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# Brushy Creek Watershed Plan

Upper Cumberland Basin, Kentucky

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May 2017

# **Brushy Creek Watershed Plan**

Upper Cumberland Basin, Kentucky

May 2017

## **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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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.

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## Abbreviations and Symbols

|                                     |   |
|-------------------------------------|---|
| Ammonia-N                           | Ammoniacal nitrogen                             |
| BMP                                 | Best management practice                        |
| CaCO <sub>3</sub>                   | 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 <sub>3</sub> <sup>+</sup>        | Un-ionized ammonia                              |
| NH <sub>3</sub> -N                  | Ammoniacal nitrogen                             |
| NH <sub>4</sub>                     | Ammonia   |
| NLCD                                | National Land Cover Dataset                     |
| NO <sub>2</sub>                     | Nitrite   |
| NO <sub>3</sub> +NO <sub>2</sub> -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 <sub>4</sub> -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 (*Epio-*blasma 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

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## 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<sup>2</sup>) to 14 for very small HUCs (e.g., less than 1 mi<sup>2</sup>). The Brushy Creek 10-digit HUC contains 44.4 mi<sup>2</sup> 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<sup>2</sup> and joins Upper Brushy, HUC 05130103040010, which drains 14.04 mi<sup>2</sup>. Clifty Creek, HUC 05130103040040, drains 6.4 mi<sup>2</sup> and joins Lower Brushy, HUC 05130103040030, which drains 7.06 mi<sup>2</sup>. 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 55.3°F, 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).

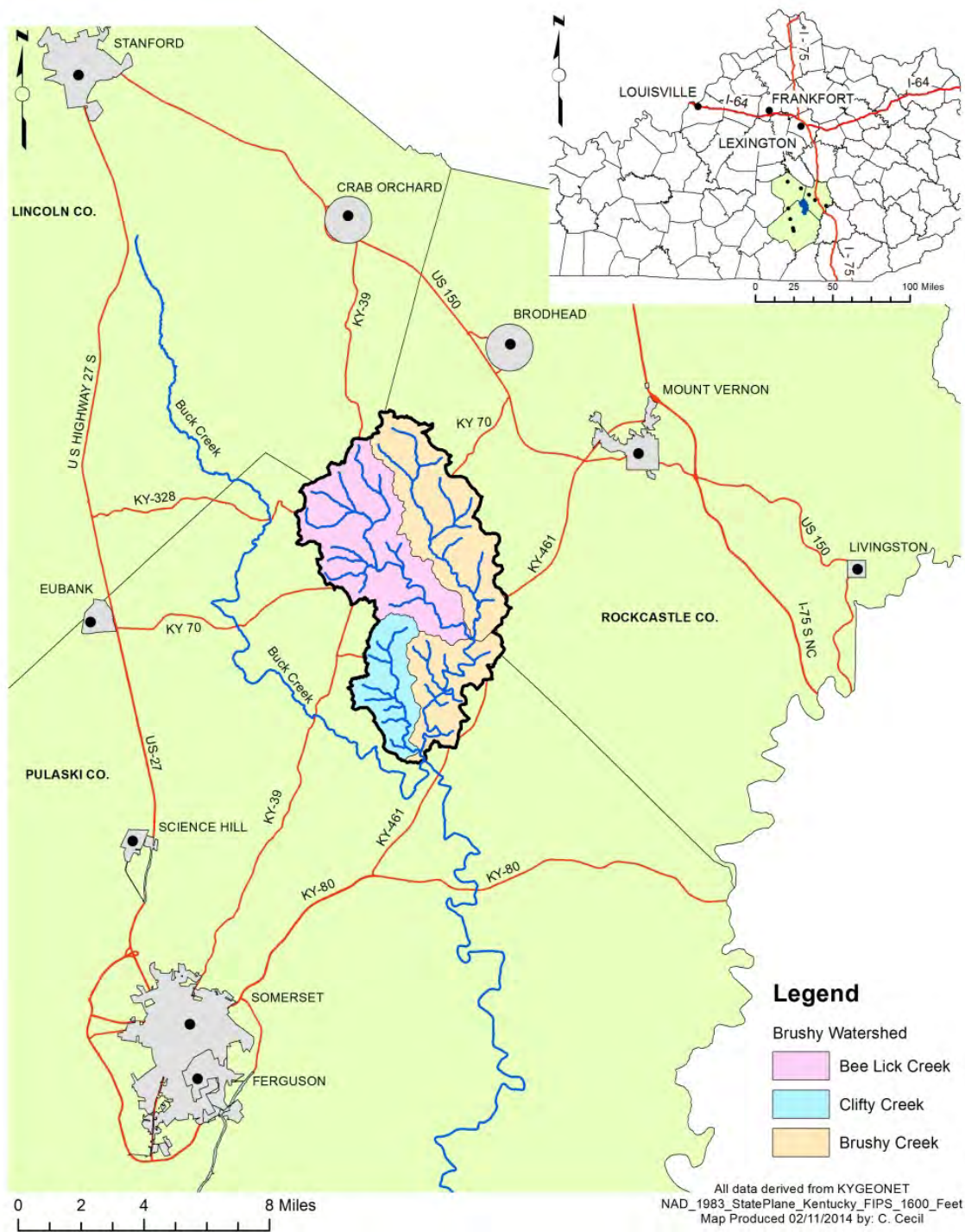
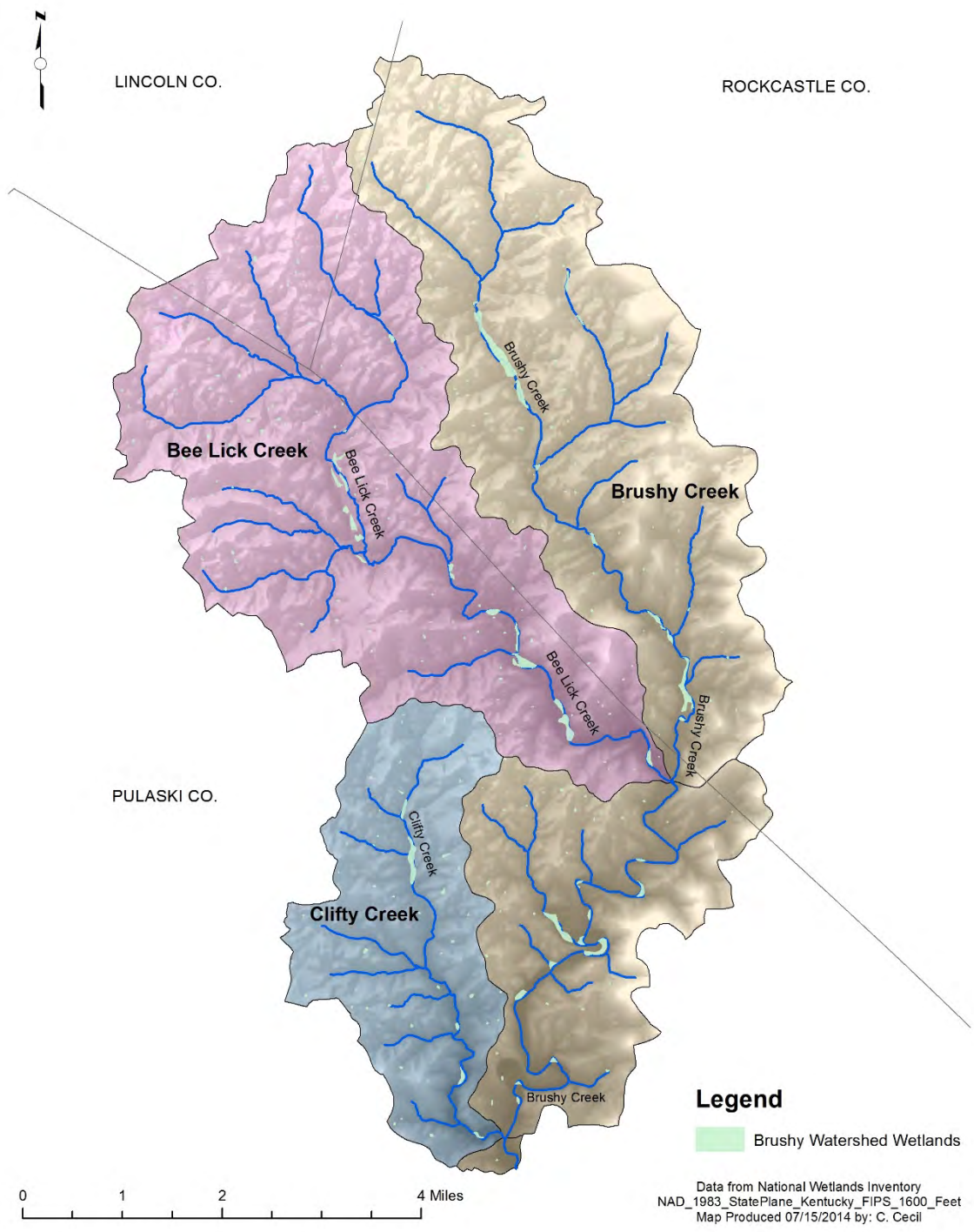


Figure 2.1 Brushy Creek watershed location map.





**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

| Month         | Temperature (°F) |             |             | Precipitation (inches) |
|---------------|------------------|-------------|-------------|------------------------|
|               | 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                   |
| <b>Annual</b> | <b>65.8</b>      | <b>44.8</b> | <b>55.3</b> | <b>52.43</b>           |

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

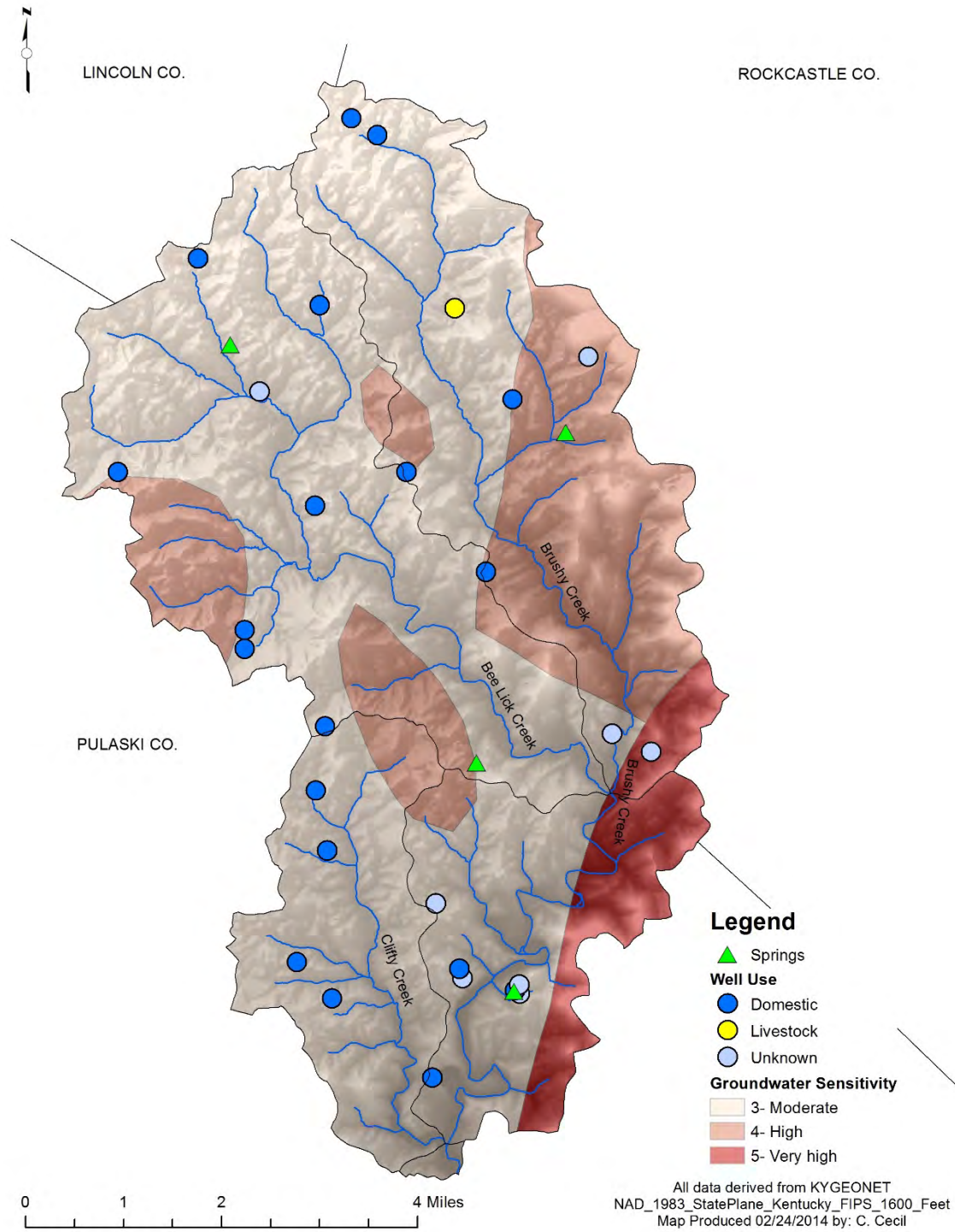
| Probability* |                              | Temperature   |               |
|--------------|------------------------------|---------------|---------------|
|              |                              | 28°F or lower | 32°F or lower |
| 50%          | Beginning and ending dates   | 4/8 to 10/29  | 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.





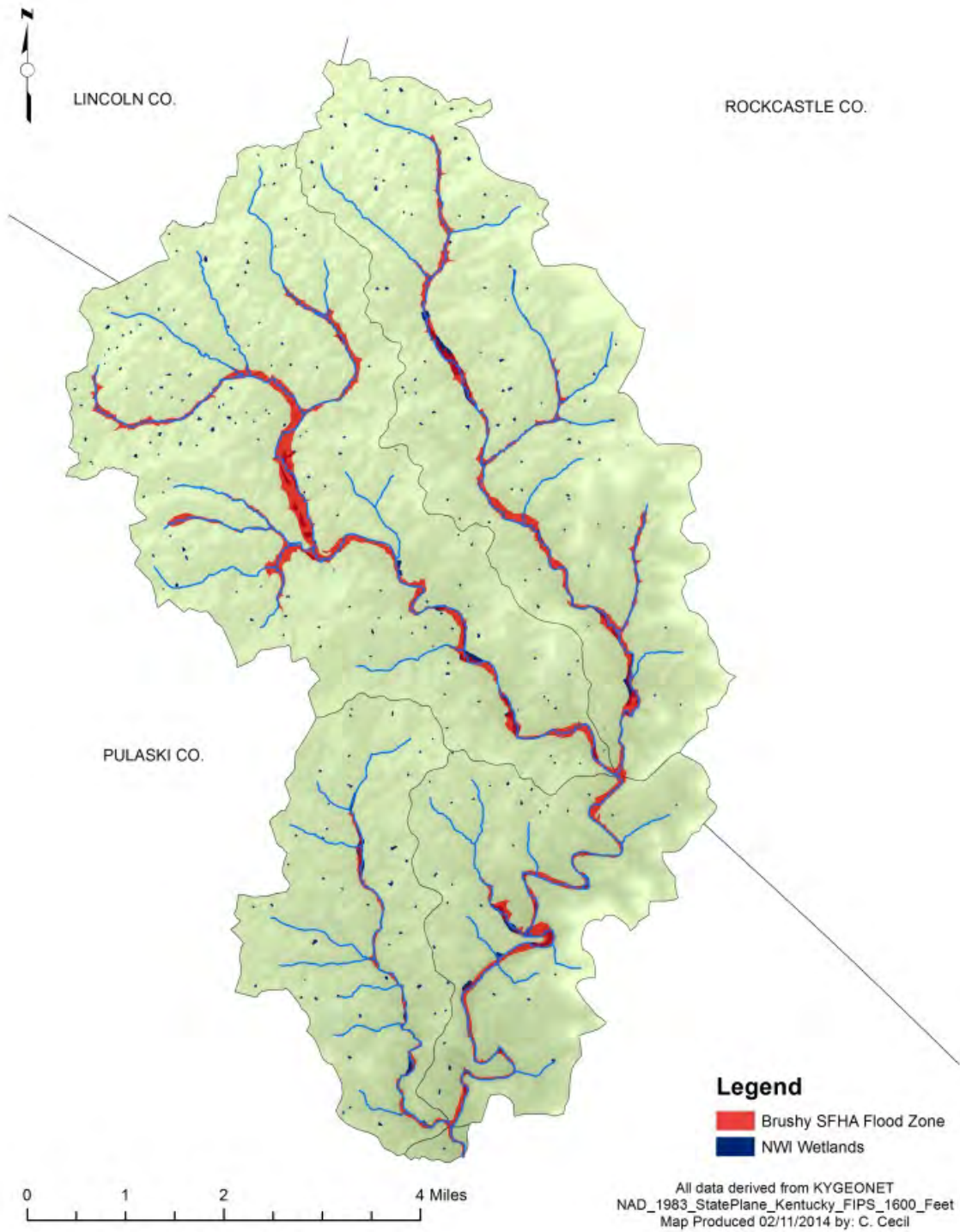
**Figure 2.3** Water use and groundwater sensitivity in the Brushy Creek watershed.

#### 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

|   | <b>Brushy Creek</b> | <b>Bee Lick Creek</b> | <b>Clifty Creek</b> | <b>Watershed Total</b> |
|---|---------------------|-----------------------|---------------------|------------------------|
| 100-yr floodplain area (mi <sup>2</sup> ) | 1.0                 | 0.9                   | 0.1                 | 2.0                    |
| Subwatershed area (mi <sup>2</sup> )      | 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

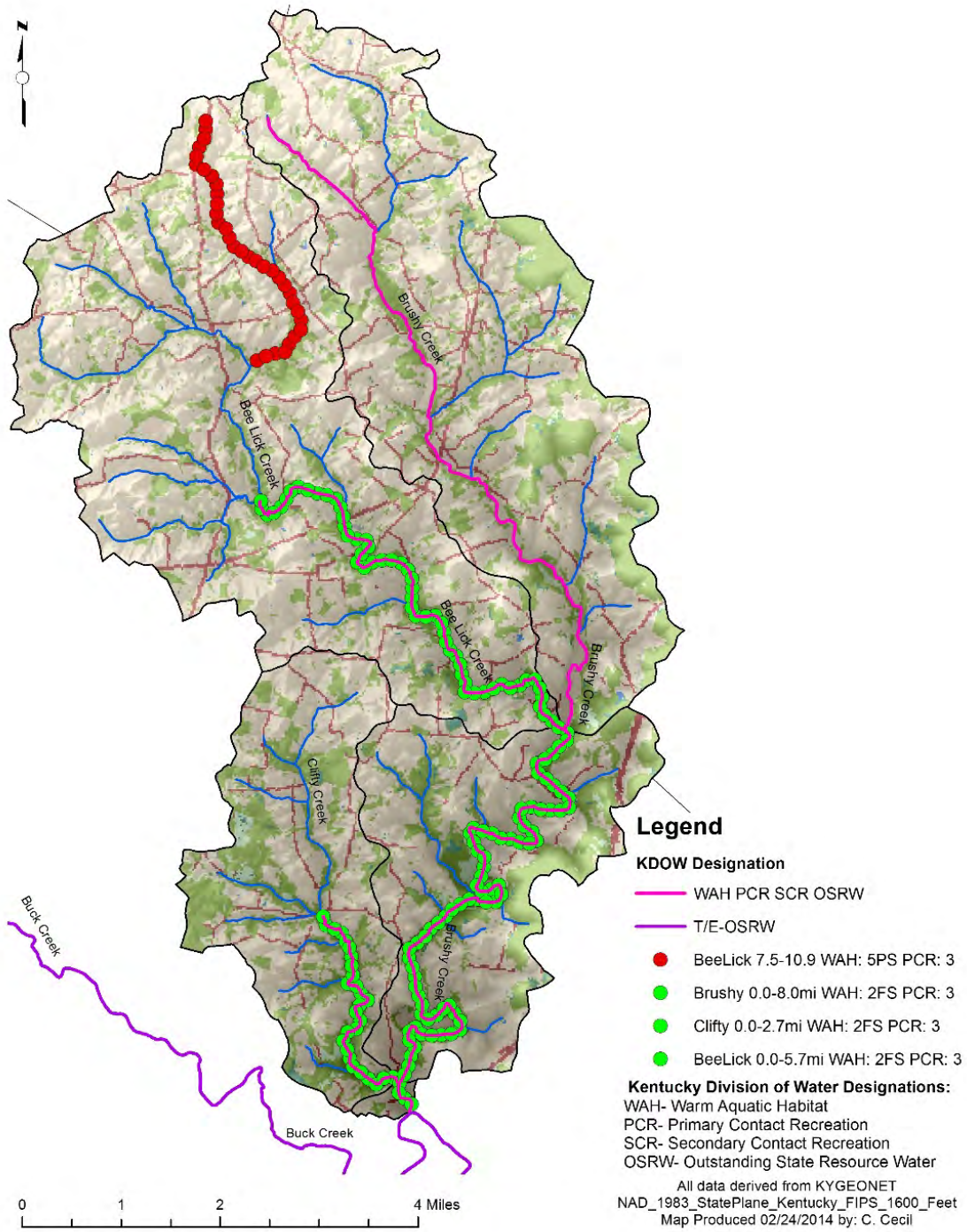
Designated uses that define water quality goals for surface waters and numeric and narrative criteria to protect those goals are specified in Kentucky Administrative Regulations (KAR). The designated uses of Brushy Creek, Bee Lick Creek, and Clifty Creek are warm water aquatic habitat (WAH), primary 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<br>7.5-10.9 | Lincoln | WAH | Nitrate/Nitrite<br>(Nitrite + Nitrate as N)<br><br>Sedimentation/<br>Siltation | Agriculture; Highway - Road - Bridge Runoff<br>(Non-construction Related);<br>Impacts from Hydrostructure Flow Regulation -<br>modification;<br>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

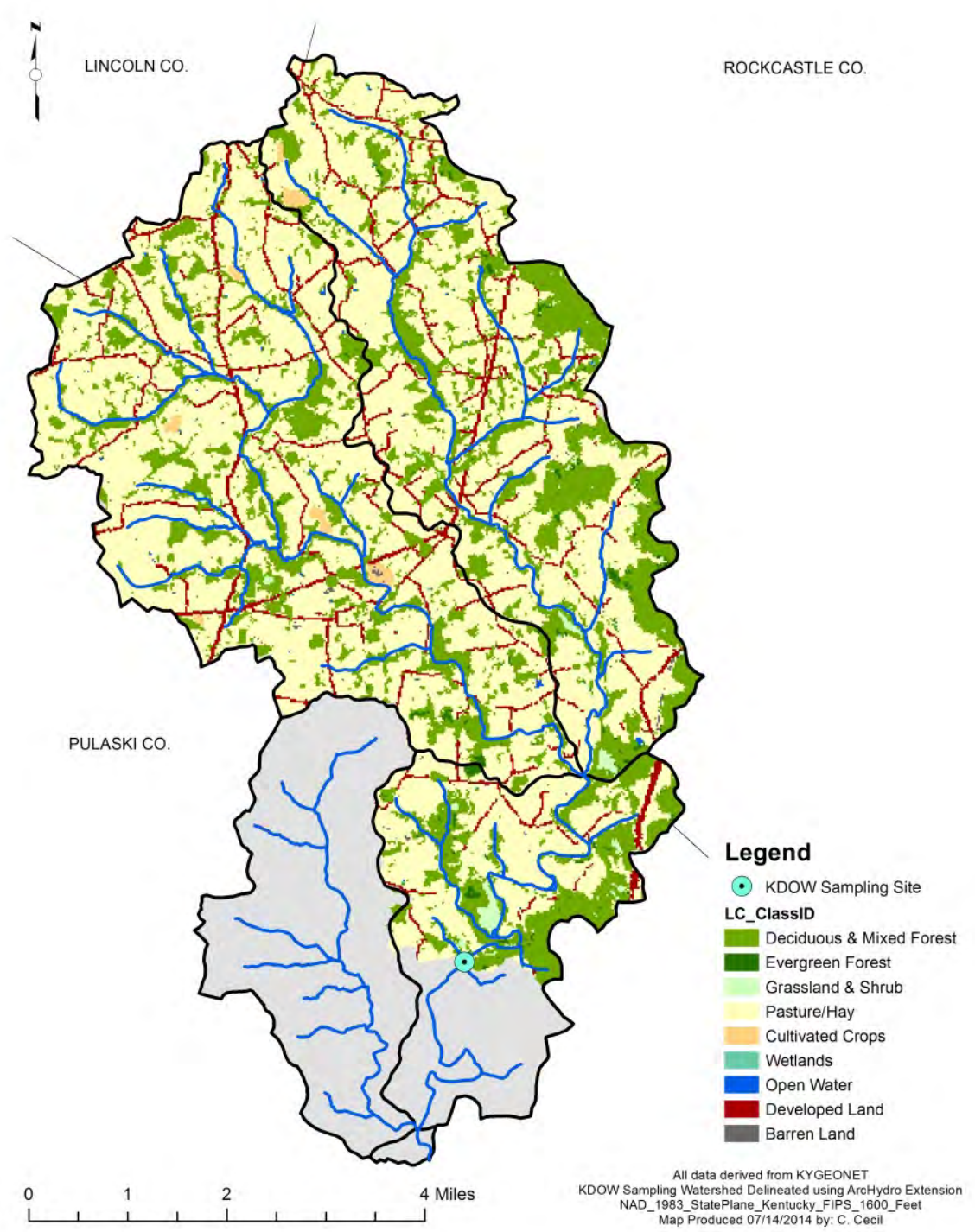
During summer 2000 and spring 2005, Kentucky Division of Water (KDOW) sampled water quality and evaluated stream habitat four times on Brushy Creek main stem at river mile 3.5 (Table 2.5 and Fig. 2.6). The sampling site is upstream from Brushy Creek's confluence with Clifty Creek and receives water from 35.6 mi<sup>2</sup> of the 44.4 mi<sup>2</sup> 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<sub>3</sub>) 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 Method            |
|------------------|---------|----------------------|------------|-------|------------------------|
| <b>11-Jul-00</b> | 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  |
| <b>19-Sep-00</b> | 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 |
| <b>20-May-05</b> | 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          |
| <b>20-Jun-05</b> | 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          |



**Figure 2.6** Location of KDOWN 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).

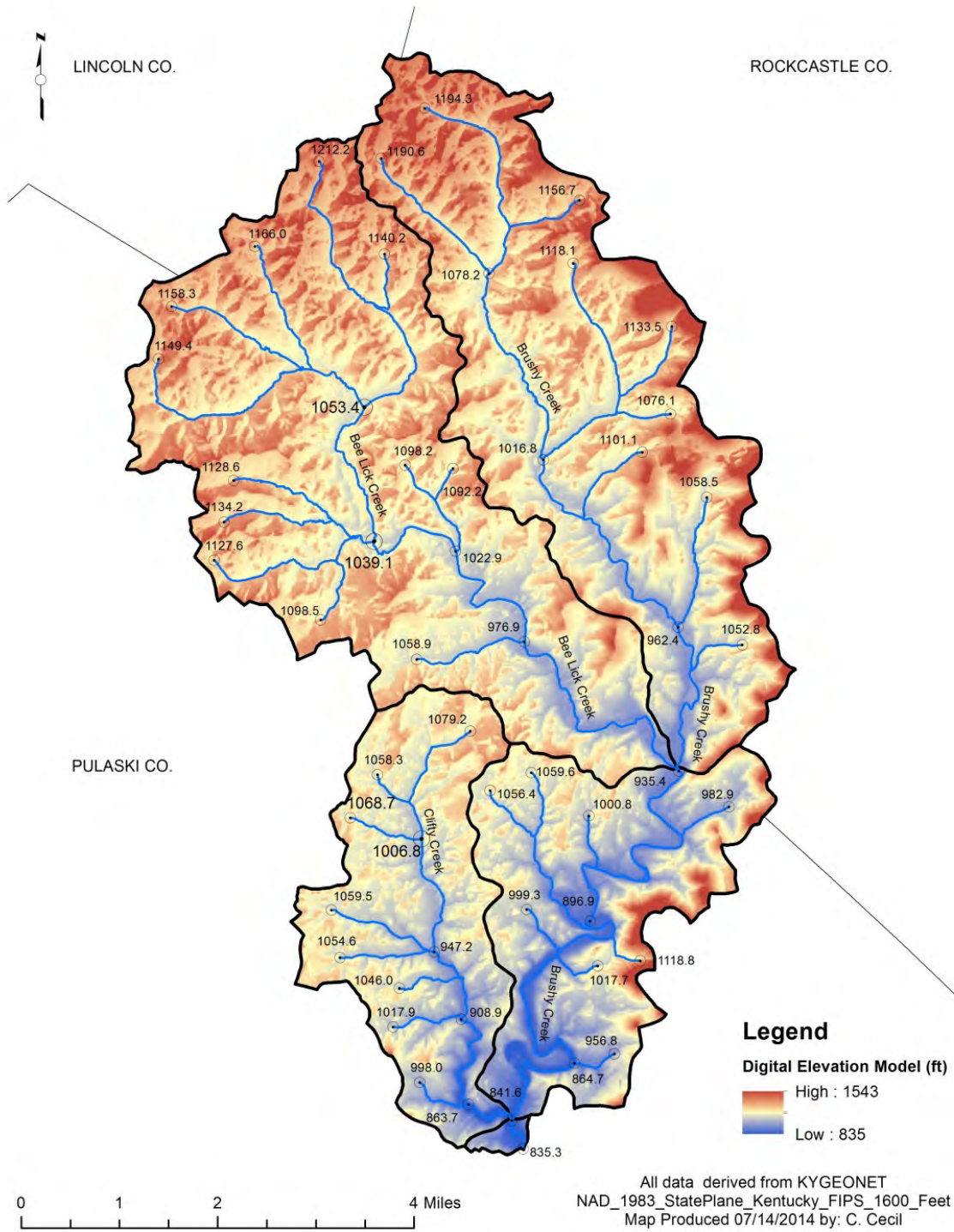
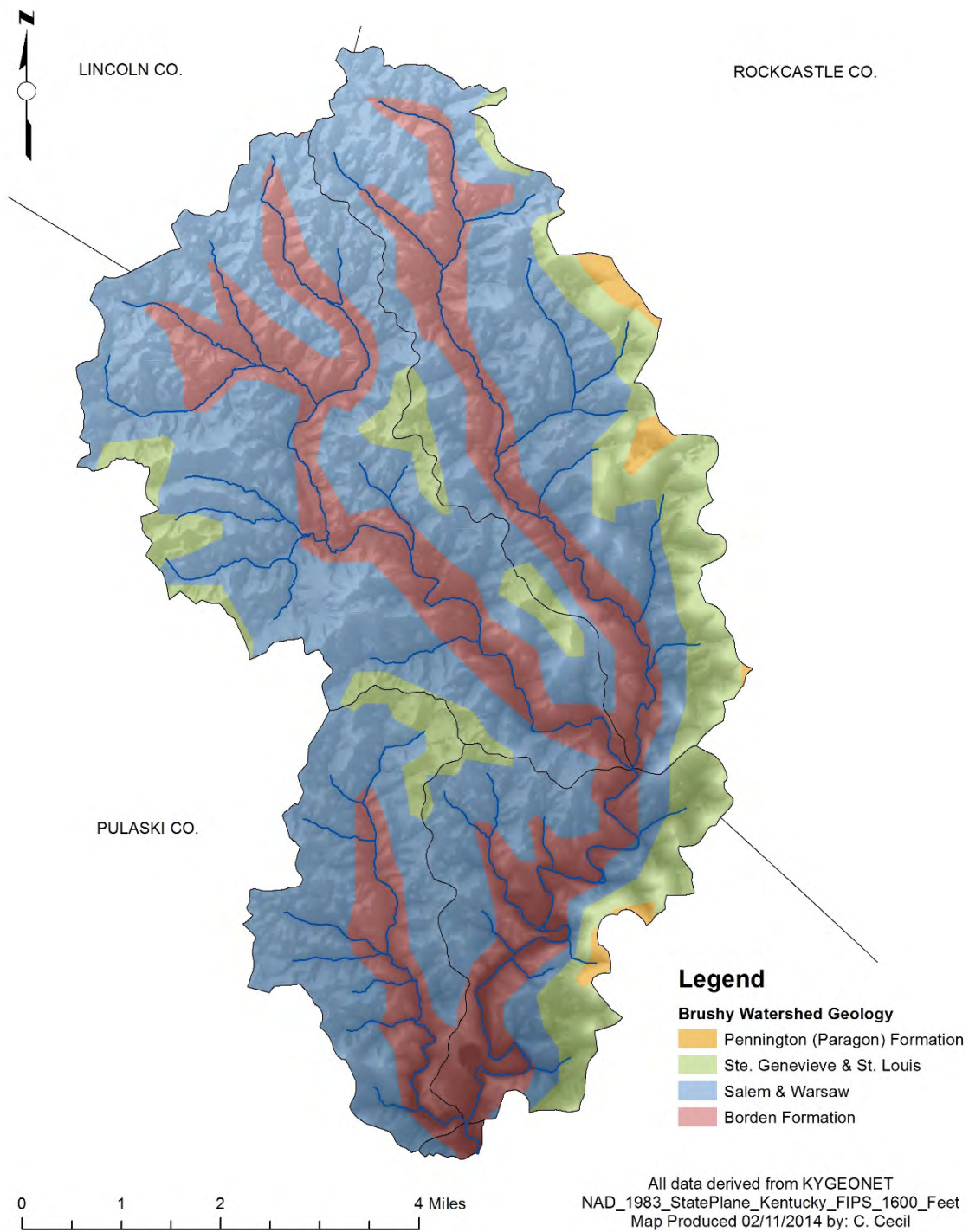


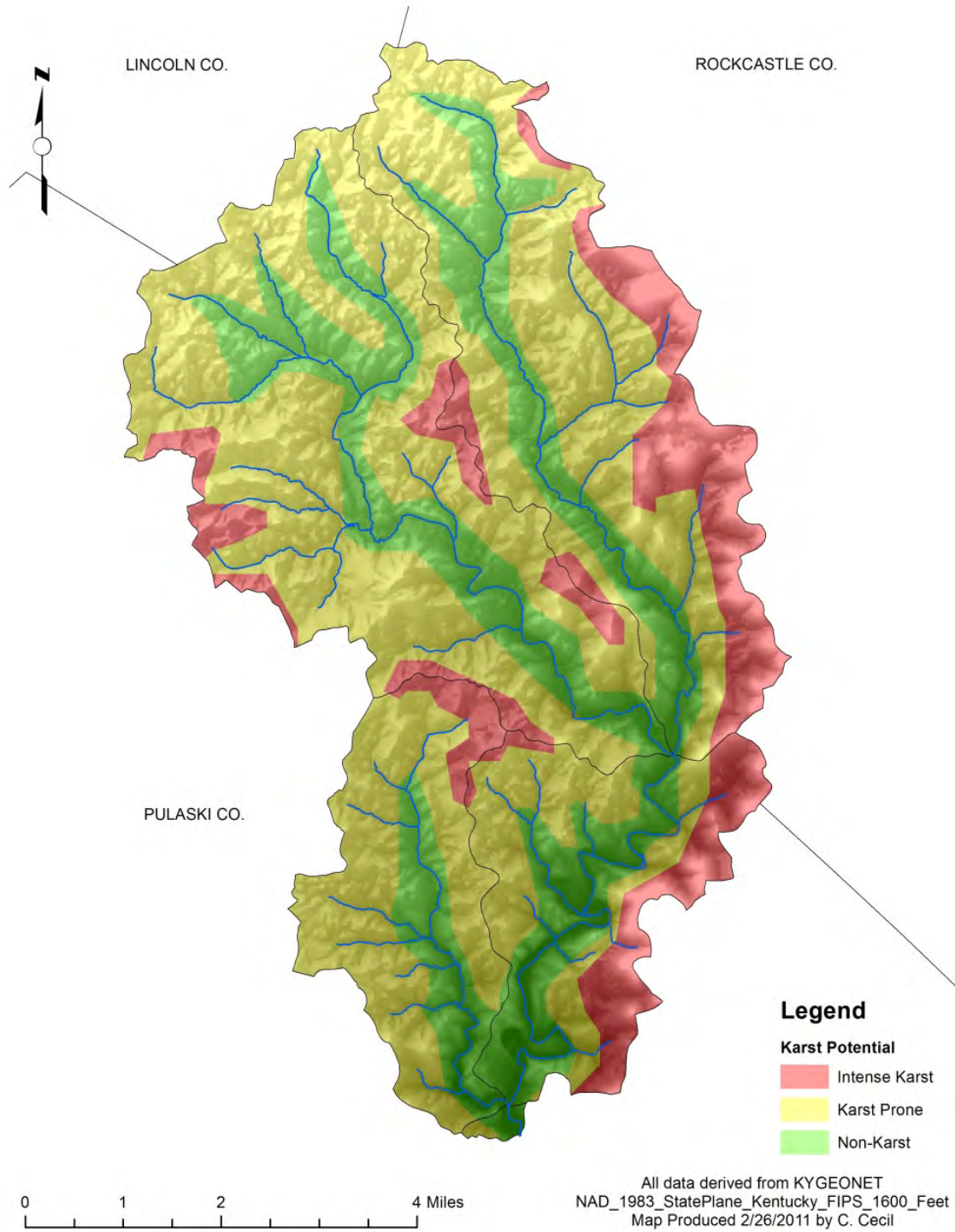
Figure 2.7 Topography and spot elevations in the Brushy Creek watershed.

All data derived from KYGEONET  
 NAD\_1983\_StatePlane\_Kentucky\_FIPS\_1600\_Feet  
 Map Produced 07/14/2014 by: C. Cecil



**Figure 2.8** Generalized geology of the Brushy Creek watershed.





**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.

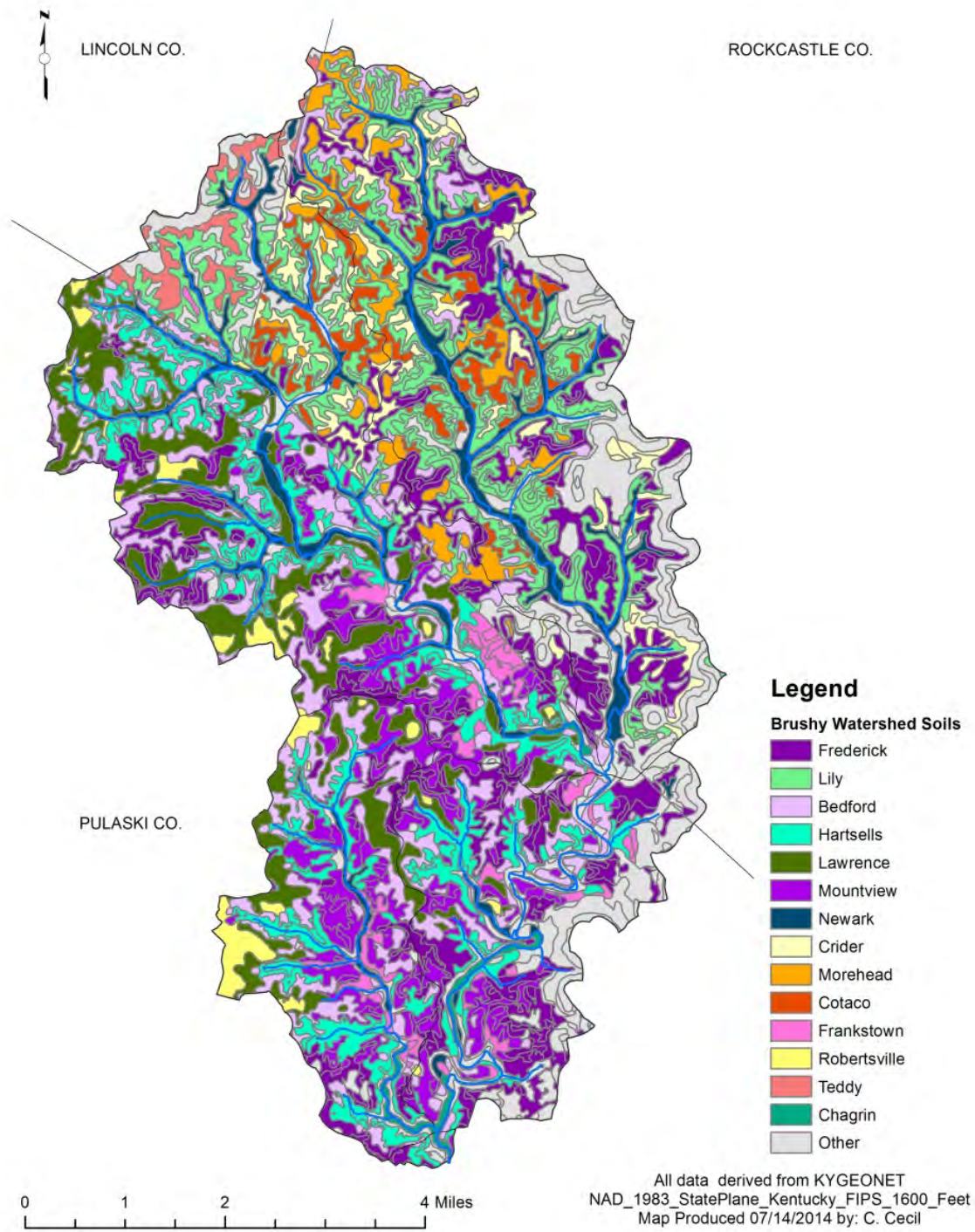
### 2.2.2 Soils

#### 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 up-land 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.



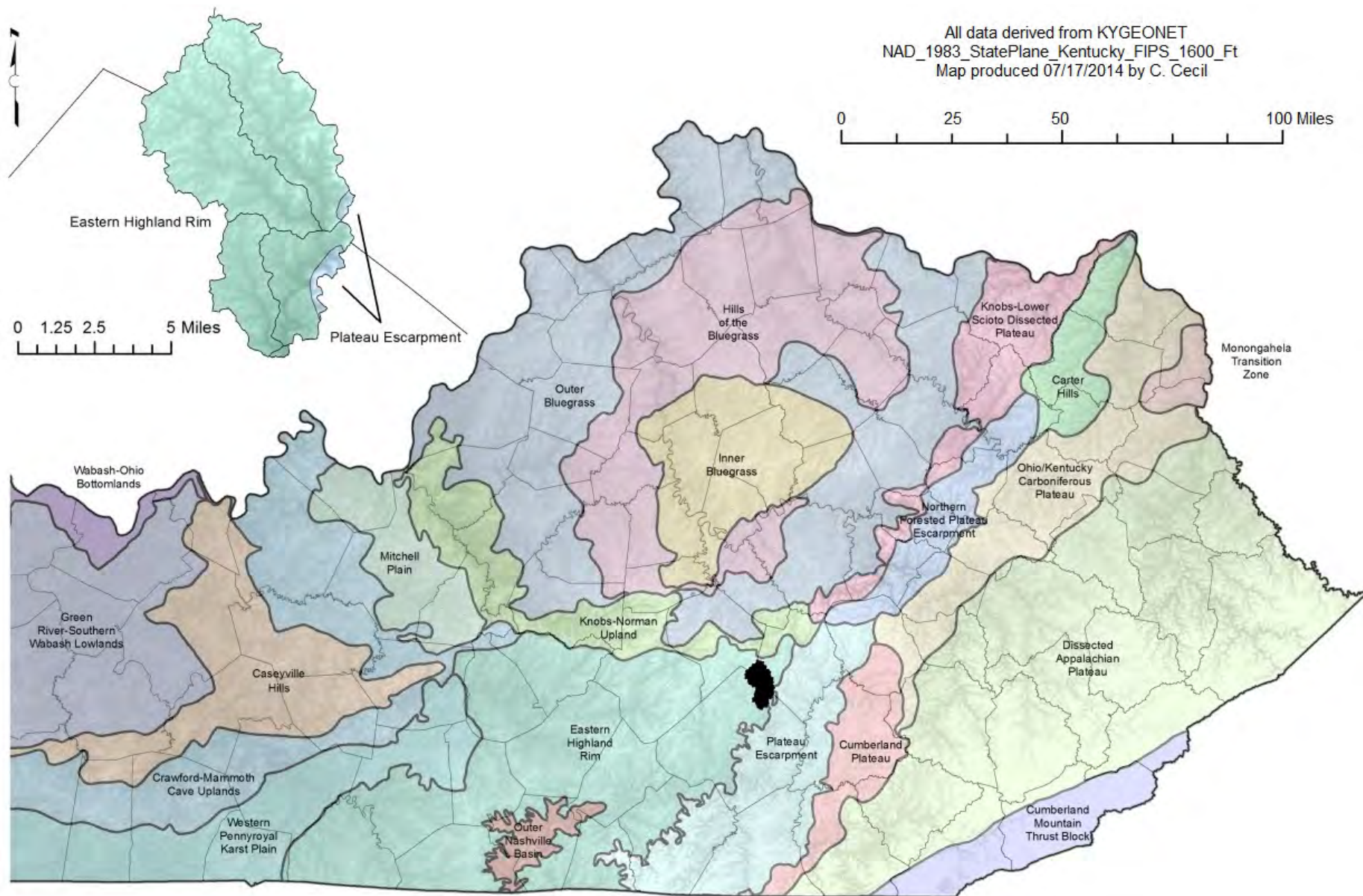
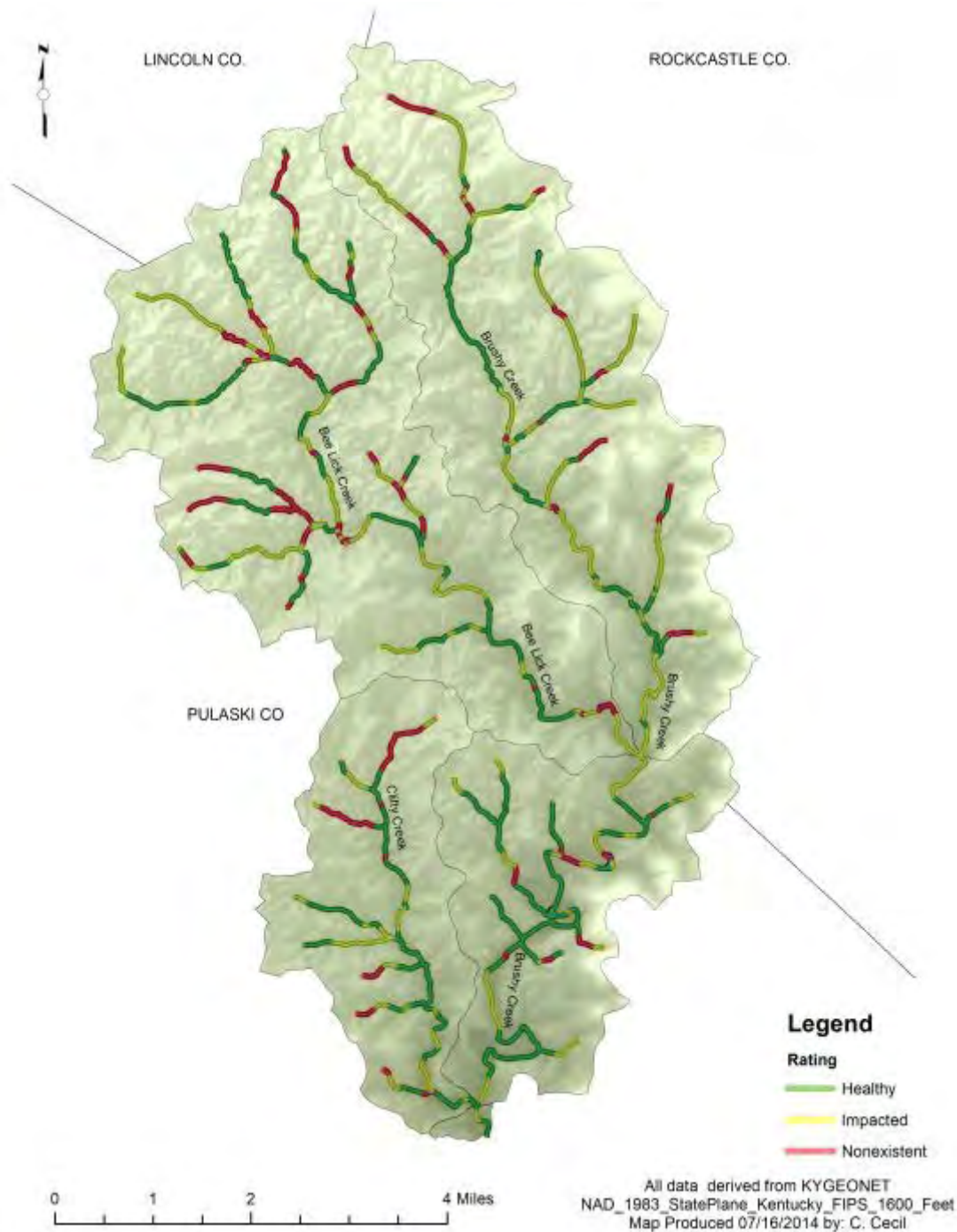


Figure 2.11 EPA Level IV ecoregions of Kentucky.



**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    | <i>Drosera brevifolia</i>     | Dwarf sundew             | E                 | Global: 5- Secure and common.<br>State: 1- Critically imperiled, at a very high risk of extirpation.                                      | E- Verified extant, ecological integrity not assessed. |
|                    | <i>Gymnopogon brevifolius</i> | Shortleaf skeleton-grass | E                 | Global: 5- Secure and common.<br>State: 1- Critically imperiled, at a very high risk of extirpation.                                      | H- Historical  |
|                    | <i>Hypericum crux-andreae</i> | St Peter's-wort          | T                 | Global: 5- Secure and common.<br>State: 2/3- Imperiled-Vulnerable, at a high to moderate risk of extirpation.                             | E- Verified extant, ecological integrity not assessed. |
|                    | <i>Lepedeza capitata</i>      | Round-head bush-clover   | S                 | Global: 5- Secure and common.<br>State: 3- Vulnerable, at a moderate risk of extirpation.   | E- Verified extant, ecological integrity not assessed. |
|                    | <i>Lobelia nuttallii</i>      | Nuttall's lobelia        | T                 | Global: 4/5- Apparently Secure, uncommon but not rare, long-term concern.<br>State: 2- Imperiled, at a high risk of extirpation.          | E- Verified extant, ecological integrity not assessed. |
|                    | <i>Ludwigia hirtella</i>      | Rafinesque's seedbox     | E                 | Global: 5- Secure and common.<br>State: 1- Critically imperiled, at a very high risk of extirpation.                                      | E- Verified extant, ecological integrity not assessed. |
|                    | <i>Lycopodiella appressa</i>  | Southern bog clubmoss    | E                 | Global: 5- Secure and common.<br>State: 1- Critically imperiled, at a very high risk of extirpation.                                      | F- Failed to find.                                     |
|                    | <i>Oenothera linifolia</i>    | Thread-leaf sundrops     | E                 | Global: 5- Secure and common.<br>State: 1/2- Critically imperiled, at a high risk of extinction due to extreme rarity.                    | E- Verified extant, ecological integrity not assessed. |
| Freshwater Mussels | <i>Rhynchospora recognita</i> | Globe beaked-rush        | S                 | Global: 5- Secure and common.<br>State: 3- Vulnerable, at a moderate risk of extirpation.   | E- Verified extant, ecological integrity not assessed. |
|                    | <i>Villosa tribalis</i>       | Cumberland bean          | E<br>LE<br>STWG   | Global: 1 Critically imperiled, at a very high risk of extinction.<br>State: 1 Critically imperiled, at a very high risk of extinction.   | E- Verified extant, ecological integrity not assessed. |
| Fishes             | <i>Entheostoma cinereum</i>   | Ashy darter              | S<br>SOMC<br>STWG | Global: 2/3- Imperiled-Vulnerable, at a high to moderate risk of extirpation.<br>State: 3- Vulnerable, at a moderate risk of extirpation. | H- Historical  |
| Breeding Birds     | <i>Ammodramus henslowii</i>   | Henslow's sparrow        | S<br>SOMC<br>STWG | Global: 4- Apparently Secure, uncommon but not rare, long-term concern.<br>State: 3- Vulnerable, at a moderate risk of extirpation.       | E- Verified extant, ecological integrity not assessed. |
| Mammals            | <i>Myotis grisescens</i>      | Gray myotis              | T<br>LE<br>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.   |  |
| <i>Nycticeius humeralis</i> | Evening bat | S<br>STWG | Global: 5- Secure and common.<br>State: 3- Vulnerable, at a moderate risk of extirpation.     | E- Verified extant, ecological integrity not assessed. |
| Communities                 | Wet meadow  | E         | Global: NR- Not Ranked.<br>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* (fresh-water 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           |
|---|-----------------------|
| <b>Severe Threat Plant Species</b>                |                       |
| <i>Achyranthes japonica</i>                       | Japanese chaff flower |
| <i>Ailanthus altissima</i>                        | Tree-of-heaven        |
| <i>Alliaria petiolata</i>                         | Garlic mustard        |
| <i>Ampelopsis brevipedunculata</i>                | Porcelain berry       |
| <i>Arthraxon hispidus</i>                         | Hairy jointgrass      |
| <i>Carduus nutans</i>                             | Musk thistle          |
| <i>Celastrus orbiculatus</i>                      | Oriental bittersweet  |
| <i>Cirsium arvense</i>                            | Canada thistle        |
| <i>Clematis terniflora</i>                        | Leatherleaf clematis  |
| <i>Conium maculatum</i>                           | Poison hemlock        |
| <i>Coronilla varia (=Securigera varia)</i>        | Crown vetch           |
| <i>Dioscorea polystachya</i>                      | Chinese yam           |
| <i>Elaeagnus umbellata</i>                        | Autumn olive          |
| <i>Euonymus alatus</i>                            | Burning bush          |
| <i>Euonymus fortunei</i>                          | Wintercreeper         |
| <i>Festuca arundinacea (=Lolium arundinaceum)</i> | Kentucky 31 fescue    |
| <i>Glechoma hederacea</i>                         | Ground ivy            |
| <i>Lespedeza cuneata</i>                          | Sericea lespedeza     |
| <i>Lespedeza stipulacea (=Kummerowia)</i>         | Korean lespedeza      |
| <i>Ligustrum sinense, L. vulgare</i>              | Privet                |

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

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

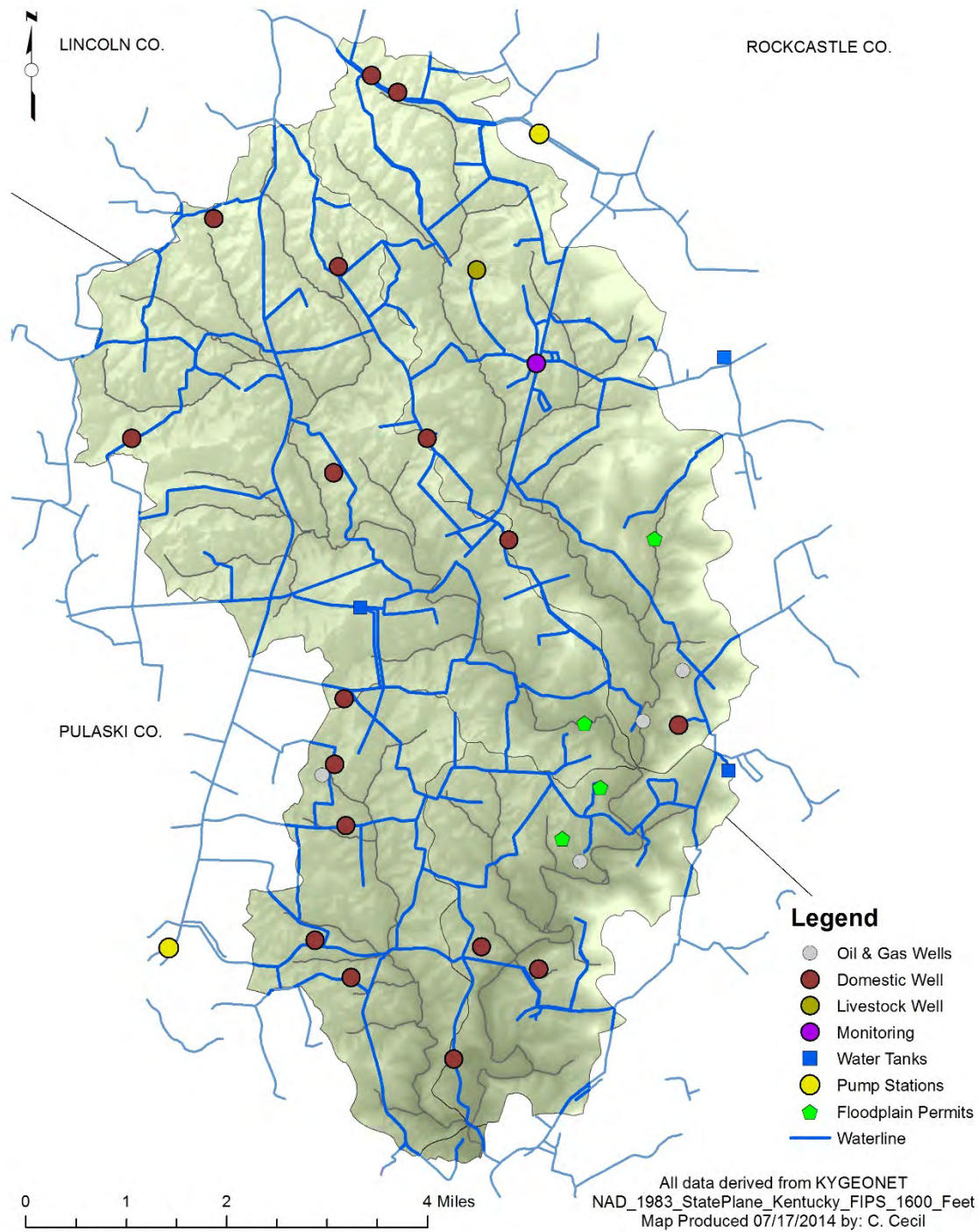


Figure 2.13 Water use in the Brushy Creek watershed.

### 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 over-grazed 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<sup>2</sup> watershed (Fig. 2.15).

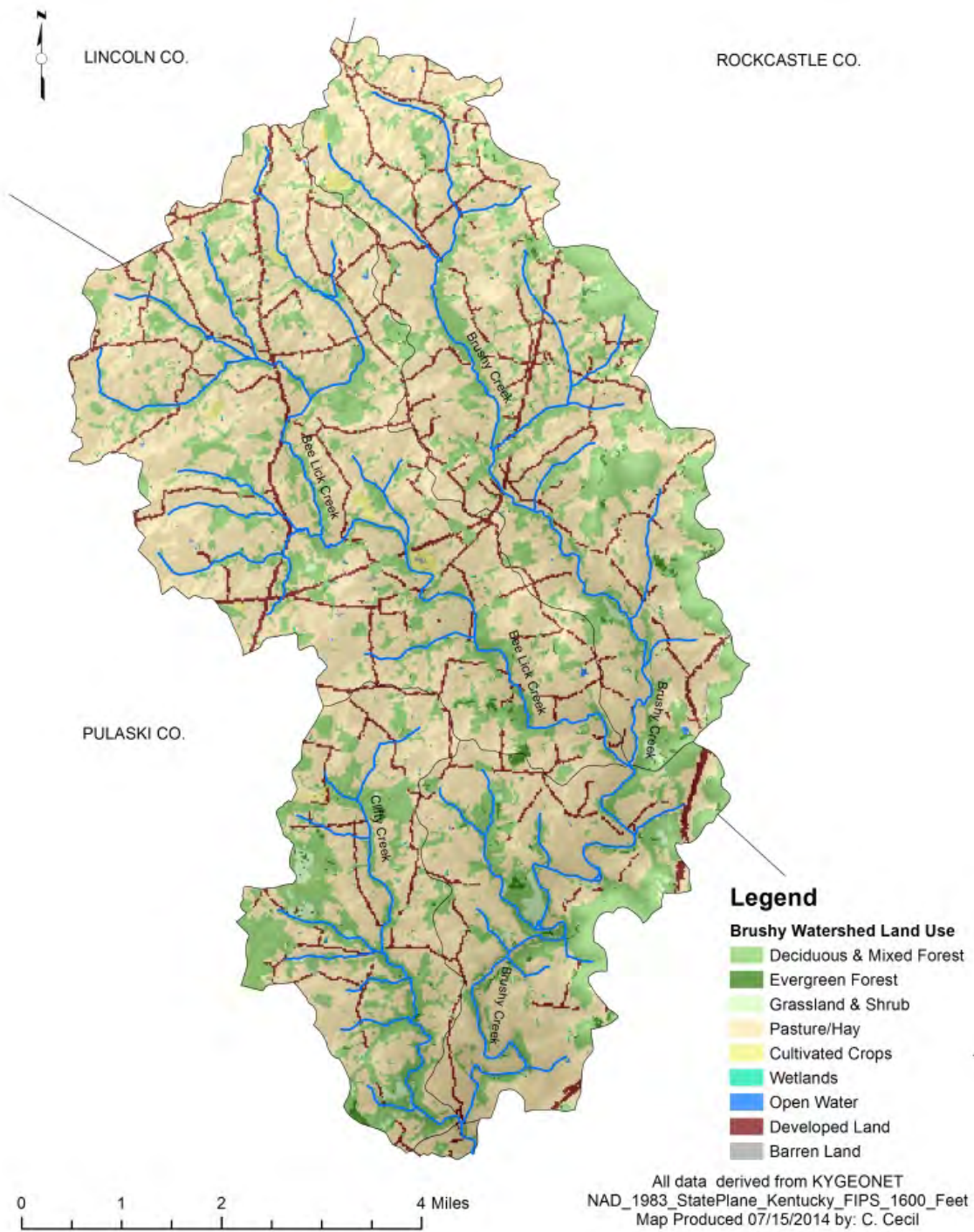
#### Agriculture

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.

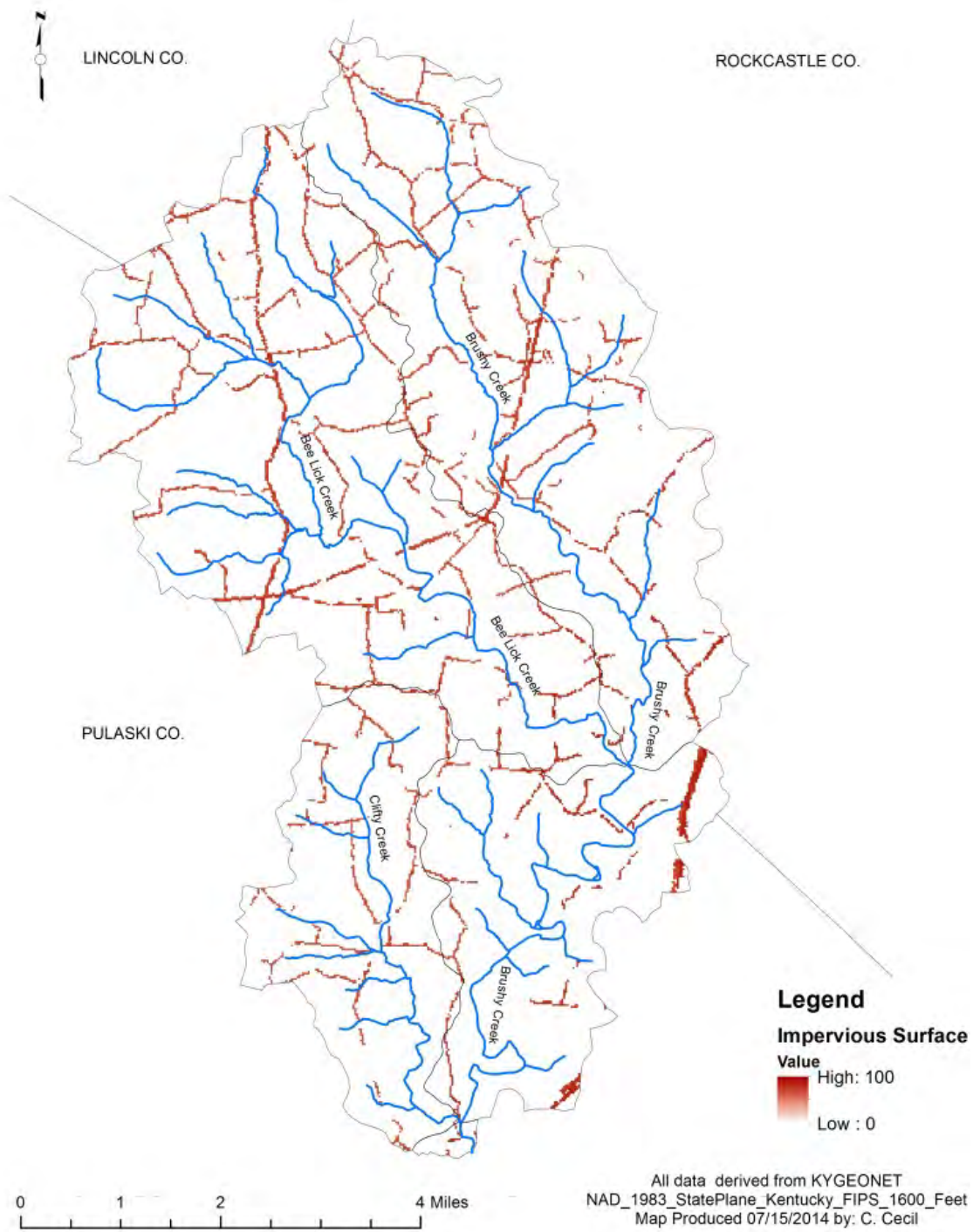
#### Cattle

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.

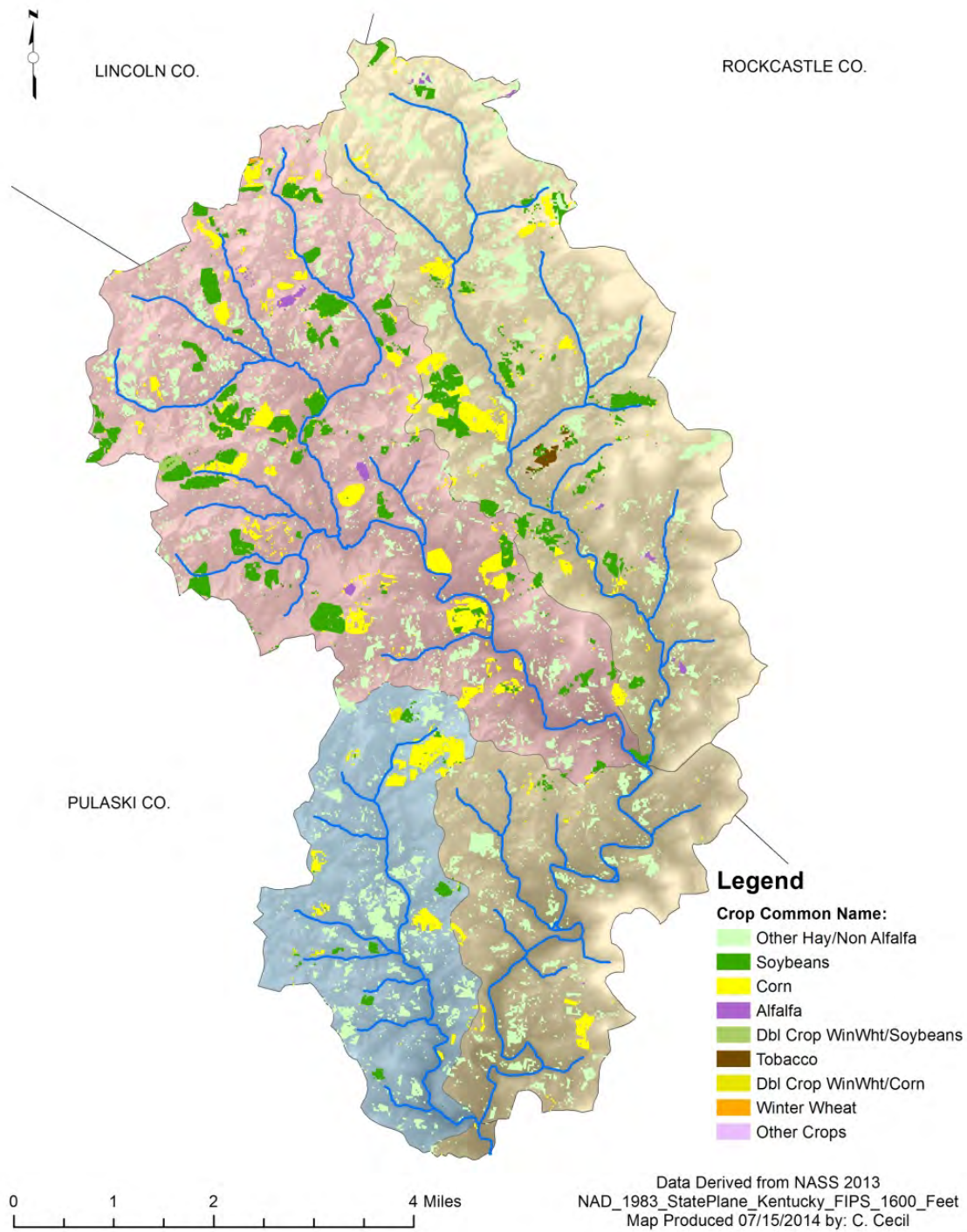




**Figure 2.14** Land cover in the Brushy Creek watershed (based on 2001 National Land Cover Dataset).

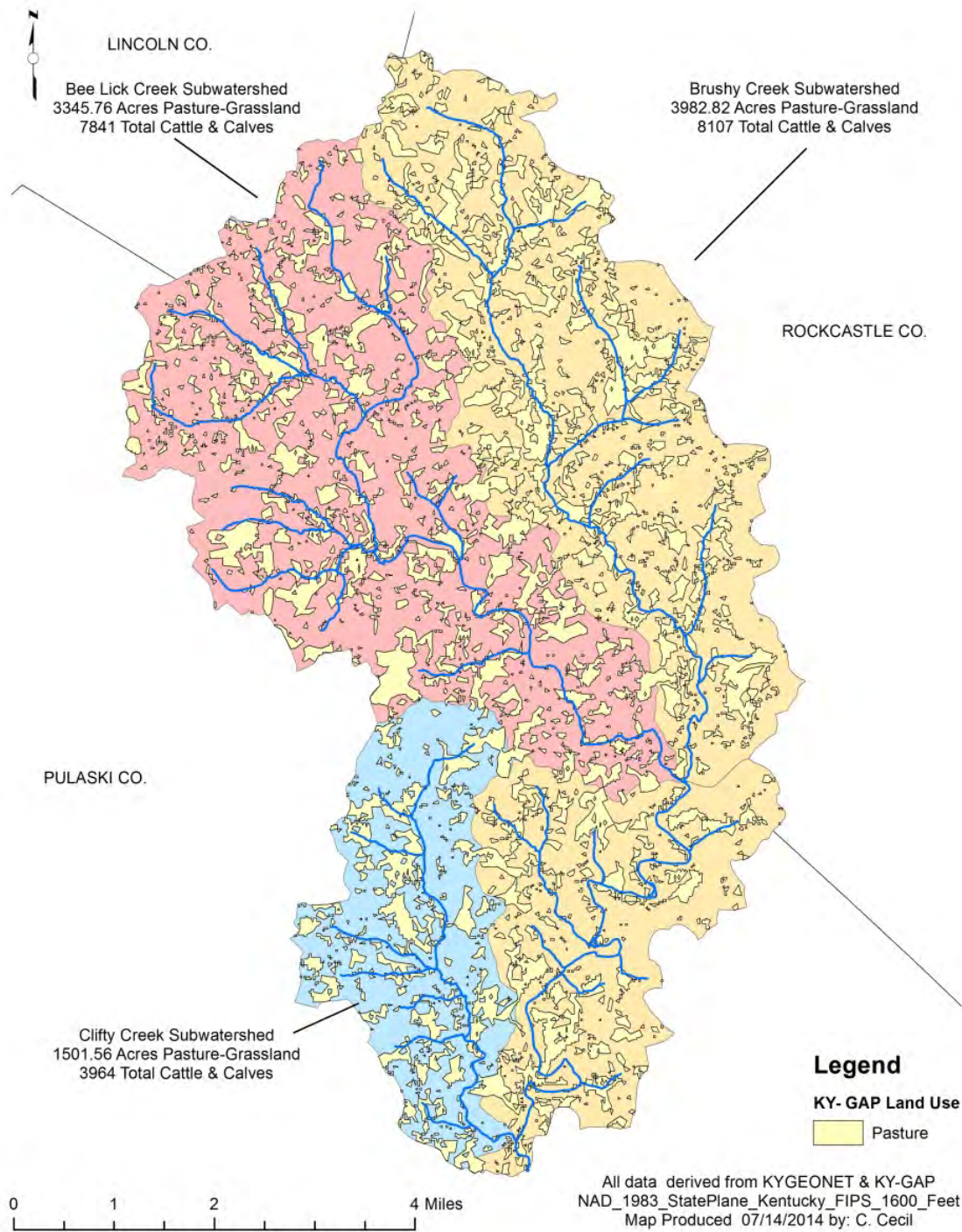


**Figure 2.15** Impervious surfaces in the Brushy Creek watershed.

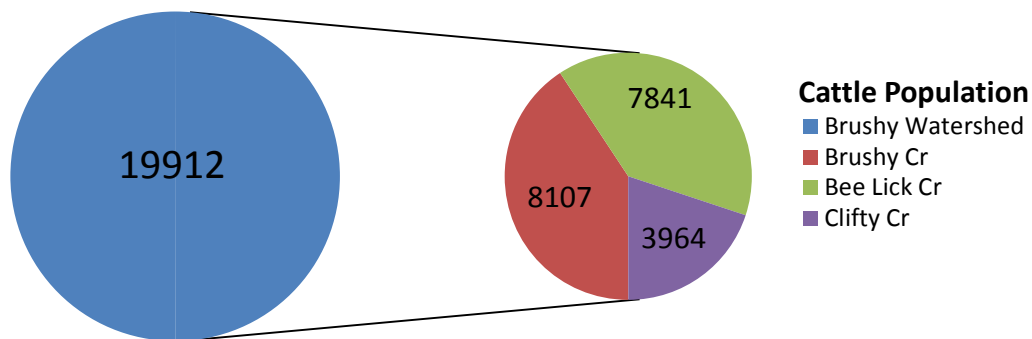


**Figure 2.16** Row crop agriculture in the Brushy Creek watershed.





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



**Figure 2.18** Distribution of cattle in the Brushy Creek subwatersheds.

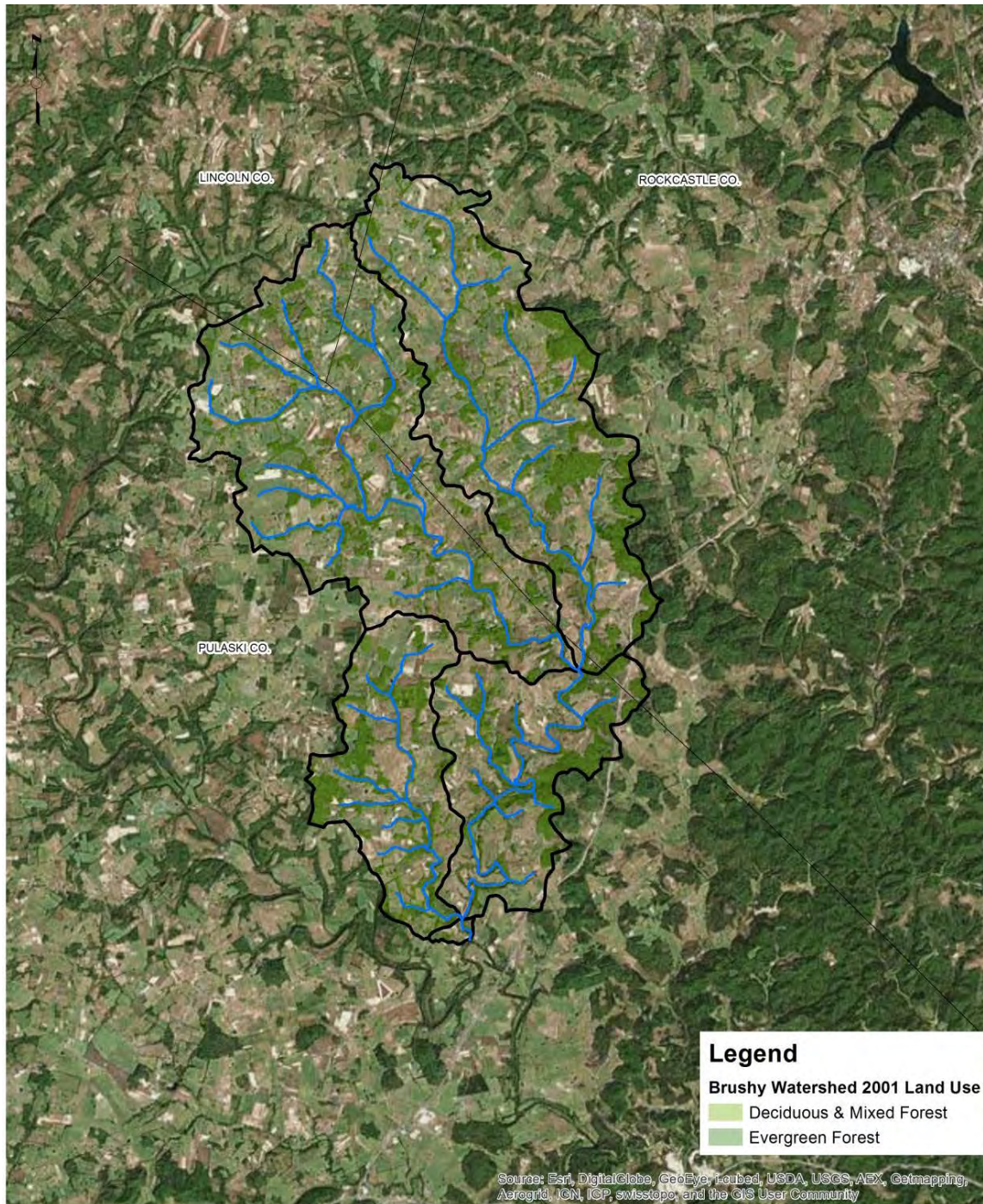
### Forestry

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 where 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).





**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<br>(per mi <sup>2</sup> ) | Household Density<br>(per mi <sup>2</sup> ) |
|------------------------|-------------|-------------|--|---|
| Clifty                 | 276         | 133         | 43.47  | 20.95                                       |
| Bee Lick               | 823         | 378         | 49.03  | 22.52                                       |
| Brushy                 | 1126        | 516         | 53.01  | 24.29                                       |
| <b>Watershed Total</b> | <b>2225</b> | <b>1027</b> | <b>50.13</b> (weighted mean)                 | <b>23.14</b> (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 <sup>2</sup> ) | 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

| RBP Parameter                         | Lower Brushy |            | Lower Brushy | Lower Bee Lick | Upper Bee Lick |
|---------------------------------------|--------------|------------|--------------|----------------|----------------|
|                                       | DOW02012002  |            | SED02012501  | SED02012502    | DOW02012021    |
|                                       | 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              |
| <b>Total</b>                          | <b>170</b>   | <b>148</b> | <b>135</b>   | <b>126</b>     | <b>117</b>     |
| 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.

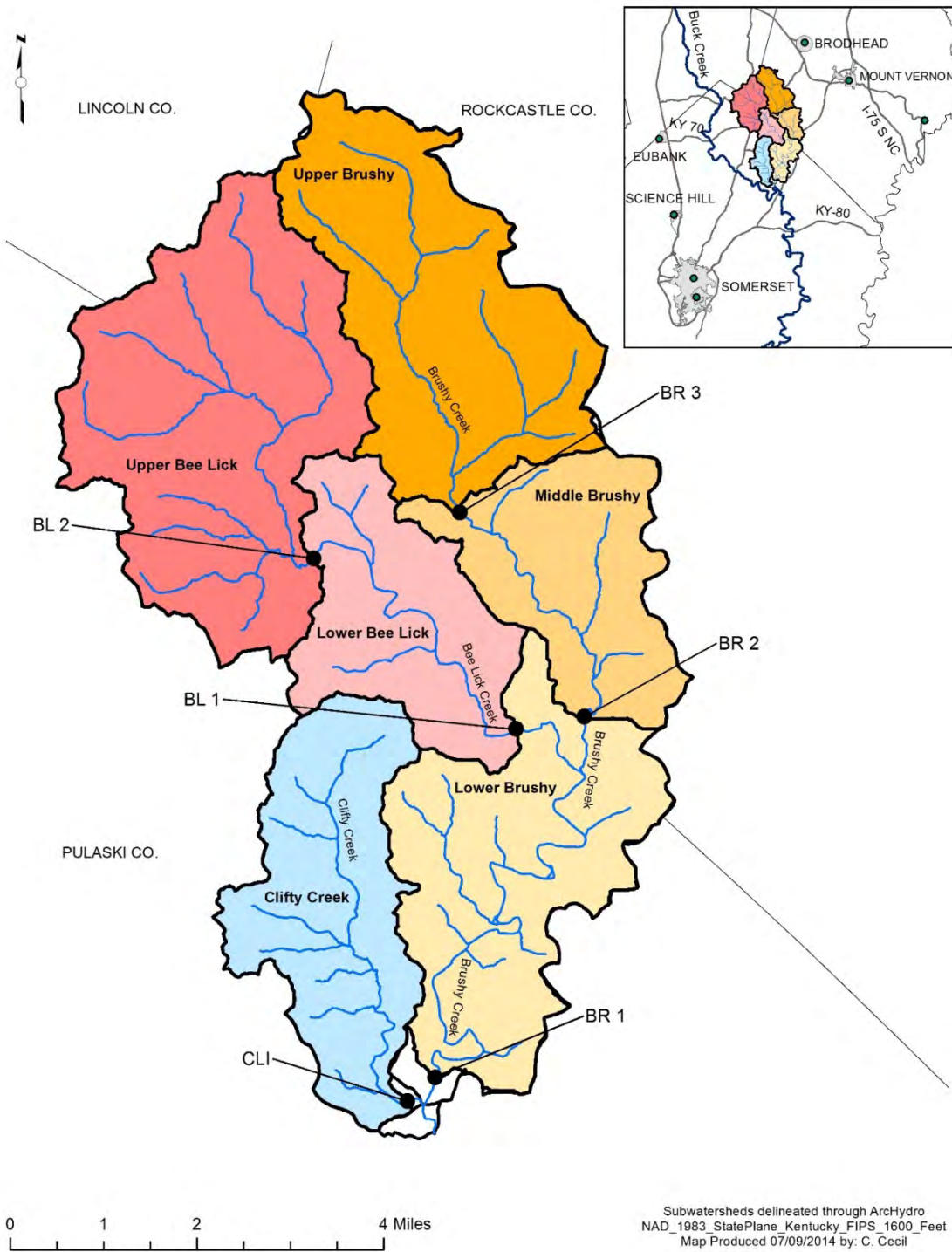
### 3.2.1 Phase 1 Monitoring

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<sup>2</sup> combined and were selected as a monitoring unit. The two northernmost HUC14s drain more than 10 mi<sup>2</sup> 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 (mi <sup>2</sup> ) | Subwatershed Drainage Area (mi <sup>2</sup> ) |
|----------------|--------------------|-----------|-----------|---|--|---|
| 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 Levellogger 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)   | <i>Wadeable flows:</i> Sontek Flowtracker.<br><i>Non-wadeable:</i> 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 <sub>5</sub>   | 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                                 |
| <i>E. coli</i>  | 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 collect 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 <sub>2</sub> )                              | EPA Method 353.2  |
| Nitrite + nitrate (NO <sub>3</sub> +NO <sub>2</sub> -N) | EPA Method 353.2  |
| Ammonia (NH <sub>4</sub> )                              | EPA Method 350.1  |
| Total Kjeldahl nitrogen (TKN)                           | EPA Method 351.2  |
| Orthophosphate (PO <sub>4</sub> -P)                     | EPA Method 365.1  |
| Total phosphorus (TP)                                   | EPA Method 365.4  |
| <i>E. coli</i>  | Colilert Quanti-Tray-2000                                       |
| cBOD <sub>5</sub>                                       | 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<sup>2</sup>. 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

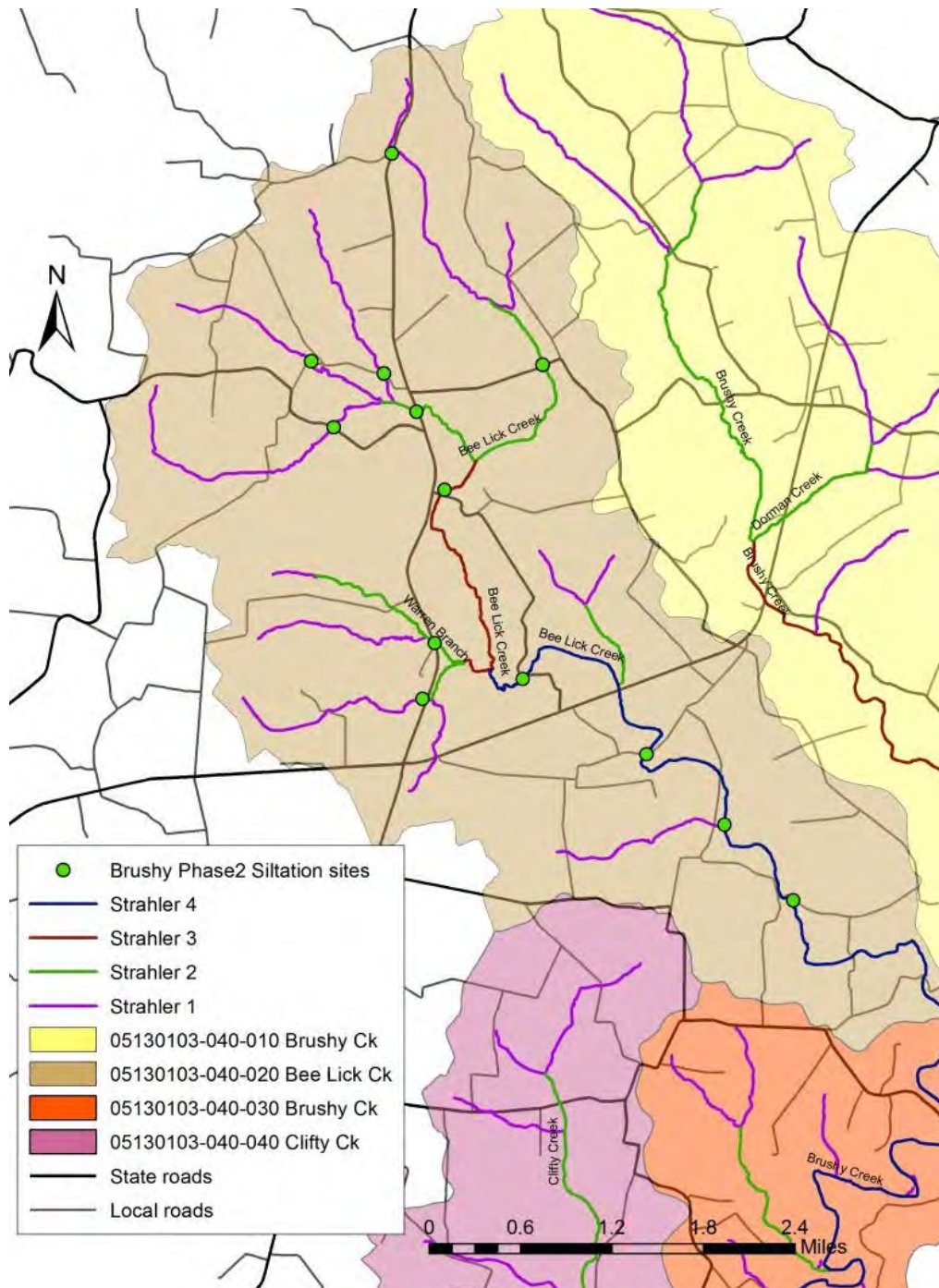
unnecessary because macroinvertebrate sampling showed that the embeddedness was not impairing the aquatic life (see Section 4.3.1).

### *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.

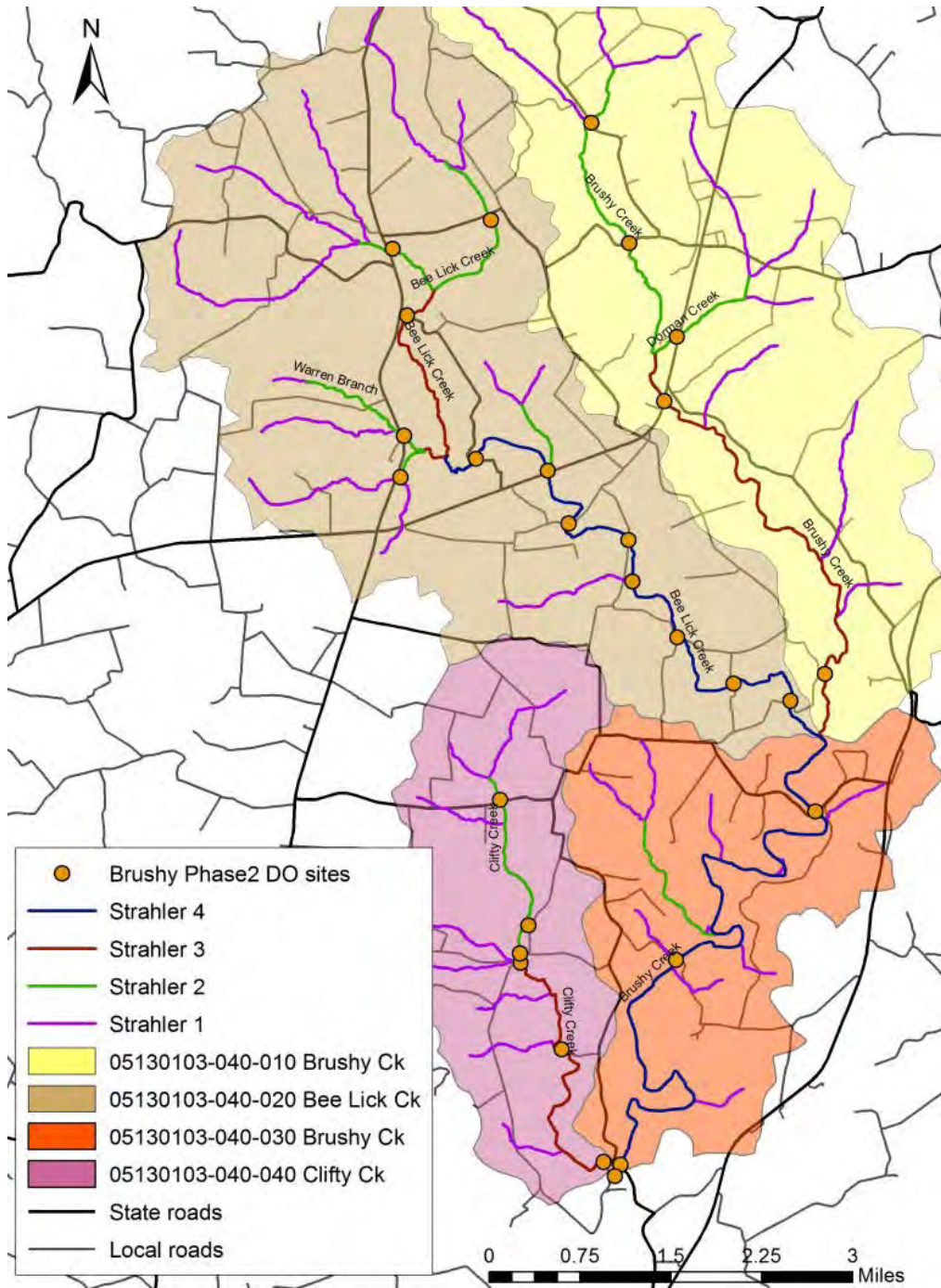
### *Nutrients and E. coli Sampling*

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.



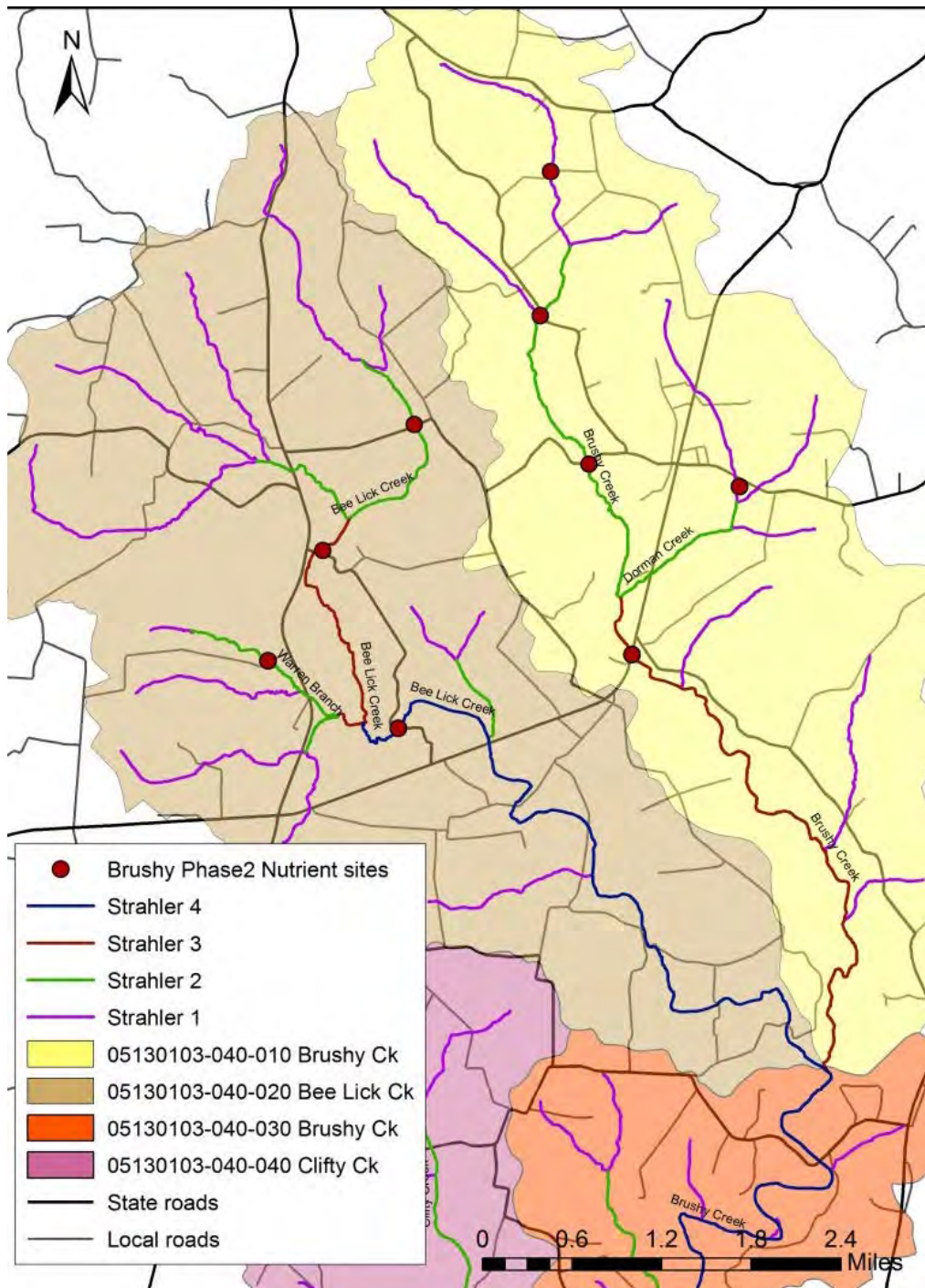
**Figure 3.3** Sites selected for sedimentation sampling.





**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:

$$\text{Annual load} = (\text{Mean concentration})(\text{annual volume of flow})(\text{conversion factor})$$

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:

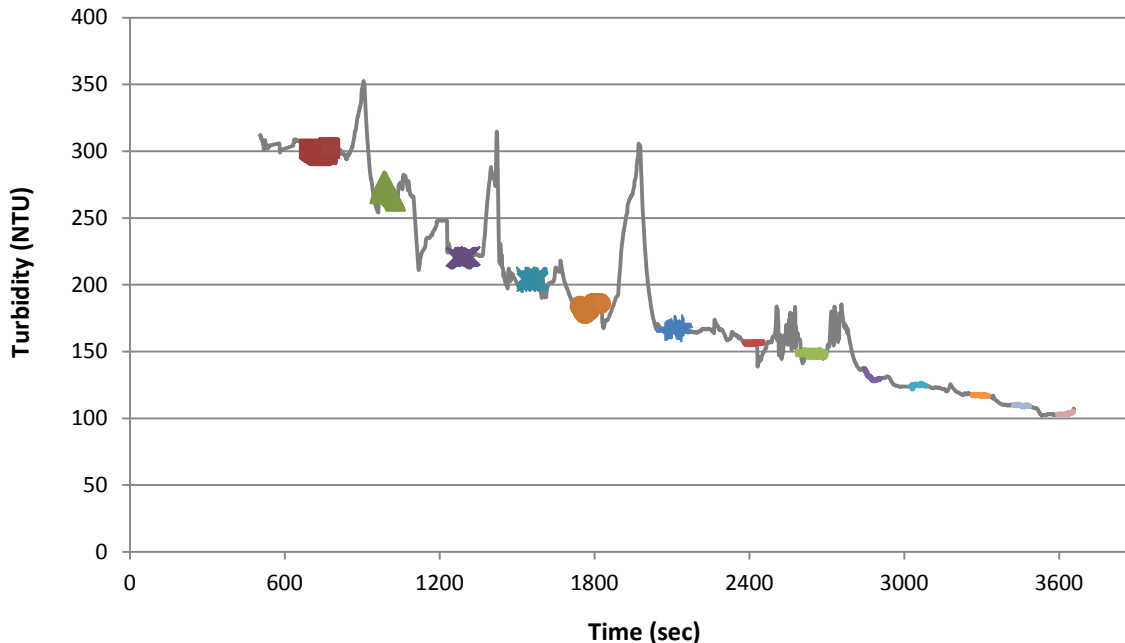
$$\text{Load}_{\text{MID BR}} = \text{Load}_{\text{BR2}} - \text{Load}_{\text{BR3}}$$

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:

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

### 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<sup>3</sup>.

For each discharge measurement, the total flow volume (ft<sup>3</sup>) for each 10-minute period was calculated. The SSC (lb/ft<sup>3</sup>) was then multiplied by the volume of flow (ft<sup>3</sup>) 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.

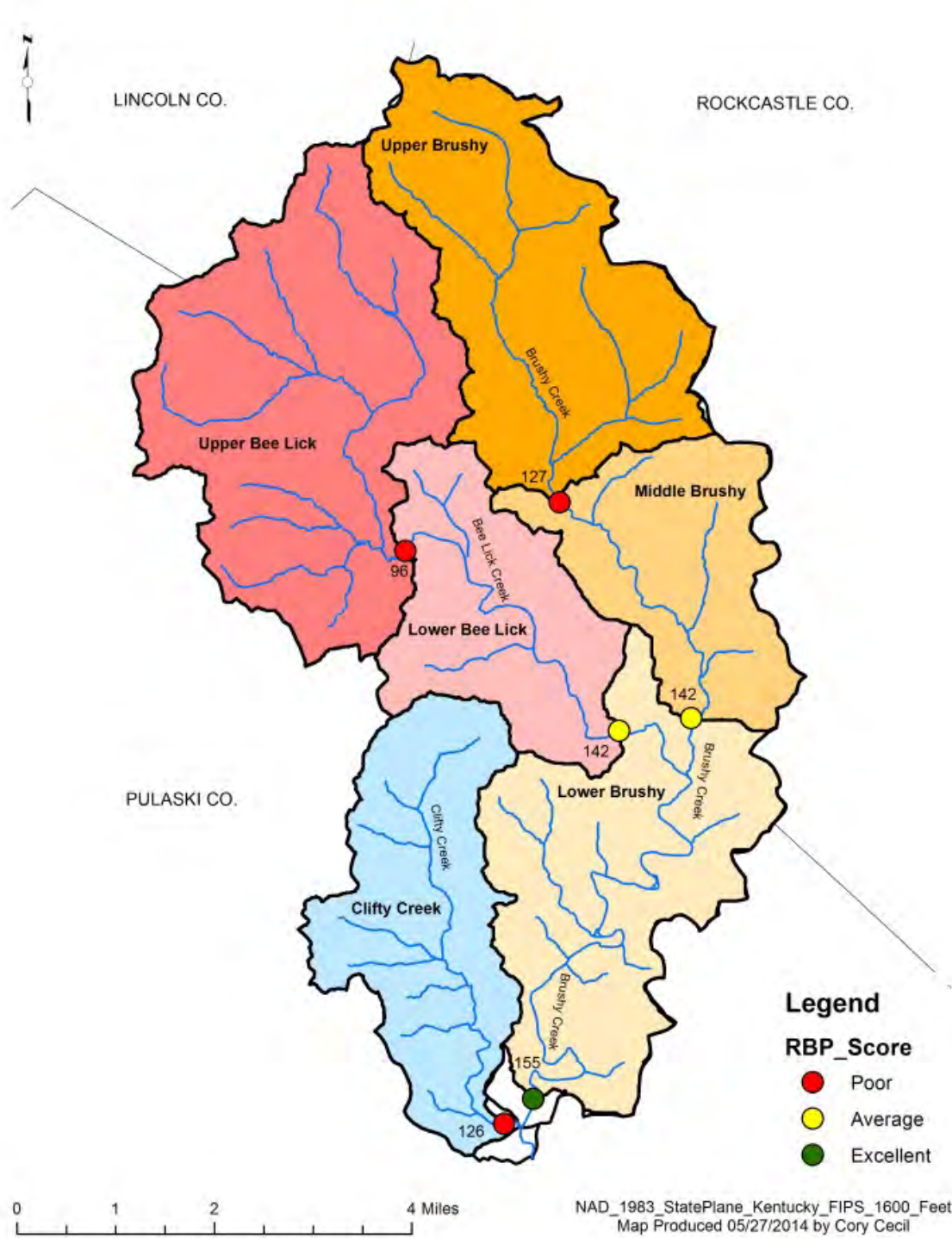
### 4.1.1 Habitat

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          |
|    | <b>Total</b>                        | <b>155</b> | <b>142</b> | <b>127</b> | <b>142</b> | <b>96</b> | <b>126</b> |
|    | 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<br>≥ 5.0 instantaneous (OSRW)   | ≥ 5.0 daily avg.<br>≥ 6.0 daily avg. (OSRW) |
| Un-ionized ammonia (mg/L)  | ≤ 0.05  | N/A   |
| <i>E. coli</i> (colonies/100 mL) for primary contact recreational (PCR) waters   | <b>May 1–Oct 31:</b> (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<br><b>Nov 1–Apr 30:</b> N/A |   |
| Fecal coliform (colonies/100 mL) for primary contact recreational (PCR) waters   | <b>May 1–Oct 31:</b> (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 | <b>Whole year:</b> 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 <sub>3</sub> ) | 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.



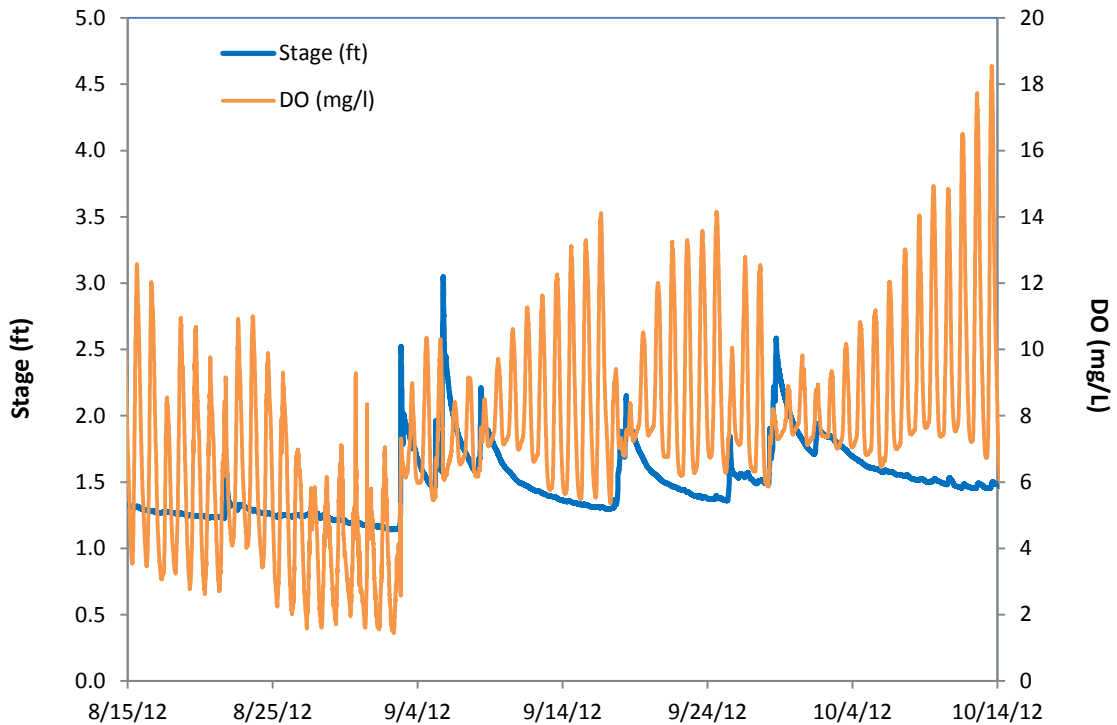
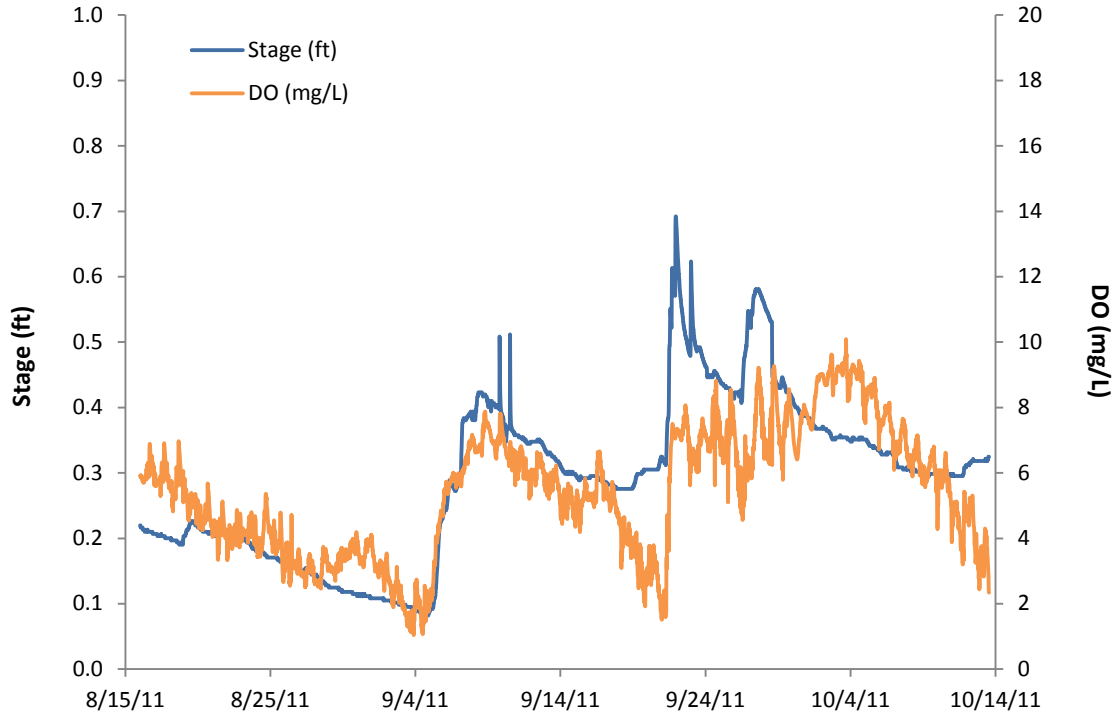
**Table 4.5** Summary of Phase 1 Physico-Chemical Parameter Results Based on Grab Samples (see [Appendix E](#))

| Parameter                           |  | BR1   | BR2   | BR 3  | BL 1  | BL 2  | CLI   |
|-------------------------------------|--|-------|-------|-------|-------|-------|-------|
| <b>Temperature (°C)</b>             | 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  |
| <b>pH (pH units)</b>                | 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     |
| <b>Dissolved oxygen (mg/L)</b>      | 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    |
| <b>Specific conductance (µS/cm)</b> | 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.

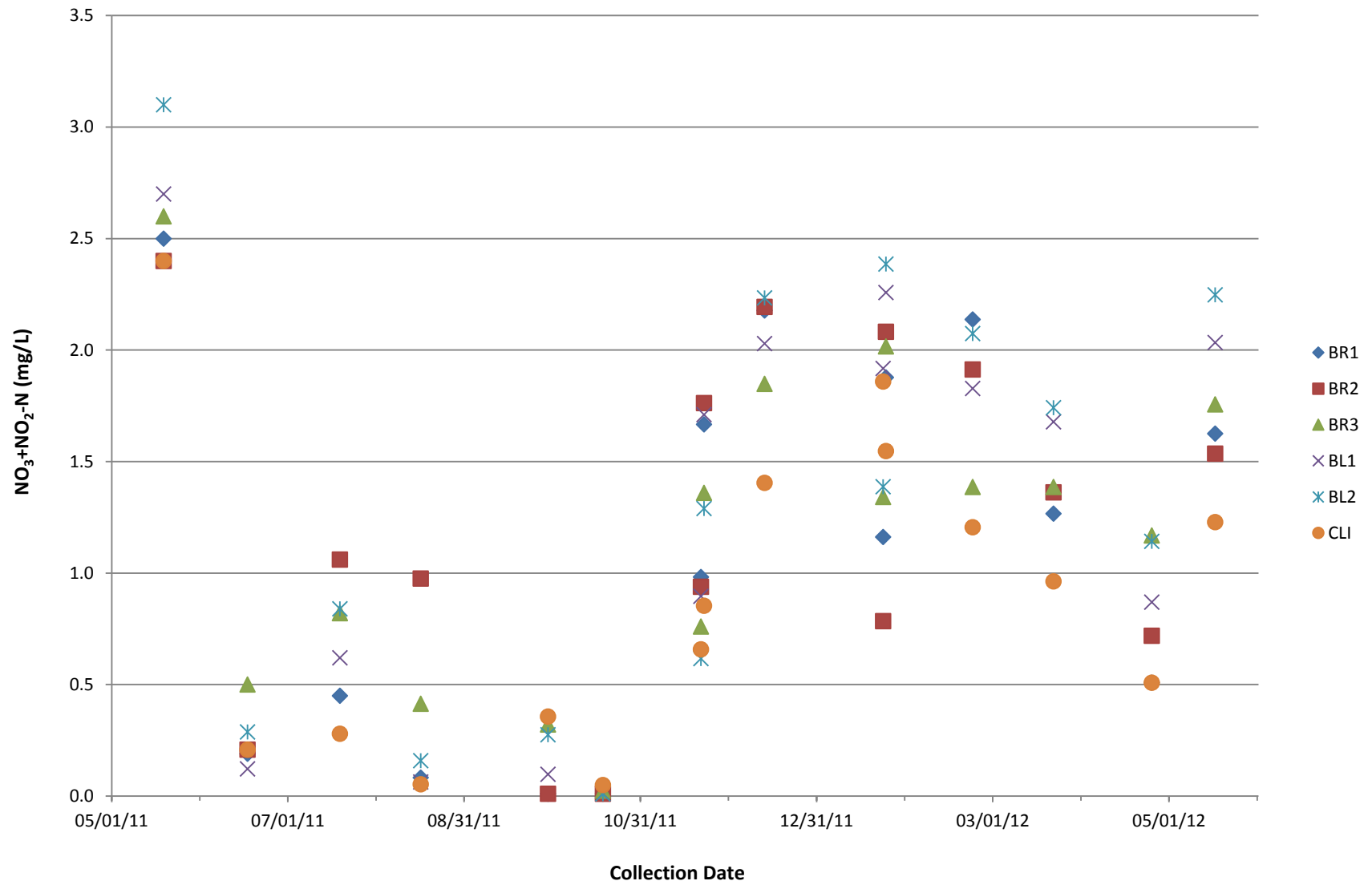
Table 4.6 Summary Statistics from Monthly and Run-off Sampling of Nutrients (see Appendix F for sampling data)

| Parameter*  |                                    | BR1    | BR2    | BR3    | BL1    | BL2    | CLI    |
|---|------------------------------------|--------|--------|--------|--------|--------|--------|
| <b>TN<br/>(1.3 mg/L)</b>                              | 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     |
| <b>NO<sub>3</sub>+NO<sub>2</sub>-N<br/>(0.9 mg/L)</b> | 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     |
| <b>TKN<sup>‡</sup><br/>(0.5 mg/L)</b>                 | 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     |
| <b>NH<sub>3</sub> - N<br/>(0.05 mg/L)</b>             | 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     |
| <b>NH<sub>3</sub> (un-ionized)<br/>[0.05 mg/L]</b>    | 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      |
| <b>TP<br/>(0.03 mg/L)</b>                             | 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     |
| <b>PO<sub>4</sub>-P (mg/L)<br/>(N/A)</b>              | 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 <sub>5</sub> (mg/L)<br>(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  |      |      |      |      |      |

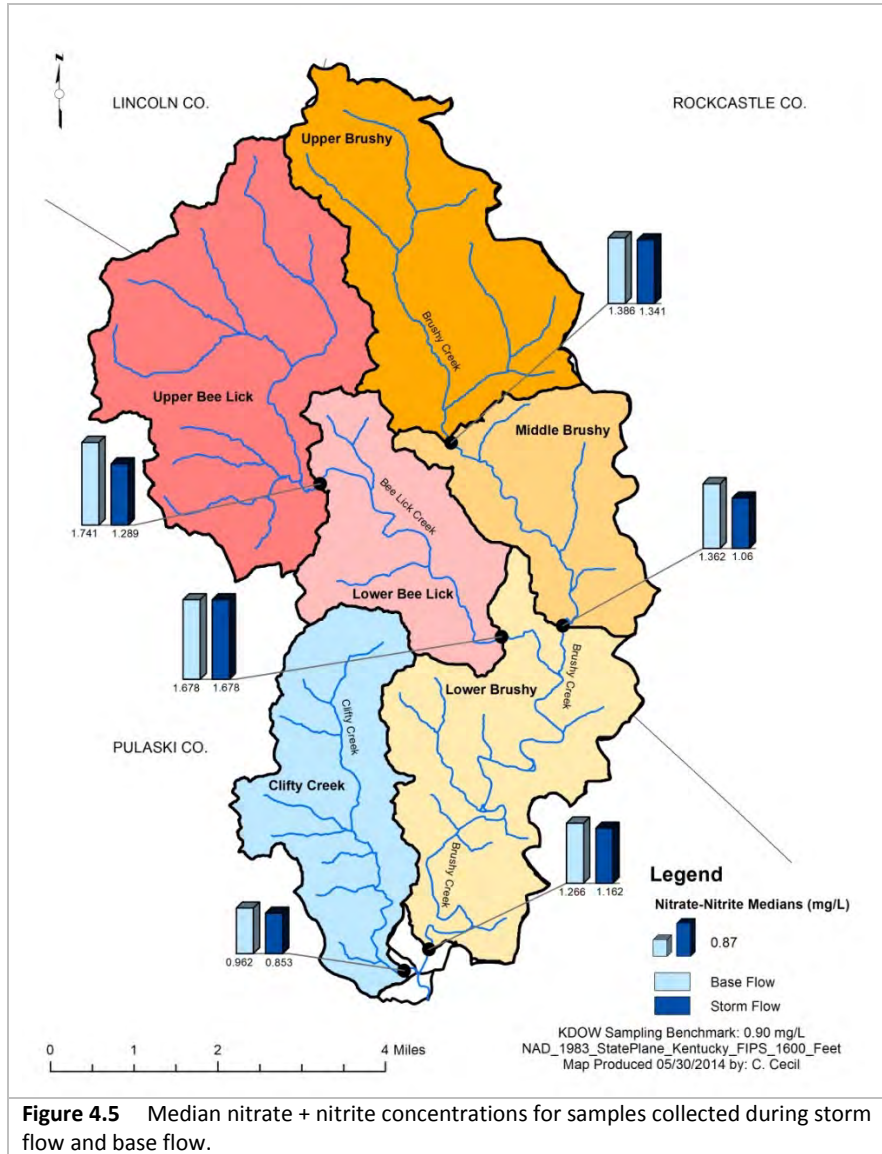
\* KDOW benchmarks are shown in parentheses (0.05 mg/L). Surface water standards are in brackets [0.05 mg/L].

‡ 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.

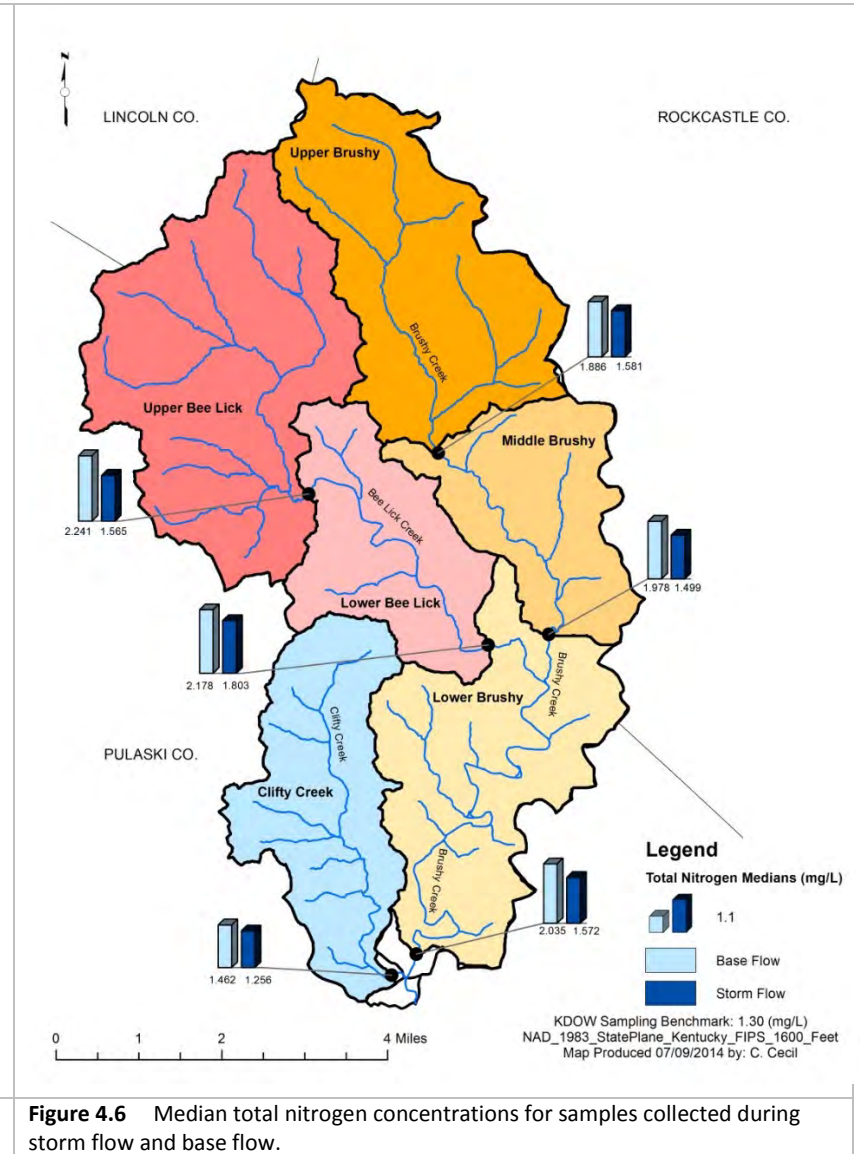


**Figure 4.4** Seasonal variations in nitrate + nitrite concentrations related to vegetative cover.

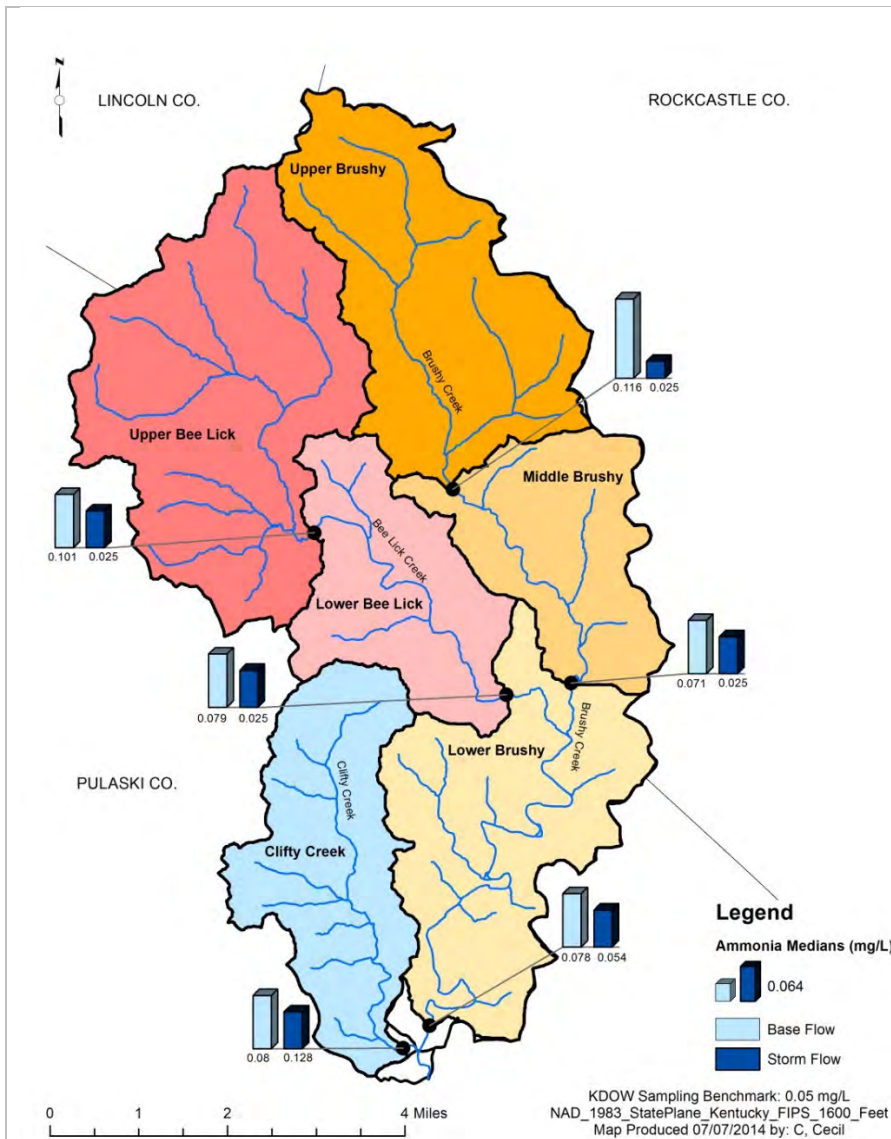




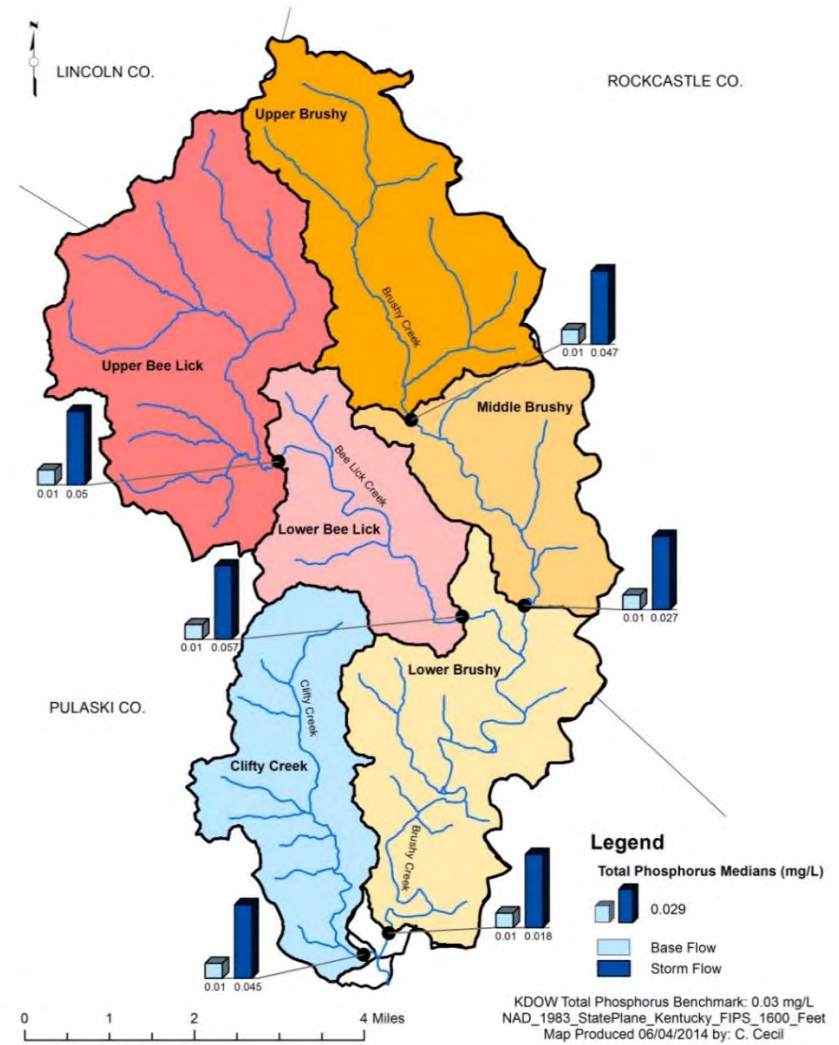
**Figure 4.5** Median nitrate + nitrite concentrations for samples collected during storm flow and base flow.



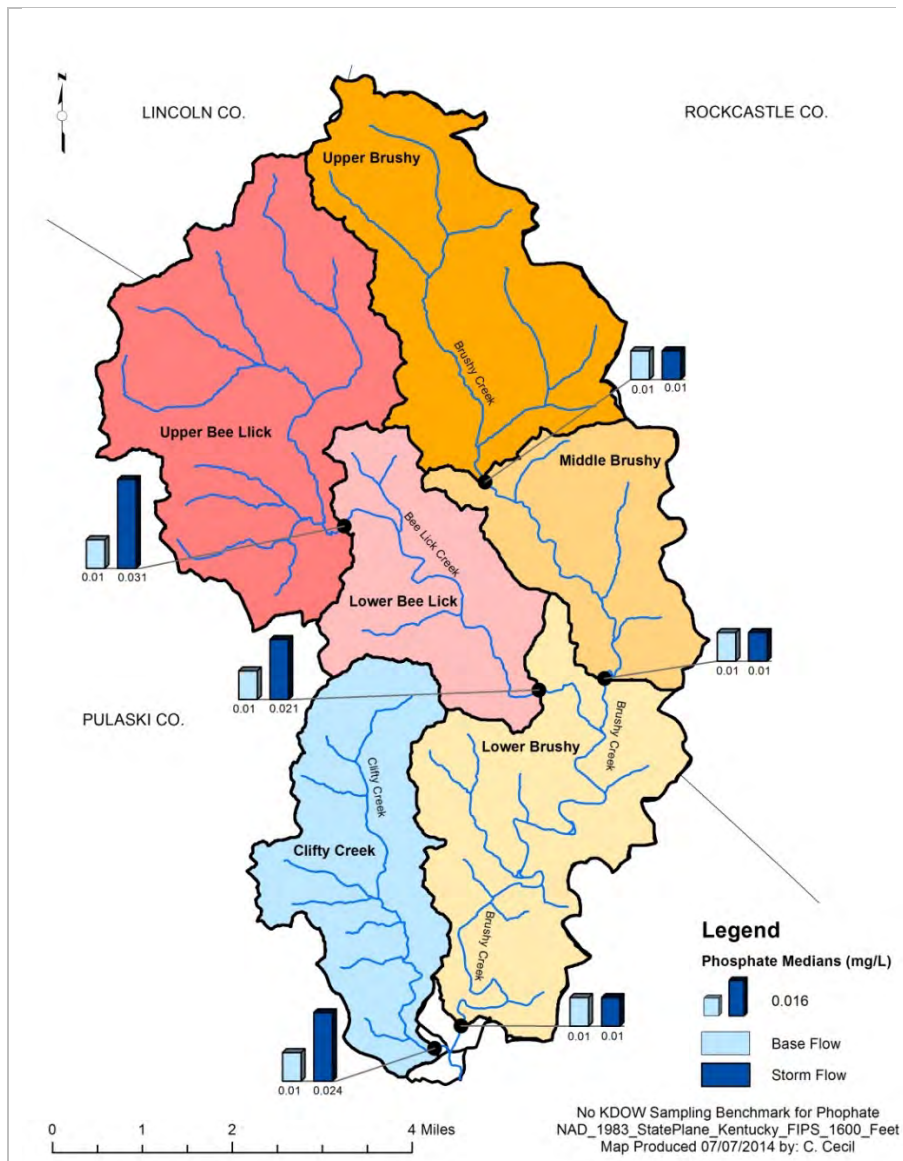
**Figure 4.6** Median total nitrogen concentrations for samples collected during storm flow and base flow.



**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.



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



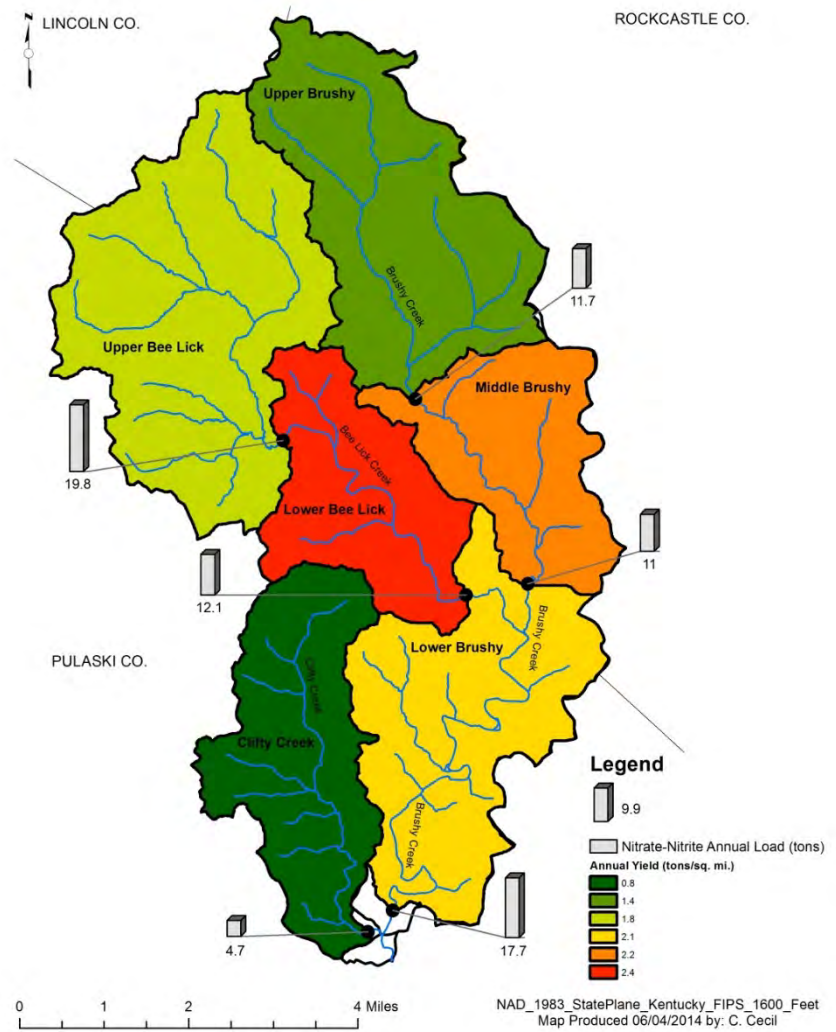
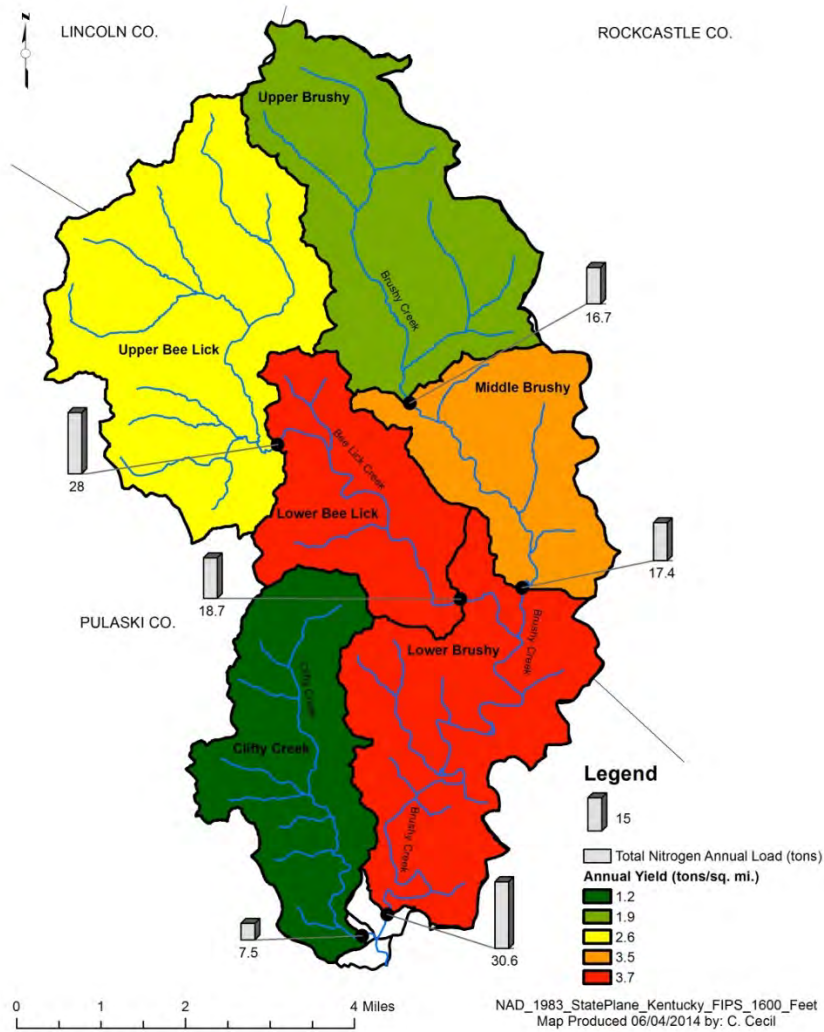
## Nutrient Loads and Yields

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)

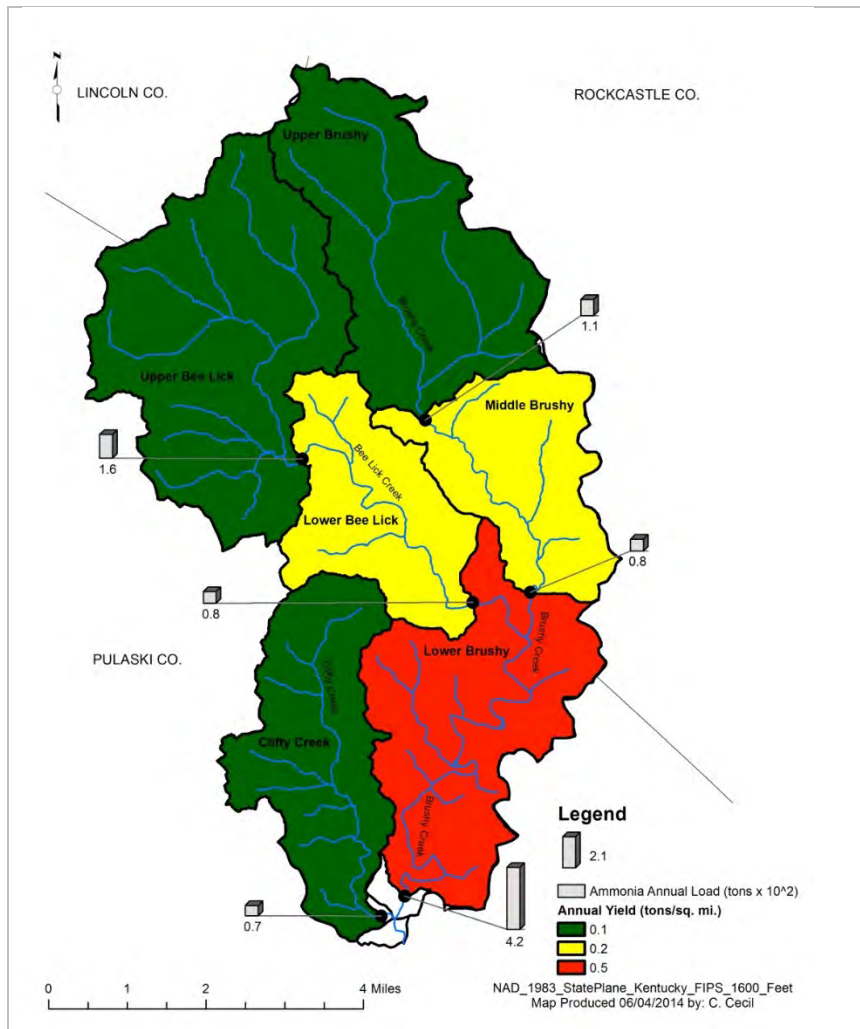
| Parameter  | Lower Brushy | Middle Brushy | Upper Brushy | Lower Bee Lick | Upper Bee Lick | Clifty |
|--|--------------|---------------|--------------|----------------|----------------|--------|
| Drainage area (mi <sup>2</sup> )   | 8.3          | 5             | 8.6          | 5.1            | 10.9           | 6.3    |
| Annual TN loads (tons)   | 30.6         | 17.4          | 16.7         | 18.7           | 28.0           | 7.5    |
| Annual TN yields (tons/ mi <sup>2</sup> )                                  | 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 <sub>3</sub> +NO <sub>2</sub> -N loads (tons)                    | 17.7         | 11.0          | 11.7         | 12.1           | 19.8           | 4.7    |
| Annual NO <sub>3</sub> +NO <sub>2</sub> -N yields (tons/ mi <sup>2</sup> ) | 2.1          | 2.2           | 1.4          | 2.4            | 1.8            | 0.8    |
| Annual benchmark NO <sub>3</sub> +NO <sub>2</sub> -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 <sub>3</sub> -N loads (tons)                                     | 4.2          | 0.8           | 1.1          | 0.8            | 1.6            | 0.7    |
| Annual NH <sub>3</sub> -N yields (tons/ mi <sup>2</sup> )                  | 0.5          | 0.2           | 0.1          | 0.2            | 0.1            | 0.1    |
| Annual benchmark NH <sub>3</sub> -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/ mi <sup>2</sup> )                   | 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     |



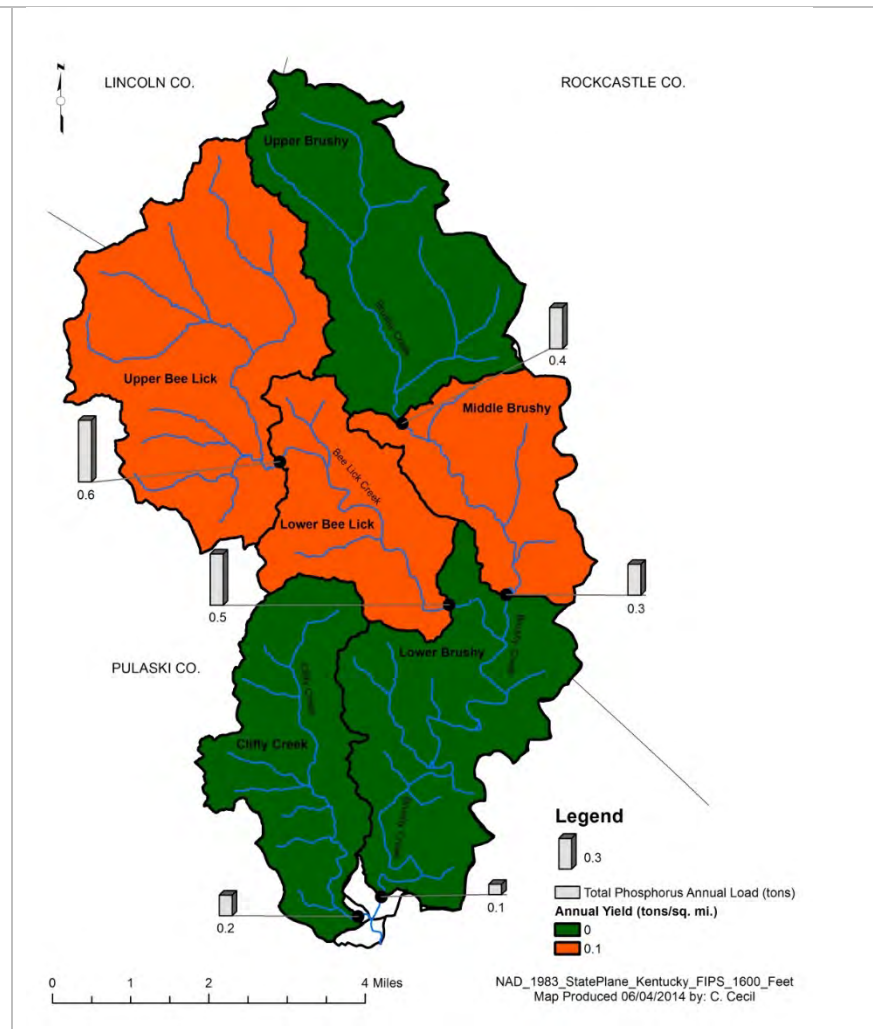
**Figure 4.10** Total nitrogen loads and yields by subwatershed.

**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

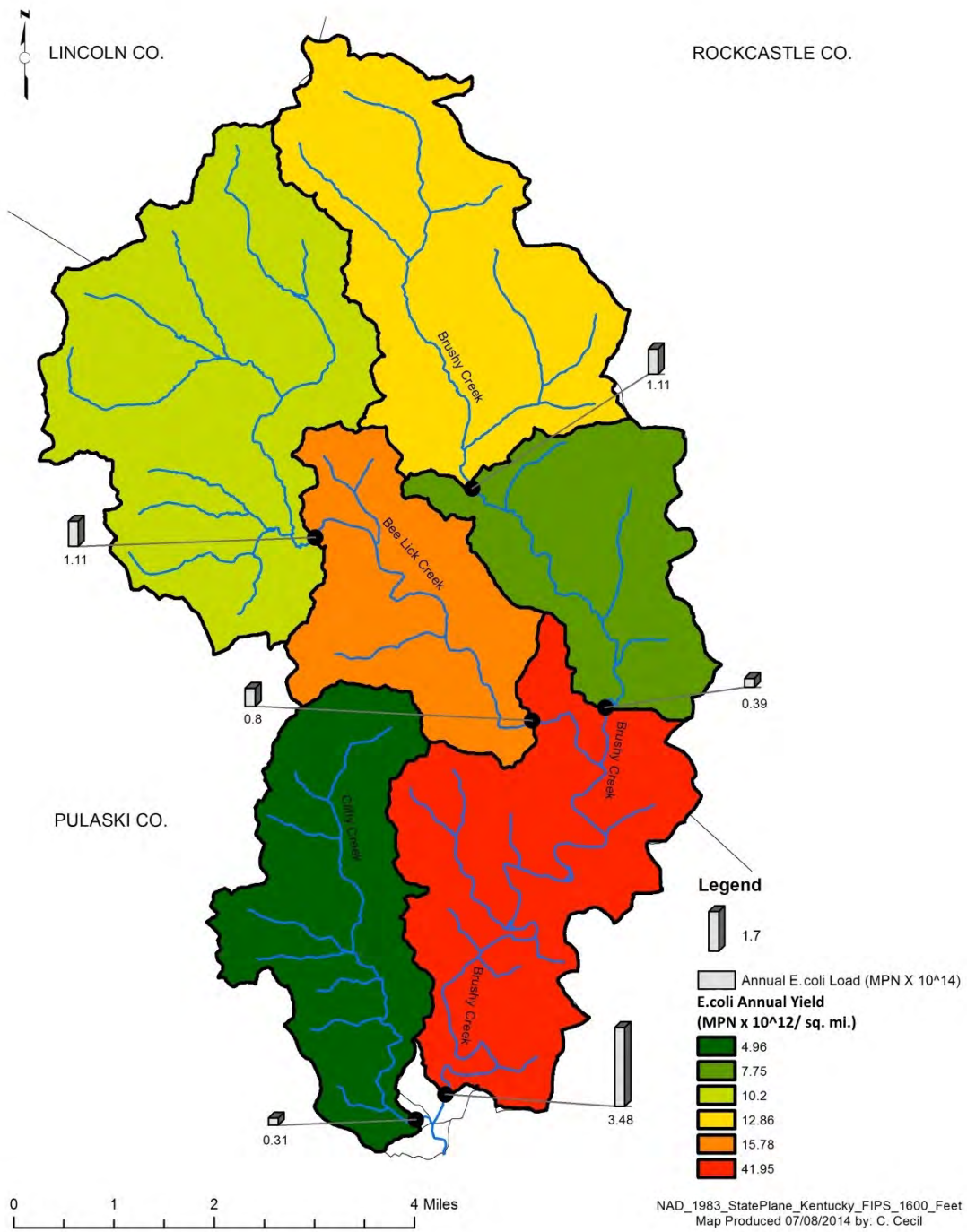
| Sample Collection Date | BR1        | BR2        | BR 3        | BL1        | BL2        | CLI        |
|------------------------|------------|------------|-------------|------------|------------|------------|
| 6/2/2011               | 64         | 210        | 1700        | 60         | 690        | 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        |
| <b>Geometric mean</b>  | <b>132</b> | <b>395</b> | <b>1318</b> | <b>173</b> | <b>527</b> | <b>325</b> |

**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 <sup>2</sup> )                                       | 8.3          | 5             | 8.6          | 5.1            | 10.9           | 6.3    |
| Annual <i>E. coli</i> loads (MPN x10 <sup>14</sup> )                   | 3.48         | 0.39          | 1.11         | 0.80           | 1.11           | 0.31   |
| Annual <i>E. coli</i> yields (MPN x10 <sup>12</sup> /mi <sup>2</sup> ) | 41.95        | 7.75          | 12.86        | 15.78          | 10.20          | 4.96   |
| Benchmark annual loads (MPN x 10 <sup>14</sup> )                       | 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.



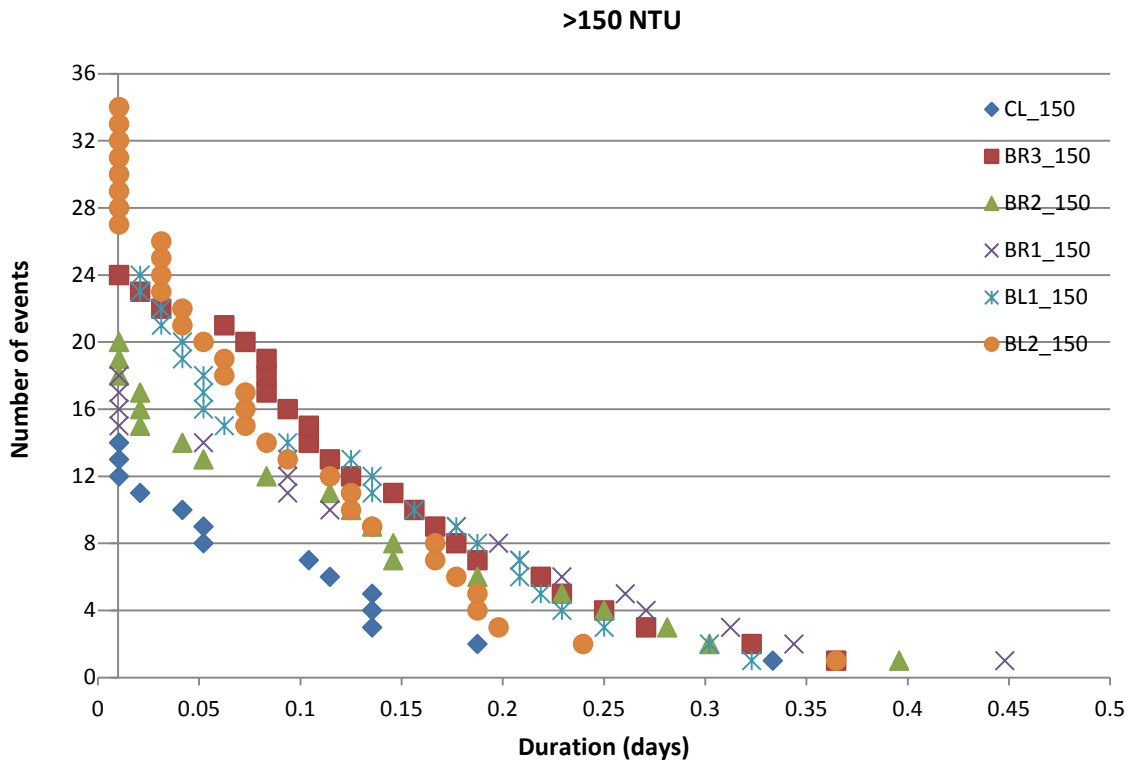


Figure 4.15 Frequency and duration of exceedances of 150 NTU threshold.

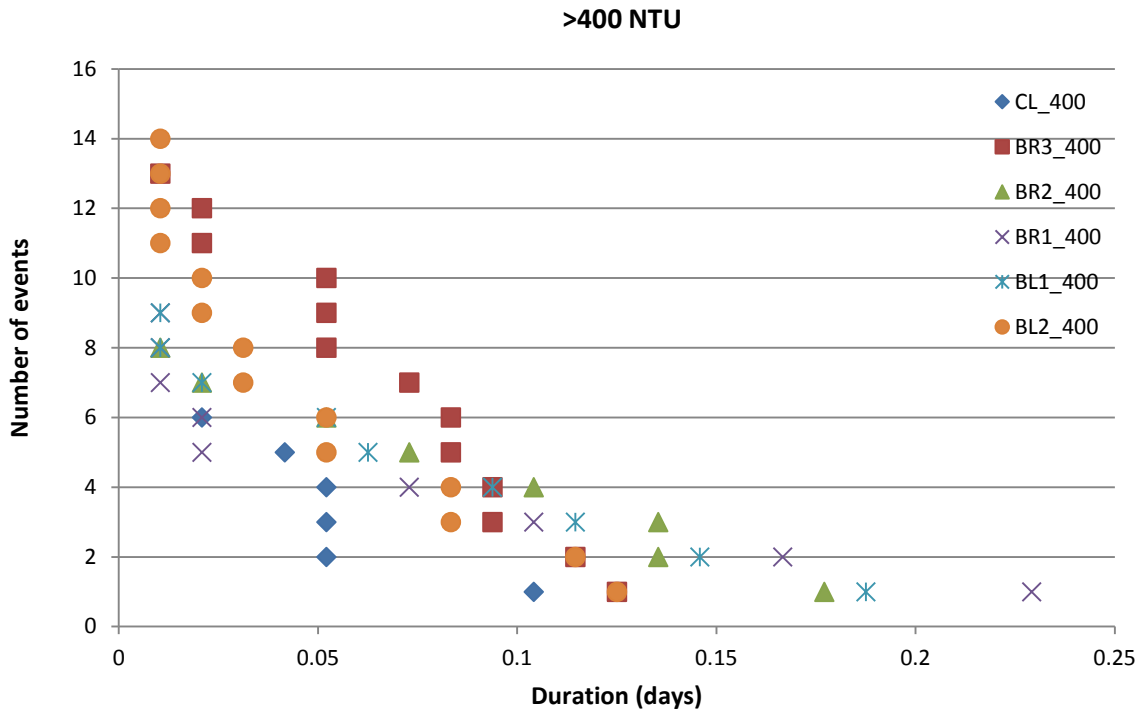


Figure 4.16 Frequency and duration of exceedances of 400 NTU threshold.

## Sediment Loads and Yields

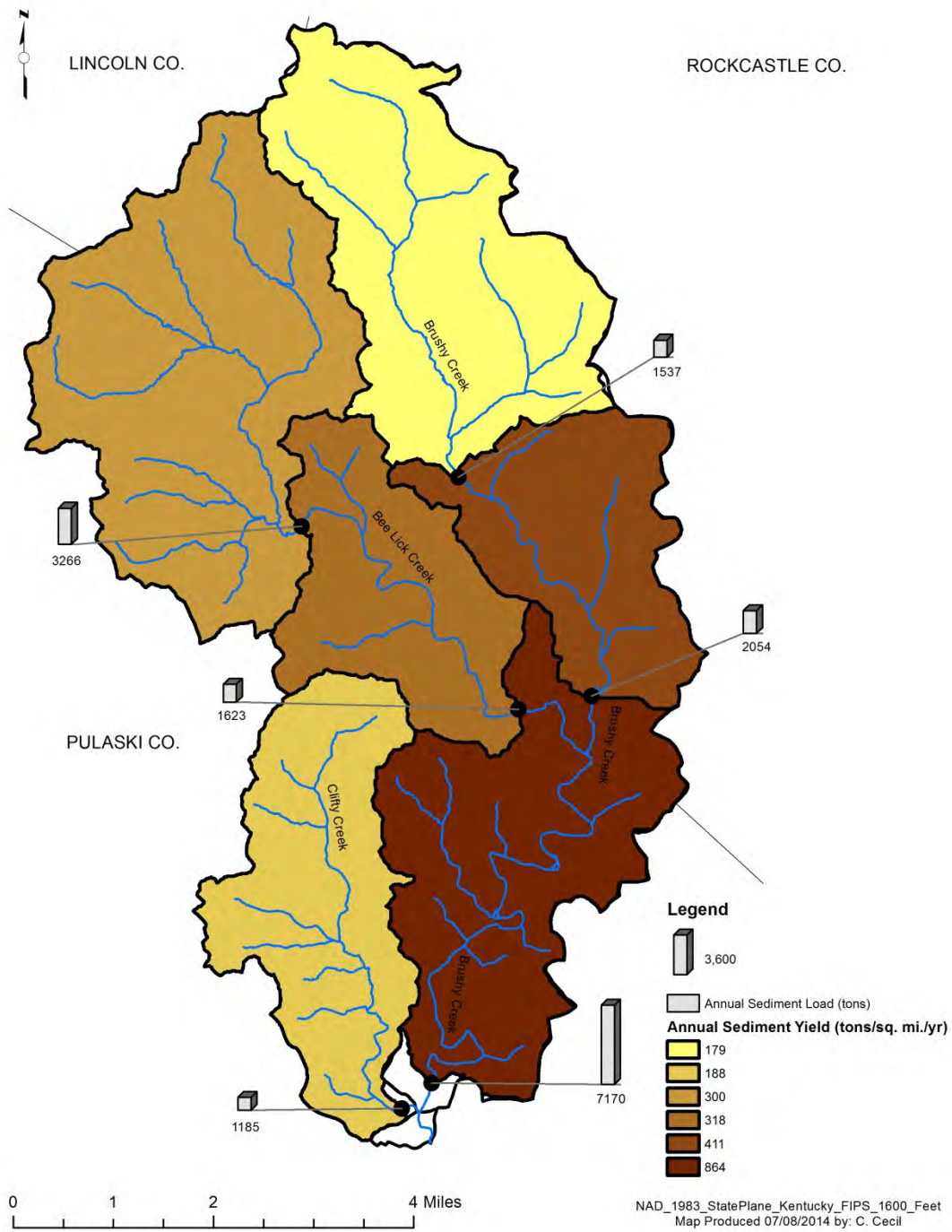
Sediment loads were highest at BR1 (Fig. 4.17), which has by far the largest contributing drainage area. Given the lack of accessible floodplain and limited storage potential in the watershed, we expected that loads would increase with increasing drainage area. Sediment yields (loads normalized by drainage 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 <sup>2</sup> ) | 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 <sup>2</sup> /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/mi<sup>2</sup>/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 ECU 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 ECU 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

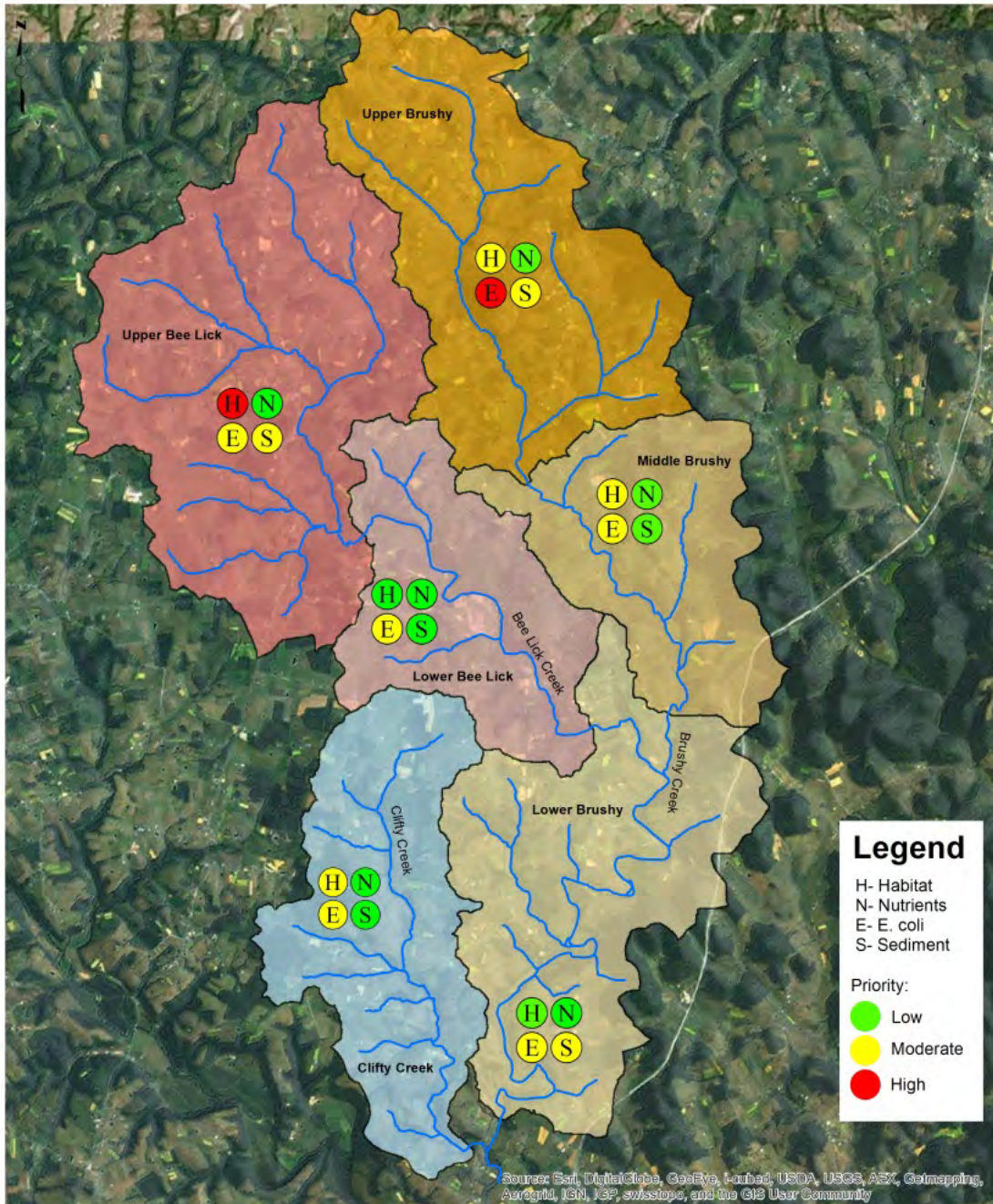
A summary of pollutants or parameters to be addressed (Table 4.12 and Fig. 4.18) was developed based on

- 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  |
|-----------------------|------------------|-----------|------------------------------------|--------------|---|
| <b>Lower Brushy</b>   | 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   |
|                       | <i>E. coli</i>   | 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              |
| <b>Middle Brushy</b>  | 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   |
|                       | <i>E. coli</i>   | Moderate  | Widespread                         | Moderate     | Dependent on landowner cooperation  |
|                       | Sediment         | Low       | N/A                                | Low          | Sustainable habitat improvements are likely to be cost prohibitive                              |
| <b>Upper Brushy</b>   | 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   |
|                       | <i>E. coli</i>   | High      | Widespread                         | Moderate     | Dependent on landowner cooperation  |
|                       | Sediment         | Moderate  | Localized                          | Moderate     | Obtaining conservation easements from multiple landowners would be required                     |
| <b>Lower Bee Lick</b> | 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   |
|                       | <i>E. coli</i>   | Moderate  | Widespread                         | Moderate     | Dependent on landowner cooperation  |
|                       | Sediment         | Low       | N/A                                | Low          | Sustainable habitat improvements are likely to be cost prohibitive                              |
| <b>Upper Bee Lick</b> | 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                             |
|                       | <i>E. coli</i>   | Moderate  | Widespread                         | Moderate     | Dependent on landowner cooperation  |
|                       | Sediment         | Moderate  | Localized                          | Moderate     | Obtaining conservation easements from multiple landowners would be required                     |
| <b>Clifty</b>         | 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                             |
|                       | <i>E. coli</i>   | Moderate  | Widespread                         | Moderate     | Dependent on landowner cooperation  |
|                       | Sediment         | Low       | N/A                                | Moderate     | Obtaining conservation easements from multiple landowners would be required                     |



**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.

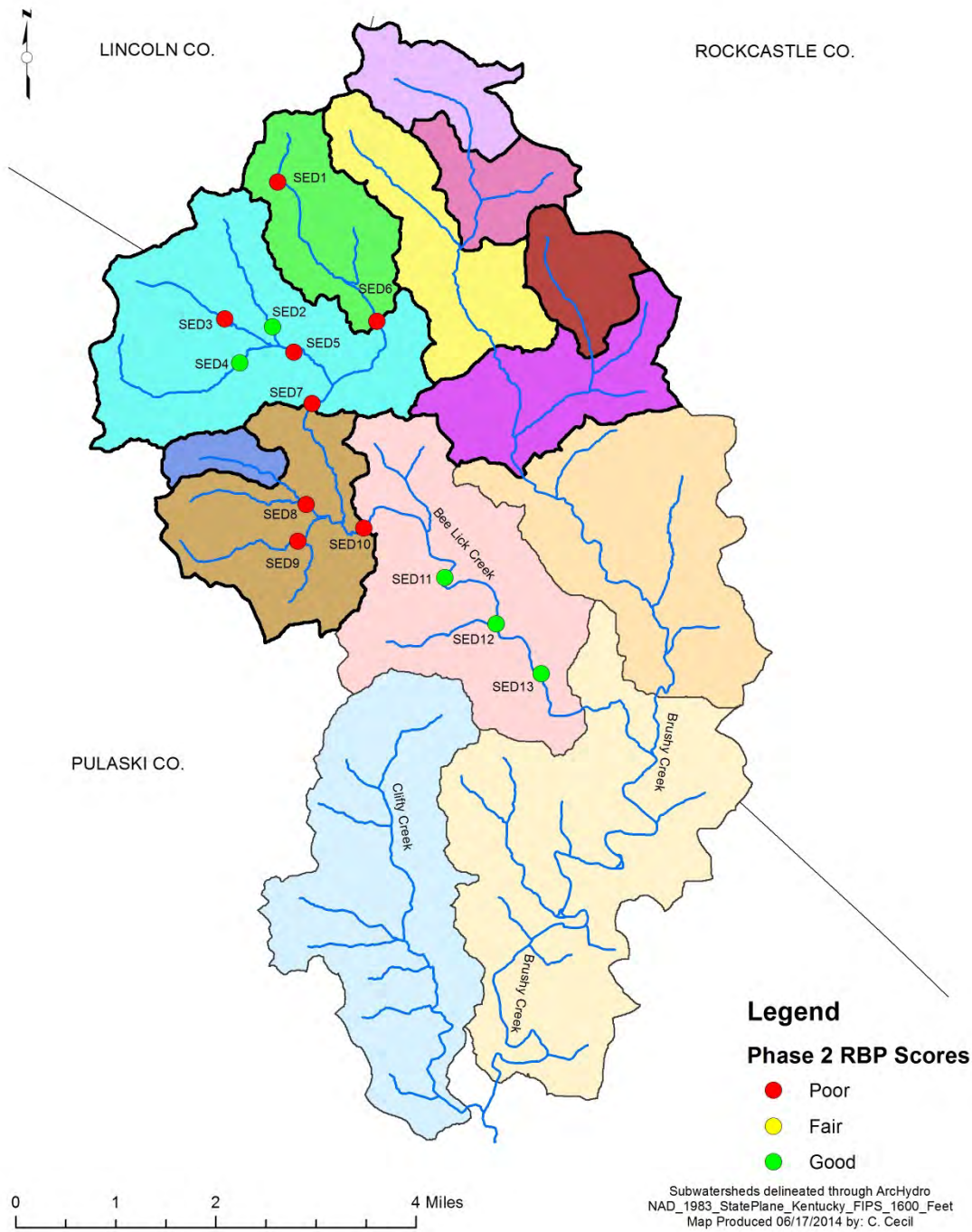
### 4.2.1 Habitat

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 unfor-ested, 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 silta-tion 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 down-stream habitat quality.

Given that the BL2 reach was identified as experiencing the most embeddedness in the subwater-shed, 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 Pen-nyroyal 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 suita-bility. 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 wa-ter 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.





**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/<br>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<br>width (L)   | 4    | 5    | 1    | 10   | 1    | 4    | 0    | 4    | 2     | 5     | 10    | 6     |
|               | Riparian vegetative zone<br>width (R)   | 4    | 5    | 5    | 10   | 5    | 5    | 0    | 4    | 6     | 5     | 6     | 10    |
|               | <b>Total</b>                            | 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 | %CIngP | MBI W full<br>(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.

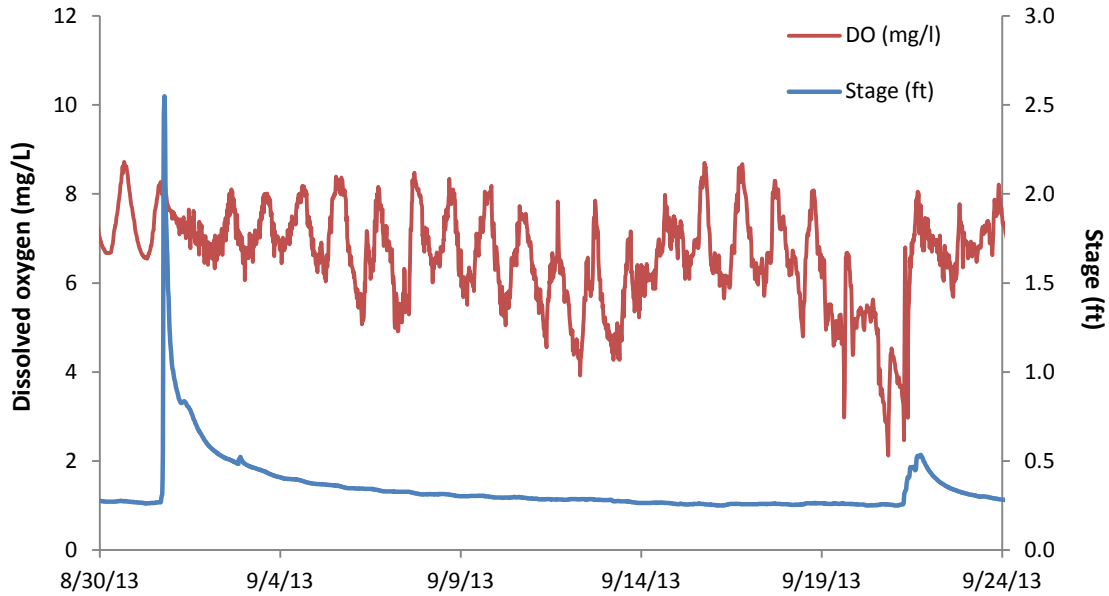
Overall, the BL1 site was “0.5 points from being in the excellent rating, while the upper site is a solid good (even though it is more diverse)” (Mark Vogel, pers. comm., July 18, 2013). The BL2 reach, with a “good” MBI rating, had the most abundant deposition and embeddedness of any site visited in 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.



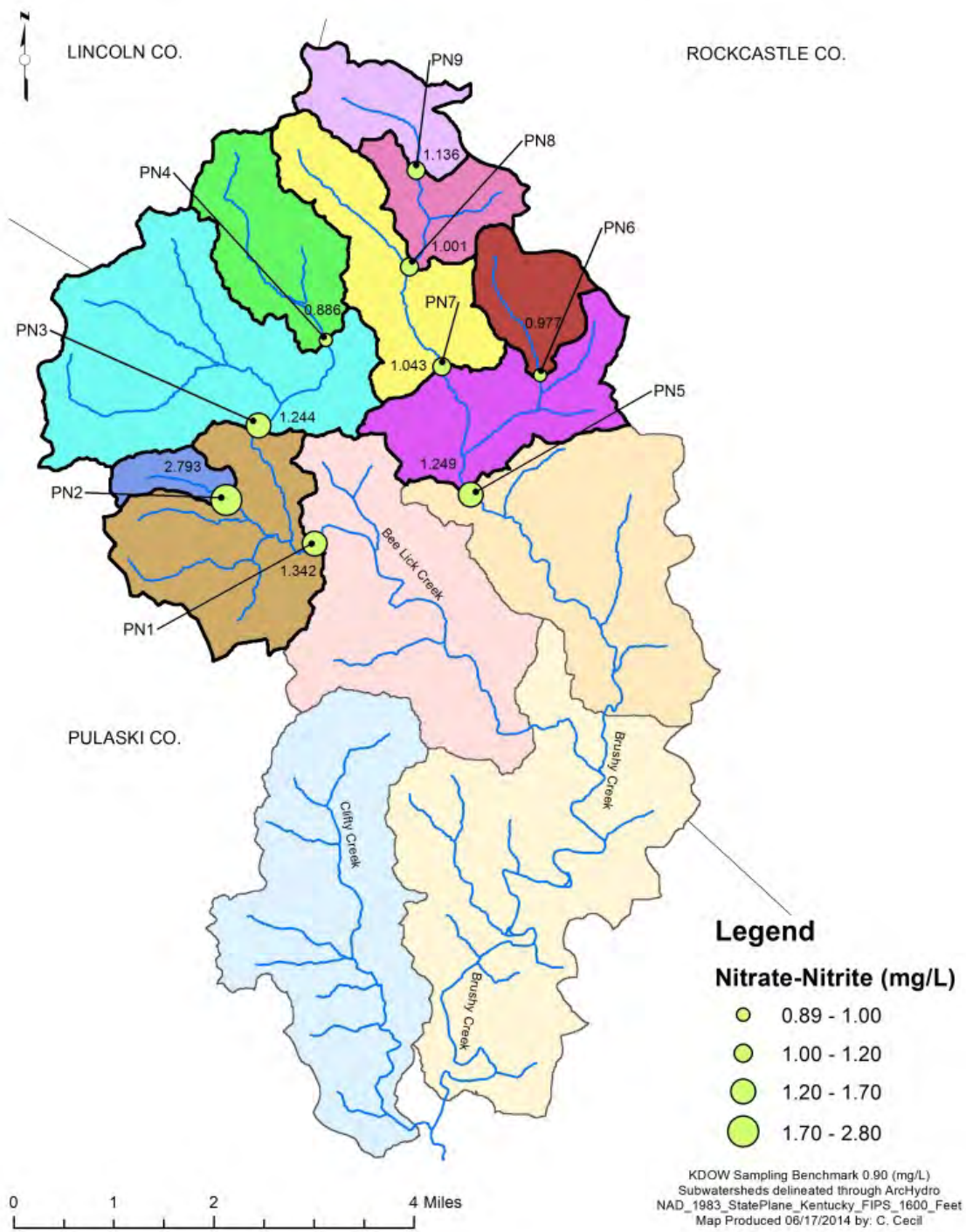
**Figure 4.20** Dissolved oxygen dropped below the surface water standard for a brief time. It went back up after a small flood event.

### 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 <sub>4</sub> -P (mg/L) | NH <sub>3</sub> -N (mg/L) | NO <sub>3</sub> +NO <sub>2</sub> -N (mg/L) | TKN (mg/L) | TP-P (mg/L) | <i>E. coli</i> (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

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## 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  |
|---------------------------------|---|--|
| <b>Agriculture</b>              | <ul style="list-style-type: none"> <li>• Livestock exclusion fencing</li> <li>• Alternative watering sources</li> <li>• Stream Crossings</li> <li>• Feeding and Heavy Use Area Protection</li> <li>• Nutrient Management</li> <li>• Riparian Area Protection</li> <li>• Prescribed Grazing</li> </ul> | <ul style="list-style-type: none"> <li>• Workshops, trainings, presentations on Ag water quality plans, nutrient management plans, &amp; State Cost Share</li> <li>• Farm Field Days</li> <li>• Technical assistance for BMP implementation</li> </ul> |
| <b>On-site Sewage Treatment</b> | <ul style="list-style-type: none"> <li>• Septic tank pump outs</li> <li>• Septic system repair or replacement</li> <li>• Septic system installation for straight pipe issues</li> </ul>   | <ul style="list-style-type: none"> <li>• Educational materials on septic system maintenance</li> <li>• Farm Field Days</li> </ul>  |

## 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 | % <i>E. coli</i> 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  $1.28 \times 10^{12}$  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 =  $6.4 \times 10^{11}$  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 Subwatershed |
|-------------------------------------|------------|---------------|------------|------------------------------|
| 5130103040010<br>Upper Brushy Creek | 25         | 7736          | 10         | 7770                         |
| 5130103040020<br>Upper Bee Lick     | 3595       | 2195          | 156        | 5947                         |
| 5130103040030<br>Lower Brushy Creek | 2001       | 62            | 0          | 2063                         |
| 5130103040040<br>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:

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

and

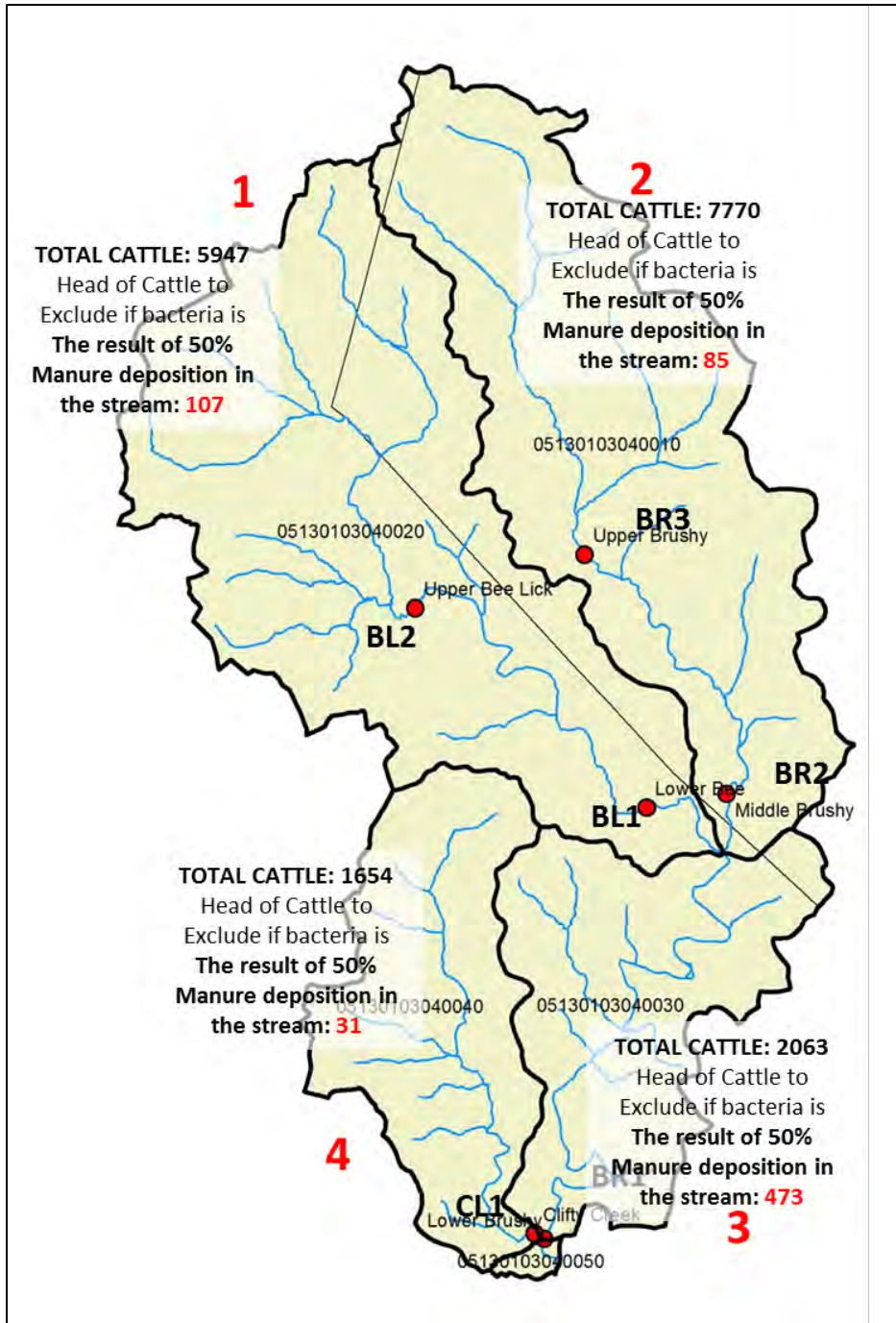
$$\frac{\text{Load reduction needed}}{(6.40 \times 10^{11} \text{ CFU E.coli/year})} = \# \text{ cattle to exclude from stream}$$

**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<br>Upper Brushy Creek   | 7770                         | 5.45E+13                         | 85                                    |
| 5130103040020<br>Upper Bee Lick Creek | 5947                         | 6.82E+13                         | 107                                   |
| 5130103040030<br>Lower Brushy Creek   | 2063                         | 3.03E+14                         | 473                                   |
| 5130103040040<br>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.

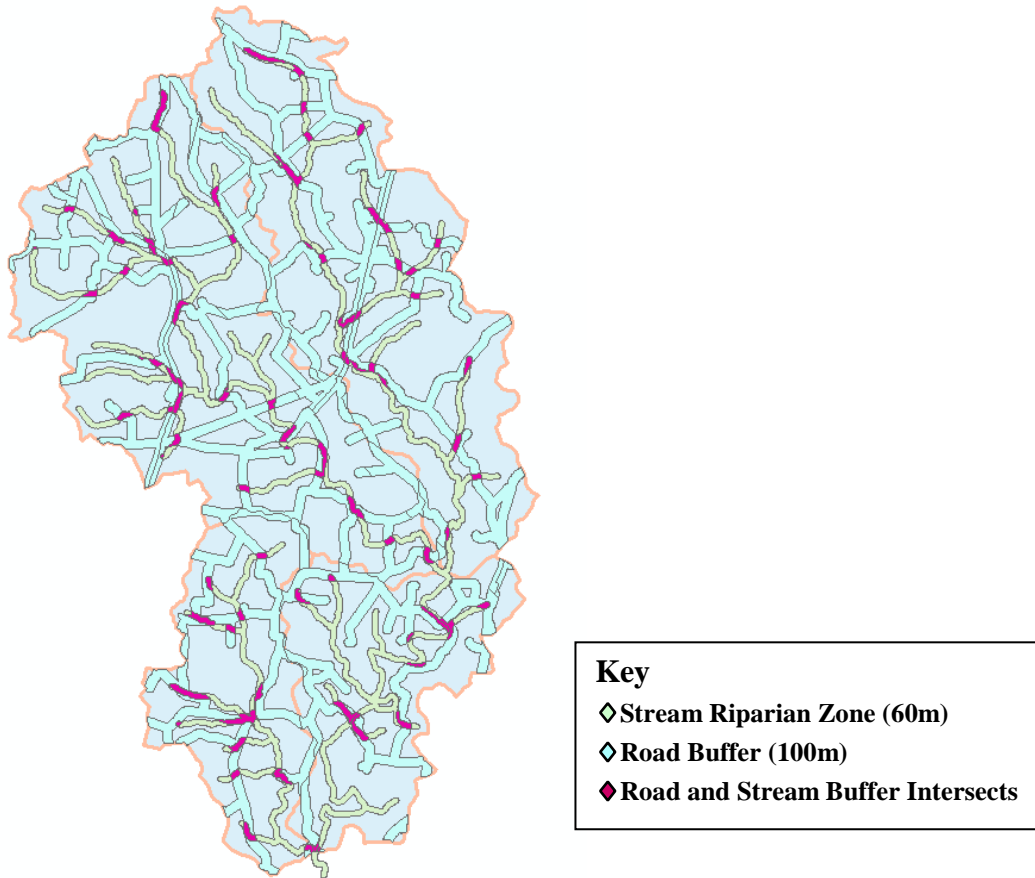
### 6.3 On-site Sewage BMPs

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.tetrattech-fx.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:

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

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:

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

Calculate the Annual Loading Rate per septic system:

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

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:

$$\frac{\text{(Load Reduction if all Systems Replaced)}}{\text{(Load Reduction Needed)}} * 100 = \text{\% of Necessary Load Reduction Accomplished if All Failing systems Replaced}$$

**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 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  |

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  $5.01 \times 10^{10}$  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).



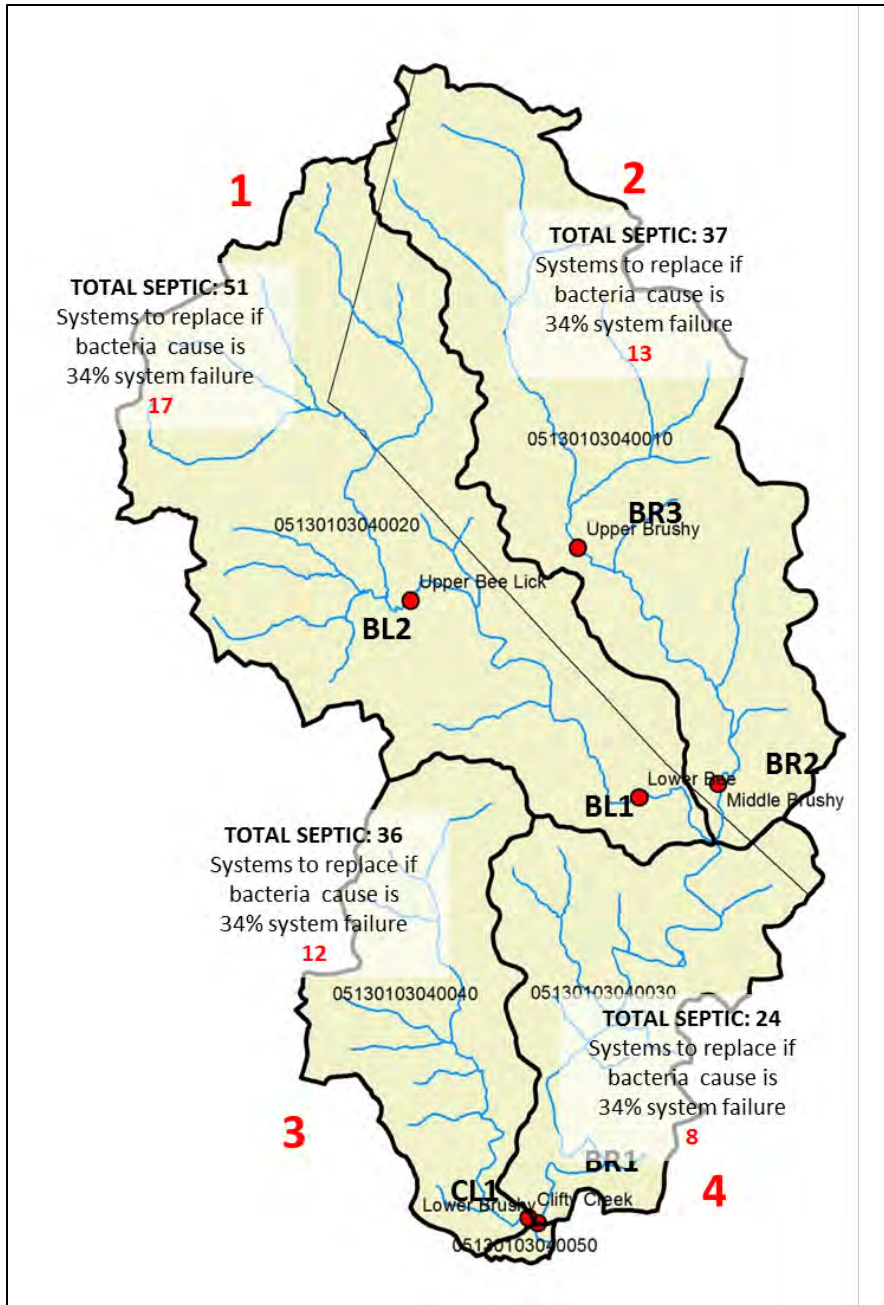
**Table 6.10** Load reductions for septic replacement of all systems.

| 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

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## 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/<br>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         |
| <b>Total Cost: Priority 1 Subwatersheds</b>       |          |                    | <b>\$97,310.75</b> |

**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<br>or replacement) | Total Cost       |
|----------------------|--------------------------|--|------------------|
| Upper Bee Lick Creek | 26                       | \$4,000                                    | \$104,000        |
| Upper Brushy Creek   | 19                       | \$4,000                                    | \$76,000         |
| <b>Total</b>         | <b>45</b>                | <b>\$4,000</b>                             | <b>\$180,000</b> |

### 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

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

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

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- A Quality Assurance Project Plan (QAPP)**
  - Phase 1 QAPP
  - TKN reporting limit revision
  - Phase 2 QAPP
- B Measurement Specifications**
- C Flowtracker Discharge Measurements**
- D Phase 1 RBP Field Data Forms**
- E Phase 1 Field Parameter Data**
- F Phase 1 Nutrient Data**
- G Phase 1 Nutrient Load Duration Curves**
- H Phase 1 *E. coli* Data and Load Duration Curves**
- I Phase 2 Habitat Assessments**
- J Brushy Creek Load Reduction Strategy**
- K Division of Conservation BMP Guide**

## 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)

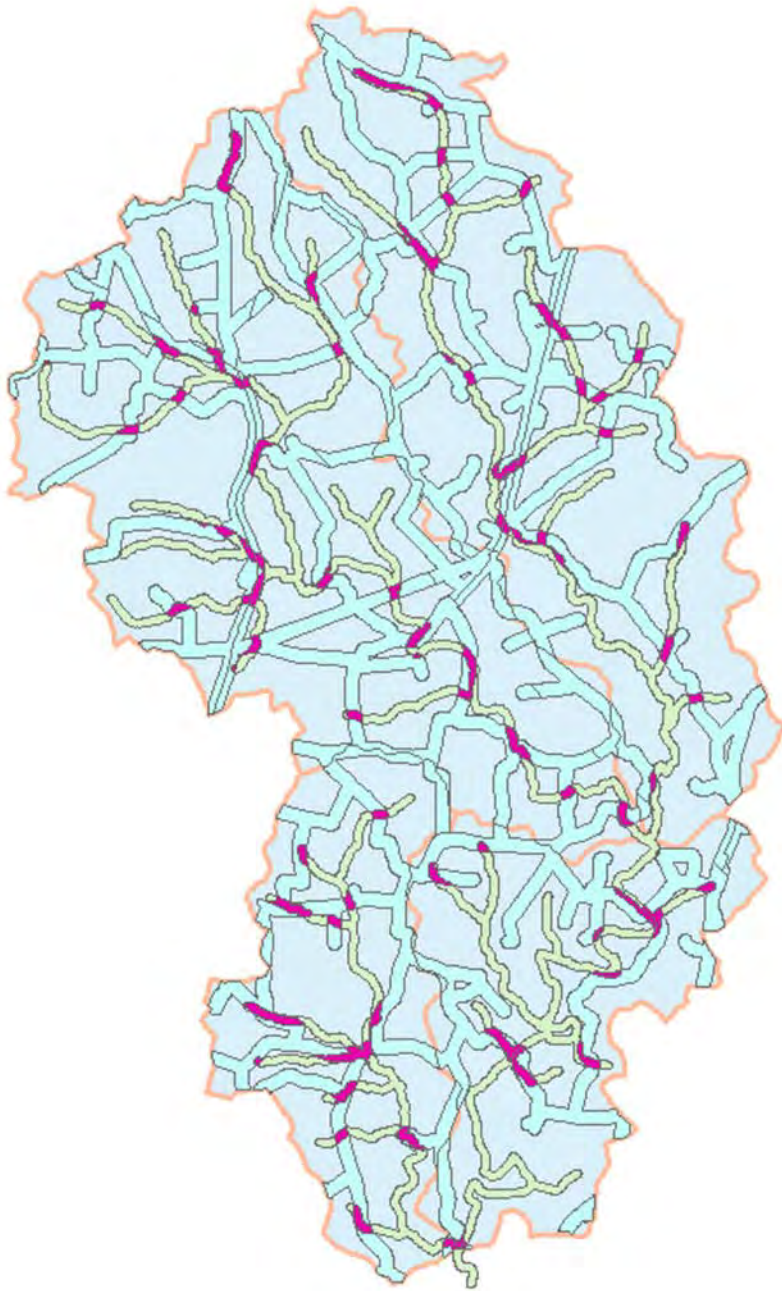
Assuming you've already calculated the annual load (CFU/yr) and the necessary load reductions for each site, you need to figure out the potential sources of bacteria. This can be complicated when you attempt to quantify all the potential sources, but for the purposes of watershed planning, we can simplify 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.tetrattech.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.

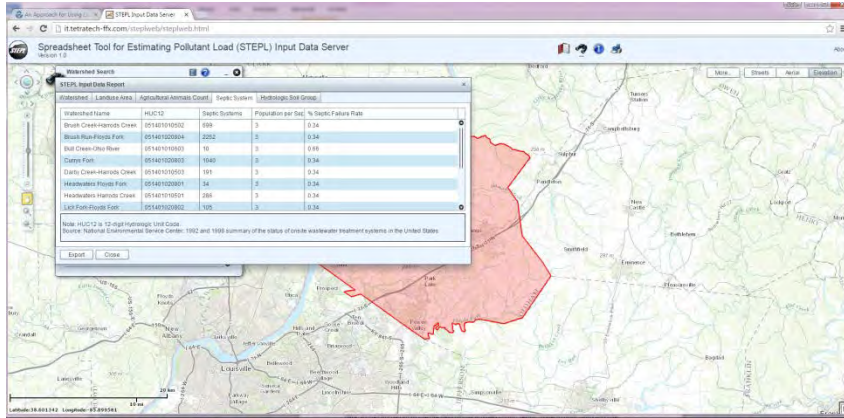


Figure 2) Screenshot of StepL model output.

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:

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

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)

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

Calculate the Annual Loading Rate per septic system:

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

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.

$$\frac{\text{(Load Reduction if all Systems Replaced)}}{\text{(Load Reduction Needed)}} * 100 = \text{\% of Necessary Load Reduction Accomplished if All Failing systems Replaced}$$

**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.

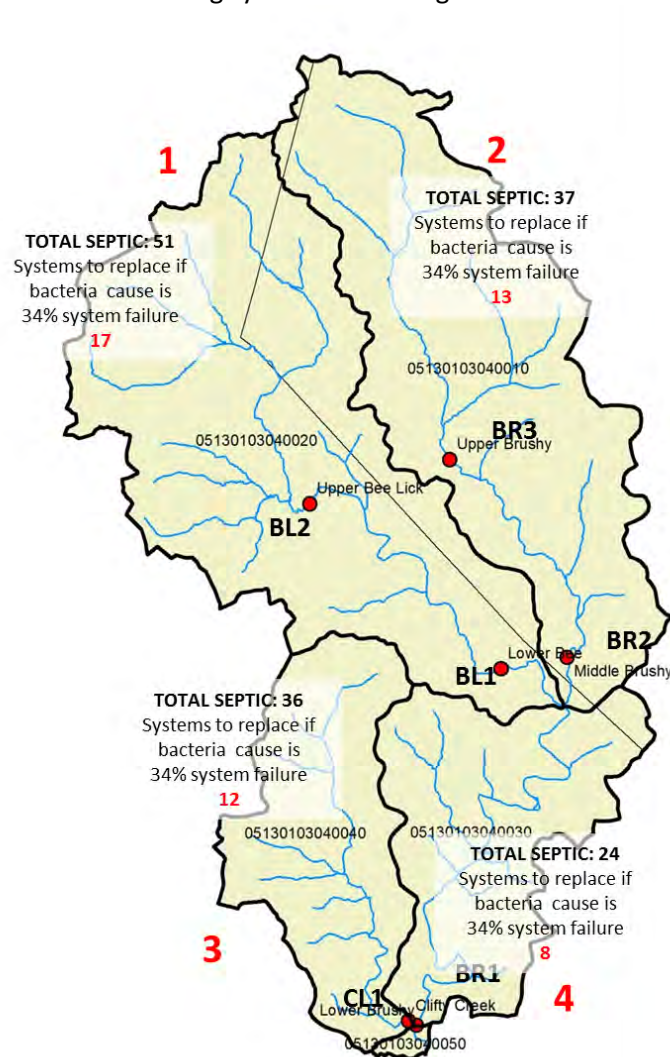


Figure 3) Map of the Brushy Creek Watershed Plan area and potential septic prioritization, with 1 being highest priority, and 4 being lowest.

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.