Chapter 1. Introduction

1.a Introduction to the Project

Mission Statement

Use watershed planning as a tool to prevent further degradation and to maintain the long-term quality of water resources within the greater Bonne Femme Watershed.

Bonne Femme Watershed Project Background

In 2001, the directors of the Missouri Department of Conservation (MDC) and Missouri Department of Natural Resources (MDNR) instructed a group of State and Federal employees to work towards protecting the streams in the greater Bonne Femme Watershed. This group, initially called the Southern Boone County Karst Team, decided one way to accomplish this goal was through a Clean Water Act, section 319 grant. These grants, awarded by the Environmental Protection Agency through MDNR, are designed to help protect streams from *nonpoint source (NPS) pollution* (see Watersheds and Nonpoint Source Pollution sidebar).

The funding for 319 grant projects stipulates that 60% of the funds are federal and 40% comes from state and local match.

Since most of the watershed is in Boone County's jurisdiction, the Karst Team invited county staff to participate on the team, and asked the county commission to sponsor the grant. In November 2001, the Boone County Commission applied for a 319 grant to be administered by the Planning and Building Inspection Department. The grant was awarded in June, 2003, providing funding for a four-year period. Members of the Karst Team became the project Steering Committee. An Urban Watershed Conservationist was hired in October 2003 as the project staff.

Partners for the project include Boone County Commission, City of Columbia, City of Ashland, Missouri Department of Conservation, Missouri Department of Natural Resources, University of Missouri-Columbia, United States Department of Agriculture (USDA)-Agricultural Research Service, Boone County Soil and Water Conservation District, Rock Bridge Memorial State Park, Chouteau Grotto, and the Friends of Rock Bridge. Their participation ensures a stronger project and increases the odds of

Why "greater Bonne Femme watershed"?

This project includes both the Bonne Femme and Little Bonne Femme Watersheds because they are connected: most of the time, all of the flowing water in the upper portion of Bonne Femme Creek flows underground to the Little Bonne Femme Creek via the Devil's Icebox Cave Branch, thus the name "greater Bonne Femme Watershed" (see Figure 1.1). For simplicity, "greater" is dropped from the project's name.

successful plan implementation. Their representation on the committee varies widely; some partners serve on the Policy Committee, and others are called upon as needed. Their participation helps meet the local match for federal funding.

Project History

There has been a long history of public interest in the natural features of the watershed. The effort to create a park at Rock Bridge began in the early 1900s, although it had been a semi-public area for over half a century. A similar effort to form Three Creeks Conservation Area began in the late 1980s.

In the late 1990s, two grants and a long-term research project in the watershed laid an excellent foundation for current project. Previous efforts increased awareness about the importance of protecting the streams within the watershed, and also provided baseline scientific data to establish pre-urbanization water quality conditions within the watershed. The first grant sponsored a project called the Bonne Femme Watershed Partnership. It established demonstration sites (lawn maintenance, residential BMPs, streambank stabilization, and on-site sewage systems), and sponsored stream cleanups, newsletters, watershed festivals, news articles, and more.

Working cooperatively with the Bonne Femme Watershed Partnership from July 1998 to June 2002, the Boone County Soil and Water Conservation District sponsored the Boone Femme Nonpoint Source Special Land Area Treatment (AgNPS SALT) grant. This grant provided cost-share money specifically for landowners in the Bonne Femme Watershed for five years, in addition to the ongoing, county-wide state and federal cost-share money available for agricultural conservation practices. More than fifty people participated in workshops for producers with livestock on small grazing acreages throughout the watershed. Fourteen other workshops (with nearly 400 participants) were held to educate and promote conservation practices on grazing and row crop land.

Practices installed on the ground included over 550 acres of practices on grazing land. Landowners installed conservation practices on over 3,650 acres of row crop. Thirty acres of riparian corridor were established.

Collectively, these projects, field days and workshops heightened community awareness of water quality issues and prepared the way for the current project.

Project Objectives

- Help Boone County, and the cities of Ashland and Columbia, adopt procedures and policies that will help protect the streams in the watershed.
- Developers and builders will be assisted in adopting best management practices (BMPs) that will help protect stream integrity within the watershed.
- Provide cost-share assistance for land owners in the watershed to implement practices that will protect and restore the streams.

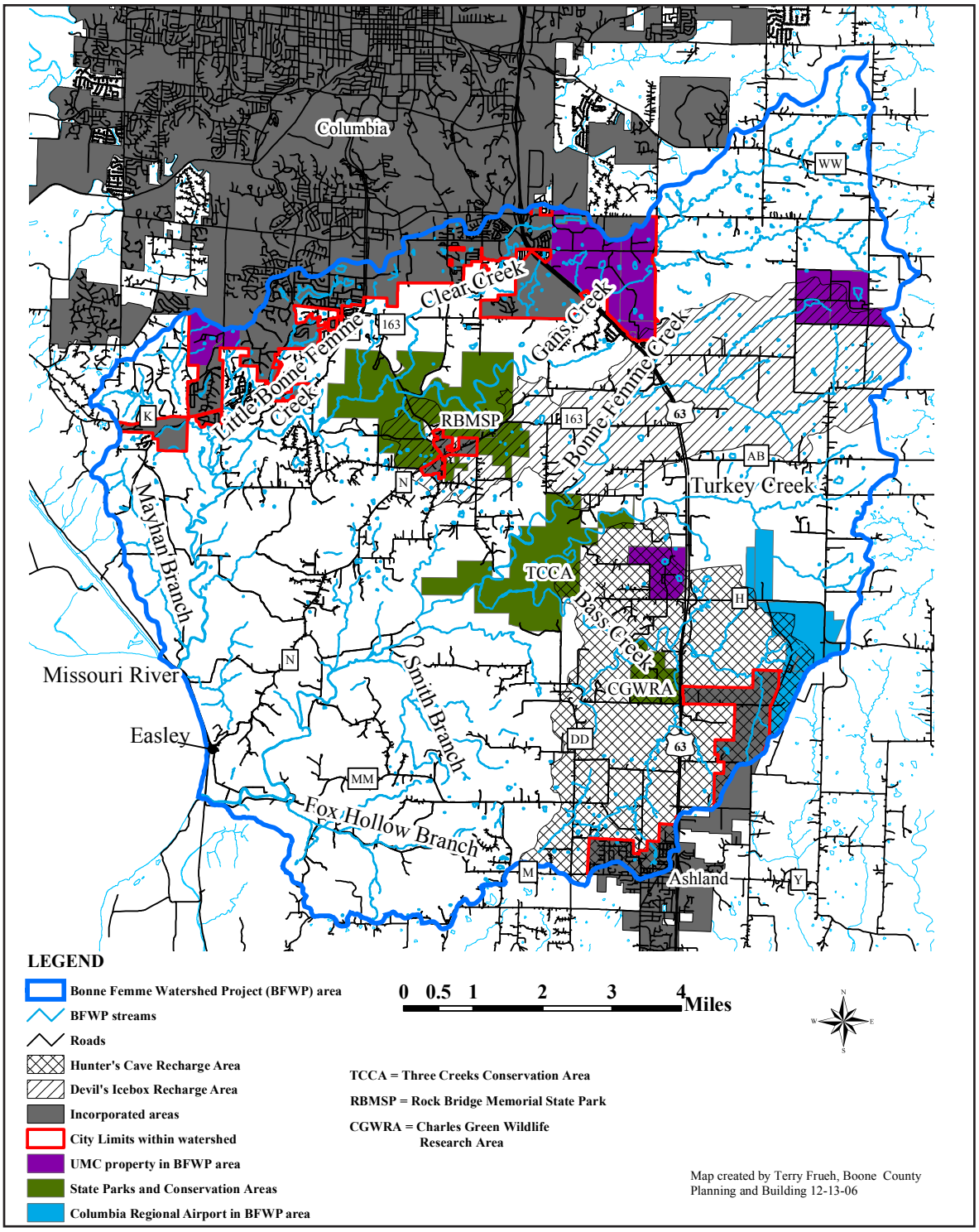

Figure 1.1 Bonne Femme Watershed Project Area

Project Committees

The overall goal of the project was to use watershed planning to protect the streams within the watershed. However, the project's initiators realized that, in addition to scientific work, a social and political context must be considered to successfully develop a land-use plan for the watershed.

The Project's committees (Steering, Policy and Stakeholder) are discussed in the order they were created (see Appendix D for their membership).

Steering Committee

In 2001, the directors of the Missouri Department of Natural Resources and Missouri Department of Conservation appointed a group of people to address stream protection in the area. This group, the Southern Boone County Karst Team , decided to pursue a Clean Water Act, section 319 grant, to protect the streams from nonpoint source pollution. After being awarded the grant, this team became the Project Steering Committee. The committee included representation from Boone County Planning, Missouri Department of Natural Resources, Missouri Department of Conservation, Rock Bridge Memorial State Park, and USDA-Agricultural Research Service.

The Steering Committee directed the entire work of the project and its staff. Members represented local, state and federal governmental agencies. They provided scientific, technical and administrative assistance to coordinate the other two committees' work. The Steering Committee was responsible for meeting the terms of the grant, which included: facilitating the development of the land-use plan, educating the public, promoting the project in the local media, and administering cost-share funds.

Policy Committee

The Steering Committee sought strong input and support from local political decision-makers. They chose to serve on the Policy Committee decision-making agencies that affect the timing and location of development in the Watershed. Each agency was invited to participate, and each designated a respective representative. The Policy Committee represents the following: University of Missouri-Columbia, City of Ashland, Boone County Water District #9, Columbia City Council, Boone County Commission, Boone County Planning and Zoning Commission, Boone County Regional Sewer District, Columbia Planning and Zoning Commission, and Consolidated Public Water Supply District #1.

The Policy Committee played several key functions throughout the life of the project. Members promoted the project and acted as liaisons with their agencies. Since the watershed lies in many different jurisdictions, interagency coordination was important to ensure that efforts were synergistic and not counterproductive. Another purpose of the members was to communicate with each other, at regular meetings, regarding actions or planned actions within the greater Bonne Femme Watershed. Members also provided input on the watershed plan and

related policy and ordinances. Finally, members will be key to acquiring broader community support, and for legal adoption and implementation of the plan.

Stakeholder Committee

The Steering Committee realized that the best way to have a successful plan was to include all of the various interests of the community in crafting the plan. These interests were represented on the Stakeholder Committee. The Steering Committee decided the Policy Committee was best suited to appoint the members of the Stakeholder Committee, since they best understood who were the best people to represent the various interests necessary to include on that committee.

The Stakeholder Committee gave a balanced, diverse perspective representing community involvement in the planning process. This breadth of representation was essential to making a successful plan the entire community can support. Members will also be important for making sure the plan gets implemented by garnering community support and speaking at public hearings.

Project Activities

Education

• The Project carried out numerous public relations efforts. A slide show has been presented to more than ten local groups. The Project's brochure was distributed widely to the public and to organizations. Annual newsletters were mailed to all landowners in the watershed and other interested parties. The Project's web page (www.CaveWatershed.org) was another method used to reach people. An annual open house educated people about the watershed and the Bonne Femme Project. The open house also gave people a chance to voice their opinions about the project. Local media, including newspapers and radio, have run stories and editorials on the Project.

• The Project has also engaged in several public education events. A driving tour of the watershed in September, 2004 demonstrated the diversity of land uses and landscapes found therein. More than 100 people attended a conservation development workshop in November, 2004 entitled "Development and Conservation: Hand in Hand." Attendees learned about both the economic and environmental benefits of conservation developments.

Science

• Water quality *grab samples* were taken on a quarterly basis at ten sites throughout the watershed. These sites were chosen to represent the major subwatersheds. The samples were analyzed for concentrations of fecal *coliform* bacteria, nutrients (total and dissolved nitrogen and phosphorus), herbicides, suspended sediment, and basic physical and chemical parameters (pH, *specific conductance*, dissolved oxygen, and temperature).

• Dye tracing is a method used to determine where underground water flows in karst systems. A nontoxic dye is introduced into flowing water, and packets of strategically-placed material that *adsorb* the dye are analyzed to determine if they picked up the dye. If dye is detected, we know water flowed from the point of dye injection to the location of the packet. This method was used by state and federal scientists to determine the sources of water to the two major cave systems within the watershed, Hunters Cave and the Devils Icebox.

• *EPT* indexing (*Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddisflies), biological orders of aquatic *macroinvertebrates*) quantifies the amount and variety of different macroinvertebrates, such as stonefly larvae, present within a stream. These species have a range of sensitivities to pollution. Stream health can be assessed by the quantity and variety of these organisms found within a particular stream.

Figure 1.2 Stonefly nymph

Subwatershed Sensitivity Analysis (SWSA)

The Bonne Femme Watershed was divided into 19 subwatersheds. The purpose of the analysis was to see which subwatersheds are more sensitive to, or more easily degraded by, development. One part of the analysis used a hydrologic model to simulate how the streams would respond to urbanization. This model looked at how changes in land use would affect the flow in the streams, which has implications for flooding, in-stream habitat, and aquatic species. Another part of the analysis looked at the existing location and quantity of impervious cover to assess current stream health.

In June 2004, Applied Ecological Services, Inc. (AES) was hired to perform the SWSA. This broad-based ecological consulting, contracting and restoration firm has successfully completed projects around the country. The company's mission is to bring the science of ecology to all land use decisions. Their Subwatershed Sensitivity Analysis team included cartographers, ecologists and engineers.

1.b Stakeholder–led Planning Methodology

Purpose of Land Use Plan

A stream's health is most affected by the use of the land in its watershed (see next page, "Nonpoint source pollution, Stormwater, and Watersheds"). Thus, in order to maintain the environmental quality of the watershed and its streams, land use and its management in the watershed needs must be addressed, preferably by means of a *land use plan* specifically designed to protect streams. A land use plan is a set of policies and guidelines for how land should be used and where growth should occur. Although there are master plans for Boone County

Nonpoint Source Pollution, Stormwater and Watersheds

Nonpoint source pollution comes from many sources spread across an area. This pollution is transported by rainfall or snow melt moving over and through the ground. As the runoff moves, it picks up and carries pollutants, finally depositing them into lakes, streams, wetlands, and even our underground sources of drinking water. NPS is contrasted with point source pollution, which comes from a single place (usually a pipe discharging to a stream).

Urbanization causes *Stormwater* runoff to change dramatically. In addition to its transporting greater amounts of nonpoint source pollutants, stormwater runoff in urban areas increases both the timing and quantity of flow (as compared with pre-development flows). These changes in flow can significantly erode stream channels, thereby destroying infrastructure, personal property, and aquatic habitat.

A *watershed* is the land area that drains water to a particular stream, river, aquifer, or lake.

In order to protect streams, lakes, wetlands and groundwater from nonpoint source pollution, action must be taken throughout the watershed since the pollution sources are spread across the watershed.

and the City of Columbia, these were not designed with stream protection as a specific objective.

This plan is meant to be a living document. It should be revisited on a five-year basis in order to incorporate new science, technology, and community values.

The Stakeholder Story

The process used to develop this plan is fairly unique. Typically, watershed planning is done by a group of technically-trained people, and the community responds during public hearings. In another common situation, planning is done by a group of citizens with vested interests. In contrast, this plan combines good technical work with strong input from a group representing the broad spectrum of community interests.

From the onset of the Project, the Steering Committee felt that strong community input was crucial to the Project's success. This input would provide a clear mandate for local decision-makers to enact the recommendations set forth in the plan. The Steering Committee delegated responsibility for the content of the plan to the Stakeholders. The Stakeholders received help from a technical team (the Steering Committee) to provide scientific and overall guidance. A political team (the Policy Committee) aided them by giving input on what is feasible from a political and legal perspective (see above, Project Committees).

With the framework set up for the Stakeholder Committee, decisions regarding the specifics of who would be invited to serve and the group's operating procedures needed to be made. The Steering Committee asked the Policy Committee to choose who to invite to serve on the Stakeholder Committee, since they knew the most about who best represented the various interests in the watershed. The Policy Committee recognized that more than just landowners

needed to be represented, since the plan would affect the larger community. They recognized the need to include diverse, even adversarial interests, from those involved in development to those with environmental interests. While the role of development and growth was recognized for its importance to the local economy, the relationship between environmental quality, the economic value of tourism, and quality of life among people living and recreating in the area were all viewed as having significant, if not equal, importance.

The Policy Committee proposed a Stakeholder Committee of eighteen people, with three general groups represented: business/construction, environmental and landowner. With such a makeup, the diverse interests could be well represented, and still have the balance needed to complete a plan palatable to the various groups. The business group would have representatives from construction, development, real estate, engineering, banking, and business. The environmental group would have representatives from educators, recreators, watershed groups, and environmental groups. The third group would be the landowners, farmers, and homeowners; this group would play the important role of representing those who live in the watershed. It should be noted that interests of the various Stakeholders often overlapped with those of other groups, and thus it is somewhat artificial to place each Stakeholder in one interest "box."

The Stakeholders held their first meeting in June 2004, and continued to work on a monthly basis until completing the plan in February 2007. Throughout the planning process, the committee elected its own co-chairs, who ran the meetings, and members decided how to organize themselves and what voting procedures to follow (see Appendix F).

1.c. Watershed Characteristics

Overview

Many people appreciate the special landscapes and streams in the area. Located near a growing urban area in the Midwest, this is a diverse watershed, including former prairie lands adjacent to steep-sloped karst topography, next to the Missouri River floodplain. The Bonne Femme Watershed is also special because of its large tracts of high-quality undeveloped lands; some are publicly-accessible, and some are on private land.

The watershed, covering 93 square miles (approximately 15% of Boone County), has many distinctive and beautiful features. Its landscape includes former prairie lands located on clay *loess* soils, steep-sloped Ozark karst areas (signified by caves, sinkholes, springs, and losing streams), and big river floodplain interspersed with thick silt loess hills. There are five *Outstanding State Re-*

Two-Mile Prairie

Boone County's "Two Mile Prairie" was roughly "two miles" wide in an east-west direction and about 25 miles long in a north-south direction. It included almost all of the land in the watershed that is east of Highway 63 and north of Ashland, MO.

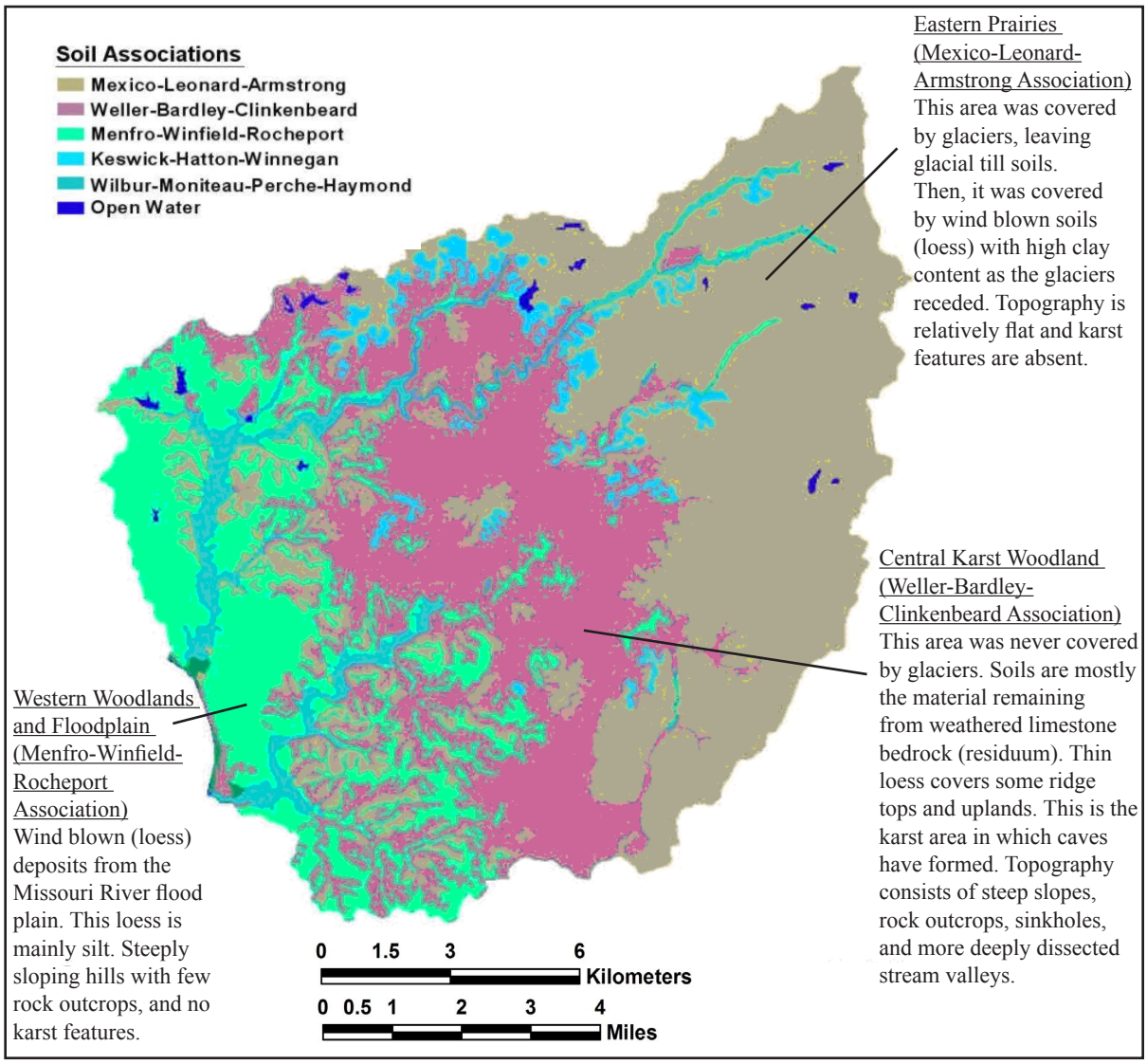

Figure 1.3 Soil Associations

source Waters (Devils Icebox Cave Branch, Bass, Turkey, Bonne Femme, and Gans Creeks), and several *endangered* and *endemic* species (*Pink Planaria*, Gray Bats, Indiana Bats, Topeka Shiner, and Cherrystone Snail). Two large tracts of public lands (Rock Bridge Memorial State Park and Three Creeks Conservation Area) provide abundant and diverse recreational opportunities, including caving, hunting, fishing, hiking, picnicking, educational activities, horseback riding, birding, rock-skipping, and more.

Introduction to Geology, Soils and Ecology by Region

The Bonne Femme Watershed has three rather distinct natural regions based upon their geology, soils and ecology (Figure 1.3). The geology and soils of each region are very different.

The geology and soils have a profound effect upon ecology. The diversity of the watershed's natural resources is reflected in the fact that two of the state's four ecological sections are within this one watershed. According to the Atlas of Missouri Ecoregions (Missouri Department of Conservation, 2002), the Bonne Femme Watershed includes the Claypan Till Plains Subsection of the Central Dissected Till Plains Section (prairie) and two subsections of the Ozark Highlands Section (Outer Ozark Border Subsection and Missouri River Alluvial Plain Subsection). Based upon these distinctions, the watershed has been divided into the following regions: eastern (former-prairie), central (*karst* woodlands) and western (*loess* woodlands and river floodplain). The natural features of each region, shaped by the interplay between geology, soils and ecology, are described below.

Eastern Former-Prairie Region

The eastern portion of the watershed, primarily located east of Highway 63, used to be a prairie landscape. Its bedrock is Burlington Limestone of the Mississippian System, same as that of the Central Karst Woodlands Region. In this region, it is covered with several feet of soil. The soil's origin is not the bedrock. Rather, glaciers deposited most of the soil during the Pleistocene Period that began about one million years ago. The two-mile thick Kansan Glacier entered Missouri from the north and pushed its way into southern Boone County before halting. Soil and rock scraped from lands to the north were left here when the glacier melted. The *glacial till* soil left behind is between 10 and 20 feet deep in the Eastern Former-Prairie Region. Fine silty *loess* soil was blown in from the dry floodplains of the Missouri River to top-off this region with an additional 5 to 10 feet of *loess* soil.

The flora and fauna of this region have historically been those of the tall grass prairie ecosystem. Grasses that once grew there commonly reached heights of 9 feet tall and sent their fibrous roots down 12 feet. The grasses and hundreds of species of colorful prairie wildflowers supported an abundance of insects and produced seeds eaten by small mammals and birds. These in turn supported predators such as coyotes, hawks and owls. While very little remains today of this prairie ecosystem, some species dependent upon open grassland habitat still remain in the area, such as the Prairie Warbler and Northern Harrier.

The primary reasons that this region supported tall grass prairie rather than woodlands were the topography and the common occurrence of fires. Fires hinder the growth of small trees, but don't harm prairie plants, since they normally sprout anew from roots each spring. Fires were set by lightning and by Native Americans. Once lit in dry prairie foliage, the fires traveled until the terrain interrupted their ability to pass. Rivers, moist

Figure 1.4 Prairie burn

valleys and rocky bluffs could stop the progress of wildfires. Therefore, the lack of those features, and the relatively flat terrain of the eastern region, fostered the passage of fires that favored prairie vegetation.

Over the years, organic matter from prairie plants and animals enriched the already deep soil of the eastern region. Once John Deere invented a plow that could cut through the tough roots of prairie plants (1837), people were able to begin farming many prairie areas. This region became part of the "Great American Bread Basket," producing food for a growing nation. Today, only tiny remnants of prairie vegetation exist among the fields of row crops and pastures – making it more accurate to call this the former-prairie region rather than the prairie region. Yet, the deep, rich soils continue to affect the characteristics of the region's streams. Stream bottoms tend to be mud or sand. Small pools of the upper Bonne Femme have supported prairie fishes, including the *endangered* Topeka Shiner. This portion of the watershed contains the headwaters, where small tributaries in open fields come together to form most of the major streams. All of the watershed's *Outstanding State Resource Waters* are partly within the former-prairie region: Turkey, Bass, Bonne Femme, Gans and Devil's Icebox Cave Branch. While Devil's Icebox Cave Branch is located in the Central Karst Woodland Region, most of its water comes from a losing section of Bonne Femme Creek that effectively drains the upper Bonne Femme Creek water into the cave. This situation of a soil-rich prairie area feeding water into a cave system is rare in Missouri, and is part of the reason that Devil's Icebox Cave has more animal life than most caves in the state.

Central Karst Woodland Region

The Central *Karst* Woodland region is in the central part of the watershed, extending from the north to south boundaries. Its geologic story starts long ago, when much of Missouri was covered periodically by shallow oceans. Sediments and the skeletal remains of organisms living in those waters were deposited and later formed sedimentary rock (approximately 350 million years ago). This sedimentary rock was raised along with the uplift of the Ozark Mountains (the last of which occurred approximately 25 million years ago). Since then, erosion has shaped the landscape into the rolling hills and valleys that are now known as the Ozarks. Cave openings in the bedrock may have formed before the uplift, and been drained by the uplift, or were formed following the uplift, and drained by valleys. In this area, meltwater from receding glaciers accelerated the process of cave formation and carried *glacial till* into caves where openings allowed it to enter. Meltwater from the glaciers eroded away much of the glacial till soil from the land surface exposing the underlying limestone and its karst features. Meltwater likely is largely responsible for the creation of

Where does the term "karst" come from?

The term karst comes from the geographical name of a region in Slovenia where karst is abundant. It is believed that the origin of this region's name comes from an Indo-European word, karasattu, referring to people who lived in caves.

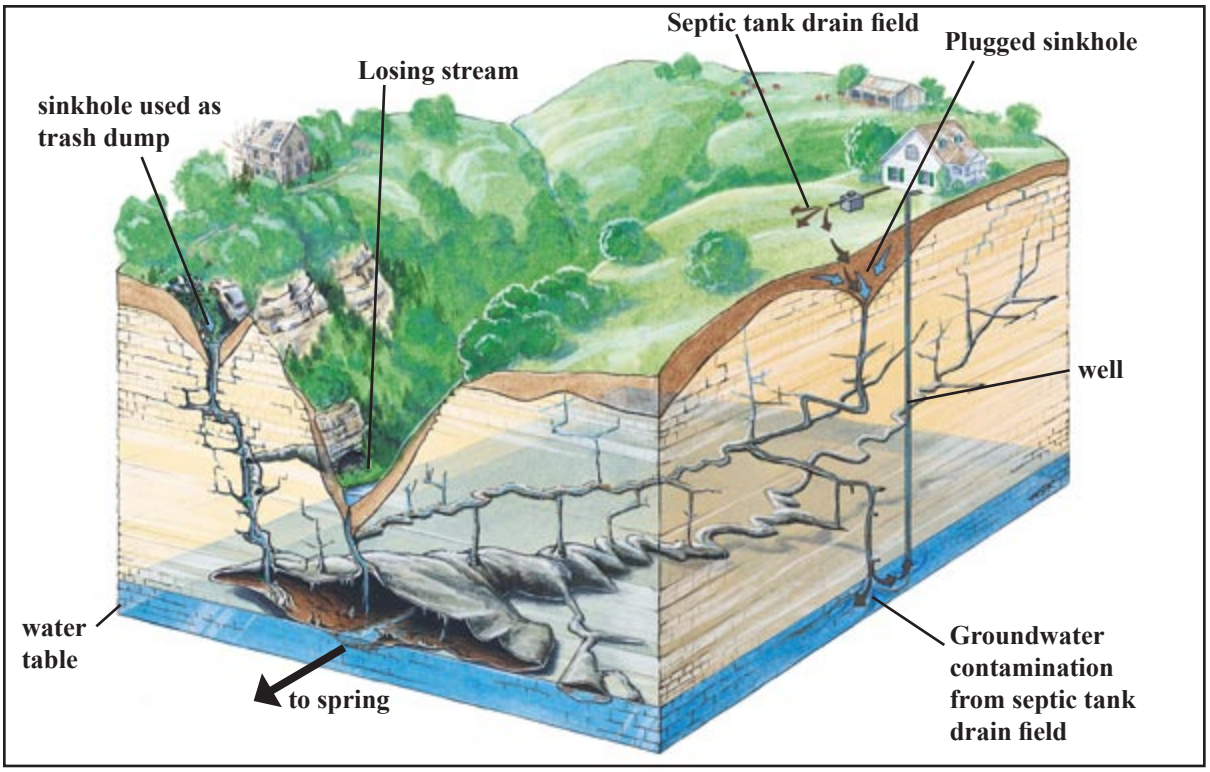

Figure 1.5 How Karst systems work

entrenched meandering streams like Gans, Bonne Femme and Turkey Creeks where the bottoms and bluff walls of the streams are solid bedrock in places.

In Boone County, the bedrock is primarily Burlington Limestone of the Mississippian System. It is approximately 100 feet thick and is visible in bluffs and outcrops, especially along streams where it has been exposed. Burlington Limestone is uniformly crystalline, white to light brown, and contains an abundance of crinoid fossils. Because of its abundance, the crinoid is our state fossil. Nodules and layers of gray to white chert (flint) exist within the limestone. Without the chert, the limestone is about 95% calcium carbonate, making it prime material for cave formation. Also known as calcite ($CaCO_3$), calcium carbonate is soluble when in contact with acidic water. Rain absorbs carbon dioxide (CO_2) from the air as it falls. Then, as it percolates through the soil, it dissolves more CO_2. This chemical reaction between water and carbon dioxide creates carbonic acid ($CO_2 + H_2O = H_2CO_3$).

The crevices and joints of limestone allow water to enter and make contact with the rock. The carbonic acid in the water puts the rock into solution due to the formation of calcium bicarbonate ($H_2CO_3 + CaCO_3 = Ca^{2+} + 2HCO_3^-$). This dissolved limestone often reverts to calcite when the water reaches cave openings (where air reacts to allow the reverse process to occur and separate the calcite, carbon dioxide and water). In the process, calcite deposits (such as stalactites) of various shapes and colors decorates cave passageways.

Areas that have types of rock susceptible to being dissolved and that have features such as caves, springs and sinkholes are called *karst* areas or are said to have karst topography. According to the Missouri Department of Conservation, Boone County ranks as one of the highest cave density counties in the state (with 104 caves). The two largest caves and 40 other caves, along with numerous springs, are located in Rock Bridge Memorial State Park and Three Creeks Conservation Area. Concentrations of sinkholes exist on both of these public lands and on surrounding private lands. The Pierpont Karst Complex is considered a highly developed karst area with hundreds of sinkholes and other karst features. The *sinkholes*, "losing streams," and cracks in the limestone bedrock allow rain water to flow freely into underground channels, increasing dramatically the potential for contaminants from the land to affect water quality in cave streams and the surface streams they feed into.

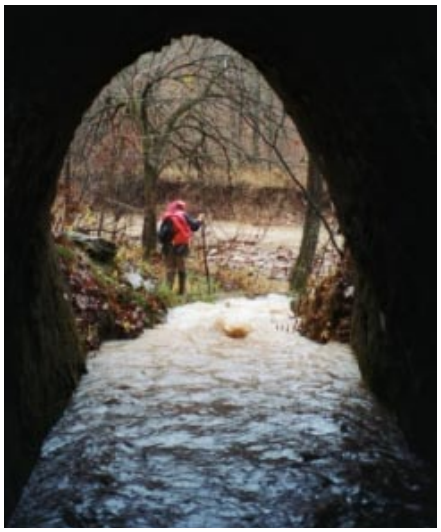

Figure 1.6 View from inside Hunter's Cave

The Missouri Department of Conservation's "Missouri Cave Life Database" currently ranks Devil's Icebox Cave as third in cave biodiversity for the state with a total of 80 species and eight *troglobites* (animals that cannot live outside of caves). An underground stream carrying an average of about 2.7 M liters/day (709,000 gallons/day) of water travels through 5,990 m (3.7 miles) of Devil's Icebox Cave. Known as Devil's Icebox Cave Branch, this stream supports several species of conservation concern, including the Pink Planarian flatworm (*Macrococotyla glandulosa*), which is considered to be *globally imperiled/vulnerable* (ranking of G2G3) due to its rarity and location within only one cave stream. In addition, the cave has a large white amphipod (*Bactrurus brachycaudus*), as well as an isopod (*Caecidotea sp.*) that was discovered in 2003 and has not yet been described by scientists. Other *species of conservation concern* that do not live in the stream but do interact in the cave ecosystem include: federally endangered Indiana Bat (*Myotis sodalis*) and Gray Bat (*Myotis grisescens*); a troglobitic spider (*Porrhomma cav-*

Interesting karst features of the watershed:

Several notable karst features of the watershed include the natural limestone tunnel that gives the Rock Bridge area its name; it is 125 ft. long, 63 ft. high and has an opening about 47 ft. across and 12 ft. high. "Devil's Icebox" is a karst window that allows entry into the seventh longest cave in the state, Devil's Icebox Cave with over 6.25 miles of passage. Hunter's Cave, in Three Creeks Conservation Area, is the 34th longest cave in a state of 6,000, caves with 1.58 miles of passage.

Figure 1.7 Pink Planarian

ernicola) and Cave Springtail (*Tomocerus missus*). Except for the bats, these animals are *troglobitic*; they usually lack eyes and have little or no pigment.

While uplands may retain some loess soil, most of the central region has soil derived directly from Burlington Limestone. These clay soils were formed from the residuum of weathered limestone. Soil depth varies from a few inches to a few feet. Many hillsides have only a few inches of clayey soil, sometimes interspersed with chert rocks left behind from the dissolved limestone within which it was once enclosed. Alluvial soils, collected along streams, are richer and deeper.

The soils and varied topography of the central region have heavily influenced the ecology, which is primarily woodland. Woodlands continue to be prevalent, particularly on hillsides that have not been converted to other land uses. Among the woodlands is large variety of species, because the terrain influences the amount of sun, soil and moisture available to trees. If a hillside faces south or west, the sun's rays strike it longer, making it dryer and hotter. These are often steep and rocky, making it even more difficult to retain moisture. Some trees, such as chinkapin oak and blue ash, are tolerant of these conditions. Grasses may vegetate the ground. On the other hand, valleys or hillsides that face the north or east are shaded for portions of the day, and tend to have more soil and moisture. These conditions are more favorable for trees, such as basswood and walnut, and for a variety of woodland wildflowers that bloom in the spring. Rich, moist alluvial soils along streams support yet another collection of trees and plants. In turn, vegetation affects where wildlife find food and shelter.

The factors of soil and topography create varied conditions and result in a mosaic of different terrestrial natural communities. These woodland terrestrial natural communities contain a multitude of animals too numerous to list (such as woodpeckers, squirrels, raccoons, deer and beavers). Two *species of conservation concern* that find their habitat in woodlands of the watershed include the Cherrystone Snail and Cerulean Warbler. The presence of over 65 *neotropical migrant birds*, including several woodland species with high *Partners in Flight* scores, has caused the National Audubon Society to designate a portion of the watershed as an Important Bird Area.

Western Woodland and Floodplain Region

The Missouri River Floodplain region is the western and farthest downstream portion of the Bonne Femme Watershed. Most of the water in this region travels in two large streams – Little Bonne Femme Creek in the northern area, and Bonne Femme Creek in the southern area. Additional small tributaries feed into these streams; the largest is Fox Hollow Branch on

the south edge of the watershed. This region has a limestone base similar to the rest of the watershed, but karst features are lacking and the limestone is covered by either alluvium or loess soils.

There are two distinct areas within this region. The actual floodplain of the Missouri River is nearly flat, and has alluvial soils that were eroded from lands upstream and were deposited due to the flooding and meandering of the river. Alluvium is also found along the Little Bonne Femme and Bonne Femme Creeks. The alluvial soils are made up of fine silt and loam, and are rich in nutrients. Rich in organic matter and about five feet deep, these soils are among the best in the state for row cropping. Since the Missouri River borders the Bonne Femme Watershed for only about three miles, and most of the floodplain is on the opposite side of the Missouri River from the watershed, the amount of alluvial floodplain in the watershed is quite limited; the alluvial floodplain along the Little Bonne Femme and Bonne Femme Creeks is also limited in width. The floodplain provides habitat for the federally listed Bald Eagle (in winter), Gray Bat and Indiana Bat (feed above the Missouri River) and Great Plains Toad (limited to floodplains), among others. Pockets of wetlands support plants such as River Bulrush.

While *glacial till* was not deposited in this region, glaciers still played a significant role in the development of the region's soils. Meltwater from the Wisconsin Glacier (located many miles from the watershed) carried and deposited finely ground rock and silt on the Missouri River floodplain. During the winter, when the glacier temporarily stopped melting, the floodplains dried. Then, winds picked up the fine silt and deposited it on the upland areas of Boone County. This material is known as *loess*. The majority of Boone County loess is of the Peorian type. Most areas of the county were covered to a depth of about 5 to 10 feet. However, some areas closer to the Missouri River have loess deposits up to 30 feet deep. These loess bluffs often have very steep slopes eroded in deep, narrow ravines.

While loess soil is productive for agricultural use, much of the landscape is too steep for row cropping, thus most of the land is primarily either in pasture or woodlands. The woodlands are pretty similar to those of the Central Karst Woodland Region, except that in many areas the abundant loess soil and the moisture it holds creates a more *mesic* environment. The Missouri River corridor tends to be an important travel route for wildlife, such as bobcats, that need large tracts of non-fragmented woodlands.

Climate

Boone County has a humid, temperate climate with average annual temperatures from about 54^{O} F to 57^{O} F, and ranging from -20^{O} to 110^{O} F. Long-term annual precipitation averages about 39 inches, with the largest amount coming in spring and the lowest in winter. As with temperature, precipitation has a large variation about the average, both annually and monthly. Annual surface runoff averages about 10 inches, with the rest being evapotranspired through plants.

Streams

The streams reflect the diversity of the landscape in the Watershed. In general, at higher elevations (east of Highway 63) they tend to have sandy channel bottoms and silty/sandy banks. As they head southwest, the streams enter areas with deeper valleys and exposed bedrock, and have cobble or bedrock channel bottoms, and cobble mixed in with the soil on the banks. Near the streams' mouths, they tend to be silty /sandy bottoms and banks.

The streams have a total elevation change of about 300 feet. The largest gradient occurs in the midsections (exceeding 60 feet/mile), and the lowest gradient situated in the lowest sections (the Missouri bottoms area). In middle section, the streams flow through *karst* topography. Ample elevation difference combined with the porous limestone has produced springs, *losing streams*, resurgences and caves. The most notable karst feature is Bonne Femme Creek losing to an underground system. This losing stream results in the upper waters of the Bonne Femme Creek being diverted to cross watersheds and flow through the Devil's Icebox Cave Branch, and emerge into the Little Bonne Femme Creek Watershed. Bass Creek also loses (over a small area), where a meander cutoff allows it to flow through Hunter's Cave.

Although there are no *recording stream gage* data available for the creeks in the watershed, it is not difficult to describe the nature of the flow. The streams tend to have a low base flow, and they rise quickly in response to storms. As with other streams in Boone County, the stream flows reflect the drainage surface area and the volume of water introduced through precipitation events, heavily attenuated by evapotranspiration, and further modified by soil moisture and quantity of surface waters prior to and during the precipitation events. The one major exception to this is the losing section of Bonne Femme Creek.

The lack of data relating stream flow to precipitation events for these streams means we have no way to determine what changes in stream flow, if any, are occurring due to changes in land use within the watershed.

History

Humans have lived in central Missouri for more than 10,000 years, though little is known about the first inhabitants of the region. Native Americans likely used the area seasonally for hunting and gathering, with the cool springs being a consistent source of water. Chert was mined for arrowheads and tools.

The earliest Europeans in the area were primarily French fur traders, seeking beaver and other prized pelts to trade at the fur trading posts of St. Louis. Only a few years after the Lewis and Clark Expedition of 1803-1806, the first settlers began arriving, although hostilities with Native Americans kept immigration to a trickle.

In 1815, when Missouri became a territory, that trickle became a steady stream. A treaty forced out most of the remaining Native Americans. Congress also awarded up to 160 acres in the Boonslick area to settlers who had lost lands as a result of the New Madrid Earthquake of 1811. Central Missouri also was the destination point for many travelers of the

Boone's Lick trail, which began in St. Louis and continued overland to Arrow Rock in present-day Saline County. These travelers undoubtedly passed through some of the richest and most diverse country some had ever seen. The abundant wildlife, the thick oak and hickory forests mixed with some rocky hilltops, native prairie, creeks and streams with rich bottomland soil, and access to the Missouri River, made the Bonne Femme watershed area an ideal location for settlement.

There were three main types of settlers. Squatters staked claims before U.S. land sales offices opened in Franklin in 1818 and in Columbia in 1825. Subsistence farmers purchased small tracts of land, many of them 80 or 160 acres in size. A third class, the gentry, were land speculators who bought several hundred acres of land and gradually sold off parcels. The majority of the early settlers were from the slave-holding states of Kentucky, Virginia and Tennessee, and they brought with them their Southern ideals of "honor, piety and slavery." Only a few, however, were wealthy enough to own more than a handful of slaves. By 1830, less than ten years after Missouri entered the Union as a slave state, most of the land in the watershed area had been parceled out.

Many of the first settlers lived along wooded creeks and rich bottomlands. While prairies were good for grazing, the general belief was that soil good enough to grow trees was the best for farming, and the wooden farming implements were often incapable of breaking the prairie sod. Also, timber along the creeks provided a ready resource for building log cabins and for heating, cooking and powering mills, distilleries and other economic operations.

Prior to 1830, most farmers in the watershed area were subsistence farmers, making enough to live on but not much surplus to ship to markets. Common farm crops included Indian corn, maize, wheat, oats, flax and barley. Women tended family gardens which contained peas, beans, sweet potatoes, and Irish potatoes. All the sowing was done by hand. Some tobacco and hemp were produced as cash crops. In the 1830s, that picture began to change.

Market hunting and habitat loss were beginning to take a toll on wildlife populations. By 1840, furbearers such as beaver and otter were almost *extirpated* from Missouri; bald eagles, prairie chickens and other species were showing signs of decline. By the 1870s, the state began enacting its first game laws to counteract the loss, but lack of funding and support made it difficult to halt decades of unrestricted hunting and fishing. The laws were unsuccessful, as evidenced by the fact that in the 1880, St. Louis was identified as the largest game market in the United States.

Land Use

Most of the Watershed is still rural, with most development occurring close to Columbia and Ashland, and some along the Highway 63 corridor. About 18% of the Watershed is in row-cropping, primarily east of Highway 63, where there is flatter land and deep soils. Pasture is about 42% of the area, spread throughout the watershed. Various forest types cover an additional 33%, most of it occurring west of Highway 63 in the areas with steeper terrain. Suburban and commercial development covers about 7% of the area.

Early Center of Commerce

Early settlers near Rock Bridge included the Reyburn family (circa 1810), Hickam (1830s), and Saunders (1850s). Though they never owned the land, brothers Thomas and Gilpin Tuttle built a mill near the Rock Bridge circa 1822 and added a distillery, general store and tanyard by 1827. In 1825, the Rock Bridge Valley area (about 800 acres) was purchased by Nathan and Peggy Glasgow for $1.25/acre.

To meet the demands of a growing population, and to make their mill more accessible, in 1823 the Tuttles built a road that connected their mill to the road that ran south from Columbia to the town of Nashville on the Missouri River. Nashville was once an important river port, providing communication and transportation access to the Missouri River.

Increased steamboat traffic brought more settlers to the area. Nathan Glasgow sold parcels to John W. Kaiser and David S. Lamme. They established a paper mill in 1834 which operated for two years before closing. Lamme also hired Brightbery McAlester to build a mansion on top of the ridge above Rock Bridge Valley. In 1835, Lamme also opened a post office known as Rockbridge Mills, and served as its first postmaster. The post office operated until 1844 when the land and supporting businesses were sold to James McConathy.

Like a rushing flood, in a few years James McConathy completely redefined the economic operations in the valley. He added a swine herd of 200-400 hogs and increased distillery operations. By 1850 he owned the second-largest distillery in the state. That year he produced 5,000 barrels of corn, wheat and rye whiskies worth $40,000, totaling 17 percent of the state's whiskey.

McConathy had several advantages over his predecessors. He could afford a larger workforce (about a dozen hired hands and eleven slaves). To take full advantage of the steamboat traffic (that had more than doubled since the 1830s), McConathy helped finance the $33,000, 12-mile Providence Plank Road in the 1850s. The road ran along present-day Hwy 163 from Columbia south on Route K to the Missouri River at Providence. Heavy wagon traffic took its toll on the road, which foreclosed after only two years and rapidly deteriorated over the next two decades.

The impact McConathy and other local industry had on the environment was tremendous. In 1847, McConathy was sued by his downstream neighbor William T. Smith. The charge was environmental pollution from hog slop and hog by-products spilling into Little Bonne Femme Creek, creating noxious smells and fish kills. The use of chemicals in the tanning operation, manure from local livestock, and heavy timber cutting with the resulting stream siltation, undoubtedly further degraded water quality.

Locally, this rising tide of economic growth and resulting environmental decline was partially stemmed by the Civil War, the loss of slave labor, McConathy's death in 1866, and a growing temperance movement.

Under the hands of the Emmitts in the 1870s and 1880s and then under the Heibels, the Rockbridge mills and distilleries operated intermittently until 1907, when Boone County outlawed the sale and production of whiskey (except for medicinal purposes). That same year, a suspicious fire destroyed the distillery. Without the distillery, economic operations, which had already considerably slowed, now collapsed. The Pierpont Store (then called A.R. Stephens General Merchandise) was moved to its current location at Hwy 163 and Rt. N along with the last remaining blacksmith shop in the area.

The land in the Rock Bridge area was eventually purchased by Dennis Ingram who, in 1922, converted part of the area into an amusement park, complete with rides, games and fairy floss (cotton candy). The amusement park did not succeed. In 1947, the mansion on top of the hill burned. In the 1960s, local citizens formed a coalition to turn the area into a park. They succeeded in 1967, when it became Rock Bridge Memorial State Park.

About 88 % of the watershed is privately owned, and the remaining 12% publicly owned (University of Missouri-3.8%, Missouri Departments of Natural Resources and Conservation-6.5%, and City of Columbia-1.9%).

Figure 1.8 Harvesting

Agricultural uses vary greatly. Most of the row cropping occurs east of highway 63 (except in a few creek floodplains), where the land is more conducive to tillage. Major crops include soybeans, corn, wheat and milo. Native plant stock, perennial seed production, vegetables, fruit and flowers are also found. The location of pasture and hay ground is located in more diverse places. The most prevalent livestock are beef cattle, horses and swine; poultry, emus and goats are also found in the watershed.

Outdoor recreation in the watershed is extremely varied, ranging from getting out in one's backyard or neighborhood, to visiting a public area. Hunting and fishing are popular on both public and private land. Over 35 miles of public-accessible trails are used for hiking, bird watching, hunting, mountain biking, horse back riding and cross-country skiing, in season. For example, the Devil's Icebox Boardwalk in Rock Bridge Memorial State Park has about 190,000 person-visits annually. Streams themselves provide numerous recreational opportunities, such as fishing, swimming, kayaking, and exploring stream critters. Caving is a popular activity as well. People from around the world participate in wild cave tours of the Devil's Icebox Cave; it is one of only a few guided wild cave tour programs offered in the state and nation.

There are several important transportation routes through the Watershed. In addition to the internal road network, two routes connect Columbia to other cities: Route WW connects to Fulton, and Highway 63 connects Columbia, Ashland, Jefferson City and points to the north and south. The Columbia Regional Airport has commercial flights to St. Louis, in addition to servicing private planes.

Boone County Horses

In a state that is third in the nation in number of horses, Boone is the tenth-ranked county. Horseback riding is popular in the watershed, with numerous trails on both private and public land. It also provides substantial economic activity.

Figure 1.9 House under construction.

The Watershed is an attractive place to live, in part because of its proximity to the major employment centers of Jefferson City and Columbia, and in part because of its natural beauty and opportunity for outdoor recreation. Since 2000, the Cities of Ashland and Columbia have each annexed approximately two square miles in the Watershed. There are numerous new subdivisions of moderate urban density recently constructed, under construction, and in the planning stages. These are concentrated in the northeast part of Ashland, along the Route K corridor south of Columbia, and north of Gans Road. There are also numerous five to ten-acre plots with new houses scattered throughout the watershed.

Commercial development in the watershed is minimal, except for a few pockets. These are concentrated around the intersections of Highways 63 and 163, and Highway 63 and Route AC. Commercial activities include a lumber yard, a few gas stations, and several retail operations.

Two major pipelines pass through the watershed, sharing the same corridor. Entering the watershed from the Missouri River side, passing through Rock Bridge Memorial State Park, they terminate at a major tank farm on the west side of Highway 63. This location straddles the Bonne Femme and Little Bonne Femme watershed divide. Other pipelines leave the tank farm, continuing through the eastern portion of the watershed. Products carried in the pipelines are petroleum products, liquid fertilizer and natural gas. The pipeline tank farm is a distribution terminal for filling tanker trucks. The storage facilities at this location are capable of storing large amounts of a variety of products, none of which would be neutral or beneficial to the environment or the waters of the watershed.

Demographics

During the 1990s, population in the watershed is estimated to have increased by 40%, and existing data indicate it will continue to grow. The Columbia Area Transportation Study Organization (CATSO) estimates Boone County's population will continue growing at a rate of 2% annually through 2030, with a total of 245,356 people (Table 1.1). Growth in dwelling units for both the entire county and the watershed is detailed in Table 1.2. Table 1.3 has rough estimates on population growth over the last five years. These estimates are included to give an indication of the area's growth. It is interesting that population in the watershed is growing considerably faster than that of the entire county for each of the last six years and the 1990s. In contrast, new dwelling units/ $mi.^2$ historically was always lower for the watershed when compared to the entire county.

Table 1.1 Columbia and Boone County census figures and census forecast.

	Columbia		Boone County	
year	population	Growth rate[1]	population	Growth rate[1]
1900	5,651		28,642	
1910	9,662	5.5%	30,533	0.6%
1920	10,392	0.7%	29,672	-0.3%
1930	14,967	3.7%	30,995	0.4%
1940	18,399	2.1%	34,991	1.2%
1950	31,974	5.7%	48,432	3.3%
1960	36,650	1.4%	55,202	1.3%
1970	58,512	4.8%	80,911	3.9%
1980	62,061	0.6%	100,376	2.2%
1990	69,101	1.1%	112,379	1.1%
2000	84,531	2.0%	135,454	1.9%
2030[2]	153,116		245,356	

1. Average annual growth rate for the previous decade
2. Projected annual growth rate assumed to be 2.0%.

Table 1.2 New dwelling units in Bonne Femme Watershed and entire Boone County.

	Single Family		Duplex		3 or 4 Family		5+ Family		Total New Dwelling Units		New dwelling units/mi.[2]	
year	BF	BC	BF	BC	BF	BC	BF	BC	BF	BC	BF	BC
2000	72	969	0	84	27	8	0	276	99	1,337	1.1	2.0
2001	60	1,085	0	54	12	36	0	60	72	1,235	.8	1.8
2002	172	1,158	0	88	27	49	0	516	199	1,811	2.1	2.6
2003	172	1,359	6	292	9	16	0	509	187	2,176	2.0	3.2
2004	116	1,586	20	396	3	16	0	628	139	2,616	1.5	3.8
2005	143	1,629	172	328	0	24	99	374	414	2,355	4.5	3.4

BF=Bonne Femme Watershed; BC=Boone County (includes all incorporated areas)

Table 1.3 Rough population estimates for Bonne Femme (BF) and Boone County (BC), based on new dwelling units.

Note: uses the 2000 U.S. census as the starting point.

	Total New Dwelling Units		New Population[1]		Total Population		Annual Population Growth Rate	
year	BF	BC	BF	BC	BF	BC	BF	BC
2000	99	1,337	198	2,674	4,698	138,128	4.4%	2.0%
2001	72	1,235	144	2,470	4,842	140,598	3.1%	1.8%
2002	199	1,811	396	3,622	5,240	144,220	8.2%	2.6%
2003	187	2,176	374	4,352	5,614	148,572	7.1%	3.0%
2004	139	2,616	278	5,232	5,892	153,804	5.0%	3.5%
2005	414	2,355	828	4,710	6,700	158,514	14.1%	3.1%

1. Assumes 2 new people/new dwelling unit.

Table 1.4 Columbia and Boone County Population and dwelling unit growth projections for 2030.

	Columbia			Boone County[1]		
year (population growth rate)	population	new dwelling units[2]	new dwelling units[3]	population	new dwelling units[2]	new dwelling units[3]
2000	84,531			135,454		
2030 (1.5%)	132,129	23,799	19,039	211,725	38,136	30,509
2030 (2.0%)	153,116	34,293	27,434	245,356	54,951	43,961
2030 (2.5%)	177,309	46,389	37,111	284,124	74,335	59,468

1. Includes all incorporated areas within Boone County.
2. Assumes 1 new dwelling unit/ 2 new people
3. Assumes 1 new dwelling unit/ 2.5 new people

Table 1.5 Projected dwelling unit growth in Bonne Femme Watershed for 2030.
Note that as of June 2006, the total new dwelling units that could be built in the watershed under existing zoning for all jurisdictions is approximately 27,000.

	Watershed[1]	
year (population growth rate)	new dwelling units[2]	new dwelling units[3]
2000		
2030 (1.5%)	5,110	4,088
2030 (2.0%)	7,363	5,891
2030 (2.5%)	9,961	7,969

1. Figures based on the watershed's aerial portion (13.4%) of the entire county.
2. Assumes 1 new dwelling unit/ 2 new people
3. Assumes 1 new dwelling unit/ 2.5 new people

1.d. Economics

Assessing economic activity in the watershed is a challenging process. This is due in part to the fact that if economic data are collected for various sectors of the economy, they are not collected on a watershed basis. In addition, some sectors have inadequate economic data collected, and various economic activities occur completely outside of the market economy. It is important to note that data in this discussion are reported using the most recent numbers, and formats; as such, the years for which different economic sectors are reported do not always coincide, nor do their categories (i.e. income, production expenses, etc.).

Farming is widespread throughout the watershed and occupies the greatest area of all land uses. The watershed occupies approximately 14% of the county; however, estimates are stated here for the entire county, since they would not likely break down on a proportional basis in an accurate way for the watershed. For 2003, county-wide cash receipts were estimated to be $20.4 million for livestock and $18.8 million for crops; other income was estimated to be $6.4 million, including government payments of $3.1 million (Bureau of Economic Analysis

(BEA), 2005). This gives an estimated total income of $45.5 million for all agricultural production in Boone County for 2003. The production expenses were estimated to be $44.7 million, leaving a realized net income of $0.9 million (BEA, 2005). In 2005, farm payments were $4.7 million for the entire county, with an average payment of $5,831 per farm (Farm Services Agency, 2006).

The value of construction activities in the watershed can be evaluated using data from both Boone County and City of Columbia building permits. These permits ask the permitholder to estimate the value of construction, whether it be new construction or an alteration to an existing building. For 2005, the total value for construction in the watershed was estimated to be $17.9 million in the county's jurisdiction (which includes Ashland and Pierpont) (Boone County Planning and Building Inspection Department, 2006), and $42.7 million in Columbia's jurisdiction (Columbia Protective Inspections Division, 2006).

Currently, retail activity is limited in the watershed, although that will change with the addition of retail space at the Bristol Lakes development. Retail activity is located primarily in Ashland and along the Highway 63 corridor. There are no estimates available for retail activity in the area.

The tourist and recreational activities of the watershed mostly do not have economic activities associated directly with them, although their presence encourages economic activity. For example, cavers need to purchase specialized equipment. In addition, the caver may be coming from outside the area, thereby bringing dollars into the Boone County economy. Other activities such as hunting, fishing, horseback riding, etc. will have similar positive economic impacts. There are no estimates available for retail activity in the area.

The environment itself provides important ecological services that are usually outside of traditional economic analyses, but are included here to help give perspective to their importance. These ecological services are diverse, including such aspects as nutrient cycling, erosion and flood control, pollination, food production, raw materials, and recreation. To better understand these services, it is helpful to look at an example. Floodplains provide numerous services that would otherwise require considerable expense. These services include helping to recharge groundwater, filtering pollutants that would otherwise enter into waterways, helping to stabilize stream banks, and providing floodwater storage (which decreases flooding downstream). The economic impact of ecological services is difficult to quantify because it exists outside of the market economy; yet, without its existence, we would have to pay for expensive alternatives. As there have not been any analyses of ecosystem services specifically completed for Missouri, estimates of the value of these services in the Bonne Femme Watershed are difficult to determine. Following one methodology, the total value of ecosystem services in the watershed is estimated at $6.7 million (Costanza *et al.*, 1997), while another methodology gives an estimate of $28 million for ecosystem services (excluding flood protection) for the watershed's acreage within the 100-year floodplain (Illinois Department of Conservation, 1993; United States Army Corps of Engineers, 1978). Appendix E outlines these calculations.

1.e. Plan Overview

The plan's chapters each discuss a different aspect of how this plan was developed.

Chapter 1 outlines the global view. It discusses how the plan relates to the Bonne Femme Watershed Project and how the Stakeholders developed the plan. The watershed's characteristics (social, physical, and biological) are addressed. Finally, economic activity in the watershed is discussed.

Chapter 2 outlines the issues the Stakeholders considered during the development of the plan. The issues are listed both in simple form, and in a consolidated grouping that explains how they are connected to one another.

Chapter 3 discusses the scientific information considered by Stakeholders in the planning process. Parts of this chapter focus on previous, and sometimes general, studies, including: karst hydrogeology and cave life. Other sections of this chapter discuss work that was completed in relation to the Bonne Femme Watershed Project, including stream life, water quality monitoring, dye tracing, and the Subwatershed Sensitivity Analysis.

Chapter 4 covers the Stakeholder vision for land use in the Bonne Femme watershed, including its purpose and how it was developed. The vision statement is detailed, along with the elements that form its basis.

> **Stakeholder vision:** In the year 2030, we envision a watershed where quality of life and economic vitality are fostered by maintaining or improving the current conditions of the water resources, having a mix of land uses and development types, and maintaining thriving agricultural activities.

Chapter 5 discusses how the Stakeholders transformed the vision into achievable goals. The obstacles to achieving these goals are discussed and rated as to their strength (i.e. how much they might impede achieving the goal).

Chapter 6 details how the Stakeholders developed their policy recommendations, lists these recommendations, and discusses how to carry the plan forward.