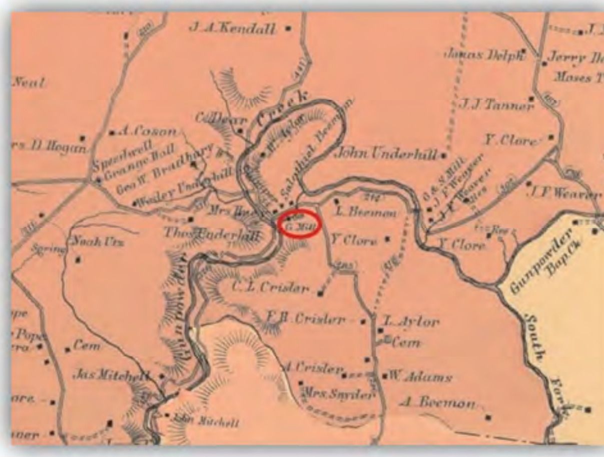

Figure 2-4: Detail of the 1883 Atlas showing a portion of the central Gunpowder valley

2.5.2 Water Use

As previously discussed, humans have been using the water resources in the Gunpowder Creek watershed since prehistoric times. The natural areas of the Lower Gunpowder feature extensive forest resources which foster biological diversity, soil protection, and hillside and stream bank stabilization. This also has positive implications for storm water mitigation and water quality.

Figure 2-5: Kayaking Gunpowder Creek

While some sections of Gunpowder Creek may be impaired for various uses, much of the watershed is already hosting recreation and other uses, including fishing. The stream is identified by the Kentucky Department of Fish and Wildlife Resources as a smallmouth bass stream, based on fish populations (Ross, undated). There are outdoor recreation opportunities throughout the watershed, both on public and private land. The more urbanized Upper Gunpowder includes the Union Pool/park and the City of Florence's South Fork Park, which is the city's most heavily utilized park.

The Lower Gunpowder has several thousand acres of good to high quality forest resources with broad local biological diversity. There are extensive opportunities for outdoor recreation ranging from hiking and nature study to fishing and even whitewater kayaking (**Figures 2-5** and **2-6**). Gunpowder Creek from Camp Ernst Road to Dale Williamson Road has been rated as a class II+ section by American Whitewater and several websites describe this stretch of the river from the viewpoint of boat paddlers. The county's 122-acre Gunpowder Creek Nature Park, located about a mile south of Burlington, has several miles of both gravel and dirt trails and is a popular fishing site. Farther downstream, the county also owns the 125-acre Volpenhein Property, which was acquired with Kentucky Land Heritage Funds due to its excellent quality forest resources along Gunpowder Creek; it is protected by a permanent conservation easement.

The YMCA operates Camp Ernst on 365 acres adjacent to Gunpowder Creek Nature Park. Camp Ernst has served as a summer camp since 1928, offering nature-oriented camps, hiking, and activities for children and families including stream access for fishing and aquatic studies. Camp Ernst's 65-acre lake is used for swimming and is stocked for fishing for campers and the general public. The even larger 675-acre Camp Michaels is owned/operated by the Dan Beard Council and is

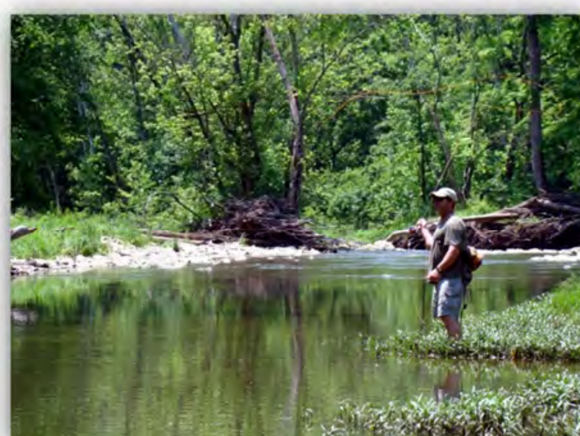

Figure 2-6: Fishing on Gunpowder Creek

one of the most actively used Boy Scout camps in the region, with opportunities for nature study, primitive camping, orienteering, and other scout activities.

The Gunpowder Valley south of the Riddles Run confluence and Hathaway Road has broad floodplains and high quality farmland. There is little whitewater potential along this calmer stretch of the creek, which may have Ohio River backwater when the river is up. Trixie's Marina on Beaver Rd. (KY 338) offers access for both motorized and non-motorized boats. Potters Ranch is a 365-acre private retreat facility on the rugged west side of the valley just north of Trixie's. The ranch has a range of accommodations for groups and conferences and offers a range of outdoor activities. The only two active public water supply groundwater wells in the watershed are both located in this downstream portion of the Gunpowder (KDOW, 2007c; KDOW, 2008b).

2.5.3 Land Use

Land cover and land uses have significant implications for runoff and water quality within the watershed, especially relative to the presence of bacteria, nitrogen, and other contaminants. The most recent analysis of current land use in Boone County resides in the Boone County Planning's Commission's Current Land Use GIS data layer, which is based on 2009 aerial photography (see **Figure 2-7 and Table 2-4**). These data segregate uses into classes ranging from Woodlands to Industrial. The following abbreviated descriptions of these classes are taken from the Land Use Element of the 2010 Boone County Comprehensive Plan:

Figure 2-7: Current land use in the Gunpowder Creek Watershed and subwatersheds

Agriculture (A) *Agricultural activity and abandoned, overgrown fields, including vacant/future development areas in urbanized areas;* ***Woodlands (W)*** *Mature wooded areas of greater than one acre;* ***Recreation (R)*** *Outdoor recreation including golf courses, parks, race tracks, private reserves, etc.;* ***Hydrology (H)*** *Water, lakes & rivers;* ***Rural Density Residential (RD)*** *Low density residential up to 1 unit/acre;* ***Suburban Residential (SR)*** *Single family housing of up to 4 units/acre;* ***High Suburban Density Residential (HSD)*** *Single-family and/or attached housing up to 8 units/acre, typified by townhouses and condominiums, but also mobile home parks;* ***Urban Density Residential (UD)*** *Generally condominiums/apartments over 8 units/acre;* ***Transportation (T)*** *Airports, major four lane roads, interstates;* ***Industrial (I)*** *Manufacturing, wholesale, warehousing, distribution, assembly, etc.;* ***Business Park (BP)*** *A mix of office warehouse, research, office, and light industrial uses in a park-*

like, office campus setting.; ***Commercial (C)*** *Retail, corporate and professional office, restaurants, services, etc.;* ***Public/Institutional (P)*** *Government offices, schools, libraries, churches, cemeteries, etc.*

Note that the Agriculture class includes both active and inactive parcels as well as some vacant lots in urban areas. The mapping/analysis methods used by the Planning Commission to create this category makes is impossible to separate the passive from active farmland without conducting a separate analysis. Note also that, despite its definition, the Hydrology land use does not reflect the actual extent of water resources (water, lakes, rivers, wetlands, etc.) in the Gunpowder Creek Watershed. They are expansive, with 143.6 miles of mapped streams and about 570 acres of mapped wetlands throughout the watershed.

Table 2-4: Existing (2009) land use in the Gunpowder Creek Watershed

	Existing Land Use By Subwatershed (acres)						
Land Use Category	Fowler Fork	Long Branch	Riddles Run	South Fork	Rest of Gunpowder	LAND USE TOTALS	% OF TOTAL
UNDEVELOPED						**19,257**	**53%**
Agriculture	1,239	839	828	1,144	3,336	7,386	20%
Woodlands	303	540	1,480	998	6,097	9,418	26%
Recreation	98	124	0	245	1,934	2,401	7%
Hydrology	0	0	0	0	52	52	<1%
RESIDENTIAL						**10,192**	**28%**
Rural Density Residential	397	224	279	809	1,462	3,171	9%
Suburban Density Residential	582	53	0	3,639	1,406	5,681	16%
High Suburban Density Residential	80	0	0	440	181	701	2%
Urban Density Residential	40	0	0	413	187	639	2%
DENSE DEVELOPMENT (transportation, industrial, commercial, institutional)						**6,841**	**19%**
Transportation	1	0	0	401	3,244	3,646	10%
Industrial	3	0	11	872	270	1,157	3%
Business Park	0	0	0	0	23	23	<1%
Commercial	12	0	0	834	516	1,362	4%
Public/Institutional	172	58	0	294	130	653	2%
WATERSHED TOTALS	**2,927**	**1,838**	**2,598**	**10,089**	**18,838**	**36,290**	**100%**

The Existing Land Use Map shows that most development is concentrated in the eastern end of the watershed and South Fork Gunpowder subwatershed. The South Fork subwatershed alone has more land devoted to Industrial (872 acres) and Commercial (834 acres) uses than anywhere else in the greater watershed. Well over half of the Suburban Density Residential (3,639 acres) is also found in the South Fork, although Fowler Fork also has an appreciable amount with 582 acres. Rural Density Residential is also prevalent in the South Fork (809 acres), but at a level that is consistent with other parts of the greater watershed. The other land use which has a strong visual presence on the map is the 3,000+ acre area of Transportation at the north end of the map, which represents approximately one third of the total CVG airport acreage in Boone County. The clearance, stormwater, runoff, streambank modification, and sewer activities associated with the development in the eastern watershed appear to correlate strongly with the locations of the segments of the Gunpowder and South Fork Gunpowder on the 303(d) list of impaired streams (see **Table 2-1**).

Other land uses which bear some discussion include the Woodlands, Recreation and Agriculture classes. Woodlands comprise more than one quarter of the land area in the watershed, with the vast majority of total 9,418 acres found in the western end of the valley, including Riddles Run. Fingers of Woodland extend up into Fowlers Fork as well. Most of the other large greenspace areas on the map are Recreation uses (both public & private), which make up about 7% of the total watershed with 2,401 acres. This includes South Fork Park, Gunpowder Creek Nature Park, YMCA Camp Ernst, Central Park, Camp Michaels, and Potters Ranch, among others. One fifth of the watershed is classified as Agriculture land use, with 7,386 acres scattered across much of the watershed and subwatersheds, with the notable exception of the airport property and areas east of I-71/75. Concentrations of Agriculture are found along Richwood Road, Long Branch, Camp Ernst Road and especially East Bend road.

2.5.4 Other Water Disturbances

This section refers to artificial disturbances and stream alteration such as channelization, artificial armoring, or piping/burial. There are certainly examples of this within the watershed (**Figure 2-8**). This is especially true in the eastern portion of the watershed where development has occurred.

2.5.5 Land Disturbances

According to the Watershed Planning Guidebook for Kentucky Communities, this section deals primarily with mining operations. This activity does not affect the Gunpowder Creek Watershed. Activities related to development, such as grading and land clearing, are discussed in other sections.

Figure 2-8: Artificial channel armoring such as concrete (Utterback Creek off Industrial Road) and tractor tires (South Fork of Gunpowder along Gunpowder Road near Sunnybrook Drive) reduce habitat quality and stream integrity

2.5.6 Hazardous Materials

Hazardous Materials are substances which, because of their properties, pose a potential risk to health, property or the environment. Boone County Code of Ordinances Chapter 95 addresses hazardous material enforcement in Boone County and designates the Emergency Management office as the primary enforcement agency. Companies that manufacture, use, transport, or store hazardous materials in Boone County are required by law to report the quantity and location of these materials to Boone County Emergency Management (BCEM) and have contingency plans in place in case of unexpected release.

According to BCEM, the top hazardous materials threats within the Gunpowder Creek Watershed are related to: (1) transportation of materials by truck along Interstate 75 and (to a lesser extent) the Norfolk-Southern Railroad, (2) businesses using/storing materials onsite in the Florence Industrial Park, (3) and potential leaks from the Mid-Valley Crude Oil Pipeline. One recent analysis showed that all USDOT recognized classes of hazardous materials are regularly trucked along Interstate 75, with Flammable Liquids, Flammable Gases, and Corrosive Liquids being the most common (NKEPC, 2011). The Norfolk-Southern RR runs along the eastern edge of the Gunpowder Creek Watershed, with spurs extending into the Florence Industrial Park. The top 10 hazardous materials transported along the rail line in 2012 included Molten Sulfer (4,600 cars), Phosphoric Acid (2,300 cars) and Sodium Hydroxide (1,300 cars) (BCEM, 2014). The BCEM considers use and storage of hazardous materials in the Florence Industrial Park to be less of a threat than transport of materials. While on-site storage of fuels (gasoline diesel, etc.) is common, some businesses do maintain inventories of potentially dangerous chemicals such as ammonia, ammonium hydroxide, or corrosive liquids (CAMEO, 2014).

The Mid-Valley Pipeline transports upwards of 200,000 barrels/day of sweet crude oil from Texas to Lima, Ohio, and was completed through Boone County in the 1950s (BCEM, 2014). The pipeline passes north/south through the heart of the Gunpowder Creek Watershed, roughly paralleling Camp Ernst Road on its way past the Mid-Valley Storage Facility on Limaburg Road on the western edge of the CVG airport. The pipeline is an ongoing potential source of crude oil spills, largely due to its age (60+ years). Indeed, in 2005, a break in the line near Carrolton sent 260,000 gallons of crude into the Kentucky River. The last problem in Boone County was in 2008, when an SD1 construction crew ruptured the line in the creek near Camp Ernst Road, resulting in a spill of 115,000 gallons. An early 2014 leak of 10,000 gallons in Colerain Township, Hamilton County, Ohio, reinforces the potential threat posed by the Mid-Valley Pipeline.

2.6 Demographics and Social Issues

From its establishment in 1799 until the mid-1950s, Boone County's population rarely rose above 15,000 (see **Figure 2-9**). From 1960 to 2010, the population increased from 21,940 to 118,811 people (BCPC 2010). The decade from 2000 to 2010 saw the most rapid increase in Boone County's history (32,830 people in 10 years). That 38.2% growth rate was one of the two fastest rates of growth in Kentucky. Much of this population growth occurred in the Gunpowder Creek watershed, especially in the eastern portions of the watershed around Florence and Union, and the Fowlers Fork and South Fork subwatersheds. Over the next 25 years, these areas are expected to experience continued population growth, with the growth spreading west into the Long Branch subwatershed and beyond. In contrast, population density in the western half of the county is not expected to grow substantially in coming years.

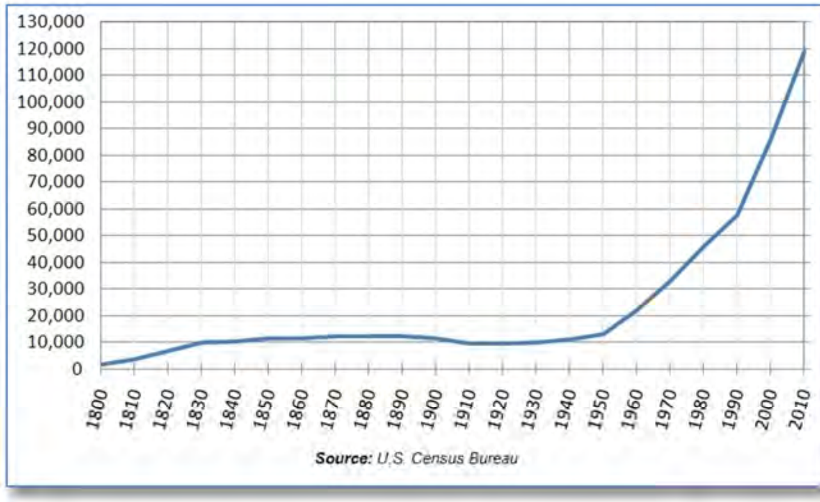

Figure 2-6: Boone County population: 1800 to 2010

The 2010 Boone County Comprehensive Plan further anticipates that in the next 25 years, Boone County will be defined by a decreasing proportion of young and middle aged persons, while the median age will continue to grow older. The percentage of Boone County's married couple households is anticipated to decrease and the county's population will continue to become more diverse in terms of race and ethnicity. At present, the county's level of educational attainment (%'s of both high school and college graduates) is higher than the state average, a trend that is also expected to continue. Boone County's population is predominantly white although the percentage of non-whites has risen from 1% in 1980 to 6.6% in 2010, roughly divided between Asian, African-Americans, and Hispanics (BCPC, 2010: 19). Regarding educational attainment, the percentage of high school graduates in Boone County was 90.5 in 2010, well above the statewide average of 81.9. The percentage of Boone Countians with at least a bachelor's degree (31.9%) was also higher than the Kentucky average of 20.5%.

In summary, Boone County's urbanized and suburbanized areas are expected to grow to the west over the next 25 years. Its population base is maturing and more affluent than that of neighboring counties and the state, trends which are also expected to continue (BCPC, 2010:22). These trends will lead to additional development of land and generation of vehicular traffic in the eastern Gunpowder Creek Watershed and its subwatersheds.

2.7 Team Observations

The Gunpowder Creek Watershed is rich in history as well as cultural and natural resources, including some of the best water resources in Boone County. The demographics and land uses have evolved during the last 50 years, and in particular the last 15 years, as population has increased and land has been rapidly converted from undeveloped to developed. These changes have brought many benefits to the county, such as increased property values; however, they have also resulted in impacts to the quality of our water resources. Sampling by KDOW has shown that several reaches of waterways are impaired and not meeting their designated uses.

It seems clear that if practices do not evolve to become more protective of water resources, Gunpowder Creek will continue to become further degraded as the rapid pace of development continues. This is one of the primary reasons why the GCWI is pursuing a watershed plan. We understood a need to collect more data to better pinpoint the sources of the water pollution. In doing so, we want to identify the most cost-effective ways to prevent future problems as the County continues to grow, as well as reverse the damages of the past. It is our hope that in so doing, Boone County can grow in a more sustainable way and provide high quality natural resources and quality of life to its citizens.

2.8 Interim Conclusions

Gunpowder Creek is impaired; however, there is reason for hope. Point source pollution, such as sewer overflows, may have been a big problem in the past but partners such as SD1 are investing large amounts of money to mitigate those pollutant sources. Impacts from stormwater runoff and nonpoint source pollution have also become more transparent as project partners such as SD1, KDOW, and Licking River Watershed Watch have conducted regional monitoring programs. As we better understand the magnitudes and sources of pollution we are confident that our expansive team of partner agencies, a well-informed and engaged public, and public officials embrace these findings and support the full implementation of this plan.

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CHAPTER 3

Learning More and Monitoring

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

December 2014

Chapter 3: Learning More and Monitoring

The two major goals of watershed planning are to protect good water quality and improve poor water quality, and therefore, a comprehensive monitoring program is necessary to understand the existing conditions of the stream network throughout the watershed. The monitoring program assists in determining the areas of the watershed to be protected and the areas of the watershed that are most impaired. Monitoring is also important because it provides data to better understand the pollutants of concern in the impaired regions of the watershed, which serves as the foundation to identify pollutant sources and develop implementation projects. The Gunpowder Creek Watershed Initiative (GCWI) monitoring program was designed to assess multiple measures of stream health using flow monitoring, hydrogeomorphic surveys, habitat assessments, water quality samples, macroinvertebrate assessments, and land use analysis. This is one of the many strengths of the dataset. In its breadth and depth, the GCWI Phase 1 and Phase 2 monitoring program includes quite a bit of data across several dimensions for a watershed plan. GCWI collected enough data in enough categories to build a weight of evidence towards the problems in the watershed and the scale of these problems. The data provides good information to understand the pollutants of concern in the watershed. The following section provides some detail regarding the GCWI Phase 1 and Phase 2 monitoring programs. Reference the 2011 Quality Assurance Project Plan for Gunpowder Creek Watershed Plan (QAPP, **Appendix 3-A**) for additional information regarding sampling parameters, methods, and frequencies.

3.1 Determining Monitoring Needs

While some water quality data already existed in the Gunpowder Watershed prior to the GCWI monitoring program, additional data were needed to fill in the gaps and provide more recent information regarding the condition of the Gunpowder stream network. The Sanitation District No. 1 of Northern Kentucky (SD1), a member agency of the GCWI steering committee, had conducted water quality monitoring at five sites in the Gunpowder Creek watershed since 2006 in order to establish a baseline condition. This SD1 data was collected using standard procedures and quality assurance measures that are consistent with those outlined in the QAPP. Given that hydromodification due to urban development is a major concern in the watershed, SD1 had also undertaken over three years of hydrogeomorphic monitoring at several sites in the watershed between 2008 and 2010.

While this existing data provided a good foundation for the monitoring program, additional data was needed to fill in the monitoring data gaps. Therefore, the GCWI monitoring program conducted water chemistry, habitat, and biological sampling (**Figure 3-1**) at six key sites in 2011 and 2012. In addition to SD1's ongoing hydrogeomorphic monitoring, GCWI surveyed four additional sites. **Table 3-1** summarizes the existing (pre-2010) and selected (2011-2012) monitoring sites. Reference **Figure 3-2** for a map illustrating the locations of these monitoring sites.

Table 3-1: Summary of existing and selected monitoring sites for Gunpowder Creek sampling

	Water Chemistry		Biological		Hydrogeomorphic	
Monitoring Sites[1]	Existing	Selected	Existing	Selected	Existing	Selected
GPC 4.6	SD1		SD1		SD1	
GPC 7.5		GCWI		GCWI		GCWI
GPC 14.7	SD1		SD1		SD1	
GPC 17.9	SD1		SD1		SD1	SD1
GPC 17.1-UNT 0.1		GCWI		GCWI	SD1	SD1
SFG 2.6	SD1		SD1		SD1	
SFG 5.3-DS	SD1				SD1	SD1
SFG 5.3-US			SD1		SD1	SD1
SFG 5.3-UNT 0.3		GCWI		GCWI	SD1	SD1
FWF 0.8		GCWI		GCWI		GCWI
LOB 0.5		GCWI		GCWI		GCWI
RDR 1.1		GCWI		GCWI		GCWI

[1]Monitoring sites were selected along the main stem of the Gunpowder Creek as well as targeted locations throughout the subwatersheds. The naming convention of each monitoring site is based on its location. The first three letters represent the stream and the numbers indicate the actual location on the stream (i.e., the number of stream miles upstream of the mouth). Therefore, site GPC 4.6 is located on Gunpowder Creek about 4.6 stream miles upstream of the confluence with the Ohio River. Similarly, site FWF 0.8 is on the Fowlers Fork and is located approximately 0.8 stream miles upstream of the confluence with the Gunpowder Creek main stem. (GPC – Gunpowder Creek, SFG – South Fork Gunpowder, FWF – Fowlers Fork, LOB – Long Branch, and RDR – Riddles Run).

3.2 Obtaining Additional Data Through Monitoring

Proper selection of monitoring locations is important because analysis of these monitoring data provide a better understanding of the issues facing each subwatershed and assist in identifying appropriate management strategies to mitigate nonpoint source pollution in specific subwatersheds. Although SD1's existing data gave an overview of the health of the watershed, per the Guidebook and in consultation with KDOW, the GCWI filled in the data gaps by selecting monitoring locations at the mouth of all major subwatersheds. We located our sampling sites by beginning at the mouth of the Gunpowder Creek, and systematically progressed upstream, with samples being collected just below the mouths of significant tributaries, as well as near the mouth of major subwatersheds, upstream of the confluence with Gunpowder Creek (Table 3-1, Figure 3-2). Analysis of these data served as the basis to the water quality data analysis presented in Chapter 4. GCWI partnered with SD1, Thomas More College, and the LRWW to conduct the water quality monitoring in 2011 and 2012 at six sites strategically selected throughout the Gunpowder Creek Watershed. These monitoring sites include one site along the main stem (GPC 7.5 at Camp Michaels), one in the headwater tributaries of the main stem (GPC 17.1-UNT 0.1 at Oakbrook Park), one in the headwaters of the South Fork Gunpowder Creek (SFG 5.3-UNT 0.3 at Sunnybrook) and one in each of the large tributaries south of the

Figure 3-1- Conducting biological sampling in Gunpowder Creek main stem, Riddles Run, Long Branch, and Fowlers Fork (RDR 1.1, LOB 0.5, and FWF 0.8, respectively). Additionally, as part of SD1's hydromodification monitoring program, four rounds of hydrogeomorphic survey data, which were collected between 2008 and 2012, were provided for five of its hydrogeomorphic monitoring sites (SFG 5.3-DS, SFG 5.3-US, SFG 5.3-UNT 0.3, GPC 17.9 and GPC 17.1-UNT 0.1). This SD1 hydrogeomorphic data was supplemented with hydrogeomorphic survey data collected in 2011 and 2012 by the Boone County Conservation District (BCCD) at the remaining water quality monitoring sites (GPC 7.5, RDR 1.1, LOB 0.5, and FWF 0.8). Water quality sampling sites and sites with 2011 and 2012 hydrogeomorphic survey data are presented in **Figure 3-2**.

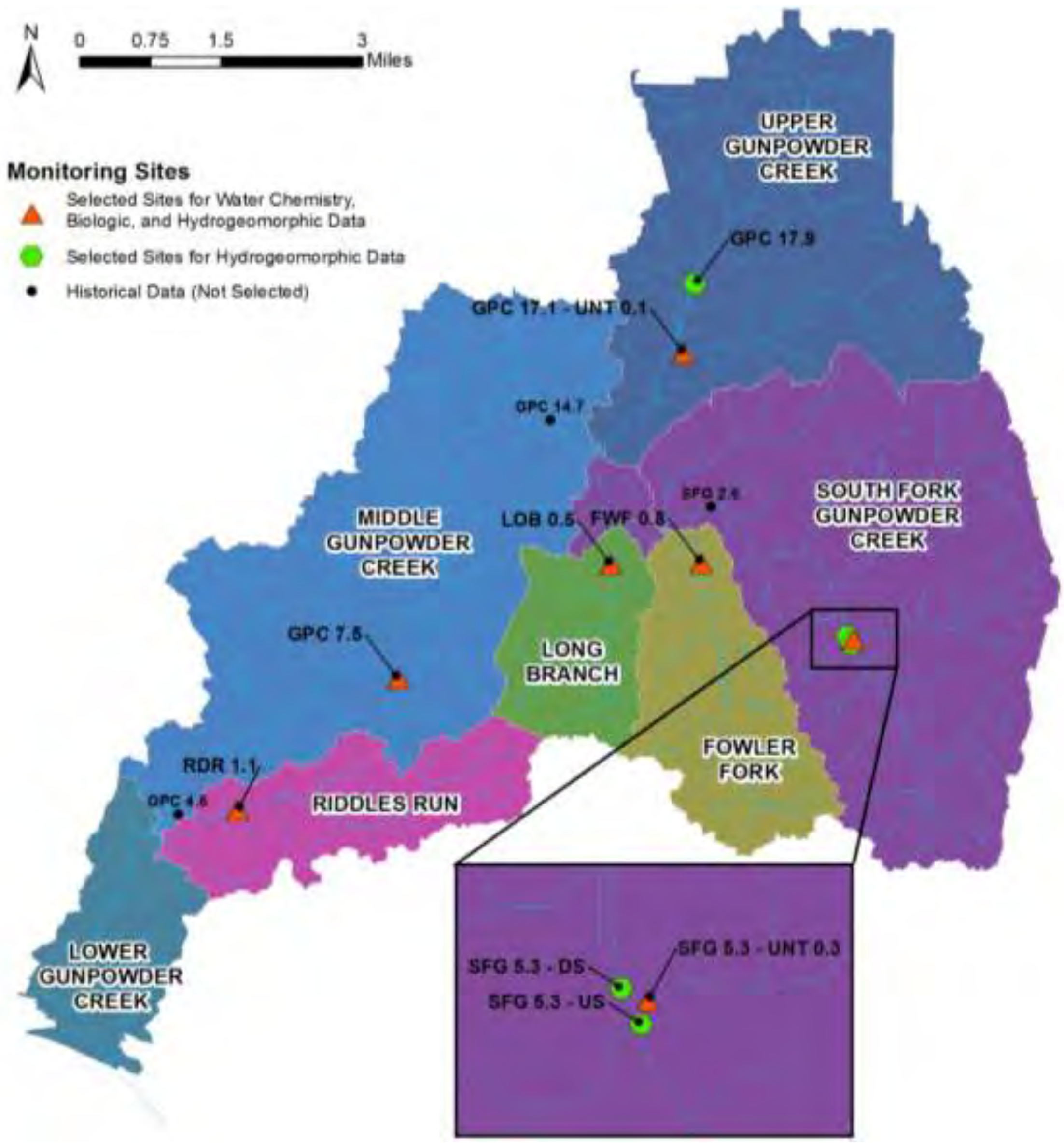

Figure 3-2: BCCD and SD1 Gunpowder Creek monitoring sites utilized in the water quality data analysis
Note: Sites GPC 4.6, GPC 7.5, GPC 14.7, and SFG 2.6 are historic SD1 water quality monitoring locations.

3.2.1 Monitoring and Data Analysis for the Gunpowder Creek Watershed

The GCWI deployed a phased monitoring model to the watershed. Phase 1 monitoring occurred during 2011 followed by Phase 2 monitoring at the same sampling locations in 2012. In accordance with the KDOW approved QAPP and project budget, GCWI did not add additional sampling locations for Phase 2 monitoring in 2012. The GCWI monitoring program and budget was developed prior to the release of the *Watershed Planning Guidebook for Kentucky Communities* (KDOW, 2010). Monitoring sites were strategically selected within each subwatershed to obtain a better understanding of the issues facing each subwatershed and assist in identifying appropriate management strategies to mitigate nonpoint source pollution. The monitoring program included water quality sampling, hydrogeomorphic surveys, habitat assessments, and biological assessments, and the following sections provide a brief summary of the GCWI monitoring efforts. As previously mentioned, please reference the 2011 Quality Assurance Project Plan for Gunpowder Creek Watershed Plan (QAPP) for additional information regarding sampling parameters, methods, and frequencies.

Water Quality

Water chemistry sampling included both dry and wet-weather sampling during the recreational contact season and was performed by students under the supervision of Dr. Chris Lorentz of Thomas More College, with field management by Mark Jacobs of BCCD. They followed procedures outlined in the QAPP and their sampling frequencies and parameters were guided by the grant budget. Monitoring data included several field measurements taken at the site as well as several parameters measured in the laboratory (**Table 3-2**).

Table 3-2 – Water quality monitoring data measured in the field versus the laboratory

Field Measurements	Parameters Measured in the Laboratory
Temperature	Bacteria (*E.coli*)
pH	Sediment (Total Suspended Solids (TSS))
Dissolved Oxygen	Nutrients (Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), Phosphate (P), Nitrate-Nitrite (NN), Ammonia as Nitrogen)
Specific Conductance	
Turbidity	
Stream Discharge	Carbonaceous Biochemical Oxygen Demand (CBOD)
Percent Saturation	

Physical Monitoring – Hydrogeomorphic Surveys

Hydrogeomorphic monitoring was designed to monitor channel instability (e.g. bank and bed erosion) in response to watershed urbanization (i.e. 'hydromodification'). The hydrogeomorphic component of the monitoring effort focused on measuring the physical changes in stream channels, as the altered flow regime associated with conventional urban development leads to flashier and larger flows, excessive stream erosion, and overall channel enlargement/instability that can cause water quality impairments (e.g. high TSS and sedimentation/siltation) and have adverse effects on aquatic biota such as fish and macroinvertebrates. Accelerated bank erosion, channel widening, and enlargement pose risks to adjacent public infrastructure (e.g., sewers, roads, and bridges) and private property mechanically damaging, undermining and elevating flood risks.

Beginning in 2011, BCCD and SD1 collected detailed hydrogeomorphic survey data according to the industry-standard methods outlined in the QAPP (including cross sections, profiles, and pebble counts) at four sites according to a standard operating procedure (SD1, 2009) based on industry standard techniques (Bunte and Abt, 2001a; Bunte and Abt, 2001b; Harrelson *et al.*, 1994; Potyondy and Bunte, 2002). Included as part of SD1's hydromodification monitoring program, SD1 has collected several years of hydrogeomorphic survey data at five additional sites for a total of nine unique hydrogeomorphic sites throughout the Gunpowder Creek Watershed. All nine sites have at least two rounds of hydrogeomorphic survey data, with each survey round separated by approximately one year. All survey data have been systematically processed and are presented in **Appendix 4-A**.

Physical Monitoring – Habitat Assessments

Monitoring also included habitat assessments during one sample event during Phase 1 monitoring in 2011 and then another during Phase 2 monitoring in 2012 according to standard KDOW methods as specified in the QAPP (e.g. Barbour *et al*., 1999; KDOW, 2001). The assessments focused on the quality of in-stream and riparian habitat and included habitat parameters such as epifaunal substrate/available cover, embeddedness, velocity/depth regime, sediment deposition, channel flow status, channel alteration, frequency of riffles or bends, left/right bank stability, left/right vegetative protection, riparian vegetative zones. All the parameters were then assessed to develop a total habitat score for the site's overall habitat condition, which provided a summary for the general habitat condition that is supporting or degrading the structure and function of the aquatic community in the stream. The qualitative habitat assessments served to complement the quantitative physical monitoring described above in Section 3.2.1.b by capturing important aspects of the channel habitat that the physical surveys did not, for example riparian vegetation condition, which can play an important role in bank stability.

Biological Assessments

Biological monitoring included benthic macroinvertebrate sampling and some fish sampling assessments during one sample event during Phase 1 monitoring in 2011 and then another during Phase 2 monitoring in 2012. A seasonal approach was utilized to capture the diversity of the biological community with priority placed on the spring sampling, as the majority of the streams sampled were "headwater" streams, for which the sampling index period is March 1 through May 31. The biological assessments were based on the EPA's Rapid Bioassessment Protocols for high gradient streams (Barbour *et al*., 1999), as adapted for Kentucky, and were collected and analyzed according to industry standard procedures as specified in the QAPP. Macroinvertebrate communities are very sensitive to changes in habitat and water quality; and therefore, benthic macroinvertebrate sampling is useful for detecting even small alterations to stream health. Benthic macroinvertebrate samples were sorted, identified, and quantified to determine standard metrics. Standard metrics measured include:

- Genus Taxa Richness
- Genus Ephemeroptera
- Modified HBI
- Modified %EPT abundance
- %Ephemeroptera
- %Chironomidae+%Oligochaeta
- %Primary Clingers

These metrics were all assessed to develop an average Macroinvertebrate Biotic Index (MBI) score for the overall site biological condition according to KDOW's regionally-specific index (Pond *et al*., 2003). The MBI is a simplified index that is based on a multi-metric approach to measure biotic integrity. Some important elements of the MBI include the abundance of macroinvertebrates present as well as the species richness, as measured by the number of distinct taxa found in the sample. The laboratory conducted a 300 pick macroinvertebrate sample at all sites, with the exception of LOB 0.5 (reference **Figure 3.2** for the location of LOB 0.5), which required a full pick due to a sample size of less than 300 organisms due to highly impaired habitat and water quality. This methodology was included in the QAPP and discussed with KDOW.

3.2.2 Phase 1 Monitoring

Scale

According to the *Watershed Planning Guidebook for Kentucky Communities* (KDOW, 2010), Phase 1 monitoring typically involves a broad scale across a watershed that measures approximately 50 mi^2. As discussed above, the GCWI monitoring program took a more detailed approach for Phase 1 monitoring because we already had data at the 50 mi^2 watershed scale. Therefore, Phase 1 monitoring occurred at the mouth of all subwatersheds, throughout the main branch, and on some unnamed tributaries of Gunpowder Creek. With the exception of GPC 7.5 (43.5 mi^2), all other monitoring locations were less than 10 mi^2. The drainage area to all other monitoring locations ranges from 2.2 to 6.9 mi^2, with an average drainage area of 4.2 mi^2. Sampling at the mouth of the subwatersheds was considered to be representative of the pollution sources within the subwatershed and no additional sampling sites were necessary.

Parameters

The GCWI monitoring program measured all required water quality parameters as well as hydrogeomorphic surveys, habitat assessments, and biological assessments. A summary of each of the monitoring efforts is included above in section 3.2.1. Reference the QAPP (**Appendix 3-A**) for detailed information regarding the monitoring procedures.

Methods

All water quality sampling methods were in accordance with the KDOW Standard Operating Procedures (SOPs). Habitat and biological assessments followed the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour *et al.*, 1999) and the biological assessments also followed the *Methods for Sampling Benthic Macroinvertebrate Communities in Wadeable Waters* (KDOW, 2009). Reference the QAPP for detailed information regarding the monitoring procedures.

Frequency

In accordance with the KDOW-approved QAPP, water quality monitoring data was conducted throughout the months of June through August. Water quality monitoring included 6 sampling events in 2011 as well as 2 additional *E.coli* samples. Although the *Watershed Planning Guidebook for Kentucky Communities* (KDOW, 2010), suggests collecting *E.coli*, nutrients, and TSS monthly for a 12 month period, GCWI preferred to focus its resources on the primary recreation season when pollutant loads could be most relevant to the general public and collect two years of data at the same sites. This turned out to be a valuable decision because the two years had varying rainfall – capturing a gradient of pollutant loads based on variant precipitation. Habitat, biological, and hydrogeomorphic assessments were performed once per year. Reference the QAPP for detailed information regarding the monitoring procedures.

3.2.3 Phase 2 Monitoring

As previously mentioned, GCWI did not add additional sampling locations for Phase 2 monitoring in 2012. This was within project budgets and in agreement with the KDOW-approved QAPP, which again, was developed before the *Watershed Planning Guidebook for Kentucky Communities* (KDOW, 2010) was released. With a set monitoring budget, GCWI did not have the additional funds and resources available to add more sites upstream of the Phase 1 sites. Therefore, the Phase 2 monitoring program involved resampling all Phase 1 monitoring locations. Sampling near the mouth of each subwatershed was considered to be representative of the pollution sources within the subwatershed and no additional sampling sites were necessary. Reference **Appendix 3-B** for all of the raw data collected as part of the Phase 2 monitoring program.

In comparing the 2011 Phase 1 monitoring results with the 2012 Phase 2 monitoring results, many water quality indicators drastically changed due to the substantial difference in rainfall that occurred during each monitoring effort. Samples collected during Phase 1 in 2011, a record rainfall year with over 70 inches of rain (NCDC, 2012), provided insight regarding the types of pollutants washed off the land during runoff events. In contrast, samples collected in 2012, a much drier year, indicated the types of pollutants released directly into the stream without the influence of rainfall.

Due to the nature of this phased monitoring program, the data analysis presented in Chapter 4 discusses Phase 1 and Phase 2 monitoring in an integrated fashion. All data is analyzed and presented in the Phase 1 monitoring section.

Scale

Phase 2 monitoring occurred at the same scale as Phase 1 monitoring because Phase 2 monitoring was performed at the same location as Phase 1 monitoring. Sampling occurred near the mouth of each subwatershed to provide insight on potential pollution sources. With the exception of GPC 7.5 (43.5 mi^2), all monitoring locations were less than 10 mi^2 and ranged 2.2 to 6.9 mi^2, with an average drainage area of 4.2 mi^2.

Parameters

The GCWI monitoring program measured all required water quality parameters as well as hydrogeomorphic surveys, habitat assessments, and biological assessments. A summary of each of the monitoring efforts is included above in section 3.2.1. Reference the QAPP for detailed information regarding the monitoring procedures.

Methods

All water quality sampling methods were in accordance with the KDOW Standard Operating Procedures (SOPs). Habitat and biological assessments followed the *Rapid Bioassessment Prototcols for Use in Streams and Wadeable Rivers* (Barbour *et al*., 1999) and the biological assessments also followed the

Methods for Sampling Benthic Macroinvertebrate Communities in Wadeable Waters (KDOW, 2009). Reference the QAPP for detailed information regarding the monitoring procedures.

Frequency

In accordance with the KDOW approved QAPP and within project budgets, water quality monitoring data was conducted throughout the months of June through August. With the exception of *E.coli,* water quality monitoring involved 5 sampling events in 2012, as KDOW approved for one sampling event in 2012 to be omitted considering there was too little flow in the streams to collect samples. Similar to Phase 1 sampling, the GCWI collected 2 additional *E.coli* samples in 2012. Although the *Watershed Planning Guidebook for Kentucky Communities* (KDOW, 2010), suggests collecting *E.coli*, nutrients, and TSS monthly for a 12 month period, GCWI preferred to focus its resources on the primary recreation season when pollutant loads could be most relevant to the general public and collect two years of data at the same sites. This turned out to be a valuable decision because the two years had varying rainfall – capturing a gradient of pollutant loads based on variant precipitation. Habitat, biological, and hydrogeomorphic assessments were performed once per year. Reference the QAPP for detailed information regarding the monitoring procedures.

3.2.4 Other Monitoring Options & Data Used in the Analysis

In addition to the aforementioned monitoring data, the water quality analysis utilized several sources of supporting information including land use data, rainfall data, flow gauge data, SD1's Stream Condition Indices, SD1's Stability Indices, and KDOW's Gunpowder Creek Watershed Monitoring Reports.

Land Use Data

As previously discussed in Chapter 2, the Boone County Planning Commission utilized its detailed Geographic Information System (GIS) database to analyze, collate, and summarize data on a watershed and subwatershed basis. Maps and landuse characterizations of each subwatershed are provided in **Appendix 3-C**. An example of the maps and land use characteristics for the Fowlers Fork subwatershed is included on the previous page (**Figure 3-3**). **Figure 3-4** on the next page presents a land use map for the watershed. Notice the large portions of commercial/developed land throughout the headwaters on the eastern side of the watershed and the predominantly agricultural/rural land on the western side of the watershed. Such land cover observations assist in explaining the types of pollutant issues in various portions of the watershed.

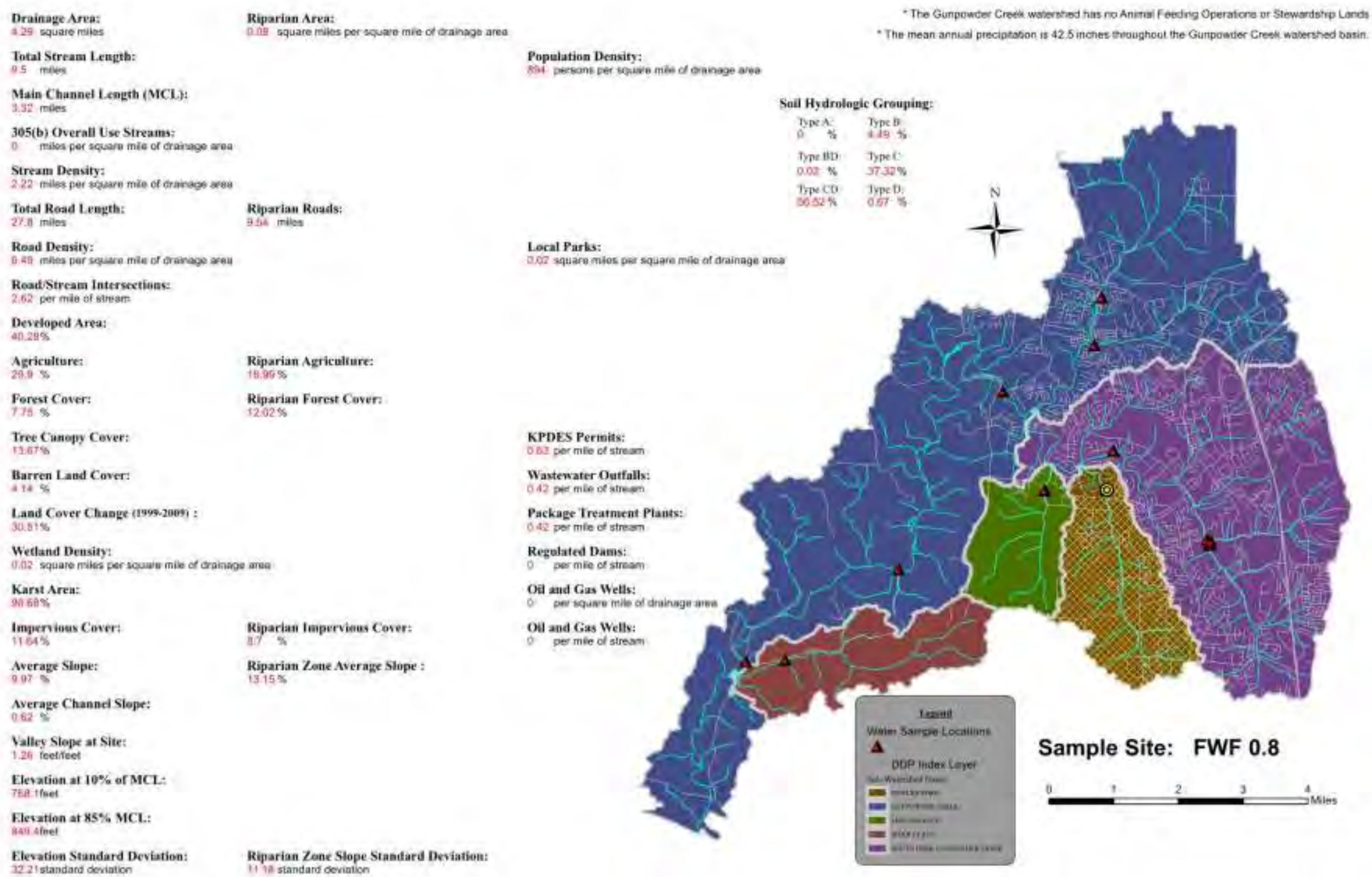

Figure 3-3- Watershed characteristics of the Fowlers Fork Subwatershed

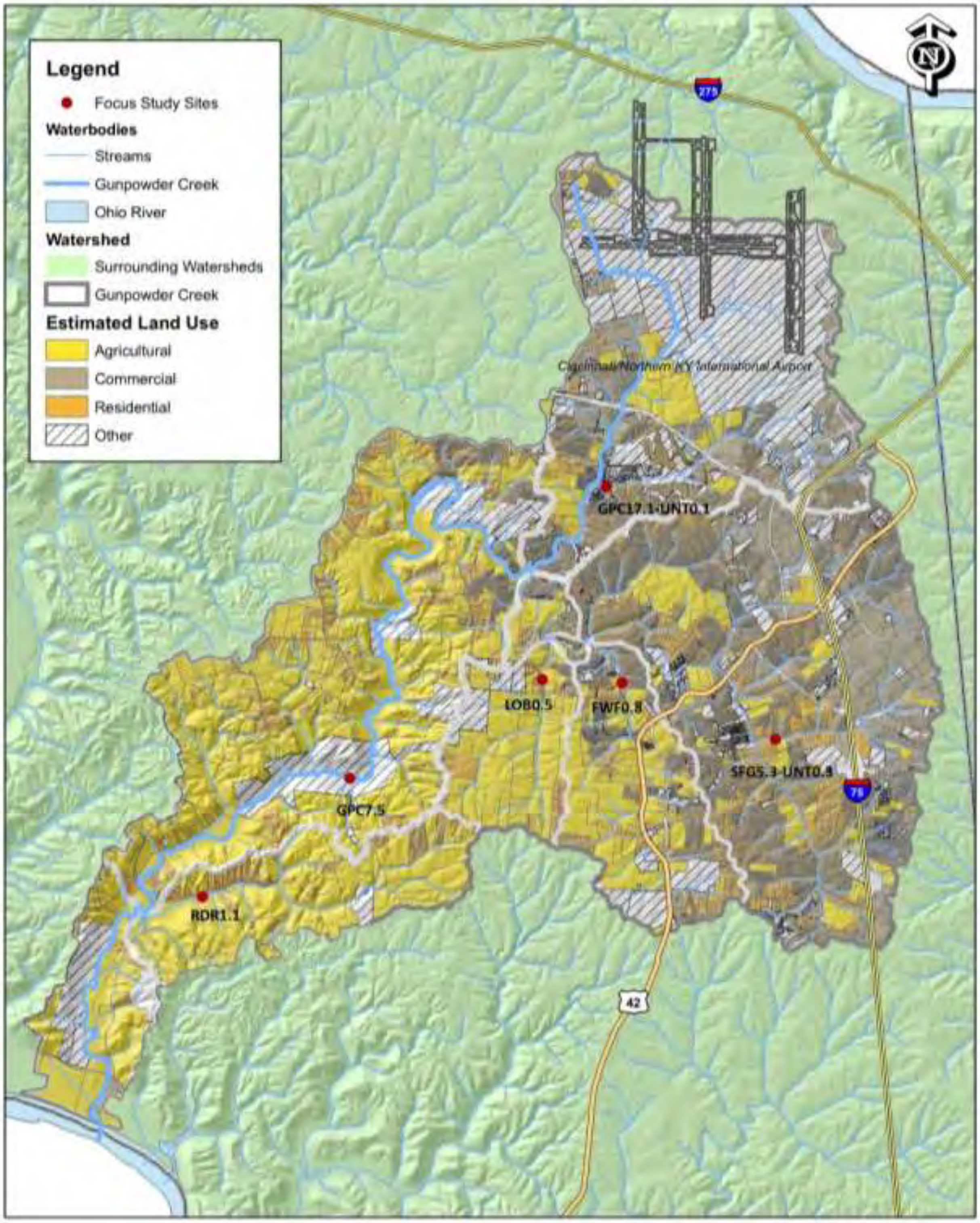

Figure 3-4 – Gunpowder Creek estimated land use (SD1)

Rainfall Data

In addition to land use data, rainfall plays a pertinent role in the hydrology of a watershed. Rainfall data collected at the Cincinnati/Northern Kentucky International Airport (CVG), which is located within the northeastern portion of the Gunpowder Creek Watershed, was analyzed to classify water quality sampling events as wet weather versus dry weather. The data analyzed was collected during the monitoring period. Daily rainfall totals within seven days prior to each sampling event were evaluated to determine sample classification. Of the 11 sampling dates, three events experienced over 0.7 inches of rainfall within 48 hours of the sample date and were classified as “wet.” The other eight sampling dates were relatively dry; however, three events were extremely dry with less than 0.01 inches of rain occurring within the 7-day period before the sampling event. Such events were classified as “dry7” for this analysis, with all other sampling classified as “dry.” Additional *E.coli* sampling (16 sampling dates total) included two more “dry7” sampling events and three more standard “dry” sampling events. All rainfall data summarized for this analysis is included in **Table 3-3**.

Table 3-3: Rainfall data summarized for each sample date

		TOTAL RAINFALL (in)			
Sample date	Wet vs Dry vs Dry7	On sample date	Day prior to sample date	Two days prior to sample date	Total 7 days prior to sample date
06/20/11	Wet	0.55	0.37	0.33	1.82
06/24/11	Wet	0.0001	0.36	0.56	2.75
07/05/11	Dry	0	0.06	0	0.11
07/07/11	Dry	0	0	0	0.06
07/13/11	Dry	0	0	0	1.17
07/29/11	Dry	0	0	0	0.04
08/04/11	Wet	0	0.73	0	1.66
08/18/11	Dry	0.0001	0	0	0.11
06/22/12	Dry	0	0	0	0.62
06/26/12	Dry7	0	0	0	0.00
06/28/12	Dry7	0	0	0	0.00
07/05/12	Dry	0	0	0	0.30
07/10/12	Dry7	0	0.0001	0.01	0.01
07/11/12	Dry7	0	0	0.0001	0.01
07/23/12	Dry	0	0	0	0.31
08/07/12	Dry7	0	0	0.01	0.01

Flow Monitoring

Flow data from U.S. Geological Survey (USGS) Gauge No. 03277075 for Gunpowder Creek at Camp Ernst Road near Union, Kentucky, was summarized to use in the water quality data analysis. Flow measurements were also taken during both the 2011 and 2012 water quality monitoring efforts according to procedures outlined in the QAPP. Each 2011 sampling event included documentation of velocities, depths, and reference distances from the shore. The flow was then calculated using the full discharge panel method after Rantz *et al*. (1982). This involves depth and velocity measurements at constant interval distances across the stream from a reference point on the shore. The constant interval determines a width of each panel measured. The flow for each panel is then calculated by multiplying the width times the depth and the velocity measurements and then all of the flow measurements are summed to obtain a flow reading for that site.

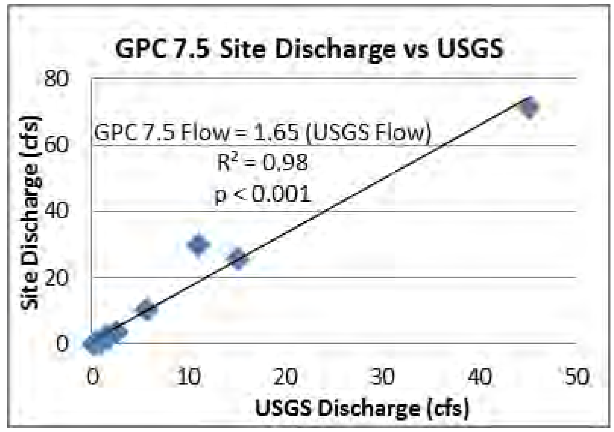

Figure 3-5-Example site discharge vs. USGS discharge regression Line

Given the extremely dry conditions of 2012, flow monitoring was challenging due to limited flow depths in the streams during sampling events, with some sampling events having no measurable flow, some having too low of water depths to obtain a velocity reading, and others having enough depth to obtain only one velocity and one depth reading at the deepest portion of the stream but not enough water to take measurements for the full discharge panel method. For the sampling events with only one velocity and one depth measurement, stream discharge was estimated by assuming a panel width of 0.3 feet, a width determined with measurements taken at GPC 7.5. On 8/7/2012, a "Dry7" sample date, the GCWI completed flow monitoring using the full discharge panel method at GPC 7.5 but also listed one depth and one velocity reading in the field data sheet. The data collected for the full panel discharge method provided an approximate flow and the GCWI used this flow as well as the depth and velocity reading to estimate an appropriate width for calculating the flow during dry conditions. The extremely dry conditions and limited flow data required the GCWI to generate regression equations to estimate the discharge at sampling events with no measurable flow, too low of water depths to obtain a velocity measurement, or a missed flow reading. The regression equations correlated the flow measurements at each site to the corresponding flow at the USGS gauge. Figure 3-5 presents an example of a regression equation developed to estimate site discharge at GPC 7.5. All site discharge versus USGS gauge relationships were significant ($p<0.001$) with R^2 values greater than 0.92.

Furthermore, the USGS gauge data was also used to develop a flow duration curve to be scaled to each monitoring site and serve as the basis for developing pollutant load duration curves. In order to develop a comprehensive curve with typical flow patterns, five years of gauge data (2007-2012) were utilized. Because of the required schedule of the analysis, data from water year 2012 had not been completely finalized by the USGS at the time of analysis and was still considered "provisional and subject to revision." However, this was not anticipated to adversely affect the analysis, because all data was checked for consistency and any 15-minute intervals without flow records were excluded from the 5 year dataset. The aforementioned regression equations were then used to properly scale the gauge flow duration curve to each monitoring site.

Additionally, water depth information from pressure transducer data loggers, installed by BCCD along three upper tributaries of similar size, was processed and analyzed to document trends across a gradient of urbanization – undeveloped, developing, and developed. The data loggers were installed near the following sampling sites: RDR 1.1 (2% impervious, 3.2 mi^2), FWF 0.8 (12% impervious, 4.3 mi^2), and GPC 17.1-UNT 0.1 (29% impervious, 3.8 mi^2). Depth information for the three sites was systematically processed and summarized, illustrating higher relative peak flows in the developed watershed when compared to the developing and undeveloped watersheds.

Sanitation District No. 1 of Northern Kentucky Stream Condition Indices

In addition to the habitat assessments and detailed water quality data collected by BCCD, the evaluation involved review of SD1's Stream Condition Indices (SCI), an evaluation and planning tool that serves as a means of compiling large amounts of data into a simple score to assess the overall health of a monitoring site. This includes complex biological, chemical, physical, and channel stability indices rated on a 0-10 scale, including an overall score that is a composite of the four individual indices. The primary purpose of the SCI score is to summarize the overall health of a monitoring site and present the information in terms easily understood to a non-technical audience. While environmental indices, such as the SCI, are frequently used to summarize complex monitoring data, the SD1 SCI is unique because it is calibrated to local conditions. The GCWI utilized this index as supporting information to illustrate that the outcomes of the data analysis were consistent with the SD1 SCI data.

The water quality component includes chemistry parameters such as bacteria (fecal coliform), dissolved oxygen, metals, nutrients, ammonia, pH, temperature, CBOD, conductivity, and turbidity. The physical habitat component utilizes the ten measures of habitat condition that are determined as part of the SD1 monitoring and assessment program, including epifaunal substrate/available cover, embeddedness, velocity/depth regime, sediment deposition, channel flow status, channel alteration, frequency of riffles (of bends), bank stability, bank vegetative protection, and riparian vegetative zone width. The biological component uses a combination of the Kentucky Index of Biological Integrity (KIBI) (fish communities) and the Kentucky macroinvertebrate Biotic Index (KMBI), utilizing the KMBI in headwater streams and both indices in wadeable streams with fish populations and larger drainage areas. Lastly, the channel stability component utilizes SD1's Stream Stability Index (Sustainable Streams, 2012). Reference the July 2013 SD1 technical memorandum titled *A Stream Condition Index for Water Utility Resource Management in Northern Kentucky* for additional information regarding each sub-index and determination of the associated scores (LimnoTech, 2013). The data collection and calculations for this index was completed around the timeframe of the watershed plan monitoring program.

Kentucky Division of Water Gunpowder Creek Watershed Health Reports

KDOW also evaluated the water quality, habitat, and biological health assessments collected by BCCD to generate Gunpowder Creek Watershed Health Reports for both the Phase 1 and Phase 2 monitoring efforts. Data was divided into indicators of water quality (dissolved oxygen, specific conductance, nutrients, total suspended solids, and *E.coli*) or indicators of biological health (total habitat, aquatic macroinvertebrates, riparian zone, and available cover). Indicators were graded A through F, by comparing them to KDOW water quality standards or benchmark data. The individual grades were averaged by KDOW to determine an overall biological health score and an overall water quality score for each subwatershed. KDOW then averaged these two scores to calculate a watershed health grade. While the purpose of these health reports is to present the results of the water quality data analysis, it is important to convey the results to both the general public as well as technical audiences. The KDOW grades summarize the overall health of the watershed in a means that is easier for the general public to understand. However, at KDOW's request, the Health Report Card Grades were not included in any of the analytical steps presented in Chapter 4 because these reports are for public informational purposes and not for analysis. The KDOW grades were only reviewed as supporting information to illustrate that although KDOW's and the GCWI's efforts to analyze the monitoring data were independent of each other, they both obtained the same conclusions.

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CHAPTER 4

Data Analysis

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

December 2014

Chapter 4: Analyzing Results

Nonpoint source runoff (i.e., stormwater) has been identified as the leading cause of impairment to stream water quality throughout the state of Kentucky. Boone County, in Northern Kentucky, is one of the most rapidly developing counties in the state, and its watersheds are currently experiencing the impacts associated with that development (i.e., streambank erosion/instability, excess sedimentation, degraded biological communities, loss of ecological function, etc.). Specifically, the Gunpowder Creek has been under increasing pressure as development continues to expand, and it has been classified on the 303(d) List of Impaired Waters for high levels of sediment, bacteria, and nutrients. Therefore, the GCWI monitoring program is important for understanding existing conditions, and analyzing the data collected in the program is an integral step for developing the Gunpowder Creek Watershed Plan. This chapter presents the results of two rounds of stream monitoring data and assessments, providing details regarding pollutants of concern, potential sources of pollutants, and various implications regarding the dominant causes of impairments.

This analysis is based upon an integrated approach to watershed planning through the stream function pyramid (**Figure 4-1**), where each component is dependent on the others, as a harmonious balance of all elements is necessary for healthy stream systems. Streams and rivers are among the most complex of physical systems with multiple interdependent components that impact the overall stream health. Streams are systems—their hydrology affects their stability, which in turn affects their water quality and biotic integrity. The stream function pyramid illustrates that how we live on the land (land use and management) affects hydrology (stream flow), as well as point and nonpoint pollutant loads. Both hydrology and pollutant loads impact the physical health of the stream, habitat/food availability, and overall water quality, which then creates impacts to and reactions within aquatic ecosystems (biological-eg, macroinvertebrate communities). The approach to this data analysis is unique in that rather than analyzing each component in isolation, we look at the system as it is—an interconnected network of dynamic parts. Quantitative analysis of the stream function pyramid components served as the foundation for identifying pollutants of concern, their potential sources, and possible solutions and best management practices (BMPs) that could be implemented to mitigate such pollutants.

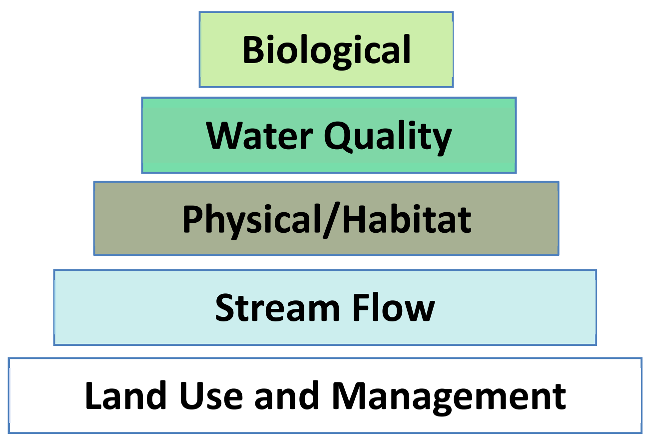


Figure 4-1: Stream Function Pyramid adapted from Center of Watershed Protection (2011)

4.1 Understanding the Goal of the Analysis

As explained, in *Chapter 3 – Learning More*, the GCWI monitoring program was designed to assess multiple measures of stream health using flow monitoring, geomorphic surveys, habitat assessments, water quality samples, macroinvertebrate assessments, and land use analysis. The overall results of both Phase I and Phase 2 monitoring are consistent with the preliminary assessment that was made during the Quality Assurance Project Plan (QAPP) development. Pollutants associated with hydromodification (e.g., TSS) seem to be the most concerning impairments, particularly in the heavily developed headwaters of the Gunpowder Creek Watershed (e.g., TSS loads ~30 to 60 times higher than benchmark levels).

> ***The monitoring program was designed to assess all aspects of stream integrity including biological, chemical, physical, stream flow, and land use.***

Indeed, the worst sites for macroinvertebrates were found along headwater tributaries to the main branch and South Fork Gunpowder Creek, which are the two most developed subwatersheds. The erosive urban flow regime has caused active bank erosion and flushed nearly all of the habitat-forming bed material at these sites, leaving featureless bedrock streams void of aquatic habitat or refugia (isolated refuges where species can survive in an otherwise broken ecosystem). The bank erosion and unstable bed material has resulted in high sediment loads throughout the Gunpowder Creek Watershed These apparent relationships observed in the Gunpowder Creek Watershed are consistent with the statistically-significant relationships from SD1's Hydromodification Monitoring Program, which includes of a robust dataset of 40 unique sites from Northern Kentucky . This dataset is separate from the GCWI monitoring program, but both illustrated similar outcomes – urbanization, as measured by impervious area, has been correlated to channel enlargement, bed coarsening, shorter riffles, and deeper, longer pools (Hawley *et al*., 2013a).

In comparing the 2011 Phase 1 monitoring results with the 2012 Phase 2 monitoring results, many water quality indicators drastically changed due to the substantial difference in rainfall that occurred during each monitoring effort. Samples collected during 2011, a record rainfall year with over 70 inches of rain (NCDC, 2012), provided insight regarding the types of pollutants washed off the land during runoff events. In contrast, samples collected in 2012, a much drier year, indicated the types of pollutants released directly into the stream without the influence of rainfall. Some examples of large differences in wet and dry monitoring (2011 versus 2012) in the Gunpowder Creek Watershed include high levels of bacteria strongly linked to wet weather (a relationship across all sites), whereas higher levels of specific conductivity and nutrients were linked to dry weather at a few monitoring locations, which could be indicative of possible direct sources in select areas such as livestock access or septic systems. Analysis of the monitoring data and how it relates to watershed conditions serves as the foundation for determining BMP implementation that will likely be the most feasible, efficient, and effective (Chapters 5 and 6).

4.2 Data Analysis Requirements for 319-Funded Watershed Plans

As previously explained in *Chapter 3 – Learning More*, the GCWI did not add extra monitoring sites during Phase 2 monitoring in 2012. This was in accordance with its KDOW-approved QAPP and the monitoring plan and budget that was proposed with the initial application. GCWI collected 6 months of data at each site for two years – Phase 1 was collected in 2011 and Phase 2 data was collected in 2012. Both Phase 1 and Phase 2 monitoring data was analyzed simultaneously and is presented in the following sections *4.2.1 Phase 1 and 2 Combined Data Analysis* and *4.2.2 Phase 1 and 2 Combined Prioritization.*

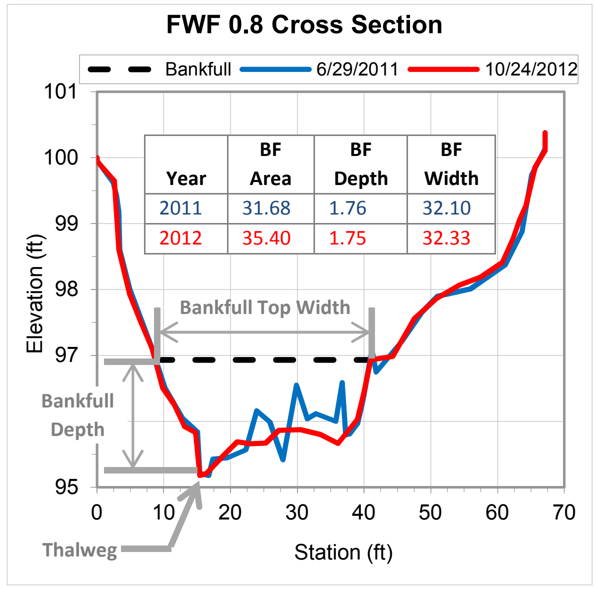
4.2.1 Phase 1 and 2 Combined Data Analysis

Methodology Used for Analysis

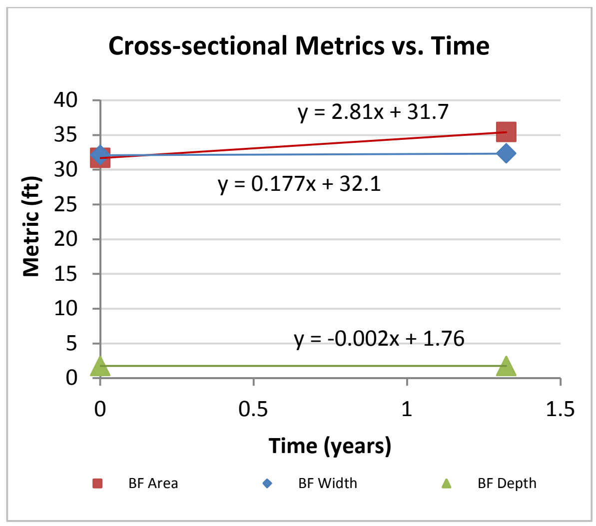
This section provides details regarding the methodology used to systematically process the Phase 1 and Phase 2 monitoring data.

Hydrogeomorphic Data

In processing the raw survey data, measurements were made on the cross section, profile, and bed material data to provide consistency across all sites. Cross-sectional measures of channel change included bankfull area, thalweg depths (i.e., depth to the lowest point of the cross section), and top width, all calculated with reference to the lowest top of bank from both survey years, defined as the point at which a defined bank breaks to an angle of less than ~15 degrees for a horizontal distance of at least three feet after the methodology used in the journal article, *Bed coarsening, riffle shortening, and channel enlargement in urbanizing watersheds* (Hawley *et al.*, 2013a). Reference the cross section (**Figure 4-2(a)**) for an illustration of these measurements. In addition, the degree of instability was classified using quantitative measures of changes in riffle length, pool length, pool depth, slope, and the pool/riffle ratio, as all profile surveys were broken into several pool-riffle reaches that were measured from the head of one riffle to the head of the next riffle upstream. Regarding bed material composition, key metrics, including the 16th, 50th, and 84th percentile particles (d16, d50, and d84), were determined and compared across each round of survey data. Rates of change over the 2011 and 2012 rounds of surveys at each site were completed using linear interpolation (a straight line between two points) of each important variable versus time between surveys. For example, at Site FWF 0.8, bankfull area increased from 31.68 to 35.40 ft^2 between surveys on June 29, 2011 and October 24, 2012, as shown in **Figure 4-2(a)**. The absolute change between surveys was an increase of 3.72 ft^2. Corresponding linear interpolation of cross sectional area versus time revealed an enlargement rate of 2.81 ft^2 per year, as shown in **Figure 4-2(b)**. Rates of measured change of key metrics at each site using linear interpolation are presented in **Appendix 4-A**.



(a) Repeated Cross Section Surveys



(b) Rates of Change Over Time

Figure 4-2: Measured Change in Cross-sectional Form and Linear Interpolation at FWF0.8

In addition to measured rates of change of the summary metrics discussed (e.g. bankfull cross sectional area, profile riffle length, d50 of the bed material, etc.), the weighted deviation between the elevation of each 2011 data point and the 2012 elevation at the same station was calculated based on the methodology used by Baker *et al.* (2012) and Hawley, *et al.* (In prep). Cross section weighted deviation measured change in the ground surface of the active channel bed; profile weighted deviation measured change along the channel thalweg; and bed material weighted deviation measured the change between the bed material gradations of the pebble count on a logarithmic scale. These measurements confirmed the unstable nature of the stream systems throughout the Gunpowder Watershed.

Lastly, SD1's Stream Stability Index (Sustainable Streams, 2012), a physically-based evaluation tool developed to incorporate the multidimensional effects of hydromodification on stream channels, was calculated for each site. This index is computed using cross-sectional shape, bedrock prevalence, left bank stability, right bank stability, pool depth, embeddedness, and riffle frequency. It presents an overall determination of the degree of stability for each monitoring location. This Stream Stability Index was not used as an integral part of the data analysis, but instead, it was incorporated as additional information to support the findings of the data analysis.

Water Quality Data

All water chemistry data was processed to evaluate variations in pollutant concentrations and understand what might be causing such variations. The analysis included an evaluation of relationships with rainfall (wet and dry weather events) and stream discharge data to examine changes in the pollutants of concern related to precipitation-driven changes and the associated changes in stream flow. As previously mentioned in Chapter 3, each sampling date was classified as wet, dry, or dry7 depending on the amount of recorded rainfall on the days preceding the sample. Sample concentrations, summarized by water quality parameter, sampling site, and type of sample (wet versus dry and dry7), were then plotted on standard box and whisker plots with the statistical software R (R Core Team, 2012). The box and whisker plots, presented in **Appendix 4-B**, provide a visual observation of the range of sample concentrations, the mean concentration for each parameter evaluated (excluding statistical outliers), and the overall relation to the water quality benchmark or standard set for that parameter. This graphical representation of sample concentrations provided additional detail regarding pollutants of concern during wet versus dry weather conditions.

In addition to the water quality box and whisker plots, the analysis included flow duration curves that served as the foundation for developing pollutant load duration curves for several pollutants of concern at all water chemistry monitoring sites. Such pollutant load duration curves were used to analyze the relationship between exceedances in water quality benchmarks and flow conditions (e.g. high flow vs. low flow conditions, wet weather vs. dry weather conditions), as well as estimate overall pollutant loads and yields. Instantaneous unit rates of pollutant loads were calculated by multiplying the volumetric flow rate of water at the time of the sample by the measured pollutant concentration (e.g. 10 liters per second x 5 mg per liter = 50 mg per second). The instantaneous pollutant load was calculated by multiplying how long that flow lasted in the sample year by the unit pollutant load (e.g. 1,000 seconds x 50 mg per second = 50,000 mg). The annual load was then the sum of all of the instantaneous pollutant loads from all of the flows that were recorded in a given year. The duration curve, which shows how long a given flow occurred in a given year, is called a flow duration curve. Each site had its own flow duration curve scaled from the USGS gage based on linear regression relationships that were discussed in Section 3.2.4 (e.g., **Figure 3-4**).

Because the resources do not exist to constantly measure pollutant concentrations at every sample location for 24 hours a day, 365 days per year, load duration methodologies typically use an averaging step. In this data analysis, samples were divided into bins, or groups of high flows, medium flows, and low flows. The bins were divided at the 35^{th} and 80^{th} percentile flows to facilitate quasi-equally spaced bins with the goal of having at least a couple of samples in each bin and no bins with zero samples. All concentrations within a given bin were then averaged to calculate the mean concentration for the bin. In the case of *E.coli*, the geometric mean was used for each bin, as is customary. The average instantaneous load for each flow in the bin is calculated by multiplying the average bin concentration by the average volumetric flow rate in the bin. Multiplying the average instantaneous load by the duration of time that occurs in the bin computes the projected load for the given bin. Doing that for all three bins and adding them up provides the annual projected load for a given pollutant at a given site.

Doing the same procedure but using the water quality benchmark concentrations provided by KDOW computes an annual benchmark load for a given pollutant at a given site. Comparing the projected loads to the benchmark loads provides a sense of whether a watershed could have too much of a pollutant of concern or whether the loads are more similar to reference/benchmark conditions and not concerning for water quality. All load duration curve figures, associated annual pollutant loads, and approximate percent load reductions necessary to meet the water quality benchmark are included in **Appendix 4-C**. In addition to pollutant loads, yields were also calculated in order to standardize the data by accounting for differences in geographic size between the subwatersheds. The pollutant yield was determined by dividing each load by the total area of the subwatershed (e.g. 20,000 pounds divided by 1,000 acres = 20 pounds per acre). The pollutant load methodology and step by step calculations are included in **Appendix 4-D**.

Statistical Relationships & Data Analysis

Statistical analysis, using the R program (R Development Core Team, 2012), was used to evaluate the strength of various relationships between water quality monitoring data and watershed characteristics such as land use data. Because hydromodification is a known water quality concern in Gunpowder Creek and can be a source of impairments such as high TSS, this analysis also incorporated the results of the hydromodification monitoring in order to identify statistically-significant relationships between every aspect of the stream function pyramid. This included correlations among and between land use, flow, water quality, habitat, and macroinvertebrate communities. The analysis assisted in identifying a greater understanding of the potential sources of all impairments as opposed to a simpler approach focusing on just one or two water quality impairments. In this light, BMPs with greater cost effectiveness for all impairments could be identified and prioritized accordingly. The strength of the correlations was assessed by the R^2 and adjusted R^2 values, and statistical significance was assessed using the *p* value. R^2 is a measure of how well a regression equation describes the actual data points. This value ranges from 0 to 1, with a value of 1 indicating that the regression equation perfectly describes the data. For example, an R-squared valued of 0.90 indicates there is a 90% chance that the variance in the dependent variable is explained by the independent variable. Adjusted R^2 values are typically less than the R^2 value and attempt to explain the proportion of variance in the data by also accounting for the number of data points as well as additional variables added to the statistical model. It considers original variance as well as residual variance. *p* values represent the probability that a correlation is due to chance and chance alone. For example, a *p* value of 0.10 would imply that there is a 10% chance that a relationship is simply a random occurrence. Any *p values* less than a threshold of 0.05 (i.e. 5%) were considered to be statistically significant. Please note that the statistical relationships presented throughout this chapter are based on a limited amount of data collected during 2011 and 2012, and while some relationships are statistically significant, this does not prove that the relationships are real. However, it does imply that there is likely a relationship between the variables tested. The fact that many of the relationships presented are physically based (i.e., cause and effect relationships that could be reproduced in a controlled laboratory setting) and consistent with previously published literature adds to a weight of evidence that the relationships are real and not attributable simply to chance or random occurrence.

Phase 1 and 2 Combined Monitoring Results

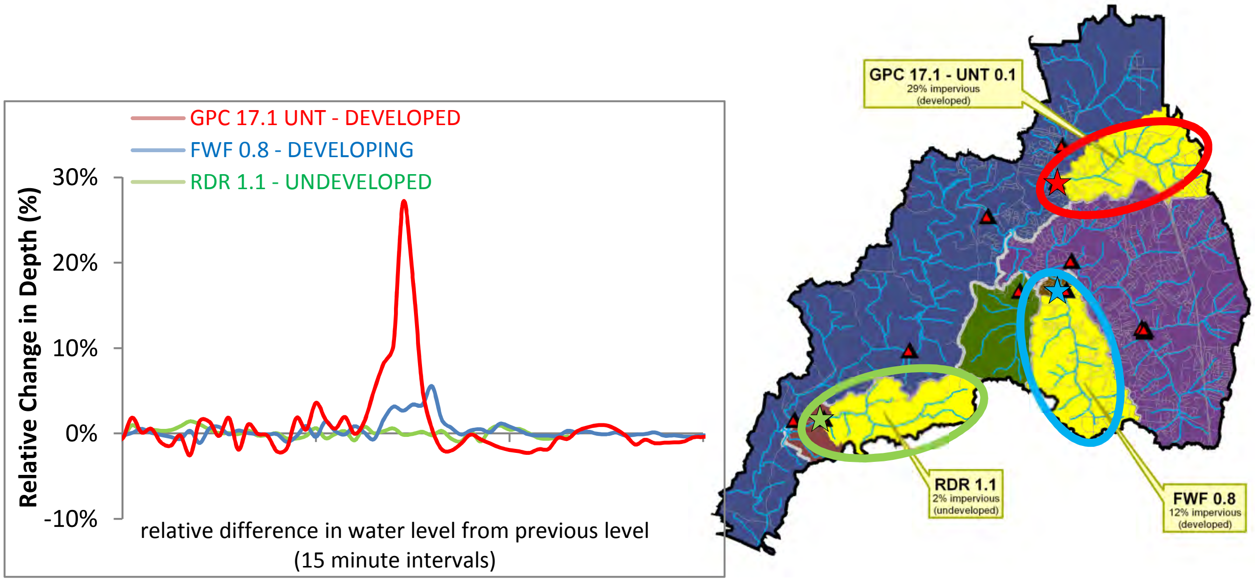
The following sections present the results from the monitoring data collected in both Phase 1 and Phase 2. The analysis is centered on the elements of the Stream Function Pyramid presented in section *4.1 Understanding the Goal of the Analysis.*

Stream Flow

The urban flow regime associated with increased development and unmitigated impervious area has greatly impacted Northern Kentucky streams (Hawley *et al.*, 2013a). **Figure 4-3** presents an example of a Northern Kentucky stream, Pleasant Run (~100 acre basin), that experiences erosive flows even on relatively small storm events (photo illustrates 11/16/10 rainfall event: magnitude: 0.45 inches; duration: 2 hours; < 2 month storm (2 hour/2 month = 0.81”). This example illustrates that very fast, erosive flows occur during many storms. Comparison of data logger information from three sites within the Gunpowder Creek Watershed of similar drainage area but varying levels of development, **Figure 4-4(b)**, illustrated that the altered flow regime associated with conventional urban development leads to flashier and larger flows. This is evidenced by the comparison of the measured flows at all three data logger locations, **Figure 4-4(a)**, which shows that the most developed site experienced much higher changes in water levels during the same rain event. The flashier and larger flows associated with unmanaged urban development lead to excessive stream erosion, overall channel enlargement/instability that can cause water quality impairments (e.g., high TSS and sedimentation/ siltation), and adverse effects on aquatic biota such as fish and macroinvertebrates.

Figure 4-3: Erosive flows during 0.45 inch storm

Stormwater runoff in the developed headwaters makes stream flow rise and fall very rapidly and can cause flooding and streambank erosion.



(a) Percent Relative Change in Water Depth Over Time [(a)] ***(b) Data Logger Locations***

Figure 4-4: Water levels rise and fall more rapidly in developed watersheds

[(a)] GPC 17.1-UNT 0.1 has been shortened to GPC 17.1 UNT in the graph above.

Physical – Hydrogeomorphic Data

Analyses of physical data indicate that streams in urban/suburban watersheds tend to be getting larger. An in-depth study of Northern Kentucky streams has demonstrated their overall shape is deepening and widening, their riffles are shrinking, their pools tend to be getting both longer and deeper, and watersheds in early stages of development (i.e., less than 15% total impervious area) were correlated with bed material coarsening as finer bed material is stripped away and moved downstream (Hawley *et al.,* 2013a). Unstable streams degrade water quality, aquatic habitat, and ultimately biological activity. Additionally, the unstable nature of many streams throughout Northern Kentucky has destroyed public and private infrastructure and adjacent property (Hawley *et al*., 2013b; **Figure 4-5**). Stability and habitat quality tend to decrease in developed watersheds and increased impervious area has been strongly correlated to channel enlargement, bed coarsening, shorter riffles, longer and deeper pools, and stream instability in Northern Kentucky streams (Hawley *et al.,* 2013a). In general, the - processed hydrogeomorphic survey data throughout Gunpowder Creek illustrated similar relationships to other Northern Kentucky streams; however, the relationships were not as significant, perhaps due to the presence of vertical grade control (bedrock) at many of the sites. In relation to percent impervious surfaces, both bankfull area and bankfull top width linear regressions were the most clear. The average annual change in bankfull area and bankfull top width

Figure 4-5: Streams widen and destroy public infrastructure

Erosive flows can degrade habitat, cause bank erosion, and create high sediment loads.

appears to have a positive relationship to percent impervious, but were not statistically significant with *p* values of 0.23 and 0.13, respectively.

Overall physica/habitat relationships illustrate concerns with channel enlargement and habitat.

When evaluating cross-sectional enlargement (annual increase in bankfull area per year) against land use, some examples of GIS parameters that illustrated significant ($p < 0.05$) relationships include percent barren land (**Figure 4-6**) and percent riparian roads (**Figure 4-7**). In a watershed comprised of predominantly clay soils (93.5% Hydrologic Soil Group Types C and D), barren land cover can behave similarly to impervious land area because it lacks the vegetation to slow down and transpire stormwater runoff. Additionally, the presence of roadways within the riparian corridor was strongly correlated to channel enlargement, indicating that the presence of riparian roads seemed to explain a greater portion of channel enlargement than watershed imperviousness. Roads often route their stormwater directly, and efficiently, to streams, whereas large developments tend to include some level of stormwater detention. Therefore, the case can be made that roadway imperviousness causes more hydrological effects than other types of impervious area. Riparian roads may also be indicative of potential channelization that may have occurred to create more optimal roadway alignments. Channelization is widely documented to increase the erosive energy of streams, which also makes them more prone to channel erosion and enlargement.

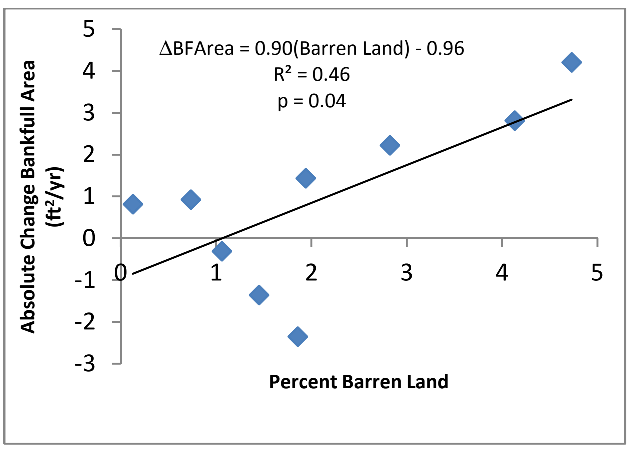


Figure 4-6: Channel enlargement is positively correlated to percent barren land

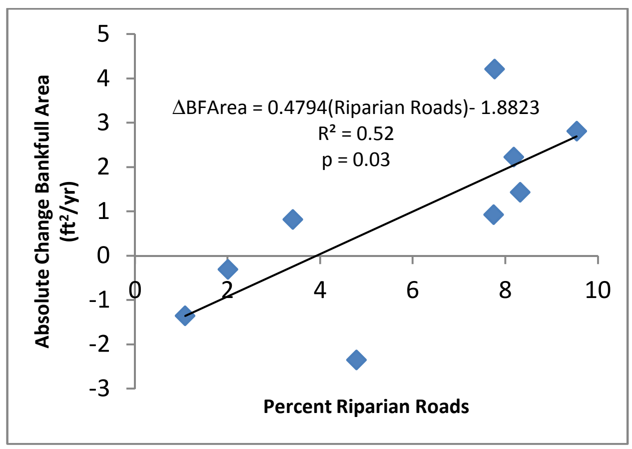


Figure 4-7: Channel enlargement is positively correlated to percent riparian roads

In addition to land cover metrics, linear regression relationships relating enlargement and water quality were evaluated. Across both high and low flows, TSS was positively associated with channel enlargement and widening. Specifically, the correlation between mean TSS concentration at low flow and channel widening was nearly statistically significant ($p = 0.05$), and the correlation with the mean high flow concentration was highly significant ($p = 0.003$) when withholding site GPC 17.1-UNT 0.1 (**Figure 4-8**), which was a physically-based outlier due to the fact that bank erosion from previous years have caused an over-widened channel with a mid-channel tree, which led to a log jam that temporarily induced deposition during the survey period (*i.e.*, see **Figure 4-15**). These finding are supported by other researchers that have documented channel erosion, enlargement, and bank failure as the dominant source of suspended sediment in many streams (Trimble, 1997; Simon and Klimetz, 2008; Wilson et al., 2007).

Further analyses illustrate that degraded habitat is also correlated to channel instability. For example, the Habitat Score (KDOW, 2008) was negatively correlated to both the change in bankfull area per year and the change in bankfull top width per year, with significant *p* values of 0.05 and 0.02 (**Figure 4-9**), respectively.

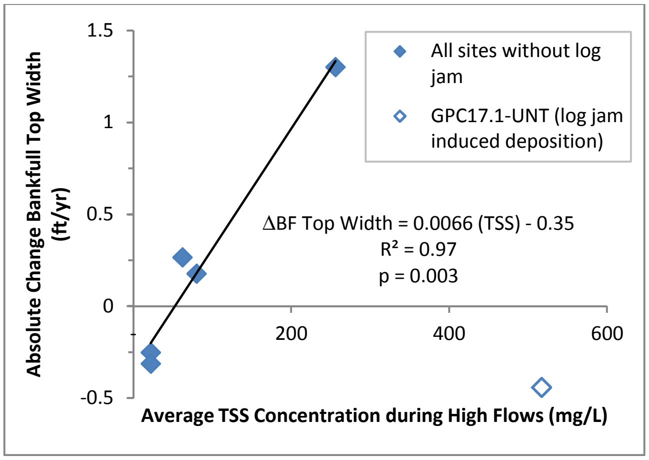


Figure 4-8: Channel widening is positively correlated to TSS

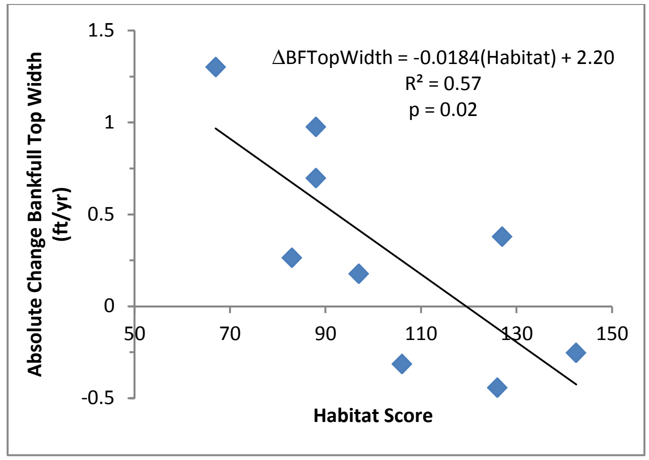


Figure 4-9: Channel enlargement is negatively correlated to habitat score

Hydromodification Monitoring Sites Case Studies

Hydromodification monitoring at sites throughout Gunpowder Creek document the physical changes that have occurred through both quantitative data captured by hydrogeomorphic surveys and observations of visual changes documented in annual photographs. Of the nine hydromodification monitoring sites assessed for this analysis, three case studies present representative examples of the problems throughout much of the Gunpowder Creek Watershed. These three locations are described below, with locations illustrated in **Figure 4-10**.

1. South Fork Gunpowder Creek (SFG 5.3-DS, 28% impervious): An extremely dynamic site that experienced bank failure and bed incision;
2. Unnamed Tributary of South Fork Gunpowder Creek (SFG 5.3-UNT 0.3, 41% impervious): A site with relatively shallow bedrock and a well-connected floodplain experiencing geotechnical mass wasting and bank widening , and;
3. Unnamed Tributary of Gunpowder Creek (GPC 17.1-UNT 0.1, 29% impervious): A site with erosive flows that transported large amounts of woody debris.

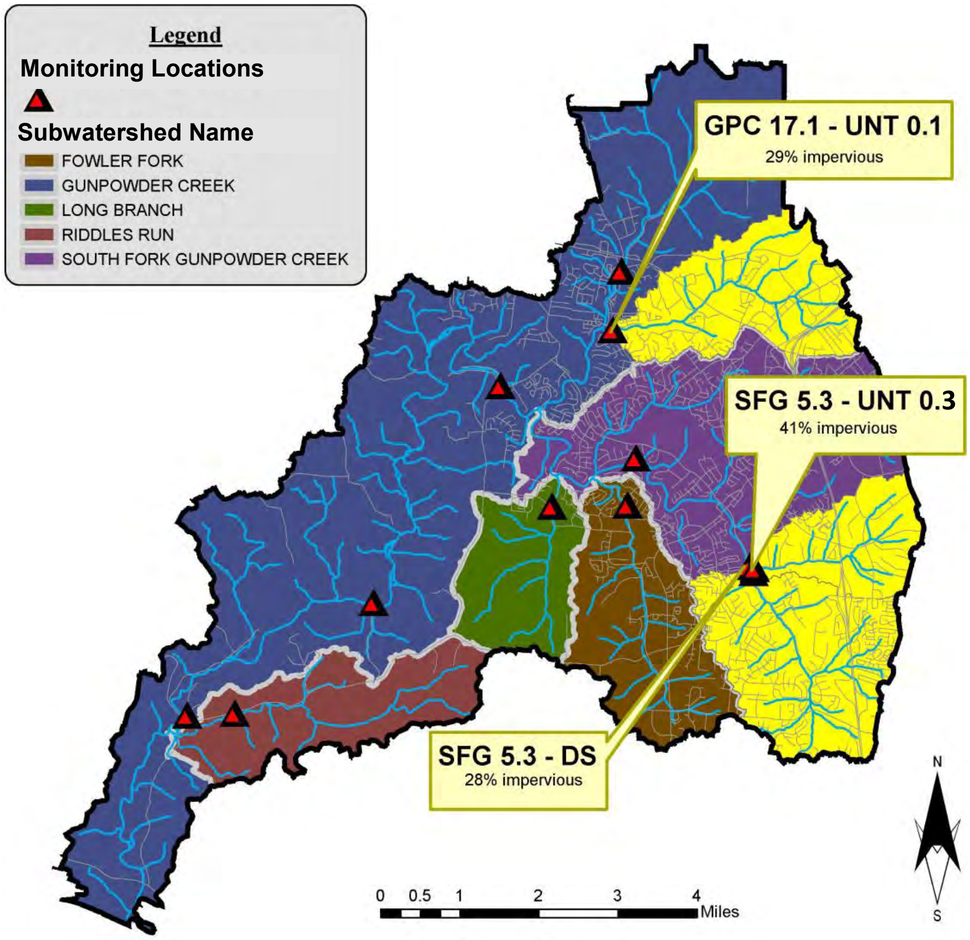


Figure 4-10: Physical/habitat case studies throughout the Gunpowder Creek Watershed

Case Study 1: South Fork Gunpowder Creek (SFG 5.3-DS)

Stream channel dynamics exhibit bank failure, tree loss, and bedrock incision.

The South Fork Gunpowder Creek is located in the southeastern portion of the watershed and includes three monitoring sites within close proximity to each other, all approximately 5.3 miles upstream of the confluence with the Gunpowder Creek main stem. While the monitoring data at all three of these survey sites has illustrated that the sites are all extremely dynamic, the downstream site (SFG5.3-DS) was the most dynamic, with lost trees, bedrock incision, and compromised storm sewer infrastructure. This site has an upstream drainage area of 6.91 square miles, and the watershed is fairly developed with approximately 29% impervious area.

Over the four rounds of surveys conducted by SD1 as part of its hydromodification monitoring program, collected between 2008 and 2012, both physical observations and quantitative data supports that the channel is enlarging, the longitudinal slope is responding to headcut migration (becoming flatter), bedrock is being fractured and mobilized, and the bed material gradation is coarsening. Storm sewer infrastructure at the site has been compromised by the eroding bank, causing a pipe outfall to become dislodged from its concrete headwall (**Figure 4-11**).

The following list presents a summary of key metrics and the corresponding percent change over this time period (2008 to 2012).

1. Bankfull area increased by 5%; benchfull area increased by 18% (Bankfull is defined in **Figure 4-2(a)**).

2. Profile slope decreased by 60%.

3. Bed material gradation became substantially coarser (d16 increasing by 467%; d50 increasing by 1760%, and d84 increasing by 278%).

Additional details regarding the changes in cross-sectional, profile, and bed material gradation can be found in **Appendix 4-A**.

Figure 4-11: Storm sewer infrastructure at Site SFG 5.3-DS compromised by erosive, urban flow regime

The erosive flow regime has caused the banks to erode, particularly the left bank, which has expanded more than three feet between 2008 and 2012, resulting in the loss of two trees (**Figure 4-12**-red). If this erosive flow regime is left unmitigated, the banks along this reach may continue to fail, impacting costly infrastructure and continuing to degrade stream habitat and water quality. Similar to most unstable Northern Kentucky streams, the South Fork Gunpowder Creek is responding to the erosive urban flow regime through headcut migrations along the longitudinal profile. The 60% decrease in slope over the four rounds of surveys can be attributed to the presence of this headcut migration (**Figure 4-12**-yellow). This type of channel response is seen as a primary cause of longitudinal slope adjustment and tends to change the nature of the stream with a decrease in riffle lengths and increase in pool lengths, which has been documented at this site and numerous other study sites across Northern Kentucky (Hawley *et al*., 2013a).

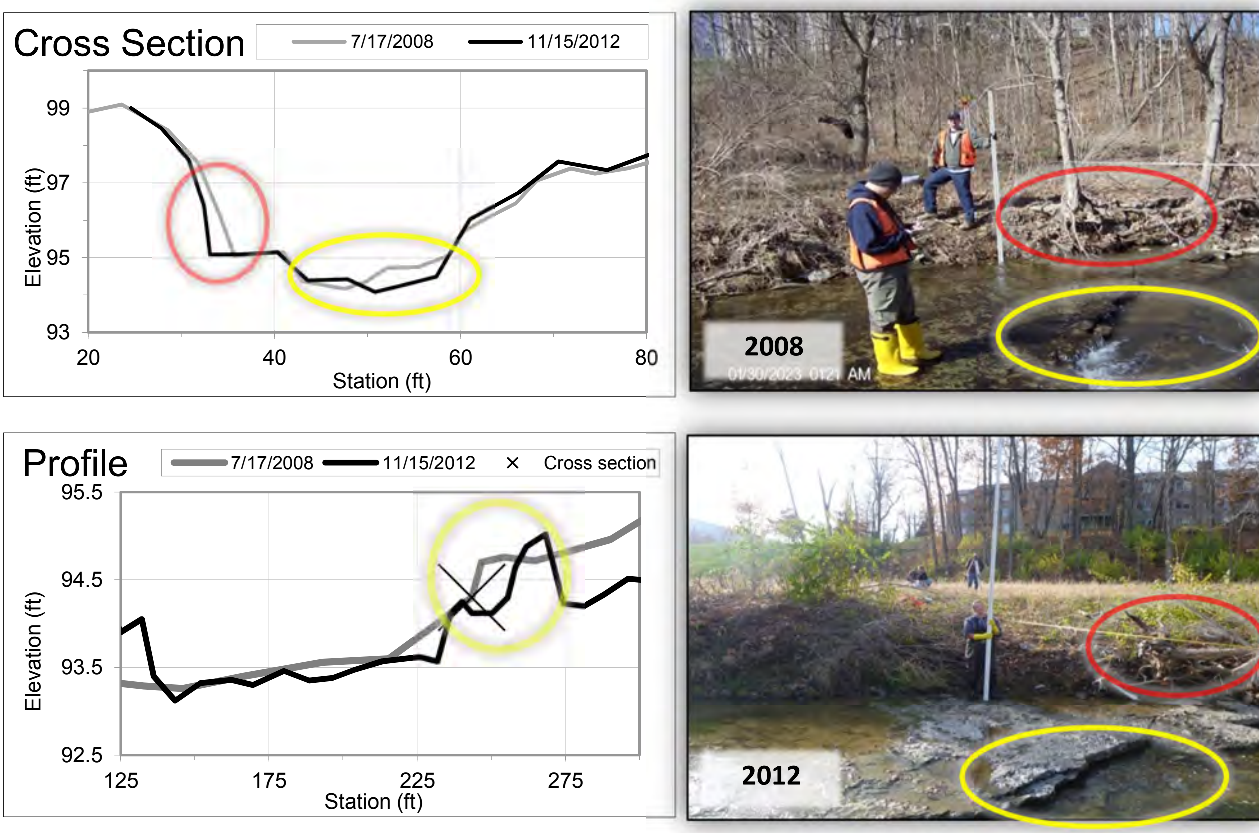


Figure 4-12: Erosive flows incise bedrock (yellow) and cause tree loss from bank failure (red)

This site is also experiencing bedrock incision as well as coarsening of the stream bed material. Conventional wisdom suggests that shallow bedrock tends to minimize or prolong channel incision by serving as a form of grade control, which makes the dominant source of channel instability bank failure and channel widening through both fluvial erosion and mass wasting mechanisms (Hawley *et al.*, 2013a). The survey data at SFG 5.3-DS confirms this response but also indicates that at times even sites with exposed bedrock can be extremely unstable and the stream bed can still degrade and incise as the exposed bedrock weathers and begins to fracture (Figure 4-12-yellow).

The active break-up of the channel bedrock and additional bed incision is concerning because bedrock in Northern Kentucky tends to be thin (approximately 6 inches to 1 foot) seams of limestone, a relatively strong rock, between thick (approximately 3 to 5 feet) layers of very weak shale. As the limestone layer gradually fractures and is mobilized, the underpinning shale layer quickly becomes eroded. This threshold condition of limestone surface weathering can result in very large increases in bank height (approximately 5 feet) on relatively shortened timescales. The energy of the urban flow regime has also resulted in sediment transport and

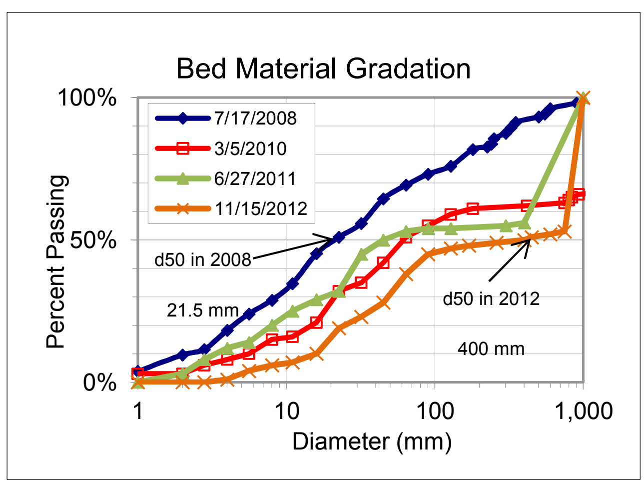


Figure 4-13: SFG 5.3-DS coarsening bed material

substantial coarsening of the bed material at this site (**Figure 4-13**). Note that the corresponding photos of this site and the following case study (SFG5.3-UNT 0.3) are nearly completely void of any habitat-forming particles and are comprised of featureless bedrock bottoms.

Case Study 2: Unnamed Tributary of South Fork Gunpowder Creek (SFG 5.3-UNT 0.3)

Another site located in the South Fork Gunpowder Creek Subwatershed (SFG 5.3-UNT 0.3) also experienced bank failure over several rounds of hydrogeomorphic monitoring. This site has an upstream drainage area of 2.2 square miles, and the watershed is very developed with approximately 41% impervious area coverage. A photo taken during 2012 monitoring captures a continuous tension crack (bank failure) along the entire length of the bank (**Figure 4-14**). This is a good example of geotechnical mass wasting and bank widening even on a bank with a relatively short height and at a site with shallow bedrock and a relatively well-connected floodplain. Such failure emphasizes the importance of a riparian buffer strip with thick vegetation to aid in stabilizing the bank.

Figure 4-14: SFG 5.3-UNT 0.3 tension crack bank failure

Case Study 3: Unnamed Tributary of Gunpowder Creek (GPC 17.1-UNT 0.1)

This site located in the headwaters of Gunpowder Creek, GPC 17.1-UNT 0.1 (29% impervious) experienced powerful erosive flows over the rounds of hydrogeomorphic monitoring. A series of photos taken in 2010, 2011, and again in 2012 (**Figure 4-15**) illustrates a tree becoming more damaged as time progresses. Additionally, the location of large woody debris is altered from year to year, indicating flows strong enough to transport heavy logs. The location of the tree (well over 10 feet into the channel) is indicative of historic widening as it is unlikely for a tree sprout to be able to take root in the middle of an active channel.

2010 2011 2012

Figure 4-15: Erosive flows at GPC 17.1-UNT 0.1 transport large woody debris and damage tree

These three case studies, as mentioned above, provide a glimpse into the types of hydromodification impacts observed in the stream. They also pair nicely with the data analysis, which supports these findings.

Habitat

Wetlands, vegetated riparian areas, native plant communities, and healthy stream channel conditions are important elements to support habitat structure and biological integrity. As previously mentioned in the section titled *Physical-Hydrogeomorphic Data*, the physical condition of a stream system strongly influences the habitat conditions, as the SD1 Habitat Score was negatively correlated to both the change in bankfull area per year and the change in bankfull top width per year, with significant *p* values of 0.05 and 0.02, respectively (**Figure 4-9**). Hydrogeomorphic data supports that the erosive urban flow regime has destroyed the nature of the Gunpowder Creek streams, leaving homogenous, featureless stream beds composed of exposed bedrock, long pools, and short riffles (**Figure 4-16**). **Table 4-1** presents the average habitat scores from the 2011 and 2012 Habitat Assessments.

(a) Pristine stream example in Northern Kentucky

(b) Homogeneous, featureless bedrock streambed

Figure 4-16: Physical characteristics of the streambed strongly influence habitat conditions

Such degraded habitat characteristics provide poor conditions for macroinvertebrate communities, and therefore also degrade the biological conditions at the sites. Even some of the less developed watersheds such as Long Branch had relatively poor habitat, which could have been attributable to historic channelization, or other factors. Notice that the most unstable monitoring site, SFG 5.3-UNT 0.3, also scored the lowest on the Habitat Assessments. Reference the Biological Assessment Section on page 26 for additional information regarding the impacts that poor habitat conditions have had on the biological communities at the sampling locations.

Table 4-1: Average habitat scores from the 2011 and 2012 habitat assessments illustrate the lowest habitat score at the most unstable site – SFG 5.3 – UNT 0.3

Monitoring Site	Habitat Score
SFG 5.3-UNT 0.3	67
LOB 0.5	83
FWF 0.8	97
RDR 1.1	106
GPC 17.1-UNT 0.1	129.5
GPC 7.5	142.5

Water Quality

Land Use Management, Erosive Flows, and Bank Erosion Are All Driving Factors that Impact Water Quality

Analysis of water chemistry data in the Gunpowder Creek Watershed provides insight about potential pollutants of concern and possible sources of the pollutants, such as land use, land use management, erosive flows, and bank erosion. All water chemistry data was processed to evaluate variations in pollutant concentrations and understand what might be causing such variations, such as changes in wet and dry weather conditions and the associated fluxes in stream discharge data. The following section, as well as supplementing appendices, presents the results of the water chemistry analysis.

Comparisons of Parameter Concentrations

Sample concentrations, summarized by water quality parameter, sampling site, and type of sample (wet versus dry and dry7) were initially analyzed using water quality box and whisker plots (**Appendix 4-B**) that provided a visual observation of the range of sample concentrations for all samples as well as samples in the wet, dry, and dry7 categories. Each box and whisker plot depicted the range of sample concentrations with excluded statistical outliers, the mean concentration for each category, and the overall relation to the water quality benchmark or standard set for that parameter. In addition to the box and whisker plots analyzed for each individual water quality parameter, this analysis involved evaluation of the ratios of sample concentrations to the water quality benchmark or standard at each monitoring location.

a) Water Quality Standards and Benchmarks

Water quality standards utilized throughout the analysis were obtained from Kentucky Administrative Regulations defined in *401 KAR 10:031 - Surface water standards*. The standards provide water quality criteria applicable to all surface waters to protect their indicated use, promote aquatic habitat, and safeguard human health. The water quality standards incorporated in this analysis include set criteria for bacteria, as measured by *E.coli,* as well as set criteria for dissolved oxygen and unionized ammonia.

All other parameters included in this analysis are compared to water quality benchmarks provided by KDOW in the *Gunpowder Creek Watershed Plan Benchmark Recommendations for Nutrient Parameters* (February 2012) and the *Gunpowder Creek Watershed Plan Benchmark Recommendations for Non-Nutrient Parameters* (February 2012) documents. These guidance documents set initial benchmarks based on typical values in comparable reference and healthy streams and are included in **Appendix 4-E**. In making the nutrient benchmark recommendations, KDOW considered regional and watershed specific nutrient expectations, regional-scale patterns in biological effects, and the specific indicators of nutrient enrichment observed in the watershed. The final benchmark recommendations provided by KDOW are primarily based on review of water quality samples at 12 ecoregional reference reaches within the Outer Bluegrass bioregion (ecoregion 71d) as well as typical literature values often cited for healthy streams.

Benchmark values provided by KDOW give a broad frame of reference to understand the general level of concern and approximate orders of load reduction that may be necessary to come within reasonable targets for water quality. While the benchmark values provide reasonable targets for water quality, desired attainment goals may be achieved without meeting benchmark concentrations. Designations such as Primary Contact Recreation (PCR) and Warm Water Aquatic Habitat (WAH) may be achieved even if the benchmarks are not met. Again, the benchmark values provided information to understand the scale of the problems and the GCWI would like to emphasize that the precise load is not the focus since the benchmark values are simply interim target values. As discussed in Chapters 5 and 6, the GCWI's approach for this Watershed Plan is to implement a reasonable level of BMPS and continue to monitor. GCWI plans to make smart investments as opportunities arise, monitor the progress, then reassess through continued monitoring.

b) Summary of All Sample Concentration Exceedances

Water chemistry parameters were evaluated to determine which pollutants were most concerning during wet versus dry weather sampling. **Table 4-2** presents the percent of water quality samples that exceeded the benchmark or standard set for each individual parameter. This represents the number of times the samples exceeded the benchmark level. Therefore, if the GCWI collected 11 samples and 9 were above the benchmark level, a percentage of 82 was included in the table. All sample exceedances greater than 80% are identified in red (most concerning) and all sample categories with less than 20% exceedance are identified in blue (least concerning). These results indicate that Total Phosphorus (TP) and Total Kjeldahl Nitrogen (TKN) are typically always above the water quality benchmark, while pollutants such as Dissolved Oxygen (DO), Nitrate-Nitrite as N (NN), and Unionized Ammonia (Union Amm) are the least concerning. Additional analysis of the nutrient concentrations and their pollutant loading indicates this type of pollutant is not as large of an issue as bacteria and sediment because the degree of exceedance is much lower. For example, 100% of all wet-weather samples from all sites exceeded the water quality standard for *E.coli*, and concentrations tended to be 1 to 2 orders of magnitude higher than the standard. The sampling results for *E.coli*, along with Total Suspended Solids (TSS)/Turbidity (Turbid) and Specific Conductance (SpCon) present interesting statistical relationships related to exceedances during wet versus dry weather sampling and are presented in additional detail in the following sections.

Table 4-2: Percent exceedances above water quality benchmark/standard concentration

(This represents the number of times the samples exceeded the benchmark level)

Water Quality Sampling Sites	Parameter:	TSS	Turbid	TP	TKN	NN	Union	DO	SpCon	*E.coli*
	No. Samples:	11	11	11	11	11	11	11	11	16
	No. Wet Samples:	3	3	3	3	3	3	3	3	3
	No. Dry Samples:	5	5	5	5	5	5	5	5	8
	No. Dry7 Samples:	3	3	3	3	3	3	3	3	5
	Benchmark[1]	7.25	8.3	0.08	0.3	0.3	0.05	**4**	522.5	**240**
	Standard[1]:	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	µS/cm	colonies/100mL
GPC 7.5	All	91%	64%	100%	100%	45%	0%	0%	36%	38%
GPC 7.5	Wet	100%	100%	100%	100%	100%	0%	0%	0%	100%
GPC 7.5	Dry	80%	40%	100%	100%	40%	0%	0%	60%	25%
GPC 7.5	Dry7[3]	100%	67%	100%	100%	0%	0%	0%	33%	20%
GPC 17.1-UNT 0.1	All	45%	55%	91%	100%	18%	0%	0%	82%	40%
GPC 17.1-UNT 0.1	Wet	67%	67%	100%	100%	33%	0%	0%	67%	100%
GPC 17.1-UNT 0.1	Dry	60%	80%	80%	100%	20%	0%	0%	80%	38%
GPC 17.1-UNT 0.1	Dry7[3]	0%	0%	100%	100%	0%	0%	0%	100%	0%
SFG 5.3-UNT 0.3	All	55%	27%	64%	100%	9%	0%	9%	91%	50%
SFG 5.3-UNT 0.3	Wet	100%	67%	100%	100%	33%	0%	33%	67%	100%
SFG 5.3-UNT 0.3	Dry	20%	20%	40%	100%	0%	0%	0%	100%	50%
SFG 5.3-UNT 0.3	Dry7[3]	67%	0%	67%	100%	0%	0%	0%	100%	20%
FWF 0.8	All	55%	36%	91%	100%	18%	0%	10%	73%	75%
FWF 0.8	Wet	100%	67%	100%	100%	67%	0%	33%	33%	100%
FWF 0.8	Dry	20%	20%	80%	100%	0%	0%	0%	80%	88%
FWF 0.8	Dry7[3]	67%	33%	100%	100%	0%	0%	33%	100%	40%
RDR 1.1[2]	All	40%	20%	90%	80%	10%	0%	50%	80%	67%
RDR 1.1[2]	Wet	67%	67%	100%	100%	33%	0%	33%	33%	100%
RDR 1.1[2]	Dry	20%	0%	80%	60%	0%	0%	40%	100%	63%
RDR 1.1[2]	Dry7[3]	50%	0%	100%	100%	0%	0%	100%	100%	50%
LOB 0.5	All	91%	64%	100%	100%	18%	0%	9%	27%	88%
LOB 0.5	Wet	100%	67%	100%	100%	67%	0%	33%	33%	100%
LOB 0.5	Dry	80%	40%	100%	100%	0%	0%	0%	40%	75%
LOB 0.5	Dry7[3]	100%	100%	100%	100%	0%	0%	0%	0%	100%

[1]Water quality standards are presented in bold and represent parameters regulated by KDOW. All other parameters are compared to a water quality benchmark, which are pollutant levels that tend to be found in the region's healthier streams according to data and analysis by KDOW. The water quality standards included in this analysis include only dissolved oxygen and E.coli

[2]Due to dry conditions sampling did not occur at RDR 1.1 on 8/7/12; therefore, this site has only two Dry7 samples and a total of 15 samples for E.coli and 10 for the remaining parameters.

[3]Dry7 defined as event with less than 0.01 inches of rain occurring within the 7-day period before the sampling event. Reference Chapter 3 for additional information regarding the classification of sampling events as wet, dry, and dry7.

c) *E.coli* Concentrations

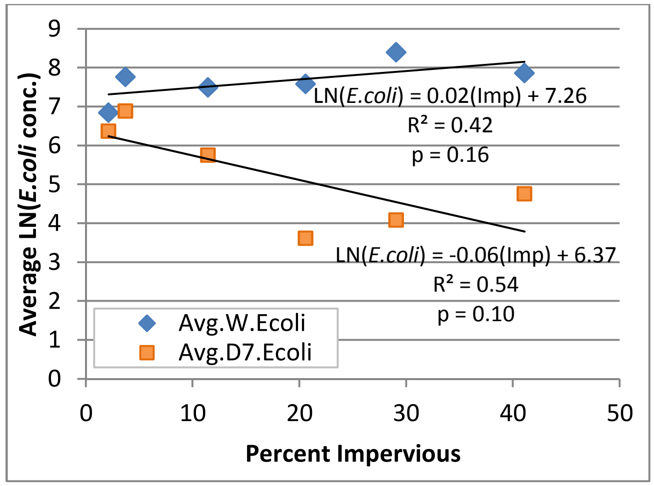


Figure 4-17: *E.coli* as a function of percent impervious

E.coli is used as an indicator of bacteria within the stream system, where an increase in concentration increases the possibility of the presence of potentially harmful pathogens. As illustrated in Table 4-2 and the *E.coli* Sample Box Plot below (Figure 4-18), 100% of wet weather *E.coli* samples at all sites exceeded the water quality standard (i.e., green line in Figure 4-18). Additionally, there is a positive association between the geometric mean of sample concentrations at each site and watershed imperviousness, illustrating that the most developed watersheds appear to have a larger concern with bacteria during wet weather (Figure 4-17). The opposite relationship is evident during dry weather sampling, as the geometric mean of the *E.coli* sample concentrations decreased with an increase in watershed imperviousness, indicating that bacteria levels during dry weather is a larger problem for rural watersheds (Figure 4-17). Both of these associations provide important insights relative to suspected sources of pollution; however, neither was statistically significant to the $p < 0.05$ level. Stormwater runoff and animal waste are suspected sources of bacteria in the developed subwatersheds, while septic systems and animals grazing in the streams are suspected sources of bacteria in the rural subwatersheds. Potential sources of bacteria in the watershed are further discussed later in this chapter. It is also important to note that the wet weather samples are based on three sampling events that occurred during 2011 prior to SD1's completion of system improvements aimed at mitigating several sanitary overflows in the Gunpowder Creek Watershed (historic overflow locations have been documented along the South Fork and tributary, Fowler Fork, and the main branch). Although there are many potential sources of bacteria throughout the Gunpowder Creek Watershed, it is possible that the high bacteria concentrations during wet weather in 2011 may have been partially attributable to sewer overflows.

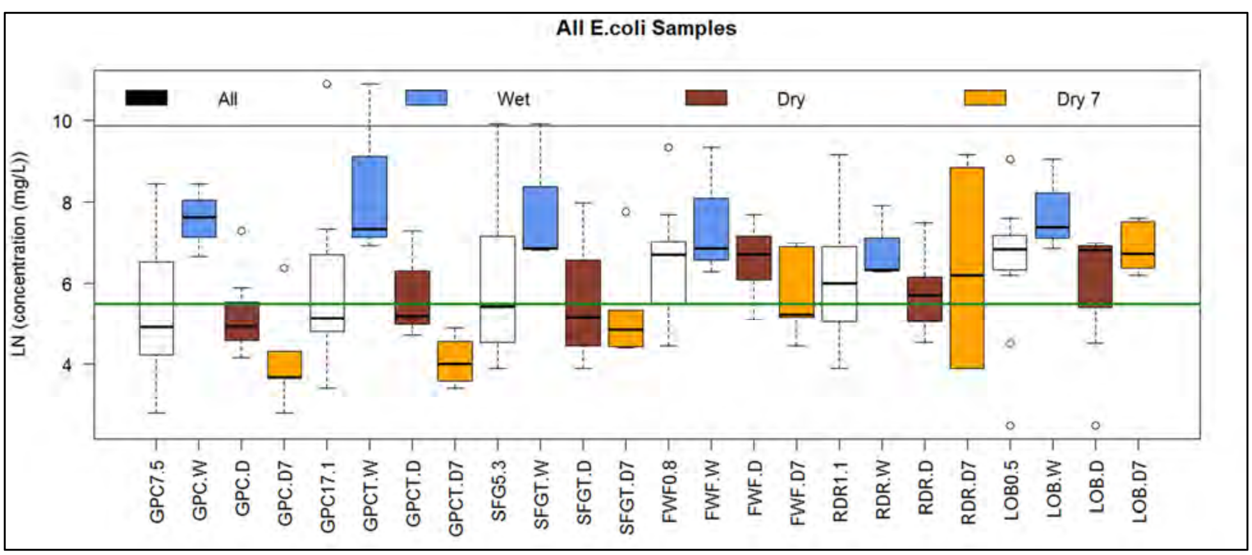


Figure 4-18: *E.coli* sample concentrations during wet and dry weather conditions (green line represents water quality standard: LN(240 colonies/100mL)) [a]

[a] In this figure, GPC 17.1-UNT 0.1 was shortened to GPC17.1. SFG 5.3-UNT 0.3 was shortened to SFG5.3.

d) TSS Concentrations

Sediment, as measured by TSS sample concentrations, is a pollutant of concern during both wet and dry weather conditions (**Figures 4-19 and 4-20**). It appears to be a larger issue during wet weather when bank erosion is caused by the urban induced erosive flow regime as well as when sediment is washed off unvegetated, barren surfaces and transported to the stream. As presented in the section of this chapter titled Physical-Hydrogeomorphic Data, TSS was strongly associated with channel enlargement (**Figure 4-8**), which was also associated with percent impervious, indicating that bank erosion and channel enlargement are a likely source of the fine sediment found in the streams, as has been well-documented in other systems (Trimble, 1997; Simon and Klimetz, 2008; Wilson et al., 2007). Such high rates of bank erosion and channel enlargement have likely been caused by the erosive urban flow regime, which is also degrading the habitat conditions and is a probable cause of biological impairments. While TSS in an indicator of erosive flows degrading habitat conditions, it also contributes to biological impairment through direct pathways (e.g. clogging gills) and indirect pathways (e.g. causing embeddedness of the bed material habitat). Bank erosion and channel enlargement are also a potential source of TSS during dry weather for several reasons. First, bank failure by mass wasting can occur during both periods of wet and dry weather. Second, once the fine sediment loads from bank failure are slumped into the stream, it can take long periods of time to flush the sediment load. Silt, and in particular clay, can remain suspended in the water column for hours and days, respectively, such that these loads can be sources even during prolonged periods of dry weather. Finally, even low flows at site GPC 7.5 would have sufficient capacity to transport silt and clay given the relatively large drainage area and reasonably high base flow, even during periods of dry weather.

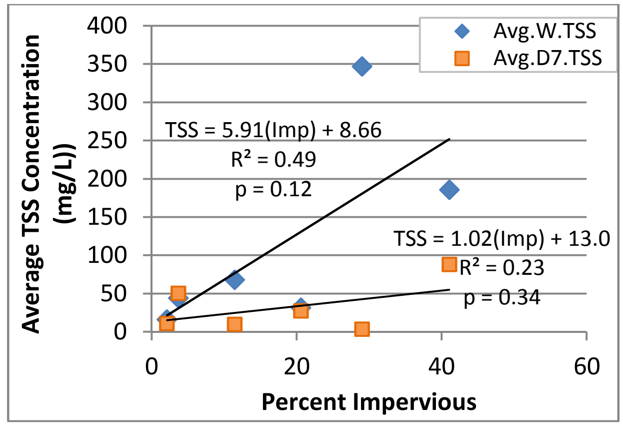


Figure 4-19: TSS as a function of percent impervious

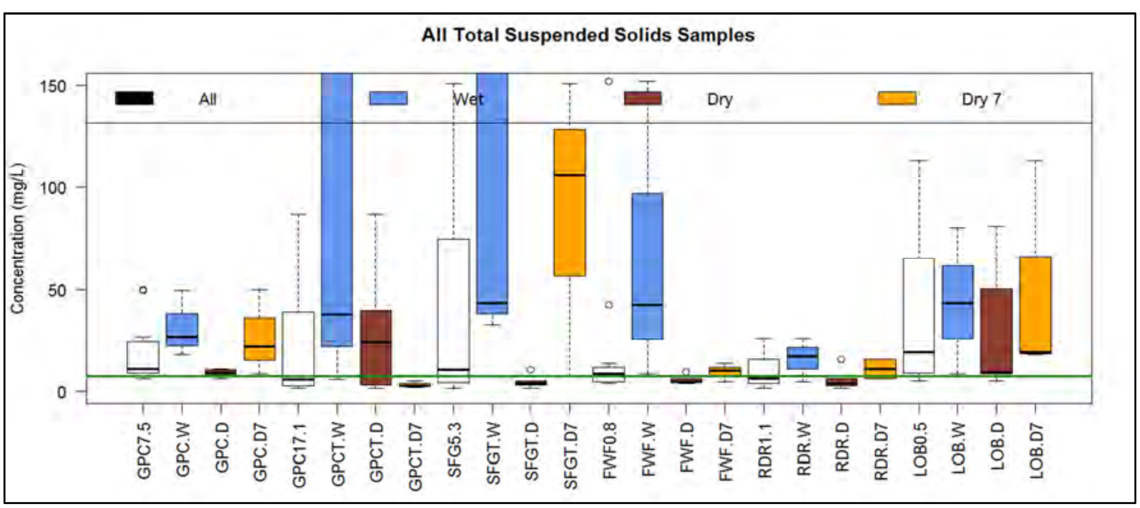


Figure 4-20: TSS sample concentrations during wet and dry weather conditions (green line represents water quality benchmark: 7.25 mg/L) [(a)]

[(a)] In this figure, GPC 17.1-UNT 0.1 was shortened to GPC17.1. SFG 5.3-UNT 0.3 was shortened to SFG5.3.

e) Specific Conductivity Measurements

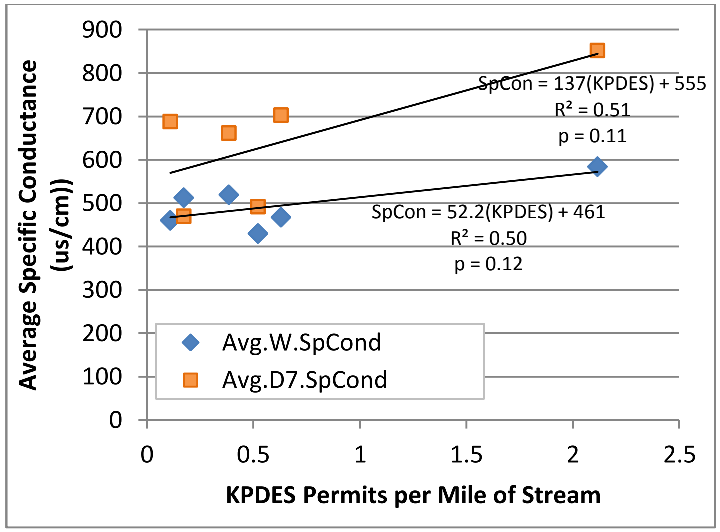


Figure 4-21: Average specific conductance concentrations are correlated to the number of KPDES permits per mile in each subwatershed

Specific conductance, which measures the water's ability to conduct electricity, can be used as a surrogate to determine if total dissolved solids are a potential pollutant of concern; however, it should be noted that specific conductivity can be naturally high in Northern Kentucky streams because of natural sources such as groundwater seeps which tend to increase conductivity from the amount of dissolved solids in the water. Sampling results indicate conductivity is worse during dry weather conditions, particularly at SFG 5.3-UNT 0.3, the subwatershed which contains the most number of KPDES permit sites per mile of stream. This observation, as well as the positive relationships presented in **Figure 4-21**, could indicate that total dissolved solids are possibly polluting the stream via KPDES discharges during dry weather conditions. In addition, specific conductivity was negatively correlated to sample flow at each site with significant *p* values less than 0.05 at four sites (GPC 17.1-UNT 0.1, SFG 5.3-UNT 0.3, FWF 0.8, and RDR 1.1). This also supports that specific conductance is more problematic during low flow conditions and that concentrations tend to become diluted during wet weather (note that the brown and orange boxes in **Figure 4-22** tend to be higher than the blue boxes at most sites).

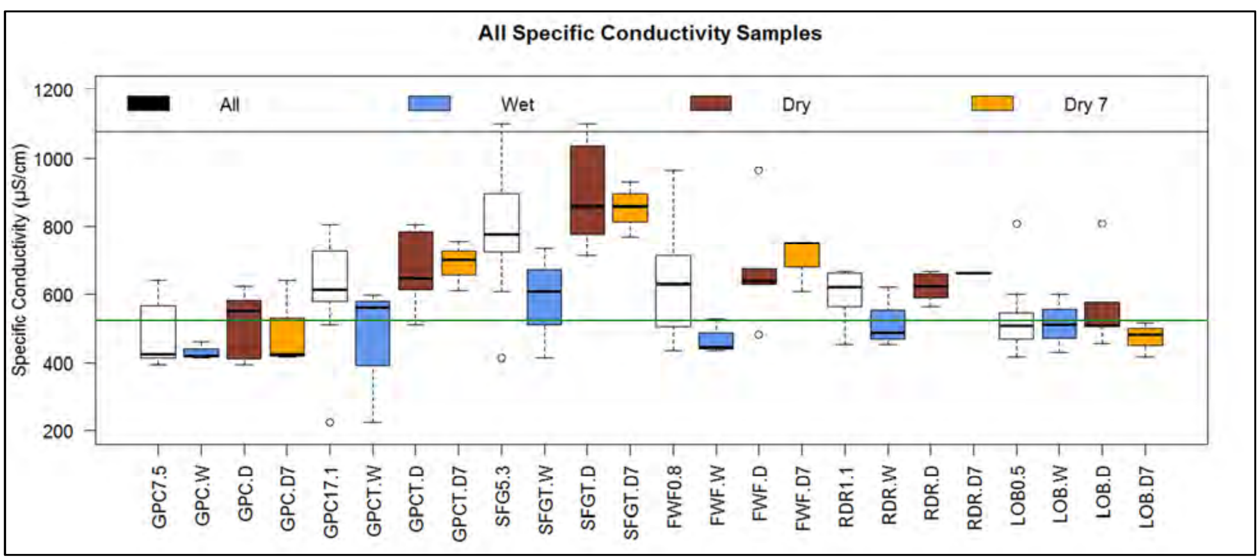


Figure 4-22: Specific conductance sample measurements during wet and dry weather conditions (green line represents water quality benchmark: 522.5 µS/cm) [(a)]

[(a)] In this figure, GPC 17.1-UNT 0.1 was shortened to GPC17.1. SFG 5.3-UNT 0.3 was shortened to SFG5.3.

Comparisons of Pollutant Loads

Pollutant load duration curves add another level of insight to the water quality analysis and allow for pollutant concentrations to be characterized at varying flow regimes, providing a visual figure of the relationship between stream flows, pollutant loading capacity, and the frequency and magnitude of exceedances in water quality benchmarks based on flow conditions. Pollutant loads, which are defined by both the concentration of the pollutant and the stream flow, determine the amount of a specific pollutant being transported by the stream in terms of weight per period of time (i.e., lbs/day). Loadings are important to evaluate because they provide a more balanced comparison between subwatersheds, as a subwatershed with a low concentration and large flows could have a higher total load than a watershed that has a high pollutant concentration but only a little flow (KDOW, 2010a). The Gunpowder Creek water quality analysis included development of pollutant load duration curves to analyze bacteria (*E.coli*), total suspended sediment (TSS), and nutrients (TP, TKN, NN) at all six water quality monitoring sites. **Figure 4-23** presents the *E.coli* Load Durations at GPC 17.1-UNT 0.1 and is an example of the pollutant load duration curves developed at all sites (**Appendix 4-C**). This load duration approach, with the limited amount of water quality data provided for this analysis, is meant to provide estimates of the scale of the problem in each subwatershed and not indicate exact loads necessary to achieve interim water quality targets.

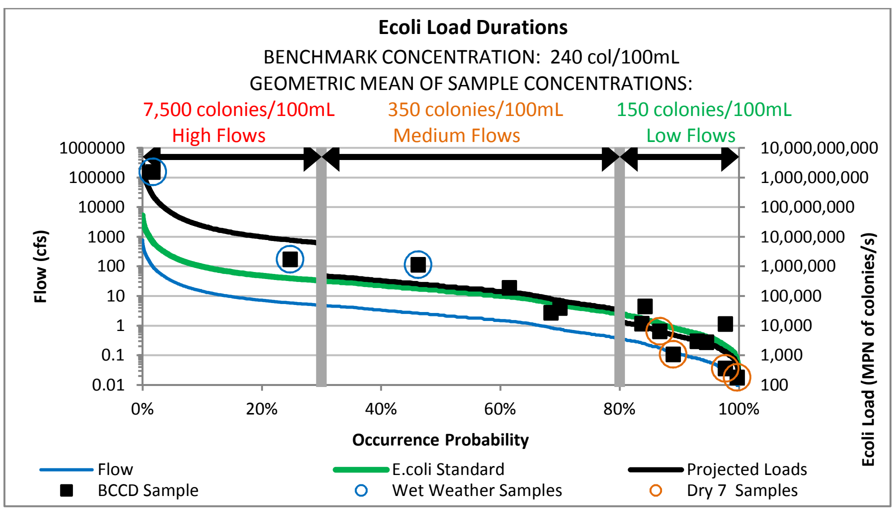


Figure 4-23: *E.coli* load durations at developed site, GPC 17.1-UNT 0.1 (29% impervious)

Note: This load duration approach with the limited amount of water quality data provided for this analysis is meant to provide estimates of the scale of the problem in each watershed and is not intended to represent precise loads. Values listed above each flow category represent the geometric mean of the concentrations sampled within that flow category

In addition to providing a visual representation of the relationship between stream flows, pollutant loading capacity, and the frequency and magnitude of exceedances in water quality benchmarks, the pollutant load duration curves provide means of estimating the total annual pollutant loads occurring at a particular site over the course of an entire year. Projected annual pollutant loads, benchmark annual pollutant loads, and the percent difference for each parameter is presented in a summary table for each water quality monitoring site (**Appendix 4-C**).

Sediment and bacteria during wet weather tended to be the biggest concern, particularly in the most developed watersheds.

With further evaluation of the annual pollutant loads, the ratio of the projected load to the benchmark load (defined by the projected load divided by the water quality benchmark) was calculated to analyze the degree of exceedance for each pollutant on the same scale, with any ratio above one being an exceedance of the water quality benchmark. **Figure 4-24** presents this ratio for total loads of each parameter analyzed at the water quality monitoring locations. This figure illustrates that both sediment (TSS) and bacteria (*E.coli*) are of greater concern than nutrient loads (TP, TKN, and NN) throughout the Gunpowder Creek Watershed. Additionally, this figure illustrates that generally two subwatersheds appear to be contributing the most pollution by weight within the watershed - the headwaters of Gunpowder Creek (GPC 17.1-UNT 0.1) and South Fork Gunpowder (SFG 5.3-UNT 0.1).

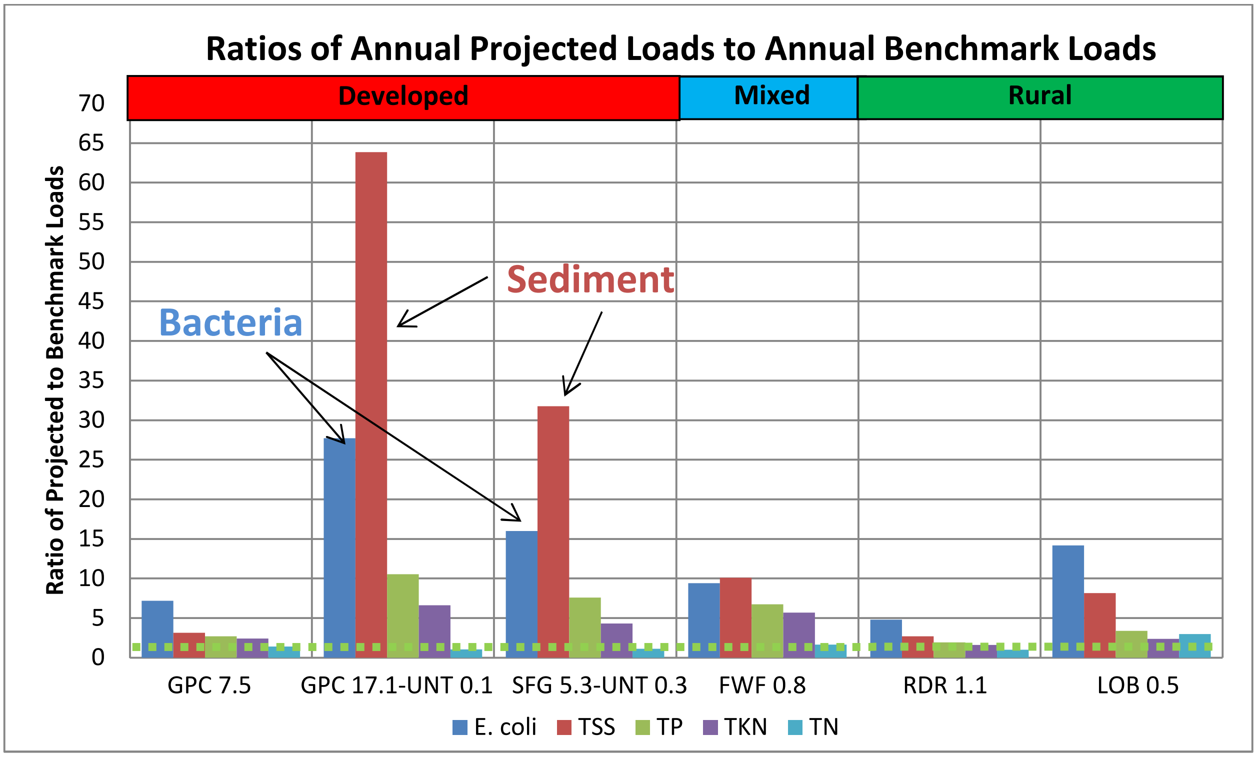


Figure 4-24: Ratios of projected loads to benchmark pollutant loads illustrate that bacteria and sediment are the greatest pollutants of concern in the Gunpowder Creek Watershed

(ratios = projected load divided by the water quality benchmark or standard; the green line represents the water quality benchmark or standard = 1)

Ratios of projected loads to benchmark loads were also evaluated during the various flow conditions (high, medium, and low). This analysis confirmed the results presented in previous sections – bacteria and sediment are of greater concern during wet weather conditions when the stream flows are high.

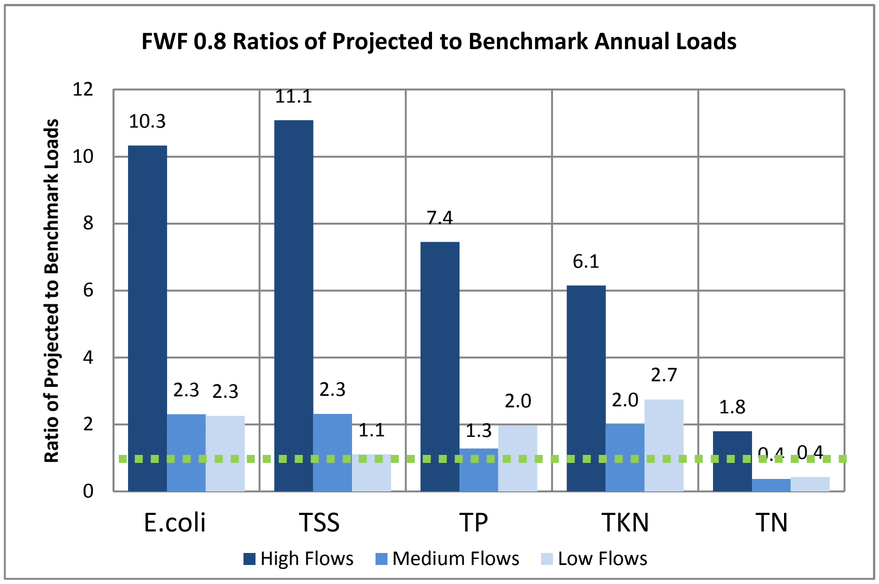


Figure 4-25: Evaluation of projected to benchmark load ratios at individual monitoring sites illustrates greater exceedances during high flows (wet weather conditions)
(ratios = projected load divided by the water quality benchmark or standard; the green line represents the water quality benchmark or standard = 1)

Figure 4-25 presents an example of this analysis. The evaluations of projected to benchmark load ratios at all monitoring sites are included in Appendix 4-C. Table 4-3 presents the projected percent load reductions necessary for each parameter at the water quality monitoring sites. The red text illustrates the highest pollutant load reductions needed throughout the watershed (greater than 80%). It further underscores the findings that 1) sediment (TSS) and bacteria (E.coli) are the pollutants in need of the greatest reductions and 2) the most developed sites of SFG 5.3-UNT 0.3 and GPC 17.1-UNT 0.1 tend to higher reductions than the less developed sites. Additionally, the percent load reductions for each flow category are included in Appendix 4-C.

Table 4-3 – Estimates of percent load reductions necessary to meet water quality benchmarks at each monitoring location

Site	*E. coli*	TSS	TP	TKN	TN
GPC 7.5	86%	68%	63%	59%	28%
GPC 17.1-UNT 0.1	96%	98%	91%	85%	4%
SFG 5.3-UNT 0.3	94%	97%	87%	77%	10%
FWF 0.8	89%	90%	85%	82%	39%
RDR 1.1	79%	63%	48%	38%	83%
LOB 0.5	93%	88%	71%	58%	67%

Comparison of Pollutant Yields

The annual loads estimated from the load duration curves were standardized by determining the pollutant yield for each subwatershed. This accounts for the geographic size differences between the subwatersheds. The pollutant yield was determined by dividing each load by the total area of the sub-watershed. Table 4-4 presents the standardized pollutant yields, which also supports the findings above that bacteria and sediment tend to be the pollutants of greatest concern and that they become worse in the developed headwaters of the watershed (SFG 5.3-UNT 0.3 and GPC 17.1-UNT 0.1).

Table 4-4 – Pollutant yields at each monitoring location

SITE	FLOW	POLLUTANT YIELD				
		E. coli (col/yr/ac)	TSS (lb/yr/ac)	TP (lb/yr/ac)	TKN (lb/yr/ac)	TN (lb/yr/ac)
SFG 5.3-UNT 0.3	High Flows	8.20E+10	1,084.3	2.8	5.8	1.5
	Medium Flows	1.15E+09	14.3	0.1	0.4	0.1
	Low Flows	1.32E+07	0.6	0.0	0.0	0.0
	Total	8.31E+10	1,099.1	2.9	6.2	1.6
RDR 1.1	High Flows	2.86E+10	112.3	0.8	2.6	1.7
	Medium Flows	2.02E+09	2.6	0.1	0.2	0.1
	Low Flows	2.64E+07	0.1	0.0	0.0	0.0
	Total	3.07E+10	115.1	0.9	2.8	1.8
LOB 0.5	High Flows	7.61E+10	277.8	1.3	3.2	4.4
	Medium Flows	2.55E+09	22.5	0.1	0.4	0.1
	Low Flows	3.62E+07	0.5	0.0	0.0	0.0
	Total	7.87E+10	300.8	1.4	3.6	4.6
GPC 17.1-UNT 0.1	High Flows	2.23E+11	3,404.9	6.1	14.4	2.0
	Medium Flows	1.31E+09	38.4	0.2	0.4	0.3
	Low Flows	1.52E+07	0.2	0.0	0.0	0.0
	Total	2.24E+11	3,443.5	6.3	14.8	2.3
FWF 0.8	High Flows	6.11E+10	436.7	3.2	10.0	2.9
	Medium Flows	1.72E+09	11.5	0.1	0.4	0.1
	Low Flows	4.53E+07	0.1	0.0	0.0	0.0
	Total	6.29E+10	448.4	3.3	10.5	3.0
GPC 7.5	High Flows	5.54E+10	143.3	1.4	4.8	2.8
	Medium Flows	1.33E+09	22.5	0.2	0.5	0.2
	Low Flows	1.02E+07	0.4	0.0	0.0	0.0
	Total	5.67E+10	166.2	1.6	5.3	3.0

Comparison of Watershed Inventory Data to Pollutant Concentrations and Loads/Yields

A better understanding of pollutants of concern and possible drivers of the pollutants is obtained by comparing the watershed inventory data to the pollutant concentrations and loads/yields. Generally, the monitoring locations can be categorized into three types of land use based on their percentage of impervious area, including developed watersheds, rural watersheds, and mixed. Differing land use can be related to certain pollutants of concern during both wet and dry weather and provide inferences regarding potential sources of pollution. This is further explained in section *4.2.2 Phase 1 and Phasee 2 Combined - Prioritization.*

Biological Assessment

Biological health in rural watersheds tended to be more impacted by habitat and dry weather pollution.

The biological health of a stream system is dependent on all other supporting factors, and it is presented at the top of the stream function pyramid. The core of this pyramid is built on land use and management, stream flow, physical/habitat conditions, and overall water quality. Macroinvertebrate communities particularly rely on their natural flow and disturbance regimes, healthy habitat conditions, and excellent water quality, all of which show negative correlations with development and were discussed earlier in this report. Statistical analysis of the Gunpowder Creek Biological Assessments in relation to percent impervious also supports that biological health suffers in the most developed watersheds, as the MBI Score and the Percent Clinger Score were both negatively associated with watershed imperviousness (Figure 4-26 and Figure 4-27). Figure 4-28 presents the aquatic macroinvertebrate scores (MBI) for each monitoring location and the influencing factors that largely impacted the aquatic macroinvertebrate health, including flow, habitat, and water quality, which are all affected by land use and land use management.

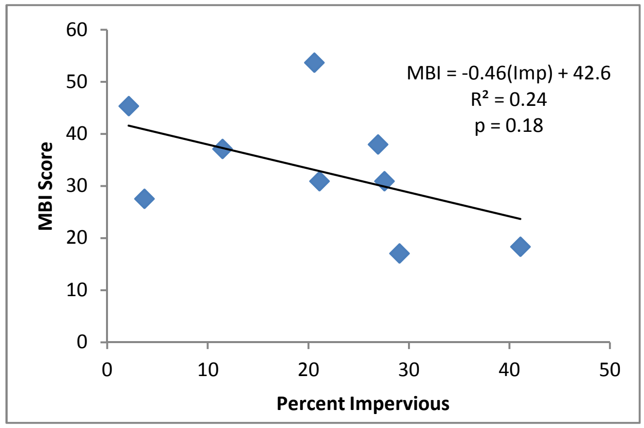


Figure 4-26: -Increased development, as measured by percent impervious, results in degraded MBI scores

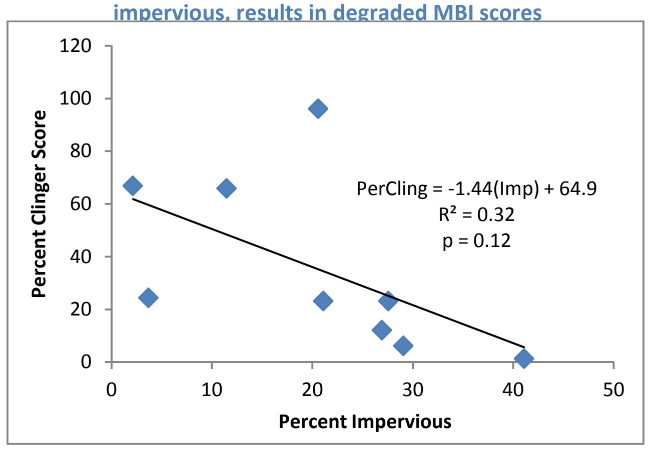


Figure 4-27: The percent clinger population is negatively associated with percent impervious

SD1 Stream Condition Indices Summarize the Overall Health of Gunpowder Creek and its Tributaries

SD1's Stream Condition Indices provide a concise summary of hydromodification, physical, water quality, and biological conditions at each monitoring location. Figure 4-29 presents a summary of the Stream Condition Indices throughout the Gunpowder Creek Watershed. Overall review of these scores illustrates that the results of the GCWI monitoring program are consistent with SD1 Stream Condition Index scores (Figure 4-29). This Stream Condition Index supports the findings of GCWI's data analysis. It was not an integral part of the analysis.

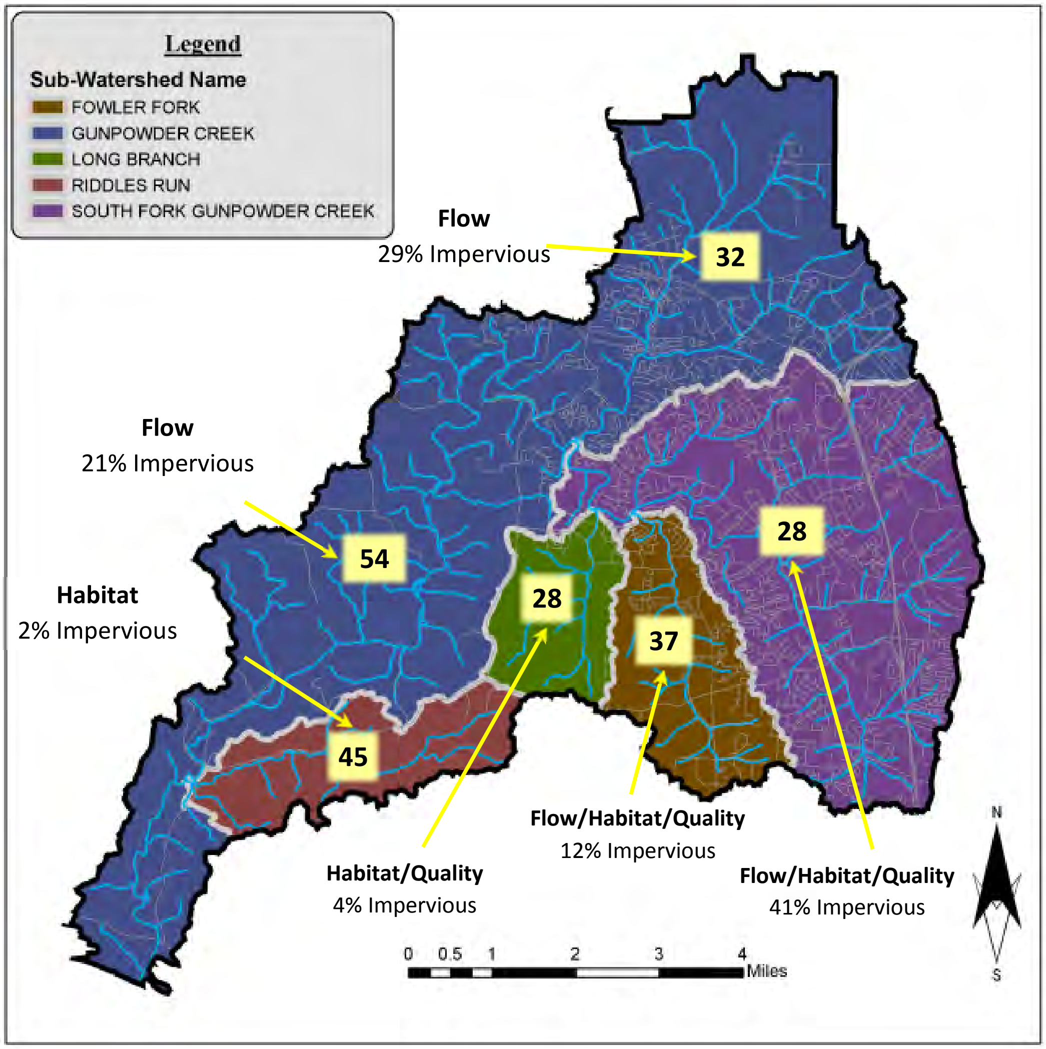


Figure 4-28: Biological health is dependent upon all pieces of the pyramid

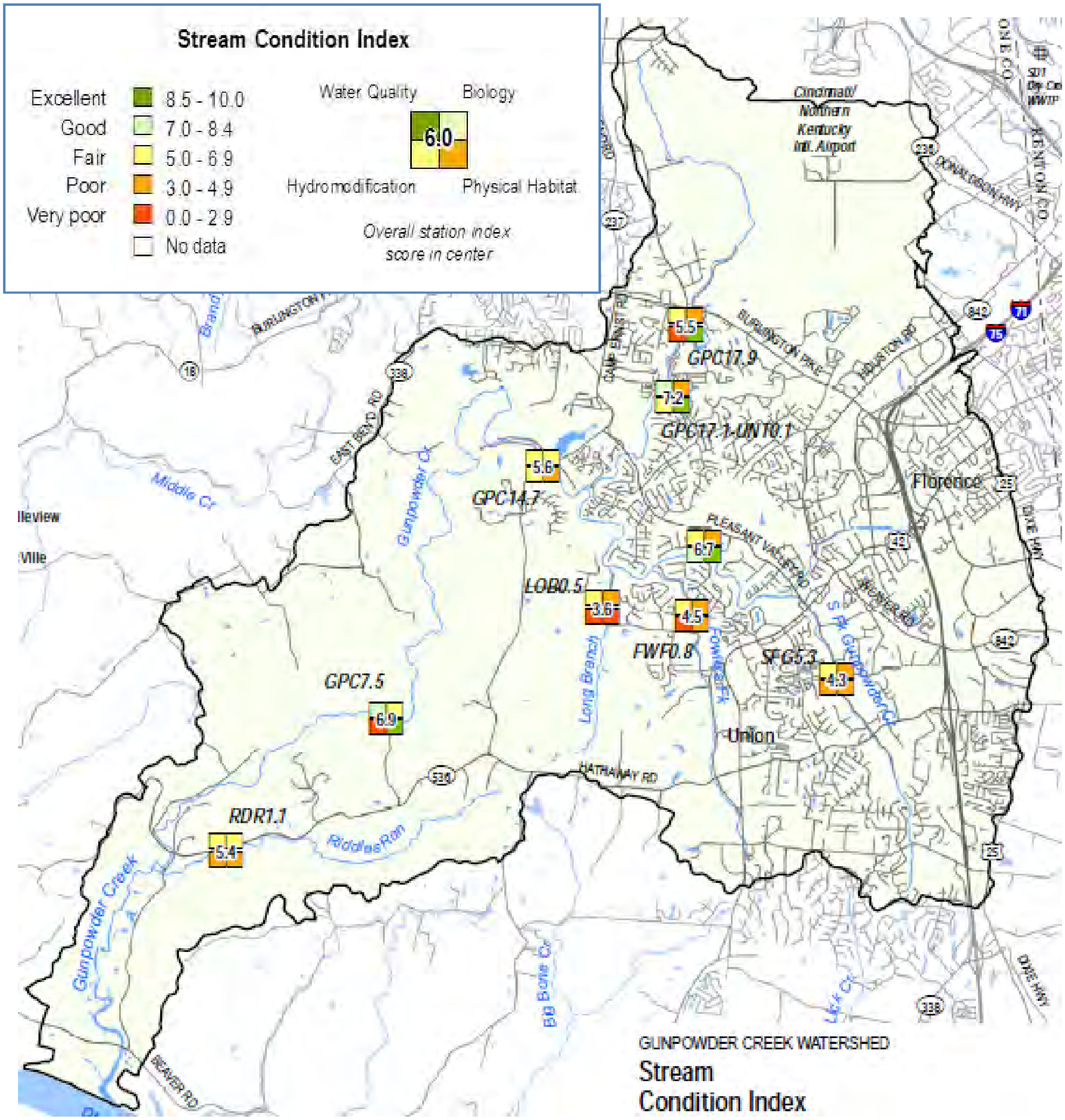


Figure 4-29: Overall stream health summarized with SD1's Stream Condition Indices

4.2.2 Phase 1 and 2 Combined - Prioritization

Further analysis of the data presented above allowed for prioritization of the subwatersheds based on the monitoring data. The analyzed monitoring data provided a better understanding of pollutant sources and which subwatersheds should be targeted for future implementation efforts. Prioritization involved organization and review of the analytical data to rank subwatersheds, evaluation of the regulatory status of the waterways, targeting of pollutants of concern and reviewing feasibility factors.

Organizing Analytical Data

In organizing the water quality data analyzed above, concentrations as well as pollutant loads and yields were all compared in order to rank the subwatersheds and understand which subwatersheds need to be prioritized in terms of lowering the pollutants in the stream and which subwatersheds need to potentially be protected from future degradation.

Comparisons of Parameter Concentrations

Table 4-5 and **Table 4-6** present the subwatersheds ranked based on analysis of the sample concentrations. First, **Table 4-5** presents the subwatersheds ranked by the number of water quality samples exceeding the benchmark concentration. **Table 4-6** presents the subwatersheds ranked by average parameter concentrations.

Table 4-5: Subwatersheds ranked from the greatest to the lowest number of samples exceeding the benchmark [(a)]

PERCENT SAMPLES IN EXCEEDANCE OF BENCHMARK									
E. coli		TSS		TP		TKN		NN	
LOB 0.5	88%	GPC 7.5	91%	GPC 7.5	100%	GPC 7.5	100%	GPC 7.5	50%
FWF 0.8	75%	LOB 0.5	91%	LOB 0.5	100%	GPC 17.1-UNT	100%	GPC 17.1-UNT	17%
RDR 1.1	67%	SFG 5.3-UNT	55%	GPC 17.1-UNT	92%	SFG 5.3-UNT	100%	FWF 0.8	17%
SFG 5.3-UNT	50%	FWF 0.8	55%	FWF 0.8	92%	FWF 0.8	100%	LOB 0.5	17%
GPC 17.1-UNT	40%	GPC 17.1-UNT	45%	RDR 1.1	91%	LOB 0.5	100%	RDR 1.1	9%
GPC 7.5	38%	RDR 1.1	40%	SFG 5.3-UNT	67%	RDR 1.1	82%	SFG 5.3-UNT	8%

[(a)] GPC 17.1-UNT 0.1 has been shortened to GPC 17.1-UNT in this table. SFG 5.3-UNT 0.3 has been shortened to SFG 5.3-UNT in this table.

Table 4-6: Subwatersheds ranked from the greatest to the lowest average sample concentrations [(a)]

AVERAGE SAMPLE CONCENTRATIONS									
E. coli (col/100mL)[(b)]		TSS (mg/L)		TP (mg/L)		TKN (mg/L)		NN (mg/L)	
LOB 0.5	724	GPC 17.1-UNT	109	GPC 17.1-UNT	0.30	FWF 0.8	0.95	GPC 7.5	0.32
FWF 0.8	661	SFG 5.3-UNT	76.7	SFG 5.3-UNT	0.22	GPC 17.1-UNT	0.85	LOB 0.5	0.26
RDR 1.1	454	LOB 0.5	39.6	FWF 0.8	0.22	SFG 5.3-UNT	0.78	FWF 0.8	0.20
SFG 5.3-UNT	368	FWF 0.8	23.6	GPC 7.5	0.19	LOB 0.5	0.77	GPC 17.1-UNT	0.19
GPC 17.1-UNT	317	GPC 7.5	19.9	LOB 0.5	0.18	GPC 7.5	0.74	RDR 1.1	0.16
GPC 7.5	203	RDR 1.1	10.0	RDR 1.1	0.13	RDR 1.1	0.42	SFG 5.3-UNT	0.15

[(a)] GPC 17.1-UNT 0.1 has been shortened to GPC 17.1 UNT in this table. SFG 5.3-UNT 0.3 has been shortened to SFG 5.3 UNT in this table.

[(b)] Average sample concentrations for *E.coli* were calculated as the geomean of the sample concentrations

Comparisons of Pollutant Loads and Yields

Excess stormwater runoff, especially in the developed headwaters, seems to be the common source for many problems throughout the Gunpowder Creek stream network.

Analysis of the pollutant loads and yields provides a better understanding of the subwatersheds in most need of restoration efforts. Pollutant loads consider the flow data and the pollutant yields standardize the data across subwatersheds of different sizes. This allows for an understanding of which subwatersheds are contributing the most pollution by weight within the watershed. **Table 4-7** presents the subwatersheds ranked by projected annual loads. GPC 7.5 is the largest subwatershed (43.5 mi^2) and is downstream of all other sites with the exception of RDR 1.1; therefore, it is no surprise that GPC 7.5 has the highest annual loads for every pollutant, minus TSS. Alternatively, GPC 7.5 drops to a much lower ranking, for all criteria but NN, when calculating pollutant yield. The most developed subwatersheds (GPC 17.1-UNT 0.1 – 29.1% impervious and SFG 5.3-UNT 0.3 – 41.1% impervious) tend to have relatively high pollutant loads, as well as pollutant yields (with the exception of NN), and are illustrated in red text for easy comparison between **Table 4-7** and **Table 4-8**.

Table 4-7: Subwatersheds ranked from the greatest to the lowest projected annual loads [(a)]

PROJECTED ANNUAL LOADS									
E. coli (col/yr)		TSS (lb/yr)		TP (lb/yr)		TKN (lb/yc)		NN (lb/yr)	
GPC 7.5	1.58E+15	GPC 17.1-UNT	8,460,316	GPC 7.5	43,917	GPC 7.5	147,552	GPC 7.5	84,810
GPC 17.1-UNT	5.51E+14	GPC 7.5	4,634,738	GPC 17.1-UNT	15,388	GPC 17.1-UNT	36,328	FWF 0.8	8,269
FWF 0.8	1.72E+14	SFG 5.3-UNT	1,549,534	FWF 0.8	9,093	FWF 0.8	28,711	LOB 0.5	7,938
LOB 0.5	1.36E+14	FWF 0.8	1,231,613	SFG 5.3-UNT	4,088	SFG 5.3-UNT	8,683	GPC 17.1-UNT	5,713
SFG 5.3-UNT	1.17E+14	LOB 0.5	521,995	LOB 0.5	2,398	LOB 0.5	6,302	RDR 1.1	3,628
RDR 1.1	6.26E+13	RDR 1.1	235,259	RDR 1.1	1,845	RDR 1.1	5,800	SFG 5.3-UNT	2,239

[(a)] GPC 17.1-UNT 0.1 has been shortened to GPC-17.1 UNT in this table. SFG 5.3-UNT 0.3 has been shortened to SFG 5.3-UNT in this table.

Table 4-8 presents the subwatersheds ranked by pollutant yields, which confirms that the most developed headwater reaches of Gunpowder Creek (GPC 17.1-UNT 0.1 (3.8 mi^2) and SFG 5.3-UNT 0.3 (2.2 mi^2)) are estimated to contribute much greater amounts of bacteria and sediment per acre of watershed than the less developed portions of the watershed.

Table 4-8: Subwatersheds ranked from the greatest to the lowest yields [(a)]

POLLUTANT YIELD									
E. coli (col/yr/ac)		TSS (lb/yr/ac)		TP (lb/yr/ac)		TKN (lb/yr/ac)		NN (lb/yr/ac)	
GPC 17.1-UNT	2.24E+11	GPC 17.1-UNT	3,443.5	GPC 17.1-UNT	6.3	GPC 17.1-UNT	14.8	LOB 0.5	4.6
SFG 5.3-UNT	8.31E+10	SFG 5.3-UNT	1,099.1	FWF 0.8	3.3	FWF 0.8	10.5	GPC 7.5	3.0
LOB 0.5	7.87E+10	FWF 0.8	448.4	SFG 5.3-UNT	2.9	SFG 5.3-UNT	6.2	FWF 0.8	3.0
FWF 0.8	6.29E+10	LOB 0.5	300.8	GPC 7.5	1.6	GPC 7.5	5.3	GPC 17.1-UNT	2.3
GPC 7.5	5.67E+10	GPC 7.5	166.2	LOB 0.5	1.4	LOB 0.5	3.6	RDR 1.1	1.8
RDR 1.1	3.07E+10	RDR 1.1	115.1	RDR 1.1	0.9	RDR 1.1	2.8	SFG 5.3-UNT	1.6

[(a)] GPC 17.1-UNT 0.1 has been shortened to GPC-17.1 UNT in this table. SFG 5.3-UNT 0.3 has been shortened to SFG 5.3-UNT in this table.

Regulatory Status of the Waterway

A common pollutant of concern between KDOW's 303(d) list and the GCWI analysis is sediment. The developed headwaters in the main branch and the South Fork were also found to be the reaches with the greatest concerns.

As previously presented in Chapter 1, several portions of the Gunpowder Creek and South Fork Gunpowder Creek have been classified on the Kentucky 303(d) List of Impaired Waters for high levels of sediment, bacteria, and nutrients. Several commonalities exist between the KDOW list and the analysis presented throughout this chapter. For example, a common pollutant of concern is sedimentation/siltation, and two common suspected sources were bank destabilization and urban stormwater. The fact that KDOW's list identifies the developed headwaters along the main branch (GPC miles 15.4-21.6) and South Fork Gunpowder Creek (SFG miles 0 to 6.8) as the impaired reaches is consistent with the dominant findings from the GCWI analysis: with the exception of Long Branch, impairments tend to be most problematic in the headwater reaches that drain the portion of the watershed with the most development. This consistency provides supporting information for the GCWI to prioritize the headwaters of Gunpowder Creek and the South Fork Gunpowder Creek as the subwatersheds in most need of immediate action. In addition to the segments of the Gunpowder streams listed as impaired, KDOW has TMDLs created for biological oxygen demand and ammonia for the airport and is in the process of developing a TMDL for *E.coli* for the entire watershed.

Feasibility Factors

Review of the analytical data as well as the regulatory status of the Gunpowder Creek waterways confirms that the most developed subwatersheds should be prioritized for targeted implementation. However, other feasibility factors should also be considered when evaluating the data. Analysis of the monitoring data from the rural and mixed watersheds illustrates that the pollutants of concern and potential sources are different than that of the developed watersheds. The most important feasibility factor included comparison of watershed inventory data to pollutant loads. Other feasibility factors, such as Planning and Zoning regulatory jurisdiction, did not directly impact one subwatershed over another because jurisdictions covered the entire watershed or large parts of several subwatersheds. The cumulative impact of all the factors presented in this section does not change the potential for successfully implementing BMPs in the most impaired subwatersheds. Reference Chapter 6 for more detailed information relating to the feasibility factors.

Comparison of Watershed Inventory Data to Pollutant Loads

The monitoring locations can be organized into three types of land use based on watershed imperviousness, including developed watersheds (20-40% impervious) on the eastern side of the Gunpowder Creek Watershed, rural watersheds (2-4% impervious) on the southern portion of the Gunpowder Creek Watershed, and mixed (developed/rural, 12% impervious). These types of landuses also come with different types of stakeholder groups which affect the feasibility factors addressed in Chapter 5. There are not specific social or cultural factors within the subwatersheds that impact prioritization.

Differing land use can be related to certain pollutants of concern during both wet and dry weather and provided some inference regarding potential sources of pollution. South Fork Gunpowder Creek and the headwaters of Gunpowder Creek have been classified as developed; Riddles Run and Long Branch are classified as rural; and Fowlers Fork is considered mixed. Sampling locations, and their related development category, are illustrated in Figure 4-30. The most impervious areas of the watershed, which are located in the headwaters, have been extremely detrimental on the health of these stream systems. In many watersheds the headwaters are typically the most pristine and healthy stream reaches, but due to the increased development in the Gunpowder Creek Watershed headwaters, these stream reaches have been degraded. Therefore, these subwatersheds have been prioritized as the areas of the watershed in most need of stormwater mitigation including both structural and nonstructural BMPs. The sections below summarize the most concerning and least concerning pollutants for the three watershed types, along with likely sources and possible causes.

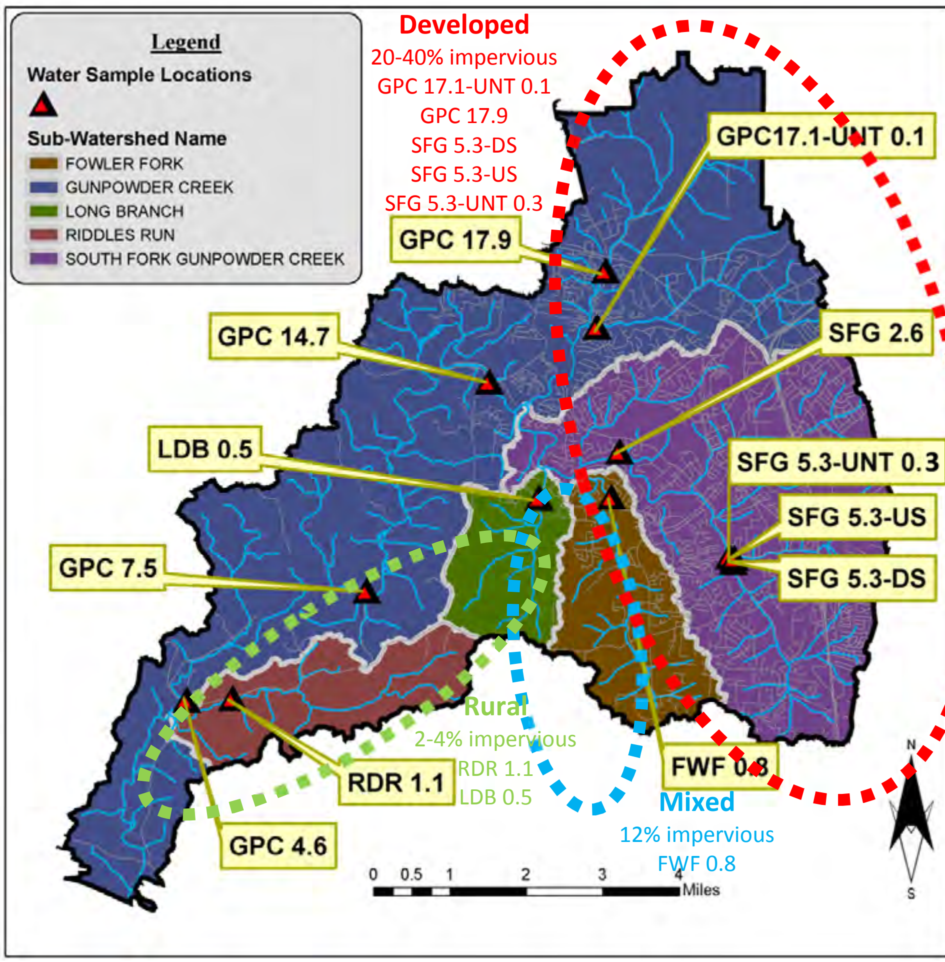


Figure 4-30: Sampling sites classified by primary land use (developed, mixed, and rural)

1. Developed Watersheds

First, the developed watersheds (20-40% impervious), located within the headwaters of Gunpowder Creek and South Fork Gunpowder Creek on the eastern side of the watershed, had high loadings of bacteria and suspended sediment during wet weather (Figure 4-31). The predominant cause of high bacteria and TSS loadings is likely excess stormwater runoff because these same developed sites have fewer issues with dry weather bacteria. This tends to indicate that the developed sites are primarily impacted by stormwater runoff and nonpoint source pollution. Nonpoint source pollution results from everyday activities such as littering, pet waste, fertilizing the lawn, land clearing for development, and agricultural activities, all allowing pollutants generated by these activities to be washed into the stormwater collection system and eventually flowing into our waterways. As discussed in *Comparisons of Parameter Concentrations*, some of the developed sites and high loadings of specific conductance during dry weather, especially the SFG 5.3- UNT 0.1 sampling location. This may be attributable to natural sources; however, this subwatershed also had a high density of KPDES dischargers and may be indicative of a direct dry weather discharge with potentially-high dissolved solids.

Most Concerning	Likely Sources	Possible Causes
Bacteria (Wet Weather)	Stormwater runoff	Animal Waste
Suspended Sediment (Wet Weather)	Bank Erosion	Erosive Flows Unvegetated Banks
Specific Conductance (Dry Weather)	Point Sources?	Point Source Treatment

Least Concerning	Likely Reason	Prevented Pollutant
Bacteria (Dry Weather)	Sanitary Sewers	Human Waste

Figure 4-31: Water quality results in developed watersheds

2. Rural Watersheds

Next, rural watersheds (2-4% impervious) tended to be impacted more during dry weather, suggesting that direct sources of pollutants (e.g., septic systems and/or animals grazing in the stream) may be the predominant issue in these watersheds (Long Branch [LOB 0.5] and Riddles Run [RDR 1.1]). The most concerning pollutants identified in the rural watersheds included high levels of bacteria, nutrients, and specific conductance, all during periods of dry weather (Figure 4-32). This suggests potential pollution from sources, such as septic systems, livestock in the stream, and/or point sources such as KPDES permitted discharges.

Most Concerning	Likely Sources	Possible Causes
Bacteria & Nutrients (Dry Weather)	Septic Systems Animal (direct)	Septic maintenance Cattle/Horse Fencing
Specific Conductance (Dry Weather)	Septic Systems Point Sources?	Septic maintenance Point Source Treatment

Least Concerning	Likely Reason	Prevented Pollution
Nutrients (Wet Weather)	Fertilizer Management	Excess Algae

Figure 4-32: Water quality results in rural watersheds

3. Mixed Watersheds

Finally, mixed watersheds (rural/developed, 12% impervious – Fowlers Fork) showed signs of both dry-weather and wet-weather pollution. The most concerning pollutants, as summarized in **Figure 4-33**, include bacteria during wet weather as well as specific conductance and nutrients during dry weather. The least concerning pollutant was bacteria during dry weather. These results provide insights on some potential sources, such as stormwater runoff, septic systems, and/or animal waste.

Most Concerning	Likely Sources	Possible Causes
Bacteria (Wet Weather)	Stormwater runoff	Animal Waste
Specific Conductance (Dry Weather)	Septic Systems Point Sources?	Septic maintenance Point Source Treatment
Nutrients (Dry Weather)	Septic Systems Animal (direct)	Septic maintenance Cattle/Horse Fencing

Least Concerning	Likely Reason	Prevented Pollutant
Bacteria (Dry Weather)	Sanitary Sewers	Human Waste

Figure 4-33: Water quality results in mixed watersheds

Regulatory Matters

Regulatory matters should not impact the prioritization of subwatersheds because most of Gunpowder Creek is under the jurisdiction of the same agencies. SD1 and the City of Florence are responsible for the stormwater networks. KDOW, which is guided by the USEPA, governs the KPDES permits and overall condition of the waterways. The city and county ordinances are the same in all of the Gunpowder subwatersheds; and therefore, the ordinances do not impact prioritization. Other than the 303(d) status discussed under the section titled *Regulatory Status of the Waterway*, there is not any spatial prioritization regarding regulatory matters. Reference *Chapter 6.1 BMP Feasibility* for additional information regarding the regulatory matters in the watershed and how they impact successful implementation.

Stakeholder Cooperation

From vested stakeholder agencies who donate their time and resources to the general public, the Gunpowder Creek Watershed has the support of stakeholders who are interested in restoring the Gunpowder Creek. The GCWI Steering Committee involves several different public agencies including KDOW representatives. Throughout the entire project, the public has been actively involved by attending meetings and providing feedback regarding pollutants of concern and prioritizing problems and solutions. The GCWI has hosted 6 public meetings at various locations throughout the watershed, and many of these public meetings had 50 to 100 people in attendance. At these meetings the public has provided valuable insights regarding the most concerning problems and potential solutions. Many local citizens are worried about development and the associated stormwater runoff and flooding issues. Therefore, the developed subwatersheds have been prioritized as part of the Watershed Plan. Stakeholders understand that this is a problem and local landowners seem to be supportive in addressing the issues in all of the subwatersheds. The only exception to this seems to be somewhat of a lack of access in Long Branch, which could limit the ability of GCWI to implement solutions in that rural watershed. Reference Chapter *6.1 BMP Feasibility* for additional information regarding stakeholder involvement and cooperation in the watershed.

Political Will

Support from local officials impacts the entire watershed. Therefore, one particular subwatershed is not more influential than others and cannot be prioritized. Reference *Chapter 6.1 BMP Feasibility* for additional information regarding stakeholder involvement and cooperation in the watershed.

Available Funding

At this time, the GCWI does not have reasons to suspect that there are particular subwatersheds in which they might be able to garner more funds than others. GCWI is working to increase the stewardship of private companies located in the watershed in hopes to build partnerships and garner support for BMP implementation. Flood control master planning by SD1 and Florence typically result in large investments in a particular watershed and is discussed further in *Chapter 6.1 BMP Feasibility*.

Areas of Local Concern

Local citizens have expressed concern about development and the associated stormwater runoff and flooding issues. Flooding issues are commonly discussed at Fiscal Court meetings, and particular problem areas include Whispering Trails in developed headwater reaches of Fowler Fork, Conner Road in the developed headwater reaches of upper Gunpowder, and locations along the developed headwater reaches of the South Fork Gunpowder. As such, the developed headwaters of the Gunpowder Creek have been prioritized because these areas are of concern to the public. Additionally, there are plans for future development throughout several areas of the watershed, particularly in the Fowler Fork subwatershed as well as the South Fork Gunpowder subwatershed. Reference *Chapter 6.1 BMP Feasibility* for additional information regarding areas of local concern throughout the watershed.

Existing Priority Status

Past work has led to resources being spent in the Fowlers Fork subwatershed. With the goal of improving flood control, SD1 recently completed a Fowler Fork Master Plan. Additionally, the City of Florence is currently planning a flood control project behind Kroger/Florence Mall in the headwaters of the Gunpowder Creek called Pheasant Watershed. Lastly, there are several existing and proposed federal, state, and local water quality efforts that exist through entities such as USDA, USEPA, KDOW, USACE, etc. Reference Chapter *6.1 BMP Feasibility* for additional information regarding existing priority status throughout the watershed.

Watershed Management Activities

All of the watershed management activities that exist throughout the Gunpowder Creek Watershed are watershed wide. Therefore, the GCWI cannot prioritize any subwatershed over the others because of watershed management activities. Reference *Chapter 6.1 BMP Feasibility* for additional information regarding watershed management activities in the watershed.

Monitoring Considerations

The holistic monitoring program has not only been a guide in understanding problems and pollutant sources, but if continued, can help to track the success of the implementation efforts proposed in Chapters 5 & 6. It can also help to make BMP implementation more adaptable to conditions in the streams and changing land uses, sources, and the extent of stormwater mitigation throughout the watershed.

4.2.3 Phase 2 - Analysis

As previously mentioned, GCWI did not add sampling locations for Phase 2 monitoring in 2012 due to the project budget and KDOW-approved QAPP, that were developed before the *Watershed Planning Guidebook for Kentucky Communities* was released. Therefore, the Phase 2 monitoring program involved resampling all Phase 1 monitoring locations. Due to the nature of this monitoring program, the Phase 2 data analysis is presented as an integrated approach with Phase 1 data and included in sections *4.2.1 - Phase 1 and 2 Combined Data Analysis* and *4.2.2 - Phase 1 and 2 Combined - Prioritization*.

4.3 Other Analysis Options for Non-319-Funded Watershed Plans

With the exception of additional monitoring locations for Phase 2 monitoring, the GCWI had the budget and resources needed to perform a detailed data analysis. The holistic stream system assessments have provided the foundation for understanding and prioritizing pollutants and suspected sources. The monitoring results have also helped to educate the public and other stakeholders through public meetings and corresponding media coverage. Therefore, the monitoring program has not only played a role in understanding existing conditions, but also in promoting public stewardship.

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CHAPTER 5

Finding Solutions

Gunpowder Creek Watershed Plan

Prepared by the

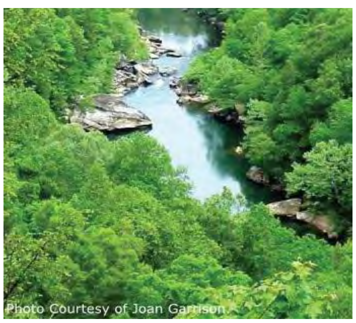
Gunpowder Creek Watershed Initiative

December 2014

Chapter 5: Finding Solutions

5.1 Overview of Best Management Practices

Methods which aim to mitigate water quality impairments via the efficient and effective use of available resources are referred to as Best Management Practices (BMPs). As outlined in the *Watershed Planning Guidebook for Kentucky Communities* (KDOW, 2010), there are two major categories of BMPs: structural and non-structural. Structural practices refer to those which are built on the ground and require construction, installation and maintenance, such as fencing, retention ponds, etc., while non-structural BMPs include less tangible practices, such as public education on water quality, stormwater ordinances, etc. A watershed management plan should include provisions for the implementation of both structural and non-structural BMPs, as they are equally important and often work best in tandem. Structural BMPs aim to treat targeted impairments in specific locations, while non-structural BMPs help to ensure the sustainability of water quality throughout the watershed and can improve the effectiveness and longevity of installed structural BMPs. This chapter will provide information on a range of BMPs, including the impairments they are designed to treat and the land uses for which they are expected to be most effective. **Figure 5-1** lists some examples of BMPs that may be used within the Gunpowder Creek watershed. In this section several details regarding BMP practices in the watershed are presented, including BMP options for specific land uses, regulatory programs, and education.



Healthy riparian zones help filter sediments and nutrients from runoff, stabilize streamside soils, and provide shade, food, and habitat for the aquatic systems and aquatic life of a waterway.

Rain gardens are shallow, depressed gardens that collect stormwater runoff from rooftops or other hard surfaces. These rain gardens help filter pollutants and act as beautiful landscape features.

Rain barrels collect and store stormwater runoff from rooftops. This water can then be used to irrigate gardens and lawns.

Fencing livestock out of streams and providing alternative water results in pathogen reduction, stream bank protection, and clean water for livestock.

Seeding or covering bare soil with mulch, blankets, mats, and other erosion prevention products as soon as possible is the cheapest way to prevent erosion. Grass seeding alone can reduce erosion by more than 90%.

Figure 5-1: Examples of structural BMPs

5.1.1 Best Management Practice Options for the Gunpowder Creek Watershed for Specific Land Uses

Prior to delving into the applicable BMPs for the Gunpowder Creek Watershed, it is worth discussing the unique circumstances of this watershed. As discussed in Chapter 4, the biggest problem within the watershed is inadequately managed stormwater runoff, which creates erosive flows that in turn lead to hydromodification concerns, including channel erosion, high concentrations of TSS, and other pollutant issues within the stream. The hydromodification problem is nearly watershed-wide but is most prominent in the developed watersheds. Due to the existing stream conditions and volume of stormwater generated from development in South Fork Gunpowder, it has been identified as the highest priority subwatershed.

As the Gunpowder Creek Watershed is an unconventional, large watershed that incorporates many land uses and anticipated continued growth, the priority subwatersheds may change as opportunities arise. To utilize spending as efficiently and effectively as possible, other subwatersheds may become higher priority during the implementation phase. The Riddles Run Subwatershed currently has a lot of agricultural activities; the Lower Gunpowder Creek Subwatershed is currently undeveloped; and as previously mentioned the South Fork Gunpowder is highly developed. Any of these subwatersheds, with the right combination of identified projects and additional funding sources may become the "low-hanging fruit;" and therefore, these three subwatersheds have been identified as GCWI's priority subwatersheds. We anticipate 319(h) grant funding to serve as a catalyst throughout the watershed, with the goal of combining the GCWI efforts with others' to improve stream benefits more than would be accomplished by GCWI alone.

The Watershed Planning Guidebook for Kentucky Communities (KDOW, 2010) provides a list of structural and non-structural BMPs categorized by land use. Categorization is based on the type of practice (structural vs. non-structural) and its associated land use. The data collection efforts and analysis described in Chapters 3 and 4, along with extensive stakeholder involvement and public input has allowed for a more specific and prioritized listing of potential BMPs for each land use, which will be addressed further in this chapter and in Chapter 6.

Many BMPs that help to prevent and mitigate water quality impairments have already been installed/implemented throughout the Gunpowder Creek Watershed, for example, conventional stormwater detention basins. However, the impairments documented in Chapter 4 indicate that the existing BMPs have not adequately protected stream integrity. Continued growth and urbanization, especially near the headwaters of Gunpowder Creek, Fowler's Fork, and South Fork Gunpowder Creek, are anticipated to further impair stream health. A strategic, watershed-scale BMP plan should yield benefits that promote stream stability, water quality, and healthy aquatic habitat. Below is a summary of types of BMPs, with some basic information on their current and potential uses within the watershed.

Stormwater

Stormwater BMPs have conventionally been designed for management of runoff for flood control with a primary focus on water quantity. This is typically achieved through the combination of storage and controlled release. Stormwater quantity-focused BMPs can have a positive impact on pollutant removal as well, through the settling out of particulate matter, extended exposure to sunlight, and nutrient uptake via contact with vegetation. These water quality benefits can be enhanced by creating increased residence time, infiltration, and other treatment processes in the design of BMPs, for example, building bioinfiltration basins (**Figure 5- 2**), wetlands, or extended/optimized detention basins as opposed to conventional detention basins.

Figure 5-2: Bioinfiltration basin with native vegetation designed by Strand Associates to promote a more natural flow regime (Photo by Chris Rust)

Another broad-scale stormwater BMP that is currently being used in the Gunpowder Creek Watershed is flood control master planning. Even with an estimated 535 existing detention basins within the watershed, flooding is perceived to be problematic in several areas. The City of Florence and the Sanitation District No. 1 of Northern Kentucky (SD1) routinely plan and conduct large efforts to improve regional flood management. These efforts typically require extensive hydrologic and hydraulic monitoring and modeling and tend to be expensive in comparison to the Gunpowder Creek Watershed Plan BMP analysis. For example, the costs of two recently performed studies commissioned by SD1 (Fowler Fork Master Plan) and the City of Florence (Pheasant Watershed Study) cost ~$175,000 and ~$85,000, respectively, for the planning alone. These costs do not include the costs to construct the recommendations. Stormwater BMPs will be implemented where opportunities arise. However, the implementation efforts for these types of BMPs will be concentrated in the developed subwatersheds, particularly the priority subwatershed of South Fork Gunpowder.

Agricultural

Agricultural BMPs include practices that are designed to mitigate the effects of pesticides, fertilizers, animal waste and other potential pollutants that can be associated with farming and may be harmful to the streams. They aim to maintain or even enhance the productivity of agricultural land, while benefitting water quality, channel stability, and/or habitat. Some BMPs that are currently in use within the Gunpowder Creek Watershed are livestock exclusion fencing, rotational grazing with pasture renovations, and animal feeding buffers. Currently, farmers within the Gunpowder Creek Watershed have available incentive programs for manure management and riparian buffer strips, as well as the Ohio River Basin Water Quality Trading Pilot Project, which encourages nutrient trading in collaboration with the Electric Power Research Institute and the American Farmland Trust. Additionally, the Environmental Quality Incentives Program (EQIP) run by the U.S. Department of Agriculture (USDA) incentivizes environmental stewardship by offering financial and technical assistance to those farmers that implement conservation practices that address natural resource concerns, such as conservation tillage, nutrient management, conservation coverage, field buffers, and riparian buffer strips. Interested farmers should contact NRCS or BCCD for more information. As the priority agricultural subwatershed, the GCWI will focus implementation of these types of BMPs in the Riddles Run Subwatershed.

Construction

Figure 5-3: Kentucky's Field Guide to Erosion Prevention and Sediment Control (KDOW)

These BMPs are designed to prevent sediment and other pollutants from leaving construction sites. Practices include silt fences, check dams, temporary entrances, erosion control blankets, inlet and outlet protection, etc. The *Kentucky Erosion Prevention and Sediment Control Field Guide* (**Figure 5-3**), produced by KDOW (2004), contains guidance for controlling erosion and sedimentation associated with construction sites. The University of Kentucky has also released a publication entitled *Best Management Practices (BMPs) for Controlling Erosion, Sediment, and Pollutant Runoff from Construction Sites* that provides similar guidance (UK, 2009).

As part of their Storm Water Rules and Regulations (2011), SD1 requires BMPs on all active construction sites that are larger than one acre or part of a larger development. Reviews of submitted plans and site inspections are completed to ensure compliance, per their Kentucky Pollutant Discharge Elimination Program (KPDES) Storm Water Management Plan (SWMP) (SD1, 2010). The City of Florence has an inspection program as well, which conducts site visits to check on erosion protection BMPs. As one of the fastest growing counties in Kentucky prior to the 2007-2011 economic recession, diligence regarding construction BMPs is extremely important for water quality in Gunpowder Creek, and SD1 and the City of Florence's emphasis on proper erosion protection and sediment control at construction sites is anticipated to continue throughout the entire Gunpowder Watershed.

Forestry

Forestry BMPs aim to protect downstream water bodies from runoff polluted by forestry activities and to promote the sustainability of forestry resources. Landowners may look to *The Kentucky Forest Landowner's Handbook* for guidance on good forestry practices that protect the value of the forest and its natural resources such as streams and wildlife (MACED, 1998). Forestry is not considered to be a dominant activity in the watershed; however, numerous local experts have identified the region's tree canopy deficiency as a cause for concern, from stormwater runoff and riparian shade to hillslope stability and the urban heat island effect.

GCWI is working with resources from the Kentucky Division of Forestry, the Northern Kentucky Urban Forestry Council, and the Boone County Urban Forest Commission to:

1) Understand if any improvements can be made on local forestry practices, and
2) Facilitate partnerships to promote reforestation, especially along stream riparian zones and on steep slopes.

As an initial step in the riparian/reforestation prioritization, BCCD's joint agency meeting in March 2014 included a panel discussion on forestry. During this meeting they discussed the local need for forestry conservation and decided to work this issue into BCCD's long range plans. Additionally, riparian reforestation will be a central component of the forestry conservation efforts.

Onsite Wastewater Treatment

Bacteria and specific conductance impairments observed during dry weather periods within the Gunpowder Creek Watershed are an indication of potentially faulty septic and/or sanitary sewer systems. Onsite wastewater treatment BMPs can help to prevent these issues by helping to ensure proper installation and maintenance of these systems. Some available online resources include the *Kentucky Onsite Wastewater Association Homeowner's Guide* (KOWA, 2001) and the *EPA Handbook for Managing Onsite and Clustered (Decentralized) Wastewater Treatment Systems* (EPA, 2005).

Both sanitary sewers and septic systems are present within the Gunpowder Creek Watershed. Less than seven percent of the parcels in the Gunpowder Creek Watershed, or an estimated 1,527 parcels, are assumed to be serviced by septic systems, as determined by those parcels with a building that do not have an active sanitary account with SD1 (Kaeff, 2014a, Pers.Comm.). **Figure 5-4** presents the locations of these septic systems throughout the watershed, and it can be seen that the majority of these parcels are in the undeveloped and rural subwatersheds, which include Lower Gunpowder Creek, Middle Gunpowder Creek, Long Branch, and Riddles Run. Faulty septic systems are regulated by the Northern Kentucky Health Department, which estimates that potentially up to ten percent of the septic systems in Northern Kentucky could be operating improperly. However, the health department does not have a record of failure rates specific to Boone County (LTI, 2009). Therefore, assuming that up to ten percent of the septic systems in the Gunpowder Watershed could be malfunctioning; approximately 153 systems could be working improperly throughout the watershed. Reference Table 5-1 for a breakdown of the approximate number of parcels served by septic systems as well as the number of potentially faulty septic systems. In regards to our priority rural and undeveloped subwatersheds where the septic systems are the most prevalent, 164 of the septic system parcels are located within Riddles Run (up to 16 of the septic systems could be faulty) and 43 of the septic system parcels are located within Lower Gunpowder (up to 4 of the septic systems could be faulty). The Northern Kentucky Health Department issues permits and conducts inspections on septic systems through its on-site sewage program.

Table 5-1: Parcels served by septic systems within the Gunpowder Creek Watershed and the number of potentially faulty septic systems by subwatershed

Subwatershed	Approximate Number of Parcels with Septic Systems	Number of Potentially Faulty Septic Systems[1]
Riddles Run[2]	164	16
Long Branch	98	10
Upper Gunpowder	103	10
Middle Gunpowder	489	49
Lower Gunpowder[3]	43	4
South Fork Gunpowder	494	49
Fowlers Fork	136	14

[1]The number of potentially faulty septic systems is likely an overestimate because the Northern Kentucky Health Department expects that up to ten percent of the septic systems (LTI, 2009) throughout the Northern Kentucky region could be faulty.

[2]Riddles Run is the priority rural subwatershed.

[3]Lower Gunpowder is the priority undeveloped subwatershed.

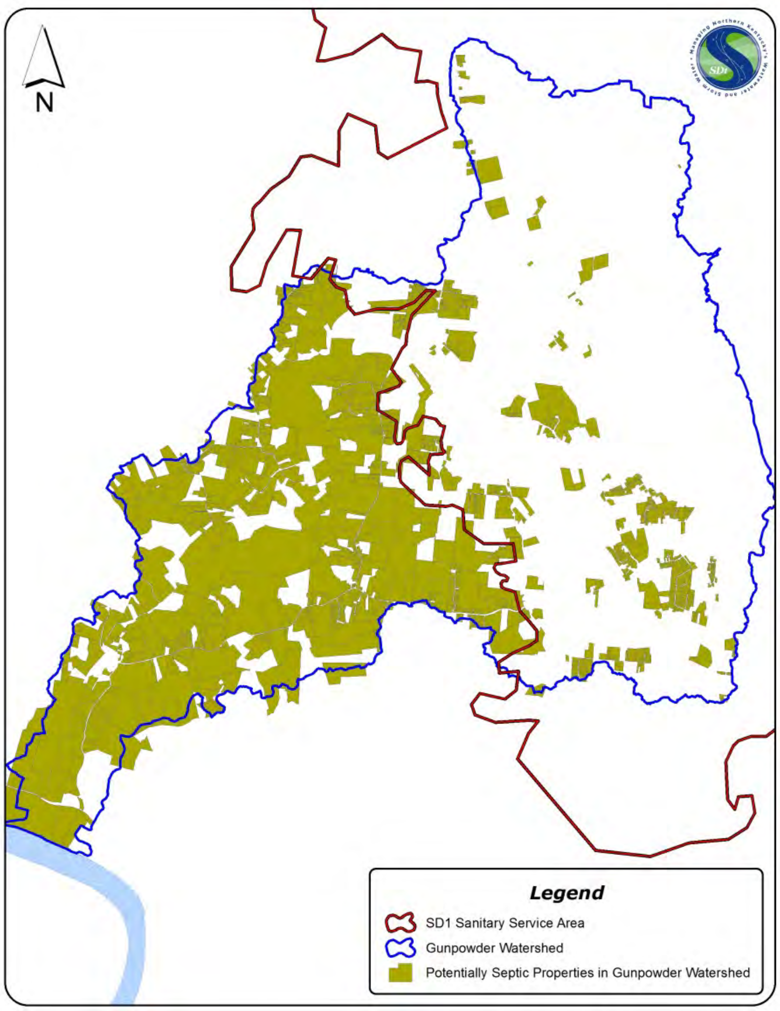


Figure 5-4: Septic systems within the Gunpowder Creek Watershed (Kaeff, 2014, Pers.Comm.)

As mentioned in Chapter 4, the largest source of bacteria is expected to be stormwater runoff. However, failing septic systems could be a contributor to the bacteria issues in the rural subwatersheds, as *E.coli* concentrations were elevated during dry, base-flow conditions. Onsite wastewater treatment BMPs and septic system improvement programs could be implemented in the prioritized undeveloped and rural subwatersheds, Lower Gunpowder and Riddles Run. Furthermore, a benefit to urbanization includes the installation of sanitary sewers. It should be noted that any efforts related to faulty septic systems should only occur in areas where development is not likely to occur in future years. As it is not possible to know exactly where future development will occur, anticipated development, indicated by darker gray shading in **Figure 5-5**, seems more likely in the headwater portions of the watershed. GCWI will coordinate with SD1 to better understand any plans for future expansion of SD1's sanitary sewer service area.

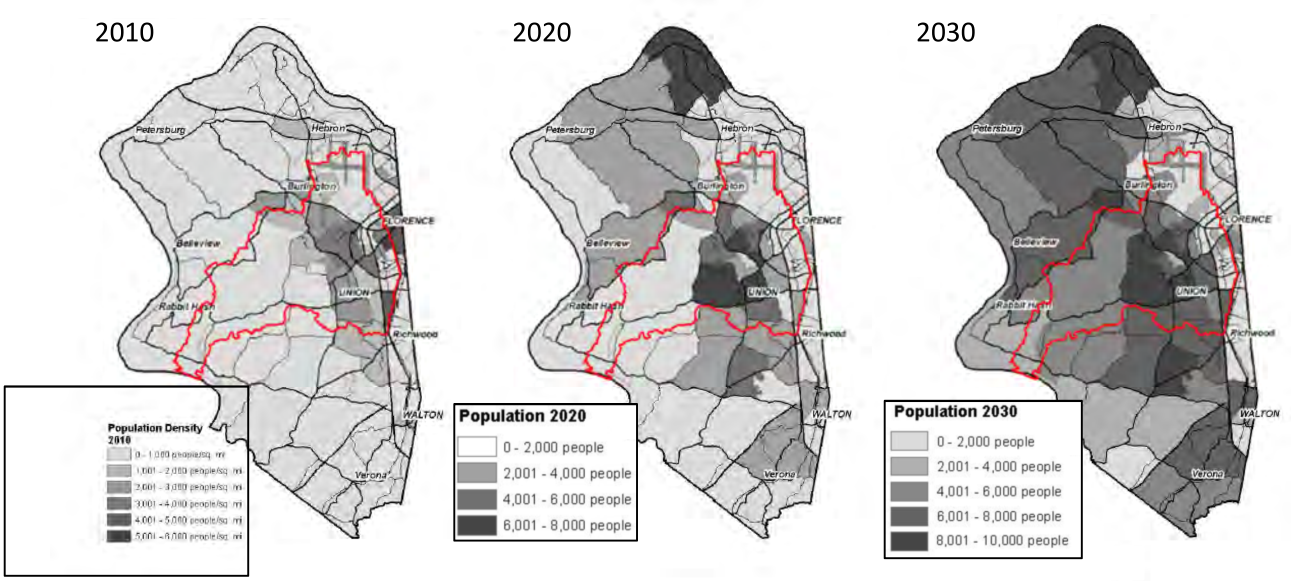


Figure 5-5: Development progression in Boone County from 2010 to 2030 (BCCD, 2012)

5.1.2 Regulatory Programs

Kentucky currently has several regulatory programs that enforce general requirements to promote water quality. It is important to understand the existing regulatory programs and how such programs might impact water quality throughout the Gunpowder Creek Watershed. It is also important to ensure coordination to avoid implementation overlap with regulatory requirements and maximize resources and BMP effectiveness.

Source Water Protection Plans, Wellhead Protection Program, and Groundwater Protection Plans

The source of the public water supplies in the Gunpowder Creek Watershed is the Ohio River via the Boone County Water District. Although the confluence of Gunpowder Creek and the Ohio River is downstream of the local water treatment plant intake, the January 2014 spill of 4-methylcyclohexane methanol in the Elk River upstream of Charleston, West Virginia reminds us of the impacts that poor watershed stewardship can have on drinking water supplies. There are countless communities downstream on the Ohio and Mississippi Rivers whose water supplies could be affected by poor watershed stewardship in Gunpowder Creek. More locally, information indicates that several rural areas in the Gunpowder Creek Watershed still rely on rural water sources such as wells, cisterns, or delivery. This includes the rural, undeveloped subwatersheds of Lower Gunpowder Creek, Riddles Run, and the majority of Long Branch and Middle Gunpowder Creek. For anyone on a well, poor watershed stewardship could directly impact their source water **Figure 5-6** highlights the locations within Gunpowder Creek that are serviced by public water supplies.

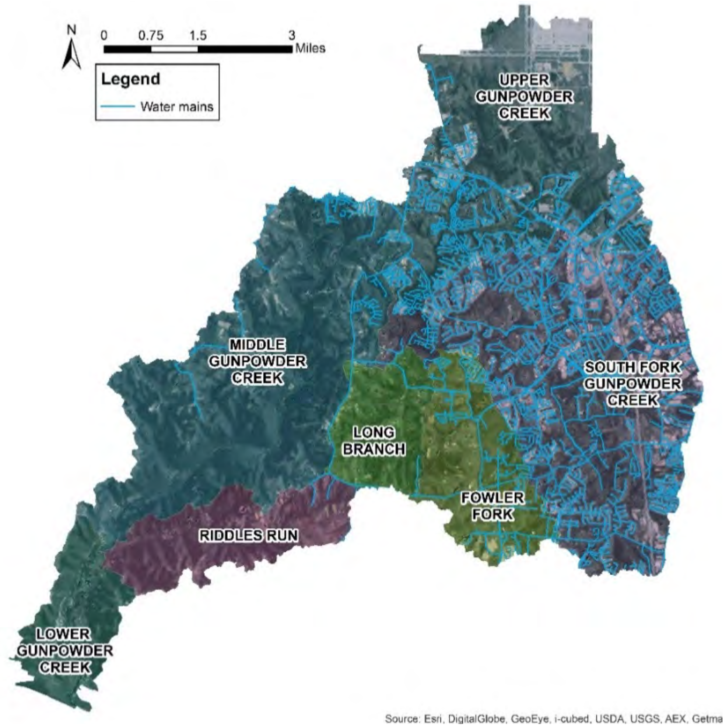


Figure 5-6: Water main locations within Gunpowder Creek

Agriculture Water Quality Plans

All agriculture and silviculture farms on ten or more contiguous acres are required to develop and implement water quality plans (KDOW, 2010). Agricultural agencies, extension offices, and conservation districts can provide assistance to farmers to help them develop and implement plans that are specific to their farms and comply with the Kentucky Agriculture Water Quality Act. The goal of the plans is to prevent or address any potential water quality impacts that would be created by the farming practices. BCCD reports that there are 102 water quality plans, along with 553 certifications on file at their offices. BCCD plans to coordinate with the farmers and work together to evaluate and review the quality of these plans.

Regulations/Programs for Wetlands and In-stream Construction or Disturbance

Over the last couple centuries, wetland loss and degradation has been a serious issue across the nation. In the contiguous United States over half of the original wetlands have been developed or converted to other uses (EPA, 2013). More specifically, between the 1780s and 1980s the EPA has reported that on average the contiguous United States was losing wetlands at a very rapid rate of approximately 60 acres every hour (Dahl, 1990). In recent decades the USEPA and the US Army Corps of Engineers have implemented programs to protect existing wetlands and encourage wetland restoration. Currently, streams and wetlands are federally protected jurisdictions, and construction activities within their boundaries require both a Federal 404 permit from the US Army Corps of Engineers and a State 401 water quality permit from KDOW. Permanent impacts typically require commensurate restoration of degraded streams or construction of new wetlands and/or fees to be paid in lieu of restoration. The fees fund a stream and wetland restoration program that is directed by the US Army Corps of Engineers and administered locally by the Northern Kentucky Stream and Wetland Restoration Program at Northern Kentucky University's Center for Environmental Restoration (CER). The CER has been very successful in restoring wetlands and stream systems throughout Northern Kentucky. As an active partner in the Gunpowder Creek Watershed Plan, the CER has funded and directed the restoration of several streams and wetlands in the region (**Figure 5-7**). There are currently approximately 0.89 square miles of wetlands throughout the Gunpowder Watershed. The approximate area of wetlands in each of the subwatersheds is summarized in **Table 5-2**, and the number of wetlands that have been disturbed is unknown. However, the GCWI has no reason to suspect that the Gunpowder Creek Watershed has been immune from wetland loss, as experienced throughout the rest of the nation. The GCWI plans to continue to work with the CER to preserve these wetland areas and promote the restoration of wetlands throughout the priority subwatersheds. Furthermore, the GCWI is planning to implement benchfull wetlands as a stormwater BMP to help mitigate the erosive flow regime.

Figure 5-7: Native riparian restoration zone at Boone Woods Park as a part of the stream and wetland mitigation project by NKU CER (Photo by Bob Hawley)

Table 5-2: Wetland areas within the Gunpowder Creek Watershed by subwatershed

Subwatershed	Approximate Wetland Area (square miles)
Riddles Run (upstream of RDR 1.1)	0.02
Long Branch (upstream of LOB 0.5)	0.03
Upper Gunpowder (upstream of GPC 17.1-UNT 0.1)	0.05
Middle Gunpowder (upstream of GPC 4.6)	0.36
Lower Gunpowder	0.17
South Fork Gunpowder (upstream of SFG 2.6)	0.21
Fowlers Fork (upstream of FWF 0.8)	0.05

Regulations for Floodplain Construction

Floodplains are an important part of maintaining overall stream health. These areas serve as a natural filter strip for overland flow that drains to the stream, settling out particles in stormwater runoff. It is beneficial to keep construction activities and development outside the floodplain so that these natural processes can occur unhindered. Construction within Kentucky's floodplain areas typically requires a permit from the KDOW Floodplain Management Section of the Surface Water Permits Branch. The Gunpowder Creek Watershed has 2.9 square miles of area that lies within the 100-year floodplain, with 0.36 square miles being located within South Fork Gunpowder (nearly 54% of the total subwatershed area). Riddles Run has only 0.10 square miles of 100-year floodplain area (2%), whereas Lower Gunpowder Creek has 1.07 square miles (34%). Since March 2003, KDOW has received 48 permit applications for activities within the floodplain in the Gunpowder Creek Watershed. South Fork Gunpowder Subwatershed has had the most with 12 applications, Riddles Run has had two applications, and Lower Gunpowder Creek has had two applications. There are three currently effective floodplain permits: one in the South Fork Gunpowder Subwatershed, one in the Long Branch Subwatershed, and one in the Riddles Run Subwatershed.

Certain BMPs, such as benchfull wetlands, may be useful to implement within a floodplain, yet may require a permit. GCWI plans to evaluate the feasibility of obtaining a single, generic permit for these activities to expedite the process. Whereas most projects completed in a floodplain would exacerbate flooding issues, applicable BMPs would improve the conditions in the floodplain.

Facility Plans for Wastewater

SD1 is the operator of the regional wastewater treatment plants and maintains all of the facility plans. SD1 is an active partner on the GCWI Steering Committee and SD1's plans for sewer line extensions, treatment plant upgrades, etc. are widely discussed in the local media and with other members of the Steering Committee. The area within the Gunpowder Creek Watershed that is serviced by these treatment plants is displayed in orange and yellow in **Figure 5-8**. As discussed in the *Onsite Wastewater Treatment* section above, outside this area is where septic systems are predominately found. Moving forward, GCWI plans to coordinate with residents, developers, SD1, and BCCD to ensure that any septic system outreach activities do not take place in areas where sewer line extensions are planned in the near future. Future outreach will continue to be coordinated as outreach programs are developed to optimize the locations of these activities, but will be directed towards the priority subwatersheds of Riddles Run and Lower Gunpowder Creek. SD1's Sanitary Sewer Rules and Regulations (2013) require the use of sanitary or combined sewers where available in addition to requiring abandonment of a private disposal system if a public system becomes available. Based on Boone County's *2010 Comprehensive Plan*, there is little anticipation that Lower Gunpowder Creek will be developed by 2030. Middle Gunpowder Creek and Riddles Run are also less likely to be developed than in headwater subwatersheds. GCWI hopes to promote conservation practices in the undeveloped portions of the watershed throughout Lower Gunpowder Creek.

As mentioned above, the Northern Kentucky Health Department has not reported any septic system failures specific to Boone County, and it is unknown at the current time where, if anywhere, plans exist to fix faulty septic or sewer systems. However, if onsite wastewater treatment BMPs are implemented in the watershed, GCWI would first evaluate this in the priority rural subwatershed, Riddles Run.

GUNPOWDER CREEK WATERSHED

Sanitary Sewer & Storm Water Service Areas

SD1 Service Area

Separate sanitary

Storm water beyond sanitary service areas

Florence Service Areas

Separate sanitary

Storm water beyond sanitary service areas

Figure 5-8: Sanitary sewer & stormwater service areas within the Gunpowder Creek Watershed (LTI, 2009)

Programs and Permits for Managing Wastewater Discharges

SD1 also maintains the corresponding permits and programs required to discharge the region's treated wastewater into the Ohio River. Including SD1's permitted discharges, there are 93 KPDES discharge locations along the 143 stream miles in the Gunpowder Creek Watershed. On average, this equates to one KPDES discharge ever 2 ¼ miles of stream; however, the density of KPDES discharges tends to be higher in the developed headwaters. For example, an unnamed tributary to South Fork Gunpowder Creek, located in the headwaters of the watershed, has the highest concentration of impervious surfaces of all study sites in the Gunpowder Creek Watershed (41% imperviousness), draining a stretch of the Interstate 71/75 corridor, along with a highly industrialized area along Weaver Road (KY-842), Empire Drive, Bluegrass Drive, and Dixie Highway (US-25). It also has more than double the density of KPDES permits than all other subwatersheds, with 13 permitted discharges over just 6.1 stream miles, averaging more than two KPDES discharges every mile (**Figure 5-9**).

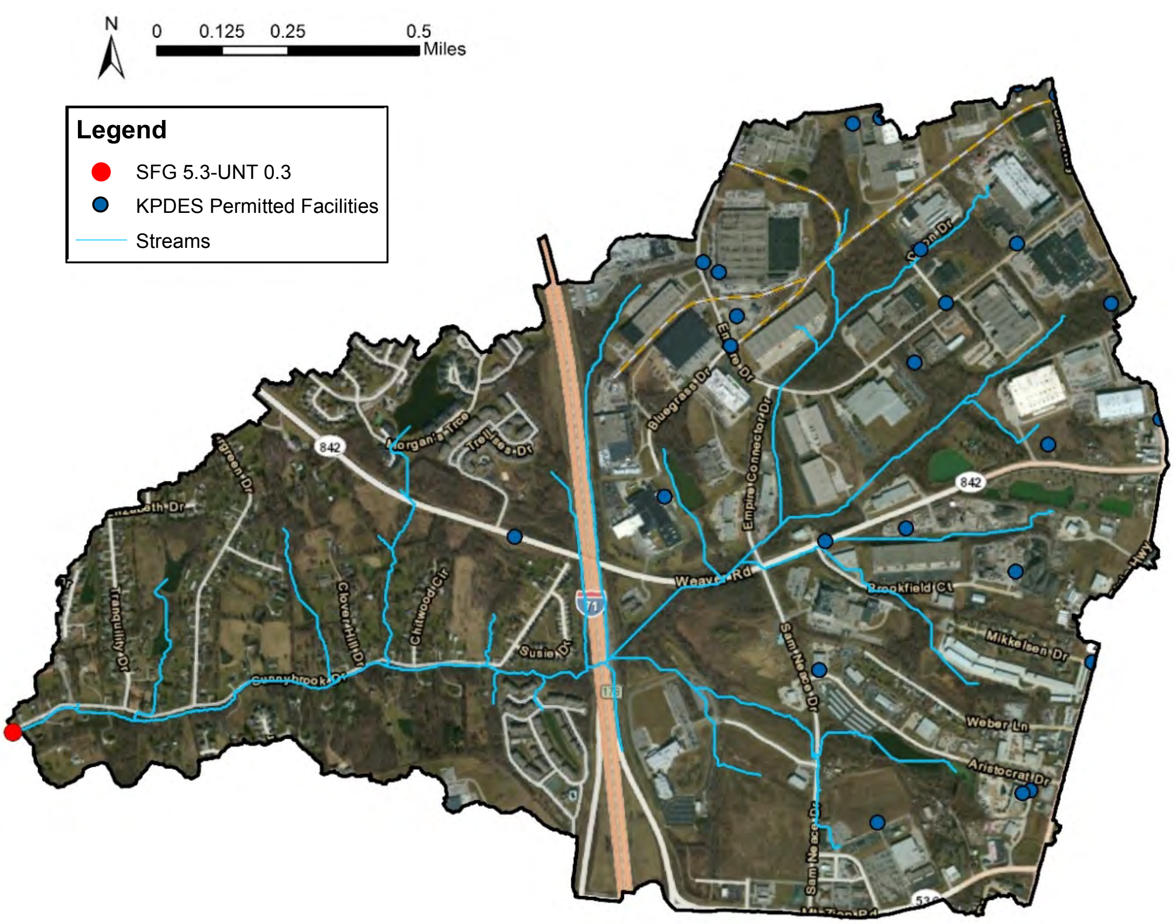


Figure 5-9: Unnamed tributary to South Fork Gunpowder Creek at SFG 5.3-UNT 0.3, highlighting KPDES discharge permits

As discussed in Chapter 4, specific conductance had a positive relationship with the number of KDPES permits per mile of stream. It would be prudent to have KDOW evaluate these permits and their discharges. While conductance is expected to be high in Northern Kentucky, this step should identify any glaring items that should be addressed with the permittees.

Programs and Permits for Managing Stormwater Discharges

SD1, the City of Florence, and the Kentucky Transportation Cabinet (KYTC) are the three major municipal stormwater permittees in the Gunpowder Creek Watershed and maintain the corresponding Municipal Separate Storm Sewer System (MS4) permits and programs required to discharge stormwater into the Gunpowder Creek stream network. Other major stormwater dischargers, such as the Cincinnati/ Northern Kentucky International Airport, are co-permittees with other agencies, such as SD1.

MS4 stormwater permits require six minimum controls, including:

- Public education/outreach
- Public involvement/participation
- Illicit discharge detection and elimination
- Construction site runoff control
- Post-construction stormwater management for new and redevelopment
- Pollution prevention/good housekeeping

All of the major stormwater dischargers are active members of the GCWI Steering Committee and openly share the activities of their stormwater programs. All parties are working toward the goal of improved stream integrity; however, it should be made clear that none of the activities funded by the 319(h) program have been reported by the project partners on their MS4 permit reporting.

Programs and Permits for Managing Combined Sewer Overflow (CSO) and Sanitary Sewer Overflow (SSO)

SD1 is the operator of the region's combined and sanitary sewers and has a Consent Decree that requires mitigation of the region's overflows. There were several SSOs in the Gunpowder Watershed, including the Kentucky Aire Pump Station, Gunpowder Pump Station, South Hampton Pump Station, Gamon Calmet Pump Station, Union Pump Station, and Manhole #2410387 (near the Oakbrook/Holbrook intersection). Some of the improvements required by the Consent Decree in the Gunpowder Creek Watershed have recently been constructed and the corresponding overflows have been reduced. This may have even been apparent in the water quality data. As mentioned in Chapter 4, the timing of the completion of construction activities indicates that it is possible that the high *E.coli* loads in the headwaters of the main branch, South Fork Gunpowder, and Fowler Fork during the three wet-weather sampling events in 2011 may have been partially attributable to sewer overflows that have since been partially mitigated. One of the largest and most impactful projects has been the tunnel to the Western Regional Wastewater Treatment Plant (WWTP), which cost ~$125 million, but has helped to reduce CSOs and SSOs throughout much of SD1's service area, including within the Gunpowder Creek Watershed. SD1's model indicates that the Western Regional WWTP improvements have had a substantial impact on water quality in the Gunpowder Watershed. Many of the SSOs listed above have been completely eliminated. More specifically, there were four SSOs that were completely eliminated and one that was significantly reduced after the Western Regional WWTP was upgraded. Modeling for

2013, the first full year with improvements, has shown that the four eliminated SSOs reduced 8.43 MG of annual SSO volume, while a reduction of 3.24 MG was achieved at the location of the reduced SSO (Kaeff, 2014b, Pers.Comm.). While the SSO at Manhole #2410387 is still considered to be active, it has been greatly reduced and is a candidate for removal from the SSO list in 2014.

Special Land Use Planning or Existing Watershed Plans

The Boone County Planning Commission works to develop the county's comprehensive plans, zoning regulations and subdivision regulations, perform studies, and evaluate the planning of proposed development projects, many of which are available on their website (BCPC, 2014). Those plans are actively reviewed and commented on by members of the GCWI Technical Committee. The Boone County Planning Commission is an active member of the GCWI Steering Committee. Their office led the writing of several chapters of this document and their GIS Department created nearly all of the mapping that is included in this Watershed Plan.

Boone County has large tracts of publicly-owned land (**Figure 5-10**). It is unknown whether any of these large open areas have associated special land use planning; however, preserving large undeveloped areas is one of the most cost-effective strategies to protect water quality (CWP, 2013). Beyond the existing publicly-owned lands, BCCD coordinates with the Boone Conservancy, an independent nonprofit organization, regarding plans for future land acquisitions. Forested hillslopes and the forested riparian corridor along Lower Gunpowder perform numerous protective services to Gunpowder Creek and are likely a primary reason why the macroinvertebrate communities at GPC 7.5 are not as impaired as the upstream sites. Ensuring that the forested riparian corridor remains intact along Lower Gunpowder is an important goal for maintaining and improving aquatic health. Preserving and acquiring land within the watershed, whether it be publicly-owned land or other available land, is a beneficial strategy for overall watershed health and many options exist to advance these efforts. The GCWI hopes to acquire and preserve some of this land as part of its implementation strategy discussed in Chapter 6. The Watershed Coordinator would lead these efforts.

At least one prior watershed study exists for the Gunpowder Creek Watershed, a Watershed Characterization Report developed by LTI (2009) on behalf of SD1, which was used throughout the data analysis and other sections of this Watershed Plan document. This report presented no action items for the watershed, but was used as the building block for many other sections of this document.

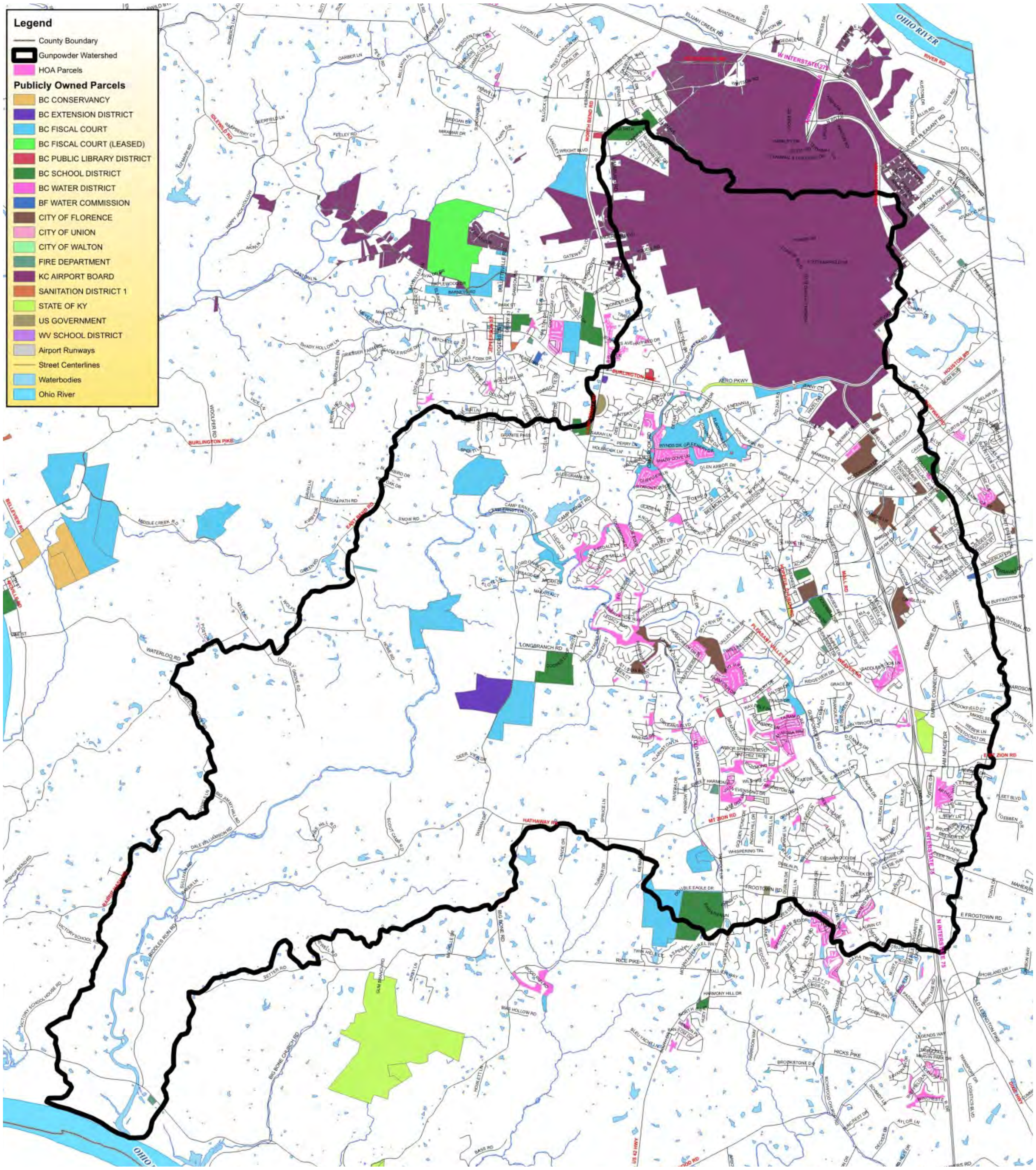


Figure 5-10: The Gunpowder Creek Watershed has large tracts of publicly-owned properties that could be targeted for conservation and/or BMP implementation (see Appendix 5-A for a 24x36 version)

5.1.3 Education as a Best Management Practice

Education and outreach programs can be effective non-structural BMPs to engage and educate the public within the watershed community. The GCWI has a multi-pronged educational strategy to engage the community and teach them about the pollutants of concern, potential sources of pollutants, and solutions to improve the condition of the streams throughout Gunpowder Creek. Education efforts have already begun in the Gunpowder Creek Watershed. Articles have been included in the *Landscapes* and *What's Happening* newsletters, which are publications distributed by the Boone County Conservancy. KDOW's report card of the watershed, along with a hydromodification summary document have been distributed to residents, and dissemination will continue. Displays have been posted, and props have been used at meetings. For example, the concept of detention basin retrofits was presented at a public meeting, and in addition to learning about this BMP strategy, the community was fortunate to see and touch a prototype example of the retrofit device. These methods and documents have already been developed and have received good feedback, and will continue during implementation. For example, the GCWI will include project updates in the widely circulated, *Landscapes* and *What's Happening* newsletters.

Figure 5-11: Effective signage and social marketing campaigns can raise public awareness about pollutants (CWC, 2006)

To educate the community on behavorial changes that will make a difference in the integrity of the watershed, the GCWI has created a Public Summary Outreach document that provides a succinct overview of this Watershed Plan and educates the community on the results of the data analysis as well as future implementation goals. The GCWI plans to distribute this document to the local community throughout the implementation phase of the project.

Furthermore, installation of signage about pollutants (*e.g.*, **Figure 5-11**), watershed health, and watershed stewardship near water bodies and near projects on public land is another way to raise public awareness. The GCWI plans to prioritize BMP implementation toward properties with greater public visibility and include educational signage in order to increase public awareness. For example, ponds located on public lands such as parks or schools will be a priority because of their greater visibility and potential education opportunities. Pet waste programs are an example of education as a BMP. Effectively implemented pet waste programs that provide facilities such as well-stocked bags and convenient trash receptacles at popular dog walking areas are some of the most cost-effective stormwater management programs that have been documented (CWP, 2013). Education and training for designers, managers, and contractors may also be beneficial, given the complexity of some of the dominant impairments in the Gunpowder Creek Watershed such as stormwater-induced bank erosion/TSS. Finally, producing videos on necessary behavioral changes and including them on social media and the BCCD website may also bring change. Such educational videos and project updates will be provided through social media and on the Boone County Conservation District's website.

5.2 Selecting Best Management Practices for the Prioritized Subwatersheds of the Gunpowder Creek Watershed

The following sections synthesize the previous contents of the plan, from land use and geology to water quality pollutant levels and suspected sources, into a tailored BMP strategy for the Gunpowder Creek Watershed prioritized subwatersheds. As the BMPs and subwatersheds are outlined, it is imperative to remember that as projects arise during implementation, the priority watersheds and seemingly most cost-effective BMPs may change. The GCWI plans to work with regional partners to implement sustainable projects as opportunities arise to work together towards more cost-effective and holistic solutions. Again, the GCWI would like to emphasize the following priority subwatersheds:

- Developed: South Fork Gunpowder
    - Selected because of high imperviousness, possibility of future expansion, and TSS as the most concerning pollutant
- Undeveloped: Lower Gunpowder
    - Selected because of high amounts of undeveloped land
- Rural (Agricultural/Forestry): Riddles Run
    - Selected because of agricultural activities and low imperviousness. This subwatershed was selected over the other rural subwatershed, Long Branch, because of feasibility factors, including lack of access along Long Branch.

While these three watersheds have ranked as highest priority, it is critical to underscore that a key component of the GCWI's implementation strategy is to utilize spending as efficiently and effectively as possible; and therefore, the priority watersheds could change with additional information gained as the GCWI moves into the implementation phase of the project. The GCWI plans to use 319(h) grant funding as a catalyst to work with stakeholders and regional partners to incorporate goals of stream channel protection and water quality into projects throughout the watershed.

5.2.1 Selecting BMPs for the South Fork Gunpowder (Predominantly Developed Area of the Gunpowder Creek Watershed)

To begin, the headwaters of the Gunpowder Creek Watershed are heavily developed and some areas are likely to continue to experience growth. South Fork Gunpowder has been identified as the developed priority subwatershed. Water quality monitoring efforts, presented in Chapter 4, have shown that the most concerning pollutant in the streams of the developed subwatersheds is total suspended solids (TSS). The primary source of TSS is suspended sediment that is likely attributable to streambank erosion. Streambank erosion is a natural process; however, developed watersheds tend to erode the streambanks much more than undeveloped watersheds due to the excess runoff that is generated by impervious surfaces and released from stormwater systems at more erosive rates. More details regarding bank erosion as the primary source of TSS in the Gunpowder streams can be found in **Appendix 5-B**.

Stormwater Volume-Based BMPs

Figure 5-12: Detention basin retrofit outlet structure with bypass, located at Toyota pilot project in Burlington, KY (Photo by Rajib Sinha)

In order to mitigate the erosive, urban flow regime, stormwater volume-based BMPs will be implemented in the developed areas of the Gunpowder Creek Watershed. This includes detention basin retrofits (**Figure 5-12**), new detention basins, and bioretention basins. Conventionally-designed detention basins are contributing to the problem of the erosive flow regime in that small events, (e.g., any storm event less than the 2-year storm) are not detained in the basin, as regulations do not require it. These more frequent storms typically allow excess stormwater runoff to cause more erosion downstream than under pre-developed conditions. However, these same BMPs can play a major role in improving the health of Gunpowder Creek. Retrofitting these existing assets to better match natural rates of stream erosion is one of the most important and cost-effective volume-based BMP strategies that can be implemented to reduce the erosive power of stormwater runoff and thereby reduce sediment pollution from bank erosion. These same kinds of BMPs that are optimal for reducing the volume and rate of stormwater runoff are also some of the best BMPs for reducing other pollutants of concern such as bacteria and phosphorus. Preliminary estimates predict that reducing stormwater release rates to the extent that bank erosion is reduced to more natural rates will inherently reduce bacteria and phosphorus loads to more acceptable levels. In addition to optimizing existing detention basin storage, new detention and bioretention basins can assist in providing additional water quality benefits and mitigating erosive flows in the developed subwatersheds. A complete analysis of the existing detention basins, opportunities to optimize existing detention, and additional/new storage needed in Gunpowder Creek has been included in **Appendix 5-C**. This strategy will also have direct benefits for stream habitat and aquatic ecosystems by better matching the pre-developed flow regime of the stream bed and, consequently, improve the conditions for macroinvertebrates that make their homes on the streambed. **Table 5-3** presents a summary of the estimated storage needed for channel protection throughout the Gunpowder Watershed.

Table 5-3: Storage estimates for Gunpowder Creek watershed upstream of gage location, approximately at GPC 14.7

Estimated Storage Needed To Achieve Channel Protection in Gunpowder Creek Watershed based on Gage Location[a]

Drainage Area	Imperviousness	Storage Target[b]	Existing Detention Basins[c]	Estimated Existing Storage[d]	Estimated Storage Shortage	Potential Additional Storage from Retrofits[e]	Potential Additional Storage from New Basins[f]
sq mi	*%*	*acre-ft*	*number*	*acre-ft*	*acre-ft*	*acre-ft*	*acre-ft*
36.6	22.6	935	535	749	186	15	171

[a]gage location is close to the confluence of the three main branches that drain the developed headwaters of Gunpowder Creek. As one moves farther downstream from that location, development intensity decreases

[b]sum of interpolated subwatershed storage targets, based on Pleasant Run, Qcritical Memo, and Toyota Retrofit data

[c]based 285 basins in the SD1 GIS layer and 250 in Florence (J.Hunt, Pers. Comm.). Assumes the 50 basins that were recently transferred from Boone County to SD1 were already included in the SD1 GIS database

[d]applies average detention basin storage volume of 1.4 acre-ft based on a subset of 8 N.Ky detention ponds from the SD1 Rules and Regs Technical Subcommittee (Dec. 2008)

[e]assumes 10% of the 535 existing basins are retrofitted in order to achieve an additional 1' of storage within their existing footprint. The estimated average footprint is based on the assumptions that the average depth is 5' and sideslopes are 3H:1V

[f]estimated remaining storage shortage after retrofitting 10% of the existing detention basins

Specifically in South Fork Gunpowder, it was interpolated that 40.90 ac-ft/mi^2 of optimized storage is necessary to provide adequate channel protection. This is equivalent to ~245 acre-feet of storage within the 6-square mile catchment area. There are nearly 150 existing basins with the South Fork Gunpowder Subwatershed, and although a detailed analysis of these has not been completed at this time, it is more than likely that many of these will be good candidates for detention basin retrofits. Again, additional details regarding this analysis is included in **Appendix 5-C**.

5.2.2 Selecting BMPs for Lower Gunpowder (Predominately Undeveloped Area of the Gunpowder Creek Watershed)

While Boone County has been one of the fastest growing counties in the state of Kentucky, a large portion (~57%) of the overall Gunpowder Creek Watershed remains undeveloped. As the economy continues to recover from the 2007-2011 economic recession, new development is anticipated, some of which will extend into previously undeveloped areas of the watershed (*e.g.,* **Figure 5-13**). Lower Gunpowder Creek is the priority subwatershed for BMPs related to undeveloped areas.

Figure 5-13: Rendering of proposed Union Town Center along the lower reach of Fowler Fork (Union, 2014)

Preserving Open Space Can Protect Water Resources

Protection, preservation, and/or conservation of publicly-owned open spaces should be considered, as this has been documented as one of the most cost-effective strategies to protect water quality (CWP, 2013). This is particularly important in large/old-growth forests, and at strategic areas along stream networks such as the riparian corridor and floodplain along Lower Gunpowder Creek. See **Figure 5-10** and **Appendix 5-A** for a map of current publicly-owned lands. Additionally, publicly-owned open spaces are ideal candidates for installation of BMPs, due to the likelihood of stakeholder cooperation. Special consideration should be given to properties that exist in low-lying areas along stream corridor for the installation of wetlands and riparian restoration, two BMPs that are anticipated to yield excellent results for relatively low installation cost. The primary cost associated with these BMPs is land acquisition, which is not anticipated to be an issue for publicly-owned land by agencies that are members of the project's Steering Committee.

Preservation of open space is one of the most cost-effective ways to protect water quality.

Reviewing Existing Rules and Regulations

Even with strategic conservation efforts of publicly-owned lands, some privately-owned lands will inevitably become developed in the near future. Watershed stewardship practices implemented prior to and/or during the development of this land is anticipated to be more cost-effective than post-development mitigation methods. In 2012, SD1 and the City of Florence released a detailed BMP manual that includes revised guidance and requirements to provide a water quality treatment volume in addition to flood control protection. The requirement of water quality treatment for the 80th percentile event (the first 0.80 inches of rain in any given storm) is an excellent improvement over the conventional design approach that focused exclusively on flood control. However, these revised regulations are not predicted to fully protect stream channels from excess erosion without being optimized by the design engineer to release all storms up to and including the 2-year storm at or below ~40% of the pre-developed 2-year flow rate (Sustainable Streams, 2012). The good news is that optimizing BMP designs to provide channel protection (*e.g.,* stream erosion control) in addition to water quality treatment is not anticipated to result in substantial cost increases relative to what is required under the current Rules and Regulations. In addition to the water quality and flood protection controls, SD1 currently has a credit program for new developments that meets this design parameter, which is referred to as $Q_{critical}$. Reviewing the participation rate of this credit policy may be a first step during implementation phases, in which outreach, training, and review/revision to the Rules and Regulations may be evaluated.

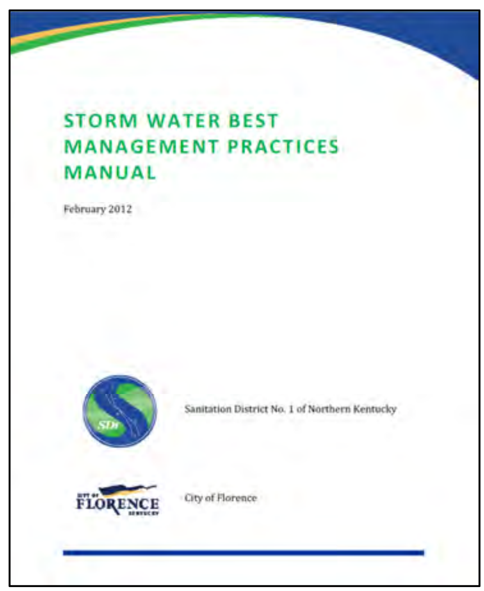


Figure 5-14: The Northern Kentucky Storm Water BMP Manual promotes numerous good practices for minimizing adverse impacts to streams

The Boone County Planning Commission, who is involved with planning and zoning requirements and subdivision regulations, is a member of the GCWI Steering Committee. An internal or external review of the current planning and zoning requirements and subdivision regulations with a focus on promoting lower impact development practices would be beneficial. Although this effort would affect all subwatersheds, Lower Gunpowder would be most benefited because it is nearly completely undeveloped presently. The subdivision regulations currently require stream buffer zones in accordance with what is required by the KDOW Permit KYR10, referred to as the SWPPP (Boone County, 2010). The subdivision regulations also refer to the Northern Kentucky Storm Water Best Management Practices Manual (SD1 & Florence, 2012; **Figure 5-14**), which promotes the following:

- Preservation of natural drainage ways and vegetated swales instead of building storm sewers
- Avoidance of steep slopes
- Fitting the development to the terrain
- Locating the development in less sensitive areas
- Reduced clearing and grading
- Utilization of open spaces
- Reduced impervious cover
- Using buffers and undisturbed areas
- Draining runoff to pervious areas instead of toward driveways and streets

Some communities have more protective rules and regulations such as defined distances for buffer zones and requiring green stormwater infrastructure to be used to the maximum extent feasible (*e.g.,* Seattle, 2013). A review of the local regulations may determine practices that are mutually agreeable by all stakeholders.

The goal of all Steering Committee members is to take reasonable steps to protect the integrity of Gunpowder Creek through locally-appropriate strategies such that future problems can be prevented and existing impairments can be cost-effectively improved. As discussed in the GCWI Steering Committee meetings, no single entity is the cause of all problems, or the source of all solutions. Therefore, working both within and across agencies will be essential for successful implementation toward the goal of improved water quality.

Improving On-Site Wastewater Treatment

It is not anticipated that improvements to septic systems will be a priority implementation activity, however because of the number of septic systems within the Lower Gunpowder Subwatershed (**Figure 5-4**), this strategy cannot be overlooked. The first step to achieving septic system improvements is to work with the Northern Kentucky Health Department to verify the parcels serviced by septic systems and those that could be malfunctioning. Furthermore, visual inspections could help to identify those systems that require maintenance or replacement.

5.2.3 Selecting BMPs for Riddles Run (Predominantly Agricultural Area of Gunpowder Creek Watershed)

Agricultural BMPs

Boone County has approximately 630 farms, ranging from ~5 to ~2,000 acres, within its boundaries. Many of these farms are located within the Gunpowder Creek Watershed, making up approximately 18% of the overall land area. As mentioned in Chapter 4, areas with bacteria concerns during dry weather monitoring highlight potential livestock and septic system issues. Riddles Run has been identified as the priority subwatershed for implementation of agricultural BMPs, as the majority of the E.coli concentrations during dry weather were above the benchmark concentrations, as shown in Chapter 4. In addition, total phosphorus and Total Kjehdahl Nitrogen exceeded the benchmark concentrations for nearly every event, which could indicate fertilizer runoff.

One of the first steps in the implementation of the Gunpowder Creek Watershed Plan will be to evaluate whether any farms in the priority rural watershed of Riddles Run are able to improve their Water Quality Plans and related practices to improve water quality in Riddles Run.

Agriculture can present a specific set of water quality issues, such as livestock disturbance of streambanks and riparian vegetation, bacteria from manure, sediment from bare fields, and nutrients associated with fertilizers and pesticides. Many of these pollutants were observed during monitoring of the streams within the Gunpowder Creek Watershed. Some BMPs that are especially important for livestock farms include fencing (to keep livestock from disturbing streambanks/beds, **Figure 5-15**), rotational grazing with pasture renovations, animal feeding buffers, and proper manure management. Pollution from crop farms can be reduced through the installation of riparian buffer strips, field buffers, conservation cover crops, conservation tillage, and nutrient management. Some incentive programs already exist for the farmers of the Gunpowder Creek Watershed, such as EQIP and a pilot program for nutrient trading.

Figure 5-15: Livestock access can impact stream bank stability, destroy riparian vegetation, and lead to direct deposits of bacteria/waste (Photo by Kelly Kuhbander)

Currently, horse farms in Boone County are not mapped or well monitored, due to horses not being considered livestock, although they present similar problems to streams as livestock farms. An initial mapping effort of horse farms would make targeting outreach efforts more feasible and easier to implement. Some additional BMPs that would be beneficial in agricultural areas with row crops are grassed waterways, contoured buffer strips, and terraces. A useful BMP for agricultural areas with livestock are waste treatment lagoons.

Improving On-Site Wastewater Treatment

Similar to in Lower Gunpowder Subwatershed, improvements to septic systems may be used as an implementation activity in Riddles Run, but will most likely not be a primary focus of implementation dollars due to the possibility of future expansion of the sewer system as development increases.

5.2.4 Selecting BMPs for the Areas of Gunpowder Creek with Active Forestry (Riddles Run & Lower Gunpowder)

Forestry is not considered to be a dominant activity in the watershed and was not anticipated to be a dominant source of any of the water quality pollutants. However, the GCWI knows that the limited forestry activities that do occur in Gunpowder Creek should be encouraged to use good practices. Beyond the BMPs listed by KDOW, one implementation step already completed by BCCD was to host a panel discussion on local forestry practices at their joint agency meeting in March of 2014. During this meeting BCCD and the other participating agencies agreed to seriously promote conservation of forested lands and particularly protect the forested areas that currently serve as riparian buffer zones. GCWI is working to promote reforestation, particularly on barren hillslopes, streambanks, and riparian zones, through partnerships with other community experts and resources such as the Northern Kentucky Urban Forestry Council and the Boone County Urban Forest Commission. These BMPs will be implemented in all priority watersheds but will be particularly focused in the rural and undeveloped priority subwatersheds of Riddles Run and Lower Gunpowder.

5.3 Finding Solutions - Summary

The *Watershed Planning Guidebook for Kentucky Communities* (KDOW, 2010) provides a list of structural and non-structural BMPs categorized by land use. Categorization is based on the type of practice (structural vs. non-structural) and its associated land use. This chapter has presented several BMP options that may be beneficial in the Gunpowder Creek Watershed, specifically tailored to the geologic setting and land uses described in Chapter 2 and the water quality impairments observed during monitoring and outlined in Chapters 3 and 4. The primary pollutant of concern in the Gunpowder streams is suspended sediment (TSS), which was most problematic in the developed headwaters of the watershed. The major source of suspended sediment is suspected to be bank erosion caused by excessively erosive stormwater flows. Therefore, the overall focus of water quality efforts will be on BMPs designed to control stormwater quantities, reducing the potential for erosion in the stream channels. These are anticipated to yield water quality benefits as well, such as bacteria and nutrient reduction. There are also priority areas where monitoring identified bacteria concerns during dry weather, such that mitigation efforts will be targeted to the direct dry-weather sources such as septic systems and cattle/horse access.

The primary pollutant of concern in these streams is suspended sediment, the major source of which is bank erosion caused by excessively erosive stormwater flows.

As previously mentioned, a key strategy of this Watershed Plan includes working together with local stakeholders and regional partners to implement cost-effective, sustainable solutions throughout the Gunpowder Watershed. The GCWI plans to use this Watershed Plan as a catalyst throughout the watershed to improve stream benefits. While South Fork Gunpowder, Lower Gunpowder, and Riddles Run have been listed as the priority subwatersheds , the GCWI emphasizes that opportunities will be evaluated as they arise, and the GCWI plans to consider any BMP that can improve the integrity of the streams. For example, although the first priority subwatersheds include South Fork Gunpowder, Lower Gunpowder, and Riddles Run, GCWI will consider any cost-effective opportunities that arise in the other subwatersheds, including Upper Gunpowder, Middle Gunpowder, Fowlers Fork, and Long Branch. **Table 5-4** on the next page is tailored to the Gunpowder Creek Watershed and includes an all-encompassing list of BMPs that are applicable to the Gunpowder Creek.

Table 5-4: BMP list tailored to the water quality issues observed in the Gunpowder Creek Watershed

	Structural Practices	Non-Structural Practices
Agriculture	Contour buffer strips	Brush management
	Field buffers	Conservation coverage
	Grassed waterways	Conservation tillage
	Herbaceous wind barriers	Fertilizer management
	Live fascines	Nutrient management plans
	Livestock exclusion fence (prevents livestock from wading into streams)	Operation of planting machines along the contour to avoid ditch formation
	Terraces	Pesticide management
	Waste treatment lagoons	Preharvest planning
		Prescribed/rotational grazing
		Residue management
		Septic system programs
		Workshops/training for developing nutrient management plans
Forestry	Culverts	Education campaign on forestry-related nonpoint source controls
	Revegetation of firelines with adapted herbaceous species	Fire management
	Temporary cover crops	Forest chemical management
	Tree planting/reforestation	Training loggers and landowners about forest management practices, forest ecology and silviculture
	Windrows	Review of local forestry practices with Kentucky Division of Forestry
Unde-veloped		Preservation of open/undeveloped space
Developed	Bioretention cells	Development of greenways in critical areas
	Bioinfiltration basins	Flood control master planning with channel erosion and water quality components
	Clustered wastewater treatment systems	Management programs for onsite and clustered (decentralized) wastewater treatment systems
	CSO separation/daylighting	Pet waste programs/signage
	Detention basin retrofits	Planning for reduction of impervious surfaces (e.g. eliminating or reducing curb and gutter)
	Green roofs	Setbacks
	Infiltration basins	Storm drain stenciling
	Permeable pavements	
	Rain barrels	
	Rain gardens	
	Stormwater ponds	
	Sand filters	
	Sediment basins	
	Tree revetments	
	Water quality swales	
Overall Watershed	Conversion of turf areas to native vegetation	Educational materials
	Establishment of riparian buffers	Erosion and sediment control plans
	Live staking	Fee-In-Lieu-Of plans to fund BMP projects
	Mulch	Fund a watershed coordinator
	Revetments	Illicit discharge detection/elimination program
	Riparian establishment/restoration	Interagency planning and coordination
	Stream Restoration	Monitoring program
	Stream Stabilization	Planning and proper road layout and design
	Wetland creation/restoration	Pollution prevention plans
		Review and revision of planning and zoning
		Review and revision of stormwater rules/regs.
		Stewardship incentives programs
		Workshops on proper installation and maintenance of structural BMPs
		Workshop/training on stormwater design for stream erosion protection

*Note that practices listed under one land use category can be applied in other land use settings as well

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CHAPTER 6

Strategy for Success

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

December 2014

Chapter 6: Strategy for Success

6.1 BMP Feasibility

Selecting the right combination of BMPs for the Gunpowder Creek Watershed depends on a number of factors, including regulatory matters, stakeholder cooperation, political will, available funding, cost-effectiveness, priority areas, existing priority efforts within the watershed, and watershed management activities. Each of these factors is discussed in Section 6.1.1 below.

6.1.1 Feasibility Factors

Regulatory Matters

The Sanitation District No. 1 of Northern Kentucky (SD1), the City of Florence, and the Kentucky Transportation Cabinet (KYTC) are responsible for the stormwater systems that drain the developed areas of the Gunpowder Creek Watershed and discharge to the stream network. They all hold permits from the Kentucky Division of Water (KDOW) that dictate the conditions that need to be met in order to discharge their stormwater to such waterways. Other entities that discharge stormwater to Gunpowder Creek, such as the Cincinnati/Northern Kentucky International Airport, are co-permittees with other agencies such as SD1.

These permits are revised on a five-year cycle. KDOW is guided by the USEPA regarding the various requirements that should be included in stormwater permits. The national guidance is currently undergoing revisions that are anticipated to include stricter conditions for stormwater discharges, particularly for developed areas. The intent of the revisions is to ensure that the health and quality of waterways is better protected from stormwater runoff as additional land is converted from undeveloped to developed.

SD1 is also regulated by KDOW regarding their combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs), which have been recently reduced via investments and upgrades to the sanitary sewer system in the Gunpowder Creek Watershed, such as the ~$125 million tunnel to the Western Regional Wastewater Treatment Plant. There are also a number of individually-permitted discharges from private sources as a part of the Kentucky Pollutant Discharge Elimination System (KPDES) Program. Approximately 63 total KPDES permits are documented in the watershed.

The Boone County Planning Commission (BCPC) has jurisdiction over the ways that the land in the Gunpowder Creek Watershed can be used and has been an active member of the GCWI Steering Committee.

Total Maximum Daily Loads (TMDLs) are developed by KDOW for waterways that are listed as impaired on the 303(d) list. TMDLs can add special conditions or restrictions to permitted discharges in a waterway depending upon the amount of load reductions that are estimated to be needed to bring a waterway into compliance with water quality standards. There is already a TMDL for ethylene glycol relative to the Airport’s use and treatment of deicing fluid. KDOW recently began the development of a TMDL for *E.coli* in Gunpowder Creek in 2014.

Stakeholder Cooperation

100% of roundtable participants said development was a land use that they were most concerned about.

The Gunpowder Creek Watershed Initiative (GCWI) Steering Committee includes a broad range of public agencies that have taken an active role in guiding the project. A technical committee and KDOW representatives have provided technical expertise throughout the project as well. Regional partners have donated their time and talents to help make this project the success that it is. Some of the contributions are summarized in **Table 6-1.**

Table 6-1: Incomplete summary of contributions of time, personnel, supplies, equipment, access, project planning, and implementation by regional stakeholders

Stakeholder Agency	Steering Committee Meetings	Public Meetings/ Roundtables	Data Collection	Implementation/ Project Planning
Boone County Conservation District	√	√	√	√
Boone County Planning Commission	√	√		
Cincinnati/Northern Kentucky Airport	√			√
City of Florence	√	√		√
City of Union	√			
Kentucky Division of Water	√	√	√	√
Kentucky Transportation Cabinet	√	√		
Licking River Watershed Watch	√		√	
Northern Kentucky Health Department	√			√
Northern Kentucky University Center for Environmental Restoration				√
Sanitation District No. 1	√	√	√	√
Thomas More College/Dr. Chris Lorentz			√	

Beyond the list of these more active stakeholders, the Steering Committee has a goal of increasing stewardship of private companies. For example, in the adjacent watershed of Woolper Creek, Toyota has been very supportive of the pilot installation of the detention basin retrofit technology developed and monitored by the USEPA and other regional partners including Boone County Conservation District (BCCD), SD1, and Sustainable Streams. Finding corporations from within the Gunpowder Creek Watershed to contribute to project funding and/or implementation, including structural and non-structural practices, is a goal for GCWI as we move to the implementation phase.

And most importantly, the public has been actively involved throughout the project. News of the project has been distributed through local media along with the *Landscapes* newsletter of Boone, Campbell, and Kenton Counties Conservation Districts. A total of 6 well-attended public meetings (**Figure 6-1**) have been held at numerous locations throughout the watershed. GCWI has also presented at meetings of local organizations, such as the Northern Kentucky Fly Fishers, who are very active in the watershed.

The public has been eager to learn about the project, hear the results of the monitoring efforts, and offer their input regarding prioritizing problems and solutions. Approximately 70 participants engaged in a series of three roundtable meetings in September of 2013. Divided into 11 total groups, they provided facilitated feedback to five questions. The questions and the dominant answers are provided in **Table 6-2**.

Table 6-2: Questions and dominant responses from 11 roundtable groups with approximately 70 participants

Question	Dominant Responses[1]
1. Why is a clean healthy stream important to you?	Recreation (73%), Aesthetics (66%), Quality of Life/Health (54%)
2. What land uses in the watershed are you most concerned about?	Development (100%)
3. What do you think are the most common problems?	Runoff (73%), Flooding/Safety (66%)
4. What BPMs do you consider feasible in Gunpowder Creek?	Detention/Retention (82%), Education (66%), Responsible Development/Ordinances (55%)
5. What issues in Gunpowder Creek do you consider a priority?	Stormwater Runoff (66%), Flooding (55%)

[1]Responses that were listed by more than half of the groups. For a summary of all responses, see supporting handout in **Appendix 6-A.**

In summary, 100% of the groups felt that development was a land use that they were most concerned about. Stormwater runoff and flooding were problems that were typically associated with development and considered priorities among a majority of the groups. BMPs such as improved stormwater detention, education, and ordinances that promote responsible development were considered feasible by 82%, 66%, and 55% of the groups, respectively. A commonly shared sentiment was that folks did not necessarily want new ordinances; they simply wanted the existing rules and regulations to be revised to work better to actually protect stream health and keep downstream properties from flooding and eroding.

Political Will

Development is an important industry of Northern Kentucky, providing jobs and housing to promote economic growth. Rules that regulate the industry must balance the costs to the industry with the benefits to the region. What this project has demonstrated is that the status quo is unsustainable: conventional stormwater regulations cost developers money but do not adequately protect stream health. In many ways the impacts to stream health create

An estimated $3.1 million in damages to Boone County's state-funded roads were attributed to stream erosion and flooding in 2011.

much greater losses to the local economy. For example, stream erosion has impacted dozens of sewers and other infrastructure that are located in stream corridors: damages to Boone County's state-funded roads alone were estimated at $3.1 million in 2011 (Hawley *et al.*, 2013a). Also, the regulatory burden that comes with cleaning up an impaired stream is almost always more expensive than keeping a stream from becoming impaired in the first place.

As previously explained under Stakeholder Cooperation, there is a growing consensus among stakeholders that stormwater rules need to be revised to better protect stream health in Northern Kentucky. In particular, stream erosion is a commonly listed problem by property owners downstream of developments. To date, the development community has generally opposed any new regulation related to stormwater, and there has been a lack of political will to update regulations to better protect against stream erosion. Stakeholders agree that new regulations are not necessarily the solution. Rather, reviewing and revising the existing regulations to better protect stream health was a leading recommendation from the roundtable meetings. Moreover, doing so is not anticipated to be a detriment to the development community. Analysis of stormwater detention basin sizing has demonstrated that optimizing basins to better protect against stream erosion, along with providing water quality treatment and flood control, is not expected to substantially increase the size of the required detention facility relative to current requirements (Sustainable Streams, 2012). Developers would likely be spending essentially the same amount of money on their stormwater controls as they currently do; however, their investments would more fully protect stream health.

Figure 6-1: One of several well-attended public meetings on the Gunpowder Creek Watershed Initiative

Elected leaders have been educated at several phases throughout this project. Numerous public officials attended the public meeting that shared the results of the water quality monitoring, including the Boone County Judge Executive, County Administrator, Director of Parks, Director of Planning, and a County Commissioner. The Watershed Project Coordinator has also presented the results of the Roundtable Meetings to the SD1 Board of Directors, which is appointed by regional elected officials.

Through continued education and public involvement, the will of elected leaders may evolve. Revisited and revised stormwater regulations and/or subdivision regulations to better protect regional streams are a logical starting point.

Beyond the will of elected leaders, technical staff and experts from regional agencies have embraced the goals of the project and have already taken several steps to support improved stream health from within their agencies. For example, both the City of Florence and SD1 have inspection and maintenance programs for existing detention basins and staff at both agencies are actively involved in attempting to find basins that would be good candidates for retrofits.

Available Funding

Solutions need to be both feasible and cost effective.

This work has been funded in part by a grant from the USEPA under §319(h) of the Clean Water Act through KDOW. Effective management and excellent partnerships have allowed the GCWI to efficiently utilize funds and have leftover grant monies at the completion of the plan document, such that some of the current funds can be applied to implementing BMPs. The GCWI has currently applied for additional funds through the 319(h) program for implementation. However, GCWI understands that the scale of the existing problems in Gunpowder Creek is much larger than the available funds through the 319(h) program. Therefore, a core mission of this project has been to:

1) Identify cost-effective BMPs,
2) Develop and expand partnerships among regional agencies,
3) Allocate public monies to achieve greater benefits for less cost, and
4) Leverage funding from partner agencies and private entities in the watershed.

In regards to developing/expanding partnerships to leverage funds and allocate monies to achieve greater benefits for less cost, SD1 and the City of Florence regularly invest large sums of money in the modeling, design and construction of projects to alleviate flooding problems. Adding goals such as improvements in stream erosion and water quality would be much more cost- and time-effective than trying to fund and implement separate projects to achieve the same goals. Indeed, conventional approaches to flood control projects typically solve flooding problems in one neighborhood, but can potentially make flooding and stream erosion worse along other parts of the network. As demonstrated in Chapters 3 and 4, streams are interdependent systems: flooding affects channel erosion, which affects the water quality. The only way to truly improve stream health is to coordinate project goals.

SD1 has already led by example in this regard by adding channel stability and water quality to two sanitary sewer improvement projects. As detailed by Hawley *et al.* (2012), SD1 was implementing two projects that removed inflow and infiltration (I/I) from the sanitary system. Removing I/I from the sanitary system is beneficial, because it helps to reduce SSOs into the stream networks. However, by taking stormwater out of the sanitary system, SD1 realized that simply discharging it to an already unstable stream could make channel erosion and water quality worse downstream.

Therefore, SD1 had the projects include stormwater BMPs that were designed to reduce the rate at which the stormwater makes its way to the stream network, thereby reducing the amount of potential erosion downstream. Doing so certainly added costs to the project that wouldn't have been incurred on a conventional I/I project; however, the approach was not only better for the stream, but it was better for all stakeholders, particularly the residents. Rather than tearing up yards, streets, and driveways once for the I/I project and then coming back later to address stormwater runoff, the residents could have all of their stormwater and sanitary sewer issues solved through one project.

Finally, solutions must be pragmatic. We must work to identify cost-effective solutions throughout the watershed. Rather than spending $2 million to fully restore a small part of the system to pre-developed conditions, it is much better to spend $200,000 in 10 separate parts of the system to create much greater overall load reductions and benefits to the entire network. The strategy for this Watershed Plan recognizes that funding is finite and keeps in mind the greatest network benefit for the available dollars (**Figure 6-2**).

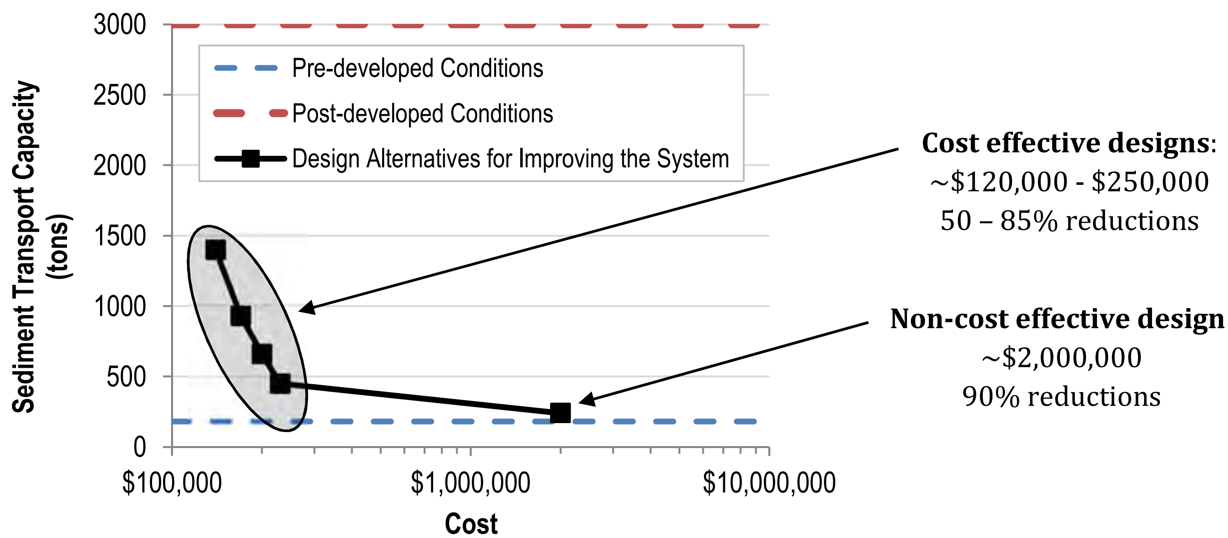


Figure 6-2: Design alternatives for stormwater BMPs to reduce the stream erosion capacity from 3,000 tons by more than half as a part of a sanitary sewer improvement project (adapted from Hawley *et al.*, 2012)

One way to achieve the greatest network benefit is to leverage funds from partner agencies, such that a project can have a greater impact with combined funds, instead of GCWI 319(h) funding alone. Similar to the projects described above, SD1 and the GCWI may pool their resources to either increase the size of a project or include additional features that provide greater benefits to the streams.

Cost-Benefit Analysis

Cost-effectiveness is a major goal of our proposed stormwater-based approach to improved stream conditions. Fortunately, some of the most effective BMPs for the treatment of the Gunpowder Creek Watershed's most concerning impairments (TSS, bacteria, phosphorous) are also relatively inexpensive

(**Table 6-3**). By focusing on solutions that are primarily aimed at restoring a more natural flow regime, such as detention basin retrofits, optimized detention basins, wetland creation/restoration, and other stormwater BMPs, we can significantly reduce TSS levels attributable to bank erosion and anticipate a positive impact on bacteria, phosphorous, and potentially nitrogen levels coming from the watershed.

Stormwater volume-based BMPs tend to be the most cost-effective structural BMPs for removing the primary pollutants in Gunpowder Creek.

Table 6-3: Table of unit costs and typical pollutant removal rates for volume-based BMPs

Volume-based BMP	Approximate Cost per Storage Volume[a]	Typical Removal Rates of Watershed-sourced Pollutants[c]			
	($/ft^3)	*E.coli*	TSS[d]	TP	TN
Detention Basin Retrofits	$1.50[b]	100%	100%	42%	TBD
Wetland Creation/Restoration	$2	19%	29%	7%	16%
Extended Detention Basins	$2	67%	64%	21%	TBD
Bioinfiltration Basins	$4	71%	78%	18%	28%
Retention Basins	$2	N/A	81%	57%	30%

[a] Cost estimates only include construction costs and do not include the costs associated with land acquisition, but do include an estimate for design and permitting. Costs for new detention/retention/wetlands are based on regional excavation costs after Hawley *et al.* (2012), with ~10-15% added for design. Costs for bioinfiltration basins are based on typical regional pricing of ~$15-20 per square foot compiled by Strand Associates (Rust, C., 2014, Pers.Comm.), and assuming a 5-foot storage depth resulting in ~$3-4 per cubic foot. Detention basin retrofits assume relatively simple retrofits with restricted pipe and bypass installation after Hawley *et al.* (2013b), limited material and installation costs, and targeted efforts by a design engineer for design optimization and permitting, for an estimated total of ~$10,000 per basin. They do not include costs/time associated with engaging property owners, determining basin access and existing capacity/appropriateness of the basin for retrofitting.

[b] Detention basin retrofit cost per storage volume refers to added volume, based on an estimated 10% overdesign of existing basins, with an estimated average volume of 1.4 ac-ft. The extra 10% would result in 0.14 ac-ft of new storage per ~$10,000 retrofit, yielding a cost of ~$1.50 per ft^3. Additionally, the existing 1.4 ac-ft of flood control storage would be converted to optimized storage, resulting in 1.54 ac-ft per retrofit. Using this volume, the cost per optimized storage volume is ~$0.15 per ft^3.

[c] Removal rates listed for wetland creation/restoration, extended detention basins, bioinfiltration basins and retention basins are the average median reduction as reported in the *International Stormwater BMP Database* (Leisenring *et al.*, 2012). Removal rates for detention basin retrofits are based on an estimated doubling of the treatment time associated with flood control detention basins and the assumption that doubled treatment time results in doubling of removal rate. See Appendix 5C for further explanation. Nitrogen removal is anticipated to be improved via detention basin retrofitting due to increased contact time with organic matter (Beaulieu, J., 2013, Pers.Comm); however, their rates are listed as TBD until local monitoring data become available. Reported wetland channel rates were used for wetland creation/restoration, due to anticipated installation of bankfull/benchfull wetlands, which should behave more similarly to wetland channels than standard wetlands. If detention basins, bioinfiltration basins, and retention basins are designed with consideration for channel protection flow rates ($Q_{critical}$), then removal rates are expected to be similar to that of detention basin retrofits.

[d] This TSS removal rate refers to the settling out of sediment within each BMP. It is important to note that for the Gunpowder Creek Watershed, the primary source of TSS in streams is not from upland erosion, but from stream bank erosion, caused by an excessively erosive flow regime. This means that the cost per optimized storage volume is a more relevant metric for determining cost-effectiveness associated with TSS removal.

Lot-level controls such as rain gardens and cisterns tend to be much less cost-effective than stormwater volume-based BMPs.

From **Table 6-3**, one can see that detention basin retrofits tend to be less expensive than constructing new volume-based BMPs. However, access/feasibility issues may limit the number of detention basins that can be retrofitted, so some level of newly constructed BMPs is also expected to be needed. Construction of new detention basins, retention basins or wetlands are all anticipated to cost ~$2 per cubic foot of storage based on regional excavation costs (Hawley *et al*., 2012), which tend to be less than bioinfiltration basins that range ~$3-4 per cubic foot of storage (*sensu* Rust, C., 2014, Pers.Comm.).

A first-order planning estimate of the total funding that may be required to reduce the stream erosion rates to more natural levels can be determined by combining the unit costs from **Table 6-3** with the estimated storage volumes listed in **Table 5C-4**. Approximately 50 detention basin retrofits at ~$10,000 per basin, plus approximately 170 acre-feet of new storage using a combination of wetlands and/or detention/retention basins at ~$2 per cubic foot would result in an estimate of approximately $15.5 million.

Table 6-4 – King County cost estimates using a mix of lot-level and volume-based BMPs, extrapolated to the Gunpowder Creek Watershed

Range of Cost Estimates to Mitigate Stormwater Runoff in King County Pilot Watershed using SUSTAIN (King County, 2013)		
Design Alternative	Costs in King County Pilot Basin	Projected Costs to Gunpowder Watershed at same unit cost as King County[a]
Min	$4,800,000	$489,000,000
"Best"	$10,700,000	$1,090,000,000
Max	$14,700,000	$1,497,000,000

[a]King County costs divided by catchment area (230 acres) multiplied by catchment area at Gunpowder Creek gage location (36.6 mi^2)

Smaller BMPs such as controls in individual lots (*e.g.,* rain gardens, rain barrels, and green roofs) or conversion of impervious surfaces to porous are not included in **Table 6-3** because they tend to treat much lower stormwater volume for the dollars spent. It does not imply that GCWI is precluding the use of such techniques in the Gunpowder Creek Watershed, but rather, that the focus is on more cost-effective controls for the watershed and problems at hand. To underscore this point, we cite a case study from King County, Washington, where the SUSTAIN stormwater treatment model was used to plan approximately $10.7 million of BMPs including rain gardens, detention, bioretention, etc., in order to meet the load reduction goals in a small pilot watershed of 230 acres (0.40 square miles). Approximately half of the $10.7 million is for installation of lot-level BMPs, such as rain gardens, cisterns, and rain barrels. Extrapolating the King County costs of nearly a half a million dollars per acre to the developed portion of the Gunpowder Creek Watershed would result in over $1 billion spent on BMPs spread over the 36.6-square-mile area (**Table 6-4**). That's nearly 100 times more than the estimates using volume-based BMPs discussed above.

Beyond the costs required to solve the problem, it is also important to acknowledge the costs associated with the status quo. We can estimate the annual costs of infrastructure repair due to damages caused by flooding and channel instability in the Gunpowder Creek Watershed based on a summary of regional costs from 2011 (**Table 6-5**). With the total impacts to state roads, sewers, and private utilities estimated at nearly $1 million per year, not including impacts to other property such as local roads and private property, reducing these impacts through more sustainable stormwater management would be beneficial to the region's environment, property owners, tax payers, and rate payers.

In summary, this Watershed Plan focuses on identifying the BMPs that will yield the greatest impact per dollar spent on stream health within the Gunpowder Creek Watershed and the locations in which those BMPs will be most effective. The plan will then be used to aid the decision making process as funds become available. BMP implementation is to be followed by monitoring, reassessing, and adjusting the strategy. For example, continued monitoring may determine that stream health objectives have been met prior to the full implementation of the estimated volumes from **Table 5C-4**.

Table 6-5 – Cost estimate for annual repairs to infrastructure in the Gunpowder Creek Watershed damaged by flooding and channel instability

Projected Repair Costs Due Damages Attributable to Flooding and Channel Instability in Developed Watersheds

Infrastructure Category	Projected Annual Unit Costs[a]	Possible Annual Costs in Gunpowder Watershed[b]
	$/mi² /y	*$/y*
State Highways[c]	$25,000	$915,000
SD1 Sewers[d]	$2,500	$91,500
Private Utilities[e]	$900	$32,900

[a]after Hawley *et al.* (2013)

[b]projected using the Gunpowder Creek drainage area to the gage location, which is close to the confluence of the three main branches that drain the developed headwaters of Gunpowder Creek (36.6 mi², 22.6% impervious). As one moves farther downstream from that location, development intensity decreases.

[c]based on estimated damages of $3,100,000 in Boone County in 2011. To account for the fact that 2011 was a record rainfall year, the estimated damages from 2011 were reduced by half to approximate more typical precipitation years. Unit rate assumes damages occurred in more developed portions of the county.

[d]estimate based on documented impacts to sewer trunk lines in Banklick Creek of more than $500,000 in 2011. Unit rate assumes impacts took 10 years to manifest.

[e]estimate based on documented impacts to Duke overhead electric and buried gas lines in the Dry Creek corridor.

Areas of Local Concern

As previously mentioned, the impacts associated with development and future development are a dominate concern for the Gunpowder Creek Watershed. Several areas in the Gunpowder Creek Watershed are approved for, or are in the planning stages for future development. Several on-going residential developments are continuing to move forward in the Gunpowder Creek Watershed that will ultimately tally to over 6,000 additional dwelling units (including single-family as well as multi-family dwellings). Harmony, with over 1,400 units remaining to be built, and Ballyshannon, with 1,200 units to come, are the two largest contributors. Harmony is located in the Fowler Fork Subwatershed and Ballyshannon is located in the Long Branch Subwatershed. Several others will add to the total as they build out including Farmview (located in our priority subwatershed – South Fork Gunpowder), Gunpowder Trails, and others (Bob Jonas, 2014). Throughout the Gunpowder Creek Watershed there are also several plans for commercial developments including the Union Town Plan in Fowler Fork, the Aeroparkway – which is expected to open up approximately 400 acres for development, the Mount Zion Interchange expansion, and Mall

Road – which is expected to open up approximately 60 additional acres of commercial development.

Regarding specific areas of concern and flooding – this was listed as a concern in the Whispering Trails subdivision of Fowler Fork. The South Fork of Gunpowder, which is the most developed subwatershed, was also reported to have flooding concerns.

Existing Priority Status

> ***Detention basin retrofits and stormwater master planning for flood and erosion control may be two of the most cost-effective BMPs for Gunpowder Creek.***

Large-scale efforts with the goal of improving flood control within the Gunpowder Creek Watershed are routinely conducted by the City of Florence and SD1, including recent and ongoing projects such as the Fowler Fork Master Plan (SD1) and the Pheasant Watershed Study (City of Florence). As development continues to increase in the coming years, studies for other areas of flooding concern are likely to be performed. Prioritizing GCWI's efforts based on local master planning efforts is important because EPA research has documented that trying to improve such large-scale problems with lot-level controls alone, even with the backing of large public awareness and financial support programs such as reverse auctions, does not appreciably improve water quality or stream habitat (Roy *et al.*, 2012). The GCWI must capitalize on flood control master planning projects because the scale of the problem requires large-scale, coordinated investments focused both on quantity and quality of stream flow. In addition to flood control master planning, SSO reduction within the watershed has also been, and will continue to be, a priority for SD1. The ~$115 million tunnel to the Western Regional Wastewater Treatment Plant has already served to reduce overflows in the Gunpowder Creek Watershed, along with other portions of SD1's service area.

Other existing efforts include agricultural incentive programs for manure management, riparian buffer strips, field buffers, conservation coverage, conservation tillage, nutrient management, nutrient trading, etc., which exist through programs such as the USDA's Environmental Quality Incentives Program (EQIP). Numerous federal (USEPA, USACE, etc.) and state (KDOW) regulations are in place to help control flooding and to protect streams from excessive disturbance and illicit discharges. The GWCI Steering Committee must consider all existing and proposed federal, state, and local water quality efforts, selecting complimentary BMPs and supporting/guiding existing programs in an attempt to maximize the effectiveness of all funding spent in the watershed.

Watershed Management Activities

There are numerous stakeholders and ongoing activities that are intended to improve/protect stream health in the Gunpowder Creek Watershed. The City of Florence and SD1 have stormwater inspection and maintenance programs, including inspection of existing detention basins. Capitalizing on these programs could lead to efficiencies in implementing a detention basin retrofit program.

The BCCD conducts numerous agricultural outreach and assistance programs that can be used to target priority rural watersheds. The City of Florence and SD1 also conduct flood control master plan modeling, design, and implementation, which could be calibrated to also provide water quality and channel protection benefits. Their MS4 stormwater programs are also critical in protecting stream health, including their outreach/education, operations and maintenance, and illicit discharge detection and elimination programs. All of these activities underscore the importance of having a watershed coordinator dedicated to the advocacy and implementation of this Plan as a key component of future success.

6.2 Developing a Plan of Action

The following list of prioritized and targeted action items was developed through a collaborative effort with the Technical Sub-committee of the Gunpowder Creek Steering Committee, including representatives from Boone County, BCCD, KDOW, the City of Florence, SD1, and Sustainable Streams during a meeting held on June 24, 2013. The group began with KDOW's (2010) list of structural and non-structural BMPs from the Guidebook and then systematically tailored the BMPs to align with the pollutants of concern, likely sources, cost effectiveness, and feasibility (**Table 5-3**). Through additional analysis and Steering Committee input, BMPs have been compiled into a preliminary Action Item list.

The primary focus of the Gunpowder Creek Watershed Plan moving forward is on flow regime restoration through implementation of optimized stormwater BMPs, with the anticipation that these BMPs will also yield meaningful reductions in bacteria, phosphorous, and nitrogen levels. These practices will be supplemented by targeted mitigation and restoration efforts aimed at pollutant sources throughout the watershed. A rigorous monitoring plan should be implemented to measure the effects of the watershed management efforts, along with regular reassessment of the effectiveness of installed BMPs, which will potentially highlight the need for adjustments to the overall strategy. It should be noted that water quality is the quickest indicator of an effective plan, while stream stability can take longer, as it relies on vegetative recovery that may take multiple growing seasons. Biological recovery can take an even longer amount of time, as it relies on water quality and stream stability as prerequisites.

6.2.1 Developing Action Items

The Gunpowder Creek Watershed Plan has been tailored to focus on the highest priority problems using the most cost-effective BMPs, stakeholder input and the most feasible opportunities. For example, rather than prescribing the precise location of all of the estimated 170 acre-feet of new stormwater storage that may be necessary to mitigate stream erosion, the plan calls for locating bankfull wetlands, extended detention, and detention basin retrofits based on access, opportunity, and overall cost-effectiveness in achieving the total optimized storage goal. For the purposes of increasing the potential impact of BMP implementation, Action Items have been targeted to priority watersheds, for example South Fork for developed areas and Riddles Run for rural areas; however, locations of BMPs within those priority areas remains flexible in order to capitalize on those that are the most cost-effective and feasible.

Items requiring technical assistance, such as engineering design, hydromodification training, etc., are evident throughout the Action Item list, and estimates of corresponding fees have been included. Responsible parties include the GCWI, its Steering Committee, and specific partners for specific projects, such as the City of Florence for the Pheasant Watershed Study. Funding mechanisms include 319(h) funding, as well as local and state sources, for example, Boone County Parks may be a partner on the installation and maintenance of the pet waste program. Even the BMPs included on the Action Item List may be flexible as new opportunities arise, for example, a septic system program via the Northern Kentucky Health Department or a steep slope reforestation program via the either one of the local urban forestry organizations. More specifically, the Northern Kentucky Urban Forestry Council recently prioritized the Gunpowder Creek Watershed as a "Priority Planting Zone" to plant ~$8,000 worth of riparian trees. BCCD plans to partner with the Urban Forestry Council's Urban Tree Committee to develop planting plans and plant trees within the riparian zone of Gunpowder Creek.

In sum, the Action Item list represents one combination of logical, high-priority BMPs that seem to be feasible based upon known opportunities at the time of the writing of this Plan; however, they are subject to change based on the changing nature of the watershed and its opportunities. The Action Items are organized by categories of overall watershed, developed areas, agricultural lands, and undeveloped areas. Cost estimates are informed by a combination of unit costs from the literature and local projects. Because the costs are for planning purposes, they err on being conservative such that if implementation costs are less than what is budgeted, additional BMPs can be implemented from the cost savings. Conceptual locations and cut sheets for several of these BMPs are included as **Appendix 6-B**. The following action items are summarized in Tables 6-6 and 6-7 (beginning on page 6-20). Additionally, a series of maps are included at the end of this chapter to illustrate potential focus areas for implementation efforts related to some of the action items.

Figure 6-3: Hydromodification surveys measure stream stability and will help to track the impact of stormwater controls on mitigating excess levels of stream erosion

Overall Gunpowder Creek Watershed

1. **Watershed Coordinator** – A watershed coordinator, who would work ~20 hrs a week, is recommended to oversee the installation, implementation, maintenance of BMPs, as well as monitoring and strategic adjustment of the Watershed Plan. The total estimated cost of funding this position is ~$30,000 per year.
2. **Revise Rules and Regulations** – While the BMP Manual developed by SD1 and the City of Florence has added a water quality treatment requirement for the 80th percentile event (0.8 inches), which is an excellent improvement over conventional flood control design, protecting stream channels from excess erosion is still not required. Doing so will allow for the optimization

of BMP designs to provide channel protection control based on local hydromodification data via the use of $Q_{critical}$ controls, which are designed to capture and release all storms up to and including the 2-year storm below the critical flow for stream erosion. The consideration of $Q_{critical}$ in stormwater BMP designs is not anticipated to result in substantial cost impacts to property owners and/or developers. While it is not yet a requirement, SD1 currently has a credit program for new developments that meet the $Q_{critical}$ design target in addition to the water quality and flood protection controls. A proposed budget of ~$15,000 for the technical support that may be needed during the review and revision of the Rules and Regulations is recommended.

3. **Success Monitoring and Analysis** – Continue monitoring water quality at currently established monitoring stations, including yearly hydromodification surveys at the same stations (**Figure 6-3**). This action item is an extremely critical part of the Watershed Plan in that it will guide future adjustments to the strategy, and may document attainment of the water quality benchmarks prior to the implementation levels that were presented in Chapter 5. Therefore, $20,000 per year to fund the monitoring/analysis program is recommended.
4. **Stewardship Programs** – Facilitating community and corporate stewardship is a critical part of the Plan's success. Education and outreach programs for home owners and large corporate or institutional properties can have relatively low cost, but can deliver measurable results if done effectively (Galvin, 2005). Therefore, a $3,000 annual budget is recommended to work with KDOW's education coordinator and other resources to develop outreach materials and programmatic activities to facilitate watershed stewardship.
5. **Coordination with NKU FILO Program** – The Northern Kentucky University (NKU) Center for Environmental Restoration (CER) runs the Stream and Wetland Restoration Program of Northern Kentucky that is funded by the Fee-In-Lieu-Of (FILO) funds that are accrued when developments or other land-disturbance projects physically alter streams. The CER has demonstrated the ability to stabilize degraded stream reaches and restore their habitat, even in urban watersheds. Many of the restoration projects have been constructed in the vicinity of the Gunpowder Creek Watershed, and CER is regularly looking for additional projects. The CER is on the GCWI Steering Committee, and continued coordination with the restoration program is strongly recommended. Up to $1,000 may be budgeted to support the development of restoration proposals for projects that could stabilize stream reaches in the Gunpowder Creek Watershed that are large sources of bank erosion and TSS.
6. **Riparian Plantings** – Buffer zones of native grasses, forbs, and woody vegetation along streams are reported as highly effective at removing pollutants from overland runoff (Wenger, 1999). They also increase habitat in streams via the addition of large woody debris, provide food sources such as leaf litter, and help to reduce bank erosion. Seeding is estimated to range between $100 and $700 per acre, which equates to an average cost of ~$0.15 per foot, if the planted buffer is 15 feet wide. Additionally, installation of one live stake per square yard should cost just over $15 per foot of buffer. Therefore, ~$90,000 is recommended in riparian plantings as a part of this Action Item, which, conservatively, should be enough for ~4,500 linear feet of buffer zones.
7. **Training and/or Technical Support Programs** – Training and/or Technical Support Programs for local designers and contractors are important to provide designers and contractors with an

understanding of the importance of channel protection controls and how they can be relatively easily added to the current design practice for stormwater BMPs. Developing training material and conducting training sessions is expected to cost ~$15,000 per year. The technical support may also be applied to assist BCCD in guiding flood control master planning projects conducted by other project partners (discussed under Item #2 below).

8. **Structural and Non-Structural BMPs** – Implementing BMPs is key to the next stage of the Plan. These BMPs can be implemented wherever in the watershed there is a cost-effective opportunity. Further details specific to the BMPs in the developed headwaters of Gunpowder Creek follow in the next section.
9. **On-site Wastewater Treatment** – On-site wastewater treatment is not a priority BMP at this time, although it may become more beneficial as implementation progresses. The Northern Kentucky Health Department will lead this effort, with possible funding or other assistance provided by the GCWI. The goal will be to identify and repair or replace faulty septic systems and/or straight pipes. Therefore, action items include working with the Northern Kentucky Health Department to determine feasibility and areas of greatest concern, identifying faulty septic systems and/or straight pipes, and pursuing funds in coordination with the Health Department or other entities to address any identified issues.
10. **Education and Outreach** – In addition to the specific education focused on training and technical support for local designers and engineers, other education and outreach efforts will be directed to those that live and work in the Gunpowder Creek Watershed. These activities will focus on educating the community to understand necessary behavioral changes that will make a difference in the integrity of the watershed.

Developed Areas (with an initial focus on the South Fork of Gunpowder Creek Subwatershed)

1. **Detention Basin Retrofits** – BCCD, SD1, USEPA, and Sustainable Streams have been piloting a simple, cost-effective technology to retrofit the outlet control structure of conventional, flood control detention facilities to be optimized to minimize channel erosion and increase water quality treatment potential (Hawley *et al.*, 2013b). Of the estimated 535 existing detention basins in the Gunpowder Creek Watershed, there are approximately 250 in Florence that are annually inspected and maintained. Florence owns approximately 16, but has access to the outlet structures of most. Recently, Boone County transferred ownership of approximately 50 detention basins to SD1. A GIS mapping effort of all major detention ponds in the watershed is already underway. Large detention ponds with large drainage areas should be the primary focus, as they are likely to yield the greatest impact for approximately the same cost. Older ponds may be better candidates as they were likely built under outdated stormwater ordinances, allowing the retrofit to result in a greater change from the current condition. The retrofitted outlet structure will provide greater benefits in basins that have more excess storage capacity than in those basins with limited freeboard storage for the 100-year design storm. Ponds located on public lands such as parks, schools, etc. are of the highest priority, due to the likelihood of stakeholder cooperation. Private landowners should be engaged in order to determine the level of willingness to cooperate in such efforts. If necessary, incentives could be implemented in order to make these watershed stewardship practices more desirable to private stakeholders.

Within the first three years, the target of 10 retrofits installed on larger ponds in the subwatershed should cost ~$100,000 total, and could result in a reduction of ~1.5 million pounds of TSS annually and significant impacts on bacteria, phosphorous, and nitrogen.

2. **New Detention Ponds and Bioinfiltration Basins** – The search for candidate locations should focus on heavily developed areas that do not currently have detention, but have open land between development and receiving streams. As with the retrofits, public lands should be prioritized and private landowners should be engaged to determine the level of potential cooperation. This Action Item could require the purchase of land or incentives for landowners willing to donate land for the installation of optimized detention ponds. BCCD should coordinate with key partners, such as the City of Florence and SD1 to ensure that capital investments for flood control are also designed to maximize channel protection, water quality, and biotic integrity benefits to the extent feasible. This includes providing target flows ($Q_{critical}$) based on hydromodification data collection, geomorphic assessments and analysis efforts of the Watershed Plan. At ~$2 per cubic foot, installation of 3 acre-feet of new detention storage in the South Fork of Gunpowder Creek Subwatershed should cost ~$260,000 and could result in removal of ~100,000 lbs of TSS annually. In the event that a property owner prefers a bioinfiltration basin as opposed to an extended detention basin, 0.4 acre-feet of bioinfiltration for a total of ~$61,000 that is estimated to remove ~11,000 lbs of TSS annually has also been included.
3. **Wetland Creation/Restoration –** A study of aerial photography of the watershed may reveal some optimal locations for wetland creation/restoration. Potential locations that may support wetlands include areas near locations where wetlands currently exist, areas with constructed farm ponds, farm fields that utilize the “lands” method of plowing and dry depressions, among other indicators (Biebighauser, 2011). Ideal candidates for the creation of bankfull or benchfull wetlands include large, low-lying swaths of land adjacent to the channel and publicly-owned lands are again a priority. Bankfull/benchfull wetlands are a relatively new BMP but they have a high potential to treat large volumes of polluted water by routing overbank stream flows through large off-line wetlands. Published performance data is limited; therefore, we have preliminarily used performance data for “wetland channels” from the International BMP Database (Leisenring *et al.*, 2012) until better data become available. These performance data are consistent with preliminary performance data from several bankfull wetlands in the Mill Creek Watershed, an impaired waterbody in Cincinnati with high TSS loads (Miller, M., 2013, Pers. Comm.) as well as an independent analysis for the South Fork of Gunpowder Creek. Therefore, the preliminary TSS removal rates developed for the order of magnitude estimates presented herein are based on an understanding of hydrology, hydraulics and sedimentation (*e.g.,* fall velocities of sand/silt/clay), as well as preliminary performance data from several bankfull wetlands in the Mill Creek Watershed, an impaired waterbody with high TSS loads (Miller, M., 2013, Pers. Comm.). For all flows above benchfull (*e.g.,* ~10 cfs in SFG 5.3-UNT 0.3) we assume that 20% of the flow is routed through the wetland with a ~29% TSS removal rate (Leisenring *et al.*, 2012). This equates to removing ~6% of the TSS load associated with flows above benchfull, or ~63,000 pounds of the estimated 1.1 million pounds annually. A conservative unit cost estimate of ~$2 per acre-feet means the installation of 2.5 acre-feet of

wetlands in the South Fork of Gunpowder Creek Subwatershed should cost approximately $220,000.

4. **Pet Waste Program/Educational Outreach –** Dog doo programs are some of the most cost-effective stormwater management practices documented (CWP, 2013). An adequately implemented pet waste program, including well-stocked and labeled stations in areas high in dog-walking traffic, and regular maintenance, could result in a bacteria reduction of ~80 billion colonies annually per dog in the program area. This estimate is based on values provided in literature for dog waste production, concentration of bacteria in dog waste, anticipated fraction of daily waste captured per dog, stream delivery ratio, and an estimated fraction of dog walkers who clean up after their dogs (Caraco, 2002; CWP, 2013). Preliminarily, the installation of 16 stations is recommended. The material, installation and maintenance (3 years) cost of the program is estimated to be ~$30,000.

Agricultural Land (with an initial focus on the Riddle Run Subwatershed)

1. **Livestock Exclusion Fencing –** GCWI should work with local farms to install exclusion fencing to keep livestock out of the streams.

a) **Map horse farms in GIS if possible** - Horse farms may or may not show up in zoning, but BCCD has a list of 30 larger operations that may be used as a starting point.

b) **Targeted outreach to horse farms** - In Riddles Run, there are horse farms in the headwaters and near the monitoring location. Known dry weather *E.coli* issues make this a good candidate.

c) **Targeted outreach to farms that lack adequate exclusion fencing** - Locate farms where fencing may be beneficial and offer assistance to those farmers. Based on the assumption that 20% of cattle waste is deposited directly into streams when available, an estimated ~600 billion colonies per year can be kept out of the streams for each cow excluded by fence installations. Exclusion fencing will not only keep livestock from disrupting and polluting streams directly, it will also result in the creation of riparian buffer zones that help to filter overland runoff. At an approximate cost of $2 per foot, a budget of $20,000 is recommended for the installation of ~10,000 linear feet of fencing.

d) **Offer assistance for other practices** – Continue to provide extension service assistance for rotational grazing, manure management, grassed waterways, cover crops, manure testing for fertilizer application, etc.

Undeveloped Areas (with an initial focus on the Lower Gunpowder Creek Subwatershed)

Boone County has been one of the fastest growing counties in the state of Kentucky. Development slowed during the economic recession; however, new development is anticipated to increase as the economy continues to recover. Beyond the pertinent Action Items listed for the overall watershed above, such as revising rules and regulations (Item #2) and providing training for local designers and contractors (Item #7), the following Action Item is recommended for areas that are currently undeveloped:

1. **Conservation of Open Areas –** BCCD should work with local authorities and stakeholders to pursue cost-effective methods to preserve, conserve, and/or improve green spaces. This includes strategies discussed above for the overall watershed including riparian buffers plantings

(Item #6) and actions pertaining to rules and regulations (Item #2) such as open space requirements, setbacks, reduced use of impervious surfaces, and other strategies to better protect Boone County's water resources. It also includes strategies to preserve/conserve undeveloped lands, especially forested areas along streams and on steep slopes, via conservation easements and other practices to promote the long-term sustainability of the natural condition. GIS mapping of publicly-owned undeveloped lands has already been completed as the first step of the preservation effort (**Figure 5-10** and **Appendix 5-A**). Coordination with private conservation groups, such as The Boone Conservancy, is also being pursued. At the time of the writing of this Plan, no specific properties had been identified as feasible candidates and no line-item funding had been allotted. However, if strategic properties for conservation become available during plan implementation, funds should be re-prioritized to the extent feasible to support the implementation of such efforts.

Subwatershed Prioritization

In order to prioritize subwatersheds for BMP implementation, the extent of impairment, known opportunities within the watershed, cost, and feasibility was all considered. The prioritization was also stratified such that we had a representative sample of the diversity of the watershed land uses and hydrogeomorphic settings. The prioritization includes:

1. South Fork (developed headwaters)
2. Lower Gunpowder (undeveloped bottomlands)
3. Riddles Run (agricultural headwaters)
4. Fowler Fork (mixed rural/developed headwaters)
5. Upper Gunpowder (developed headwaters)
6. Long Branch (agricultural headwaters)

It should be acknowledged that the prioritization could change depending upon the opportunities that arise during the timeframe of implementation funding. For example, flood control master planning projects require large investments for modeling, design, and construction. If a stakeholder agency was planning to develop or implement a master plan in one of the subwatersheds, it should immediately be reconsidered as a possible priority watershed due to the opportunity to leverage large amounts of resources for improvement to both water quantity and quality issues.

Even if smaller opportunities arise such as local flooding concerns, prioritization may be given if there are opportunities to help improve habitat and water quality in addition to flooding. For example, at the Boone County Fiscal Court meeting on February 4, 2014, flooding issues were discussed regarding the property at 1846 Conner Road in Hebron, Kentucky, in the headwaters of Gunpowder Creek (priority area #5 in the list above). From a preliminary inspection of the small upstream catchment area, it seems to be apparent that the lack of adequate stormwater detention at Connor Middle and High Schools is likely a primary cause of the problem (**Figure 6-4**). Increasing the size of the culvert near the property at 1846 Conner Road is certainly one way to improve local flooding; however, it does nothing to improve flooding, channel erosion, or water quality downstream. A larger culvert simply uses public resources to push the flooding problem downstream and allows for stream erosion and water quality pollution to potentially become worse as a consequence.

Figure 6-4 – Aerial photo of the 1846 Connor Road property where flooding issues were discussed at the February 4, 2014 Fiscal Court Meeting. The small upstream catchment area includes Connor Middle School, which appears to have inadequate stormwater controls to protect against downstream flooding and stream erosion. As opposed to strictly focusing on increasing the size of the downstream culvert, public funding could be invested in volume-based stormwater controls to solve the root cause of the problem provide numerous benefits to downstream property owners and the health of Gunpowder Creek.

Alternatively, if partnerships could be established between stakeholders such as Conner Middle and High Schools, Boone County, and others, it could be possible to invest in solutions that address the root cause of the flooding problem. Simple BMPs such as routing downspouts and gutters to open spaces and/or installing new detention could not only help to address flooding at 1846 Conner Road, but also improve flooding, stream erosion, water quality, and habitat throughout the Gunpowder Creek. Implementing such activities in the headwaters of the network can be even more cost-effective than at other locations for this very reason. If such a holistic approach was embraced by the necessary stakeholders, GCWI may reprioritize Upper Gunpowder to be the priority developed watershed as opposed to South Fork (priority area #1 in the list above) in order to more actively support a comprehensive solution.

BMP Feasibility/Priority List

There are any number of combinations of volume-based stormwater BMPs, rural dry-weather BMPs, and education/outreach BMPs that will result in load reductions to meet the water quality benchmarks in the Gunpowder Creek and its tributaries. **Table 6-6** includes the Action Items listed above, with potential funding mechanisms, responsible parties, and goals for implementation. **Table 6-7** includes a prioritized list based on Steering Committee and Technical Committee input, load reduction effectiveness, feasibility, and a preliminary cost target of $1,000,000 for the initial implementation phase. For the focus areas related to the action items and implementation goals, refer to **Figure 6-5** to **Figure 6-7**.

Table 6-6: Prioritized BMP list including action items, potential funding mechanisms, responsible parties, and goals for implementation

BMP	Action Items	Potential Funding Mechanism	Responsible Parties	Goals for Implementation[e] Short-term	Intermediate	Long-term	Total	
Overall Watershed								
Coordination with NKU FILO Program	1. Coordinate projects with NKU. 2. Provide guidance on best project locations.	319(h) grant[d] NKU FILO funds	GCWI NKU	0	1	2	3	years
Revise Rules and Regulations	1. Review participation rate in the SD1 Qcritical credit program for new developments. 2. Continue coordination with SD1 and Florence regarding channel protection controls. 3. Coordinate with BCPC to incorporate more LID strategies into Planning/Zoning Requirements and Subdivision Regulations.	319(h) grant[d]	GCWI SD1 & Florence BCPC	1	0	0	1	revision
Riparian Plantings	1. Identify areas along the stream corridor that are lacking vegetation. 2. Facilitate partnerships to promote reforestation, especially along stream riparian zones and on steep slopes. 3. Plant vegetation along the stream banks.	319(h) grant[d]	GCWI	500	2,500	1,500	4,500	linear feet
Success Monitoring and Analysis	1. Complete water quality and hydromodification monitoring at strategic locations downstream of constructed projects. 2. Evaluate monitoring data for future implementation guidance.	319(h) grant[d]	GCWI	0	1	2	3	years
Stewardship Programs (public/private/individual)	1. Identify entities willing to contribute to project funding and/or implementation efforts. 2. Continue to engage and educate the local community to garner support for project implementation and future success monitoring efforts.	319(h) grant[d]	GCWI Private Companies Individual Landowners	1	1	1	3	years
Training/Technical Support Program	1. Develop training material and conduct training sessions to educate local designers and contractors on the importance of water quality and channel protection controls.	319(h) grant[d]	GWCI SD1 & Florence	1	1	1	3	years

BMP	Action Items	Potential Funding Mechanism	Responsible Parties	Goals for Implementation[e]				
				Short-term	Intermediate	Long-term	Total	
Watershed Coordinator (half time)	1. Administer, manage, and implement the Watershed Plan.	319(h) grant[d]	GCWI	1	1	1	3	years
Structural and non-structural BMPs	1. Design and construct any BMP's listed in Table 5-3.	-	-	As needed	As needed	As needed	-	
On-site Wastewater Treatment	1. Work with the N. KY Health Department to determine feasibility and areas of greatest concern. 2. Identify potential faulty septic system and/or straight pipes. 3. Pursue funding sources in coordination with the N. KY Health Department or other entities to address identified issues.	-	N. KY Health Department	0	As needed	As needed	-	
Education and Outreach	1. Publish project updates on the BCCD website and in the *Landscapes* and *What's Happening* newsletters. 2. Incorporate educational signage into any projects, whenever feasible.	319(h) grant[d]	GCWI	1	1	1	3	years
Developed Headwaters [a]								
Bioinfiltration	1. Locate opportunities for bioinfiltration. 2. Coordinate with landowners. 3. Design and construct bioinfiltration.	319(h) grant[d] Landowners	GCWI SD1 & Florence Landowners	0	0	0	0	acre-feet
Detention Basin Retrofits	1. Locate existing basins with potential based on capacity, impact, and potential owner cooperation. 2. Work with owners to secure grant money where possible. 3. Design and install the retrofits, overcompensating locally if necessary to reach the design target for the entire subwatershed, considering impact of BMPs.	319(h) grant[d] Landowners	GCWI SD1 & Florence Landowners	2	4	4	10	retrofits

BMP	Action Items	Potential Funding Mechanism	Responsible Parties	Goals for Implementation[e]				
				Short-term	Intermediate	Long-term	Total	
Detention Basins	1. Locate opportunities for new detention basins in heavily developed areas that do not currently have detention. 2. Coordinate with landowners to allow construction of a new basin or obtain property to construct new detention basins. 3. Design and construct the detention basins that provide channel protection controls.	319(h) grant[d] Landowners	GCWI SD1 & Florence Landowners	1	1	1	3	acre-feet
Pet Waste Program/Educational Outreach	1. Identify locations with frequent dog walkers. 2. Identify roles and responsibilities for supplying bags and maintaining receptacles. 3. Install educational signage as well as pet waste bags and trash receptacles.	319(h) grant[d]	GCWI	2	8	6	16	stations
Wetland Creation/ Restoration	1. Evaluate feasibility of obtaining a single, generic permit from KDOW to perform this type of work in the floodplain. 2. Continue coordination and cost-sharing with NKU FILO. 3. Design and construct/restore wetlands.	319(h) grant[d] NKU FILO funds	GCWI KDOW NKU	0	2	1	3	acre-feet
Agricultural Areas [b]								
Livestock Exclusion Fencing	1. Map hourse farms in GIS if possible 2. Targeted outreach to horse farms 3. Targeted outreach to livestock farms that lack adequate exclusion fencing 4. Continue to promote incentive programs for manure management, fencing, and riparian buffer strips.	319(h) grant[d] USDA (EQUIP)	GCWI USDA Landowners	2,000	4,500	3,500	10,000	linear feet

BMP	Action Items	Potential Funding Mechanism	Responsible Parties	Goals for Implementation[e]				
				Short-term	Intermediate	Long-term	Total	
Undeveloped Areas/Forestry[c]								
Conservation of Open Areas	1. Continue to promote conservation of forested lands, particularly those that currently serve as riparian buffer zones. 2. Conduct meeting with local conservation groups regarding efforts to identify potential properties for conservation.	-	GCWI N. KY Urban Forestry Council	1	1	1	3	meetings

[a] Developed BMP strategies will be evaluated first in the priority subwatershed of South Fork Gunpowder. However, GCWI plans to implement these strategies in any subwatershed in which opportunities are optimal and cost-effective.
[b] Agricultural BMP strategies will be evaluated first in the priority subwatershed of Riddles Run. However, GCWI plans to implement these strategies in any subwatershed in which opportunities are optimal and cost-effective.
[c] Undeveloped Areas/Forestry BMP strategies will be evaluated first in the priority subwatershed of Lower Gunpowder. However, GCWI plans to implement these strategies in any subwatershed in which opportunities are optimal and cost-effective.
[d] 319(h) grant monies include a 40 percent non-federal match. Reference Table 6-7 for additional information regarding the cost of each BMP.
[e] Implementation is dependent on receiving 319(h) grant money and takes us through 2018 and goals following 2018 should be determined based on the project implementation and success monitoring.

Table 6-7: Prioritized BMP list/budget including estimated costs and load reductions

BMP	Unit Cost		#	Total Cost	Estimated Load Reductions in Priority Watershed			
					TSS	Bacteria	TP	TN
Overall Watershed								
Coordination with NKU FILO Program	$ 333	per year	3	$ 1,000	-	-	-	-
Revise Rules and Regulations	$ 15,000	ea	1	$ 15,000	100 %[a]	100 %[a]	100 %[a]	100 %[a]
Riparian Plantings [b]	$ 20	per lf	4500	$ 90,000	74 %[c]	629 billion colonies per livestock animal excluded per yr [d]	48 %[c]	35 %[c]
Success Monitoring and Analysis	$ 20,000	per year	3	$ 60,000	-	-	-	-
Stewardship Programs (public/private/ individual)	$ 3,000	per year	3	$ 9,000	-	-	-	-
Training/ Technical Support Program	$ 15,000	per year	3	$ 45,000	-	-	-	-
Watershed Coordinator (half time)	$ 30,000	per year	3	$ 90,000	-	-	-	-
Developed Headwaters [e]								
Bioinfiltration [f]	$ 174,000	per ac-ft	0.35	$ 61,000	11,000 lbs	2,000 billion colonies/yr	20 lbs/yr	TBD
DB Retrofits [f][g][h]	$ 10,000	ea	10	$ 100,000	1,520,000 lbs	240,000 billion colonies/yr	2,000 lbs/yr	TBD
Detention Basins [f][i]	$ 87,000	per ac-ft	3	$ 261,000	100,000 lbs	20,000 billion colonies/yr	100 lbs/yr	TBD
Pet Waste Program [j]	$ 1,845	per station	16	$ 30,000	-	82 billion colonies per dog in the program area per year [k]	3,000 lbs/yr	23,000 lbs/yr
Wetland Creation/ Restoration [l]	$ 87,000	per ac-ft	2.5	$ 218,000	63,000 lbs	4,000 billion colonies per year	60 lbs/yr	70 lbs/yr

BMP	Unit Cost	#	Total Cost	TSS	Estimated Load Reductions in Priority Watershed Bacteria	TP	TN
Agricultural Areas							
Livestock Exclusion Fencing [m]	$ 2 per lf	10,000	$ 20,000	TBD	629 billion colonies per livestock animal excluded per yr [d]	9 lbs per head of cattle excluded per yr [n]	60 lbs per head of cattle excluded per yr [n]
Undeveloped Areas/Forestry							
Conservation of open areas	$ - -	-		-	-	-	-
		TOTAL	$ 1,000,000				

[a] Load reductions for revised rules and regulations assume that rules can be revised to reduce 100% of the excess future loads from future development relative to the current rules and regulations.

[b] Cost per linear foot assumes a ~15 ft wide riparian buffer strip along the top of the stream bank using average seeding cost estimates from EQIP ranging from ~$100 to ~$700 per acre. Buffer will be sewn with native riparian vegetation seeds, with 1 live stake per square yard, averaging ~1.5 live stakes per lineal foot of riparian buffer strip. Live staking is estimated to cost $10 per stake for material and installation.

[c] Reported values for TSS, phosphorous and nitrogen removal refer to pollutants flowing from upland and filtered by the riparian zone adjacent to the channel (Wenger, 1999). Absolute reductions will depend on drainage areas for restored riparian segments and pollutant levels coming from those drainage areas, and would need to be calculated per case. Reduction in TSS due to stream bank stabilization by vegetation is not included in the estimated reductions, but could have a larger impact than filtration where existing banks are bare and unstable.

[d] Bacteria production by livestock estimates were taken from BWC, 2009, which reports 2.5 million cfu per gram of raw manure. This falls within the range of values reported in literature (e.g. Wright et. al., 2001). The Banklick Watershed Plan also reports 4,160 tons of manure produced annually by 3000 livestock, for an average of 1.38 tons per livestock per year. Assuming 20% of livestock waste is deposited directly into streams when available, exclusion fencing and/or riparian buffers will reduce bacteria from manure by 20% per livestock excluded.

[e] The South Fork of Gunpowder Creek has the highest impervious cover, highest TSS levels, and most excessive bank erosion. It is also likely that this subwatershed has the largest shortage of detention volume. SD1 reports that there are 139 detention basins in the subwatershed. Assuming the 1.4 ac-ft per basin estimate, there is an estimated 200 ac-ft of detention storage. Based on interpolation from case studies, the South Fork subwatershed could need approximately 550 ac-ft of optimized storage for channel protection. This means the South Fork could be up to 350 ac-ft short of the target volume. Comparing this to the estimated 185 ac-ft shortage for the entire watershed upstream of the gage shows the limitations of using average detention basin sizes from a limited sample size to develop watershed-scale estimates. Even so, the anlaysis underscores the likelihood that the South Fork of Gunpowder Creek is the watersehd with the largest stormwater storage deficit. Therefore, early efforts for mitigating the erosive flow regime should be focused here, including all new detention volume and retrofits.

[f] [illegible]

(f) Bioinfiltration, detention basin retrofits, and detention basins are assumed to have optimized storage. Reduction rates were calculated under the assumptions that storage time is approximately doubled when release rates are optimized, and that an approximate doubling of treatment time will result in an approximate doubling of pollutant load removal over that of standard detention basins as reported in the Internation Storm Water BMP Database (Leisenring, 2012). See Tables 5-5 and 5-6.

(g) Assume that the larger basins within the watershed are targeted for retrofits, with an average existing volume of 5 ac-ft. This yields an estimated 5.5 ac-ft of optimized storage per basin.

(h) Detention basin retrofits should be designed to control the release of stormwater to minimize excess rates of bed material and bank erosion in receiving streams. Local case studies to date suggest load reductions of 80-120% of corresponding TSS loads from future bank failure that would be attributable to the local catchment area draining to the respective detention basin. Assuming an average TSS reduction rate of 100%, installing 10 in the South Fork subwatershed, targeting the largest available ponds (estimated at an average of 5 ac-ft), the retrofits may remove up to 1.5 million pounds of TSS from the stream they drain to.

(i)The calculated TSS load reduction from detention basins is based on 100% reduction of TSS that would be attributable to bank erosion induced by excess stormwater from the land area that is drained by the detention basin. By installing these new detention basins in the South Fork subwatershed, where there is an estimated ~600,000 lb/mi2yr - or 9.8 million lbs total - generated by bank erosion, 3 ac-ft of new storage in this subwatershed results in an estimated 100,000 lbs of TSS removal in the South Fork subwatershed.

(j) Costs for the installation and maintenance of pet waste stations include $200 per station for materials, an estimated 4 hrs per station at $70 per hr (2 workers) for installation, and an estimated 15 minutes per week for 3 years at $35 per hr for maintenance. These are consistent with national references and local pricing experience. Phosphorous and Nitrogen cost-effectiveness rates are taken directly from CWP (2013), with Nitrogen removal as $0.44 per lb removed and Phosphorous removal as $3.36 per lb. These are very approximate rates based on several assumptions, and should be revised as more appropriate, regional data become available.

(k) Bacteria reduction by a pet waste program is not calculated as a function of # of stations. Instead, stations are expected to be installed at a proper density to adequately serve the population of pet owners who will use them. The reduction was calculated as a function of daily wast production per dog (Caraco 2002), fecal concentration in dog waste (Caraco 2002), anticipated fraction of daily waste captured (CWP 2013), percentage of dog owners who are expected to clean up after their dogs (Caraco 2002), and stream delivery ratio (Caraco 2002).

(l) Removal rates by wetland channels as reported in the International Storm Water BMP Database (Leisenring, 2012) were used to calculate those for wetlands here, under the anticipation that bankfull/benchfull wetlands would be utilized in the SFG 5.3 UT watershed. It was assumed that enough wetlands would be constructed so that approximately 20% of the flow in the stream would be routed through these wetlands, removing ~29% of TSS, ~19% of bacteria, ~7% of phosphorous, and ~16% of nitrogen from that ~20%.

(m) Livestock exclusion fencing cost estimates are based on EQIP standards for fence installation ($1.53 per ft) and access control ($19.98 per acre). Access control was converted to a cost per foot by assuming square lots (660'x660' per acre), resulting in an estimated $0.03 per foot. The costs provided by EQIP represent 75% of total estimated cost, so these numbers were mulitplied by 1.33 to approximate the total (~$2.08 per ft).

The following figures present initial focus areas for implementation efforts.

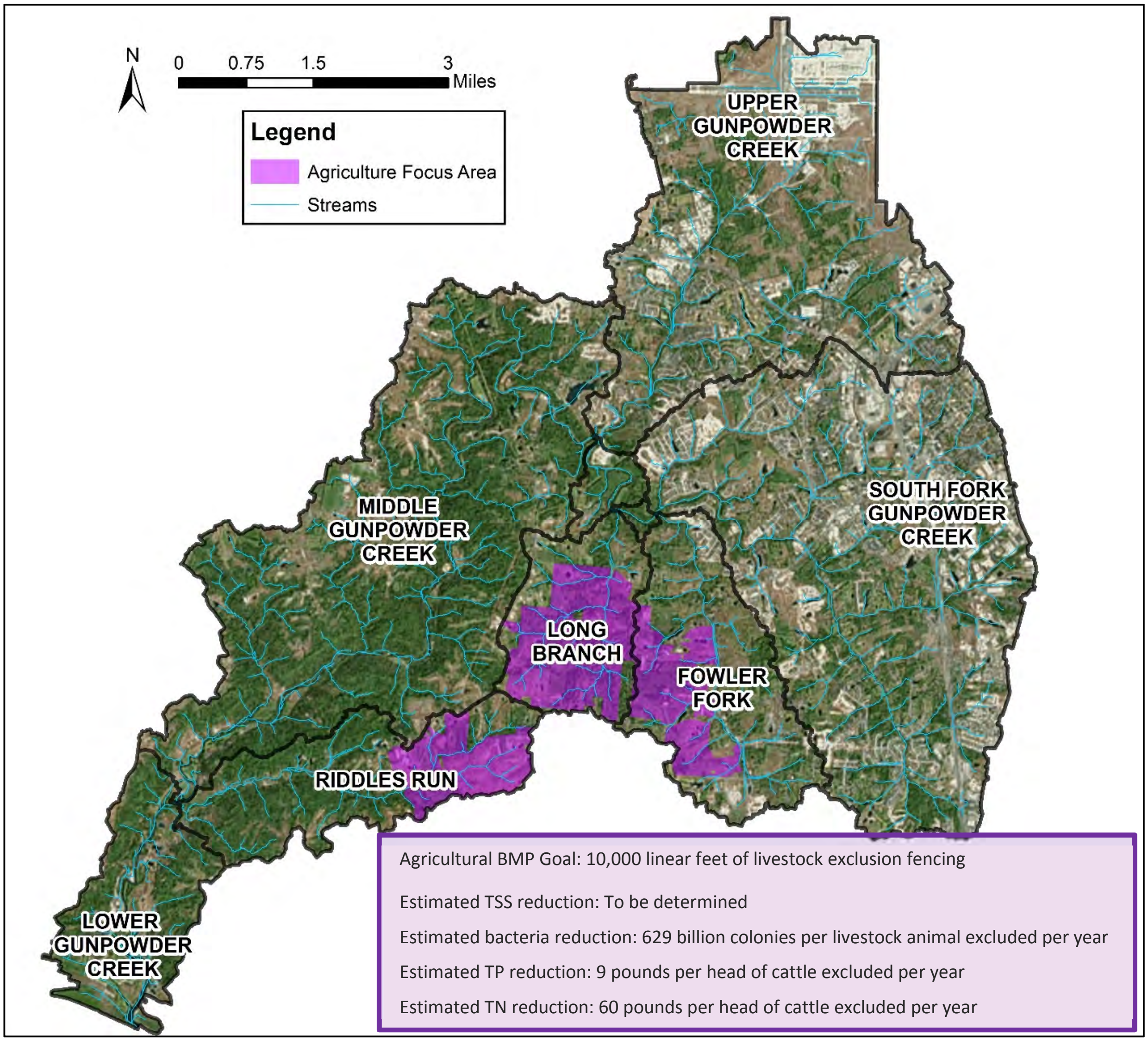
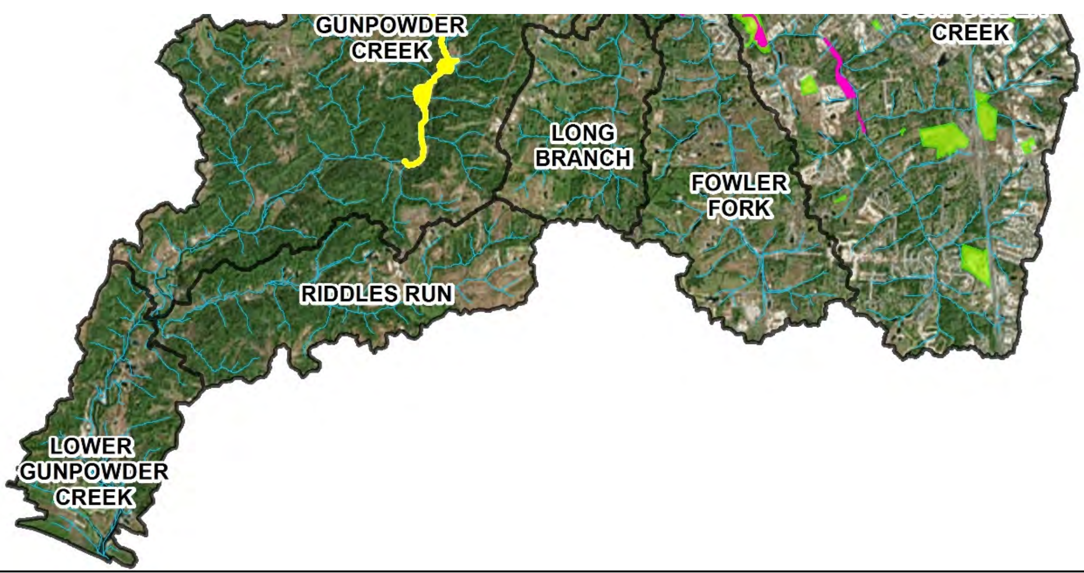


Figure 6-5: Potential Focus Areas for Agricultural BMP Implementation (See Table 6-7 for further details)

Note: The depicted agricultural BMP focus areas were identified by Boone County Conservation District.



Riparian Buffer BMP Goal: 4,500 linear feet

Estimated TSS reduction: 74%

Estimated bacteria reduction: 629 billion colonies per year

Estimated TP reduction: 48%

Estimated TN reduction: 35%

Bioinfiltration BMP Goal: 0.35 acre-feet of storage

Estimated TSS reduction: 11,000 pounds

Estimated bacteria reduction: 2,000 billion colonies per year

Estimated TP reduction: 20 pounds per year

Estimated TN reduction: To be determined

Bankfull Wetlands BMP Goal: 2.5 acre-feet of storage

Estimated TSS reduction: 63,000 pounds

Estimated bacteria reduction: 4,000 billion colonies per year

Estimated TP reduction: 60 pounds per year

Estimated TN reduction: 70 pounds per year

Figure 6-6: Potential Focus Areas for Riparian Buffer and Stormwater BMP Implementation (See Table 6-7 for further details)

Note: Initial bioretention focus areas were determined by highlighting large parcels of land with high levels of impervious surface. Nearly all of the parcels identified above are public properties. Riparian buffer focus areas were identified by Boone County Conservation District. Bankfull wetlands were determined by evaluating low-lying areas near the streams.

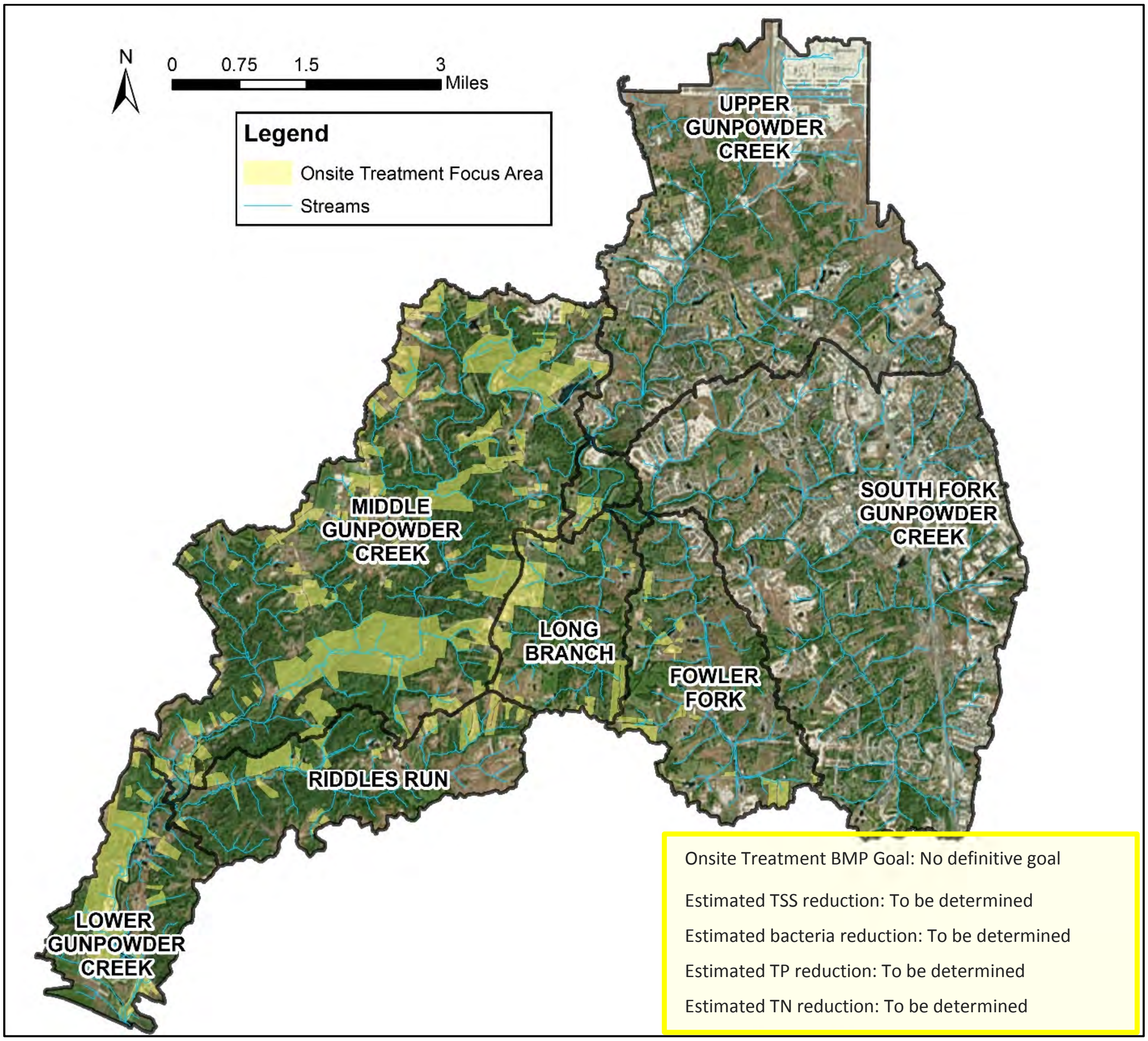


Figure 6-7: Potential Focus Areas for Onsite Wastewater Treatment Implementation (See Table 6-7 for further details)

Note: Initial onsite wastewater treatment focus areas were determined by parcels that have a building on them but are not served by SD1's sanitary sewer system, as presented in Chapter 5 of this Watershed Plan.

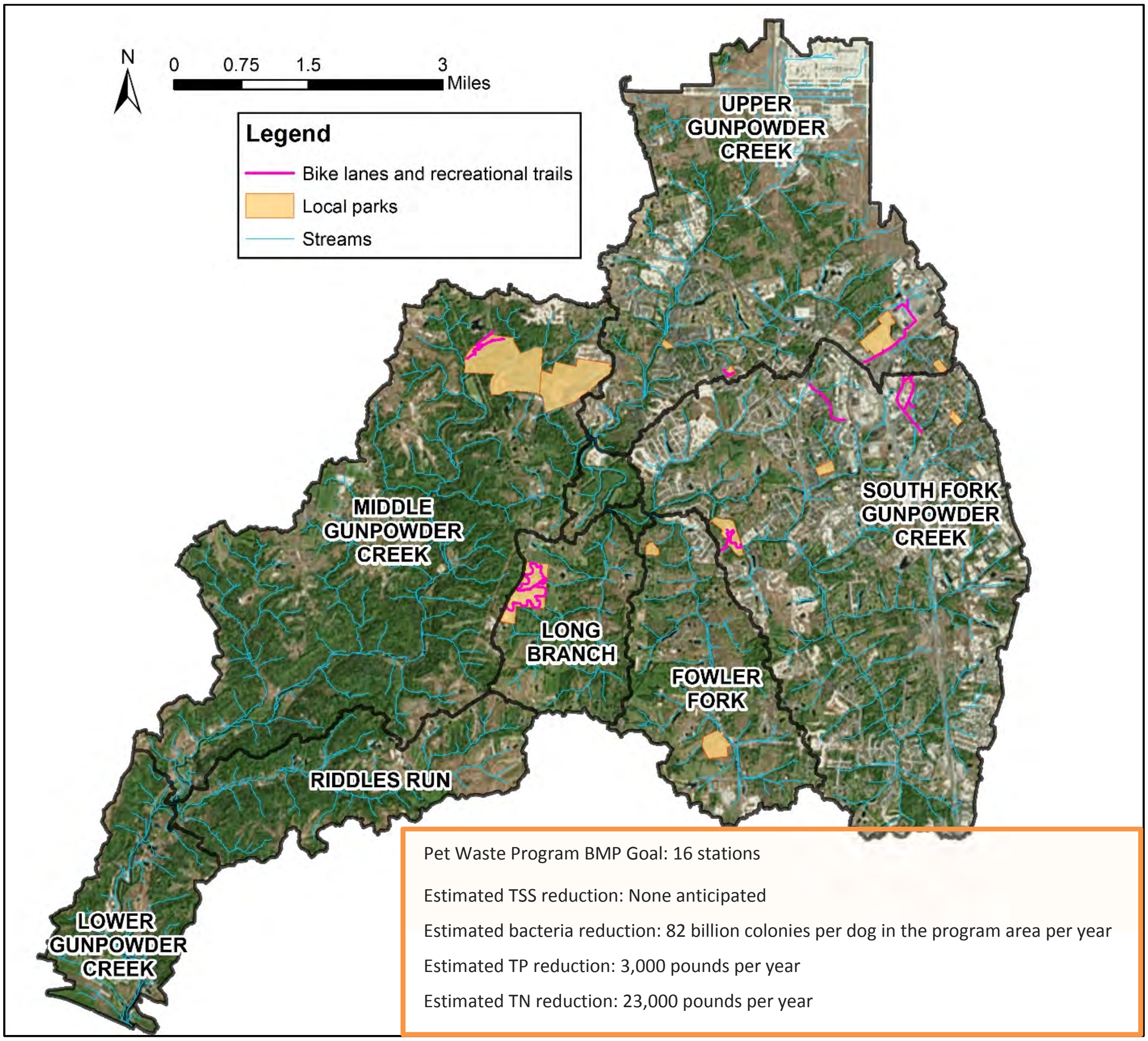


Figure 6-8: Potential Focus Areas for Pet Waste Program Implementation (See Table 6-7 for further details)

Note: Initial pet waste program focus areas were determined by highlighting the locations of local parks and recreational trails and bike lanes to determine where dog walkers may be most prevalent. There are no dog parks within the watershed.

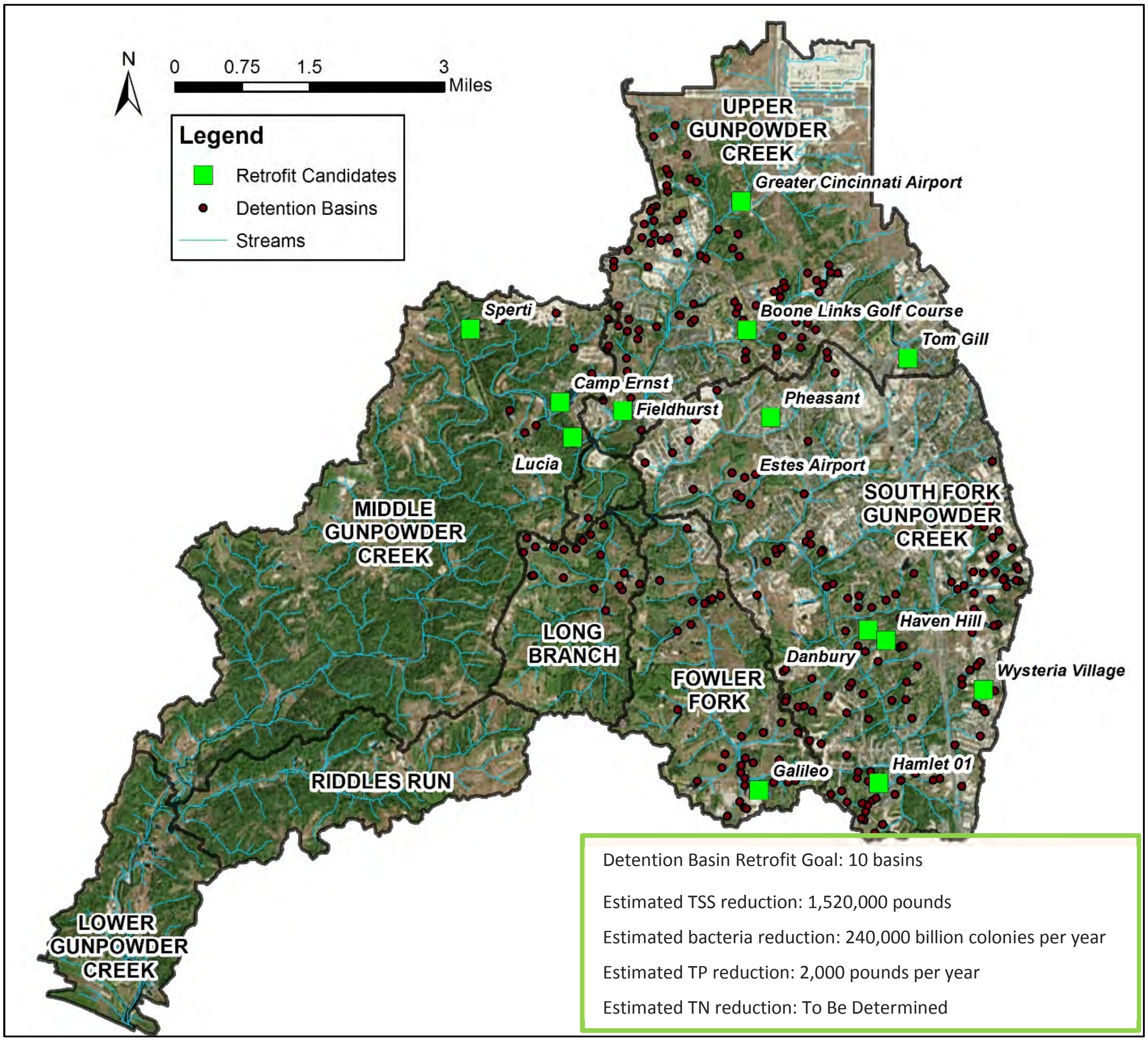


Figure 6-9: Potential Focus Areas for Detention Basin Retrofit Implementation (See Table 6-7 for further details)

Note: The initial detention basin retrofit focus areas were determined using field data from approximately 20 basins within the watershed and engineering judgment identify the most optimal configurations for retrofitting.

6.2.2 Plan Examples

The GCWI has used a wide array of local, regional, and national examples of watershed plans, technical guidance, and critical reviews of planning and guidance. **Table 6-6** regarding the Action Items is a framework that was developed from example guidance. The KDOW-approved Banklick Creek Watershed Plan (BWC, 2009) is from a neighboring watershed and was also referenced in the development of this plan. Technical reports and peer reviewed papers on hydromodification management were also very informative (*e.g.,* Hawley *et al.*, 2012).

6.3 Finding the Resources

The GCWI continues to expand its pool of human and monetary resources to contribute to the success of this project. The Steering Committee, Technical Committee, and BCCD's web of human resources include representatives from local stakeholder agencies and experts across different land management areas (*e.g.,* forestry, agriculture, and development/planning), stream integrity monitoring (*e.g.,* biology, chemistry, habitat, geomorphology, and hydrology), and BMP design/planning (*e.g.,* stormwater, wetlands, stream restoration, wastewater, etc.).

6.3.1 Potential Resources

Numerous partners have contributed and continue to contribute to this project. This provides a list of potential resources and is by no means inclusive of all the possible funding/agency resources that could be available.

NRCS Resources

The National Resources Conservation Service (NRCS) run the Conservation of Private Grazing Land (CPGL) program, which may be using in the Gunpowder Creek Watershed. This program can provide technical assistance to cattle farmers in the watershed on better land management to preserve water quality.

319(h) Nonpoint Source Funds

As mentioned in Section 6.6.1, the GCWI is currently applying for additional 319(h) funding for implementation efforts. The current grant does have remaining funds that will be used for implementation also. Additional details can be found in Chapter 7.

Kentucky EXCEL

Kentucky's Environmental and Public Protection Cabinet runs a program called Excellence in Environmental Leadership (EXCEL). Upon brief evaluation of the list of participating members, it does appear that some businesses that are part of the program are located within the Gunpowder Creek Watershed. Further evaluations and beginning discussions with some of these entities may provide additional resources.

In-Lieu Fee Program for Stream and Wetland Mitigation

This resource has been discussed throughout the chapter and is highlighted in both **Table 6-6** and **Table 6-7**. The GWCI is very aware of the FILO program that is run through NKU and anticipates utilizing this resource.

Additional Resources

NKU and SD1 have been big contributors in terms of project matching sources and monitoring expertise. These partners, along with the City of Florence and others may be able to contribute matching projects on future grant applications. The single largest and underutilized resources in the Gunpowder Creek Watershed are the ~535 existing detention basins valued at ~$60 million. Systematically retrofitting these existing resources will provide much greater benefits to stream health than they are currently providing. The second largest sources of potential resources are the flood control improvement efforts underway by SD1 and the City of Florence. Capitalizing on those large investments to ensure that water quality and stream erosion protection are also improved through those investments would ensure that regional investments of public funds return the greatest cumulative benefit for the least cost. Conservation of any of the large tracts of public or privately owned land could also provide immense benefits regarding the protection of Gunpowder Creek and possibly provide large amounts of potential matching funds to future projects.

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CHAPTER 7

Making It Happen

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

December 2014

Chapter 7: Making It Happen

This chapter details the implementation of the Gunpowder Creek Watershed Initiative (GCWI), including key personnel, public involvement, fundraising, monitoring, evaluation and future updating of the plan.

7.1 Advocating for the Gunpowder Creek Watershed Plan

The GCWI Steering Committee has met regularly throughout the watershed planning process and will continue to meet at least every other month following the plan's completion to guide its implementation. The Steering Committee includes representatives of the following agencies (see Chapter 1 for a list of personnel and their roles):

- Boone County Conservation District
- Northern Kentucky Health Department
- Sanitation District No. 1 of Northern Kentucky
- Northern Kentucky University Center for Environmental Restoration
- Boone County Fiscal Court/Public Works
- City of Florence and City of Union
- Kentucky Transportation Cabinet
- Kenton County Airport Board
- Boone County Planning Commission
- Northern Kentucky Area Development District
- Kentucky Division of Water

7.1.1 Reach Out

In addition to keeping the Steering Committee on task, the Watershed Coordinator will be key in reaching out to engage the community in the efforts in the Gunpowder Creek Watershed. The community has been an asset in the development of the Plan, and their continued assistance and interest will be integral to implementation. The GCWI will organize education and outreach events and continue to garner support from the community and work with regional partners to implement the goals of the Watershed Plan.

Figure 7-1: Bluegill caught in Gunpowder Creek

7.1.2 Communication Alternatives

Throughout the planning process, the GCWI's public outreach campaign has included outreach through various forms of media, presentations to stakeholder groups/agencies, surveys, and public meetings including three open houses and three roundtable working sessions. The Watershed Coordinator has also presented and met with groups ranging from City/County officials to fly fishing and kayaking enthusiasts. The Steering Committee fully expects to continue with similar meetings throughout the plan's implemenation.

The ongoing media campaign will continue to utilize email, direct mail, and press releases as well as regular articles in (1) the Conservation District's quarterly *Landscapes* newsletter, which has a distribution of 6,000, and (2) *What's Happening in Boone County*, a unique quarterly publication distributed to over 43,000 households in Boone County. Through press releases, the GCWI has also published periodic articles in *The Boone County Recorder*, the weekly newspaper of record. In addition to *The Recorder's* online presence on www.cincinnati.com and www.nky.com, the GCWI will continue to use the Conservation District's website www.boonecountyky.org/bccd/ and will establish a social media presence via Facebook.

At the time this Plan was written, the finishing touches are being put on a public outreach document that briefly summarizes the Plan. This document will serve as a useful tool for those that do not wish to read the entire plan. The format of the document is similar to the Plan's and the two should be able to be followed congruently.

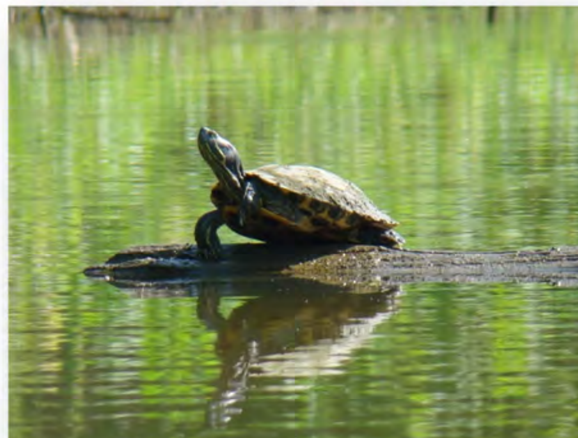

Figure 7-2: Painted turtle sunning itself in Gunpowder Creek

7.2 Securing and Managing Financial Resources

The GCWI has been funded primarily through a FFY 2009 Kentucky Nonpoint Source Pollution Control Program grant, or 319(h) grant, supported by matching funds from a variety of non-Federal sources. The FFY 2014 grant request for the BMP implementation phase of the GWCI is for $1,000,000, including $600,000 in Federal funds with a $400,000 match. Many of the BMP Action Items listed in the Gunpowder Creek Watershed Plan will be fully or partially implemented through this grant. Non-Federal matching funds will likely be associated with project partners in the following forms, among others:

- Boone County Conservation District in the form of personnel time, operating expenses, supplies, publication(s), travel, outreach, etc.
- SD1 and/or City of Florence installing new BMPs or detention basin retrofits that will create additional stormwater storage to better restore the natural flow regime, mitigate streambank erosion, reduce TSS levels, improve habitat, and create a more natural flow regime for benthic macroinvertebrates.

- City of Florence and/or Boone County Parks for installation and maintenance of 16 anticipated dog-doo stations with additional in-kind services from donated time related to the stewardship program.
- Contractual support for the development and implementation of a success monitoring program.
- Contractual support related to technical aspects of the project.
- Volunteer time may be utilized to increase public awareness of the project(s) and provide matching funds, for example, during the riparian planting.

In addition to Federal 319(h) grant funding, additional funding for the GWCI will be sought through local and regaional private foundations as well as local, State, and Federal grant sources that may be identified as potential sources. Private individuals and local non-profit organizations will be encouraged to participate in plan implementation and funding. City and County agencies will be encouraged to include funding for GCWI implementation in their annual budgets, particularly in the form of project-specific BMPs.

The Northern Kentucky Area Development District is providing financial administration of the grant. Effectively, however, BCCD acts as the overall managers of the Plan and approves invoices and budgets.

7.3 Implementation Functions and Roles

Mark Jacobs of the Boone County Conservation District will continue to serve as the **Watershed Coordinator** for the GCWI. Plan implementation will primarily be undertaken by Mr. Jacobs, members of the Steering Committee and Technical Sub-committee. Mr. Jacobs will also be in charge of leading the public outreach and education efforts.

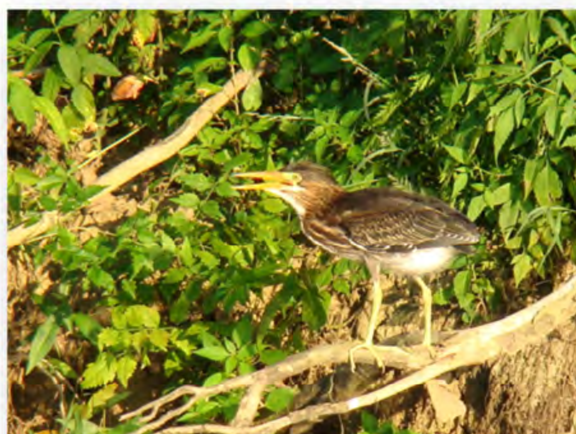

Figure 7-3: Little Green Heron along Gunpowder Creek

The **Technical Sub-committee,** consisting of representatives from the Conservation District, City of Florence, City of Union, SD1, and Sustainable Streams, LLC, will be important to the success of the Plan. As projects are identified, the expertise of this group will help to assess the value of each opportunity, comparing multiple opportunities where necessary, and identifying possible additional funding sources or volunteer groups that may be willing to assist with the Plan. GCWI plans to continue monitoring at strategic locations throughout the watershed to track progress and reassess the implementation goals based on the success of installed projects.

Volunteers and Partner Agencies have donated time and resources for tasks such as Steering Committee meetings, public meetings, and data collection, and these resources will continue to be used for implementation. As mentioned above, volunteer time may be used to meet the local match for the 319(h) grant funding. It is also anticipated that students from Thomas More College will again be used in data collection/monitoring efforts to save costs relative to consultant services, as well as expand awareness through greater levels of involvement of younger stakeholders. As occurred during data collection before the Plan was written, specific, trained individuals will be present to ensure the quality of the samples.

7.4 Adapting to Changes and Challenges

A key element of the GCWI's approach for this Watershed Plan includes continued data collection and monitoring to serve as the basis of reassessing the plan (**Figure7-4**). The GCWI is expecting to make changes to the plan over the course of implementation. In order to achieve the most beneficial impact to the stream, the priority sub-watersheds may change as large projects by stakeholder agencies are planned and implemented. The intent of GCWI is to utilize the Plan's funding to partner with other local entities and groups to either include BMPs where they may have otherwise been excluded or expand the effectiveness of the project, for example, by adding channel protection and water quality components to an otherwise conventional flood control project.

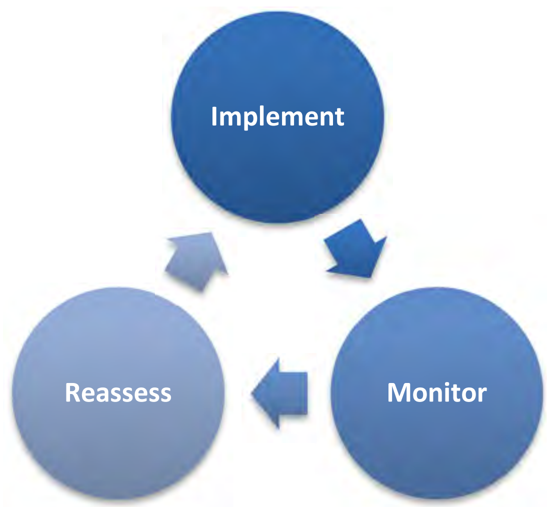

Figure 7-4: GCWI Watershed Plan Approach

Other, unforeseen changes may be necessary as well during implementation. These will be addressed as they arise through the Steering Committee meetings and advice from the Technical Sub-committee.

7.5 Measuring Progress and Success

7.5.1 Tracking Progress

Monitoring, tracking progress, and adjusting the implementation efforts to improve stream health is central to the GCWI's approach (**Figure 7-4**). Progress will be tracked to measure the improvements in the watershed and Gunpowder Creek's water quality. These records will be kept and monitored by the Watershed Coordinator. Once tracked, the projects and next steps will be reassessed to make sure the implementation is achieving the desired and anticipated results.

7.5.2 Improvements in Watershed Health or Practices

The GCWI will measure success in numerous ways, such as the implementation rate of the proposed activities (e.g. 10,500 feet of exclusion fencing installed out of a goal of 10,000). However, the GCWI will also work with KDOW to develop and implement an in-stream success monitoring program to truly measure water quality results. The sampling program will be comparable to the sampling that was performed during the planning process and will be conducted under a KDOW-approved Quality

Assurance Project Plan (QAPP). Depending on available funding and input from KDOW, success monitoring of individual BMPs may also be conducted, for example, via grab sampling and flow monitoring.

For verifying how implementation efforts have affected the conditions of the watershed, SD1 and the cities of Florence and Union will be useful partners. Through plan review with these entities, it will be clear if volume-based stormwater controls are being implemented. For other implementation activities, surveys or feedback at public meetings may be used depending on the activity.

7.5.3 Improvements in Water Quality

As previously mentioned, documenting in-stream success is a primary goal of the GCWI. Provided with sufficient funding, GCWI will develop a KDOW-approved monitoring plan and QAPP continue to monitor at the established stations, including biological, water quality, hydrological, habitat, and geomorphic surveys. This action item will also guide future adjustments to the BMP implementation strategy and document BMP effectiveness in the local setting.

Figure 7-5: Crayfish on the bank of Gunpowder Creek

7.5.4 Group Vitality

Both the Steering Committee and Technical Sub-committee want to see the successful implementation of the *Gunpowder Creek Watershed Plan* and improvements in the water quality and stream stability of the creek. We intend that these groups will continue to be excited and interested in the work that is being done. Through bi-monthly meetings, the Steering Committee will receive progress updates on current efforts. The Technical Sub-committee will receive these updates as their expertise is needed on current efforts.