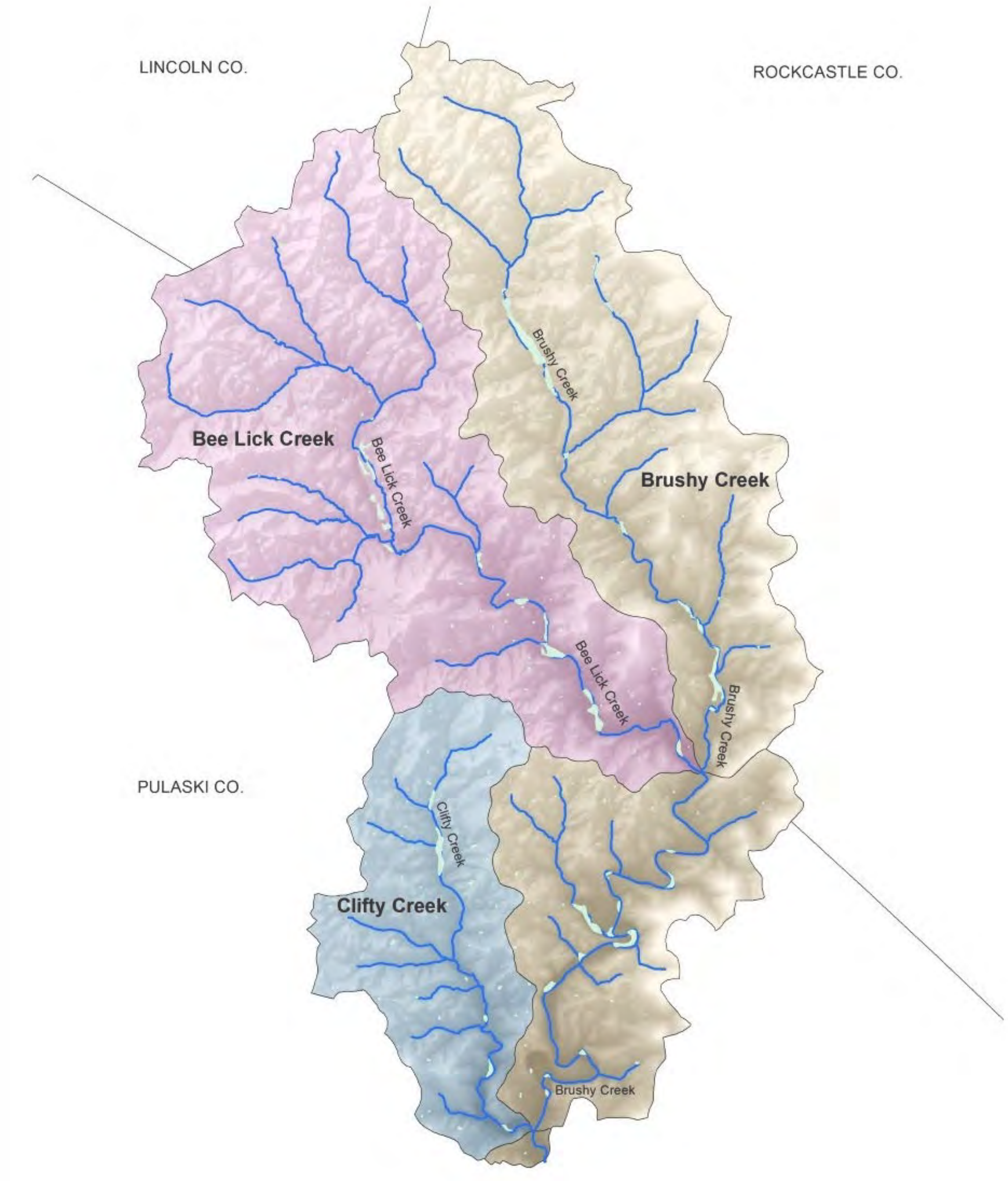
Brushy Creek Watershed Plan

Upper Cumberland Basin, Kentucky



May 2017

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Chapters 1-4

University of Louisville Stream Institute
for
Pulaski County Conservation District

Chapters 5-8

Kentucky Division of Water
Nonpoint Source Pollution and Basin Team Section

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Acknowledgments for Chapters 1-4

Michael A. Croasdaile, PhD, Assistant Professor of Civil and Environmental Engineering (CEE) at the University of Louisville, was the principal investigator for this project and directed the data collection and analysis.

Arthur C. Parola, Jr., PhD, PE, Professor of CEE and Director of the Stream Institute (ULSI), provided technical advice regarding data collection, analysis, and interpretation.

Raja M. Nagisetty, PhD, PE, ULSI Research Project Engineer, supervised the collection and analysis of water quality data and contributed to the analysis.

Jeong Park, PhD, PE, ULSI Research Project Engineer, conducted fieldwork and data analysis.

Deven Carigan, Technical Advisor for the Kentucky Nonpoint Source Pollution Control Program, Kentucky Division of Water (KDOW NPS), reviewed and edited the final report.

CEE students Ian R. Van Lierop, Donald Helstern, and Daniel Warren assisted with data collection and sample processing.

Chandra Hansen, ULSI Research Technical Writer, edited the final report.

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Contents

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Abbreviations and Symbols

Ammonia-N	Ammoniacal nitrogen
BMP	Best management practice
$CaCO_3$	Calcium carbonate
cBOD	Carbonaceous biochemical oxygen demand
DO	Dissolved oxygen
FEMA	Federal Emergency Management Agency
HUC	Hydrologic unit code
KAR	Kentucky Administrative Regulations
KDOW	Kentucky Division of Water
KPDES	Kentucky Pollutant Discharge Elimination System
LDC	Load duration curve
N	Nitrogen
NH_3^+	Un-ionized ammonia
NH_3-N	Ammoniacal nitrogen
NH_4	Ammonia
NLCD	National Land Cover Dataset
NO_2	Nitrite
NO_3+NO_2-N	Nitrite + nitrate as nitrogen
NTU	Nephelometric turbidity unit
NWI	National wetlands inventory
OSRW	Outstanding state resource water
P	Phosphorus
PCR	Primary contact recreation
PDSI	Palmer Drought Severity Index
PO_4-P	Orthophosphate as phosphorus
RBP	Rapid bioassessment protocol
SCR	Secondary contact recreation
SFHA	Special flood hazard area
SSC	Suspended sediment concentration
T/E	Threatened/endangered
TDS	Total dissolved solids
TKN	Total Kjeldahl nitrogen
Total P	Total phosphorus
TP	Total phosphorus
TSS	Total suspended solids
WAH	Warm water aquatic habitat

1 Introduction

1.1 The Watershed

Brushy Creek is a tributary to Buck Creek in the Upper Cumberland River basin in south central Kentucky. These watersheds are located in the Eastern Highland Rim Ecoregion (Level IV) within the larger Interior Plateau Ecoregion (Level III). The climatic and geologic history of the Interior Plateau has made it one of the more biologically diverse ecoregions in the United States (USEPA 2013). The region remained unglaciated during the Pleistocene Epoch. As the northern glaciers retreated, the region became a migratory hot spot for both northern and southern species, enabled by the north-south orientation of the mountains and valleys. The incredible diversity of plant and animal species in the region also make it an ecologically rare and valuable resource; many of the species are not found in other areas.

Buck Creek is considered to harbor the most diverse surviving mussel fauna of any of the major tributaries in the Upper Cumberland River system and is listed an Outstanding State Resource Water (OSRW). Buck Creek provides refugia (i.e., areas where environmental circumstances have allowed species to survive after their local extinction in surrounding areas) for several federally endangered Cumberlandian aquatic species, including the Cumberland combshell (*Epioblasma brevidens*), oyster mussel (*E. capsaeformis*), little-wing pearly mussel (*Pegias fabula*), and the Cumberland bean pearly mussel (*Villosa trabalis*). Although these species have not been formally documented in Brushy Creek, the hydrological and geological conditions are similar to the Buck Creek segments of stream, or "reaches," where they are present. Given Brushy Creek's similarity and proximity to those Buck Creek reaches, the Brushy watershed may be a potential area for expanding the species' current range through natural recruitment or migration and/or human repopulation efforts.

The entire main stem of Brushy Creek, river miles 0.0−16.5 from its mouth, where it flows into Buck Creek, to its headwaters, where flow begins, is designated as an outstanding state resource water and a reference reach stream. The lower reaches of Bee Lick Creek (mouth to Warren Branch, river miles 0.0−5.7) and Clifty Creek (mouth to Rocky Branch, river miles 0.0−2.7) are designated as outstanding state resource waters and exceptional waters. The upper 3.4 miles of Bee Lick Creek, however, are listed as partial support for warm water aquatic habitat (WAH) due to nitrate/nitrite, and sedimentation/siltation. Suspected sources for these pollutants include agriculture, highway/road/bridge runoff, livestock, and loss of riparian (streamside) habitat (KDOW 2010b).

Many of the water quality threats that previously have been identified by project partners in the Brushy Creek watershed stem from agricultural practices. Livestock have widespread access to the stream channels, and erosion from row crops, eroding stream banks, and a limited riparian buffer (unmowed vegetated/forested streamside land) are thought to contribute to excessive sediment loads to the streams (USFWS 2011). Data collected by Eastern Kentucky University suggest that the widespread impairment of primary contact recreation and secondary contact recreation designated uses in this watershed may be due to livestock.

Strong partnerships focused on agricultural BMPs are thriving throughout the Buck Creek area. The Pulaski County Conservation District (PCCD) would like to see these partnerships grow, particularly in the Brushy Creek watershed. Despite prior studies on Buck Creek, Brushy remains an understudied watershed. Little biological information for Brushy Creek was available to form a scientific foundation for conservation, preservation, or restoration efforts. This watershed data analysis project addresses this deficiency, provides a detailed baseline against which to judge future BMPs, and may be a catalyst for further water quality improvements in the watershed. These actions could result in restoration of full support for warm water aquatic habitat and the delisting of Bee Lick Creek as an impaired stream, and they could ultimately lead to major water quality improvements in the years to come. In addition, this watershed data analysis report will provide the first four chapters for a watershed based plan as outlined in the *Watershed Planning Guidebook for Kentucky Communities* (KWA and KDOW 2010).

1.2 Partners and Stakeholders

Pulaski County Conservation District
Role: Project management; education, training, and outreach; technical assistance.
Contact: Beth Whitson, 606-678-4842 ext.3

University of Louisville
Role: Collect monitoring data and develop the watershed data analysis report.
Contact: Michael Croasdaile, (502) 852-4567

The Nature Conservancy of Kentucky
Role: Provide a cell phone and vehicle for the Buck Creek watershed coordinator and provide any technical assistance needed throughout the watershed based plan development.
Contact: Terry Cook, (859) 259-9655

Kentucky Division of Forestry, Energy and Environment Cabinet
Role: Provide technical guidance to private landowners and assist with woodland planning and education related to water quality issues in Brushy Creek.
Contact: Connie Woodcock, (270) 465-5071

USDA Natural Resources Conservation Service
Role: Provide a technical representative at meetings and provide information toward the watershed based plan.
Contact: Joe Montgomery, (606) 678-4842 ext. 114

Eastern Kentucky Environmental Research Institute,
Eastern Kentucky University
Role: Provide information on distribution of *E. coli* contamination in Brushy Creek and help with development of Chapters 5−7 of the watershed based plan.
Contact: Alice Jones, (859) 622-6914

2 The Brushy Creek Watershed

2.1 Water Resources

2.1.1 Watershed Boundary and Hydrology

Brushy Creek originates in the southern portions of Lincoln and Rockcastle counties and flows south through Pulaski County, where it joins Buck Creek, which is listed as an Outstanding State Resource Water and contains several federally endangered Cumberlandian mussel species. Brushy is a fourth-order stream. Stream orders range from 1 to 12 and describe the relative location of a stream segment within a watershed's channel network as drawn on USGS topographic maps. The headwater segments that have no tributaries are first-order. At the confluence of two first-order streams, the stream becomes a second-order; at the confluence of two second-order streams, it becomes third-order; and so on.

The Brushy Creek watershed has a 10-digit Hydrologic Unit Code (HUC) of 0513010301. HUCs are numeric strings assigned to drainage areas to describe them as nested units. The number of digits in the string ranges from 2 for very large HUCs (e.g., 180,000 mi^2) to 14 for very small HUCs (e.g., less than 1 mi^2). The Brushy Creek 10-digit HUC contains 44.4 mi^2 of predominately agricultural and pasture land and is subdivided into four 14-digit HUCs (Fig. 2.2). Bee Lick, HUC 05130103040020, drains 16.8 mi^2 and joins Upper Brushy, HUC 05130103040010, which drains 14.04 mi^2. Clifty Creek, HUC 05130103040040, drains 6.4 mi^2 and joins Lower Brushy, HUC 05130103040030, which drains 7.06 mi^2. No towns lie within the boundaries of the watershed. Somerset is approximately 10 miles south, and Mount Vernon is 2 miles to the northeast (Fig. 2.1).

The watershed has no active or inactive USGS gaging stations. The closest USGS gauging station used to be located on Buck Creek just downstream of the Brushy Creek confluence (37°12'38", −84°27'52"). This station began monitoring daily discharge October 1, 1952, but was discontinued in 1992. The National Wetlands Inventory identifies 312 acres of wetlands in the watershed (Fig. 2.2) (USFWS 2014).

2.1.2 Climate

The average annual temperature for nearby Mount Vernon, Kentucky, is 55.3ºF, with an annual average precipitation of 52.4 inches (Table 2.1) (NOAA 2002). The growing season is approximately 200 days from April through October (Table 2.2) (NOAA n.d.). Rainfall in winter is generally produced by frontal systems, while summer rainfall is produced by afternoon thunderstorms. While the number of days of rainfall during these two periods is similar, precipitation tends to be more intense with the summer storms (Hodgkins and Martin 2003).

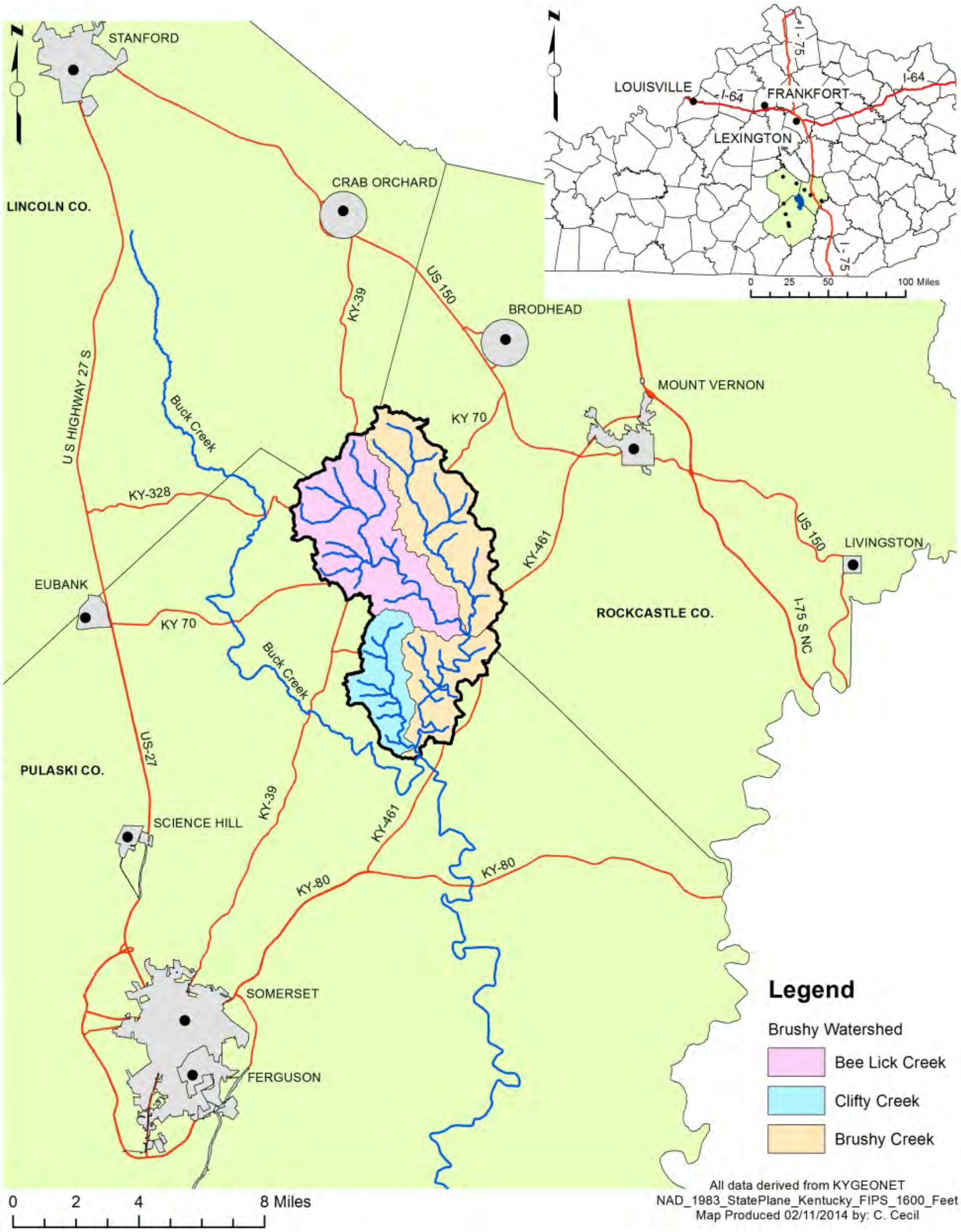
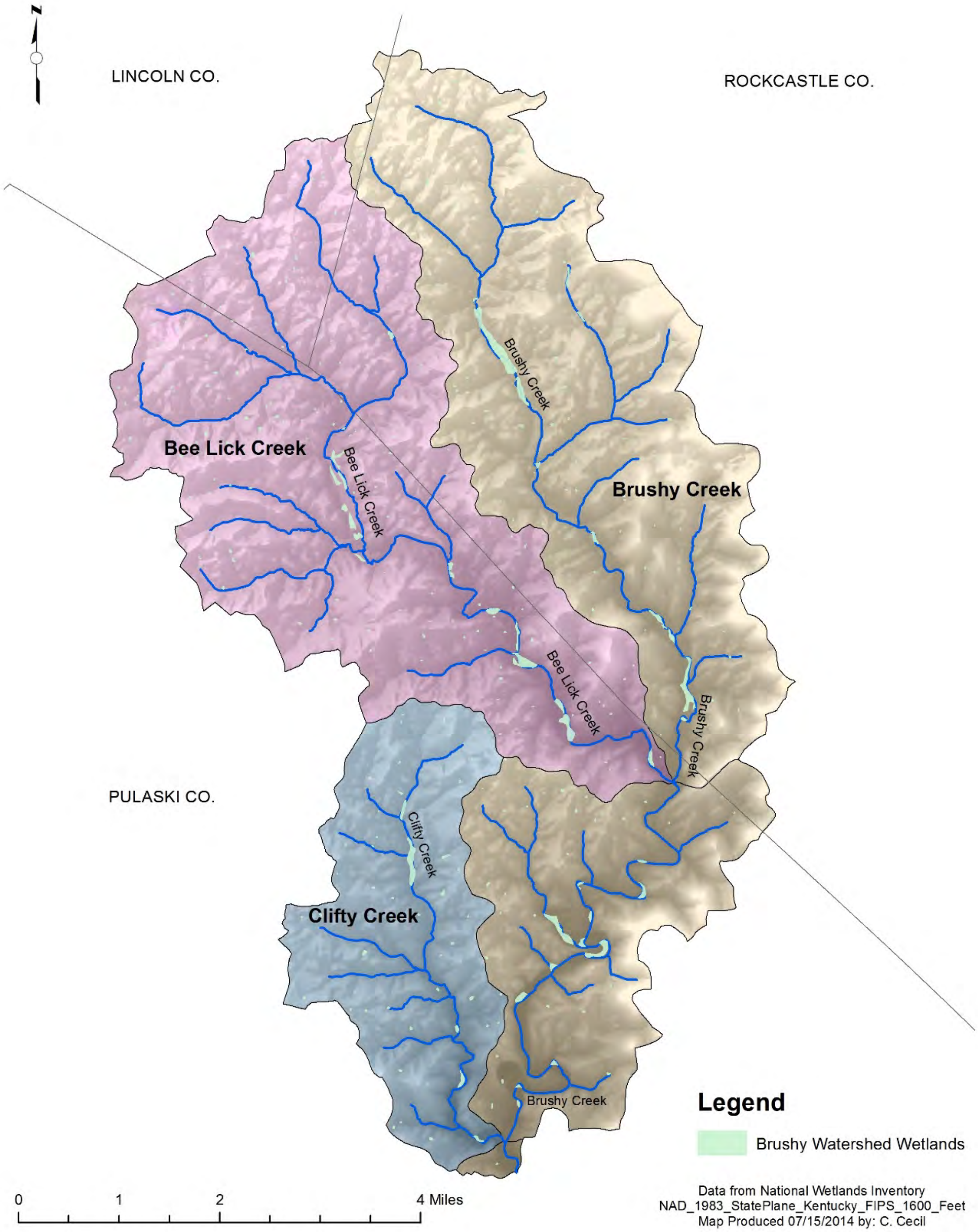


Figure 2.1 Brushy Creek watershed location map.



Data from National Wetlands Inventory
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Map Produced 07/15/2014 by: C. Cecil

Figure 2.2 Streams and wetlands (USFWS 2014) in the Brushy Creek watershed.

Table 2.1 Temperature and Precipitation Normals, Mt. Vernon, KY, 1971–2000

	Temperature (ºF)			Precipitation (inches)
Month	**Max**	**Min**	**Avg**	**Avg**
Jan	41.7	23.9	32.8	4.32
Feb	47.1	26.8	37	3.84
Mar	56.7	34.7	45.7	5.05
Apr	66.3	42.9	54.6	4.18
May	74.8	52.6	63.7	5.56
Jun	82.1	61.4	71.8	4.77
Jul	85.8	65.7	75.8	4.64
Aug	85	63.7	74.4	3.94
Sep	79.2	56.8	68	3.79
Oct	68.4	44.3	56.4	3.3
Nov	56.6	36.6	46.6	4.22
Dec	46.2	28.4	37.3	4.82
Annual	**65.8**	**44.8**	**55.3**	**52.43**

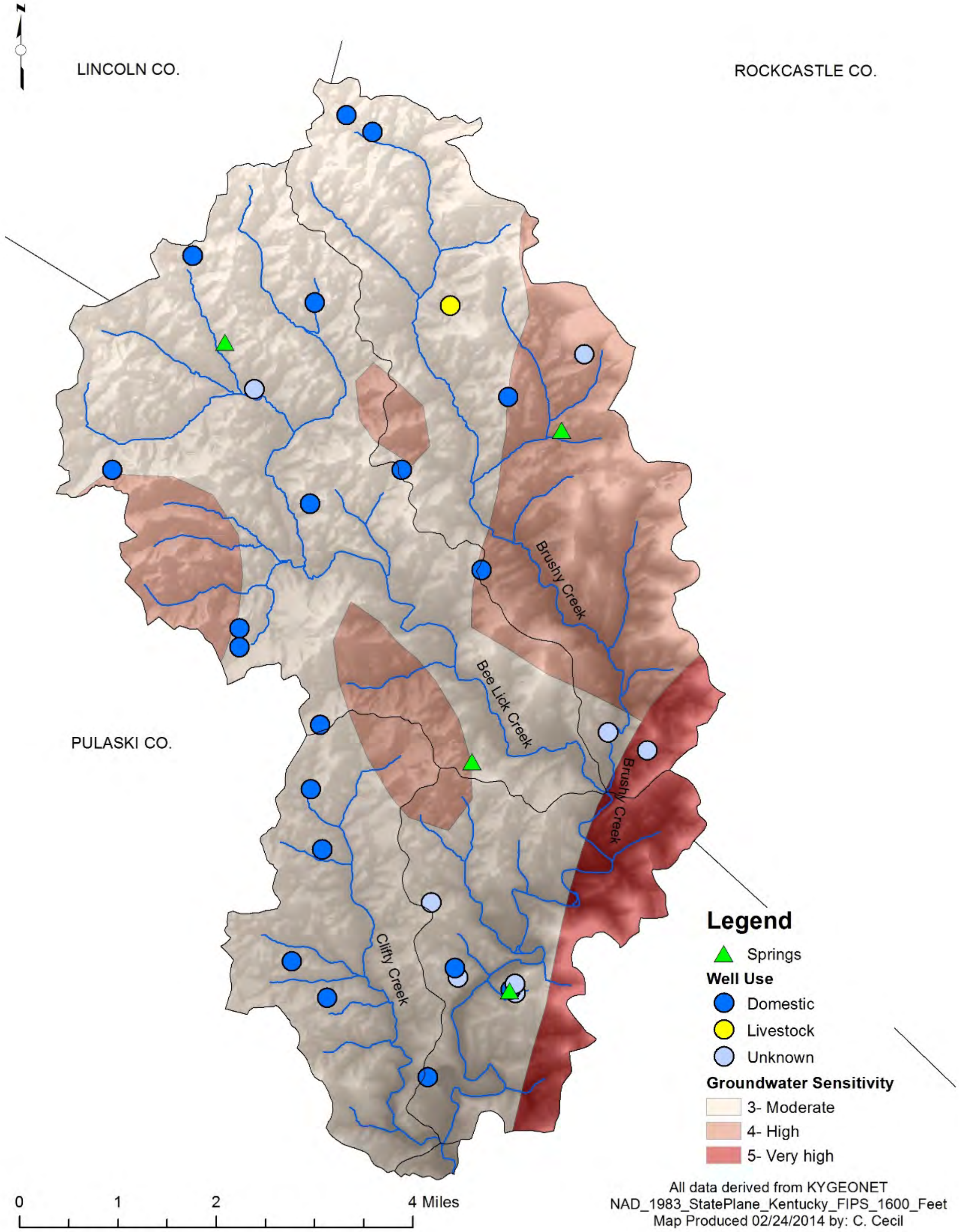
Table 2.2 Growing Season Probabilities, Mt. Vernon, KY, 1971–2000

		Temperature	
Probability*		**28ºF or lower**	**32ºF or lower**
50%	Beginning and ending dates	4/8 to 10/29	4/24 to 10/14
	Growing season length (days)	203	172

* Percent chance of the growing season occurring between the beginning and ending dates.

2.1.3 Groundwater–Surface Water Interaction

In 1994, a general map of groundwater sensitivity was compiled for the entire Commonwealth (Ray et al. 1994). The map was derived from analysis of USGS geologic quadrangle maps, detailed data compiled from numerous studies, and hydrologic investigations atlas maps. Sensitivity ratings of 1 (Low) to 5 (Very High) were determined based on relative ease of recharge, groundwater flow velocities, and discharge. Areas identified as having low sensitivity are likely to be naturally well protected from surface contaminants, whereas groundwater in high sensitivity areas could easily be impacted by surface activities. The majority of Brushy Creek watershed is ranked as moderate sensitivity (3), with minor areas of high (4) and very high (5) sensitivity. These moderately and highly sensitive areas coincide with karst-prone limestones, which allow surface water runoff to quickly permeate and interact with aquifers (see Section 2.2.1). Most of the wells reported in the watershed are used for domestic or agricultural water supply and are located in areas with moderate groundwater sensitivity (Fig. 2.3). Only one well was shown to be located in a highly sensitive area, but none of the land use in the area draining to this well was agricultural or industrial. Only four springs are reported in the watershed.



All data derived from KYGEONET
NAD_1983_StatePlane_Kentucky_FIPS_1600_Feet
Map Produced 02/24/2014 by: C. Cecil

Figure 2.3 Water use and groundwater sensitivity in the Brushy Creek watershed.

2.1.4 Flooding

The Federal Emergency Management Agency (FEMA) has determined that just 4.6% of the Brushy watershed is within the 100-year floodplain (Table 2.3 and Fig. 2.4). No houses had been constructed within the FEMA floodplain as of 2010 (Esri 2014; FEMA 2014).

Table 2.3 FEMA Floodplain Areas by Subwatershed

	Brushy Creek	Bee Lick Creek	Clifty Creek	Watershed Total
100-yr floodplain area (mi²)	1.0	0.9	0.1	2.0
Subwatershed area (mi²)	21.3	16.8	6.4	44.4
Floodplain/watershed area (%)	4.6	5.6	2.1	4.6

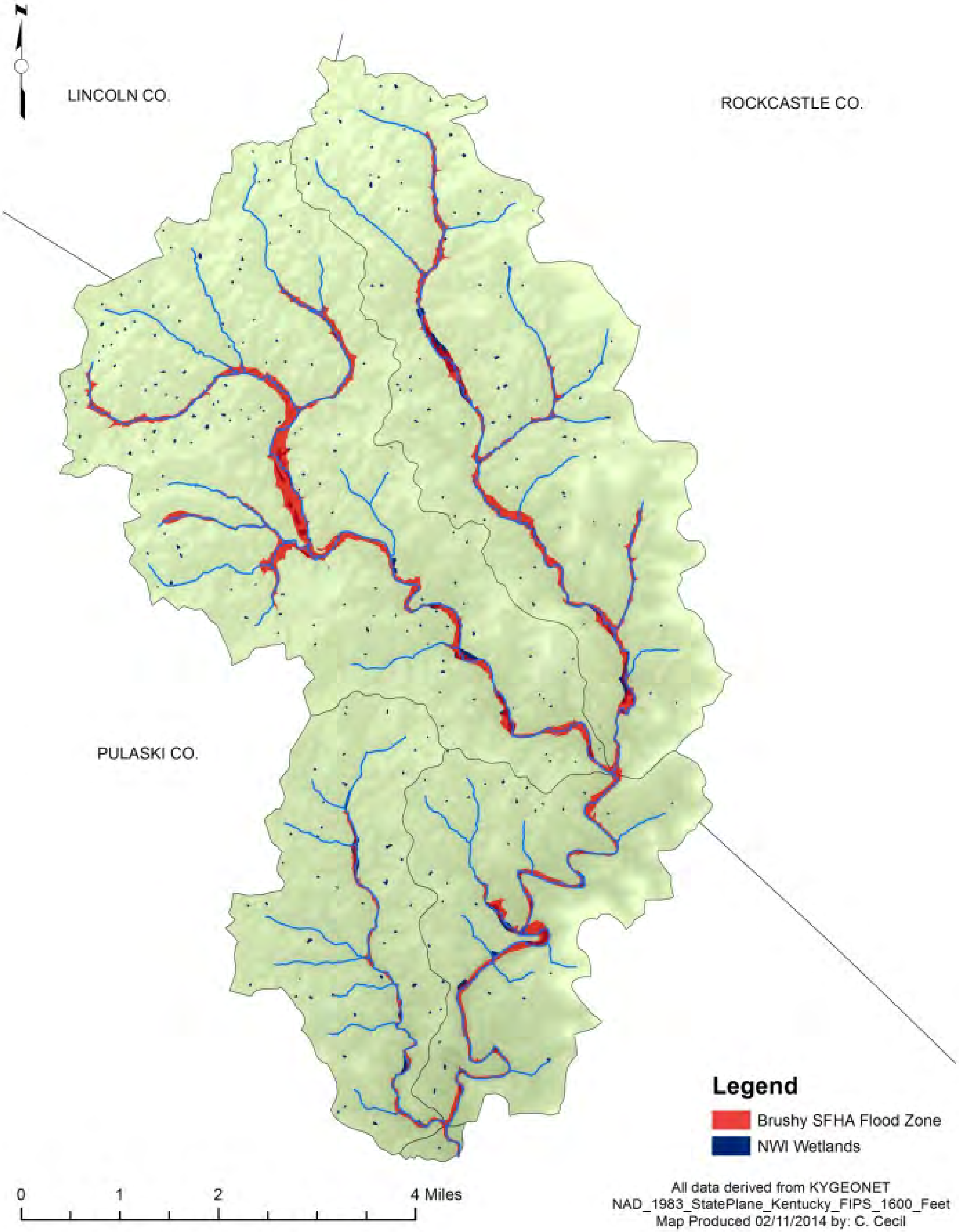


Figure 2.4 FEMA flood zones in the Brushy Creek watershed.

2.1.5 Regulatory Status of Waterways

Designated uses that define water quality goals for surface waters and numeric and narrative criteria to protect those goals are specified in Kentucky Administrative Regulations (KAR). The designated uses of Brushy Creek, Bee Lick Creek, and Clifty Creek are warm water aquatic habitat (WAH), primary contact recreation (PCR, which includes activities that will likely result in full body immersion, such as swimming) and secondary contact recreation (SCR, which includes activities with incidental contact with water, such as boating, fishing, and wading) (401 KAR 10:026 §5(2)(a)).

The main stem of Brushy Creek (mouth to headwaters, river miles 0.0−16.5) is designated as an outstanding state resource water and a reference reach. A reference reach is a stream or segment of a stream that is considered to be the least impacted, or disturbed, within a bioregion. The lower reaches of Bee Lick Creek (mouth to Warren Branch, river miles 0.0−5.7) and Clifty Creek (mouth to Rocky Branch, river miles 0.0−2.7) are designated as outstanding state resource waters and exceptional waters. WAH impairments (Table 2.4 and Fig. 2.5) have been documented for 3.4 river miles of streams in the Brushy Creek watershed: Bee Lick Creek from river mile 7.5 to 10.9.

Table 2.4 CWA Section 303(d) Impaired Water Bodies, Brushy Creek Watershed (KDOW 2010b)

Segment	County	Use	Pollutant	Suspected Sources
Bee Lick Creek 7.5-10.9	Lincoln	WAH	Nitrate/Nitrite (Nitrite + Nitrate as N) Sedimentation/ Siltation	Agriculture; Highway - Road - Bridge Runoff (Non-construction Related); Impacts from Hydrostructure Flow Regulation - modification; Livestock (Grazing or Feeding)

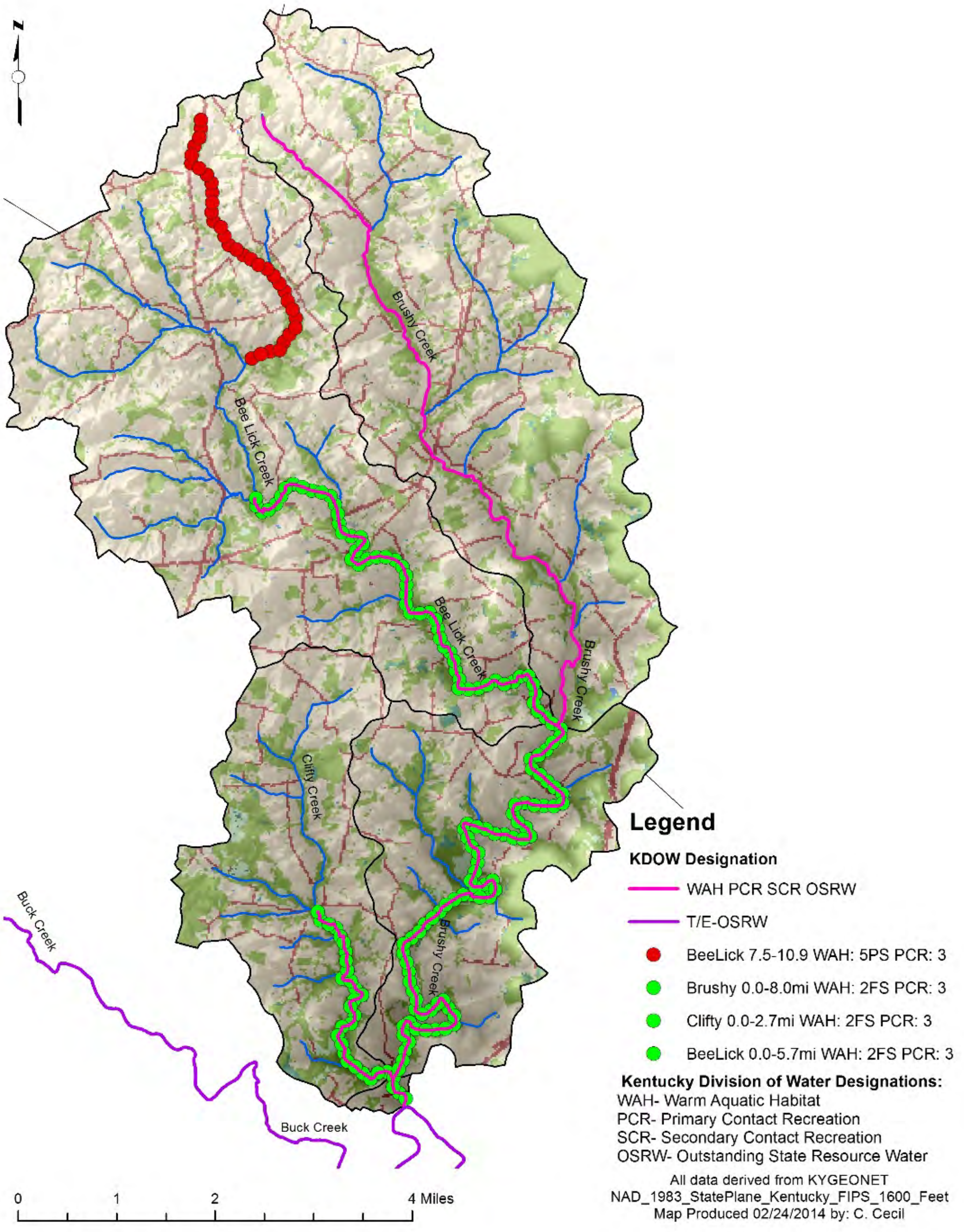


Figure 2.5 Regulatory status of Brushy Creek streams. A designation of "5PS" indicates a category 5 (KDOW 2010b) reach with partial support of the designated use, while "2FS" represents category 2 reaches with full support of the assessed use (although not all uses were assessed). Category 3 reaches either have not been assessed or available data are insufficient to determine whether the designated use is being met.

2.1.6 Water Chemistry and Biology

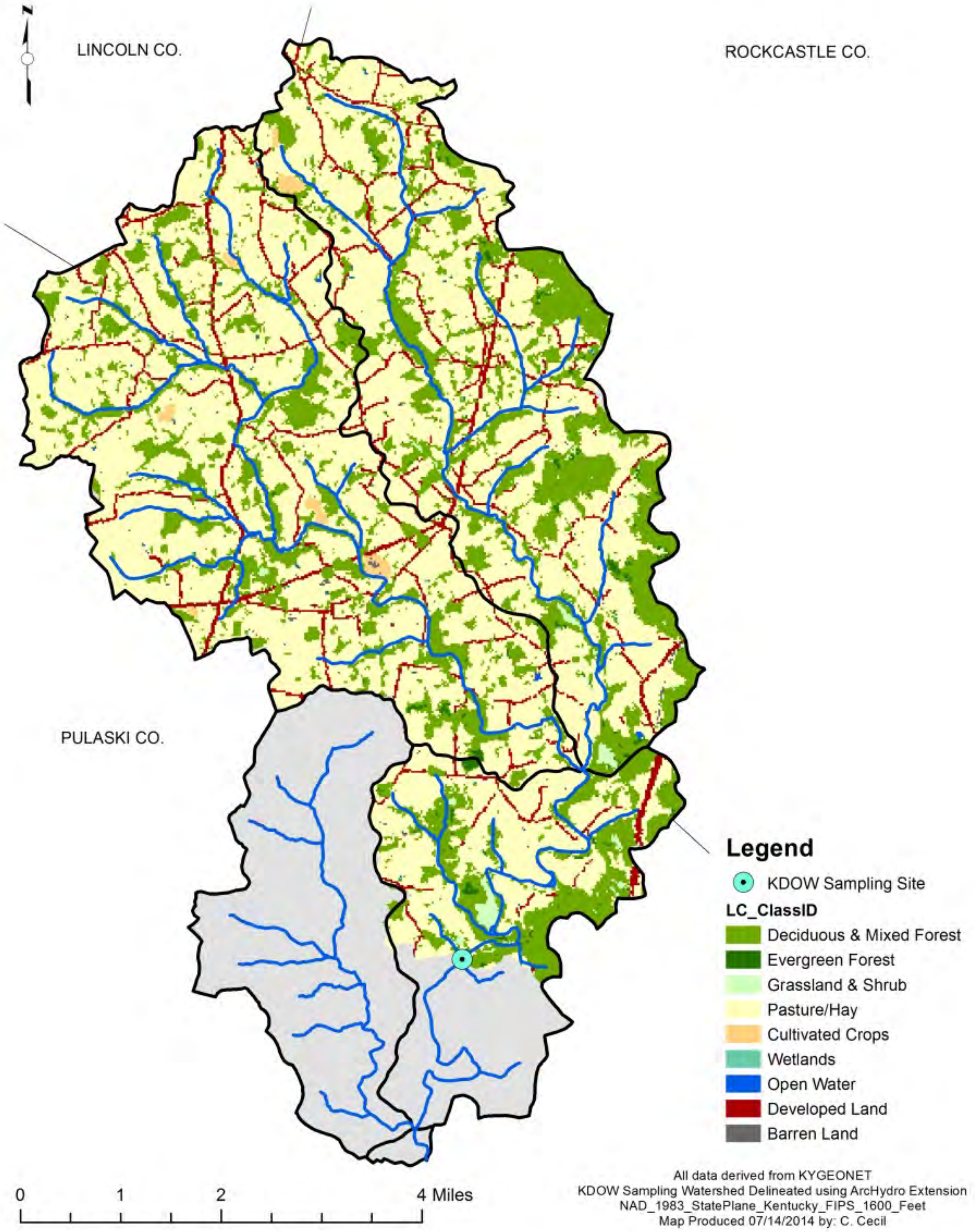
During summer 2000 and spring 2005, Kentucky Division of Water (KDOW) sampled water quality and evaluated stream habitat four times on Brushy Creek main stem at river mile 3.5 (Table 2.5 and Fig. 2.6). The sampling site is upstream from Brushy Creek's confluence with Clifty Creek and receives water from 35.6 mi^2 of the 44.4 mi^2 watershed. In July and September of 2000, dissolved oxygen (DO), pH, specific conductance, and temperature were recorded using a multi-parameter meter; turbidity with a single parameter meter; and alkalinity with a colorimeter. The measured parameters suggest that Brushy Creek was a warm, clear, slightly basic stream with seasonal low dissolved oxygen and moderately high specific conductance.

On July 11, 2000, KDOW assessed Brushy Creek's habitat using the EPA Rapid Bioassessment Protocol (RBP). Habitat scores are divided into ratings of good, fair, and poor, and the divisions are different for each bioregion. Brushy Creek received an RBP score of 170 and was compared with the ratings for the Pennyroyal region. An RBP score of 170 indicates a healthy physical habitat. Later that year, however, on September 19, 2000, the same site scored only 135, which is considered to be at the low end of the range of scores for fair quality stream habitat in the Pennyroyal bioregion (KDOW 2011).

During May and June 2005, Kentucky Division of Water collected grab samples. The sampling on May 20, 2005, reported low amounts of ammonium, phosphorus, nitrate, and nitrite. The hardness value of 76.9 (mg/L as $CaCO_3$) indicates that this system is naturally moderately hard (USGS 2014), and the quantity of organic carbon is sufficient for sustaining a diverse aquatic ecosystem. The June 20, 2005, sampling recorded low amounts of ammonium, fluoride, chloride, phosphorus, nitrate, nitrite, and sulfates. The water on this date registered harder than the May sampling with a lower amount of organic carbon. The results were positive, with none of the parameters raising immediate concerns; at the time of the June sampling, the site's habitat received an RBP score of 148, which corresponds to good quality stream habitat in the Pennyroyal bioregion (KDOW 2011).

Table 2.5 Water Quality Sampling Parameters, Brushy Creek mile 3.5, Pulaski County (KDOW 2010a)

Coll Date	Program	Chem Parameter	Chem Value	Units	Coll Methed
11-Jul-00	REF	% Saturation	59.7	%	Multi-Parameter Meter
	REF	DO	4.8	mg/L	Multi-Parameter Meter
	REF	pH	7.4	mg/L	Multi-Parameter Meter
	REF	Specific Conductance	205.2	µS/cm	Multi-Parameter Meter
	REF	Temperature	25.8	°C	Multi-Parameter Meter
19-Sep-00	SED	Alkalinity	120	mg/L	Colorimetric
	SED	DO	7.43	mg/L	Multi-Parameter Meter
	SED	pH	7.9	mg/L	Single-Parameter Meter
	SED	Specific Conductance	245	µS/cm	Multi-Parameter Meter
	SED	Temperature	17.6	°C	Multi-Parameter Meter
	SED	Turbidity	2.7	NTU	Single-Parameter Meter
20-May-05	REF	Ammonia	0.303	mg/L	Grab;reported
	REF	Hardness	76.9	mg/L	Grab;reported
	REF	Nitrate+Nitrite	1.18	mg/L	Grab;reported
	REF	Organic Carbon	6.53	mg/L	Grab;reported
	REF	TKN	2.2	mg/L	Grab;reported
	REF	Total P	0.246	mg/L	Grab;reported
20-Jun-05	REF	Alkalinity	105	mg/L	Grab;reported
	REF	Ammonia	0.0288	mg/L	Grab;reported
	REF	Chloride	8.07	mg/L	Grab;reported
	REF	DO	6.34	mg/L	Multi-Parameter Meter
	REF	Fluoride	0.1	mg/L	Grab;reported
	REF	Hardness	115	mg/L	Grab;reported
	REF	Nitrate+Nitrite	0.114	mg/L	Grab;reported
	REF	Organic Carbon	2.47	mg/L	Grab;reported
	REF	pH	7.95	mg/L	Grab;reported
	REF	Specific Conductance	241	µS/cm	Grab;reported
	REF	Sulfate	5	mg/L	Grab;reported
	REF	TDS	132	mg/L	Grab;reported
	REF	Temperature	21.35	°C	Multi-Parameter Meter
	REF	TKN	0.475	mg/L	Grab;reported
	REF	Total P	0.0516	mg/L	Grab;reported
	REF	TSS	39.5	mg/L	Grab;reported
	REF	Turbidity	18.2	NTU	Grab;reported



All data derived from KYGEONET
KDOW Sampling Watershed Delineated using ArcHydro Extension
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Figure 2.6 Location of KDOW water quality sampling site and upstream land use.

2.2 Natural Features

2.2.1 Geology and Topography

The headwaters of Brushy Creek begin at an elevation of approximately 1190 ft. Water flows to the south through gently rolling hills. Bee Lick Creek flows south-southeast from a roughly 1212-ft elevation to its confluence with Brushy Creek at a 935-ft elevation (Fig. 2.7). Clifty Creek drains the southwestern portion of the watershed, starting at an elevation of 1124 ft, and flows into Brushy at an elevation of 841 ft. Brushy joins Buck Creek at an elevation of 835 ft.

The Brushy watershed is underlain by limestones, siltstone, and shales of Mississippian age (Fig. 2.8). The majority of the streams in the watershed flow over the Borden formation, mainly the Renfro Member in the north, cutting into the Halls Gap Member as the streams flow south. Smaller tributaries and hillslopes are underlain by Salem and Warsaw limestones. Hilltops and ridgelines are comprised of the St. Genevieve and St. Louis limestones of the Newman Formation, except in a few areas in the west of the watershed where rocks of the Pennington (Paragon) Formation are present above the Newman. Near the confluence with Buck Creek, the valley of Brushy Creek is underlain by alluvial deposits (Schlanger 1963).

Some of the limestone rocks in the watershed are soluble, which makes them susceptible to being dissolved by weakly acidic water. As the water flows through joints, fractures, and crevices in the rock, it slowly dissolves material, enlarging the fractures. This process leads to the development of features such as sinkholes, caves, and springs. This type of topography is called “karst.” Flow of surface water and groundwater are quite different in karst areas than in other types of aquifers. Water can quickly enter the surface through a sinkhole and travel very rapidly through a system via caves and smaller conduits, and then re-emerge through a spring. In some cases, water may flow underground through the karst system and be delivered to a neighboring watershed.

The development of karst features is dependent on site-specific conditions (KGS 2014). Therefore, karst development varies in the Brushy watershed. The floodplains and valley bottoms are predominantly non-karst (Fig. 2.9 and Table 2.6), whereas hillslopes are underlain by limestones that are karst prone. Subsurface flow may be considerable in small headwater tributaries through those limestone rocks, but the conduits typically intersect a shale layer above the elevation of the larger named streams. The shale acts as an aquatard, a layer of low permeability, so groundwater flows along this shale-limestone interface. Only a small area in Brushy Creek is underlain by rock formations that have intense karst development, with karst features such as caves, sinkholes and springs. These intense karst areas are mostly located along the eastern ridges of the watershed.

The Paragon Formation limestones form the steep slopes located along the eastern border of the Brushy Creek watershed. This geologic group comprises 1% of the entire watershed (Carey and Stickney 2004). The Paragon Formation is quarried and mined for construction aggregate and agricultural stone. It is fine- to coarse-grained and thin- to thick-bedded. Thin interbeds of shale occur in the upper part of the formation.

The Salem and Warsaw Limestone underlies 55% of the Brushy watershed. These limestones are fine- to coarse-grained and soluble, and they have the potential for karst development. Springs can form where these limestones contact rocks that do not allow water to flow through as freely, such as siltstone or other limestones that are rich in clay minerals. Springs may also occur where the Warsaw limestone intersects with the Fort Payne formation (Carey and Stickney 2004).

The Borden formation shale is featured throughout 20% of the watershed, primarily in the valley bottoms. The formation is not karst prone but develops discrete aquifers that yield 100–500 gallons per day except in late summer/early fall, when they tend to dry. Wells in this shale produce soft, silty water low in dissolved solids (Carey and Stickney 2004).

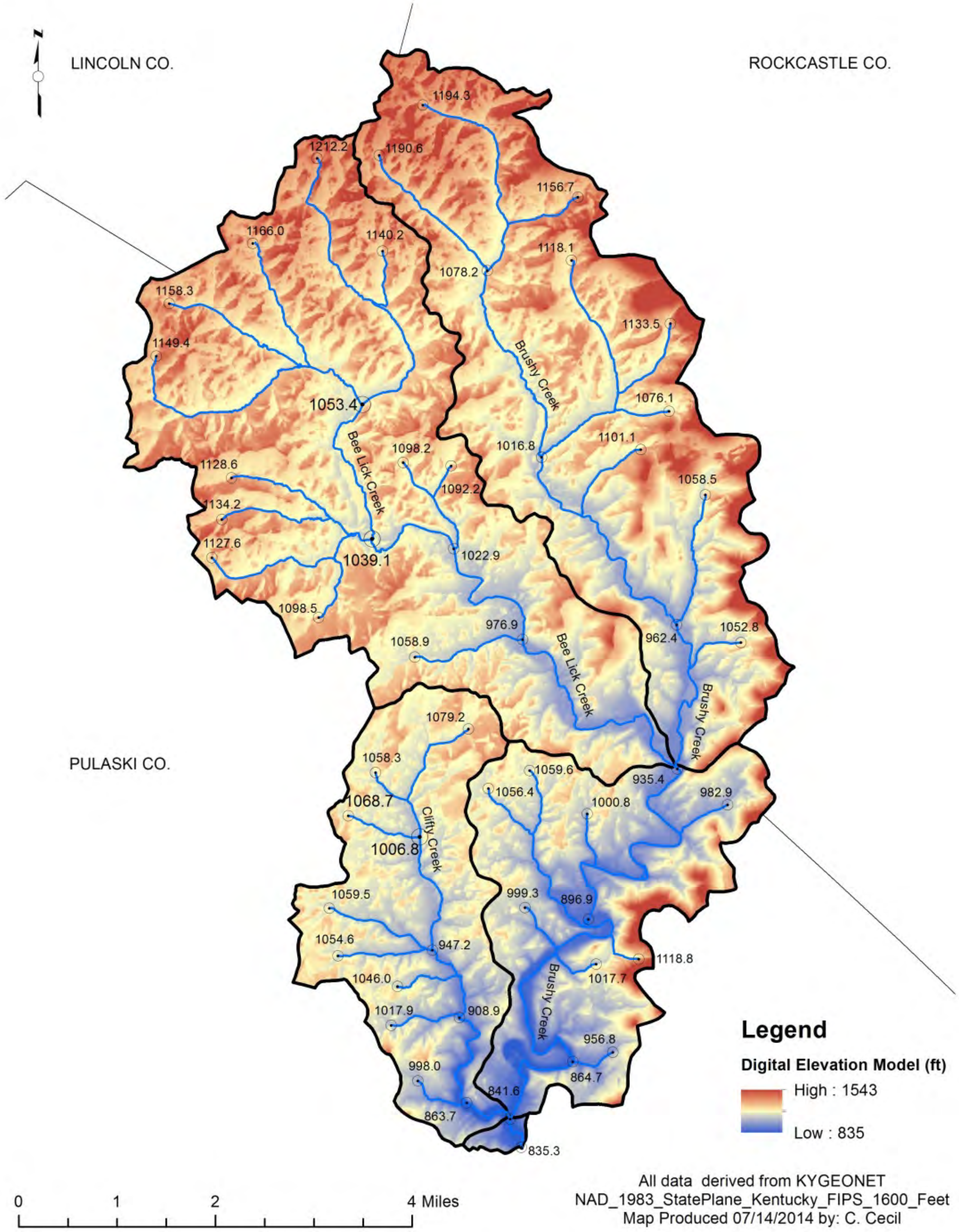

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Figure 2.7 Topography and spot elevations in the Brushy Creek watershed.

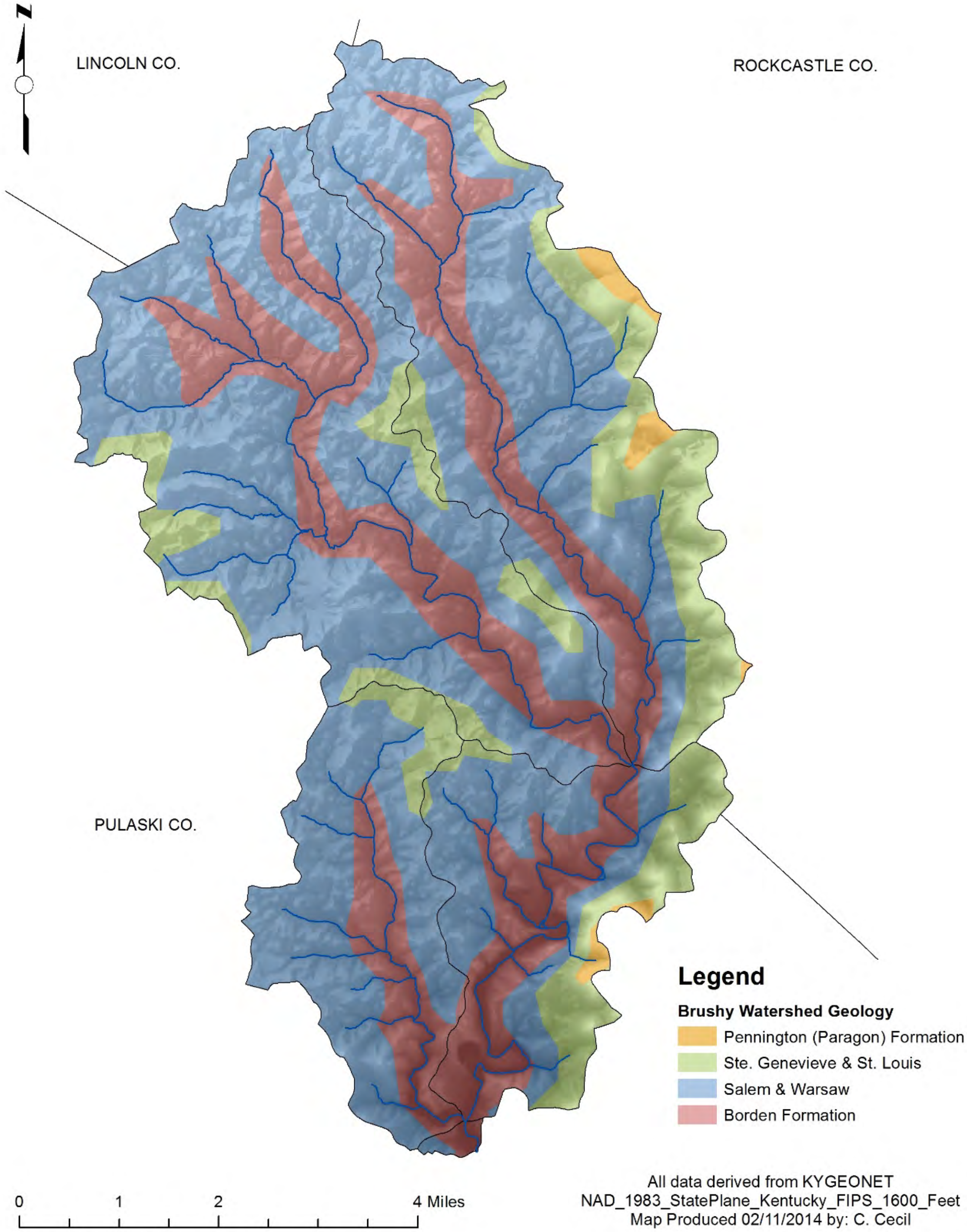

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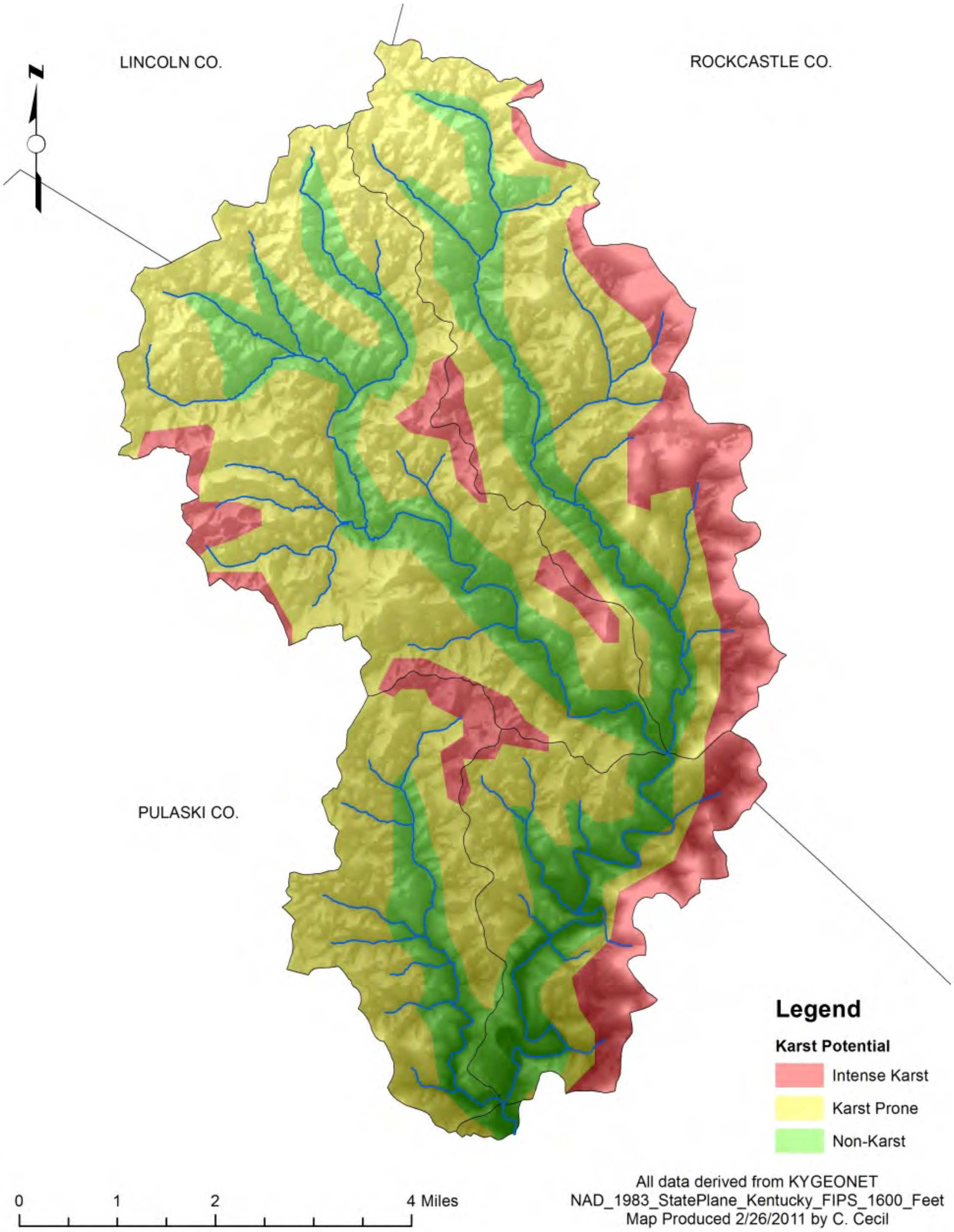
Figure 2.8 Generalized geology of the Brushy Creek watershed.



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Map Produced 2/26/2011 by C. Cecil

Figure 2.9 Karst potential in the Brushy Creek watershed.

Table 2.6 Karst Susceptibility of Brushy Creek Watershed Geologic Formations

Geologic Formation	Karst Susceptibility
Paragon Formation	Non-karst
Ste Genevieve & St Louis Limestones	Intense
Salem and Warsaw Limestone	Prone
Borden Formation	Non Karst

The Ste. Genevieve is white or yellow-white, well-sorted, medium-grained limestone with localized beds of gray, dense limestone. The St. Louis Member represents deposition in a subtidal environment. Its deposition in northeastern and most of east-central Kentucky was interrupted by tectonic uplift. These limestones are considered intensely karst by geologists, and where the units are thicker they can contain very large karst features. Further west, the Mammoth Cave system extends throughout the entire thickness of the St. Genevieve (100-120 ft) and the upper half of the St. Louis (~100ft). Several springs can form at the same elevation near the stream level or more commonly where two rock layers come together and the upper rock layer allows water to flow more freely than the lower rock layer. This formation's susceptibility to karst leads to the preferential enlargement of fractures through dissolution processes that produce wells of varying flow conditions based on the local groundwater supply (Carey and Stickney 2004). The geographic extent of both of these rock units is very limited within the watershed, and no dye trace data are known to be associated with springs identified. The USGS 7.5-minute quadrangle maps show only 13 sinkholes in the entire watershed, all associated with these two rock units. However, intensive survey and field reconnaissance would likely reveal more sinkholes than the maps display.

2.2.2 Soils

Uplands

The soils on the uplands of the Brushy watershed (Fig. 2.10) are dominated by the Frederick, Lily, Bedford, Hartsells, and Mountview soil types (Ross 1974). These four soils are very deep and well-drained, with moderate permeability. Slopes range from 0–20%. The potential for surface runoff is medium to low depending on local conditions. These soils are used for a variety of domestic crops, hay, and pasture. Native woody vegetation consists of oaks, hickory, tulip poplar, and pines. The Lily and Hartsells soils are mostly located on side slopes. The Frederick and Mountview found at higher elevations are consistently cleared for agriculture or pasture.

Valley Bottoms

The predominant soils in the valley bottoms are Newark and Chagrin (Ross 1974). Newark soils are more prevalent in the valleys of Bee Lick Creek, Brushy Creek north of the confluence with Bee Lick Creek, and the upper reaches of Clifty Creek. Newark soils are very deep but poorly drained. They have moderate fertility and low organic matter content. With proper drainage, the Newark soils are suitable for most crops, pasture, and hay. Chagrin soils are dominant in the lower reaches of Brushy

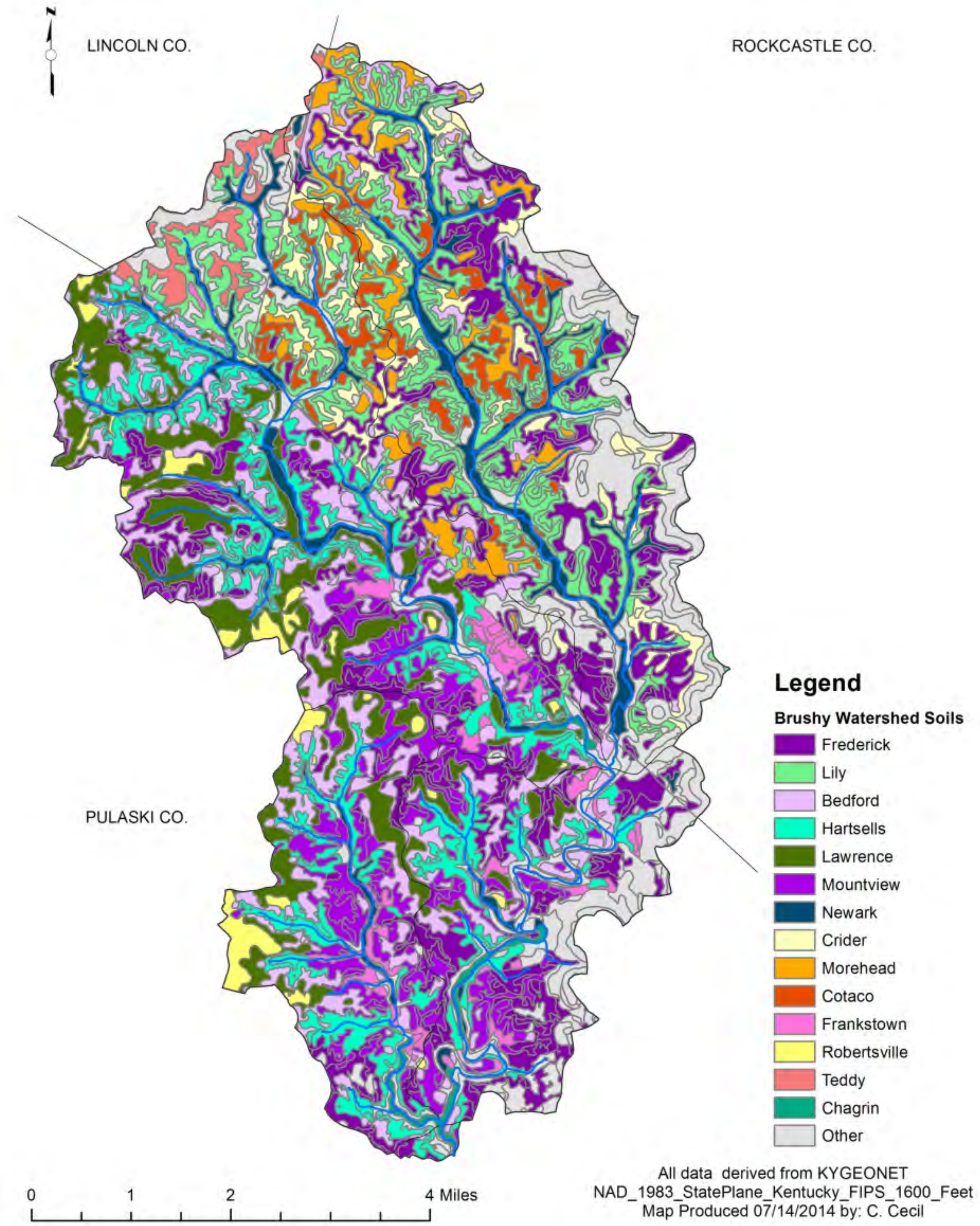


Figure 2.10 Brushy Creek watershed soils.

Creek and Clifty Creek. Chagrin soils are generally deep, well drained, and have moderate or high natural fertility and low organic content. These soils are suitable for most crops and pasture and hay.

2.2.3 Ecoregions

The Brushy Creek watershed lies at the intersection of two EPA Level IV ecoregions (Fig. 2.11): the Eastern Highland Rim (71g) and the Plateau Escarpment (68c). Most (97%) of the watershed is in the Eastern Highland Rim. The Plateau Escarpment is found on the far eastern hills of Brushy Creek's main stem.

The Eastern Highland Rim is characterized by temperate meadows and rolling hills. Streams are nutrient rich with moderate gradient and greater biotic richness and diversity than in neighboring ecoregions. Potential natural vegetation is predominately oak-hickory forest but present day upland forests are dominated by white oak with bottomland trees along streams (Woods et al. 2002).

The Plateau Escarpment is more rugged, dissected, and forested than the Eastern Highland Rim, with narrow ridges, cliffs, and gorges. The streams of the Plateau Escarpment are known for high water quality and for supporting many of the endangered species of Kentucky, with a high diversity of fish and mussel species. Effects of logging and coal mining have lowered the biological productivity of many stream reaches in the ecoregion (Woods et al. 2002), but the Brushy Creek watershed has not been mined for coal.

2.2.4 Riparian/Streamside Vegetation

The riparian zone is the land next to a stream. A vegetated riparian zone can act as a buffer for the stream, filtering the water that flows through it and thus reducing the amount of sediment, nitrogen, phosphorous, pesticides, and other pollutants that make their way into the stream. Riparian vegetation also provides shade for the stream, which may help a stream maintain conditions necessary to support aquatic life. Several factors influence the effectiveness of the riparian buffer, such as width of the buffer, vegetation type, soil characteristics, and watershed hydrology. The factors necessary for an effective buffer are also different for each pollutant. For example, for nutrients, the soil type, the amount of soil carbon, and the amount of subsurface flow are more important factors than the buffer width (Mayer et al. 2006).

Recent (2010) aerial photos were examined to determine the extent of riparian vegetation in the Brushy Creek watershed (Esri 2014). Areas with developed hardwood forests within 100 ft of the stream were designated as "Intact/Healthy" (Fig. 2.12 and Table 2.7). Of the four subwatersheds, Lower Brushy Creek had the most abundant riparian zones greater than 100 ft in width. Reaches where vegetative cover was less than 100 ft in width were classified as "Impacted"; these areas have visibly been cleared via human activity at some point in the past. Reaches with no riparian vegetation represented 18% of blue-line stream length (i.e., the streams that flow all or most of the year and are drawn as blue lines on USGS 7.5-minute topographic maps). Unvegetated reaches were present in all subwatersheds but were most prevalent in Upper Bee Lick and Upper Brushy Creek.

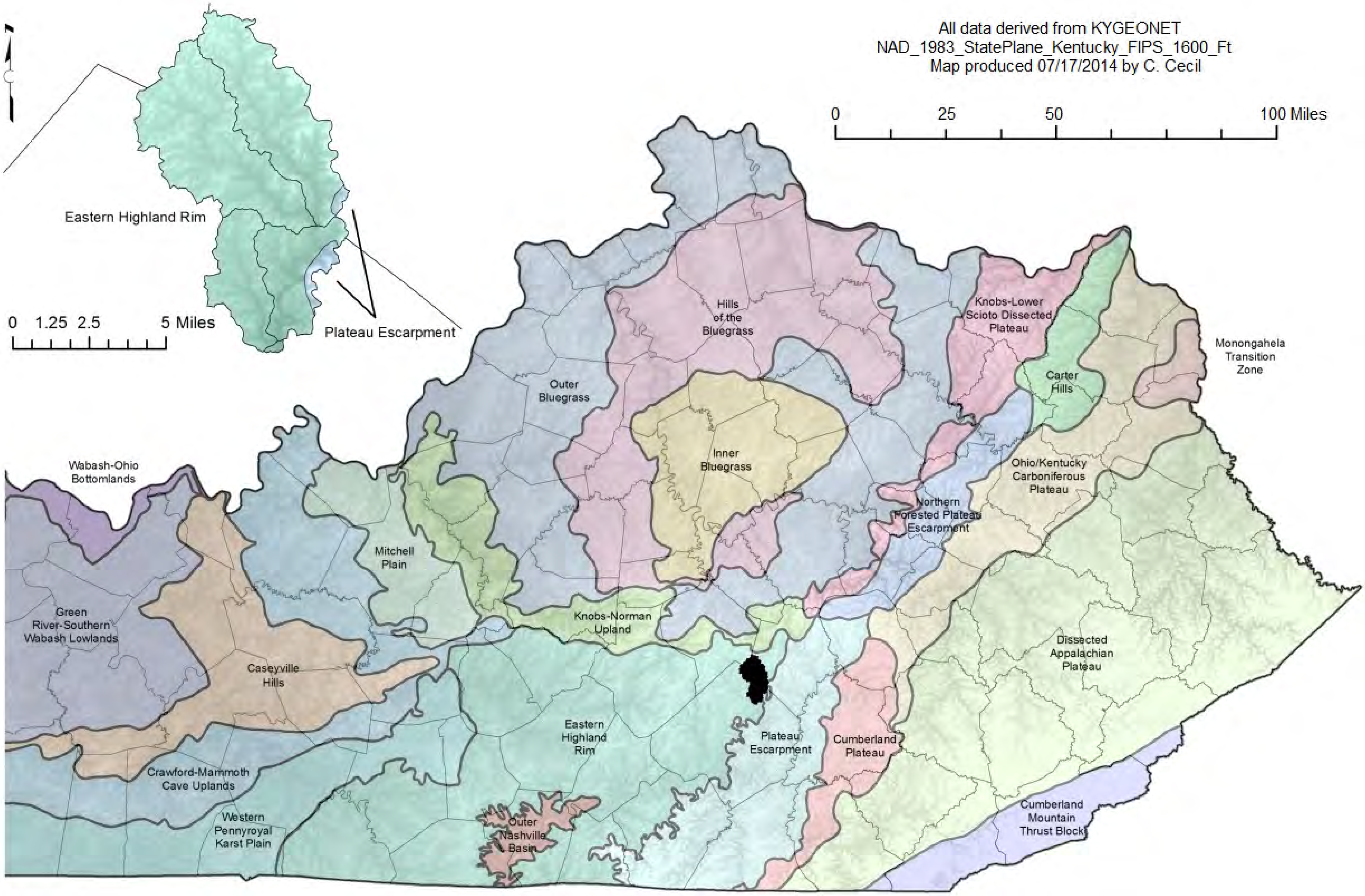
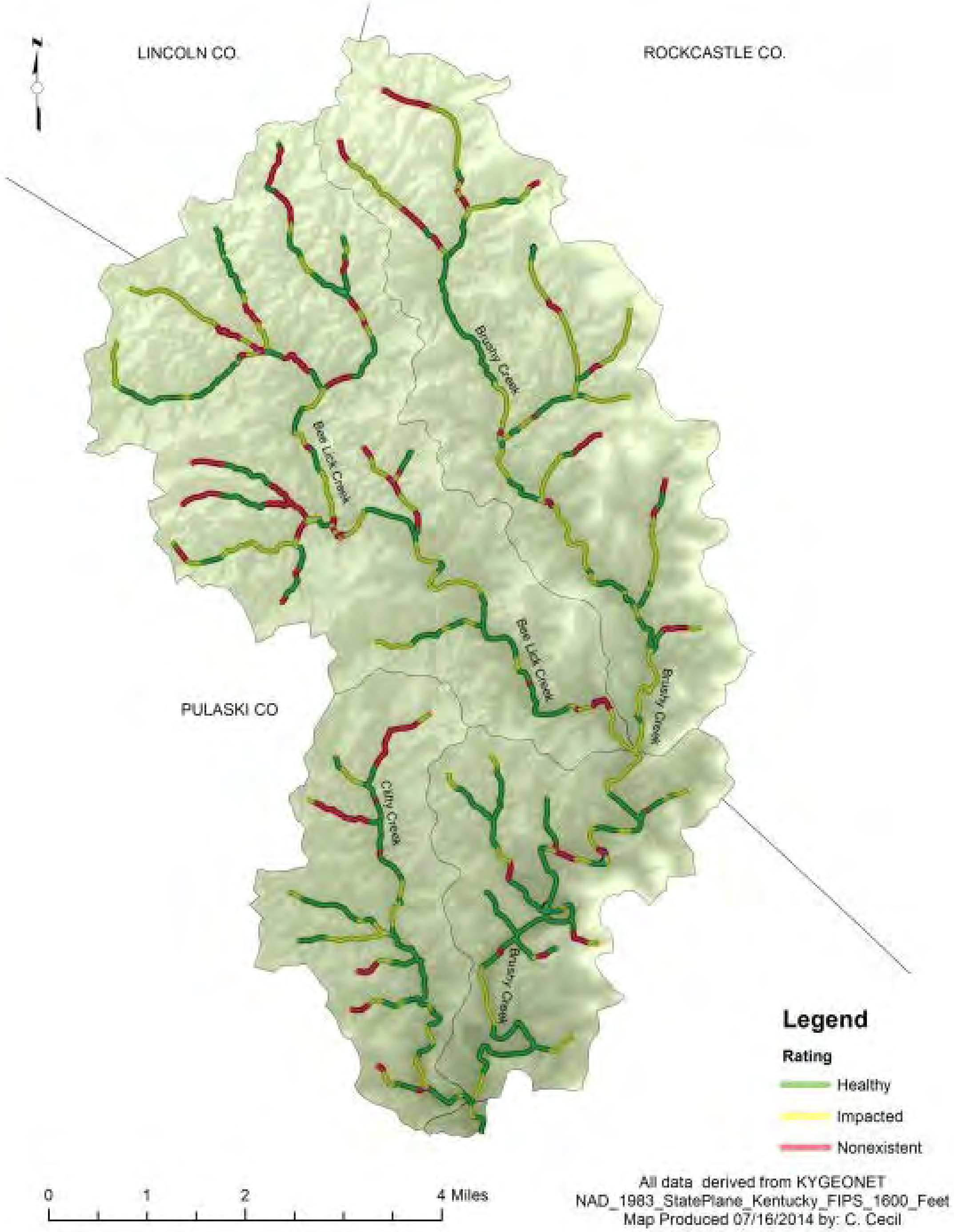


Figure 2.11 EPA Level IV ecoregions of Kentucky.



All data derived from KYGEONET
NAD_1983_StatePlane_Kentucky_FIPS_1600_Feet
Map Produced 07/16/2014 by: C. Cecil

Figure 2.12 Riparian vegetation in the Brushy Creek watershed.

Table 2.7 Length of Stream Reaches by Riparian Vegetation Quality, in ft and (%)

Riparian Vegetation Quality	Brushy Creek*	Brushy Creek†	Bee Lick Creek†	Clifty Creek†
Healthy	167,399 (45)	81,109 (46)	56,607 (41)	30,526 (52)
Impacted	137,366 (37)	73,798 (42)	48,832 (35)	16,842 (29)
No riparian zone	66,421 (18)	22,280 (13)	32,200 (23)	10,941 (19)

* Includes all named streams in the watershed.

† Includes main stem and blue-line tributaries.

2.2.5 Rare Plants and Animals

Fifteen species that are listed as rare at the state and/or federal level (Table 2.8) have been identified within the Brushy Creek watershed (KSNPC 2014).

Table 2.8 Rare Plants, Animals, and Natural Communities in the Brushy Creek Watershed (KSNPC 2014)

	Scientific Name	Common Name	Status*	Ranks	Occurrences
Vascular Plants	*Drosera brevifolia*	Dwarf sundew	E	Global: 5- Secure and common. State: 1- Critically imperiled, at a very high risk of extirpation.	E- Verified extant, ecological integrity not assessed.
	Gymnopogon brevifolius	Shortleaf skeleton-grass	E	Global: 5- Secure and common. State: 1- Critically imperiled, at a very high risk of extirpation.	H- Historical
	Hypericum crux-andreae	St Peter's-wort	T	Global: 5- Secure and common. State: 2/3- Imperiled-Vulnerable, at a high to moderate risk of extirpation.	E- Verified extant, ecological integrity not assessed.
	Lespedeza capitata	Round-head bush-clover	S	Global: 5- Secure and common. State: 3- Vulnerable, at a moderate risk of extirpation.	E- Verified extant, ecological integrity not assessed.
	Lobelia nuttallii	Nuttall's lobelia	T	Global: 4/5- Apparently Secure, uncommon but not rare, long-term concern. State: 2- Imperiled, at a high risk of extirpation.	E- Verified extant, ecological integrity not assessed.
	Ludwigia hirtella	Rafinesque's seedbox	E	Global: 5- Secure and common. State: 1- Critically imperiled, at a very high risk of extirpation.	E- Verified extant, ecological integrity not assessed.
	Lycopodiella appressa	Southern bog clubmoss	E	Global: 5- Secure and common. State: 1- Critically imperiled, at a very high risk of extirpation.	F- Failed to find.
	Oenothera linifolia	Thread-leaf sundrops	E	Global: 5- Secure and common. State: 1/2- Critically imperiled, at a high risk of extinction due to extreme rarity.	E- Verified extant, ecological integrity not assessed.
	Rhynchospora recognita	Globe beaked-rush	S	Global: 5- Secure and common. State: 3- Vulnerable, at a moderate risk of extirpation.	E- Verified extant, ecological integrity not assessed.
Freshwater Mussels	*Villosa tribalis*	Cumberland bean	E LE STWG	Global: 1 Critically imperiled, at a very high risk of extinction. State: 1 Critically imperiled, at a very high risk of extinction.	E- Verified extant, ecological integrity not assessed.
Fishes	*Entheostoma cinereum*	Ashy darter	S SOMC STWG	Global: 2/3- Imperiled-Vulnerable, at a high to moderate risk of extirpation. State: 3- Vulnerable, at a moderate risk of extirpation.	H- Historical
Breeding Birds	*Ammodramus henslowii*	Henslow's sparrow	S SOMC STWG	Global: 4- Apparently Secure, uncommon but not rare, long-term concern. State: 3- Vulnerable, at a moderate risk of extirpation.	E- Verified extant, ecological integrity not assessed.
Mammals	*Myotis grisescens*	Gray myotis	T LE STWG	Global: 3- Vulnerable, at a moderate risk of extirpation.	E- Verified extant, ecological integrity not assessed.

	Scientific Name	Common Name	Status*	Ranks	Occurrences
				State: 2- Imperiled, at a high risk of extirpation.	
	Nycticeius humeralis	Evening bat	S STWG	Global: 5- Secure and common. State: 3- Vulnerable, at a moderate risk of extirpation.	E- Verified extant, ecological integrity not assessed.
Communities		Wet meadow	E	Global: NR- Not Ranked. State: 1-Critically imperiled, at a very high risk of extirpation.	E- Verified extant, ecological integrity not assessed.

* Endangered (E), Threatened (T), Special Concern (S), Federal Listed Endangered (LE), Species of Management Concern (SOMC), State and Tribal Wildlife Grant (STWG)

2.2.6 Exotic/Invasive Plants and Animals

Exotic plants and animals are those that are not native to an area. They have been introduced by human activity, intentionally or accidentally. The introduced species have evolved in a different ecosystem, and the local ecosystem has evolved as a unit without the introduced species. The introduction of new species can be disruptive in many ways; some exotic plants and animals spread aggressively and displace the native species, reducing diversity of plant species and thus animal species (by removing the vegetation that animals rely on); vegetation changes can change the soil quality; vegetation changes can change the erodibility of soils. Table 2.9 includes all exotic invasive plants identified in Kentucky by the Kentucky Exotic Pest Plant Council as of 2013 (KY-EPPC 2013). Two other species are not on the EPPC list but have been identified as noxious weeds (USDA NRCS 2014): *Setaria faberi* (Japanese bristlegrass) and *Solanum ptycanthum* (West Indian nightshade). *Corbicula fluminea* (Asian clam) and *Craspedacusta sowerbyi* (freshwater jellyfish) are the only two non-native animal species identified by the USGS within the Brushy Creek watershed's counties (Foster et al. 2014).

Table 2.9 Brushy Creek Watershed Exotic Invasive Plants (KY-EPPC 2013)

Scientific Name	Common Name
Severe Threat Plant Species	
Achyranthes japonica	Japanese chaff flower
Ailanthus altissima	Tree-of-heaven
Alliaria petiolata	Garlic mustard
Ampelopsis brevipedunculata	Porcelain berry
Arthraxon hispidus	Hairy jointgrass
Carduus nutans	Musk thistle
Celastrus orbiculatus	Oriental bittersweet
Cirsium arvense	Canada thistle
Clematis terniflora	Leatherleaf clematis
Conium maculatum	Poison hemlock
Coronilla varia (=Securigera varia)	Crown vetch
Dioscorea polystachya	Chinese yam
Elaeagnus umbellata	Autumn olive
Euonymus alatus	Burning bush
Euonymus fortunei	Wintercreeper
Festuca arundinacea (=Lolium arundinaceum)	Kentucky 31 fescue
Glechoma hederacea	Ground ivy
Lespedeza cuneata	Sericea lespedeza
Lespedeza stipulacea (=Kummerowia)	Korean lespedeza
Ligustrum sinense, L. vulgare	Privet

Scientific Name	Common Name
Lonicera japonica	Japanese honeysuckle
Lonicera maackii, L. fragrantissima, L. standishii	Bush honeysuckles
Lysimachia nummularia	Moneywort
Lythrum salicaria	Purple loosestrife
Melilotus alba	White sweet clover
Melilotus officinalis	Yellow sweet clover
Microstegium vimineum	Japanese stiltgrass
Miscanthus sinensis	Chinese silver grass
Paulownia tomentosa	Princess tree
Phragmites australis	Common reed
Polygonum cuspidatum	Japanese knotweed
Pyrus calleryana	Callery pear
Pueraria lobata	Kudzu
Ranunculus ficaria	Lesser celandine
Rhamnus cathartica	European buckthorn
Rosa multiflora	Multiflora rose
Sorghum halepense	Johnson grass
Stellaria media	Chickweed
Significant Threat Plant Species	
Agrostis stolonifera	Weeping love grass
Akebia quinata	Akebia
Albizia julibrissin	Mimosa
Alternanthera philoxeroides	Alligatorweed
Berberis thunbergii	Japanese barberry
Bromus inermis	Smooth brome
Bromus tectorum, B. japonicus	Cheat grass
Cardiospermum halicacabum	Balloon vine
Centaurea biebersteinii	Spotted knapweed
Chrysanthemum leucanthemum	Ox-eye daisy
Cirsium vulgare	Bull thistle
Daucus carota	Queen Anne's lace
Dipsacus sylvestris, D. laciniata	Common teasel, cutleaf teasel
Echinochloa crus-galli	Barnyard grass
Eleusine indica	Goose grass
Galium pedemontanum	Cleavers
Hedera helix	English ivy
Hemerocallis fulva	Day-lily
Humulus japonicus	Japanese hops
Hydrilla verticillata	Hydrilla
Lespedeza bicolor, Lespedeza thunbergii	Bicolor lespedeza and shrubby lespedeza
Lespedeza striata (= Kummerowia)	Kobe lespedeza
Medicago lupulina	Black medic
Mentha xpiperata	Peppermint
Morus alba	White mulberry
Mosla dianthera	Miniature beefsteak
Najas minor	Water nymph
Ornithogalum umbellatum	Star-of-Bethlehem
Pastinaca sativa	Wild parsnip
Perilla frutescens	Beefsteak
Poa compressa	Canada bluegrass
Poa pratensis	Kentucky bluegrass

Scientific Name	Common Name
Polygonum cespitosum	Bunchy knotweed
Polygonum persicaria	Lady's thumb
Populus alba	White poplar
Potamogeton crispus	Curlyleaf pondweed
Rhodotypos scandens	Jetbead
Rorrippa nasturtium-aquaticum	Water-cress
Rubus phoenicolasius	Wineberry
Schedonorus pratensis	Meadow fescue
Setaria faberi	Giant foxtail
Setaria viridis	Green foxtail
Spiraea japonica	Japanese spiraea
Thlaspi alliaceum	Garlic peppergrass
Tussilago farfara	Coltsfoot
Typha xglacua	Cattail
Ulmus pumila	Siberian elm
Verbascum thapsus	Common mullein
Vinca minor	Lesser periwinkle

2.3 Human Influences and Impacts

2.3.1 Water Uses: Withdrawals and Discharges

Water withdrawals of 10,000 gallons or more per day require a KDOW permit. Withdrawals for domestic and agricultural use or steam-powered electrical generation, however, are exempt from KDOW permitting requirements.

The Kentucky Geologic Survey maintains a database of all water wells reported in Kentucky. Brushy Creek watershed has 20 reported groundwater wells that may be used as a domestic/residential water source (Fig. 2.13).

As of January 2010, the watershed had no facilities with active Kentucky Pollutant Discharge Elimination System (KPDES) permits, which control the input of waste water from sanitary, municipal, and industrial facilities to waters within the Commonwealth. Two previously issued permits in the watershed have expired: one for S&M Lumber and one for the Kentucky Army National Guard. No KDOW-regulated dams, source water and wellhead protection areas, or stormwater discharge sites are within the Brushy watershed boundaries.

No municipally maintained sewer lines have been installed within the Brushy Creek watershed. The residents must depend on individual septic tanks for waste management. Septic systems, if not properly maintained, can leach household chemicals and human waste into the groundwater. Residences without septic systems may use "straight piping," which is the running of a pipe from the home that dumps household waste directly into streams or other water bodies.

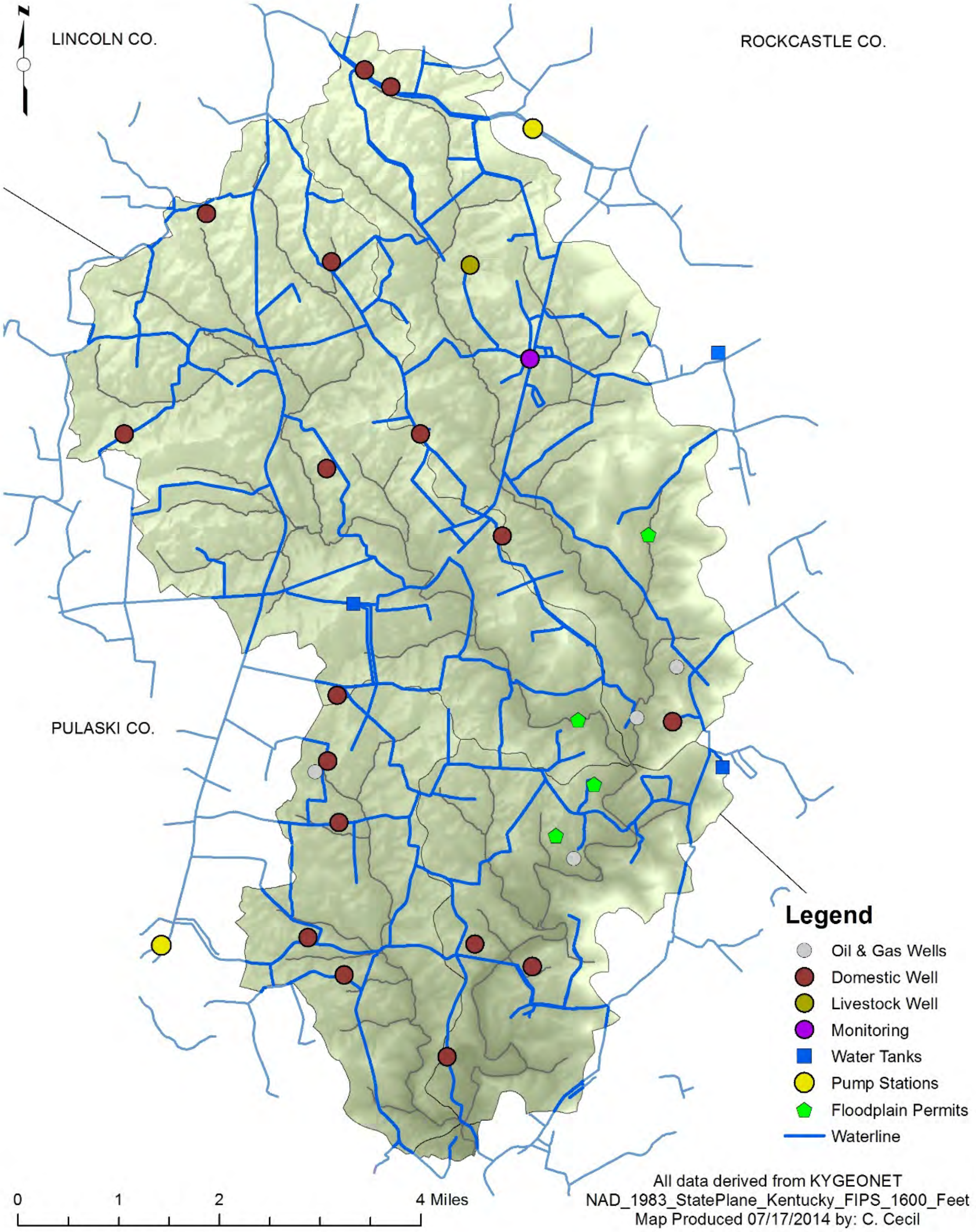


Figure 2.13 Water use in the Brushy Creek watershed.

2.3.2 Land Use and Land Cover

Land cover in the Brushy watershed is currently 55% pasture/hay, which is the dominant land cover on the ridge tops; the remainder of the watershed is primarily forest (36%). The watershed contains only a few ridge-top residences and roads, and no industry (Fig. 2.14). Impervious surfaces are surfaces where water cannot soak in. Examples are roads, roofs, parking lots, and overgrazed livestock areas (livestock compact the soil and shorten or remove the vegetation while grazing). This increases the runoff of rainwater and pollutants into streams by keeping water from seeping into the ground. Impervious surfaces cover only a small fraction of the watershed.

Urban Development

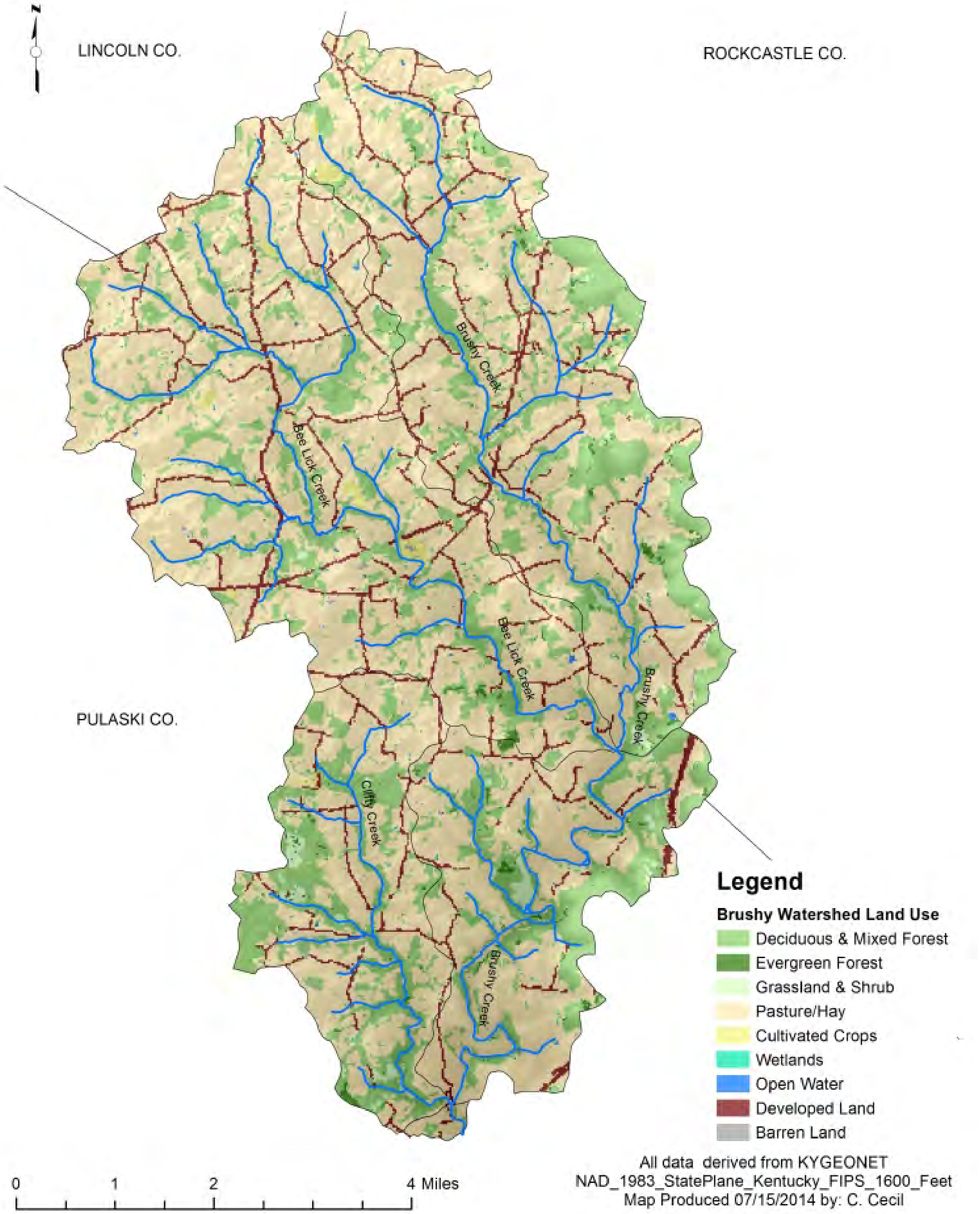
Pollutants associated with urban runoff include chemicals and fertilizers used in and around homes and gardens, vehicle emissions and fluids, leaking or poorly functioning septic systems, and pet waste. Because the Brushy watershed is largely comprised of pasture, agriculture, and deciduous forests, the impacts of urban runoff are limited. The developed land within the watershed is exclusively transportation roadways. Developed impervious surfaces account for 4.7% of the 44 mi^2 watershed (Fig. 2.15).

Agriculture

The Brushy watershed's agriculture was analyzed through the National Agricultural Statistics Service's CropScape. CropScape is an interactive spatial display of cultivated crops throughout the United States. The data are rigorously analyzed through aerial imagery from Landsat 7 and 8, and the crop types are differentiated using NASA's Moderate Resolution Imaging Spectroradiometer. The Brushy watershed is dominated by three crops: hay, soybeans, and corn (Fig. 2.16). Cultivated crops can be a major source of nonpoint source pollution from standard fertilizer and pesticide practices. Coordinating with local farmers to develop Best Management Practices regarding the use of these chemical enhancements and maintaining an adequate riparian buffer for farms next to streams is essential to the overall health and stability of the streams.

Cattle

Pulaski and Lincoln County have the second- and seventh-largest inventory of cattle and calves in Kentucky. Livestock can be a major contributor to NPS pollution when liquids or particles of their waste are carried into streams in rainwater runoff, and especially when the waste is deposited directly into surface waters when cattle are allowed access to streams. Additionally, cattle grazing can increase runoff through the compaction of soils, and can increase soil erosion through the removal of vegetation. Using the USDA (2014) National Agricultural Statistics Service, the total acreage of pasture and inventory of cattle and calves was used to estimate the density of cattle per acre in Lincoln, Pulaski, and Rockcastle counties for 2002 and 2007. The acreage of pasture within each subwatershed (Fig. 2.17) was delineated from the USGS (2002) Kentucky Gap Analysis Program Land Cover. The KY GAP land cover was chosen over the National Land Cover Dataset (NLCD) because it differentiates livestock pasture from hay cultivation, thus rendering a more selective land cover for analysis. Each subwatershed's acreage of pasture was separated by county so the proper density could be applied. Estimated cattle and calves (Fig. 2.18) outnumber estimated people in the watershed by approximately seven-to-one.



All data derived from KYGEONET
NAD_1983_StatePlane_Kentucky_FIPS_1600_Feet
Map Produced 07/15/2014 by: C. Cecil

Figure 2.14 Land cover in the Brushy Creek watershed (based on 2001 National Land Cover Dataset).

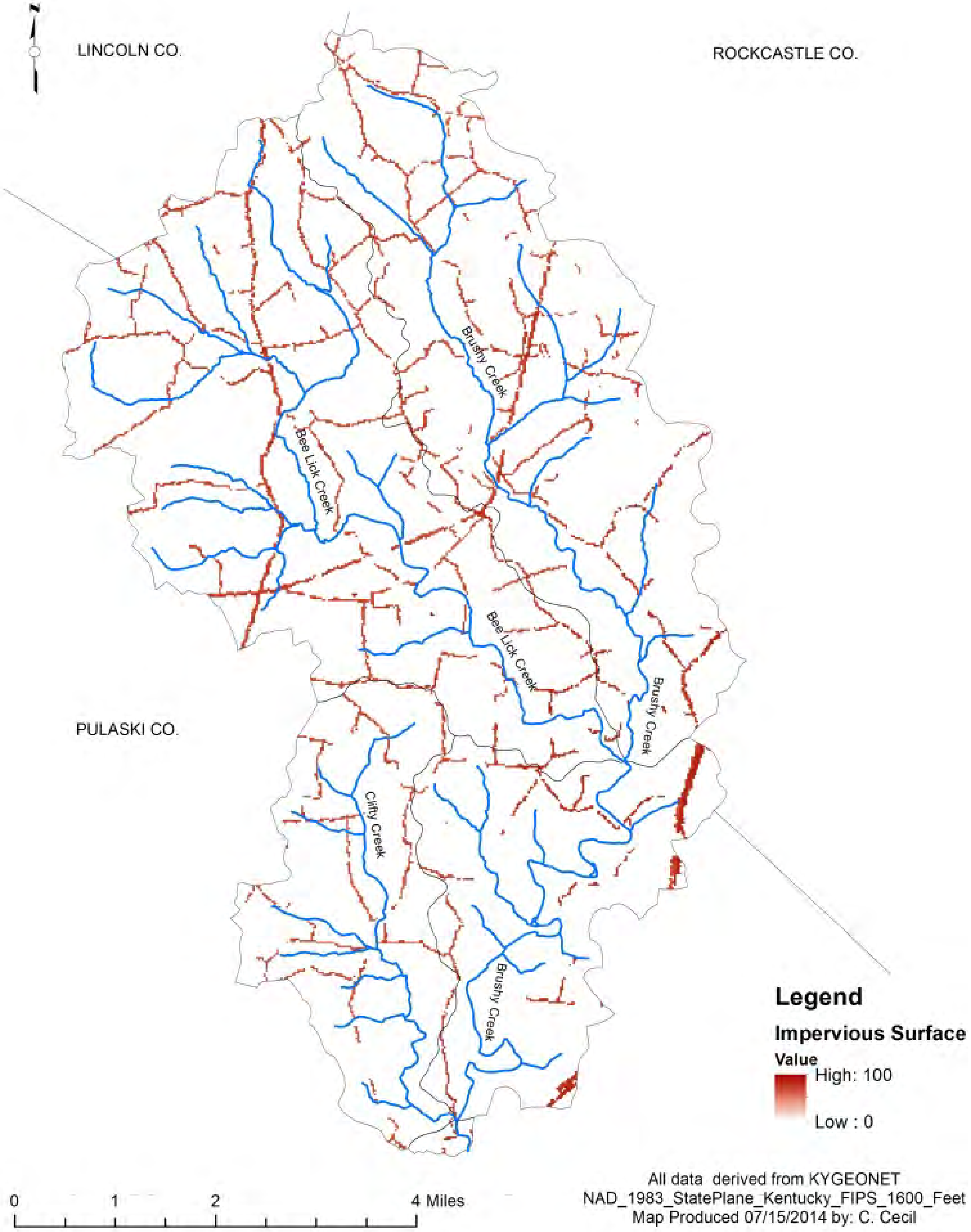


Figure 2.15 Impervious surfaces in the Brushy Creek watershed.

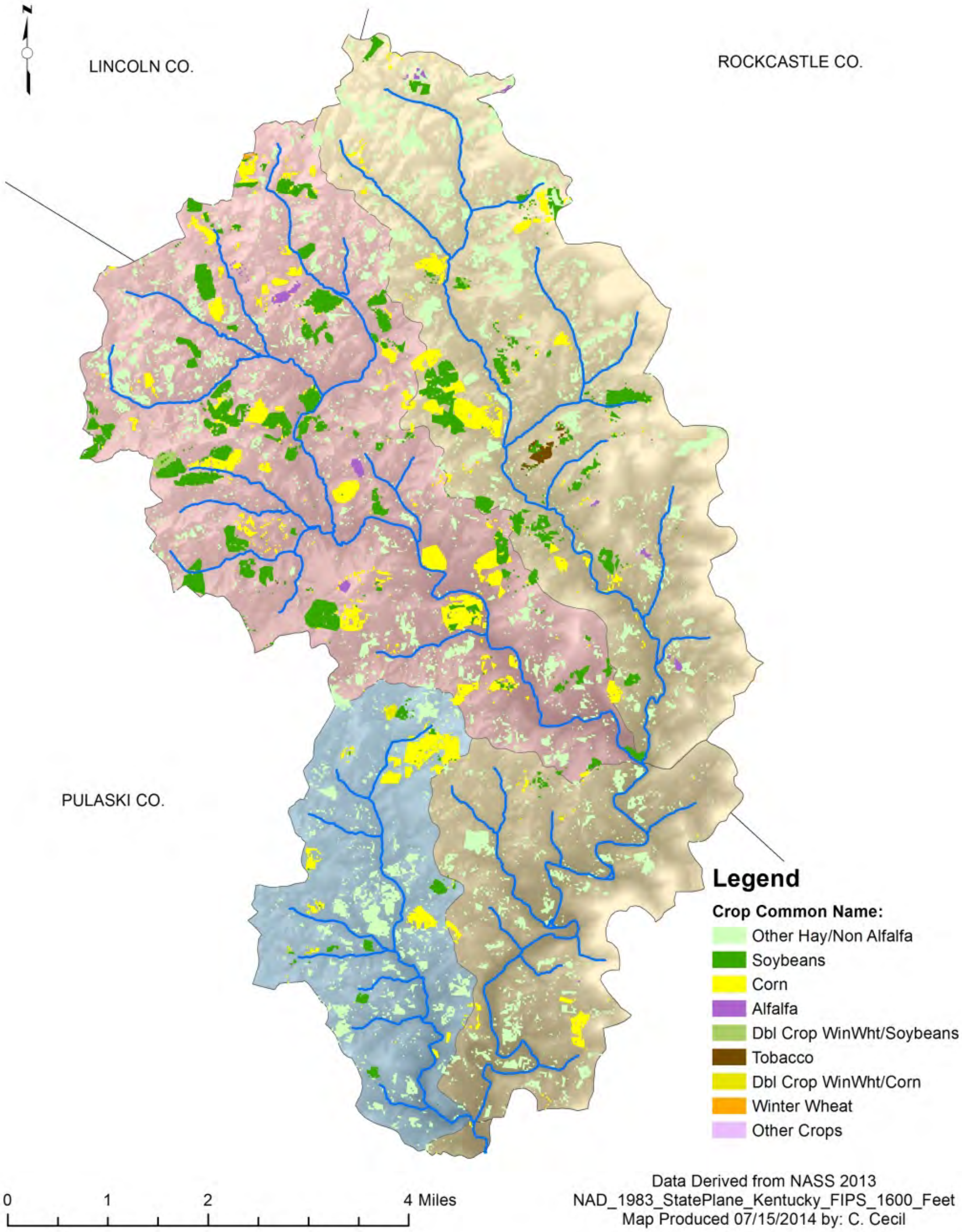


Figure 2.16 Row crop agriculture in the Brushy Creek watershed.

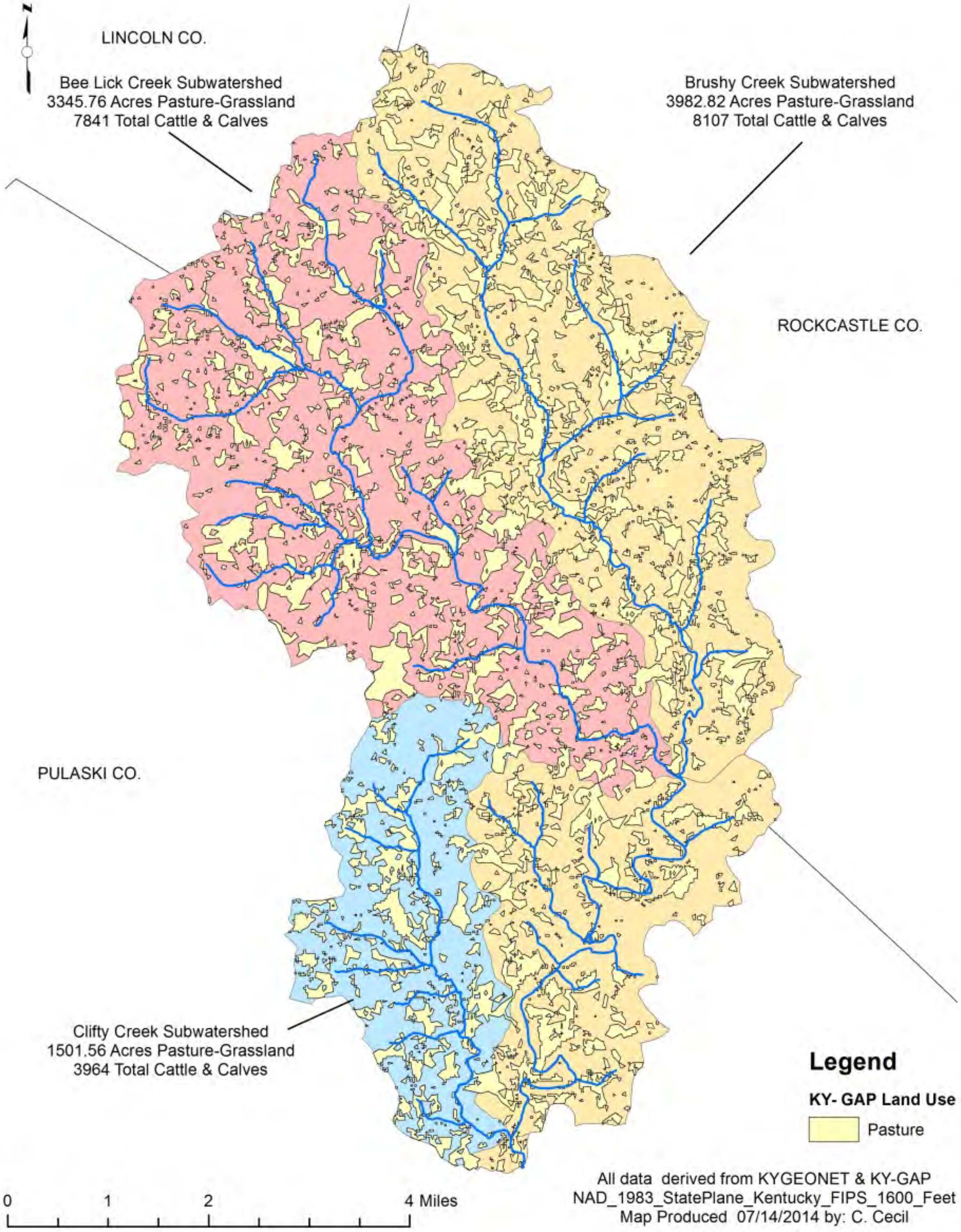


Figure 2.17 Pasture and estimated cattle population in the Brushy Creek watershed.

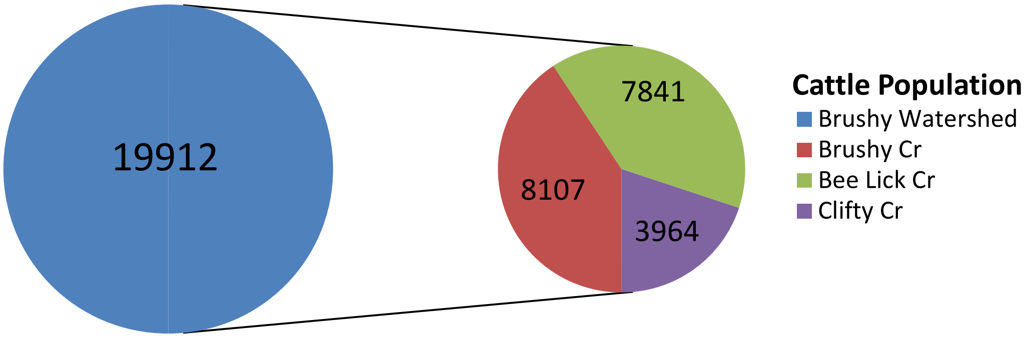


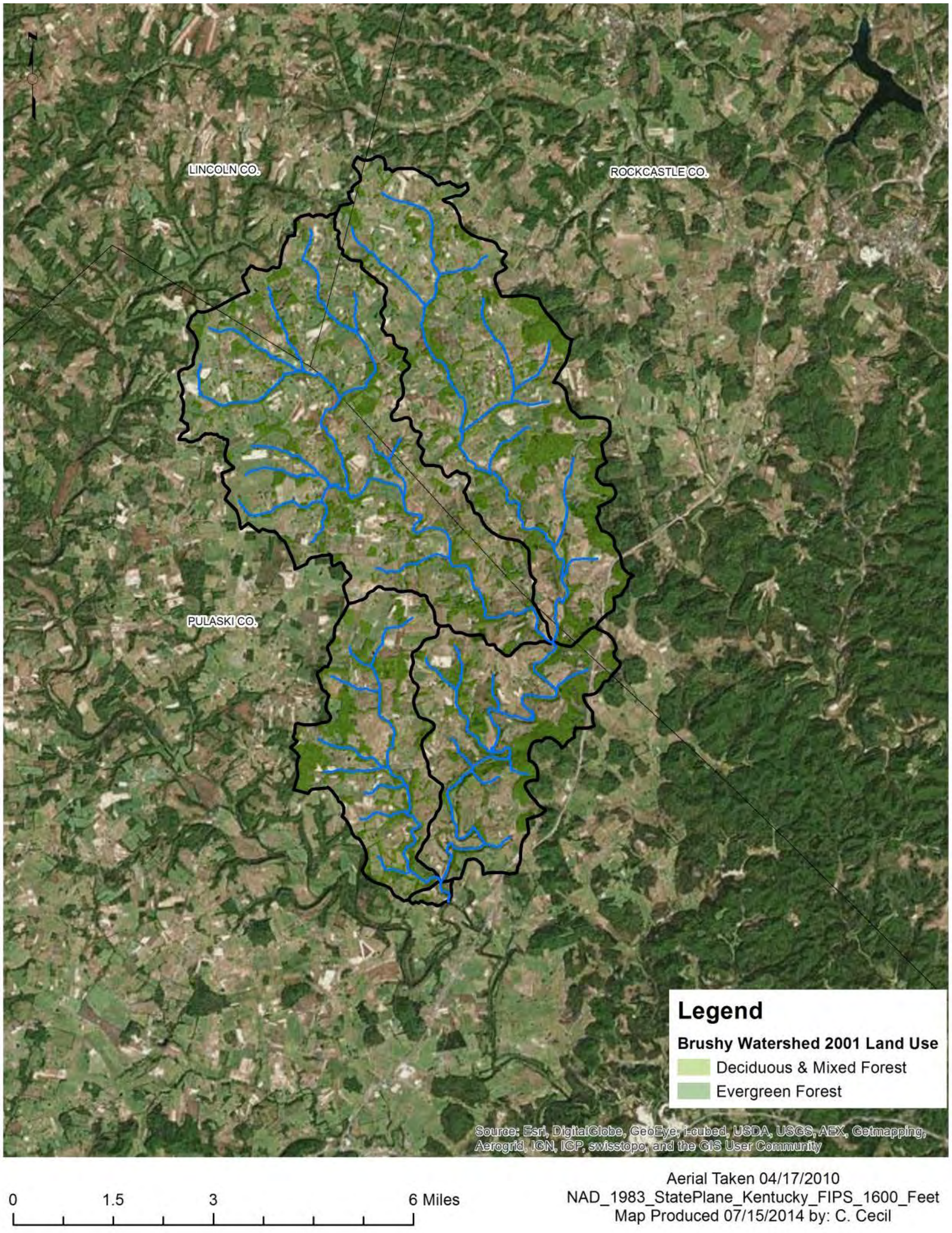
Figure 2.18 Distribution of cattle in the Brushy Creek subwatersheds.

Forestry

The National Agriculture Imagery Program's 2-ft resolution aerial image captured in 2006 (KYGIS 2008) shows very little evidence that any present logging activity is occurring within the Brushy Creek watershed. Aerial imagery was examined for evidence of logging roads, patches of barren land within forested areas where trees had been clear cut, and areas of young growth were extensive logging had recently occurred and the land was recovering with saplings and shrubbery. The forested areas delineated in the 2001 NLCD have remained intact the last nine years, based on 2010 aerials of the watershed (Fig. 2.19) (Esri 2014).

2.3.3 Stream Projects

Dredging, channelization, and other stream alteration projects damage water quality by disturbing sediment, rock, and debris. When the sediment is stirred up in the stream, the water becomes cloudy, making it difficult for fish to find food and potentially clogging their gills. The sediment can move into other areas of streams or lakes, smothering benthic organisms (i.e., those living on or in the stream bed) and degrading aquatic habitat. These practices also contribute to stream degradation by increasing erosion at the site and downstream after the work is completed, adding more sediment to the stream. Many channels in Brushy Creek show some sign of past channel straightening, which was done to increase the amount of farmable land in the valley bottom, but no evidence was found that such straightening has occurred in the last few decades. Recent modifications in the Brushy Creek watershed are primarily due to gravel mining, although this is very limited in scope relative to nearby watersheds (Lowe 1999; Kelley 2001). Four floodplain permits were issued in the watershed from 2006–2008 (Fig. 2.13): three were for stream/streambank stabilization, and one was for a stream crossing (KDOW 2008).



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Aerial Taken 04/17/2010
NAD_1983_StatePlane_Kentucky_FIPS_1600_Feet
Map Produced 07/15/2014 by: C. Cecil

Figure 2.19 Evidence is minimal that any present logging activity is occurring within the Brushy Creek watershed.

2.3.4 Mining

Reclaimed mining sites can leach acidic materials deposited from past activities into groundwater sources or surface runoff during and after rains. USGS topographic maps and the Kentucky Mine Mapping Information System indicate no evidence of active or historical mining located within the Brushy Creek watershed.

2.3.5 Hazardous Materials

USEPA (2014) has not listed any approved superfund sites for hazardous materials within the Brushy watershed.

2.4 Demographics and Social Issues

The population for the Brushy watershed was estimated using 2010 Census Block data. The watershed intersected several different census blocks so population was estimated assuming a uniform density within each block. Each census block density was multiplied by the area of coverage within each sub watershed, with an estimated 2225 residents in total (Table 2.10).

Although these population estimates are rough, Brushy Creek is nevertheless a predominately rural watershed with low population density. The property boundaries in the watershed are very fragmented with no majority landowner or publicly held land in any of the subwatersheds. Any BMPs or management activities impacting more than 1000 ft of stream length will likely be dependent on the cooperation of multiple landowners. Upland BMPs are more likely to be located within a single property boundary.

Table 2.10 Estimated Population and Density within Brushy Creek

Subwatershed	Population	Households	Population Density (per mi^2)	Household Density (per mi^2)
Clifty	276	133	43.47	20.95
Bee Lick	823	378	49.03	22.52
Brushy	1126	516	53.01	24.29
Watershed Total	**2225**	**1027**	**50.13** (weighted mean)	**23.14** (weighted mean)

3

Monitoring

3.1 Existing Data

Few data were available for Brushy Creek. KDOW has collected some biological data in the Brushy Creek watershed, but the spatial and temporal frequency was insufficient to make inferences about the distribution of nonpoint source pollution in the watershed. The four locations that KDOW sampled for biological data were in the lower reaches of Brushy Creek (two sites very close to one another), in the lower reaches of Bee Lick Creek near the confluence with Brushy Creek, and in the headwaters of Bee Lick Creek (Tables 3.1 and 3.2). Fish and macroinvertebrate data suggest that the habitat and water quality in Brushy Creek downstream of the confluence with Bee Lick Creek are fully supporting for WAH, although some of the data are more than 10 years old (Table 3.2).

Table 3.1 Existing KDOW Data

StationID	Stream Name	Location	Latitude	Longitude	Fish	Bugs	Habitat	Water Chemistry
DOW02012002	Brushy Creek	Above Smith Hollow Road Ford	37.2417	−84.4597	Y	Y	Y	Y
SED02012501	Brushy Creek	At Smith Hollow Road Crossing	37.2412	−84.4600	Y		Y	Y
SED02012502	Bee Lick Creek	Friendship Church Road Crossing	37.2722	−84.4423	Y		Y	Y
DOW02012021	Bee Lick Creek	KY-39, nr Flatwoods School Rd	37.3576	−84.5027		Y	Y	Y

Table 3.2 Existing KDOW Data Collection Sites for Fish and Macroinvertebrates

StationID	Stream	Collection Date	Drainage Area (mi^2)	KIBI Score	KIBI Ranking	MBI Score	MBI Ranking
DOW02012002	Brushy Creek	7/28/1999	34.8	N/A	N/A	84.3	Excellent
DOW02012002	Brushy Creek	7/11/2000	34.8	49	Fair	84.6	Excellent
DOW02012002	Brushy Creek	6/20/2005	34.8	86	Excellent	90.4	Excellent
DOW02012002	Brushy Creek	8/13/2009	34.8	51	Fair	N/A	N/A
DOW02012002	Brushy Creek	5/9/2011	34.8	58	Good	N/A	N/A
DOW02012002	Brushy Creek	7/10/2012	34.8	68	Good	N/A	N/A
SED02012501	Brushy Creek	9/19/2000	37.0	76	Excellent	N/A	N/A
SED02012502	Bee Lick Creek	9/19/2000	16.0	69	Excellent	N/A	N/A
DOW02012021	Bee Lick Creek	5/10/2005	0.2	N/A	N/A	55.4	Fair

The results from KDOW's habitat evaluation (Table 3.3) suggested that the physical habitat in the lower reaches of the Brushy Creek watershed is not a cause for concern or an impediment to aquatic life, supporting the fair-to-excellent fish and bug populations identified in the sampling. The habitat assessment in the headwaters of Bee Lick was conducted on a reach that had very limited riparian vegetation. The habitat assessment conducted in the lower part of the Bee Lick subwatershed was conducted in late summer (September 2000) and scored poor for velocity/depth regime and channel flow status. Presumably, these parameters would have been much higher had the assessment been conducted in the spring when baseflow was probably much higher.

Water chemistry samples collected in Brushy Creek were single grab samples. Although none of the samples exceeded surface water standards, no broader conclusions can be drawn from them. Dr. Alice Jones at Eastern Kentucky University has conducted several studies on the water quality, particularly *E. coli* but also other parameters. At the time of this report, these studies had not been published, but developers of Chapters 5−7 of the watershed plan for Brushy Creek should consult with Dr. Jones prior to identification of suitable BMPs.

USGS has no gauges in the Brushy Creek watershed, and the USGS gauge at Buck Creek (USGS 03407500 Buck Creek near Shopville) was discontinued in early 1992. Although historic data were to be used to evaluate the magnitude of flood events in Brushy Creek, the removal of the gauge house and associated benchmarks negated this approach.

Table 3.3 Visual Based Habitat Evaluations in the Brushy Creek Watershed Conducted by KDOW Personnel

		Lower Brushy		**Lower Brushy**	**Lower Bee Lick**	**Upper Bee Lick**
		DOW02012002		SED02012501	SED02012502	DOW02012021
	RBP Parameter	7/11/2000	6/20/2005	9/19/2000	9/19/2000	5/10/2005
1	Epifaunal substrate/available cover	17	16	15	13	15
2	Embeddedness	18	17	17	15	16
3	Velocity/depth regime	18	18	8	8	10
4	Sediment deposition	16	10	13	13	13
5	Channel flow status	17	15	13	9	15
6	Channel alteration	18	17	18	18	15
7	Frequency of riffles	17	12	10	18	10
8	Bank stability (L)	8	7	7	5	9
	Bank stability (R)	9	6	7	6	8
9	Vegetative protection (L)	8	7	6	6	2
	Vegetative protection (R)	8	7	8	5	2
10	Riparian vegetative zone width (L)	8	8	5	6	1
	Riparian vegetative zone width (R)	8	8	8	4	1
	Total	**170**	**148**	**135**	**126**	**117**
	Habitat rating	Good	Good	Fair	Poor	Poor

3.2 Monitoring Strategy

Based on the review of the limited existing data for the entire Brushy watershed and the guidance provided in the *Watershed Planning Guidebook for Kentucky Communities* (KWA and KDOW 2010), monitoring of all subwatersheds was determined to be necessary. The goal of the monitoring effort was to characterize the water quality and habitat of the Brushy Creek watershed and to provide information that will be used to develop preliminary recommendations for future BMP implementation.

Two phases of monitoring were implemented to achieve this goal:

1. *Phase 1 pollutant identification:* One year of monitoring was conducted to identify parameters of concern and subwatersheds not meeting water quality standards.
2. *Phase 2 source identification*: Further monitoring was used to locate the sources for parameters of concern.

The results of Phase 1 sampling were used to identify subwatersheds for Phase 2 sampling. Priority was given to those subwatersheds where nonpoint source pollutants were in excess of surface water standards (if available) or aquatic life benchmarks. Where standards are not available, priority was given where the pollutants were elevated relative to other reaches in Brushy Creek.

3.2.1 Phase 1 Monitoring

Phase 1 data were collected from May 2011 to May 2012. Data collection focused on four specific aspects of watershed health:

1. Habitat
2. Water quality affecting WAH (general physico-chemical parameters and nutrients)
3. Water quality affecting contact recreation in the watershed (*E. coli*)
4. Sediment (which can affect water quality and habitat)

Site Selection

The Brushy Creek HUC10 watershed (see Section 2.1.1) comprises four HUC14 subwatersheds. Of these, the two southern subwatersheds, Clifty Creek and Lower Brushy Creek, drain less than 10 mi^2 combined and were selected as a monitoring unit. The two northernmost HUC14s drain more than 10 mi^2 each, and both were subdivided into two monitoring units—Upper and Lower Bee Lick Creek, and Upper and Middle Brushy Creek—to capture variation within the HUC14. The main criterion for four of the Phase 1 monitoring sites was proximity to the mouth of a HUC14 to capture the loads from these subwatersheds (Fig. 3.1 and Table 3.4) and to permit comparisons between each subwatershed to be made, as suggested in the *Watershed Planning Guidebook for Kentucky Communities*. In the northern HUC14s of Brushy and Bee Lick creeks, an additional monitoring station was needed to split each HUC14 into two subwatersheds of relatively similar sizes. In Brushy Creek, the additional site was selected primarily based on road access. In Bee Lick Creek, the additional site was identified based on field visits and input from project partners who had identified that siltation was common in that reach. For all sites, the specific location of monitoring equipment was based on safety and accessibility of equipment, proximity to a bridge for flood flow measurement and sample collection, and landowner cooperation.

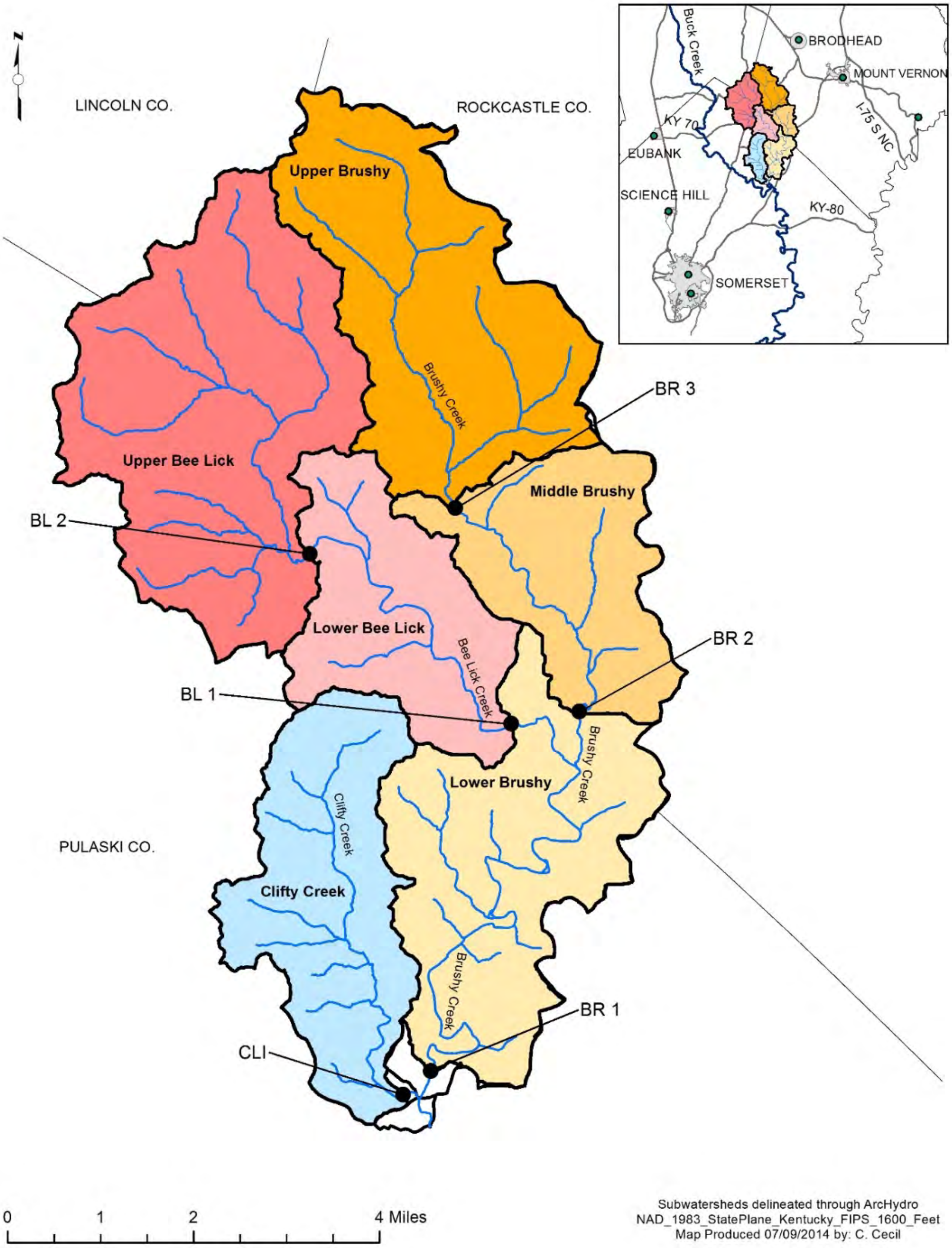


Figure 3.1 Project area map with the sampling stations.

Table 3.4 Phase 1 Monitoring Subwatersheds and Monitoring Stations

Sub-watershed	Monitoring Site ID	Latitude	Longitude	Description	Total Drainage Area (mi²)	Subwatershed Drainage Area (mi²)
Lower Brushy	BR1	37.21677	−84.46897	Brushy Creek nr Buck confluence at KY3268	37.9	8.3
Middle Brushy	BR2	37.27610	−84.43730	Brushy Creek above confluence with Bee Lick	13.6	5.0
Upper Brushy	BR3	37.308502	−84.46064	Brushy Creek at KY70	8.6	8.6
Lower Bee Lick	BL1	37.27443	−84.45084	Bee Lick nr Walnut Grove	16.0	5.1
Upper Bee Lick	BL2	37.30164	−84.48917	Bee Lick at KY3267	10.9	10.9
Clifty Creek	CLI	37.21757	−84.47061	Clifty Creek nr Brushy confluence at Silver Star Rd	6.3	6.3

Field Data Collection Methods

Water quality was assessed using a combination of grab samples and continuous measurements. Water level (stage) was also measured continuously because variations in water level are an important influence on pollutant transport. In addition, continuous measurements of conductivity, turbidity, and temperature were made at all monitoring stations. The continuous data provide information on the stream response to rainfall events, which are often hard to sample effectively on small streams, and these data provide a better understanding of cause-and-effect relations than a few grab samples would (Gibs 2008). At each monitoring station, the following data were collected (see also Table 3.5):

1. Continuous monitoring (every 15 minutes) of water level (pressure transducers), and temperature, conductivity, and turbidity (YSI sondes).
2. Monthly measurements of water quality parameters (temperature, pH, conductivity, dissolved oxygen and turbidity) and discharge (Sontek Flowtracker or RDI StreamPro).
3. Monthly grab samples for nutrients (nitrate, nitrite, Total Kjeldahl nitrogen (TKN), orthophosphate, total phosphorus), ammonia, carbonaceous biochemical oxygen demand (cBOD), and *E. coli*.
4. Five grab samples in 30 days during May/June for *E. coli*.
5. At the BL1 site, pH and dissolved oxygen also were continuously monitored.
6. At BR1, BR2, BL1 and CLI—one site in each HUC14—a passive suspended sediment sampler (Fig. 3.2) was installed for at least one flood event with the assumption that suspended sediment characteristics would not vary significantly within a HUC14.

Table 3.5 Water Quality Parameter Data Collection Details

Parameter	No. Stations	Continuous/Discrete (frequency/duration)	Instrument	Comments
Water stage	6	Continuous (15 mins/2 years)	Solinst Levelogger 3001	In field
Discharge	6	Semi-continuous (15 mins during flood/2 floods per site)	Sontek Argonaut	In field
Discharge	6	Discrete (2-3 readings per site)	*Wadeable flows*: Sontek Flowtracker. *Non-wadeable*: RDI StreamPro	In field
Temperature	6	Continuous (15 mins/ 1year)	YSI 6920 V2-2 Sonde (one) and YSI 600OMS V2 Sondes (five)	In field
Temperature	6	Discrete (monthly/1 year)	YSI Professional plus	In field before grab sample collection
Conductivity	6	Continuous (15 mins/1 year)	YSI 6920 V2-2 Sonde (one) and YSI 600OMS V2 Sondes (five)	In field
Conductivity	6	Discrete (monthly/1 year/1 year/1 year/1 year/1 year)	YSI Professional plus	In field before grab sample collection
pH	1	Continuous (15 mins/1 year)	YSI 6920 V2-2 Sonde	In field
pH	6	Discrete (monthly/1 year)	YSI Professional plus	In field before grab sample collection
Dissolved oxygen	1	Continuous (15 mins/1 year)	YSI 6920 V2-2 Sonde	In field
Dissolved oxygen	6	Discrete (monthly/1 year)	YSI Professional plus	In field before grab sample collection
Turbidity	6	Continuous (15 mins/1 year)	YSI 6920 V2-2 Sonde (one) and YSI 600OMS V2 Sondes (five)	In field
SSC	6	Passive sampler	ASTM D3977-80 (evaporation)	In lab
$cBOD_5$	6	Discrete (monthly/1 year)	Hach LBOD and Hach Incubator	In lab
Nutrients (ammonia, nitrate + nitrite, phosphate, total phosphorus)	6	Discrete (monthly)	FIAlab 2500 Flow Injection analyzer and AIM block digester	In lab
E. coli	6	Discrete (5 grab samples in 30 days during May/June and monthly thereafter –1-year duration)	Microbac Analytical Laboratories, Lexington	In lab

Figure 3.2 Passive sediment samplers were used to collect suspended sediment during flood events.

YSI 600 OMS sondes were installed at BR1, BR2, BR3, BL2, and CLI sites. At BL1, a YSI 6920 V2-2 sonde, which has additional dissolved oxygen and pH sensors (compared with YSI 600 OMS), was installed. At all sites, the sondes were positioned to record measurements in areas of flow that were well mixed, typically immediately downstream of a riffle. In the summer and fall, some of the sondes were repositioned into deeper sections of a pool to ensure that sensors were continuously submerged. The field water quality data collection sensor types, accuracy, precision and other relevant details can be found in Section A.7 of the KDOW-approved QAPP (see Appendices A and B). Sampling events were scheduled to collect grab samples from both baseflow and stormflow. Rather than use an arbitrary precipitation threshold to separate dry and wet weather events, the stage data were used to differentiate between baseflow and stormflow. Passive sediment samplers were installed to collected suspended sediment during flood events. These samplers have been shown to effectively trap sediment that is statistically representative of the ambient sediment load (Phillips et al. 2000), and they have been used successfully in other Kentucky streams (Fox et al. 2010). These samplers were attached to bankline trees that were leaning into the streamflow (Fig. 3.2).

During each sampling event, the reach was photo-documented with synchronized photos and GPS readings. Any changes in channel configuration (e.g., bank erosion or bar deposition) were recorded. The flow status over riffles was recorded.

Habitat assessments were conducted at each monitoring reach following the protocols in USEPA's Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers (Barbour et al. 1999). Each habitat assessment was conducted in a reach at least 500 ft in length but not exceeding 800 ft. All habitat assessments were conducted by the same operator to minimize operator variance. The habitat evaluation consists of ten parameters rated on a numerical scale from 0–20:

1. Epifaunal substrate/ available cover
2. Embeddedness
3. Velocity/depth regime
4. Sediment deposition
5. Channel flow status
6. Channel alteration
7. Frequency of riffles
8. Bank stability (left and right banks scored separately on a 0–10 scale)
9. Vegetative protection (left and right banks scored separately on a 0–10 scale)
10. Riparian vegetative zone width (left and right banks scored separately on a 0–10 scale)

The scores for each parameter are then summed to provide an overall score, which is also assigned to a rating category (poor, fair, or good).

Laboratory Analysis

Nutrient analyses (Table 3.6) were performed using a flow injection analyzer (FIAlab 2500) at the University of Louisville Stream Institute's laboratory. *E. coli* analysis was performed by Microbac laboratories in Lexington, Kentucky. Method specifications such as accuracy and precision are presented in tables A9, A10, and A11 of the KDOW-approved QAPP (Appendix A).

Table 3.6 Nutrient Laboratory Methods

Parameter	Method
Nitrite (NO_2)	EPA Method 353.2
Nitrite + nitrate (NO_3+NO_2-N)	EPA Method 353.2
Ammonia (NH_4)	EPA Method 350.1
Total Kjeldahl nitrogen (TKN)	EPA Method 351.2
Orthophosphate (PO_4-P)	EPA Method 365.1
Total phosphorus (TP)	EPA Method 365.4
E. coli	Colilert Quanti-Tray-2000
$cBOD_5$	Hach Method 10360 (EPA accepted method, adapted from SM 5210 B)

To estimate a relationship between turbidity and suspended sediment concentration (SSC) for sediment load calculations, an experimental setup was used in place of a cost-prohibitive field sampling program (see Lewis et al. 2007 for further details). Sediment-water samples collected during floods were progressively diluted to adjust the suspended sediment concentration, and turbidity was continuously measured using the same YSI sensor used for field turbidity measurements. All measurements were made in a clean bucket with a YSI 600OMS sonde with turbidity sensor connected to laptop running EcoWatch software. A variable speed drill with paint stirrer was also in the bucket. The bucket was calibrated such that the volume could be calculated from the depth. Experience showed that as long as the stirrer did not produce breaking surface waves, then it did not affect turbidity. Likewise, the position of the stirrer in the bucket was investigated and shown to not be an influence on turbidity measurements.

Samples were emptied into the bucket through a 1 mm sieve to remove larger particles (typically leaf fragments), and the initial depth was recorded. The paint stirrer was set on the highest setting that did not produce breaking surface waves, and then turbidity was recorded. An initial 20-second period was found to be sufficient for the reading to stabilize. Readings were taken at 0.5 Hz. Readings were continued for at least another 90 seconds, and then 500 mL of deionized water was added to reduce the concentration. If necessary, the speed of the paint stirrer was increased. This was continued until the water surface was approaching the top of the bucket, which put the sample at risk of being lost. At this time, the sample was split using a USGS cone splitter. The sample was split into three subsamples, representing 10%, 40%, and 50% of the original sediment mass. Each subsample was then emptied back into a cleaned bucket, and the procedure was repeated.

Once sufficient dilutions had been performed to ensure a wide range of turbidity and suspended sediment concentration values, the remaining water-sediment was allowed to settle, the supernatant (clear water above the sediment) was removed, and the remaining mixture was analyzed for SSC using ASTM D3977-80 (evaporation). The SSC for each dilution was then calculated.

3.2.2 Phase 2 Monitoring

Parameter and Site Selection

Parameters selected for further investigation were those determined through Phase 1 assessment and project partner experience to be exceeding benchmark concentrations or to be otherwise impairing the designated uses in Brushy Creek (either WAH or PCR). The selection process was conducted in conjunction with personnel from KDOW’s Watershed Management and Water Quality branches and PCCD. The subwatersheds selected were those in which the parameter concentrations were observed or where the designated use appeared to be most impaired. Siltation was assessed in the Lower and Upper Bee Lick subwatersheds, dissolved oxygen throughout the Brushy Creek HUC10 watershed, and nutrients within Upper Bee Lick and Upper Brushy Creek subwatersheds (Figs. 3.3−3.5). These sites were selected as provisional based on accessibility by road and drainage area greater than 1 mi^2. Final site selection was made during the field visits and was based on the presence of a specific problem (riffle embeddedness) or exceedance of a water quality threshold (DO <5 mg/L).

Field Data Collection Methods

Habitat

At each site, a habitat assessment was conducted in a reach between 500 and 800 ft in length. The assessment followed the same standard protocol as in Phase 1 (Barbour et al. 1999). Each reach was photodocumented (see Appendix I) with particular focus on the riffle substrate and potential sediment sources such as eroding stream banks. The presence or absence of cattle in the creek was also noted. At any site where widespread embeddedness was noted, a detailed evaluation of sediment sources and loads was initially planned to be conducted, but this proved to be unnecessary because macroinvebrate sampling showed that the embeddedness was not impairing the aquatic life (see Section 4.3.1).

Dissolved Oxygen

The YSI 6920 V2-2 sonde at BL1 was deployed in late summer and utilized through fall of 2013 to provide online measurements of dissolved oxygen. The data were monitored to identify periods when DO was approaching surface water standards. Prolonged low DO was then the criterion for additional field sampling at the sites identified in Fig. 3.4. A cellular modem enabled the data to be viewed online within one hour after they were collected. The online DO data were monitored to identify a decline in DO values to the point where additional sampling would be conducted to determine the spatial extent of the low dissolved oxygen. The additional DO sampling was completed using the same handheld instrument as in Phase 1.

Nutrients and E. coli Sampling

Samples were collected May 6, 2013, following a period of rainfall, in order to capture runoff samples. Grab samples were collected one time at each site for nutrient parameters (Fig. 3.5). In addition, *E. coli* samples were collected because the additional sample analysis cost was small relative to the cost of travel and personnel.

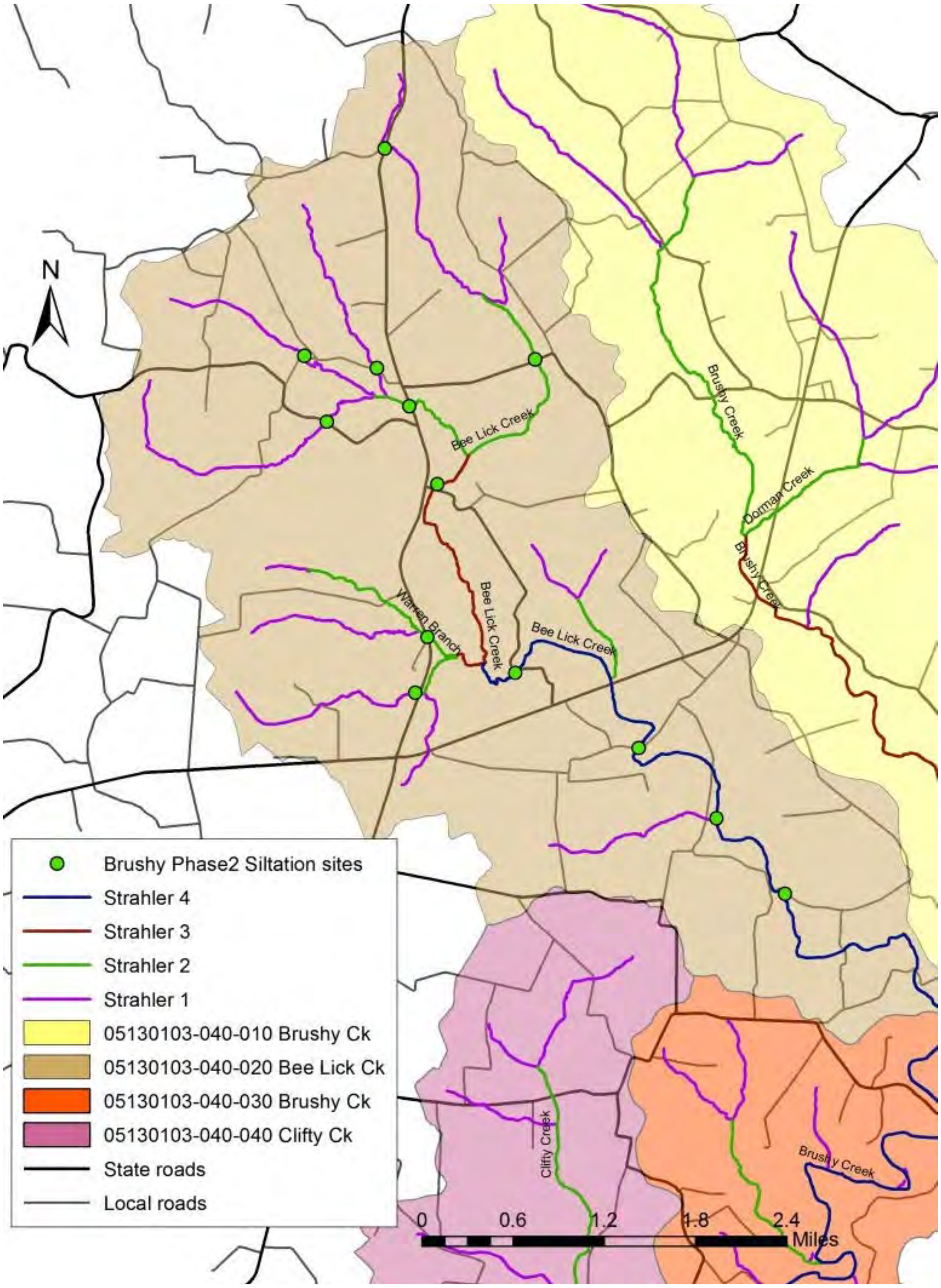


Figure 3.3 Sites selected for sedimentation sampling.

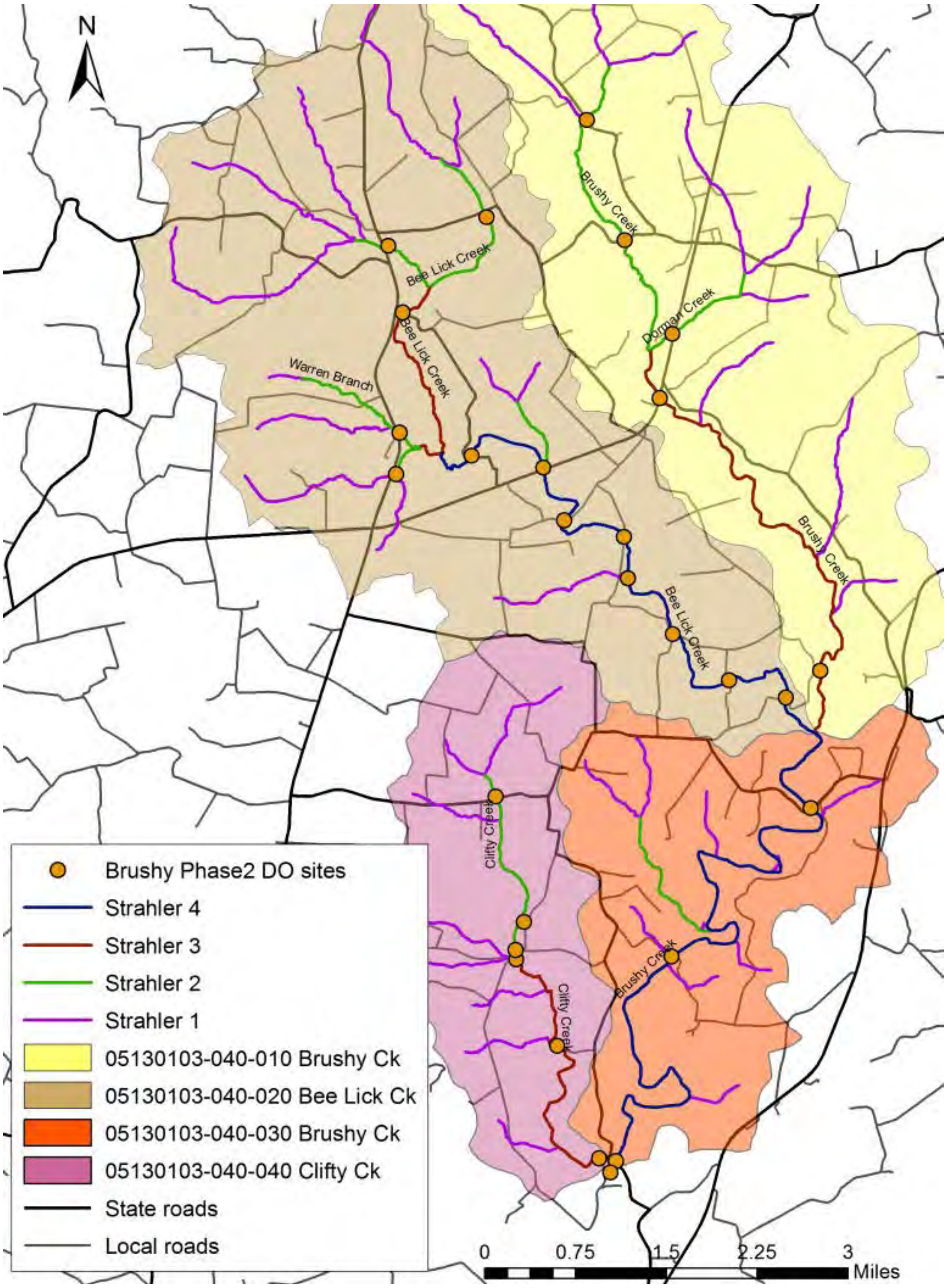


Figure 3.4 Sites selected for dissolved oxygen sampling.

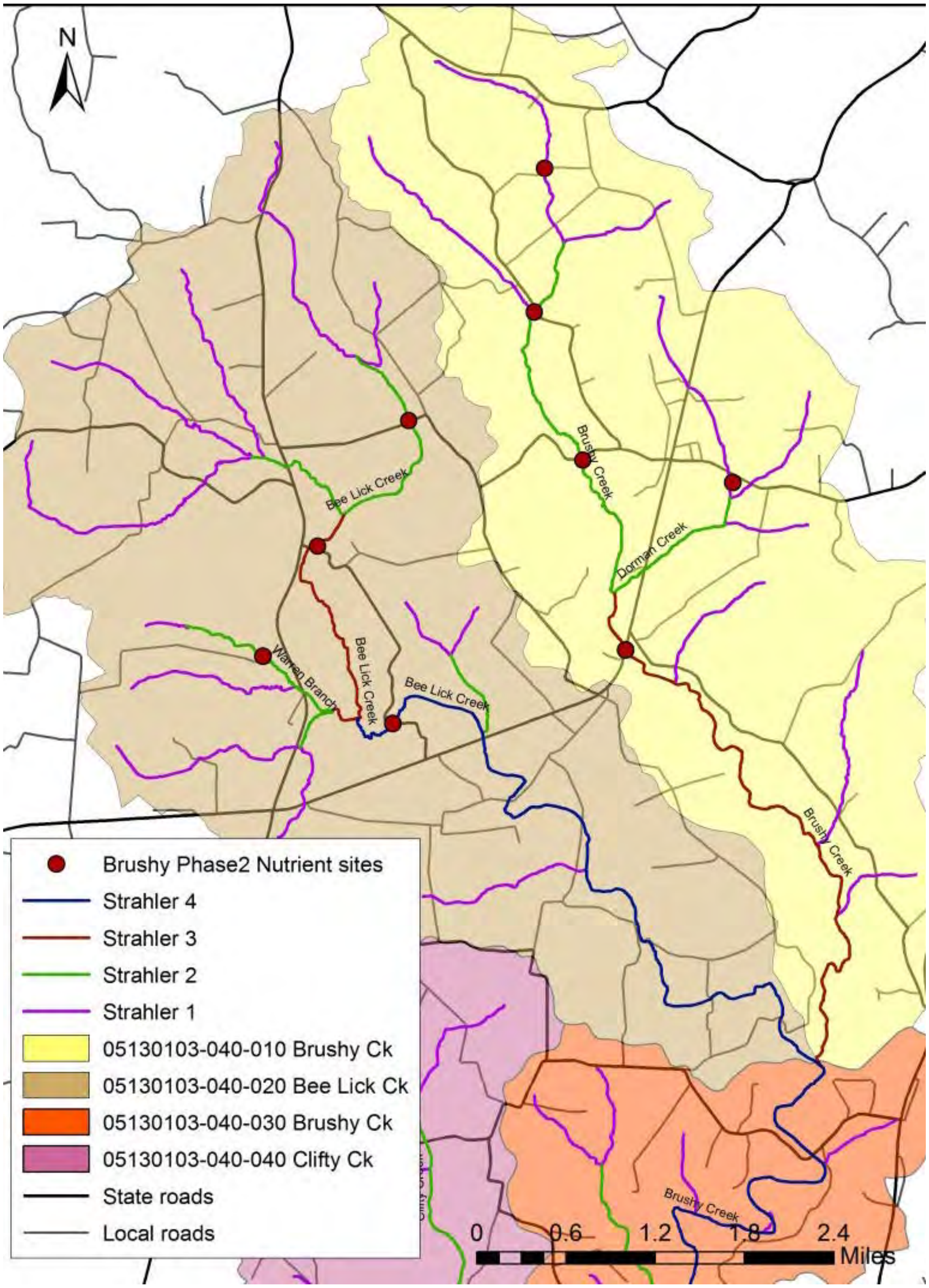


Figure 3.5 Sites selected for nutrient and *E. coli* sampling.

Data Analysis

Stage–Discharge Measurements

A stage-discharge rating curve was developed for each site through regression of stage and discharge measurements from both a continuous recording Argonaut (stage above 0.75 ft) and wading measurements using a FlowTracker (Appendix C). Separate power function relations were developed to represent flow in different depth ranges using non-linear regression.

Load Duration Curves

Flow duration curves serve as the foundation for the development of load duration curves. Flow duration curves for all the subwatersheds were developed as described by Searcy (1959). Flows computed from the stage-discharge rating curve and the stage measurements were used to compute the flow duration curve. A flow duration curve is a plot of flow on the y-axis and percent of time that particular flow was equaled or exceeded on x-axis. To prepare a flow duration curve, all the flows during a given period are sorted from highest to lowest and then the percent of time during which the flow equaled or exceeded the specified values is computed.

A load duration curve (LDC) is a graph representing the percentage of time during which the load of a particular parameter value is equaled or exceeded. A benchmark load duration curve is developed by multiplying the flow duration curve and the KDOW numeric benchmark recommendation. Ambient water quality data and the corresponding flow data can be used to compute the instantaneous load. Using the relative percent exceedance from the flow duration curve that corresponds to stream discharge at the time the water quality sample is taken, the computed load can be plotted in a duration curve format (USEPA 2007).

Annual Nutrient Load Estimations

Pollutant loads are important in watershed planning because they allow a more balanced comparison of the subwatersheds. For Brushy Creek watershed, annual loads for nutrients and *E. coli* were estimated using the following equation:

Annual load = (Mean concentration)(annual volume of flow)(conversion factor)

A few researchers (e.g., Stubblefield et al. 2007; Rasmussen et al. 2008) have used regression methods to estimate nutrient loads if a strong correlation existed with continuously monitored field parameters (stage and turbidity) or time or season. The Brushy Creek nutrients parameter data did not show significant correlation with any continuously measured parameters, so regression methods were not applicable to Brushy watershed load estimations.

In addition to annual nutrient loads estimated at each subwatershed sampling point, loads were also estimated for the watersheds between the monitoring stations. For example, the annual load contributed by the Middle Brushy subwatershed, $\text{Load}_{\text{MID BR}}$ (lbs/yr), was estimated by using the following equation:

$$\text{Load}_{\text{MID BR}} = \text{Load}_{\text{BR2}} - \text{Load}_{\text{BR3}}$$

where Load_{BR2} and Load_{BR3} are the loads measured at BR2 and BR3, respectively. Annual yields were also computed by dividing annual loads by watershed area. Annual allowable benchmark loads were calculated using KDOW benchmark recommendations for the Brushy watershed. In cases where the annual nutrient load exceeded the KDOW benchmark recommendation, the percent load reduction required was calculated using the following equation:

$$Percent\ reduction\ required = \frac{(annual\ load - annual\ benchmark\ load)}{annual\ load}\ X\ 100$$

Sediment Loads

To generate the SSC–turbidity relationship, the outputs from the bucket tests (time and turbidity in NTU) were entered into an Excel spreadsheet and plotted (Fig. 3.6). The times of the dilutions also were entered. Periods of 40 to 80 readings (20 to 40 seconds) were identified for each dilution. Spikes in the dataset representing more than 10 NTU between subsequent readings were removed.

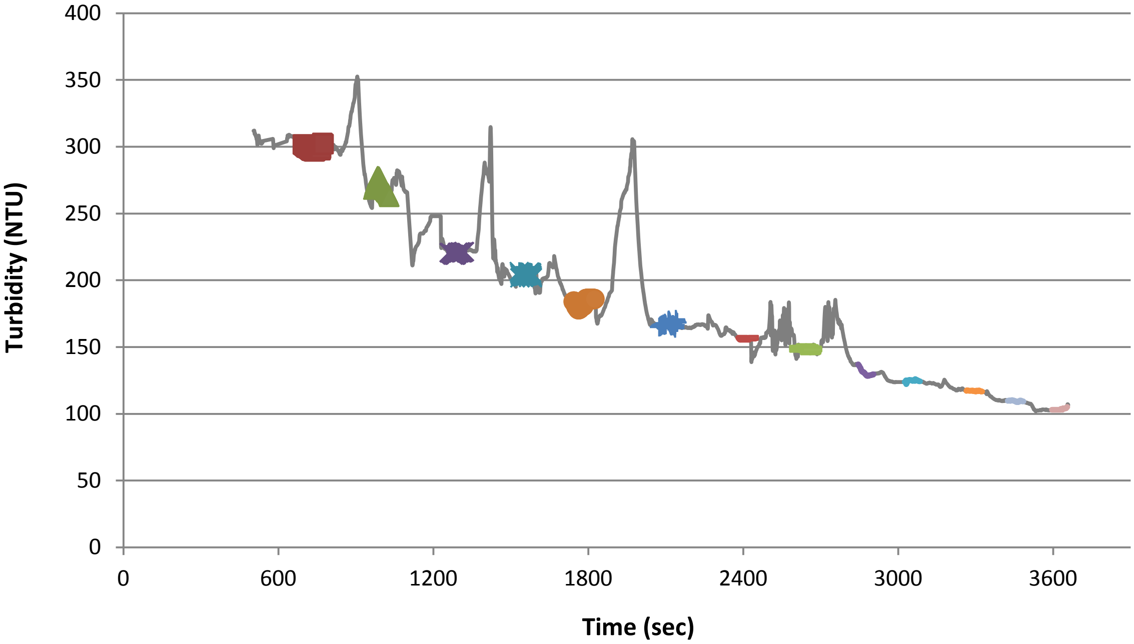


Figure 3.6 Bucket test outputs (time and turbidity).

The average turbidity for each stable period was plotted against the volume of the sample at that time. An SSC-turbidity relationship was developed by ordinary least squares regression between the SSC from water samples and the turbidity readings recorded during the same time intervals (Fig. 3.7). This relationship was then applied to all turbidity readings to estimate SSC for each reading. Each SSC reading was multiplied by a conversion factor to convert from mg/L to lb/ft^3.

For each discharge measurement, the total flow volume (ft^3) for each 10-minute period was calculated. The SSC (lb/ft^3) was then multiplied by the volume of flow (ft^3) for each measurement interval to give the sediment load (lb) for each 10-minute period. All sediment transport in each time interval was summed over the duration of the sampling period (May 2011 to May 2012) to calculate total annual load (lb/yr).

4 Analysis

4.1 Phase 1 Analysis

Phase 1 data were analyzed and were evaluated along with previously existing data to identify priorities for collection of Phase 2 data.

4.1.1 Habitat

Only the reach at BR1 was rated as good in the RBP assessment; the reaches at all other sites had specific issues that are considered to be detrimental to aquatic life (Table 4.1 and Fig. 4.1). The epifaunal substrate was generally better in the larger drainage areas than in the smaller sites; BR1 and BR2 were the only reaches where stable wood was providing instream habitat. The riffles at all sites but BL2 were generally clean and not embedded, not just during the time of the RBP assessment but at all site visits throughout the year. Algal growth on the riffles was generally negligible, except at BR3 near the bridge where the bedrock had limited shading and filamentous algae was present throughout the monitoring period. Riffles at BR3 that had good shade had far less abundant algae. A good cover of diatoms was typically observed at all sites. Channel alteration at all sites was generally limited to the presence of a bridge, localized movement of gravel by heavy machinery or by placement of riprap. Signs of recent straightening or realignment of the channel were not observed, although most of the reaches are likely to have been straightened in the past. Most of the reaches had a high frequency of riffles with the exception of BR3, which was scoured to bedrock and had few riffles.

Table 4.1 Results from RBP Assessment of Physical Habitat (see Appendix D for field data forms)

	RBP Parameter	BR1	BR2	BR3	BL1	BL2	CLI
1	Epifaunal substrate/available cover	18	16	8	14	9	12
2	Embeddedness	17	16	18	16	6	12
3	Velocity/depth regime	19	18	6	16	11	15
4	Sediment deposition	12	15	15	14	7	8
5	Channel flow status	16	18	17	15	15	10
6	Channel alteration	15	15	11	18	11	13
7	Frequency of riffles	19	16	10	18	15	18
8	Bank stability (L)	6	7	6	4	5	3
	Bank stability (R)	8	6	9	7	5	8
9	Vegetative protection (L)	9	5	6	5	4	5
	Vegetative protection (R)	5	5	9	7	4	8
10	Riparian vegetative zone width (L)	9	3	3	4	2	5
	Riparian vegetative zone width (R)	2	2	9	4	2	9
	Total	**155**	**142**	**127**	**142**	**96**	**126**
	Habitat rating	Good	Fair	Poor	Fair	Poor	Poor

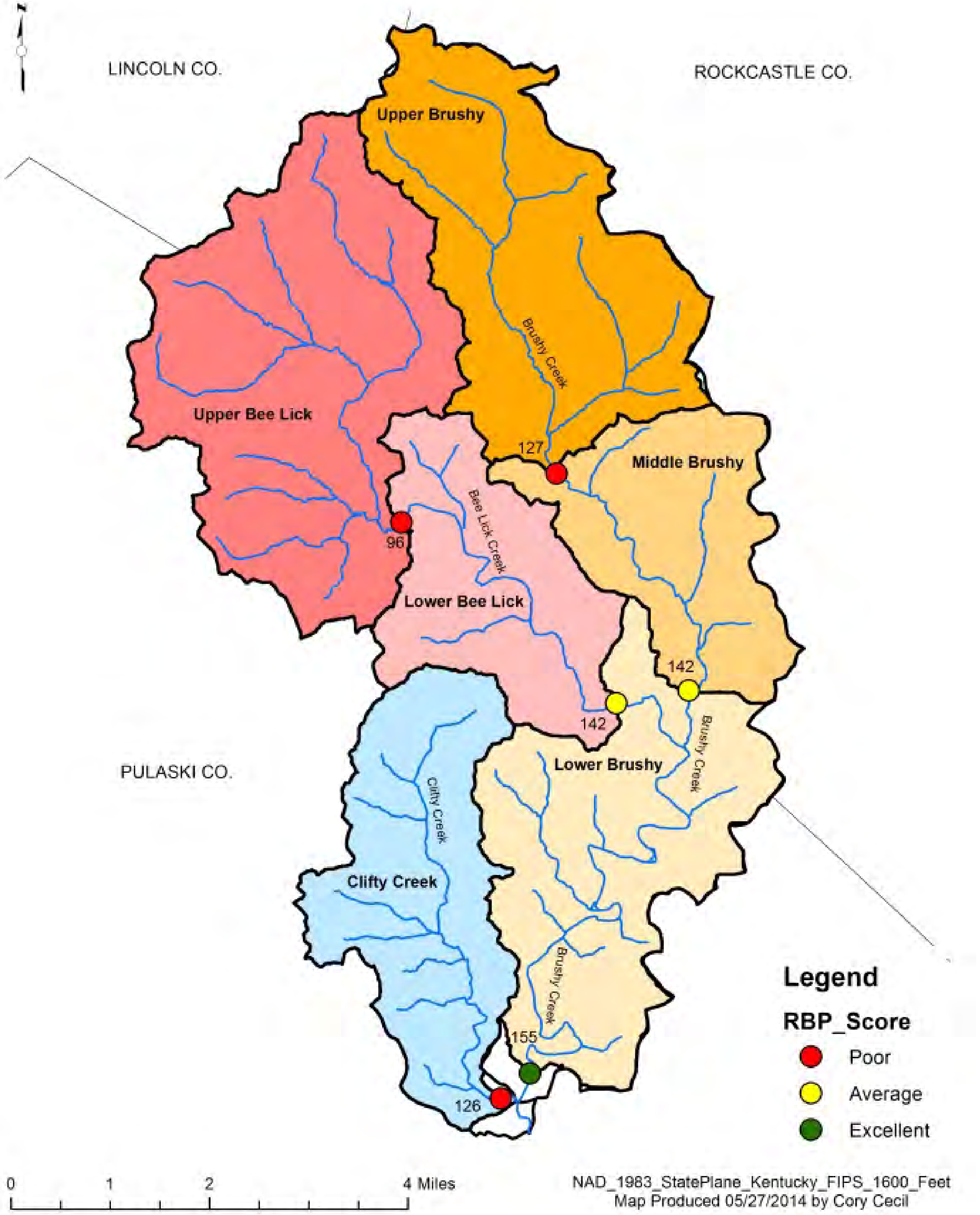


Figure 4.1 Phase 1 reach-scale RBP scores and ratings.

The most common cause of habitat impairment was incision and entrenchment of the channel. Although these parameters are not measured directly in the RBP, they are reflected in the stability of epifaunal substrate, the velocity/depth regime, the frequency of riffles, and the stability of banks. At BR3, the incision of the channel was to bedrock with very infrequent pools and few riffles. Local sediment supply of gravel/cobble at CLI and sand at BL2 was sufficient that the stream had not scoured to bedrock. The majority of riffles at CLI, however, were mobilized to some degree during the Phase 1 assessment, and the reach at BR2 was buried in sand. Both frequent mobilization of the bed and burial by sand could be expected to impair benthic macroinvertebrates (Allan and Castillo 2007). The embeddedness of riffles at BR2 was clearly related to local supply of sediment, so it was identified for Phase 2 investigation.

The riparian vegetation at all sites was limited on one or both stream banks. Farming of the valley bottom for hay was the most common cause of lack of vegetation. None of the valley bottoms of the Phase 1 reaches had row crop agriculture (but see Phase 2 results). Herbicide spraying of streambank vegetation at Clifty (about 500 ft upstream of CLI sampling site) was observed and was clearly impeding the establishment of stabilizing vegetation (Fig. 4.2).

Figure 4.2 Application of herbicide has impeded the re-establishment of riparian vegetation at CLI, a downstream reach of Clifty Creek.

4.1.2 Water Quality (WQ)

The water quality sampling results from each site were compared against Kentucky surface water standards, against aquatic life benchmarks developed for this project by KDOW, and against one another to assess the relative concentrations and loads within the watershed.

Standards and Benchmarks

Kentucky established water quality standards that consist of water quality criteria necessary for the surface waters of the Commonwealth to support their designated uses (Table 4.2). Nutrient benchmark recommendations (Table 4.3) represent the best information available to Kentucky Division of Water at the time of this project. The goal was to provide estimates of how high in-stream nutrient concentrations could be without causing aquatic life impairments. In making these recommendations, KDOW considered regional and watershed-specific nutrient expectations, regional-scale patterns in biological effects, and relevant published literature.

Benchmark recommendations for non-nutrient parameters were intended by KDOW to be estimates of typical in-stream values in the region for streams with relatively low levels of impacts (Table 4.4). Values above these benchmarks (or, in the case of alkalinity, above or below) are not necessarily cause for concern. A pattern of higher numbers (higher or lower for alkalinity), however, may help to identify potential stressors or unusual conditions in the watershed.

WQ1: General Physico-Chemical Parameters

Temperature met the criterion of being below 31.7 °C at all sites for all sampling events, and pH was within the surface water standard range of 6.0 to 9.0 pH units for all sampling events at all sites. The DO met the surface water criterion of greater than 5.0 mg/L for OSRWs during sampling events at BR1 (1 sample), BR2 (4 samples), BL2 (5 samples), and CLI (6 samples). All BR3 and BL1 DO samples met the surface water standard. The specific conductance aquatic life benchmark of 318 µS/cm was exceeded twice at both BR1 and BL1 (Table 4.5).

Continuous measurements from the sondes showed a more complete view of water quality. Of all the general water quality parameters measured, dissolved oxygen was the single cause for concern: continuous measurements at BL1 showed concentrations well below the acute (5.0 mg/L instantaneous, as stated above) and chronic (6.0 mg/L daily average) surface water standards for Exceptional Waters during the fall of 2011 (Fig. 4.3). Discrete measurements at all sites suggested this period of low dissolved oxygen may have been even more severe at other sites than at the BL1 reach. We suspect that concentrations may have been even lower at BL2 and CLI, but we did not have continuous DO data at those sites. At BL1, the DO was less than 4 mg/L for nearly 16 days in total and less than 3 mg/L for 6.5 days. The longest consecutive period that the DO was below 3 and 4 mg/L was 2.5 and 4.4 days, respectively. Although rainfall in August 2011 was 25−50% of the average monthly amount for August based on data from 1971-2000 (MRCC 2011), regional estimates of the Palmer Drought Severity Index (PDSI) produced by the National Weather Service (NWS 2011) were near normal, indicating that Brushy Creek had not experienced moderate or severe drought conditions for the months preceding August.

Low dissolved oxygen concentrations are sometimes attributed to high levels of nutrients, but this was not the case at BL1. The continuous DO data clearly show that the diurnal fluctuations in DO were muted, whereas in high nutrient systems these daily fluctuations are very large due to photosynthesis during the day and respiration at night (Fig. 4.3). Field visits to the site clearly showed no extensive algal community; the DO was due to a lack of flow and associated lack of mixing (aeration). Most of the algae and diatoms had died, perhaps due to lack of nutrients as the small amount of flow in the channel was from nutrient-poor groundwater.

Table 4.2 Specific Water Quality Standards as Specified by 401 KAR 10:031

Parameter	Acute Criteria	Chronic Criteria
Temperature (°C)	≤31.7	N/A
pH (pH units)	≥ 6.0 and ≤ 9.0 and does not fluctuate by more than 1 pH unit in 24 hours	N/A
Dissolved oxygen (mg/L)	≥ 4.0 instantaneous ≥ 5.0 instantaneous (OSRW)	≥ 5.0 daily avg. ≥ 6.0 daily avg. (OSRW)
Un-ionized ammonia (mg/L)	≤ 0.05	N/A
E. coli (colonies/100 mL) for primary contact recreational (PCR) waters	***May 1–Oct 31***: (a) Geometric mean based on at least 5 samples, collected within 30-day period, shall be less than or equal to 130; and (b) Content shall not exceed 240 colonies/100mL in 20% or more of the samples during 30-day period ***Nov 1–Apr 30***: N/A	
Fecal coliform (colonies/100 mL) for primary contact recreational (PCR) waters	***May 1–Oct 31***: (a) Geometric mean based on at least 5 samples, collected within 30-day period, shall be less than or equal to 200; and (b) Content shall not exceed 400 colonies/100mL in 20% or more of the samples during 30-day period	
Fecal coliform (colonies/100 mL) for secondary contact recreational (SCR) waters	***Whole year***: Fecal coliform content shall not exceed 1000 colonies per 100 mL as a 30-day geometric mean based on at least 5 samples; nor exceed 2000 colonies per 100 mL in 20% or more of all samples taken during 30-day period	

Table 4.3 Nutrient Benchmarks

Parameter	Recommended Benchmark (mg/L)
Total P	0.03
TKN	0.5
Nitrate+Nitrite-N	0.9
Total N	1.3

Table 4.4 Non-Nutrient Benchmarks

Parameter	Recommended Benchmark
Ammonia-N	0.05 mg/L
Sulfate	18.0 mg/L
Specific conductance	318 µS/cm
Alkalinity (as $CaCO_3$)	107–142 mg/L
TSS	8.5* mg/L
Turbidity	3.0* NTU

* For TSS and turbidity, use the screening numbers only to compare base level April–October flow conditions and not high-flow periods or winter samples. The reference stream data came exclusively from biology sampling visits, which are conducted only during stable flow conditions during these months.

Table 4.5 Summary of Phase 1 Physico-Chemical Parameter Results Based on Grab Samples (see Appendix E)

Parameter		BR1	BR2	BR 3	BL 1	BL 2	CLI
Temperature (^{o}C)	Mean	16.7	16.0	17.6	15.7	16.6	16.0
	Median	17.5	15.8	17.9	15.4	17.1	17.3
	Min	4.3	3.9	5.6	3.4	4.8	5.0
	Max	25.5	26.1	27.6	26.6	26.8	23.3
pH (pH units)	Mean	7.79	7.67	7.95	7.67	7.52	7.54
	Median	7.80	7.68	7.99	7.68	7.51	7.52
	Min	7.10	6.89	7.02	6.89	6.76	6.93
	Max	8.52	8.30	8.71	8.15	8.01	8.39
	Percentage of days exceeding surface water standard	0	0	0	0	0	0
Dissolved oxygen (mg/L)	Mean	9.07	8.66	10.15	9.09	8.34	8.44
	Median	8.64	8.92	9.84	8.92	8.55	8.12
	Min	5.57	5.40	6.18	6.55	3.68	4.22
	Max	13.48	13.74	13.67	13.59	13.47	13.60
	Percentage measurements exceeding instantaneous surface water standard	3	13	0	0	17	21
Specific conductance (µS/cm)	Mean	234.4	253.0	231.9	218.5	206.9	202.8
	Median	233.0	266.3	245.8	228.1	223.0	221.3
	Min	94.7	224.5	178.2	197.3	195.2	123.7
	Max	338.4	291.1	287.6	483.1	253.6	264.1
	Percentage of days exceeding KDOW daily average benchmark	7	0	0	7	0	0

Continuous measurements of specific conductance at all sites showed no “first flush” pollution that would have been indicated by a rapid rise following rainfall. Generally, flood events at all sites showed a dilution due to rainfall. This was consistent with the minimally developed land use of Brushy Creek watershed. Common sources of conductivity from industrial sources or past mining are not present, and relatively little road salt is used in winter months.

Based on the water quality monitoring for general physico-chemical parameters, the impairment of aquatic life in Brushy Creek by conductivity, pH, or temperature was of little concern. Data regarding the influence of dissolved oxygen were mixed: monthly sampling did not reveal any exceedances of the surface water standards, but continuous data from one site (BL1) showed that the DO was very low during low flow conditions in late summer.

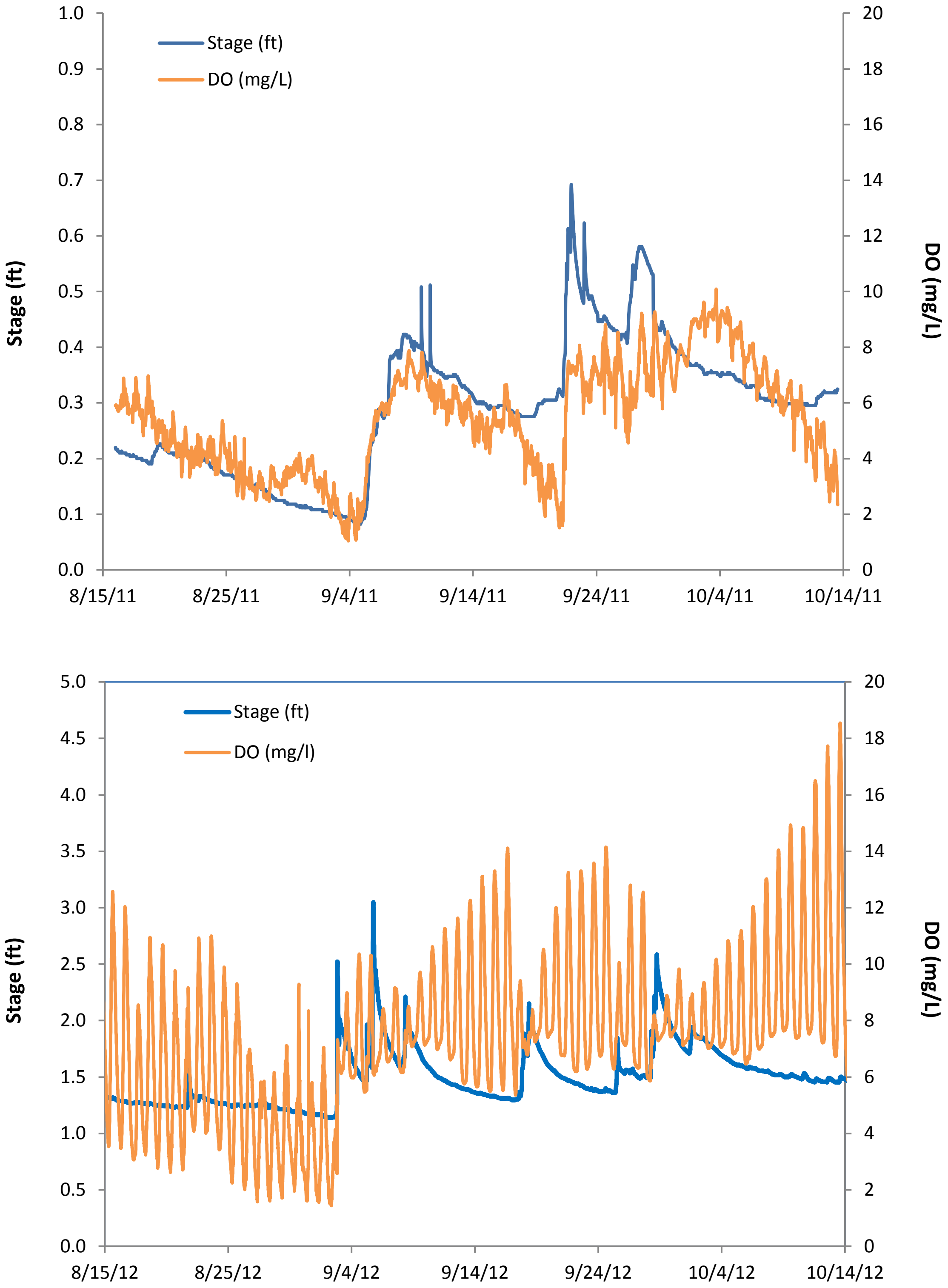


Figure 4.3 Comparison of daily DO fluctuations in a stream reach with relatively low nutrient concentrations (top graph) and relatively high nutrient concentrations (bottom graph). The top graph is from Bee Lick, where declining DO concentrations correspond to declining flow and poor mixing. The bottom graph is from Jessamine Creek in the Inner Bluegrass and shows very large daily swings in DO concentrations due to very high rates of primary production by algae.

WQ2: Nutrients

Nutrient Concentrations

Table 4.6 provides summary data for nutrients sampled throughout the year (see also Appendix F). Figs. 4.5−4.9 compare concentrations for the samples collected during baseflow with those collected during stormflow. Nitrate concentrations of nitrate + nitrite varied considerably at all sites (Table 4.6). Nitrate + nitrite showed a very strong seasonal trend with much higher concentrations during winter months than in the summer (Fig. 4.4). This seasonal variation was common to all sites, indicating that nitrogen uptake during plant growth and release during leaf die off in the fall were strong controls on nitrate dynamics in the Brushy Creek watershed. Generally, nitrogen uptake by plants is dependent on biomass, with uptake by trees typically much higher than uptake by grasses (Dosskey et al. 2010). Harvesting crops can also remove nitrogen from the watershed, but reduces organic matter content that is important for nutrient processing. Given the strong vegetative control on nitrate concentrations, subsurface denitrification is of secondary importance, and increasing groundwater denitrification might be a good strategy for reducing nutrient concentrations. The same seasonal trends found in Total Nitrogen (TN) concentrations reflected the nitrate component of TN. Concentrations of nitrate + nitrite and TN did not show significant differences between baseflow and stormflow events (Figs. 4.5 and 4.6); benchmark values were exceeded during both.

TKN measures the sum of ammonia and organic nitrogen in water. High measurements of TKN typically result from sewage and manure discharges to water bodies. Interpretation of the TKN data in this project was hampered by the relatively high reporting limits (i.e., the smallest concentration of TKN that laboratory analysis methods could accurately measure from a sample). Although the first sampling event was analyzed at a commercial laboratory and had a relatively low reporting limit (0.5 mg/L, which equals the benchmark), the remainder of the samples were analyzed at the ULSI laboratory. The majority of those sample concentrations were below ULSI's reporting limit of 1.0 mg/L. The information lost through the relatively high TKN reporting limit is limited, however, because cBOD, ammonia, and *E. coli* concentrations respond to the same sources as TKN.

The ammonia concentrations (Fig. 4.7) were consistent between sites, with baseflow concentrations slightly higher than stormflow concentrations. Depending on pH levels, un-ionized ammonia can be much more toxic to fish than the ionized form because it diffuses across fish gill membranes more readily. The proportion of un-ionized ammonia increases with pH. The pH readings at Brushy Creek watershed, however, were not high enough for un-ionized ammonia toxicity to be a concern for fish populations. The cBOD was also consistently low at all sample sites, which reflects the lack of wastewater treatment facilities or industry and the low residential density in the watershed.

Total phosphorus and orthophosphate concentrations (Figs. 4.8 and 4.9) were generally low. Few samples exceeded the aquatic life benchmarks, and the average values for all sites were only just above the benchmark value of 0.03 mg/L.

Table 4.6 **Summary Statistics from Monthly and Run-off Sampling of Nutrients (see Appendix F for sampling data)**

Parameter*		BR1	BR2	BR3	BL1	BL2	CLI
TN (1.3 mg/L)	Mean	1.71	1.80	1.69	1.84	1.87	1.43
	Median	1.77	1.86	1.84	2.18	1.79	1.35
	Min	0.51	0.51	0.52	0.51	0.51	0.55
	Max	2.90	2.85	3.07	3.34	3.57	2.83
	% Samples exceeding KDOW benchmark	69	77	69	69	69	54
NO_3+NO_2-N (0.9 mg/L)	Mean	1.11	1.20	1.18	1.26	1.32	0.90
	Median	1.16	1.06	1.34	1.68	1.29	0.85
	Min	0.01	0.01	0.02	0.01	0.01	0.05
	Max	2.50	2.40	2.60	2.70	3.10	2.40
	% Samples exceeding KDOW benchmark	60	67	60	53	60	47
TKN‡ (0.5 mg/L)	Mean	0.57	0.55	0.50	0.56	0.54	0.49
	Median	0.50	0.50	0.50	0.50	0.50	0.50
	Min	0.40	0.45	0.47	0.50	0.47	0.43
	Max	1.53	1.26	0.50	1.09	1.04	0.50
	% Samples exceeding KDOW benchmark	92	92	92	100	92	92
NH_3 - N (0.05 mg/L)	Mean	0.125	0.075	0.096	0.070	0.081	0.107
	Median	0.076	0.025	0.070	0.025	0.025	0.080
	Min	0.025	0.025	0.025	0.025	0.025	0.025
	Max	0.305	0.445	0.292	0.194	0.370	0.281
	% Samples exceeding KDOW benchmark	69	38	69	46	46	62
NH_3 (un-ionized) [0.05 mg/L]	Mean	0.0025	0.0007	0.0037	0.0008	0.0008	0.0014
	Median	0.0011	0.0004	0.0009	0.0005	0.0002	0.0007
	Min	0.0002	0.0002	0.0001	0.0002	0.0001	0.0001
	Max	0.0088	0.0030	0.0287	0.0030	0.0037	0.0066
	% Samples exceeding KDOW benchmark	0	0	0	0	0	0
TP (0.03 mg/L)	Mean	0.018	0.025	0.029	0.034	0.031	0.028
	Median	0.010	0.018	0.025	0.025	0.025	0.018
	Min	0.010	0.010	0.010	0.010	0.010	0.010
	Max	0.051	0.082	0.098	0.111	0.065	0.071
	% Samples exceeding KDOW benchmark	7	21	29	36	43	36
PO_4-P (mg/L) (N/A)	Mean	0.014	0.011	0.013	0.013	0.014	0.016
	Median	0.010	0.010	0.010	0.010	0.010	0.010
	Min	0.010	0.010	0.010	0.010	0.010	0.010
	Max	0.046	0.028	0.028	0.039	0.034	0.036
	% Samples exceeding KDOW benchmark	N/A					

Parameter*		BR1	BR2	BR3	BL1	BL2	CLI
cBOD$_5$ (mg/L) (N/A)	Mean	1.17	1.31	1.59	1.41	1.72	1.09
	Median	1.00	1.00	1.00	1.00	1.00	1.00
	Min	1.00	1.00	1.00	1.00	1.00	1.00
	Max	2.23	3.32	4.19	3.03	3.99	2.30
	% Samples exceeding KDOW benchmark	N/A					

* KDOW benchmarks are shown in parentheses (0.05 mg/L). Surface water standards are in brackets [0.05 mg/L].

‡ Since the reporting limit (1.0 mg/L) was greater than the benchmark (0.5 mg/L), non-detects were reported as the benchmark as a conservative measure.

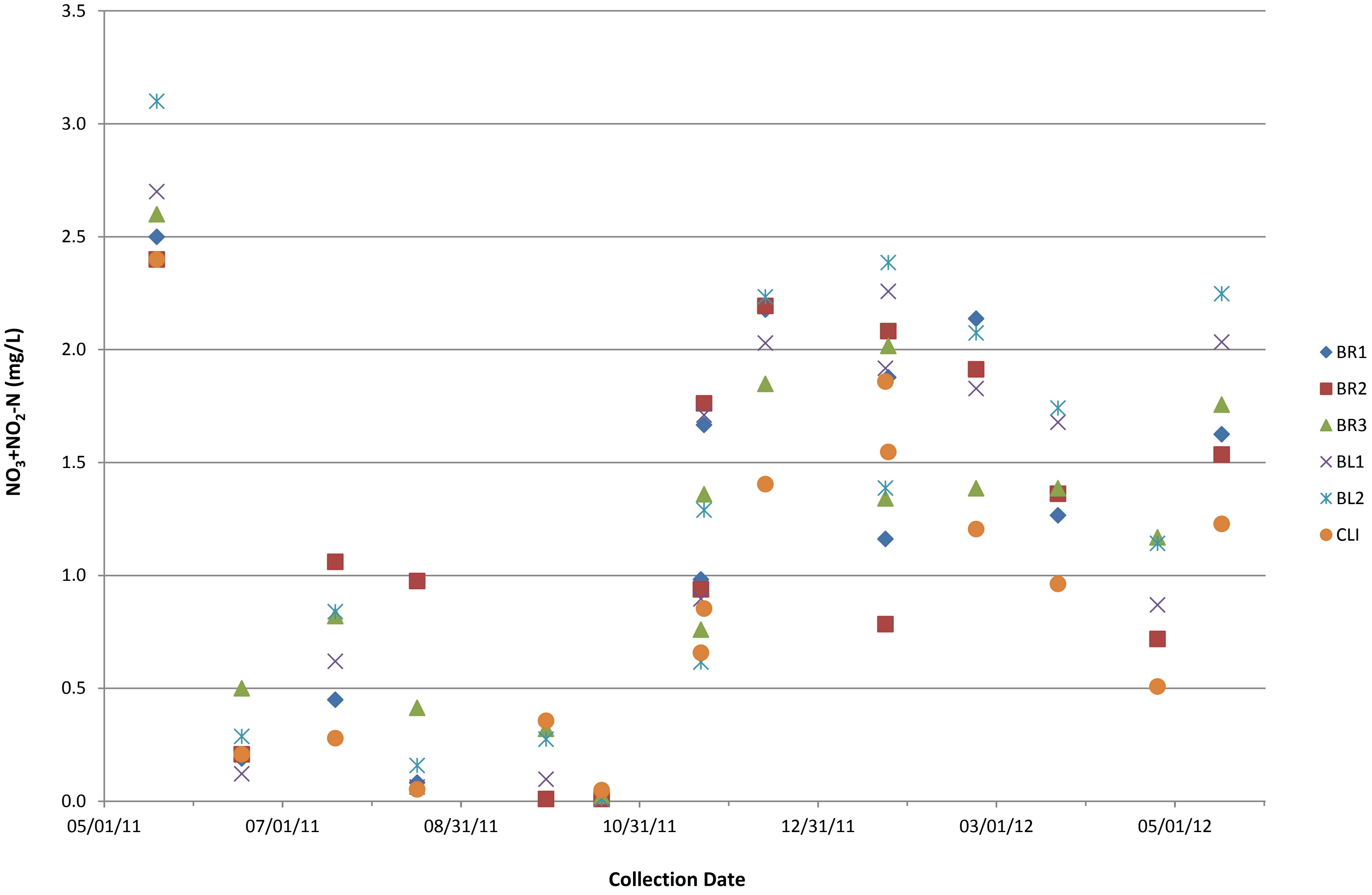


Figure 4.4 Seasonal variations in nitrate + nitrite concentrations related to vegetative cover.

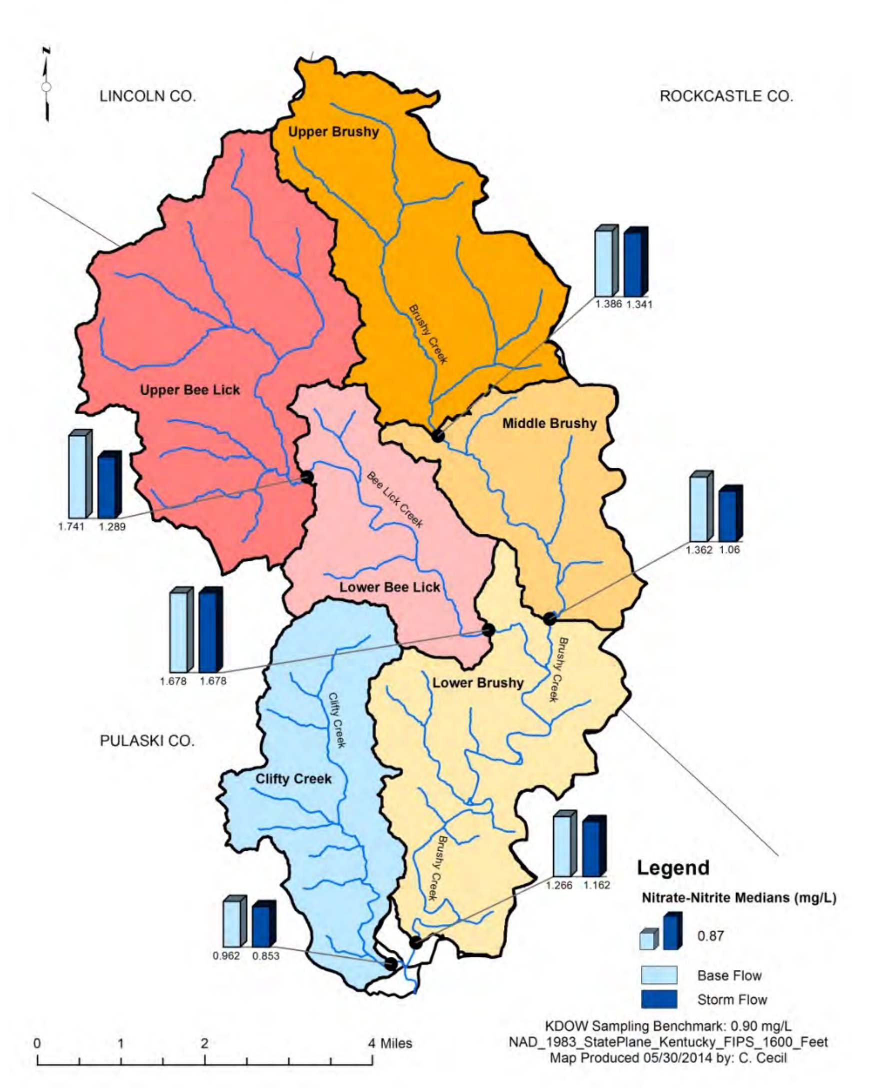


Figure 4.5 Median nitrate + nitrite concentrations for samples collected during storm flow and base flow.

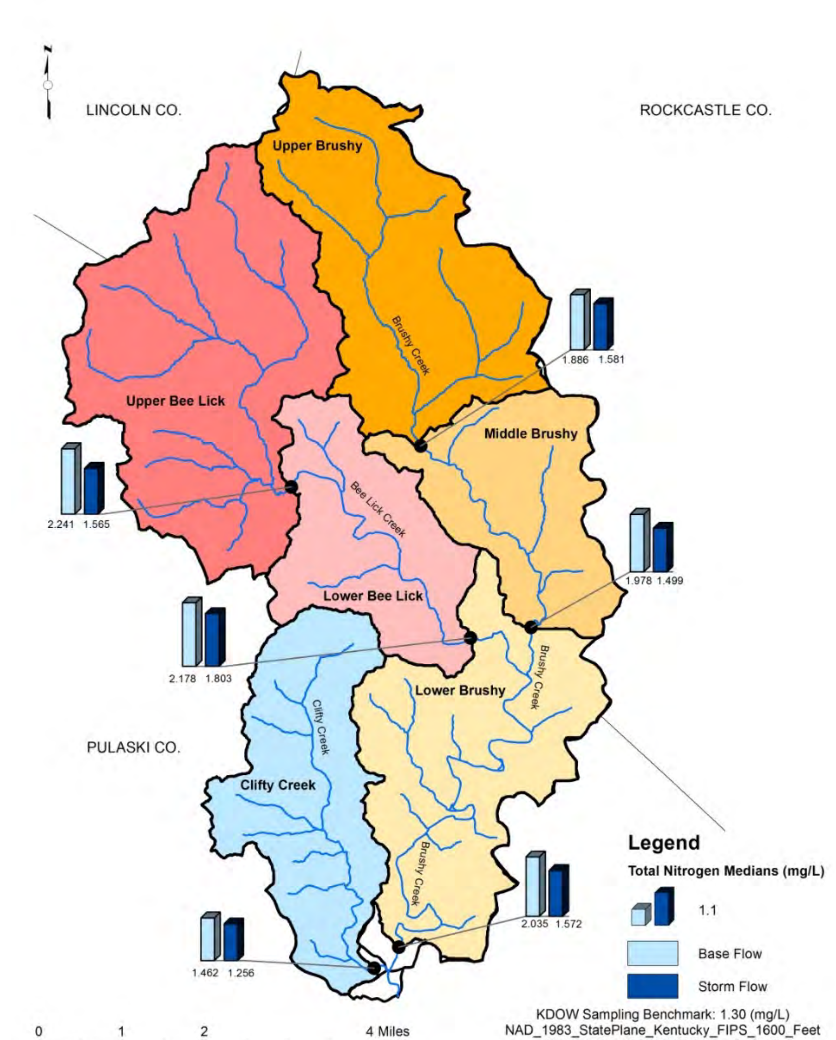


Figure 4.6 Median total nitrogen concentrations for samples collected during storm flow and base flow.

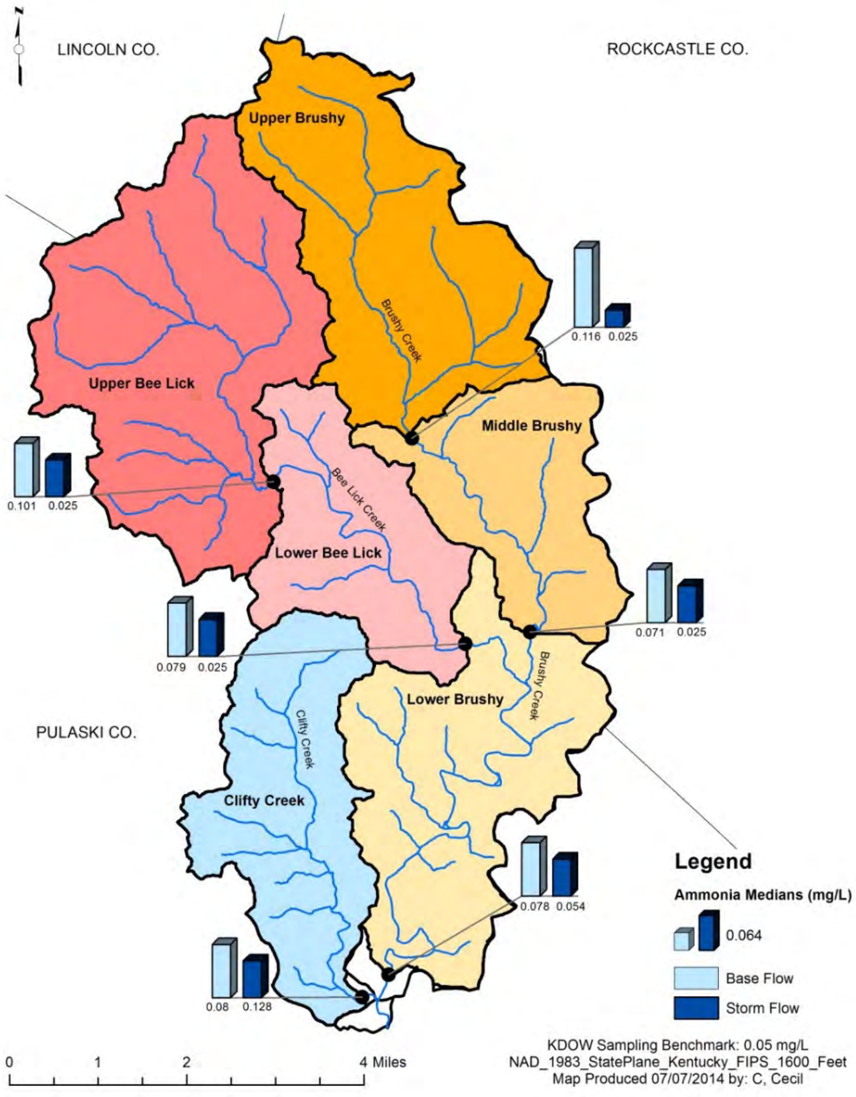


Figure 4.7 Median ammonia concentrations for samples collected during storm flow and base flow.

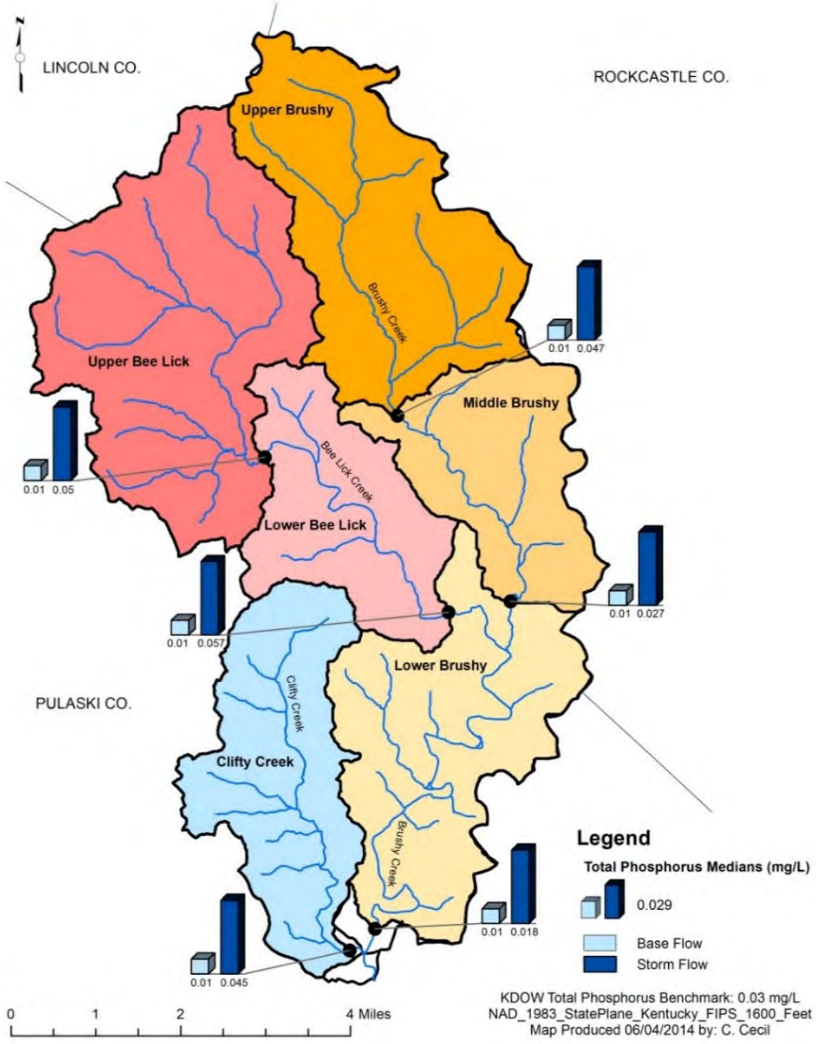
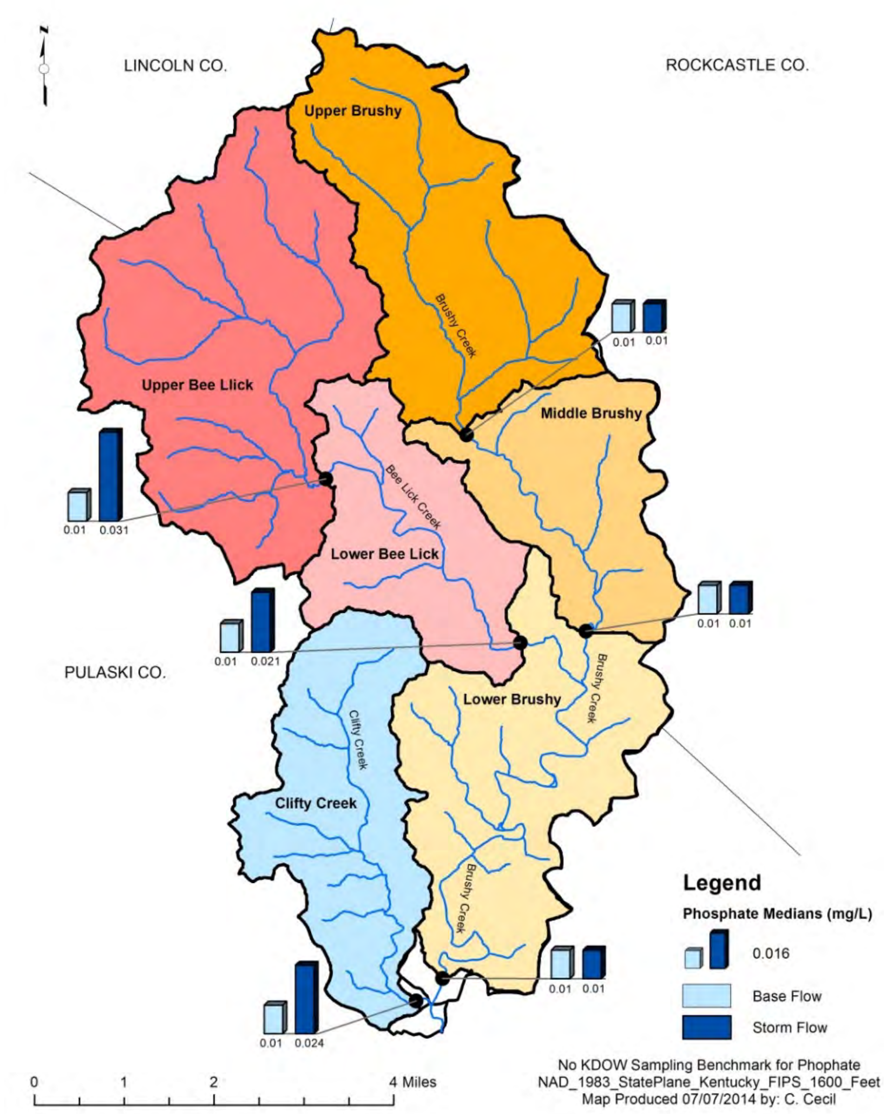


Figure 4.8 Median total phosphorus concentrations for samples collected during storm flow and base flow.



No KDOW Sampling Benchmark for Phophate
NAD_1983_StatePlane_Kentucky_FIPS_1600_Feet
Map Produced 07/07/2014 by: C. Cecil

Figure 4.9 Median orthophosphate as phosphorus concentrations for samples collected during storm flow and base flow.

Nutrient Loads and Yields

Loads of TN (Table 4.7 and Figs. 4.10 and 4.11) were consistently a little greater than the benchmark loads (using the benchmark of 1.3 mg/L). Some of this exceedance is probably due to the poor resolution of the TKN data, which are part of the total nitrogen calculation. As discussed previously, most of the TKN samples were run using a reporting limit of 1.0 mg/L, which is double the benchmark. To somewhat correct for this error, for samples reported to be below the 1.0 mg/L reporting limit, we substituted with the value of 0.5 mg/L, which is the benchmark. This likely was an overestimation of the TKN load reduction requirement in many of the samples. Loads and yields of nitrate + nitrite were close to or less than the benchmark loads (using the benchmark of 0.9 mg/L) in the lower Brushy and Clifty subwatersheds. The percentage reduction needed to meet the target load in the other four watersheds was relatively small (all less than one-third) but could be addressed. Exceedances of ammonia loads (using the benchmark of 0.05 mg/L) were greater, with loads ranging from 36% higher than the benchmark in Lower Bee Lick to 76% higher in Lower Brushy (Fig. 4.12).

Total phosphorus loads (Fig. 4.13) in the Lower and Middle Brushy subwatersheds were at or below the benchmark loads. The Lower Bee Lick subwatershed required the greatest load reduction to meet benchmarks, but given the small exceedance of phosphorus concentrations, the relatively low benchmark (0.03 mg/L), and the lack of nutrient-related algal or water quality problems in the watershed, little evidence suggests that phosphorus load reductions are warranted.

Table 4.7 Estimated Nutrient Loads from Each Subwatershed (see Appendix G for load duration curves)

Parameter	Lower Brushy	Middle Brushy	Upper Brushy	Lower Bee Lick	Upper Bee Lick	Clifty
Drainage area (mi²)	8.3	5	8.6	5.1	10.9	6.3
Annual TN loads (tons)	30.6	17.4	16.7	18.7	28.0	7.5
Annual TN yields (tons/ mi²)	3.7	3.5	1.9	3.7	2.6	1.2
Annual benchmark TN loads (tons)	26.9	11.8	12.9	13.5	19.5	6.8
Annual reduction required (tons)	3.6	5.7	3.8	5.2	8.5	0.7
% Annual reduction	12	33	23	28	30	9
Annual NO_3+NO_2-N loads (tons)	17.7	11.0	11.7	12.1	19.8	4.7
Annual NO_3+NO_2-N yields (tons/ mi²)	2.1	2.2	1.4	2.4	1.8	0.8
Annual benchmark NO3+NO2-N loads (tons)	18.7	8.1	8.9	9.4	13.5	4.7
Annual reduction required (tons)	0	2.9	2.8	2.8	6.3	0.0
% Annual reduction	0	26	24	23	32	1
Annual NH_3-N loads (tons)	4.2	0.8	1.1	0.8	1.6	0.7
Annual NH_3-N yields (tons/ mi²)	0.5	0.2	0.1	0.2	0.1	0.1
Annual benchmark NH_3-N loads (tons)	1.0	0.5	0.5	0.5	0.7	0.3
Annual reduction required (tons)	3.2	0.3	0.6	0.3	0.8	0.4
% Annual reduction	76	41	56	36	52	60
Annual TP-P loads (tons)	0.1	0.3	0.4	0.5	0.6	0.2
Annual TP-P loads per unit area (tons/ mi²)	0.0	0.1	0.0	0.1	0.1	0.0
Annual benchmark TP-P loads (tons)	0.6	0.3	0.3	0.3	0.4	0.2
Annual reduction required (tons)	0	0.0	0.1	0.2	0.1	0.0
% Annual reduction	0	1	19	37	22	17

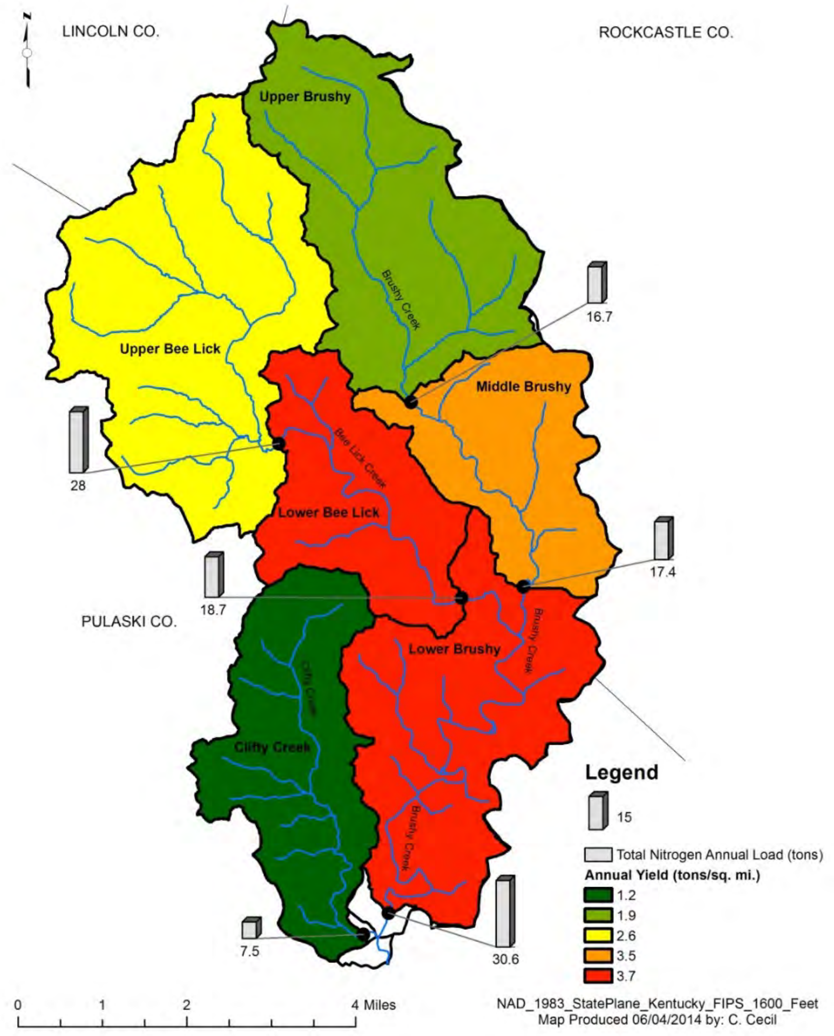


Figure 4.10 Total nitrogen loads and yields by subwatershed.

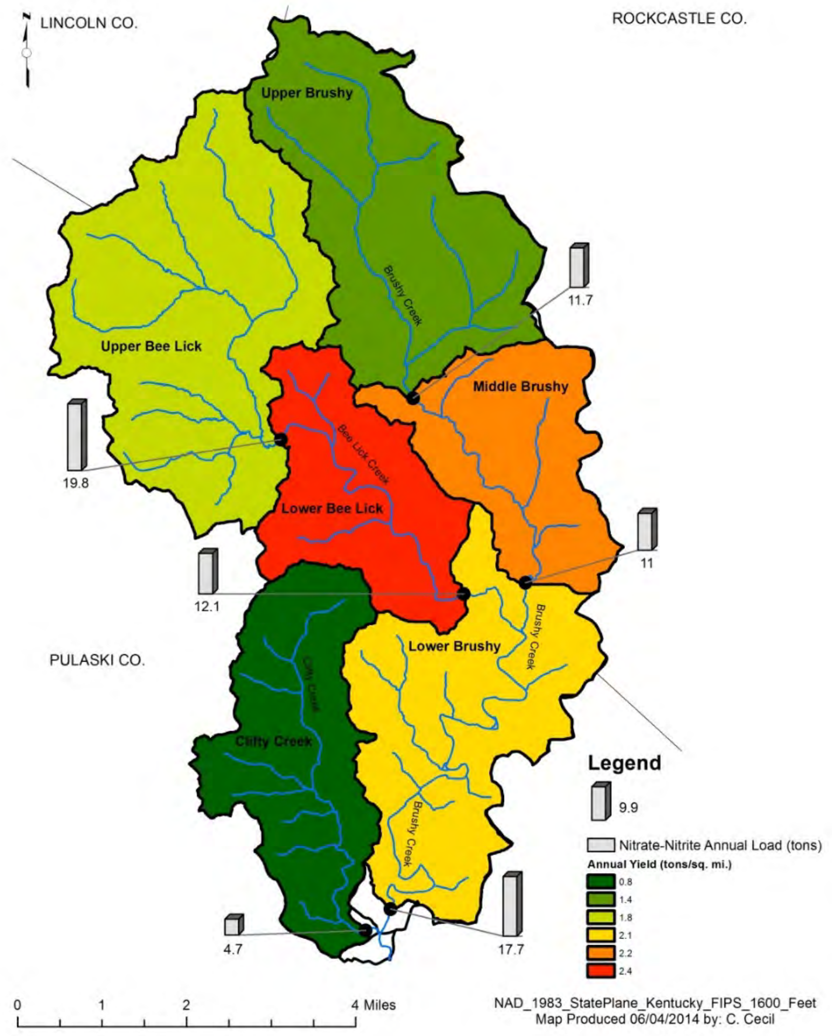


Figure 4.11 Nitrate + nitrite loads and yields by subwatershed.

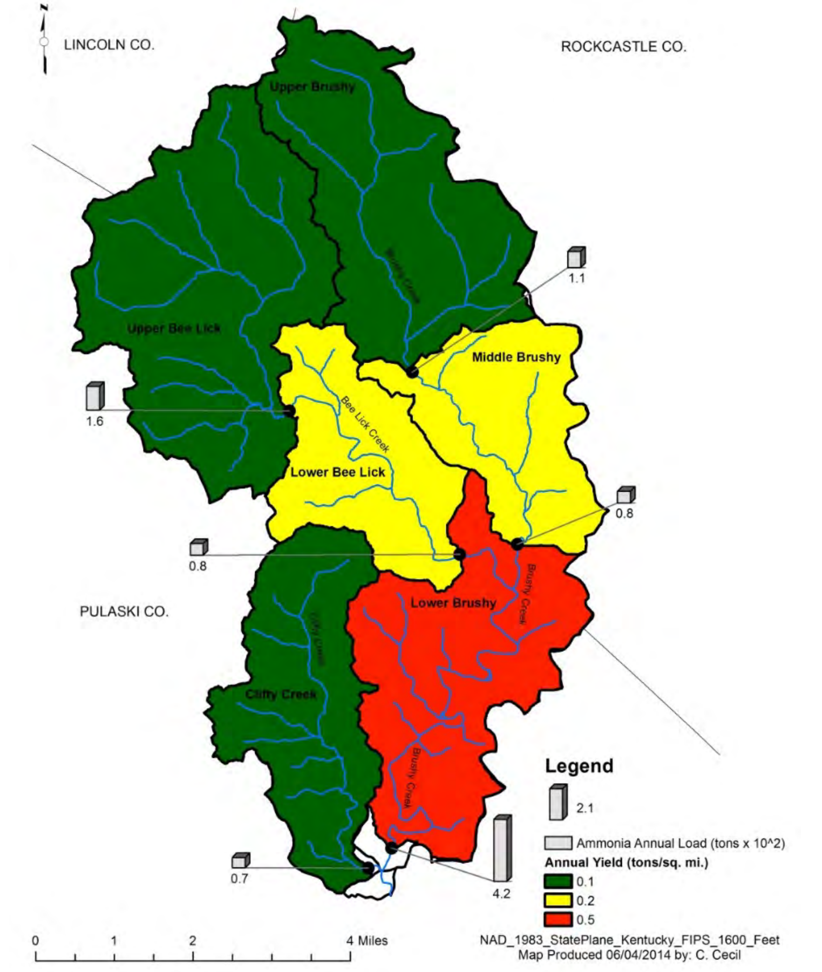


Figure 4.12 Ammonia loads and yields by subwatershed.

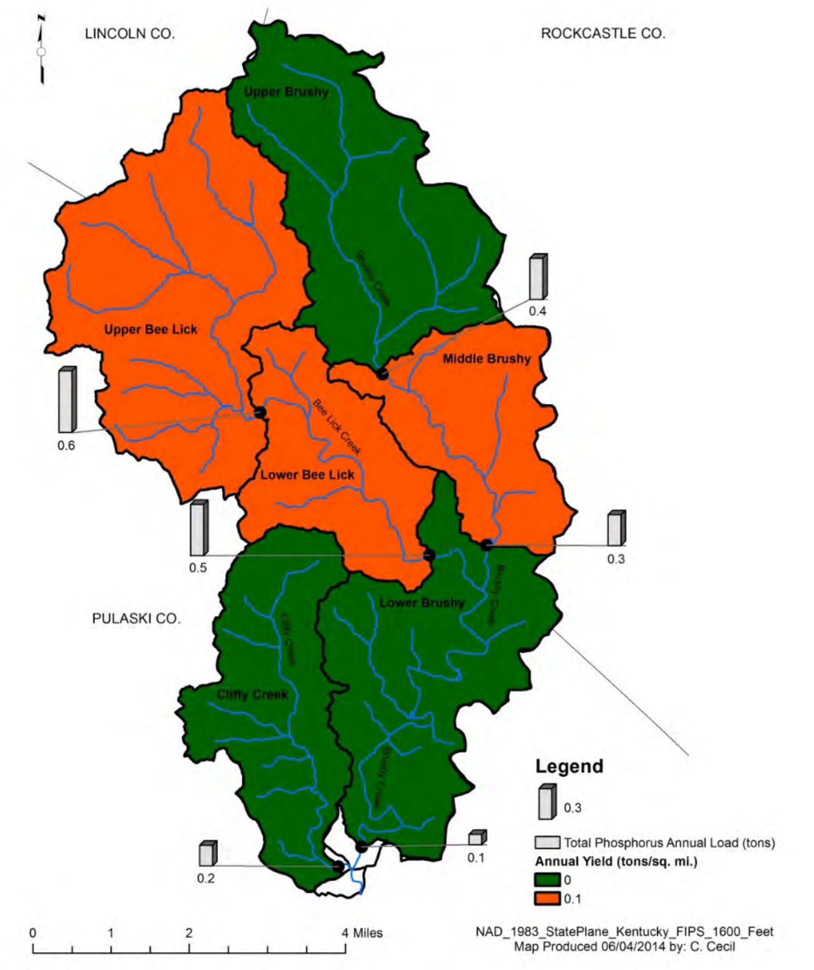


Figure 4.13 Total phosphorus loads and yields by subwatershed.

WQ3: *E. coli*

E. coli Concentrations

The geometric mean of five samples taken within 30 days exceeded surface water standards for *E. coli* (130 colonies per 100 mL) at all sites (Table 4.8). The highest concentrations were measured in the headwaters of the watershed at BR3 and, to a lesser extent, at BL2. During the annual data collection, the instantaneous standard (240 colonies per 100 mL) was exceeded at all sites by a factor of 10 or more, indicating that *E. coli* contamination is common and represents a significant impediment to the watershed meeting PCR usage standards (Table 4.9 and Appendix H).

E. coli Loads

The *E. coli* loads exceeded the benchmark loads calculated from flow and the surface water standard at all sites (Table 4.10 and Fig. 4.14). The annual yield calculated for the Lower Brushy subwatershed was the highest, but this value was somewhat skewed by the collection of a sample during a large flood, when concentration was very high and flow volumes were also very high. Because *E. coli* concentrations can vary by three or four orders of magnitude, these sources of variation exert more of an influence on the total load calculations than variation in nutrient concentrations, which generally vary by one order of magnitude or less. Required load reductions for all sites were around 50% or greater. This should be viewed as a lower limit target for reduction for two reasons. First, the greatest loads are transported during floods, so the overall annual load could be met by just reducing flood loads. This would not affect the exceedance of surface water standards during baseflow, which is primarily when people might be using the creek for primary contact recreation. Secondly, studies of *E. coli* loads that have combined water-borne bacteria and those attached to sediment have shown that water samples alone may grossly underestimate the *E. coli* load (Bai and Lung 2005; Droppo et al. 2011; Pandey and Soupir 2013). The inclusion of sediment-borne bacteria does present additional monitoring requirements but also would be more compatible with implementation of BMPs that trap or store sediment.

Table 4.8 *E. coli* Concentrations (colonies/100 mL) Collected During a 30-day Period

Sample Collection Date	BR1	BR2	BR 3	BL1	BL2	CLI
6/2/2011	64	210	1700	60	690	91
6/9/2011	86	185	960	127	365	71
6/16/2011	99	461	2420	166	548	74
6/23/2011	310	770	790	360	690	980
6/30/2011	99	350	720	150	340	411
Geometric mean	**132**	**395**	**1318**	**173**	**527**	**325**

Table 4.9 *E. coli* Concentrations (colonies/100 mL) Collected over an Annual Period

Sample Collection Date	BR1	BR2	BR 3	BL 1	BL 2	CLI
5/18/2011	517	488	1986	114	866	285
6/2/2011	64	210	1700	60	690	91
6/9/2011	86	185	960	127	365	71
6/16/2011	99	461	2420	166	548	74
6/23/2011	310	770	790	360	690	980
6/30/2011	99	350	720	150	340	411
7/18/2011	310	2420	24200	1300	610	2420
8/15/2011	71	310	610	86	340	200
9/29/2011	100	210	2000	120	190	60
10/18/2011	32	520	610	50	19	2
11/22/2011	2000	2420	24200	2420	2420	2420
12/13/2011	370	380	420	550	390	320
1/23/2012	16000	4100	2500	7700	4400	3300
1/24/2012	340	110	100	130	120	60
2/23/2012	82	490	160	740	170	310
3/22/2012	200	330	820	460	660	190
4/25/2012	61	690	550	110	310	80
5/17/2012	280	1200	990	340	1600	580
Mean	1168	869	3652	832	818	659
Median	150	474.5	890	158	469	242.5
Max	16000	4100	24200	7700	4400	3300
Min	32	110	100	50	19	2
Days (out of 18) exceeding surface water standard (240 CFU/100 mL)	8	14	16	8	14	9
% samples exceeding surface water standard	44	78	89	44	78	50

Table 4.10 Loads and Yields of *E. coli* in each Subwatershed (see Appendix H for load duration curves)

Parameter	Lower Brushy	Middle Brushy	Upper Brushy	Lower Bee Lick	Upper Bee Lick	Clifty
Drainage area (mi^2)	8.3	5	8.6	5.1	10.9	6.3
Annual *E. coli* loads (MPN x10^{14})	3.48	0.39	1.11	0.80	1.11	0.31
Annual *E. coli* yields (MPN x10^{12}/mi^2)	41.95	7.75	12.86	15.78	10.20	4.96
Benchmark annual loads (MPN x 10^{14})	0.45	0.20	0.22	0.23	0.33	0.11
% reduction required	87	49	81	72	71	64

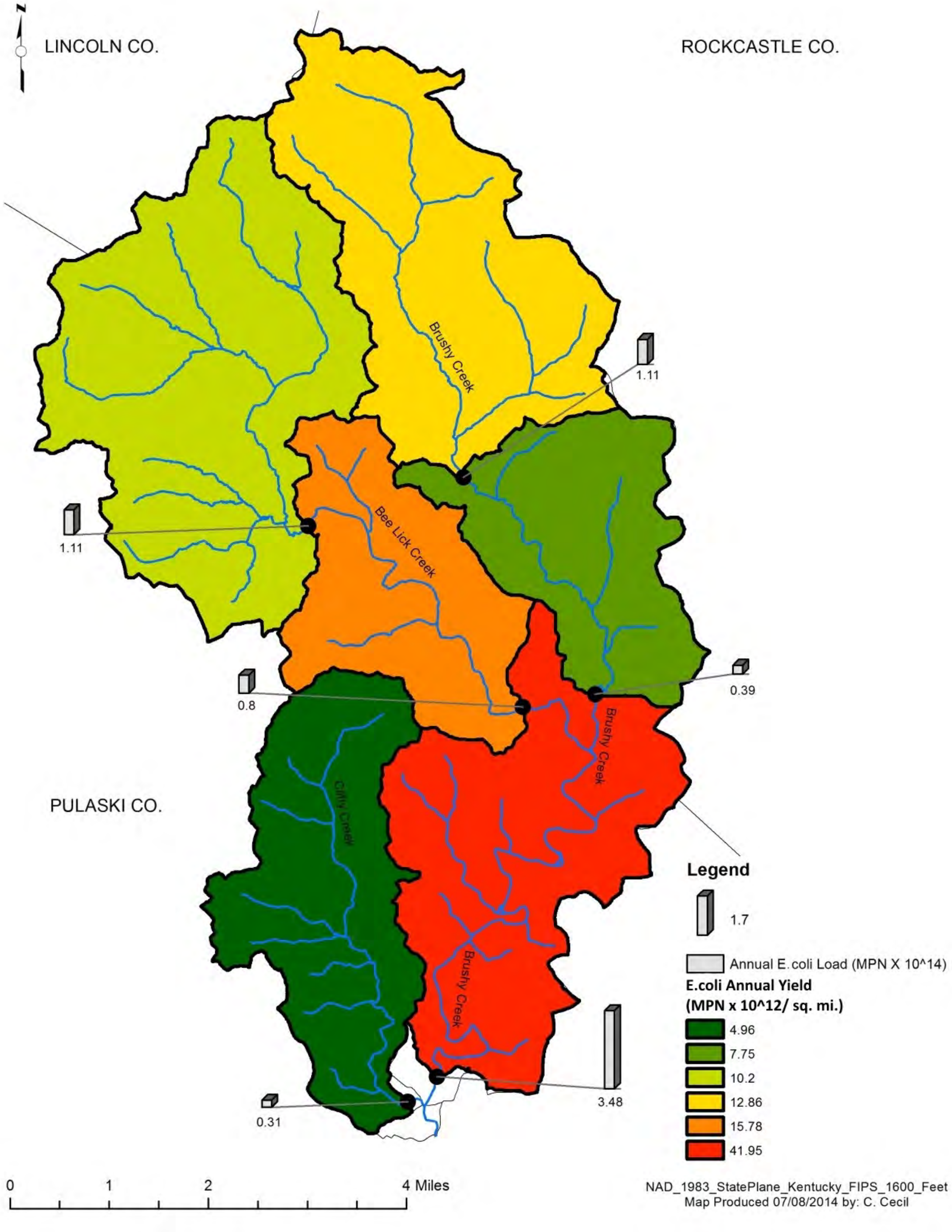


Figure 4.14 Annual *E. coli* load and yields. Each subwatershed is shaded to correspond with the annual yield (the load being contributed from the defined drainage area for the subwatershed). The load for each subwatershed point, however, includes *E. coli* loads from upstream watersheds.

4.1.3 Sediment

Sediment Concentrations (Turbidity)

The benchmarks for TSS (8.5 mg/L for April through October baseflow conditions) and turbidity (3.0 NTU for April through October baseflow conditions) were exceeded at every site for every flood event. This was expected, given that the benchmarks were collected primarily during baseflow periods, when sediment was not being transported. Turbidity was strongly correlated with the amount of suspended sediment at all sites. Suspended sediment is a major stressor on aquatic communities because it can reduce primary productivity, clog gills of fish, and disrupt predator-prey relationships. Suspended sediment can also deposit on the stream bed, choking spawning gravels, impairing food sources, and reducing habitat complexity. The effects of turbidity are dependent on the magnitude (how turbid the water is), duration (how long the water remains turbid), and frequency (how often the water becomes turbid). The combination of these three measures of turbidity was examined for each site at a range of turbidities: turbidity thresholds followed those used in an impact assessment for fish exposed to cloudy water (Newcombe 2003).

At all turbidity thresholds, the frequency and duration of events was relatively similar between sites. BL2 site experienced moderately turbid flows more frequently than the other sites based on the frequency of exceedance of the 150 NTU threshold (Fig. 4.15), and BR3 and BL2 both had very turbid flows more often than the other sites (Fig. 4.16). The duration of the turbidity varied with drainage area: as expected, the larger sites had flood events that lasted longer than the smaller sites. No site experienced any flood event where turbidity was higher than at baseflow conditions for more than a day. Generally, turbidity was high for very short durations, presumably due to the lack of clay- and silt-sized material that stays in suspension much longer than sand. Both the relatively short period of elevated turbidity and the similarity in behavior between sites suggest that action to address prolonged turbidity is not warranted.

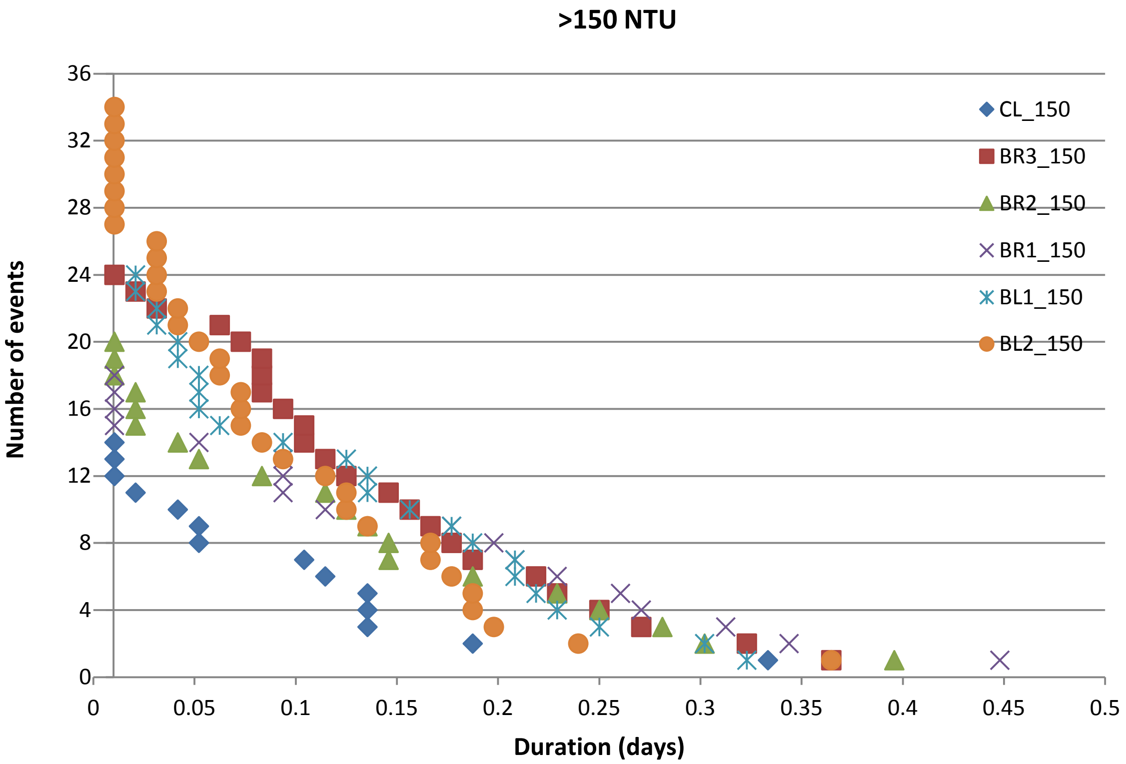


Figure 4.15 Frequency and duration of exceedances of 150 NTU threshold.

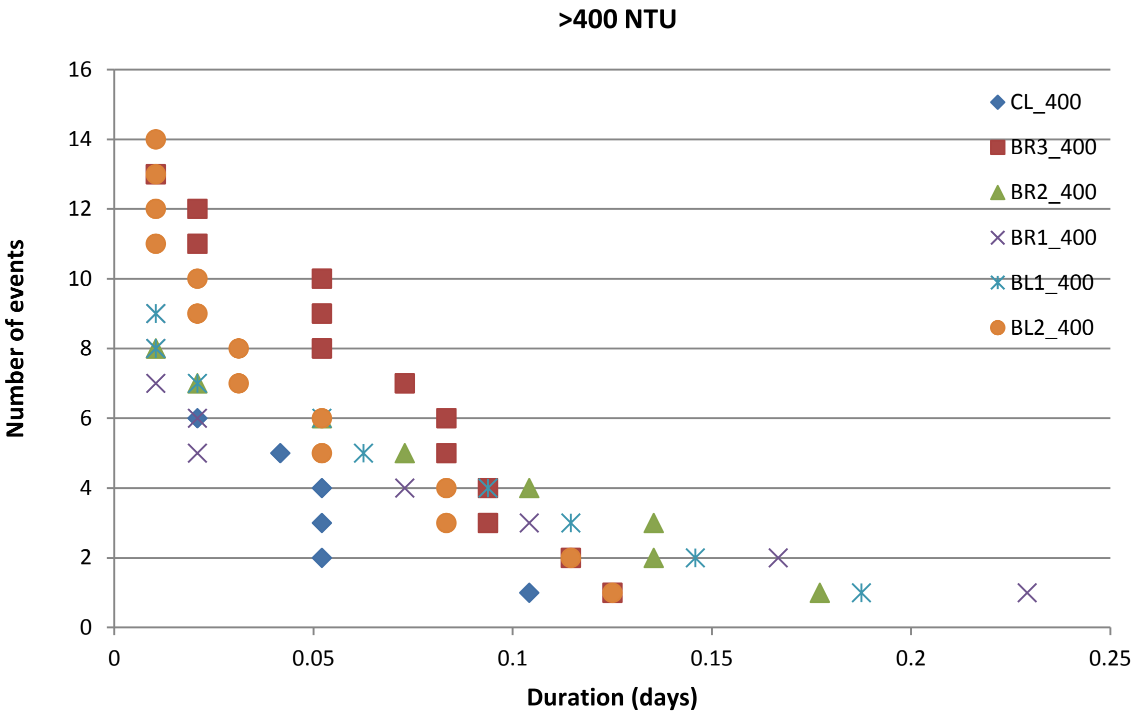


Figure 4.16 Frequency and duration of exceedances of 400 NTU threshold.

Sediment Loads and Yields

Sediment loads were highest at BR1 (Fig. 4.17), which has by far the largest contributing drainage area. Given the lack of accessible floodplain and limited storage potential in the watershed, we expected that loads would increase with increasing drainage area. Sediment yields (loads normalized by drainage area) were also highest in the lower reaches of Brushy Creek and lowest in the Clifty and Upper Brushy subwatersheds (Table 4.11). The main difference in the subwatersheds that would influence sediment yields was the bank height of the channel in Lower Brushy, which was, on average, much higher than in other subwatersheds. Higher banks will produce more sediment per foot of channel due to erosion than lower banks. The slopes in the Lower Brushy subwatershed were also steeper, which may lead to more hillslope erosion and steeper tributaries, although field observations did not indicate that soil erosion was a particular issue in this subwatershed or any other.

The benchmark values of TSS and turbidity were generated from data collected during baseflow periods, when very little sediment is being transported. Loads based on those flows and corresponding very low benchmarks would be impossible to achieve. Comparable values for sediment yield are not readily available for the Pennyroyal physiographic region, but values at sites in the Bluegrass were of similar magnitude (Croasdaile and Parola 2013), whereas values from the Eastern Kentucky Coal Field region were typically about an order of magnitude higher when they were measured 36 years ago (Curtis et al. 1978).

Table 4.11 Sediment Loads and Yields for Subwatersheds

Subwatershed	Lower Brushy	Middle Brushy	Upper Brushy	Lower Bee Lick	Upper Bee Lick	Clifty
Drainage area (mi^2)	8.3	5	8.6	5.1	10.9	6.3
Sediment load (lbs/yr)	14,340,607	4,107,363	3,073,114	3,245,744	6,532,763	2,370,253
Sediment load (tons/yr)	7170	2054	1537	1623	3266	1185
Yield (tons/mi^2/yr)	864	411	179	318	300	188
Benchmark load* (lbs/yr)	12,444	5433	5943	6246	8992	3139
Benchmark load* (tons/yr)	6.2	2.7	3.0	3.1	4.5	1.6

* The reference stream data came exclusively from biology sampling visits between April and October during baseflow conditions and do not represent flood flows.

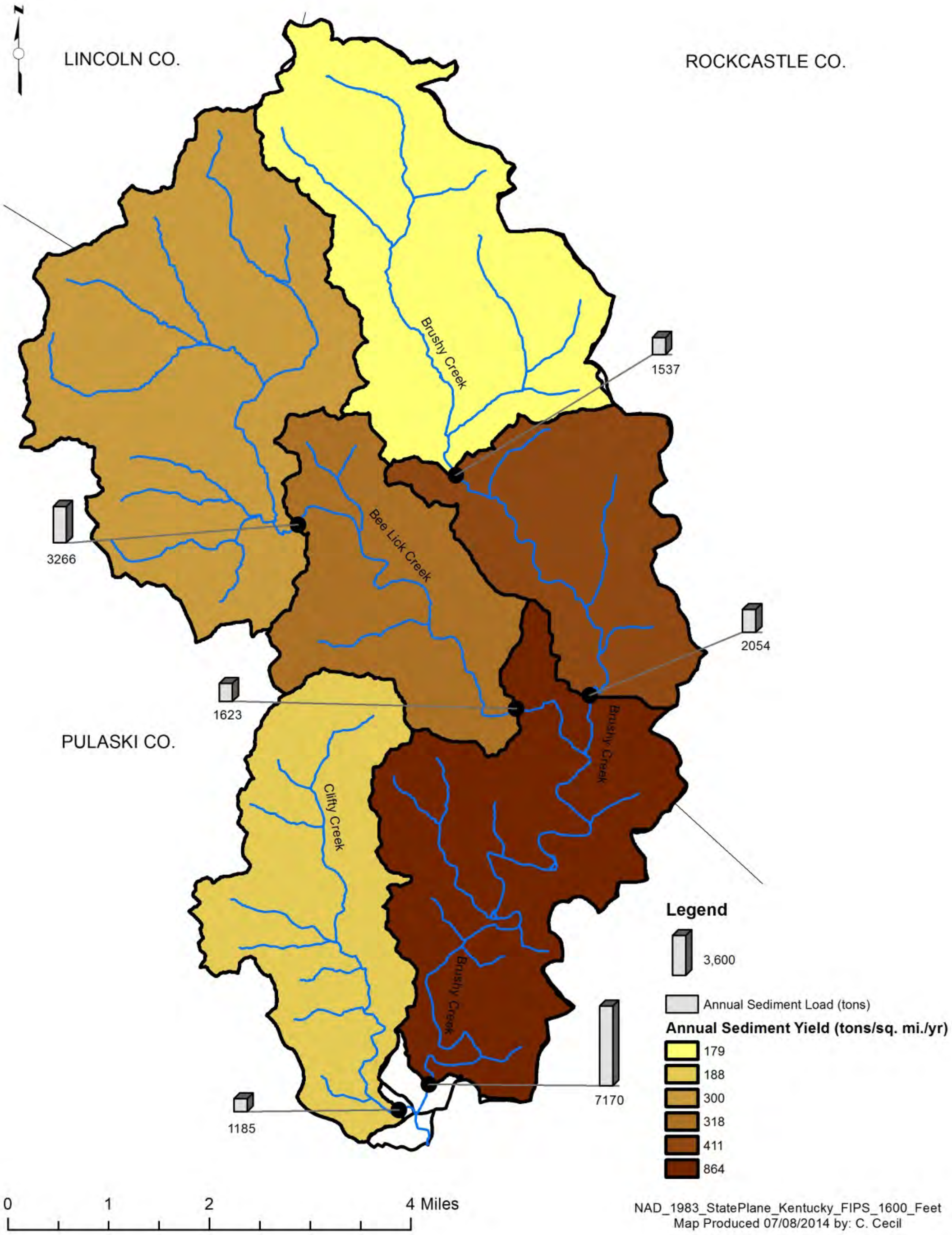


Figure 4.17 Annual sediment loads (tons/yr) and yields (tons/mi2/yr). Each subwatershed is shaded to correspond with the annual yield (the load being contributed from the defined drainage area for the subwatershed). The load for each subwatershed point, however, includes sediment loads from upstream watersheds.

4.2 Phase 1 Prioritization

4.2.1 Habitat

The habitat in all of the subwatersheds could be improved: wood was generally absent from the channel, reaches were incised and entrenched, and floodplain connection was generally poor. Bed stability was low at the reaches in Upper Brushy and Clifty subwatersheds; this was not due to nonpoint source loads but rather to high shear stress conditions during floods. To address the shear stress would require a change in the overall channel configuration (i.e., a stream restoration project) rather than a reduction in load of sediment to the reach. The reach at BL2 was the only site where riffles were consistently embedded due to fine sediment.

> **Determination of the scope and cause of embeddedness in the Upper Bee Lick subwatershed was selected as an objective of Phase 2.**

4.2.2 Water Quality

Physico-chemical Parameters

Water quality in the watershed is generally good, with pH, specific conductance, and dissolved oxygen in the ranges suitable for supporting aquatic life. The exception to this is during extremely dry periods; during these periods, dissolved oxygen levels become correspondingly low. Continuous data showing this low DO pattern were only collected at BL1, but the discrete samples indicate that other sites were similar in terms of DO trends. Hence, we infer that other subwatersheds would also have had very low DO during this period. There was no indication that low DO was due to elevated nutrient concentrations: where this occurs, the diurnal fluctuations tend to be very large with supersaturation during the day followed by a crash at night. This was not observed in Bee Lick Creek (Fig. 4.3): instead the diurnal fluctuations relating to photosynthesis and respiration actually became smaller as flows declined and delivery of nutrients to primary producers was restricted.

> **Additional sampling was identified for Phase 2 to confirm whether this DO finding was an isolated case or was more common throughout the watershed.**

Nutrients

Evidence that nutrients are impairing water quality was limited: algal growth was typically limited, and diurnal fluctuations in dissolved oxygen and pH were small. Nutrient concentrations exhibited no distinct spatial trends within the watershed, which is to be expected given the relatively widespread nature of agriculture in the watershed. Nitrate concentrations showed a strong seasonal pattern: concentrations were much higher in the winter than in the summer for all sites. The seasonal trend was consistent between all sites even though the different subwatersheds have different amounts of agriculture; that consistency indicates a broad change in nutrient dynamics across the watershed rather than a local change in supply. The seasonal pattern indicates that direct uptake of nutrients by vegetation is an important influence in nutrient delivery in Brushy Creek watershed; this relationship has also been widely reported in other studies (see review in Dosskey et al. 2010).

Based on review of Phase 1 data with project partners, nutrients were determined to not generally be a problem, but more information on the distribution of nutrient concentrations in the headwaters would be beneficial for watershed planning.

> **An additional round of sampling for nutrients in the Upper Brushy and Upper Bee Lick subwatersheds was determined to be desirable based on project partner feedback.**

E. coli

E. coli concentrations exceeded the surface water standard for primary contact recreation at all sites. Concentrations were highest in the headwaters of Brushy and Bee Lick north of KY-70. Microbial source tracking conducted by EKU showed that the main source of stream *E. coli* was cattle, and field observations support this conclusion. Testing of groundwater springs indicated a human source of fecal contamination (A. Jones, pers. comm., August 20, 2013).

After all available data were reviewed with project partners, *E. coli* was determined to be a potential pollutant at all sites. The primary sources of the *E. coli* are cattle, and BMP implementation could be widespread in all subwatersheds. The prioritization of BMPs will be more dependent on landowner cooperation than on more detailed source identification, and information both from this project and from the detailed MST study conducted by EKU is sufficient to enable development of a watershed based plan.

> **Based on Phase 1 data, *E. coli* concentrations were determined to exceed PCR standards in all subwatersheds, and cooperation from landowners would be more important for BMP planning and implementation than additional study.**

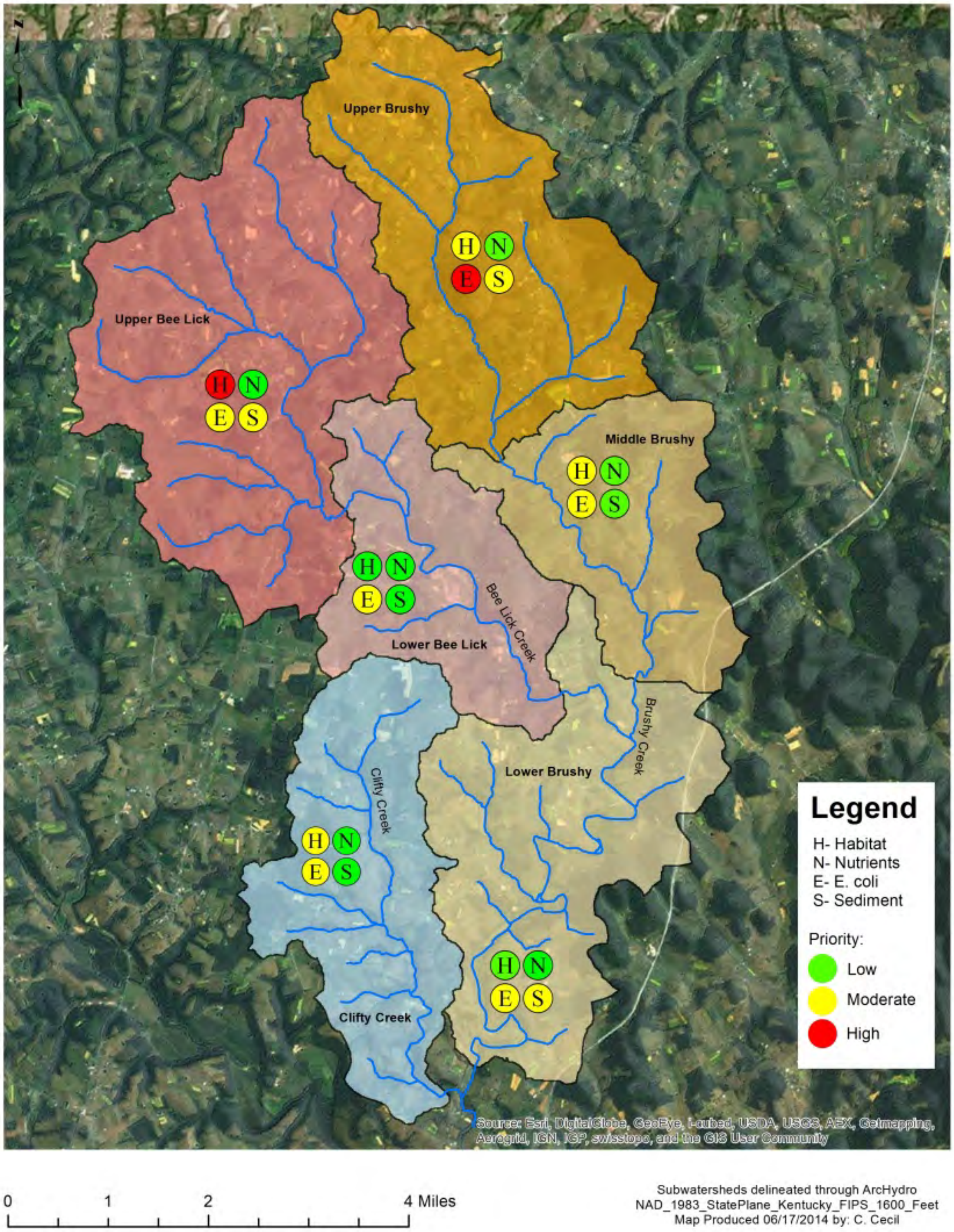
4.2.3 Phase 1 Prioritization Summary

A summary of pollutants or parameters to be addressed (Table 4.12 and Fig. 4.18) was developed based on

- The necessity (the degree that a benchmark or standard was exceeded)
- The scope of the problem (whether it was widespread throughout the subwatershed or restricted to a few specific reaches)
- The practicality of addressing the issue (cost relative to realistic funding available; the amount of landowner cooperation that would be required)

Table 4.12 Summary of Actions Suggested by Monitoring Results

	Parameter	Necessity	Scope	Practicality	Comments
Lower Brushy	Habitat	Low	Widespread	Very low	Sustainable habitat improvements in such a large channel are very likely to be cost prohibitive
	Physico-chemical	Low	N/A	N/A	N/A
	Nutrients	Low	Widespread	Low	No evidence that BMPs would be cost effective
	E. coli	Moderate	Widespread	Moderate	Dependent on landowner cooperation
	Sediment	Moderate	Widespread	Low	Sediment reductions in such a large channel are very likely to be cost prohibitive
Middle Brushy	Habitat	Moderate	Widespread	Low	Sustainable habitat improvements are likely to be cost prohibitive
	Physico-chemical	Low	N/A	N/A	N/A
	Nutrients	Low	Widespread	Low	No evidence that BMPs would be cost effective
	E. coli	Moderate	Widespread	Moderate	Dependent on landowner cooperation
	Sediment	Low	N/A	Low	Sustainable habitat improvements are likely to be cost prohibitive
Upper Brushy	Habitat	Moderate	Widespread	Low–Moderate	Obtaining conservation easements from multiple landowners would be required
	Physico-chemical	Low	N/A	N/A	N/A
	Nutrients	Low	Widespread	Low	No evidence that BMPs would be cost effective
	E. coli	High	Widespread	Moderate	Dependent on landowner cooperation
	Sediment	Moderate	Localized	Moderate	Obtaining conservation easements from multiple landowners would be required
Lower Bee Lick	Habitat	Low	Widespread	Low	Sustainable habitat improvements are likely to be cost prohibitive
	Physico-chemical	Low	N/A	N/A	N/A
	Nutrients	Low	Widespread	Low	No evidence that BMPs would be cost effective
	E. coli	Moderate	Widespread	Moderate	Dependent on landowner cooperation
	Sediment	Low	N/A	Low	Sustainable habitat improvements are likely to be cost prohibitive
Upper Bee Lick	Habitat	High	Widespread but locally significant	Moderate	Obtaining conservation easements from multiple landowners would be required
	Physico-chemical	Low	N/A	N/A	N/A
	Nutrients	Low	Widespread	Low	More sample points required to identify contribution from row crops
	E. coli	Moderate	Widespread	Moderate	Dependent on landowner cooperation
	Sediment	Moderate	Localized	Moderate	Obtaining conservation easements from multiple landowners would be required
Clifty	Habitat	Moderate	Widespread	Moderate	Obtaining conservation easements from multiple landowners would be required
	Physico-chemical	Low	N/A	N/A	N/A
	Nutrients	Low	Widespread	Low	More sample points required to identify contribution from row crops
	E. coli	Moderate	Widespread	Moderate	Dependent on landowner cooperation
	Sediment	Low	N/A	Moderate	Obtaining conservation easements from multiple landowners would be required



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Subwatersheds delineated through ArcHydro
NAD_1983_StatePlane_Kentucky_FIPS_1600_Feet
Map Produced 06/17/2014 by: C. Cecil

Figure 4.18 Summary of Phase 1 findings in each subwatershed.

4.2 Phase 2 Analysis

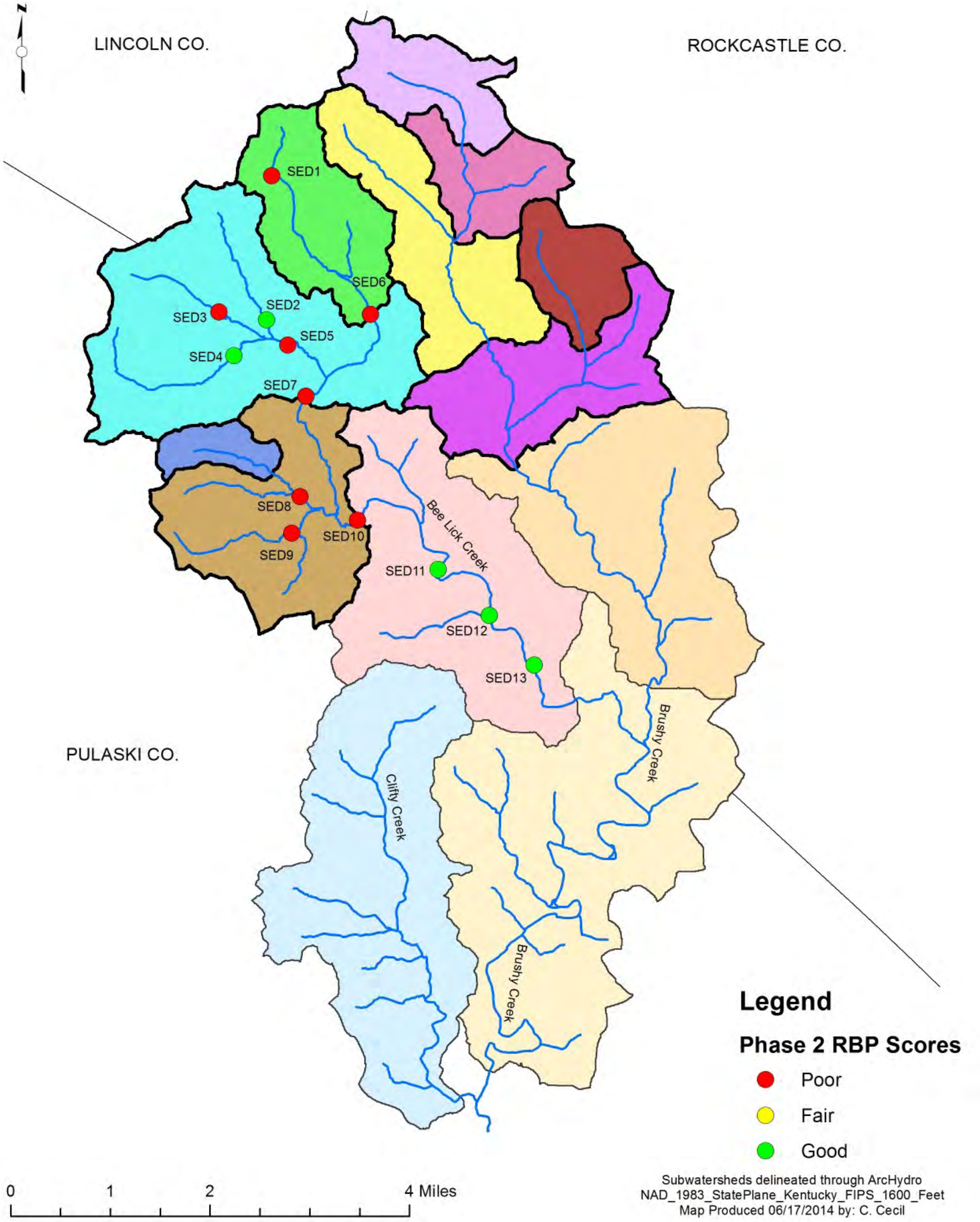
Results from Phase 2 data collection were used to evaluate the scope and severity of the issues in selected subwatersheds. The importance of other aspects of watershed health, particularly the drying of the channel, became apparent during the Phase 2 monitoring period, and their potential impacts were evaluated to the extent that the data permitted.

4.2.1 Habitat

The reaches showed a wide variety of habitat quality, with lower reaches being generally good and the headwaters being of mixed quality (Fig. 4.19 and Table 4.13; see Appendix I for photos and general findings). In general, where cattle had access to the creek and the reach was unforested, the habitat was poor. In the Upper Bee Lick subwatershed reaches that scored good (SED2 and SED4), a culvert or narrow bridge provided stable grade control at the downstream extent of the reach, which limited scouring of the bed. Based on field visits and habitat assessments, the BL2 reach was determined to be the most affected by sediment deposition, with widespread siltation of the majority of riffles. The reaches within the Lower Bee Lick subwatershed (SED11, 12, and 13), however, supported an incredible array of macroinvertebrates with many clean riffles. Sediment production that occurred in the upper reaches of Bee Lick was not impacting downstream habitat quality.

Given that the BL2 reach was identified as experiencing the most embeddedness in the subwatershed, the impact of this sediment deposition on the macroinvertebrate community was evaluated relative to downstream BL1 reach, which has comparable water quality, climate, geology etc. Differences in the overall MBI between BL1 and BL2 were slight, although individual metrics differed significantly (Table 4.14).

The Genus Taxa Richness (G-TR) at both sites was high relative to reference reaches in the Pennyroyal region (Pond et al. 2003). This metric refers to the total number of genera present in the composited sample and reflects, in general, good water quality, habitat diversity, or habitat suitability. The Genus-level *Ephemeroptera, Plecoptera, Trichoptera* Richness (G-EPT) (Pond et al. 2003) was slightly higher at BL2 than at BL1. *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies) and *Trichoptera* (caddisflies) are generally pollution sensitive insect orders and reflect good water quality, habitat diversity, or habitat suitability. Both sites scored a little below the average values for reference stream reaches in the Pennyroyal but significantly higher than non-reference stream reaches.



Subwatersheds delineated through ArcHydro
NAD_1983_StatePlane_Kentucky_FIPS_1600_Feet
Map Produced 06/17/2014 by: C. Cecil

Figure 4.19 RBP scores and ratings from Phase 2 habitat assessment.

Table 4.13 Results from Phase 2 RBP Assessment of Physical Habitat (see Appendix I for field data forms)

	RBP Parameter	SED1	SED2	SED3	SED4	SED6	SED7	SED8	SED9	SED10	SED11	SED12	SED13
1	Epifaunal substrate/ available cover	12	16	6	18	15	11	14	15	14	15	18	18
2	Embeddedness	16	16	13	15	16	12	11	14	10	20	19	18
3	Velocity/depth regime	10	10	13	16	11	16	11	11	15	15	18	19
4	Sediment deposition	15	18	18	15	16	8	10	13	8	11	17	17
5	Channel flow status	15	18	10	18	15	15	10	15	9	15	17	18
6	Channel alteration	11	15	13	19	11	13	14	15	15	18	18	18
7	Frequency of riffles	15	17	8	19	14	10	10	16	15	15	18	18
8	Bank stability (L)	3	9	2	8	3	8	5	6	3	5	10	8
	Bank stability (R)	8	9	3	8	8	9	5	6	8	8	6	9
9	Vegetative protection (L)	5	5	2	9	1	6	1	5	2	7	10	6
	Vegetative protection (R)	5	5	6	9	5	6	1	5	6	7	7	8
10	Riparian vegetative zone width (L)	4	5	1	10	1	4	0	4	2	5	10	6
	Riparian vegetative zone width (R)	4	5	5	10	5	5	0	4	6	5	6	10
	Total	123	148	100	174	121	123	92	129	113	146	174	173
	Habitat rating	Poor	Good	Poor	Good	Poor	Poor	Poor	Poor	Poor	Good	Good	Good
	Cows in creek?	No	Yes	Yes	No	No	No	Yes	Yes	No	No	No	No

Table 4.14 MBI* Results from Reaches at BL1 (downstream) and BL2. Samples were collected June 20, 2013. Data courtesy of Mark Vogel (KDOW).

Station ID	TotInd	G-TR	G-EPT	mHBI	m%EPT	%-Chiro+Olig	%ClngP	MBI W full (new)
DOW02012028 – BL1	2221	96.5	80.8	75.9	87.0	90.8	55.0	81.0
DOW02012029 – BL2	3984	100	84.6	72.6	28.4	80.4	84.3	75.0

* The %*Ephemeroptera* variable is not included because it is used only for headwaters MBIs and cannot be compared for these two reaches.

The Modified Hilsenhoff Biotic Index (mHBI) was slightly higher at BL1 than BL2. The mHBI was developed to assess organic enrichment by summarizing the overall pollution tolerance of a benthic arthropod community with a single value (Klemm et al. 1990). An increasing mHBI value indicates decreasing water quality. Both reaches scored above (i.e., worse than) the majority of reference reaches but at the lower end of scores from non-reference reaches in the Pennyroyal. The Modified Percent EPT Abundance (m%EPT) showed a very large difference between the sites, as other insect orders were more prevalent at BL2 even though the absolute numbers of EPT taxa were similar. The Percent *Chironomidae+Oligochaeta* (%Chir+%Olig) was higher at BL1 than BL2, which generally suggests lower water quality conditions. The BL2 reach, which had abundant sand and silt deposition on the bed, had a higher Percent Primary Clingers (%Clingers), which measures the relative abundance of those organisms that need hard, silt-free substrates on which to cling. This metric is generally correlated with substrate stability, but the abundance may reflect the stability of bed substrate in side channels that had formed due to widening of the channel by bank retreat and lower shear stress over the riffles due to the widened channel. Indeed, the BL2 site, because of the bank erosion and the resulting fallen trees, had a wider variety of microhabitats even though the local supply of sand and silt load was clearly higher than at BL1.

Overall, the BL1 site was "0.5 points from being in the excellent rating, while the upper site is a solid good (even though it is more diverse)" (Mark Vogel, pers. comm., July 18, 2013). The BL2 reach, with a "good" MBI rating, had the most abundant deposition and embeddedness of any site visited in the watershed but still supported a diverse insect community. Of all the reaches visited in the Brushy Creek watershed, the BL2 reach was the one that would be expected to have an insect community impacted by fine sediment. Given that BL2 had the most severe bank erosion but still supported a good benthic macroinvertebrate population, we concluded that local sediment supply from bank erosion was probably not impairing benthic macro-invertebrate populations in Brushy Creek.

4.2.2 Phase 2 Water Quality

Phase 2 DO

Very low dissolved oxygen was recorded at BL1 during the fall of 2012, with concentrations below the chronic surface water standard (5 mg/L) for 12 consecutive days. Regional estimates of the Palmer Drought Severity Index (PDSI) were near normal, indicating that Brushy Creek had not experienced moderate or severe drought conditions for the months preceding August, although rainfall in August 2011 was below normal. To investigate how widespread an issue the low DO was, follow-up sampling was planned for fall of 2013. DO was continuously monitored at BL1, and data were transmitted via cellular modem so sampling could be timed around periods of low DO. The fall of 2013 was wetter than 2012, and only one instance of low DO (lower than 4 mg/L) occurred during this period, on Friday, September 20 (Fig. 4.20). Sampling was planned for the following Monday, but a small flood event returned DO values to above 6 mg/L. DO remained higher than 6 mg/L thereafter. Additional field visits at the Phase 1 sites in the fall of 2013 to check for low DO values also found concentrations of around 7−8 mg/L.

During the fall of years with below average rainfall, low dissolved oxygen concentrations in Brushy Creek are possible and may be widespread. Although low dissolved oxygen can be detrimental to aquatic fauna, very little can be done to increase DO when the main cause is lack of mixing due to lack of water in the channel. Increasing the amount of groundwater in the channel during baseflow periods through extensive construction of groundwater dams and streamside wetlands would be a possible approach to address this issue, although groundwater level monitoring would be required to determine how effective this BMP would be.

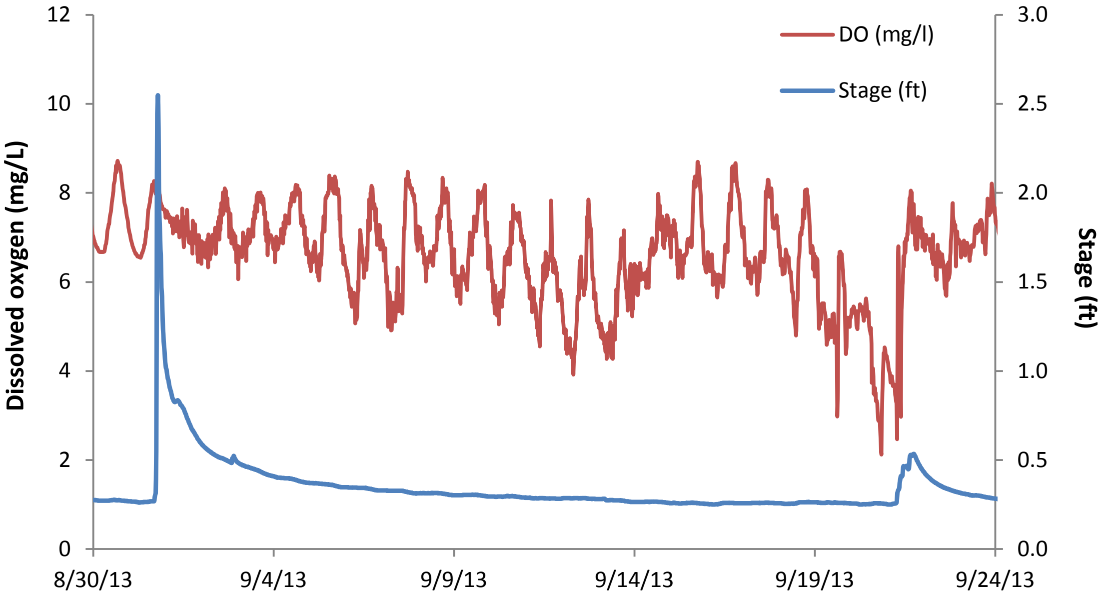


Figure 4.20 Dissolved oxygen dropped below the surface water standard for a brief time. It went back up after a small flood event.

Phase 2 Nutrients

The Phase 2 sampling showed considerable variation in nitrate+nitrite concentrations in the headwaters of Upper Brushy and Bee Lick subwatersheds (Table 4.15 and Fig. 4.21). The percentage of row crops upstream of each sampling point may be related to the nutrient concentration: the site with highest row crop percentage also had the highest nitrate concentration by far. This site (PN2) also has little pastoral agriculture and had the lowest *E. coli* concentration.

Table 4.15 Phase 2 Nutrient Concentrations

Latitude	Longitude	Site Name	Sampling Time	PO_4-P (mg/L)	NH_3-N (mg/L)	NO_3+NO_2-N (mg/L)	TKN (mg/L)	TP-P (mg/L)	*E. coli* (MPN/100mL)
37.301863	−84.489073	PN1	13:45	<0.02	<0.05	1.342	<0.5	0.062	4950
37.301863	−84.489073	PN1 – Duplicate	13:45	<0.02	<0.05	1.353	<0.5	0.128	9320
37.308366	−84.50493	PN2	13:15	<0.02	<0.05	2.793	<0.5	0.086	520
31.318946	−84.4981	PN3	13:03	<0.02	<0.05	1.244	<0.5	0.138	14670
37.331164	−84.486716	PN4	12:55	<0.02	<0.05	0.886	<0.5	0.110	12460
37.308504	−84.460659	PN5	11:30	<0.02	<0.05	1.249	<0.5	0.107	4950
37.3247	−84.447277	PN6	11:53	<0.02	<0.05	0.977	<0.5	0.105	4260
37.327069	−84.465559	PN7	11:50	<0.02	<0.05	1.043	<0.5	0.176	15150
37.341605	−84.471223	PN8	12:10	<0.02	<0.05	1.001	<0.5	0.152	6910
37.355592	−84.469721	PN9	12:30	<0.02	<0.05	1.136	<0.5	0.027	5810

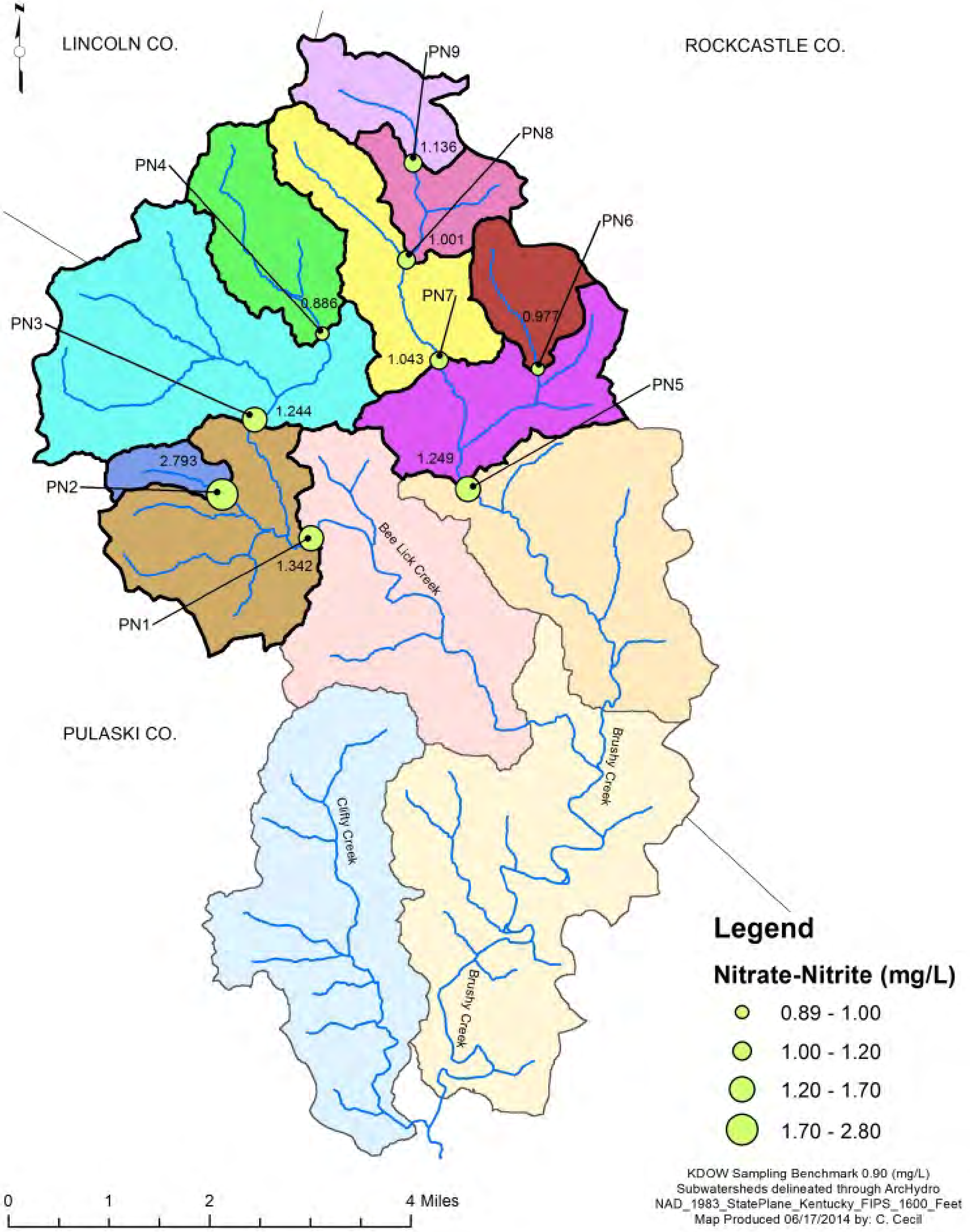


Figure 4.21 Nitrate + nitrite concentrations from Phase 2 sampling.

4.2.3 Implications for BMPs

Overall, the habitat in Brushy Creek was mixed: lower reaches with larger drainage areas had good habitat with good fish populations and good macroinvertebrates. Reaches with smaller drainage areas had poorer habitat with issues primarily relating to sediment deposition (Bee Lick subwatershed) or unstable substrate (Upper Brushy and Clifty Creek). Floodplain wetlands, which are often thought to be important sites for affecting water quality, providing wildlife habitat, and attenuating floods (Conner and Day 1982; Wharton et al. 1982; Junk et al. 1989; Ward 1989; Naiman and Décamps 1997), were almost entirely absent from the watershed. Although wetlands were not a particular focus of this assessment, future BMPs could add a great deal of ecological diversity to the watershed by increasing the amount of wetland habitat. These wetlands might increase the amount of water in nearby stream reaches during periods of low flow and improve the water quality within the watershed by retaining sediment, reducing pathogens, and processing nutrients (Comin et al. 2013; Marton et al. 2013).

Two main sediment related issues were identified in the watershed: embeddedness in the Bee Lick subwatershed due to localized bank erosion, and instability of riffle sediments throughout the watershed. Macroinvertebrate sampling in the Bee Lick subwatershed showed that the embeddedness was not dramatically impacting aquatic insects, at least not in number and type of species. Overall biomass was not investigated. Instability of riffle sediments was due to the incised and entrenched condition of most stream reaches. Removing floodplain sediments to lower bank heights and hence reduce shear stress during floods would be the most effective approach to address both issues.

Given the incised and entrenched condition of most reaches, implementation of piecemeal approaches, such as installation of habitat features in the existing channel configuration, would not be successful. Stream restoration that would lower the banks, reduce shear stress, create stable instream habitat, and connect the channel with new floodplain wetlands would dramatically improve habitat in almost every reach in the watershed. Although stream restoration has the potential to address both habitat and water quality improvements, the potential for such a BMP in Brushy Creek requires co-operation with multiple landowners and requires a large financial investment. The stream reaches in all subwatersheds have multiple landowners, and reaches within a single property boundary are generally less than 2000 ft in length, which is small for economically efficient compensatory mitigation projects. The reach immediately upstream of the BL2 site had the highest sediment supply and was causing the most embeddedness, so it would be the highest priority for restoration.

All subwatersheds had reaches with limited riparian vegetation on one or both banks. Increasing the quality and quantity of the riparian corridor could be beneficial for physical habitat (through the supply of wood to the channel) and for water quality (for shading, for supply of organic leaf litter, and for nutrient processing). Because majority of the reaches are incised and entrenched with bank heights in excess of 4 feet, however, tree planting on the existing floodplain would be unlikely to spur any improvement in processing of groundwater and removal of nitrate. Although tree planting is a common BMP for nutrient reduction, particularly nitrate, research has shown that where groundwater bypasses both the root zone and surface soil layers, the retention of nitrogen is minimal (Mayer et al. 2006). Moreover, trees planted on banks in excess of 4 ft in height are unlikely to be very long-lived because of bank instability: as the high banks erode, trees will fall into the channel and move downstream to form jams and/or threaten infrastructure, and would potentially increase local flooding.

Phase 1 monitoring indicated that low dissolved oxygen may sometimes be a problem in Brushy Creek watershed. Monitoring during Phase 2 was conducted during a wetter year and did not record the same low DO conditions. The macroinvertebrate and fish data indicate that the need to address DO in the watershed is not pressing: if this problem were consistent and persistent, these aquatic communities would have been affected. The data suggest that the low DO is caused by lack of mixing during low-flow periods and not by excess nutrients. BMPs that would increase the amount of flow in the channel, possibly by increasing the connection with groundwater, could be used, but this is a relatively unproven approach and few published studies report having successfully increased dissolved oxygen in a stream channel.

The clearest issue in Brushy Creek in terms of the watershed meeting its designated uses was the widespread fecal contamination. The concentrations of *E. coli* in the watershed frequently exceed surface water standards in all subwatersheds. BMPs to reduce the fecal loading from cattle and human sources are recommended and could be applied successfully in all subwatersheds where landowner cooperation can be obtained.

5 Loads Summary

5.1 Watershed Pollution Loads and Reduction Requirement Summary

Pollutant loads, target loads and load reductions needed to meet the water quality standards (WQS) were calculated for each parameter at each sampling site (Tables 4.7, 4.10 and 4.11). Kentucky Division of Water has regulatory water quality standards for some parameters (401 KAR 10:031) and sets benchmarks for other parameters. A benchmark is set for individual watersheds or streams based on conditions in other streams within the bioregion. Using the concentrations of parameters found in the stream, the benchmarks and water quality standards are used for calculating the target loads, and the present load and the target load are compared to determine the load reduction needed to meet the benchmark or the WQS.

There are 2 sets of Water Quality Standards for *E. coli*, depending on the sampling time frame. For a “five in thirty” event, which is 5 samples collected within 30 days during the Primary Contact Recreation season of May 1 through October 31, the WQS is set at 130 colony-forming units (CFU) per 100 mL for the average of the five samples. During an annual data collection period, the instantaneous standard is set at 240 colonies per 100 mL, not to be exceeded in more than 20 percent of the samples. Neither of these two standards shall be exceeded during the Primary Contact Recreation season. For the “five in thirty” sampling event, four of the sites sampled exceeded the WQS of 240 CFU/100 mL (Table 4.8). For the annual sampling period, all sampling sites exceeded the water quality standard of 240 CFU/100 mL in at least 44 percent of the samples taken at each site, three of which exceeded the standard in greater than 75 percent of the samples taken (Table 4.9).

Each sampling site will require approximately 50 percent reduction or greater in *E. coli* loads to reach the WQS. Upper and Lower Brushy sites will require greater than 80 percent load reductions to meet the standard (Table 4.10).

Nutrient samples were collected and loads were compared with KDOW benchmarks for each. The benchmark for TKN was set at 0.5 mg/L; however, for the majority of the sampling events, the laboratory detection limit was set at 1.0 mg/L. U of L calculated the loads using 0.5 mg/L to be conservative but the TKN and the calculated TN data could not be used for BMP prescription due to the lab not reaching the KDOW required detection limit of 0.5 mg/L (Table 4.6). The load reductions are considered accurate enough to suggest BMPs to limit nitrogen entering the stream because of the accompanied affect they will have on the other pollutants causing impairments in the watershed.

Phosphorus isn’t a major contributor to pollutant loads at any of the sampled sites; however many of the BMPs that will be implemented to address the other pollutants will also address the phosphorus loading. The site with the highest Phosphorus loading was Upper Bee Lick (BL2) with 43 percent exceedance of the KDOW benchmark set for Total Phosphorus (TP).

6 Best Management Practices

6.1 Best Management Practices

The Brushy Creek watershed does not support primary contact recreation due to *E. coli* and nutrient loading from both agriculture and on-site sewage treatment runoff. The primary land use is pasture for livestock, mostly cattle. There is no sewer service within the Brushy Creek Watershed; the wastewater from households is handled by onsite septic systems with the probability of some straight pipes scattered throughout the watershed.

Best Management Practices (BMPs) are implemented to reach goals set within the watershed plan. Therefore, the selection of BMPs is fundamental to the success of the watershed plan. The Pulaski County Conservation District and the Lake Cumberland District Health Department were consulted to determine the most effective BMPs as well as the most likely areas for recovery potential in the watershed.

Microbial source tracking was performed in the Brushy Creek watershed, although the method utilized was not considered to be reliable for abundance of any source tested. However, the tracking did confirm both human and bovine (cattle) source presence (phone conversation with Dr. Alice Jones 6/18/15).

Table 6.1 - Agriculture and On-site Sewage System BMPs for the Brushy Creek Watershed

	Structural BMPs	Non-Structural BMPs
Agriculture	• Livestock exclusion fencing • Alternative watering sources • Stream Crossings • Feeding and Heavy Use Area Protection • Nutrient Management • Riparian Area Protection • Prescribed Grazing	• Workshops, trainings, presentations on Ag water quality plans, nutrient management plans, & State Cost Share • Farm Field Days • Technical assistance for BMP implementation
On-site Sewage Treatment	• Septic tank pump outs • Septic system repair or replacement • Septic system installation for straight pipe issues	• Educational materials on septic system maintenance • Farm Field Days

6.2 Agriculture BMPs

The aforementioned agriculture BMPs were selected to achieve the reduction levels needed to acquire water quality standards for each sampling site (Table 6.1). These BMPs were identified as ones that would achieve the greatest water quality improvement, all of which are of high priority.

Kentucky's pasture based grazing systems often rely solely on rivers, lakes, streams, and springs for livestock water sources. The bordering area of these waterbodies is called the riparian area and that riparian area in an un-grazed system acts as a buffer of pollutants prior to reaching the surface water.

Where livestock are allowed to graze up to the water's edge, that riparian area is stripped of all vegetation, which causes soil compaction and erosion, an accumulation of animal excrement, and instability of the banks and channel, all of which contribute to increased sediments, nutrients, and pathogens entering the water source (AEN-105). This scenario is observed throughout the Brushy Creek Watershed and is the primary cause of stream impairment. Beef cattle are of primary concern in the Brushy Creek watershed and on average beef cattle deposit 6.6 kg (14.5 lb) of feces daily, of which 7.5% is found to be *E. coli* (Vadas 2015 and Omisakan et al. 2003). It is imperative that livestock, especially beef cattle, have limited access to streams through use of exclusion fencing and alternative water sources. If an alternative water source is not a viable option for certain landowners, then livestock will be excluded except where designated crossings and watering sites are created.

Rotational grazing is another critical piece to this improvement strategy. The herd is grazed alternately in two or more pastures to give the soil and vegetation a resting and re-growth period. When adequate amounts of vegetative cover are allowed to remain on the surface, this will slow the flow of surface runoff, allowing water to percolate into the soil and be used by the vegetation, and therefore reducing livestock manure and nutrients that are delivered to the streams through runoff. When these materials remain in place on the ground, they are able to break down into the soil and be used by the vegetation as well.

6.2.1 *E.coli* Contribution by Livestock

The 2007 USDA Agriculture Census recorded 4,232 beef cattle and 290 dairy cattle in the estimated 18,795 acres of pastureland of the Brushy Creek watershed. After determining the approximate number of cattle per subwatershed it was calculated that, on average, 97 percent of the *E.coli* loading in each subwatershed was being contributed by cattle. It is also estimated that the majority of this loading is occurring between the months of April and November when cattle are grazing heavily and spending more time in and near the streams to keep cool and maintain hydration. During the winter months of December through March cattle spend more time near the barn where feed is provided since there is a lack of vegetation available on the pasture and cattle are not trying to cool themselves in the different waterbodies.

Table 6.2 – Agriculture BMPs, Costs, Effectiveness, and Maintenance

BMP	NRCS Code	% E. coli Effectiveness*	Est. Cost $/unit	Life Span (yrs)
Fence	382	-	1.98/Ft	20
Livestock Pipeline	516	-	2.22/Ft	20
Watering Facility	614	-	1,221.33/Ea	20
Heavy Use Area Protection	561	85%	1.08/Sq.Ft.	10
Stream Crossing	578	50%	5.41/Sq.Ft.	10
Nutrient Management	590	-	5.67/Ac	1
Riparian Area Protection	390	60%	486.06/Ac	5

Prescribed Grazing	528	70%	11.47/Ac	1
Filter Strip	393	55-70%	383.72/Ac	10
Grassed Waterway	412	-	.04/Sq.Ft.	10
Forage and Biomass Planting	512	70%	232.88/Ac	5
Spring Development	574	-	1025.54/Ea.	20
Streambank & Shore Protection	580	60%	39.43/ton	20
Cover Crop	340	-	66.88/Ac	1

*Approximate percent reduction based on previous studies (KDOW)

6.2.2 Load reductions met by cattle exclusion practices

To determine the number of cattle per subwatershed within the whole Brushy Creek watershed, the following assumptions were made:

1. All cattle are found within areas designated as Pasture/Hay in the NLCD layer (81)
2. Each head of cattle produces 1.28 x10^{12} CFU *E.coli*/animal/year (Metcalf and Eddy, 1991).
3. Beef cattle spend ~50% of their time in the stream, so the yearly deposition directly in to a stream = 6.4 x10^{11} CFU *E.coli*/animal/year
4. All beef cattle/dairy cattle/ and calves are counted as equal contributors
5. Cattle density is based on number of cattle per acre of Pasture as determined using the 2011 NLDC GIS Layer
6. Where a subwatershed has two sampling points, Load Reductions needed were averaged to generate a single load reduction for the area

To begin we had to know how many head of cattle were present in each Brushy subwatershed by utilizing the USDA NASS data using the number from the “All Cattle & Calves” column. The most recent report for cattle in each county was taken and using the GIS’s most recent NLCD layer, determined the number of acres of pasture present in each county included in the watershed. Brushy Creek actually includes 3 counties so three different cattle/acre of pasture calculations were made. By using the HUC 12 layer, we determined the total number of acres of pasture in each subwatershed within the whole Brushy Creek watershed and then calculated the number of cows per subwatershed by multiplying the number of acres of pasture in each watershed by the number of cattle/acre of pasture previously calculated. (Tables 6.3 & 6.4)

Table 6.3 Cattle/acre of pasture calculations by county.

	Pulaski Co	Rockcastle Co	Lincoln Co
Total Acres, county	433374	203560	215263
Total Acres Pasture, county	90512	44101	96559
Total Cattle, county	64000	59000	14800
Cattle/ Acre of pasture	0.707	1.338	0.153

Table 6.4 Number of cattle in each subwatershed based on cattle/acre of pasture in Oldham Co.

HUC NUM/Subwatershed	Pulaski Co	Rockcastle Co	Lincoln Co	Total Cattle in Sub-watershed
5130103040010 Upper Brushy Creek	25	7736	10	7770
5130103040020 Upper Bee Lick	3595	2195	156	5947
5130103040030 Lower Brushy Creek	2001	62	0	2063
5130103040040 Clifty Creek	1654	0	0	1654

After determining the number of cattle/acre of pasture in each subwatershed the number of cattle needed to be excluded in each subwatershed was next determined. There are many variables affecting the actual load reaching the stream and there are multiple calculations to choose from to determine the amount of *E.coli* that is contributed per cow. Because of these factors, the number of cows to restrict from the waterbodies in a given watershed is a rough figure. The following are the calculations used to determine CFU/year and #cattle to exclude/subwatershed:

$$\left(5.4\ \mathrm{x}\ 10^{9}\frac{CFU\ Fecal\ Coliform}{day}\right)\left(\frac{130}{200}\right)\left(365\frac{days}{yr}\right) = 1.28\ \mathrm{x}\ 10^{12}\frac{CFU\ E.coli}{year}$$

and

$$\frac{\text{Load reduction needed}}{(6.40\ \mathrm{x}\ 10^{11}\ \text{CFU}\ \textit{E.coli}/\text{year})} = \#\ \text{cattle to exclude from stream}$$

Table 6.5 Number of cattle to be excluded from the stream in the Brushy Creek watershed.

HUC NUM/Subwatershed	Total Cattle in Subwatershed	Load Reduction Needed (CFU/year)	Head of Cattle to Exclude From Stream
5130103040010 Upper Brushy Creek	7770	5.45E+13	85
5130103040020 Upper Bee Lick Creek	5947	6.82E+13	107
5130103040030 Lower Brushy Creek	2063	3.03E+14	473
5130103040040 Clifty Creek	1654	1.98E+13	31

When calculating these numbers the assumption was that 100% of the E.coli loading was coming from 50% of the cattle in each subwatershed. These estimations are overly simplified in that they do not take into consideration wildlife, other livestock or septic problems as sources of E. coli loading.

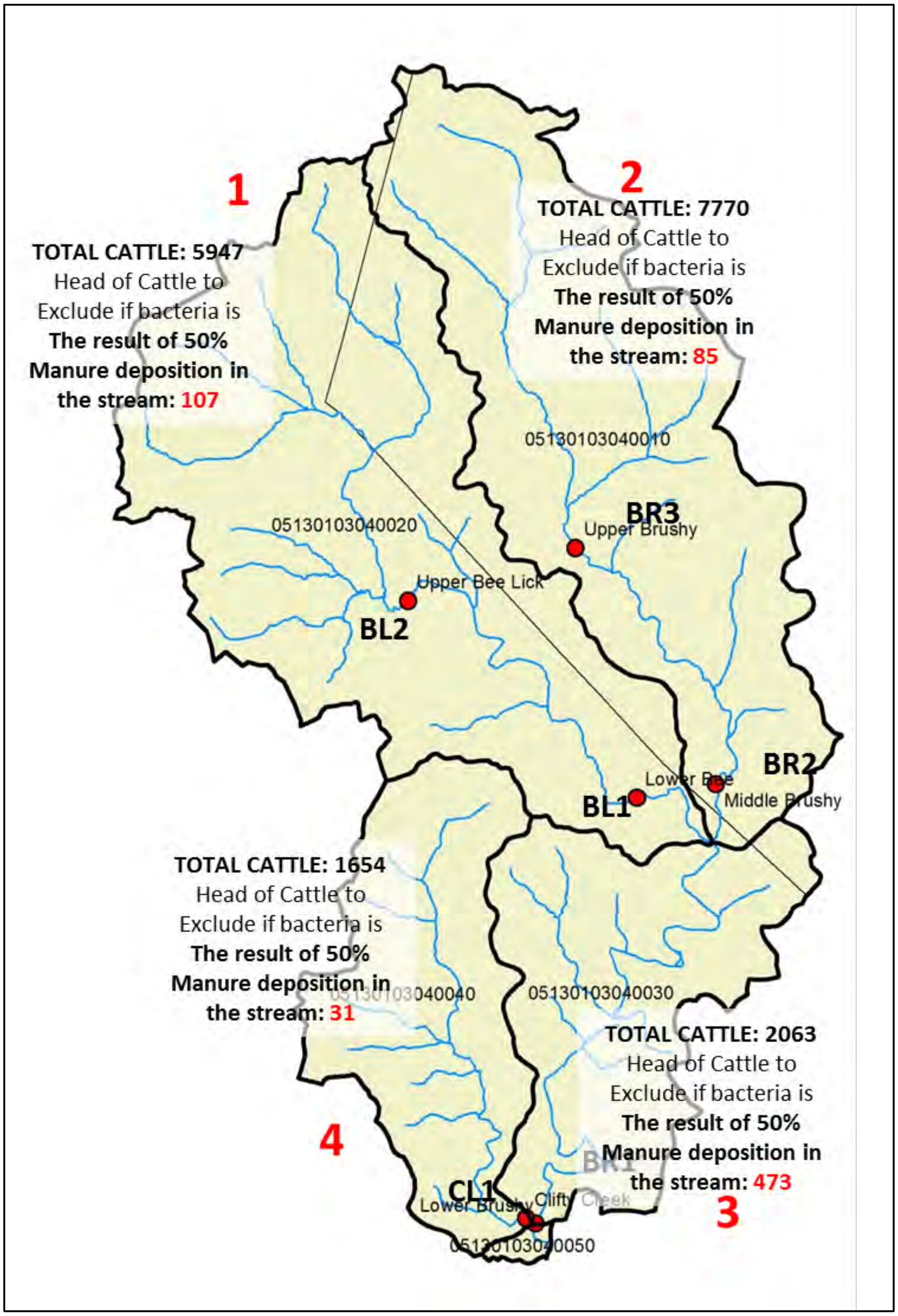


Figure 6.1 Agriculture Priority Areas. Map of the Brushy Creek Watershed Planning Area. Large red numbers indicate the suggested priority status of each subwatershed based on areas most in need of agricultural BMPs. Each subwatershed also shows, in small red numbers, how many head of cattle would be necessary to exclude from the creeks to reduce the bacteria load to meet water quality standards.

6.3 On-site Sewage BMPs

The on-site sewage BMPs (Table 6.1) were chosen to reduce the bacterial levels in the watershed by identifying properties with problem systems or without systems. In the case of a malfunctioning system, depending on the degree of malfunction, the applicable BMP would be tank pump out, repair, or replacement. In the case where residences are straight piping their septic waste, the applicable BMP would be the installation of a new system. These BMPs are expected to reduce the *E. coli* loading within the watershed and are considered a high priority to achieve safe primary contact recreation use.

Houses nearer the streams have greater potential for failing septic systems or straight pipes to discharge into the stream or riparian area. KDOW created a map in GIS using a population filter to determine the number of people residing in the riparian zone. The map was created using the following assumptions, and is displayed below (Figure 6.2):

- The entire population lives within 300 feet of a road.
- The population is evenly dispersed along the roads.
- The stream corridor was set at 180 feet.
- Areas with sewer were removed, with a 180-ft buffer set around sewer lines.
- All households outside the sewer buffer were assumed to have septic systems.
- The 2010 census was used to determine population density

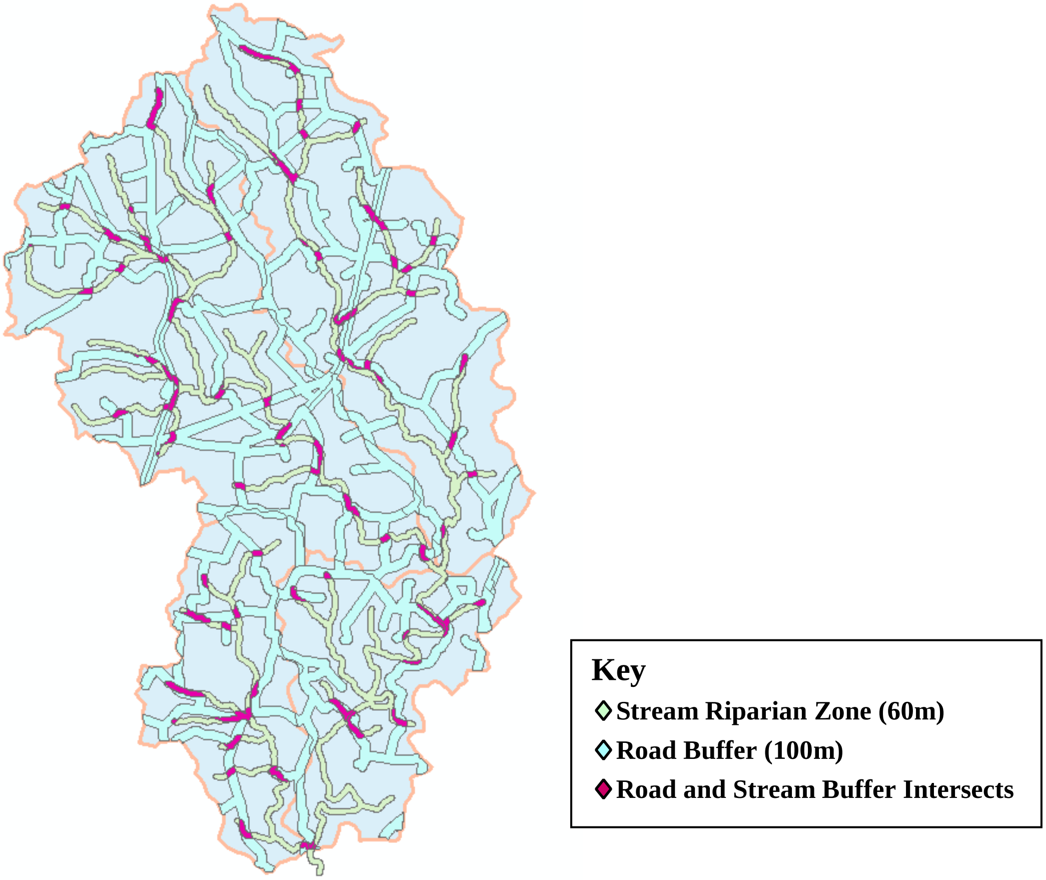


Figure 6.2 Stream Riparian Zones and Road Buffers

Using those data, we estimated the population within the riparian zone for each subwatershed.

Table 6.6 Estimated Riparian Zone Population

Estimate of Riparian Zone Population in Brushy Creek		
HUC_NUM	HUC Name	Population
05130103-040-010	Brushy Creek	92.1
05130103-040-020	Bee Lick Creek	127.7
05130103-040-030	Brushy Creek	60.4
05130103-040-040	Clifty Creek	90.8

Once the population using septic within the riparian zone was determined, the number of households on septic was calculated by using the number of 2.5 adults per household (EPA, 2002).

Table 6.7 Calculated number of households on septic.

HUC_NUM	Subwatershed Name	Watershed Population in Riparian Corridor	# households on Septic
05130103-040-010	Brushy Creek	92.1	37
05130103-040-020	Bee Lick Creek	127.7	51
05130103-040-030	Brushy Creek	60.4	24
05130103-040-040	Clifty Creek	90.8	36

Based on TetraTech's online STEPL Tool (http://it.tetratech-ffx.com/steplweb/steplweb.html), the failure rate for the watershed was determined to be 34% of all households on septic. That information was provided for the entire HUC 12 Brushy Creek watershed. This is likely an underestimate due to difficulty getting current information on where septic systems are located. (Appendix J). Using that information we determined the total number of assumed failing septic systems within each subwatershed (Table 6.8).

Table 6.8 Number of septic systems needing replacement.

HUC_NUM	Subwatershed Name	Watershed Population in Riparian Corridor	# households on Septic	# Systems needing replacement
05130103-040-010	Brushy Creek	92.1	37	13
05130103-040-020	Bee Lick Creek	127.7	51	17
05130103-040-030	Brushy Creek	60.4	24	8
05130103-040-040	Clifty Creek	90.8	36	12

To calculate the bacteria load reduction possible if all the failing systems are replaced, the following process was used. One failing septic system produces wastewater with a bacteria level of 10^4.57 CFU/100 mL of Fecal Coliform, and the average household produces 150 gal/day of wastewater (from the EPA Onsite Wastewater Treatment Manual, 2002). We calculate the daily wastewater fecal bacteria load from a failing system by:

$$\left(\mathbf{150}\,\frac{gal}{day}\right)\left(\mathbf{3785.41}\,\frac{mL}{gal}\right)\left(\frac{10^{4.57}\,CFU}{100mL}\right) = \mathbf{2.11 \text{ x } 10^{8}\ \textbf{CFU Fecal Coliform/day}}$$

From this, we must convert from fecal coliforms to E. *coli*. Standards for how to accomplish this vary, as relationships seem to be highly influenced by environment. In the absence of location specific conversion equations, we will use the TMDL standard conversion:

$$\left(\mathbf{2.11 \text{ x } 10^{8}}\,\frac{CFU\ Fecal\ Coliform}{day}\right)\left(\frac{\mathbf{130}}{\mathbf{200}}\right) = \mathbf{1.37 \text{ x } 10^{8}}\,\frac{CFU\ E.coli}{day}$$

Calculate the Annual Loading Rate per septic system:

$$\left(\mathbf{1.37 \text{ x } 10^{8}}\,\frac{CFU\ E.coli}{day}\right)\left(\frac{365\ days}{yr}\right) = \mathbf{5.01 \text{ x } 10^{10}}\,\frac{CFU\ E.coli}{yr}$$

Once you have this number you can find out what load reduction would be achieved if you replace all the failing septic systems (see Table 6.9), by multiplying the number of systems that should need replacing by the Annual E.coli Loading Rate. Then determine how much of the required load reduction is addressed by replacing the failing systems:

(Load Reduction if all Systems Replaced) / (Load Reduction Needed) * 100 = % of Necessary Load Reduction Accomplished if All Failing systems Replaced

Table 6.9 Load reductions for septic replacement of failing systems.

HUC NUM	Subwatershed Name	Site Name	Load reduction Needed (CFU/year)	# Systems Needing Replacement (34% Failure Rate)	Load Reduction if All Failing Systems Replaced	% of Necessary Load Reduction Accom-plished if All Failing Systems Replaced
5130103040010	Brushy Creek	BR2, BR3	5.45E+13	**13**	6.513E+11	1
5130103040020	Bee Lick Creek	BL1, BL2	6.82E+13	**17**	8.517E+11	1
5130103040030	Brushy Creek	BR1	3.03E+14	**8**	4.008E+11	0
5130103040040	Clifty Creek	CL1	1.98E+13	**12**	6.012E+11	3

Note: Where there were two or more sampling sites in a watershed, load reduction needed is calculated as the average of these.

Assuming each failing septic system produces wastewater with 5.01×10^{10} CFU *E.coli*/year, the number of septic systems to repair would be all that are present in each watershed. Although all septic systems are suggested to be replaced, when calculating out the load reductions that would provide, we would only be reducing a maximum of 9% of the total E.coli loads to the stream in any given subwatershed (Table 6.10).

Table 6.10 Load reductions for septic replacement of all systems.

HUC NUM	Subwatershed name	Load reduction Needed (CFU/year)	# households assumed on septic	Load Reduction if all systems in the watershed are replaced	% of Necessary Load Reduction Accomplished if All Systems are Replaced
5130103040010	Brushy Creek	5.45E+13	37	1.8537E+12	3
5130103040020	Bee Lick Creek	6.82E+13	51	2.5551E+12	4
5130103040030	Brushy Creek	3.03E+14	24	1.2024E+12	0
5130103040040	Clifty Creek	1.98E+13	36	1.8036E+12	9

Based on the information, replacing all of the failing septic systems in the watershed would result in 9% or less improvement in bacteria loads in each of the subwatersheds, suggesting that human inputs are not likely to be as important as agricultural inputs in this region. Septic BMPs should focus in on the headwaters in Brushy Creek (HUC# 10) and Bee Lick Creek. The greatest potential improvement is in Clifty Creek, but it is still well below what improvements would be achieved by implementation of Ag BMPs.

The lowest priority would be Brushy Creek (HUC# 30), mainly due to its position relative to the Brushy Creek (HUC# 10) and Bee Lick Creek subwatersheds, and due to the fact that there are fewer failing systems in this region.

Based on these numbers, septic BMPs should focus on the headwaters in Upper Bee Lick and Upper Brushy Creeks to achieve the greatest E.coli load reductions when paired with agriculture BMPs. See Figure 6.3.

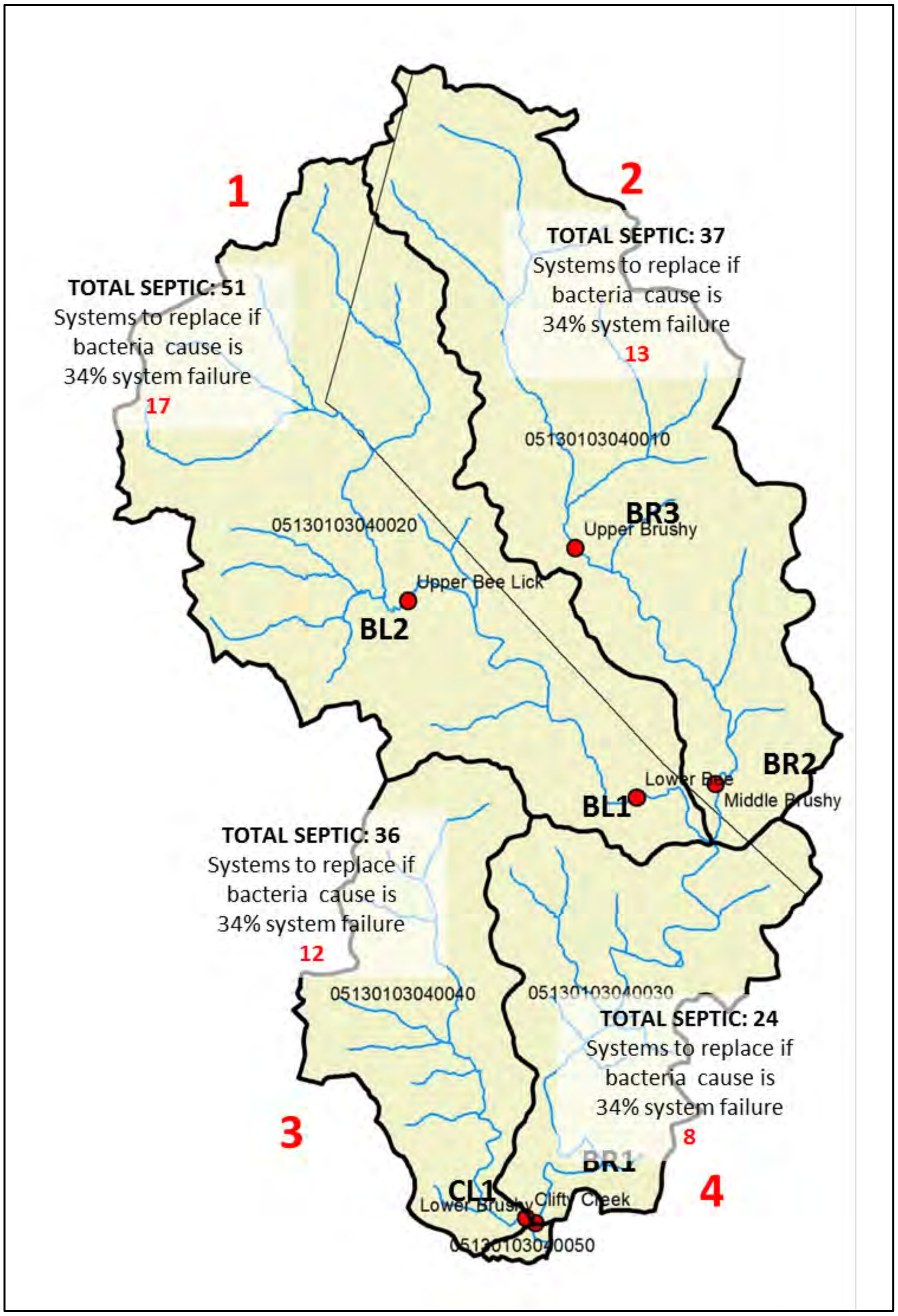


Figure 6.3 Septic Priority Areas. Map of the Brushy Creek Watershed Plan area and potential septic prioritization. 1 is the highest priority, and 4 is the lowest.

6.4 Education and Outreach BMPs

The educational BMP component is a critical step toward load reduction and should be a continuing effort during execution of the long term protection part of the plan. Initially an education and outreach campaign will be directed to a target audience of landowners and cattle farmers. Pulaski County Conservation District (PCCD) staff will contact those landowners/farm operators to arrange and conduct site visits to determine the type and amount of assistance that can be provided for the most effective agricultural BMPs on their land. The home owners that are in the target area will be contacted through the Lake Cumberland District Health Department via informational fact sheets in the mail and then through a home visit by a certified septic installer or pumper to determine the onsite needs of the interested residents. Farm field days to demonstrate BMPs, school visits to educate children on both septic and agriculture pollution issues, and educational signage will also be utilized throughout the execution of the plan. In the past, effectiveness of these activities has been tracked by simply keeping record of the number of participants at each event to determine the approximate number of people educated.

7 Implementation

7.1 Implementation Strategy

The Pulaski, Lincoln, and Rockcastle County Conservation Districts along with the Lincoln and Rockcastle County Health Departments and Lake Cumberland Health District will partner with KDOW to implement the most cost effective and goal achieving BMPs in the Brushy Creek Watershed. This strategy will target key areas to implement those BMPs as well as to conduct public outreach, implementation, and success monitoring.

After evaluating the data collected through the U of L Stream Institute, KDOW's estimated load reduction needs and abilities, and local knowledge of the watershed from Pulaski County Conservation District and Lake Cumberland Health District, the Upper Brushy and Upper Bee Lick Creek subwatersheds were selected as first priority. Therefore, implementation efforts will focus in these subwatersheds first.

Bee Lick Creek has also been designated by USDA/NRCS as a priority watershed through their 2016 Mississippi River Basin Initiative, where resources will be focused independent of this watershed plan. Middle Brushy and Lower Bee Lick are set as second priority subwatersheds with Lower Brushy and Clifty Creek being third on our priority list.

The maintenance and repair of septic systems will be performed by a Kentucky certified septic pumping company and/or septic system installer. If that company determines that there is a problem, the homeowner knows of an issue, or the health department has record of an issue with that system, they can apply for the repair program by submitting an application to the PCCD for funding assistance up to the specified dollar amount on the application. The application will include the location of the home, distance to a stream, well or sinkhole/depression, current wastewater situation, and household income. Applications will be prioritized based on these factors; homes within the target subwatershed and with the closest proximity to a stream, well, or sinkhole will be given highest priority.

Landowners seeking funding assistance will go through an application process, wherein the applications will be ranked through a process to ensure maximum protection of surface and groundwater. The KDOW and partnering agencies will work with the landowners to design and implement BMPs geared toward protection of the Brushy Creek water bodies.

When an application is selected to receive financial assistance through the program, the homeowner will be required to sign a contractual commitment to pay for the required permit fees and site evaluation costs as well as to maintain the system with proper care and regular pumping out of the tank.

Mailings to landowners will be produced to distribute to agricultural producers within the watershed to notify them of the timeframe in which to apply with the Pulaski County Conservation

District. This will begin the process for producers to receive funding from the PCCD to reduce their farm's impacts on water quality within the Brushy Creek Watershed. The producers will fill out an application that will then be ranked according to the greatest potential positive impact on water quality.

7.2 Cost Estimates

Funding through Section 319(h) of the Clean Water Act was directed by EPA to KDOW's Non-point Source Pollution (NPS) Control Program. The PCCD has secured a KDOW 319 grant to implement the watershed plan. Those funds will be matched at a 60/40 rate with Division of Conservation (KDOC) State Cost Share. The grant will also cover a selected number of the recommended BMPs. Additional funding is needed to put more BMPs on the ground and ensure the long term success of them. The KDOW will contract with the Pulaski, Lincoln, and Rockcastle County Conservation Districts as well as the local health departments in those counties to implement this plan. The following estimates are for Phase I subwatersheds, Upper Brushy and Upper Bee Lick Creeks (Table 7.1):

Table 7.1 KDOC's Estimates of BMP costs for Phase 1 Implementation in Upper Brushy Creek and Upper Bee Lick Creek

Best Management Practice	Quantity	Cost share/ BMP	Total Cost
Tank (ea)	8	$1,782.00	$14,256.00
Pipeline (ft)	3,000	$1.98	$5,940.00
Heavy Use Area Protection (sq ft)	3,500	$1.55	$5,425.00
Cover Crop - N Scavenging (ac)	150	$49.11	$7,366.50
Cover Crop - Soil Health (ac)	50	$78.15	$3,907.50
Fence (ft)	5,000	$1.53	$7,650.00
Filter Strip (ac)	1	$215.00	$215.00
Prescribed Grazing (ac)	100	$12.06	$1,206.00
Stream Crossing (sq ft)	2,000	$2.79	$5,580.00
Riparian Forest Buffer (ac)	1	$707.80	$707.80
Grassed Waterway (ac)	2	$1,547.00	$3,094.00
Forage and Biomass Planting (ac)	40	$211.86	$8,474.40
Spring Development (ea)	1	$2,005.00	$2,005.00
Streambank & Shore Protection (linear feet (LFT))	100	$52.00	$5,200.00
Critical Area Planting (ac)	1	$698.05	$698.05
Diversion (ft)	150	$1.97	$295.50
Nutrient Management (ac)	90	$10.00	$900.00
Pasture and Hayland Renovation (ac)	60	$142.00	$8,520.00
Pond (cu yd)	1,000	$2.35	$2,350.00
Roof Runoff Management (LFT)	100	$7.90	$790.00
Tree/Shrub Establishment (ac)	1	$176.00	$176.00
Waste Storage Facility (sq ft)	2,000	$4.22	$8,440.00
Waste Treatment Lagoon (cu ft)	10,000	$0.27	$2,700.00
Well (ft)	100	$14.14	$1,414.00
Total Cost: Priority 1 Subwatersheds			**$97,310.75**

Table 7.2 Estimated Cost of Onsite Sewage Disposal Systems Best Management Practices in Priority 1 Subwatersheds

Subwatershed	# Failing Septic Systems	Cost/BMP (Septic Repair or replacement)	Total Cost
Upper Bee Lick Creek	26	$4,000	$104,000
Upper Brushy Creek	19	$4,000	$76,000
Total	45	$4,000	$180,000

7.3 Public Education and Participation

KDOW will work with local partners in the watershed to provide proper educational materials regarding water quality issues and appropriate BMPs as well as funding sources. The outreach will include mailings through utility billing, site visits, field days and potentially other mechanisms as the project develops. KDOW staff will work with partnering health departments to conduct workshops for landowners in the watershed to inform them of proper septic system operation and maintenance. Within these workshops, a water quality update of the watershed will be included to inform the attendees of the importance of proper maintenance. At the beginning of the septic repair program an inspection and pump out will be offered to those interested, to determine needs for that specific site. The number of applicants will be recorded as well as the number of applicants that receive funding assistance to determine effectiveness as well as future needs.

Table 7.3 Implementation Schedule and Milestones

BMP	Start Date	End Date
Submit all draft materials to NPS staff for approval	Duration	
Submit written notice on all workshops, demonstrations, and/or field days to NPS staff	Duration	
Submit annual reports	Duration	
Form Project Oversight Committee (POC)	August 2016	October 2016
Identify and contact key stakeholders	August 2016	December 2016
Develop and submit BMP Implementation Plan	October 2016	December 2016
Develop and submit Education and Outreach Plan	October 2016	December 2016
POC to assist with outreach and project awareness	November 2016	March 2017
Conduct public outreach	December 2016	March 2017
Identify potential cooperators and agree on practice	December 2016	March 2017
Identify potential cooperators for soil health plots	December 2016	September 2017
POC review proposed BMPs	March 2017	April 2017
Design and install BMPs	March 2017	March 2019
Prepare and submit annual report	May 2017	June 2017
Conduct adult training workshop and/or field day	August 2017	October 2017
Conduct environmental education at schools	August 2017	May 2018
Implement soil health cover and collect data	September 2017	December 2018
Install > 50% of BMPs	March 2017	March 2018
POC to review 1st year BMP installation	March 2018	April 2018
Prepare and submit annual report	May 2018	June 2018

Conduct adult training workshop and/or field day	August 2018	October 2018
Conduct environmental education at schools	August 2018	May 2019
POC to review completion of BMP installation	March 2019	April 2019
Conduct meeting with stakeholders	April 2019	May 2019
Prepare and submit two copies of the Final Report and submit three copies of all products by this project	May 2019	June 2019

7.4 Evaluation of Effectiveness

Monitoring will be conducted in the PCR season of 2018 to determine if the BMPs that have been implemented are achieving a reduction in the E. coli loads in the Upper Bee Lick and Upper Brushy Creek streams. The monitoring that will be performed will be a “five in 30” - five samples are collected within a 30-day period during the PCR season at each site that E. coli sampling occurred during Phase Two of the initial data collection. This monitoring plan will help to determine if the BMPs being implemented are addressing the E. coli loading. If, after the sampling events, it is determined that PCR water quality has been met, we can infer that the proper BMPs have been installed. If the data from these sampling events show that the BMPs have not achieved PCR water quality standards then alternate or additional BMPs will be added to the future course of action.

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Appendices

Appendix J

PRIORITIZATION METHODOLOGY: Brushy Creek Bacteria

Standard operating procedure to estimate subwatershed prioritization and BMP needs for watershed plan development. Developed by Dale Booth, Salt River Basin Coordinator, 2/2016.

To determine which areas of your watershed should be prioritized for specific bacteria BMPs you have to know:

- The reduction of the pollutant load required for the subwatershed
- The likely source of the pollutant (human vs ag)
- The number of those sources (number of septic systems, head of cattle, etc)
- The amount of bacteria contributed per unit (per one failing septic, per one head of cattle in the stream

Assuming you've already calculated the annual load (CFU/yr) and the necessary load reductions for each site, you need to figure out the potential sources of bacteria. This can be complicated when you attempt to quantify all the potential sources, but for the purposes of watershed planning, we can simplify the process while still making a big impact by focusing in on cattle and septic sources. This means you need data on how many septic systems and livestock are present in each HUC14 (or whatever level HUC you are investigating). For this document we will use **the Brushy Creek Watershed Plan** as a case study.

Septic Prioritization

To determine the number of septic systems in a subwatershed you need to know your population and where they are living. Create a GDA help desk request (if you are a Watershed Coordinator, contact your Basin Coordinator. Turn-around time will be 1-2 weeks)
Generate a map of target area that estimates the population in the riparian corridor on septic. The following assumptions apply:

- The entire population lives within 100 m of a road.
- The population is evenly dispersed along the roads.
- The stream corridor was set at 60 m.
- Areas with sewer were removed, with a 60 m buffer set around sewer lines.
- All households outside the sewer buffer were assumed to have septic systems.
- The 2010 census was used to determine population density (if you have more recent information you should use it.)

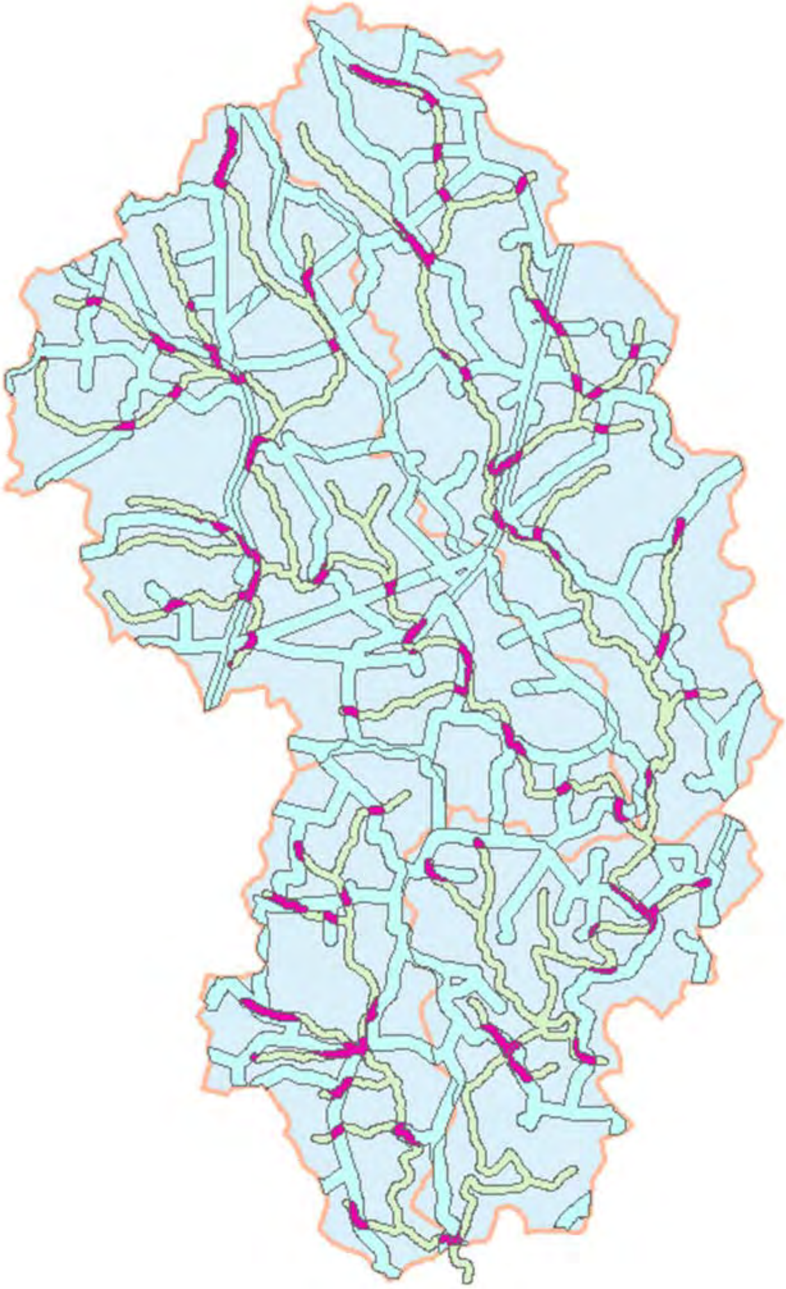


Fig. 1) Example of GDA Map of Brushy Creek Watershed population using septic systems within the riparian corridor. (KDOW, 2016)

Table 1) Example of population estimate within the riparian corridor, calculated using GIS analysis. (KDOW, 2016)

Estimate of Riparian Zone Population in Brushy Creek		
HUC_NUM	Subwatershed Name	Watershed Population in Riparian Corridor
05130103-040-010	Brushy Creek	92.1
05130103-040-020	Bee Lick Creek	127.7
05130103-040-030	Brushy Creek	60.4
05130103-040-040	Clifty Creek	90.8

Once you know the population using septic systems within the riparian corridor, you estimate the number of households on septic assuming that there are on average 2.5 adults per household (EPA, 2002).

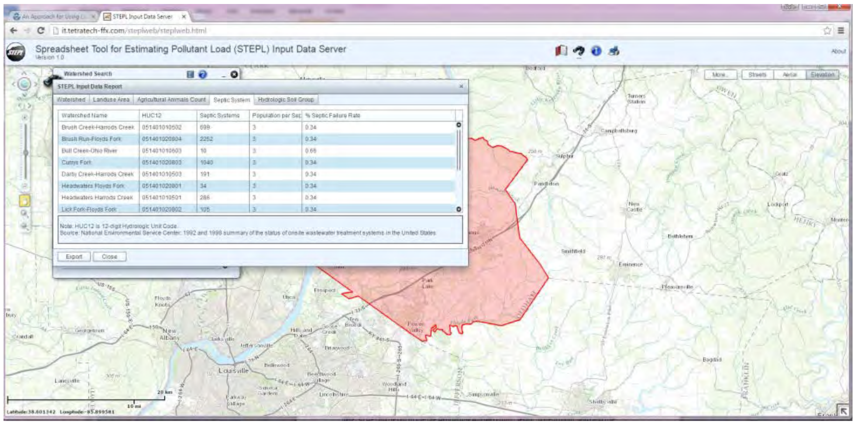
Table 2) Calculated number of households on septic.

HUC_NUM	Subwatershed Name	Watershed Population in Riparian Corridor	# households on Septic
05130103-040-010	Brushy Creek	92.1	37
05130103-040-020	Bee Lick Creek	127.7	51
05130103-040-030	Brushy Creek	60.4	24
05130103-040-040	Clifty Creek	90.8	36

Use TetraTech's online STEPL Tool to find out the failure rate for the target area. (http://it.tetratech-ffx.com/steplweb/steplweb.html)

1. Select the state
2. Select the county
3. Run the report
4. Select the Septic System Tab, and find the Septic Failure Rate for your watershed

This gives you information at the HUC 12 level for the whole county. Some of this information is out of date, so we choose not to use the Agricultural Animals Count, Septic System count, and Land Use information that is generated. The model uses some different assumptions about # of adults per household, and also the data at the HUC 12 level may be the wrong resolution for most watershed planning efforts, as we tend to focus on the HUC 14 level. However, the calculation of septic failure rate is one that we will use for the purposes of watershed planning (NESC, 1998). It is likely an underestimate, as getting up to date info on where septic systems are is fairly difficult.



Watershed Name	HUC12	Septic Systems	Population per Sep	% Septic Failure Rate
Brush Creek-Harrods Creek	051401010502	699	3	0.34
Brush Run-Floyds Fork	051401020804	2252	3	0.34
Bull Creek-Ohio River	051401010603	10	3	0.66
Currys Fork	051401020803	1040	3	0.34
Darby Creek-Harrods Creek	051401010503	191	3	0.34
Headwaters Floyds Fork	051401020801	34	3	0.34
Headwaters Harrods Creek	051401010501	286	3	0.34
Lick Fork-Floyds Fork	051401020802	105	3	0.34

Note: HUC12 is 12-digit Hydrologic Unit Code.
Source: National Environmental Service Center: 1992 and 1998 summary of the status of onsite wastewater treatment systems in the United States

Figure 2) Screenshot of StepL model output.

Use the StepL Septic Failure Rate to calculate the number of septic systems in each subwatershed that will need replacement.

Table 3.) Number of systems needing replacement given the StepL septic failure rate of 34%.

HUC_NUM	Subwatershed Name	Watershed Population in Riparian Corridor	# households on Septic	# Systems Needing Replacement (34% Failure Rate)
05130103-040-010	Brushy Creek	92.1	37	13
05130103-040-020	Bee Lick Creek	127.7	51	17
05130103-040-030	Brushy Creek	60.4	24	8
05130103-040-040	Clifty Creek	90.8	36	12

Now calculate the bacteria load reduction possible if all the failing systems are replaced.
One failing septic system produces wastewater with a bacteria level of 10^4.57 CFU/100ml of Fecal Coliform, and the average household produces 150 gal/day of wastewater (from the EPA Onsite Wastewater Treatment Manual, 2002). We calculate the daily wastewater bacteria load from a failing system by:

$$\left(150\,\frac{gal}{day}\right)\left(3785.41\,\frac{mL}{gal}\right)\left(\frac{10^{4.57}\,CFU}{100mL}\right) = \mathbf{2.11 \times 10^{8}\ CFU\ Fecal\ Coliform/day}$$

Standards have changed in the last few years to using *E.coli* instead of Fecal Coliforms, so this number must be converted. Standards for how to accomplish this vary, as relationships seem to be highly influenced by environment. In the absence of location specific conversion equations, we will use the TMDL standard conversion:

> *"In the event that compliance with the WQC is determined using E. coli concentrations as opposed to fecal coliform concentrations, the final fecal coliform allocations can be converted to E. coli by multiplying by the figure (240/400) for instantaneous values, or by the figure (130/200) for the 30- day geometric mean value, assuming 5 or more samples are taken within a 30-day period."* (From the Total Maximum Daily Load for Fecal Coliform and E. coli, 9 Stream Segments

and 2 Springs within the South Elkhorn Creek Watershed, Fayette, Franklin, Jessamine, Scott, and Woodford Counties, Kentucky. Nov. 2011)

$$\left(\mathbf{2.11\ x\ 10^{8}}\,\frac{\boldsymbol{CFU\ Fecal\ Coliform}}{\boldsymbol{day}}\right)\left(\frac{\mathbf{130}}{\mathbf{200}}\right)=\mathbf{1.37\ x\ 10^{8}}\,\frac{\boldsymbol{CFU\ E.coli}}{\boldsymbol{day}}$$

Calculate the Annual Loading Rate per septic system:

$$\left(\mathbf{1.37\ x\ 10^{8}}\,\frac{\boldsymbol{CFU\ E.coli}}{\boldsymbol{day}}\right)\left(\frac{\mathbf{365}\ \boldsymbol{days}}{\boldsymbol{yr}}\right)=\mathbf{5.01\ x\ 10^{10}}\,\frac{\boldsymbol{CFU\ E.coli}}{\boldsymbol{yr}}$$

Once you have this number you can find out what load reduction would be achieved if you replace all the failing septic systems, by multiplying the number of systems that should need replacing by the Annual E.coli Loading Rate (see Table 4).

Next, determine how much of the required load reduction is addressed by replacing these systems.

(Load Reduction if all Systems Replaced) / (Load Reduction Needed) * 100 = % of Necessary Load Reduction Accomplished if All Failing systems Replaced

Table 4. Example of calculations for load reductions when septic systems are replaced for the Brushy Creek Watershed Project. Note: Load reduction needed is calculated as the average for the subwatershed where there were two or more sample sites.

HUC NUM	Subwatershed Name	Site Name	Load reduction Needed (CFU/year)	# Systems Needing Replacement (34% Failure Rate)	Load Reduction if All Failing Systems Replaced	% of Necessary Load Reduction Accomplished if All Failing Systems Replaced
5130103040010	Brushy Creek	BR2, BR3	5.45E+13	**13**	6.513E+11	1
5130103040020	Bee Lick Creek	BL1, BL2	6.82E+13	**17**	8.517E+11	1
5130103040030	Brushy Creek	BR1	3.03E+14	**8**	4.008E+11	0
5130103040040	Clifty Creek	CL1	1.98E+13	**12**	6.012E+11	3

Table 5. Example of calculations assuming that all possible septic systems in the watershed are failing and then replaced.

HUC NUM	Load reduction Needed (CFU/year)	# households assumed on septic	Load Reduction if all systems in the watershed are failing and all are replaced	% of Necessary Load Reduction Accomplished if All Systems are Failing and Replaced
5130103040010	5.45E+13	37	1.8537E+12	3
5130103040020	6.82E+13	51	2.5551E+12	4
5130103040030	3.03E+14	24	1.2024E+12	0
5130103040040	1.98E+13	36	1.8036E+12	9

Apply this information to prioritize watershed Septic BMPs:

Based on the information, replacing all of the failing septic systems in the watershed would result in 9% or less improvement in bacteria loads in each of the subwatersheds suggesting that human inputs are not likely to be as important as agricultural inputs in this region. Septic BMPs should focus in on the headwaters in HUC 5130103040010 and HUC 5130103040020. The greatest potential improvement is in Clifty Creek (HUC #40), but it is still well below what improvements would be achieved by implementation of Ag BMPs.

The lowest priority would be HUC# 30, mainly due to its position relative to the HUC #s 10 and 20, and due to the fact that there are fewer failing systems in this region.

Figure 3) Map of the Brushy Creek Watershed Plan area and potential septic prioritization, with 1 being highest priority, and 4 being lowest.

Each subwatershed shows how many systems should need replacing if there is a failure rate of 34%, and shows how much replacing these systems will improve the overall load in the area. The large red numbers indicate the priority level assigned to each subwatershed based on the amount of improvement estimated by the calculations.