Watershed Monitoring Report

Wolf Run Watershed
Fayette County, Kentucky

Prepared for
Kentucky Division of Water
200 Fair Oaks Lane
Frankfort, KY 40601

and

Lexington-Fayette Urban County Government
Division of Environmental Quality

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Environmental Analysis & Restoration

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I. BACKGROUND

Wolf Run was first listed as impaired for swimming use (non-support) in the 1998 303(d) list of Kentucky impaired waters. This impaired status has remained since that time with additional impairments (partial support of warmwater aquatic habitat use and non-support of secondary contact use) being identified in subsequent years (KDOW 2010a). The impairment of Wolf Run, in addition to other Lexington streams, led the US Environmental Protection Agency (USEPA) and the Kentucky Environmental and Public Protection Cabinet (KY EPPC) to file a lawsuit against Lexington in 2006 for violations of the Clean Water Act. The lawsuit was due to failure of the city to maintain the sanitary and storm sewer systems, which caused raw sewage discharges into streams. On March 14, 2008 Lexington-Fayette Urban County Government (LFUCG) entered into a Consent Decree in order to resolve this lawsuit (United States 2006). Within the Consent Decree, LFUCG agreed to make extensive improvements to its sewer systems and address sanitary sewer overflows and associated MS4 permit violations, as well as to reduce the discharge of pollutants via stormwater. With the Consent Decree in place, LFUCG is furthering its efforts to improve water quality in Wolf Run.

A federal grant under a Section 319(h) Nonpoint Source Implementation Program Cooperative Agreement (#C9994861-09) was awarded by the Commonwealth of Kentucky, Energy and Environment Cabinet, Department for Environmental Protection, Division of Water (KDOW) to LFUCG for development of a Wolf Run Watershed Based Plan. Third Rock was selected as the environmental consultant for work under this grant through a request for proposal issued by LFUCG. Friends of Wolf Run was also issued grant funding through a memorandum of agreement with LFUCG, primarily to engage, educate, and solicit input from the public during the development of this plan.

In the development of the Wolf Run Watershed Based Plan, all known and relevant existing information pertaining to the watershed was compiled and evaluated for data quality. The purpose of the data compilation and assessment was to thoroughly describe the Wolf Run watershed and to determine what additional data would be necessary in order to identify the impairments in the watershed and their causes and sources, to calculate the extent of the impairments, and to determine solutions for improving water quality. Based on this analysis, six major sampling needs were identified, which include:

- measurements to characterize the discharge hydrograph for the Preston Springs karst basin
- watershed conductivity survey
- macroinvertebrate collections on tributaries and headwaters
- watershed-wide habitat assessments
- hydrogeomorphic assessment of the watershed
- a water quality monitoring data set meeting the specifications of KDOW's "Watershed Planning Guidebook for Kentucky Communities" (KWA and KDOW, 2010)

A Quality Assurance Project Plan (QAPP) (Evans 2012c, Appendix A) was written to establish the quality criteria and collection process necessary to produce data which will fill the identified gaps and allow for the determination of the locations in the watershed in which BMPs will be most feasible, efficient, and effective. This report provides the results of the water quality monitoring conducted under this QAPP to meet the needs for the watershed.

II. METHODS

The objective of the water quality monitoring was to provide sufficient temporal and geographic data to evaluate the sources and loadings of water quality pollutants.

Water quality monitoring was conducted during 10 monthly sampling events at 12 sampling stations in the watershed during dry and wet conditions. The sampling period of 10 months was selected in order to evaluate at least one sample from all seasons. The 12 sampling stations (as described in Table 1 and shown on Exhibit 1, page 3) were selected in order to evaluate the relative contributions of the stream reaches throughout the watershed. The sampling date within each month was flexible in order to ensure at least two of the events were considered "wet-weather" and two were considered "dry-weather." As requested by the KDOW, representative conditions for "dry" and "wet" weather sampling were to be defined by an antecedent dry period (<0.1 inch precipitation recorded) of seven days. However, with the wettest year on record, the antecedent dry period was reduced to 72 hours with <0.1-inch precipitation recorded. Wet weather events were also conducted during the hydrographic rise during a rain event with a total accumulation of at least 0.1 inch. Additional sampling for *E. coli* was scheduled in order to obtain a total of five sampling events within 30 days during the primary contact recreation period (May 1 to October 31).

TABLE 1 – DESCRIPTION OF MONITORING LOCATIONS

SITE NAME	STREAM	LOCATION	LATITUDE	LONGITUDE	UPSTREAM AREA (ACRES)	UPSTREAM SITES
W01	Wolf Run	Old Frankfort Pike	38.067303	-84.554182	6614* **	All
W02	McConnell Branch	Prestons Cave	38.057333	-84.542169	418*	-
W03	Wolf Run	Valley Park	38.053742	-84.550782	3532**	W05, W06, W09, W10, W12
W04	Vaughn's Branch	Valley Park	38.054904	-84.549624	1966	W07, W08, W11***
W05	Cardinal Run	Devonport Drive	38.048594	-84.553867	1033**	-
W06	Wolf Run	Wolf Run Park	38.045274	-84.550661	2234	W09, W10, W12
W07	Vaughn's Branch	Pine Meadow Park	38.044927	-84.536148	1630	W08, W11***
W08	Vaughn's Branch	Picadome Golf Course	38.037453	-84.525057	575	-
W09	Wolf Run	Faircrest Drive	38.029954	-84.537091	1024	W12
W10	Springs Branch	Faircrest Drive	38.029855	-84.537196	428	-
W11	Big Elm Tributary	Harrodsburg Road	38.031245	-84.526027	581	-
W12	Wolf Run	Lafayette Parkway	38.022932	-84.528581	749	-

* Includes 402 acres of misbehaved karst in the Town Branch watershed that flow to McConnell Springs.
** Includes 121 acres of misbehaved karst in the South Elkhorn watershed that flow to the Kenton Blue Hole.
*** The Big Elm Tributary only flows into Vaughn's Branch under conditions of excessive rainfall when the Picadome sinkhole is overwhelmed.

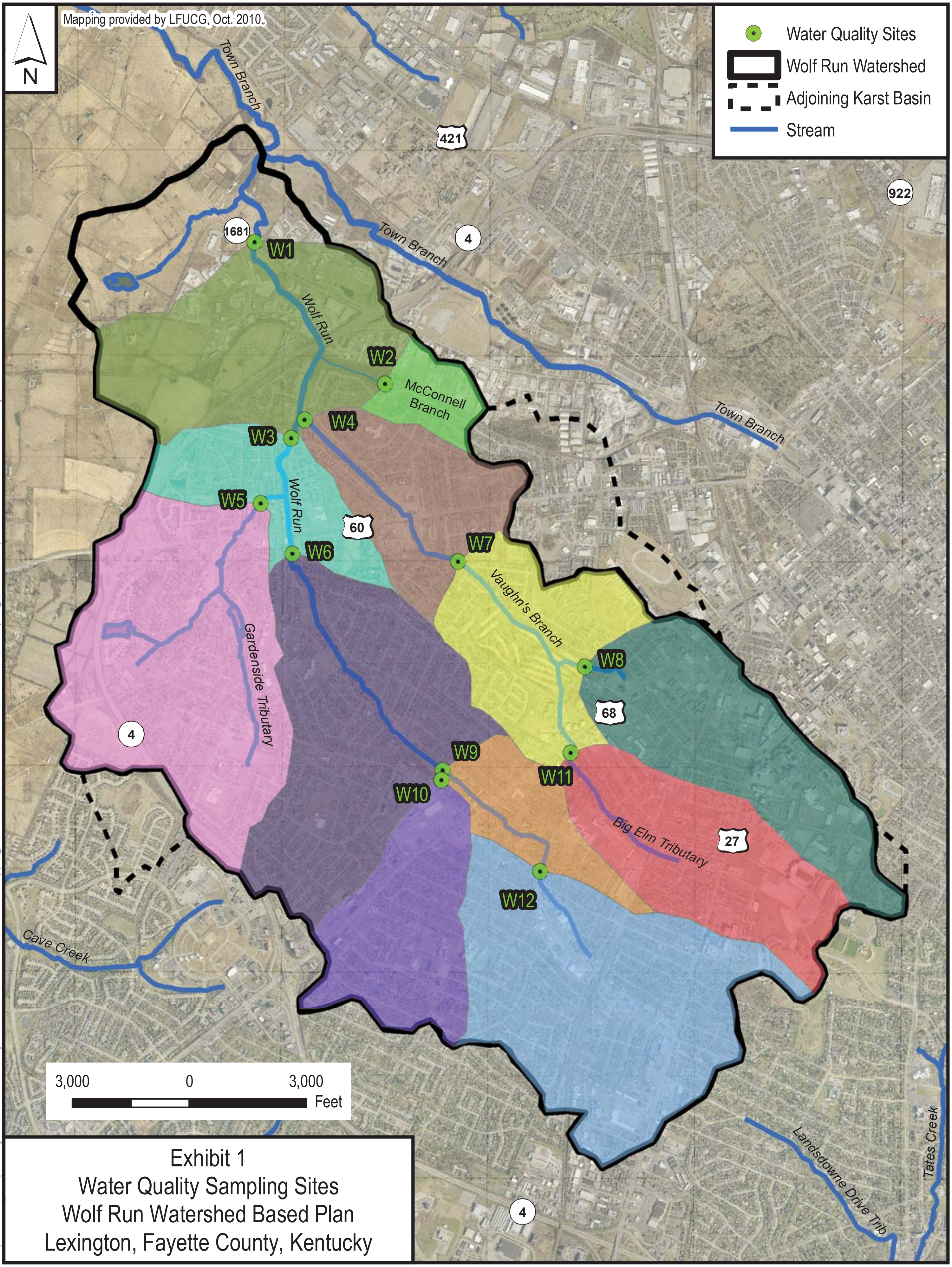


Exhibit 1
Water Quality Sampling Sites
Wolf Run Watershed Based Plan
Lexington, Fayette County, Kentucky

Map Document: (P:\Project_Files\Kentucky\KY10-030_LFUCG_WolfRunMapping\GIS\QAPP_Exhibits\QAPP_Exhibit_1_Sampling_Sites.mxd) 3/11/2011 -- 11:00:05 AM sje

During the monthly sampling, grab samples were collected by volunteers and delivered within six hours of collection to the LFUCG Town Branch laboratory for analysis of *E. coli*, fecal coliform, total suspended solids (TSS), ammonia, nitrite, total dissolved solids (TDS), alkalinity, and hardness. Samples for total phosphorus, ortho-phosphorus, total kjeldahl nitrogen, and nitrate were delivered to the Kentucky Geological Survey laboratory. Volunteers performed field measurements of turbidity, dissolved oxygen, specific conductance, temperature, and pH. Third Rock accompanied the volunteers during each event to conduct discharge monitoring, collect the field filtered ortho-phosphorus sample, and to provide monitoring oversight. Third Rock also performed the entire collections for two wet-weather sampling events.

Volunteers also collected an additional four events for *E. coli* and fecal coliform to evaluate the geometric mean for the primary contact period. A Third Rock staff member accompanied the volunteers during each event to conduct discharge monitoring. Only flow, *E. coli* and fecal coliform were collected during these events. The LFUCG Town Branch laboratory performed the analyses.

Flow measurements were conducted using a Marsh McBirney Flomate 2000 according to KDOW's *Measuring Stream Discharge Standard Operating Procedure* (KDOW 2010a). Grab sampling was conducted according to KDOW's *Sampling the Surface Water Quality in Lotic Systems* (KDOW 2011). One field duplicate sample was collected for all parameters per sampling event. For *in-situ* measurements, volunteers utilized sampling methods specified in the "the Watershed Watch Water Chemistry Sampling Methods for Field Chemistry and Lab Analysis." Third Rock utilized Hydrolab multimeters to record the dissolved oxygen, specific conductance, temperature, and pH for comparison to the volunteer data and for the wet weather events conducted without volunteers. The procedures specified in *In-situ* Water Quality Measurements and Meter Calibration Standard Operating Procedure (KDOW 2009) were used in those measurements. Field notes and chain of custody forms associated with data collection are included in Appendix B.

III. BENCHMARK COMPARISONS

In order to evaluate the nature and extent of impairments in the Wolf Run Watershed, results were compared to applicable water quality benchmarks. Both regulatory and non-regulatory benchmarks are applicable for this analysis.

A. Regulatory Benchmarks

The regulatory statute for surface waters in Kentucky is found in 401 KAR 10:031. The statute provides minimum water quality standards for all surface waters as well as specific standards that apply to particular designated uses. All streams monitored have designated uses of warmwater aquatic habitat (WAH), primary contact recreation (PCR), secondary contact recreation (SCR), and fish consumption (FC).

1. Warmwater Aquatic Habitat Standards

Warmwater aquatic habitat standards apply for the protection of productive warm water aquatic communities, fowl, animal wildlife, arboreous growth, agricultural, and industrial uses. The standards that are applicable to this program are listed in Table 2, page 5.

2. Recreational Standards

Recreational standards are divided into two types. Standards for PCR are applicable to full body contact during the recreation season of May 1 through October 31. SCR standards are applicable to partial body contact, with minimal threat to public health due to water quality, and these standards apply for the entire year. The

TABLE 2 – WARMWATER AQUATIC HABITAT STANDARDS

PARAMETER	WARMWATER AQUATIC HABITAT STANDARD
pH	Between 6.0 and 9.0 SU, and not to fluctuate more than 1.0 SU over 24 hours
Flow	Not be altered to a degree that will adversely affect the aquatic community
Temperature	Not to exceed 31.7°C (89°F)
Dissolved oxygen	Not less than 5.0 mg/L as a 24-hour average; or less than 4.0 mg/L for instantaneous measurements
Total dissolved solids or specific conductance	Not be changed to the extent that the indigenous aquatic community is adversely affected
Total suspended solids	Not be changed to the extent that the indigenous aquatic community is adversely affected
Un-ionized Ammonia*	Not greater than 0.05 mg/L*

*Un-ionized ammonia shall be determined from values for total ammonia as N, in mg/l, pH and temperature, by means of the equation: un-ionized ammonia (mg/L) = 1.2[Total ammonia as N / (1 + 10^{pKa-pH})], where pKa = 0.0902 +[2730/(273.2 +T_c)] and T_c = temperature, °C.

recreational standards applicable to this monitoring are fecal coliform and *E. coli*, as summarized in Table 3. For the purposes of this report, the units for reporting bacteria concentrations under different methods, colony forming units (CFU) and most probable number (MPN), will be considered equivalent.

TABLE 3 – *E. COLI* AND FECAL COLIFORM RECREATIONAL STANDARDS

PARAMETER	PCR STANDARDS (CFU/100MLS)		SCR STANDARDS (CFU/100MLS)	
	GEOMETRIC MEAN*	INSTANTANEOUS**	GEOMETRIC MEAN*	INSTANTANEOUS**
Fecal Coliform	200	400	1000	2000
E. coli	130	240	N/A	N/A

* Geometric mean based on not less than five samples taken during a 30-day period.
**Not to exceed in 20 percent or more of all samples taken during a 30-day period. If less than five samples are taken in a month, this standard applies.

3. *Other Standards*

The regulatory statute mentions nutrient limits for nitrogen, phosphorus, carbon, and contributing trace element discharges where eutrophication problems may exist. These limits apply to effluent limits for point source discharges. No in-stream numeric nutrient criteria have been developed and therefore the narrative criteria apply to these pollutants in-stream. The narrative criteria states that "substances … are chronically or acutely toxic to or produce adverse physiological or behavioral responses in humans, animals, fish, and other aquatic life; [or] produce undesirable aquatic life or result in the dominance of nuisance species."

B. *Non-Regulatory Reference Points*

Regulatory criteria are specified for parameters in which a given concentration of the pollutant is directly linked with impairment in the designated use. For other parameters, such as nutrients, specific conductance, TSS or TDS, no regulatory numeric standard has been established due to the variable relationship between biological integrity and concentration levels in different streams. Only narrative criteria have been established due to the difficulty in determining impairment thresholds for these parameters as well as the natural geographic variation of these parameters.

For example, certain levels of nutrients are required to support biological life in streams and are due to geologic and natural inputs. However, when nutrient levels are excessively high, heavy algal growth can reduce the amount of dissolved oxygen available for aquatic organisms to breathe. Many variables affect whether algal growth is present including nutrient concentrations, water flow, and exposure to sunlight. Therefore, establishing a threshold for nutrients independent of these other variables is difficult.

Excessive nutrient levels have other short and long-term effects on stream ecosystems besides episodic oxygen depletion. For the Wolf Run Watershed however, the ultimate goal is to restore the designated use of the watershed. Multiple factors are impacting warmwater aquatic habitat use of the watershed, including poor riparian and instream habitat and poor hydrology/ flow regime as well as elevated water quality parameters. Because of the uncertainty in assigning a definitive nutrient threshold as well as the feasibility and cost-effectiveness of reducing these concentrations, a phased approach towards non-regulatory water quality parameters has been utilized.

Using this phased approach, non-regulatory reference points are initially established higher than reference conditions since the reference levels may be well below the level necessary to restore support of the use. These target levels are established based the extent and magnitude of the problem as well as technological feasibility, cost, and achievability. The goals would be reassessed through the watershed planning process on regular time intervals and lowered if the designated use does not become fully supported through the implementation plan efforts when target levels are achieved. Table 4, page 7, lists the non-regulatory reference points for the Wolf Run Watershed. These levels were developed in consideration of the recommendations made by KDOW, are applicable only for the Wolf Run Watershed, and are not intended to have any regulatory use. A discussion of these reference points was held between LFUCG and KDOW on June 21, 2013 during which a detailed justification for alternate reference points was provided by LFUCG to KDOW. This document is included in Appendix D.

The nutrient levels (total phosphorus at 0.35 mg/L and total nitrogen at 3.0 mg/L) were each established between the 75th and 90th percentile concentrations for reference reaches in the Inner Bluegrass. The ammonia benchmark of 0.1 mg/L was near the 75th percentile for the Wolf Run data collected. These higher concentrations were utilized based on Pond *et al.* (2003), which indicates that nutrient concentrations are not well correlated with macroinvertebrate metrics in the Bluegrass Bioregion.

The main stem of the Ohio River has a specific conductance limit of 800 μS/cm, which was considered too high for this region. The benchmark of 650 μS/cm was established near the average of the Wolf Run sampling site medians. The TDS benchmark was derived based on the ratio to conductivity as measured in the study.

The TSS benchmark was established at 80 mg/L based on a number of studies that indicate that concentrations above this level impact fisheries (as listed in Rowe *et al.* 2003).

TABLE 4 – NON-REGULATORY REFERENCE POINTS

PARAMETER	BENCHMARK	PARAMETER	BENCHMARK
Total Phosphorus as P	0.35 mg/L	Specific Conductance	650 µS/cm
Total Nitrogen as N	3.0 mg/L	Total Dissolved Solids	373 mg/L
Ammonia (as N)	0.1 mg/L	Total Suspended Solids	80 mg/L

IV. DATA QUALITY

The quality of the data generated under this monitoring effort is evaluated in this section. The QAPP (Evans 2012c) established data quality objectives for accuracy, precision, and sensitivity are shown in Table 5. These objectives were established based on laboratory capabilities, industry standards, and KDOW recommendations. The conformance of the data to these objectives is discussed in the following sections as well use of non-conforming data.

TABLE 5 – ACCEPTANCE CRITERIA FOR WATER CHEMISTRY AND *IN-SITU* MEASUREMENTS

PARAMETER	UNITS	METHOD	ACCURACY (%R OR ±)	PRECISION* (% RPD)	SENSITIVITY (REPORTING LIMIT)
Dissolved Oxygen	mg/L	LaMotte	±1.5	20	0.5
Specific Conductance	µS/cm	Oakton	95-105	20	10
pH	SU	Watershed Watch	±0.5	20	NA
Water Temperature	˚C	Watershed Watch	±0.5	20	-5 to 45
Turbidity	Visual	Visual Observation	NA	NA	NA
Flow	cfs	DOWSOP03019	±0.05 ft/sec	N/A	0.01 ft/sec
Total Dissolved Solids	mg/L	EPA 160.1	80-120	20	10
Total Suspended Solids	mg/L	SM 2540 D	80-120	20	2
Total Alkalinity	mg/L $CaCO_3$	SM 2320 B	80-120	20	0
Hardness	mg/L $CaCO_3$	SM 2340 C	80-120	20	0
E. coli	MPN/100mLs	SM 9221 E	N/A	±0.5 log	1
Fecal Coliform	CFU/100mLs	SM 9221 F	N/A	±0.5 log	1
Orthophosphorous as P	mg/L PO_4-P	EPA 365.1	80-120	20	0.05
Phosphorus, Total as P	mg/L PO_4-P	EPA 365.2	80-120	20	0.02
Ammonia as N	mg/L NH_3-N	EPA 350.1	80-120	20	0.05
Nitrate as N	mg/L NO_3-N	EPA 300.0	80-120	20	0.02
Nitrite as N	mg/L NO_2-N	SM 4500-NO_2 B	80-120	20	0.02
Total Kjeldahl Nitrogen as N	mg/L TKN-N	SM 4500-Norg C	80-120	20	0.5

*Indicates minimum laboratory precision for all parameters except *in-situ* measurements. For *in-situ*, this indicates field precision.

A. Precision

The data precision for the water quality data is summarized in Tables 6 and 7, page 8. Precision was measured by internal laboratory duplicates as well as field duplicates. The precision of lab duplicates met the QAPP specifications for most parameters during the project. Total hardness, carbonaceous biochemical oxygen demand (cBOD), ammonia, nitrite, TKN, nitrate, orthophosphorus and total phosphorus each met the precision criteria in all sampling events. As expected the field duplicate samples showed greater variability due to the sampling environment.

TABLE 6 – EVALUATION OF LABORATORY PRECISION

PARAMETER	QAPP REQUIREMENT	RELATIVE PERCENT DIFFERENCE (%RPD) OR LOG DIFFERENCE BETWEEN VALUES															
		5/25	6/13	7/8	7/11	7/15	7/25	7/29	8/2	8/29	9/30	10/13	11/16	12/12	1/11	2/17	Average
Fecal Coliform	0.5 log difference	NA	NA	NA	NA	NA	0.20	0.11	0.15	NA	0.61	0.04	0.34	0.14	0.41	0.32	0.33
E. coli	0.5 log difference						0.13	Note	0.55	0.26	0.19	0.01	0.05	0.06	0.17	0.07	0.16
cBOD	20% RPD			Not Sampled		Not Sampled	Not Sampled	Not Sampled	Not Sampled	40%	67%	0%	0%	0%	0%	40%	21%
TSS	20% RPD									15%	46%	0%	0%	40%	6%	29%	20%
TDS	20% RPD									18%	28%	128%	37%	11%	8%	19%	36%
Alkalinity, Total	20% RPD									1%	5%	24%	11%	4%	8%	1%	8%
Total Hardness	20% RPD									1%	2%	0%	5%	1%	1%	1%	2%
Ammonia	20% RPD									0%	0%	1%	0%	15%	1%	0%	2%
Nitrite	20% RPD									0%	0%	0%	0%	0%	4%	29%	5%
TKN	20% RPD	2%	2%		0%					0%	0%	0%	0%	0%	0%	0%	0%
Nitrate	20% RPD	0%	0%		1%					0%	0%	1%	2%	2%	0%	2%	1%
Orthophosphorus	20% RPD	0%	0%		10%					3%	1%	0%	0%	1%	1%	3%	2%
Phosphorus, Total	20% RPD	0%	0%		11%					4%	0%	0%	3%	0%	5%	4%	3%

NOTE: *E.coli* duplicate sample result was rejected due to an error made by the sampling technician. Green indicates that the relative percent difference was higher than the DQO, but the actual difference is small due to low levels in the sample.

TABLE 7 – EVALUATION OF FIELD PRECISION

PARAMETER	UNITS	RELATIVE PERCENT DIFFERENCE (%RPD) OR LOG DIFFERENCE BETWEEN VALUES															
		5/25	6/13	7/8	7/11	7/15	7/25	7/29	8/2	8/29	9/30	10/13	11/16	12/12	1/11	2/17	Average
Fecal Coliform	log difference	0.26	0.07	0.28	0.07	0.23	0.42	0.55	0.00	0.61	0.18	0.66	0.12	0.00	0.88	0.19	0.28
E. coli	log difference	0.16	0.36	0.12	0.11	0.24	0.03	Note	0.49	0.19	0.43	0.49	0.15	0.00	0.46	0.31	0.25
cBOD	% RPD	29%	0%	Not Sampled	29%	Not Sampled	Not Sampled	Not Sampled	Not Sampled	0%	0%	10%	33%	50%	15%	0%	17%
TSS	% RPD	86%	67%		18%					5%	141%	16%	67%	57%	3%	40%	50%
TDS	% RPD	2%	3%		49%					27%	38%	11%	21%	1%	67%	2%	22%
Alkalinity, Total	% RPD	16%	11%		3%					2%	2%	4%	9%	1%	4%	10%	6%
Total Hardness	% RPD	2%	6%		3%					3%	2%	9%	13%	1%	27%	7%	7%
Ammonia	% RPD	0%	4%		6%					42%	0%	29%	5%	0%	1%	50%	14%
Nitrite	% RPD	0%	0%		0%					0%	13%	100%	7%	64%	0%	0%	18%
TKN	% RPD	3%	0%		0%					0%	0%	0%	0%	0%	0%	0%	0%
Nitrate	% RPD	0%	132%		4%					0%	4%	67%	6%	0%	8%	0%	22%
Orthophosphorus	% RPD	0%	0%		0%					28%	1%	0%	2%	1%	2%	0%	3%
Phosphorus, Total	% RPD	4%	0%		4%					17%	23%	13%	0%	10%	14%	21%	11%

NOTE: *E.coli* duplicate sample result was rejected due to an error made by the sampling technician. Green indicates that the relative percent difference was higher than the DQO, but the actual difference is small due to low levels in the sample.

Fecal coliform, *E. coli*, TSS, and TDS did not meet the QAPP requirements for laboratory precision for one or more events. For several parameters (cBOD on August 29, September 30, and February 17; TSS on December 12 and February 17; total alkalinity on October 13; and nitrite on February 17), results were acceptable because although the relative percent difference was higher that 20 percent, the actual difference was small due to results near the reporting limit. Fecal coliform (September 30) and *E. coli* (August 2) each had one event in which the log difference between the sample and duplicate was greater than 0.5 log MPN/100 mLs. On July 29, the *E.coli* duplicate sample result was rejected due to an error made by the sampling technician, and on August 29 a fecal coliform duplicate result was not supportable. Total dissolved solids had the most exceedances of the laboratory precision criteria with three events (September 30, October 13, and November 16) that exceeded the criteria, while TSS had one exceedance.

For the first three sampling events, the LFUCG Town Branch laboratory did not analyze internal laboratory duplicates for fecal coliform, *E. coli*, cBOD, TSS, TDS, total alkalinity, total hardness, ammonia, and nitrite. The laboratory was notified of the error and rectified it after the July 15 sampling event. Field duplicates were analyzed during each of these events, and all met the requirements with the exception of total dissolved solids on July 11.

An inter-laboratory study was conducted on July 8, 2011 between the University of Kentucky Environmental Research and Training Laboratory (UK ERTL), Microbac Laboratory Services, and LFUCG Town Branch Laboratory with sampling performed by the Friends of Wolf Run. The results, as shown in Table 8, indicate that the maximum log difference between laboratories was 0.38 log MPN/100mLs.

TABLE 8 – EVALUTATION OF INTER-LABORATORY PRECISION FOR *E. COLI* SAMPLES COLLECTED JULY 8, 2011

SITE ID	MICROBAC	UK ERTL	LFUCG-TB	MICROBAC	UK ERTL	LFUCG-TB	MAXIMUM LOG DIFFERENCE
	(MPN/100MLS)			(LOG MPN/ 100MLS)			
W01	24,000	24,192	32554	4.38	4.38	4.51	0.13
W02	24,000	>24,192	21426	4.38	4.38	4.33	0.05
W03	24,000	>24,192	34480	4.38	4.38	4.54	0.16
W04	24,000	>24,192	29093	4.38	4.38	4.46	0.08
W05	17,000	12,997	12809	4.23	4.11	4.11	0.12
W06	20,000	24,192	13169	4.30	4.38	4.12	0.26
W07	13,000	11,199	15525	4.11	4.05	4.19	0.14
W08	20,000	>24,192	17216	4.30	4.38	4.24	0.14
W09	16,000	17,329	17233	4.20	4.24	4.24	0.04
W10	8,200	8,664	7328	3.91	3.94	3.86	0.08
W11	11,000	24,192	26125	4.04	4.38	4.42	0.38
W12	8,200	12,033	9599	3.91	4.08	3.98	0.17

Based on comparison of the field and laboratory precision quality indicators, total suspended solid results from September 30th have been rejected due to high variability in both the field and laboratory duplicates. Due to poor precision in both laboratory and field precision, the results for total dissolved solids will be only used for site screening and not for loading calculations under this study. Fecal coliform and *E. coli* events with laboratory duplicates with differences above the criteria are used with qualification. Averages of all field and laboratory duplicates were used in the data analysis and load reduction calculations presented subsequently in this document for all acceptable results.

The precision for field measurements is shown in Table 9 for flow and in Table 10 for dissolved oxygen, pH, conductivity, and water temperature. All field measurements met the precision requirements for the project. Although the flow measurements were above 20 percent precision during three events, the actual difference between the measurements was small. *In-situ* measurements using field kits by the Friends of Wolf Run were duplicated by Third Rock with Hydrolab readings. Results indicating good quality from the field measurements using volunteer measurements. The Friends of Wolf Run volunteer sampling structure, which pairs volunteer samplers with several years of experience with less experienced volunteer samplers, has ensured consistency amongst measurements for the project.

TABLE 9 – PRECISION OF FLOW MEASUREMENTS

DATE	5/25	6/13	7/8	7/11	7/25	7/29	8/2	8/29	9/30	10/13	1/11	2/17
Site	W10	W04	W12	W09	W05	W06	W08	W11	W07	W07	W12	W4
Original	1.5	0.02	21.5	0.4	0.1	0.3	0.5	0.00	0.04	9.1	23.8	0.52
Duplicate	1.8	0.05	22.6	0.5	0.1	0.3	0.5	0.00	0.10	9.1	20.8	0.51
Duplicate %RPD	18%	86%	5%	22%	0%	0%	0%	0%	86%	0%	13%	2%

TABLE 10 – *IN-SITU* MEASUREMENT PRECISION BY PARAMETER

COMPARISON	QAPP REQUIREMENT	DISSOLVED OXYGEN	pH	CONDUCTIVITY	WATER TEMPERATURE
Number of Duplicates	10	37	40	46	35
Maximum %RPD	20%	18%	6%	12%	15%
Median %RPD		4%	1%	6%	4%

B. Accuracy

The accuracy of the monitoring data is summarized in Table 11, page 11. For most parameters, the percent recovery of internal laboratory control samples of known value met the project quality specifications. However, cBOD, TDS, and nitrite had some non-conformances from the QAPP specifications.

As previously mentioned, the QAPP (Appendix A) specifies that accuracy is to be measured by an internal QC sample of known value to be analyzed for all parameters. No known samples were analyzed by the LFUCG Town Branch Laboratory for TDS or nitrite during the first three events. The laboratory was notified of the error and analysis began in August for these parameters.

For cBOD, the laboratory analyzes two GGA (glucose + glutamic acid) samples of 198 mg/L expected concentration with every batch of samples. As cBOD samples have a 48-hour hold time and a five-day analysis period, laboratories cannot reanalyze samples when results do not meet quality criteria. For all events except the February 2012 event, at least one GGA sample met the QAPP criteria of 80 to 120 percent. Results with one failed GGA sample were qualified and used in the analysis, but the February 2012 results were rejected due to the low recovery on both known samples.

TABLE 11 – EVALUATION OF DATA ACCURACY

PARAMETER	QAPP	5/25		6/13		7/11		8/29		9/30		10/13		11/16		12/12		1/11		2/17	
cBOD	80-120%	69	92	84	64	109	83	83	65	71	97	95	83	81	96	77	98	75	80	62	59
TSS	80-120%	97		98		83		96		86		101		88		87		99		97	
TDS	80-120%	Not Analyzed						101		72		114		85		96		92		112	
Alkalinity, Total	80-120%	101		100		102		100		100		106		102		101		100		104	
Total Hardness	80-120%	102		93		95		101		99		99		98		102		102		99	
Ammonia	80-120%	106	99	103	98	105	102	108	100	99	110	100	97	103	103	105	92	107	99	116	96
Nitrite	80-120%	Not Analyzed						97		105		78		123		108		111		131	
TKN	80-120%	99	102	98	97	100	106	105	106	98	105	98	107	97	92	99	91	102	103	103	104
Nitrate	80-120%	108	108	98	97	98	99	99	95	98	106	98	109	100	103	96	98	103	104	91	109
Orthophosphorus	80-120%	101	100	105	99	102	101	94	94	104	104	99	100	106	99	103	100	103	104	103	104
Phosphorus, Total	80-120%	99	99	105	105	94	94	102	102	102	102	102	102	100	100	93	94	105	108	99	98

For total dissolved solids, the September event had a low recovery of 72 percent. Sample results associated with this event are rejected from the analysis due to the low recovery. For nitrite, accuracy exceeded QAPP criteria during events in October, November and February at 78 percent, 123 percent, and 131 percent recovery, respectively. These results will be qualified and used to calculate the total nitrogen for these events.

C. *Other Quality Concerns*

All results were analyzed according to the specified methods and met the sensitivity requirements of the QAPP (Appendix A). The sampling also met the completeness requirements with two wet weather events and two dry weather events sampled for the period and five *E. coli* samples collected within 30 days. As previously mentioned, a technician error on six *E. coli* samples of July 29 initiated an additional sampling event on August 2 to meet the sampling requirement.

Some samples were rejected or replaced due to known or suspected quality issues during the analysis. A typographic error was suspected on the specific conductance measurement of 210 µS/cm at W08 on August 29. The site was re-sampled the following day with a measurement of 1170 µS/cm. This re-sampling was used in the data analysis. Orthophosphorus samples collected on August 29 were not field-filtered, and therefore the results have been rejected from the analysis.

Another issue identified by KDOW is the analysis of samples collected under pooled conditions. During the June 13, 2011 dry weather event, W11 was completely dry, while W07, W08, W12 were sampled under pooled conditions. Site W07 was also pooled on July 15, 2011 when a sample was collected at this location for *E. coli* and fecal coliform. Field personnel were notified and did not collect samples under pooled conditions for the remainder of the project. Pooled samples were reject and not utilized in the data analysis.

Although not a quality concern, the time required to perform the field dissolved oxygen measurement is typically the time limiting measurement at each site and can discourage the participation of volunteers. In order to improve sampling efficiency, the Friends of Wolf Run have purchased field dissolved oxygen meters and worked throughout the project to develop a process for calibrating and validating their use. Although these meters were never used during the sampling, they should improve the time required for sampling during future events.

This project was also unique in that the sampling efforts were coordinated between consultant staff and volunteer samplers. It is believed that the collaboration between the volunteers and consultants enhanced the experience of the volunteers and provided additional insight into their understanding of stream water quality and sampling methodology. As a result of the collaborative experience, new field equipment has been purchased for volunteer use and should improve future efforts. However, the scheduling of sampling activities with volunteers and consultants proved challenging due to conflicts in time availability.

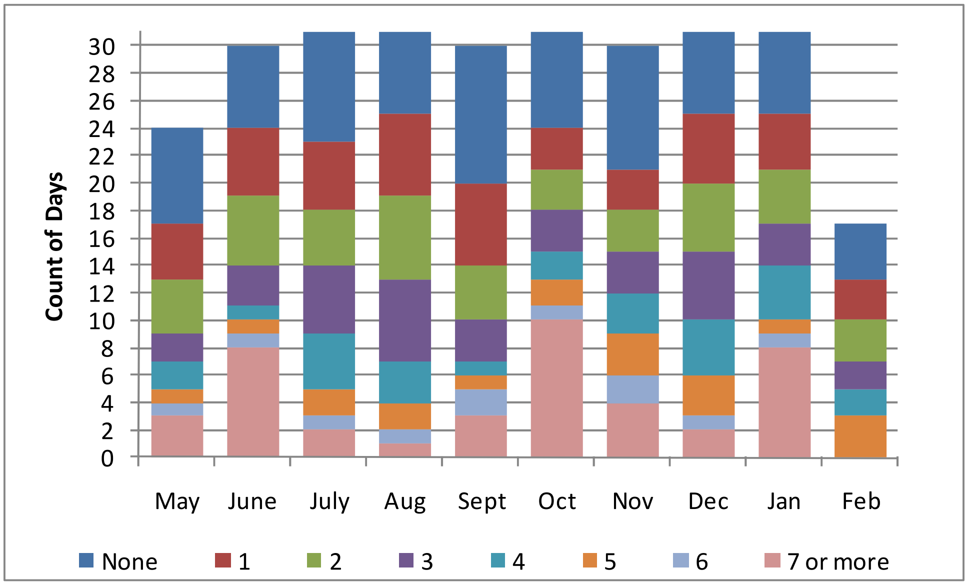
V. RESULTS

Monitoring was conducted on 15 days from May 25, 2011 to February 17, 2012 at the locations shown in Exhibit 1, page 3. The results for the water quality monitoring are summarized in the following sections. Field notes and chain of custody forms associated with data collection are included in Appendix B. Detailed breakdowns of the monitoring results by site are located in Appendix C. Results of all laboratory and field duplicates have been averaged for use in this analysis.

A. Antecedent Conditions

The monitoring was conducted between May 2011 and February 2012. Year 2011 was the wettest year on record for Fayette County, presenting unique challenges for water quality sampling. Figure 1, page 13, indicates the length of time (in days) prior to each day of the month in which the cumulative rainfall was less than 0.1 inch. Only 14 percent of days within the entire monitoring period had an antecedent dry period of seven days, which was originally specified in the QAPP per KDOW's recommendation. With these specifications, sampling could only be conducted on four days within a month, making coordination difficult, particularly for wet weather conditions that can occur in evenings or on weekends. Additionally, the headwater site on the Big Elm Tributary (W11) is dry after a seven-day dry period. Therefore, a three-day (72-hour) antecedent dry period was used to define wet and dry weather events. These dry conditions occurred on 46 percent of the days within the monitoring period. Wet events of over 0.1 inch of precipitation occurring after a three-day (72-hour) antecedent dry period occurred on 12 percent of the days in the monitoring period. Events conducted less than 72 hours after precipitation of more than 0.1 inch, which occurred during 42 percent of the period, were categorized as intermediate events.

FIGURE 1 – MONTHLY ANTECEDENT DRY PERIOD LENGTHS FOR THE MONITORING PERIOD



NOTE: Precipitation values based on KLEX weather station data from http://www.wunderground.com. Values indicate the length of time (in days) prior to each day of the month in which the cumulative rainfall was less than 0.1 inches.

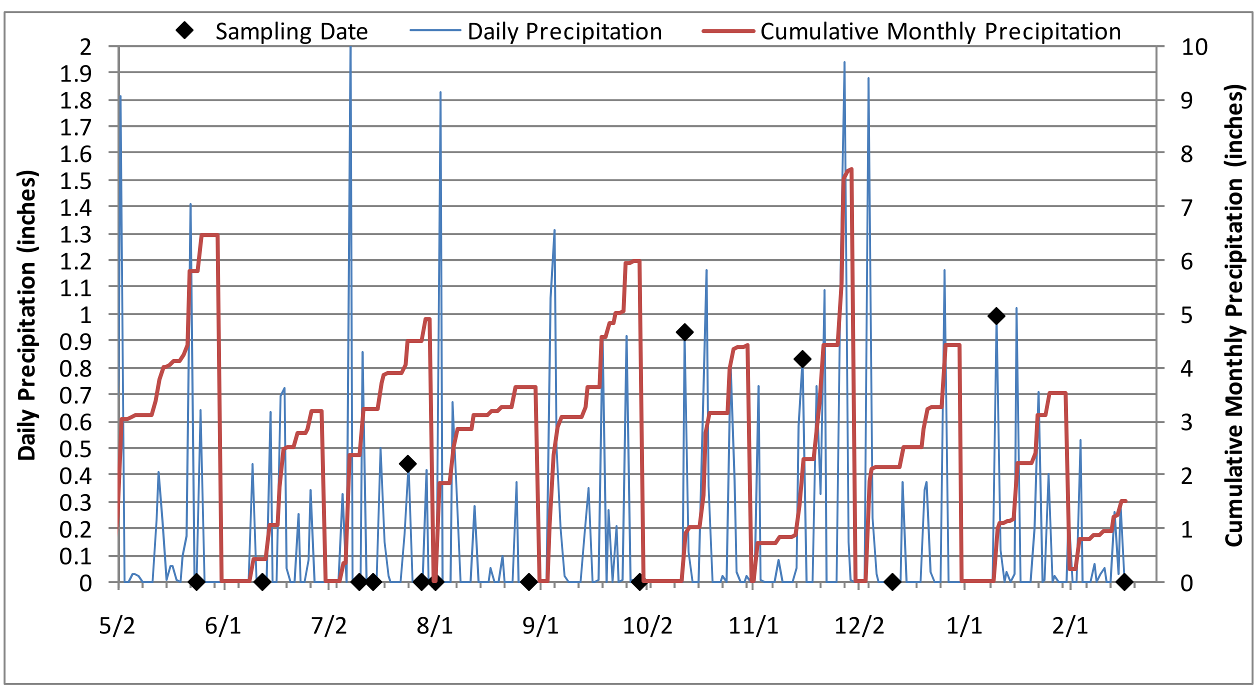
Water quality sampling events were collected on the dates shown in Table 12 and in Figure 2, page 14. Table 12 indicates the prior rainfall based on the closest USGS gage (03289200) located in the Town Branch watershed at Yarnallton Road that recorded precipitation in five-minute intervals. Figure 2 shows the sampling events in relation to the daily precipitation and cumulative monthly rainfall, as recorded at the KLEX airport in the North Elkhorn watershed. Monthly sampling included four dry-weather sampling events, two wet-weather events, and four intermediate events, one of which was conducted during rainfall. The low cumulative rainfall results (shown in Table 12) prior to the wet weather sampling are due to initiation of the wet weather event at the beginning of the hydrographic rise within the watershed. The *E. coli* geomean sampling events are categorized as five intermediate events (one conducted during rainfall) and one dry event. Due to a laboratory error on six of the samples collected on intermediate July 29 event, and re-collection event was performed on August 2 at the six sites to allow for the geomean calculations.

TABLE 12 – SAMPLING DATES AND EVENT TYPES

Date	Event	Cumulative Rainfall in Prior:		
		7 days	72 hours	24 hours
5/25/2011	Intermediate	2.1	1.69	0.03
6/13/2011	Dry	0.08	0.08	0
7/8/2011	*E.coli* - Intermediate while Raining	1.68	1.41	0.99
7/11/2011	Intermediate	3.86	2.46	0
7/15/2011	*E.coli* - Dry	2.52	0.08	0
7/25/2011	*E.coli* - Intermediate	1.51	1.39	1.39
7/29/2011*	*E.coli* - Intermediate	2.5	1.11	1.11
8/2/2011*	*E.coli* - Intermediate	1.78	0.67	0
8/29/2011	Dry	0	0	0
9/30/2011	Dry	1.34	0	0
10/13/2011	Wet	0.01	0.01	0.01
11/16/2011	Intermediate while Raining	1.25	1.22	0.85
12/12/2011	Dry	1.51	0	0
1/11/2012	Wet	Trace**	Trace**	0
2/17/2012	Intermediate	0.38	0.21	0

NOTE: Precipitation records are based on USGS gage 03289200 Town Branch at Yarnallton Road.
*Sampling on 8/2 occurred due to laboratory error at 6 sites during analysis of the 7/29 event.
Precipitation data from the USGS gauge for this period could not obtained. Trace precipitation was recorded from the KLEX weather station.

FIGURE 2 – PRECIPTATION DURING MONITORING PERIOD



NOTE: Precipitation values based on KLEX weather station data from http://www.wunderground.com.

B. *In-situ Measurements*

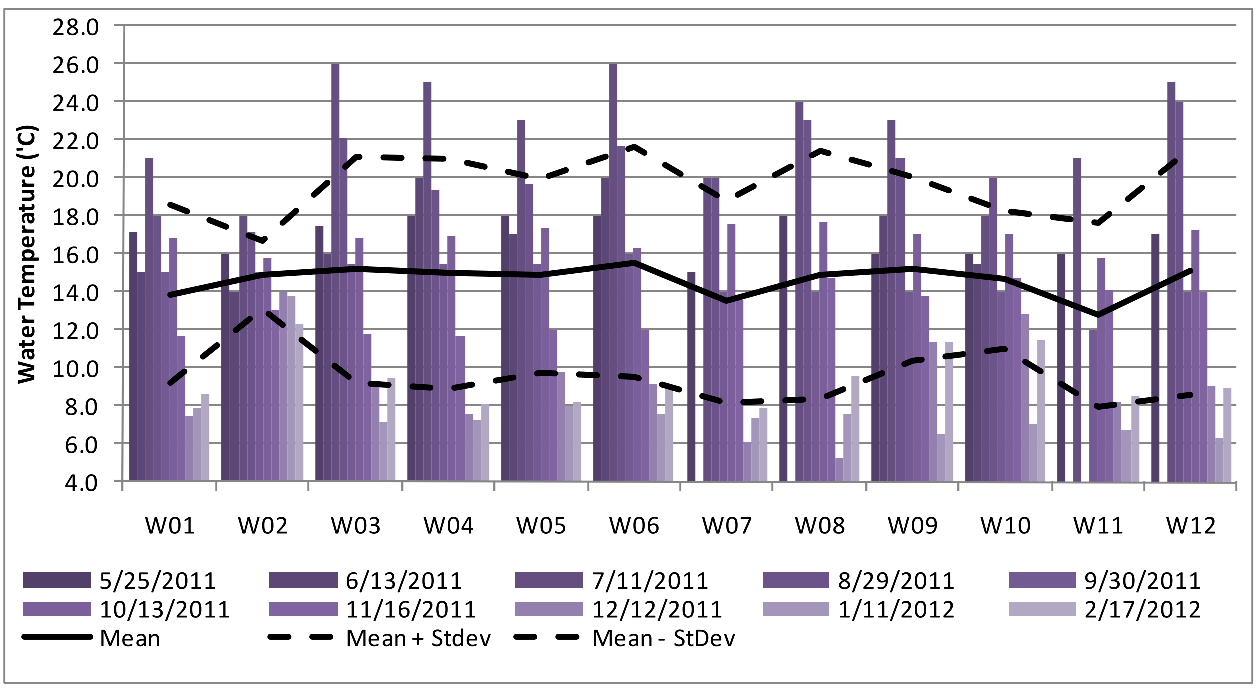
In-situ measurements (which include water temperature, pH, dissolved oxygen, specific conductance, and a visual observation of turbidity) were performed by Friends of Wolf Run volunteers at each site. Third Rock utilized a Hydrolab multimeter to perform such readings and to evaluate the data quality of the volunteer measurements. Where multiple measurements were recorded, an average of the results was utilized for analysis purposes.

Results of the *in-situ* measurements are discussed in the following sections with the exception of specific conductance, which is discussed in conjunction with TDS.

1. *Water Temperature*

Water temperature ranged from 5.3˚C (41.5˚F) at W08 on January 11, 2012 to 26.0˚C (78.8˚F) at W12 on July 11, 2011. Results for each site are shown in Figure 3 along with the mean and standard deviation from the mean. All values are below the warmwater aquatic habitat maximum of 31.7°C (89°F). For the period sampled, the greatest variability in temperature was shown at W08 and W12 due to the shallow bedrock nature of these streams. These sites, as well as W03 and W06, were also slightly warmer than other sites on average. Sparse canopy coverage of the wide, shallow streams contribute to these higher averages. W02, located at Preston's Cave, had the least variability in temperature measurements due to the groundwater flow source regulating temperature fluctuations.

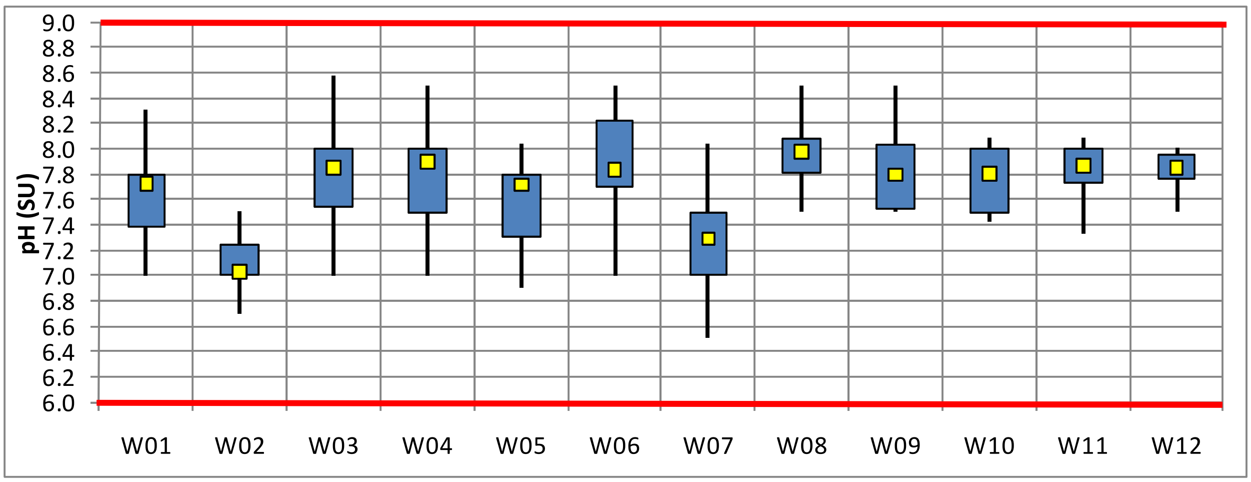
FIGURE 3 – WATER TEMPERATURE FOR WOLF RUN WATER QUALITY SITES



2. *pH*

A boxplot of the pH values for each site is shown in Figure 4. The pH values ranged from a maximum of 8.6 SU at W03 on August 29, 2011 to a low of 6.5 measured at W07 on December 12, 2011, each measured under dry conditions. Thus, all values were within the warmwater aquatic habitat standards of 6.0 to 9.0 SU, although the upper threshold was approached. The limestone bedrock geology and heavy algal growth in some areas are suspected as contribute to the higher pH levels observed in the watershed.

FIGURE 4 – *IN SITU* PH RANGES FOR WOLF RUN WATER QUALITY SITES



NOTE: Yellow dot indicates the median value. Boxes indicate the middle 50% of the results while the lines indicate the maximum and minimum values measured at each site. Red lines indicate the maximum and minimum regulatory values.

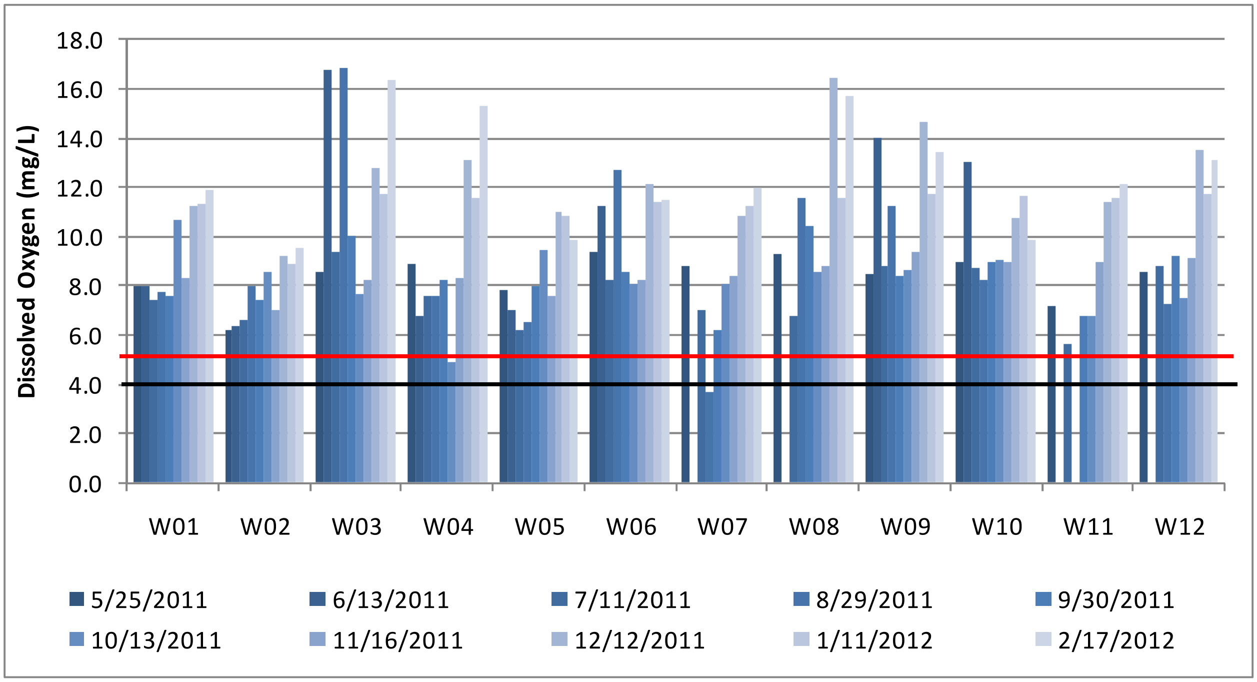
3. *Dissolved Oxygen*

As shown in Figure 5, page 17, dissolved oxygen levels were detected below the instantaneous water quality limit (4.0 mg/L) once on August 29, 2011 at W07 and was once found below the chronic water quality limit (5.0 mg/L) at W04. All other measurements meet the minimum water quality standard. Measurements were recorded between 7:30 AM and 2:20 PM at all sites, so diurnal drops in dissolved oxygen may not have been detected during the time period measured.

Aquatic plants and algae, which produce oxygen during the day through photosynthesis, consume dissolved oxygen after sunset, when no photosynthesis occurs. If a large volume of aquatic plant material is present in the stream, the plants may use so much dissolved oxygen that conditions toxic to aquatic life are produced at night. Additionally, abundant decaying plant matter leads to excessive oxygen use during bacterial decomposition. Fish require at least five to six mg/L of dissolved oxygen for normal activity. Levels below four mg/L are stressful, and levels below two mg/L are lethal.

Average dissolved oxygen levels ranged from 7.8 mg/L at W02 to 11.8 mg/L at W03. The consistently lower levels measured at W02 are due, in part, to lower oxygen levels in the groundwater system. The highest dissolved oxygen levels recorded, 22.0 mg/L at W12, occurred along with the highest pH levels measured. Algal growth was extremely abundant at the site during the measurements and bubbles from the algae could be observed in the near-stagnant water.

FIGURE 5 – DISSOLVED OXYGEN FOR WOLF RUN WATER QUALITY SITES



NOTE: The black line indicates the chronic water quality standard of 5.0 mg/L and the red line the instantaneous standard of 4.0 mg/L.

4. *Turbidity*

Turbidity was visually assessed on a scale from 0 (clear) to 3 (turbid) during each field visit. During dry and intermediate sampling events, all sites were scored either 0 or 1 during all events, except for the July 11, 2011 event at W07 that was scored as 3. The total suspended solid result was 78 mg/L at W07 on that date indicating a source of sediment input on Vaughn's branch on that date. During wet weather events, most sites were scored as 3, although some lower scores were recorded.

C. Flow Measurements

In-stream flow was measured concurrent with grab sample collections for each event. The results of these measurements are shown in Table 13, page 18. The Wolf Run watershed is very flashy, with streams quickly rising and failing in response to rain events. The high percentage of impervious surface in the watershed causes increased runoff volume and velocities in the watershed. The high percentages of impervious surface, as well as the karst geology of the watershed, also contribute to frequent dry or low flow conditions in the watershed, particularly in the headwaters.

One example of the flashy nature of the watershed is illustrated by the July 8, 2011 sampling event. Sampling was completed at all sites within a 2.5-hour period during rainfall. While discharge from the mouth of the watershed measured only 36.2 cfs, flow levels as high as 173 cfs were measured in the headwaters just 37 minutes later.

Wet weather conditions are typically one to two orders of magnitude higher than dry weather conditions. Also, during dry weather conditions, the groundwater flow from Preston's Cave (W02) represents a much greater percentage of the flow contribution at the mouth of the watershed due to the karst re-direction of surface flow from the headwaters of Vaughn's Branch and Wolf Run into the groundwater system. Because flow at W02 is primarily due to groundwater sources, the difference between wet and dry weather flows is much less than at other locations in the watershed.

TABLE 13 – FLOW MEASUREMENTS FOR ALL EVENTS

DATE	EVENT	FLOW (CFS)											
		W01	W02	W03	W04	W05	W06	W07	W08	W09	W10	W11	W12
5/25/11	Intermediate	30.6	10.3	11.5	1.6	5.0	7.0	0.5	0.7	1.0	1.5	2.3	1.4
6/13/11	Dry	2.7	1.3	0.5	0.02	0.4	0.4	Pooled	Pooled	0.3	0.01	Dry	Pooled
7/8/11	Intermediate while Raining – *E. coli*	36.2	15.6	Too Fast	Too Fast	Too Fast	Too Fast	9.7	173.0	Too Fast	20.6	Too Fast	21.5
7/11/11	Intermediate	7.8	4.2	3.0	0.4	1.4	1.6	0.2	0.3	0.4	0.6	0.6	0.02
7/15/11	Dry – *E. coli*	6.3	3.9	0.2	1.7	0.5	1.1	Pooled	0.04	0.1	0.4	0.2	0.05
7/25/11	Intermediate – *E. coli*	6.3	4.0	8.7	2.8	0.1	3.1	3.9	3.0	2.0	0.9	1.6	1.5
7/29/11	Intermediate – *E. coli*	1.9	1.4	0.3	<0.01	0.2	0.3	0.02	0.2	<0.01	0.5	0.05	0.04
8/2/11	Intermediate – *E. coli* Recollection	---	---	---	---	---	0.3	<0.01	0.5	0.01	0.4	<0.01	---
8/29/11	Dry	1.1	0.8	0.04	0.03	0.10	0.15	<0.01	0.01	0.01	0.11	Dry	0.03
9/30/11	Dry	10.9	2.4	2.6	0.4	1.6	1.1	0.04	0.14	0.12	0.5	0.14	0.04
10/13/11	Wet	69.9	8.6	20.7	13.3	1.0	0.04	9.1	5.8	39.6	20.1	1.9	0.2
11/16/11	Intermediate while Raining	47.9	16.8	16.0	5.0	6.7	12.1	3.9	3.8	6.2	1.7	4.8	11.8
12/12/11	Dry	12.8	3.9	4.2	0.7	2.4	1.8	0.14	0.08	0.6	0.8	0.3	0.4
1/11/12	Wet	148.9	14.4	96.7	55.9	11.7	47.8	28.8	20.0	55.1	18.8	19.0	23.8
2/17/12	Intermediate	11.7	5.1	3.1	0.52	1.8	2.4	0.02	0.16	0.26	0.84	0.6	0.41
Overall Average		**27.6**	**5.9**	**12.9**	**6.3**	**2.5**	**6.1**	**4.2**	**2.9**	**8.1**	**3.6**	**2.9**	**3.3**
Wet Average		109.4	11.5	58.7	34.6	6.4	23.9	19.0	12.9	47.4	19.5	10.5	12.0
Intermediate Average		17.7	7.0	7.1	1.7	2.5	4.4	1.4	1.4	1.6	1.0	1.7	2.5
Dry Average		6.8	2.5	1.5	0.6	1.0	0.9	0.1	0.1	0.2	0.4	0.2	0.1

NOTE: Intermediate average excludes the event on 7/8/2011 in which most sites could not be measured due to high velocities. Pooled and dry sites were excluded from calculations. For streams with flow levels less than 0.01 cfs, 0.005 cfs was utilized for calculation purposes.

D. E. coli / Fecal Coliform

One of the most significant impairments observed in the Wolf Run watershed was high concentrations of *E. coli* and fecal coliform that indicate a high risk for exposure to waterborne pathogens. *E. coli* and fecal coliform concentrations regularly exceeded the primary and secondary contact limits throughout the watershed. Because significant fecal contributions were identified as coming from human sources in microbial source tracking studies (Brion 2011), these results suggest a considerable health hazard in many areas.

Five samples were collected at each site within a 30-day period in July / August for comparison to the water quality criteria (fecal coliform 200 MPN/100mLs; *E. coli* 130 MPN/100mLs) applicable during the PCR period. Four of these events were intermediate with one dry weather event. For the dry weather event, W07 was pooled during sample collection, so the only four events were used in the geometric mean calculation at that site. Geometric mean concentrations exceeded the regulatory criteria at all sites ranging from 770 to 9071 MPN/100mLs *E. coli* and from 1188 to 8477 MPN/100mLs fecal coliform, as shown in Table 14. All sites also exceed the SCR geometric mean criteria of 1000 MPN/100mLs fecal coliform.

TABLE 14 – GEOMETRIC MEAN CONCENTRATIONS OF FECAL INDICATORS COMPARED TO WATER QUALITY CRITERIA

SITE	W01	W02	W03	W04	W05	W06	W07*	W08	W09	W10	W11	W12	WQS
Geomean *E. coli* (MPN/100mLs)	3009	1366	3031	2237	1482	2267	9071	2946	6395	1353	4795	770	130
Geomean Fecal Coliform (MPN / 100mLs)	3074	1188	4354	5528	1559	5294	8477	1974	5861	3274	6221	2266	200

*Geometric mean of only four samples due to pooled water during 7/15/11 event.

Figures 6 and 7, page 20, show the *E. coli* and fecal coliform concentrations, respectively, at each site along with average concentrations during wet weather events, intermediate events, and dry weather events and the geometric mean of the 30-day sampling. Results ranged from less than 100 to 81,641 MPN/100mLs fecal coliform and from less than 100 to 198,629 MPN/100mLs *E. coli*. The highest overall results for both parameters were collected at W03 on the wet weather event on October 13, 2011. Only 17 percent of the fecal coliform results were below the PCR limit of 400 MPN/100mLs while 38 percent were below the SCR limit of 1000 MPN/100mLs. *E. coli* concentrations only met the PCR limit of 240 MPN/100mLs in 14 percent of the results.

Average concentrations varied considerably by event type, but generally wet weather events had much higher concentrations than dry weather events. W08 and W02 were each exceptions with W08 being high during dry weather and W02 being low during wet weather. Despite the high concentrations of fecal coliform and *E. coli*, no sanitary sewer overflows were documented by LFUCG for the dates in which the wet weather sampling was conducted. This may indicate sanitary sewer exfiltration from sources other than known overflowing manhole locations or additional sources of input including urban wildlife, pet waste, or other sources.

E. Nitrogen

Stream nitrogen levels were analyzed in five forms: ammonia (NH_3-N), nitrate (NO_3-N), nitrite (NO_2-N), total Kjeldahl nitrogen (TKN), and unionized ammonia level, which is calculated from ammonia, pH, and temperature. Ammonia is a component of TKN, and TKN, nitrate and nitrite are summed in order to calculate total nitrogen (TN). When high nitrogen levels are found in conjunction with high phosphorus levels and sunlight, eutrophication often occurs, causing abundant aquatic plant growth. At nighttime, this abundant plant matter can lower dissolved oxygen levels, causing aquatic organisms to suffocate. In addition, high nutrient levels contribute to hypoxia in the Gulf of Mexico and have other short and long term effects on stream ecosystems.

FIGURE 6 – *E. COLI* CONCENTRATIONS IN WOLF RUN

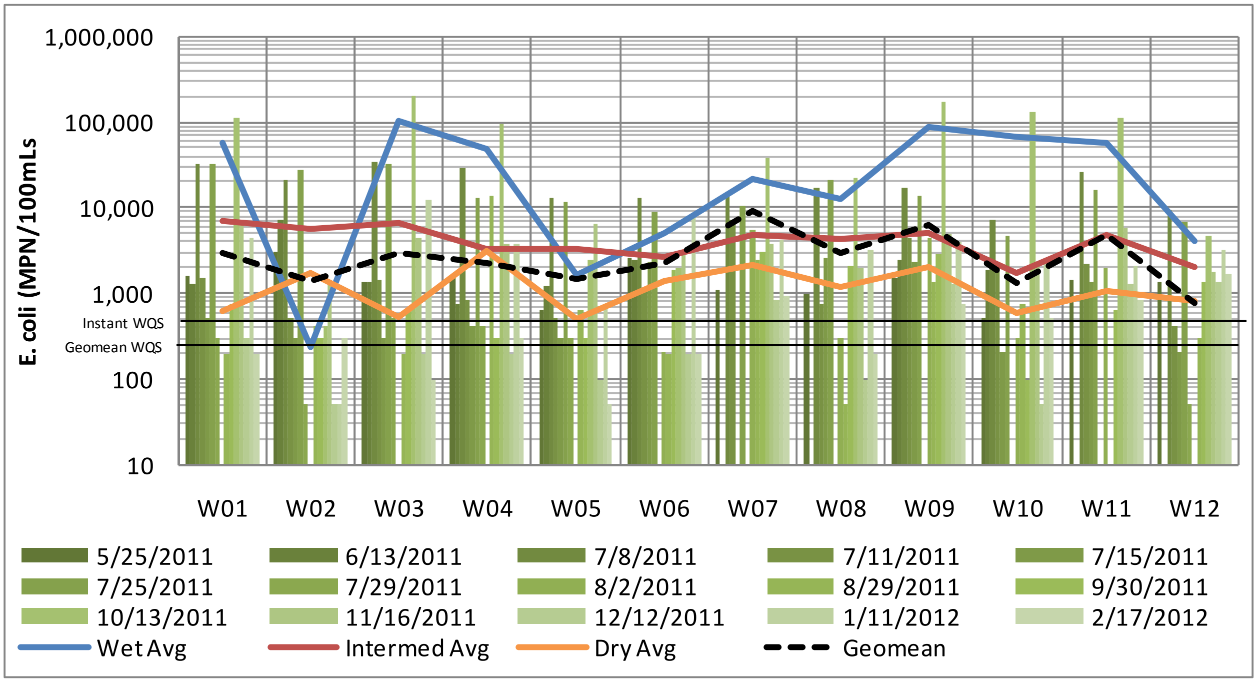
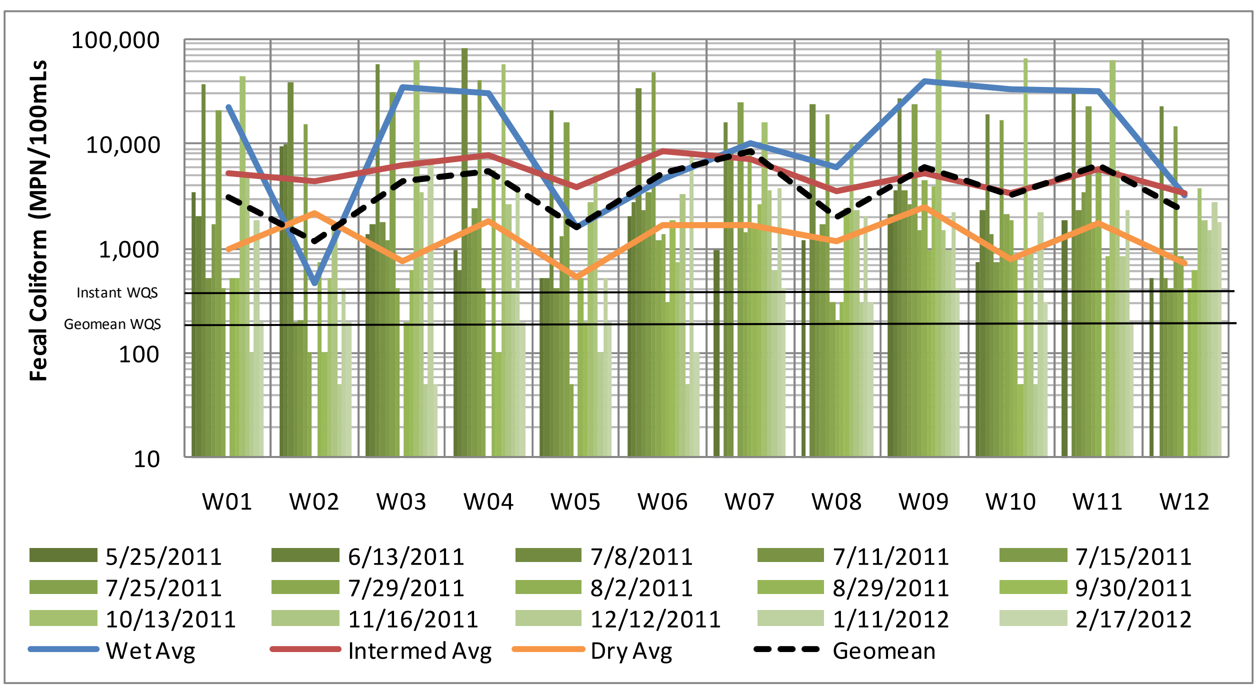


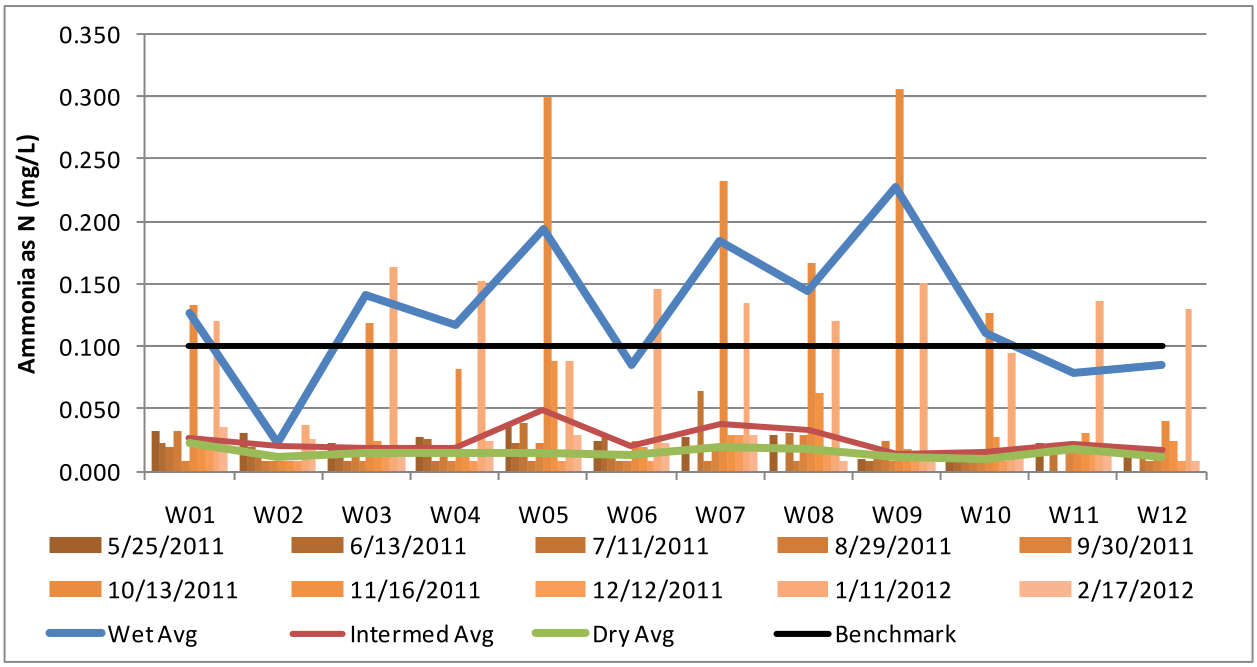
FIGURE 7 – FECAL COLIFORM CONCENTRATIONS IN WOLF RUN



Ammonia results, as shown in Figure 8, ranged from less than 0.015 mg/L to 0.306 mg/L at W09. Wet weather averages, ranging from 0.086 mg/L to 0.228 mg/L, were much higher at all sites than dry averages (highest at 0.22 mg/L at W01) or intermediate averages (highest was 0.049 mg/L at W05). Only W02 was lower during wet weather, averaging 0.023 mg/L. All sites except W02 had one measurement above 0.1 mg/L with five sites with two measurements above that concentration.

The pH and water temperature measured at the time of collection were used to calculate the unionized ammonia at each site. The highest calculated unionized ammonia was 0.007 mg/L, which is well below the warmwater aquatic habitat regulatory limit of 0.05 mg/L.

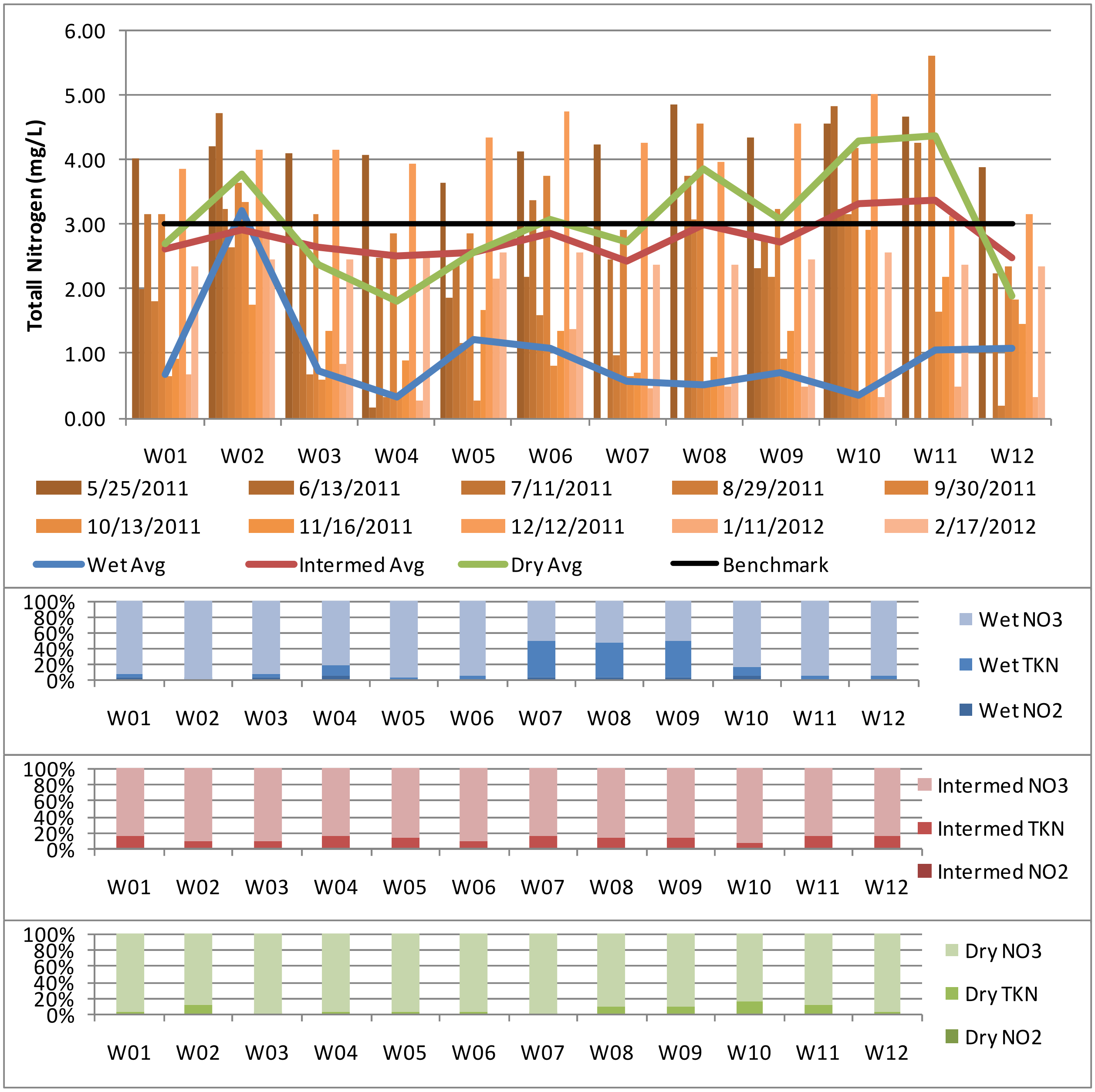
FIGURE 8 – AMMONIA CONCENTRATIONS IN WOLF RUN



Unlike the ammonia concentrations, the total nitrogen concentrations, as shown in Figure 9, page 22, were lowest during wet weather and highest during dry weather. Total nitrogen results ranged from below the reporting limit to 5.6 mg/L (at W11). Wet weather averages ranged from 0.33 mg/L at W04 to 3.2 mg/L at W02. Dry weather averages ranged from 1.82 mg/L at W04 to 4.36 mg/L at W11 similar to intermediate averages, which ranged from 2.44 mg/L at W07 to 3.36 mg/L at W11. Average concentrations across weather events were most similar at W02, ranging from 2.91 to 3.79 mg/L, due to the more narrow range of flows measured at the site. W02 had concentrations above 3.0 mg/L the most frequently, in seven of ten events. W10, W08, and W11 also exceeded 3 mg/L during 50 percent or more of the measurements.

The total nitrogen was comprised primarily of nitrate in all events, with TKN and nitrite commonly below detection limits. The highest nitrite level detected was 0.88 mg/L and it only reached as high as 5 percent of the total nitrogen averages. TKN comprised a greater percentage of the total nitrogen particularly during wet events at sites W07, W08, and W09 where it comprised 44 to 47 percent of the total nitrogen during wet weather. Under dry and intermediate conditions, TKN formed less than 20 percent of the average total nitrogen.

FIGURE 9 – TOTAL NITROGEN CONCENTRATIONS IN WOLF RUN



F. Phosphorus

Phosphorus was measured in two forms: orthophosphorus and total phosphorus. Orthophosphorus is the available form of phosphorus that can be utilized by plants and algae while total phosphorus includes orthophosphorus and other forms. Orthophosphorus is a dissolved form of phosphorus while total phosphorus includes both dissolved and particle-bound phosphorus. The problems linked to high phosphorus levels have been previously described in the previous section on nitrogen.

Orthophosphorus levels were relatively consistent across event types and sites in the watershed. Concentrations ranged from below the reporting limit to a maximum of 0.604 mg/L (Figure 10). The average ranges for dry (0.123 mg/L to 0.418 mg/L), intermediate (0.132 mg/L to 0.323 mg/L), and wet (0.120 mg/L to 0.351 mg/L) weather events had similar ranges, with an overall average of 0.255 mg/L. Sites W12 and W08 were consistently lower than other sites with overall averages of 0.118 and 0.157 mg/L, respectively. Sites W11 and W07 were also consistently higher than other sites, each averaging 0.319 mg/L.

Unlike orthophosphorus, total phosphorus concentrations were not consistent across event types, with wet weather concentrations much higher than dry or intermediate averages (Figure 11, page 24). While dry weather events averaged at 0.304 mg/L and intermediate events at 0.280 mg/L, wet weather events averaged 0.428 mg/L. These higher levels during wet weather events are suspected to be due to the increased suspended sediment levels during these events. Sites with high total phosphorus levels during wet weather also had high TSS levels. Site W04 had the highest measured total phosphorus concentration at 1.12 mg/L on a field duplicate result. All sites except W12 had at least one measurement above 0.35 mg/L. Site W07 had concentrations above 0.35 mg/L the most frequently, exceeding that level during six of the ten measurements. Site W07 was also the only site to measure above 0.35 mg/L in a non-precipitation event.

FIGURE 10 – ORTHOPHOSPHORUS (OP) CONCENTRATIONS IN WOLF RUN WATERSHED

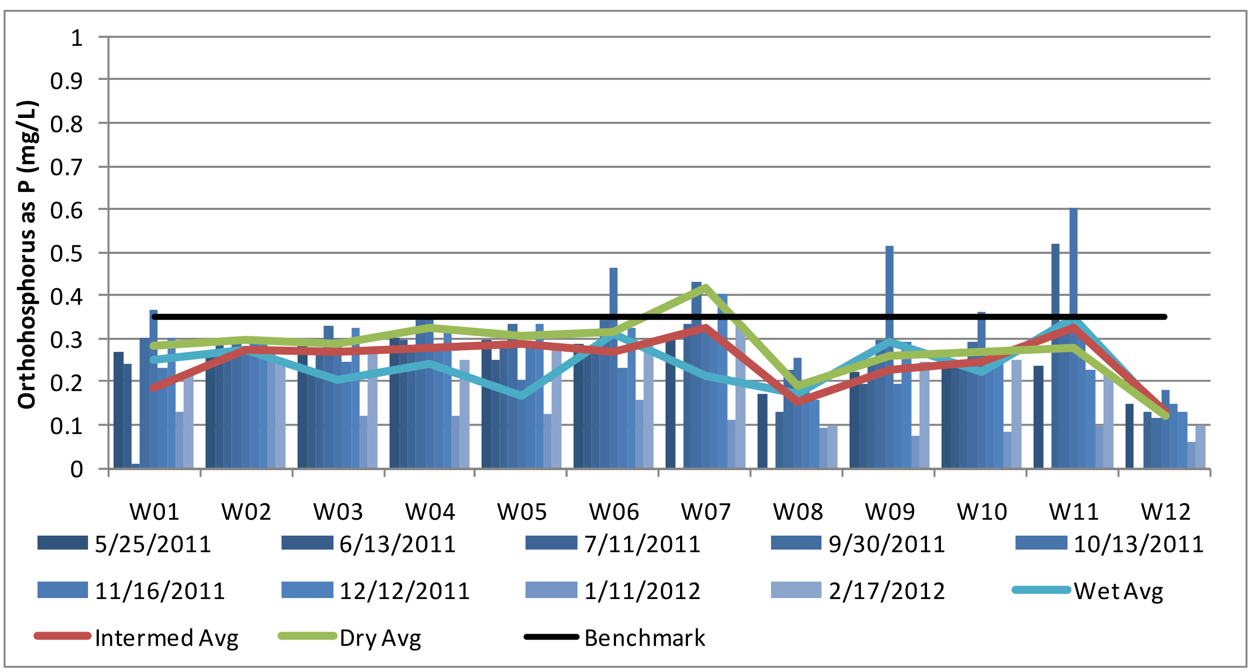
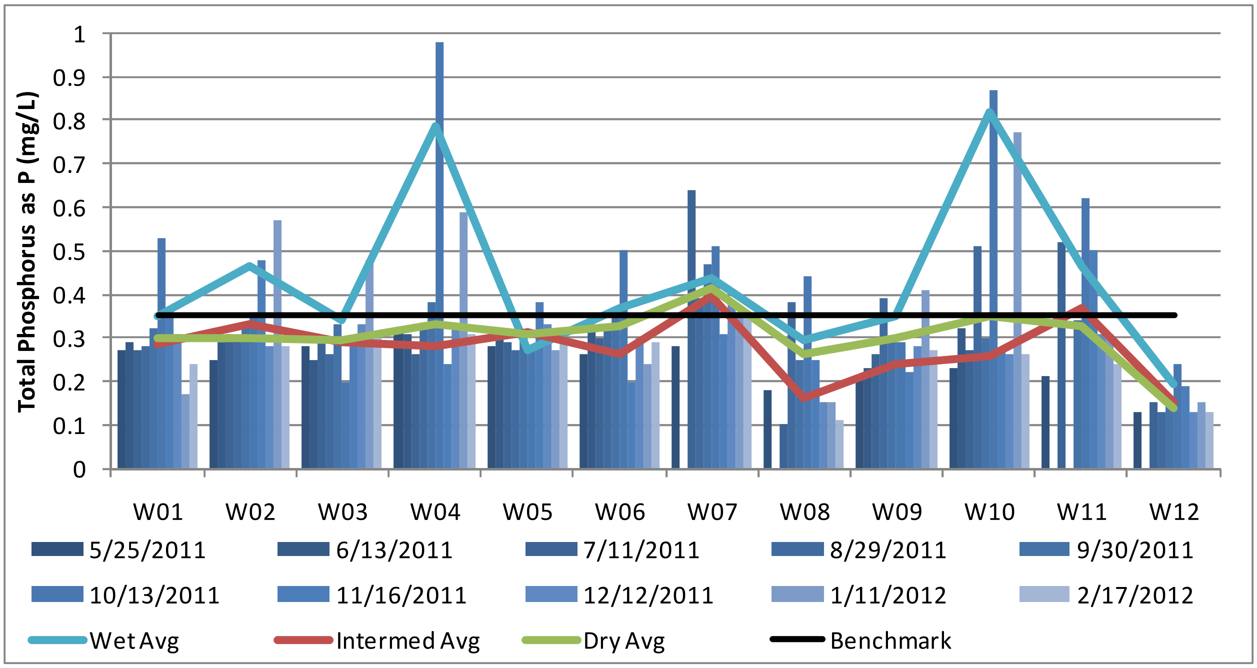


FIGURE 11 – TOTAL PHOSPHORUS (TP) CONCENTRATIONS IN WOLF RUN WATERSHED



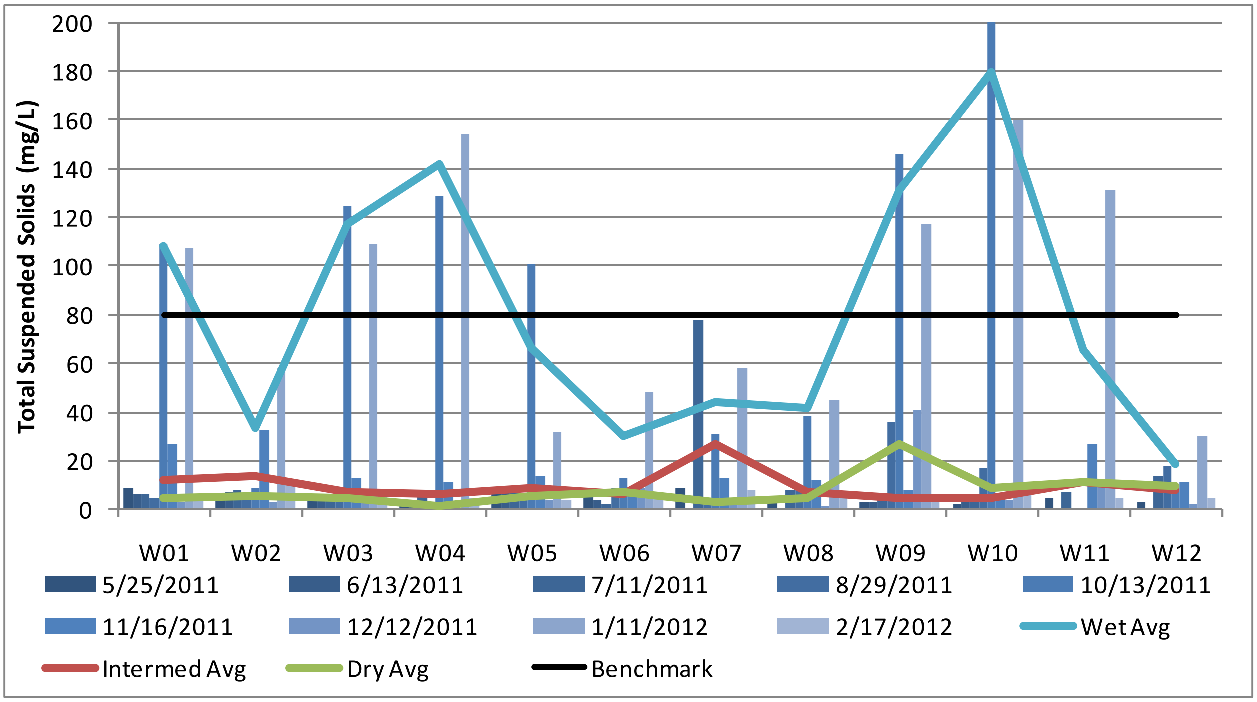
Heavy algal growth frequently occurred throughout the watershed, even at W12 where the lowest phosphorus concentrations were measured. Although no known fish kills were recorded during the monitoring period, as previously mentioned both high dissolved oxygen levels and levels below the instantaneous water quality limit were recorded in the watershed. The excessive algal growth frequently occurred in areas of stagnant water with little to no overhead canopy to shade the stream.

G. Total Suspended Solids

TSS were, as expected, higher in wet weather events than during dry and intermediate events (Figure 12, page 25). Dry and intermediate weather events averaged near 7 to 8 mg/L, with the exception of one intermediate event collected during precipitation, which averaged 15 mg/L. Wet weather events averaged over 80 mg/L across all sites with a high of 200 mg/L measured at W10 on October 13. Sites W01, W03, W04, W09, and W10 each had suspended solid levels exceeding 80 mg/L, all of which occurred during wet events

During wet weather events with high concentrations of suspended sediment, the color of the water is typically black or gray rather than brown like the soil color. Although erosion is a contributor to the suspended sediment load, the color of the turbidity indicates that stormwater runoff is a greater contributor to suspended sediments in Wolf Run.

FIGURE 12 – TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN WOLF RUN WATERSHED



H. *Alkalinity and Hardness*

Although both alkalinity and hardness are often used interchangeably and reported with the same units (mg/L of calcium carbonate ($CaCO_3$)), these two terms describe different water parameters. Alkalinity is a measure of the acid-neutralizing capacity of water. Total alkalinity is a measurement of all titratable bases, which in surface waters are primarily carbonate (CO_3^{-2}), bicarbonate (HCO_3^-), or hydroxides (OH^-), but may also include borates, phosphates, silicates, or other bases if present. In the Wolf Run Watershed where the pH is typically high, total alkalinity is primarily carbonate and bicarbonate. Total hardness measures the positive ions dissolved in the water, the most common of which are calcium (Ca^{++}) and magnesium (Mg^{++}).

In the Wolf Run Watershed, total alkalinity averaged 161 mg/L and total hardness averaged 227 mg/L. Dry weather events were higher on average than wet weather events for both total alkalinity and hardness. The concentrations for each parameter are shown in Figures 13 and 14, page 26.

FIGURE 13 – TOTAL ALKALINITY IN WOLF RUN WATERSHED

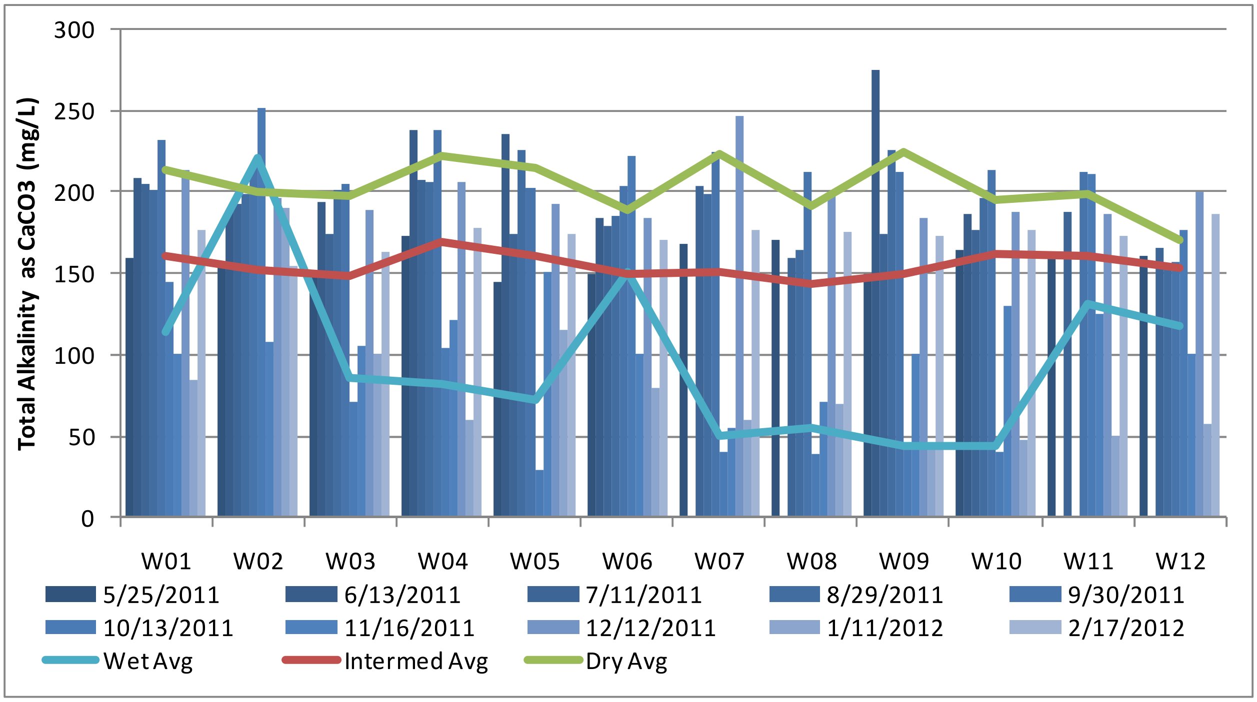
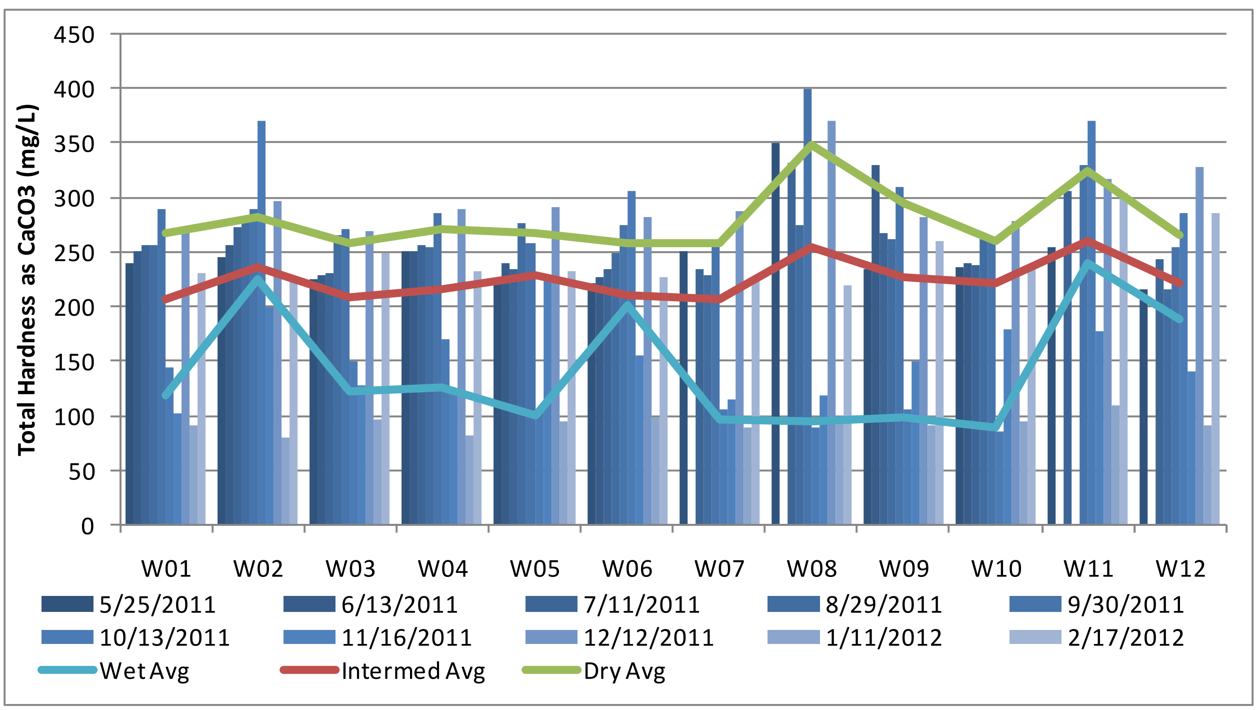


FIGURE 14 – TOTAL HARDNESS IN WOLF RUN WATERSHED



I. Total Dissolved Solids and Specific Conductance

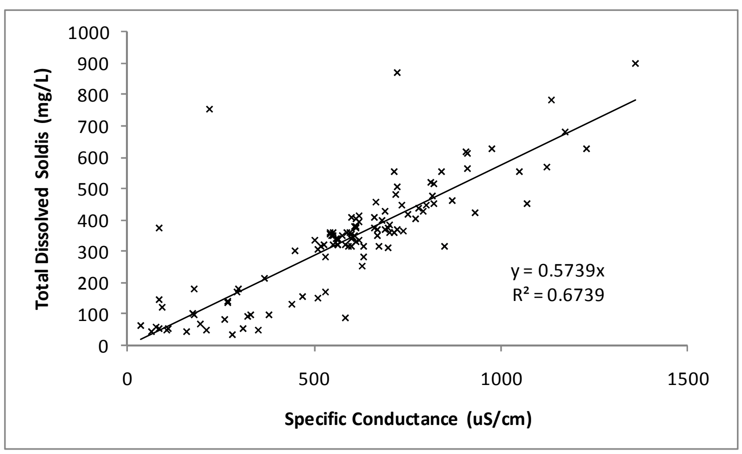
TDS and specific conductance or conductivity are discussed together because of the relationship between the two parameters. Dissolved ions in the water column have a weight, which is measured in TDS, and an ionic charge, which is measured by specific conductance. The conversion factors between the concentration of a given ion and its conductivity is summarized in Table 15. For the Wolf Run Watershed, TDS concentrations (mg/L) are approximately 57 percent of the specific conductance value (µS/cm), as shown in Figure 15.

TABLE 15 – EQUIVALENT SPECIFIC CONDUCTANCE BY ION

ION	CONDUCTIVITY FACTOR (µS/cm per mg/L)
Ca^{+2}	2.60
Mg^{+2}	3.82
K^{+}	1.84
Na^{+}	2.13
HCO_3^{-}	0.715
Cl^{-}	2.14
SO_4^{-}	1.54
NO_3^{-}	1.15
CO_3^{-2}	2.82

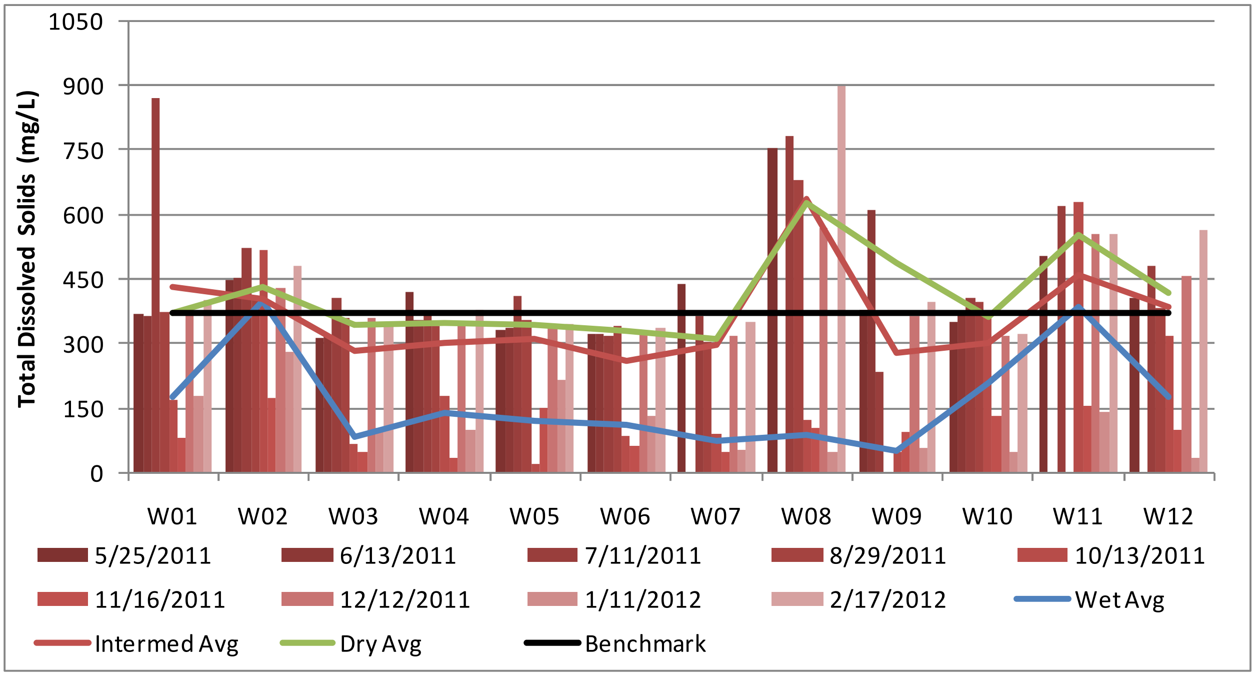
Source: McPherson 1995

FIGURE 15 – RELATIONSHIP BETWEEN SPECIFIC CONDUCTANCE AND TOTAL DISSOLVED SOLIDS IN WOLF RUN WATERSHED



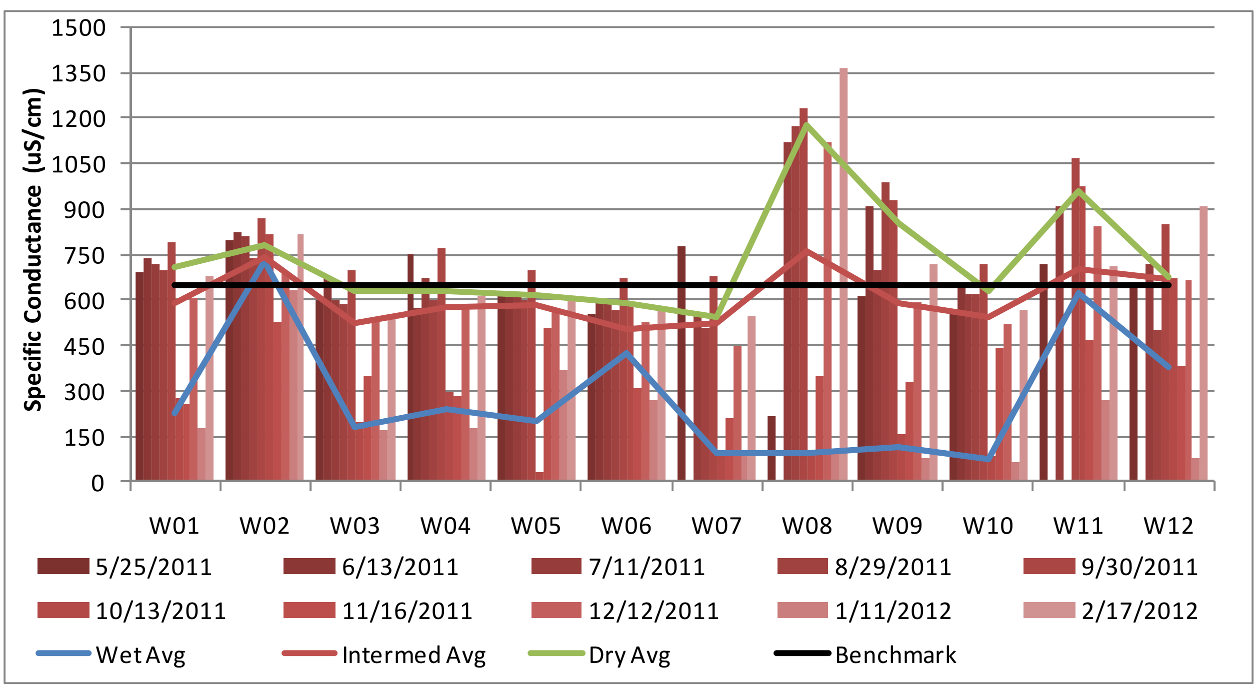
High conductivity or TDS may be due to nutrients, metals, or other compounds from sources such as natural geology or pollutants. TDS and specific conductance levels in the Wolf Run Watershed are shown in Figures 16 and 17, page 28. Specific conductance, which averaged 581 µS/cm was higher in dry weather (averages ranging from 545 to 1174 µS/cm) than during intermediate (averages ranging from 504 to 7630 µS/cm) or wet (averages ranging from 74 to 725 µS/cm) weather events. These trends were similar for total dissolved solids, which averaged 325 mg/L.

FIGURE 16 – TOTAL DISSOLVED SOLIDS CONCENTRATION IN WOLF RUN WATERSHED



NOTE: The 8/29/2011 result at W09 of 2060 mg/L was excluded as an outlier. Results are for screening purposes only due to poor precision.

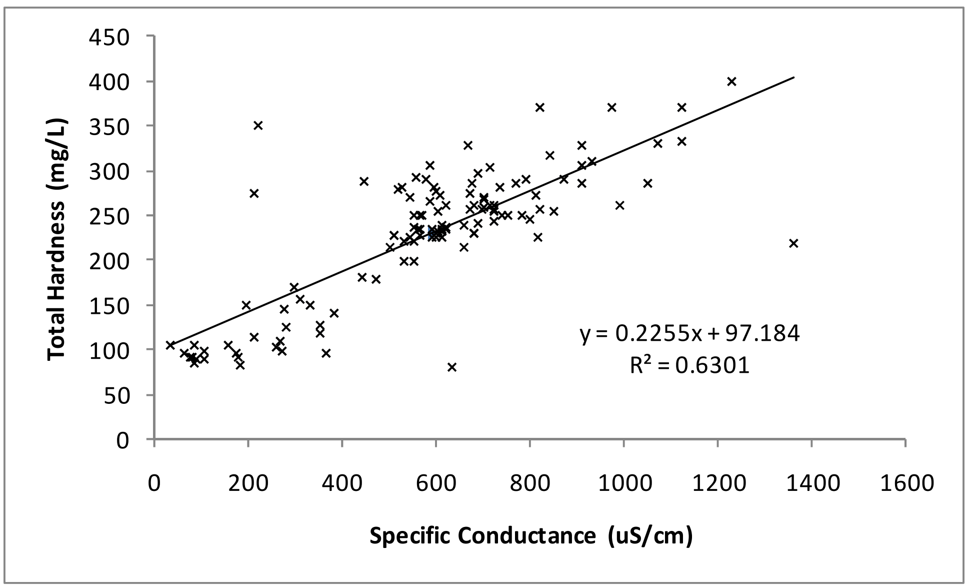
FIGURE 17 – SPECIFIC CONDUCTANCE IN WOLF RUN WATERSHED



Under dry and intermediate conditions, W08, W11, and W02 had the highest levels. Sites W02 and W11 were also high during wet weather. Sites W02, W11, W08, W12, and W01 all exceeded 650 µS/cm in more than half of the measurements at those sties. Sites W03, W05, W06, and W07 had the lowest conductivity levels with only one measurement exceeding 650 µS/cm during the monthly monitoring.

Limestone ($CaCO_3$), when saturated with water containing carbon dioxide, converts to calcium bicarbonate ($Ca(HCO_3)_2$) which is soluble in water. Due to the large amount of limestone geology present within the Wolf Run Watershed, a relationship between the alkalinity and hardness values and the dissolved solids and conductivity values is present, as shown in Figure 18. Using some assumptions about the relative composition of the alkalinity and hardness (namely, all alkalinity was bicarbonate and all hardness is calcium and magnesium with the calcium to magnesium ratio of 9:1), baseline conductivity values were calculated at an average of 372 +/- 120 µS/cm for the Wolf Run watershed.

FIGURE 18 – RELATIONSHIP BETWEEN SPECIFIC CONDUCTANCE AND TOTAL HARDNESS IN WOLF RUN WATERSHED



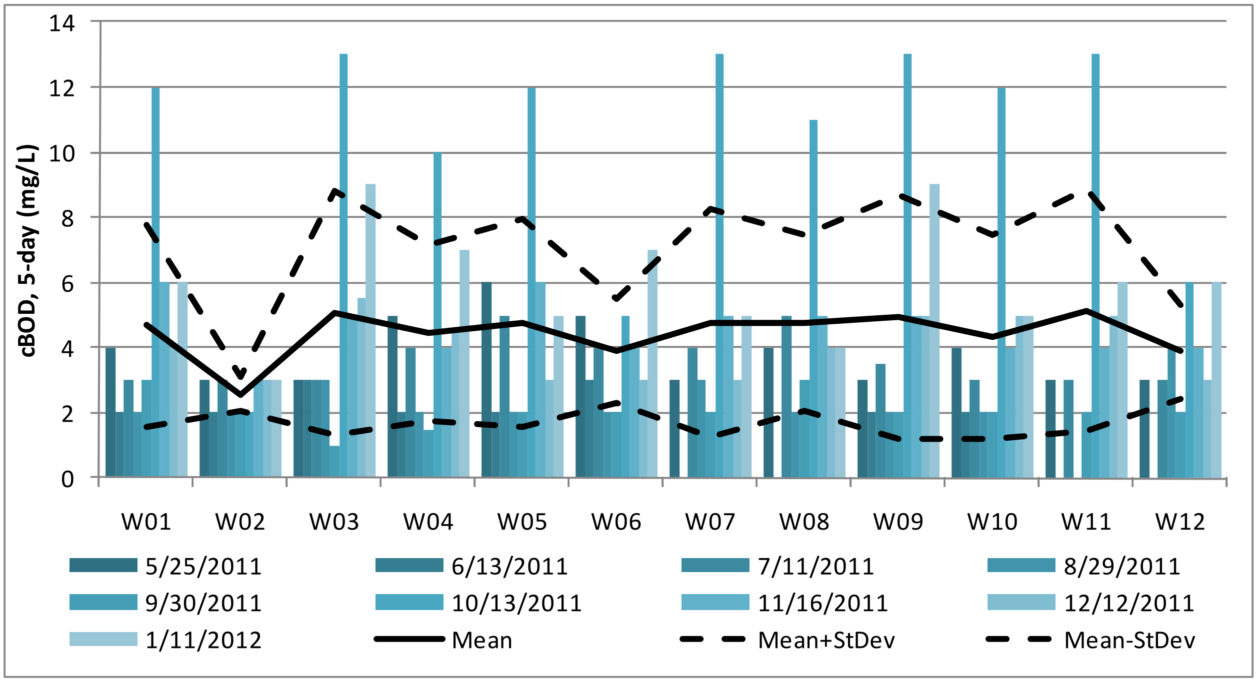
Based on review of Kentucky River Watershed Watch samples, chloride levels (which have a high ionic conversion factor) were high at several locations in Wolf Run. Future studies should include chloride as a parameter to measure levels throughout the watershed.

In addition to the monthly conductivity measurements, a conductivity survey was conducted throughout the Wolf Run watershed, the results of which are presented in a Conductivity Survey Report (Evans 2012a).

J. Oxygen Demand

Carbonaceous biochemical oxygen demand (or cBOD, 5-day) levels were evaluated on a monthly basis across the watershed. This is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period. Results are shown in Figure 19. The cBOD averaged 4.4 mg/L with a range from 1 mg/L to 13 mg/L.

FIGURE 19 – CARBONACEOUS BIOCHEMICAL OXYGEN DEMAND IN WOLF RUN WATERSHED



VI. POLLUTANT LOAD AND PRIORITY AREAS

A. Description of Calculations

According to the *Watershed Planning Guidebook for Kentucky Communities* (KDOW 2010b), the pollutant load must be calculated for each subwatershed using the monitoring data. The guidebook recommends the following generalized formula as a minimum requirement for load calculation:

Actual Concentration x Discharge (cfs) x Conversion Factor = Actual Load

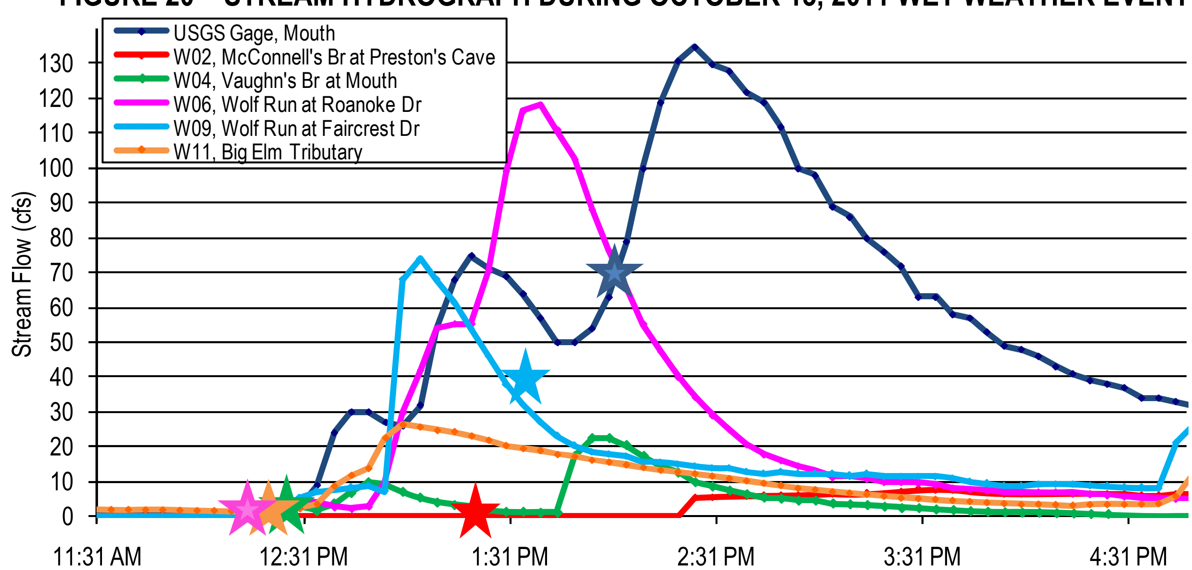
This formula converts the concentration data into a mass (or CFUs) per time period unit, with days being the typical time unit. The guidebook recommends using the formula and the measured flows to calculate an individual load for each sampling event at each site and then averaging the individual loads for an overall annual load. However, the document also allows for other more robust models to be utilized if necessary. For the Wolf Run Watershed, the planning team decided to go beyond the minimum requirements for calculating load due to several biases in the generalized approach.

First, the sampling events collected over the monitoring period are not necessarily representative of the frequency of occurrence. For instance, dry, intermediate, and wet weather conditions occurred on 46 percent, 42 percent, and 12 percent, respectively, of the days in the monitoring period, but the monthly sampling collected four dry-weather events (40 percent), four intermediate events (40 percent), and two wet-weather events (20 percent). By averaging all of the events collected, the annual load is weighted more on the type of event collected rather than the actual frequency of occurrence of the event of which it is representative.

To account for this bias, concentrations for each parameter were averaged first for each event type (dry, wet, intermediate). Second, a flow was determined for each event type. Third, for each event type the average concentration and flow were utilized in the generalized formula above to develop a daily load value for each site. Lastly, an annual load was calculated by weighting the daily load for each event type by the percentage of days in the period in which that type of condition was present and multiplying by 365.

A second bias in the load calculation method recommended in *Watershed Planning Guidebook for Kentucky Communities* is due to the stream flows utilized in the load calculations. During dry and intermediate events, an average of the measured flows at each site is appropriate because there is little fluctuation in the stream flow across sites during the time of the sampling event. However, during storm event flows, large variations in the measured stream flows were recorded due to the fast hydrographic rise and fall of streams in response to precipitation. Because the wet weather loading typically has the highest pollutant concentrations as well as the highest flow, the flow utilized in the calculations is critical to accurate results. Figure 20 shows the hydrographs for several sites during the wet weather event sampled on October 13, 2011. While most samples (time of each sample indicated by stars) were captured on the hydrographic rise, the amount of flow present at the time of the collection was variable from site to site. Table 16, page 31, indicates the measured flows at each site during each wet weather event and the average of these flows. As shown by the wide variation between the measured flows between events and sites, utilizing field measured flow individually or as an average would bias loading calculations based on the time of collection at the various sites, rather than the amount of pollution input. Therefore, several methods were explored in an attempt to lessen the sampling bias in wet weather load calculation.

FIGURE 20 – STREAM HYDROGRAPH DURING OCTOBER 13, 2011 WET WEATHER EVENT



NOTE: Stars indicate sampling time at each site for this event.

TABLE 16 – WET WEATHER FLOW CALCULATION ANALYSIS SUMMARY

Flow Calculation Method	Flow (cfs)											
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12
Measured Flow October 13, 2011 Wet Event	69.9	8.6	20.7	13.3	1.0	0.04	9.1	5.8	39.6	20.1	1.9	0.2
Measured Flow January 11, 2012 Wet Event	148.9	14.4	96.7	55.9	11.7	47.8	28.8	20.0	55.1	18.8	19.0	23.8
Average of Two Measured Flow	109.4	11.5	58.7	34.6	6.35	23.92	18.95	12.9	47.35	19.45	10.45	12.0
Land Area Scaling of Average Flow at Mouth	110.0	7.0	58.7	32.7	17.2	37.2	27.1	9.6	17.0	7.1	9.7	12.5
Hydrographic Average Flow	109.4	16.9	-	15.7	-	42.4	-	-	13.3	-	13	-
Simple Method Annual Runoff Based Flows	106	16	57	25	13	40	20	13	19	8	10	14

Wet weather flows across sampling sites were calculated according to three other methods, with the results shown in Table 16. These methods included land area scaling, hydrograph averages, and simple method annual runoff based flows.

First, the land area scaling method utilized the average measured wet weather flows at the mouth of the watershed (rounded up) and multiplied it by the percentage of the total watershed area located upstream of each site. This approach avoids the sampling time bias, but does not account for differences in flow levels due to upstream land use. Therefore, it was not considered as representative as other methods.

Second, the hydrographic average flow was calculated using the flow duration curves generated at six sites in the watershed under the *Karst Hydrograph Characterization Report* (Evans 2012c). Since wet weather conditions represented 12 percent of the monitoring period, the top 12 percent of flows measured in the watershed were averaged as an approximation of the average wet weather flow. Although a range of flows may have been present during a wet event, some of these high flows may have occurred subsequent to storm events. This average provides a reasonable approximation of representative wet weather flows for each station. Unfortunately, hydrographs were not generated for all subwatersheds so this method could not be utilized in load calculations, but it does provide a helpful comparator to the flow calculations according to other methods.

The third method utilized to calculate wet weather flows was a modification of the Simple Method to calculate annual pollutant loads (Schueler 1987 as detailed NY DEC 2012). Typically this method is utilized to generate annual pollutant load using the land use areas, annual runoff, and pollutant concentrations in the runoff from various land uses. Thus the amount of impervious and pervious surface in the subwatershed areas is included in calculations as well as the amount of area. As this method relies on runoff volumes, it would only be applicable in heavily urban watersheds, but Wolf Run fits this criteria. Therefore, this method was chosen for use in wet weather load calculations based on the presumption that it provides the most accurate method of determining the wet weather flow.

To calculate wet weather flow (cubic feet per second) according to this method, the annual runoff volume (cubic feet) was assumed to occur over a specified time (seconds). In this case, it was assumed that all annual rainfall occurred during the percentage of the year in which wet weather conditions occurred (12 percent). Thus a duration (T) of 1972.6 seconds (12 percent of a year) was assumed in the following equation:

$$Q = \sum (V_1 + V_2 + V_n) / T$$

Where Q = Flow (cfs),
V = Annual Runoff (cubic feet),
$\sum(V_1 + V_2 + V_n)$ = Sum of upstream annual runoff (cubic feet), and
T = Duration of wet weather flows (seconds).

While this assumption may overestimate the volume of runoff that occurred over this period, it was assumed for worst-case scenario. The total annual runoff volume (V) was calculated for each subwatershed area by utilizing GIS derived measurements of the impervious and pervious surfaces located in the subwatershed according to the equation:

$$V = 3630*[(R_{imp}*A_{imp}) + (R_{per}*A_{per})]$$

Where V = Total Annual Runoff (cubic feet)
R_{imp} = Runoff of Impervious Surfaces (inches),
R_{per} = Runoff of Pervious Surfaces (inches),
A_{imp} = Impervious Surface Area (acres),
A_{per} = Pervious Surface Area (acres), and
3630 = conversion from acre-inches to cubic feet.

The annual runoff volume (R) of the impervious and pervious surfaces was calculated according to the following equation:

$$R = P * P_j * Rv$$

Where R = Annual runoff (inches)
P = Annual rainfall (inches)
P_j = Fraction of annual rainfall events that produce runoff
Rv = Runoff coefficient

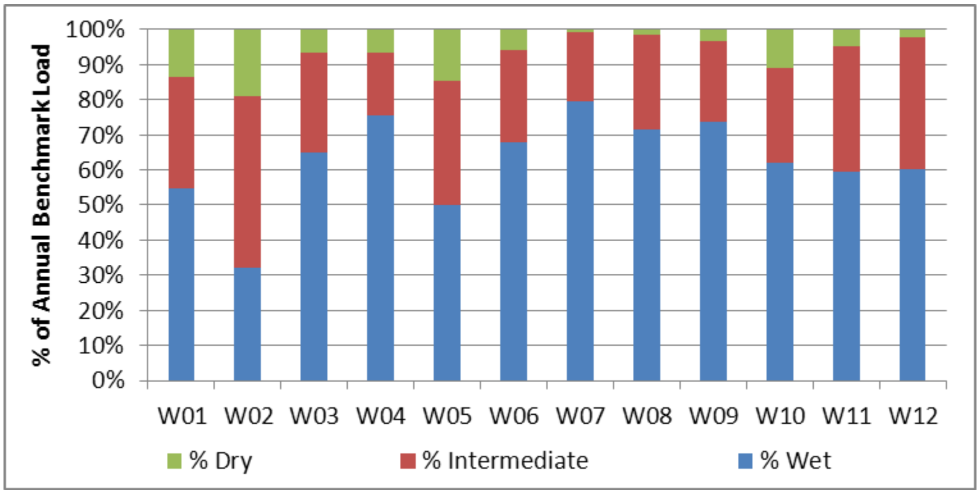
The annual rainfall value, 45.81 inches was derived by converting the rainfall measured at the KLEX station over the monitoring period (33.76 inches) to an annual basis. The fraction of annual rainfall events that produce runoff was assumed to be 0.9 as is typical. The runoff coefficient (Rv) for pervious surfaces was assumed to be 0.95 and 0.05 for impervious surfaces.

For future watershed based plan load calculations, it is recommended that KDOW conduct research and provide guidance on the most appropriate and accurate methods for calculating annual pollutant loads considering the costs associated with sampling and the needs of the plans. The Simple Method was considered as the most representative approach for this study, but research and guidance would aid future plans and sampling activities.

To summarize, the annual load was calculated by summing the weighted daily load for each event type. For dry an intermediate events, the average concentration was multiplied by the average flow for the respective events. For the wet events, the average concentration was multiplied by the Simple Method Annual Runoff Based Flow.

To calculate the target load for each site, the benchmark concentrations were substituted for the measured concentrations in the same calculation process. The relative proportion of each event type to the overall annual target load is shown in Figure 21, page 33. As mentioned previously, wet weather events had the highest load contributions, with target load contributions of over 50 percent for all sites, except W02. The target loads were subtracted from the measured annual load to determine the load reduction needed.

FIGURE 21 – DISTRIBUTION OF TARGET ANNUAL LOAD CONTRIBUTIONS BY EVENT TYPE



Finally, for purposes of prioritization, the annual loads were normalized to a load per unit drainage area. This normalized load, the pollutant yield, was determined by dividing each load by the drainage area for each sub-watershed.

B. *E. coli Loading*

Daily *E. coli* loadings for each event type and site are shown in Figure 22, page 34. The average daily load values range from a minimum of 1.49 billion MPN for dry weather at W08 to a maximum of 151 trillion MPN for wet weather at W01. For all sites except W02, the daily load is highest for the wet events, typically near 100 times greater, indicating significant loading is added from sanitary sewer exfiltration as well as runoff sources. Fecal coliform shows a similar pattern of loading as *E. coli* for each site.

Table 17, page 34, indicates the load reductions necessary to achieve the primary contact recreation standards of 130 and 240 MPN/100 mLs during all weather conditions. A reduction of over 90 percent is required at all sites in the watershed in order to achieve these results (88.2 percent at W05 is the lowest reduction to achieve the instantaneous standard). For most sites, over 70 percent of the loading comes in wet weather conditions and in some sites (W04, W09, W10), 98 percent of the loading is due to wet weather. The loading for W02 is more evenly distributed across dry and intermediate conditions while loading at W05 is distributed more evenly between wet and intermediate conditions. Dry weather loading was a very small percentage (less than 4 percent) of the annual loading at all sites except W02. The large reductions needed to meet targets indicate that supporting recreational use in the Wolf Run Watershed will require significant remediation efforts.

C. *Nitrogen Loading*

Figure 23, page 35, indicates the relative contribution to the annual load for each event type at each site. At all sites except W02, the actual annual load is below benchmark load levels. Although concentrations exceeded 3.0

mg/L at dry and intermediate weather conditions for all sites, most sites had very low concentrations (below 1.25 mg/L) during wet weather conditions due to dilution. Wet weather loading was below intermediate load amounts at all sites, indicating a lesser contribution due to runoff. Intermediate conditions had the greatest load contribution annually at all sites due to the higher flows in conjunction with high concentrations.

As shown in Table 18, page 35, the only site that requires a reduction to reach the target annual loading is W02, which averaged 3.2 mg/L during wet weather events. Removal of 2,020 lbs of nitrogen/year will achieve the target reduction. Because W02 is located at Preston's Cave, these load reductions will need to be targeted in the upstream karst basin.

FIGURE 22 – DAILY *E. COLI* LOADING BY EVENT TYPE

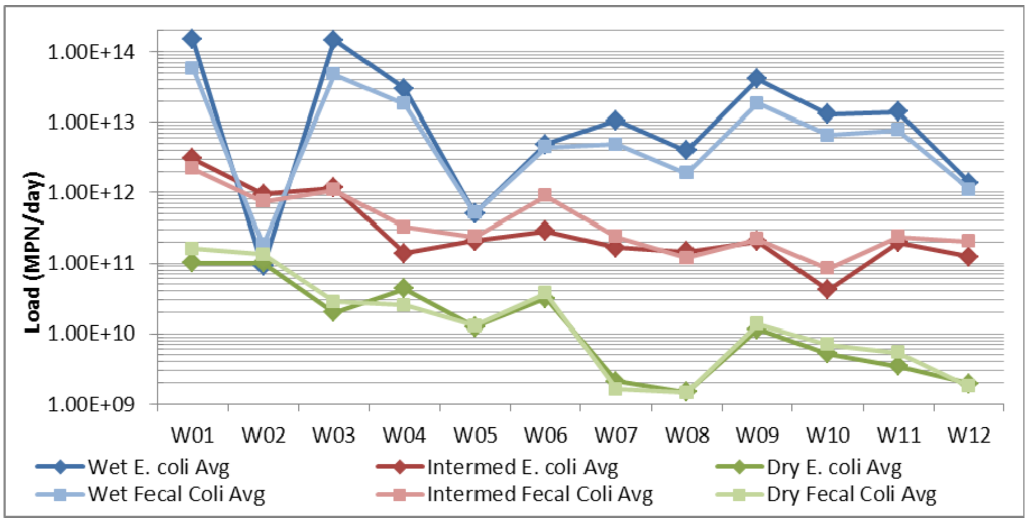


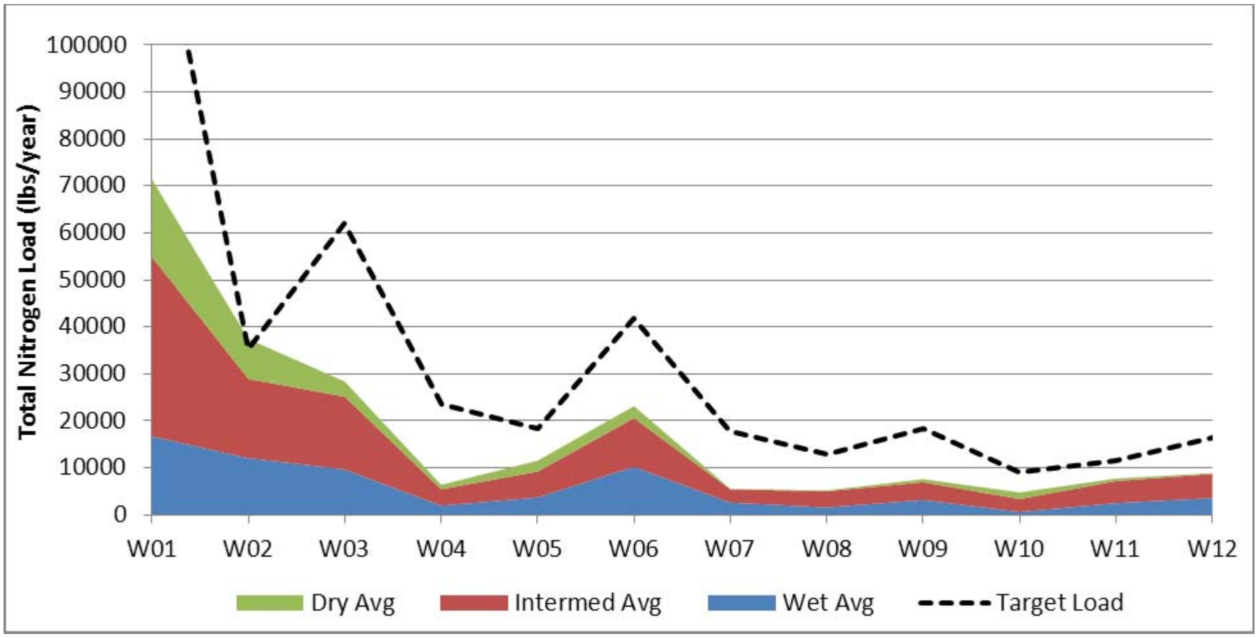
TABLE 17 – *E. COLI* ANNUAL LOAD REDUCTION

SITE	ANNUAL LOAD (TRILLION CFU/YEAR)	30-DAY GEOMETRIC MEAN TARGET LOAD* (TRILLION CFU/YEAR)	REQUIRED REDUCTION (TRILLION CFU/YEAR)	% REDUCTION	INSTANTANEOUS STANDARD TARGET LOAD* (TRILLION CFU/YEAR)	REQUIRED REDUCTION (TRILLION CFU/YEAR)	% REDUCTION
W01	7098	26.93	7072	99.6%	49.73	7049	99.3%
W02	166	6.94	159	95.8%	12.82	153	92.3%
W03	6621	12.18	6609	99.8%	22.48	6599	99.7%
W04	1334	4.60	1329	99.7%	8.50	1325	99.4%
W05	56.2	3.60	52.6	93.6%	6.65	49.6	88.2%
W06	264	8.18	256	96.9%	15.11	249	94.3%
W07	486	3.48	482	99.3%	6.43	479	98.7%
W08	197	2.51	194	98.7%	4.64	192	97.6%
W09	1834	3.59	1830	99.8%	6.63	1827	99.6%
W10	572	1.79	571	99.7%	3.30	569	99.4%

W11	640	2.29	637	99.6%	4.22	635	99.3%
W12	79.2	3.21	76.0	95.9%	5.93	73.3	92.5%

*Targets load based on 130 and 240 CFU/100mLs primary contact recreation standards for *E. coli*, respectively.

FIGURE 23 – ANNUAL TOTAL NITROGEN LOADING CONTRIBUTIONS BY EVENT TYPE



*Target load based on 3.0 mg/L non-regulatory reference point.

TABLE 18 – TOTAL NITROGEN ANNUAL LOAD REDUCTION

Site	Annual Load	Target Load*	Load Reduction	% Reduction
	(lbs nitrogen as N/year)			
W01	71,400	137,000	-	-
W02	37,400	35,400	2,020	5%
W03	28,400	62,100	-	-
W04	6,400	23,500	-	-
W05	11,600	18,400	-	-
W06	23,100	41,700	-	-
W07	5,540	17,700	-	-
W08	5,220	12,800	-	-
W09	7,620	18,300	-	-
W10	4,790	9,120	-	-
W11	7,750	11,600	-	-
W12	8,890	16,400	-	-

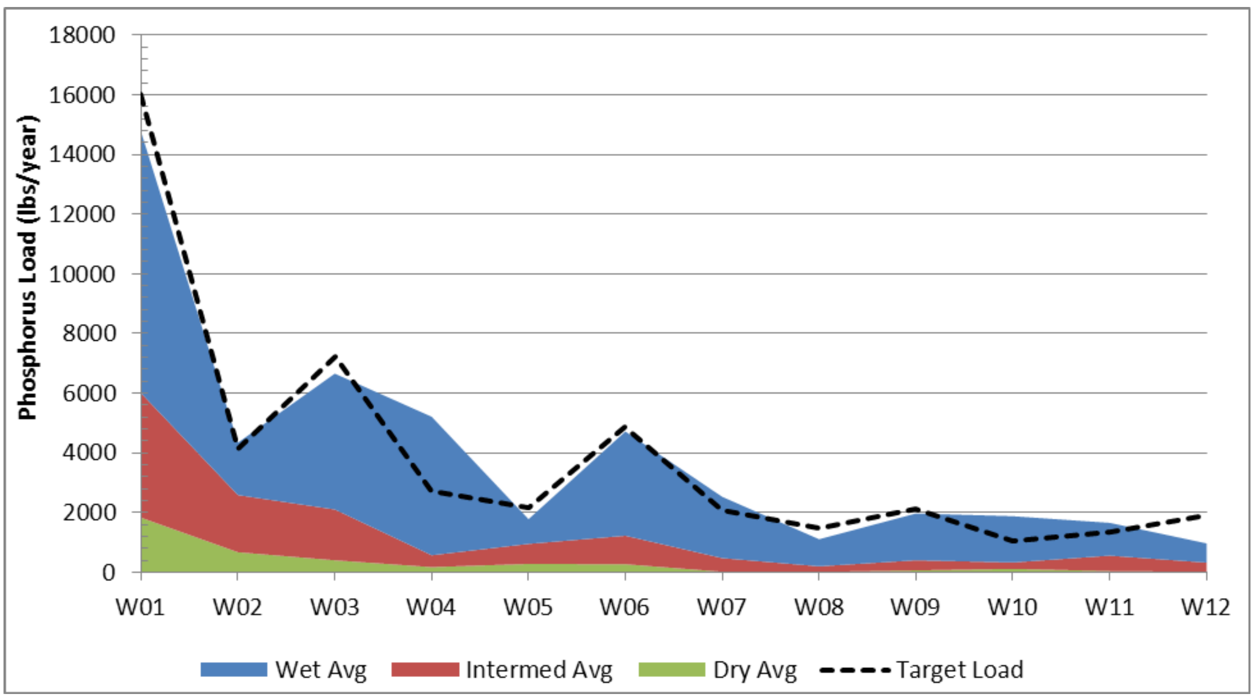
*Target load based on 3.0 mg/L non-regulatory reference point.

D. Phosphorus Loading

The relative contribution of total phosphorus annual loading for each event type and site are shown in Figure 24. As previously indicated, the total phosphorus concentrations under wet and dry conditions typically average near 0.3 mg/L; wet weather concentrations are higher, particularly for sites W04 and W10, which averaged near 0.8 mg/L. Together with high flow levels, the annual wet weather load contribution was disproportionate to the occurrence frequency, averaging 70 percent of the total load while only occurring on 12 percent of the days.

In order to reach the target loading, load reductions are required at four sites in the watershed, as shown in Table 19, page 37. The greatest annual reduction is necessary on Vaughn's Branch with 2,470 pounds near the mouth (W04) and 460 of which are needed upstream of the Pine Meadows Park (W07) primarily from the Picadome Golf Course area. Sizeable annual reductions of 820 pounds in the Spring Branch subwatershed (W10) and 295 pounds from the Big Elm Tributary subwatershed are also required. These reductions should be achieved by erosion reduction and storm event filtration methods.

FIGURE 24 – ANNUAL TOTAL PHOSPHORUS LOADING CONTRIBUTIONS BY EVENT TYPE



*Target load based on 0.35 mg/L non-regulatory reference point.

TABLE 19 – TOTAL PHOSPHORUS ANNUAL LOAD REDUCTION

SITE	ANNUAL LOAD	TARGET LOAD*	LOAD REDUCTION	% REDUCTION
	(POUNDS PHOSPHORUS AS P/YEAR)			
W01	14,800	16,000	-	-
W02	4,340	4,130	210	5%
W03	6,660	7,240	-	-
W04	5,210	2,740	2,470	47%
W05	1,780	2,140	-	-
W06	4,720	4,870	-	-
W07	2,530	2,070	460	18%
W08	1,100	1,490	-	-
W09	1,970	2,130	-	-
W10	1,880	1,060	820	44%
W11	1,650	1,360	290	18%
W12	966	1,910	-	-

*Target load based on 0.35 mg/L non-regulatory reference point.

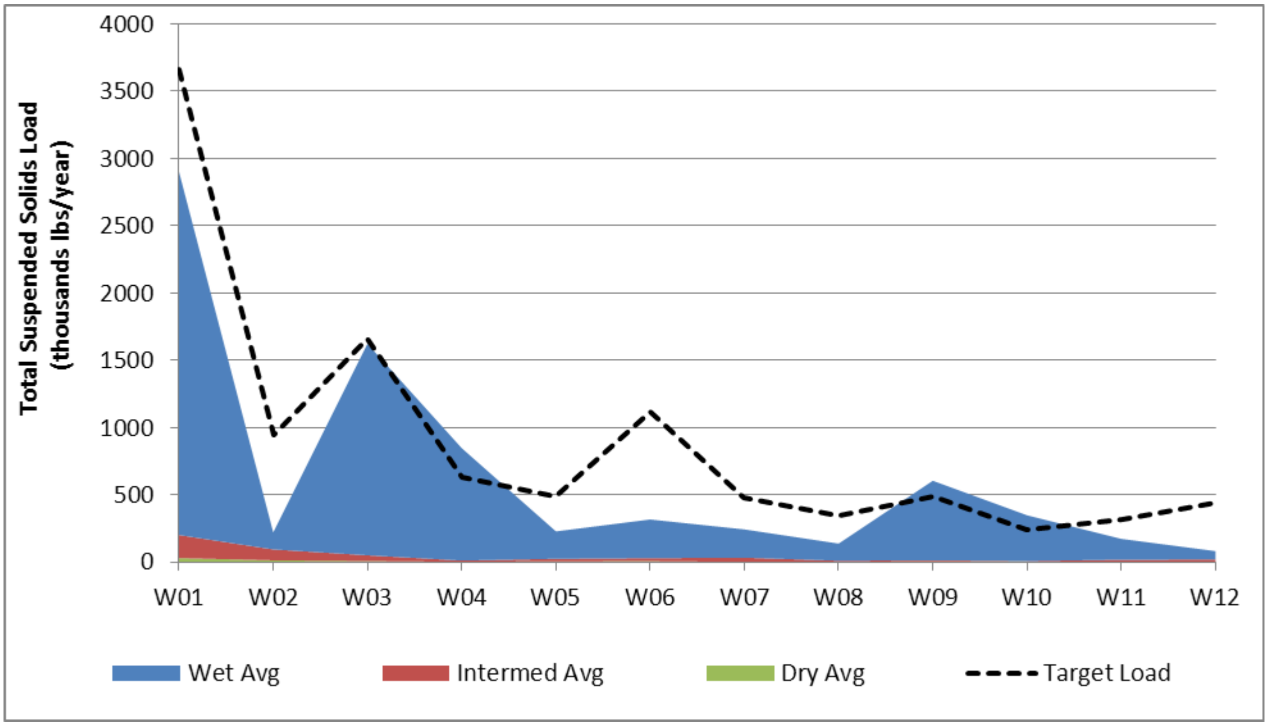
E. Suspended Solids

The TSS annual loading and reductions are shown in Figure 25 and Table 20, page 38. Dry weather events comprised less than two percent of the total annual load at all sites except W02, which is below Preston's Cave Spring. Wet weather loading averaged 89 percent of the total annual load for all sites as expected due to the higher flows and higher concentrations. Three sites require load reductions to meet target levels. Vaughn's Branch near the mouth (W04) requires a 26 percent reduction of 221,000 pounds/year. Springs Branch (W10) and Wolf Run between Faircrest Drive and Lafayette Drive (W09) also require annual reductions near 110,000 pounds, which are 30 percent and 19 percent of the total loads, respectively. Reduction of the erosive flow levels, restoration of eroded banks, and filtration of stormwater runoff will aid in achieving these target loads.

F. Pollutant Yield

The pollutant yields for each site were calculated by dividing the annual load by the area upstream of each site (subwatershed drainage area). The results are shown in Tables 21 and 22, page 39. Based on the yields, W10 is worst overall site with the highest yield for total phosphorus and total suspended solids and ranked 3rd and 4th in *E. coli* and total nitrogen load. W11 is second highest with above average rankings for all parameters. The lowest yields are found at W05, W07, and W12.

FIGURE 25 – ANNUAL TOTAL SUSPENDED SOLIDS LOADING CONTRIBUTIONS BY EVENT TYPE



*Target load based on 80 mg/L non-regulatory reference point.

TABLE 20 – TOTAL SUSPENDED SOLIDS ANNUAL LOAD REDUCTION

SITE	ANNUAL LOAD (POUNDS/YEAR)	TARGET LOAD* (POUNDS/YEAR)	LOAD REDUCTION (POUNDS/YEAR)	% REDUCTION
W01	2,900,000	3,660,000	-	-
W02	219,000	944,000	-	-
W03	1,620,000	1,660,000	-	-
W04	847,000	626,000	221,000	26%
W05	227,000	490,000	-	-
W06	316,000	1,110,000	-	-
W07	242,000	473,000	-	-
W08	136,000	342,000	-	-
W09	604,000	488,000	116,000	19%
W10	347,000	243,000	104,000	30%
W11	171,000	311,000	-	-
W12	80,600	437,000	-	-

*Target load based on 80 mg/L non-regulatory reference point.

TABLE 21 – ANNUAL YIELD OF POLLUTANTS

PARAMETER	UNIT	ANNUAL YIELD											
		W01	W02	W03	W04	W05	W06	W07	W08	W09	W10	W11	W12
Upstream Area	Acres	6614	1996*	3532	1966	1033	2234	1630	575	1024	428	581	749
E. coli	Billion CFU/year/acre	1073	83	1875	678	54	118	298	343	1791	1337	1101	106
Total Nitrogen	lbs/year/acre	10.8	18.7	8.04	3.25	11.2	10.4	3.40	9.08	7.44	11.2	13.3	11.9
Total Phosphorus	lbs/year/acre	2.23	2.18	1.88	2.65	1.72	2.11	1.55	1.92	1.92	4.38	2.85	1.29
Total Suspended Solids	lbs/year/acre	439	110	459	431	220	141	148	237	590	810	295	108

*Adjusted to include 402 acres of misbehaved karst in the Town Branch watershed that flow to McConnell Springs as well as all area in Big Elm Tributary and 50% of area in karst basin.

TABLE 22 – RANK OF SITES BY ANNUAL YIELD

PARAMETER	W01	W02	W03	W04	W05	W06	W07	W08	W09	W10	W11	W12
E. coli	5	11	1	6	12	9	8	7	2	3	4	10
Total Nitrogen	6	1	9	12	5	7	11	8	10	4	2	3
Total Phosphorus	4	5	9	3	10	6	11	8	7	1	2	12
Total Suspended Solids	4	11	3	5	8	10	9	7	2	1	6	12
Overal Rank by Yield	3	7	5	6	10	9	12	8	4	1	2	11

VII. SUMMARY OF WATERSHED CONDITIONS

Based on the analysis of all monitoring results, multiple factors are impacting the water quality in the Wolf Run watershed. Average concentrations of nitrogen, phosphorus, specific conductance, suspended solids, and *E. coli* each exceeded benchmarks for one or more event type. Table 23, page 41, identifies the relative priority of remediation of each site by parameter. All sites with high priority require reductions in order to achieve regulatory or target loading levels. Low and medium priority levels were determined by relative frequency of exceeding reference point concentrations. The percentage reductions required at the high priority sites are summarized in Table 24, page 41. This information is also presented spatially for each monitoring site on Exhibit 2, page 40.

Map Document: (P:\Project_Files\Kentucky\KY10-030_LFUCG_WolfRun\Mapping\GIS\Results\WQ_Exhibit_2_Sampling_Sites.mxd) 7/24/2012 -- 11:27:46 AM sje

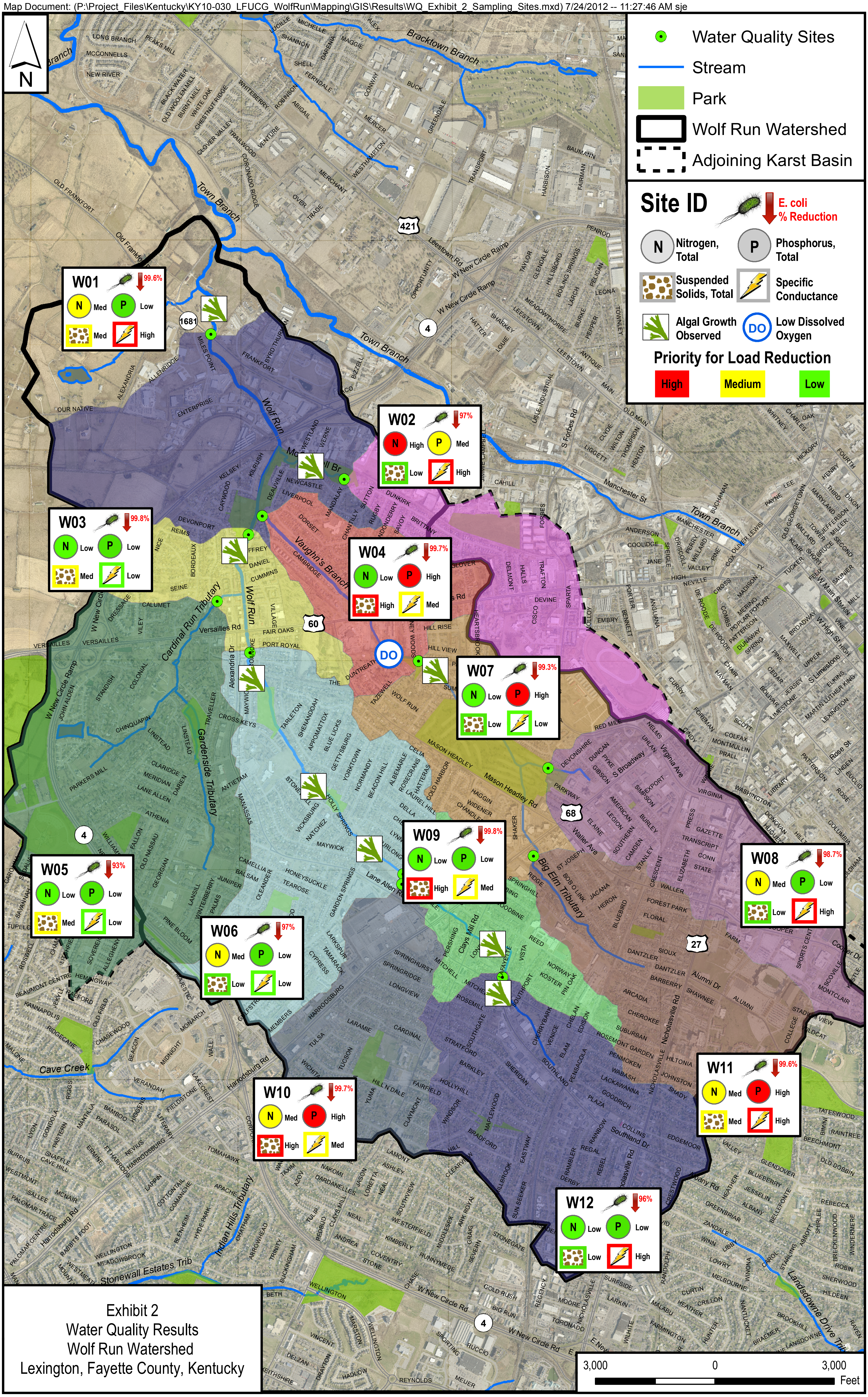


Exhibit 2
Water Quality Results
Wolf Run Watershed
Lexington, Fayette County, Kentucky

TABLE 23 – PRIORITY OF SITES FOR POLLUTANT REDUCTION BY PARAMETER

PARAMETER	W01	W02	W03	W04	W05	W06	W07	W08	W09	W10	W11	W12
E. coli	High	High	High	High	High	High	High	High	High	High	High	High
Total Nitrogen	Medium	High	Low	Low	Low	Medium	Low	Medium	Low	Medium	Medium	Low
Total Phosphorus	Low	Medium	Low	High	Low	Low	High	Low	Low	High	High	Low
Total Suspended Solids	Medium	Low	Medium	High	Medium	Low	Low	Low	High	High	Medium	Low
Specific Conductance	High	High	Low	Medium	Low	Low	Low	High	Medium	Medium	High	High

NOTE: High priority sites require a loading reduction or the concentration exceeded the benchmark in more than 50% of the measurements. Low priority sites had concentrations that exceeded the non-regulatory indicator level for less than 40% of samples for nitrogen, less than 30% for phosphorus, 0% for suspended solids, and less than 20% for specific conductance.

TABLE 24 – PERCENTAGE ANNUAL LOADING REDUCTION BY SITE

PARAMETER	% REDUCTION											
	W01	W02	W03	W04	W05	W06	W07	W08	W09	W10	W11	W12
E. coli – 130 CFU/100mLs	99.6%	95.8%	99.8%	99.7%	93.6%	96.9%	99.3%	98.7%	99.8%	99.7%	99.6%	95.9%
E. coli – 240 CFU/100mLs	99.3%	92.3%	99.7%	99.4%	88.2%	94.3%	98.7%	97.6%	99.6%	99.4%	99.3%	92.5%
Total Nitrogen	-	5%	-	-	-	-	-	-	-	-	-	-
Total Phosphorus	-	5%	-	47%	-	-	18%	-	-	43%	18%	-
Total Suspended Solids	-	-	-	26%	-	-	-	-	19%	30%	-	-

Overall, the most severe problem throughout the watershed is the pathogen indicator parameters, *E. coli* and fecal coliform, for which averages were above the instantaneous benchmark levels at all sites for all event types. Only 17 percent of the fecal coliform results were below the instantaneous PCR limit of 400 MPN/100mLs while 38 percent were below the SCR limit of 1000 MPN/100mLs. *E. coli* concentrations only met the instantaneous PCR limit of 240 MPN/100mLs in 14 percent of the results. Even lower percentages met the criteria for the geometric mean over a 30-day period for fecal coliform (10 percent below 200 CFU/100mLs) or *E. coli* (seven percent below 130 CFU/100mLs). With a human source likely for much of this load (Brion 2011), these levels pose a risk for recreational users of waters within the Wolf Run Watershed and reductions will be necessary throughout the watershed. Over 90 percent load reductions are required for *E. coli* at all sites with the most significant loading coming during wet weather. Remediation of the sanitary sewer system, including private laterals as well as public lines, will be critical to reducing the load in the watershed.

Excessive nutrient loading is impacting the Wolf Run Watershed as evidenced by the abundant algal growth present throughout much of the watershed, dissolved oxygen levels measured below the regulatory limit, and pH levels approaching the upper threshold of regulatory limits. Exhibit 2, page 40, identifies specific areas across the watershed where excessive algal growth was observed.

For nitrogen, load reductions are necessary at Preston's Cave Spring (W02) but due to the karst influence, remediation for these levels should be targeted to the area of the Town Branch Watershed captured by the McConnell Springs drainage as well as in the Big Elm Tributary subwatershed area (W11). Although annual load levels were acceptable, dry and intermediate concentrations of total nitrogen should be reduced particularly near the mouth of Wolf Run (W01), Wolf Run between Versailles Road and Beacon Hill Road (W06), the urban headwaters of Vaughn's Branch (W08), and in the Spring Branch subwatershed. Ammonia levels were high at many locations in the watershed during wet weather events, but should be addressed through efforts to reduce the fecal load.

For total phosphorus, background concentrations are high throughout the watershed, with orthophosphorus averaging about 0.25 mg/L for all conditions and total phosphorus averaging around 0.29 mg/L for dry and intermediate events. Load reductions are necessary for all of Vaughn's Branch except upstream of Picadome Golf Course (W04 and W07), on Spring Branch (W10), on Big Elm Tributary (W11) due in part to increased loading of wet particulate-bound phosphorus. Reduction of stream erosion and increased filtration of storm flows will aid in reducing the phosphorus levels in priority areas.

Suspended sediments, which contribute to in-stream siltation and sedimentation, are elevated in several areas including Vaughn's Branch near the mouth (W04), Spring Branch (W10), and Wolf Run between Faircrest Drive and Lafayette Drive (W09) and require reductions in storm loadings. Reduction of the erosive flow levels, restoration of eroded banks, and filtration on stormwater runoff will aid in achieving these target loads.

Specific conductance levels are frequently elevated at several locations in the watershed including the headwaters of Wolf Run (W12) and Vaughn's Branch (W08), Big Elm Tributary (11), McConnell's Branch (W02) and near the mouth of Wolf Run (W01). While background levels due to geology are around 375 μS/cm, additional dissolved ion contributions can elevate these levels to above 650 μS/cm. Additional studies should examine the prevalence of chloride as volunteer data indicates it may be a large contributor to the conductivity in Wolf Run. Follow up investigations to the conductivity survey of the watershed should indicate additional remediation activities.

Overall, Spring Branch (W10) and the Big Elm Tributary (W11) are the worst areas in the watershed for water quality. While some sites are better than others, no sites are identified for protection of good water quality conditions.

While individual pollutants are a contributor to both recreational use and warmwater aquatic habitat use impairments in the Wolf Run Watershed, remediation activities should also focus on habitat and flow regime improvements, as each are also contributors to the impairment of the streams of the watershed.

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APPENDICES

APPENDIX A – QAPP

APPENDIX B – FIELD NOTES

APPENDIX C – MONITORING RESULTS

Site	Date	Time	Duplicate ID	Event Type	Prior 7 day rainfall* in	Prior 72 hrs rainfall* in	Prior 24 hr Rainfall* in	Sampler	Flow cfs	Turb Visual	DO mg/L	pH SU	Specific Conductance uS/cm	Water Temperature °C	Fecal Coliform MPN/100mL	E. Coli MPN/100mL	CBOD mg/L	TSS mg/L	TDS mg/L	Alkalinity, Total mg/L CaCO3	Total Hardness mg/L CaCO3	Ammonia mg/L as N	Nitrite mg/L as N	TKN mg/L as N	Nitrate mg/L as N	Ortho - Phophosphate mg/L as P	Phosphorus, Total Recoverable mg/L as P
W01-11-0525	5/25/2011	9:32	---	INT	2.1	1.69	0.03	KEN COOKE	30.6	1	8.0	8.0	690	17.2	3405	1613	4	9	368	159	240	0.032	0.053	1.17	2.8	0.271	0.27
W02-11-0525	5/25/2011	10:13	---	INT	2.1	1.69	0.03	KEN COOKE	10.3	0	6.2	7.5	800	16.0	9322	2976	3	4	448	155	246	0.030	<0.050	1.07	3.1	0.270	0.25
W03-11-0525	5/25/2011	11:20	---	INT	2.1	1.69	0.03	KEN COOKE	11.5	0	8.6	8.0	600	17.5	1336	1336	3	5	314	149	225	0.023	0.054	0.94	3.1	0.286	0.28
W04-11-0525	5/25/2011	10:50	---	INT	2.1	1.69	0.03	KEN COOKE	1.6	0	8.9	8.0	750	18.0	979	1596	5	3	418	173	250	0.027	0.053	1.23	2.8	0.300	0.32
W05-11-0525	5/25/2011	11:50	---	INT	2.1	1.69	0.03	KEN COOKE	5.0	1	7.85	8.0	610	18.0	521	632	6	8	332	145	225	0.037	0.068	1.06	2.5	0.295	0.28
W06-11-0525	5/25/2011	12:20	---	INT	2.1	1.69	0.03	KEN COOKE	7.0	0	9.4	8.0	550	18.0	1989	2559	5	6	322	149	222	0.025	<0.015	0.73	3.4	0.29	0.26
W07-11-0525	5/25/2011	9:36	---	INT	2.1	1.69	0.03	BRUCE HUTCHESON	0.5	1	8.8	7.0	780	15.0	969	1100	3	9	436	168	250	0.027	0.065	1.37	2.8	0.306	0.28
W08-11-0525	5/25/2011	10:10	---	INT	2.1	1.69	0.03	BRUCE HUTCHESON	0.7	1	9.3	8.5	220	18.0	1187	969	4	4	752	170	350	0.029	0.088	1.37	3.4	0.174	0.18
W09-11-0525	5/25/2011	10:50	---	INT	2.1	1.69	0.03	BRUCE HUTCHESON	1.0	1	8.5	7.5	610	16.0	2109	1547	3	3	380	149	234	0.010	<0.015	1.33	3	0.224	0.21
W10-11-0525	5/25/2011	11:25	---	INT	2.1	1.69	0.03	BRUCE HUTCHESON	1.5	1	9.0	7.5	550	16.0	745	521	4	2	352	164	236	0.010	<0.015	0.64	3.9	0.246	0.23
W11-11-0525	5/25/2011	12:10	---	INT	2.1	1.69	0.03	BRUCE HUTCHESON	2.3	1	7.2	8.0	720	16.0	1869	1464	3	5	504	159	255	0.022	<0.015	1.85	2.8	0.235	0.21
W12-11-0525	5/25/2011	12:30	---	INT	2.1	1.69	0.03	BRUCE HUTCHESON	1.4	1	8.6	8.0	660	17.0	516	1350	3	3	406	160	215	0.016	0.051	1.34	2.5	0.147	0.13
WDD-11-0525	5/25/2011	---	W10	INT	2.1	1.69	0.03	BRUCE HUTCHESON	1.8	---	---	---	---	---	413	745	3	5	358	140	232	0.010	<0.015	0.66	3.9	0.246	0.24
Lab Precision			% RPD														Laboratory duplicates were not analyzed for these samples							1.5%	0.0%	0.5%	0.0%
Field Precision			%RPD						18%						57%	35%	29%	86%	2%	16%	2%	0%	0%	3%	0%	0%	4%
Lab Accuracy 1			% Recovery														69%	97%		101%	102%	106%		99%	108%	101%	99%
Lab Accuracy 2			% Recovery														92%					99%		102%	108%	100%	99%
W01-11-0613	6/13/2011	9:30	---	DRY	0.08	0.08	0	KEN COOKE	2.7	0	8.0	7.75	740	15.0	2010	1310	2	6	364	208	251	0.023	0.051	<0.07	1.9	0.242	0.29
W02-11-0613	6/13/2011	10:10	---	DRY	0.08	0.08	0	KEN COOKE	1.3	0	6.4	7.0	820	14.0	9910	7380	2	7	454	189	257	0.020	<0.015	1.6	3.1	0.291	0.29
W03-11-0613	6/13/2011	10:45	---	DRY	0.08	0.08	0	KEN COOKE	0.5	0	16.8	7.75	680	16.0	1730	1350	3	4	318	194	229	0.018	0.020	<0.07	1.4	0.218	0.25
W04-11-0613	6/13/2011	11:30	---	DRY	0.08	0.08	0	KEN COOKE	0.02	0	6.8	8.5	570	20.0	630	750	2	2	354	238	251	0.026	<0.015	<0.07	0.11	0.295	0.31
W05-11-0613	6/13/2011	12:10	---	DRY	0.08	0.08	0	KEN COOKE	0.4	0	7.0	7.5	610	17.0	510	1210	2	7	334	236	239	0.023	0.027	<0.07	1.8	0.253	0.32
W06-11-0613	6/13/2011	12:40	---	DRY	0.08	0.08	0	KEN COOKE	0.4	0	11.2	8.5	590	20.0	2790	2490	3	4	320	184	226	0.029	0.040	<0.07	2.1	0.277	0.32
W07-11-0613	6/13/2011	9:40	---	DRY	0.08	0.08	0	BOB EDWARDS	Pooled	1	9.8	8.0	530	18.0	6630	5560	4	3	284	210	222	<0.015	0.026	<0.07	0.97	0.380	0.42
W08-11-0613	6/13/2011	10:30	---	DRY	0.08	0.08	0	BOB EDWARDS	Pooled	1	11.0	8.0	1050	22.0	46110	86640	8	6	554	174	285	0.101	<0.015	<0.07	<0.02	0.071	0.24
W09-11-0613	6/13/2011	11:40	---	DRY	0.08	0.08	0	BOB EDWARDS	0.3	1	14.0	8.5	910	18.0	3550	2490	2	3	610	275	329	<0.015	0.024	0.7	1.6	0.193	0.23
W10-11-0613	6/13/2011	11:40	---	DRY	0.08	0.08	0	BOB EDWARDS	0.01	1	13.0	8.0	660	15.5	2280	1850	2	5	374	186	239	<0.015	0.023	1.6	3.2	0.247	0.32
W11-11-0613	6/13/2011	NS	---	DRY	0.08	0.08	0	*Not Sampled*	Dry	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
W12-11-0613	6/13/2011	12:40	---	DRY	0.08	0.08	0	BOB EDWARDS	Pooled	1	21.1	8.75	550	20.1	5210	4040	4	5	322	200	198	0.019	0.023	<0.07	1	0.046	0.11
WDD-11-0613	6/13/2011	---	W04	DRY	0.08	0.08	0	BOB EDWARDS	0.05	---	---	---	---	---	740	1710	2	4	344	214	237	0.025	<0.015	<0.07	0.54	0.295	0.31
Lab Precision			% RPD														Laboratory duplicates were not analyzed for these samples							1.5%	0.0%	0.5%	0.0%
Field Precision			%RPD						86%						16%	78%	0%	67%	3%	11%	6%	4%	0%	0%	132%	0%	0%
Lab Accuracy 1			% Recovery														84%	98%		100%	93%	103%		98%	98%	105%	105%
Lab Accuracy 2			% Recovery														64%					98%		97%	97%	99%	105%
W01-11-0708	7/8/2011	10:08	---	NT in Rain	1.68	1.41	0.99	KEN COOKE	36.2	2	---	---	280	---	36540	32554	---	---	---	---	---	---	---	---	---	---	---
W02-11-0708	7/8/2011	10:43	---	NT in Rain	1.68	1.41	0.99	JACK DICKEY	15.6	1	---	---	310	---	38732	21426	---	---	---	---	---	---	---	---	---	---	---
W03-11-0708	7/8/2011	11:10	---	NT in Rain	1.68	1.41	0.99	JACK DICKEY	Too Fast	3	---	---	190	---	57943	34480	---	---	---	---	---	---	---	---	---	---	---
W04-11-0708	7/8/2011	11:21	---	NT in Rain	1.68	1.41	0.99	JACK DICKEY	Too Fast	3	---	---	210	---	81641	29093	---	---	---	---	---	---	---	---	---	---	---
W05-11-0708	7/8/2011	12:00	---	NT in Rain	1.68	1.41	0.99	JACK DICKEY	Too Fast	3	---	---	250	---	20982	12809	---	---	---	---	---	---	---	---	---	---	---
W06-11-0708	7/8/2011	12:24	---	NT in Rain	1.68	1.41	0.99	JACK DICKEY	Too Fast	3	---	---	110	---	34480	13169	---	---	---	---	---	---	---	---	---	---	---
W07-11-0708	7/8/2011	10:15	---	NT in Rain	1.68	1.41	0.99	KEN COOKE	9.7	---	---	---	---	---	16071	15525	---	---	---	---	---	---	---	---	---	---	---
W08-11-0708	7/8/2011	10:45	---	NT in Rain	1.68	1.41	0.99	KEN COOKE	173.0	---	---	---	---	---	24003	17216	---	---	---	---	---	---	---	---	---	---	---
W09-11-0708	7/8/2011	11:30	---	NT in Rain	1.68	1.41	0.99	KEN COOKE	Too Fast	---	---	---	---	---	27551	17233	---	---	---	---	---	---	---	---	---	---	---
W10-11-0708	7/8/2011	12:00	---	NT in Rain	1.68	1.41	0.99	KEN COOKE	20.6	---	---	---	---	---	19179	7328	---	---	---	---	---	---	---	---	---	---	---
W11-11-0708	7/8/2011	11:38	---	NT in Rain	1.68	1.41	0.99	KEN COOKE	Too Fast	---	---	---	---	---	32554	26125	---	---	---	---	---	---	---	---	---	---	---
W12-11-0708	7/8/2011	12:10	---	NT in Rain	1.68	1.41	0.99	KEN COOKE	21.5	---	---	---	---	---	22818	9599	---	---	---	---	---	---	---	---	---	---	---
WDD-11-0708	7/8/2011	---	W12	NT in Rain	1.68	1.41	0.99	KEN COOKE	22.6	---	---	---	---	---	43517	7200	---	---	---	---	---	---	---	---	---	---	---
Lab Precision			% RPD												Laboratory duplicates were not analyzed for these samples												
Field Precision			%RPD						5%						62%	29%											
W01-11-0711	7/11/2011	9:30	---	INT	3.86	2.46	0	JAMIE ANDERSON	7.8	0	7.4	7.2	720	21.0	510	1480	3	6	868	205	257	0.019	<0.015	0.36	2.8	0.010	0.27
W02-11-0711	7/11/2011	10:05	---	INT	3.86	2.46	0	JAMIE ANDERSON	4.2	1	6.6	6.7	810	18.0	200	520	3	8	522	193	272	0.017	<0.015	<0.07	3.2	0.270	0.31
W03-11-0711	7/11/2011	10:55	---	INT	3.86	2.46	0	JAMIE ANDERSON	3.0	0	9.4	7.1	600	26.0	1750	1440	3	4	406	175	230	<0.015	0.016	<0.07	2.6	0.270	0.30
W04-11-0711	7/11/2011	10:25	---	INT	3.86	2.46	0	JAMIE ANDERSON	0.4	0	7.6	7.2	670	25.0	1580	860	4	7	370	207	257	<0.015	<0.015	0.27	2.2	0.284	0.26
W05-11-0711	7/11/2011	11:20	---	INT	3.86	2.46	0	JAMIE ANDERSON	1.4	0	6.2	6.9	620	23.0	410	520	5	8	412	175	234	0.039	0.019	0.29	2.1	0.282	0.29
W06-11-0711	7/11/2011	11:35	---	INT	3.86	2.46	0	JAMIE ANDERSON	1.6	0	8.2	7.5	590	26.0	2330	1090	4	2	318	179	235	0.017	<0.015	0.36	3	0.279	0.30
W07-11-0711	7/11/2011	9:45	---	INT	3.86	2.46	0	GRANT MUTERSBAUGH	0.2	3	7.0	7.5	560	20.0	8600	7330	4	78	362	204	235	0.065	0.023	<0.07	2.4	0.335	0.64
W08-11-0711	7/11/2011	10:25	---	INT	3.86	2.46	0	GRANT MUTERSBAUGH	0.3	1	6.8	7.8	1120	24.0	1200	750	5	8	780	159	332	0.031	0.018	<0.07	3.7	0.129	0.10
W09-11-0711	7/11/2011	11:15	---	INT	3.86	2.46	0	GRANT MUTERSBAUGH	0.4	1	8.8	7.8	700	23.0	3640	4350	4	6	234	174	267	0.017	<0.015	<0.07	2.7	0.248	0.26
W10-11-0711	7/11/2011	11:30	---	INT	3.86	2.46	0	GRANT MUTERSBAUGH	0.6	1	8.7	7.8	620	18.0	1340	2180	3	4	404	177	237	<0.015	<0.015	<0.07	3.2	0.243	0.27
W11-11-0711	7/11/2011	12:00	---	INT	3.86	2.46	0	GRANT MUTERSBAUGH	0.6	1	5.6	7.8	910	21.0	2350	2260	3	7	618	188	306	0.02	<0.015	<0.07	4.2	0.519	0.52
W12-11-0711	7/11/2011	12:40	---	INT	3.86	2.46	0	GRANT MUTERSBAUGH	0.02	1	8.8	7.8	720	25.0	520	410	3	14	482	166	244	0.018	<0.015	<0.07	2.2	0.132	0.15
WDD-11-0711	7/11/2011	---	W09	INT	3.86	2.46	0	GRANT MUTERSBAUGH	0.5	---	---	---	---	---	3090	3410	3	5	386	179	258	0.016	<0.015	<0.07	2.6	0.248	0.25
Lab Precision			% RPD														Laboratory duplicates were not analyzed for these samples							0%	0.70%	9.52%	10.53%
Field Precision			%RPD						22%						16%	24%	29%	18%	49%	3%	3%	6%	0%	0%	4%	0%	4%
Lab Accuracy 1			% Recovery														109%	83%		102%	95%	105%		100%	98%	102%	94%
Lab Accuracy 2			% Recovery														83%					102%		106%	99%	101%	94%

Site	Date	Time	Duplicate ID	Event Type	Prior 7 day rainfall* in	Prior 72 hrs rainfall* in	Prior 24 hr Rainfall* in	Sampler	Flow cfs	Turb Visual	DO mg/L	pH SU	Specific Conductance uS/cm	Water Temperature °C	Fecal Coliform MPN/100mL	E. Coli MPN/100mL	CBOD mg/L	TSS mg/L	TDS mg/L	Alkalinity, Total mg/L CaCO3	Total Hardness mg/L CaCO3	Ammonia mg/L as N	Nitrite mg/L as N	TKN mg/L as N	Nitrate mg/L as N	Ortho - Phophosphate mg/L as P	Phosphorus, Total Recoverable mg/L as P
W01-11-0715	7/15/2011	9:35	---	DRY	2.52	0.08	0	JAMIE ANDERSON	6.3	0	---	---	720	---	1712	516	---	---	---	---	---	---	---	---	---	---	---
W02-11-0715	7/15/2011	9:35	---	DRY	2.52	0.08	0	KEN COOKE	3.9	0	---	---	770	---	202	306	---	---	---	---	---	---	---	---	---	---	---
W03-11-0715	7/15/2011	10:20	---	DRY	2.52	0.08	0	JAMIE ANDERSON	0.2	1	---	---	580	---	1223	304	---	---	---	---	---	---	---	---	---	---	---
W04-11-0715	7/15/2011	10:30	---	DRY	2.52	0.08	0	JAMIE ANDERSON	1.7	0	---	---	660	---	2378	413	---	---	---	---	---	---	---	---	---	---	---
W05-11-0715	7/15/2011	10:05	---	DRY	2.52	0.08	0	JAMIE ANDERSON	0.5	0	---	---	620	---	1323	306	---	---	---	---	---	---	---	---	---	---	---
W06-11-0715	7/15/2011	9:50	---	DRY	2.52	0.08	0	KEN COOKE	1.1	0	---	---	600	---	3405	2281	---	---	---	---	---	---	---	---	---	---	---
W07-11-0715	7/15/2011	10:05	---	DRY	2.52	0.08	0	KEN COOKE	Pooled	---	---	---	570	---	3877	2133	---	---	---	---	---	---	---	---	---	---	---
W08-11-0715	7/15/2011	10:20	---	DRY	2.52	0.08	0	KEN COOKE	0.04	---	---	---	1300	---	1712	2621	---	---	---	---	---	---	---	---	---	---	---
W09-11-0715	7/15/2011	9:35	---	DRY	2.52	0.08	0	BOB EDWARDS	0.1	1	---	---	750	---	2590	2307	---	---	---	---	---	---	---	---	---	---	---
W10-11-0715	7/15/2011	9:45	---	DRY	2.52	0.08	0	BOB EDWARDS	0.4	1	---	---	650	---	731	202	---	---	---	---	---	---	---	---	---	---	---
W11-11-0715	7/15/2011	10:00	---	DRY	2.52	0.08	0	BOB EDWARDS	0.2	1	---	---	890	---	3405	1336	---	---	---	---	---	---	---	---	---	---	---
W12-11-0715	7/15/2011	10:10	---	DRY	2.52	0.08	0	BOB EDWARDS	0.05	1	---	---	720	---	413	202	---	---	---	---	---	---	---	---	---	---	---
WDD-11-0715	7/15/2011	---	W06	DRY	2.52	0.08	0	KEN COOKE	---	---	---	---	---	---	1989	1323	---	---	---	---	---	---	---	---	---	---	---
Lab Precision			% RPD												Laboratory duplicates were not analyzed for these samples												
Field Precision			%RPD												53%	53%											
W01-11-0725	7/25/2011	10:15	---	INT	1.51	1.39	1.39	KEN COOKE	6.3	1.5-2.0	6.49	7.5	300	22.6	20980	32410	---	---	---	---	---	---	---	---	---	---	---
W02-11-0725	7/25/2011	10:50	---	INT	1.51	1.39	1.39	KEN COOKE	4.0	1.5	5.99	6.8	310	22.2	15150	27890	---	---	---	---	---	---	---	---	---	---	---
W03-11-0725	7/25/2011	11:40	---	INT	1.51	1.39	1.39	KEN COOKE	8.7	0.5	8.24	7.7	420	24.6	30760	32550	---	---	---	---	---	---	---	---	---	---	---
W04-11-0725	7/25/2011	11:20	---	INT	1.51	1.39	1.39	KEN COOKE	2.8	1	7.01	7.0	330	25.3	41060	13140	---	---	---	---	---	---	---	---	---	---	---
W05-11-0725	7/25/2011	12:05	---	INT	1.51	1.39	1.39	KEN COOKE	0.1	0.5	3.5	7.5	580	23.9	16160	11530	---	---	---	---	---	---	---	---	---	---	---
W06-11-0725	7/25/2011	12:30	---	INT	1.51	1.39	1.39	KEN COOKE	3.1	1	7.71	7.6	260	24.5	48840	9060	---	---	---	---	---	---	---	---	---	---	---
W07-11-0725	7/25/2011	10:15	---	INT	1.51	1.39	1.39	JAIME ANDERSON	3.9	2	6.2		530	23	24810	10710	---	---	---	---	---	---	---	---	---	---	---
W08-11-0725	7/25/2011	10:45	---	INT	1.51	1.39	1.39	JAIME ANDERSON	3.0	1	6.0		210	23	19180	21430	---	---	---	---	---	---	---	---	---	---	---
W09-11-0725	7/25/2011	11:05	---	INT	1.51	1.39	1.39	JAIME ANDERSON	2.0	1	5.5		280	23	23330	13740	---	---	---	---	---	---	---	---	---	---	---
W10-11-0725	7/25/2011	11:20	---	INT	1.51	1.39	1.39	JAIME ANDERSON	0.9	1	8.2		460	19	16640	4590	---	---	---	---	---	---	---	---	---	---	---
W11-11-0725	7/25/2011	11:35	---	INT	1.51	1.39	1.39	JAIME ANDERSON	1.6	1	6.0		360	22	22820	16160	---	---	---	---	---	---	---	---	---	---	---
W12-11-0725	7/25/2011	11:55	---	INT	1.51	1.39	1.39	JAIME ANDERSON	1.5	1	7.6		300	24	14500	6830	---	---	---	---	---	---	---	---	---	---	---
WDD-11-0725	7/25/2011	---	W06	INT	1.51	1.39	1.39	KEN COOKE	0.1	---	---	---	---	---	18500	8550	---	---	---	---	---	---	---	---	---	---	---
TB Lab Duplicate			W10	INT	1.51	1.39	1.39	---	---	---	---	---	---	---	10460	6130											
Lab Precision			% RPD												46%	29%											
Field Precision			%RPD												90%	6%											
W01-11-0729	7/29/2011	9:35	---	INT	2.5	1.11	1.11	MARGARET SHANKS	1.9	1	7.0	7.6	710	19	410	306	---	---	---	---	---	---	---	---	---	---	---
W02-11-0729	7/29/2011	10:20	---	INT	2.5	1.11	1.11	MARGARET SHANKS	1.4	1	8.9	6.9	770	16	100	<100	---	---	---	---	---	---	---	---	---	---	---
W03-11-0729	7/29/2011	11:15	---	INT	2.5	1.11	1.11	MARGARET SHANKS	0.3	1-2	23.4	8.96	520	27	410	521	---	---	---	---	---	---	---	---	---	---	---
W04-11-0729	7/29/2011	11:00	---	INT	2.5	1.11	1.11	MARGARET SHANKS	<0.01	1	6.8	7.8	620	23	410	413	---	---	---	---	---	---	---	---	---	---	---
W05-11-0729	7/29/2011	11:45	---	INT	2.5	1.11	1.11	MARGARET SHANKS	0.2	1	6.4	7.6	580	23	<100	304	---	---	---	---	---	---	---	---	---	---	---
W06-11-0729	7/29/2011	12:10	---	INT	2.5	1.11	1.11	MARGARET SHANKS	0.3	1	12.8	7.8	588	24	1220	Tech Error	---	---	---	---	---	---	---	---	---	---	---
W07-11-0729	7/29/2011	9:40	---	INT	2.5	1.11	1.11	KEN COOKE	0.02	0	---	---	530	---	1450	Tech Error	---	---	---	---	---	---	---	---	---	---	---
W08-11-0729	7/29/2011	10:00	---	INT	2.5	1.11	1.11	KEN COOKE	0.2	0	---	---	690	---	310	Tech Error	---	---	---	---	---	---	---	---	---	---	---
W09-11-0729	7/29/2011	10:45	---	INT	2.5	1.11	1.11	KEN COOKE	<0.01	0	---	---	800	---	1480	Tech Error	---	---	---	---	---	---	---	---	---	---	---
W10-11-0729	7/29/2011	10:45	---	INT	2.5	1.11	1.11	KEN COOKE	0.5	0	---	---	670	---	2130	Tech Error	---	---	---	---	---	---	---	---	---	---	---
W11-11-0729	7/29/2011	10:30	---	INT	2.5	1.11	1.11	KEN COOKE	0.05	0	---	---	911	---	1750	Tech Error	---	---	---	---	---	---	---	---	---	---	---
W12-11-0729	7/29/2011	11:15	---	INT	2.5	1.11	1.11	KEN COOKE	0.04	0	---	---	670	---	840	<100	---	---	---	---	---	---	---	---	---	---	---
WDD-11-0729	7/29/2011	---	W05	INT	2.5	1.11	1.11	MARGARET SHANKS	---	---	---	---	---	---	410	201	---	---	---	---	---	---	---	---	---	---	---
TB Lab Duplicate	7/29/2011	---	W10	---	---	---	---	---	---	---	---	---	---	---	2750	Tech Error	---	---	---	---	---	---	---	---	---	---	---
Lab Precision			% RPD												25%	NA											
Field Precision			%RPD												112%	NA											
W06-11-0802	8/2/2011	14:30	---	INT	1.78	0.67	0	GERRY FISTER	0.3	---	---	---	---	---	1350	202	---	---	---	---	---	---	---	---	---	---	---
W07-11-0802	8/2/2011	14:20	---	INT	1.78	0.67	0	GERRY FISTER	<0.01	---	---	---	---	---	8803	5555	---	---	---	---	---	---	---	---	---	---	---
W08-11-0802	8/2/2011	14:05	---	INT	1.78	0.67	0	GERRY FISTER	0.5	---	---	---	---	---	202	306	---	---	---	---	---	---	---	---	---	---	---
W09-11-0802	8/2/2011	13:45	---	INT	1.78	0.67	0	GERRY FISTER	0.01	---	---	---	---	---	4519	4500	---	---	---	---	---	---	---	---	---	---	---
W10-11-0802	8/2/2011	13:45	---	INT	1.78	0.67	0	GERRY FISTER	0.4	---	---	---	---	---	1849	306	---	---	---	---	---	---	---	---	---	---	---
W11-11-0802	8/2/2011	13:35	---	INT	1.78	0.67	0	GERRY FISTER	<0.01	---	---	---	---	---	5573	1989	---	---	---	---	---	---	---	---	---	---	---
WDD-11-0802	8/2/2011	---	W8	INT	1.78	0.67	0	GERRY FISTER	0.5	---	---	---	---	---	202	100	---	---	---	---	---	---	---	---	---	---	---
TB Lab Duplicate	8/2/2011	---	W10	INT	1.78	0.67	0	GERRY FISTER	---	---	---	---	---	---	1323	1089	---	---	---	---	---	---	---	---	---	---	---
Lab Precision															33%	112%											
Field Precision															0%	101%											

Site	Date	Time	Duplicate ID	Event Type	Prior 7 day rainfall* in	Prior 72 hrs rainfall* in	Prior 24 hr Rainfall* in	Sampler	Flow cfs	Turb Visual	DO mg/L	pH SU	Specific Conductance uS/cm	Water Temperature °C	Fecal Coliform MPN/100mL	E. Coli MPN/100mL	CBOD mg/L	TSS mg/L	TDS mg/L	Alkalinity, Total mg/L CaCO3	Total Hardness mg/L CaCO3	Ammonia mg/L as N	Nitrite mg/L as N	TKN mg/L as N	Nitrate mg/L as N	Ortho - Phophosphate mg/L as P	Phosphorus, Total Recoverable mg/L as P
W01-11-0829	8/29/2011	9:23	---	DRY	0	0	0	KEN COOKE	1.1	0	7.73	7.78	697	18.1	520	200	2	5	374	202	257	0.033	<0.015	0.21	1.6	0.274	0.28
W02-11-0829	8/29/2011	9:46	---	DRY	0	0	0	KEN COOKE	0.8	0	7.96	7.00	736	17.1	750	410	2	6	406	199	282	<0.015	<0.015	<0.07	2.6	0.283	0.30
W03-11-0829	8/29/2011	10:15	---	DRY	0	0	0	KEN COOKE	0.04	0	16.85	8.58	585.1	22.1	200	200	3	3	360	202	266	0.015	0.027	<0.07	0.61	0.249	0.26
W04-11-0829	8/29/2011	10:38	---	DRY	0	0	0	KEN COOKE	0.03	0	7.62	7.91	601	19.4	5460	13760	2	3	340	206	255	0.018	<0.015	<0.07	0.27	0.289	0.32
W05-11-0829	8/29/2011	11:15	---	DRY	0	0	0	KEN COOKE	0.10	0	6.51	7.74	598	19.7	510	630	2	5	356	226	277	<0.015	<0.015	0.14	1.0	0.261	0.27
W06-11-0829	8/29/2011	11:35	---	DRY	0	0	0	KEN COOKE	0.15	0	12.67	8.30	564	21.7	300	200	2	9	340	185	249	<0.015	0.028	0.17	1.4	0.322	0.33
W07-11-0829	8/29/2011	9:35	---	DRY	0	0	0	BOB EDWARDS	<0.01	1	3.7	7.0	510	20.0	1730	2490	3	2	304	199	228	<0.015	0.044	<0.07	0.9	0.373	0.39
W08-11-0829	8/29/2011	9:55	---	DRY	0	0	0	BOB EDWARDS	0.01	1	11.6	8.0	210*	23.0	310	<100	2	9	678	164	275	<0.015	0.041	<0.07	3.0	0.175	0.38
W09-11-0829	8/29/2011	10:20	---	DRY	0	0	0	BOB EDWARDS	0.01	1	11.2	7.5	990	21.0	980	1350	2	36	2060	225	261	0.025	0.037	<0.07	2.1	0.446	0.39
W10-11-0829	8/29/2011	10:35	---	DRY	0	0	0	BOB EDWARDS	0.11	1	8.2	7.5	620	20.0	860	750	2	17	396	196	262	<0.015	0.027	<0.07	3.1	0.836	0.51
W11-11-0829	8/29/2011	NS	---	DRY	0	0	0	BOB EDWARDS	Dry	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
W12-11-0829	8/29/2011	11:00	---	DRY	0	0	0	BOB EDWARDS	0.03	1	7.3	7.5	500	24.0	410	310	4	18	382	153	215	<0.015	<0.015	<0.07	0.14	0.081	0.13
WDD-11-0829	8/29/2011	---	W12	DRY	0	0	0	BOB EDWARDS	---	---	---	---	---	---	100	200	4	19	290	157	222	0.023	<0.015	<0.07	0.14	0.107	0.11
TB Lab Duplicate	8/29/2011	---	W02	DRY	0	0	0	---	---	---	---	---	---	---	---	---	3	7	484	201	280	<0.015	<0.015	---	---	---	---
TB Lab Duplicate	8/29/2011	---	W10	DRY	0	0	0	---	---	---	---	---	---	---	NA	410	---	---	---	---	---	---	---	---	---	---	---
Lab Precision									*Suspected typo, measured 1170 on 8/30/2011 12:30						NA	59%	40%	15%	18%	1%	1%	0%	0%	0%	0%	3%	4%
Field Precision															122%	43%	0%	5%	27%	2%	3%	42%	0%	0%	0%	28%	17%
Lab Accuracy 1															---	---	83%	96%	101%	100%	101%	108%	97%	105%	99%	94%	102%
Lab Accuracy 2															---	---	65%	---	---	---	---	100%	---	106%	95%	94%	102%
																										Not filtered - Reject	
W01-11-0930	9/30/2011	9:39	---	DRY	1.34	0	0	KEN COOKE	10.9	0	7.60	8.30	790	15.0	520	750	3	6	426	232	290	<0.015	<0.015	<0.07	3.1	0.303	0.32
W02-11-0930	9/30/2011	10:41	---	DRY	1.34	0	0	KEN COOKE	2.4	0	7.40	7.00	870	15.0	100	310	2	10	460	216	290	<0.015	<0.015	<0.07	3.6	0.301	0.33
W03-11-0930	9/30/2011	12:03	---	DRY	1.34	0	0	KEN COOKE	2.6	0	10.00	8.00	700	15.5	630	630	1	6	358	205	270	<0.015	<0.015	<0.07	3.1	0.328	0.33
W04-11-0930	9/30/2011	11:25	---	DRY	1.34	0	0	KEN COOKE	0.4	0	8.20	8.00	770	15.5	100	310	2	8	348	238	285	<0.015	<0.015	<0.07	2.8	0.344	0.38
W05-11-0930	9/30/2011	12:40	---	DRY	1.34	0	0	KEN COOKE	1.6	0	8.00	7.80	700	15.5	200	310	2	11	382	202	258	0.023	0.015	<0.07	2.8	0.334	0.31
W06-11-0930	9/30/2011	1:20	---	DRY	1.34	0	0	KEN COOKE	1.1	0	8.60	7.90	670	16.0	1850	1850	2	9	350	203	275	<0.015	<0.015	<0.07	3.7	0.342	0.35
W07-11-0930	9/30/2011	9:45	---	DRY	1.34	0	0	KEN COOKE	0.04	1	6.20	7.0	680	14.0	2590	3090	2	23	302	224	260	0.021	0.017	<0.07	2.9	0.431	0.47
W08-11-0930	9/30/2011	10:30	---	DRY	1.34	0	0	KEN COOKE	0.14	1	10.4	8.5	1230	14.0	2430	2110	3	6	628	212	400	0.029	<0.015	0.84	3.7	0.227	0.25
W09-11-0930	9/30/2011	11:15	---	DRY	1.34	0	0	KEN COOKE	0.12	1	8.4	8.0	930	14.0	3990	2880	2	5	422	212	310	<0.015	<0.015	<0.07	3.2	0.297	0.29
W10-11-0930	9/30/2011	11:00	---	DRY	1.34	0	0	KEN COOKE	0.5	1	9.0	8.0	720	14.0	<100	100	2	7	370	213	260	0.015	<0.015	0.86	3.3	0.294	0.3
W11-11-0930	9/30/2011	11:45	---	DRY	1.34	0	0	KEN COOKE	0.14	1	6.8	8.0	1070	12.0	840	630	2	8	452	212	330	0.018	<0.015	0.79	4.8	0.327	0.34
W12-11-0930	9/30/2011	12:15	---	DRY	1.34	0	0	KEN COOKE	0.04	1	9.2	8.0	850	14.0	630	1340	2	5	314	157	255	0.018	<0.015	<0.07	2.3	0.117	0.15
WDD-11-0930	9/30/2011	---	W07	DRY	1.34	0	0	KEN COOKE	0.10	---	7.31	7.43	579.6	15.71	1730	1160	2	4	206	220	255	0.021	<0.015	<0.07	2.8	0.427	0.59
TB Lab Duplicate	9/30/2011	---	W04	DRY	1.34	0	0	---	---	---	---	---	---	---	410	200	1	5	462	251	292	<0.015	<0.015	---	---	---	---
Lab Precision															122%	43%	67%	46%	28%	5%	2%	0%	0%	0%	0%	1%	0%
Field Precision									86%		16%	6%	16%	12%	40%	91%	0%	141%	38%	2%	2%	0%	13%	0%	4%	1%	23%
Lab Accuracy 1															---	---	71%	86%	72%	100%	99%	99%	105%	98%	98%	104%	102%
Lab Accuracy 2															---	---	97%	---	---	---	---	110%	---	105%	106%	104%	102%
W01-11-1013	10/13/2011	14:00	---	WET	0.01	0.01	0.01	STEVE EVANS	69.9	3	10.66	7.57	276	16.84	43517	111987	12	109	170	145	145	0.133	0.008	<0.07	0.61	0.369	0.53
W02-11-1013	10/13/2011	13:10	---	WET	0.01	0.01	0.01	STEVE EVANS	8.6	1	8.54	7.06	819	15.81	521	413	2	9	516	251.5	370	<0.015	<0.001	<0.07	3.3	0.273	0.36
W03-11-1013	10/13/2011	12:40	---	WET	0.01	0.01	0.01	STEVE EVANS	20.7	3	7.70	7.48	196	16.82	61314	198629	13	125	66	70.5	150	0.118	0.018	<0.07	0.54	0.290	0.2
W04-11-1013	10/13/2011	12:25	---	WET	0.01	0.01	0.01	STEVE EVANS	13.3	3	4.92	7.36	297	16.95	20142	46111	10	129	178	103.5	170	0.082	<0.001	<0.07	0.34	0.359	0.98
W05-11-1013	10/13/2011	12:10	---	WET	0.01	0.01	0.01	STEVE EVANS	1.0	3	9.44	7.25	33	17.32	2718	2462	12	101	22	33	105	0.300	<0.001	<0.07	0.23	0.204	0.27
W06-11-1013	10/13/2011	12:00	---	WET	0.01	0.01	0.01	STEVE EVANS	0.04	2	8.08	7.76	584	16.29	731	2034	5	13	86	222	305	0.024	0.020	<0.07	0.75	0.464	0.5
W07-11-1013	10/13/2011	14:20	---	WET	0.01	0.01	0.01	CORY BLOYD	9.1	2	8.11	7.98	84.6	17.56	16071	38732	13	31	92	39.5	105	0.233	0.005	0.27	0.38	0.314	0.51
W08-11-1013	10/13/2011	14:00	---	WET	0.01	0.01	0.01	CORY BLOYD	5.8	2	8.6	7.81	90.5	17.67	9881	21872	11	38	124	39.5	90	0.167	0.018	0.19	0.34	0.256	0.44
W09-11-1013	10/13/2011	13:40	---	WET	0.01	0.01	0.01	CORY BLOYD	39.6	3	8.6	7.79	156.6	17.06	77010	173289	13	146	46	43.5	106	0.306	0.025	0.39	0.5	0.516	0.29
W10-11-1013	10/13/2011	13:15	---	WET	0.01	0.01	0.01	CORY BLOYD	20.1	3	9.1	7.81	82.7	17.06	64882	129965	12	200	372	40	85	0.127	0.004	<0.07	0.32	0.361	0.87
W11-11-1013	10/13/2011	12:15	---	WET	0.01	0.01	0.01	CORY BLOYD	1.9	1	6.8	7.80	975.1	15.83	61314	111987	13	0	628	211	370	0.020	0.004	<0.07	1.6	0.604	0.62
W12-11-1013	10/13/2011	9:55	---	WET	0.01	0.01	0.01	CORY BLOYD	0.2	1	7.54	7.77	674	17.22	3692	4798	6	8	318	177	285	0.041	0.004	<0.07	1.8	0.18	0.24
WDD-11-1013	10/13/2011	---	W04	WET	0.01	0.01	0.01	CORY BLOYD	9.1	---	---	---	---	---	92084	141361	11	110	198	107.5	155	0.061	0.003	<0.07	0.68	0.359	1.12
TB Lab Duplicate	10/13/2011	---	W05	WET	0.01	0.01	0.01	---	---	---	---	---	---	---	2462	2530	12	101	100	26	105	0.304	<0.001	---	---	---	---
Lab Precision															10%	3%	0%	0%	128%	24%	0%	1%	0%	0%	1%	0%	0%
Field Precision								Flow was duplicated at W07	0%						128%	102%	10%	16%	11%	4%	9%	29%	100%	0%	67%	0%	13%
Lab Accuracy 1															---	---	95%	101%	114%	106%	99%	100%	78%	98%	98%	99%	102%
Lab Accuracy 2															---	---	83%	---	---	---	---	97%	---	107%	109%	100%	102%
W01-11-1116	11/16/2011	9:35	---	NT in Rain	1.25	1.22	0.85	BRAD REDMON	47.9	3	8.3	7.00	260	11.70	5200	6370	6	27	82	100	102	0.021	<0.015	<0.07	0.86	0.234	0.36
W02-11-1116	11/16/2011	11:10	---	NT in Rain	1.25	1.22	0.85	BRAD REDMON	16.8	2	7.0	6.80	530	13.00	1460	1460	3	33	172	108	199	<0.015	<0.015	<0.07	1.7	0.302	0.48
W03-11-1116	11/16/2011	12:20	---	NT in Rain	1.25	1.22	0.85	BRAD REDMON	16.0	2	8.2	7.00	350	11.80	3410	4430	5	13	50	105	127	0.025	<0.015	<0.07	1.3	0.248	0.28
W04-11-1116	11/16/2011	11:50	---	NT in Rain	1.25	1.22	0.85	BRAD REDMON	5.0	2	8.3	7.00	280	11.70	2590	3680	4	11	36	121	125	0.016	0.015	<0.07	0.84	0.275	0.24
W05-11-1116	11/16/2011	10:40	---	NT in Rain	1.25	1.22	0.85	BRAD REDMON	6.7	2	7.6	7.00	510	12.00	5210	6630	6	14	152	151	227	0.089	0.021	<0.07	1.6	0.290	0.38
W06-11-1116	11/16/2011	13:00	---	NT in Rain	1.25	1.22	0.85	BRAD REDMON	12.1	2	8.2	7.00	310	12.00	3230	2880	4	9	64	100	156	0.019	<0.015	<0.07	1.3	0.230	0.2
W07-11-1116	11/16/2011	9:54	---	NT in Rain	1.25	1.22	0.85	KEN COOKE	3.9	1	8.4	7.50	210	13.59	3590	3730	5	13	48	55	115	0.029	0.019	<0.07	0.63	0.315	0.31
W08-11-1116	11/16/2011	10:21	---	NT in Rain	1.25	1.22	0.85	KEN COOKE	3.8	2	8.8	7.50	350	14.69	2280	2010	5	12	104	71	118	0.062	0.026	<0.07	0.88	0.205	0.25
W09-11-1116	11/16/2011	11:05	---	NT in Rain	1.25	1.22	0.85	KEN COOKE	6.2	1	9.4	7.50	330	13.77	1480	4870	5	8	96	100	149	0.018	<0.015	0.13	1.2	0.193	0.22
W10-11-1116	11/16/2011	11:00	---	NT in Rain	1.25	1.22	0.85	KEN COOKE	1.7	1	9.0	7.50	440	14.72	980	2180	4	6	132	130	180	0.028	0.021	0.39	2.5	0.254	0.27
W11-11-1116	11/16/2011	12:00	---	NT in Rain	1.25	1.22	0.85	KEN COOKE	4.8	1	9.0	7.50	470	14.13	5560	5730	4	27	154	125	178	0.030	0.018	0.27	1.9	0.317	0.5
W12-11-1116	11/16/2011	12:30	---	NT in Rain	1.25	1.22	0.85	KEN COOKE	11.8	1	9.1	7.50	380	13.98	1850	1750	4	11	98	100	140	0.025	0.016	<0.07	1.4	0.151	0.19
WDD-11-1116	11/16/2011	---	W08	NT in Rain	1.25	1.22	0.85	KEN COOKE	---	---	9.6	7.82	296	14.71	1710	2850	7	6	84	78	134	0.059	0.028	<0.07	0.93	0.201	0.25
TB Lab Duplicate	11/16/2011	---	W06	NT in Rain	1.25	1.22	0.85	---	---	---	---	---	---	---	1460	2590	4	9	44	90	164	0.019	<0.015	---	---	---	---
Lab Precision															75%	11%	0%	0%	37%	11%	5%	0%	0%	0%	2%	0%	3%
Field Precision											9%	4%	17%	0%	29%	35%	33%	67%	21%	9%	13%	5%	7%	0%	6%	2%	0%
Lab Accuracy 1															---	---	81%	88%	85%	102%	98%	103%	123%	97%	100%	106%	100%
Lab Accuracy 2															---	---	96%	---	---	---	---	103%	---	92%	103%	99%	100%

Site	Date	Time	Duplicate ID	Event Type	Prior 7 day rainfall* in	Prior 72 hrs rainfall* in	Prior 24 hr Rainfall* in	Sampler	Flow cfs	Turb Visual	DO mg/L	pH SU	Specific Conductance uS/cm	Water Temperature °C	Fecal Coliform MPN/100mL	E. Coli MPN/100mL	CBOD mg/L	TSS mg/L	TDS mg/L	Alkalinity, Total mg/L CaCO3	Total Hardness mg/L CaCO3	Ammonia mg/L as N	Nitrite mg/L as N	TKN mg/L as N	Nitrate mg/L as N	Ortho - Phophosphate mg/L as P	Phosphorus, Total Recoverable mg/L as P
W01-11-1212	12/12/2011	9:40	---	DRY	1.51	0	0	KEN COOKE	12.8	0	11.2	7.80	606	7.50	100	310	4	3	378	213	273	0.025	<0.015	<0.07	3.8	0.304	0.31
W02-11-1212	12/12/2011	10:35	---	DRY	1.51	0	0	KEN COOKE	3.9	0	9.18	7.29	689	14.00	<100	<100	3	3	428	196	297	<0.015	<0.015	<0.07	4.1	0.298	0.28
W03-11-1212	12/12/2011	11:45	---	DRY	1.51	0	0	KEN COOKE	4.2	0	12.80	7.90	541.6	9.27	<100	200	5.5	8	358	189	269	0.017	0.016	<0.07	4.1	0.324	0.33
W04-11-1212	12/12/2011	11:05	---	DRY	1.51	0	0	KEN COOKE	0.7	0	13.13	7.89	576	7.60	410	200	4.5	0	352	206	289	<0.015	<0.015	<0.07	3.9	0.330	0.32
W05-11-1212	12/12/2011	12:10	---	DRY	1.51	0	0	KEN COOKE	2.4	0	10.97	7.69	557.2	9.76	100	100	3	4	340	193	292	<0.015	<0.015	<0.07	4.3	0.333	0.33
W06-11-1212	12/12/2011	12:40	---	DRY	1.51	0	0	KEN COOKE	1.8	0	12.12	7.70	527	9.20	<100	200	3	9	322	184	282	<0.015	<0.015	<0.07	4.7	0.327	0.3
W07-11-1212	12/12/2011	9:50	---	DRY	1.51	0	0	BOB EDWARDS	0.14	1	10.86	6.50	446	6.12	630	860	3	4	316	247	288	0.029	<0.015	<0.07	4.2	0.404	0.38
W08-11-1212	12/12/2011	10:25	---	DRY	1.51	0	0	BOB EDWARDS	0.08	1	16.40	8.08	1122	5.28	310	100	4	1	570	198	370	0.016	<0.015	0.15	3.8	0.157	0.15
W09-11-1212	12/12/2011	11:20	---	DRY	1.51	0	0	BOB EDWARDS	0.6	1	14.66	7.60	594	11.35	980	1320	5	41	362	184	282	<0.015	0.015	0.35	4.2	0.293	0.28
W10-11-1212	12/12/2011	11:00	---	DRY	1.51	0	0	BOB EDWARDS	0.8	1	10.77	7.43	519	12.86	<100	<100	5	4	318	187	278	<0.015	<0.015	0.3	4.7	0.269	0.26
W11-11-1212	12/12/2011	12:15	---	DRY	1.51	0	0	BOB EDWARDS	0.3	1	11.40	7.33	841	8.23	860	1320	5	11	554	186	317	0.019	0.017	0.31	2.8	0.227	0.31
W12-11-1212	12/12/2011	11:50	---	DRY	1.51	0	0	BOB EDWARDS	0.4	1	13.52	7.85	666	9.01	1460	1350	3	2	456	200	328	<0.015	0.017	<0.07	3.1	0.129	0.13
WDD-11-1212	12/12/2011	---	W06	DRY	1.51	0	0	KEN COOKE	---	---	---	---	---	---	100	200	5	5	318	185	279	<0.015	0.029	<0.07	4.7	0.331	0.33
TB Lab Duplicate	12/12/2011	---	W07	DRY	1.51	0	0	---	---	---	---	---	---	---	860	750	3	6	284	238	284	0.025	<0.015	---	---	---	---
Lab Precision															31%	14%	0%	40%	11%	4%	1%	15%	0%	0%	2%	1%	0%
Field Precision															0%	0%	50%	57%	1%	1%	1%	0%	64%	0%	0%	1%	10%
Lab Accuracy 1															---	---	77%	87%	96%	101%	102%	105%	108%	99%	96%	103%	93%
Lab Accuracy 2															---	---	98%	---	---	---	---	92%	---	91%	98%	100%	94%
W01-12-0111	1/11/2012	10:50	---	WET	Trace	Trace	0	BERT REMLEY	148.9	3	11.3	7.70	179	7.90	1890	4500	6	107	178	84	91	0.121	0.030	<0.07	0.61	0.132	0.17
W02-12-0111	1/11/2012	10:15	---	WET	Trace	Trace	0	BERT REMLEY	14.4	3	8.90	7.30	631	13.80	413	<100	3	58	280	190	80	0.037	0.017	<0.07	3.00	0.275	0.57
W03-12-0111	1/11/2012	9:00	---	WET	Trace	Trace	0	BERT REMLEY	96.7	3	11.70	7.80	172	7.20	7380	12356	9	109	102	101	96	0.163	0.029	<0.07	0.77	0.121	0.48
W04-12-0111	1/11/2012	9:30	---	WET	Trace	Trace	0	BERT REMLEY	55.9	3	11.60	8.00	180	7.30	3405	3839	7	154	98	60	82	0.153	0.040	<0.07	0.20	0.120	0.59
W05-12-0111	1/11/2012	8:25	---	WET	Trace	Trace	0	BERT REMLEY	11.7	3	10.80	7.80	366	8.00	521	738	5	32	214	115	95	0.089	0.020	<0.07	2.10	0.127	0.27
W06-12-0111	1/11/2012	7:40	---	WET	Trace	Trace	0	BERT REMLEY	47.8	3	11.40	7.70	270	7.60	8296	8014	7	48	134	80	99	0.146	0.024	<0.07	1.30	0.156	0.24
W07-12-0111	1/11/2012	10:00	---	WET	Trace	Trace	0	CORY BLOYD	28.8	3	11.22	8.04	107.1	7.40	3786	4195	5	58	54	60	90	0.135	0.026	0.25	0.18	0.113	0.36
W08-12-0111	1/11/2012	9:35	---	WET	Trace	Trace	0	CORY BLOYD	20.0	3	11.58	7.98	105.2	7.62	2011	3197	4	45	48	70	98	0.121	0.024	0.27	0.20	0.092	0.15
W09-12-0111	1/11/2012	8:45	---	WET	Trace	Trace	0	CORY BLOYD	55.1	3	11.69	8.05	76.7	6.54	2230	4044	9	117	58	45	92	0.150	0.024	0.27	0.20	0.073	0.41
W10-12-0111	1/11/2012	9:05	---	WET	Trace	Trace	0	CORY BLOYD	18.8	3	11.68	8.05	64.3	7.06	2182	2530	5	160	46	48	95	0.094	0.029	<0.07	0.25	0.082	0.77
W11-12-0111	1/11/2012	8:30	---	WET	Trace	Trace	0	CORY BLOYD	19.0	3	11.53	8.08	269.1	6.76	2307	2109	6	131	142	50	110	0.137	0.031	<0.07	0.41	0.097	0.31
W12-12-0111	1/11/2012	7:30	---	WET	Trace	Trace	0	CORY BLOYD	23.8	3	11.70	7.90	78.5	6.25	2813	3225	6	30	36	58	91	0.130	0.018	<0.07	0.27	0.060	0.15
WDD-12-0111	1/11/2012	---	W12	WET	Trace	Trace	0	CORY BLOYD	20.8	3	11.76	8.18	89.9	6.34	1100	2751	7	31	72	55	120	0.131	0.018	<0.07	0.25	0.061	0.13
TB Lab Duplicate	1/11/2012	---	W08	WET	Trace	Trace	0	---	---	---	---	---	---	---	1464	2847	4	48	52	64	97	0.122	0.025	---	---	---	---
Lab Precision															31%	12%	0%	6%	8%	8%	1%	1%	4%	0%	0%	1%	5%
Field Precision									13%	0%	1%	3%	14%	1%	88%	16%	15%	3%	67%	4%	27%	1%	0%	0%	8%	2%	14%
Lab Accuracy 1															---	---	75%	99%	92%	100%	102%	107%	111%	102%	103%	103%	105%
Lab Accuracy 2															---	---	80%	---	---	---	---	99%	---	103%	104%	104%	108%
W01-12-0217	2/17/2012	9:45	---	INT	0.38	0.21	0	BRIAN RADCLIFF	11.67	1	11.89	7.32	679.1	8.66	200	200	2	5	400	177	230	0.036	<0.015	<0.07	2.3	0.224	0.24
W02-12-0217	2/17/2012	10:15	---	INT	0.38	0.21	0	BRIAN RADCLIFF	5.08	1	9.52	7.07	814.2	12.29	200	310	1	11	478	155	225	0.026	<0.015	<0.07	2.4	0.251	0.28
W03-12-0217	2/17/2012	11:30	---	INT	0.38	0.21	0	BRIAN RADCLIFF	3.11	1	16.34	8.31	551.7	9.43	<100	100	2	7	352	163	249	0.021	<0.015	<0.07	2.4	0.269	0.30
W04-12-0217	2/17/2012	11:00	---	INT	0.38	0.21	0	BRIAN RADCLIFF	0.52	1	15.33	7.87	609.8	8.11	200	200	2	4	376	178	232	0.025	<0.015	<0.07	2.5	0.252	0.31
W05-12-0217	2/17/2012	9:53	---	INT	0.38	0.21	0	KEN COOKE	1.83	0	9.90	8.04	603	8.26	200	<100	2	4	344	174	232	0.029	0.020	<0.07	2.5	0.282	0.30
W06-12-0217	2/17/2012	10:09	---	INT	0.38	0.21	0	KEN COOKE	2.35	0.5	11.50	8.29	564	8.9	100	200	2	7	334	171	227	0.022	0.016	<0.07	2.5	0.283	0.29
W07-12-0217	2/17/2012	10:00	---	INT	0.38	0.21	0	BOB EDWARDS	0.02	1	11.94	7.29	545.6	7.9	410	950	2	8	348	176	226	0.029	0.029	<0.07	2.3	0.335	0.35
W08-12-0217	2/17/2012	10:45	---	INT	0.38	0.21	0	BOB EDWARDS	0.16	1	15.74	7.84	1361	9.6	310	200	3	6	898	176	219	<0.015	0.031	<0.07	2.3	0.100	0.11
W09-12-0217	2/17/2012	10:30	---	INT	0.38	0.21	0	KEN COOKE	0.26	0	13.40	8.42	715	11.4	410	740	3	3	396	173	260	<0.015	<0.015	<0.07	2.4	0.244	0.27
W10-12-0217	2/17/2012	10:24	---	INT	0.38	0.21	0	KEN COOKE	0.84	0	9.84	8.09	564	11.5	310	520	1	7	322	177	235	0.019	0.029	<0.07	2.5	0.250	0.26
W11-12-0217	2/17/2012	11:15	---	INT	0.38	0.21	0	BOB EDWARDS	0.6	1	12.10	7.93	713.3	8.51	200	860	1	5	554	173	304	0.016	0.020	<0.07	2.3	0.224	0.24
W12-12-0217	2/17/2012	11:40	---	INT	0.38	0.21	0	BOB EDWARDS	0.41	1	13.08	7.96	909.5	8.97	1750	1710	1	5	562	187	286	<0.015	<0.015	<0.07	2.3	0.096	0.13
WDD-12-0217	2/17/2012	---	W04	INT	0.38	0.21	0	BRIAN RADCLIFF	0.51	1	15.36	8.1	609.7	8.12	310	410	2	6	368	197	250	<0.015	<0.015	<0.07	2.5	0.251	0.25
TB Lab Duplicate	2/17/2012	---	W09	INT	0.38	0.21	0	---	---	---	---	---	---	---	850	860	2	4	326	171	263	<0.015	0.020	---	---	---	---
Lab Precision															70%	15%	40%	29%	19%	1%	1%	0%	29%	0%	2%	3%	4%
Field Precision									2%	0%	0%	3%	0%	0%	43%	69%	0%	40%	2%	10%	7%	50%	0%	0%	0%	0%	21%
Lab Accuracy 1															---	---	62%	97%	112%	104%	99%	116%	131%	103%	91%	103%	99%
Lab Accuracy 2															---	---	59%	---	---	---	---	96%	---	104%	109%	104%	98%

Total dissolved solids data for screening use only due to poor precision of quality controls.

One or more quality control parameters exceed QAPP criteria. Results to be rejected.

Quality Control exceeded QAPP criteria. Results to be used but qualified as "estimated".

Tech or field error. Results to be rejected.

Suspected Typo, utilize follow-up sampling data results.

Flow levels not measurable by electromagnetic flow meter. For <0.01, use 0.005cfs for estimate. For dry or pooled sites or too fast conditions, no estimates made.

APPENDIX D – NON-REGULATORY REFERENCE POINTS

4. Benchmarks

The Kentucky Division of Water provided nutrient and non-nutrient benchmarks (Feb. 2, 2012) for evaluating the data being collected and analyzed as part of the ongoing effort to develop the Wolf Run Watershed Plan. The KDOW indicates that their goal in providing these benchmarks "is to provide estimates of typical in-stream concentrations below which it is unlikely that nutrients would be a cause of observed impairments." KDOW notes, "these benchmarks may be different than targets to be used ultimately as management endpoints." The benchmarks provided by KDOW are summarized in the table below.

KDOW NON-REGULATORY TARGETS

Nutrient Parameter	Benchmark	Non-Nutrient Parameter	Benchmark
Total Phosphorus as P	0.30 mg/L	Ammonia-N	0.025-0.050 mg/L
TKN as N	0.20 mg/L	Unionized Ammonia	0.001-0.002 mg/L
Nitrate-Nitrite as N	1.3 mg/L	Sulfate	61.05 mg/L
Total Nitrogen	1.7 mg/L	Specific Conductance	509 µS/cm
		Alkalinity	220 mg/L as $CaCO_2$
		TSS	10 mg/L
		Turbidity	8.7 NTU

LFUCG has several concerns with the provided benchmarks, as listed below:

- Transfer of benchmarks from a voluntary watershed based plan into a mandated regulatory limit
- Stymied implementation due to unrealistic / overly conservative benchmarks
- Lack of clear causative link between benchmark levels and aquatic life impairment (i.e. will managing loading to the designated levels eliminate aquatic life impairment?)
- Benchmarks supported by small dataset
- Some parameters already have a regulatory limit and others should not require one
- Arbitrary use of median concentration from ecoregional reference reaches to establish an impairment threshold
- Lack of allowance for assimilative capacity above background levels

In addition to these specific concerns, there is a more general concern that these parameters are not the most significant source of impairment in the watershed. Riparian and instream habitat, as well as hydrology/flow regime are key factors in impairment and are suspected to be of greater significance. Also some BMPs may be more economically feasible and practical to implement than others while achieving similar results. For instance, problems associated with higher nutrient levels (i.e. algal blooms and dissolved oxygen drops) can be addressed by shading the stream or by reducing the nutrient concentrations. Since the benchmark levels utilized for watershed plan will direct significant resources in the implementation plan, overly conservative benchmark levels may result in significant costs with reduced ecological gains.

It is LFUCG's position that a phased approach should be utilized to direct resources at achieving reasonable targets in a step-wise fashion. In this approach, initially conservative goals would be established based on technology feasibility and reasonableness. These reduction goals would allow for voluntary efforts to improve water quality to be targeted to the areas and problems of the greatest concern. The goals would be re-assessed through the watershed planning process on regular intervals and lowered if the designated use does not become fully supported through the implementation plan efforts. Under this approach, watershed specific benchmarks would consider the existing conditions as well as reference reach data in determining what reasonable and feasible as well as what is ideal.

Below are LFUCG's recommendations for concentration based benchmarks and how these benchmarks translate into load reductions. For the Wolf Run Watershed Based Plan, LFUCG proposes to measure progress in water quality over time by tracking reductions in pollutant loadings from current levels. This approach will allow LFUCG staff to evaluate implemented BMP effectiveness and allow for dynamic planning to produce the greatest benefit.

LFUCG'S BENCHMARK RECOMMENDATIONS CONCENTRATION BASED

Nutrient Parameter	Benchmark	Non-Nutrient Parameter	Benchmark
Total Phosphorus as P	0.35 mg/L	Ammonia-N	0.1 mg/L
Ortho-Phosphorus as P	0.35 mg/L	Specific Conductance / TDS	650 µS/cm / 373 mg/L
Total Nitrogen	3.0 mg/L	TSS	80 mg/L

LFUCG'S PERCENTAGE REDUCTION TOTAL LOAD AT MOUTH OF WOLF RUN

Nutrient Parameter	Benchmark	Non-Nutrient Parameter	Benchmark
Total Phosphorus as P	14% Wet Only	Ammonia-N	21% Wet
Ortho-Phosphorus as P	0%	Specific Conductance / TDS	3-13% Dry / Int
Total Nitrogen	11-14% Dry /Int	TSS	26% Wet Weather

The following comments apply to the specific benchmarks recommended by KDOW and the rationale behind the LFUCG proposed benchmarks.

- Nutrients:
  - Insufficient Reference Reach Data (only 13-14 samples from Inner Bluegrass)
  - 75th percentile or 90th percentile may be more appropriate
    - Fully supporting Steele's Run has levels of TP 0.382 (between 75th and 90th percentile reference reach) and TN 5.58 mg/L (above the 90th percentile of the reference reach). These values indicate that concentrations well above the reference reach medians may be present and the designated use still met.
  - Pond et al.[1] state that nutrient concentrations are not well correlated with macroinvertebrate metrics in the Bluegrass Bioregion.

- Phosphorus:
  - Orthophosphorus should have a benchmark as it represents the phosphorus available for use by aquatic vegetation.

[1] "[Bluegrass Bioregion (BG)] fauna are thus perhaps adapted to deleterious effects caused by elevated nutrient concentrations. Another possibility is that the region experiences hydrological stress. For example, even low-nutrient streams with good instream habitat are hydrologically unstable (i.e., drought-prone, intermittent/interrupted) in this region. This can lead to excessive temperatures and reduced dissolved oxygen (D.O.) concentrations for extended periods throughout the summer months. Comparatively, nutrient enrichment can also indirectly lead to diel sags in D.O. due to increased biological oxygen demand or respiration of increased biomass. It is probable that the BG invertebrate fauna are thus naturally facultative or tolerant to nutrient enrichment (as expressed in higher tolerance values, fewer sensitive species, more colonizers)."
Pond, G.J., S.M. Call, J.F. Brumley and M.C. Compton. 2003. The Kentucky macroinvertebrate bioassessment index: derivation of regional narrative ratings for wadeable and headwater streams. Kentucky Department for Environmental Protection, Division of Water, Frankfort, KY.

- Draft Town Branch TMDL has historic phosphorus results ranging from 2.1 to 4.6 mg/L (1967 – 1988). The report indicates the assimilative capacity of the streams may be much higher with these historic values. 0.5 mg/L was target value in this document.
- 0.35 mg/L orthophosphorus and total phosphorus is between the 75th and 90th percentiles for reference reaches in the Inner Bluegrass (0.338 to 0.396 mg/L) and some watershed areas are above this level.

- Nitrogen:
  - How would benchmarks for TKN, nitrate and nitrite be utilized? Recommend using only a benchmark for total nitrogen.
  - A total nitrogen benchmark of 3.0 mg/L is between the 75th and 90th percentiles for reference reaches in the Inner Bluegrass (2.953 to 3.272 mg/L) and some watershed areas are above this level.

- Ammonia-N:
  - The benchmark is a range that is near the detection limit for ammonia, this is unreasonable
  - Recommend benchmark of 0.1 mg/L, near the 75th percentile of Wolf Run data.

- Unionized Ammonia:
  - There is already a regulated limit for unionized ammonia (0.05 mg/L). No additional benchmark is necessary.

- Sulfate:
  - This parameter was not sampled. Recommend eliminating this benchmark.

- Specific Conductance:
  - Specific conductance seems unduly low, particularly with the high level of limestone bicarbonates. The natural conductivity is higher in Wolf Run than in many other regions
  - A benchmark of 650µS/cm specific conductance is near the average of the medians for the Wolf Run sites.

- Alkalinity:
  - What is the purpose / application of an alkalinity benchmark? Recommend eliminating this benchmark.

- TSS / Turbidity:
  - TSS and turbidity benchmarks are not feasible as currently specified. The EPA specified a turbidity level of 280 NTU for construction site runoff that has since been withdrawn. A turbidity of 8.7 NTU is not feasible for a watershed with development. Likewise 10 mg/L suspended solids.
  - Total Suspended Solids set as Kentucky River Watershed Watch Screening level of 80 mg/L. They cite a study indicating that at a TSS of 80mg/L the macroinvertebrate population decreased by 60%.