Gunpowder Creek Watershed TMDL Alternative: 2023 Progress Report

Reporting Period: September 2021 – October 2023

1.0 Summary

In February 2018, the Kentucky Division of Water (DOW) and EPA Region 4 accepted the Gunpowder TMDL Alternative plan (TMDL Alt), which consists of the Gunpowder Creek Watershed Plan and the Primary Contact Recreation (PCR) supplement. This plan addresses the 303(d)–listed segments within Gunpowder Creek Watershed (Figure 1.1 and 1.2).

A progress report was submitted to DOW annually from 2019-2021. The submittal schedule was updated to every two years to incorporate complete data sets from monitoring years and the implementation from that timeframe. The following sections provide an overview of the implementation that has occurred in the subwatersheds of Gunpowder Creek and the results of monitoring from September 2021 – October 2023.

1.1 Updates to 303(d)-listed Segments

The TMDL Alt and the 2019-2021 progress reports included the 2016 303(d)-listed segments (Figure 1.1). Changes that have occurred since that time are reflected in the most recent published 2022 303(d) list. The 2022 listed segments are displayed in Figure 1.2 and the changes are noted in Table 1.0.

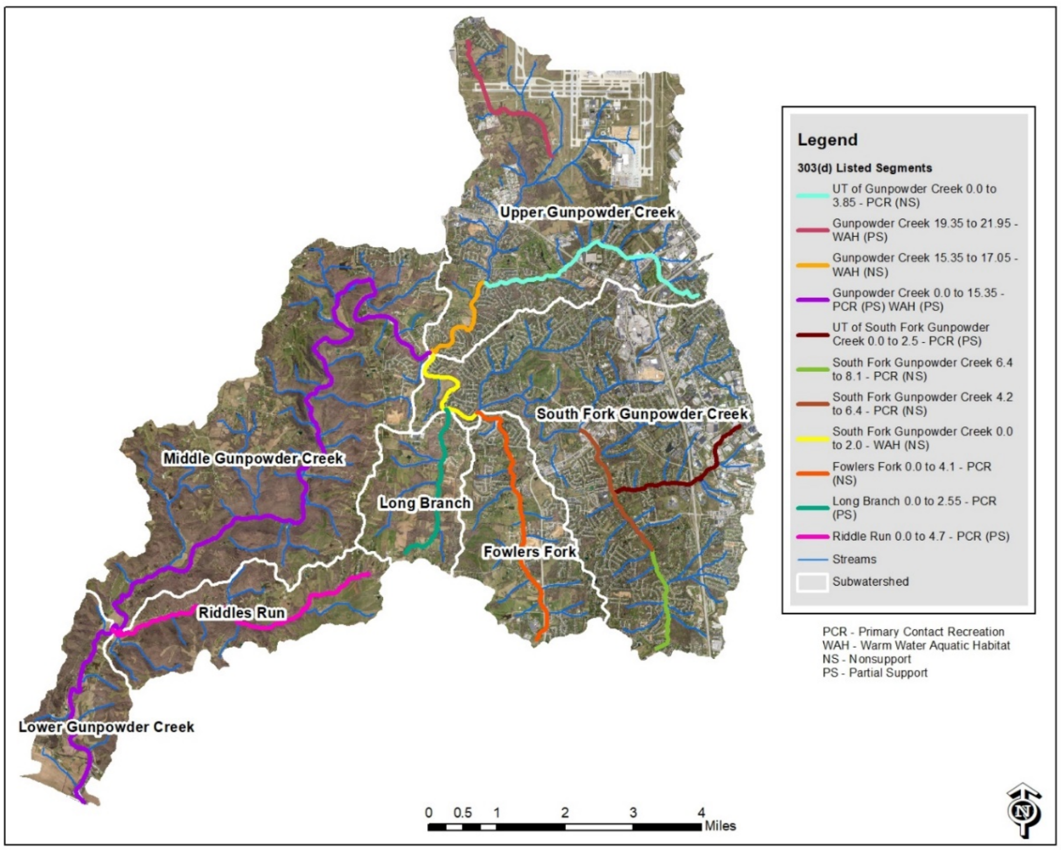

Figure 1.1: Gunpowder Creek Watershed, Subwatersheds and 2016 303(d)-listed Segments

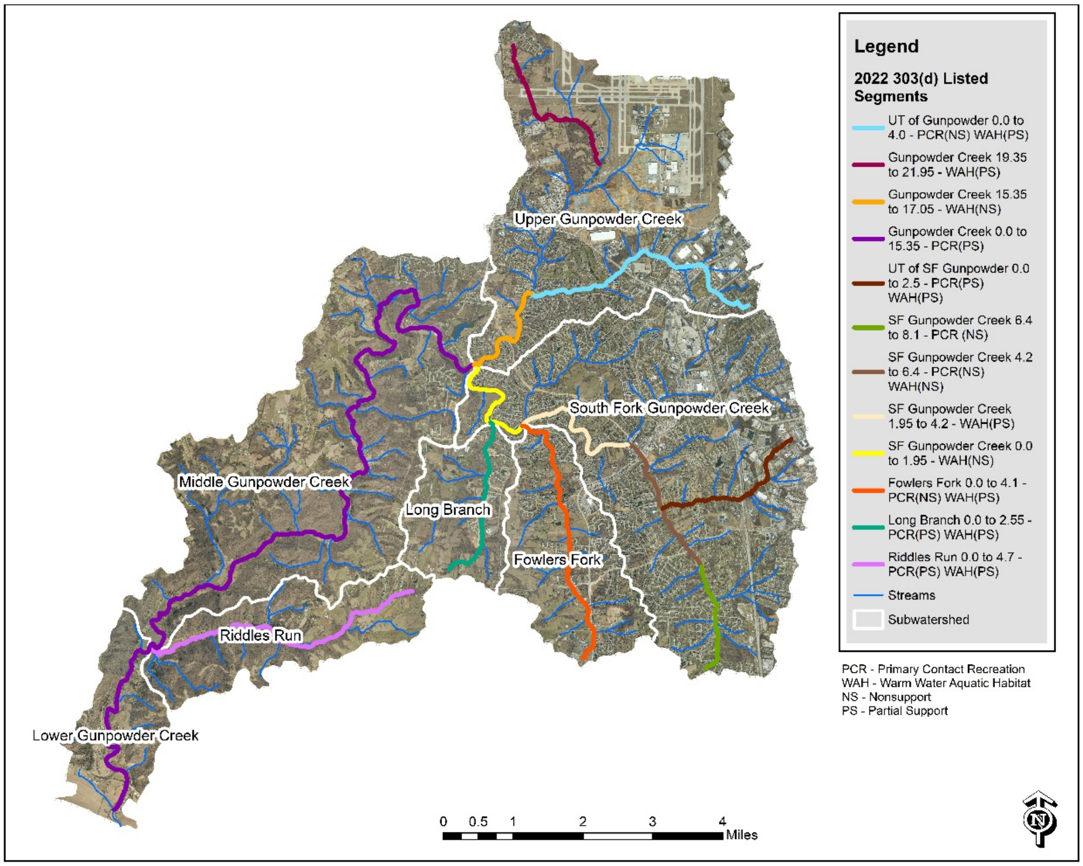

Figure 1.2: Gunpowder Creek Watershed, Subwatersheds and 2022 303(d)-listed Segments

One important item of note is the delisting of Gunpowder Creek 0.0 to 15.35 for Warm Water Aquatic Habitat (WAH). Additional details regarding the delisting are included in the Nonpoint Source Success Story.

There were no changes in the listings for Primary Contact Recreation (PCR). Seven segments that had previously been unassessed for Warm Water Aquatic Habitat (WAH) are now identified as impaired. Five of these segments are impaired but not on the 303(d) list because they are assigned category 4c, which indicates the impairment is not attributable to a pollutant or a combination of pollutants and does not require a TMDL (e.g. habitat assessment). Two new impairments were added to the 303(d) list as partial support, due to Sedimentation/Siltation. Although these Sedimentation/Siltation impairment listings are new and were not identified officially on the 303(d) until the 2022 list, sediment impacts have been previously been recognized in these streams. The Gunpowder Creek Watershed plan will improve sedimentation through activities such as stream restoration and riparian protection, detention basin retrofits, implementation of the critical flow requirement for new development and education programing. The Division of Water plans to consider these two new impairments for inclusion under the Gunpowder Creek TMDL Alternative during development of the 2024 303(d) list. If approved, the listings will show that a plan is in place for these listings and the TMDL priority is Low.

Table 1.0 Summary of Changes for 303(d) Listed Segments in Gunpowder Creek (2016 to 2022)

AU_ID	Segment	Use	2016 303(d) Listings	2022 303(d) Listings*	Category 5 Parameters for Impairment	Summary of Changes
KY-875	Gunpowder Creek UT 0.0 to 4.0	PCR	5 - NS	5 - NS	E.coli; Sedimentation/Siltation	No Change
		WAH	Not Assessed	5 - PS		New Listing
KY-874	Gunpowder Creek 19.35 to 21.95	PCR	Not Assessed	Not Assessed	Cause Unknown	No Change
		WAH	5 - PS	5 - PS		No Change
KY-873	Gunpowder Creek 15.35 to 17.05	PCR	Not Assessed	Not Assessed	Organic Enrichment (Sewage) Biological Indicators; Nutrient/Eutrophication Biological Indicators; Sedimentation/Siltation	No Change
		WAH	5 - NS	5 - NS		No Change
KY-872	Gunpowder Creek 0.0 to 15.35	PCR	5 - PS	5 - PS	E.coli	No Change
		WAH	5 - PS	Full Support		Delisted
KY-1767	South Fork Gunpowder Creek UT 0.0 to 2.5	PCR	5 - PS	5 - PS	E.coli	No Change
		WAH	Not Assessed	4c - PS		New Listing
KY-1766	South Fork Gunpowder Creek 6.4 to 8.1	PCR	5 - NS	5 - NS	E.coli	No Change
		WAH	Not Assessed	Not Assessed		No Change
KY-1765	South Fork Gunpowder Creek 4.2 to 6.4	PCR	5 - NS	5 - NS	E.coli	No Change
		WAH	Not Assessed	4c - NS		No Change
KY-3368	South Fork Gunpowder Creek 1.95 to 4.2	PCR	Not Assessed	Not Assessed	N/A	No Change
		WAH	Not Assessed	4c - PS		New Listing
KY-1764	South Fork Gunpowder Creek 0.0 to 1.95	PCR	Not Assessed	Not Assessed	Sedimentation/Siltation; Organic Enrichment (Sewage) Biological Indicators; Nutrient/Eutrophication Biological Indicators; Turbidity	No Change
		WAH	5 - NS	5 - NS		No Change
KY-784	Fowlers Fork 0.0 to 4.1	PCR	5 - NS	5 - NS	E.coli	No Change
		WAH	Not Assessed	4c - PS		New Listing
KY-1183	Long Branch 0.0 to 2.55	PCR	5 - PS	5 - PS	E.coli	No Change
		WAH	Not Assessed	4c - PS		New Listing
KY-1576	Riddles Run 0.0 to 4.7	PCR	5 - PS	5 - PS	E. coli; Sedimentation/Siltation	No Change
		WAH	Not Assessed	5 - PS		New Listing

Notes: *Segments with 4c are impaired but not on the 303(d) list, PCR - Primary Contact Recreation, WAH - Warm Water Aquatic Habitat, NS – Nonsupport, PS - Partial Support, 5 – impaired and is attributable to a pollutant or a combination of pollutants TMDL required, 4c - impaired, but is not attributable to a pollutant or a combination of pollutants and does not require a TMDL

2.0 Implementation

The Gunpowder Creek Watershed Plan and the Primary Contact Recreation (PCR) supplement outline implementation measures for each of the subwatersheds with the goal of improving water quality. The implementation ranges from education and outreach efforts to on-the-ground projects such as detention basin retrofits. The implementation measures and progress during this reporting period are identified in the tables below as well as the corresponding maps and photos.

2.1 Overall Watershed

Table 2.1.1 Overall Watershed Implementation

BMP Category	Action Items	Progress Report Updates (*Sept 2021 - Oct 2023*)
Watershed Plan (Adapted from Table 6-6 of the Gunpowder Creek Watershed Plan)		
1. Revise Rules and Regulations	a) Continue coordination with SD1 and Florence regarding channel protection controls.	(1a) Since this goal was originally established in the watershed plan, SD1 has implemented a Q-critical requirement for better channel protection in new development. This requirement became effective on Oct 1, 2015. Specific details of the requirement were included in the revised SD1 Rules and Regulations, which was approved by KDOW on August 3, 2020.
	b) Coordinate with BCPC to incorporate more LID strategies into Planning/Zoning Requirements and Subdivision Regulations.	(1b) SD1 provided comments to the BCPC on the 2023 Boone County Subdivision Regulations Update. One comment recommended BCPC to include a requirement for the critical flow (Q-critical) for stream erosion.
2. Stewardship Programs	a) Identify entities willing to contribute to project funding and/or implementation efforts.	(2a) BCCD continues to work closely with the KDFWR Stream Mitigation Team to identify possible stream mitigation projects in Boone County.
	b) Continue to engage and educate the local community to garner support for project implementation and future success monitoring efforts.	
3. Training/Technical Support Program	Develop training material and conduct training sessions to educate local designers and contractors on the importance of water quality and channel protection controls.	The Southwest Ohio and Northern Kentucky Storm Water Collaborative hosted annual Stormwater Field Days in September of 2021-2023. There were over 100 attendees at each event that learned about construction and post-construction BMP requirements, design and maintenance (Figure 2.1.1).
4. Education and Outreach	a) Publish project updates on the BCCD website and in the Landscapes and What's Happening newsletters.	See Table 2.1.2 and Boone County Conservation District Education Programs (Figures 2.1.2, 2.1.3, and 2.1.4)
	b) Incorporate educational signage into any projects, whenever feasible.	

BCPC - Boone County Planning Commission, SD1 - Sanitation District No. 1 of Northern Kentucky, BCCD - Boone County Conservation District, KDFWR - Kentucky Department of Fish and Wildlife Resources

Table 2.1.2 Boone County Conservation District Education and Outreach Events Sept 2021 - Oct 2023

Date	Event	Reach
10/8/21	Electrofishing in Gunpowder tributary for KY Jr. Master Naturalist program	15
1/7/22	Watershed Lesson at elementary school	40
3/10/22	Macroinvertebrate lesson at elementary school	40
3/10/22	Boone County Stream Team salamander search at Boone County Nature Center	15
4/23/22	Stream Clean Up	50
5/2/22	Jr. Board bank stability work day at Camp Ernst Lake	10
6/7/22 – 6/10/22	Conservation Kids Camp at Potter's Ranch	55
6/9/22	Boone County Stream Team field trip to Gunpowder Creek	12
6/18/22	Stream Clean Up	10
6/22/22	LEAF Academy snorkeling and fly fishing in Gunpowder	8
7/12/22	LEAF Academy snorkeling and fly fishing in Gunpowder	14
7/28/22	Boone County Stream Team kayak in Gunpowder Creek	8
8/2/22	Mussel survey training for college interns	6
8/20/22	Pond Scum field day at Camp Ernst Lake	10
10/12/22	Stream Ecology lesson for homeschool group	22
1/5/23	Watershed lesson at elementary school	30
3/3/23	Water Quality lesson at elementary school	30
3/6/23 – 3/9/23	Conservation Kids Camp at Boone County Nature Center	30
3/23/23	Salamander Search for homeschool group	25
7/11/23	LEAF Academy snorkeling and fly fishing in Gunpowder	12
7/5/23	Macroinvertebrate lesson for homeschool group	10
7/31/23	Tour of Gunpowder Creek wetland	9
	Total	**461**

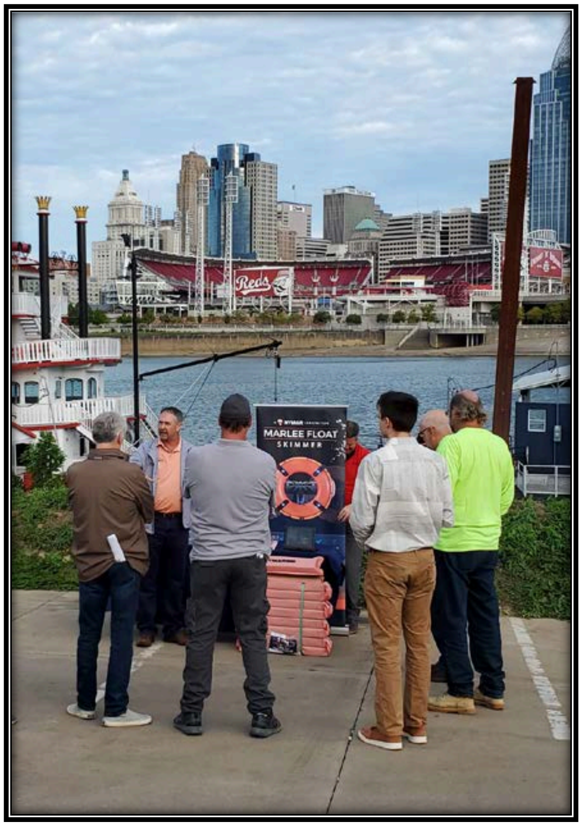

Figure 2.1.1: Stormwater Field Day

Figure 2.1.2: Jr. Board Bank Stability Work Day

Figure 2.1.3: Conservation Kids Camp

Figure 2.1.4: LEAF Academy Fly Fishing

2.2 Upper Gunpowder Creek Subwatershed

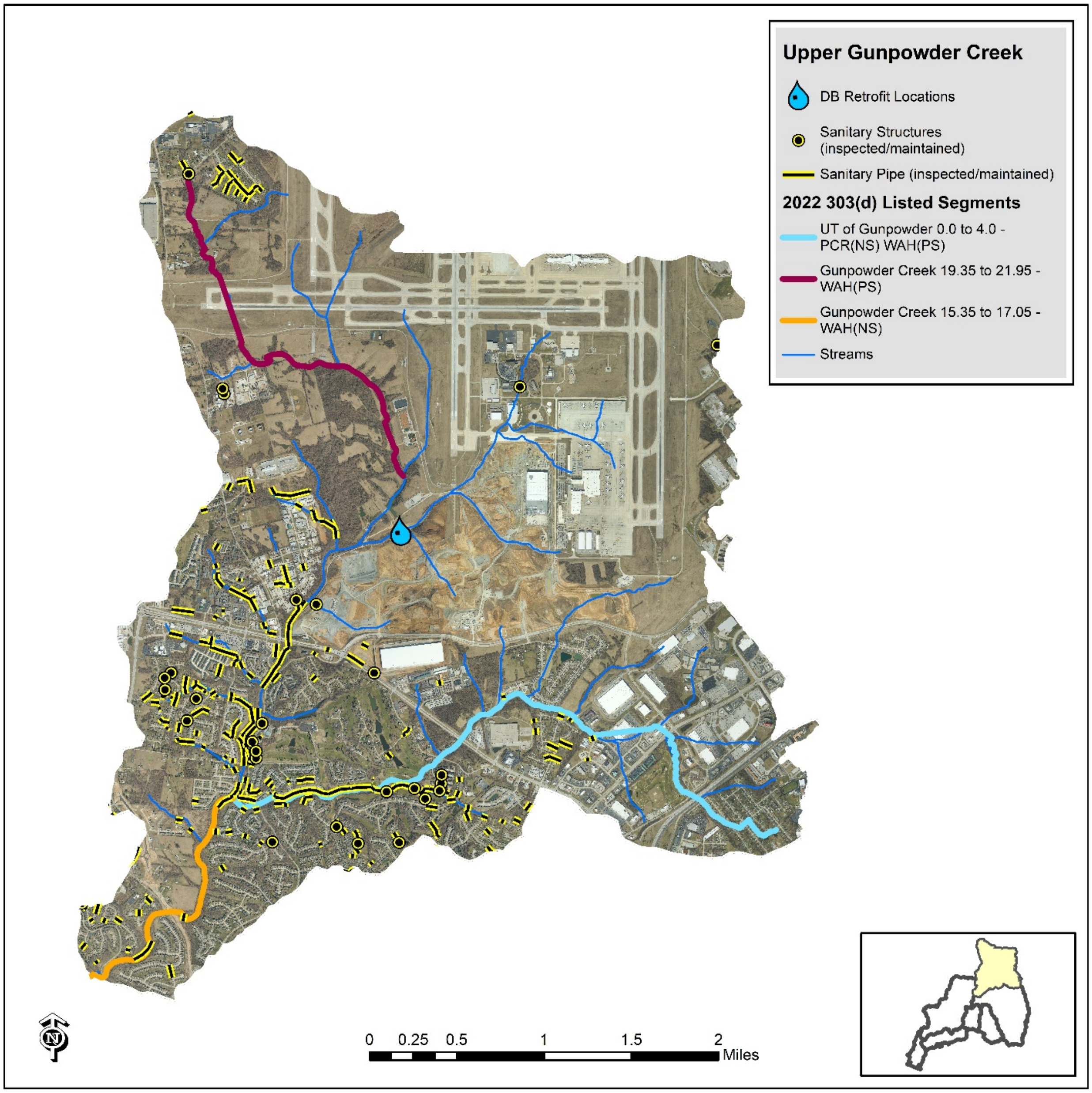

Figure 2.2.1: Upper Gunpowder Creek Subwatershed Implementation

Table 2.2 Upper Gunpowder Creek Subwatershed Implementation

BMP Category	Action Items	Progress Report Updates (*Sept 2021 - Oct 2023*)
Watershed Plan (Adapted from Table 6-6 of the Gunpowder Creek Watershed Plan)		
1. Coordination with NKU FILO Program and KDFWR	a) Coordinate projects with NKU and KDFWR	No information for this reporting period
	b) Provide guidance on best project locations	
2. Riparian Plantings	a) Identify areas along the stream corridor that are lacking vegetation	No information for this reporting period
	b) Facilitate partnerships to promote reforestation, especially along stream riparian zones and on steep slopes	
	c) Plant vegetation along the stream banks	
3. Bioinfiltration	a) Locate opportunities for bioinfiltration	No information for this reporting period
	b) Coordinate with landowners	
	c) Design and construct bioinfiltration	
4. Detention Basin Retrofits	a) Locate existing basins with potential based on capacity, impact, and potential owner cooperation	(4a,b) The airport was awarded 319(h) funding to implement controls on the property's southwest detention basin, which controls a five sq. mi. drainage area in the upper portion of the sub-watershed. The implementation occurred in the summer of 2023, which included a retrofit of the basin's outlet structure using CMAC technology to optimize the retrofit with predictive weather forecast driven real time control technology (Figure 2.2.2). Based on sediment transport analysis using Q-critical flows for stream bed morphology, Strand Associates, LLC determined that the retrofit of the southwest basin could reduce the post-developed sediment transport in Gunpowder Creek by nearly 53 percent. SD1 has monitoring locations downstream of the project and will continue to evaluate the impacts of the project. For additional project detail, the 319(h) Final Report is available at [Project Print (epa.gov)].
	b) Work with owners to secure grant money where possible	
	c) Design and install the retrofits, overcompensating locally if necessary to reach the design target for the entire subwatershed, considering impact of BMPs	
5. Detention Basins	a) Locate opportunities for new detention basins in heavily developed areas that do not currently have detention	No information for this reporting period

Table 2.2 cont.

BMP Category	Action Items	Progress Report Updates (*Sept 2021 - Oct 2023*)
Watershed Plan (Adapted from Table 6-6 of the Gunpowder Creek Watershed Plan)		
5. Detention Basins (cont.)	b) Coordinate with landowners to allow construction of a new basin or obtain property to construct new detention basins	No information for this reporting period
	c) Design and construct the detention basins that provide channel protection controls	
6. Wetland Creation/ Restoration	a) Evaluate feasibility of obtaining a single, generic permit from KDOW to perform this type of work in the floodplain	No information for this reporting period
	b) Continue coordination and cost-sharing with NKU FILO	
	c) Design and construct/restore wetlands	
PR Supplement (Adapted from Appendix A of the Gunpowder Creek Watershed Plan Supplement)		
7. Pet Waste Management	a) Develop educational materials and programing to inform and encourage the public to properly manage pet waste	No information for this reporting period
	b) Conduct workshops and participate in community events to provide education	
	c) Establish pet waste disposal stations in key locations such as parks and community areas	
	d) Integrate the information into Boone County Cooperative Extension programing	
8. Illicit Discharge Detection & Elimination (IDDE) Program Implementation	a) Continue to implement the MS4 IDDE programs in SD1 and Florence Storm Water Service Areas	(8a) Implementation of the MS4 IDDE programs in the Florence and SD1 Service Area continued. (8b) No illicits were found within the subwatershed during this reporting period.
	b) Document and track eliminated illicit discharges associated with wastewater (failing septics, broken laterals, etc.)	

Table 2.2 cont.		
BMP Category	**Action Items**	**Progress Report Updates (*Sept 2021 - Oct 2023*)**
PCR Supplement (Adapted from Appendix A of the Gunpowder Creek Watershed Plan Supplement)		
9. Sanitary Improvements	a) Continue to implement the CMOM program in the SD1 service area	(9a,b) Over 60,400 feet of sanitary sewer and 29 sanitary structures were inspected and/or maintained during this reporting period.
	b) Document all repairs, improvements and upgrades for the sanitary system within the watershed	

*GCWI - Gunpowder Creek Watershed Initiative, BCCD - Boone County Conservation District, NKHD - Northern Kentucky Health Department, NRCS - Natural Resources Conservation Service, SD1 - Sanitation District No. 1 of Northern Kentucky, NKU - Northern Kentucky University, KDFWR- Kentucky Department of Fish and Wildlife Resources, FILO - Fee In Lieu of, CMOM - Capacity, Management, Operations and Maintenance

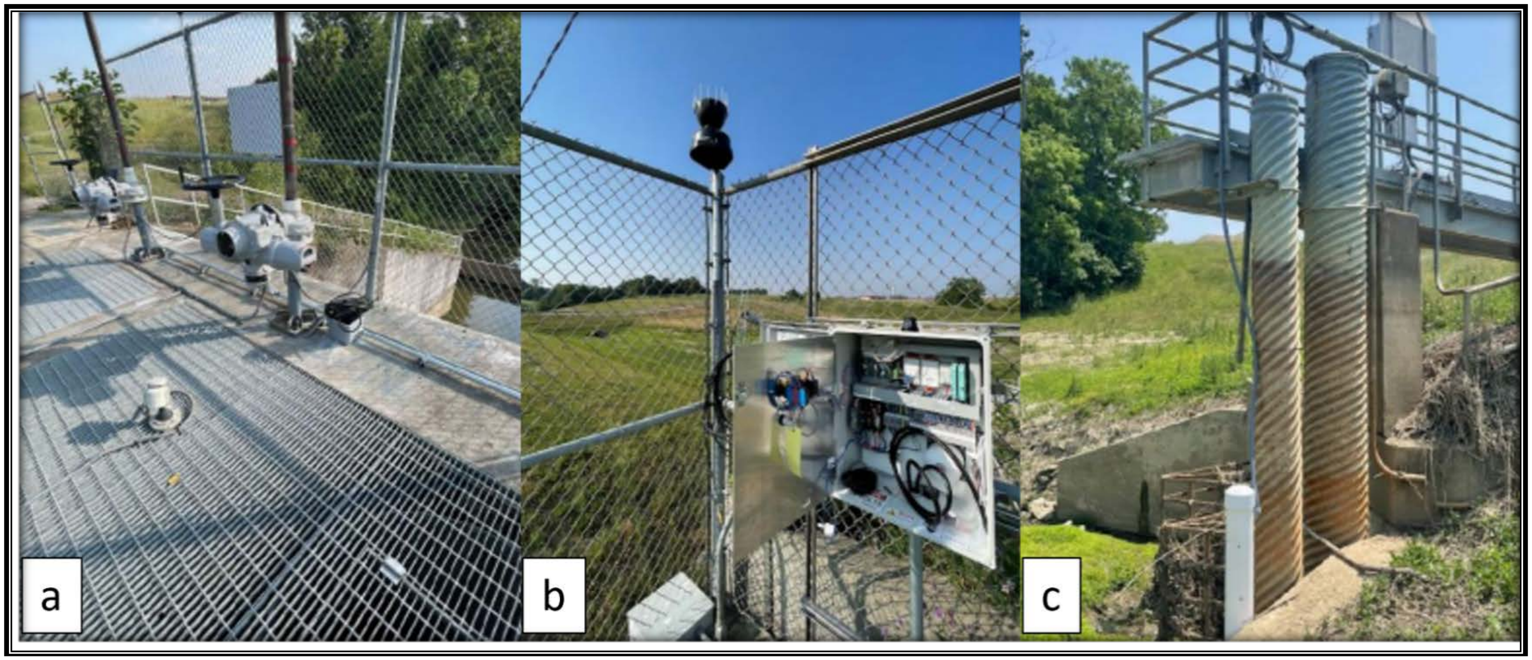

Figure 2.2.2 Airport Southwest Detention Basin Retrofit (a) actuator connections controlling the gates, (b) rain gauge and control panel, (c) Water level sensor in stilling well. Photos from 319(h) Project Final Report (2023).

2.3 South Fork Gunpowder Creek Subwatershed

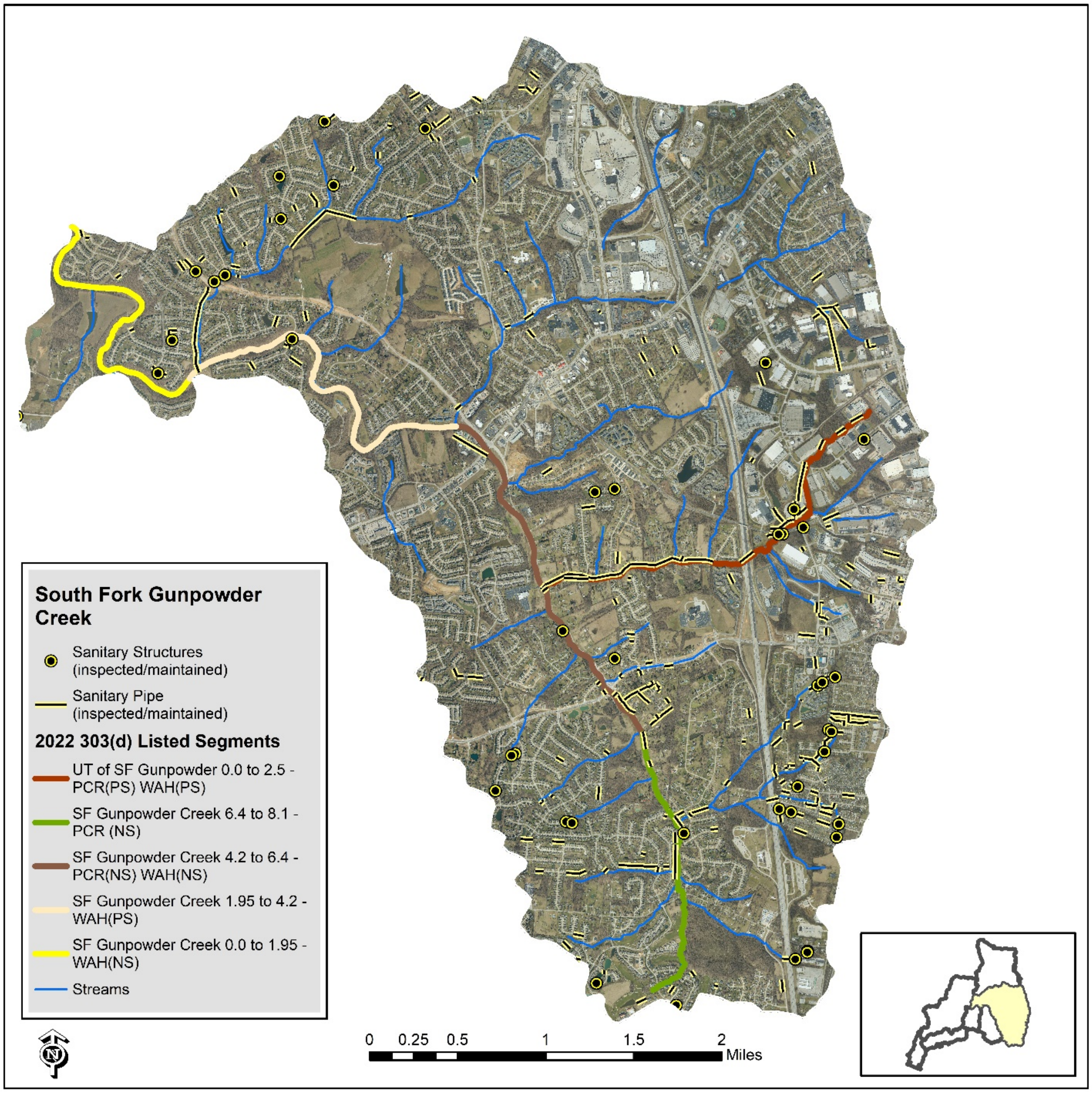

Figure 2.3.1: South Fork Gunpowder Creek Subwatershed Implementation

Table 2.3 South Fork Gunpowder Creek Subwatershed Implementation

BMP Category	Action Items	Progress Report Updates (*Sept 2021 - Oct 2023*)
Watershed Plan (Adapted from Table 6-6 of the Gunpowder Creek Watershed Plan)		
1.Coordination with NKU FILO Program and KDFWR	a) Coordinate projects with NKU and KDFWR	No information for this reporting period
	b) Provide guidance on best project locations	
2. Riparian Plantings	a) Identify areas along the stream corridor that are lacking vegetation.	No information for this reporting period
	b) Facilitate partnerships to promote reforestation, especially along stream riparian zones and on steep slopes.	
	c) Plant vegetation along the stream banks.	
3. Bioinfiltration	a) Locate opportunities for bioinfiltration.	No information for this reporting period
	b) Coordinate with landowners.	
	c) Design and construct bioinfiltration.	
4. Detention Basin Retrofits	a) Locate existing basins with potential based on capacity, impact, and potential owner cooperation.	No information for this reporting period
	b) Work with owners to secure grant money where possible.	
	c) Design and install the retrofits, overcompensating locally if necessary to reach the design target for the entire subwatershed, considering impact of BMPs.	
5. Detention Basins	a) Locate opportunities for new detention basins in heavily developed areas that do not currently have detention.	No information for this reporting period
	b) Coordinate with landowners to allow construction of a new basin or obtain property to construct new detention basins.	
	c) Design and construct the detention basins that provide channel protection controls.	

Table 2.3 cont.		
BMP Category	**Action Items**	**Progress Report Updates (*Sept 2021 - Oct 2023*)**
Watershed Plan (Adapted from Table 6-6 of the Gunpowder Creek Watershed Plan)		
6. Wetland Creation/ Restoration	a) Evaluate feasibility of obtaining a single, generic permit from DOW to perform this type of work in the floodplain.	No information for this reporting period
	b) Continue coordination and cost-sharing with NKU FILO.	
	c) Design and construct/restore wetlands.	
7. Agriculture Improvement	Implement water quality projects with NRCS cost-share programs	No information for this reporting period
PCR Supplement (Adapted from Appendix A of the Gunpowder Creek Watershed Plan Supplement)		
8. Onsite Wastewater Improvement	a) Meet with key stakeholders (responsible parties) and determine future sewer and onsite wastewater options for homes on septic	No information for this reporting period
	b) Based on stakeholder discussions, develop a strategy that may include running sewers to existing homes, repairing septic systems, installing alternative onsite wastewater systems, etc.	
	c) Secure appropriate funding source(s) for implementation of the strategy	
	d) Implement strategy	

Table 2.3 cont.		
BMP Category	**Action Items**	**Progress Report Updates (*Sept 2021 - Oct 2023*)**
PCR Supplement (Adapted from Appendix A of the Gunpowder Creek Watershed Plan Supplement)		
9. Pet Waste Management	a) Develop educational materials and programing to inform and encourage the public to properly manage pet waste	No information for this reporting period
	b) Conduct workshops and participate in community events to provide education	
	c) Establish pet waste disposal stations in key locations such as parks and community areas	
	d) Integrate the information into Boone County Cooperative Extension programing	
10. IDDE Program Implementation	a) Continue to implement the MS4 IDDE programs in SD1 and Florence Storm Water Service Areas.	(10a) Implementation of the MS4 IDDE programs in the Florence and SD1 Service Area continued. (10b) No illicits were found within the subwatershed during this reporting period.
	b) Document and track eliminated illicit discharges associated with wastewater (failing septics, broken laterals, etc.)	
11. Sanitary Improvements	a) Continue to implement the CMOM program in the SD1 service area	(10a,b) Over 74,200 feet of sanitary sewer and 44 sanitary structures were inspected and/or maintained during this reporting period.
	b) Document all repairs, improvements and upgrades for the sanitary system within the watershed	

*GCWI - Gunpowder Creek Watershed Initiative, BCCD - Boone County Conservation District, NKHD - Northern Kentucky Health Department, NRCS - Natural Resources Conservation Service, SD1 - Sanitation District No. 1 of Northern Kentucky, NKU - Northern Kentucky University, KDFWR - Kentucky Department of Fish and Wildlife Resources, FILO - Fee In Lieu of, CMOM - Capacity, Management, Operations and Maintenance

2.4 Fowlers Fork Subwatershed

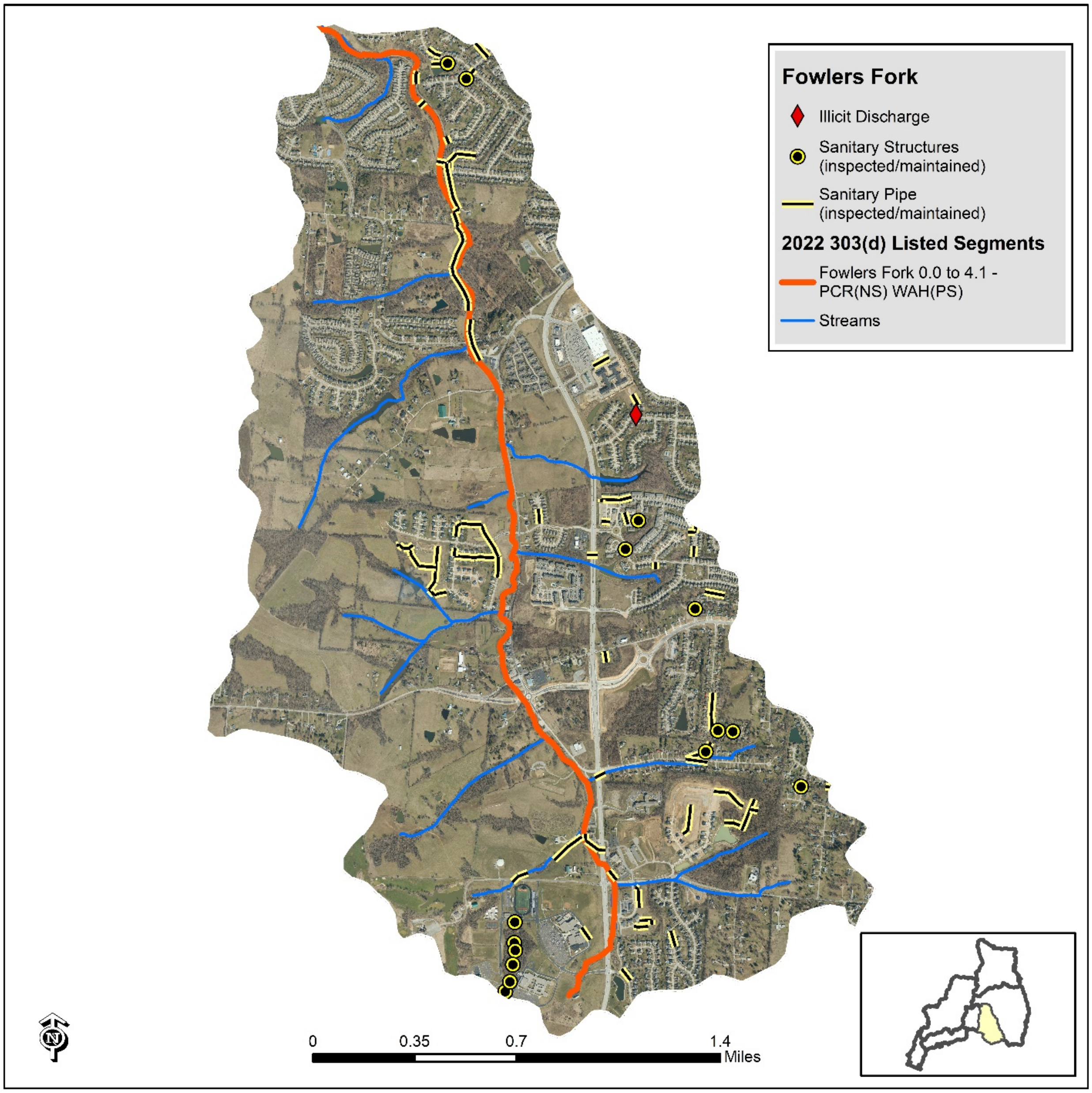

Figure 2.4.1: Fowlers Fork Subwatershed Implementation

Table 2.4 Fowlers Fork Subwatershed Implementation

BMP Category	Action Items	Progress Report Updates (*Sept 2021 - Oct 2023*)
Watershed Plan (Adapted from Table 6-6 of the Gunpowder Creek Watershed Plan)		
1. Coordination with NKU FILO Program and KDFWR	a) Coordinate projects with NKU and KDFWR	No information for this reporting period
	b) Provide guidance on best project locations	
2. Riparian Plantings	a) Identify areas along the stream corridor that are lacking vegetation	No information for this reporting period
	b) Facilitate partnerships to promote reforestation, especially along stream riparian zones and on steep slopes	
	c) Plant vegetation along the stream banks	
3. Bioinfiltration	a) Locate opportunities for bioinfiltration	No information for this reporting period
	b) Coordinate with landowners	
	c) Design and construct bioinfiltration	
4. Detention Basin Retrofits	a) Locate existing basins with potential based on capacity, impact, and potential owner cooperation	No information for this reporting period
	b) Work with owners to secure grant money where possible	
	c) Design and install the retrofits, overcompensating locally if necessary to reach the design target for the entire subwatershed, considering impact of BMPs	
5. Detention Basins	a) Locate opportunities for new detention basins in heavily developed areas that do not currently have detention	No information for this reporting period
	b) Coordinate with landowners to allow construction of a new basin or obtain property to construct new detention basins	
	c) Design and construct the detention basins that provide channel protection controls	

Table 2.4 cont.		
BMP Category	**Action Items**	**Progress Report Updates (*Sept 2021 - Oct 2023*)**
Watershed Plan (Adapted from Table 6-6 of the Gunpowder Creek Watershed Plan)		
6. Wetland Creation/ Restoration	a) Evaluate feasibility of obtaining a single, generic permit from DOW to perform this type of work in the floodplain	No information for this reporting period
	b) Continue coordination and cost-sharing with NKU FILO	
	c) Design and construct/restore wetlands	
PCR Supplement (Adapted from Appendix A of the Gunpowder Creek Watershed Plan Supplement)		
7. Onsite Wastewater Improvement	a) Meet with key stakeholders (responsible parties) and determine future sewer and onsite wastewater options for homes on septic	No information for this reporting period
	b) Based on stakeholder discussions, develop a strategy that may include running sewers to existing homes, repairing septic systems, installing alternative onsite wastewater systems, etc.	
	c) Secure appropriate funding source(s) for implementation of the strategy	
	d) Implement strategy	
8. Agriculture Improvement	Livestock Exclusion Fencing	No information for this reporting period
9. Pet Waste Management	a) Develop educational materials and programing to inform and encourage the public to properly manage pet waste	No information for this reporting period
	b) Conduct workshops and participate in community events to provide education	
	c) Establish pet waste disposal stations in key locations such as parks and community areas	
	d) Integrate the information into Boone County Cooperative Extension programing	

Table 2.4 cont.		
BMP Category	**Action Items**	**Progress Report Updates (*Sept 2021 - Oct 2023*)**
PCR Supplement (Adapted from Appendix A of the Gunpowder Creek Watershed Plan Supplement)		
10. IDDE Program Implementation	a) Continue to implement the MS4 IDDE programs in SD1 and Florence Storm Water Service Areas	(10a) Implementation of the MS4 IDDE programs in the Florence and SD1 Service Area continued. (10b) One illicit discharge was found within the subwatershed during this reporting period. The illicit discharge was due to the dumping of paint into a catch basin. Verbal enforcement was issued to the company requiring clean-up and the use of best management practices in the future.
	b) Document and track eliminated illicit discharges associated with wastewater (failing septics, broken laterals, etc.)	
11. Sanitary Improvements	a) Continue to implement the CMOM program in the SD1 service area	(11a,b) Over 22,000 feet of sanitary sewer and 15 sanitary structures were inspected and/or maintained during this reporting period.
	b) Document all repairs, improvements and upgrades for the sanitary system within the watershed	

*GCWI - Gunpowder Creek Watershed Initiative, BCCD - Boone County Conservation District, NKHD - Northern Kentucky Health Department, NRCS - Natural Resources Conservation Service, SD1 - Sanitation District No. 1 of Northern Kentucky, NKU - Northern Kentucky University, KDFWR - Kentucky Department of Fish and Wildlife, FILO - Fee In Lieu of, CMOM - Capacity, Management, Operations and Maintenance

2.5 Long Branch Subwatershed

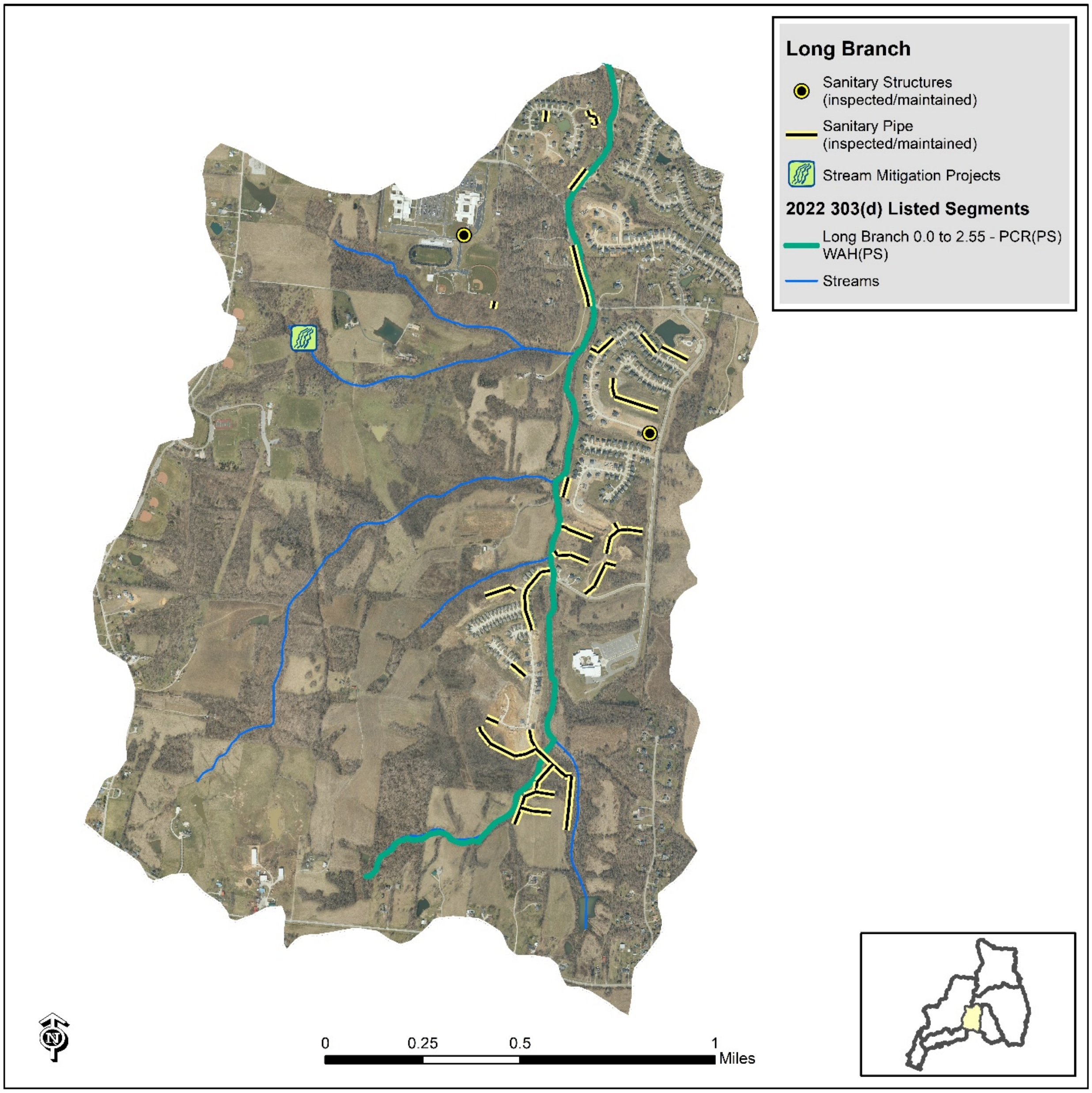

Figure 2.5.1: Long Branch Subwatershed Implementation

Table 2.5 Long Branch Subwatershed Implementation

BMP Category	Action Items	Progress Report Updates (*Sept 2021 - Oct 2023*)
Watershed Plan (Adapted from Table 6-6 of the Gunpowder Creek Watershed Plan)		
1. Coordination with NKU FILO Program and KDFWR	a) Coordinate projects with NKU and KDFWR	NKU is currently implementing a stream restoration project in Boone County's Central Park along a tributary to Long Branch. In 2022 they began honeysuckle clearing in the riparian corridor. In 2023 they initiated the stream restoration construction with expected completion in 2024.
	b) Provide guidance on best project locations	
2. Riparian Plantings	a) Identify areas along the stream corridor that are lacking vegetation.	No information for this reporting period
	b) Facilitate partnerships to promote reforestation, especially along stream riparian zones and on steep slopes.	
	c) Plant vegetation along the stream banks.	
3. Bioinfiltration	a) Locate opportunities for bioinfiltration.	No information for this reporting period
	b) Coordinate with landowners.	
	c) Design and construct bioinfiltration.	
4. Detention Basin Retrofits	a) Locate existing basins with potential based on capacity, impact, and potential owner cooperation.	No information for this reporting period
	b) Work with owners to secure grant money where possible.	
	c) Design and install the retrofits, overcompensating locally if necessary to reach the design target for the entire subwatershed, considering impact of BMPs.	
5. Detention Basins	a) Locate opportunities for new detention basins in heavily developed areas that do not currently have detention.	No information for this reporting period
	b) Coordinate with landowners to allow construction of a new basin or obtain property to construct new detention basins.	
	c) Design and construct the detention basins that provide channel protection controls.	

Table 2.5 cont.		
BMP Category	**Action Items**	**Progress Report Updates (*Sept 2021 - Oct 2023*)**
Watershed Plan (Adapted from Table 6-6 of the Gunpowder Creek Watershed Plan)		
6. Wetland Creation/ Restoration	a) Evaluate feasibility of obtaining a single, generic permit from DOW to perform this type of work in the floodplain.	No information for this reporting period
	b) Continue coordination and cost-sharing with NKU FILO.	
	c) Design and construct/restore wetlands.	
7. Conservation of Open Areas	a) Continue to promote conservation of forested lands, particularly those that currently serve as riparian buffer zones.	No information for this reporting period
	b) Conduct meeting with local conservation groups regarding efforts to identify potential properties for conservation.	
PCR Supplement (Adapted from Appendix A of the Gunpowder Creek Watershed Plan Supplement)		
8. Onsite Wastewater Improvement	a) Meet with key stakeholders (responsible parties) and determine future sewer and onsite wastewater options for homes on septic	No information for this reporting period
	b) Based on stakeholder discussions, develop a strategy that may include running sewers to existing homes, repairing septic systems, installing alternative onsite wastewater systems, etc.	
	c) Secure appropriate funding source(s) for implementation of the strategy	
	d) Implement strategy	
9. Agriculture Improvement	Livestock Exclusion Fencing	No information for this reporting period

Table 2.5 cont.		
BMP Category	**BMP Category**	**Progress Report Updates (*Sept 2021 - Oct 2023*)**
PCR Supplement (Adapted from Appendix A of the Gunpowder Creek Watershed Plan Supplement)		
10. IDDE Program Implementation	a) Continue to implement the MS4 IDDE programs in SD1 and Florence Storm Water Service Areas.	(10a) Implementation of the MS4 IDDE programs in the Florence and SD1 Service Area continued. (10b) No illicits were found within the Long Branch Subwatershed during this reporting period.
	b) Document and track eliminated illicit discharges associated with wastewater (failing septics, broken laterals, etc.)	
11. Sanitary Improvements	a) Continue to implement the CMOM program in the SD1 service area	(11a,b) Over 12,500 feet of sanitary sewer and 2 sanitary structures were inspected and/or maintained during this reporting period (Figure 2.5.2).
	b) Document all repairs, improvements and upgrades for the sanitary system within the watershed.	

*GCWI - Gunpowder Creek Watershed Initiative, BCCD - Boone County Conservation District, NKHD - Northern Kentucky Health Department, NRCS - Natural Resources Conservation Service, SD1 - Sanitation District No. 1 of Northern Kentucky, NKU - Northern Kentucky University, KDFWR - Kentucky Department of Fish and Wildlife, FILO - Fee In Lieu of, CMOM - Capacity, Management, Operations and Maintenance

Figure 2.5.2: SD1 performing sewer maintenance

2.6 Middle and Lower Gunpowder Creek Subwatershed

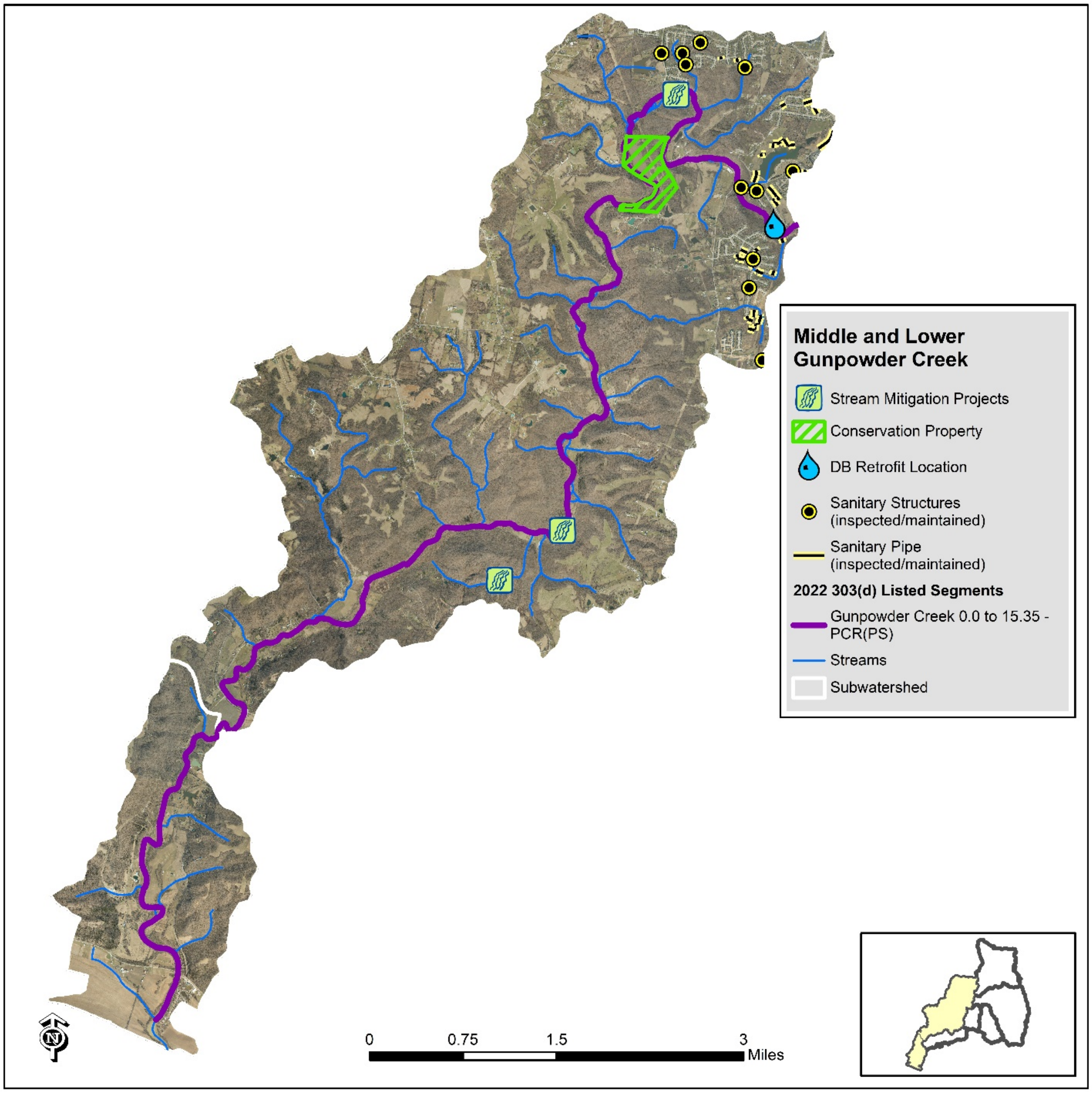

Figure 2.6.1: Middle and Lower Gunpowder Creek Subwatershed Implementation

Table 2.6 Middle and Lower Gunpowder Creek Implementation

BMP Category	Action Items	Progress Report Updates *(Sept 2021 - Oct 2023)*
Watershed Plan (Adapted from Table 6-6 of the Gunpowder Creek Watershed Plan)		
1. Coordination with NKU FILO Program and KDFWR	a) Coordinate projects with NKU and KDFWR b) Provide guidance on best project locations	Three sites have been selected within this subwatershed and are in the planning phase. One project is located on the YMCA and County Park's property and will include restoration of 2.2 miles on the mainstem of Gunpowder Creek and multiple tributaries. The second project is located on the Camp Michaels property and will include restoration of 2.25 miles on the mainstem of Gunpowder Creek and multiple tributaries. The third project is adjacent to Camp Michaels with multiple tributaries to Gunpowder Creek.
2. Riparian Plantings	a) Identify areas along the stream corridor that are lacking vegetation. b) Facilitate partnerships to promote reforestation, especially along stream riparian zones and on steep slopes. c) Plant vegetation along the stream banks.	No information for this reporting period
3. Conservation of Open Areas	a) Continue to promote conservation of forested lands, particularly those that currently serve as riparian buffer zones. b) Conduct meeting with local conservation groups regarding efforts to identify potential properties for conservation.	The Boone County Conservation District (BCCDKY) recently purchased ~ 97 acres of land in the watershed. The property is a mostly forested natural area with ~ 20 acres of bottomland along 0.9 miles of Gunpowder Creek. This area has been the focus of conservation efforts for many years and is an ideal location to expand public access for outdoor recreation, conservation education, nature study, biodiversity, and wildlife habitat. (Figure 2.62).
4. Detention Basin Retrofits	a) Locate existing basins with potential based on capacity, impact, and potential owner cooperation. b) Work with owners to secure grant money where possible. c) Design and install the retrofits, overcompensating locally if necessary to reach the design target for the entire subwatershed, considering impact of BMPs.	One SD1-owned detention basin was retrofitted in 2023. This basin detains runoff from 5.85 acres. With the retrofit, the basin manages Q-critical up to the 10-year storm event (Figure 2.63).

Table 2.6 cont.

BMP Category	Action Items	Progress Report Updates (Sept 2021 - Oct 2023)
PCR Supplement (Adapted from Appendix A of the Gunpowder Creek Watershed Plan Supplement)		
5. Onsite Wastewater Improvement (cont.)	d) Conduct onsite inspections to determine septic condition and appropriate fix if needed	No information for this reporting period
	e) Implement identified fix	
	f) Track all inspections, including location, condition of septic and implementation	
	g) Continue landowner education	
6. Agriculture Improvement	Continued coordination and implementation of the NRCS NWQI	Multiple NRCS projects were completed including 2 watering facilities, 1200 sq ft of heavy use area, 950 ft of fencing and about 15 acres of brush management. The location is not disclosed but occurred in this sub-watershed.
7. IDDE Program Implementation	a) Continue to implement the MS4 IDDE programs in SD1 and Florence Storm Water Service Areas.	(6a) Implementation of the MS4 IDDE programs in the SD1 Service Area continued. (6b) No illicits were found during this reporting period. The Middle and Lower Gunpowder Subwatersheds are outside of the Florence Service Area.
	b) Document and track eliminated illicit discharges associated with wastewater (failing septics, broken laterals, etc.)	
8. Sanitary Improvements	a) Continue to implement the CMOM program in the SD1 service area	(7a,b) Over 8,600 feet of sanitary sewer and 11 sanitary structures were inspected and/or maintained during this reporting period.
	b) Document all repairs, improvements and upgrades for the sanitary system within the watershed.	

*GCWI - Gunpowder Creek Watershed Initiative, BCCD - Boone County Conservation District, NKHD - Northern Kentucky Health Department, NRCS - Natural Resources Conservation Service, SD1 - Sanitation District No. 1 of Northern Kentucky, NKU - Northern Kentucky University, KDFWR - Kentucky Department of Fish and Wildlife, FILO - Fee In Lieu of, CMOM - Capacity, Management, Operations and Maintenance

Figure 2.6.2 Property purchased by BCCD for conservation along Gunpowder Creek

Figure 2.6.3 Detention basin retrofit with plates on outlet control structure

3.0 Monitoring

Monitoring the health of impaired streams involves measuring and tracking trends in stream conditions over time to show improvements in water quality and areas in need of new or additional implementation efforts. There are many types of monitoring for assessing overall stream health including water quality monitoring (measures the amount of pollutants in a stream), biological monitoring (identifying populations of macroinvertebrate and fish species to indicate water quality health), and assessing physical features of a stream (such as habitat and erosion). An important component of a TMDL alternative plan is to have a monitoring plan in place to evaluate the effectiveness of implementation efforts so that progress can be demonstrated and adaptive management can be applied where needed to stay on track for achieving water quality standards.

3.1 Monitoring Sites and Events

SD1 established five long-term monitoring sites within the Gunpowder Creek Watershed (Figure 3.1).

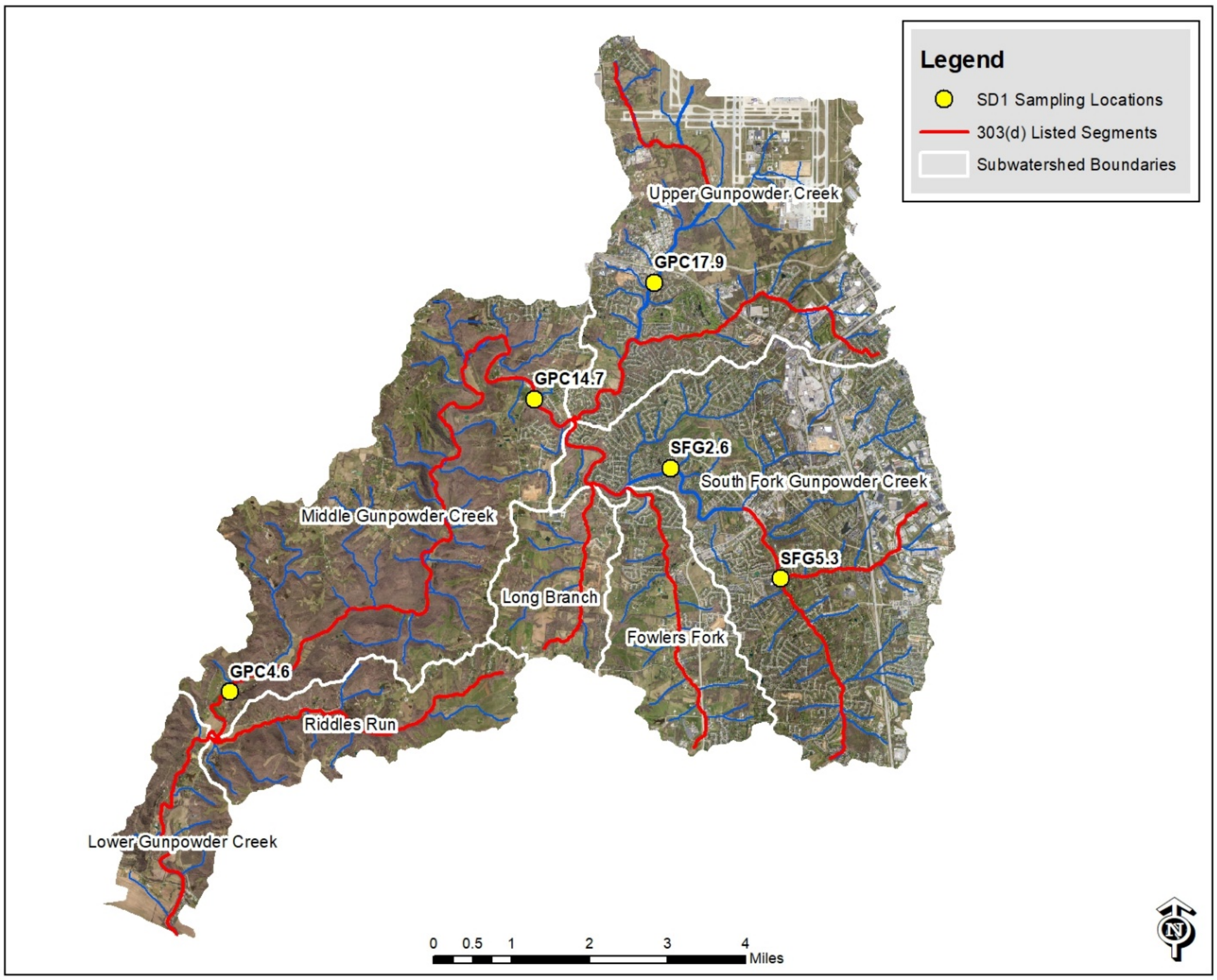

Figure 3.1 SD1 Sampling locations in Gunpowder Creek

All five sites were part of SD1's monitoring network within the SD1 West Basin monitoring cycle. These sites were sampled once during dry weather conditions (i.e. no precipitation in watershed 72 hours prior to event and prevailing dry weather conditions throughout event) between May – Oct every four years. Water quality assessments (bacteria, nutrients, solids, velocity measurements and field chemistry), biological surveys (macroinvertebrate and habitat assessments), and rapid stream channel stability assessments were conducted at four sites.

One site (GPC 14.7) is part of SD1's ambient monitoring network. This site was sampled twelve times between March through November on an annual basis. Sampling dates were established at the beginning of the season and may include samples collected under various weather and flow conditions. The water quality monitoring at this location included the assessment of in-stream pollutant levels of bacteria, nutrients and solids. Field chemistry (DO, pH, temperature, conductivity and turbidity) was collected during each event. A USGS stream gage is located at this site, which provides stream flow data (gage height and discharge) in 15 minutes intervals. A full stream stability survey was also conducted on an annual basis at GPC 14.7, which includes the assessment of stream channel alterations caused by changes in hydrology and include quantitative measurements to determine cross-sections and profiles. Table 3.1.1 provides a summary of the monitoring events.

In 2021, SD1 updated the monitoring approach within the region, including the Gunpowder Creek Watershed. The major changes include the removal of one of the five previously sampled sites (SFG 2.6), increasing the number of samples collected during the West Basin cycle from once to ten times, and limiting the collection timeframe to April through October. The next round of sampling in the West Basin will occur in 2024. Site GPC 14.7 remains an ambient site and will be sampled 10 times per year during the same timeframe, April – October. Table 3.1.1 outlines the overall program and events.

Table 3.1.1 Summary of SD1 Monitoring in Gunpowder Creek Watershed (2021 - 2024 cycle)

SD1 West Basin Monitoring Cycle Locations	**Type of Monitoring (10 samples collected between April - Oct every 4 years. Will occur in 2024)**			
Site ID	Water Quality	Macroinvertebrates	Habitat	Channel Stability*
SFG 5.3	X	X	X	X
GPC 17.9	X	X	X	X
GPC 14.7	X	X	X	X
GPC 4.6	X	X	X	X
Annual Monitoring Location	**Type of Monitoring (10 samples collected between April - Oct every year)**			
Site ID	Water Quality	Macroinvertebrates	Habitat	Channel Stability*
GPC 14.7	X	-	-	X

*A full stream channel stability assessment will be performed every year at GPC 14.7. A rapid stream channel stability assessment is performed at the other identified locations every 4 years.

SD1 will continue to conduct all monitoring in accordance with established monitoring plans and standard operating procedures (SOPs). Any updates to the plans and SOPs will be provided in future progress reports. Table 3.1.2 provides a reference to the plans, which are included in Appendix A.

Table 3.1.2 Monitoring Plans and Procedures

SD1 Monitoring Plans and Procedures	
Document Title	**Monitoring Type**
Ambient Sampling Field Monitoring & Sampling Plan for Northern Kentucky Watersheds	Water Quality (Ambient)
Base Flow Characterization - Field Monitoring & Sampling Plan for Northern Kentucky Watersheds - Phase 3	Water Quality (West Basin)
Standard Operating Procedures for Field Procedures for Macroinvertebrate Collections	Macroinvertebrates & Total Habitat
Standard Operating Procedures for Hydromodification Field Surveys	Channel Stability (Full Assessment)
Technical Memorandum: Regionally-Calibrated Channel Stability Index for Northern Kentucky Streams	Channel Stability (Rapid Assessment)

3.2 Monitoring Results and Analysis

Building upon the results provided in the previous progress report, the ambient water quality monitoring results for site GPC 14.7 are included in this progress report. This includes results collected through October 2023. The stream channel stability assessment results for the site are included as well.

Water quality standards are from Kentucky Administrative Regulations defined in 401 KAR 10:031. All other parameters included in this analysis are compared to water quality benchmarks provided by DOW 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. According to the Total Suspended Solids (TSS) and Turbidity benchmarks values provided by DOW, the values should only be compared to normal April-October flow conditions and not high flow events or winter samples. Due to this limitation, only April-October dry weather condition samples were used for those parameters.

The results and analyses are summarized below.

Ambient Monitoring Results

Table 3.2.1 provides a summary of the ambient monitoring results for site GPC 14.7. The table includes the number of samples analyzed for each weather condition (#), the average of those sample results (AVG) and the percent of the samples that exceeded the water quality standard or water quality benchmark (%EX). The entire data set for the results in Table 3.2.1 is included in Appendix B.

The data are compiled according to weather conditions. Samples with no precipitation 72 hours prior to event and prevailing dry weather conditions throughout event are classified as dry and all others are classified as wet.

Table 3.2.1 Ambient Monitoring Results for Site GPC 14.7

PARA-METERS		TOTAL SUSPENDED SOLIDS (TSS)*			TURBIDITY*			TOTAL PHOSPHORUS (TP)			Nitrate-Nitrite-N			TKN			DISSOLVED OXYGEN (DO)			pH			SPECIFIC CONDUCTANCE (SC)			ESCHERICHIA COLI (E.COLI)**		
Units		mg/L			NTU			mg/L			mg/L			mg/L			mg/L			su			µS/cm			mpn/100mL		
Benchmark		<7.25			<8.3			<0.08			<0.3			<0.3									<522.5					
Standard																	> 4			6-9						<240		
		#	AVG	%EX	#	AVG	%EX	#	AVG	%EX	#	AVG	%EX	#	AVG	%EX	#	AVG	%EX	#	AVG	%EX	#	AVG	%EX	#	AVG	%EX
2018	ALL	5	4.14	20	5	6.1	40	12	0.19	92	12	0.75	75	12	0.61	100	10	9	0	9	8	0	11	665.5	73	9	2228	78
	WET	0			0			5	0.23	100	5	0.92	80	5	0.72	100	4	9	0	3	8	0	4	561.3	25	4	4368	100
	DRY	5	4.14	20	5	6.1	40	7	0.17	86	7	0.63	71	7	0.53	100	6	10	0	6	8	0	7	725.0	100	5	517	60
2019	ALL	8	4.57	13	7	7.43	43	10	0.14	70	10	0.57	40	10	0.51	90	10	10	0	10	8	0	10	600.8	80	7	341	41
	WET	0			0			0			0			0			0			0			0			0		
	DRY	8	4.57	13	7	7.43	43	10	0.14	70	10	0.57	40	10	0.51	90	10	10	0	10	8	0	10	600.8	80	7	341	41
2020	ALL	7	20.6	57	7	29.7	57	10	0.32	100	10	1.86	60	10	0.57	80	10	9	0	10	8	0	10	561.4	60	9	3132	56
	WET	0			0			3	0.24	100	3	0.35	67	3	0.84	100	3	10	0	3	8	0	3	466.9	67	2	12,444	100
	DRY	7	20.6	57	7	29.7	57	7	0.35	100	7	2.51	43	7	0.45	71	7	9	0	7	8	0	7	601.9	57	7	471	43
2021	ALL	6	3.67	17	6	9.7	17	10	0.26	100	10	0.37	60	10	0.73	100	10	9	0	10	8	0	10	725.3	100	9	4365	67
	WET	0			0			4	0.46	100	4	0.43	75	4	1.04	100	4	8	0	4	8	0	4	630.8	100	4	9454	100
	DRY	6	3.67	17	6	9.7	17	6	0.14	100	6	0.33	50	6	0.53	100	6	9	0	6	8	0	6	788.2	100	5	294	40
2022	ALL	9	4.89	33	9	12.1	56	10	0.19	100	10	0.42	60	10	0.58	90	10	9	0	10	8	0	10	694.7	80	9	1454	44
	WET	0			0			1	0.34	100	1	0.42	100	1	0.94	100	1	8	0	1	8	0	1	432.5	0	1	11200	100
	DRY	9	4.89	33	0	12.1	56	9	0.18	100	9	0.43	56	9	0.54	89	9	9	0	9	8	0	9	723.9	89	8	236	38
2023	ALL	8	5.38	25	8	6.7	25	10	0.21	100	10	0.66	70	10	0.80	100	10	9	0	10	8	0	9	678.1	89	9	937	22
	WET	0			0			2	0.17	100	2	0.37	100	2	0.95	100	2	9	0	2	8	0	2	562.4	50	2	3839	100
	DRY	8	5.38	25	8	6.7	25	8	0.22	100	8	0.74	63	8	0.76	100	8	9	0	8	8	0	7	711.2	100	7	107	0

* Only samples collected between April – Oct, excluding high flow events, were used for comparison to the benchmarks
** Only samples collected between May – Oct were used for comparison to the standard

Ambient Monitoring Analysis – Water Quality

The following figures provide a comparison of the percent of samples exceeding the standard or established benchmark for the complete 2018 - 2023 sample results. Figure 3.2.1 represents all events with the total number of sampling events included above the bar.

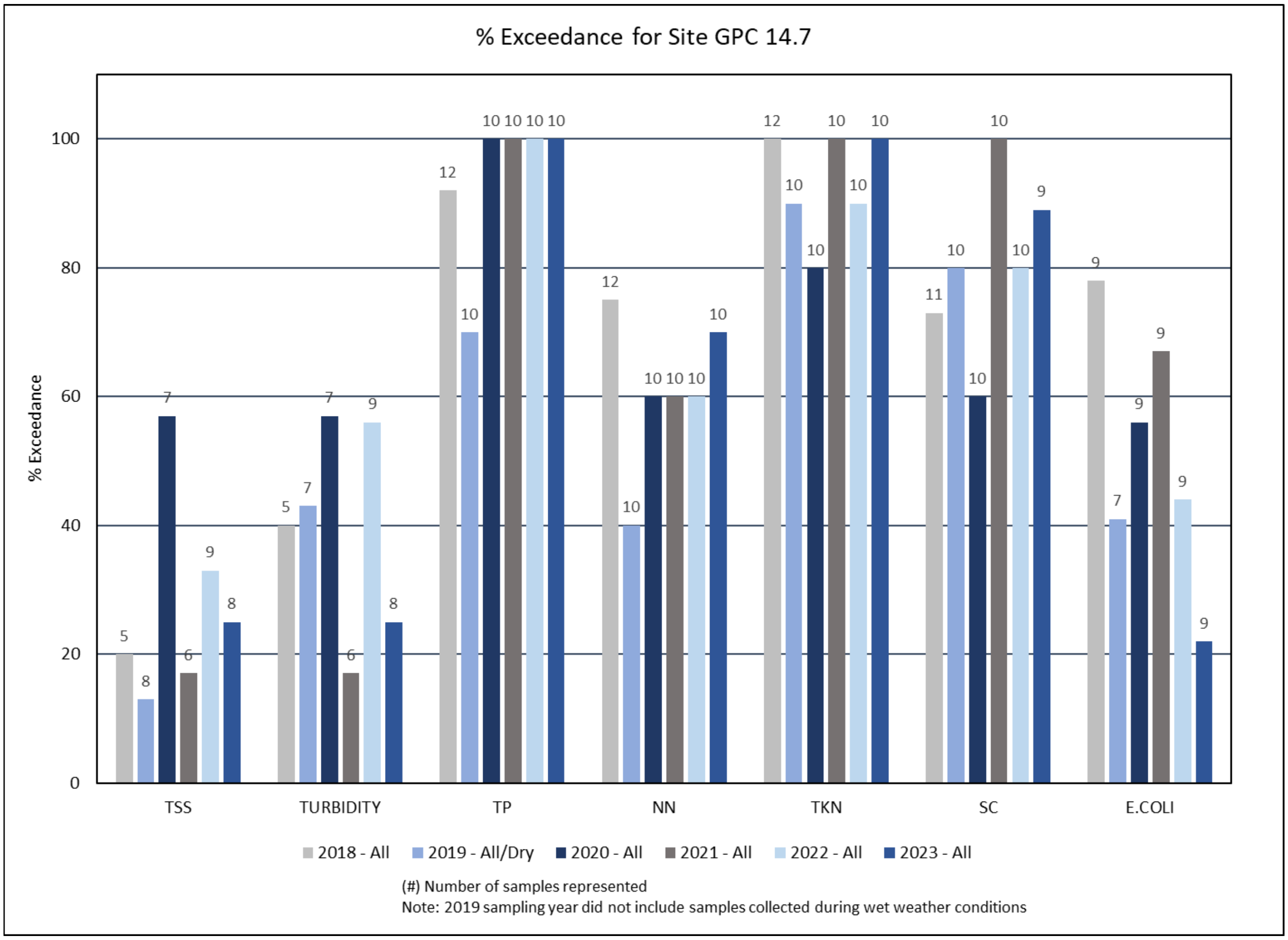

Figure 3.2.1 Comparison of the percent of samples exceeding the established standard or benchmark for all conditions

Nutrient parameters (TP, NN, abd TKN) and Specific Conductance (SC) have remained elevated over the sampling years. Total Suspended Solids (TSS), Turbidity and *E.coli* levels decreased in 2023 compared to 2022.

For 2023, 22% percent of *E.coli* samples exceeded the PCR standard (240 colonies/100 mL), which confirms the partial support listing. However, this percent exceedance has decreased compared to previous years and is approaching the fully support range of a percent exceedance ≤ 20% of six monthly samples collected over the recreation period (Consolidated Assessment and Listing Methodology: Surface Water Quality Assessment in Kentucky). As noted below, the exceedances occurred during wet weather events only. Site GPC 14.7 will continue to be monitored annually. If the trend towards improvement for PCR continues, SD1 will work with KDOW to determine additional success monitoring needed for a potential delisting.

Figure 3.2.2 represents the dry weather events. For most parameters the pattern of percent exceedance is similar to the overall conditions (Figure 3.2.1) but as noted above, all seven of the *E.coli* samples collected in dry conditions did not exceed the standard.

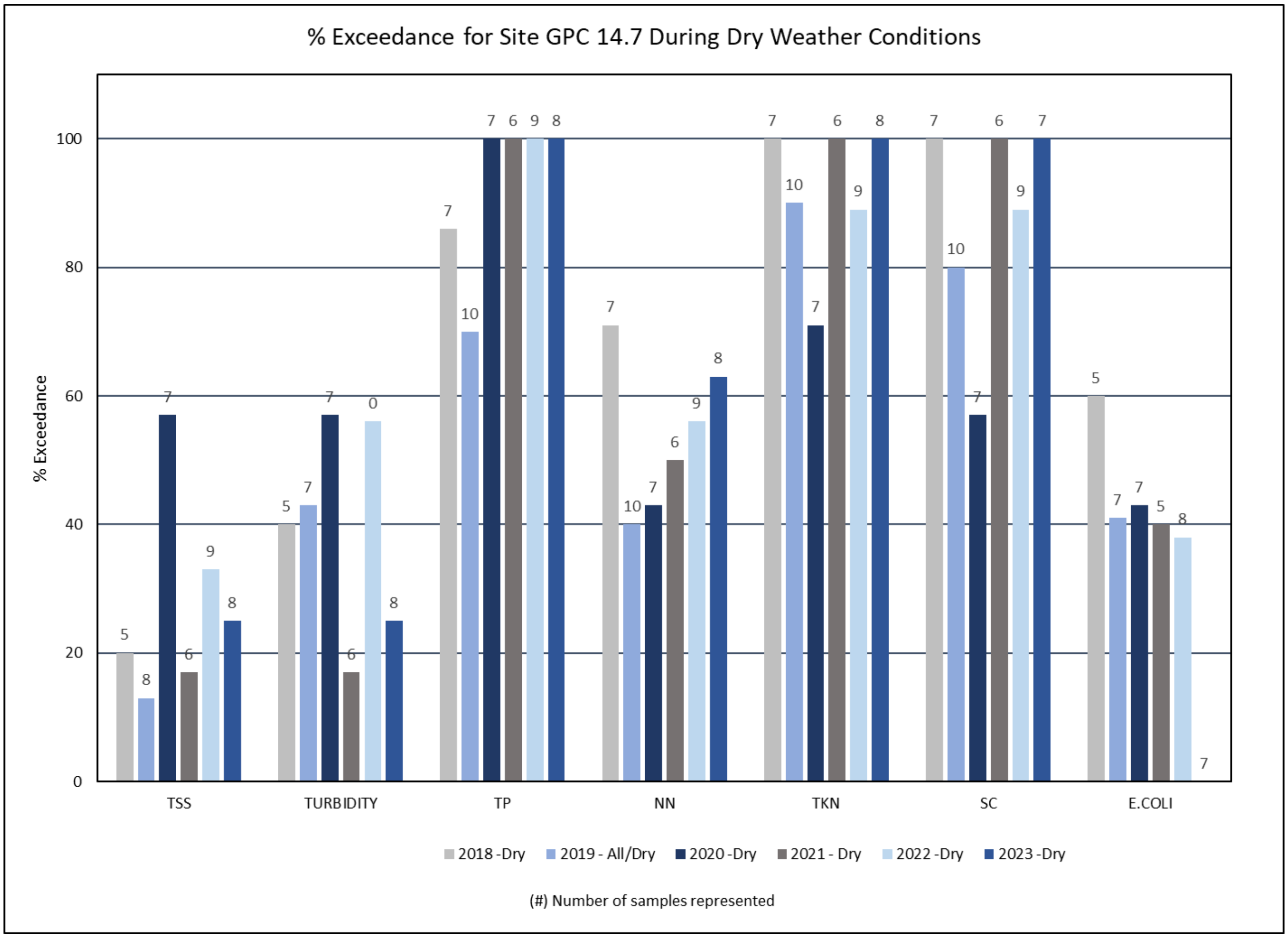

Figure 3.2.2 Comparison of the percent of samples exceeding the established standard or benchmark for dry conditions

Figure 3.2.3 represents the wet weather events for 2018 – 2023 except for 2019, which had no wet weather conditions. As noted above, benchmarks for TSS and Turbidity do not apply to high flow conditions and were not included in the wet weather comparisons. All events show a high percent exceedance across years.

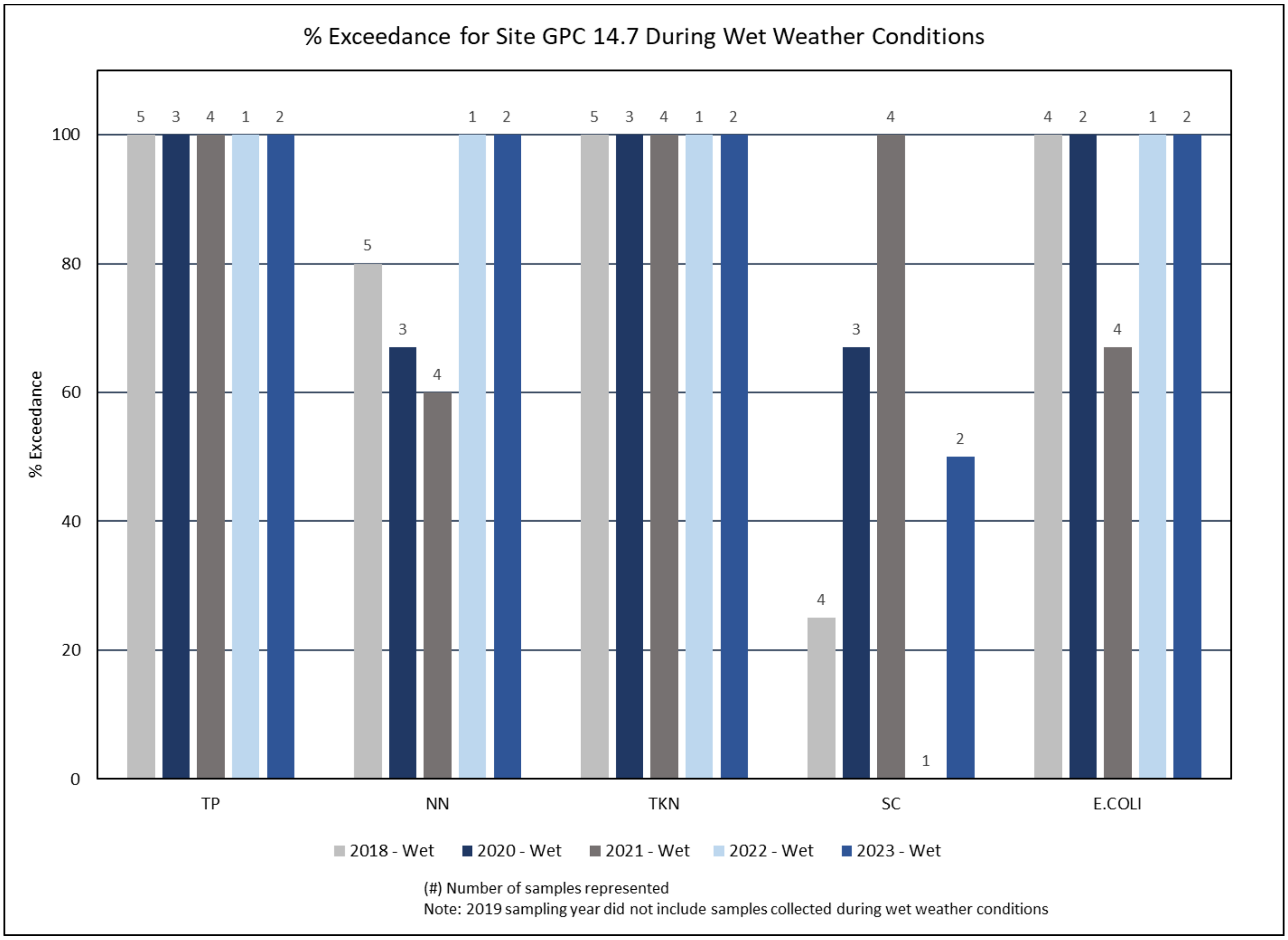

Figure 3.2.3 Comparison of the percent of samples exceeding the established standard or benchmark for wet conditions

Ambient Monitoring Analysis – Steam Channel Stability

The full stream channel stability assessment was conducted at site GPC 14.7. This site was historically dynamic but may be showing signs of potential recovery (relatively stable cross section and accumulation of finer cobbles and gravels). Although head cutting from the downstream portion of the profile may still present a risk for future downcutting. Appendix C includes the comparisons for cross section, profile and bed material gradation from 2008 – 2022.

3.4 Future Monitoring

SD1 will continue to conduct all monitoring in accordance with established monitoring plans, standard operating procedures (SOPs) and the schedule outlined in Table 3.1.1. Any trends indicating improvements will be relayed to KDOW and additional success monitoring will be evaluated when needed.

Appendix A: Monitoring Plans and SOPs

AMBIENT SAMPLING
FIELD MONITORING & SAMPLING PLAN
FOR NORTHERN KENTUCKY WATERSHEDS

Northern Kentucky Sanitation District No.1
1045 Eaton Drive
Fort Wright, KY 41017

2023

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

1. *INTRODUCTION*

Sanitation District No. 1 (SD1) a clean water agency that serves over 30 communities in Campbell, Kenton and Boone Counties, Kentucky, as both the wastewater and storm water utility, is implementing a watershed management approach to cost-effectively meet numerous regulatory requirements (e.g., Combined Sewer Overflow (CSO) Program and Municipal Separate Storm Sewer System (MS4) Program). Additionally, SD1 has entered into a Consent Decree (CD) with state and federal environmental regulators to address sanitary overflows in these communities. In complying with these regulatory requirements, SD1 is applying an adaptive approach for identifying impairments and prioritizing areas for action. This approach will help ensure that available resources are most effectively used. SD1 has developed an Adaptive Watershed Management Plan that identifies Watershed Characterization in sixteen sub watersheds to relate in-stream conditions to watershed characteristics. The results of this Watershed Characterization will be used to identify impaired watersheds and prioritize them for consideration of control alternatives.

SD1 initiated a comprehensive watershed wide monitoring program in 2006 that involved the collection of instream water quality data in each of the sixteen watersheds in Northern Kentucky to characterize background conditions in the region. These sixteen watersheds represent varying conditions with respect to the amount of development, as well as sources of stream pollution. The variation in the stream conditions can range from undeveloped watersheds that have been categorized as "exceptional" waters by the State, while other watersheds are more highly developed and are identified as "impaired" by the State. As a result of the vast differences between these watersheds, SD1 implemented a biweekly sampling program over a two year period to further characterize stream conditions under a wide range of environmental conditions at 20 locations throughout Northern Kentucky.

After the biweekly sampling program concluded in June 2017, the ambient sampling program began in July 2017 as on ongoing sampling program. This sampling program has the same sampling protocol, but the schedule and sites have changed, instead of 20 locations there are 15. In 2020 after three years of sampling and an evaluation of the data, it was decided to add four reference sites to the schedule. In 2021 there was the decision to add core basin sites to the schedule. Each year beginning in the East Basin in 2021, Central Basin in 2022, North Basin in 2023 and West Basin in 2024 the core sites in that basin will be added. These sites will then rotate by basin each year.

The following ambient sampling *Field Monitoring and Sampling Plan* (FMSP) is designed to ensure that all monitoring activities undertaken result in representative data necessary to support the characterization of the watershed being sampled.

Monitoring and sampling stations have been selected to provide appropriate coverage to meet the assessment and modeling needs of the watershed characterization process.

1.1 Program Overview

This FMSP describes the water quality monitoring program for the ambient sampling of Northern Kentucky streams. The purpose of the FMSP is three fold:

- To supplement the Quality Assurance Project Plan (QAPP)
- To provide project and field staff with an understanding of the program and how to complete the base flow monitoring program; and,
- To define the level of effort and analytical needs.

The FMSP is intended to provide practical assistance in obtaining representative and reliable data in a technically sound and safe manner.

The procedures and protocols presented in this document address the following water quality and quantity monitoring program components:

- Monitoring and sampling criteria
- Stream water quality monitoring
- Sample handling and transportation
- QA/QC requirements
- Program Health and Safety

This program was designed to collect data that will be used to assess variation of water quality concerns identified in Northern Kentucky watersheds. The ambient data collected in Northern Kentucky streams is required to support water quality modeling, and pollutant source identification.

Figure 1 shows locations in the watersheds of the Northern Kentucky area that have been identified as monitoring and sampling stations. The sampling locations shown in Figure 1 are discussed in more detail in Section 3.

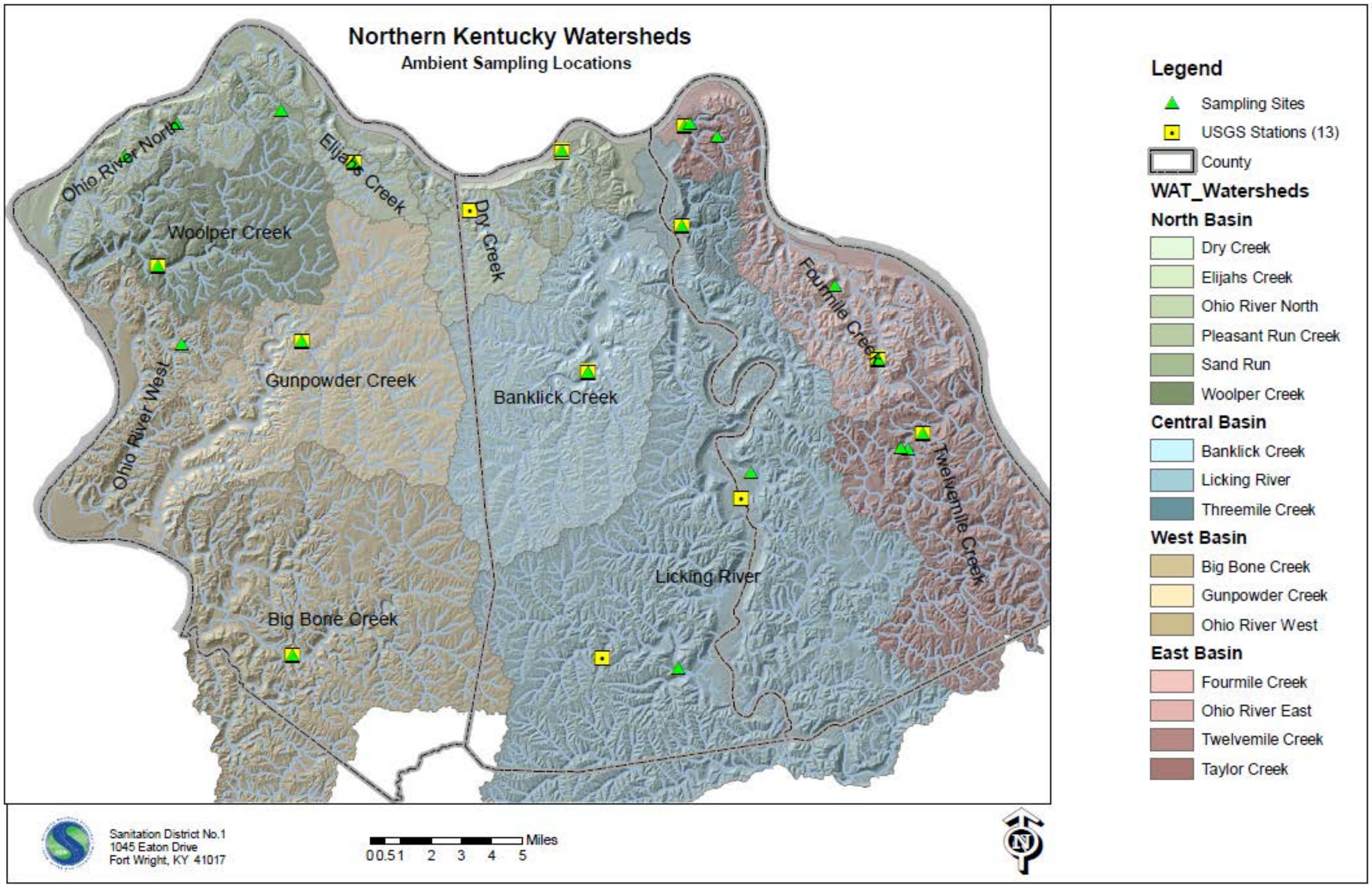

Figure 1 Monitoring and Sampling Stations

1.2 Monitoring Team

The monitoring team consists of the Project Manager, the Field Manager, and sampling crew. Responsibilities of key team members are listed in Table 1.

Table 1 Team Member Responsibilities

Position	SD1 Team Member	Responsibilities
Project Manager	Mindy Scott	• Assess suitability of sampling events • Perform System Audits • Circulation of reports and results • Staff Training • Review Reporting • Ensure necessary resources are available • Creation of event reports • QA/QC review
Field Manager	Elizabeth Fet	• Implementation of FMSP • Initiate sampling events • Coordinate with laboratory • Mobilize field crews • Collection and review of field logs, lab results, and other program documentation • Ongoing management of field staff and equipment

Prior to the first sampling event, a flowchart will be created which contains all members of the different sampling crews and laboratory contacts along with their respective contact numbers (home, work, and/or cellular numbers). This will allow for a network of communication prior to and during the monitored events. A communication network for the sampling team is essential to the ability to adapt the sampling program to changing environmental or weather conditions and/or equipment malfunctions.

2. *MONITORING AND SAMPLING CRITERIA*

The objective of the ambient monitoring and sampling program is to represent varying conditions with respect to the amount of development, as well as sources of stream pollution in each watershed. SD1 is implementing this program to further characterize stream conditions under a wide range of environmental conditions.

The criteria used to define the ambient sampling include:

- Weather conditions will vary, but sampling will be conducted unless deemed unsafe

The goal will be to conduct the sampling in varying weather conditions. The sampling will be distributed throughout the monitoring period by basin to characterize Northern Kentucky streams during fluctuating flow conditions.

Local conditions may require these criteria to be modified as the study progresses. Best professional judgment will be necessary to assess the suitability of a particular Ambient sampling event.

3. STREAM CHARACTERIZATION

Stream monitoring and sampling will be conducted at designated stations along Northern Kentucky streams as shown in Figure 1. Water quality monitoring and sampling will be conducted as follows:

- Samples will be collected at all sites on the designated day as shown on the corresponding schedule according to the surface water quality monitoring program protocols;
- All sites will be characterized on-site for in-stream water quality measurements (temperature, dissolved oxygen, pH, conductivity and turbidity).

Table 2 describes each of the stations as depicted in Figure 1. Station selection was based on an initial watershed reconnaissance, which focused upon suitable site configuration for stream sampling and location relative to key pollutant source inputs. Once final sampling locations were identified, latitude and longitude coordinates were obtained with a Global Positioning System (GPS) unit and recorded.

Standard operating procedures (SOPs) referenced in the following sections are provided in Appendix A.

Table 2 Ambient Monitoring Locations

Basin	Watershed/Sites	Locations	Description
Central	Banklick (1)	BLC8.1	Richardson Road Bridge (USGS)
	Threemile (1)	THC0.7	Threemile Creek Road (USGS)
	Cruises (1)	CRC2.5	Cruises Creek
East	Fourmile (1)	FMC6.9	Poplar Ridge Road (USGS)
	Twelvemile (1)	TMC3.0	Route 1997 (USGS)
	Taylor (1)	TYC0.6	Donnermeyer Drive under 471 (USGS)
North	Woolper (4)	WPC5.0	Woolper Road (USGS)
		DLC1.0	Double Lick (Reference Site)
		ALF0.1	Huffman-Clifford Bridge on Easton Lane
		WPC8.8	Bridge on Route 338
	Elijahs (2)	EJC0.3	Bridge on Route 8
		EJC2.8	Elijah Creek Road (USGS)
	Dry Creek (3)	DRC1.4	Dry Creek WWTP (USGS)
		DRC3.0-WFD1.5	Bridge on Erlanger Road from Houston Road
		DRC4.4	On Eubanks Road from Anderson Road
	Pleasant Run (2)	PRC0.3	Bridge on Oak Street (USGS)
		PRC2.0	Bridge over Bromley Crescent Springs Road
	Sand Run (2)	SDR0.6	End of Route 8
		SDR4.0	Thornwilde Subdivision
	Garrison (1)	GAC1.7	Garrison Creek Road (Reference Site)
	Second (1)	SEC1.6	Second Creek Road (Reference Site)
West	Gunpowder (1)	GPC14.7	Camp Ernst Road (USGS)
	Big Bone (1)	MLC3.0	Bridge at US 42 (USGS)
	Middle (1)	MDC5.5	Middle Creek Road (Reference Site)

3.1 On-Site Water Quality Measurements

All sites will be subject to on-site measurements during sampling events. On-site measurements will include DO, pH, temperature, conductivity and turbidity.

On-site water quality instrumentation will be calibrated and maintained in accordance with *Standard Operating Procedures Hydrolab Series 5 Water Quality Instrumentation.*

3.2 Ambient Sampling

Most sampling locations are accessible by bridges or by wading. Table 3 presents the monitoring schedule for the surface water sampling program for ambient sampling. All sampling will be performed by SD1 staff. Ambient samples will be collected as grab samples in accordance with *Standard Operating Procedures for the Collection of*

<u>Discrete Water Samples</u>. Ambient sampling events will be completed by day, utilizing two person crews as described in Table 3.

All grab samples will be collected with a sampling pole, stainless steel bucket or glove method. Sampling events will start at the downstream site and progress upstream. This approach to ambient sampling is designed to collect a representative sample of current conditions in the stream. Immediately after sample collection, on-site measurements will be taken as previously described.

Table 3 Ambient Monitoring Schedule

Day One

Watershed	Site	Description
Big Bone	MLC3.0	Bridge at US 42 (USGS)
Gunpowder	GPC14.7	Camp Ernst Road (USGS)
Middle	MDC5.5	Middle Creek Road (Reference Site)
Woolper	WPC5.0	Woolper Road (USGS)
Second	SEC1.6	Second Creek Road (Reference Site)
Woolper	DLC1.0	Happy Jack (Reference Site)
Woolper	WPC8.8	Bridge on Route 338
Woolper	ALF0.1	Huffman-Clifford Bridge on Easton Lane
Elijahs	EJC2.8	Elijah Creek Road (USGS)

Day Two

Watershed	Site	Description
Banklick	BLC8.1	Richardson Road Bridge
Cruises	CRC2.5	Hempfling Road
Twelvemile	TMC3.0	Route 1997 (USGS)
Fourmile	FMC6.9	Poplar Ridge Road (USGS)
Threemile	THC0.7	Threemile Creek Road (USGS)
Taylor	TYC0.6	Donnermeyer Drive under 471 (USGS)
Pleasant Run	PRC0.3	Bridge on Oak Street (USGS)
Dry Creek	DRC1.4	Dry Creek WWTP (USGS)

Day Three

Watershed	Site	Description
Pleasant Run	PRC2.0	Bridge over Bromley Crescent Springs Road
Dry Creek	DRC4.4	On Eubanks Road from Anderson Road
Dry Creek	DRC3.0-WFD1.5	Bridge on Erlanger Road from Houston Road
Garrison	GAC1.7	Garrison Creek Road (Reference Site)
Sand Run	SDR4.0	Thornwilde Subdivision
Sand Run	SDR0.6	End of Route 8
Elijahs	EJC0.3	Bridge on Route 8

3.3 Summary

Table 4 presents a summary of the field monitoring and sampling plan for Northern Kentucky watersheds.

Table 4 Summary of Water Quality Monitoring and Sampling Program

Type	Locations	Description	Parameters
Ambient Sampling	24 total locations, throughout Northern Kentucky 4 basins (North, Central, West, East)	♦ Samples collected one week per month (April, June, August, October) ♦ Samples collected twice per month (May, July, and September) ♦ 1 grab sample per site	♦ On-site measurements will include: ***temperature, dissolved oxygen, pH, conductivity and turbidity.*** ♦ Water quality parameters will include: ***bacteria (EC), nitrogen (TKN, NH_3, NO_3-NO_2), phosphorus, total suspended solids.***

Table 5 summarizes the number of samples to be collected exclusive of quality control protocols.

Table 5 Summary of Number of Samples to be Collected

Task	Day One	Day Two	Day Three
Day Sampled	Tuesday	Wednesday	Thursday
No. of Events per week	1	1	1
No. of Sites	9	6	7
Bacteria			
E. coli	9	6	7
Nutrients			
NH_3	9	6	7
NO_3- NO_2	9	6	7
TKN	9	6	7
Total Phosphorus	9	6	7
Ortho Phosphate (field filtered)	4	3	4
Solids			
TSS	9	6	7
Total Sample Load	**58**	**39**	**46**

4. *FIELD MEASUREMENTS*

In-stream dissolved oxygen, temperature, pH, conductivity, and turbidity will be measured using appropriate field instruments concurrent with sample collection at each of the sampling locations. Each on-site parameter will be measured at each location during each sampling event. Table 6 lists the parameters, location of measurement at each site, and method of measurement.

Field measurements will be conducted following the Standard Operating Procedures in Appendix A. Field instruments will be calibrated before initiating monitoring activities for each event. A post-monitoring calibration check will also be conducted at the end of each monitoring event. All calibration and maintenance activities will be documented on the Multiprobe Instrumentation Calibration and QA Sheet (see Appendix A).

Measurements will be documented on the Field Data Sheet (see Appendix C). Documentation will include: date/time, location, type of measurement, personnel, equipment and associated calibration specifications, and general site observations (e.g., weather conditions).

Table 6. Field Measurements

Parameter	Location of Measurement	Method
Temperature	Mid-channel, mid-depth where possible	Hydrolab
Conductivity		
pH		
Dissolved Oxygen		
Turbidity		

5. *SAMPLING HANDLING AND CUSTODY*

The following sections outlines the sample labeling procedures, sample handling, chain-of-custody and record keeping required.

5.1 Sample Labeling

All samples will be assigned a unique identification code such that all necessary information can be attained from the sample label. The labels will be available in an electronic template and can be printed once the information has been added to the template. The code will identify the following:

Label: ___ ___ ___ ___. ___

1 2 3 4 5

Characters 1-5: Sample Site ID

Example: FMC0.5

In addition to the label, the sample bottles will be clearly marked using waterproof ink with the following information:

- Client – SD1
- Analyses – List of requested analyses to be performed from the container
- Preservative – Preservative in sample container
- Date – Date sample was collected
- Time – Time sample was collected
- Crew – Crew identification

5.2 Sampling Collection, Handling and Transport

General guidelines for sample collection are listed below. Refer to *Standard Operating Procedures for the Collection of Discrete Water Samples* for detailed procedures.

- All samples collected in intermediate sampling containers should be transferred to their appropriate laboratory sample bottle as quickly as possible.
- Sampling location codes will be used to distinguish each distinct sampling location.
- Sample labels and chains of custody must be filled out completely.

The following procedures will be followed when handling and transporting samples:

- Samples will be preserved using ice and transported in sample coolers. It should be ensured that plenty of ice is used for each sample cooler to maintain the temperatures inside the cooler at approximately 4° C.
- Laboratory chain-of-custody forms will be included with all sample submissions. Field staff will keep copies.
- Sample bottles and coolers should be handled with care to prevent breakage/spillage.
- All sample bottle labels must be properly completed and placed firmly on each bottle by the field sampling crews.

5.3 Chain-of-Custody

Field crews will complete chain-of-custody forms to document the transfer of sample custody to the designated custodian and subsequent personnel, see Appendix B. Signatures of all personnel involved in the collection, transport, and receipt of each sample will be recorded on the chain-of-custody forms.

In certain instances, sample custody will be transferred to runners to transport the samples directly to the laboratory at designated times during sampling to avoid missing holding times. The chain-of-custody form outlines sample location, identification, collection time and date, and specific parameters to be analyzed for each sample. A properly completed chain-of-custody form must accompany all samples.

Use of the chain-of-custody form will terminate when laboratory personnel receive the samples and sign the form. The laboratory will open the sample coolers and carefully check the contents for evidence of leakage and to verify that samples were kept on ice. The laboratory will then verify that all information on the sample container label is correct and consistent with the chain-of-custody form. Any discrepancy between the sample bottle and the chain-of-custody form, any leaking sample containers, or any other abnormal situation will be reported to the Laboratory Manager. The Laboratory Manager will inform the Project Manager of any such problem, and corrective actions will be discussed and implemented.

5.4 Field Logs and Records

Field crews will document all activities associated with the monitoring program at each monitoring site, including unusual or anomalous conditions. In addition, a description of any problems encountered during the monitoring period and/or any deviations to the FMSP will also be documented. This information may subsequently be used for data interpretation and analyses.

All pertinent information will be recorded on Field Data Sheets which are included as Appendix C.

At the conclusion of each monitored event, all Field Data Sheets will be submitted to the Field Manager to serve as a chronological representation of the monitored event. At a minimum each data field sheet should include the following information:

- Project name, site/river name, sample type;
- Crew identification, date, start time/end time;
- Weather conditions, stream conditions, site conditions;
- Physical parameter data (on-site measurements);
- On-site water quality meter identification number used to measure physical parameter data;
- Field observations.

All entries will be completed with a permanent ink pen with no erasures, correction fluid, or tape used. Erroneous entries will be noted using a single line drawn through the mistake that is then dated and initialed.

5.5 Sample Containers and Preservation

Table 7 presents details of sample containers and preservatives to be used. The laboratory will provide all bottles pre-preserved.

Table 7 Guidelines for Sample Container Preparation and Preservation

Parameter	Container	Recommended Sample Volume	Preservation	Maximum Storage Time
Bacteria				
E. coli	Pre-Sterilized Polyethylene or Glass	120 ml	Add $Na_2S_2O_7$ [1] Refrigerate to 4°C	12 hours[2]
Nutrients				
NH_3 TKN NO_3-NO_2 Total Phosphorus	Polyethylene or Glass	1000 ml	Add H_2SO_4, pH<2 Refrigerate to 4°C	28 days
Ortho Phosphate	Polyethylene or Glass	120 ml	Field filter Refrigerate to 4°C	48 hours
Conventional				
TSS	Polyethylene or Glass	1000 ml	Refrigerate to 4°C	7 days

1. Sodium Thiosulfate ($Na_2S_2O_7$) prevents continuation of bacteriocidal action.
2. The maximum allowable holding time for bacteria samples will be 12 hours with a goal of 6 hours when practical.

6. QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

The purpose of any quality assurance/quality control (QA/QC) program is to ensure that all sampling protocols and procedures are followed such that samples are representative of the water quality to which they are associated. The program is designed to be a systematic process, which together with the laboratory QA/QC program ensures a high degree of confidence in the data collection. The proposed QA/QC program includes the following elements:

- Training of all field staff;
- Field quality control procedures;
- Equipment cleaning protocol;
- QA/QC samples; and,
- Equipment calibration.

6.1 Training

Training sessions will be carried out for all field staff on proper sampling, sample handling and submission and general field procedures. Specific emphasis will be placed on QA/QC issues as well as on health and safety. Field crews will receive training involving the operation, maintenance and calibration of water quality meters, and all other on-site equipment used throughout the field program. SOPs for all program elements will be distributed to staff and available at all times.

6.2 Field Quality Control

The quality of data generated in a laboratory depends primarily on the integrity of the samples that arrive at the laboratory. Consequently, necessary precautions must be taken to protect samples from contamination and deterioration. Procedures detailed in *Standard Operating Procedures for the Collection of Discrete Water Samples* and *Standard Operating Procedures for Hydrolab Series 5 Water Quality Instrumentation* will be followed to ensure field quality control.

6.3 Equipment Cleaning Protocol

All sampling equipment (i.e. intermediate containers, sampling buckets, etc.) will follow the QA/QC protocol outlined in *Standard Operating Procedures for the Collection of Discrete Water Samples* to ensure representative sample collection. When using the sampling pole or stainless steel bucket, only step 2 (Blank Water Rinse) of the decontamination procedure needs to be utilized.

6.4 QA/QC Samples

The monitoring team will use three types of QA/QC samples collected in the field to assist in validating chemical data sets – sample duplicates, equipment blanks, and field blanks. Each type of QA/QC sample is described in the following sections. Tables 8 and 9 present the schedule and number of QA/QC samples to be collected during the field program.

Table 8 QA/QC Sample Schedule

Ambient Sampling			
Day	Tuesday	Wednesday	Thursday
	Dup*, FB, MB	Dup*, FB, MB	Dup*, FB, MB
MB= Method Blank Dup = Duplicate FB = Field Blank * = Dup will rotate between days			

Table 9 Number of QA/QC Samples

Ambient Sampling	Field Blanks[2]	Method Blanks[3]	Duplicate Samples[4]	Total per Event
Day 1	1	1	1	3
Day 2	1	1	0	2
Day 3	1	1	0	2
Totals	**3**	**3**	**1**	**7**

1. Each QA/QC sample set is performed on the complete series of samples submitted for laboratory analysis.
2. One set of field blanks per day will be collected during each day of the week.
3. One set of method blanks (at one site) per day will be collected during each day of the event.
4. One set of duplicates (at one site) will be collected during each week.

6.4.1 *Sample Duplicates*

Sample duplicates will be collected for laboratory analysis for each parameter. The purpose of these analyses is to evaluate sample collection precision by comparing the duplicate analytical results. One set of duplicate samples at a sampling location, randomly identified, will be collected by each field crew during the sampling event. Duplicates will be rotated among streams between sampling rounds. Approximately 10 percent of the samples will be collected in duplicate.

6.4.2 *Method Blanks*

Method blanks (MB) will be collected for laboratory analysis for orthophosphate only. The purpose of these analyses is to assess potential cross-contamination of samples by the method in which the sample was collected. These blanks will be taken at the conclusion of each sampling shift by each crew.

6.4.3 *Field Blanks*

Field blanks will be collected for laboratory analysis for all parameters. The purpose of these analyses is to determine if samples collected have been contaminated by field handling and cleaning methods. Each field crew will collect these blanks immediately following the collection of the AEB equipment blanks.

6.5 Equipment Calibration

On-site physical parameters will be measured in-stream by water quality meters and recorded on data sheets. These instruments will be calibrated each sampling day before use according to the manufactures operating manual as outlined in *Standard Operating Procedures for Hydrolab Series 5 Water Quality Instrumentation*.

At the conclusion of the sampling event, each meter will be checked with the standards used during calibration. The purpose of these readings is to evaluate the meter's precision (electronic drift) by comparing the readings recorded during calibration and the readings recorded during the check at the end of the sampling day.

At the conclusion of each sampling event, all Calibration Sheets will be submitted to the Field Manager to serve as a record of the meter's performance during the sampling event.

7. PROGRAM SAFETY

The most critical component of a sampling program is crew safety. Safety is of paramount importance as stream sampling can be extremely dangerous. The element of danger is accentuated if personnel are unfamiliar with their surroundings and/or procedures, consequently staff must be properly trained in both safety and monitoring procedures, following a well thought out program.

With stream monitoring, common sense is essential. Two hazards that field staff may face more often, especially if wet weather occurs during sampling, are high stream conditions and slippery footing. If stream levels are deemed to be too high or too fast, under no circumstances should any field staff enter the stream or operate near its banks. With surfaces being wet and slippery, special care must be taken when walking and working around bridges.

Wading is one of the easiest methods to collect samples from many streams, and it may also be extremely dangerous. Wading permits the investigator to examine stream flow and decide where to sample. Rubber boots or even chest-high waders are standard equipment. If the wader has any uncertainty about their ability to wade a stream, they should be attached by a rope to a rigid mooring and wear an approved floatation device.

If creek conditions are high and fast, field staff will wear a safety belt or harness and will be appropriately tethered when working in close proximity to the creek. Along with being attached by rope, field staff must wear an approved floatation device.

There must be a minimum of two field staff working together during any sampling event.

7.1 General Safety Practices

- Water depth during wading operations must be checked with a pole before steps are taken.
- When wading equipment is worn, the support straps must be outside the clothing.
- In all situations field parties are required to leave accurate sampling schedules and expected itineraries in the office.

- Sampling must never be carried out in weather that is considered by the Field Manager or field member to be hazardous to the well-being of the field staff and/or equipment.
- Field staff are required to wear approved floatation devices and be tethered if conditions warrant use.
- First aid kits will be issued to all field crews.
- Each field crew will have a cellular phone and have been instructed on emergency procedures and numbers.
- Each field crew will report upon leaving and returning from any sampling or field work to their Field Manager.
- Each field crew will have appropriate lights, markers, etc. to be able to perform their work safely under poor visibility/nightfall.
- Each field crew will have the appropriate road safety equipment as required.

7.2 Health Hazards

Disease causing bacteria, viruses, and parasites are always present in sewers and discharge streams. They occur in both liquid sewage and dry sludge which coats pipes, and other surfaces. The serious threats are Hepatitis A (virus), Hepatitis B (virus), Tetanus (bacteria), Typhoid (bacteria), and Polio (virus). Proper hygiene methods must be followed. Wash hands before eating or smoking. Protective clothing must be laundered and equipment kept clean. Workers should avoid touching their eyes to prevent any inflammation. Cuts and abrasions of the skin should be covered by bandages or gloves to minimize the chance of infection by organisms.

APPENDIX A

STANDARD OPERATING PROCEDURES FOR FIELD MONITORING AND SAMPLING

APPENDIX B

NORTHERN KY SANITATION DISTRICT NO.1
CHAIN OF CUSTODY

APPENDIX C

NORTHERN KY SANITATION DISTRICT NO.1
FIELD DATA SHEET

BASE FLOW CHARACTERIZATION
FIELD MONITORING & SAMPLING PLAN
FOR NORTHERN KENTUCKY WATERSHEDS
PHASE 3
2016-2019

Northern Kentucky Sanitation District No.1
1045 Eaton Drive
Fort Wright, KY 41017

April 2016

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APPENDICES

1. INTRODUCTION

Sanitation District No. 1 (SD1) a clean water agency that serves over 30 communities in Campbell, Kenton, and Boone Counties, Kentucky as both the wastewater and storm water utility, is implementing a watershed management approach to cost-effectively meet numerous regulatory requirements (e.g., Combined Sewer Overflow (CSO) Program and Municipal Separate Storm Sewer System (MS4) Program). Additionally, SD1 has entered into a Consent Decree (CD) with state and federal environmental regulators to address sewer overflows in these communities. In complying with these regulatory requirements, SD1 is applying an adaptive approach for identifying impairments and prioritizing areas for action. This approach will help ensure that available resources are most effectively used. SD1 has developed an Adaptive Watershed Management Plan that includes Watershed Characterization in sixteen sub watersheds to relate in-stream conditions to watershed characteristics. The results of this Watershed Characterization will be used to identify impaired watersheds and prioritize them for consideration of control alternatives.

An initial element of the Plan is to establish baseline conditions throughout the three county area. Initial surveys were conducted in 2006 and continued through 2010. The 2006 surveys included two rounds of sampling at approximately 50 sites; where as in 2007 and 2008, the program was expanded to include 75 sites to be sampled once annually. In 2009-2010 the program was expanded to include 77 total sites. The 2011 season was a 'catch-up' year, with only five sites sampled. In the 2012 season, only sites within the East Basin were sampled. The 2012 sampling year marked the beginning of the Phase 2 portion of the monitoring program. Sites in the East Basin were originally sampled in 2007, and were resampled in 2012. During the 2013 season, only sites in the Central Basin were sampled and during the 2014 season, sites were sampled in the North Basin. During the 2015 sampling season the West Basin was sampled.

Beginning in 2016, sampling will be back in the East Basin and will then rotate each year to a separate basin: 2017 Central Basin, 2018 North Basin and 2019 West Basin.

The following base flow characterization *Field Monitoring and Sampling Plan* (FMSP) is designed to ensure that all monitoring activities undertaken result in representative data necessary to support the characterization of the watershed being sampled. Dry weather water quality sampling will be conducted to characterize current base flow stream conditions.

Monitoring and sampling stations have been selected to provide appropriate coverage to meet the assessment and modeling needs of the watershed characterization process.

1.1 Program Overview

This FMSP describes the water quality monitoring program for the base flow watershed characterization of Northern Kentucky streams. The purpose of the FMSP is three fold:

- To supplement the Quality Assurance Project Plan (QAPP)
- To provide project and field staff with an understanding of the program and how to complete the base flow monitoring program; and,
- To define the level of effort and analytical needs.

The FMSP is intended to provide practical assistance in obtaining representative and reliable data in a technically sound and safe manner.

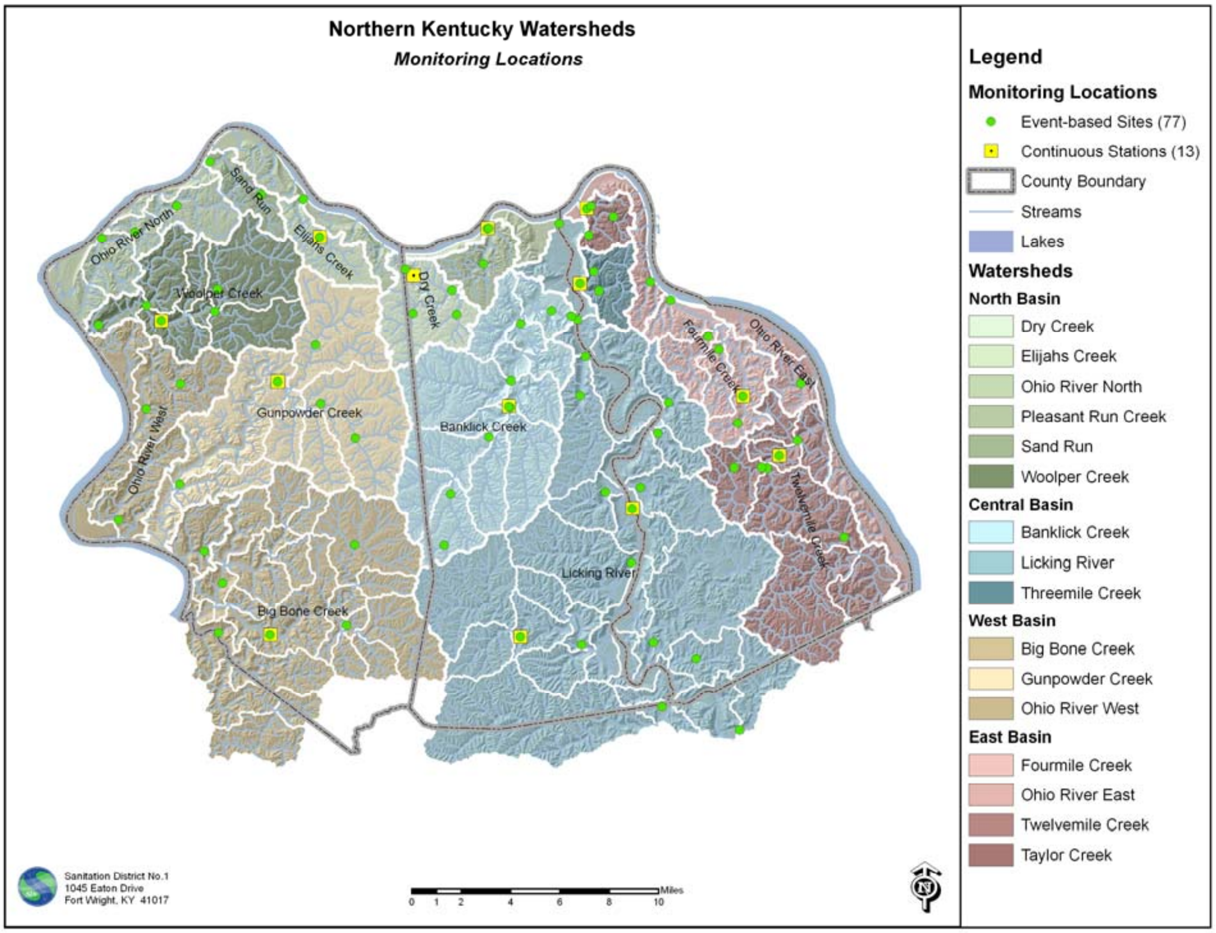
The procedures and protocols presented in this document address the following water quality and quantity monitoring program components:

- Monitoring and sampling criteria
- Stream water quality monitoring
- Sample handling and transportation
- QA/QC requirements
- Program Health and Safety

This program was designed to collect data that will be used to assess base flow water quality concerns identified in Northern Kentucky watersheds. The base flow data collected in Northern Kentucky streams is required to support water quality modeling, and pollutant source identification. The monitoring and sampling program will be conducted during the contact recreation season May 1st – October 31st.

Figure 1 shows locations in the watersheds of the Northern Kentucky area that have been identified as monitoring and sampling stations. The sampling locations shown in Figure 1 are discussed in more detail in Section 3.

Figure 1 Monitoring and Sampling Stations



1.2 Monitoring Team

The monitoring team consists of the Project Manager, the Field Manager, and sampling crew. Responsibilities of key team members are listed in Table 1.

Table 1 Team Member Responsibilities

Position	SD1 Team Member	Responsibilities
Project Manager	Mindy Scott	• Assess suitability of sampling events • Perform System Audits • Circulation of reports and results • Staff Training • Review Reporting • Ensure necessary resources are available • Creation of event reports • QA/QC review
Field Manager	Elizabeth Fet	• Implementation of FMSP • Initiate sampling events • Coordinate with laboratory • Mobilize field crews • Collection and review of field logs, lab results, and other program documentation • Ongoing management of field staff and equipment

Prior to the first sampling event, a flowchart will be created which contains all members of the different sampling crews and laboratory contacts along with their respective contact numbers (home, work, pager, and/or cellular numbers). This will allow for a network of communication prior to and during the monitored events. A communication network for the sampling team is essential to the ability to adapt the sampling program to changing environmental or weather conditions and/or equipment malfunctions.

2. *MONITORING AND SAMPLING CRITERIA*

The objective of the base flow monitoring and sampling program is to characterize water quality during the contact recreational season under dry weather conditions by providing current background data in each watershed.

The criteria used to define a dry weather monitoring and sampling event include:

- No precipitation in the watershed 72 hours before the event; and,
- Dry weather conditions must prevail throughout the monitoring and sampling event.
- Sampling must take place during the contact recreational season beginning May 1st and ending October 31st.

One round of dry weather monitoring will be completed each year. The goal will be to conduct the sampling by basin. The sampling will be distributed throughout the monitoring period by basin to characterize Northern Kentucky streams during typical base flow conditions.

The dry weather criteria will serve as the minimum requirements for initiating sampling. Local conditions may require these criteria to be modified as the study progresses. Best professional judgment will be necessary to assess the suitability of a particular dry weather sampling event.

3. *Stream Characterization*

Stream monitoring and sampling will be conducted at designated stations along Northern Kentucky streams as shown in Figure 1. Water quality monitoring and sampling will be conducted as follows:

- One round of water quality monitoring will be sampled at all sites in the designated basin during base flow conditions according to the surface water quality monitoring program protocols;
- All sites will be characterized on-site for in-stream water quality measurements (temperature, dissolved oxygen, pH, conductivity and turbidity).

Table 2 describes each of the stations as depicted in Figure 1. Station selection was based on an initial watershed reconnaissance, which focused upon suitable site configuration for stream sampling and location relative to key pollutant source inputs. Once final sampling locations were identified, latitude and longitude coordinates were obtained with a Global Positioning System (GPS) unit and recorded.

Standard operating procedures (SOPs) referenced in the following sections are provided in Appendix A.

Table 2 Base Flow Sampling Locations

Station ID	Stream	Location	Study Basin
BLC0.3	Banklick	Route 177 at Banklick	Central
BLC1.2	Banklick	Route 16 bridge on Winston Avenue	Central
BLC3.9	Banklick	Eaton Drive bridge	Central
BLC8.1	Banklick	Richardson Road bridge	Central
BLC11.6	Banklick	Independence Station Road	Central
BLC15.6	Banklick	Maher Road bridge	Central
BPC0.1	Bullock Pen	Bridge on Bullock Pen Road	Central
FWC0.1	Fowler	Bridge on Marshall Road	Central
BMC0.7	Bowman	Bridge on 177, park on Conley Rd.	Central
CRC2.5	Cruises	Bridge on Hempfling Road	Central
CRC8.1	Cruises	USGS Station on Route 17 near Piner, KY	Central
DCC0.4	DeCoursey	Locust Pike Road	Central
DCC2.2	DeCoursey	Bridge on Porter Rd off Rt 177	Central
GRC0.5	Grassy	Bridge on Rt 177, just passed the Pendleton Co. line	Central
LIR0.5	Licking	5th St Bridge in Covington	Central
LIR4.9	Licking	Kenton County Water Intake	Central
LIR19.3	Licking	Visalia Bridge on Rt 536	Central
LIR35.5	Licking	Bridge @ Butler, KY	Central
PHC2.3	Phillips	Gravel pull off on side of Morningview Rd.	Central
PLC1.8	Plum	Bridge @ intersection of Hissem and Aulick Rd	Central
POC0.9	Pond	Bridge on Indian Trace @ intersection with Joann Ln	Central
RFC0.9	Riffle	Rt 915 south of Licking Valley Baptist Church	Central
SCC0.6	Scaffold	Bridge on Rifle Range Rd off Rt 915	Central
STC1.2	Steep	Bridge on Case Rd off Steep Cr. Rd	Central
THC0.4	Threemile	USGS Station on Johns Hill Rd	Central
THC0.5-NBT0.8	North Branch Threemile	Moock Rd, bridge to Woodland Hills Condos	Central
THC1.4	Threemile	Gibson Lane	Central
FMC0.5	Fourmile	Silver Grove Pump Station off Rt 8	East
FMC6.9	Fourmile	USGS Gage Station on Poplar Ridge Rd	East
FMC8.2	Fourmile	Off 547, bridge on Appleblossom Ln	East
OWC0.4	Owl	Rt 547 to Owl Creek Road	East
TUC0.4	Tug	Bridge on Darlington Road	East
TEC1.3	Tenmile	Intersection of Ten Mile and Fender Rd	East
TIC0.2	Threemile	Upstream of Highland Heights PS on Blangey Rd	East
TYC0.6	Taylor	USGS Station on Donnermeyer Dr under I-471	East
TYC1.6-UNT0.4	Taylor	Alexandria Pike in Southgate, KY	East
TYC0.9-WLC1.3	Woodlawn	Waterworks Road	East
TYC0.7-CVR0.2	Covert Run	Across from Ben Flora Gym on Tiger Lane	East
TMC1.9	Twelvemile	Bridge @ intersection of 1566 & 2921	East
TMC3.0	Twelvemile	USGS Gage Station on 1997	East
TMC3.9	Twelvemile	Bridge on Route 10	East
TMC9.3	Twelvemile	Intersection of Route 10 and California Cross Rds	East

Table 2 continued

BRC0.3	Brush	Bridge on Route 10	East
BRC2.0	Brush	Eastern Regional Water Reclamation Facility	East
DRC1.4	Dry	Bridge @ Dry Creek WWTP	North
DRC4.4	Dry	On Eubanks Rd of Anderson Rd off Buttermilk	North
DRC5.9	Dry	Bridge on Shinkle Rd in residential area	North
DRC3.0-WFD1.5	Dry	Bridge on Erlanger Rd off Houston Rd	North
EJC0.3	Elijah	Bridge on Rt 8	North
EJC2.8	Elijah	USGS gage station on Elijah Creek Rd	North
GAC1.7	Garrison	First bridge on Garrison Cr. Rd.	North
PRC0.3	Pleasant	Bridge on Oak St	North
PRC2.0	Pleasant	Bridge over Bromley Crescent Springs Rd @ Amsterdam	North
PRC0.4-UNT0.0	Pleasant	Oak Street behind the BINGO hall	North
SDR0.6	Sand	End of Rt 8, beyond end of state maintenance	North
SDR4.0	Sand	Thornwilde Subdivision	North
SEC1.6	Second	End of Second Creek Road	North
TAC0.5	Taylor	Lawrenceburg Ferry Rd	North
WPC1.4	Woolper	Bridge on Rt 20	North
WPC5.0	Woolper	USGS station on Woolper Rd	North
WPC8.8	Woolper	Bridge on Rt 338	North
ALF0.1	Allen Fork	Huffman-Clifford Bridge on Easton Lane from Rt 338	North
ASF0.0	Ashbys Fork	Intersection of Ashby & Woolper Rd	North
BBC3.9	Big Bone	Off Rt 1925 to Bender Rd	West
MLC3.0	Mud Lick	USGS Station, bridge @ US 42	West
MLC12.0	Mud Lick	Richwood pump station, on Rt 338	West
BSF1.8	Big South Fork	US 42 to bridge on South Fork Church Rd	West
MCF1.7	McCoys Fork	I-75 to Walton-Verona exit	West
GPC4.6	Gunpowder	Sullivan road; path by bus turn around	West
GPC14.7	Gunpowder	USGS gage station and SD1 pump station	West
GPC17.9	Gunpowder	Oakbrook Rd and Limaburg Rd	West
SFG2.6	South Fork Gunpowder	Woodcreek Rd bridge off Pleasant Valley	West
SFG5.3	South Fork Gunpowder	Bridge on Gunpowder Rd to Grace Fellowship Church	West
LAC1.4	Landing	Bridge on Rt 338 at inter.of Big Bone Church/Ryle Rd	West
LIC1.6	Lick	Bridge on Rt 338, near East Bend Power Plant	West
MDC1.8	Middle	Bridge on Waterloo Road	West
MDC5.5	Middle	Middle Creek Road by barn	West

3.1 On-Site Water Quality Measurements

All sites will be subject to on-site measurements during sampling events. On-site measurements will include DO, pH, temperature, conductivity and turbidity.

On-site water quality instrumentation will be calibrated and maintained in accordance with *Standard Operating Procedures Hydrolab Series 5 Water Quality Instrumentation.*

3.2 Dry Weather Sampling

Most sampling locations are accessible by bridges or by wading during dry weather. A minimum of 72 hours without precipitation will be required prior to the beginning of a sampling event, and dry weather conditions must prevail throughout sampling.

Table 3 presents the monitoring schedule for the surface water sampling program for dry weather monitoring. All sampling will be performed by SD1 staff. Base flow samples will be collected as grab samples in accordance with *Standard Operating Procedures for the Collection of Discrete Water Samples.* Dry weather sampling events will be completed by basin, utilizing two person crews as described in Table 3.

All grab samples will be collected with a sampling pole, stainless steel bucket or glove method. Sampling events will start at the downstream site and progress upstream. This approach to dry weather sampling is designed to collect a representative sample of base flow conditions in the stream. Immediately after sample collection, on-site measurements will be taken as previously described.

Table 3 Base Flow Monitoring Schedule

Study Basin	Watershed	Base flow (1 Basin/year)				
		# of Sites	2016	2017	2018	2019
Central	**Licking**	4		X		
Central	**Banklick**	8		X		
Central	**Threemile**	3		X		
Central	Bowman	1		X		
Central	Cruises	2		X		
Central	Decoursey	2		X		
Central	Grassy	1		X		
Central	Phillips	1		X		
Central	Plum	1		X		
Central	Pond	1		X		
Central	Riffle	1		X		
Central	Scaffold	1		X		
Central	Steep	1		X		
		27		**27**		
East	**Fourmile**	5	X			
East	**Twelvemile**	6	X			
East	**Taylor**	4	X			
East	Tenmile	1	X			
East	Threemile	1	X			
		17	**17**			
North	**Woolper**	5			X	
North	**Elijahs**	2			X	
North	**Dry Creek**	4			X	
North	**Pleasant Run**	3			X	
North	**Sand Run**	2			X	
North	Garrison	1			X	
North	Second	1			X	
North	Taylor	1			X	
		19			**19**	
West	**Gunpowder**	5				X
West	**Big Bone**	5				X
West	Landing	1				X
West	Lick	1				X
West	Middle	2				X
		14				**14**

3.3 Summary

Table 4 presents a summary of the field monitoring and sampling plan for Northern Kentucky watersheds.

Table 4 Summary of Water Quality Monitoring and Sampling Program

Type	Locations	Description	Parameters
Base flow Sampling	77 total locations, throughout Northern Kentucky 4 basins (North, Central, West, East)	***Dry Weather*** ♦ 1 basin per year ♦ 1 grab sample per site	♦ On-site measurements will include: ***temperature, dissolved oxygen, pH, conductivity and turbidity.*** ♦ Water quality parameters will include: ***bacteria (EC and FC), nitrogen (TKN, NH_3, NO_3-NO_2), phosphorus (total and ortho), total suspended solids, and $CBOD_5$.***

Table 5 summarizes the number of samples to be collected exclusive of quality control protocols.

Table 5 Summary of Number of Samples to be Collected

Task	East Basin	Central Basin	North Basin	West Basin
Year Sampled	2016	2017	2018	2019
No. of Events	1	1	1	1
No. of Sites	17	27	19	14
Bacteria				
E. coli	17	27	19	14
Nutrients				
NH_3	17	27	19	14
NO_3- NO_2	17	27	19	14
TKN	17	27	19	14
Total Phosphorus	17	27	19	14
Ortho Phosphate (field filtered)	17	27	19	14
Solids				
TSS	17	27	19	14
Other				
$CBOD_5$	17	27	19	14
Total Sample Load	**136**	**216**	**152**	**112**
QA/QC Samples are not included.				

4. *Field Measurements*

In-stream dissolved oxygen, temperature, pH, conductivity, and turbidity will be measured using appropriate field instruments concurrent with sample collection at each of the sampling locations. Each on-site parameter will be measured at each location during each sampling event. Table 6 lists the parameters, location of measurement at each site, and method of measurement.

Field measurements will be conducted following the Standard Operating Procedures in Appendix A. Field instruments will be calibrated before initiating monitoring activities for each event. A post-monitoring calibration check will also be conducted at the end of each monitoring event. All calibration and maintenance activities will be documented on the Multiprobe Instrumentation Calibration and QA Sheet (see Appendix A).

Measurements will be documented on the Field Data Sheet (see Appendix C). Documentation will include: date/time, location, type of measurement, personnel, equipment and associated calibration specifications, and general site observations (e.g., weather conditions).

Table 6. Field Measurements

Parameter	Location of Measurement	Method
Temperature	Mid-channel, mid-depth where possible	Hydrolab
Conductivity		
pH		
Dissolved Oxygen		
Turbidity		

5. *SAMPLING HANDLING AND CUSTODY*

The following sections outlines the sample labeling procedures, sample handling, chain-of-custody and record keeping required.

5.1 Sample Labeling

All samples will be assigned a unique identification code such that all necessary information can be attained from the sample label. The labels will be available in an electronic template and can be printed once the information has been added to the template. The code will identify the following:

Label: ___ ___ ___ ___. ___

1 2 3 4 5

Characters 1-5: Sample Site ID

Example: FMC0.5

In addition to the label, the sample bottles will be clearly marked using waterproof ink with the following information:

- Client – SD1
- Analyses – List of requested analyses to be performed from the container
- Preservative – Preservative in sample container
- Date – Date sample was collected
- Time – Time sample was collected
- Crew – Crew identification

5.2 Sampling Collection, Handling and Transport

General guidelines for sample collection are listed below. Refer to *Standard Operating Procedures for the Collection of Discrete Water Samples* for detailed procedures.

- All samples collected in intermediate sampling containers should be transferred to their appropriate laboratory sample bottle as quickly as possible.
- Sampling location codes will be used to distinguish each distinct sampling location.
- Sample labels and chains of custody must be filled out completely.

The following procedures will be followed when handling and transporting samples:

- Samples will be preserved using ice and transported in sample coolers. It should be ensured that plenty of ice is used for each sample cooler to maintain the temperatures inside the cooler at approximately 4^{o} C.
- Laboratory chain-of-custody forms will be included with all sample submissions. Field staff will keep copies.
- Sample bottles and coolers should be handled with care to prevent breakage/spillage.
- All sample bottle labels must be properly completed and placed firmly on each bottle by the field sampling crews.

5.3 Chain-of-Custody

Field crews will complete chain-of-custody forms to document the transfer of sample custody to the designated custodian and subsequent personnel, see Appendix B. Signatures of all personnel involved in the collection, transport, and receipt of each sample will be recorded on the chain-of-custody forms.

In certain instances, sample custody will be transferred to runners to transport the samples directly to the laboratory at designated times during sampling to avoid missing holding times. The chain-of-custody form outlines sample location, identification, collection time and date, and specific parameters to be analyzed for each sample. A properly completed chain-of-custody form must accompany all samples.

Use of the chain-of-custody form will terminate when laboratory personnel receive the samples and sign the form. The laboratory will open the sample coolers and carefully check the contents for evidence of leakage and to verify that samples were kept on ice. The laboratory will then verify that all information on the sample container label is correct and consistent with the chain-of-custody form. Any discrepancy between the sample bottle and the chain-of-custody form, any leaking sample containers, or any other abnormal situation will be reported to the Laboratory Manager. The Laboratory Manager will inform the Project Manager of any such problem, and corrective actions will be discussed and implemented.

5.4 Field Logs and Records

Field crews will document all activities associated with the monitoring program at each monitoring site, including unusual or anomalous conditions. In addition, a description of any problems encountered during the monitoring period and/or any deviations to the FMSP will also be documented. This information may subsequently be used for data interpretation and analyses.

All pertinent information will be recorded on Field Data Sheets which are included as Appendix C.

At the conclusion of each monitored event, all Field Data Sheets will be submitted to the Field Manager to serve as a chronological representation of the monitored event. At a minimum each data field sheet should include the following information:

- Project name, site/river name, sample type;
- Crew identification, date, start time/end time;
- Weather conditions, stream conditions, site conditions;
- Physical parameter data (on-site measurements);
- On-site water quality meter identification number used to measure physical parameter data;
- Field observations.

In addition, the recreational use survey form (also provided in Appendix A) will be completed at each site and submitted to the Field Manager at the conclusion of each monitored event. The recreational use survey should include the following information:

- Project name, site/river name, sample type;
- Crew identification, date, start time/end time;
- Photo file name and corresponding description;
- Description of recreational uses observed at the site; and,
- Description of other human evidence of use.

All entries will be completed with a permanent ink pen with no erasures, correction fluid, or tape used. Erroneous entries will be noted using a single line drawn through the mistake that is then dated and initialed.

5.5 Sample Containers and Preservation

Table 7 presents details of sample containers and preservatives to be used. The laboratory will provide all bottles pre-preserved.

Table 7 Guidelines for Sample Container Preparation and Preservation

Parameter	Container	Recommended Sample Volume	Preservation	Maximum Storage Time
Bacteria				
E. coli	Pre-Sterilized Polyethylene or Glass	120 ml	Add $Na_2S_2O_7$ [1] Refrigerate to 4°C	12 hours[2]
Nutrients				
NH_3 TKN NO_3-NO_2 Total Phosphorus	Polyethylene or Glass	1000 ml	Add H_2SO_4, pH<2 Refrigerate to 4°C	28 days
Ortho Phosphate	Polyethylene or Glass	120 ml	Field filter Refrigerate to 4°C	48 hours
Conventional				
TSS	Polyethylene or Glass	1000 ml	Refrigerate to 4°C	7 days
$CBOD_5$	Polyethylene or Glass	1000 ml	Refrigerate to 4°C	48 hours

1. Sodium Thiosulfate ($Na_2S_2O_7$) prevents continuation of bacteriocidal action.
2. The maximum allowable holding time for bacteria samples will be 12 hours with a goal of 6 hours when practical.

6. *QUALITY ASSURANCE/QUALITY CONTROL PROGRAM*

The purpose of any quality assurance/quality control (QA/QC) program is to ensure that all sampling protocols and procedures are followed such that samples are representative of the water quality to which they are associated. The program is designed to be a systematic process, which together with the laboratory QA/QC program ensures a high degree of confidence in the data collection. The proposed QA/QC program includes the following elements:

- Training of all field staff;
- Field quality control procedures;
- Equipment cleaning protocol;
- QA/QC samples; and,
- Equipment calibration.

6.1 Training

Training sessions will be carried out for all field staff on proper sampling, sample handling and submission and general field procedures. Specific emphasis will be placed on QA/QC issues as well as on health and safety. Field crews will receive training involving the operation, maintenance and calibration of water quality meters, and all other on-site equipment used throughout the field program. SOPs for all program elements will be distributed to staff and available at all times.

6.2 *Field Quality Control*

The quality of data generated in a laboratory depends primarily on the integrity of the samples that arrive at the laboratory. Consequently, necessary precautions must be taken to protect samples from contamination and deterioration. Procedures detailed in *Standard Operating Procedures for the Collection of Discrete Water Samples* and *Standard Operating Procedures for Hydrolab Series 5 Water Quality Instrumentation* will be followed to ensure field quality control.

6.3 *Equipment Cleaning Protocol*

All sampling equipment (i.e. intermediate containers, sampling buckets, etc.) will follow the QA/QC protocol outlined in *Standard Operating Procedures for the Collection of Discrete Water Samples* to ensure representative sample collection. When using the sampling pole or stainless steel bucket, only step 2 (Blank Water Rinse) of the decontamination procedure needs to be utilized.

6.4 *QA/QC Samples*

The monitoring team will use three types of QA/QC samples collected in the field to assist in validating chemical data sets – sample duplicates, equipment blanks, and field blanks. Each type of QA/QC sample is described in the following sections. Tables 8 and 9 present the schedule and number of QA/QC samples to be collected during the field program.

Table 8 QA/QC Sample Schedule

Crew	**Dry Weather / Base Flow Sampling**			
	East Basin	Central Basin	North Basin	West Basin
Day 1	BEB*,Dup, FB, MB, AEB*	BEB*, Dup, FB, MB, AEB*	BEB*, Dup, FB, MB, AEB*	BEB*, Dup, FB, MB, AEB*
Day 2	BEB*, FB, MB, AEB*	BEB*, FB, MB, AEB*	BEB*, FB, MB, AEB*	BEB*, FB, MB, AEB*
Day 3		BEB*, FB, MB, AEB*		
BEB = Before Equipment Blank MB= Method Blank Dup = Duplicate AEB = After Equipment Blank FB = Field Blank * = As needed				

Table 9 Number of QA/QC Samples

Base Flow Sampling	Field Blanks[2]	Equipment Blanks[3]	Method Blanks[4]	Duplicate Samples[5]	Total per Event
Day 1	1	6	1	1	18
Day 2	1	4	1	0	8
Day 3			1	0	
Totals	**6**	**10**	**6**	**4**	**26**

1. Each QA/QC sample set is performed on the complete series of samples submitted for laboratory analysis.
2. One set of field blanks per day will be collected during each day of the event.
3. Two sets of equipment blanks (BEB, AEB) per day will be collected during each day of the event only if a bucket was used during sampling.
4. One set of method blanks (at one site) per day will be collected during each day of the event.
5. One set of duplicates (at one site) will be collected during each sampling event.

6.4.1 *Sample Duplicates*

Sample duplicates will be collected for laboratory analysis for each parameter. The purpose of these analyses is to evaluate sample collection precision by comparing the duplicate analytical results. One set of duplicate samples at a sampling location, randomly identified, will be collected by each field crew during the sampling event. Duplicates will be rotated among streams between sampling rounds. Approximately 10 percent of the samples will be collected in duplicate.

6.4.2 *Equipment Blanks*

Equipment blanks will be collected for laboratory analysis for all parameters. The purpose of these analyses is to assess potential cross-contamination of samples by the equipment, including intermediate sample containers. These blanks will be taken before each sampling shift (BEB) and at the conclusion of each sampling shift (AEB) by each crew.

6.4.3 *Method Blanks*

Method blanks (MB) will be collected for laboratory analysis for orthophosphate only. The purpose of these analyses is to assess potential cross-contamination of samples by the method in which the sample was collected. These blanks will be taken at the conclusion of each sampling shift by each crew.

6.4.4 *Field Blanks*

Field blanks will be collected for laboratory analysis for all parameters. The purpose of these analyses is to determine if samples collected have been contaminated by field handling and cleaning methods. Each field crew will collect these blanks immediately following the collection of the AEB equipment blanks.

6.5 Equipment Calibration

On-site physical parameters will be measured in-stream by water quality meters and recorded on data sheets. These instruments will be calibrated each sampling day before use according to the manufactures operating manual as outlined in *Standard Operating Procedures for Hydrolab Series 5 Water Quality Instrumentation*.

At the conclusion of the sampling event, each meter will be checked with the standards used during calibration. The purpose of these readings is to evaluate the meter’s precision (electronic drift) by comparing the readings recorded during calibration and the readings recorded during the check at the end of the sampling day.

At the conclusion of each sampling event, all Calibration Sheets will be submitted to the Field Manager to serve as a record of the meter’s performance during the sampling event.

7. PROGRAM SAFETY

The most critical component of a sampling program is crew safety. Safety is of paramount importance as stream sampling can be extremely dangerous. The element of danger is accentuated if personnel are unfamiliar with their surroundings and/or procedures, consequently staff must be properly trained in both safety and monitoring procedures, following a well thought out program.

With stream monitoring, common sense is essential. Two hazards that field staff may face more often, especially if wet weather occurs during sampling, are high stream conditions and slippery footing. If stream levels are deemed to be too high or too fast, under no circumstances should any field staff enter the stream or operate near its banks. With surfaces being wet and slippery, special care must be taken when walking and working around bridges.

Wading is one of the easiest methods to collect samples from many streams, and it may also be extremely dangerous. Wading permits the investigator to examine stream flow and decide where to sample. Rubber boots or even chest-high waders are standard equipment. If the wader has any uncertainty about their ability to wade a stream, they should be attached by a rope to a rigid mooring and wear an approved floatation device.

If creek conditions are high and fast, field staff will wear a safety belt or harness and will be appropriately tethered when working in close proximity to the creek. Along with being attached by rope, field staff must wear an approved floatation device.

There must be a minimum of two field staff working together during any sampling event.

7.1 General Safety Practices

- Water depth during wading operations must be checked with a pole before steps are taken.
- When wading equipment is worn, the support straps must be outside the clothing.
- In all situations field parties are required to leave accurate sampling schedules and expected itineraries in the office.
- Sampling must never be carried out in weather that is considered by the Field Manager or field member to be hazardous to the well-being of the field staff and/or equipment.
- Field staff are required to wear approved floatation devices and be tethered if conditions warrant use.
- First aid kits will be issued to all field crews.
- Each field crew will have a cellular phone and have been instructed on emergency procedures and numbers.
- Each field crew will report upon leaving and returning from any sampling or field work to their Field Manager.
- Each field crew will have appropriate lights, markers, etc. to be able to perform their work safely under poor visibility/nightfall.
- Each field crew will have the appropriate road safety equipment as required.

7.2 Health Hazards

Disease causing bacteria, viruses, and parasites are always present in sewers and discharge streams. They occur in both liquid sewage and dry sludge which coats pipes, and other surfaces. The serious threats are Hepatitis A (virus), Hepatitis B (virus), Tetanus (bacteria), Typhoid (bacteria), and Polio (virus). Proper hygiene methods must be followed. Wash hands before eating or smoking. Protective clothing must be laundered and equipment kept clean. Workers should avoid touching their eyes to prevent an inflammation. Cuts and abrasions of the skin should be covered by bandages or gloves to minimize the chance of infection by organisms.

APPENDIX A

STANDARD OPERATING PROCEDURES FOR FIELD MONITORING AND SAMPLING

Standard Operating Procedures

for the

Collection of Discrete Water Samples

Northern Kentucky Sanitation District No. 1
1045 Eaton Drive
Fort Wright, KY 41017

Revision Number: 1
September 2006

Introduction
This document describes the procedures for the collection of discrete water samples in Northern KY watersheds by Sanitation District No.1. These methods allow for the collection of grab or composite samples utilizing various sample collection techniques. This standard operating procedures document (SOP) has been developed to maintain consistent data collection procedures, and to ensure the quality of the data collected.

1.0.0 Field Equipment
The following equipment is needed to implement the sampling techniques.

- Stainless Steel Bucket w/ Rope
- Sampling Pole
- Kemmerer Sampling Bottle Kit
- Churn Sample Splitter
- Chemical Decontamination Agent (Solvent or Weak Acid)
- Chemical Waste Bucket
- Blank Water (Distilled or Reagent Grade Deionized – RGDI)
- Sample Bottles
- Coolers and Ice
- Scrub Brush
- Disposable Gloves
- Field Sampling Plan
- Permanent Marker (Sharpie)

Individuals handling solvents or acids should wear rubber gloves and eye protection to prevent possible injuries.

The following parameters can be collected with the ensuing sampling techniques: bacteria (fecal coliform and *E. coli*), oxygen demand (BOD_5 , $CBOD_5$, COD), chlorophyll *a*, nutrients (total phosphorus, orthophosphate, nitrate-nitrite, Total Kjeldahl Nitrogen, ammonia), total hardness, metals, and solids (TSS, TDS).

Refer to Attachment 1 for an alternative collection procedure for parameters that do not require preservatives utilizing the glove method.

Refer to Attachment 2 for filtration procedures for orthophosphate collection.

2.0.0 Preparation
Before collecting samples, properly fill out the label (date, time, sampling point, sample ID number, analysis required, preservative, and the name of the collecting entity and sampling crew member) on all bottles using a permanent marker and affix the labels to the bottles. Ideally, the labels are filled out (except date and time) and attached to the sample bottles before the sampling event occurs. In addition to the sample label, identify the lid of each container with the sample ID number using the permanent marker.

Prior to collecting samples, both the coolers and the sample bottles should be visually inspected for presence of any dirt, chemicals, or other contaminants. If a sample bottle has any contaminants present, discard it and use another. The coolers should be wiped down or washed with a mild soap and thoroughly rinsed if it has any contaminants present. In addition all sampling equipment must be inspected for proper operation.

The sampler's hands should be washed with a mild soap and water immediately before the sampling event begins. When actually collecting the samples, disposable gloves shall be worn and care taken to avoid touching or otherwise contaminating the inner surface of the sample bottles or lids.

3.0.0 Procedures

Keep all sampling bottles closed until they are ready to be filled. At each collection site, the sampler will wear a new set of gloves for decontamination procedures and new set of gloves for sample collection. If sampling from a boat or structure, collect the sample from the upstream side. Avoid placing the sampling device in contact with the streambed or bank. Once the sample is collected and sealed, the sample bottle should be immediately placed in a cooler and covered with crushed ice.

3.1.0 Stainless Steel Bucket

Prior to sampling, the stainless steel bucket must be inspected to ensure that is in good condition, and that the nylon rope is not torn or frayed.

3.1.1 Decontamination Procedures

The stainless steel bucket must be cleaned before each sample is collected.

Step 1 – Alconox Detergent Wash (Optional)

- Using a small brush, scrub the outer lip and the inside of the bucket with an Alconox detergent solution (blank water).
- Discard the detergent solution.
- Rinse the outer lip and the inside of the bucket with blank water.
- Discard the blank water.
- Repeat the rinsing cycle until all the detergent has been removed.

Step 2 – Chemical Rinse – Solvent or Weak Acid (Optional)

- Rinse the inside of the bucket thoroughly with the chemical.
- Discard the chemical into the waste container.
- Rinse the inside of the bucket with blank water.
- Discard the blank water into the waste container.

Step 3 – Blank Water Rinse

- Rinse the outer lip and the inside of the bucket with blank water.
- Discard the blank water.
- Repeat Step 3.

3.1.2 Sample Collection Procedures

Discrete surface grab samples (most often used for shallow water sampling from a bridge or stream bank) are collected using the following procedures.

Step 1 – River Rinse

- Rinse the bucket with river water by submerging the bucket into the stream at the collection site.
- Remove the bucket from the stream and discard its contents downstream of where the sample will be collected.

Step 2 – Sample Collection

- Lower the bucket into the stream to obtain a surface grab sample.
- Remove the bucket from the stream.
- Fill the required sample bottles.

3.2.0 Sampling Pole
The pole must be inspected to ensure it is clean and all parts are working properly. Prior to sampling, ensure the bottle is properly attached and snapper band is securely fastened. Once pole is extended, verify that the locking mechanism is secured.

3.2.1 Decontamination Procedures
The sampling pole and bottle attachment must be cleaned before each sample is collected.

Step 1 – Alconox Detergent Wash (Optional)
- Using a small brush, scrub the entire pole with an Alconox detergent solution (blank water).
- Discard the detergent solution.
- Rinse the entire pole with blank water.
- Discard the blank water.
- Repeat the rinsing cycle until all the detergent has been removed.

Step 2 – Blank Water Rinse
- Rinse the bottle attachment with blank water.
- Discard blank water.
- Repeat Step 2.

3.2.2 Sample Collection Procedures
Discrete surface grab samples (most often used for shallow water sampling from a bridge or stream bank) are collected using the following procedures.

Step 1 – Sample Collection
- Attach a clean unpreserved bottle onto the pole.
- Lower the bottle into the stream to obtain a surface grab sample.
- Make sure the bottle does not touch the bottom of the stream and try to avoid floating debris entering the bottle.
- Remove the bottle from the stream.
- Repeat as necessary to fill the required sample bottles. (Attempt to proportional divide the sample volume equally between sample bottles in order to average out any temporal variations.)
- Detach the bottle from the pole and:
    a) If using a sample bottle, place in the cooler.
    b) If using a transfer bottle, discard when finished.

3.3.0 Kemmerer Sampling Bottle

Prior to sampling, the Kemmerer must be inspected to ensure that the triggering mechanism is functioning properly, and that the nylon rope is not torn or frayed.

3.3.1 Decontamination Procedures

The Kemmerer must be cleaned before each sample is collected.

Step 1 – Chemical Rinse – Solvent or Weak Acid (Optional)

- Rinse the inside of the Kemmerer thoroughly with the chemical.
- Purge a small amount of the chemical from the drain valve into the waste container.
- Open the top and discard the remaining chemical into the waste container.
- Rinse the inside of the Kemmerer with blank water.
- Purge a small amount of the blank water from the drain valve into the waste container.
- Open the top and discard the remaining blank water into the waste container.

Step 2 – Blank Water Rinse

- Rinse the inside of the Kemmerer with blank water.
- Purge a small amount of the blank water from the drain valve.
- Discard the remaining blank water.
- Repeat Step 2.

3.3.2 Sample Collection Procedures

Discrete water column grab samples (most often used for deep water sampling from a boat) are collected using the following procedures.

Step 1 – River Rinse

- Open the Kemmerer bottle.
- Rinse the Kemmerer with river water by submerging it into the stream at the collection site.
- Remove the Kemmerer from the stream.

Step 2 – Sample Collection

- Lower the Kemmerer to the appropriate depth (utilize the boat fathometer to determine mid-depth and bottom depth).

  a) Surface – Lower the Kemmerer to a depth of approximately one-foot below the surface.
  b) Mid-Depth – Lower the Kemmerer to the appropriate depth.
  c) Bottom – Lower the Kemmerer to a depth of approximately two-feet from the bottom (If Kemmerer contacts bottom sediment, repeat decontamination procedures before sample collection).

- Activate the closing mechanism of the Kemmerer to acquire sample volume.
- Remove the Kemmerer from the stream.
- Purge a small amount of sample volume from the drain valve.
- Fill the required sample bottles.

3.4.0 Churn Sample Splitter

Prior to sampling, the churn sample splitter must be inspected to ensure that is in good condition, and that it is functioning properly.

3.4.1 Decontamination Procedures

The churn sample splitter must be cleaned before sub-samples are homogenized. In addition, the appropriate sample collection device must also be cleaned (stainless steel bucket – 3.1, sampling pole – 3.2 or Kemmerer – 3.3).

Step 1 – Alconox Detergent Wash (Optional)

- Using a small brush, scrub the plunger and the inside of the churn splitter with an Alconox detergent solution (blank water).
- Purge a small amount of the wash solution from the spigot.
- Discard the remaining detergent solution.
- Rinse the plunger and the inside of the churn splitter with blank water.
- Purge a small amount of the blank water from the spigot.
- Discard the remaining blank water.
- Repeat the rinsing cycle until all the detergent has been removed.

Step 2 – Chemical Rinse – Weak Acid (Optional)

- Rinse the plunger and the inside of the churn splitter thoroughly with the chemical.
- Purge a small amount of the chemical from the spigot into the waste container.
- Discard the remaining chemical into the waste container.
- Rinse the plunger and the inside of the churn splitter with blank water.
- Purge a small amount of the blank water from the spigot into the waste container.
- Discard the remaining blank water into the waste container.

Step 3 – Blank Water Rinse

- Rinse the plunger and the inside of the churn splitter with blank water.
- Purge a small amount of the blank water from the spigot.
- Discard the remaining blank water.
- Repeat Step 3.

3.4.2 Sample Collection Procedures

Sub-samples (vertical or horizontal), obtained with a stainless steel bucket, sampling pole or Kemmerer bottle are homogenized into composite samples using the following procedures.

Step 1 – River Rinse

- River rinse by filling the churn splitter with the sampling device at the collection site.
- Purge a small amount of the stream water from the spigot.
- Discard the remaining contents.

Step 2 – Sample Collection

- Obtain sub-samples following either stainless steel bucket, sampling pole, or Kemmerer collection procedures.
- Fill the churn splitter with approximately equal volumes from each sub-sample.

Step 3 – Homogenizing Sub-samples

- Mix the contents of the churn splitter, at a uniform churning rate, for 10 strokes prior to withdrawal of the first sample.
- Purge a small amount of sample volume from the spigot.
- While continuing to churn the sample volume, fill the required sample bottles.

4.0.0 Quality Assurance

Quality assurance samples should comprise at least 10 percent of the total number of stream samples collected.

4.1.0 Duplicate Samples

To collect duplicate grab samples fill the required bottles from the same stainless steel bucket, sampling pole, or Kemmerer. To collect duplicate composite samples fill the required bottles from the Churn Splitter sample volume.

4.2.0 Blanks

Blanks should be collected during each day of the survey. The sampler should wear a new set of gloves for each blank processed. Once the blank is collected and sealed, the sample bottle should be immediately placed in a cooler and covered with crushed ice.

4.2.1 Field Blanks

Pour blank water from an unopened container directly into the sample bottle.

4.2.2 Equipment Blanks

Equipment blanks should be collected at the beginning and end of each survey day.

Stainless Steel Bucket

- Perform the "Blank Water Rinse" (Decontamination Procedure) for a total of three rinses.
- Fill the stainless steel bucket with enough blank water to fill the sample bottles.
- Fill the required sample bottles.

Sampling Pole

- The method for this device does not require a blank.

Kemmerer Bottle

- Perform the "Blank Water Rinse" (Decontamination Procedure) for a total of three rinses.
- Fill the Kemmerer with enough blank water to fill the sample bottles.
- Purge a small amount of blank water from the Kemmerer.
- Fill the required sample bottles.

Churn Sample Splitter

- Perform the "Blank Water Rinse" (Decontamination Procedure) for a total of three rinses.
- Fill the appropriate collection device (Kemmerer or stainless steel bucket) with enough blank water to fill the sample bottles.
- Purge a small amount of blank water from the appropriate collection device.
- Pour the blank water from the collection device into the churn splitter.
- Mix the contents of the churn splitter, at a uniform churning rate, for 10 strokes prior to withdrawal of the first sample.
- Purge a small amount of sample volume from the spigot.
- While continuing to churn the sample volume, fill the required sample bottles.

4.2.3 Trip Blanks (Optional)

Depending on study design, a trip blank may be utilized. This is a sample of RGDI water taken from the laboratory to the sampling site and returned to the laboratory unopened.

5.0.0 Chain of Custody Procedures

All samples are to be recorded on a Chain of Custody form with its identifying information. The Chain of Custody form is to be signed and submitted to the laboratory along with the samples.

Attachment 1
Collection of Unpreserved Parameters Utilizing the Glove Method

Introduction
This attachment describes the procedures for the collection of grab samples into unpreserved bottles utilizing the glove method. This method has been implemented to eliminate the use of sampling equipment (i.e. stainless steel bucket or Kemmerer) for collecting surface samples. The elimination of equipment reduces cleaning procedures and possible sources of contamination. In addition, this method significantly reduces sampling time.

1.0 Field Equipment
The following equipment is needed to implement the Glove Method collection technique.

- Disposable Gloves
- Sterilized Unpreserved Sample Bottles
- Cooler and Ice
- Permanent Marker (Sharpie)
- 1 Gallon Container of Blank Water (Distilled or RGDI)
- Anti-Bacteria Soap
- Knife

2.0 Preparation
Before collecting the sample, properly fill out the label (date, time, sampling point, sample ID number, analysis required, preservative and the name of the collecting entity and crew member) using a permanent marker and affix the label to the bottle. Ideally, the label is filled out (except data and time) and attached to the sample bottle before the sampling event occurs. In addition to the sample label, identify the lid of the bottle with the sample ID number using the permanent marker.

Prior to collecting samples, both the coolers and the sample bottles should be visually inspected for presence of any dirt, chemicals, or other contaminants. If a sample bottle has any contaminants present, discard it and use another. The coolers may be wiped down or washed with a mild soap and thoroughly rinsed if they have any contaminants present.

The sampler's hands should be washed with anti-bacteria soap and water immediately before the sampling event begins. When actually collecting the samples, disposable gloves shall be worn and care taken to avoid touching or otherwise contaminating the inner surface of the bottle or lid.

3.0 Procedures
Keep sample bottles closed until they are to be filled. At the collection site, the sampler will wear a new set of gloves and detach the lock mechanism from the lid. Fill the bottle by holding the bottle upright and plunging it into the stream directed toward the current. Keep the lid closed (so as not to lose the dechlorination tablet) until you have reached a depth of 6 to 12 inches below the surface. When the sample is collected, leave ample air space in the bottle to facilitate mixing by shaking. Avoid placing the sample bottle in contact with the streambed or bank. If sampling from a boat or structure, collect the sample from the upstream side.

Fill the bottle to the appropriate level (if more water is collected than needed, carefully pour out the excess) and properly close the lid. If taking a bacteria sample shake the bottle for 30 seconds to expedite dissolving the dechlorination tablet.

After the sample is collected and sealed, the sample bottle should be placed in a cooler and covered with crushed ice. A new set of sterile gloves will be worn for each sample collected.

4.0 QA Samples

Quality assurance samples should comprise at least 10 percent of the total number of stream samples collected.

4.1 Duplicate Samples

To collect duplicate samples, plunge bottles into the river and fill one immediately after another.

4.2 Blanks

Blanks should be collected at the completion of each survey day. The sampler should wear a new set of gloves for each blank processed. Once the blank is collected and sealed, the sample bottle should be immediately placed in a cooler and covered with crushed ice.

4.2.1 Field Blank

Pour blank water from an unopened gallon container directly into the sample bottle.

4.2.2 Method Blank

With a clean pocketknife, cut off the top of the container used for the first field blank. Simulate stream collection by plunging the bottle, while wearing gloves, into the cut open gallon container. Keep the bottle upright and let the water flow over the top of the bottle until it is filled.

5.0 Chain of Custody Procedures

All samples are to be recorded on a Chain of Custody form with its identifying information. The Chain of Custody form is to be signed and submitted to the laboratory along with the samples.

If the sample bottles used have a tie, this tie must be cut in order to open the bottle, and should provide a measure of sample security and integrity.

6.0 Reference

USEPA. 1978. Microbiological Methods for Monitoring the Environment, Water and Wastes. Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio. EPA/600/8-78/017.

Attachment 2
Collection of Orthophosphate Samples

Introduction
This attachment describes the additional procedures needed for the collection of orthophosphate samples.

1.0 Additional Field Equipment
The following additional equipment is needed to implement the orthophosphate filtration method.

- Disposable 60cc Syringes (Luer-Lok tip)
- Disposable 25 mm Filter Cartridges (1μm Glass Fiber Filter and 0.45μm Nylon Membrane Filter)
- Sample Bottles

2.0 Procedures
A new disposable syringe and filter cartridge (syringe filtration unit) will be used for each sample.

2.1 Decontamination Procedures
The syringe filtration units must be cleaned before each sample is filtered.

Step 1 - Blank Water Rinse

- Rinse the inside of the syringe by plunging 50mls of blank water through the housing.
- Attach the filter cartridge to the syringe.
- Rinse the inside of the entire unit by plunging 50mls of blank water through the unit.

2.2 Sample Collection Procedures
Samples can be filtered from the Kemmerer bottle, sampling pole, stainless steel bucket, or churn splitter using the following procedures.

Step 1 – Sample Filtration/Collection

Fill the syringe filtration unit with sample from the appropriate collection device.
Place the plunger into the syringe.
Purge a small amount of sample volume through the filter.
Discharge water through the filtration unit into a sample bottle.
Repeat the previous three bullets until enough sample has been filtered into the sample bottle.
Discard the syringe filtration unit.

3.0 Quality Assurance

Quality assurance samples should comprise at least 10 percent of the total number of stream samples collected.

3.1 Duplicate Samples

To collect duplicate samples continue to fill the syringe filtration unit from the same Kemmerer, sampling pole, or stainless steel bucket drop and filter into the required bottles.

3.2 Blanks

Blanks should be collected during each day of the survey. Once the blank is collected and sealed, the sample bottle should be immediately placed in a cooler and covered with crushed ice.

3.2.1 Field Blanks

Pour blank water from an unopened container directly into the sample bottle.

3.2.2 Equipment Blanks

Equipment blanks should be collected at the beginning and end of each survey day.

Unfiltered Equipment Blank

An equipment blank utilizing the appropriate collection device should be collected at the beginning of each survey day.

- Fill the appropriate collection device (Kemmerer, sampling pole (utilize clean transfer bottle), stainless steel bucket, or churn splitter) with enough blank water to fill the sample bottle.
- Purge a small amount of blank water from the appropriate collection device.
- Fill the required sample bottle.

Filtered Equipment Blank

An equipment blank utilizing the syringe filtration unit should be collected at the end of each survey day. The syringe filtration unit is decontaminated using the previously outlined procedure before the blank is collected.

- Fill the appropriate collection device (Kemmerer, sampling pole (utilize clean transfer bottle), stainless steel bucket, or churn splitter) with enough blank water to fill the sample bottle.
- Purge a small amount of blank water from the appropriate collection device.
- Fill the syringe filtration unit with sample from the appropriate collection device.
- Place the plunger into the syringe.
- Purge a small amount of blank water through the filter.
- Discharge water through the filtration unit into a sample bottle.
- Repeat the previous three bullets until enough volume has been filtered into the sample bottle.
- Discard the syringe filtration unit.

Standard Operating Procedures

for

Hydrolab Series 5
Water Quality Instrumentation

Sanitation District No. 1 of Northern Kentucky
1045 Eaton Drive
Fort Wright, KY 41017
(859) 578-7460

Revision Number: 1
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Introduction

This document contains information and directions on using Hydrolab water quality instrumentation (DS5 Water Quality Multiprobe and Surveyor® 4a Water Quality Data Display). This standard operating procedures document (SOP) has been developed to maintain properly functioning equipment, and to ensure the quality of the data collected.

1.0.0 Instrumentation Maintenance

The following procedures are to be utilized to maintain the Hydrolab instrumentation.

1.1.0 DS5 Multiprobe

The outside housing of the sonde should be kept free of sediments, bio-films, oils, etc. by cleaning with soap and water. The storage cup must be installed (filled with tap water) at all times when the unit is not in use to protect the sensors from damage and from drying out. Refer to section 6.1.1 of the *DS5 User's Manual*. The unit's operating range is 23°F to 122°F (-5°C to 50°C). Exposure of the unit to temperatures outside of this range may result in mechanical or electronic damage. Refer to section 5.1.2 of the *DS5 User's Manual*. The DS5 contains an internal lithium system battery that is good for approximately two years. Refer to section 6.2.3 of the *DS5 User's Manual* for replacement procedures.

1.1.1 Temperature Sensor

The temperature sensor should be kept clean from deposits, otherwise it does not require any scheduled maintenance. Refer to section 6.9 of the *DS5 User's Manual*.

1.1.2 Luminescent Dissolved Oxygen (LDO) Sensor

LDO sensor is not affected by fouling or other debris, unless the growth is an organism that locally consumes or produces oxygen, such as barnacles, or algae growing on the sensor cap. Nevertheless, the manufacturer recommends periodic maintenance to remove contaminates such as oil, biological growth, dirt, etc. Sensor maintenance should be conducted after every deployment cycle. Refer to the Instruction Sheet – **Hach LDO Sensor** in the *DS5 User's Manual*. Yearly maintenance of the sensor should include the replacement of the sensor cap.

1.1.3 pH Sensor

The pH reference electrolyte and porous reference junction should be replaced at least twice a year. Refer to section 6.8 of the *DS5 User's Manual* for these procedures. The pH glass electrode can be generally cleaned with a cotton ball/"Q" tip using mild detergent and water; while a cotton ball/"Q" tip with methanol can be used to remove any oil, sediment or biological growth on the glass, as needed. Once maintenance has been performed on the sensor, the sensor should re-equilibrate for approximately 12 hours in tap water before it is calibrated, especially if methanol has been used. If the 12-hour re-equilibrate period cannot be met, record the estimated re-equilibrate time in the Comments section of the Sanitation District No.1 Multiprobe Instrumentation Calibration & QA Sheet and note if stable "instream" readings are achievable before calibration.

1.1.4 Conductivity Sensor

The annular rings inside the slot in the sensor housing of the conductivity sensor should be cleaned with a small bottle brush using a mild detergent and water, as needed. Methanol and a cotton swab should be used to remove any films or deposits on the electrodes. Refer to section 6.6 of the *DS5 User's Manual* for these procedures.

1.1.5 Self –Cleaning Turbidity Sensor

The self-cleaning turbidity sensor offers higher accuracy turbidity measurements and a wiper mechanism to reduce the effects of fouling. An internal motor automatically wipes the optical face at the start of every measurement. Turbidity sensor maintenance is required when any of the optical surfaces have a coating, or when a zero check using Hach StablCal <0.1 reads>0.9 NTU. Refer to the Instruction Sheet – **Self-Cleaning Turbidity Sensor** in the *DS5 User's Manual*. During unattended deployment, the turbidity wiper should be replaced every 3 months, or as needed (a gap should not be present between the wiper and the lens after reattachment).

1.1.6 Depth Sensor

The depth sensor generally does not need maintenance. If deposits (calcium, biological growth, etc.) begin forming in the port rinse with a very weak acid, such as acetic. Refer to the Sensor Specific Instruction Sheet of the *DS5 User's Manual*.

1.1.7 Circulator

The circulator is used during deployment to ensure adequate flow across the sensors for reliable readings. Refer to section 6.1.3 of the *DS5 User's Manual*.

1.1.8 Internal Battery Power

The DS5 contains an optional internal battery pack that is installed during manufacturing that consists of 8 "C" alkaline batteries that provide 12 volts when fully charged. When the battery pack becomes exhausted (below 6.4 volts) the batteries should be replaced in order for the logger to continue unattended monitoring. Refer to section 6.2 of the *DS5 User's Manual* for replacement procedures. The DS5 also contains an internal lithium system battery that is good for approximately two years. Refer to section 6.2.3 of the *DS5 User's Manual* for replacement procedures.

1.2.0 Surveyor® 4a Data Display

The data display should be protected from mechanical shock and excessive vibrations. The unit's operating range is 23°F to 122°F (-5°C to 50°C). Exposure of the unit to temperatures outside of this range may result in mechanical or electronic damage. Refer to section 3.1 of the *Surveyor 4 User's Manual* for maintenance and cleaning procedures.

1.2.1 Surveyor® 4a Internal Battery Power

The Surveyor 4a contains an internal 7.2-volt rechargeable nickel metal hydride battery. The battery power is exhausted at 6.5 volts and should be recharged for approximately 3.5 hours to ensure a full charge. The Surveyor 4a also contains an internal lithium system battery that is good for approximately two years. Refer to section 3.1 of the *Surveyor 4 User's Manual* for charging and replacement procedures.

1.2.2 Internal Barometer

The barometric pressure sensor does not require any scheduled maintenance. The sensor should be calibrated every six months and checked monthly with an accurate mercury barometer or the barometric pressure provided by the local weather service, corrected to site altitude. Refer to appendix 3 of the *Surveyor 4 User's Manual*.

1.3.0 External Rechargeable Battery Pack

The external rechargeable battery pack provides 12 volts when fully charged. The battery pack is exhausted below 9 volts and should be recharged for 12 hours to ensure a full charge. To prevent "charge memory", recharge the battery pack only when the battery power is exhausted. Refer to section 3.3 of the *DS5 User's Manual*.

1.4.0 Cables

Cables should be kept clean and protected from abrasion, unnecessary tension, repetitive flexure (fatigue), and bending over sharp radii (such as a bridge railing). Connections that plug into terminals are not waterproof and should be kept dry at all times. When cables are not in use, be sure to insert all dummy plugs and dust caps to protect the electrical connectors. Refer to section 6.3.2 of the *DS5 User's Manual*.

1.5.0 Flow Cell

The pressure in the flow cell should not exceed 15psi. Refer to section 5.2.5 of the *DS5 User's Manual*.

2.0.0 Instrumentation Setup
Communication to the *DS5* for setup or calibration can be established via the *Surveyor 4a* or a computer using Hydras 3LT software. The following settings should be configured for normal operation.

2.1.0 Parameter Display
For routine monitoring the following parameter display should be utilized. Refer to section 4.1 of the *DS5 User's Manual.*

- Date/Time Format – MDY/HMS
- Temperature – Celsius
- LDO – mg/L
- LDO – Percent Saturation
- pH – units
- Specific Conductance – μS/cm
- Turbidity – NTU
- Depth25 – Feet
- Battery – Choose appropriate display (internal vs. external and/or volts vs. % remaining)
- Radix – Decimal Point
- Interval – 000001

2.2.0 Parameter Setup
For routine monitoring, the following sensor setup should be utilized. Refer to section 4.1 of the *DS5 User's Manual.*

- Specific Conductance – mS/cm, Fresh Water Temperature Compensation, Autorange
- Salinity – ppt, Method 2311

2.2.1 Using the Surveyor for Parameter Setup
Refer to section 4.1.1 of the *DS5 User's Manual.*

2.2.2 Using Hydras 3 LT for Parameter Setup
Refer to section 4.1.2 of the *DS5 User's Manual.*

2.2.0 System Setup
For routine monitoring the following system setup should be utilized. Refer to *DS5 User's Manual* for additional information.

- Circulator – On during use, Off during calibration
- Audio – Off during normal profiling use, On during logging runs
- Terminal Baud Rate – 19200
- Autolog – Off during normal profiling use, On during logging runs

2.3.0 SDI-12 Setup
For SDI-12 communications with an external data logger the following setup should be utilized. Refer to **Appendix B External Communications** of the *DS5 User's Manual.*

- SDI Address – 1
- SDI Delay – 120 (Note: multiprobe has 5 second built in delay, thus actual delay = 125)

3.0.0 Instrumentation Calibration

Refer to section 4.2 of the *DS5 Users Manual* for sensor calibration procedures. The multiprobe and the standards must be at thermal equilibrium before the calibration procedures are performed. If a stand is used to hold the sonde during calibration, secure the sonde only around the end caps, **never** around the housing. Use either distilled or deionized water as rinse water during the calibration procedures. The multiprobe should be calibrated and post checked after each use to track any electronic drift. Record all calibration information on the Sanitation District No.1 Multiprobe Instrumentation Calibration & QA Sheet – Attachment A.

3.1.0 Procedures

Multiprobe calibration is performed using the stated procedures for each parameter as described. If calibration fails, refer to the appropriate section under Multiprobe Maintenance, Section 6.1 of the *DS5 User's Manual.* After performing the recommended maintenance, reattempt the calibration procedure.

The multiprobe sensor accuracy for each parameter (utilizing certified standards) is stated as follows:

LDO: ± 0.1 mg/L (0 - 8 mg/L)	Conductivity: ± 1% of reading (± 10 µS/cm for a 1000 standard)
± 0.2 mg/L (>8 mg/L)	Turbidity: ± 1 % (0 - 100 NTUs)
pH: ± 0.2 units	± 5 % (400 – 3,000 NTUs)

3.2.0 Temperature

The temperature sensor is factory-set and does not require further calibration. Refer to section 4.2.4 of the *DS5 User's Manual*. The accuracy of the sensor is ± 0.1°C.

3.3.0 Luminescent Dissolved Oxygen (LDO)

There are three standard methods for calibrating the LDO sensor. Each method requires a single point calibration for measurement of concentration in mg/l. In order to calibrate the sensor for percent saturation reading, the local barometric pressure (corrected to local altitude above sea level) must be determined independently by the user and input into the software during calibration. Once calibrated, the sensor reading is verified to an oxygen solubility calculation as a QA/QC check. Refer to the Sanitation District No.1 Multiprobe Instrumentation Dissolved Oxygen Calibration Technical Sheet (Attachment B) for the elevation correction factors and the oxygen solubility calculation. In order to retain calibration accuracy between multiple deployments, store with sensor fully immersed in water at all times. Calibration will be completed by using of Method 1 – **Air Saturated Water.** Refer to the Instruction Sheet **– Hach LDO Sensor** in the *DS5 User's Manual*.

3.4.0 pH

Refer to section 4.2.8 of the *DS5 User's Manual* for pH calibration procedures. Since in-stream pH levels are generally above 7.0, the pH sensor is calibrated using a standard of 10.0 to determine the slope. If levels below 7.0 are expected, calibrate using a standard of 4.0 to determine the slope.

3.5.0 Conductivity

Refer to section 4.2.5 of the *DS5 User's Manual* for specific conductance calibration procedures. Since in-stream conductivity concentrations are generally below 1000µS/cm the specific conductance sensor is calibrated using a standard of 1000µS/cm to determine the slope. If lower concentrations are expected, calibrate using a standard of 500µS/cm to determine the slope.

3.6.0 Turbidity

Refer to the Instruction Sheet **– Self-Cleaning Turbidity** Sensor in the *DS5 User's Manual* for turbidity calibration procedures. Since in-stream turbidity readings can be highly variable the turbidity sensor is calibrated using a standard of 800 NTUs to determine the slope. If the sensor fails to properly calibrate, reset the sensor.

3.7.0 Depth
Refer to the **Sensor Specific Instruction Sheet** of the *DS5 User's Manual* for depth calibration procedures. The depth sensor is zeroed in air at the monitoring site to account for the current barometric pressure.

3.8.0 Time
Refer to the **Sensor Specific Instruction Sheet** of the *DS5 User's Manual* to enter the correct time (HHMMSS) and date (MMDDYY).

3.9.0 Quality Assurance/Quality Control
The following procedures are to be utilized to preserve and maintain QA/QC for the calibration of the Hydrolab instrumentation.

3.9.1 QA Standards
Calibration standards may be reused between calibration periods by employing procedures that prevent contamination. Only the quantity of standard used during the actual sensor calibration is saved for reuse. The quantity of standard used for the sensor rinse should always be discarded. Refer to the appropriate calibration section for each sensor in the *DS5 User's Manual.* Standard that is retained for reuse is kept in clean polyethylene bottles with Teflon sealed caps. Used standard is never remixed with the certified standard in the original container. Fresh or "certified" standard is continually added to the polyethylene bottles during the calibration steps to replenish the quantity used for the sensor rinses.

The standards original container is identified with date received and date opened using a permanent marker. Standards that have exceeded the manufacturer's expiration date are discarded.

3.9.2 QC Calibration Sheets
Calibration sheets are retained as quality control records and are reviewed to address individual multiprobe/sensor issues that may arise, such as electronic "drift".

4.0.0 Data Logging Setup & Data Retrieval
Refer to Section 4.3.3.1 & 4.3.3.2 of the *DS5 User's Manual* for logging and data retrieval.

4.1.0 Logging Setup
Before the DS5 is setup for an unattended logging run, check the logging status in regards to available memory and remove any nonessential files, if needed. In addition, make sure the status of the audio, circulator, and enabled parameters are correct before the logging run is setup. Enable Autolog if desired.

Make sure the DS5 is correctly deployed before the logging run begins.

4.2.0 Retrieval
Once the DS5 has been retrieved from an unattended logging run, check the logging status in regards to the created log file. The log file should be transferred from the DS5 as soon as practicable (refer to Section 4.3.3.2 of the *DS5 User's Manual*). Transfer the log file from the DS5 to a computer in spreadsheet importable form by utilizing the Hydras 3LT software (when specifying a file name for the transfer, save the log file with a .csv extension, this will allow the log file to be directly opened in Microsoft Excel).

5.0.0 Attended Profiling
The DS5 can be utilized for discrete profiling at different stream depths or equipped with a flow cell for continuous profiling (e.x. surface profiling on a boat utilizing a pitot tube) or pumping.

5.1.0 Quality Assurance
- The unit should be recalibrated after each use to assess sensor drift.
- The unit should be cleaned periodically to maintain sensor performance.

6.0.0 Unattended Deployment

The DS5 can be positioned upright (probes pointing down) or horizontally for deployment. Avoid placing the unit in areas of swift currents, areas that might receive deep deposits of sediment during periods of heavy rainfall, or areas where potential vandalism may occur. Attempt to use any available protection that a site may provide (e.x. attach to downstream of bridge piling to protect from floating debris).

6.1.0 Temporary/Portable Installations

PVC piping can be utilized as a protective capsule to house the multiprobe at unsecured locations.

6.1.1 Specifications

- Cut 4" diameter PVC pipe to the desired length (approximately 3') to create protective sleeve.
- Drill approximately 1" diameter holes throughout the sleeve to allow adequate water flow through the capsule.
- Drill approximately 3/4" diameter holes throughout the top of the end caps.
- Glue one end cap to the bottom of the sleeve.
- Place the other end cap on the open end of the sleeve and drill 5/8" hole through the end cap and the sleeve.
- Place a ½" bolt through the end cap and the sleeve and secure with two nuts.

6.1.2 Deployment

- Wrap the DS5 with duct insulation (keeping away from the probes).
- Place the DS5 into the PVC capsule (probes pointing down).
- Place the top end cap on the PVC capsule and align the 5/8" holes.
- Suspend the DS5 inside of the PVC capsule with the ½" bolt passing through the capsule and the DS5 bail.
- Secure the PVC capsule to an appropriate structure with heavy-duty cables and locks.

6.1.3 Quality Assurance

- The unit should be cleaned and recalibrated at least once a week depending on water quality conditions (i.e. solids loading and biological growth – bio-films).
  - Download the logging file and check the battery status.
  - Clean and recalibrate the sensors.
  - Setup the next logging file.
- Use portable unit to check permanent station readings before and after calibration.
- Use portable unit to check temporary station readings (logged data) between calibration schedules to assess sensor drift.

7.0.0 References

Hydrolab DS5X, DS5, and MS5 Water Quality Multiprobes, User Manual. February 2006 Edition 3. Hach Company.

Surveyor® 4 Water Quality Data Display, User's Manual. Revision D. Hydrolab Corporation. April 1999.

Hydras 3 LT Quick Start, Software Manual. December 2005 Edition 2. Hach Company.

Attachment A: SANITATION DISTRICT NO.1 MULTIPROBE INSTRUMENTATION CALIBRATION & QA SHEET

Instrument Model ____________ Serial Number ____________
Date ________ Analyst(s) ________ Instrument I.D. ____________
Site Location ____________ Note ____________

CALIBRATION READINGS	POST CHECK READINGS
1) Dissolved Oxygen (DO) Elevation (ft) ⇒ Correction Factor ________ Uncorrected BP Conversion (mmHg) ________ Temperature (°C) ________ Probe DO Reading (mg/L) ________ Percent Saturation ________ O_2 Solubility Calculation (mg/L) ________ Comments: Air Saturated Water	1) Dissolved Oxygen (DO) Elevation (ft) ⇒ Correction Factor ________ Uncorrected BP Conversion (mmHg) ________ Temperature (°C) ________ Probe DO Reading (mg/L) ________ Percent Saturation ________ O_2 Solubility Calculation (mg/L) ________ Comments: ________
2) Conductivity Standard (µS/cm) / Reading / Adjusted ________ ____ ____ ________ ____ ____ Comments: Specific Conductance	2) Conductivity Standard (µS/cm) / Reading ________ ____ ________ ____ Comments: Specific Conductance
3) pH Buffer / Reading / Adjusted 4.00 ____ ____ 7.00 ____ ____ 10.00 ____ ____ Comments: ________	3) pH Buffer / Reading 4.00 ____ 7.00 ____ 10.00 ____ Comments: ________
4) Turbidity Standard (NTU) / Reading / Adjusted ________ ____ ____ ________ ____ ____ Comments: ________	4) Turbidity Standard (NTU) / Reading ________ ____ ________ ____ Comments: ________

NOTE: Do NOT make adjustments during Post Check. Simply record values observed.

Attachment B: SANITATION DISTRICT NO.1 MULTIPROBE INSTRUMENTATION DISSOLVED OXYGEN CALIBRATION TECHNICAL SHEET

Pressure Conversions

1. Inches to Metric Conversion
   1in = 25.4mm
   Example: 30.15in * (25.4mm/1in) = 765.8mm

2. Corrected to Uncorrected Pressure Conversion
   Obtain the corrected pressure from the National Weather Service.
   Corrected Pressure - (2.5 * (Elevation/100)) = Uncorrected Pressure
   Example: 765.8mm - (2.5 * (455/100)) = 754.4mm

Table 1: Barometric pressure correction factors for selected monitoring sites.

Stream	Site	Gage Datum	Correction
Banklick Creek	KY Route 1829	540.3	13.5
Cruises Creek	KY Route 17	656.9	16.4
Elijahs Creek	Elijahs Creek Road	759.1	19.0
Four Mile Creek	Popular Ridge Road	535.2	13.4
Gunpowder Creek	Camp Ernest Road	683.1	17.1
Mud Lick Creek	KY Route 14	487.7	12.2
Twelve Mile Creek	KY Route 1997	505.9	12.6
Woolper Creek	Woolper Road	490.7	12.3
Note: Gage Datum = feet above mean sea level			
Note: Correction = mm Hg			

Table 2: Barometric pressure correction factors for selected sites.

Stream	Site	Elevation	Correction
Ohio River	Markland Normal Pool	455	11.4
Licking River	12th Street	460	11.5
District Office	Prep Room	505	12.6
Note: Elevation = approximate feet above mean sea level			
Note: Correction = mm Hg			

SANITATION DISTRICT NO.1 MULTIPROBE INSTRUMENTATION
DISSOLVED OXYGEN CALIBRATION TECHNICAL SHEET

Oxygen Solubility Calculation

To verify the probe DO reading, utilize the following steps.

1. Determine the DO solubility of the standard's temperature at 760mm
   Example: Stable Temperature = 20.7°C
   From Table 2 -- 20.7°C at 760mm = 8.96mg/L

2. Determine the DO solubility of the standard's temperature at the current pressure
   Example: 20.7°C, 754.4mm Hg
   DOsol(760mm Hg) * Current Pressure / 760mm Hg
   = DOsol(Current Pressure)
   8.96 * (754.4/760) = 8.89mg/L

Table 2: Solubility of oxygen in water in equilibrium with air at 760mm Hg pressure and 100% relative humidity (EAWAG 1973). Units = mg/L

(°C)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	14.60	14.56	14.52	14.48	14.44	14.40	14.36	14.33	14.29	14.25
1	14.21	14.17	14.13	14.09	14.05	14.02	13.98	13.94	13.90	13.87
2	13.83	13.79	13.75	13.72	13.68	13.64	13.61	13.57	13.54	13.50
3	13.46	13.43	13.39	13.36	13.32	13.29	13.25	13.22	13.18	13.15
4	13.11	13.08	13.04	13.01	12.98	12.94	12.91	12.88	12.84	12.81
5	12.78	12.74	12.71	12.68	12.64	12.61	12.58	12.55	12.52	12.48
6	12.45	12.42	12.39	12.36	12.33	12.29	12.26	12.23	12.20	12.17
7	12.14	12.11	12.08	12.05	12.02	11.99	11.96	11.93	11.90	11.87
8	11.84	11.81	11.78	11.76	11.73	11.70	11.67	11.64	11.61	11.58
9	11.56	11.53	11.50	11.47	11.44	11.42	11.39	11.36	11.34	11.31
10	11.28	11.25	11.23	11.20	11.17	11.15	11.12	11.10	11.07	11.04
11	11.02	10.99	10.97	10.94	10.91	10.89	10.86	10.84	10.81	10.79
12	10.76	10.74	10.72	10.69	10.67	10.64	10.62	10.59	10.57	10.55
13	10.52	10.50	10.47	10.45	10.43	10.40	10.38	10.36	10.34	10.31
14	10.29	10.27	10.24	10.22	10.20	10.18	10.15	10.13	10.11	10.09
15	10.07	10.04	10.02	10.00	9.98	9.96	9.94	9.92	9.89	9.87
16	9.85	9.83	9.81	9.79	9.77	9.75	9.73	9.71	9.69	9.67
17	9.65	9.63	9.61	9.59	9.57	9.55	9.53	9.51	9.49	9.47
18	9.45	9.43	9.41	9.39	9.37	9.36	9.34	9.32	9.30	9.28
19	9.26	9.24	9.23	9.21	9.19	9.17	9.15	9.13	9.12	9.10
20	9.08	9.06	9.05	9.03	9.01	8.99	8.98	8.96	8.94	8.92
21	8.91	8.89	8.87	8.86	8.84	8.82	8.81	8.79	8.77	8.76
22	8.74	8.72	8.71	8.69	8.67	8.66	8.64	8.63	8.61	8.59
23	8.58	8.56	8.55	8.53	8.51	8.50	8.48	8.47	8.45	8.44
24	8.42	8.41	8.39	8.38	8.36	8.35	8.33	8.32	8.30	8.29
25	8.27	8.26	8.24	8.23	8.21	8.20	8.18	8.17	8.16	8.14
26	8.13	8.11	8.10	8.08	8.07	8.06	8.04	8.03	8.01	8.00
27	7.99	7.97	7.96	7.94	7.93	7.92	7.90	7.89	7.88	7.86
28	7.85	7.84	7.82	7.81	7.80	7.78	7.77	7.76	7.74	7.73
29	7.72	7.70	7.69	7.68	7.66	7.65	7.64	7.63	7.61	7.60
30	7.59	7.57	7.56	7.55	7.54	7.52	7.51	7.50	7.49	7.47

APPENDIX B

NORTHERN KY SANITATION DISTRICT NO.1
CHAIN OF CUSTODY

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
1045 Eaton Drive
Fort Wright, KY 41017
Phone: (859)578-7460 Fax: (859)331-2436

Chain Of Custody Record

Page ______ of ______

Project Name		Watershed	Survey Location
Contact Person	**Sampler(s) Signature**	**Survey Type (Circle One)** Wet or Dry	

Lab ID	Sample ID Code	Date	Time	Composite / Grab	Pole / Bucket / Glove	Sample Location	No. of Containers	Analysis Required									Remarks
								E. coli	TSS	CBOD5	TP, N-N, TKN, NH3	Orthophosphate					

Relinquished By: Sampler	Date	Time	Accepted By: Lab Runner	Date	Time	Remarks
Relinquished By: Lab Runner	Date	Time	Received By: Laboratory	Date	Time	Remarks

APPENDIX C

NORTHERN KY SANITATION DISTRICT NO.1
FIELD DATA SHEET

SANITATION DISTRICT NO.1 FIELD DATA SHEET

PROJECT NAME: ____________________ DATE: ____________________

SITE / STREAM NAME: ____________________ START TIME: ____________________

SITE LOCATION: ____________________ END TIME: ____________________

LABORATORY: ____________________ SAMPLERS: ____________________

SAMPLE TYPE

GRAB COMPOSITE

CIRCLE ONE

SAMPLE MATRIX

SEDIMENT WATER

CIRCLE ONE

EQUIPMENT ID: MULTIPROBE SONDE: ____________________

STREAM CONDITIONS: ____________________

SITE CONDITIONS: ____________________

WEATHER CONDITIONS: SUNNY CLOUDY OVERCAST WINDY RAIN SNOW AIR TEMP (F): __________

(CIRCLE APPROPRIATE CONDITIONS)

PROJECT DESCRIPTOR: ____________________

SITE / SAMPLE ID (BANK & DEPTH)	TEMP. (C)	pH	D.O. (mg/L)	SP. COND. (µS/cm)	TURBIDITY (NTU)	FLOW	SAMPLE TIME

FIELD OBSERVATIONS:

IF FOUND, RETURN TO:
SANITATION DISTRICT NO.1
1045 EATON DRIVE
FORT WRIGHT, KY 41017
(859) 578-7460

Standard Operating Procedures

for

Field Procedures for Macroinvertebrate Collections

Northern Kentucky Sanitation District No. 1
1045 Eaton Drive
Fort Wright, KY 41017

Revision Number: 1
April 2007

Methods for the collection of biological samples follow the protocols of USEPA document 841-B-99-002 (Barbour *et al*. 1999) and modified to reflect KDOW protocol requirements (KDOW 2002). The EPA document is readily available via the EPA website http://www.epa.gov/owow/monitoring/rbp/download.html. Specific modifications and reasons for these modifications are described below.

MACROINVERTEBRATE COLLECTION AND TAXONOMIC PROCEDURES FOR WADABLE STREAMS

A. Field Equipment

1. D-frame dip net (500 µm mesh)
2. Kick Seine (500µm mesh)
3. 0.25m frame
4. Sieve pan (500 µm mesh)
5. Sample containers and labels
6. Water bottle
7. Field data sheet, pencil, permanent markers
8. Waders
9. Rubber gloves

B. Laboratory Equipment

1. Forceps
2. Dissecting microscopes
3. Compound microscope
3. Preservatives
4. Sample containers
5. Waterproof label paper and fine point pen
6. Identification references
7. Microscope slides and cover slips
8. Bench sheets

C. Preparation

Benthic invertebrates will be collected after the site habitat assessment has been completed. Physical Characterization/Water Quality field data sheets (Attachment A) will be completed at the time of habitat assessment or prior to benthic invertebrate collection and the percentage of available substrates will be determined.

Sample containers shall be labeled with permanent markers.

D. Field Collection

Primary Method
Riffle samples are collected in areas of the stream with moderate to high currents and cobble or gravel substrates. Four (4) 0.25m^2 samples are taken from mid-riffle or the thalweg (past of deepest thread of water), dislodging benthos by vigorously disturbing the 0.25m^2 (20" x 20") in front of the kick seine. Large rocks should be hand washed in to the net. The contents of the net are then washed and all four samples are composited into a 500µm mesh wash bucket. This sample must be kept separate from all other subhabitat collections.

Alternate method
Macroinvertebrate collections will consist of five jabs with a standard D-Net using the Modified Traveling-Kick method (TKM). Samples will be taken in proportion to the habitat types present (i.e., undercut banks, vegetative areas, inorganic substrate, roots/snags, run and/or riffle areas) within the 100-meter stream reach previously defined in the habitat assessment. A jab will consist of an approximate 1.5-meter agitation of substrate resulting in approximately 0.5-m^2 of sampled habitat area. Each jab collection from a site will be processed as a single sample. Sample collection will begin at the downstream end of the site and with collection proceeding upstream.

Initially, collected samples will be sieved in the field using standard 500-micron sieve to remove small debris and excess sediment. Extremely large debris will be thoroughly washed into the sieve and discarded. Immediately following collection, samples will be placed in pre-labeled containers. Additional labels will be placed inside all biological samples to identify the sample in the event the outer label is accidentally removed or obliterated. Samples will be shipped to Third Rock's laboratory for processing. All samples collected will be accompanied by chain-of-custody documents.

Multi-Habitat Sample
Sweep samples involve sampling a variety of non-riffle habitat with aid of a triangular or d-frame dip net. Each habitat is sampled in at least three (3) replicates, where possible. Examples of areas to sweep include, but are not limited to: undercut banks, root mats, marginal emergent vegetation, bedrock, weed beds, and leaf packs.

Additionally, a rock pick sample will be collected by hand picking macroinvertebrates from 15 rocks throughout the length of the sampling reach. These organisms are added to the multi-habitat collections. All sweeps and rock picks are composited into one sample, but must be kept separate from riffle samples.

Macroinvertebrate sampling equipment will be thoroughly rinsed and picked free of debris and organisms after each sample. Any organisms found shall be placed in sample containers. Biological community sampling and fish shocking will not occur at the same site on the same day in order to avoid sampling disturbed areas.

E. Laboratory Procedures

Sample Receipt and Preservation

Upon receipt by Third Rock's laboratory, chain-of custody documents will be completed and samples will be logged into the laboratory logbook and/or laboratory database Samples will be preserved with 70% ethyl alcohol for long-term storage.

Taxonomic Procedures

Laboratory taxonomic evaluations for macroinvertebrate samples will be performed according to sorting and identification procedures in EPA document 841-B-99-002 (Barbour *et al.* 1999). Benthic samples will be sorted and separated into major phylogenetic categories. All organisms will be removed with fine-tipped forceps or a pipette and placed in shell vials containing a 70% ethyl alcohol solution. All identifications will be performed by experienced taxonomists and verified in accordance with the Third Rock QA/QC program. All identifications and enumerations will be recorded on standardized sheets for consistency and ease of data entry.

Subsampling techniques may be necessary in case of large sample volume. Dual voucher sets (in-house and client) will be produced. A full comprehensive voucher set will be retained along with identified specimens.

Taxonomic QA/QC

QA/QC checks will occur on no less than 10% of the samples processed. A minimum of 10% of all sorted samples will be checked for completeness. Completeness checks will be accomplished by resorting the residual sample material by a different technician. If the animals removed from the residual material total 5% or more of the total number of animals in the sample, this constitutes a QC failure, and all samples sorted by that technician shall be resorted back until the time of the last acceptable QC check.

For identification tasks, at least 10% of all identified samples will be checked for identification and enumeration accuracy. Taxonomic checks will be performed by the reidentification of the selected samples by a different taxonomist. A discrepancy of 5% or more constitutes a QC failure, and all samples identified by the taxonomist on that project are reworked.

Data entry will be facilitated by the use of standardized sheets to record organism identifications and counts for each sample. A visual check of all data will be performed by an experienced referee or by the Taxonomy Task Manager to assure completeness and accuracy of the data. Third Rock Consultants uses a comprehensive QA/QC program to assure accuracy and completeness of processing, identifications, data analysis, and reporting.

F. Analyses

Taxonomic data will be initially recorded on standardized lab bench sheets. Data will be transferred into a spreadsheet, and ultimately applied to a relational database (MACLIMS) currently under development by Third Rock that will produce index scores developed by the Kentucky Division of Water (KDOW 2002)

MACROINVERTEBRATE COLLECTION AND TAXONOMIC PROCEDURES FOR NON-WADABLE STREAMS

Methods for collecting biological samples from non-wadeable locations are described below and follow the guidelines developed for large rivers developed by the Ohio River Valley Water Sanitation Commission. These methods were developed specifically for the Ohio River and its large tributaries, and therefore are the most appropriate protocols for sampling. Each method will have 3 distinct methodologies, Shallow Hester-Dendy's, Deep Hester-Dendy's and Multi-habitat.

Shallow Hester-Dendy

The following describes the procedures for aquatic macroinvertebrate population surveys using the modified Hester-Dendy multiplate shallow water sampling method.

Sampling Schedule

Ideally, sampling schedules should be established which take advantages of the low flow conditions of the summer and early fall. The samplers are set out in mid July to early September, and are collected six to eight weeks after placement.

Sampling Procedures

Hester-Dendy (H-D) Specifications

The sampler is constructed of 1/8 inch tempered masonite cardboard cut into three inch square plates and one inch square spacers. A 3/8 inch hole is drilled in the center of each plate and spacer. Eight plates and twelve spacers are placed on a 1/4 inch X 4 inch eye bolt so that there are three single spaces (1/8”), three double spaces (1/4”), and one triple space (3/8”) between the plates. The plates and spacers are secured to the eye bolt with two 1/4 inch washers and one standard 1/4 inch nut. For a more specific description of the H-D sampler, see Hester and Dendy (1968).

Assembly of sampling unit

A sampling unit is a series of five H-D samplers bound together with twine or cords and secured to a cement block. The five samplers are tied together, eyebolt to eyebolt in a circular pattern. The group is then lashed securely to the top of the block with cord of at least 1/8” diameter. A two-foot piece of reinforcing rod is secured vertically to the block to be partially driven into the substrate for additional stability.

Placement

The sampling unit should be placed in an area which is safe from disturbance and has a substrate which is representative of the sampling zone. In the event that the zone is simply not suitable for unit placement, the collector may then choose to set it in an area that the collector feels would best represent the zone. Once a location is chosen, the sampling unit is lowered into the water and the rod driven into the substrate. The sampling unit must be placed in two to three feet of water to ensure good light penetration for the duration of the exposure period. This will ensure that there is sufficient light to support life. The sampling unit should not be exposed to air, as this will cause the sample to dry out. Therefore, natural fluctuations in the river level must be taken into consideration. The National Weather Service and U.S. Corps. Of Engineers river data systems should be consulted prior to sampling.

Colonization period

The sampling unit must remain undisturbed for a period of at least six weeks, but should not exceed eight weeks.

Sampling Unit Retrieval

During retrieval, the sampling unit is approached from the downstream side to ensure minimal disturbance. This eliminates covering the sampler in a mud cloud. A five-gallon bucket is submerged and positioned next to the block. The five H-D samplers are then carefully cut from the block and slid into the bucket. The bucket is then taken to the boat and the plates disassembled.

Plate Disassembly and Preservation

The five H-D samplers are disassembled in the bucket with special care taken not to spill or lose any of the sample material. The plates are brushed or scraped using another plate while submerged and all sampler parts rinsed with distilled water and discarded. The bolts may be kept for reuse. After all parts have been rinsed and removed from the bucket, the water is then poured through a standard #30 sieve, the bucket is rinsed through the sieve until clean and all residue placed in a sample container. The sieve is rinsed repeatedly into a white sorting pan or bucket to ensure that all organisms have been removed from the sieve. Once all organisms and residue are in the sample container, 10% formalin is added to cover the sample with at least one inch of preservative.

Sample Packaging and Labeling

Each sample is properly preserved in a plastic sample container, the lid is then sealed shut with electrical tape and labeled. Each container is labeled with collection site, date of collection, sample number and GPS coordinates. An additional tag made of waterproof paper and permanent ink is placed in the jar. All samples are recorded on a standard chain of custody form (Attachment A).

Sample Storage

Samples are held at the District office until they can be shipped to the contractor.

Documentation

Habitat and environmental conditions, such as water quality parameters at each sampling location are noted and recorded in a log. A standard macroinvertebrate-sampling sheet is used to record the locations of sampler placement and retrieval.

Materials List

Needed for each location:

<u>PLACEMENT:</u>

1. Hip waders
2. Assembled H-D samplers
3. Cement block
4. 2 ft. piece of rebar
5. Twine or small rope
6. Hammer

<u>RETRIEVAL:</u>

1. Waders
2. Knife
3. 5 gal. bucket
4. Crescent wrench
5. Common screwdriver
6. Squirt bottle
7. Distilled water
8. Sorting pan or bucket
9. #30 sieve
10. Plastic sample jar and lid
11. Electrical tape
12. Permanent marker
13. Waterproof paper and ink for labels in sample jar
14. Any instruments needed for measuring WQ parameters

Deep Hester-Dendy's

This document describes the procedures aquatic macroinvertebrate population surveys using the modified Hester-Dendy multiplate sampling method in deep water.

Sampling Schedule

Ideally, sampling schedules should be established which take advantages of the low flow conditions of the summer and early fall. The samplers are set out in mid July to early September (ideally, for the sake of consistency, the last week of August or first week of September), and are collected six to eight weeks after placement.

Sampling Procedures

Hester-Dendy (H-D) Specifications

The sampler is constructed of 1/8 inch tempered masonite cardboard cut into three inch square plates and one inch square spacers. A 3/8 inch hole is drilled in the center of each plate and spacer. Eight plates and twelve spacers are placed on a 1/4 inch X 4 inch eye bolt so that there are three single spaces (1/8"), three double spaces (1/4"), and one triple space (3/8") between the plates. The plates and spacers are secured to the eye bolt with two 1/4 inch washers and one standard 1/4 inch nut. For a more specific description of the H-D sampler, see Hester and Dendy (1968).

Assembly of sampling unit

A sampling unit is a series of five H-D samplers bound together with twine or cords and secured to a cement paver stone. The five samplers are tied together, eyebolt to eyebolt in a circular pattern. The group is then clipped securely to a line of desired length. The line is then ran through an eyebolt which has been placed in the center of the paver stone (a masonry bit should be used to drill a in the center of each stone, with an eyebolt properly secured in each hole).

Placement

The sampling unit should be placed in an area which is safe from disturbance and is within 10 meters of the shallow sampling unit placement. In the event that the zone is simply not suitable for unit placement, the collector may then choose to set it in an area that the collector feels would best represent the zone. Once a location is chosen, a boat driver backs out slowly from shore, until a deep of 10 feet is achieved. The sampling unit is lowered into the water by the line and allowed to settle on the bottom. The boat then returns to shore, letting line out so that it may be tied off securely. The line may be tied to anything deep secure by the collector, but efforts need to be made to disguise the line to prevent vandalism. A float may be attached to the sampling unit to aid in retrieval, but the collector needs to be sure that the float does not prevent the sampling unit from reaching the bottom.

Colonization period

The sampling unit must remain undisturbed for a period of at least six weeks, but should not exceed eight weeks.

Sampling Unit Retrieval

During retrieval, the sampling unit is approached from the downstream side to ensure minimal disturbance. Upon location of the retrieval line, the collector will cut the line, being sure to keep the line taught to minimize disturbance. The collector then, while on the boat, backs out slowly until the boat is directly over the sampling unit, at which time the unit is slowly pulled to the surface. A five-gallon bucket is submerged and positioned next to the unit. The five H-D samplers are then carefully cut from the block and slid into the bucket. The bucket is then taken to the boat and the plates disassembled.

Plate Disassembly and Preservation

The five H-D samplers are disassembled in the bucket with special care taken not to spill or lose any of the sample material. The plates are brushed or scraped using another plate while submerged and all sampler parts rinsed with distilled water and discarded. The bolts may be kept for reuse. After all parts have been rinsed and removed from the bucket, the water is then poured through a standard #30 sieve, the bucket is rinsed through the sieve until clean and all residue placed in a sample container. The sieve is rinsed repeatedly into a white sorting pan or bucket to ensure that all organisms have been removed from the sieve. Once all organisms and residue are in the sample container, 70% ethanol or 10% formalin (as directed by processing lab) is added to cover the sample with at least one inch of preservative.

Sample Packaging and Labeling

Each sample is properly preserved in a plastic sample container, the lid is then sealed shut with electrical tape and labeled. Each container is labeled with collection site, date of collection, sample number and GPS coordinates. An additional tag made of waterproof paper and permanent ink is placed in the jar. All samples are recorded on a standard chain of custody form (Attachment A).

Sample Storage

Samples are held at the District office until they can be shipped to the contractor.

Documentation

Habitat and environmental conditions, such as water quality parameters at each sampling location are noted and recorded in a log. A standard macroinvertebrate-sampling sheet is used to record the locations of sampler placement and retrieval.

Materials List

Needed for each location:

PLACEMENT:

1. Waders
2. Assembled H-D samplers
3. Paver stone
4. 2 ft. piece of rebar
5. Rope
6. Hammer

RETRIEVAL:

1. Waders
2. Knife
3. 5 gal. bucket
4. Crescent wrench
5. Common screwdriver
6. Squirt bottle
7. Distilled water
8. Sorting pan or bucket
9. #30 sieve
10. Plastic sample jar and lid
11. Electrical tape
12. Permanent marker
13. Waterproof paper and ink for labels in sample jar
14. Any instruments needed for measuring WQ parameters

Multi-habitat

This document describes the procedures for aquatic macroinvertebrate population surveys using the qualitative multiple habitat sampling method.

Sampling Schedule

The qualitative sampling methods are to be performed upon **retrieval** of the Hester-Dendy sampling units.

Sampling Procedures

Net Specifications

Samples are collected with standard D-frame dip nets made of 500µm mesh.

Collecting technique

Multihabitat samples are collected at 6 transects, every 100m, throughout each zone, similar to the habitat collection technique. At each transect, 10 of any combination of jabs, sweeps, kicks, etc are taken within 10m of the transect point. Efforts should be made to sample all available habitats within this 10m radius. The net is rinsed of debris and organisms into a bucket at each transect, with all transects being combined to make one composite sample.

Sample Preparation and Preservation

After all 6 transects have been collected, the remaining slurry is then poured through a standard #30 sieve, the bucket is rinsed through the sieve until clean and all residue placed in a sample container. The sieve is rinsed repeatedly into a white sorting pan or bucket to ensure that all organisms have been removed from the sieve. Once all organisms and residue are in the sample container, 70% ethanol or 10% formalin (as required by contractor) is added to cover the sample with at least one inch of preservative.

Sample Packaging and Labeling

Each sample is properly preserved in a plastic sample container, the lid is then sealed shut with electrical tape and labeled. Each container is labeled with collection site, date of collection, sample number and GPS coordinates. An additional tag made of waterproof paper and permanent ink is placed in the jar. All samples are recorded on a standard chain of custody form (Attachment A).

Sample Storage

Samples are held at the District office until they can be shipped to the contractor.

Documentation

Habitat and environmental conditions, such as water quality parameters at each sampling location are noted and recorded in a log. A standard macroinvertebrate-sampling sheet is used to record the locations of sampler placement and retrieval.

Materials List

1. Waders
2. D-frame net
3. Bucket
4. Squirt bottle
5. Distilled water
6. Sorting pan or bucket
7. #30 sieve
8. Plastic sample jar and lid
9. Electrical tape
10. Permanent marker
11. Waterproof paper and ink for labels in sample jar
12. Any instruments needed for measuring WQ parameters

Attachment A

Chain of Custody and Physical Characterization/Water Quality Field Sheets

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME	LOCATION	
STATION #________ RIVERMILE________	STREAM CLASS	
LAT _____________ LONG _____________	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS		
FORM COMPLETED BY	DATE ________ TIME ________ AM PM	REASON FOR SURVEY

WEATHER CONDITIONS	**Now** / **Past 24 hours** ❑ storm (heavy rain) ❑ ❑ rain (steady rain) ❑ ❑ showers (intermittent) ❑ ____%❑ %cloud cover ❑___% ❑ clear/sunny ❑ **Has there been a heavy rain in the last 7 days?** ❑ Yes ❑ No **Air Temperature**_____ ° C **Other**________________________________
SITE LOCATION/MAP	**Draw a map of the site and indicate the areas sampled (or attach a photograph)**
STREAM CHARACTERIZATION	**Stream Subsystem** ❑ Perennial ❑ Intermittent ❑ Tidal **Stream Type** ❑ Coldwater ❑ Warmwater **Stream Origin** ❑ Glacial ❑ Spring-fed ❑ Non-glacial montane ❑ Mixture of origins ❑ Swamp and bog ❑ Other__________ **Catchment Area**__________km^2

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

WATERSHED FEATURES	**Predominant Surrounding Landuse** ❑ Forest ❑ Commercial ❑ Field/Pasture ❑ Industrial ❑ Agricultural ❑ Other ______ ❑ Residential	**Local Watershed NPS Pollution** ❑ No evidence ❑ Some potential sources ❑ Obvious sources **Local Watershed Erosion** ❑ None ❑ Moderate ❑ Heavy
RIPARIAN VEGETATION (18 meter buffer)	**Indicate the dominant type and record the dominant species present** ❑ Trees ❑ Shrubs ❑ Grasses ❑ Herbaceous **dominant species present** ______	
INSTREAM FEATURES	**Estimated Reach Length** ______m **Estimated Stream Width** ______m **Sampling Reach Area** ______m^2 **Area in km^2 (m^2x1000)** ______km^2 **Estimated Stream Depth** ______m **Surface Velocity (at thalweg)** ______m/sec	**Canopy Cover** ❑ Partly open ❑ Partly shaded ❑ Shaded **High Water Mark** ______m **Proportion of Reach Represented by Stream Morphology Types** ❑ Riffle______% ❑ Run______% ❑ Pool______% **Channelized** ❑ Yes ❑ No **Dam Present** ❑ Yes ❑ No
LARGE WOODY DEBRIS	**LWD** ______m^2 **Density of LWD** ______m^2/km^2 **(LWD/ reach area)**	
AQUATIC VEGETATION	**Indicate the dominant type and record the dominant species present** ❑ Rooted emergent ❑ Rooted submergent ❑ Rooted floating ❑ Free floating ❑ Floating Algae ❑ Attached Algae **dominant species present** ______ **Portion of the reach with aquatic vegetation** ____%	
WATER QUALITY	**Temperature**______ °C **Specific Conductance**______ **Dissolved Oxygen** ______ **pH** ______ **Turbidity** ______ **WQ Instrument Used** ______	**Water Odors** ❑ Normal/None ❑ Sewage ❑ Petroleum ❑ Chemical ❑ Fishy ❑ Other______ **Water Surface Oils** ❑ Slick ❑ Sheen ❑ Globs ❑ Flecks ❑ None ❑ Other______ **Turbidity (if not measured)** ❑ Clear ❑ Slightly turbid ❑ Turbid ❑ Opaque ❑ Stained ❑ Other______
SEDIMENT/ SUBSTRATE	**Odors** ❑ Normal ❑ Sewage ❑ Petroleum ❑ Chemical ❑ Anaerobic ❑ None ❑ Other______ **Oils** ❑ Absent ❑ Slight ❑ Moderate ❑ Profuse	**Deposits** ❑ Sludge ❑ Sawdust ❑ Paper fiber ❑ Sand ❑ Relict shells ❑ Other______ **Looking at stones which are not deeply embedded, are the undersides black in color?** ❑ Yes ❑ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	**Diameter**	**% Composition in Sampling Reach**	**Substrate Type**	**Characteristic**	**% Composition in Sampling Area**
Bedrock			Detritus	sticks, wood, coarse plant materials (CPOM)	
Boulder	> 256 mm (10")				
Cobble	64-256 mm (2.5"-10")		Muck-Mud	black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1"-2.5")				
Sand	0.06-2mm (gritty)		Marl	grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	< 0.004 mm (slick)				

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME	LOCATION	
STATION #_________ RIVERMILE_________	STREAM CLASS	
LAT _____________ LONG _____________	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS		
FORM COMPLETED BY	DATE _______ TIME _______ AM PM	REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

Total Score __________

BENTHIC MACROINVERTEBRATE FIELD DATA SHEET

STREAM NAME	LOCATION	
STATION #________ RIVERMILE________	STREAM CLASS	
LAT ____________ LONG ____________	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS		LOT NUMBER
FORM COMPLETED BY	DATE ______ TIME ______ AM PM	REASON FOR SURVEY

HABITAT TYPES	**Indicate the percentage of each habitat type present** ❑ Cobble_____% ❑ Snags_____% ❑ Vegetated Banks_____% ❑ Sand_____% ❑ Submerged Macrophytes_____% ❑ Other ( )_____%
SAMPLE COLLECTION	**Gear used** ❑ D-frame ❑ kick-net ❑ Other ________________________ **How were the samples collected?** ❑ wading ❑ from bank ❑ from boat **Indicate the number of jabs/kicks taken in each habitat type.** ❑ Cobble_____ ❑ Snags_____ ❑ Vegetated Banks_____ ❑ Sand_____ ❑ Submerged Macrophytes_____ ❑ Other ( )_____
GENERAL COMMENTS	

QUALITATIVE LISTING OF AQUATIC BIOTA
Indicate estimated abundance: 0 = Absent/Not Observed, 1 = Rare, 2 = Common, 3= Abundant, 4 = Dominant

Periphyton	0 1 2 3 4	Slimes	0 1 2 3 4
Filamentous Algae	0 1 2 3 4	Macroinvertebrates	0 1 2 3 4
Macrophytes	0 1 2 3 4	Fish	0 1 2 3 4

FIELD OBSERVATIONS OF MACROBENTHOS
Indicate estimated abundance: 0 = Absent/Not Observed, 1 = Rare (1-3 organisms), 2 = Common (3-9 organisms), 3= Abundant (>10 organisms), 4 = Dominant (>50 organisms)

Porifera	0 1 2 3 4	Anisoptera	0 1 2 3 4	Chironomidae	0 1 2 3 4
Hydrozoa	0 1 2 3 4	Zygoptera	0 1 2 3 4	Ephemeroptera	0 1 2 3 4
Platyhelminthes	0 1 2 3 4	Hemiptera	0 1 2 3 4	Trichoptera	0 1 2 3 4
Turbellaria	0 1 2 3 4	Coleoptera	0 1 2 3 4	Other	0 1 2 3 4
Hirudinea	0 1 2 3 4	Lepidoptera	0 1 2 3 4		
Oligochaeta	0 1 2 3 4	Sialidae	0 1 2 3 4		
Isopoda	0 1 2 3 4	Corydalidae	0 1 2 3 4		
Amphipoda	0 1 2 3 4	Tipulidae	0 1 2 3 4		
Decapoda	0 1 2 3 4	Empididae	0 1 2 3 4		
Gastropoda	0 1 2 3 4	Simuliidae	0 1 2 3 4		
Bivalvia	0 1 2 3 4	Tabinidae	0 1 2 3 4		
		Culcidae	0 1 2 3 4		

Standard Operating Procedures

for

Hydromodification Field Surveys

Northern Kentucky Sanitation District No. 1
1045 Eaton Drive
Fort Wright, KY 41017

Revision Number: 1
August 2009

HYDROMODIFICATION FIELD SURVEYS

A. Field Equipment (quantity)

1. Level and Tripod (1)
2. 16’ survey rod, graduated in tenths/hundredths (2)
3. 100m fiberglass tape measure (1)
4. 50m fiberglass tape measure (1)
5. Gravelometer (2)
6. Chest/hip waders
7. Waterproof field notebook (2)
8. 3/8” x 24” rebar (several)
9. 2 lb sledge hammer (1)
10. Machete (1)
11. Flagging tape
12. Spray paint
13. Quarter meter square
14. Camera
15. Metal detector (1)

B. Preparation

All equipment should be inspected to ensure that it is in proper working condition and replaced/refurbished accordingly. Level should be periodically checked by establishing two permanent benchmarks 10-20 meters apart. If elevation is greater than 0.02” different from previous measurements, then equipment will be sent in for service. All personnel participating in the survey should be familiar with the survey equipment and its proper use.

C. Field Surveys

Step 1. Cross-section placement and set-up

The portion of stream identified in prior SD1 site assessments (i.e. biological and/or water quality sample sites) will be the focus of the survey area. New survey sites may be added at the discretion of the project manager.

Upon survey site selection, a cross-section of the stream is put into place at a riffle area, oriented perpendicularly to the flow direction, guided primarily by the methods described by Harrelson *et al.* (1994). To establish this cross-section, rebar pins are driven into the ground above the “bank-full” line on each side of the stream (**Figure 1**). These pins act as “benchmarks” for the survey. Care is taken with the placement of each pin in order to maximize “line of sight”, minimize the chance for vandalism and/or pin movement, and to facilitate finding the pins during re-visits. Additionally, if the stream area is located near lawns, or other areas that are maintained, pins are to be driven down to the point that lawn maintenance equipment is not damaged. To further facilitate pin location during re-visits, each pin is triangulated to permanent landmarks nearby (i.e. large trees, boulders, utility poles, pavement edges, etc.) (**Figure 2**). After triangulation, a metal detector may be used to locate the precise location of the pin.

Once pin placement is established, a vinyl tape measure is stretched across the riffle area, such that the tape runs parallel with the riffle. The “0” end of the tape is placed at the pin on the left bank (looking downstream) and is labeled “R1”. The cross-section ends at the pin on the right descending bank (looking downstream) and is labeled “R2” (**Figure 1**).

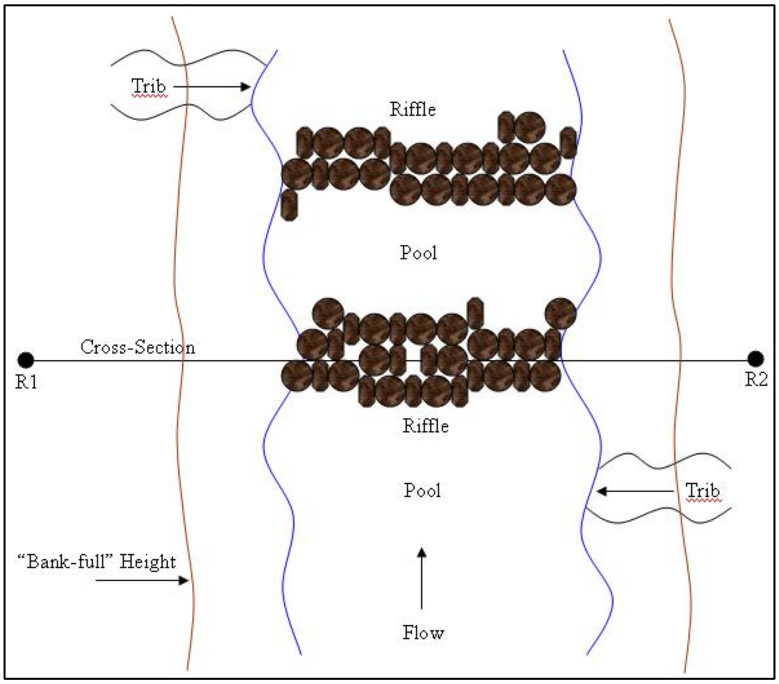


Figure 1. The cross-section is established in parallel with the riffle.

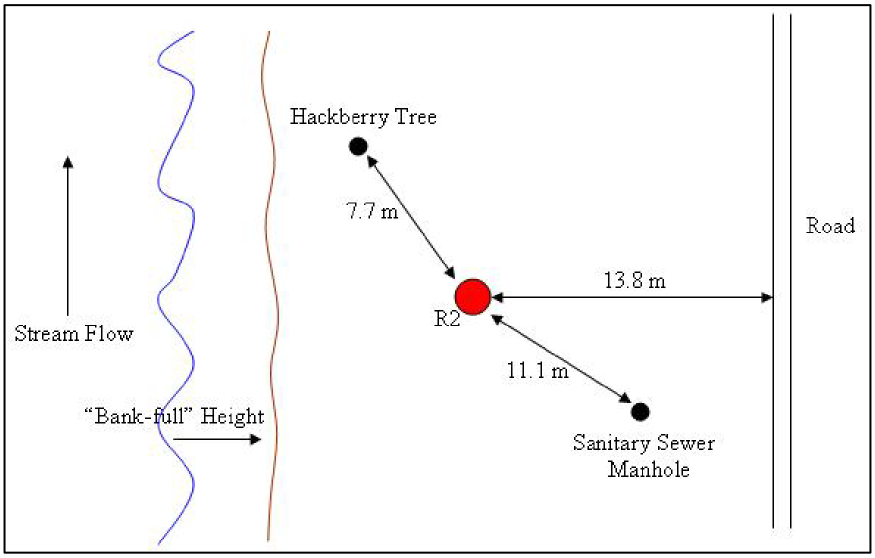


Figure 2. Triangulation of a survey pin (R2).

Step 2. Level and tripod set-up

Level and tripod set-up is conducted in such a manner as to minimize the number of times the set-up is moved. To set up the station, open the tripod and extend the legs so the top platform is flat. Next, attach the level to the tripod using the set screw. Using the adjustable legs on the tripod and the bubble on the level, roughly level the instrument (**Figure 3**). Line up the lens of the level perpendicular to one of the tripod legs and center the bubble on the level using the fine adjustment screws on the base of the instrument. Rotate the instrument 90° and repeat the process on the two remaining legs. The instrument is level when it can be spun 360 degrees and the bubble remains centered (**Figure 4)**.

Figure 3. Adjust the legs and fine adjustment knobs to make the instrument level.

Figure 4. The instrument is level when the bubble remains centered at any orientation along the 360° circumference.

Step 3. Shooting the cross-section/reading the survey rod

Once the set-up is level, field personnel will hold the survey rod on top of the R1 pin to take the first shot ("backsight"). Efforts should be made by personnel holding the survey rod to remain as vertically level as possible, using a rod level if necessary. Always orient the rod toward the instrument for ease in reading the rod. Additionally, the survey rod should be gently rocked back and forth toward the instrument level, allowing for more accurate measurements. The rod is read by looking through the level to the rod where the cross-hairs on the lens of the instrument intersect the rod at the lowest point during the rocking motion (**Figure 5, Figure 6**). The second shot ("foresight") is on the ground beside R1, or "ground at R1". This is station "0" on the measuring tape.

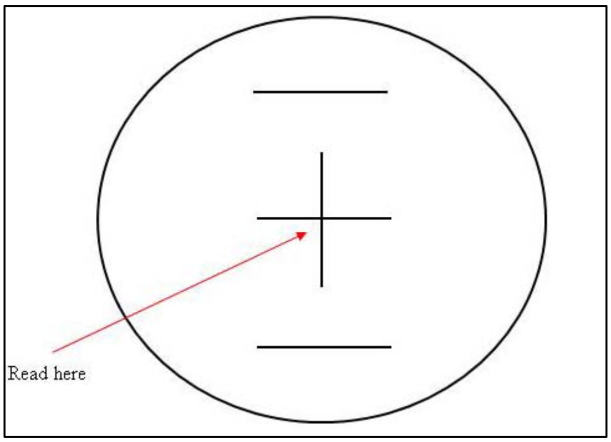


Figure 5. To read the rod correctly, intersect the middle set of cross-hairs in the lens with the line on the rod.

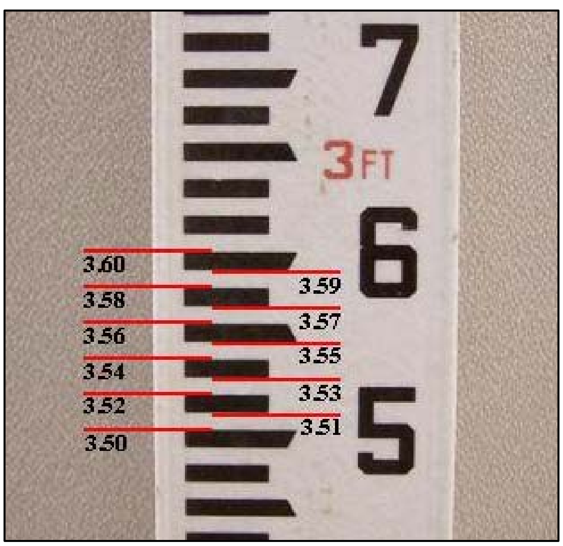


Figure 6. To get a measurement, first determine the ones place on the rod by locating the red number. The tenths place is the larger number on the right of the rod. The hundredths place is either on the top or bottom of each line.

Foresight shots proceed across the stream, noting the station measurement on the tape, and any significant changes in topography that are encountered (i.e. "top of bank", "toe of bank", etc). Shots should be taken at all major grade breaks (i.e. changes in slope) with particularly close spacing at each bank and at major changes in stream bed topography. The final shot on the cross-section is on top of the R2 pin. All shot stations, rod measurements, and notes are recorded in the field notebook (**Figure 7**).

BLC 17.1	Downstream from Picnic Area		11/5
		Profile	
BS (ft)	STA (m)	FS (ft)	Notes
	0	11.42	Toe of Riffle
	1.2	11.33	
	3.1	11.20	Head of Riffle
	3.8	11.27	Toe of Pool
	5.2	11.66	
	6.9	11.69	
	8.8	11.47	Head of Pool
	10.1	11.43	Toe of Riffle
	12.0	11.31	
	14.6	11.09	
	16.2	11.20	Head of Riffle
	17.2	11.33	Toe of Pool

Figure 7. The field notebook includes the station measurement, the level reading (backsight or foresight) at that point, and any notes about the topography of the station.

Ideally, the entire cross-section is shot from a single set-up. In the event that a second set-up is needed (i.e. obstructed view, severe elevation change, etc.), the following steps are required for moving the level.

1. Shoot to a visible, stable location on the cross-section (e.g. top of a large bedrock slab as opposed to sand that may sink).
2. This location is recorded as 'temporary benchmark'.
3. Rod holder remains at that precise location with extreme care not to move the rod from the exact spot that it was held for the first shot.
4. Move instrument to desired location, level as described above, and shoot to same temporary benchmark. The first shot from the new station is recorded as "backsight" in the field notebook and is also noted as a "turning point" in the field notebook.
5. Continue with the remainder of the cross-section, recording the shots as "foresights".
6. Repeat process every time a set-up move is required.

Note: Although care and precision should be taken on all shots, extreme care should be taken during back/foresighting of all benchmarks and at all "turning points."

Step 4. Shooting a stream profile

The stream profile is a longitudinal section of a given stream area. The profile can vary in length, but includes the cross-section riffle and ideally, one additional riffle-pool sequence both up and downstream (e.g. riffle-pool, riffle-pool, riffle-pool) (**Figure 8**). (typically 100m – 200m). To establish the profile, again as discussed by Harrelson et al (1994), the 100m tape measure is strung from downstream to upstream (downstream end would be "0") until the desired length or channel morphology has been achieved, making sure that the tape is strung along the thalweg of the stream. The thalweg is defined as the deepest point in the stream at any cross section, and typically meanders from one side of the channel to the other as one moves up or downstream. The first shot is taken at station "0", with following shots taken moving upstream in varying increments, based on stream heterogeneity. These major changes in channel morphology should be noted in the field notebook (i.e. "toe of riffle", "head of riffle", "nick point", etc.). Again, efforts should be made to shoot the steam profile from one level set-up, but should an additional set-up be necessary, follow the procedure outlined above.

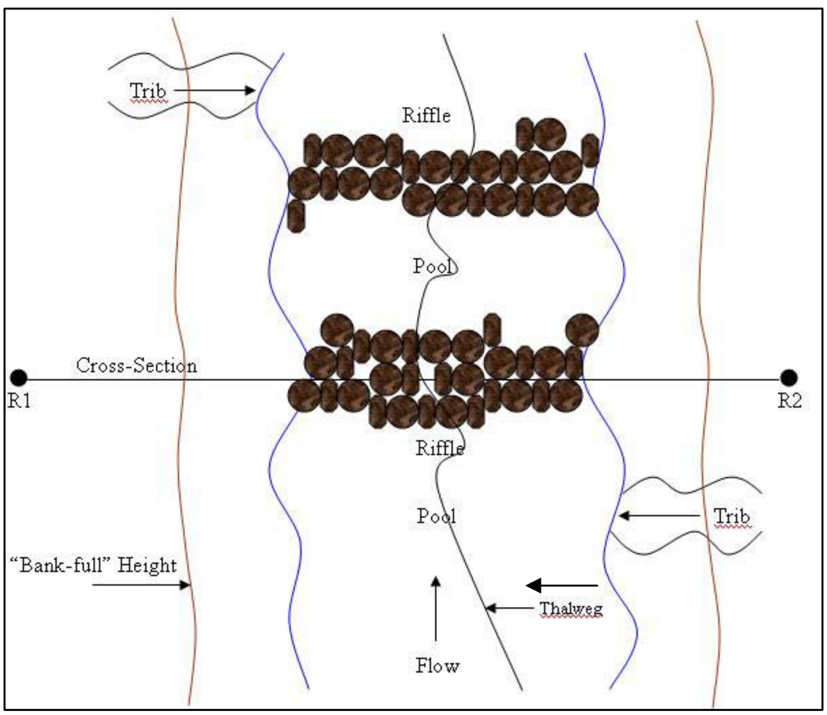
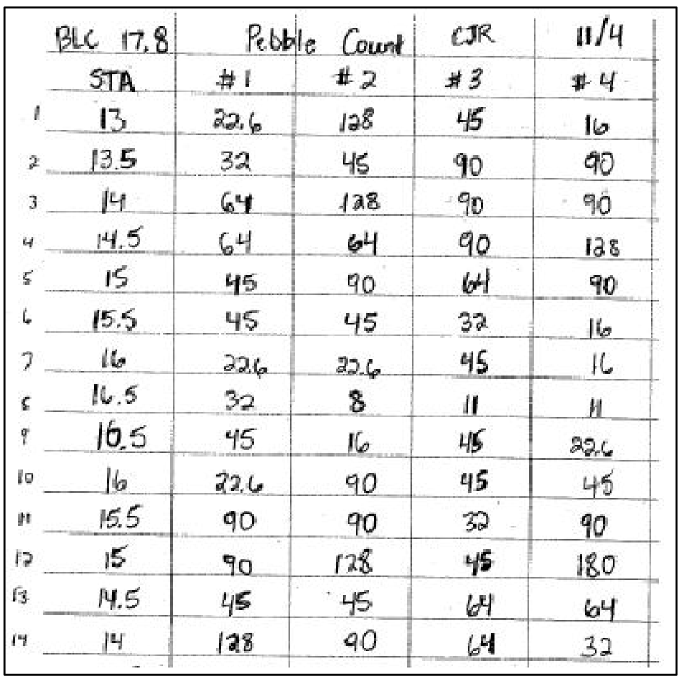


Figure 8. The stream profile includes two riffles and two pools with the measuring tape following the thalweg of the stream.

Step 5. Pebble count

In order to establish stream substrate classification, pebble counts based on methods described by Bunte and Abt (2001a, 2001b) are conducted along the established cross-section. To begin the pebble count, place the square in the stream at the edge of the water along the tape measure of the cross-section. Each corner of the square will be touching a rock. The four rocks at each corner are then passed through smallest hole possible of the gravelometer and each number is recorded in the field notebook, along with the station on the cross-section (**Figure 9)**. The square is then moved to another station on the cross-section and the process is repeated. Sampling stations should be spaced evenly (e.g. every 0.5 or 1.0 m) to avoid bias from sampling one section of the stream more than others. This process is repeated a minimum of 25 times for a minimum total of 100 rocks measured. If the 100th particle is in the middle of the cross section, the sampling should continue at evenly spaced samples across the entire transect to avoid the potential bias discussed above. To avoid "re-measuring" any rocks, measured rocks are not returned to the cross-sectional area. In the event that a rock is too large to pick up, the scale on the side of the gravelometer is used to measure across the intermediate (i.e. not the narrowest nor the widest) axis of the rock.



	BLC 17.8	Pebble	Count	CJR	11/4
	STA	#1	#2	#3	#4
1	13	22.6	128	45	16
2	13.5	32	45	90	90
3	14	64	128	90	90
4	14.5	64	64	90	128
5	15	45	90	64	90
6	15.5	45	45	32	16
7	16	22.6	22.6	45	16
8	16.5	32	8	11	11
9	16.5	45	16	45	22.6
10	16	22.6	90	45	45
11	15.5	90	90	32	90
12	15	90	128	45	180
13	14.5	45	45	64	64
14	14	128	90	64	32

Figure 9. A field notebook is also kept for the pebble count. The station and size of each rock is recorded.

Step 6. Photographs

At least three photos should be taken at each site. All photos should include the rod (and/or person) for scale. One "overview" photo should be taken looking upstream at the cross section and attempt to capture the entire width of the channel. Additionally, each bank should be photographed at the precise location of the cross section for visual documentation of bank stability (or instability) captured by the survey.

Instrument (Level) QA/QC

During all instrument setups, the person responsible for running the instrument should regularly check to verify that the instrument is level. If at any point the instrument is bumped, or for some reason falls out of level, the instrument should be re-leveled and the original backsight of the setup should be re-shot. Record the re-shot of the backsight in the field book and check to see if it varied from the original backsight. If the variability between the two backsights is more than 0.05 ft ($5/100^{ths}$), all shots taken since the previous level check should be re-shot. If there was no previous level check, the entire cross-section should be re-shot.

Conclusions and General Reminders

Remember to adhere to SD1's standard field procedures for safe and effective stream surveys. Although this list is not exhaustive, there are three very important things to remember:

1) TRAFFIC: Always be visible to traffic and NEVER turn your back to oncoming traffic

2) Bacteria/Toxins: All streams can have dangerous pathogens and/or toxins. Remember to always wash/sanitize your hands before eating, itching your eyes, etc.

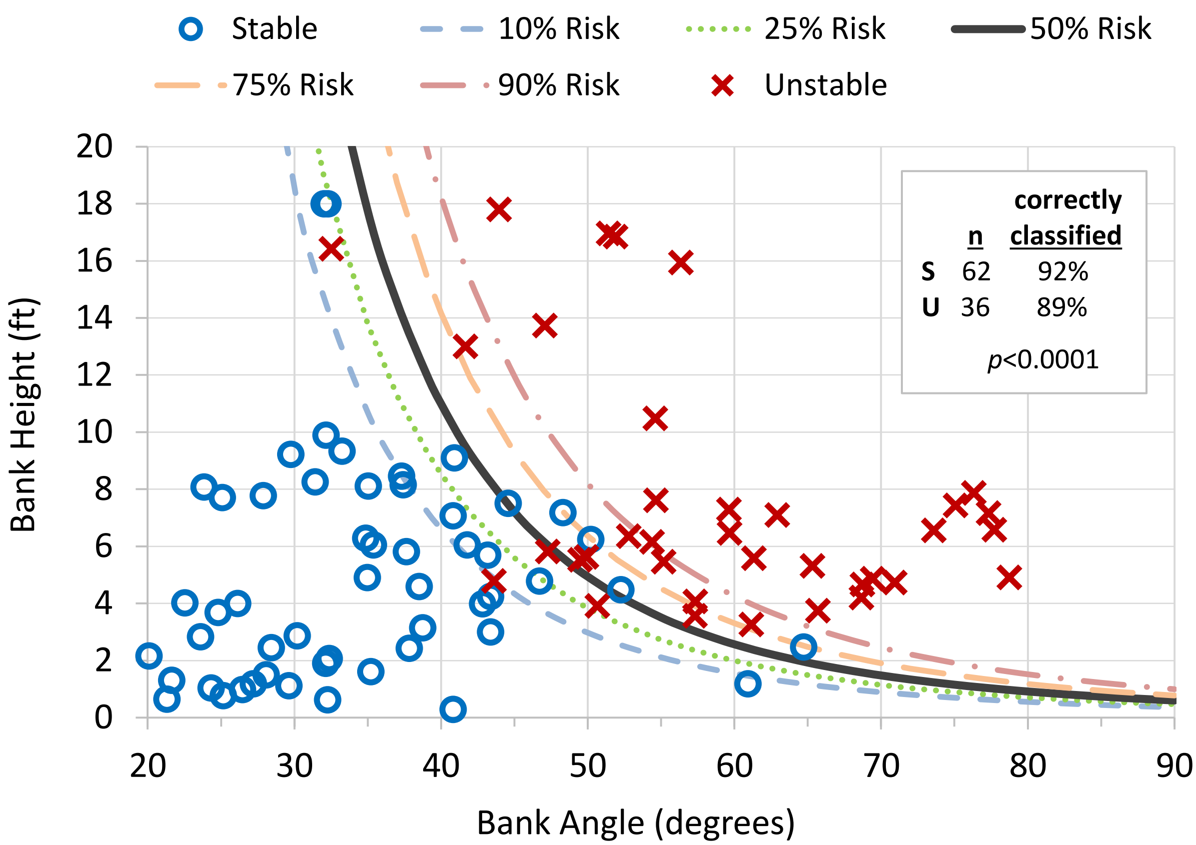
3) Water/current Hazards: Although most sites are relatively shallow, remember that flowing water can be dangerously powerful. Us care when entering a stream and never sample during rain events/swift current

References

Bunte, K. and Abt, S.R. 2001a. Sampling frame for improving pebble count accuracy in coarse gravel-bed streams. *Journal of the American Water Resources Association*, 37(4): 1001-1014.

Bunte, K. and Abt, S.R. 2001b. Sampling surface and subsurface particle-size distributions in wadable gravel-and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. In: F.S. U.S. Department of Agriculture (Editor). Gen. Tech. Rep. RMRS-GTR-74, Rocky Mountain Research Station Fort Collins, CO, pp. 428.

Harrelson, C.C., Rawlins, C. L., Potyondy, J. P. 1994. Stream channel reference sites: an illustrated guide to field technique. In: F.S. U. S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station (Editor), Gen. Tech. Rep. RM-245, Fort Collins, CO, pp. 61.



Risk of Bank Failure by Mass Wasting in N.KY Stream Banks

Logistic Regression thresholds ($p < 0.0001$) developed for stable vs. unstable banks with failure dominated by mass wasting, withholding bedrock banks and unstable banks dominated by fluvial failure.

Technical Memorandum

Regionally-Calibrated Channel Stability Index for Northern Kentucky Streams

Prepared for

SD1 of Northern Kentucky

July 2012

Sustainable Streams LLC
Science · Service · Solutions

1.0 Executive Summary:

A stream stability index was developed using hydrogeomorphic field data at 35 unique sites in Northern Kentucky. Stream stability was quantified using annually repeated surveys at 28 of the 35 sites, with eight of the sites having two rounds of surveys and 20 of the sites having three rounds of repeated surveys. Expert scores, which were only assigned to sites with at least two rounds of surveys, encompassed measured rates of instability across five individual dimensions, including 1) Left Bank, 2) Right Bank, 3) Cross Section, 4) Profile, and 5) Bed Material. These individual dimension expert scores were then synthesized into a composite overall expert score on a 0 to 10 scale. The synthesis into an overall expert score was guided by independent classifications of each site as Unstable (U), Transitional (T), or Stable (S), which were considered *a priori* overall scores.

The next step was to statistically test the power of simple, field-derived, non-temporal metrics in predicting both the individual expert scores and overall expert scores. In doing so, individual stability indices for each dimension, along with an overall stability index (i.e., 'Stability Index') that could be calculated in the field in about 15 minutes were developed. Channel shape, bank heights and angles, embeddedness, riffle frequency, and the depth of the deepest pool were all significant at $p < 0.10$ in predicting the overall expert score. Approximately 74% of the variance in the overall expert score could be explained by channel shape, embeddedness, and the depth of the deepest pool, which were all significant at $p \leq 0.05$.

The stability index attempts to balance the statistical strength of metrics in predicting stability at the given sites with 1) a physically-based framework, 2) ease of application in the field, and 3) a preference toward quantitative over qualitative metrics. The stability index explains ~80% of the variability in the overall expert score, and is computed as:

$$\begin{aligned} Stability\ Index &= -8.5 + 0.15 * LB + 0.15 * RB + 0.3 * Shape + 0.15 * Bedrock \\ &+ 0.25 * Embeddedness + 0.25 * Pool\ Depth + 0.25 * Riffle\ Freq. \end{aligned}$$

Where:

LB	=	Left Bank Score
RB	=	Right Bank Score
Shape	=	Shape Score
Bedrock	=	Bedrock Score
Embeddedness	=	Embeddedness Score
Pool Depth	=	Pool Depth Score
Riffle Freq.	=	Riffle Frequency Score

All of the variables are significant at $p < 0.05$, with the exception of the Right Bank (RB, $p = 0.54$), Bedrock Score ($p = 0.28$), and Riffle Frequency ($p = 0.09$). Preliminary validation compared stability index scores against values of macroinvertebrate biotic integrity (MBI scores), Habitat scores, and watershed development (i.e., impervious surfaces), showing positive correlations against MBI and Habitat and negative correlations against watershed development. Several important parameters, including expert scores, *a priori* scores, and stability indices are presented in a summary table included in Appendix A.

The stability index is recommended for review by SD1 and a field testing period at sites that were not used for index calibration. Although a simpler index could be developed with fewer metrics, the seven parameter model is a recommended starting point such that SD1 would be collecting field measurements for all of the metrics that showed some level of statistical significance during the calibration phase. In this regard, a model recalibration effort (if needed) could include field data from an expanded list of sites. Preliminary Field Forms for collecting the data and computing the stability index are included as Appendix B.

2.0 Introduction:

Managing storm water to promote channel stability is becoming increasingly important to SD1 (e.g., Hawley et al., 2012). Several years of channel stability monitoring and modeling have documented that historical and contemporary storm water management has tended to exacerbate channel instability. Exacerbated rates of channel instability in the urban/suburban environment are unsustainable because they can cause increased impacts to adjacent infrastructure such as sewers and roads. Not only does this shorten the life of public infrastructure, it causes private property loss, water quality impacts, habitat degradation, and overall loss of ecological function.

SD1 has collected detailed survey and geomorphic data at a subset of 35 of its ~100 regional sampling sites over the last four years. The detailed data have been valuable to 1) document the problem of channel instability and 2) calibrate more holistic storm water management tools and solutions. Because the channel stability data collection effort is time intensive (~2-4 hours per site), there was a desire to develop a simplified, statistically valid, channel stability index that could be used as a surrogate for full surveys during more routine monitoring efforts.

A physically-based channel stability index framework was developed to incorporate the multidimensional effects of hydromodification on stream channels. The framework was informed by a recent literature review of other monitoring and data collection programs relevant to hydromodification by Bledsoe et al. (2008). For example, see Vermont (2004) for a rather comprehensive stream geomorphic assessment program. Additionally, stream stability is an important component for macroinvertebrate and fish habitat, and therefore the stability index was also informed by a review of regional habitat evaluation indices (e.g., Barbour et al., 1999; KDOW, 2008; OEPA, 2009; Rankin, 1989).

Stream channels respond to disturbance in a variety of ways including incision (Booth, 1990), longitudinal headcutting, bed material transport (i.e., degradation and/or aggradation), fluvial attack of the banks and bank erosion, bank failure by geotechnical instability (i.e., mass wasting), widening (Schumm et al., 1984), and planform shifts, such as braiding (Hawley et al., In Press). Furthermore, system boundary conditions affect the degree of channel instability and the rate of responses. The relative resistance of the banks and bed material affects whether a channel may incise or widen (Allen et al., 2002; Booth, 1990). Proximity to geomorphic thresholds, such as incision (Bledsoe and Watson, 2001b) or bank failure by mass wasting (Thorne and Osman, 1988) affect channel evolution sequences and rates, and have implications regarding quantity and duration of sediment load that may be supplied from channel erosion (e.g., Watson et al., 2002).

Channel response magnitude can also be significantly affected by bed and/or bank hardpoints. For example, Hawley (2009) and Hawley et al. (In Press) showed that channel enlargement, incision depth, and bank height all increased moving upstream from a hardpoint, such as natural bedrock or artificial grade control (e.g., a concrete encased utility line). This trend has been verified in Northern Kentucky with data collected for two recent pilot projects in the headwaters of the Pleasant Run and Threemile Creek watersheds (Hawley et al., 2012).

SD1 synthesized this knowledge to inform its channel stability monitoring program, which has since documented all of the listed responses discussed above with the exception of planform shifts to braiding. The responses and associated risk factors can be classified into geomorphic categories of vertical (e.g., bed material, channel shape, and longitudinal profile) and lateral susceptibility (bank strength and proximity to mass wasting threshold) after Bledsoe et al. (In Press). The preliminary stability index developed herein was synthesized from this nexus of recent and relevant literature, a fundamental understanding of fluvial geomorphology in the urban/suburban environment, and the incredibly rich dataset collected by SD1.

3.0 Data Collection:

Initiated in 2008, the SD1 hydromodification monitoring program established 24 detailed hydrogeomorphic survey locations (including cross sections, profiles, and pebble counts) and has since been expanded by 11 for a total of 35 unique sites. Each was surveyed 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). 28 of the sites have at least two rounds of survey data and 20 sites have three rounds of survey data, with each survey round separated by approximately one year. These data have been systematically processed, including adjustments for field errors, and are presented as an Appendix to a complementary memo entitled, “Three Rounds of Hydromodification Field Surveys.”

4.0 Methods:

Measuring and Rating Observed Instability:

SD1 collected detailed data along three distinct dimensions: 1) channel cross section survey, 2) longitudinal profile survey, and 3) bed material particle counts. Because bank stability is an often integral component of overall channel stability (e.g., Bledsoe et al., In Press; Pfankuch, 1978; Rosgen, 1996; Simon and Rinaldi, 2000; Watson et al., 2002; Watson et al., 1988), the bank height and angle of each bank was measured using the channel cross section survey. This expanded the total subcategories of overall channel stability to five, including:

1) Left Bank Stability
2) Right Bank Stability
3) Channel Cross Section Stability
4) Channel Profile Stability
5) Bed Material Stability

Repeated surveys and pebble counts document how each dimension changed between survey dates, with systematic measurements made for each dimension for consistency across all sites. For example, top of bank was 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. This determination was considered to be appropriate in representing the risk of mass wasting geotechnical failure after Osman and Thorne (1988). The threshold is likely conservative given the generally cohesive nature of Northern Kentucky banks; however, these expert assessments adhere to the precautionary principal to err on the side of attributing greater risk when making subjective decisions.

Accordingly, the stability of each bank height and angle was classified based on photographs into categories of stable, unstable dominated by fluvial erosion, or unstable dominated by mass wasting. Again, according to the precautionary principal, banks were classified as geotechnically unstable (mass wasting) when the photograph was unclear whether failure was dominated by fluvial detachment or geotechnical mass wasting. The implications of such decisions would be to make the regionally-calibrated threshold of mass wasting bank failure (discussed below, see Section 5 Results – Bank Stability) potentially more conservative.

'Bankfull' elevation for each cross section was determined as the top of bank (discussed above) of the lowest bank. Using the measured rates of change in cross-sectional area (i.e., channel enlargement), the 'bankfull' depth and width were computed and factored into the stability rating for the subcategory of the channel cross section. An additional factor that informed the expert channel stability score was the width to depth ratio, which is a quantitative measure of channel entrenchment and has also shown significance in predicting risk of braiding (Fredsøe, 1978; Rosgen, 1996). With little risk of braiding in Northern Kentucky, higher width-to-depth ratios are indicative of a well-connected floodplain, which is important because it dissipates the erosive energy of high flows without large increases in flow depth. Without a well-connected floodplain, large flows result in stream-bed incision, which leads large increases in depth in the main channel, which leads to higher shear stress and a greater potential for channel erosion (i.e., see *Site Selection for Sediment Transport Modeling* section and *Tables 4 and 5* of the related SD1 memo entitled “Development of a Regionally-calibrated $Q_{critical}$ for Storm Water Management”). Finally, the degree of cross section variability was considered in the score (i.e., heterogeneous cross section with several benches vs. flat, homogenous bottom with shear banks). This visual determination was quantitatively supported by cross sectional hydraulic geometry relationships that were developed for each cross section after Buhman et al. (2002).

Regarding channel profile stability, quantitative measures of changes in riffle length, pool length, pool depth, slope, and the pool/riffle ratio were used to classify the degree of instability relative to other sites. Having such time-integrated data along a channel profile is rare in hydrogeomorphic studies; however, pool depth and riffle-pool frequency are two metrics that have been used in Ohio and Kentucky habitat assessment protocols (KDOW, 2008; OEPA, 2009; Rankin, 1989). The visual amount of bed profile agreement between survey years, as well as the degree in profile variability (i.e., pool-riffle development vs. plain bed form) was included in the expert score. Because some of these metrics (e.g., pool/riffle ratio, pool depth) tend to be correlated with physical characteristics, such as drainage area and slope, ratings were evaluated for potential bias toward steeper, smaller streams.

In order to determine the bed material stability expert score, bed material gradations were visually compared across survey years. Quantitative differences in key metrics, such as the 16^{th}, 50^{th}, and 84^{th} percentile particles (d_{16}, d_{50}, and d_{84}) and percentage of sand, informed the expert score, as well as the volumetric proportion of bedrock captured by the particle count.

In sum, the relative stability of each site was rated with an expert score in each stability dimension, which was based on how much change was observed at a given site relative to the full range of change observed at the other sites. Additional factors that informed the expert scores were related to the intrinsic instability of a given site for each category. For example, although a bank failure may not be captured with survey data, if the photo, geometry, and vegetation (or lack thereof) were all supportive of a classification of mass wasting failure, the bank was rated as unstable and considered to be failing. That is, physical properties that are indicative of past (and likely future) instabilities support unstable classifications in the absence of active change during the survey period.

a priori Overall Scores and Expert Score Validation:

Independent to the development of a stability index, sites had been previously classified as Unstable (U), Transitional (T), or Stable (S) based on an integration of dominant quantitative responses captured by the repeat surveys. Classifications were developed based on clear thresholds in the data, which coincided with initial “Gestalt” classifications of each site (i.e., what was Dr. Hawley's expert judgment of the relative stability of each site during the initial site visits, independent of watershed characteristics or detailed data). Those classifications are summarized below:

S = Stable (relative equilibrium):
- ≤ 1 UA banks
- no UC banks
- < ~5% enlargement
- < 50% bed material coarsening

T = Transition (intermediate):
- ≤ 1 UC bank
- < ~5% enlargement
- OR both banks UA
- OR Extremely active profile

U = Unstable (actively adjusting in multiple dimensions):
- > 1 UC bank
- OR > ~5% enlargement
- OR 1 UC and 1 UA bank
- OR ≥ 1 UA bank AND > 100% bed material coarsening
- OR both banks UA AND Active profile (e.g., 25% decrease in riffle length, headcut migration, etc.)

Where: UA = acutely unstable banks due primarily to fluvial erosion, and
UC = chronically unstable banks due primarily to geotechnical failure via mass wasting.

These classifications were considered *a priori* overall scores, which were used to validate the inclusion of the individual expert scores from each dimension into the overall expert score.

Analytical and Statistical Methods:

After developing expert scores by rating the overall and individual stabilities of each site using multi-year data, statistical analysis was used to identify simple, physically-based indices that could be used as surrogate measures of channel stability. The publicly available R (R, 2012) software was used to test an array of potential surrogate metrics. Measures such as smallest bank height and bankfull width were tested as an attempt to represent the width to depth ratio. Departure from reference width or reference pool depth for a given drainage area or slope was also tested.

Two of the simplest, but quantitative, measures of channel stability are bank height and angle. Hawley (2009) used logistic regression analysis of bank height and angle to develop a regionally calibrated threshold for mass wasting in Southern California as a part of a screening tool for susceptibility to hydromodification (Bledsoe et al., In Press). Identical steps to this novel approach were used to develop a regionally-calibrated threshold for Northern Kentucky, including Hawley's (2009) treatment of non-planar banks. The logistic regression model was then tested as a potential surrogate for the bank stability rating and overall stability rating.

Finally, several indices from the KDOW (2008) Habitat Index that could be related to channel stability were also tested as potential surrogates for measured change. This involved epifaunal substrate/available cover, embeddedness, sediment deposition, and frequency of riffles/bends. Although these metrics are somewhat subjective in nature, it was prudent to test such well-established indices (as opposed to new indices) in places where quantitative indices either performed too poorly or proved to be too cumbersome. In places where quantitative measures were simple to measure and had high performance in predicting stability (i.e., bank height and angle), the qualitative habitat scores (i.e., left and right bank stability) were not tested.

In sum, over 20 metrics were tested using regression analysis to identify statistically powerful, physically-based indices to include in the stability index. Informed by a literature review and extensive experience in statistical analysis, standard data transformations were tested and used where appropriate (e.g., logarithmic transformation of drainage area, bank height and angle, etc.). Variables were tested for collinearity and standard diagnostics were performed to evaluate homoscedasticity of residuals. Model performance and individual variable significance were assessed using R^2, adjusted R^2, p values, and partial R^2.

Synthesizing a Composite Stability Index:

The composite index (referred to as the stability index) attempts to balance the statistical strength of metrics with: 1) a physically-based framework, 2) ease of application in the field, and 3) a preference toward quantitative over qualitative metrics. For example, there is no physically based reason why one bank should be included over another such that any differences in the predictive power of the left and right bank are truly due to chance and chance alone. Therefore, a physically-based composite index should either include both banks (equally weighted) or neither bank. Therefore, the final statistical model was adjusted to accommodate such physical truths of geomorphology (i.e., an R^2 of 1.0 was not the absolute goal). The goal was to calibrate a physically-based model that explains a high proportion of variance at the current sites, but can be anticipated to perform reasonably well at sites with similar watershed characteristics during application.

Preliminary Validation Methods:

Preliminary validation of the stability index was performed using three independent measures– MBI, Habitat quality, and watershed imperviousness. Both MBI and Habitat quality tend to be negatively correlated with channel instability (Allan, 1995; Booth et al., 2004; Paul and Meyer, 2001; Roesner and Bledsoe, 2002), and watershed imperviousness tends to be positively correlated with channel instability (Bledsoe, 2002; Bledsoe and Watson, 2001a; Booth, 1990; Hawley, 2009). Analysis of data collected by SD1 has demonstrated that these trends seem to be apparent in Northern Kentucky as well (Hawley et al., 2012; Wooten and Hawley, 2010); therefore, a stability index should show some level of consistency with such correlations.

However, it should be stressed that this preliminary validation step is just that—preliminary. For a more complete validation step, the index should be fully tested on independent validation sites. Collection of testing-level data on independent sites may also supply additional data for a re-calibration step if deemed to be necessary after initial testing.

5.0 Results:

Sustainable Streams evaluated the statistical performance of a multitude of bivariate, multivariate, and logistic regression models at predicting both overall stability and individual dimensions of stability. The best-performing models are presented in the following subsections, beginning with individual stability dimensions of banks, channel cross section, profile, and bed material. Models of overall channel stability and their preliminary validation follow, with the final model explaining ~80% of the variance of the overall expert scores and showing positive correlations with MBI and Habitat Scores, and negative correlations with watershed imperviousness.

Bank Stability:

Based on the approach developed in Hawley's (2009) Ph.D. dissertation and the corresponding peer-reviewed journal article (Bledsoe et al., In Press), logistic regression analysis of regional bank data was used to predict the risk of mass-wasting bank failure in Northern Kentucky stream banks. Although the approach was developed in Southern California, the empirical model is consistent with the theoretical relationship for mass wasting geotechnical failure after Osman and Thorne (1988). Results showed that the approach was very transferable to Northern Kentucky, producing a model (as evaluated by the chi-squared statistic) that was highly significant with an overall p-value < 0.0001. Additional transferability was demonstrated by the significance of the individual variables (bank height and angle), which was also high ($p < 0.01$).

The model correctly classified 92% of the stable banks and 89% of the unstable banks, which is another indication of very high overall performance (Figure 1). Misclassification of ~10% of the points can be explained by a combination of measurement errors and natural variability in bank strength. For example, bank angles are very sensitive to the tape station reading, which can be challenging to measure on high banks. Secondly, the systematic method to express irregular bank geometries as a composite measurement after Osman and Thorne (1988) and Hawley (2009) erred on the side of caution following the precautionary principle. In general, this tends to identify the angle of the steepest section of the bank, combined with the total bank height to the point at which it breaks to an angle of less than 15 degrees. Third, although bank material is relatively homogeneous throughout the region (i.e., high silt/clay content), alluvial material and bedrock composition varied and could influence composite bank strength. In sum, the degree of overlap from the ~10% misclassification rate directly informs the range of the probabilities of being in either category, making the model more reflective of what the 'true' risk might be when accounting for measurement errors and bank material composition.

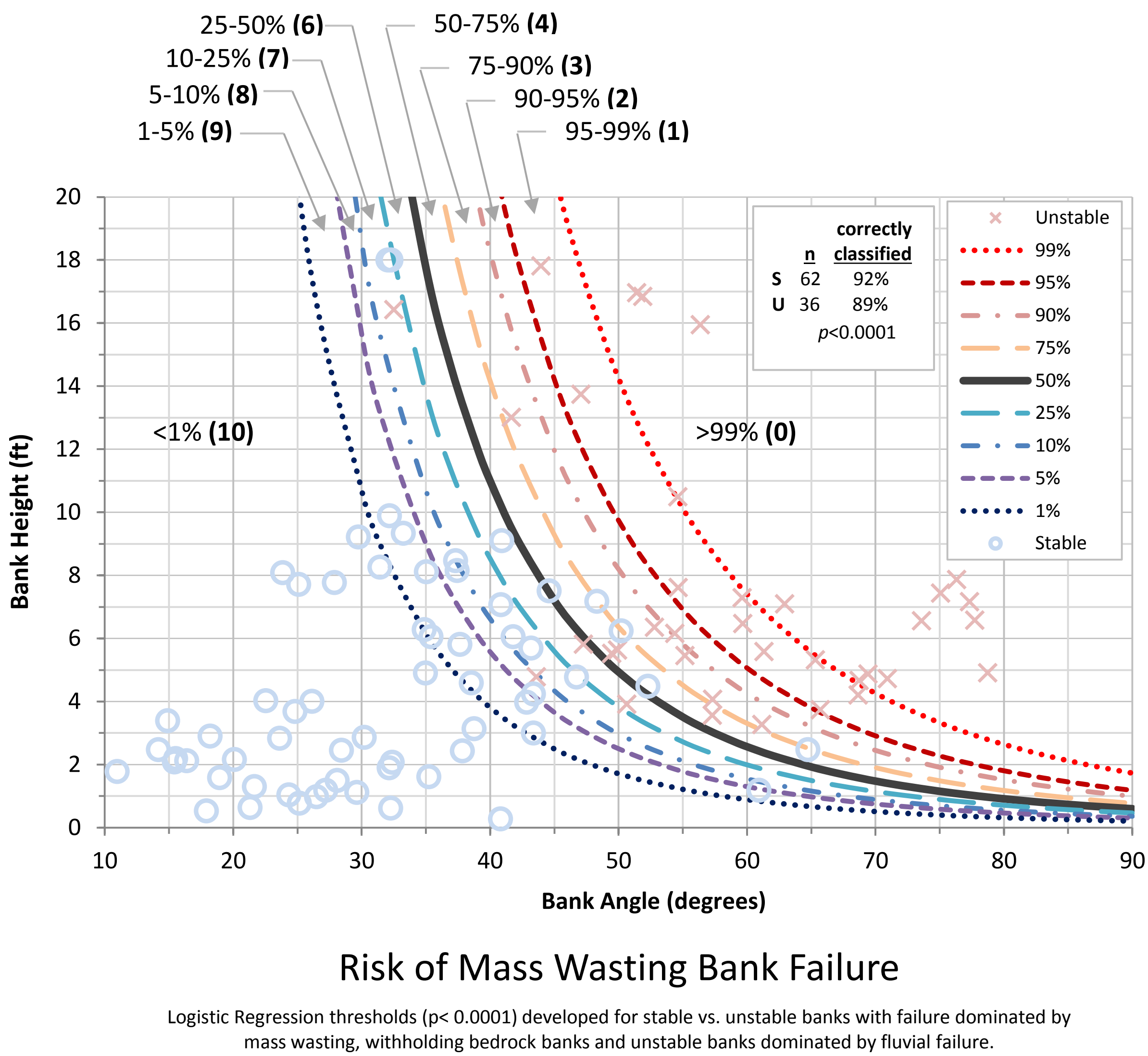
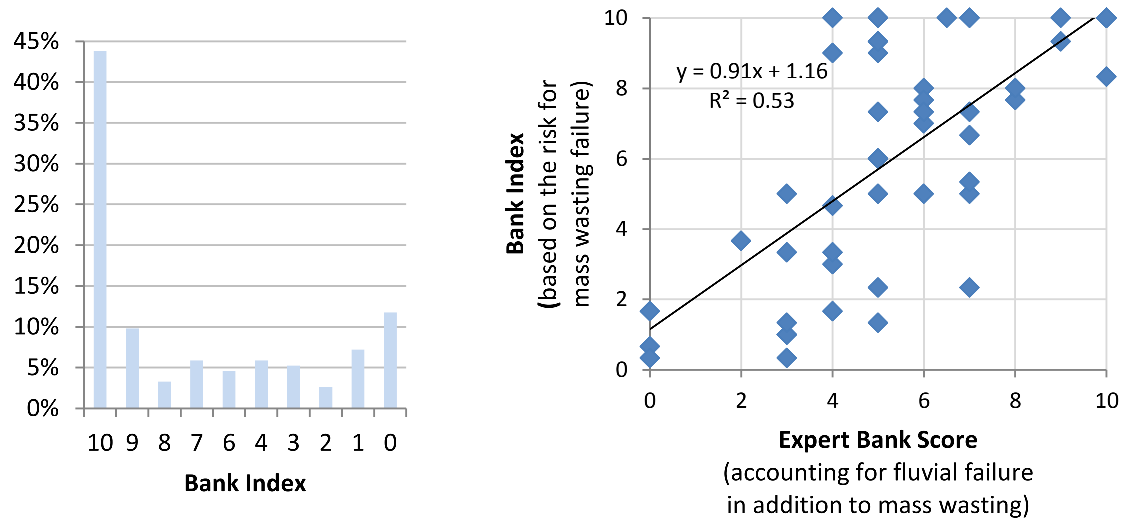


Figure 1 – Probabilities of Mass Wasting Bank Failure with Superimposed Bank Index Ratings (expressed parenthetically) and Corresponding Risk Ranges

Based on a range of probabilities from less than 1% to greater than 99% risk of being unstable, a bank index was developed on a 0 to 10 scoring system. The bank index attempted to balance the distribution of scores across the scale, along with reasonable performance of predicting the bank expert score (Figure 2).



(a) Distribution (b) Performance

Figure 2 – Bank Index

The risk of using a bank threshold that only accounts for mass wasting bank failure is that it does not explicitly account for active fluvial failure. Expert assessments of each site can account for such risk; however, a central goal to the stability index is transferability across multiple users of varying levels of geomorphic experience. Furthermore, regarding bank failure severity, mass wasting tends to have much greater potential to cause major infrastructure damage and property losses.

The bank index achieves the goal of using only quantitative measurements and removes subjectivity regarding the degree or severity of the bank failure. The relatively strong correlation with the expert score (R^2 = 0.53) suggests the bank index can reasonably account for overall bank stability. The distribution of scores is relatively even, with the exception of banks rated as 10 (44%); however, it is difficult to physically justify a rating of less than 10 for any bank with less than a 1% risk of mass wasting failure. Examples of a highly unstable bank experiencing mass wasting failure and a stable bank are presented in Figure 3 and 4, respectively.

Figure 3 – Highly Unstable Bank Experiencing Mass Wasting
(Site TUC0.4 – Right Bank Index = 0)

Figure 4 – Stable Bank Located on an Unnamed Tributary
(Site GPC-UNT – Right Bank Index = 10)

Channel Stability:

Numerous variables were tested as potential surrogates for time-integrated measures of channel stability. Channel width, depth, width to depth ratio, departure from reference channel width, departure from reference depth, height of smallest bank, and departure from reference smallest bank height were all tested as quantitative measures of stable or reference channel geometry. This analysis was attempting to represent floodplain connectivity and/or evidence of channel widening in a quantitative way.

The departure from reference width for a given drainage area (i.e., reference width ratio) was positively correlated to the cross section expert score; however, the correlation was relatively weak (R^2 = 0.09). Because of its relatively poor performance and the fact that it would require field staff to know the site's contributing drainage area before going into the field, other surrogate measures for channel stability were explored.

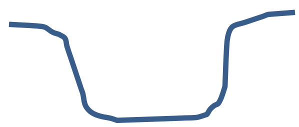
Smallest bank height (SBH) and departure from reference height of the smallest bank performed even weaker than reference width (R^2 = 0.04 and 0.01, respectively); however, the metric did show signs of a potential threshold-based relationship. For example, if the SBH at a given site was more than double the reference smallest bank height (SBH_{ref}), the cross section expert score was likely to be low (e.g., SFG 5.3_Trib, SBH = 4.18, SBH_{ref} = 2.04, cross section expert score = 2.5). This was a quantitative way to suggest that the stream was currently entrenched and relatively disconnected from the adjacent floodplain. It may also be a sign of historic incision.

Beyond a single measure of depth and width (i.e., 'bankfull' depth and width), hydraulic geometry relationships for each site were developed after Buhman et al. (2002). This involved developing a power function that predicts a hydraulic metric (e.g., cross sectional area) for all depths contained by the cross section. The exponent of the power function is often referred to as the 'shape' parameter, and the coefficient of the function referred to as the 'scale' parameter (Buhman et al., 2002). The 'shape' parameter could account for 13% of the variance in the cross section expert score when withholding three outliers (DRC1.0, GPC14.7, and LOC0.8). Higher values of the 'shape' parameter were consistent with greater irregularity in cross section form, and lower values tended to represent more "U" shaped cross sections. The exceptions were the three aforementioned outliers, which had irregular shapes but were highly unstable resulting in low cross section expert scores.

These efforts provided justification to explore more qualitative representations of the key physical measures behind those weak but physically-based correlations. Rather than focusing too heavily on specific measurements that can be time intensive to measure in the field, the key aspects to channel cross-section stability can be simplified to 1) how does the shape of the channel exacerbate or mitigate the ability of high flows to cause erosion, and 2) is the shape of the channel reflective of one that is actively being eroded or one that is in relative equilibrium?

The first question addresses floodplain connectivity, and the second question addresses cross section irregularity (Table 1). As discussed above, the better connected a channel to a broad floodplain, the less damaging high-magnitude flows are, whereas entrenched channels are more likely to exacerbate the erosive energy of high-magnitude flows. The more homogenous a cross section is, the more likely that erosive flows have scoured much of the habitat forming particles, whereas an irregular channel may be more representative of a system in greater balance.

Table 1 – Preliminary Cross Section Index Scoring System for Channel Shape

Measure	Poor (Score = 0)	Good (Score = 5)
Floodplain Connectivity on small streams (< 10 sq. mi., < 50 feet wide)	Depth to floodplain > 3 to 3.5 feet, or floodplain terrace less than 10 feet wide	Depth to floodplain < 3 to 3.5 feet, with floodplain terrace > 10 feet wide
Floodplain Connectivity on large streams (> 10 sq. mi., or > 50 feet wide)	Depth to floodplain > 6 to 6.5 feet, or floodplain terrace less than 30 feet wide	Depth to floodplain < 6 to 6.5 feet, with floodplain terrace > 30 feet wide
Bed Irregularity	Uniform "U" shaped cross section with minimal bed irregularity 	Irregular channel cross section with point bars and/or clear changes in elevation prior to reaching the toe of bank (> 6 inches on small streams, > 1 foot on large streams) 

In order to develop the cross section index, several combinations of thresholds and scoring schemes were tested; however, a simple binary scoring system for each component of channel shape seemed to balance model performance with simplicity of field application. It is possible to move to a more continuous (or three tiered) scoring system; however, this binary approach could account for nearly 50% of the variance in the time-integrated expert channel scores (Figure 5). Figure 6 and corresponding Table 2 present examples of good and poor channel stability for the cross section index.

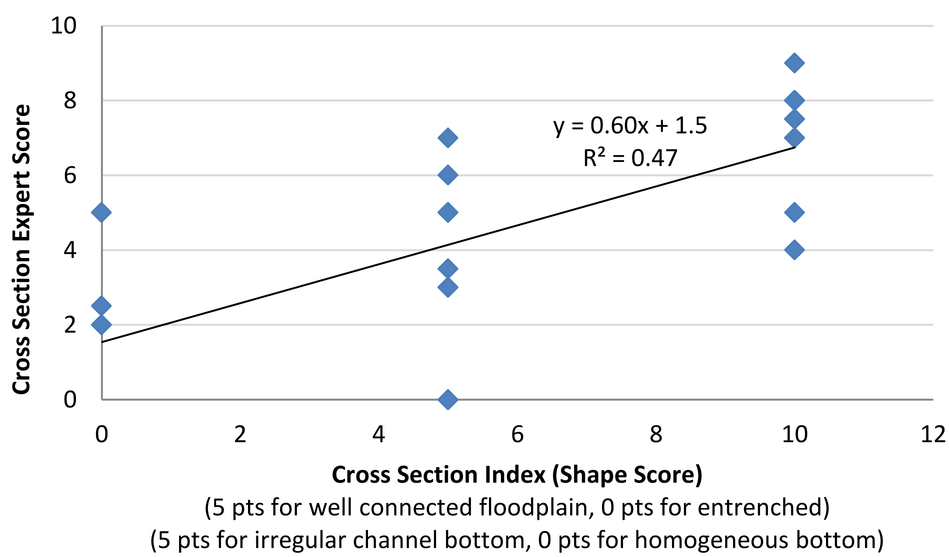


Figure 5 – Performance of Cross Section Index (Shape Score) in Predicting the Cross Section Expert Score

Poor Channel Stability (Site OWC0.4)

Good Channel Stability (Site DLC1.0)

Figure 6 – Cross Section Channel Stability Examples

Table 2 – Example Cross Section Index Scoring for Channel Shape

Site	**OWC0.4 (POOR)**	**DLC1.0 (GOOD)**
Expert Score	**2**	**9**
Floodplain Connectivity Score	0	5
Bed Irregularity Score	0	5
Cross Section Index (Shape Score)	0	10

Profile Stability:

Profile stability tends to be positively correlated with high quality habitat (Figure 7). The same physical characteristics that make a profile stable tend to be important for habitat as well. Pools and riffles (or steps and pools in steeper systems) provide hydraulic roughness that dissipates the erosive energy of the flowing water and a variety of habitats needed for a diverse biologic community. Heterogeneity within the stream bed provides a good mix of well-developed, stable pools and riffles (or step-pools) serving both geomorphic and habitat functions, as different groups of macroinvertebrates and fishes tend to prefer distinct habitat settings, such as fast flowing-riffles or slow-flowing pools.

One response that SD1 has been measuring since 2008 is the shortening of riffles and the lengthening of pools in urban watersheds (see corresponding memo, entitled "Three Rounds of Hydromodification Field Surveys"). The ratio of pool length to riffle length in a reach offers a simple way to compare these lengths across different sites. Another way to think of the 'pool/riffle ratio' is as a measure of how many riffles does it take to fit in one pool. A high pool/riffle ratio indicates that the pools are much longer than the corresponding riffles.

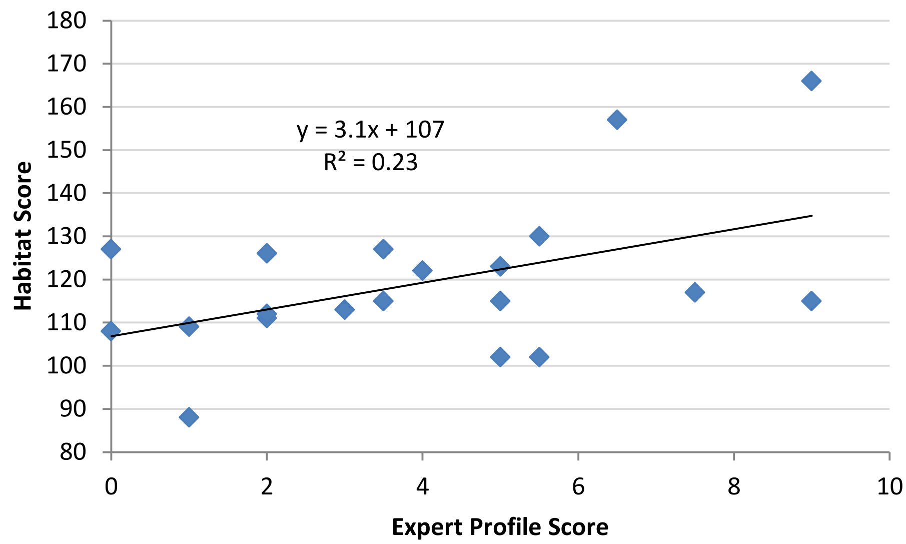


Figure 7 – Habitat Scores Positively Correlated with Expert Profile Scores Based on Relative Profile Stability over 2 to 3 Years of Repeated Surveys

The shortening of riffles and/or the increase of the pool/riffle ratio over repeated surveys directly informed the profile expert scores. However, it was difficult to account for this measure in a simple profile index. This is largely because the pool/riffle ratio is highly sensitive to channel slope (Figure 8), which would require detailed surveys and data processing.

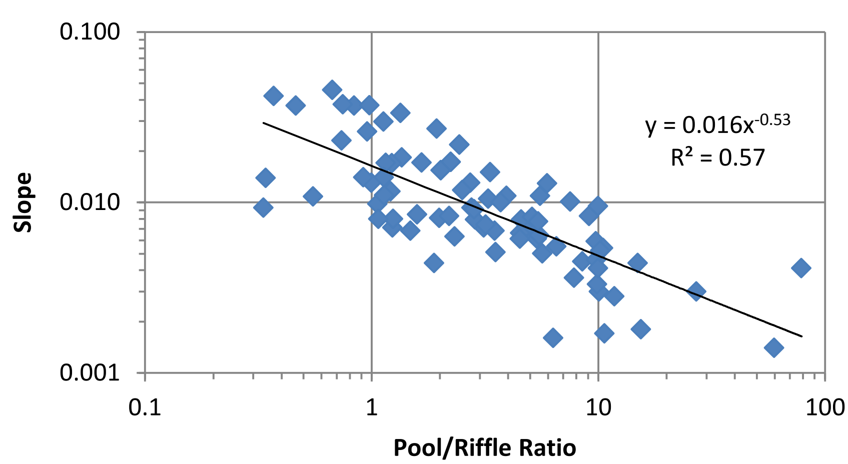


Figure 8 – Slope Negatively Correlated to the Pool/Riffle Ratio

In this case, the ease of a more qualitative measure such as the 'Frequency of Riffles/Bends' score from the KDOW (2008) habitat index proved to be much more appropriate for a simple profile index. Independent checks were performed to verify that both the expert profile score and the 'frequency of riffle/bends' score were not biased toward steep streams (i.e., there was a good mix of scores across all slopes).

Another trend that SD1 has been measuring is a deepening of pools in streams with urbanizing basins (see corresponding memo, entitled "Three Rounds of Hydromodification Field Surveys"). In contrast to the pool/riffle ratio discussed above, the maximum pool depth (at low flow) is something that can be very easily measured in the field. Because pool depth naturally increases with increasing drainage area (Figure 9), testing the departure of the max pool depth from a reference depth for a given drainage area was also considered. Additionally, a compartmentalized approach, where a reference pool depth range of 0.25 to 1.5 feet is typical on small streams (< 50 feet wide or < 10 square miles), and a range of 1 to 2 feet is typical on larger streams, was also tested. Such an approach has both a physical basis and a precedent in the qualitative habitat literature (Barbour et al., 1999; e.g., OEPA, 2009; Rankin, 1989).

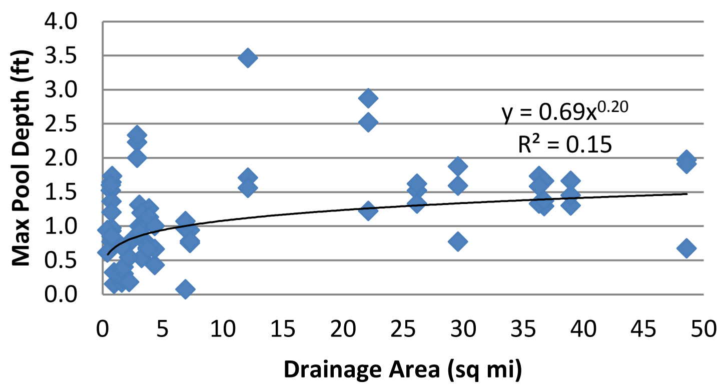


Figure 9 – Max Pool Depth Positively Correlated to Drainage Area

In the dataset, however, a simpler method proved to have greater predictive power for accounting for departure from reference pool depth and indications of profile instability. A maximum pool depth threshold of 2.5 feet proved to have the best performance at screening those sites with excessively deep pools—pools that had been scoured out by a very erosive flow regime and also had very active bed profiles. Alternatively, the prevalence of bedrock (as classified by the scoring scheme discussed below) proved to have high performance at screening sites with very shallow pools and poorly developed riffles.

In aggregate, the riffle frequency score (KDOW, 2008), pool depth score (<2.5 feet = 10, > 2.5 feet = 0), and the bedrock score (<2% = 10, 2-10% = 4, >10% = 0) explained ~45% of the variance in the Expert Profile Scores (Figure 10). Each of the variables were significant at the $p < 0.25$ level (Riffle Freq. $p = 0.03$, Pool Depth Score $p = 0.15$ and Bedrock Score $p = 0.24$). Figure 11 presents examples of profile data and significant changes over three years of data.

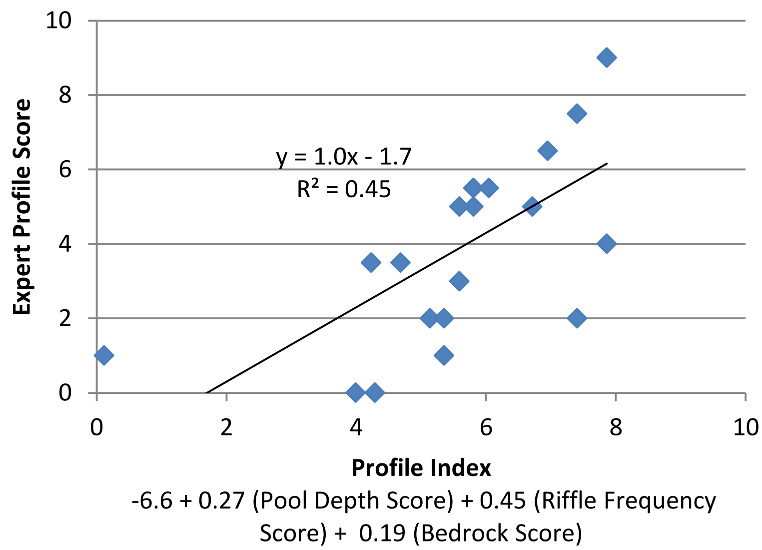
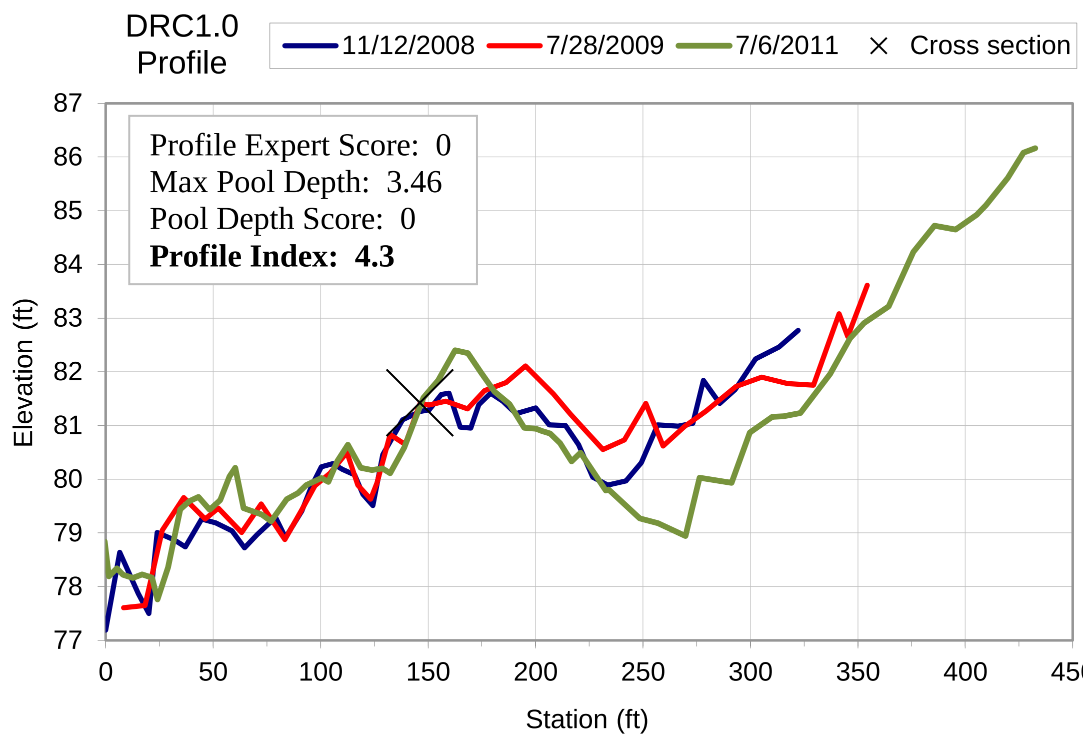


Figure 10 – Expert Profile Score Well-predicted by Weighted Combinations of Pool Depth, Riffle Frequency, and Bedrock Scores



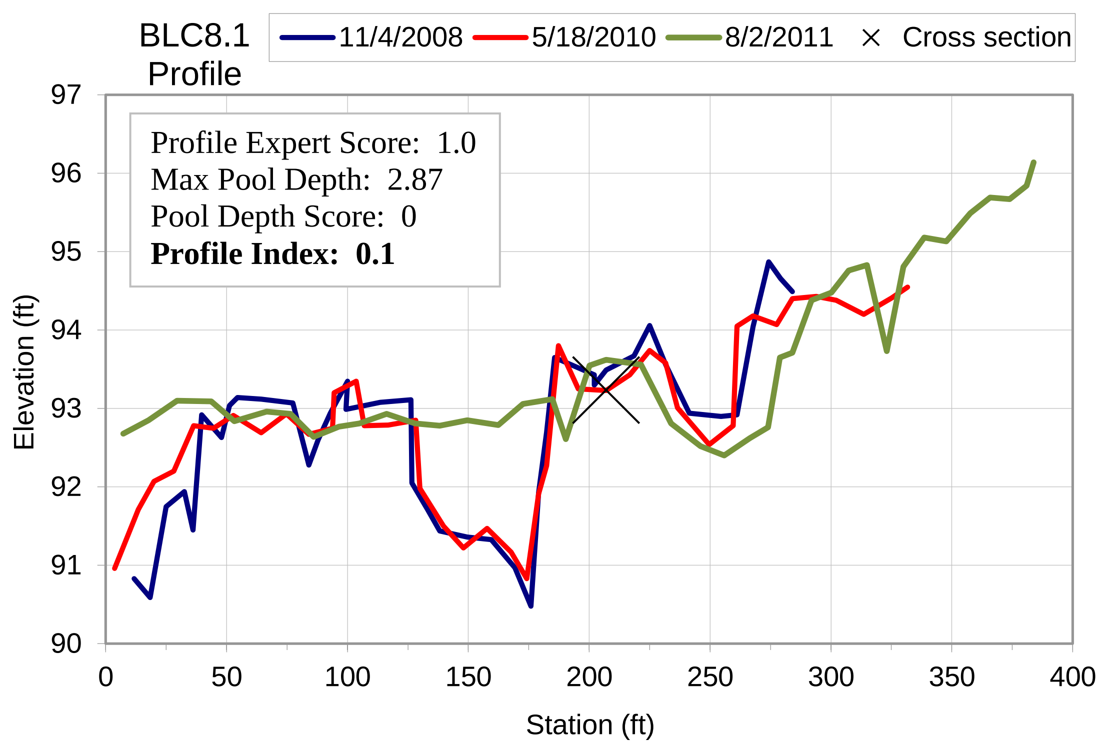


Figure 11 – Examples of Profiles that have Changed Over Three Years of Data

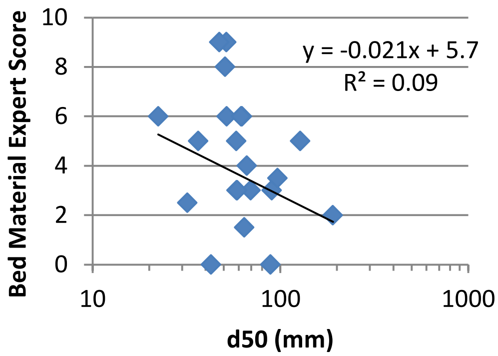
Bed Material Stability:

Expert bed material scores were assigned based on monitored changes in bed material composition over three years of annually-repeated pebble counts. Other factors that influenced the expert scores were the relative spread of bed material particles (i.e., having a good distribution of different size ranges), and the absence or dominance of bedrock.

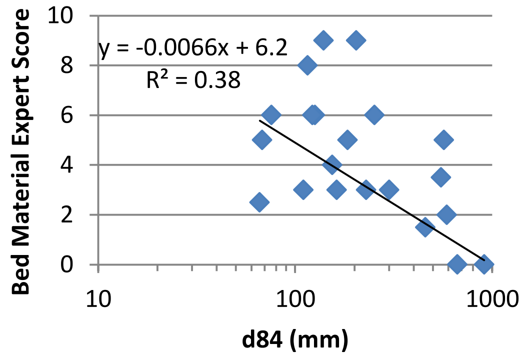
Bed coarsening was observed at many of the sites in developing watersheds (< 15% impervious area), but the trend was only significant to the $p < 0.15$ level (see corresponding memo, entitled "Three Rounds of Hydromodification Field Surveys"). The response has a strong physical basis in that increases in erosive energy to a system would increase the sediment transport capacity. Without increased supply of sediment to the reach, bed coarsening (by downstream transport of the finer materials) is an expected response.

Without annually repeated pebble counts at all of SD1 sites, more simplistic measures were tested for their statistical power in predicting the expert bed material scores. Median grain size (d50) and the 84^{th} percentile particle (d84) were both negatively correlated to the expert bed material scores (Figure 8 (a) and (b)); however, those metrics would require collecting and processing 100-particle pebble counts at each site. Doing so would add potentially unnecessary time and cost to the stability index.

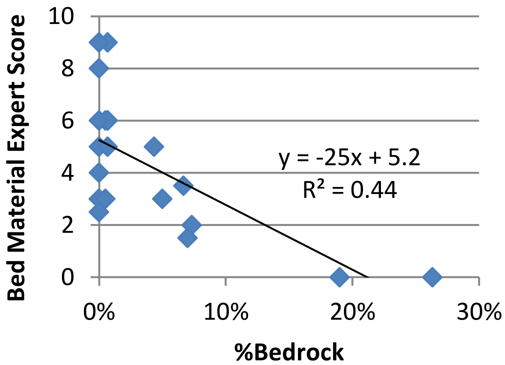
The percentage of bedrock comprising the 100-particle pebble count explained a greater portion of the variance of the bed material expert score. Moreover, the data fell out into three groupings, which supported a relatively simple incorporation into the bed material index. Sites with essentially no bedrock (< 2%) scored relatively well, sites with some exposed bedrock (2-10%) relatively poorly, and sites with a large amount of exposed bedrock (> 10%) scored very poorly (Figure 12 (c)). Statistical optimization ($R^2 = 0.39$) resulted in scores of 10, 4, and 0 for the respective ranges (Figure 12 (d)). Examples of the ranges of bedrock and associated bedrock scores are illustrated in Figure 13. Appendix C includes several example photos of SD1 sites and their associated bedrock score, depending on the percent bedrock at the site.



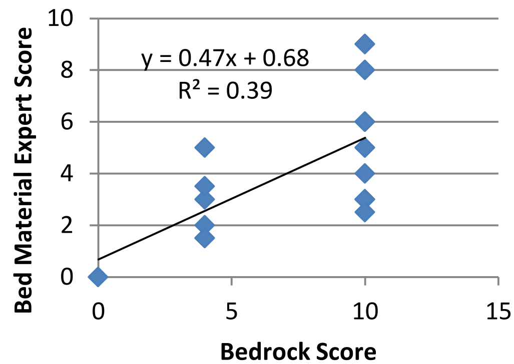
(a) d50



(b) d84



(c) %Bedrock



(d) Bedrock Score

Figure 12 – Four Bivariate Correlations of Expert Bed Material Score

%BEDROCK	< 2%	2 - 10%	> 10%
BEDROCK SCORE	10	4	0
EXAMPLE PHOTOS			

Figure 13 – Percent Bedrock and Corresponding Bedrock Score

Related measures from the KDOW (2008) habitat index—scores which SD1 would already have evaluated at a given site—were tested for statistical significance as well, including Epifaunal Substrate/Available Cover, Embeddedness, and Sediment Deposition. A multivariate regression model that included the bedrock score and embeddedness explained approximately 50% of the variability in the expert scores with corresponding *p* values of 0.003 and 0.14 for bedrock score and embeddedness, respectively (Figure 14).

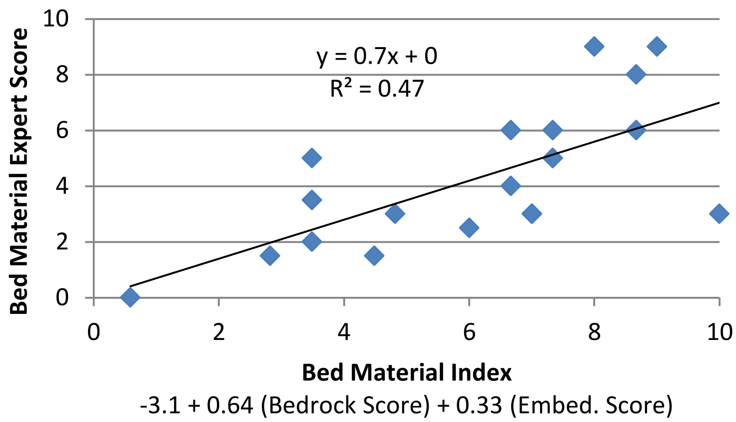


Figure 14 – Expert Bed Material Well-predicted by Weighted Combinations of Bedrock Score and Embeddedness Score

Overall Stability:

An overall stability score was developed as a several-step process. First, statistical analysis was used to determine the relative weights that the individual expert scores should have in developing an overall expert score. This was done using multivariate regression analysis to predict the *a priori* overall stability score (U, T, S, scored as 2, 5, and 8, respectively). The relative weights and statistical significance were ordered in the following ways:

1) expert cross section score (weight = 0.35, p = 0.11)
2) expert profile score (weight = 0.34, p = 0.13)
3) expert left bank score (weight = 0.24, p = 0.13)
4) expert right bank score (weight = 0.04, p = 0.82)
5) expert bed material score (weight = 0.005, p = 0.98)

These statistically-based weights then informed a physically-based composite 'expert overall score' (Figure 15). Because the cross section and profile scores tended to have greater power in predicting overall stability, they were given greater weight than the bank scores, which were given equal weight. Despite its poor statistical performance, the bed material scores were still included in the overall score because they capture a completely separate dimension from the other components. For this physical basis, the bed material score was given equal weight as the channel cross section and profile scores.

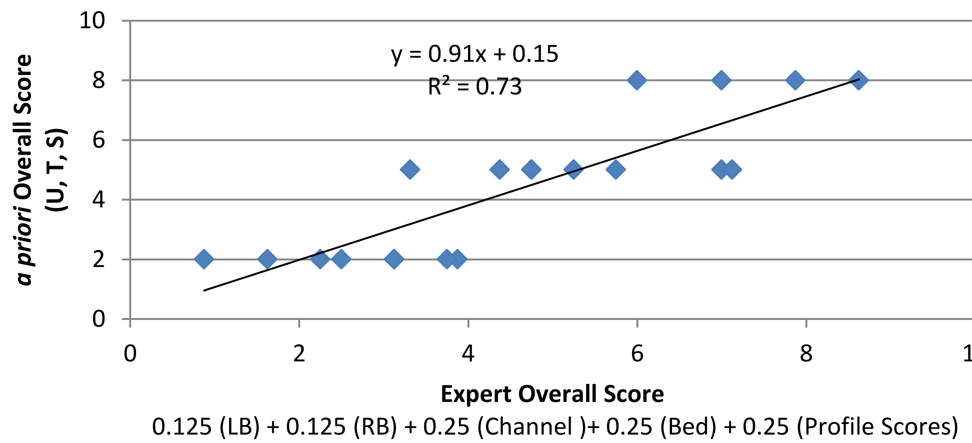


Figure 15 – *a priori* Overall Score (U, T, S) Well-predicted by Weighted Combinations of Individual Expert Scores

Next, statistical analysis verified that those same weights were applicable to the individual stability indices that were developed in the subsections above (Figure 16). By using weighted combinations of the individual indices (i.e., each bank index, cross section index (shape score), profile index (pool depth score, riffle frequency score, bedrock score), and bed material index (bedrock score, embeddedness score), a weighted stability index could account for about 70% of the variability in the expert overall score. However, in the interest of tool utility, backward selection was used to determine if a simpler stability index could be developed from the most statistically-powerful metrics that comprised the individual sub-indices. That is, rather than calculating individual scores for bed material, profile, etc. in the field, could an overall stability index be computed from similar components using less steps?

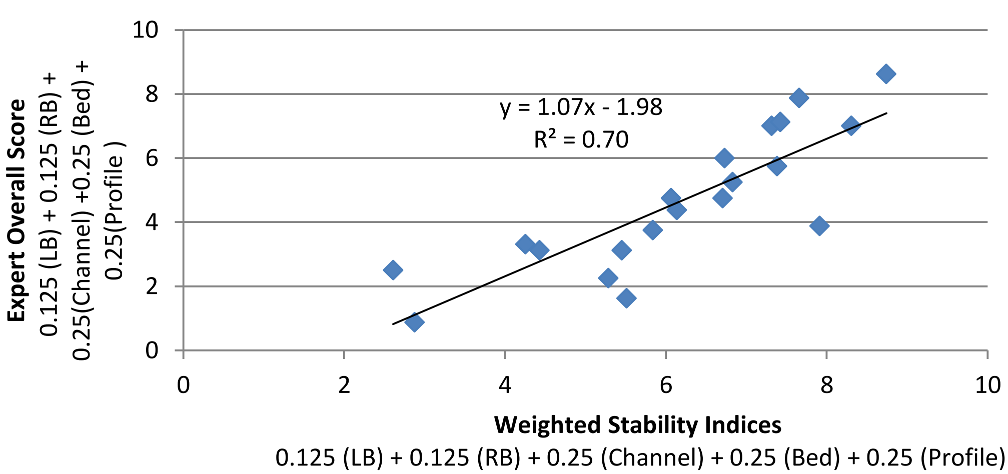


Figure 16 – Expert Overall vs. Weighted Individual Stability Indices

Indeed, approximately 80% of the variance in the Expert Overall Score could be predicted using statistically-weighted, physically-based combinations of each bank, channel shape score, bedrock score, pool depth score, embeddedness score, and riffle frequency score. The proposed preliminary stability index is presented below, with model performance depicted in Figure 17. It is important to note that all of the variables were significant to the $p < 0.05$ level, with the exceptions of the right bank (p = 0.54), the bedrock score (p = 0.28), and riffle frequency (p = 0.09).

$$Stability\ Index = -8.5 + 0.15 * LB + 0.15 * RB + 0.3 * Shape + 0.15 * Bedrock + 0.25 * Embeddedness + 0.25 * Pool\ Depth + 0.25 * Riffle\ Freq.$$

Where:

LB	=	Left Bank Score
RB	=	Right Bank Score
Shape	=	Shape Score
Bedrock	=	Bedrock Score
Embeddedness	=	Embeddedness Score
Pool Depth	=	Pool Depth Score
Riffle Freq.	=	Riffle Frequency Score

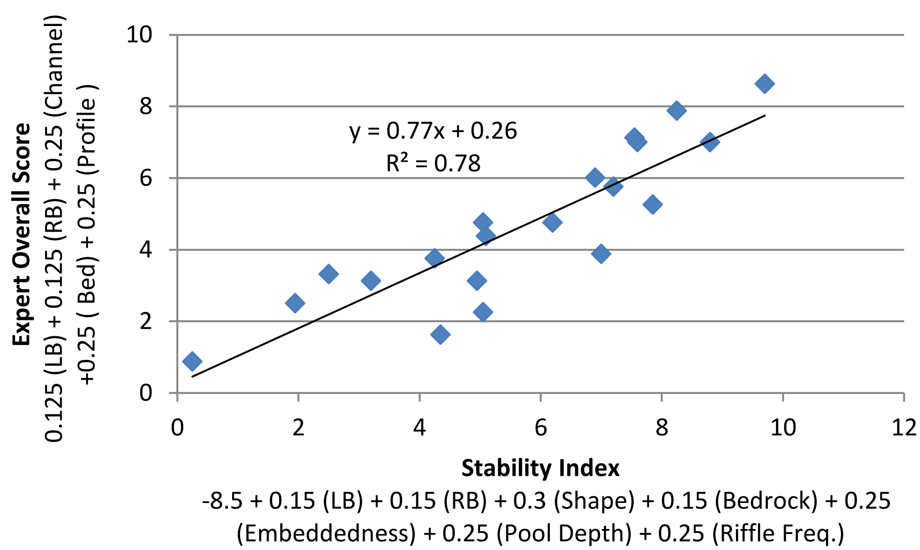


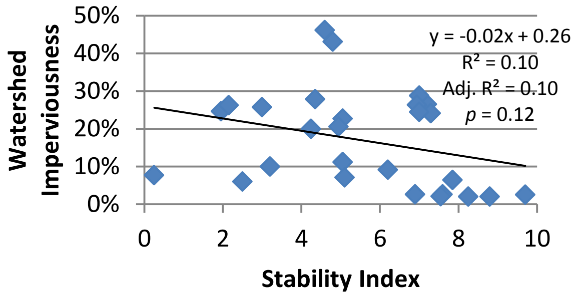
Figure 17 – Expert Overall Score vs. Stability Index

Preliminary Validation:

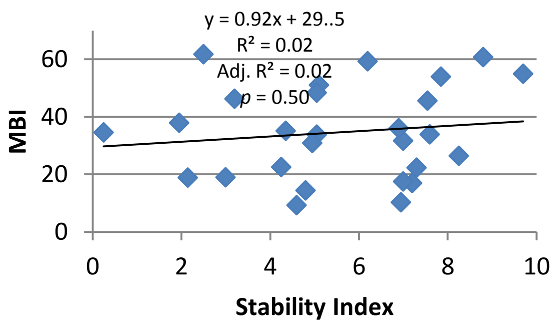
The stability index was correlated to three independent metrics as a preliminary validation step. These metrics included watershed imperviousness, MBI, and Habitat scores. Directions of the correlations were consistent with previous literature, providing a level of confidence in the stability index. It should be noted that the statistical significance of the correlations was relatively weak when evaluating all sites (Figure 18). However, Hawley (2009) and Hawley et al. (In Press) showed that proximate grade control such as bedrock and pipe crossings can artificially protect against localized stream instability. This trend has since been verified in Northern Kentucky (Hawley et al., 2012) because once the sites with proximate grade control were withheld from the dataset, the strength of the relationships substantially improved (Figure 19).

Examination of the table in Appendix A will indicate that this validation step did include seven sites which were not used during model calibration. Four sites associated with the Pleasant Run project and three sites associated with the Vernon Lane project did not have time-series data. As such, these sites were not assigned expert scores like the sites that did have repeated surveys. However, because the sites had Habitat and MBI scores, the sites were assigned overall stability ratings and included in the validation correlations in Figures 18 and 19.

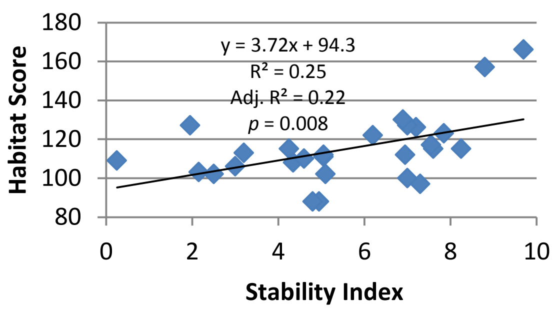
In contrast, four sites on Loders Creek, BLC17.6, BLC18.0, SFG5.3-DS, and SFG5.3-Trib informed the expert scores but could not be used for calibration of the stability index because habitat evaluations were not performed at those sites (and the Riffle Frequency and Embeddedness scores from the Habitat Evaluation directly inform the Stability Index). Performing habitat evaluations at these eight sites would be a simple way to provide an additional round of validation during the initial testing period of the stability index.



(a) Imperviousness

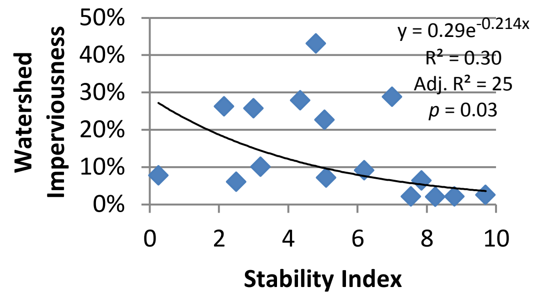


(b) MBI

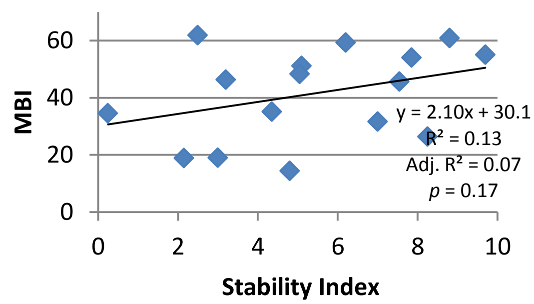


(c) Habitat Score

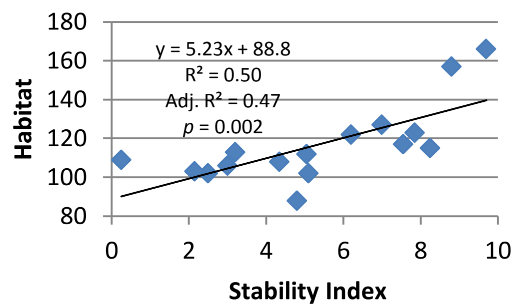
Figure 18 – Stability Index Validation Using All Sites



(a) Imperviousness



(b) MBI



(c) Habitat Score

Figure 19 – Stability Index Validation Using Sites without Grade Control

6.0 Conclusions:

Sustainable Streams evaluated well over 100 models in developing this stability index. The first goal was to rate stream stability using three years of data across five different dimensions including left bank, right bank, cross section, profile, and bed material. In each dimension, individual expert scores were developed to rate the stability at each site relative to the full range of the observed instability measures across all of the sites. An overall expert score was developed from weighted combinations of the individual expert scores.

The weights of the individual expert scores were calibrated based on performance in predicting an *a priori* overall stability rating (U, T, S). Results of the statistical calibration were then transferred to a physically-based model in that equal weight was given to both banks and each dimension was weighted somewhat equally. That is, because the time-series data shows instabilities of proportional magnitude across each dimension, it made physical sense for the expert overall score to incorporate individual expert scores from each dimension relatively equally. Because it can be argued that the banks are actually a part of the cross section, along with the fact that the banks had less statistical significance than the most of the other dimensions, it made physical and statistical sense to give the banks expert scores less weight than the other dimensions. In the end, the overall expert score that incorporates 3 years of data weighted the individual expert scores from the cross section, profile, and bed material with a value of 0.25 and the left and right bank with a value of 0.125.

The next component of this task was to develop a stability index that could be calculated with relative ease in the field. **The goal of the stability index would be to rate stability at sites without hydromodification field data on the same scale as those sites with time-series hydromodification data**. The first phase of this process was to develop individual stability indices for each of the five dimensions of channel stability. In sum, over 20 metrics were evaluated as potential surrogate measures of time-series channel stability. Multivariate models of these surrogate measures showed that individual stability indices (e.g., bank stability index, cross section channel stability index, profile stability index, and bed material stability index) predicted approximately 50% of the variance of the corresponding individual expert score for a given dimension.

The second phase of this process was to develop an overall stability index (i.e., 'stability index') that would provide reasonable agreement with the overall expert score. Individual stability indices could be combined into an overall stability index that explained ~70% of the variability in the overall expert score. However, this approach seemed overly cumbersome in that a user would first calculate the individual stability indices for each dimension and then combine them through another step to develop an overall stability rating.

As a more straightforward alternative, an overall stability index was developed that is directly predicted from seven components. Using weighted combinations of the left bank, right bank, shape, bedrock, pool depth, embeddedness, and riffle frequency scores, the overall stability index could account for 78% of the variance in the overall expert scores. Using combinations of relatively simple measures that can be computed in about 15 minutes, the stability index can achieve nearly the same rating as those obtained from 3 years of hydromodification field surveys.

The stability index was correlated with measures of watershed imperviousness, MBI, and Habitat as a preliminary validation step. The respective directions of these correlations were consistent with the literature, and the correlations gained statistical significance when withholding sites with frequent or proximate grade control, such as bedrock. However, Sustainable Streams recommends a trial period of testing and potential re-calibration depending on performance. For example, adding more sites at intermediate and large watershed areas may offer insights that were not evident in the present dataset.

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Appendix B: Monitoring Results for GPC 14.7

- Ambient Water Quality Results for GPC 14.7

Appendix B: Monitoring Results for GPC 14.7

Date	Time	Location	tot-NH3, mg/L-N	Ecoli, #/100ml	tot-NO3+NO2, mg/L-N	TKN, mg/L-N	TN, mg/L	TP, mg/L-P	TSS, mg/L	Temp, degrees Celsius	pH, su	DO, mg/L	Conductivity	Turbidity NTU	CBOD5, mg/L	PO4_as_P, mg/L-P	Condition	Discharge USGS Gage
3/27/2018	9:35:00 AM	GPC14.7	<0.042	100	0.023	0.694	0.717	0.076	2	8.49	7.77	9.34	1340	6.8	<2	0.009	Dry	58.1
4/17/2018	9:40:00 AM	GPC14.7	<0.079	664	0.148	0.509	0.657	0.081	4	6.42	7.85	11.11	521.4	19.9	3	0.028	Wet	71.6
5/8/2018	10:05:00 AM	GPC14.7	<0.079	588	0.02	0.517	0.537	0.081	2	17.36	8.1	9.99	696.6	9.4	<2	0.05	Dry	20.2
5/22/2018	9:30:00 AM	GPC14.7	<0.079	14140	0.804	1.28	2.084	0.446	62	21.34	7.79	7.18	381	124.1	4	0.142	Wet	212
6/12/2018	9:45:00 AM	GPC14.7	<0.079	548	1.63	0.539	2.169	0.151	5	23.04		7.8	911.8	0	<2	0.101	Wet	10.5
7/10/2018	9:40:00 AM	GPC14.7	<0.079	124	0.571	0.653	1.224	0.171	4	25.55	8.4		678.2	4.8	<2	0.128	Dry	1.59
7/24/2018	9:40:00 AM	GPC14.7	<0.079	284	0.387	0.654	1.041	0.151	9	21.95	8.55	8.78	646	9.9	<2	0.088	Dry	13.4
8/21/2018	9:45:00 AM	GPC14.7	<0.079	1460	0.468	0.464	0.932	0.128	5	23.86	SD	8.19	556.7	6.5	<2	0.093	Dry	25.6
9/11/2018	10:05:00 AM	GPC14.7	<0.079	716	0.992	0.55	1.542	0.189	6						<2	0.135	Wet	51
9/25/2018	9:35:00 AM	GPC14.7	<0.079	2068	1.02	0.717	1.737	0.276	10	20.41	8.18	8.41	430.8	20.7	<2	0.205	Wet	116
10/16/2018	10:00:00 AM	GPC14.7	<0.079	128	2.16	0.319	2.479	0.457	<1.4	10.71	8.4	11.35	627.3	0	<2	0.457	Dry	10.5
11/13/2018	9:50:00 AM	GPC14.7	<0.079	172	0.809	0.396	1.205	0.12	<1.4	4.97	8.54	12.08	530.2	1.3	<2	0.097	Dry	23.3
3/19/2019	9:25:00 AM	GPC14.7	<0.079	64	0.235	0.504	0.739	0.051	4	4.62	8.18	12.79	668.2	6.9	2	0.015	Dry	31.2
4/23/2019	9:55:00 AM	GPC14.7	<0.079	396	0.26	0.583	0.843	0.074	<1.4	15.12	8.55	11.2	563	4	<2	0.023	Dry	37.9
5/7/2019	9:55:00 AM	GPC14.7	<0.079	104	0.951	0.318	1.269	0.103	2	16.65	8.03	11.08	617.2	3.5	<2	0.056	Dry	28.5
5/21/2019	9:40:00 AM	GPC14.7	<0.079	1104	2.38	0.147	2.527	0.303	7	16.6	7.87	9.14	533.9	10.1	<2	0.254	Dry	18.6
6/11/2019	10:20:00 AM	GPC14.7	<0.079	612	1	0.613	1.613	0.209	5	18.37	7.41	10	519.3	15.9	<2	0.141	Dry	20.8
7/9/2019	10:05:00 AM	GPC14.7	<0.079	260	0.173	0.509	0.682	0.075	3	25.24	8.01	7.99	643.8	1.1	2	0.06	Dry	2.9
9/10/2019	9:25:00 AM	GPC14.7	<0.079	148	0.076	0.533	0.609	0.121	5	20.7	6.48	8.04	584.6	11	<2	0.085	Dry	2.4
9/24/2019	9:50:00 AM	GPC14.7	<0.079	124	0.145	0.66	0.805	0.132	8	18.59	7.98	8.19	780.4	6.4	<2	0.095	Dry	1.63
10/22/2019	10:15:00 AM	GPC14.7	<0.079	32	0.032	0.554	0.586	0.111	2	14.43	8.42	10.48	353.5	***	<2	0.084	Dry	2.13
11/12/2019	10:15:00 AM	GPC14.7	<0.079	608	0.409	0.633	1.042	0.177	8	3.45	8.11	12.91	744.1	23	2	0.083	Dry	35.6
5/5/2020	9:45:00 AM	GPC14.7	<0.079	688	0.531	0.785	1.316	0.132	23	14.42	8.22	9.16	616.8	31.3	**	**	Wet	87.2
5/19/2020	10:00:00 AM	GPC14.7	<0.079	24200	0.374	1.29	1.664	0.451	122	15.74	7.95	8.71	186.9	168.2	**	**	Wet	2240
6/9/2020	9:15:00 AM	GPC14.7	<0.079	156	0.612	0.596	1.208	0.118	8	23.54	8.12	8.16	742.6	6.7	**	**	Dry	3.9
7/14/2020	9:40:00 AM	GPC14.7	<0.079	320	0.367	0.808	1.175	0.206	30	23.09	8.15	8.17	504.3	39.7	**	**	Dry	6.8
7/28/2020	9:35:00 AM	GPC14.7	<0.079	1380	0.251	0.616	0.867	0.247	33	24.69	8.08	7.55	508.3	40.2	**	**	Dry	14.1
8/11/2020	9:45:00 AM	GPC14.7	<0.079	1232	0.239	0.641	0.880	0.302	59	22.92	8.22	7.83	392.7	103.3	**	**	Dry	23.9
9/8/2020	9:55:00 AM	GPC14.7	<0.070	64	0.231	0.487	0.718	0.092	6	21.85	8.26	8.88	727.1	9.3	**	**	Dry	3.58
9/22/2020	9:45:00 AM	GPC14.7	<0.070	108	8.81	<0.218	8.810	0.501	6	14.04	8.1	9.85	776.8	5.4	**	**	Dry	0.77
10/6/2020	9:50:00 AM	GPC14.7	<0.070	40	7.09	<0.218	7.090	0.987	2	10.65	8.21	10.64	561.7	3.3	**	**	Dry	1.52
11/17/2020	9:30:00 AM	GPC14.7	<0.070	144	0.143	0.448	0.591	0.133	1	6.36	8.22	12.36	597	3.4	**	**	Wet	15.1
4/13/2021	9:35:00 AM	GPC14.7	<0.094	188	0.037	0.571	0.608	0.097	3	12.58	7.94	10.51	1013.7	5.7	**	**	Dry	24.5
5/4/2021	9:50:00 AM	GPC14.7	<0.094	24200	0.209	1.49	1.699	1.24	146	17.46	7.84	8.25	574.4	147.4	**	**	Wet	137
5/18/2021	10:05:00 AM	GPC14.7	0.113	1844	0.539	0.856	1.395	0.166	15	15.85	7.84	9.08	669.5	31.1	**	**	Wet	76.8
6/8/2021	10:05:00 AM	GPC14.7	0.162	3610	0.555	0.845	1.4	0.206	28	21.51	7.92	8.93	622.9	41	**	**	Wet	62.1
7/6/2021	9:50:00 AM	GPC14.7	<0.094	152	0.594	0.563	1.157	0.13	4	25.45	8.15	9.35	802.5	7.9	**	**	Dry	7.18
7/20/2021	10:45:00 AM	GPC14.7	<0.094	520	0.642	0.52	1.162	0.2	8	22.61	8.18	9.46	668.1	30.2	**	**	Dry	28.3
8/10/2021	9:35:00 AM	GPC14.7	<0.094	8160	0.398	0.982	1.38	0.208	24	23.06	7.82	6.72	656.6	35.2	**	**	Wet	14.5
8/24/2021	9:50:00 AM	GPC14.7	<0.094	52	0.153	0.565	0.718	0.123	4	25.71	7.96	7.45	733.9	6.8	**	**	DRY	2.72
9/14/2021	9:30:00 AM	GPC14.7	<0.094	76	0.098	0.555	0.653	0.095	2	22.3	8.18	8.02	799.8	4	**	**	DRY	2.02
10/19/2021	9:35:00 AM	GPC14.7	<0.094	668	0.429	0.385	0.814	0.174	1	11.84	7.98	10	711.1	3.6	**	**	DRY	8.33
4/12/2022	9:30:00 AM	GPC14.7	<0.094	220	0.173	0.7	0.873	0.096	3	12.24	7.96	10.28	990.4	5.2	**	**	DRY	44.99
5/10/2022	9:15:00 AM	GPC14.7	<0.094	112	0.991	0.244	0.991	0.19	3	17.59	8.34	10.63	702.8	5.1	**	**	DRY	22.7
5/24/2022	9:40:00 AM	GPC14.7	<0.094	160	0.668	0.37	1.038	0.177	8	15.21	7.59	10.97	677.6	25.4	**	**	DRY	37.2
6/7/2022	9:00:00 AM	GPC14.7	<0.094	11200	0.416	0.942	1.358	0.338	61	20.29	8.1	7.9	432.5	73.1	**	**	WET	157
7/12/2022	9:40:00 AM	GPC14.7	<0.094	168	0.236	0.516	0.752	0.141	1	25.2	8.03	8.35	711.4	13.6	**	**	DRY	5.48
7/26/2022	9:40:00 AM	GPC14.7	<0.094	364	0.276	0.632	0.908	0.109	5	24.09	8	8.11	861.8	10.9	**	**	DRY	7.78
8/9/2022	9:25:00 AM	GPC14.7	<0.094	420	0.539	0.534	1.073	0.182	9	25.17	8.19	8.32	661.1	19.3	**	**	DRY	15.8
8/23/2022	9:20:00 AM	GPC14.7	<0.094	372	0.31	0.974	1.284	0.155	13	21.13	7.83	8.85	528.2	22.7	**	**	DRY	8.37
9/13/2022	9:30:00 AM	GPC14.7	<0.094	208	0.579	0.502	1.081	0.284	1	19.17	8.05	8.37	494.8	5.3	**	**	DRY	5.26
10/18/2022	9:25:00 AM	GPC14.7	<0.094	80	0.053	0.408	0.461	0.241	1	8.5	7.87	10.07	886.7	1.4	**	**	DRY	1.57
4/18/2023	9:15:00 AM	GPC14.7	<0.094	58	0.185	0.479	0.664	0.137	1	9.12	8.22	11.49	851	1.5	**	**	DRY	10
5/9/2023	9:40:00 AM	GPC14.7	<0.094	408	0.409	0.821	1.23	0.161	2	17.85	8.1	10.04	625	2	**	**	WET	21.9
5/23/2023	9:40:00 AM	GPC14.7	<0.094	44	1.72	0.665	2.385	0.271	3	18.49	8.15	8.76	751	6.3	**	**	DRY	5.05
6/14/2023	10:05:00 AM	GPC14.7	<0.094	204	2.75	0.838	3.588	0.384	4	19.15	8.07	8.8	756.7	0.9	**	**	DRY	4.64
7/12/2023	9:50:00 AM	GPC14.7	<0.094	116	0.439	0.969	1.408	0.223	11	23.22	8.06	7.91	647.1	8	**	**	DRY	3.57
7/24/2023	9:55:00 AM	GPC14.7	<0.094	108	0.316	0.921	1.237	0.202	9	23.55	8.17	8.7	666	13.2	**	**	DRY	3.41
8/9/2023	9:35:00 AM	GPC14.7	<0.094	72	0.173	0.89	1.063	0.164	7	22.79	7.77	8.05	657.8	10.1	**	**	DRY	4.81
8/23/2023	10:05:00 AM	GPC14.7	<0.094	92	0.247	0.523	0.77	0.173	7	24.69	8.16	8.18	648.5	8.1	**	**	DRY	2.18
9/13/2023	10:00:00 AM	GPC14.7	<0.094	7270	0.34	1.07	1.41	0.176	9	19.04	7.98	8.05	499.8	28	**	**	WET	10.7
10/18/2023	10:05:00 AM	GPC14.7	<0.094	116	0.053	0.799	0.852	0.236	1	10.62	8.32	10.77	***	5.6	**	**	DRY	7.21
Benchmark			0.025-0.050		<0.3	<0.3	<0.6	<0.08	<7.25	*			<522.5	<8.3	*	*		
Standard				<240							6-9	>4						

Note 1: Only results with gray shading were used for E.coli, TSS and Turbidity analysis. Numbers in red font indicate the value exceeds the established benchmark or standard

Note 2: March and April sampling was suspended in 2020 due to COVID-19. Safety measures were implemented to complete the May-Aug events

Red font indicates a result that exceeds the standard or benchmark

* indicates no established standard or benchmark

** No longer collecting this parameter

*** Instrumentation issue - not collected

Appendix C: Hydromodification Analysis for Site GPC 14.7

Gunpowder Creek

GPC 14.7

35.2 mi^2

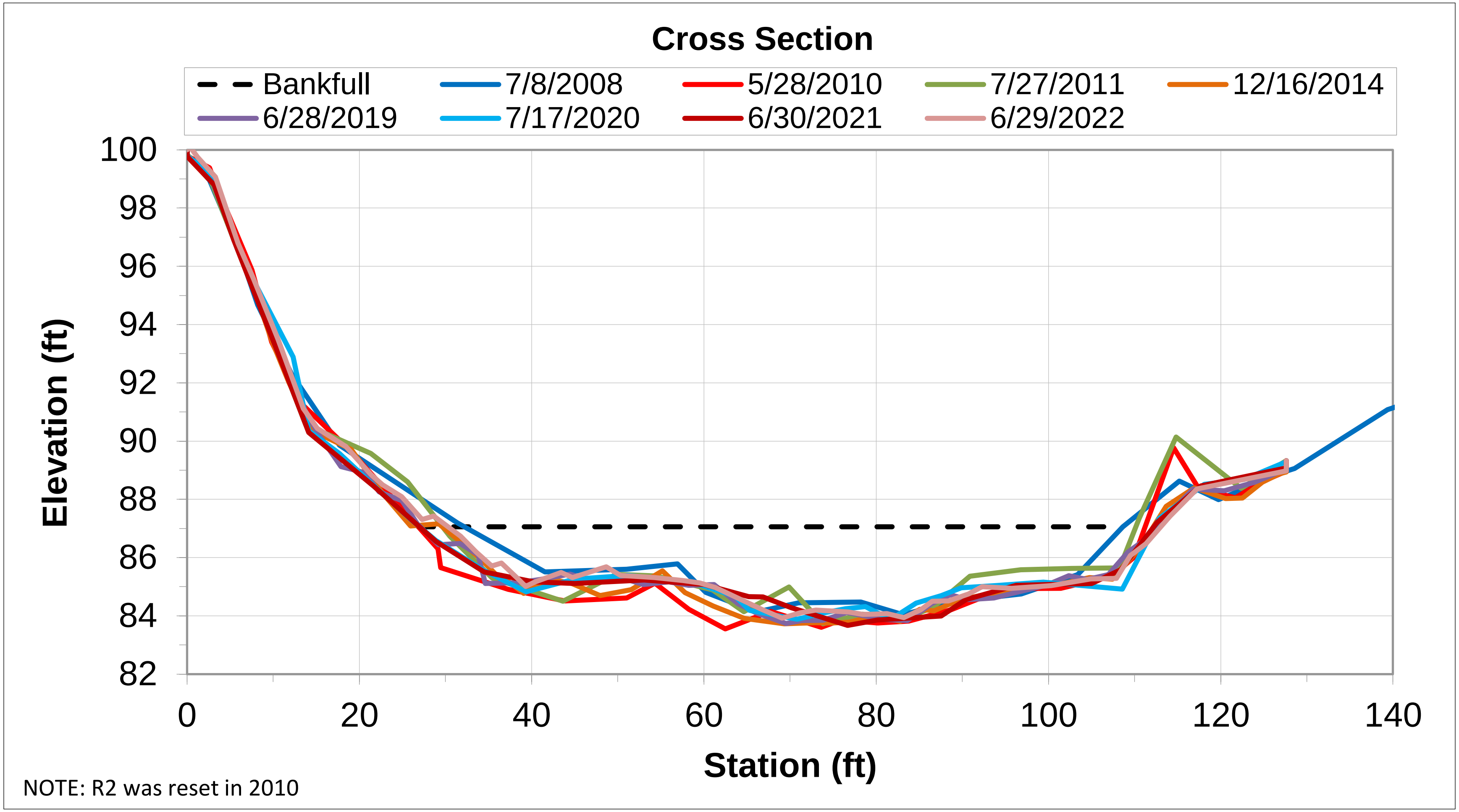
21.8% impervious [2016 NLCD Data]

GPC 14.7 was historically dynamic but may be showing signs of potential recovery (relatively stable cross section and accumulation of finer cobbles and gravels). Although headcutting from the downstream portion of the profile may still present a risk for future downcutting.

2010 – looking upstream

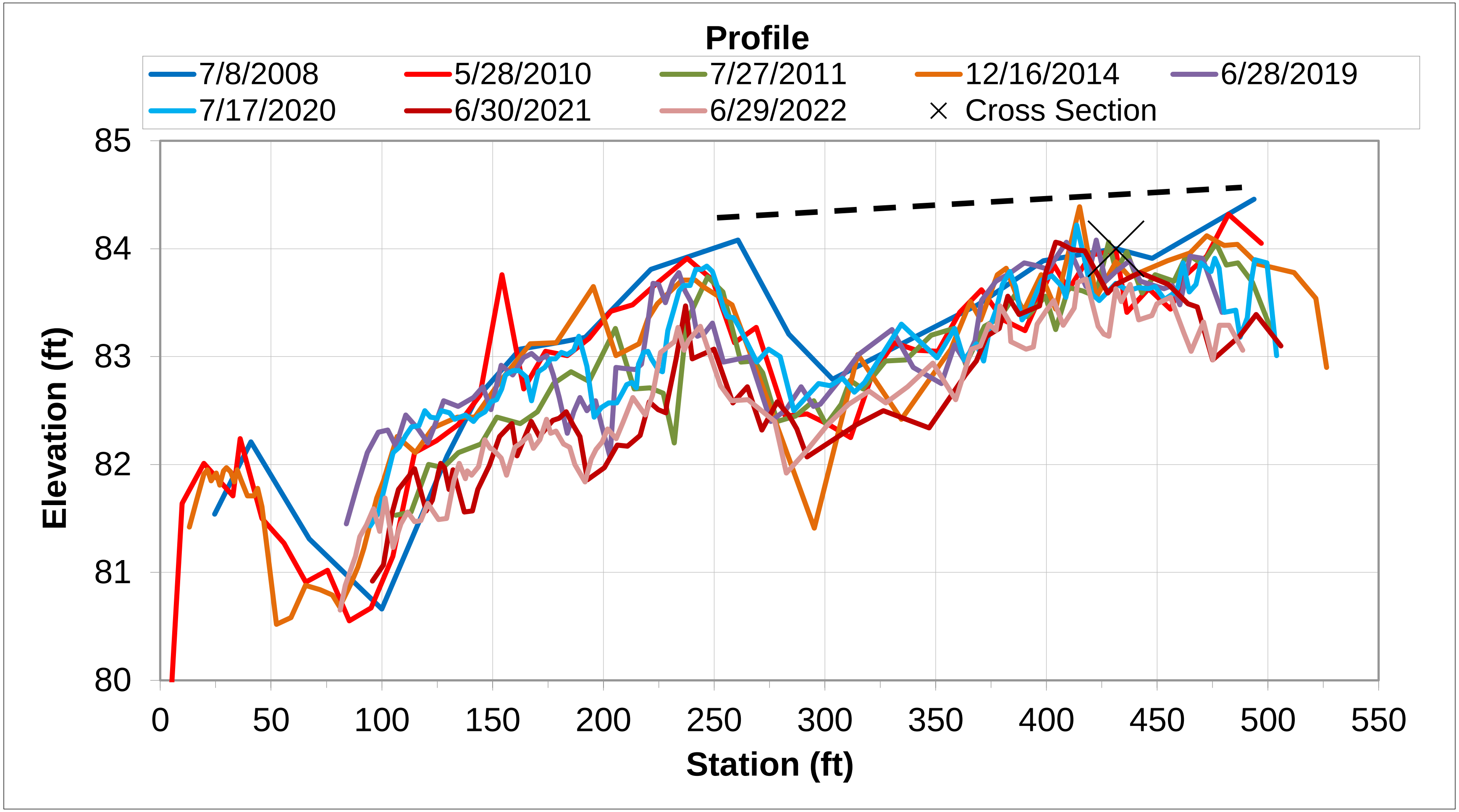
2022 – looking upstream

GPC 14.7



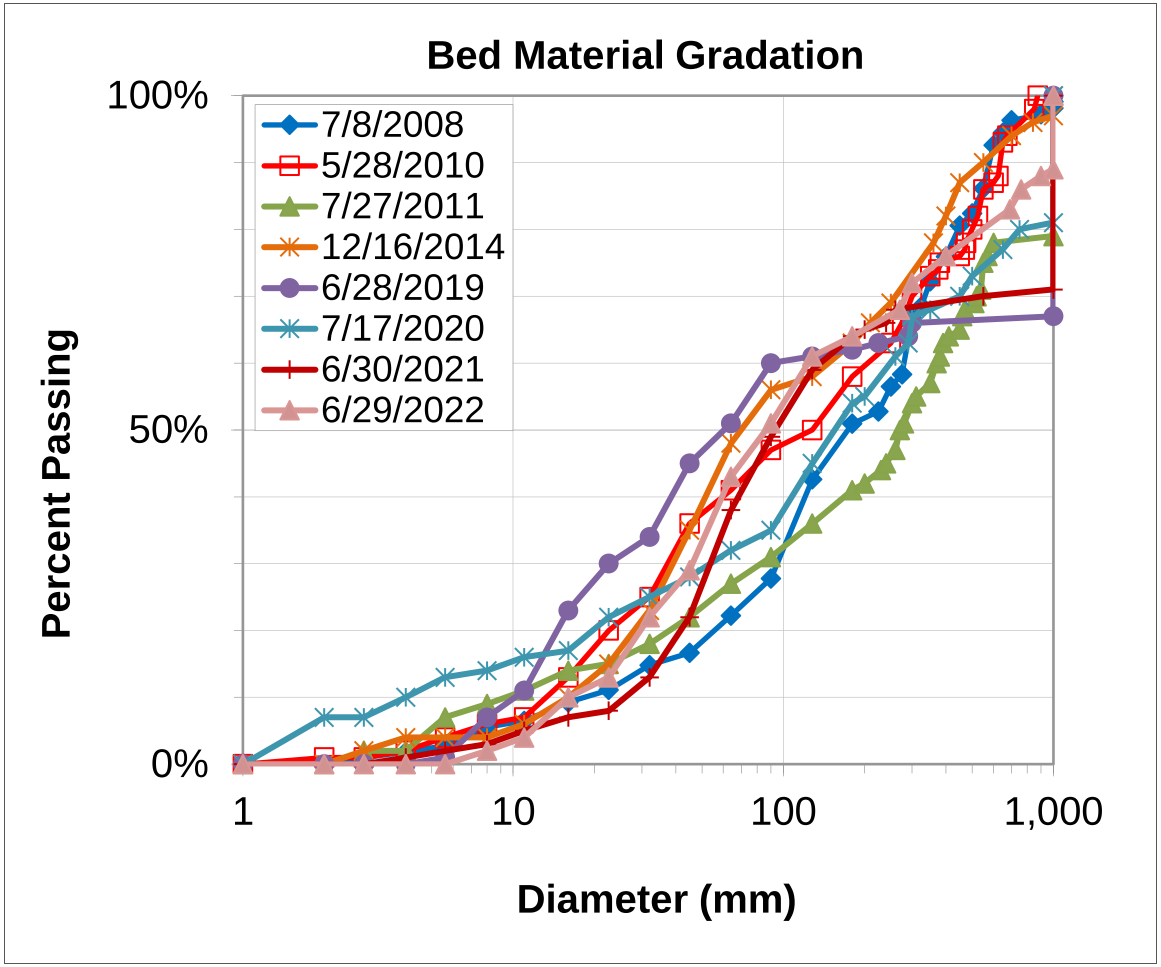
Cross Section
Bankfull
7/8/2008
5/28/2010
7/27/2011
12/16/2014
6/28/2019
7/17/2020
6/30/2021
6/29/2022
Elevation (ft)
100
98
96
94
92
90
88
86
84
82
0
20
40
60
80
100
120
140
Station (ft)
NOTE: R2 was reset in 2010

GPC 14.7



Profile
7/8/2008
5/28/2010
7/27/2011
12/16/2014
6/28/2019
7/17/2020
6/30/2021
6/29/2022
Cross Section
Elevation (ft)
85
84
83
82
81
80
0
50
100
150
200
250
300
350
400
450
500
550
Station (ft)

GPC 14.7



Bed Material Gradation
100%
50%
0%
Percent Passing
1
10
100
1,000
Diameter (mm)
7/8/2008
5/28/2010
7/27/2011
12/16/2014
6/28/2019
7/17/2020
6/30/2021
6/29/2022